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 multiple 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°4’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 preayed 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 limmellum*, 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)](image)
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; Campiño 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 of interest when hunting in the dark as P. cancrivorus is known to be a nocturnal creature, 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 insights 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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### Table. Items reported in the diet of the crab eating racoon (*Procyon cancrivorus*) reported in the literature between 1986 and 2019.

| Taxon               | Number of individuals | Reference                                                                                           |
|---------------------|-----------------------|-----------------------------------------------------------------------------------------------------|
| Animals             |                       |                                                                                                      |
| Arthropoda          | 14                   | Quintela *et al.*, 2014                                                                            |
| Araneae             | 2                    | Aguiar *et al.*, 2011; Bisbal, 1986                                                                 |
| Belostomatidae      | 16                   | Quintela *et al.*, 2014                                                                            |
| Blattodea           | 1                    | Aguiar *et al.*, 2011; Bisbal, 1986; Gatti *et al.*, 2006; Aguiar *et al.*, 2011; Martinelli and Volpi, 2010; Quintela *et al.*, 2014; Dias and Bocchiglieri, 2015 |
| 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                                                                                      |
| Chasmognathus sp.   | 100                  | Novaes, 2002                                                                                      |
| Dilocarcinus dentatus (Randall, 1840) | 2      | Bisbal, 1986                                                                                      |
| Coniopsis sp.       | 29                   | 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 NI      | 10                   | Dias and Bocchiglieri, 2015                                                                       |

(Continued)
| Taxon                                | Number of individuals | Reference                                      |
|--------------------------------------|-----------------------|------------------------------------------------|
| Bothriurus bonarrensis (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                         |
| Dasyypodidae                         | 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                                  |
| Metachira 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                         |
| Dasyopus sp.                         | 1                     | Gatti et al., 2006                            |
| Myocaster coyus (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                                    |
| Leptodactyliidae                     | 3                     | Novaes, 2002                                  |
| Reptil NI                            | 1                     | Dos Santos and Hartz, 1999                    |
| Trachemys dorbigni (Duménil & Bibron, 1835) | 2                 | Dos Santos and Hartz, 1999                    |
| Lizard NI                            | 6                     | Gatti et al., 2006; Dias and Bocchiglieri, 2015 |

(Continued)
### Crab-eating raccoon diet

| Taxon                                      | Number of individuals | Reference                                |
|--------------------------------------------|-----------------------|------------------------------------------|
| Brasiliscincus agilis (Raddi, 1823)        | 2                     | Gatti et al., 2006                       |
| *Tropidurus gr. turquetus*                 | 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                             |
| *Phiodryas 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 antiochana* Bertol.              | 54                    | Dos Santos and Hartz, 1999; Quintela et al., 2014               |
| *Cactaceae*                                |                       |                                                                 |
| *Cereus ferrambucensis* 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*                                 | 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*                                | 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                                              |
| *Neomitrantes 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)
### Crab-eating raccoon diet

| 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                        |
| Miscellaneous (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                         |