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Predation of anurans across multiple life stages in an Amazon–Cerrado transitional zone

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Throughout their life cycle amphibians play an important role in food chains (Moura et al., 2012; Krawczyk et al., 2013; Maffei et al., 2014; Sales et al., 2015; Ceron et al., 2017). Among the groups commonly reported as amphibian predators, snakes dominate, accounting for ~45% of predation reports (Toledo et al., 2007; Wells, 2007; Bernarde and Abe, 2010). Some groups of invertebrates—mostly spiders and hemipteran water-bugs—are also often documented as amphibian predators (Toledo et al., 2005; Santana et al., 2009; Caldart et al., 2011; Baracho et al., 2014; Ceron et al., 2017). Predator–prey relationships influence community composition, therefore knowledge of predator–prey interactions are crucial to understanding ecological relationships and trophic connections (Costa and Vonesh, 2013; Arribas et al., 2014, 2018). Nevertheless, field efforts aiming exclusively to describe interactions between amphibians and their predators are difficult to conduct as these events are rarely observed in the wild (Pombal Jr., 2007). Most observations of amphibians as prey are opportunistic, and reported from field expeditions when studying predation is not the main goal (Eterovick and Sazima, 2000; Marques and Sazima, 2004; Da Silva et al., 2010). One important data source for predation of amphibians is the analysis of stomach contents from specimens deposited in museum collections (Andrade and Silvano, 1996). This is particularly true for animals such as snakes that swallow their prey whole, which facilitates the identification of food items, providing the digestive process was not at an advanced stage at the time of collection/specimen preparation (Schwenk, 2000).

Given the difficulty of studying amphibian–predator interactions, the description of opportunistically observed events represents an important contribution to knowledge (e.g., Barta et al., 2004; Blaustein et al., 2011). Here we describe six observations of larval to adult amphibians as prey of invertebrate and vertebrate taxa. All events were recorded during nocturnal visual encounter surveys in the ecotone between the Amazon and Cerrado biomes, located in Caseara and Pium municipalities (09°16'42" S, 49°57'20" W, 174 m a.s.l.), west of Tocantins state, northern Brazil (Figure 1). With one exception (Observation 3: see below) both predator and prey were collected as specimens and deposited in the Zoological Collection of Universidade Federal de Mato Grosso do Sul (ZUFMS). Voucher specimens were euthanised by submersion in solution (invertebrates), or a topical application (anurans), or injection (reptiles) of lidocaine (following Conselho Federal de Biologia resolution CFBio nº148/2012; CFB 2012), fixed in 10% formalin, and preserved in alcohol 70% (Papavero 1994).

Observation 1: 21 November 2017, 21:00 h. In a lagoon surrounded by pasture at Guaíra Farm, Caseara municipality (9.3505° S, 49.9475° W, WGS84, 178 m a.s.l.), we captured a male *Helicops angulatus* (Linnaeus, 1758) (snout-vent length [SVL] 602 mm; ZUFMS-REP03321). The stomach region of this specimen was distended and during dissection we removed a recently ingested adult *Leptodactylus pustulatus* (SVL 35.26 mm; ZUFMS-AMP11070) (Figure 2A).

Observation 2: 23 January 2018, 19:00 h. At Canadá Farm, Caseara (9.4156° S, 49.9745° W, WGS84, 180 m a.s.l.), we observed an adult female *L. pustulatus* (Peters,

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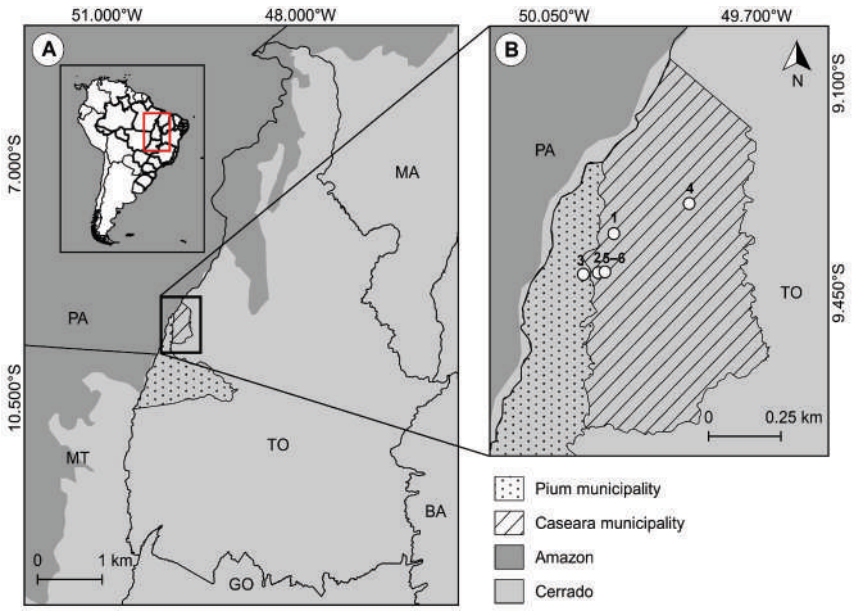

Figure 1. (A) Locality of the study region within Caseara and Pium municipalities of Tocantins state, Brazil (inset) where the six predation events were observed: MA = Maranhão state, TO = Tocantins state, BA = Bahia state, GO = Goias state, MT = Mato Grosso state, PA = Pará state. (B) 1: Guaíra Farm (*Helicops angulatus* and a *Leptodactylus pustulatus*); 2: Canadá Farm (*Belostoma* sp. and a tadpole of *Leptodactylus pustulatus*); 3: Parque Estadual do Cantão (*Ancylometes concolor* and a *Dendropsophus melanargyreus*); 4: Santa Juliana Farm (*Helicops angulatus* and a probable *L. chaquensis*); 5–6: (*Lethocerus* sp. and a metamorphosing hylid frog, and *Belostoma* sp. and a juvenile hylid frog).

1870) surrounded by a shoal of tadpoles (corresponding with the description of parental care reported by De Sá et al., 2007). One of the larvae moved away from the shoal, and was seized by a giant water-bug (*Belostoma* sp. Latreille, 1807) (Figure 2B) upon which we collected both tadpole (SVL 18.90 mm; ZUFMS-AMP11072) and beetle (SVL 30 mm; ZUFMS-HEM00238).

Observation 3: 28 January 2018, 22:00 h. In a flooded area inside the Parque Estadual do Cantão, Pium municipality, near to the Rio do Coco (9.4184° S, 50.0003° W, WGS84, 167 m a.s.l.), we observed the arachnid *Ancylometes concolor* (Perty, 1833) in a tree-trunk crevice feeding upon an adult *Dendropsophus melanargyreus* (Cope, 1887) (Figure 2C). The treefrog appeared dead. After we had taken photographs the spider retreated into the crevice carrying with it the treefrog, preventing collection of either specimen.

Observation 4: 22 May 2018, 21:00 h. In a wetland area at Santa Juliana Farm, Caseara (9.3004° S, 49.8173° W, WGS84, 173 m a.s.l.), we captured a female *H. angulatus* (SVL 500 mm; ZUFMS-REP03322). The stomach region of this individual appeared distended, and during dissection we recovered a juvenile/small *L. chaquensis* Cei, 1950 in an advanced digestive state, which prevented recording of standard measurements (ZUFMS-AMP11073) (Figure 2D).

Observations 5–6: 23 May 2018, 19:00 h. In a floodplain area at Canadá Farm, Caseara (9.4144° S, 49.9629° W, WGS84, 182 m a.s.l.), we observed two simultaneous predation events; (i) a *Lethocerus* sp. Mayr, 1853 water-bug (SVL 9.23 mm; ZUFMS-HEM00236) preying upon a metamorphosing hylid frog (SVL 20.60 mm; ZUFMS-AMP11068) (Figure 2E); and (ii) a *Belostoma* sp. water-bug (SVL 19.20 mm; ZUFMS-HEM00237) predating a juvenile hylid frog (SVL 12.54 mm; ZUFMS-AMP11069) (Figure 2F). Both anurans were dead at the point of collection.

Helicops angulatus is predominantly nocturnal and reported to feed on invertebrates (Strüssmann et al., 2013), fish (Sturaro and Gomes, 2008; Guimarães et al., 2010), amphibians (including tadpoles) and lizards (Martins and Oliveira, 1998; Albuquerque et al., 2013; Teixeira et al., 2017). Among adult amphibians recorded in the diet of *H. angulatus* are *Allobates femoralis*

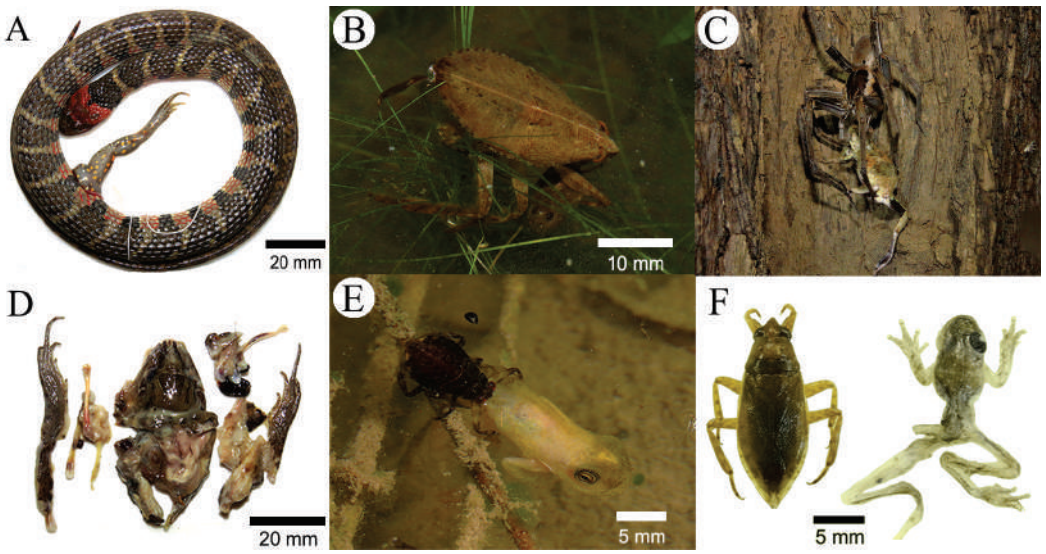

Figure 2. (A) *Helicops angulatus* (ZUFMS-REP03321) showing a *Leptodactylus pustulatus* (ZUFMS-AMP11070) protruding through an incision in the stomach region of the snake; (B) water-beetle specimen (*Belostoma* sp. ZUFMS-HEM00238) preying upon a *Leptodactylus pustulatus*' tadpole (ZUFMS-AMP11072); (C) *Ancylometes concolor* preying an adult of *Dendropsophus melanargyreus*; (D) *Leptodactylus chaquensis* (ZUFMS-AMP11073) predated by *Helicops angulatus* (ZUFMS-REP03322); (E) water-beetle (*Lethocerus* sp. ZUFMS-HEM00236) preying on a metamorphosing hylid frog (ZUFMS-AMP11068); (F) water-beetle (*Belostoma* sp. ZUFMS-HEM00237) that preyed upon a juvenile hylid frog (ZUFMS-AMP11069). All photos by Leandro Alves da Silva.

(Boulenger, 1884) (Costa-Campos et al., 2017), *Boana boans* (Linnaeus, 1758) (Rocha and López-Baucells, 2014), *S. nasicus* (Cope, 1862) (Ávila et al., 2006), *Rhinella mirandaribeiroi* (Gallardo, 1965), *R. marina* (Linnaeus, 1758), *P. paradoxa* (Linnaeus, 1758), and *S. ruber* (Laurenti, 1768) (Teixeira et al., 2017). There are records of the consumption of *Leptodactylus* taxa by *H. angulatus* (e.g., Albolea, 1998; Martins and Duarte, 2003; Aguiar and Di-Bernardo, 2004; Marques and Sazima, 2004; Ávila et al., 2006; Albuquerque et al., 2013), but we report the first recorded incidence of *L. pustulatus* and likely (due to the partially digested state of the specimen) first incidence of *L. chaquensis* as prey items for this species.

Anurophagy is a trophic strategy commonly used by arthropods and widely reported among neotropical arachnid families (Menin et al., 2005). Spiders of the genus *Ancylometes* Bertkau, 1880 are commonly found in humid neotropical forests and riparian vegetation (Höfer and Brescovit, 2000) and predation by *A. rufer* has been reported on *D. melanargyreus* (Walckenaer, 1837) (Moura and Azevedo, 2011), and by *A. concolor* on *D. minutus* (Bocchiglieri et al., 2010). However, the observation of *A. concolor* predation on *D. melanargyreus* is a novel record, and only the second report of this arachnid genus preying on *Dendropsophus* taxa.

Giant water-bugs are generalist carnivores (China, 1955; Lauck and Menke, 1961) widely reported as amphibian predators (Eterovick and Sazima, 2000; Toledo, 2003, 2005; Figueiredo-de-Andrade et al., 2010; Barachos et al., 2014; Ceron et al., 2017) that play an important role in the structuring of amphibian communities (Duellman and Trueb, 1994; Menin et al., 2005). Observations of water-bug predation on amphibians regularly report adults as prey items (Toledo, 2005) but predation on tadpoles has been observed for many hylid frogs, including *Boana faber* (Wied-Neuwied, 1821), *Boana raniceps* (Cope, 1862), *Pseudis platensis* Gallardo, 1961, *Scinax fuscovarius* (Lutz, 1925); and at least one microhylid, *Elachistocleis bicolor* (Guérin-Méneville, 1838) (Martins et al., 1993; Gambale et al., 2014; Ceron et al., 2017). Predation risk by invertebrates may be higher during the transition from an aquatic to a terrestrial lifestyle (Toledo, 2003, 2005), and our observations certainly provide indication

of such risks to anuran larvae at this critical life-stage. To our knowledge, predation on *L. pustulatus* larvae by an aquatic insect is a new record (Figure 2B).

In amphibians, some life-history-specific periods increase predation risk, such as during reproduction when many species congregate in and around water-bodies, and during metamorphosis when individuals may be less-well adapted for movement in both aquatic and terrestrial habitats (Toledo, 2003). Consequently, amphibians may face a number of predators in both environments. Anurans play a key role in ecosystems as both predators and prey, linking a variety of terrestrial and aquatic biomes (Duellman and Trueb, 1994). Observation, and reports of predation events are therefore crucial in understanding trophic interactions and the functional role of predator-prey relationships in tropical ecosystems.

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