

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 n°148/2012; 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 Guáira 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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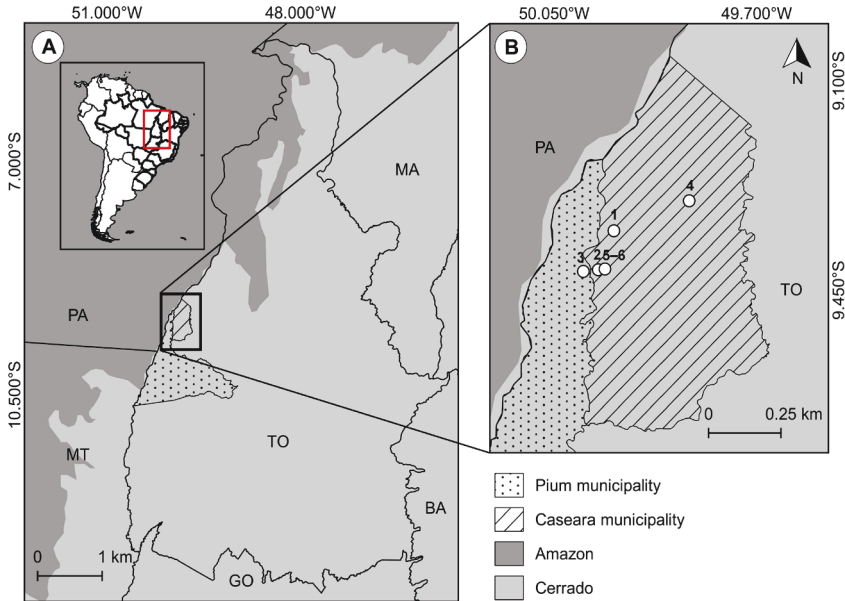


Figure 1. (A) Locality of the study region within Caseara and Pium municipalities of Tocantins state, Brazil (inset) where the six predation events were observed: MA = Maranhão state, TO = Tocantins state, BA = Bahia state, GO = Goiás state, MT = Mato Grosso state, PA = Pará state. (B) 1: Guaira Farm (*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 hyloid frog, and *Belostoma* sp. and a juvenile hyloid 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 hyloid frog (SVL 20.60 mm; ZUFMS-AMP11068) (Figure 2E); and (ii) a *Belostoma* sp. water-bug (SVL 19.20 mm; ZUFMS-HEM00237) preying upon a juvenile hyloid 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*

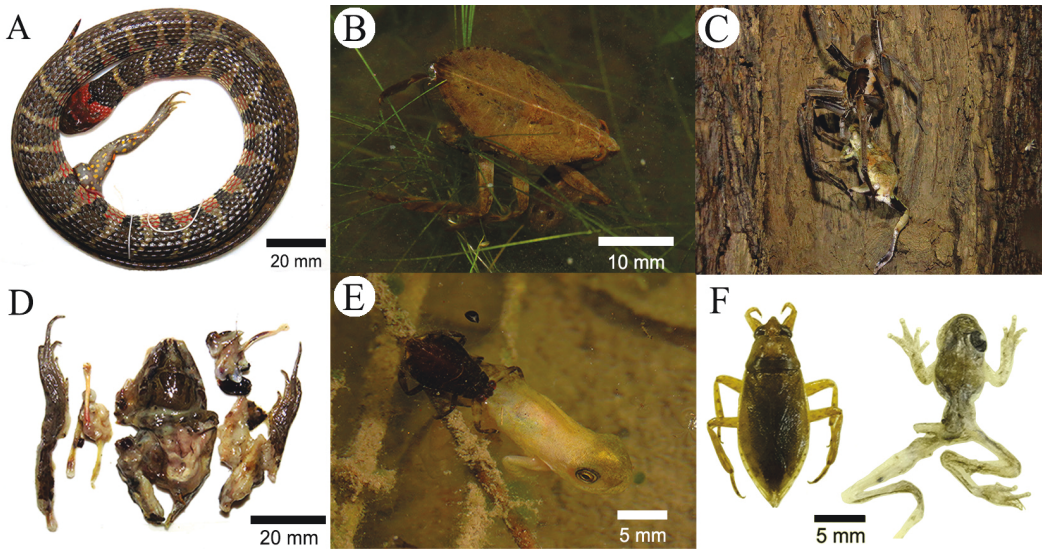


Figure 2. (A) *Helicops angulatus* (ZUFMS-REP03321) showing a *Leptodactylus pustulatus* (ZUFMS-AMP11070) protruding through an incision in the stomach region of the snake; (B) water-beetle specimen (*Belostoma* sp. ZUFMS-HEM00238) preying upon a *Leptodactylus pustulatus* tadpole (ZUFMS-AMP11072); (C) *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. rufus* 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 waterbodies, 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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References

- Aguiar, L.F.S., Di-Bernardo, M. (2004): Diet and feeding behavior of *Helicops infrataeniatus* (Serpentes: Colubridae: Xenodontinae) in Southern Brazil. *Studies on Neotropical Fauna and Environment* **39**: 7–14.
- Albolea, A.B.P. (1998): Padrões de atividade em serpentes não peçonhentas de interesse médico: *Helicops modestus* (Colubridae: Xenodontinae) e *Liophis miliaris* (Colubridae: Xenodontinae) e sua relação com a epidemiologia. Unpublished M.Sc. Dissertation Universidade de Guarulhos, São Paulo, Brazil.
- Albuquerque, R. L., Laranjeiras, D.O., Protázio, A. S., Rodrigues, R., Mesquita, D.O., França, F.G.R. (2013): *Helicops angulatus* (Watersnake). Diet. *Herpetological Review* **44** (3): 522–523.
- Andrade, R.O., Silvano, R.A.M. (1996): Comportamento alimentar e dieta da “falsa-coral” *Oxyrhopus guibei* Hoge e Romano 1978 (Serpentes, Colubridae). *Brasileira de Zoologia* **13** (1): 143–150.
- Arribas, R., Díaz-Paniagua, C., Gomez-Mestre, I. (2014): Ecological consequences of amphibian larvae and their native and alien predators on the community structure of temporary ponds. *Freshwater Biology* **59** (9): 1996–2008.
- Arribas, R., Touchon, J.C., Gomez-Mestre, I. (2018): Predation and competition differentially affect the interactions and trophic niches of a neotropical amphibian guild. *Frontiers in Ecology and Evolution* **6**: 28.
- Avila, R.W., Ferreira, V.L., Arruda, J.A. (2006): Natural history of the South American water snake *Helicops leopardinus* (Colubridae: Hydropsini) in the Pantanal, central Brazil. *Journal of Herpetology* **40** (2): 274–279.
- Baracho, E.B.O., Silva, J.S., Nascimento, B.H.M., Fonseca, E.M.F., Magalhães, F.M. (2014): *Dendropsophus branneri* (Cochran, 1948) (Anura: Hylidae) as prey to invertebrates in northeastern Brazil. *Herpetology Notes* **7**: 17–19.
- Barta, Z.N., Liker, A.S., Mónus, F. (2004): The effects of predation risk on the use of social foraging tactics. *Animal Behaviour* **67**: 301–308.
- Bernarde, P.S., Abe, A.S. (2010): Hábitos alimentares de serpentes em Espigão do Oeste, Rondônia, Brasil. *Biota Neotropica* **10** (1): 167–173.
- Blaustein, A.R., Han, B.A., Relyea, R.A., Johnson, P.T.J., Buck, J.C., Gervasi, S.S., Kats, L.B. (2011): The complexity of amphibian population declines: understanding the role of cofactors in driving amphibian losses. *Annals of the New York Academy of Sciences* **1223**: 108–119.
- Bocchiglieri, A., Mendonça, A.F., Motta, P.C. (2010): *Dendropsophus minutus* (Lesser Treefrog). Predation. *Herpetological Review* **41** (3): 335.
- Caldart, V.M., Iop, S., Rocha, M.D., Cechin, S.Z. (2011): Diurnal and nocturnal predators of *Crossodactylus schmidti* Gallardo, 1961 (Anura, Hylodidae) in southern Brazil. *North-Western Journal of Zoology* **7** (2): 342–345.
- Ceron, K., Ferreira, V.L., Tomas, W.M., Santana, D.J. (2017): Battle of giants: Predation on giant tadpole of *Pseudis platensis* (Anura: Hylidae) by a giant water bug (Hemiptera: Belostomatidae). *Herpetology Notes* **10**: 263–265.
- Conselho Federal de Biologia – CFBio Nº 148/2012. “Regulamenta os procedimentos de captura, contenção, marcação e coleta de animais vertebrados previstos nos Artigos, 4º, 5º, 6º e 8º da Resolução CFBio nº 301/2012. Available at: <http://www.cfbio.gov.br/artigos/RESOLUCAO-N%C2%BA-301-DE-8-DE-DEZEMBRO-DE-2012>. Accessed on 13th June 2019.
- China, W.E. (1955): The evolution of the water bugs. In Symposium on organic evolution. Bulletin of the National Institute of Sciences of India **7**: 91–103.
- Costa, Z.J., Vonesh J.R. (2013): Prey subsidy or predator cue? Direct and indirect effects of caged predators on aquatic consumers and resources. *Oecologia* **173**: 1481–1490.
- Costa-Campos, C.E., Silva, P.H.E., Guerra, L.E.S., Sousa, J.C. (2017): Predation on the brilliant-thighed poison frog *Allobates femoralis* (Aromobatidae) by the Amazonian watersnake *Helicops angulatus* (Dipsadidae). *Herpetology Notes* **10**: 665–667.
- Da Silva, M.V., de Souza, M.B., Bernarde, P.S. (2010): Riqueza e dieta de serpentes do Estado do Acre, Brasil. *Revista Brasileira de Zoociências* **12** (2): 165–176.
- De Sá, R.O., Brandão, R., Guimarães, L.D.A. (2007): Description of the tadpole of *Leptodactylus pustulatus* Peters, 1870 (Anura: Leptodactylidae). *Zootaxa* **1523** (1): 49.
- Duellman, W.E., Trueb, L. (1994): *Biology of Amphibians*. John Hopkins. Baltimore, London. University Press.
- Eterovick, P.C., Sazima, I. (2000): Structure of an anuran community in a montane meadow in southeastern Brazil: effects of seasonality, habitat, and predation. *Amphibia-Reptilia* **21**:

- 439–461.
- Figueiredo-de-Andrade, C.A., Santana, D.J., de Carvalho-e-Silva, S.P. (2010): Predation on *Scinax x-signatus* (Anura: Hylidae) by the giant water bug *Lethocerus annulipes* (Hemiptera: Belostomatidae) in a Brazilian Restinga habitat. *Amphibia-Reptilia* **14**: 307–309.
- Gambale, P.G., Batista, V.G., Oda, F.H., Campos, R.M., Takemoto, R.M., Bastos, R.P. (2014): Anuran larvae as prey and hosts of invertebrates in Neotropical aquatic habitats. *Revista Chilena de Historia Natural* **87** (1): 31.
- Guimarães, J.A.R., Dias, E.J.R., Oliveira, A.R. (2010): *Helicops angulatus* (Watersnake). Diet and Reproduction. *Herpetological Review* **41** (1): 93.
- Krawczyk, A. J., Bogdziewicz, M., Czyz, M. J. (2013): Diet of the American mink *Neovison vison* in an agricultural landscape in western Poland. *Folia Zoologica* **62** (4): 304–310.
- Lauck, D.R., Menke, A.S. (1961): The higher classification of the Belostomatidae (Hemiptera). *Annals of the Entomological Society of America* **54** (5): 644–657.
- Maffei, F., Ubaid, F.K., Jim, J. (2010): Predation of herps by spiders (Araneae) in the Brazilian Cerrado. *Herpetology Notes* **3**: 167–170.
- Marques, O.A.V., Sazima, I. (2004): História natural dos répteis da Estação Ecológica Jurêia-Itatins. Pp. 257–277 in O.A.V. Marques and W. Duleba (ed.), Estação Ecológica Jurêia-Itatins. Ambiente físico, Flora e Fauna, Ribeirão Preto, Brazil. Editora Holos.
- Martins, I.A., Duarte, M.R. (2003): *Physalaemus nattereri*. Predation. *Herpetological Review* **34**: 233.
- Martins, M., Sazima, I., Eglar, S.G. (1993): Predators of the nest building gladiator frog, *Hyla faber*, in southeastern Brazil. *Amphibia-Reptilia* **14**: 307–309.
- Martins, M., Oliveira, M.E. (1998): Natural history of snakes in forests of the Manaus region, Central Amazonia, Brazil. *Herpetological Natural History* **6**: 78–150.
- Menin, M., de Rodrigues, D.J., de Azevedo, C.S. (2005): Predation on amphibians by spiders (Arachnida, Araneae) in the Neotropical region. *Phyllomedusa* **4**: 39–47.
- Moura, M.R., Godinho, L.B., Feio, F.N. (2012): *Bothrops moojeni* (Squamata, Viperidae) predation on *Hypsiboas crepitans* (Anura: Hylidae) in southeastern Brazil. *Herpetology Notes* **5**: 247–248.
- Moura, M.R., Azevedo, L.P. (2011): Observation of predation of the giant fishing spider *Ancylometes rufus* (Walckenaer, 1837) (Araneae, Ctenidae) on *Dendropsophus melanargyreus* Cope, 1877 (Anura, Hylidae). *Biota Neotropica* **11** (4): 349–352.
- Papavero, N. (1994): Fundamentos práticos de taxonomia zoológica: coleções, bibliografia, nomenclatura. UNESP.
- Pombal Jr, J.P. (2007): Notas sobre predação em uma taxocenose de anfíbios anuros no sudeste do Brasil. *Revista Brasileira de Zoologia* **24** (3): 841–843.
- Rocha, R., López-Baucells, A. (2014): Predation attempt of *Hypsiboas boans* (Anura: Hylidae) by *Helicops angulatus* (Squamata: Dipsadidae) with notes on defensive behavior. *Alytes* **30** (1-4): 78–81.
- Sales, R.F.D., da Silva Jorge, J., de Carvalho Kokubum, M.N., Freire, E.M.X. (2015): Predation of *Leptodactylus troglodytes* by *Leptodactylus macrosternum* (Anura: Leptodactylidae) in the Brazilian Caatinga. *Herpetology Notes* **8**: 421–423.
- Santana, D.J., Silva, E.T., de Oliveira, E.F. (2009): Predação de *Dendropsophus elegans* (Anura, Hylidae) por *Phoneutria nigriventer* (Araneae, Ctenidae) em Viçosa, Minas Gerais, Brasil. *Boletim do Museu de Biologia Mello Leitão* **26**: 59–65.
- Schwenk, K. (Ed.). (2000): Feeding: form, function and evolution in tetrapod vertebrates. Elsevier.
- Silva, M.V., de Souza, M.B., Bernarde, P.S. (2010): Riqueza e dieta de serpentes do Estado do Acre, Brasil. *Revista Brasileira de Zootecias* **12** (2).
- Strüssmann, C., de Brito, E.S., Marques, O.A. (2013): What do water snakes eat? First report of predation by a Neotropical Hydropsini snake on giant earthworms (Glossoscolecidae). *Salamandra* **49** (1): 48–50.
- Sturaro, M.J., Gomes, J. O. (2008): Feeding behavior of the Amazonian water snake *Helicops hagdmani* Roux, 1910 (Reptilia: Squamata: Colubridae: Hydropsini). *Boletim do Museu Paraense Emílio Goeldi Ciências Naturais* **3** (3): 225–228.
- Teixeira, C.C., de Assis Montag, L. F., dos Santos-Costa, M.C. (2017): Diet composition and foraging habitat use by three species of water snakes, *Helicops* Wagler, 1830 (Serpentes: Dipsadidae) in eastern Brazilian Amazonia. *Journal of Herpetology* **51** (2): 215–222.
- Toledo, L.F., Silva, R.R., Haddad, C.F.B. (2007): Anurans as prey: an exploratory analysis and size relationships between predators and their prey. *Journal of Zoology* **271**: 170–177.
- Toledo, L.F. (2003): Predation on seven South American anuran species by water bugs (Belostomatidae). *Phyllomedusa Journal of Herpetology* **2** (2): 105–108.
- Toledo, L.F. (2005): Predation of juvenile and adult anurans by invertebrates: current knowledge and perspectives. *Herpetological Review* **36** (4): 395–400.
- Wells, K.D. (2007): *The Ecology and Behavior of Amphibians*. Chicago, USA, The University of Chicago Press.