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Opening a turtle graveyard: Size distribution of dead individuals of *Phrynops geoffroanus* (Pleurodira, Chelidae)

João Fabrício Mota Rodrigues[1], Natália Rizzo Friol[2], Wagnar C. Silva[3], Erica Demondes[3], Antonio Millas Pinto[3], Hugo Fernandes-Ferreira[3]

1 *Departamento de Ecologia, Laboratório de Ecologia Teórica e Síntese (LETS) – Campus II - Universidade Federal de Goiás, Avenida Esperança, s/n, Goiânia, 74001-970, GO, Brazil*
2 *Departamento de Zoologia, Instituto de Biociências, Universidade de São Paulo, Rua do Matão, Travessa 14, São Paulo, 05508-090, SP, Brazil*
3 *Laboratório de Conservação de Vertebrados Terrestres (Converte). Universidade Estadual do Ceará. Avenida José de Queiroz Pessoa, 2554, Quixadá, 63900-000, CE, Brazil*

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Corresponding author: *João Fabrício Mota Rodrigues* (fabriciorodrigues303@gmail.com)

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Abstract

Aquatic animals, such as freshwater turtles, are much dependent on the water bodies where they live. Here we describe the size distribution of a population of *Phrynops geoffroanus* complex that died after the total drought of the artificial water reservoir where it lived in Caatinga. Amongst the 438 animals we found dead in the Cedro water reservoir, we measured the maximum carapace length of 72 individuals. The population was mainly composed of adult individuals and dead turtles measured in areas that kept water for longer were larger than animals from areas that dried up early.

Key Words

body size, Caatinga, Cedro, drought, freshwater turtles

Introduction

Freshwater organisms are vulnerable to occasional droughts or time periods with low precipitation which results in the demand for strategies to deal with these harsh conditions (Brock et al. 2003; Humphries and Baldwin 2003; Willson et al. 2006; Roe and Georges 2008). The Caatinga is a semi-arid biome endemic to north-eastern Brazil, where precipitation is very seasonal and most aquatic systems dry up for some period of the year (Barbosa et al. 2012). This seasonal climate strongly influences the natural history and communities of organisms living in this biome (Souza and Abílio 2006; Chellappa et al. 2009; Rodrigues and Silva 2014).

Phrynops gr *geoffroanus* (Pleurodira, Chelidae) is a side-neck turtle widely distributed in freshwater drainages of South America, including Caatinga (Turtle Taxonomy Working Group 2017); it currently forms a still much-debated species complex (Pritchard and Trebbau 1984; Ernst and Barbour 1989; Rueda-Almonacid et al. 2007; Ceríaco and Bour 2012; Friol 2014; Carvalho et al. 2017; hereafter simply *Phrynops geoffroanus*). Hatchlings of *P. geoffroanus* have, on average, 3.83cm of carapace length (Ferreira Júnior et al. 2011), while adult females of this species may reach up to 39 cm of carapace length (Friol 2014). Although Chelidae is the most diverse freshwater turtle family in Brazil and *P. geoffroanus* is the most widely distributed species in this country (Turtle Taxonomy

Working Group 2017), no strategies to deal with severe drought periods have been described for this species, which commonly inhabits large and perennial aquatic systems, even urban polluted streams, where it performs activities like feeding, copulating and resting (Souza and Abe 2001; Rueda-Almonacid et al. 2007; Souza et al. 2008). In this study, we aim to describe a population of *P. geoffroanus* which inhabited an artificial water reservoir that was drastically influenced by a complete drought in 2016. We used data on the dead turtles found there to describe the size distribution of individuals of *P. geoffroanus* that died and to evaluate whether the drying process of a water reservoir may influence its turtle population.

Methods

The research was carried out in the municipality of Quixadá, located in the central region of the Ceará State, north-eastern Brazil. The climate is considered as Aw (tropical savannah / tropical wet and dry) (Köppen-Geiger classification) with an annual rainfall of 765 mm and average temperature 26–28°C. This semi-arid region is characterised by long and severe periods of drought. Its rainy season generally occurs between February and April (IPECE 2017).

Data were collected in the 512-ha Cedro Water Reservoir (CWR) (Fig. 1). This artificial water reservoir was built between 1890 and 1906 by the Portuguese Empire on the bed of the Sitiá River, whose source is in Quixadá city and flows to Banabuiú River. The CWR and its margins are impacted by agriculture, removal of ciliary forest and river siltation. In December 2016, CWR dried up completely. We carried out fieldwork in the last remaining 115.7 ha that stored water before the rainy season of 2016. According to local residents, drying of our study area occurred in two parts: A) area that dried between July 2016 and October 2016 (4°58'40"S, 39°4'1"W – 73.7ha) and B) area that dried between October 2016 and December 2016 (4°58'31"S, 39°3'44"W – 42 ha) (Fig. 1).

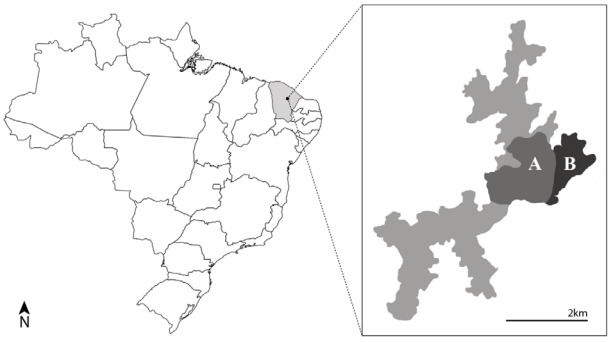

Figure 1. Location of the Cedro Water Reservoir, Ceará State, in Brazil and the delimitation of the areas that dried between July 2016 and October 2016 (A) and between October 2016 and December 2016 (B).

On 27 and 28 December 2016, four persons counted all individuals found in the 115.7 ha investigated. The whole 115.7 ha area was searched with the same search effort and the sample was performed when it was completely dry. We found 438 dead individuals of *P. geoffroanus* (263 individuals in area A and 175 individuals in area B) but no living ones. During the second week of January 2017, we conducted another field expedition to record the maximum straight carapace length (MCL, up to the nearest mm) of individuals found in each area using a caliper. We only measured MCL of animals with intact shells to ensure reliability of our measurements. Amongst the individuals captured, only those, larger than 15 cm, were classified as adults following Molina (1989). Unfortunately, it was not possible to identify the sex of these individuals using only remaining shell fragments. We compared the shell length of the measured animals found in the two areas using a Mann-Whitney test. All statistical analyses were performed with the software R ver. 3.3.1 (R Core Team 2016).

Results

The shells of most dead turtles were broken or partially disjointed precluding a reliable measurement of MCL and thus reducing our effective sample size. We recorded the MCL of 72 individuals that were well conserved (mean = 21.51 cm, median = 22.36 cm, SD = 4.42 cm, range = 11.90–29.99 cm) and most of them were adult (65 individuals were larger than 15 cm, while seven juveniles were smaller) (Fig. 2). Animals collected in area B were significantly larger than those collected in area A (U = 182, p = 0.003, N = 13 in area A, N = 59 in area B; Fig. 3).

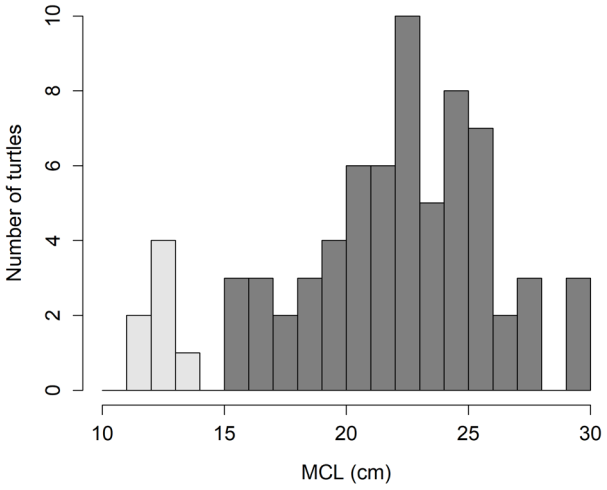

Figure 2. Body size distribution (maximum carapace length, MCL, in cm) of *Phrynops geoffroanus* individuals found dead in the Cedro Water Reservoir (N = 72). Light grey bars are juveniles (individuals < 15 cm) and dark grey are adults (individuals > 15 cm).

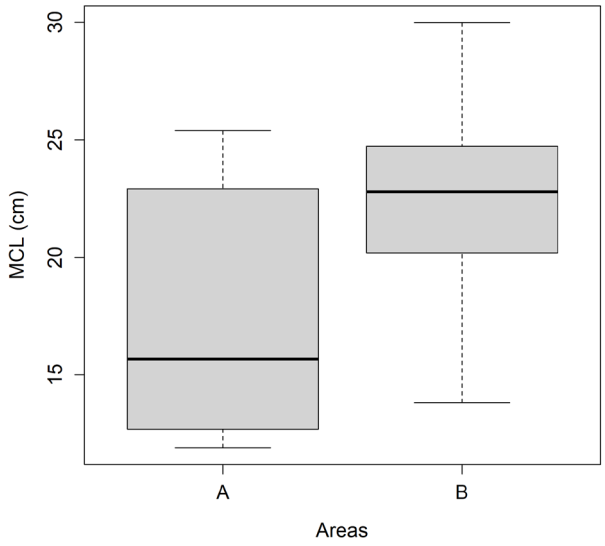

Figure 3. Box plots for body size (maximum carapace length, MCL, in cm) of *Phrynops geoffroanus* individuals found dead in the Cedro Water Reservoir in areas that dried in two different time periods: A = areas that dried between July 2016 and October 2016, N = 13; B = areas that dried between October 2016 and December 2016, N = 59. Horizontal lines inside the boxes are medians; lower and upper box limits represent 1st and 3rd quartiles, respectively; and lower and upper horizontal lines outside the boxes represent the most extreme data points.

Discussion

This high mortality of individuals of *P. geoffroanus* in the CWR was noticed by many non-scientific newspapers (e.g. Guimarães 2017; Hospital and Rogers 2017). However, this study represents the first proper evaluation of this event, including data regarding body size of the dead animals. Unfortunately, we could not measure many individuals from area A because, once this area dried up first, these animals were more exposed to human and environmental pressure which advanced their degradation.

The body size distribution of the *P. geoffroanus* population in Cedro is similar to size distribution patterns found in other turtle studies, which suggests a population structure with a dominance of adult individuals (e.g. Souza and Abe 2001; Brito et al. 2009; Famelli et al. 2011; Marques et al. 2013; Rodrigues and Silva 2015). However, it is important to note that the number of small turtles in the population is likely higher than reported because this group has a more fragile shell, has higher decomposition rates than large turtles and is more difficult to be detected, besides being scavenged more quickly by other animals.

We found that area B had larger animals than area A. A similar pattern where large turtles also responded better to harsh conditions than small turtles may be found in turtles living in areas experiencing cold winters, another type of extreme environmental change, where overwintering occurs: Bodie and Semlitsch (2000) recorded that *Graptemys pseudogeographica* and *Trachemys scripta* that were dead after overwintering were usually smaller than individuals found alive. One possible explanation for this pattern is that larger animals are more resistant to the changes in water temperatures and to dehydration than smaller animals and were able to survive and to track the water availability. A similar mechanism has been used to explain why amphibians from arid areas are larger than those living in mesic conditions (Gouveia and Correia 2016). Thus, we hypothesise that large individuals of *P. geoffroanus* were better able to track the drought of the water reservoir, being more abundant in areas that dried up last and dying only after the whole water source disappeared. Another potential explanation for this pattern is that, after the reduction of water level and the increase in turtle density per area, small turtles were also more susceptible to predation.

Although we did not find any living individual of *P. geoffroanus* during our survey, some months later (in May 2017) in the rainy season, when the water reservoir started to gain some water, we observed an adult individual of this species in CWR. Freshwater turtles may move long distances towards water bodies in the neighbourhood or may estivate (Ligon and Stone 2003; Roe and Georges 2008; Pérez-Pérez et al. 2017; Purcell et al. 2017). The fast re-appearance of adult *P. geoffroanus* in CWR suggests that this species may also have strategies to deal with droughts. However, a large number of specimens (N = 438) did not succeed in moving to a permanent water body and died. According to Rueda-Almonacid et al. (2007), *P. geoffroanus* does not leave water for long periods, reinforcing the water dependency of this species, where it performs its basic activities like resting and feeding. To properly understand whether and which of those strategies are utilised by this species, future studies should further monitor this *P. geoffroanus* population and use radio-transmitters or another individual marking system such as painting or scute marks (Cagle 1939; Kornilev et al. 2012) to study this species movement pattern, mainly in the dry season. These results would be valuable to freshwater turtle studies in other arid and semi-arid areas, where these animals can suffer from similar environmental pressures.

Large individuals of *P. geoffroanus* were mainly found in areas that dried later. Our results reinforce the importance of studying physiological and behavioural strategies in freshwater turtles to deal with drought. Finally, future studies in this water reservoir are also important to document the developing characteristics of the new population of *P. geoffroanus* living there.

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