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Population structure and activity pattern of one species of *Adenomera* Steindachner, 1867 (Anura: Leptodactylidae) in northeastern Brazil

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Abstract. We analyzed the population structure and sexual size dimorphism of an *Adenomera* species occurring in the municipality of São Gonçalo do Amarante, from September 2010 to August 2011, using pitfall traps and active searches. We captured 116 individuals; 36 males, 23 females and 57 juveniles. Sexual size dimorphism was not observed. The smallest individuals were found in the middle of the rainy season, and the higher abundance of juveniles during this period may be related to recruitment. Females were captured in pitfall traps more often than males, while males were captured during active searches more often than females due to their calling behavior. We provide basic information regarding this *Adenomera* population, located in a region of severe environmental degradation, which may serve as a source of information for future studies of the area aiming to evaluate how the construction of industrial complexes affects anuran populations.

Keywords. Amphibian, Ceará, *Leptodactylus marmoratus* group, sexual size dimorphism.

Constant environmental degradation, mainly caused by human action, has brought about serious changes in global diversity, with habitat loss being the greatest threat to biodiversity (Vitousek et al., 1997). Elimination or modification of specific anuran microhabitats has been considered the main factor responsible for population declines of several species of this taxonomic group (Young et al., 2001; Becker et al., 2007).

Basic information studies detailing the population structure of anurans have increased over the years, but they are concentrated in biomes such as the *Cerrado* (Giaretta and Menin, 2004; Kokubum and Giaretta, 2005; Giaretta et al., 2008), Neotropical rainforest (Sá et al., 2014) and Amazon forest (Menin et al., 2007; Kokubum and Sousa, 2008; Waldez et al., 2011). Some studies report data on the abundance, size classes and population recruitment (which mainly occurs in the wet period) of amphibian species, and sexual dimorphism, with females typically larger than males (e.g., Giaretta and Menin, 2004; Kokubum and Giaretta, 2005; Kokubum and Sousa, 2008; Waldez et al., 2011). In addition, adult and juvenile size, and sex-ratio data are important to better understand the population structure, expanding on knowledge that generally focuses on reproduction and diet.

Members of the genus *Adenomera* are recognized by their small size (snout vent length average is 18-25mm), have terrestrial habits and some species lay their eggs in underground chambers with tadpoles completing development in foam nests (Angulo et al., 2003; Kokubum and Giaretta, 2005; Kok et al., 2007; Kokubum and Sousa, 2008), or in pools originated by flooding of the nest (De la Riva, 1995; Almeida and Angulo, 2002; Carvalho and

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Giaretta, 2013) or in holes in fallen tree trunks (Menin and Rodrigues, 2013). In this paper, we aim to analyze the population structure, the activity pattern, and sexual size dimorphism of one species of *Adenomera* in an area that suffers strong disturbance due to the installation of an industrial complex. Furthermore, we aim to expand the knowledge of the *Adenomera* group, and provide data for future studies that seek to resolve its current taxonomic confusion.

We performed the fieldwork in the municipality of São Gonçalo do Amarante, Ceará state, Brazil (Fazenda Maceió da Taíba: 03°30'54"S, 38°55'07"W) from September 2010 to August 2011. The climate is defined by two periods: dry (July-December) and rainy (January-June). Mean annual rainfall is 1,026 mm and mean annual temperature is 27°C (FUNCEME–Fundação Cearense de Meteorologia e Recursos Hídricos). The study area is a forest fragment mostly composed of coastal, inter-dune, semi-deciduous forest (*mata de tabuleiro*), where approximately 382 plant species have been recorded (Castro et al., 2012), largely consisting of small trees. The nearest water source is an inter-dune pond located approximately 500 to 1000 meters from the sampling point.

We conducted samplings once a month lasting three days per field trip to observe a population of *Adenomera* sp. This undescribed species has been recorded until now only from São Gonçalo do Amarante (Borges-Leite et al., 2014), and has been analyzed and confirmed by experts as a new species (Kokubum, pers. comm.). This species has a seasonal reproductive pattern with breeding occurring only in wetter months, and tadpole development has no aquatic stage (Borges-Leite et al., 2015).

Active searches, unlimited by time, were performed by two people mainly in areas of forest without a water source, from 3 p.m to 12 a.m. Pitfall traps were also disposed in a forest fragment of semi-deciduous forest (*mata de tabuleiro*), but in a different location to those used for active searches. Pitfall traps were composed of a five-station line; each station (trap) consisting of four plastic buckets of 60 L arranged in a "Y" (Heyer et al., 2001), totaling five traps per day of effort.

We sexed all captured individuals based on external morphology (shovel-shaped snout on males) and measured snout-vent length (SVL) with a digital caliper (accurate to 0.01 mm) to ascertain the presence of sexual size dimorphism. To classify individuals as juvenile or adult, we used the method of Waldez et al. (2011), in which the size of the smallest calling male is used to classify juvenile individuals (juveniles had SVL < 18.8 mm in our study). Individuals larger than 18.8 mm were classified in males or females according to the external morphology described above.

We used Welch's *t* test to analyze sexual dimorphism in snout-vent length, since this variable had a normal distribution. We used the Kruskal-Wallis (K-W) test to evaluate variation in SVL of juveniles, males, females, and the total population between the months in which they were sampled. We used Chi-Squared tests to evaluate the number of males and females captured in each sampling method used in this study (active searches and pitfall traps). All statistical analyses were performed using stats packages available in R, version 2.13.2 (R Development Core Team, 2014). The alpha value was set to 5% for all statistical tests. Descriptive statistics are presented in this paper as mean ± standard deviation.

After 12 months of sampling, the applied effort was 180 traps × days (five pitfall traps × three days × 12 months) and 720 hours of active searches (10 hours × three days × 12 months × two persons). We captured 116 individuals: 36 males, 23 females and 57 juveniles (Fig. 1-2 and Table 1). Adult females were captured in all samplings during the rainy season (January-June) and adult males were captured between January and April. We captured juveniles from February to June, with a peak in number in May. Juveniles were sampled throughout the rainy season, except at its onset, in January, and their size varied during the sampling period (K-W test, H = 37.68, df = 4, P < 0.001, Fig. 3A), being small at the beginning of the rainy season and larger close to the dry season.

Males had SVL ranging between 18.8-22.6 mm (mean = 20.77 ± 0.87 mm, n = 36), while females ranged between 18.8-25.5 mm (mean = 21.46 ± 1.94 mm, n = 23). The size of males did not change during the study (K-W test, H= 2.38, df = 3, P = 0.50, Fig. 3B), but SVL of females (K-W test, H = 11.49, df = 4, P = 0.04, Fig. 3C) and the total population (K-W test, H = 43.81, df = 4, P < 0.001, Fig. 3D) were larger at the beginning of the rainy season. There was no evidence of sexual dimorphism in size (t = 1.62, df = 27.66, P = 0.11). Morphological differences between males and females were observed, with males having a more shovel-shaped snout. The proportion of males and females captured in pitfall traps was significantly different with a higher number of females than males captured (χ^2 = 17.19, df = 1, P < 0.001; Table 1). The captures were also sex-biased in active searches, with a higher number of males than females (χ^2 = 26.95, df = 1, P < 0.001; Table 1).

Significant differences in sex ratio with a male-biased sample may result from behavioral differences between the sexes (Giaretta and Menin, 2004) or even the choice of sampling method (Fogarty and Vilella, 2002). Active search, for example, may bias the result of the sex ratio towards males (Fogarty and Vilella, 2002; Waldez et al., 2011). The male-biased capture in active search may be

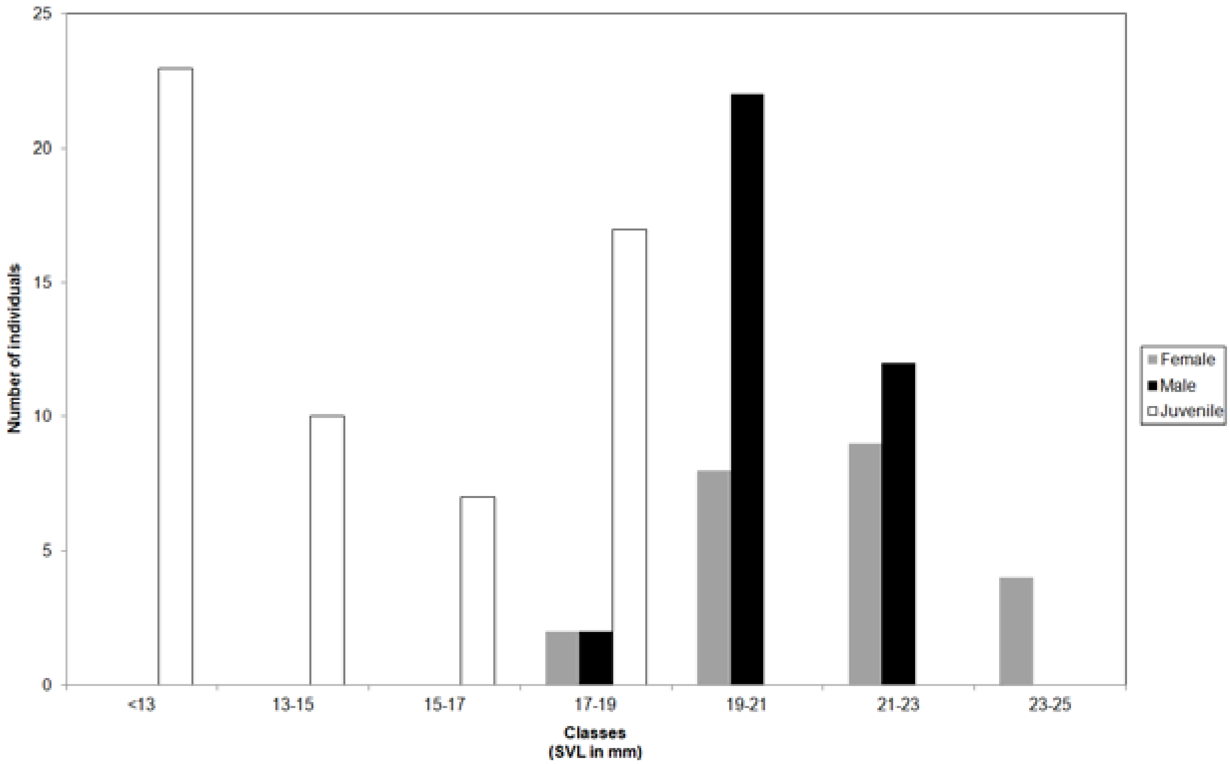

Fig. 1. Snout-vent length (SVL) class-size distribution in *Adenomera* sp. females, males and juveniles.

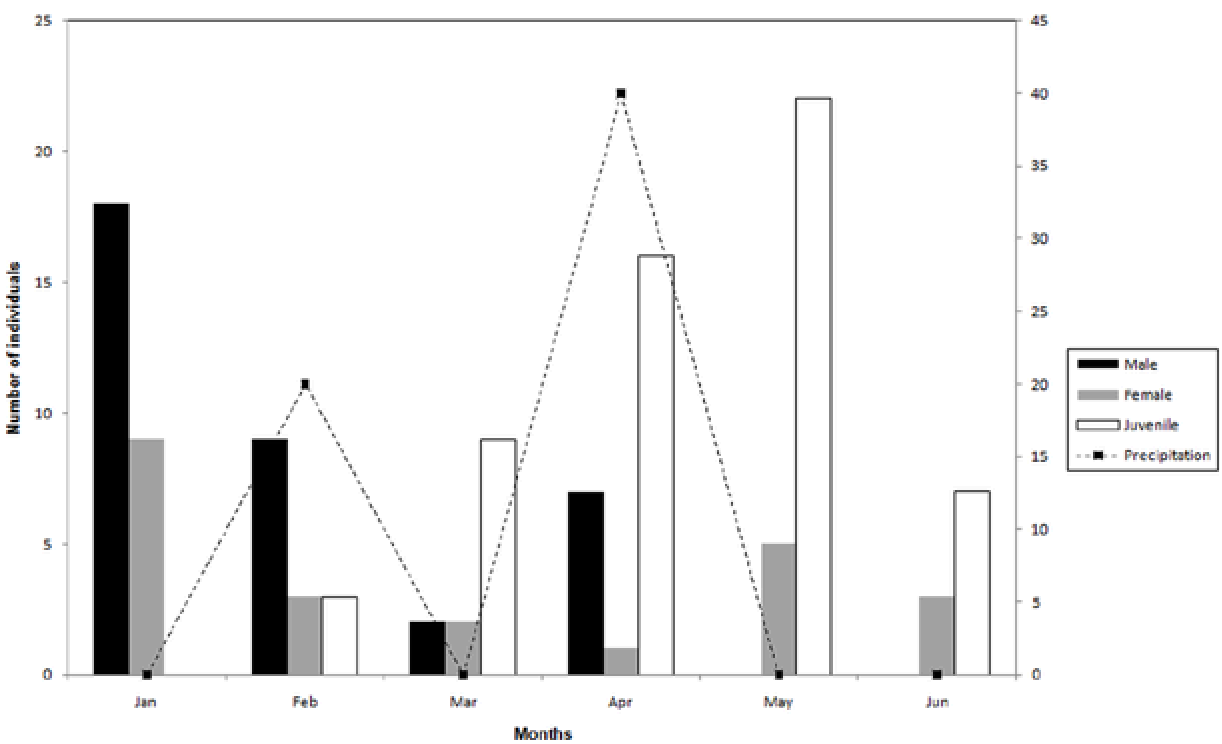

Fig. 2. Number of *Adenomera* sp. males, females and juveniles sampled each month from January – June 2011 at São Gonçalo do Amarante, Ceará, Brazil.

Table I. Number and sex of *Adenomera* sp. individuals captured using pitfall traps and active search methods.

Categories	Method of capture	
	Pitfall traps	Active searches
Male	1	35
Female	20	3

due to researchers being guided by the calling behavior of males, while females go unnoticed. This bias was also found in our results for active searches (Table 1).

In most anurans, there is no difference in activity pattern between males and females (Lemckert, 2004). However, we found that females were captured in pitfall traps more frequently than males, suggesting higher mobility for this sex because active animals are more captured by this trap than inactive ones. Females usually use larger areas than males due to increased energetic demands and nutritional requirements (Muths, 2003). This difference in movement pattern was not observed by Kokubum and Giaretta (2005), who found a non-significant difference in the number of individuals of each sex captured in pitfall traps in Uberlândia, Minas Gerais.

Amphibians that have a long reproductive period can recruit juveniles during most of the year (López et al., 2011). Some studies of species with terrestrial reproduction showed that a peak in reproductive activity and juvenile growth occurs in the rainy season (Moreira and Lima, 1991; Ovaska, 1991; Kokubum and Giaretta, 2005; Borges-Leite et al., 2015). Once the number of juveniles is increasing in the population, a decrease in the average body size of the population is expected, as previously observed in other genera, suggesting the occurrence of recruitment events (Menin et al., 2007; Waldez et al., 2011). In our study the rainy season was marked by a variation in the size and number of captured juveniles, and by the occurrence of a greater abundance of juveniles than adults in the last months of the season. These characteristics suggest the existence of recruitment events in this population in the rainy period, beginning in February and peaking in May. This recruitment can also be observed by the decrease in SVL of the total population during the study (Fig. 3D). It can also be seen that in May, three months after recruitment started, the size of females is smaller than in previous months, indicating that some of the individuals previously classified as juveniles have already become adult. This observation in females supports the results of Sá et al. (2014), with regard to adult body size variation in anurans with prolonged reproduction, although we did not find the same variation in males. Although there are some stud-

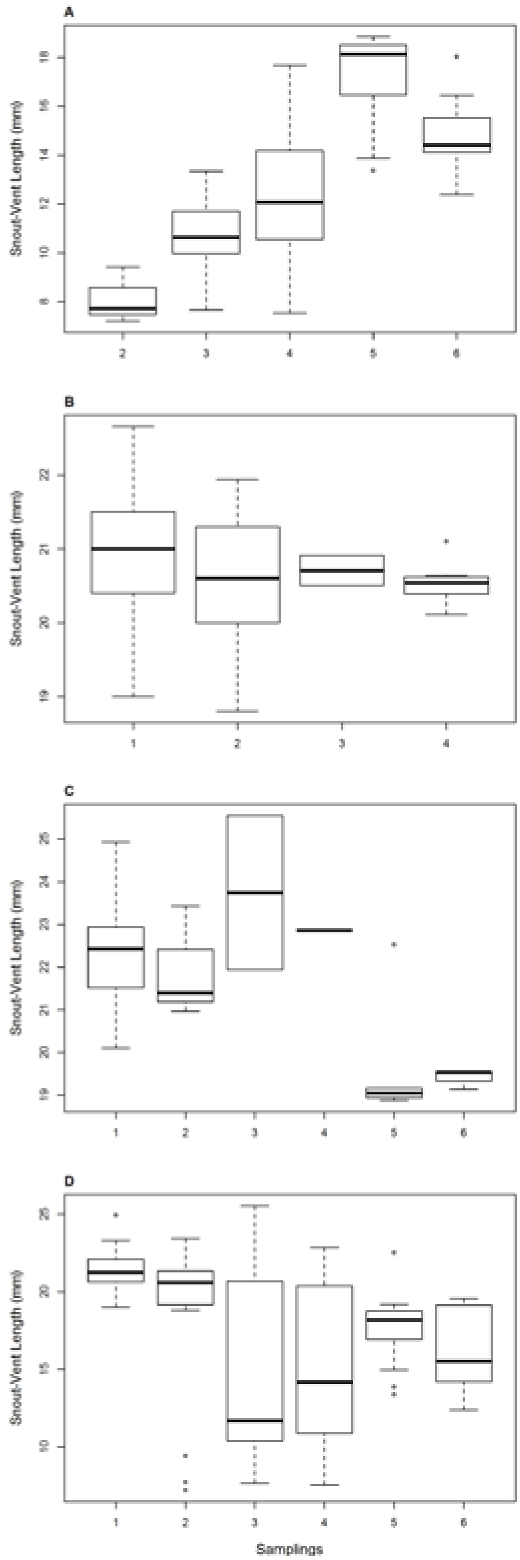

Fig. 3. Variation in snout-vent length of *Adenomera* sp. from January – June 2011. A) Juveniles; B) Males; C) Females; and D) Total population (1 = January, 2 = February, 3 = March, 4 = April, 5 = May and 6 = June).

ies in Brazilian coastal regions focusing on reproductive patterns and sexual dimorphism of anurans (e.g. Giasson and Haddad, 2007), to our knowledge, our study is the first to explore the population structure of a coastal anuran. Our study showed that in this population of *Adenomera* there is no sexual size dimorphism, contrary to 90% of frog species in which females are larger than males (Shine, 1979) and also to other species of the genus *Adenomera* (e.g. Kokubum and Giaretta, 2005; Kok et al., 2007). This sexual difference in anurans may arise, for example, because females delay their reproduction and invest more time in growth than males, which grow up fast and start reproductive activity early (Zhang and Lu, 2013). However, in an environment where the rainy season is reduced, such as in our study area, it may be advantageous for females not to delay reproduction.

We conclude that juvenile recruitment in this population of *Adenomera* occurs in the rainy season, and there was no sexual size dimorphism. Hence, we add new important data to the problematic *Adenomera* group. The taxonomic problems of this group, which include great intra- and inter-population morphological variation and cryptic species (De la Riva, 1996; Angulo et al., 2003), need more population studies in order to help understand its variation. Regarding the population from São Gonçalo do Amarante, this study may be a starting point for future studies aiming to evaluate the impact of the Port and Industrial Complex over a year-long interval in an anuran population. At the current moment, the *Adenomera* population has a high recruitment, favoring its maintenance, but only future detailed studies will be able to evaluate its ability to co-occur alongside strong human disturbance.

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