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NOTA BREVE / SHORT NOTE

ZOOLOGÍA

DIURNAL FEEDING BEHAVIOUR OF CRAB-EATING RACCOON UPON A PARADOXAL FROG, WITH A REVIEW OF ITS DIET

Alimentación diurna del mapache cangrejero sobre una rana paradoxal, con una revisión de su dieta

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ABSTRACT

The crab-eating raccoon (*Procyon cancrivorus*) is considered one of the less-studied Neotropical carnivores. Observations about its behavior are difficult as it is mainly nocturnal, shy, and inconspicuous. This species is considered opportunistic, with a frugivorous-omnivorous diet. It is known to feed on fruits and invertebrates as well as small mammals and lizards. Herein, we describe a first direct observation of a crab-eating raccoon hunting for frogs during the daytime. It is also a first record of predation on a paradoxal frog (*Pseudis platensis*) by *P. cancrivorus*. We further present a detailed literature review about its diet. We compiled a total of 14 papers published from 1986 to 2019, including eight studies that characterize the diet of *P. cancrivorus*. According to these studies, the diet of *P. cancrivorus* constitutes of 35 vegetal taxa and 96 animal taxa. Thus, the here presented record of predation on a frog by *P. cancrivorus* is not only the first visual description of this behavior, it also reinforces the knowledge about its generalist and opportunistic diet. It is further the first evidence of the daytime behavior for the crab-eating raccoon in the Pantanal.

Keywords: Pantanal, *Procyon cancrivorus*, *Pseudis platensis*, trophic ecology.

RESUMEN

El mapache cangrejero es considerado uno de los carnívoros neotropicales menos estudiados, debido a sus hábitos nocturnos y discretos que dificultan las observaciones sobre su comportamiento. Esta especie es considerada una especie frugívora-omnívora, con hábitos oportunistas, que se alimenta desde invertebrados hasta otros mamíferos y lagartos. En este documento, proporcionamos un nuevo informe de depredación por un mapache cangrejero sobre una rana paradójica (*Pseudis platensis*) y presentamos una revisión bibliográfica detallada sobre su dieta. Recopilamos un total de 14 artículos publicados de 1986 a 2019, de los cuales se utilizaron ocho estudios para caracterizar la dieta de *P. cancrivorus*. La dieta de *P. cancrivorus* estuvo constituida por 96 taxones animales y 35 vegetales. Nuestro registro de depredación sobre una rana refuerza la dieta generalista y oportunista conocida de *P. cancrivorus* y es además la primera evidencia de actividad diurna para el mapache cangrejero en el Pantanal y el primer informe de depredación sobre *P. platensis* por parte de un mamífero.

Palabras clave: Ecología trófica, Pantanal, *Procyon cancrivorus*, *Pseudis platensis*.

The crab-eating raccoon (*Procyon cancrivorus*) is a medium-sized nocturnal carnivore widely distributed in the Neotropics, from Costa Rica to Uruguay. It inhabits forested and open areas, generally associated with limnic systems (González *et al*., 2010). Due to its nocturnal and inconspicuous behavior, the crab-eating raccoon is considered one of the less-studied Neotropical carnivores. The species is opportunistic, and its omnivorous diet (Paglia *et al*., 2012) includes fruits and invertebrates as well as small mammals and lizards (e.g., Gatti *et al.,* 2006; Quintela *et al*., 2014; Dias and Bocchiglieri, 2015). In this paper, we investigate the diet of *P. cancrivorus* and report a predation event by *P. cancrivorus* upon a paradoxal frog (*Pseudis platensis*) in the Southern Pantanal.

We searched for studies in the Web of Science (<https://webofknowledge.com/ >) and Scopus (< https://www.scopus.com >) databases, using the keywords '*Procyon cancrivorus*' AND 'Diet*' OR 'feed*' OR 'trophic ecology* up to 2019. Besides, we gather all data from direct searches of references in Google Scholar (https://scholar.google.com.br/). Among these compiled references, we selected only studies presenting absolute data on the diet of *P. cancrivorus*.

We compiled a total of 14 papers published from 1986 to 2019, with eight publications characterizing the diet of *P. cancrivorus*. Seven studies were performed in Brazil, distributed in Northeast, Southeast, and South, and only one study was performed in Venezuela with multiples localities. These studies accessed *P. cancrivorus* diet, analyzing fecal samples and stomach content. According to these studies, the diet incorporates 96 animal taxa and 35 vegetal taxa (Supplementary material. *Aratus* sp. (Brachyura: Decapoda) and *Syagrus romanzoffiana* (Arecaceae) were reported to be the animal and plant most abundant in the diet of *P. cancrivorus*. Coleoptera and Orthoptera were the items most frequent among six of the eight studies compiled.

Besides this information from existing literature, were here report a direct observation on *P. cancrivorus* foraging in a freshwater lake at Fazenda Barranco Alto Lodge in the Southern Pantanal, municipality of Aquidauana, Mato Grosso do Sul (19°34'S, 56°8' W, 114 m.a.s.l). The observation occurred by chance during fieldwork on 4 Jun 2011 from 07:10 am to 07:19 am. An adult *P. cancrivorus* was observed while it was catching anurans in a lagoon. The species was foraging among aquatic macrophytes, moving its hands quickly back and forth to feel possible catch underneath the water plants. It was hunting exclusively haptic and did not try to move the plants to the side to visualize possible prey in the water. In this manner, the raccoon captured and ate six anurans during nine minutes of observation. Only one of these anurans preyed by *P. cancrivorus* could be identified as the paradoxal frog (*Pseudis platensis*) (Fig. 1), an aquatic diurnal/nocturnal hylid that occurs in permanent and semi-permanent ponds (Dixon *et al.,* 1995). Paradoxal frog could be identified by its medium size (greater than *Lysapsus limmelum*, another aquatic hylid) and by the coloration of its thigh, with thick dark lines (Garda *et al*., 2010) (Fig.1c). This is the first visual record of *P. cancrivorus* feeding upon an anuran and the first report of predation upon *P. platensis* by a mammal.

Despite the wide distribution of *P. cancrivorus*, dietary studies were concentrated in Brazil, mainly in Protected Areas (e.g., Santos and Hartz, 1999; Gatti *et al*., 2016). The elevate abundance of *Aratus* sp. (n = 114) can be related to the mangrove environment where this species is common (Novaes, 2002). *Syagrus romanzoffiana* is a common palm in a semideciduous forest in South Brazil and frequently is reported in dietary studies of mammals like squirrels, tapirs, peccary, brown-nosed coatis and maned wolfs (e.g., Bueno and Motta-Junior, 2004; Keuroghlian and Eaton, 2008; Giombini *et al*., 2009). Fruits are produced throughout the year, showing ovoid shape (ca. 2.5 cm diameter), with a soft exocarp and woody endocarp (Galetti *et al*., 1992). The elevated frequency of Coleoptera and Orthoptera in *P. cancrivorus* diet is related to wide distribution and the great abundance of these orders in the environment, which facilitate their visualization and capture (Rafael *et al*., 2012).

Earlier studies on *P. cancrivorus* diet show an elevated number of aquatic preys (e.g., *Aratus* sp.), confirming that this species forages next to water (Trolle, 2003). In these analyses, on the diet of *P. cancrivorus,* anurans were identified only to the family level, with Bufonidae, Hylidae, and Leptodactylidae being cited. Thus, our record of *P. cancrivorus* preying on *P. platensis* was the first one to analyze the preyed anuran to species level.

Figure 1. (a-c) An adult crab-eating racoon (*Procyon cancrivorus*) searching and preying an adult paradoxal frog (*Pseudis platensis*) in a lagoon in Pantanal, Mato Grosso do Sul, Brazil. (Photos: Lydia Möcklinghoff)

Paradoxal frog has diurnal and nocturnal habits, vocalizing on the water surface, among macrophytes (Dixon *et al.,* 1995). Information on *P. platensis* natural history is scarce, with the majority being related to the diet of its giant tadpoles and on parasites (e.g., Emerson, 1988; Arias *et al.*, 2002; Campião *et al.*, 2010; Ceron *et al.*, 2017; Landgref Filho *et al.*, 2019). Reports of animals preying on adults of *P. platensis* include five bird species, another frog species, snakes, fishes, and caimans (Landgref-Filho *et al.*, 2019). Until now it was not known that also mammals hunt for this frog species. Our observation shows that the ability of the crab-eating raccoon to catch frogs in the water without visual reference, as recorded here, is possible due to the well-developed tactile abilities, using their forepaws skilfully, and other sensory skills of the species (Nowak and Walker, 1999). This tactile way of hunting might be especially of interest when hunting in the dark as *P. cancrivorus* is known to be mainly nocturnal, such as its congeners *Procyon lotor* (Greenwood, 1982). However, the observations here presented of diurnal foraging activity of *P. cancrivorus* are rare, also shows that the animal hunts in a tactile and not visual way during daytime and that this hunting strategy enables the animal to hunt in water with limited visibility and catch the frogs under the floating vegetation.

Few studies have reported diurnal habits to *P. cancrivorus* (Brooks, 1993; Carrillo and Vaughan, 1993; Gómez *et al.*, 2005). For the Pantanal, this is even the first evidence of a crab-eating raccoon being active during the daytime. Several factors may affect on activity times of raccoons, such as the hunting success in the previous night and individual fitness (Gehrt and Fritzell, 1998). Due to the difficulty to observe predatory events in nature, these records are an important source, as they directly contribute to the knowledge of a species' natural history. Our observation reinforces the known generalist and opportunistic diet of *P. cancrivorus*, gives new insides about the hunting strategy of this mammal species, and it is the first record of predation on *P. platensis* by a mammal.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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SUPPLEMENTARY MATERIAL

Table. Items reported in the diet of the crab eating racoon (*Procyon cancrivorus*) reported in the literature between 1986 and 2019. NI = not identified.

Taxon	Number of individuals	Reference
Animals		
Arthropoda NI	14	Quintela *et al.,* 2014
Araneae NI	2	Aguiar *et al.,* 2011; Bisbal, 1986
Belostomatidae	16	Quintela *et al.*, 2014
Blattodea	1	Aguiar *et al.,* 2011
Coleoptera	90	Bisbal, 1986; Dos Santos and Hartz, 1999; Gatti *et al.*, 2006; Aguiar *et al.,* 2011; Martinelli and Volpi, 2010; Quintela *et al.*, 2014; Dias and Bocchiglieri, 2015
Decapoda	3	Bisbal, 1986
Parastacus sp.	1	Dos Santos and Hartz, 1999
Brachyura	39	Quintela *et al.*, 2014
Aegla castro Schmitt, 1942	1	Aguiar *et al.*, 2011
Aegla sp.	2	Dos Santos and Hartz, 1999
Aratus sp.	114	Novaes, 2002
Armases sp.	28	Novaes ,2002
Callinectes sp.	17	Novaes, 2002
Cardisoma sp.	4	Novaes, 2002
Chasmagnathus sp.	100	Novaes, 2002
Dilocarcinus dentatus (Randall, 1840)	2	Bisbal, 1986
Goniopsis sp.	10	Novaes, 2002
Metasesarma sp.	35	Novaes, 2002
Sesarma sp.	48	Novaes, 2002
Ocypodidae	67	Martinelli and Volpi, 2010
Ocypode quadrata (Fabricius, 1787)	13	Gatti *et al.,* 2006
Ucides sp.	33	Novaes, 2002
Diplopoda	4	Quintela *et al.*, 2014
Hymenoptera	29	Quintela *et al.*, 2014; Dias and Bocchiglieri, 2015
Insecta NI	23	Gatti *et al.*, 2006; Dos Santos and Hartz, 1999; Aguiar *et al.,* 2011
Isopoda	6	Quintela *et al.* 2014
Isoptera	14	Dias and Bocchiglieri, 2015
Odonata	11	Dos Santos and Hartz, 1999; Aguiar *et al.*, 2011; Quintela *et al.,* 2014
Orthoptera	35	Bisbal, 1986; Dos Santos and Hartz, 1999; Gatti *et al.*, 2006; Aguiar *et al.*, 2011; Quintela *et al.*, 2014; Dias and Bocchiglieri, 2015
Scorpionida N I	10	Dias and Bocchiglieri, 2015

(*Continued*)

Taxon	Number of individuals	Reference
Bothriurus bonariensis (L. C. Koch, 1842)	1	Quintela *et al.*, 2014
Molluscs NI	1	Gatti *et al.,* 2006
Pomacea glauca (Linnaeus, 1758)	3	Bisbal, 1986
Pomacea sp.	46	Quintela *et al.*, 2014
Planorbidae	6	Quintela *et al.*, 2014
Mammalia NI	51	Dos Santos and Hartz, 1999; Quintela *et al.,* 2014
Artibeus sp.	1	Novaes, 2002
Sus scrofa Linnaeus, 1758	1	Quintela *et al.*, 2014
Dasypodidae	2	Quintela *et al.,* 2014
Didelphimorphia	1	Gatti *et al.,* 2006
Didelphis albiventris (Lund, 1840)	7	Quintela *et al.*, 2014
Didelphis sp.	9	Novaes, 2002
Metachirus sp.	5	Novaes, 2002
Rodentia	4	Dos Santos and Hartz, 1999; Gatti *et al.,* 2006; Aguiar *et al.,* 2011
Akodon sp.	5	Novaes, 2002
Cavia fulgida Wagler, 1831	3	Gatti *et al.*, 2006; Martinelli and Volpi, 2010
Cavia sp.	38	Novaes, 2002; Quintela *et al.,* 2014
Ctenomys sp.	1	Quintela *et al.*, 2014
Dasypus sp.	1	Gatti *et al.,* 2006
Myocastor coypus (Molina, 1782)	2	Quintela *et al.*, 2014
Nectomys sp.	11	Novaes, 2002
Oryzomys sp.	1	Gatti *et al.*, 2006
Rattus rattus (Linnaeus, 1758)	1	Gatti *et al.,* 2006
Scapteromys tumidus (Waterhouse, 1837)	3	Quintela *et al.*, 2014
Wiedomys pyrrhorhinus (Wied-Neuwied, 1821)	2	Dias and Bocchiglieri, 2015
Cricetidae	15	Quintela *et al.,* 2014
Holochilus brasiliensis (Desmarest, 1819)	3	Quintela *et al.,* 2014
Amphibia NI	3	Bisbal, 1986; Gatti *et al.*, 2006; Aguiar *et al.*, 2011
Anura	7	Quintela *et al.,* 2014
Bufonidae	5	Novaes, 2002
Hylidae NI	2	Novaes ,2002
Pseudis platensis Gallardo, 1961	1	This study
Leptodactylidae	3	Novaes, 2002
Reptil NI	1	Dos Santos and Hartz, 1999
Trachemys dorbigni (Duméril & Bibron, 1835)	2	Dos Santos and Hartz, 1999
Lizard NI	6	Gatti *et al.*, 2006; Dias and Bocchiglieri, 2015

(*Continued*)

Taxon	Number of individuals	Reference
Brasiliscincus agilis (Raddi, 1823)	2	Gatti *et al.*, 2006
Tropidurus gr. *torquatus*	4	Gatti *et al.,* 2006
Tropidurus hispidus (Spix, 1825)	4	Dias and Bocchiglieri, 2015
Tropidurus semitaeniatus (Spix, 1825)	1	Dias and Bocchiglieri, 2015
Teiidae NI	1	Bisbal, 1986
Ameiva ameiva (Linnaeus, 1758)	3	Gatti *et al.*, 2006
Salvator merianae Duméril & Bibron, 1839	1	Quintela *et al.*, 2014
Snake NI	1	Gatti *et al.,* 2006
Bothrops jararaca (Wied, 1824)	1	Gatti *et al.,* 2006
Colubridae NI	7	Gatti *et al.*, 2006
Dipsadidae NI	11	Quintela *et al.,* 2014
Erythrolamprus semiaureus (Cope, 1862)	34	Quintela *et al.*, 2014
Erythrolamprus jaegeri (Günther, 1858)	1	Quintela *et al.*, 2014
Erythrolamprus sp.	5	Novaes, 2002
Philodryas patagoniensis (Girard, 1858)	5	Quintela *et al.*, 2014
Birds NI	15	Dos Santos and Hartz, 1999; Gatti *et al.*, 2006; Dias and Bocchiglieri, 2015
Aramides sp.	11	Novaes, 2002
Butorides sp.	24	Novaes, 2002
Casmerodius sp.	17	Novaes, 2002
Fishes NI	8	Bisbal, 1986; Gatti *et al.,* 2006; Aguiar *et al.*, 2011; Quintela *et al.,* 2014
Centropomus sp.	12	Novaes, 2002
Geophagus sp.	3	Novaes, 2002
Mugil sp.	14	Novaes, 2002
Sardinella sp.	16	Novaes, 2002
Synbranchus marmoratus Bloch, 1795	1	Quintela *et al.*, 2014
Characidae	1	Dos Santos and Hartz, 1999
Siluriformes	5	Quintela *et al.,* 2014
Tachysurus sp.	5	Novaes, 2002
Vertebrates NI	12	Gatti *et al.*, 2006; Martinelli and Volpi, 2010; Quintela *et al.*, 2014
Egg shell (embryo)	1	Dias and Bocchiglieri, 2015
Vegetal		
Anacardiaceae		
Anacardium occidentale L.	1	Dias and Bocchiglieri, 2015
Schinus terebinthifolius Raddi	3	Gatti *et al.*, 2006

(*Continued*)

Taxon	Number of individuals	Reference
Arecaceae		
Allagoptera arenaria (Gomes) Kuntze	101	Gatti *et al.,* 2006; Martinelli and Volpi, 2010
Butia capitata (Mart.) Becc.	5	Santos and Hartz, 1999
Syagrus romanzoffiana (Cham.) Glassman	127	Santos and Hartz, 1999; Aguiar *et al.*, 2011; Quintela *et al*., 2014
Bromeliaceae		
Bromelia antiacantha Bertol.	54	Dos Santos and Hartz, 1999; Quintela *et al.*, 2014
Cactaceae		
Cereus fernambucensis Lem.	11	Gatti *et al.,* 2006
Pilosocereus gounellei (F.A.C.Weber) Byles & Rowley	3	Dias and Bocchiglieri, 2015
Pilosocereus pachycladus F.Ritter	1	Dias and Bocchiglieri, 2015
Ebenaceae		
Diospyros inconstans Jacq.	1	Quintela *et al.*, 2014
Fabaceae NI	5	Dias and Bocchiglieri, 2015
Prosopis L.	5	Dias and Bocchiglieri, 2015
Goodeniaceae		
Scaevola plumieri (L.) Vahl	4	Gatti *et al.*, 2006
Moraceae		
Ficus L.	5	Dias and Bocchiglieri, 2015
Ficus organensis (Miq.) Miq.	6	Dos Santos and Hartz, 1999
Myrtaceae NI	3	Dos Santos and Hartz, 1999; Dias and Bocchiglieri, 2015
Eugenia L.	2	Gatti *et al.,* 2006
Marlierea neuwiedeana (O.Berg) Nied.	4	Gatti *et al.,* 2006
Neomitranthes obscura (DC.) N.Silveira	6	Gatti *et al.*, 2006
Psidium cattleianum Sabine	1	Gatti *et al.,* 2006
Psidium guajava L.	3	Dos Santos and Hartz, 1999
Psidium cf. *cattleianum*	23	Quintela *et al.,* 2014
Rhamnaceae		
Hovenia dulcis Thunb.	2	Dos Santos and Hartz, 1999
Poaceae	1	Aguiar *et al.,* 2011
Polygonaceae	1	Dias and Bocchiglieri, 2015
Rosaceae		
Eriobotrya japonica (Thunb.) Lindl.	1	Aguiar *et al.,* 2011
Rubiaceae		
Tocoyena bullata (Vell.) Mart.	4	Gatti *et al.,* 2006
Sapotaceae		
Sideroxylon obtusifolium (Roem. & Schult.) T.D.Penn.	2	Dias and Bocchiglieri, 2015

(*Continued*)

Taxon	Number of individuals	Reference
Smilacaceae		
Smilax L.	2	Quintela *et al.,* 2014
Solanaceae NI	3	Quintela *et al.,* 2014
Solanum L.	5	Quintela *et al.,* 2014
Miscelaneous (grass and fibers)	10	Dias and Bocchiglieri, 2015
Fruit NI	3	Dos Santos and Hartz, 1999
Seeds NI	24	Gatti *et al.,* 2006; Martinelli and Volpi, 2010; Dias and Bocchiglieri, 2015
Metaphyta NI	2	Aguiar *et al.,* 2011