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Original Article

Diet of crab-eating fox (*Cerdocyon thous*) in two conservation units of the Amazon rainforest, Brazil

Dieta do cachorro-do-mato (*Cerdocyon thous*) em duas unidades de conservação da Floresta Amazônica, Brasil

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Abstract

The present study aimed to evaluate the diet of the free-living crab-eating fox by identifying the stomach contents of the 17 crab-eating foxes (*Cerdocyon thous*) roadkilled in two conservation units, both located in the Amazon rainforest. The food items were quantified by frequency of occurrence (FO) and percentage of occurrence (PO). The stomach contents were analysed for dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE), and mineral matter (MM). Nitrogen-free extractives (NFE), metabolisable energy (ME) values, as well as the energy need for maintenance were estimated. The composition of the diet for the crab-eating fox presented 29 food items from the different taxonomic groups, with a greater diversity of items of animal origin (n=22), although the highest frequency of occurrence was gramineae (Poaceae) (41.18%). Among the items of animal origin, 21% were mammals, 18% reptiles, 10% amphibians, 9% invertebrates and 3% birds. A high content of CF (62.76%) were determined. Nitrogen-free extractive and dry matter averages were 5.91% and 141.82 kcal/100g, respectively. The average maintenance energy was 447.01 kcal/day. These findings suggesting that the crab-eating foxes have a generalist diet with an omnivorous diet in the Amazon basin, feeding on gramineae, fruits, insects, snakes, amphibians, birds and small mammals and have the same feeding habit that present in other Brazilian biomes.

Keywords: bromatology, food items, neotropical canid, roadkill.

Resumo

Este estudo objetivou analisar a dieta do cachorro-do-mato, de vida livre, por meio da identificação do conteúdo estomacal de 17 *Cerdocyon thous* atropelados em duas unidades de conservação da Floresta Amazônica. O conteúdo estomacal foi analisado e os itens alimentares foram quantificados pela frequência de ocorrência (FO) e percentagem de ocorrência (PO). Também foram avaliados os teores de matéria seca (MS), proteína bruta (PB), fibra bruta (FB), extrato etéreo (EE) e, matéria mineral (MM). Foram estimados o extrativo não-nitrogenado (ENN), a energia metabolizável (EM) e a necessidade energética de manutenção. A composição da dieta do cachorro-do-mato apresentou 29 itens alimentares dos diferentes grupos taxonômicos, tendo uma maior diversidade de itens de origem animal (n=22), ainda que a maior FO tenha sido de gramíneas (Poaceae) (41.18%). Dentre os itens de origem animal, 21% eram mamíferos, 18% répteis, 10% anfíbios, 9% invertebrados e 3% aves. Determinou-se um alto teor de FB (62.76%). A média do ENN e da MS foi 5.91% e 141.82 kcal/100g, respectivamente. A média da energia de manutenção foi 447.01 kcal/dia. Estes achados sugerem que o cachorro-do-mato encontrado na Bacia Amazônica é um animal generalista com uma dieta onívora, se alimentando de gramíneas, frutos, insetos, serpentes, anfíbios, aves e pequenos mamíferos, portanto com o mesmo hábito alimentar relatado a esta espécie quando encontrada em outros biomas brasileiros.

Palavras-chave: atropelamento, bromatologia, canídeo neotropical, itens alimentares.

1. Introduction

Carnivora mammals can influence the dynamics of the plant community and plant diversity, since they prey on herbivorous animals and their competitors, in addition to being able to carry a large amount of seeds over long distances acting as efficient dispersers (Rocha et al., 2004). The carnivores are at the top of the food pyramid,

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and present great ecological importance, regulating the population of natural prey and, thus, influencing the entire dynamics of the ecosystem in which they live (Pitman et al., 2002).

The crab-eating fox (*Cerdocyon thous*, Linnaeus, 1766) is a medium-sized Neotropical canid (average body mass of 6 kg), which lives in pairs or small groups and is considered widely distributed and is common in South America (Eisenberg and Redford, 1999). Although not a typical species in the Amazon rainforest, there are records of the presence of this animal in the north of the State of Mato Grosso (southern region of the Amazon Forest, in an area of forest impacted by deforestation) (Michalski and Peres, 2007), northeast of Pará (east of the biome, in forest remnants) (Stone et al., 2009), and southeast of the state of Pará (in areas of environmental preservation) (Carvalho et al., 2014).

The crab-eating fox is considered of little concern, not appearing in the Red Book of Endangered Brazilian Fauna (ICMBio, 2018) and in none of the Brazilian state lists of threatened species. Despite this, many populations are impacted by the roadkilling of individuals on the highways, since this is one of the species of carnivores with the highest occurrence of deaths of this type (Vieira, 1996; Cândido-Junior et al., 2002; Gumier-Costa and Sperber, 2009; Lemos and Facure, 2011). Although death by roadkill of wild species is one of the challenges for Conservation Biology (Forman and Alexander, 1998), roadkilled animals can provide important biological information (Vieira, 1996).

One of the possibilities for scientific use of roadkilled animals is the study of the diet based on stomach contents (Aguiar et al., 2011). The knowledge of food habits is essential to understand the trophic structures of an ecosystem and can show the organization of communities and how species overlap in the use of food resources, since these patterns of food exploitation are important for the study of ecology species (Poulin et al., 1994). Although this is one of the most studied aspects in research with carnivores, there is little research that addresses the bromatological composition of food items consumed. Thus, this study aimed to describe the diet of crab-eating fox roadkilled in two conservation units in the Southeast of the State of Pará, Brazil, by identifying the food items present in the stomach content and bromatological analysis of the food items.

2. Material and Methods

2.1. Study area

The roadkill animals were collected in two conservation units, Carajás National Forest (6º4'14.972" S, 50º4'6.886" W) and Tapirapé Aquiri National Forest (5°35'52" and 5º57'13" S, 50°01'57" and 51°04'20" W), both located in the Amazon rainforest, Southeastern of the State of Pará, Brazil. These are part of a mosaic of protected areas, in the municipality of Parauapebas, state of Pará, Brazil (Figure 1). The predominant vegetation is classified as open ombrophilous forest, with local variations, associated with changes in relief. The dense ombrophilous forest

Figure 1. Location of study area, indicated by symbol, in Amazon rainforest (stippled area), Brazil.

predominates on the tops of the plateaus and, specifically in the National Forest of Carajás, the ferruginous rupestrian field occurs (IBAMA, 2006; ICMBio, 2018). The climate of the region is humid tropical climate, with dry winter and with average precipitation of the driest month below 60 mm. The climatic seasons are well defined, with the period of greatest precipitation occurring between the months of December to April and the driest period between July and August (IBAMA, 2006; Raiol, 2010).

2.2. Animals

A total of 17 stomach content samples were taken from roadkilled adult crab-eating foxes (*Cerdocyon thous*), 12 males and 5 females, on two roads that cross the National Forests of Carajás and Tapirapé Aquiri National Forest. This study was authorized by the Committee on the Use of Animals of School of Veterinary Medicine and Animal Science, UNESP (CEUA 0227/2017), and by Brazilian Institute of the Environment and Renewable Natural Resources (SISBIO 66964).

The collection of run over animals was part of programs for monitoring of roadkill fauna from 2008 to 2018. For each animal collected, the date, time of collection, kilometer and road were recorded. In addition, body size, tail size and body mass of animals were verified according to Emmons and Feer (1997). Subsequently, the carcasses were taken to Anatomy and Zoology laboratory of the Universidade Federal Rural da Amazônia (UFRA), Parauapebas Campus, where they were dissected and the contents of each stomach were removed, frozen and destined for studies of food and bromatological items.

The analysis of stomach contents was performed with stereoscopic and optical microscopes, where the

different food items were separated and identified at the least inclusive taxonomic level whenever possible. The identification of plant items was carried out by comparison with the reference material deposited in the scientific collection of the herbarium of Vale Zoo and Botanical Park. The items of animal origin were identified using identification keys and also compared to reference collection of the zoological collections available at Vale Zoo and Botanical Park and UFRA, both in Parauapebas, Pará, Brazil.

2.3. Bromatological analysis

The analyzis were performed in the Animal Nutrition Laboratory of the UFRA, Parauapebas, state of Pará, Brazil. Stomach content samples were thawed and then pre-dried in an oven at 55ºC for 72 hours. Then they were sent to grinding, in a Willey mill using a sieve with 1 mm holes. The samples were then placed in closed pots and identified for further analysis to determine the composition of dry matter (DM), mineral matter (MM), crude protein (CP), ether extract (EE) and crude fiber (CF) (Silva and Queiroz, 2006).

2.4. Data analysis

Food items were quantified according to their frequency of occurrence (FO) and percentage of occurrence (PO). The presence of a certain item in a stomach was considered an occurrence and the FO was calculated using the formula: FO = (ni / N) x 100, where FO is the frequency of occurrence of food item i in the sample; ni indicates the number of stomachs in the sample that contains the food item i; N corresponds to the total number of stomachs with content in the sample. The percentage of occurrence (PO) was calculated using the formula: PO = (Ni / ΣNi) x 100; where Ni represents the number of occurrences of each item, and Σni represents the sum of the occurrence of all items, which indicates the importance of each item in the diet (Tófoli et al., 2009).

The determination of dry matter (DM), crude fiber (CF), ether extract (EE), crude protein (CP) and mineral matter (MM) were submitted to descriptive statistics. The nitrogen-free extractive (NFE) was obtained by subtracting the sum of CP, CF, EE and MM from 100 (expressed as a percentage of DM). To predict the metabolisable energy (ME) of the diet, the modified Atwater factors for dogs and cats were used (NRC, 2006), according to the formula ME (Kcal/100g food) = [(3.5 x %CP)] + [(8.5 x %EE)] + [(3.5 x %NFE)]. The maintenance energy requirement was calculated according to the NRC (2006), using the formula K x (BM) 0.75; where K represents the correction factor for different types of activity, and BM the body mass in Kg. The correction factor used was active adult dogs with an average need of 130.

3. Results

The body size, tail size and body mass averages of the crab-eating foxes studies were 68.8 cm ± 7.3, 29.3 cm ± 3.5 and 5.19 kg ± 1.25, respectively.

3.1. Description of food items

The stomach contents presented exclusive items of animal origin (24%), plant items (18%), and both animal and plant items (59%). A total of 29 food items was found in the crab-eating fox diet, 07 of which were of plant origin and 22 of animal origin, totaling 57 occurrences (Tables 1 and 2, Figure 2). Among the food items identified, gramineae (Poaceae) were the most consumed by the animals studied, with a FO of 41.18%, and PO of 12.28%. Within the items of plant origin, species such as *Byrsonima crassifolia*, *Physalis angulata* and *Mangifera indica* were observed. *Byrsonima crassifolia* and *Physalis angulata* presented a FO of 11.76%. In addition to these plants, species such as *Bellucia grossularioides* and *Cecropia* sp. were found with a FO of 5.88% each.

Among animal items found in the stomach contents, invertebrates and vertebrates represented 9% and 52%, respectively, of the total items. Among invertebrates, specimens of the order Odonata and family Scolopendridae were the most common with FO of 11.76% and 5.88%, respectively. Mammals, reptiles, amphibians and birds were examples of vertebrates found in the stomach content of the Amazon crab-eating fox (Figure 2).

Among the reptiles, one specie of lizard and six species of snakes were identified: the *Ameiva ameiva* (Linnaeus, 1758), *Spilotes pullatus* (Linnaeus, 1758), *Dipsas catesbyi* (Sentzen, 1796), *Boa constrictor* (Linnaeus, 1758), *Oxyrhopus petolarius* (Linnaeus, 1758), *Anilius scytale* (Linnaeus, 1758), and *Oxybelis fulgidus* (Daudin, 1803). Within the Amphibia class, three species of amphibians were identified: *Rinella marina*, *Amphisbaena amazonica* and *Proceratophrys concavitympanum*. An amphibian belonging to the family Hyllidae was also found in the stomach contents of the Amazon crab-eating fox.

Three mammalian species were identified: *Didelphis marsupialis* (Linnaeus, 1758), *Dasypus novemcinctus* (Linnaeus, 1758) and the exotic rodent *Rattus rattus* (Linnaeus, 1758), in addition to unidentified individuals belonging to orders Rodentia and Didelphimorphia.

3.2. Bromatological analysis

The nutritional contents found in the stomach content of *Cerdocyon thous* were: The dry matter (DM) ranged from

Table 1. Frequency of occurrence (FO) and percentage of occurrence (PO) of plant items, discriminating parts and items found in stomachs of crab-eating foxes in the Amazon rainforest.

Plants	Found item	N	FO (%)	PO (%)
Byrsonima crassifolia	Fruit	2	11.76%	3.51%
Bellucia grossularioides	Fruit	2	11.76%	3.51%
Cecropia sp.	Fruit	1	5.88%	1.75%
Physalis angulata	Fruit	2	11.76%	3.51%
*Mangifera indica**	Fruit	2	11.76%	3.51%
Poaceae	leaves	7	41.18%	12.28%
UI**	-	6	35.29%	10.53%

*exotic species; **unidentified.

Table 2. Frequency of occurrence (FO) and percentage of occurrence (PO) of animal items found in stomachs of crab-eating foxes in the Amazon rainforest.

Animals	Common names	N	FO (%)	PO (%)
INVERTEBRATES				
Order Odonata	dragonfly	2	11.76%	3.51%
Family Scolopendridae	centípede	1	5.88%	1.75%
UI*		2	11.76%	3.51%
AMPHIBIANS				
Rhinella marina (Linnaeus, 1758)	cane toad	1	5.88%	1.75%
Proceratophrys concavitympanum (Giaretta, Bernarde & Kokubum, 2000)	Darwin's frog	1	5.88%	1.75%
Family Hylidae	snouted treefrog	2	11.76%	3,51%
UI*		1	5.88%	1.75%
REPTILES				
Ameiva ameiva (Linnaeus, 1758)	giant ameiva	2	11.76%	3.51%
Oxybelis fulgidus (Daudin, 1803)	green vine snake	1	5.88%	1.75%
Spilotes pullatus (Linnaeus, 1758)	yellow rat snake	1	5.88%	1.75%
Dipsas catesbyi (Sentzen, 1796)	ornate snail-eater	2	11.76%	3.51%
Boa constrictor (Linnaeus, 1758)	common boa	1	5.88%	1.75%
Oxyrhopus petolarius (Linnaeus, 1758)	false coral	1	5.88%	1.75%
Anilius scytale	american pipe snake	1	5.88%	1.75%
*Amphisbaena amazonica (*Vanzolini, 1951)	amphisbaenian	1	5.88%	1.75%
Lacertilia	lizard	1	5.88%	1.75%
BIRDS				
UI*		2	11.76%	3.51%
MAMMALS				
Didelphis marsupialis (Linnaeus, 1758)	opossum	1	5.88%	1.75%
Dasypus novemcinctus (Linnaeus, 1758)	armadillo	1	5.88%	1.75%
*Rattus rattus*** (Linnaeus, 1758)	black rat	3	17.65%	5.26%
Order Rodentia	unidentified	6	35.29%	10.53%
Family Didelphidae	unidentified	1	5.88%	1.75%

*unidentified; **exotic species.

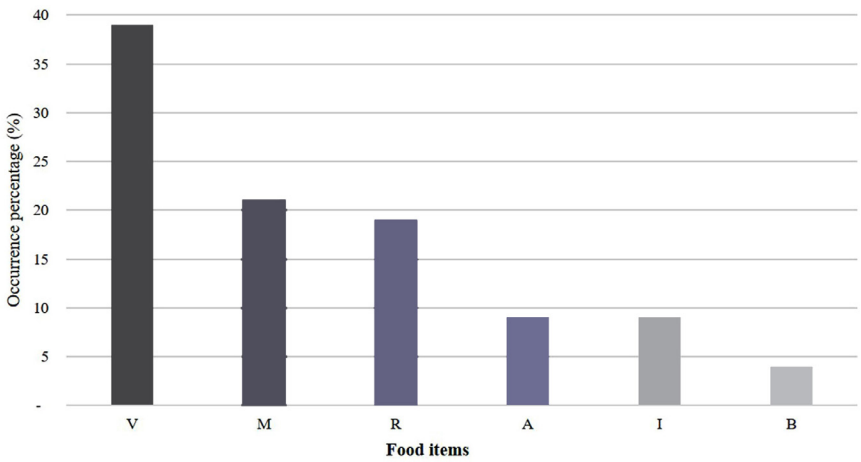

Figure 2. Percentage of occurrence of food items in the diet of the crab-eating fox, *Cerdocyon thous,* according identified taxa, in the Amazon rainforest in southeastern Pará, Brazil. V. vegetables, M. mammals, R. reptiles, A. amphibians, I. invertebrates, B. birds.

14.21% to 23.87%, with an average of 18.85% ± 3.62; crude protein (CP) varied between a minimum of 18.10% and a maximum of 35.12%, with an average of 27.75% ± 7.15; the ether extract (EE) between a minimum of 1.22% and a maximum of 7.28%, with an average of 3.52% ± 2.32, and the crude fiber (CF) between a minimum of 49.99% and a maximum of 76.89%, with an average of 62.76% ± 9.09. The mineral matter (MM) ranged from 0.032% to 0.080%, with an average of 0.059% ± 0.016.

The nitrogen-free extractive (NFE) was 5.91%, and the metabolisable energy (ME) was 141.82 kcal/100g of food. Considering the average metabolic weight of the animals studied, it was possible to verify the maintenance energy requirement of 447.01 kcal/day.

4. Discussion

The diet of crab-eating fox (*Cerdocyon thous*) has been reported in several Brazilian geographic areas such as Cerrado (Juarez and Marinho-Filho, 2002), southeastern Brazil (Gatti et al., 2006), southern Brazil (Rocha et al., 2004; Pedó et al., 2006; Rocha et al., 2008), Pampa (Bossi et al., 2019), and Caatinga (Dias and Bocchiglieri, 2016; Souza et al., 2021). However, this is not specific to the Amazon basin, because, generally this animal is not common distributed in this biome (Facure et al., 2003), being this the first report on diet of the crab-eating fox that inhabits the Brazilian Amazon.

In the region analyzed in this study, the crab-eating fox showed a generalist feeding habits, with an omnivorous diet, without food preference, being composed of invertebrates, amphibians, reptiles, birds, small mammals, fruits and grasses. This feeding habit observed in the stomach content of *C. thous* corroborates with that reported for crab-eating foxes that inhabit the Atlantic Forest (Facure et al., 2003), southern Brazil (Rocha et al., 2004; Pedó et al., 2006; Rocha et al., 2008), Cerrado (Juarez and Marinho-Filho, 2002), and Caatinga (Dias and Bocchiglieri, 2016). This diversity in the feeding habit can be explained by the fact that the animal consumes the most abundant food resources (Courtenay and Maffei, 2004; Pedó et al., 2006).

In this study, the consumption of Poaceae leaves was higher than other kinds of leaf, and this may be related to the function of aid food digestion of the animal (Motta-Júnior et al., 1994; Rocha et al., 2004; Pedó et al., 2006). Although gramineae represent little or no importance for energy return (Dietz, 1984), they are usually common items found in the crab-eating foxes diet (MacDonald and Courtenay, 1996; Rocha et al., 2004; Pedó et al., 2006; Dias and Bocchiglieri, 2016).

The food content of vegetable origin was also characterized by the presence of fruits such as murici fruits (*Byrsonima crassifolia*), mess apple (*Bellucia grossularioides*) and cape gooseberry (*Physalis angulata*), demonstrating the species potential for seed dispersal, which emphasizes its ecological importance in the ecosystems in which it is inserted (Courtenay and Maffei, 2004). Dias and Bocchiglieri (2016) reported that the fruits are an important item in crab-eating fox diet. Cazetta and Galetti (2009) claimed that the crab-eating fox act as a secondary disperser of *Eugenia umbelliflora* (Myrtaceae), being important for the recruitment of plants in a forest of Restinga in southeastern Brazil. The crab-eating fox was also considered as seed disperser in the Brazilian Caatinga (Souza et al., 2021).

The presence of invertebrates was uncommong in the stomach contents of the animals in this study, and probably, it was associated more with accidental ingestion than a preference for this item, since the species feeds on insects, while looking for other foods. Facure et al. (2003) claimed that insects may be ingested accidentally with fruit or carrion.

Mammals and reptiles corresponded to the most constant groups of vertebrates in the stomach content of crab-eating fox of this study. The presence of mammals such as armadillo (*Dasypus novemcinctus*) and opossum (*Didelphis marsupialis*) in the crab-eating fox diet reflects an opportunistic habit of the species (Pedó et al., 2006; Lemos and Facure, 2011). Facure et al. (2003) reported that opossums, rabbits and cavies were the largest prey of the *C. thous* in the Mantiqueira Range. Moreover, in this study, wild rodents were the most frequent and important items in the *C. thous* diet. Small rodent species were also the most important food item in the diet of the crab-eating fox in a suburban area of southern Brazil (Pedó et al., 2006). Therefore, the presence of exotic rodent such as *Rattus rattus* found as a food items was observed in this study, which is not in agreement with previous observations to the crab-eating fox (Gatti et al., 2006; Pedó et al., 2006; Rocha et al., 2008). Gatti et al. (2006) reported the presence of *Rattus rattus* as a food item in raccoon (*Procyon cancrivorus*) scats, which is other Neotropical carnivore. Probably, this is can be explained by the opportunistic habit of the crab-eating fox which in anthropogenic environments, it may feed on these rodents, as the area of this study was close to human communities.

Reptiles such as snakes were the second most frequently consumed vertebrates in the stomach contents of the Amazon crab-eating foxes. Snakes have been identified in the diet of the crab-eating foxes (Juarez and Marinho-Filho, 2002; Facure et al., 2003; Gatti et al., 2006; Rocha et al., 2008). In addition, there are studies that claimed that this Neotropical canid can prey on snakes. Gonzalez et al. (2016) reported a predatory event of *C. thous* upon the water snake *Erythrolamprus miliaris*. Silva et al. (2018) also described a cooperative predation by two crab-eating foxes upon an adult short-tailed boa (*Boa constrictor amarali*) at a Brazilian Cerrado.

Due to the fact that the crab-eating foxes withstand anthropic interference in their habitat, in some cases they take advantage of the greater supply of food provided by close contact with the human species (Courtenay and Maffei, 2004). On the other hand, Lima (2017) verified the food preference of *Cerdocyon thous* in remnant of the Atlantic Forest and demonstrated the effect that the nutritional quality of the resources and the competition for interference of a co-specific exercise on the selective feeding behavior and, despite being considered a generalist species in its feeding habit, the crab-eating fox has a preference for the item with the greatest nutritional value.

According to the National Research Council (NRC, 2006), to obtain the nutritional value of food, food composition

tables can be used or estimated using bromatological analysis and the use of appropriate equations. However, studies with bromatological analysis of the stomach contents of wild animals are scarce, making comparisons difficult. Bromatological analyzes are necessary, as they provide subsidies to infer the nutritional requirements of species in free life, aiming to contribute to the conservation of species kept in captivity, through the formulation of specific and appropriate rations for each stage of development of the animal in captivity.

For a species of omnivorous habit, such as the crab-eating fox, the need for animal protein, lipids and energy can be a determining factor for its survival and performance as a predator, since they are nutrients that are difficult to acquire in nature, similar to other carnivorous animals (Clauss et al., 2010).

In the present study, the values observed for crude fiber (CF) are considered high, when compared to the values for domestic dogs (NRC, 2006), in which diets must contain a maximum of 8% CF. Apparently, the high CF content may be associated with the constant presence of gramineae in the stomach content, combined with the low digestion capacity of the fiber in the stomach and the low nutritional value of tropical forages. These data show the influence of this low dry matter digestibility on the reduced content of crude protein (CP) and minerals (Euclides, 1995).

The stomach contents of the bush dogs (*Spheotus venaticus*) run over in the Carajás National Forest presented crude protein (CP) of 38.35%, ether extract (EE) of 6.21%, and mineral matter (MM) of 55.43% (Nobre, 2016). The lowest level of CP and MM obtained in the present study in relation to reported to the bush dogs, may be associated with the different feeding habit of the species, since the bush dog in nature is strictly carnivorous, thus presenting higher levels of CP and MM, while the crab-eating fox is an omnivorous canid, having a more diversified diet.

The composition of the diet of the free living crab-eating fox showed to be diversified, presenting food items belonging to the different taxonomic groups, having a greater diversity of items of animal origin. Although the crab-eating fox of this study inhabits a characteristic biome, the Amazon rainforest, its diet were not very different from those reported for this species in other Brazilian geographic regions (Juarez and Marinho-Filho, 2002; Facure et al., 2003; Rocha et al., 2004; Gatti et al., 2006; Pedó et al., 2006; Rocha et al., 2008), suggesting that although the crab-eating foxes may inhabit different biomes, their diet is very similar and the crab-eating foxes found in the Amazon basin are generalists with an omnivorous diet. Furthermore, through these findings, it is also suggested which dietary components are pivotal for nutrition of animals kept in captivity, since in captivity, the crab-eating foxes receive a food similar to the domestic dog.

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