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Diet and seed dispersion of the crab-eaten fox, *Cerdocyon thous* (Linnaeus, 1766) in Restinga de Jurubatiba National Park, Rio de Janeiro State, Brazil

Dieta e dispersão de sementes pelo cachorro-do-mato, *Cerdocyon thous* (Linnaeus, 1766), no Parque Nacional da Restinga de Jurubatiba, Estado do Rio de Janeiro, Brasil

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Abstract

This article aims to investigate the diet and seed dispersion of the crab-eaten fox, *Cerdocyon thous* (Linnaeus, 1766), in the Restinga de Jurubatiba National Park, Rio de Janeiro State, Brazil trough the analysis of fecal samples collected in two seasons of the year. During a period of four years, 28 fecal samples of *Cerdocyon thous* were collected in different parts of Restinga de Jurubatiba, being 19 out of them from dry season and nine from rainy season. In each season and between seasons, data analysis showed that invertebrates, vertebrates and fruits consumption did not significantly differ. Among vertebrates, mammals were the most eaten item (50%) in relation to reptiles (43%) and birds (32%). The rice-rat, *Cerradomys subflavus,* and the collared-lizard, *Tropidurus torquatus*, were mainly eaten during the rainy season, whereas birds, during the dry season. Furthermore, the only item identified that differed among seasons was the lizard *Tropidurus torquatus* that appeared in 77.8% of samples derived from the rainy season and 21.0%, in those from the dry season, with a total frequency of 39.3%. In relation to seed dispersion, five species found in lees were identified and their viabilities were evaluated through germination tests in Petri dishes. Excepting for Brazilian cherry (*pitanga*), *Eugenia umbelliflora*, from which 56% of the seeds germinated, no other seed species consumed have germinated after passing through the *C. thous* digestive tract.

Key words: *Cerdocyon thous,* diet, vertebrates, *Tropidurus torquatus,* digestive tract, seeds.

Resumo

Este artigo visa investigar a dieta e a dispersão de sementes do cachorro-do-mato, *Cerdocyon thous* (Linnaeus, 1766), no Parque Nacional da Restinga de Jurubatiba, Estado do Rio de Janeiro, Brasil, através da análise de amostras fecais coletadas em duas estações do ano. Durante o período de quatro anos, 28 amostras fecais de *Cerdocyon thous* foram coletadas em diferentes partes da Restinga de Jurubatiba, sendo 19 delas na estação

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seca e nove na chuvosa. A análise dos dados mostrou que o consumo de invertebrados, vertebrados e frutos não diferiu significativamente entre as estações. Entre os vertebrados, os mamíferos foram os itens mais consumidos (50%) em relação aos répteis (43%) e aves (32%). O rato-do-arroz, *Cerradomys subflavus*, e o lagarto, *Tropidurus torquatus*, foram consumidos principalmente durante a estação chuvosa, enquanto as aves, durante a estação seca. Além disso, o único item identificado que diferiu entre as estações foi o lagarto *Tropidurus torquatus*, que ocorreu em 77,8% das amostras obtidas na estação chuvosa e em 21,0% na estação seca, com uma frequência total de 39,3%. Em relação à dispersão de sementes, cinco espécies encontradas na amostras fecais foram identificadas, e suas viabilidades foram avaliadas através de testes de germinação em placas de Petri. Com exceção da pitanga, *Eugenia umbelliflora*, da qual 56% das sementes germinaram, não ocorreu germinação das demais espécies após terem passado pelo trato digestivo de *C. thous*.

Palavras-chave: *Cerdocyon thous,* dieta, vertebrados, *Tropidurus torquatus,* trato digestório, sementes.

Introduction

Except for some parts of the Amazon, the crab-eaten fox, *Cerdocyon thous,* has a wide geographical distribution, being found from Uruguay, and Northern Argentina up to Brazil, Bolivia, Venezuela, Colombia and Guyana (Crespo, 1984; Wilson and Reeder, 1993). It has a twilight and nightly habits, being usually observed foraging lonely or in pairs (Bergallo *et al*., 2004; Peracchi *et al.,* 2002).

The few works about *C. thous* indicate an omnivorous diet, constituted by fruits, arthropods and small vertebrates, mainly rodents (Gatti *et al*., 2006; Juarez and Marinho-Filho, 2002; Peracchi *et al*., 2002; Rocha *et al*., 2004c). Despite being a common species in South America, there are little information about its food habits and its role as a seed disperser.

Animals' basic prerequisites for seed dispersal is that they don't destroy the seeds of fruits consumed, carrying them still viable for suitable sites for germination (Schupp, 1993). After passing through the digestive tract, further evaluation of the germination rate is the first step in determining whether an animal is a good disperser or not (Galetti *et al.,* 2003).

The hypothesis of this study is that *C. thous*'s diet could differ in a different environment such as a sandbank (*restinga*), with well defined dry and rainy seasons (Henriques *et al.,* 1986). Another expectation was that this canid is an efficient seed disperser, as it is an animal that consumes several kinds of fruit, as well as, travels great distances (Cheida *et al*., 2006).

The aim of this work is to study the diet of the crab-eaten fox in a salt marsh/sandbank area (*restinga*). It was also evaluated if this canid's diet changed during different seasons. It was investigated the *C. thous* role as a seed disperser by testing the seed viability after having passed through the animal digestive tract.

Material and methods

Study area

Restinga de Jurubatiba National Park is located in Northern Rio de Janeiro coastline, comprehending Macaé, Carapebus and Quissamã counties. The park has a total area of 144,5 km² (coordinates 22°16´57.38´´S, 41°40´15.93´´W), formed by a coastline sandy plain, representing the largest salt marsh/sandbank area of Rio de Janeiro State and one of the largest in Brazil (Rocha *et al*., 2003, 2004a).

Rain distribution is strongly linked to seasons, with a monthly minimum during the winter (41 mm) and a maximum during the summer (189 mm) (Henriques *et al.,* 1986). The year mean temperature is 22.6°C, having its maximum in January (29.7°C) and minimum in July (20.0°C) (Henriques *et al*., 1986). According to the ombrothermic diagram (Araújo and Henriques, 1984), the dry season occurs from May to August and the rainy season, from November to March.

There are 10 plant communities in the park, which occurrences are associated to topographic variations (Araújo *et al.,* 2004). The largest and best studied is the "*Clusia* opened formation", occupying about 40% of the park total area (Henriques et *al*., 1986). This formation is constituted by thick bushes of various sizes, intercalated by bare sand corridors where plant covering is sparse.

The most frequent plants among the shrubby extract of *Clusia* opened formation are *Clusia hilariana* (Clusiaceae), *Protium icicariba* (Burseraceae), *Myrcia lundiana* (Myrtaceae), *Erytroxylum subsessile* (Erithroxylaceae), *Myrsine parvifolia* (Myrsinaceae), *Ocotea notata* (Lauraceae) and *Eugenia umbelliflora* (Myrtaceae) (Araújo *et al*., 2004).

Diet analysis

Cerdocyn thous lees were collected between November 2001 and February 2005, not in a systematic but in a random way. Collects occurred in the proximity of five distinct lagoons (Cabiúnas, Amarra-Boi, Garças, Comprida and Visgueiro), but always in *Clusia* opened formation.

Those lees that were found and presented a good preservation state, were removed.

We consider in good preservation state those lees that, apparently, had not been touched by other animals (which could remove sample items), and those that do not show a dried up aspect and present its original shape. The majority of lees was found in bare sand, nearby bushes and always followed by *C. thous* footprints. Lees were placed in plastic bags marked with the date and gathering place. In the laboratory, those lees were washed in running water with a nylon sieve with a net of 1 mm and, afterwards, scrutinized with a magnifying glass.

Those items of the animal's origin and seeds found in the lees were identified in the lowest classification level possible. Remains of mammals and reptiles were identified in UERJ, comparing their hair or scale with those of previously collected species. Birds were identified by bones and feathers' fragments. Arthropods were classified in orders; especially with the help of legs and heads. For their identification, seeds found in lees were compared to those of a seed bank in Restinga de Jurubatiba National Park. Relative frequency of each item found in samples was calculated dividing lees number, where each item occurred, by the total of the collected lees. Relative frequencies of invertebrates, vertebrates and fruits were compared during and between seasons using Kolmogorov-Smirnov non-parametric test (Zar, 1984). All tests were calculated in the software Systat 11.0.

Seeds viability

Seeds found in lees were identified and their viability was evaluated in the laboratory through germination tests in Petri dishes. Petri dishes were covered with filter paper, which was wetted with tap water. The number of seeds taken from *C. thous* lees for the germination test varied according to the frequency that these seeds were found in samples, but almost all of them were tested. Some seeds were separated for identification.

Light intensity was kept similar to the place where the fecal samples had been collected. No chemical product was used for seeds preservation, being the germination condition the most possibly similar to that one found in the field. Part of the seeds, taken directly from ripe fruits in the field, was placed to germinate in the same conditions and period of the preceding ones, serving, this way, as a control.

It was impossible to obtain a large number of independent samples as it would be one seed for lees or fruit. The number of seeds tested in the control was more than five per fruit, and when possible in different individuals. This measure was taken to prevent that seed coming from fruits with high or low germination added different numbers in the analysis, making the results biased.

Taken directly from the fruits and using chi-square, results of seeds germination were compared, to those obtained in the seeds that derived from the crab-eaten fox lees in order to verify if that animal influenced the rates of seed germination that passed through its digestive tract.

Results

Diet analysis

In different parts of Restinga de Jurubatiba, during the period from 2001 until 2005, 28 fecal samples of *Cerdocyon thous* were collected being 19 out of them from dry season and nine from rainy season. Among vertebrates, mammals were the most eaten items (50%) in relation to reptiles (43%) and birds (32%). The rice-rat, *Cerradomys subflavus*, and the collared-lizard, *Tropidurus torquatus*, were mainly eaten during the rainy season, whereas birds, in the dry season. Among invertebrates, Orthoptera were the most eaten item during the rainy season (44%) and dry season (47%). Fruits species consumed by the crab-eaten fox varied a lot in relation to frequency (Table 1). Species of Polygonaceae and Myrtaceae families were the most frequent in *C. thous*' lees.

Invertebrates, vertebrates and fruits consumption was not significantly different in each season and between seasons (Tables 2 and 3). In addition, the only item identified that differed among seasons was the lizard *Tropidurus torquatus*, that appeared in 77.8% of the samples derived from the rainy season, and 21.05% in those from the dry season, with a total frequency of 39.3% (Table 1). Birds and small mammals were quite representative items, being mammals more eaten than birds mainly in the rainy season. The rodent *Cerradomys subflavus* was quite consumed by *C. thous,* appearing in both rainy and dry seasons, and presenting frequencies of 44.4% and 31.6% respectively (Table 1).

Seed viability

For seed germination tests, we used just five fruit species consumed by the crab-eaten fox, once only in that area it was possible to collect the fruits from those species to serve as control and to check the precise identification. The species used were: *Passiflora mucrunata*, *Pilosocereus arrabidae*, *Ficus tomentela*, *Coccoloba confusa*, and *Eugenia umbelliflora.* Excepting for *Eugenia umbelliflora*, from which 56% of the seeds germinated, no other seed species consumed have germinated after passing through *C. thous* digestive tract (Table 4). Furthermore, *Ficus tomentela* was the only species in which seeds, taken directly from the plant, did not germinate. And also, *Pilosocereus arrabidae* and *E. umbelliflora* presented high germination rates, 86% and 62% respectively, in the experience control (Table 4).

The rates of seeds germination for *P. mucrunata, F. tomentela* and *E. umbelliflora* after passing through

Table 1. Number of times that one item was found in crab-eaten fox diet and its percentage (%) during dry and rainy seasons in Restinga de Jurubatiba National Park. Abbreviations: NI, not identified; SP, plant species not identified.

Taxonomic category	dry	%	Rainy	%	total	%
	Invertebrates					
Araneae	2	10,52	0	0	2	7,14
Coleoptera	6	31,57	2	22,22	8	28,57
Orthoptera	9	47,36	4	44,44	13	46,42
Crustaceae						
Ocypode quadrata	3	15,78	2	22,22	5	17,85
Total of invertebrates	14	73,68	6	66,66	20	71,42
	Vertebrates					
Reptiles						
Tropidurus torquatus	4	21,05	7	77,77	11	39,28
Cnemidophorus litorallis	0	0	1	11,11	1	3,57
Typhlops brongersmianus	1	5,26	0	0	1	3,57
Mammals						
Cerradomys subflavus	6	31,57	4	44,44	10	35,71
Mammals NI	3	15,78	1	11,11	4	14,28
Birds NI	7	36,84	2	22,22	9	32,14
Vertebrates NI	0	0	3	33,33	3	10,71
Total of vertebrates	16	84,21	9	100	25	89,28
	Fruits					
Sapindaceae						
SP 1	0	0	1	11,11	1	3,57
SP 2	2	10,52	0	0	2	7,14
Rubiaceae						
Psychotria carthaginensis	3	15,78	0	0	3	10,71
Erythroxylaceae						
Erythroxylum ovalifolium	3	15,78	0	0	3	10,71
Polygonaceae						
Coccoloba confusa	6	31,57	3	33,33	9	32,14
Myrtaceae						
Eugenia umbelliflora	10	52,68	3	33,33	13	46,42
Eugenia sp	2	10,52	1	11,11	3	10,71
SP 3	4	21,05	0	0	4	14,28
Moraceae						
Ficus tomentela	1	5,26	3	33,33	4	14,28
Passifloraceae						
Passiflora mucrunata	0	0	2	22,22	2	7,14
Cactaceae						
Pilosocereus arrabidae	0	0	1	11,11	1	3,57
Total of fruits	17	89,47	7	88,88	25	89,28

Table 2. Significance levels of Kolmogorov-Smirnov test, comparing the frequencies of fruits, invertebrates and vertebrates consumed in dry season (values in the superior right corner), and rainy season (values in the inferior left corner).

	Fruits	Invertebrates	Vertebrates
Fruits	-	0.544	1.00
Invertebrates	0.495	-	0.657
Vertebrates	0.814	1.00	-

Table 3. Values of Kolmogorov-Smirnov (KS) test and significance level (P) for the comparison of invertebrates, vertebrates and fruits consumption between dry and rainy seasons.

Taxonomic category	KS	P
Invertebrates	0,600	0,320
Vertebrates	0,286	0,919
Fruits	0,364	0,421

Table 4. Total of seeds put to germinate (Total) and that have germinated (Germinated). Seeds that were collected directly from the plant (Control) or from *Cerdocyon thous*' lees.

Species	Control		Lees	
	total	germinated	total	germinated
Passiflora mucrunata	200	23	22	0
Pilosocereus arrabidae	200	172	36	0
Ficus tomentela	200	0	100	0
Coccoloba confusa	50	15	62	0
Eugenia umbelliflora	50	31	50	28

C. thous digestive tract do not differ significantly from experience control (X^2 =2.82, p>0.05; X^2= 0, p>0.05; X^2 = 0.37, p >0.05, respectively). The rates of seed germinations for *P. arrabidae* and *C. confusa* after passing through *C. thous* digestive tract were negatively affected when compared with the experience control (X^2=114.17, p<0.05 and X^2=12.418, p< 0.05, respectively).

Discussion

In Restinga de Jurubatiba National Park, the diet of *C. thous* showed to be quite diversified, including fruit, vertebrate and invertebrate consumption, just as described in literature (Juarez and Marinho-Filho, 2002; Peracchi *et al*., 2002; Rocha *et al.,* 2004c). Although invertebrates have contributed with a high frequency, it was not an item that presented a great biomass in lees, for in the majority of cases they appeared just as traces in lees. On the other hand, the invertebrate traces that appeared could just be the non-digestible parts and represented important protein resources.

Ghost-crab, *Ocypode quadrata,* consumption is supposed to be restricted to the individuals that forage in the beach, once this crab is seen there, by twilight or sooner in the morning. Footprints of *Cerdocyon thous* were easily identified on the beach in the morning where they forage.

The great consumption of the rice-rat *Cerradomys subflavus* was already expected, considering the fact that rodents were the most common vertebrate in *Cerdocyon thous*'s diet previously described (Delgado and Zurc, 2007; Facure *et al*., 2003; Juarez and Marinho-Filho, 2002; Pedó *et al*., 2006; Peracchi *et al*., 2002; Rocha *et al.,* 2004c; Rocha *et al*., 2008; Uchoa and Moura-Britto, 2004). In addition, *C. subflavus,* besides occurring in, at least, five plant formations found in Jurubatiba is also the most abundant rodent in all the open formations that have been studied in Restinga de Jurubatiba, except in the wood (Bergallo *et al.,* 2004). Yet, the fact that lees have been collected in *Clusia* opened formation does not mean that the crab-eaten fox fed exclusively in this formation.

Lizard consumption by *C. thous* was very high, if compared to other works, which had its frequency ranging from zero to 16.7% (Delgado and Zurc, 2007; Facure *et al*., 2003; Juarez and Marinho-Filho, 2002; Pedó *et al*., 2006; Peracchi *et al*., 2002; Rocha *et al.,* 2004c; Rocha *et al*., 2008; Uchoa and Moura-Britto, 2004). Probably, it can be ascribed to the lizard great abundance in salt marsh/sandbank areas as it occurs in Restinga de Jurubatiba (Rocha *et al.,* 2004b). The great number of *Tropidurus torquatus* consumed by *C. thous* in the rainy season was unexpected. According to Rocha *et al.* (2004b), *T. torquatus* is the most abundant lizard in the area and has a bimodal pattern of activity. During the rainy season, this lizard presents activity peaks in the middle of the morning and afternoon, remaining active even after sunset (Hatano *et al.,* 2001; Rocha *et al.,* 2002; Rocha *et al.,* 2004b). Therefore, the lizard activity pattern overlaps with the beginning of *C. thous* forage time. According to Tortato and Althoff (2009), the *C. thous*'s activity is basically nocturnal (54%) and crepuscular (25%), and the records made during the day (21%) are more frequent before 9:00 am and after 17:00 pm hours. During the cold and dry season, this overlap between *T. torquatus and C. thous* forage activities possibly occurs in a smallest intensity, once the lizard concentrates the greatest part of its activity by midday (Hatano *et al.,* 2001; Rocha *et al.,* 2004b).

Germination of seeds that were taken directly from the lees was not as efficient as those presented in other

works, such as Cheida (2002), Peracchi *et al.* (2002), and Rocha *et al.* (2004c). In this study, seeds of *F. tomentela* did not germinate after having passed through the *C. thous* digestive tract. The germination rates of seeds for *P. arrabidae* and *C. confusa* after having passed through the *C. thous* digestive tract were negatively affected when compared with the experience control. Although only Brazilian cherry (*pitanga*) has germinated in laboratory tests, this fact does not invalidate *C. thous*'s activities as a seeds disperser, once all seeds excreted by this animal have been found without apparent damage, and also because, as other works had shown, *C. thous* is a good seed disperser in other environments (Cheida, 2002; Peracchi *et al.,* 2002; Rocha *et al.,* 2004c).

Lack of other seeds germination can be related to the spot where lees were deposited. During summer, the sandy soil of *Clusia* opened formation, where lees were collected, can reach temperatures up to 60°C (Rocha *et al.,* 2004b). Hence, lees are subjected to high temperatures, which can possibly damage the viability of some seeds. However, lees were not found in bushes, or in woods, where the action of high temperatures on the excreted seeds would be lesser. To evaluate if this fact really occurs, it would be important to test the hypothesis that lees released in more closed environments, and, consequently, having less exposition to sunstroke, would have seeds with larger germination rates. On the other hand, two hypotheses cannot be discarded: (i) that such seeds can tolerate high temperatures, but *C. thous* is not an effective disperser of those plants; and (ii) that, for those plants eaten by *C. thous*, the break of seeds dormancy happens in high temperatures found in the sand. In the laboratory, this extreme situation could not be kept up during germination tests.

The reason that lees were not found in shady regions of Restinga de Jurubatiba can be attributed to the fact that *C. thous* forages more in *Clusia* opened formation than in other plant formations. This hypothesis is based in the following observations: (i) a greater extension of tracks in *Clusia* opened formation; (ii) a greater dominance of *C. subflavus* lees among mammals, and of *Tropidurus torquatus* among lizards; and (iii) a greater abundance of fruits consumed by *C. thous,* such as *Eugenia umbelliflora, Coccoloba confusa* and *Erythroxylum ovalifolium* (Araújo *et al.,* 2004), besides *Passiflora mucrunata* and *Pilosocereus arrabidae*, that are found in open areas. The first observation can be tendentious, since the tracks visualization is easier in open areas than in bushes or woods.

Actually, this explains, partly, why lees were not found in the shady regions of the park. Moreover, the effort undertaken in these areas was lesser, because it was impossible to follow the *C. thous*' footprints when they leave the bare sand shifting into the bushes and woods. The second and third observations are those that seem to corroborate with the hypothesis that *C. thous* forages mainly in *Clusia* opened formation, since *T. torquatus, C. subflavus* as well as the plant species occur in larger quantity in that *Clusia* opened formation (Araújo *et al.,* 2004; Bergallo *et al*, 2004; Rocha *et al.,* 2004b). Moreover, this formation encompasses an extensive area in the Park.

The present work showed that there were no significant differences in the frequencies of consumed items during or between seasons, and suggests that the greater frequency of specific items can be associated to *Cerdocyon thous* differentiated use of its habitat. This study also showed that *Cerdocyon thous* is not an efficient seed disperser in the most exposed areas of Clusia opened formation.

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