

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/](https://www.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, we 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 elevated 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 wolves (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 raccoon (*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; Landgraf Filho *et al.*, 2019). Reports of animals preying on adults of *P. platensis* include five bird species, another frog species, snakes, fishes, and caimans (Landgraf-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 <i>et al.</i> , 2014
Araneae NI	2	Aguiar <i>et al.</i> , 2011; Bisbal, 1986
Belostomatidae	16	Quintela <i>et al.</i> , 2014
Blattodea	1	Aguiar <i>et al.</i> , 2011
Coleoptera	90	Bisbal, 1986; Dos Santos and Hartz, 1999; Gatti <i>et al.</i> , 2006; Aguiar <i>et al.</i> , 2011; Martinelli and Volpi, 2010; Quintela <i>et al.</i> , 2014; Dias and Bocchiglieri, 2015
Decapoda	3	Bisbal, 1986
<i>Parastacus</i> sp.	1	Dos Santos and Hartz, 1999
Brachyura	39	Quintela <i>et al.</i> , 2014
<i>Aegla castro</i> Schmitt, 1942	1	Aguiar <i>et al.</i> , 2011
<i>Aegla</i> sp.	2	Dos Santos and Hartz, 1999
<i>Aratus</i> sp.	114	Novaes, 2002
<i>Armases</i> sp.	28	Novaes, 2002
<i>Callinectes</i> sp.	17	Novaes, 2002
<i>Cardisoma</i> sp.	4	Novaes, 2002
<i>Chasmagnathus</i> sp.	100	Novaes, 2002
<i>Dilocarcinus dentatus</i> (Randall, 1840)	2	Bisbal, 1986
<i>Goniopsis</i> sp.	10	Novaes, 2002
<i>Metasesarma</i> sp.	35	Novaes, 2002
<i>Sesarma</i> sp.	48	Novaes, 2002
Ocypodidae	67	Martinelli and Volpi, 2010
<i>Ocypode quadrata</i> (Fabricius, 1787)	13	Gatti <i>et al.</i> , 2006
<i>Ucides</i> sp.	33	Novaes, 2002
Diplopoda	4	Quintela <i>et al.</i> , 2014
Hymenoptera	29	Quintela <i>et al.</i> , 2014; Dias and Bocchiglieri, 2015
Insecta NI	23	Gatti <i>et al.</i> , 2006; Dos Santos and Hartz, 1999; Aguiar <i>et al.</i> , 2011
Isopoda	6	Quintela <i>et al.</i> , 2014
Isoptera	14	Dias and Bocchiglieri, 2015
Odonata	11	Dos Santos and Hartz, 1999; Aguiar <i>et al.</i> , 2011; Quintela <i>et al.</i> , 2014
Orthoptera	35	Bisbal, 1986; Dos Santos and Hartz, 1999; Gatti <i>et al.</i> , 2006; Aguiar <i>et al.</i> , 2011; Quintela <i>et al.</i> , 2014; Dias and Bocchiglieri, 2015
Scorpionida NI	10	Dias and Bocchiglieri, 2015

(Continued)

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

(Continued)

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

(Continued)

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

(Continued)

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