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# Different foraging strategies within congenerics? The diet of *Proceratophrys cristiceps* (Müller, 1883) from a dry forest in northeast Brazil

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**Abstract.** In the present study we analyze the diet of *Proceratophrys cristiceps* from a caatinga dry forest in northeast Brazil. Thirteen individuals of *P. cristiceps* were analysed in order to access gut content, all of which had food in their stomachs. Prey was identified with a stereomicroscope and proper identification keys. Isoptera was the most frequent item and also the most important numerically and volumetrically, displaying the highest index of relative importance. Other important preys were Coleoptera and Orthoptera. Although the presence of sedentary clustered prey, such as Isoptera, in the diet is typically considered a characteristic of active foragers, *Proceratophrys* species are usually regarded as sit-and-wait predators. Considering the generally hot and dry environment in which this population was found, the high proportion of Isoptera in *P. cristiceps* diet may be due to the sharing of the same moist microhabitats by frogs and termites. We believe this to be a case where feeding strategy is phylogenetically determined, while diet composition is the result of recent ecological interactions. Information on the seasonal variation in the diet of *P. cristiceps*, as well as of other species in the genus will surely help to elucidate such relationships.

**Keywords.** Amphibia, Anura, Cycloramphidae, Caatinga, Diet, Trophic ecology, Isoptera.

## Introduction.

The understanding of how food webs and energy transference work in natural communities requires the knowledge of what species eat. Anurans are, in general, considered to be opportunistic predators with their diet being made up of the available food items that are within an adequate size range for ingestion (Giaretta et al., 1998). Intuitively one might expect that "availability of food" will depend on the microhabitat occupied by the species, with those that occupy different spatial niches having different prey available to them, in which case diet may be a reflection of local ecological interactions (Simon and Toft, 1991; Böhning-Gaese, Schuda and Helbig, 2003). On the other hand, feeding strategy and diet may be strongly influenced by phylogeny, with certain patterns conserved within closely related species (Caldwell, 1996; Wiens and Graham, 2005).

Low abundance and/or secretive habitats may act as limiting factors when accessing the diet of some species of anurans (Boquimpani-Freitas, Rocha and Van Sluys, 2002). The genus *Proceratophrys* Miranda-Ribeiro, 1920 compromises a total of 22 species distributed in northeastern, eastern and southeastern Brazil, and northeastern Argentina and Paraguay (Frost, 2011). Despite the relatively large number of species, information regarding their dietary habits is restricted to only four species (Moreira and Barreto, 1996; Giaretta et al., 1998; Boquimpani-Freitas, Rocha and Van Sluys, 2002; Teixeira and Coutinho, 2002; Araújo et al., 2007). The cryptic coloration of many *Proceratophrys* can make encounters especially difficult (Sazima, 1978), which may explain the reduced amount of information concerning the trophic ecology of these frogs. Nevertheless, knowledge and understanding of feeding relations in different tropical assemblages is essential

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**Table 1.** Diet composition of *Proceratophrys cristiceps* collected from a caatinga area in Milagres, northeast Brazil... After "...categories are in bold." please insert UAR = unidentified arthropods remains.

| | No. (FN) | FO | FV | IRI |
|---|---|---|---|---|
| Gastropoda | 2 (0.027) | 0.154 | 0.002 | 0.004 |
| Crustaceae (Isopoda) | 4 (0.053) | 0.154 | 0.017 | 0.011 |
| Hexapoda | | | | |
| Blattodea | 1 (0.013) | 0.077 | 0.012 | 0.002 |
| **Coleoptera** | 8 (0.107) | 0.538 | 0.140 | **0.133** |
| Formicidae | 3 (0.04) | 0.231 | 0.006 | 0.011 |
| **Isoptera** | 52 (0.693) | 0.846 | 0.582 | **1.079** |
| **Orthoptera** | 4 (0.013) | 0.231 | 0.196 | **0.058** |
| Miriapoda | | | | |
| Diplopoda | 1 (0.013) | 0.077 | 0.001 | 0.001 |
| Plant remains | - | 0.538 | 0.008 | - |
| Minerals | - | 0.154 | 0.001 | - |
| UAR | - | 0.923 | 0.035 | |
| $B_A$ | 0.143 | | | |

in the planning of appropriate conservation strategies (Solé et al., 2009).

*Proceratophrys cristiceps* (Müller, 1883) is widely distributed in the dry "caatinga" savannahs of northeast Brazil from the State of Bahia north to the States of Pernambuco, Piauí, Paraíba, Rio Grande do Norte, and Ceará (Carnaval and Borges-Nojosa, 2004; Frost, 2011). Studies on its ecological aspects are few and restricted to information on its tadpole and some scarce information on its breeding activity and call description (Arzabe, 1999; Nunes and Juncá, 2006; Vieira, Vieira and Santana, 2007). Herein we provide information on the diet of *Proceratophrys cristiceps* from a dry forest within the Caatinga Biome in northeastern Brazil. We compare its diet with that of congeners, searching for patterns and underlying components of feeding behavior and diet composition determination within this group of frogs.

## Material and Methods.

The study was conducted in the municipality of Milagres, State of Ceará (7°18'48"S, 38°56'44"W), Northeast Brazil in April, 2008 during a herpetofauna monitoring survey. The area presents a dry semi-arid climate, with average annual precipitation of 939 mm and average temperature varying from 24 to 26°C. The rainfall period extends from December to April. The main phytophysionomy of the area is the arboreal Caatinga (Silva et al., 2007)

Frogs were captured using pitfall traps with drift fences (Cechin and Martins, 2000). Four pitfall arrays, each one with eight (60-liter) buckets placed three meters apart, were installed and checked daily during a nine days period. Individuals collected were euthanized with 5% xylocaine cream, fixed with 10% formalin, and later preserved in 70% isopropyl alcohol. All specimens were deposited in the Museu Nacional do Rio de Janeiro (MNRJ) collection; voucher number: (MNRJ 75156 - 75168).

In the laboratory each individual had its snout-vent length (SVL) and mouth width (MW) measured with a digital caliper (precision 0.01mm) and had its stomach removed through a ventral incision. Stomach contents were placed on a scaled petri dish and identified under a stereomicroscope. After identification, stomach contents were photographed in order to have their length and width measured with the aid of program Image J (Abramoff, Magelhaes and Ram, 2004). These measurements were then used to calculate prey volume according to the ellipsoid formula:

$$Volume = \frac{4}{3}\pi\left(\frac{l}{2}\right)\left(\frac{w}{2}\right)^2$$

where $l$ and $w$ represent length and width of prey, respectively. For each prey category we calculated its proportional contribution in terms of number (FN = number of prey "i" divided by total number of prey), volume (FV = volume occupied by prey "i" divided by total volume), and occurrence (FO = number of frog in which prey "i" occurred divided by total number of frogs). Next we calculated the index of relative importance (IRI) proposed by Pinkas, Oliphant and Iverson (1971): $IRI_i = (FO_i)(FN_i + FV_i)$

In order to facilitate comparisons between different studies, dietary niche breadth was calculated using Levin's standardized index:

$$B_A = \frac{B-1}{n-1}$$

where

$$B = \frac{1}{\sum P_i^2}$$

$n$ is the number of prey categories and $P_i$ is the numeric proportion of prey $i$. This measure was chosen because it gives a value of niche breadth on a standardized scale that ranges from 0 to 1, where 0 and 1 represent minimum and maximum values, respectively (Krebs, 1989).

In order to verify the existence of relationship between morphological variables (SVL and MW) and prey variables (number of items per stomach, maximum length, mean length, maximum volume, and mean volume), simple linear regression was used (Zar, 1996). To investigate if total prey volume was related to number of prey, Spearman´s rank correlation was used (Zar, 1996). Significance level used in all analyzes was α = 0.05. Data throughout the text are given as mean ± SD (range), unless stated otherwise.

**Table 2.** Comparison of dietary aspects of species in the genus *Proceratophrys*. N = sample size; SVL = snout-vent length; ND = data not available.

| Species | Biome | N | SVL (mm) | Prey/ stomach | Most representative preys | | | Authors |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1st | 2nd | 3rd | |
| *P. appendiculata* | Trop. Rain Forest | 18 | 49.4 – 72.2 | 1 | Orthoptera | Blattodea | Gastropoda | Boquimpani-Freitas et al., 2002 |
| *P. boiei* | Trop. Rain Forest | 38 | 18.2 – 73.5 | 2 | Coleoptera | Orthoptera | Insect larvae | Giaretta et al., 1998 |
| *P. boiei* | Trop. Rain Forest | 43 | 26.5 – 51.0 | 3 | Blattodea | Araneae | Orthoptera | Teixeira and Coutinho, 2002 |
| *P. cristiceps* | Caatinga | 13 | 31.54 – 49.23 | 6 | Isoptera | Coleoptera | Orthoptera | This study |
| *P.* gr. *moratoi* | Cerrado | 50 | ND | 4 | Hemiptera | Coleoptera | Orthoptera | Araújo et al., 2007 |
| *Proceratophrys* sp. | Cerrado | 10 | ND | ND | Coleoptera | Isoptera | Orthoptera | Moreira and Barreto, 1996 |

## Results

Thirteen individuals of *Proceratophrys cristiceps* were analysed in order to access gut content, all of which had food in their stomachs. Mean SVL was 38.72 ± 4.69mm (31.54 – 49.23mm) and mouth width was 15.26 ± 2.21mm (12.20 – 18.75mm). A total of 75 food items belonging to eight categories were identified. Plant remains, mineral fragments and unidentified animal remains (UAR) were not considered as prey categories, but were present in 53.85, 15.38 and 92.31% of individuals, respectively. UAR accounted for 3.5 ± 2.5% (0 – 7.8%) of total volume in stomachs. Number of prey items per stomach was 5.77 ± 2.89 (1 – 11) and was not significantly related to SVL ($F = 2.77$; $p = 0.12$) or mouth width ($F = 2.79$; $p = 0.12$). Mean prey length was 8.64 ± 2.18mm (1.73 – 14.56mm) and was also not significantly related to SVL ($F = 3.81$; $p = 0.07$) or mouth width ($F = 1.21$; $p = 0.29$). We also did not detect any significant relationship between morphological variables (SVL and MW) and length or volume of largest prey, total stomach volume or mean prey volume per stomach (all $p > 0.05$). No relationship was detected between prey volume and number of preys ($t = -0.19$; $p = 0.85$).

The diet of *Proceratophrys cristiceps* was composed of different arthropod categories and Gastropoda (Table 1). Four categories were consumed by more than five percent of individuals analysed: Isoptera, Coleoptera, Orthoptera and Isopoda (Table 1). Isoptera was the most frequent prey (84.61%), being also the most representative prey both numerically (69.33%) and volumetrically (58.20%). According to the index of relative importance, Isoptera was the most important prey category, with Coleoptera and Orthoptera being the second and third, respectively (Table 1). Levin´s standardized niche breadth was 0.143 (Table 1).

## Discussion

The size of *P. criticeps* in the present study fell within the size range of other species in the genus for which diet data are available (Table 2), reducing possible bias associated with ontogenetic variation, as has been observed in other species of anurans (Lima, 1998; Hirai and Matsui, 2000). The lack of empty stomachs can be interpreted as a positive energetic balance within the studied population as has been suggested by Huey, Pianka and Vitt (2001).

The lack of relationship between morphological variables and prey variables in the present study was also detected in *P. boiei* from Espírito Santo (Teixeira and Coutinho, 2002), but contrasted with the patterns observed in *P. appendiculata* and *P. boiei* from São Paulo, where SVL is positively related to size of largest prey (Giaretta et al., 1998; Boquimpani-Freitas, Rocha and Van Sluys, 2002). According to Teixeira-Filho, Rocha and Ribas (2003), this lack of relationship is to be expected in species that specialize on small prey that have reduced size variation and are easily consumed by individuals of different sizes within a population, such as termites. Although we cannot affirm that *P. cristiceps* is specializing its diet on termites, the importance of this prey among studied individuals make the above explanation just as plausible.

Among other *Proceratophrys* species that had their `diet composition analysed (Giaretta et al., 1998; Boquimpani-Freitas, Rocha and Van Sluys, 2002; Teixeira and Coutinho, 2002; Araujo et al., 2007), *P. cristiceps* seems unique in being the only one that has Isoptera as its main prey. The exception is *Proceratophrys* sp. from the Cerrado savannahs of central Brazil, where termites occurred in nine of ten individuals analysed (Moreira and Barreto, 1996), although in terms of biomass and abundance it was not the most representative. Isoptera was not reported for *P. appendiculata* or *P. boei* from Espirito Santo (Boquimpani-Freitas, Rocha and Van Sluys, 2002; Teixeira and Coutinho, 2002). In *P.* gr. *moratoi* and *P. boiei* from São Paulo, Isoptera made up no more than five percent of preys (Giaretta et al., 1998; Araújo et al., 2007). The clustered aspect of termites was probably the reason for the highest mean number of prey per stomach in *P. cristiceps* in relation to the other species (Table 1).

Termites are relatively small and slow moving prey that occur clustered in space and are considered a typical prey item of active foragers (Huey and Pianka, 1981; Teixeira-Filho, Rocha and Ribas, 2003; Duré and Kehr, 2004). On the other hand, Orthoptera has been considered a large and mobile prey characteristic of predators with a sit-and-wait behavior (Toft, 1980, 1981). Considering the hot and dry conditions in the studied area, it is possible *P. cristiceps* seeks refuge and concentrates its activities in microhabitats that retain some moisture, usually under dead trees; if termites are seeking refuge in these same microhabitats, then *P. cristiceps* may retain a sit-and-wait behavior and still include such items in its diet. The presence of Gastropoda and Isopoda, preys associated with humid microhabitats, supports this hypothesis. Such hypothesis is further supported by the presence of Orthoptera as one of the most important prey and by the stocky, wide mouthed and cryptic aspect of *P. cristiceps* (Toft, 1981). The association between diet composition and use of microhabitats has been observed in some termite specialists (Vitt et al., 2007). In the Caatinga Biome termites are the most abundant terrestrial macroinvertebrates, with peak of abundance and biomass occurring through-out the rainy season (Vasconcelos et al. 2007; Araújo, Bandeira and Vasconcelos, 2010; Vasconcelos et al., 2010). Given that frogs were collected at the end of the rainy season, it is possible the large consumption of termites was a result of the high abundance of this prey during the period of study.

Ants (Formicidae) have been found to be amongst the most important preys in some species closely related with cycloramphid frogs, such as the Hylodidae *Crossodactylus gaudichaudii*, *Hylodes phyllodes*, as well as in the cycloramphids *Thoropa miliaris* and *T. taophora* (Siqueira et al., 2005; Almeida-Gomes et al., 2007; Brasileiro, Martins and Sazima, 2010). Although this prey category is usually associated with active foragers (Toft, 1980, 1981), Brasileiro, Martins and Sazima (2010) make a distinction in foraging mode between males and females in *T. taophora*. Considering the above and based on the most important preys of the congeneric species studied so far, we believe the sit-and-wait behavior seems to be somewhat phylogenetic restricted within the genus *Proceratophrys* (Table 2). In turn, diet composition seems to be more influenced by local prey abundance and ecological interactions.

Recent researches have called attention to the importance of niche conservatism in the retention of certain ecological characteristics within closely related lineages (Peterson, Soberón and Sánchez-Cordero, 1999; Wiens, 2004; Wiens and Graham, 2005). Although at the moment we can only be speculative on such a theme, more data on the diet of other species of *Proceratophrys*, as well as on their evolution, will clarify the importance of ecological interactions and phylogeny in the determination of feeding behavior and other ecological niche aspects.

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## References

Abramoff, M.D., Magelhaes, P.J., Ram, S.J. (2004): "Image Processing with ImageJ". Biophotonics International **11**(7): 36-42.

Araújo, M.S., Reis, S.F., Giaretta, A.A., Machado, G., Bolnick, D.I. (2007): Intrapopulation Diet Variation in Four Frogs (Leptodactylidae) of the Brazilian Savannah. Copeia **2007**(4): 855-865.

Araújo, V.F.P., Bandeira, A.G., Vasconcelos, A. (2010): Abundance and stratification of soil macroarthropods in a Caatinga forest in Northeast Brazil. Braz. J. Biol. **70**(3): 737-746.

Arzabe, C. (1999): Reproductive activity patterns of anurans in two different altitudinal sites within the Brazilian Caatinga. Rev. Bras. Zool. **16**(3): 851-864.

Böhning-Gaese, K., Schuda, M.D., Helbig, A.J. (2003): Weak phylogenetic effects on ecological niches of *Sylvia* warblers. J. Evol. Biol. **16**: 956-965.

Boquimpani-Freitas, L., Rocha, C.F.D., Van Sluys, M. (2002): Ecology of the Horned Leaf-Frog *Proceratophrys appendiculata* (Leptodactylidae), in an insular Atlantic Rain-Forest Area of Southeastern Brazil. J. Herpetol. **36**(2): 318-322.

Caldwell, J.P. (1996): The Evolution of myrmecophagy and its correlates in poison frogs (Family Dendrobatidae). J. Zool. **240**: 75-101.

Carnaval, A.C., Borges-Nojosa, D. (2004). *Proceratophrys cristiceps*. In: IUCN 2010. IUCN Red List of Threatened Species. Accessible at http://www.iucnredlist.org. Downloaded on 07 April 2011.

Cechin, S.Z., Martins, M. (2000): Eficiência de armadilhas de queda (*pitfall traps*) em amostragens de anfíbios e répteis no Brasil. Rev. Bras. Zool. **17**(3): 729-740.

Duré, M.I., Kehr, A.I. (2004): Influence of microhabitat on the trophic ecology of two leptodactylid from northeastern Argentina. Herpetologica **60**(3): 295-303.

Frost, D. R. (2011): Amphibian Species of the World: an Online Reference. Version 5.4 Museum of Natural History, New York, USA. Accessible at http://research.amnh.org/vz/herpetology/amphibia/American. Downloaded on 07 February 2011.

Giaretta, A.A., Araújo, M.S., Medeiros, H.F., Facure, K.G. (1998): Food Habits and Ontogenetic Diet Shifts of the Litter Dwelling Frog *Proceratophrys boiei* (Wied). Rev. Bras. Zool. **15**(2): 385-388.

Hirai, T., Matsui, M. (2000): Myrmecophagy in a Ranid Frog *Rana rugosa*: Specialization or Weak Avoidance to Ant Eating? Zool. Scien. **17**: 459-466.

Huey, R.B., Pianka, E.R., Vitt, L.J. (2001): How Often do Lizards "Run on Empty"? Ecology **82**(1): 1-7.

Krebs, C. J. (1989): Ecological methodology. New York, Harper and Row.

Moreira, G., Barreto, L. (1996): Alimentação e variação sazonal da freqüência de capturas de anuros em duas localidades do Brasil Central. Rev. Bras. Zool. **13**(2): 313-320.

Nunes, I., Juncá, F.A. (2006): Advertisement call of three leptodactylid frogs in the State of Bahia, Northeastern Brazil (Amphibia, Anura, Leptodatylidae), with consideration in their taxonomic status. Arq. Mus. Nac. **64**(2): 151-157.

Peterson, A.T., Soberón, J., Sánchez-Cordero, V. (1999): Conservatism of Ecological Niches in Evolutionary Time. Science **285**: 1265-1267.

Pinkas, L., Oliphant, M.S., Iverson, Z.L. (1971): Food habits of albacore bluefin, tuna and bonito in California waters. Calif. Dept. of Fish and Game **152**: 1-350.

Sazima, I. (1978): Convergent defensive behavior of two leaf litter frogs of southeastern Brazil. Biotropica **10**: 158.

Silva, M.A.M., Araújo, T.M.C., Mendonça, F.G.T.,Souz, M.M.A. (2007): Fitofisionomia de uma Caatinga no municipio de Milagres, CE. Cad. Cult. Cienc. **2**(1): 1-9.

Simon, M.P., Toft, C.A. (1991): Diet Specialization in Small Vertebrates: Mite-Eating in Frogs. Oikos **61**(2): 263-278.

Solé, M., Dias, I.R., Rodrigues, E.A.S, Marciano-Jr, E., Branco, S.M.J., Cavalcante, K.P., Rödder, D. (2009): Diet of *Leptodactylus ocellatus* from a cacao plantation in southern Bahia, Brazil. Herpetology Notes **2**: 9-15.

Teixeira, R.L., Coutinho, E.S. (2002): Hábito alimentar de *Proceratophrys boei* (Wied) (Amphibia, Anura, Letodactylidae) em Santa Teresa, Espirito Santo, sudeste do Brasil. Bol. Mus. Biol. Mello Leitão (N. Ser.) **14**: 13-20.

Toft, C.A. (1980): Feeding Ecology of Thirteen Syntopic Species of Anurans in a Seasonal Tropical Environment. Oecologia **45**: 131-141.

Toft, C.A. (1981): Feeding Ecology of Panamanian Litter Anurans: Patterns in Diet and Foraging Mode. J. Herpetol. **15**(2): 139-144.

Vasconcelos, A., Andreazze, R., Almeida, A.M., Araújo, H.F.P., Oliveira, E.S., Oliveira, U. (2010): Seasonality of insects in the semi-arid Caatinga of Northeastern Brazil. Rev. Bras. Entomol. **54**(3): 471-476.

Vasconcelos, A., Araújo, V.F.P., Moura, F.M.S., Bandeira, A.G. (2007): Biomass and population structure of *Costrictotermes cyphergaster* (Silvestri) (Isoptera: Termitidae) in the dry forest of Caatinga, Northeastern Brazil. Neotrop. Entomol. **36**(5): 693-698.

Vieira, W.L.S., Vieira, K.S., Santana, G.G. (2007): Description of the tadpoles of Proceratophrys cristiceps (Anura: Cycloramphidae, Odontophrynini). Zootaxa. **1397**: 17-24.

Vitt, L.J., Shepard, D.B., Caldwell, J.P., Vieira, G.H.C., França, F.G.R., Colli, G.R. (2007): Living with your food: geckos in termitaria of Cantão. J. Zool. **272**(3): 321-328.

Wiens, J.J. (2004): Speciation and ecology revisited: phylogenetic niche conservatism and the origin of species. Evolution **58**(1): 193-197.

Wiens, J.J., Graham, C.H. (2005): Niche Conservatism: Integrating Evolution, Ecology and Conservation Biology. Annu. Rev. Ecol. Evol. S. **36**: 519-539.

Zar, J.H. (1996): Biostatistical Analysis, 3rd edition. New Jersey, Prentice-Hall, Inc.

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