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Original article

# Does climate influence assemblages of anurans and lizards in a coastal area of north-eastern Brazil?

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ABSTRACT

Environmental factors influence diverse assemblage features such as species abundances, richness, and nestedness. Amphibians and reptiles play important roles in terrestrial ecosystems, but there is still a lack of information about the assemblages of these animals in many regions. In this study, we aimed to understand how environmental factors influence the anurans and lizards assemblages from São Gonçalo do Amarante, Ceará, Brazil. Herpetofauna samplings were performed monthly in São Gonçalo do Amarante from January 2008 to May 2009, excluding April 2008. We sampled animals (anurans and lizards) using pitfall traps and active searches. The abundance and richness of lizards were positively related to temperature and negatively related to precipitation. Anuran assemblage was not influenced by precipitation, but its abundance was negatively influenced by temperature. Temperature generated a nested pattern in the lizard assemblage, but precipitation did not produce this pattern in anurans. Finally, our results reinforce the importance of environmental factors, mainly temperature, in structuring assemblages of anurans and lizards.

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## 1. Introduction

Understanding the processes that influence temporal distributions of species is an ancient goal in ecology. Many studies have found that climatic variables such as temperature and precipitation are commonly related to species richness and abundance over time in ecological communities (Vasconcelos and Rossa-Feres, 2005; Borges and Juliano, 2007; Santos et al., 2008; Winck et al., 2011). However, this environmental influence varies spatially, reinforcing the need to study assemblages in different regions and biomes.

Although environmental factors are commonly associated to abundance and richness patterns in assemblages in the ecological literature, they can also influence their composition, generating nested patterns (Elmendorf and Harrison, 2009). Nestedness occurs when species-poor assemblages are subsets of species occurring in rich assemblages, and this process is traditionally evaluated at different sites along a spatial scale (Atmar and Patterson, 1993). However, some recent studies have also evaluated the occurrence of nestedness at temporal scales (Taylor and Warren, 2001; Elmendorf and Harrison, 2009; Petsch et al., 2015), but so far, no study has evaluated temporal patterns of nestedness in anurans and lizards.

Amphibians and reptiles play important roles in terrestrial ecosystems. However, these animals are suffering a strong pressure toward their extinction due to habitat degradation and loss, invasive species, and unsustainable use in the pet trade, among others (Gibbons et al., 2000). Assemblages of amphibians and reptiles are commonly influenced by abiotic factors, such as precipitation (Martins and Oliveira, 1999; Marques et al., 2000; Borges and Juliano, 2007; Hartmann et al. 2009) and temperature (Fitzgerald et al., 1999; Winck et al., 2011), which influence many life history traits, principally reproduction and activity patterns, in these ectothermic animals (Cascon unpublished data; Arzabe, 1999; Vieira et al., 2009; Winck et al., 2011).

The majority of faunal studies of the north-eastern coastal zone of Brazil are focused on Atlantic Forest areas (e.g. Santos and Carnaval, 2002; Camurugi et al., 2010; Buarque and Moura, 2011; Morato et al., 2011; Silva et al., 2011, 2013; Magalhães et al.,

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2013). The vegetation complex of the coastal zone of Ceará, which presents ecotonal characteristics and shares species with Caatinga, Atlantic Forest, and Cerrado (Castro et al., 2012; Borges-Leite et al., 2014), is still poorly understood. This region has seasonal precipitation, and its vegetation is characterised by open areas with a mean height of 3.8 m, having approximately 390 plant species that also occur in savannah and rainforest areas (Castro et al., 2012). Although some recent studies have studied its herpetofauna (Cascon and Borges-Nojosa, 2003; Borges-Leite et al., 2014; Roberto et al., 2014a, 2014b), they were mainly focused on recording and describing the species living in the vegetation complex of the coastal zone of Ceará, without evaluating how the environmental factors influence the assemblages of amphibians and reptiles.

This study aims to describe the assemblages of anurans and lizards from an area of this vegetation complex of the coastal zone of Ceará, focusing on understanding how precipitation and temperature influence the temporal distribution (abundance, richness, and nestedness) of both groups. Our study represents a case study to understand how these two climatic components influence assemblages of anurans and reptiles from coastal regions of tropical environments and also represents the first evaluation of temporal nestedness in these animal groups.

## 2. Materials and methods

We conducted field samplings of herpetofauna in the São Gonçalo do Amarante municipality, Ceará, Brazil, every month from January 2008 to May 2009, excluding April 2008, when data were not collected. The mean annual temperature in the region is 27 °C, and the mean annual rainfall is 1026 mm, which mainly occurs from January to May (Instituto de Pesquisa e Estratégia Econômica do Ceará – IPECE, 2013). The study area is part of the vegetation complex of the coastal zone of Ceará, and its herpetofauna is comprised of species commonly found in Caatinga areas nearby, as well as having some species from Cerrado and rainforest biomes (Borges-Leite et al., 2014). Furthermore, the herpetofauna of the coastal region of São Gonçalo do Amarante is also facing a strong disturbance owing to the installation of wind turbines as well as the ongoing construction of a port and industrial complex in the region since 2001, with a total planned area of 13,337 ha.

We sampled the herpetofauna in three close sites with similar climatic characteristics that are covered by the vegetation complex of the coastal zone: Dunas (03°32′43.9″ S, 38°51′28.2″ W), Fazenda Maceió (03°30′54.9″ S, 38°55′07.7″ W), and Jardim Botânico (03°34′27.1″ S, 38°53′19.3″ W), in order to ensure a proper evaluation of species occurrence in this vegetation formation. In the analyses, all species and individuals collected in these sites were considered together. Fieldwork was performed by two people collecting for a total of four days per month split between the three sampled areas, and the sampling effort and sampling methods were the same in all areas and months because the areas had similar sizes and we wanted to ensure that the areas were equally sampled. Animals were sampled using pitfall traps with drift fences (five traps in each sampled area). Each trap comprised four 60L buckets linked by a plastic fence, forming a “Y” (Cechin and Martins, 2000; Heyer et al., 2001), that were opened and inspected on three consecutive days each month (total effort = five traps x three days x 16 samplings = 240 trap-days for each area); each 24 h the buckets were checked, and the animals were identified and released. We also performed two kinds of active search: time-constrained searches (visual transects) lasting 1 h along a transect of 100 m (total effort = two people x 1 h x 16 samplings = 32 person-hours for each area) in areas distant from the pitfall stations; and time-unconstrained searches (total effort = two persons x 4 h (average per day) x three days x 16 samples = 384 person-hours). Data from time-constrained and unconstrained searches were pooled together in our analyses.

Considering that we did not collect all sampled animals and that captured animals were not marked, we compared the three sampled days of each month and used the abundance data of the day with the highest abundance of each species as our estimate of monthly abundance for the species. For example, if we captured 10, 15, and 13 individuals of species A in a given month, the abundance of this species for this month would be 15 because it was the highest abundance obtained in this month. The highest abundance is a better representation of monthly abundance of the species because the two lowest abundances were probably a consequence of undersampling. This same procedure was repeated for all species in each month for both capture methods. A similar approach is commonly used in calling studies of anurans (Vasconcelos and Rossa-Feres, 2005) to avoid pseudoreplication problems. We summed the filtered abundances (see explanation above) obtained in pitfall traps and active searches for each species in each month to generate an abundance matrix (species in columns and months in rows) because these methods are complementary (Ribeiro-Júnior et al., 2008). While pitfall traps are more efficient for small and ground animals, the active searches are able to find arboreal and less active animals, such as snakes and some lizards (Cechin and Martins, 2000; Mesquita et al., 2013). Animal handling and collection were approved by the national environmental organisations (see Acknowledgments). Some voucher specimens of each species were deposited in the Coleção de Herpetologia da Universidade Federal do Ceará (CHUFC) at the Núcleo Regional de Ofiologia da Universidade Federal do Ceará (NUROF-UFC) (see Borges-Leite et al., 2014 for a full list of the collected specimens). In brief, our sampling design and data are reliable according to the recommendations of Battisti et al. (2014) because we used standard capture methods that had temporal and spatial replicates, distributed our sampling effort considering the heterogeneity of the study area, used different capture methods in order to capture species with different detectabilities, and avoided pseudo-replication problems.

We used Generalised Least Squares (GLS) analyses to assess the influence of temperature and precipitation on the total abundance (calculated as described in the last paragraph) and richness (total number of species) of anurans and lizards in each month. Data regarding total precipitation and mean temperature of each month during the study at São Gonçalo do Amarante were obtained from Fundação Cearense de Meteorologia e Recursos Hídricos (FUNCEME). However, we only had temperature data from July 2008 to May 2009. In order to account for temporal autocorrelation between the months, we included a matrix of temporal correlation in the analysis generated using an autoregressive model. The abundances of anurans and lizards were log-transformed ($\log(x+1)_e$) in order to reach normality according to Shapiro-Wilk tests. Since we had different sampling sizes for precipitation and temperature, we performed a GLS analysis for each predictive variable.

We used the NODF metric (Nestedness Overlap and Decreasing Fill; Almeida-Neto et al., 2008) to evaluate nestedness in anuran and lizard assemblages, because this metric is better able to reliably detect nestedness patterns when compared to other metrics. Since we aimed to detect whether nested patterns were determined by environmental factors (precipitation for anurans and temperature for lizards, the main environmental factors related to temporal patterns in these animals (Vasconcelos and Rossa-Feres, 2005; Winck et al., 2011)), we reorganised the rows of our abundance matrix (monthly samples) in a decreasing order of precipitation for anurans and temperature for lizards. The abundance matrices were converted in presence-absence matrices prior to the analyses. To evaluate the deviation of the NODF calculated for both groups to

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