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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.

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 values obtained for random processes independent from environmental factors, we randomly reorganised the rows of both matrices 1000 times, recalculated the NODF metric for each randomised matrix and compared the observed values to the distribution of values obtained through the permutations (see Melo et al., 2014).

All analyses were performed using the software R ver. 3.1.2 (R Core Team, 2013). The GLS was performed in the package nlme (Pinheiro et al., 2015) using the function “gls”. NODF was calculated in the package vegan (Oksanen et al., 2013) using the function “nestednodf”.

3. Results

The 281 lizard specimens we sampled were comprised of 13 species while for the 1319 anuran specimens, there were 19 species (see Borges-Leite et al., 2014 for a full checklist of the herpetofauna found in the study area). Both assemblages were dominated by few species (Fig. 1), with *Adenomera hylaedactyla*, *Physalaemus cuvieri*, and *Elachistocleis piauiensis* being the most common anurans (Fig. 1A), and *Tropidurus hispidus*, *Ameiva ameiva*, *Micrablepharus maximiliani*, and *Colobosauroides cearensis* the most common lizards (Fig. 1B).

Precipitation had no effect on anurans, and a negative influence on lizard abundances and richness (see Table 1 and Fig. 2). Temperature had a negative effect on anuran abundance, and a positive effect on lizard abundance and richness (see Table 1 and Fig. 2). We did not find a nested pattern consistent with the precipitation data for anurans (NODF = 42.10, P = 0.113; Fig. 3A), but temporal lizard assemblages were nested due to temperature (NODF = 62.93, P = 0.004; Fig. 3B).

Table 1
Relationships between the assemblages of anurans and lizards and the environmental descriptors (precipitation and temperature) in São Gonçalo do Amarante, CE, Brazil.

Assemblage	Precipitation		Temperature	
	Abundance	Richness	Abundance	Richness
Anurans	b < 0.001	b = 0.008	b = −0.59	b = −1.01
	t = 0.38	t = 1.65	t = −2.62	t = −1.13
	P = 0.71	P = 0.12	P = 0.02	P = 0.29
Lizards	b = −0.002	b = −0.006	b = 0.59	b = 1.74
	t = −2.56	t = −2.27	t = 3.79	t = 6.43
	P = 0.02	P = 0.04	P = 0.005	P < 0.001

4. Discussion

Assemblages of anurans and lizards were dominated by few species. This dominance pattern has already been observed in other anuran (Vieira et al., 2007; Maltchik et al., 2008) and lizard assemblages (Fitzgerald et al., 1999; Werneck et al., 2009; Ramírez-Bautista and Cruz-Elizalde, 2013). *Physalaemus cuvieri* is commonly found in Caatinga, but *Adenomera hylaedactyla* and *Elachistocleis piauiensis* are not common (Borges-Nojosa et al., 2010). However, *A. hylaedactyla* and *P. cuvieri* are the most common anurans found in our study area, which are also species frequently associated with human-modified environments (Cardoso, 1981; Haddad and Sazima, 1992; Kokubum and Giaretta, 2005), suggesting the occurrence of anthropogenic effects on the studied anuran assemblage. *Tropidurus hispidus* and *Ameiva ameiva* are lizards commonly found in Caatinga (Borges-Nojosa et al., 2010; Passos et al., 2016), reinforcing the influence of this biome on the fauna of the vegetation complex of the coastal zone of Ceará.

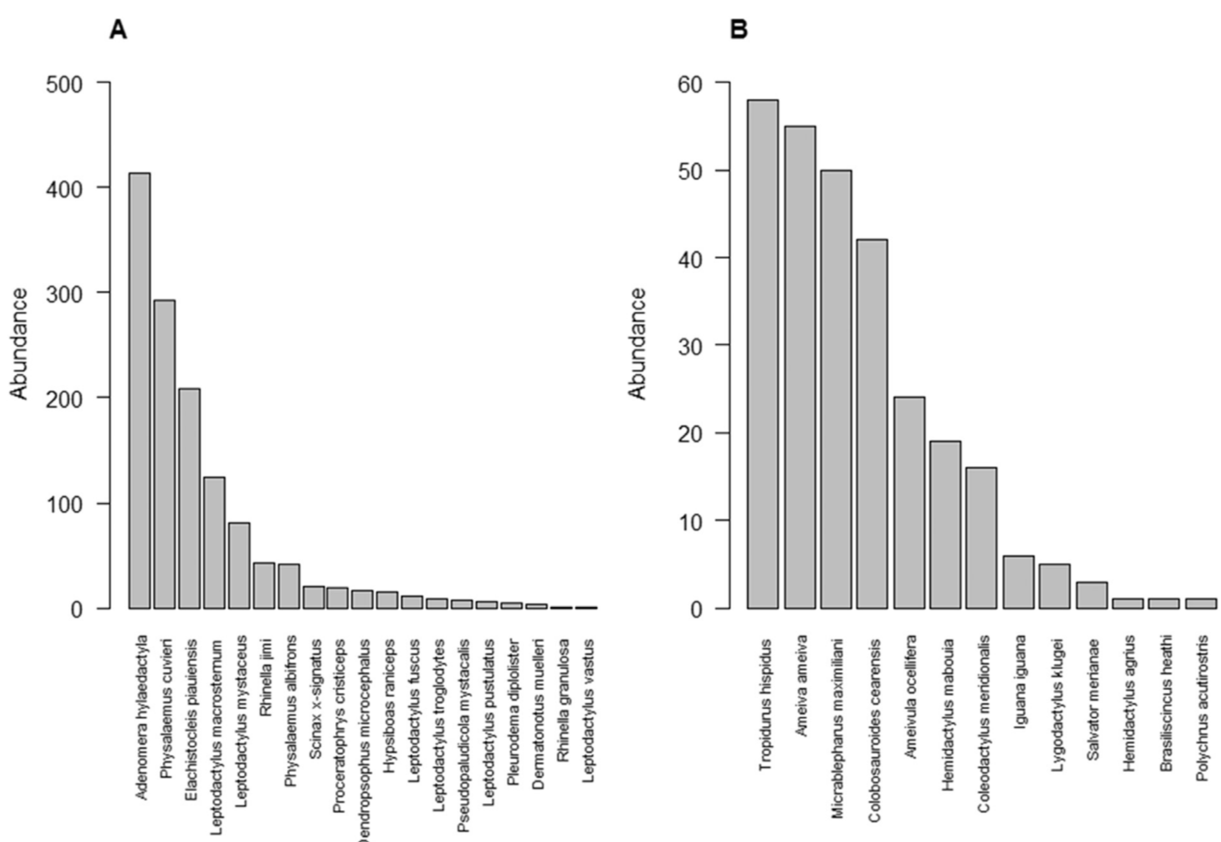

Fig. 1. Abundance distribution of anurans (A) and lizards (B) in São Gonçalo do Amarante, CE, Brazil.

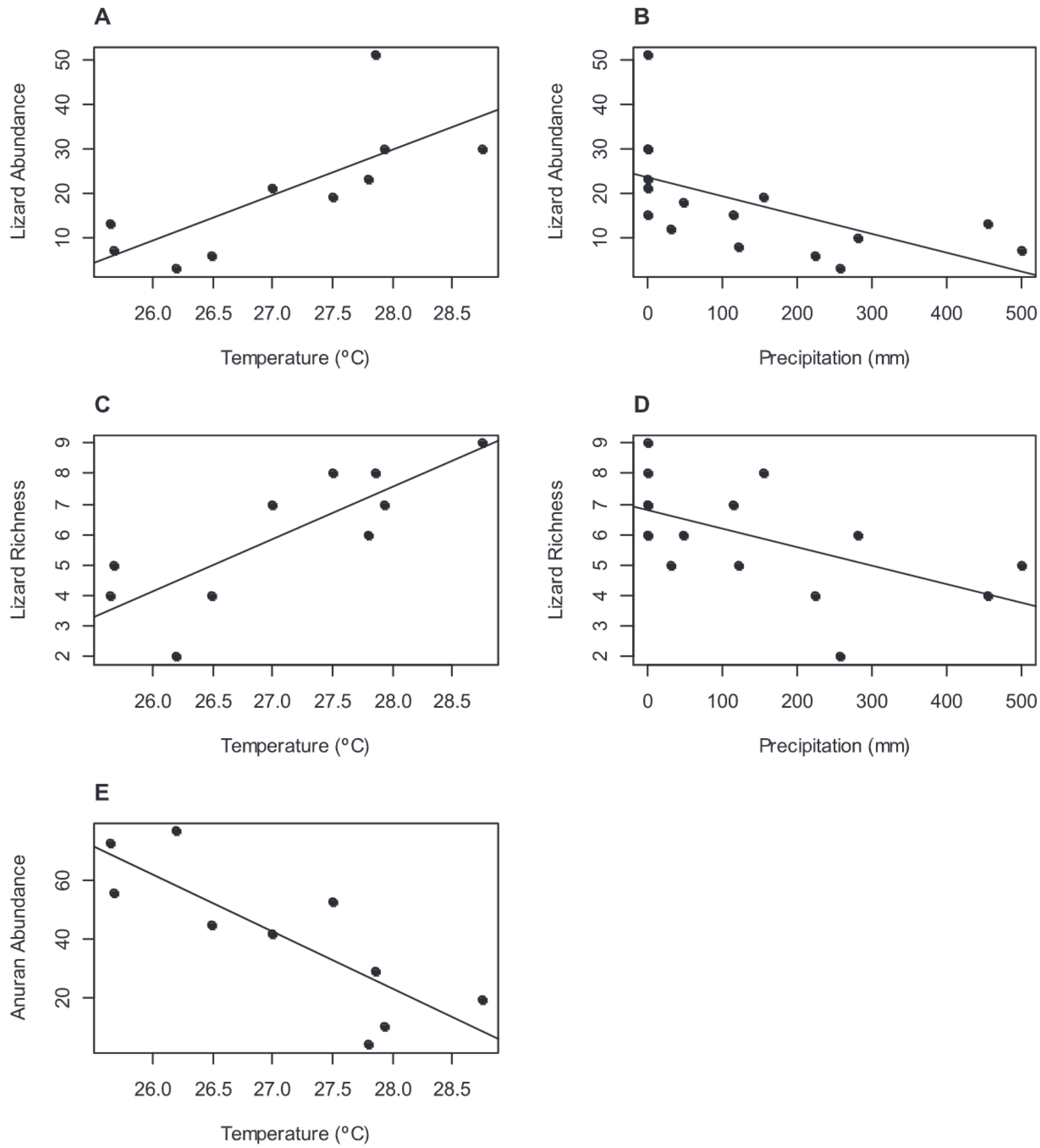

Fig. 2. Relationships between the studied assemblages (anurans and lizards) and environmental descriptors in São Gonçalo do Amarante, CE, Brazil. Relationship between lizard assemblage and temperature (A and C) and precipitation (B and D). Relationship between anuran abundance and temperature (E).

Positive relationships between the abundance and richness of anurans and precipitation have been found in other studies describing temporal assemblages of these animals (e.g. Vasconcelos and Rossa-Feres, 2005; Borges and Juliano, 2007; Santos et al., 2008), but the anurans from São Gonçalo do Amarante did not follow this pattern. However, many studies reporting these positive relationships are mainly focused on reproductive phenology, using only active sampling to capture individuals and finding mainly calling males. Since the number of vocalising males is usually correlated to precipitation in many species (e.g. Sá et al., 2014; Borges-Leite et al., 2015; Protázio et al., 2015), it could explain these findings that population abundance is related to rainfall. Our study did not have this reproductive bias because we also used pitfall traps to capture individuals, which could explain the results we found. Furthermore, the study area is also influenced by its proximity to the sea and the presence of subterranean waters could provide more adequate and humid microhabitats for anurans, thus explaining the lack of influence of rainfall on the abundance of these animals. The negative relationship between anuran abundance and temperature may be explained by characteristics of anurans skin, which is highly permeable, increasing desiccation risk (Withers et al., 1984).

Lizards depend on external environmental sources to obtain the necessary heat to regulate their body temperatures (Pianka and Vitt, 2003). These animals use behavioural mechanisms to adjust their body temperature and maintain it within a range that meets their physiological and ecological needs (Cowles and Bogert, 1944; Huey, 1982). Thermoregulatory behaviour involves costs and associated benefits, which reflect individual ecological and thermoregulatory priorities (Downes and Shine, 1998). Here, lizard assemblages were more abundant and richer in months with high temperatures and low precipitation. The positive effects of temperature on lizard abundances and richness were expected because these reptiles are more active in warmer climates (Winck et al., 2011), which is mainly related to their thermoregulatory behaviour. Furthermore, months with high precipitation are usually

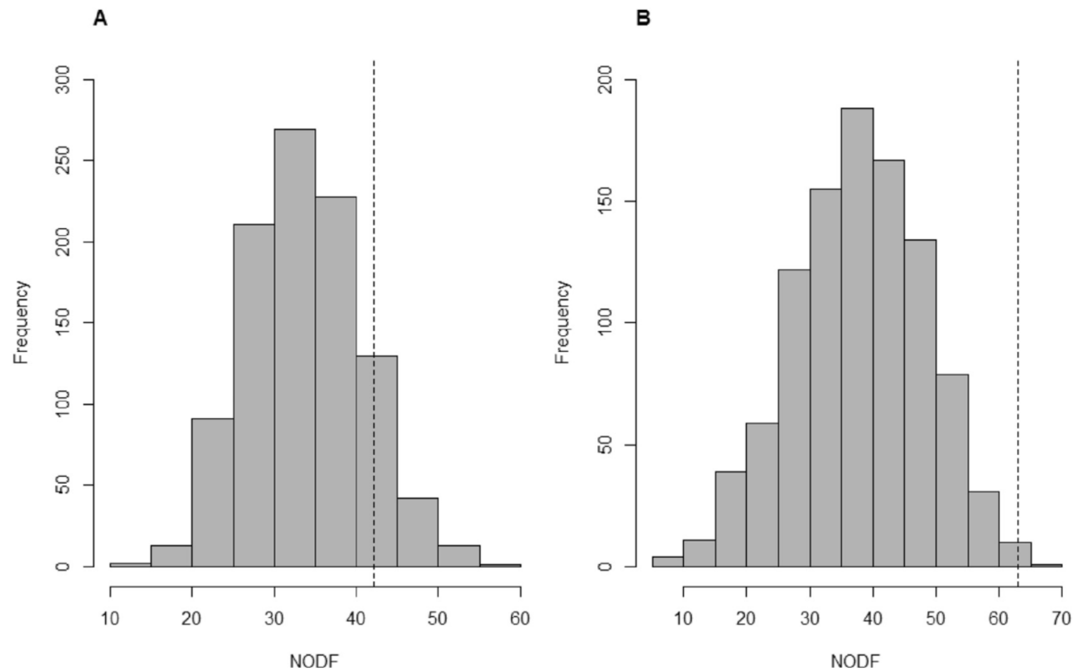

Fig. 3. Distribution of NODF values obtained for presence-absence matrices with rows (sampling months) randomly reordered 1000 times. A) Anurans; B) Lizards. Vertical dash lines are the NODF values obtained when the rows of the original matrices were reordered following a decreasing order of precipitation (anurans) and temperature (lizards).

cloudier, which also explains the negative relationship between lizard assemblage and precipitation.

Precipitation was not responsible for generating nested patterns in anurans, but temperature generated nested patterns in lizards. These results are in accordance with our previous results where precipitation did not influence abundance and richness of anurans, but temperature influenced both metrics in lizards. Nested patterns may occur when species of an assemblage are influenced by the same environmental effect, but at different magnitudes (Elmendorf and Harrison, 2009). Differences in activity pattern among lizard species influence the temporal structure of their assemblage (Fitzgerald et al., 1999), and activity patterns of lizards, in general, are commonly influenced by temperature (Winck et al., 2011). Then, differences in temperature optima may explain the nested pattern we found for this group.

Our results reinforce the importance of environmental factors, mainly temperature, in structuring assemblages of anurans and lizards. Temperature influenced the temporal distribution of anurans and lizards from São Gonçalo do Amarante. However, precipitation only affected the temporal distribution of lizards. We also found that temperature generates temporal nested patterns in lizard assemblages. To the best of our knowledge, it is the first time that temporal nestedness has been evaluated in lizards and anurans.

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References

Almeida-Neto, M., Guimarães, P., Guimarães Jr., P.R., Loyola, R.D., Ulrich, W., 2008. A consistent metric for nestedness analysis in ecological systems: reconciling concept and measurement. Oikos 117, 1227–1239.

Atmar, W., Patterson, B.D., 1993. The measure of order and disorder in the distribution of species in fragmental habitat. Oecologia 96, 373–382.

Arzabe, C., 1999. Reproductive activity patterns of anurans in two different altitudinal sites within the Brazilian Caatinga. Rev. Bras. Zool. 3, 851–864.

Battisti, C., Dodaro, G., Franco, D., 2014. The data reliability in ecological research: a proposal for a quick self-assessment tool. Nat. Hist. Sci. 1, 75–79.

Borges-Leite, M.J., Rodrigues, J.F.M., Borges-Nojosa, D.M., 2014. Herpetofauna of a coastal region of northeastern Brazil. Herpetol. Notes 7, 405–413.

Borges-Leite, M.J., Rodrigues, J.F.M., Gondim, P.M., Borges-Nojosa, D.M., 2015. Reproductive activity of *Adenomera* aff. *hylaedactyla* (Anura: Leptodactylidae) in a coastal area of Brazil. Anim. Biol. 65, 101–111.

Borges-Nojosa, D.M., Prado, F.M.V., Borges-Leite, M.J., Gurgel Filho, N.M., Bacalini, P., 2010. Avaliação do Impacto do Manejo Florestal Sustentável na Herpetofauna de Duas Áreas de Caatinga nos Municípios de Caucaia e Pacajus, no Estado do Ceará. In: Gariglio, M.A., Sampaio, E.V.S.B., Cestão, L.A., Kageyama, P.Y. (Eds.), Uso Sustent. Conserv. dos Recur. Florestais Caatinga, Volume 1. Serviço Florestal Brasileiro, Brasília, pp. 315–330.

Borges, F.J.A., Juliano, R.F., 2007. Temporal and spatial distribution in an anuran community in municipality of Morrinhos, Goiás, Brazil (Amphibia: Anuran). Neotrop. Biol. Conserv. 2, 21–27.

Buarque Jr., D.V., Moura, G.J.B., 2011. Anurofauna da cidade de Barreiros, remanescente de Mata Atlântica- Nordeste do Brasil- PE. In: Moura, G.J.B., Santos, E.M., Oliveira, M.A.B., Cabral, M.C.C. (Eds.), Herpetologia do Estado de Pernambuco. Ministério do Meio Ambiente; Brasília, pp. 149–162.

Camurugi, F., Lima, T.M., Mercês, E.A., Juncá, F.A., 2010. Anurans of the Reserva Ecologica da Michelin, municipality of Igrapiúna, state of Bahia, Brazil. Biota Neotrop 10, 305–312.

Cardoso, A.J., 1981. Biologia e sobrevivência de *Physalaemus cuvieri* Fitz., 1826 (Amphibia, Anura), na natureza. Ciênc. Cult. 33, 1224–1228.

Cascon, P., Borges-Nojosa, D.M., 2003. Anfíbios. In: Campos, A.A., Monteiro, A.Q., Monteiro-Neto, C., Pollete, M. (Eds.), A Zona Costeira do Ceará: Diagnóstico para a Gestão Integrada, vol. 1. Fortaleza, Gráfica e Editora Pouchain Ramos, p. 125.

Castro, A.S.F., Moro, M.F., Menezes, M.O.T., 2012. O complexo vegetacional da Zona Litorânea no Ceará: Pecém, São Gonçalo do Amarante. Acta Bot. Bras. 26, 108–124.

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, 729–740.

Cowles, R.B., Bogert, C.M., 1944. A preliminary study of the thermal requirements of desert reptiles. Bull. Am. Mus. Nat. Hist. 83, 265–296.

Downes, S., Shine, R., 1998. Heat, safety or solitude? Using habitat selection experiments to identify a lizard's priorities. Anim. Behav. 55, 1387–1396.

Elmendorf, S.C., Harrison, S.P., 2009. Temporal variability and nestedness in

California grassland species composition. Ecology 90, 1492–1497.
Fitzgerald, L.A., Cruz, F.B., Perotti, G., 1999. Phenology of a lizard assemblage in the dry Chaco of Argentina. J. Herpetol. 33, 526–535.
Gibbons, J.W., David, E.S., Travis, J.R., Kurt, A.B., Tracey, D.T., Brian, S.M., Judith, L.G., Tony, M., Yale, L., Sean, P., Winne, C.T., 2000. The global decline of reptiles, déjà vu amphibians. Bioscience 50, 653–666.
Haddad, C.F.B., Sazima, I., 1992. Anfíbios anuros da Serra do Japi. In: Morellato, L.P.C. (Ed.), História natural da Serra do Japi: ecologia e preservação de uma área florestal no Sudeste do Brasil. UNICAMP/FAPESP, Campinas, pp. 188–211.
Hartmann, P.A., Hartmann, M.T., Martins, M., 2009. Ecology of a snake assemblage in the Atlantic forest of southeastern Brazil. Pap. Avulsos Zool. 49, 343–360.
Heyer, R.W., Donnelly, M.A., Hayek, L.C., Foster, M.S., 2001. Medición y Monitoreo de la Diversidad Biológica: Métodos estandarizados para Anfíbios, vol. 1. Chebut, Editorial Universitária de la Patagônia.
Huey, R.B., 1982. Temperature, physiology and the ecology of reptiles. In: Gans, C., Pough, F.H. (Eds.), Biology of the Reptilia: Physiological Ecology. Academic Press, New York, pp. 25–91.
IPECE, 2013. Perfil Básico Municipal: São Gonçalo do Amarante. Governo do Estado do Ceará. http://www.ipece.ce.gov.br/publicacoes/perfil_basico/pbm-2013/Sao_Goncalo_do_Amarante.pdf (accessed 20 August 2016).
Kokubum, M.N.C., Giaretta, A.A., 2005. Reproductive ecology and behaviour of a species of *Adenomera* (Anura, Leptodactylinae) with endotrophic tadpoles: systematic implications. J. Nat. His. 39, 1–15.
Magalhães, F.M., Dantas, A.K.B.P., Brito, M.R.M., Medeiros, P.H.S., Oliveira, A.F., Pereira, T.C.S.O., Queiroz, M.H.C., Santana, D.J., Silva, W.P., Garda, A.A., 2013. Anurans from an Atlantic forest-caatinga ecotone in Rio Grande do norte state, Brazil. Herpetol. Notes 6, 1–10.
Maltchik, L., Peixoto, C.D., Stenert, C., Moreira, L.F.B., Machado, I.F., 2008. Dynamics of the terrestrial amphibian assemblage in a flooded riparian forest fragment in a Neotropical region in the south Brazil. Braz. J. Biol. 68, 763–768.
Marques, O.A.V., Eterovic, A., Endo, W., 2000. Seasonal activity of snakes in the Atlantic forest in southeastern Brazil. Amphib. Reptil. 22, 103–111.
Martins, M., Oliveira, M.E., 1999. Natural history of snakes in forests in the Manaus region, Central Amazonia, Brazil. Herpetol. Nat. His. 6, 78–150.
Melo, A.S., Cianciaruso, M.V., Almeida-Neto, M., 2014. treeNODF: nestedness to phylogenetic, functional and other tree-based diversity metrics. Methods Ecol. Evol. 5, 563–572.
Mesquita, P.C.M.D., Passos, D.C., Cechin, S.Z., 2013. Efficiency of snake sampling methods in the Brazilian semiarid region. An. Acad. Bras. Ciênc. 85, 1127–1139.
Morato, S.A.A., Lima, A.M.X., Staut, D.C.P., Faria, R.G., Souza-Alves, J.P., Gouveia, S.F., Scupino, M.R.C., Gomes, R., Silva, M.J., 2011. Amphibians and Reptiles of the Refugio de Vida Silvestre Mata do Junco, municipality of Capela, state of Sergipe, northeastern Brazil. CheckList 7, 756–762.
Oksanen, J., Blanchet, F.G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P.R., O'Hara, R.B., Simpson, G.L., Solymos, P., Stevens, M.H.H., Szoecs, E., Wagner, H., 2013. Vegan: Community Ecology Package. R Package Version 2.0-10.
Passos, D.C., Mesquita, P.C.M.D., Borges-Nojosa, D.M., 2016. Diversity and seasonal dynamics of a lizard assemblage in a Neotropical semiarid habitat. Stud. Neotrop. Fauna E. 51, 119–128.
Petsch, D.K., Pinha, G.D., Dias, J.D., Takeda, A.M., 2015. Temporal nestedness in Chironomidae and the importance of environmental and spatial factors in species rarity. Hydrobiologia 745, 181–193.
Pianka, E.R., Vitt, L.J., 2003. Lizards: Windows to the Evolution of Diversity. University of California Press, Berkeley.
Pinheiro, J., Bates, D., Debroy, S., Sarkar, D., R Core Team, 2015. nlme: linear and nonlinear mixed-effect models. R. Package version 3, 1–120.
Protázio, A.S., Albuquerque, R.L., Falkenberg, L.M., Mesquita, D.O., 2015. Acoustic ecology of an anuran assemblage in the arid Caatinga of Northeastern Brazil. J. Nat. His. 49, 957–976.
R Core Team, 2013. R: a Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna.
Ramírez-Bautista, A., Cruz-Elizalde, R., 2013. Reptile community structure in two fragments of cloud forest of the Sierra Madre Oriental, Mexico. Northwest. J. Zool. 9, 410–417.
Ribeiro-Júnior, M.A., Gardner, T.A., Ávila-Pires, T.C., 2008. Evaluating the effectiveness of herpetofaunal sampling techniques across a gradient of habitat change in a tropical forest landscape. J. Herpetol. 42, 733–749.
Roberto, I.J., Brito, L.B.M., Ávila, R.M., 2014a. A new six-pored *Amphisbaena* (Squamata: Amphisbaenidae) from the coastal zone of northeast Brazil. Zootaxa 3753, 167–176.
Roberto, I.J., Pinto, T., Schlickmann, A., Fraga, A., 2014b. From Amazonia to the semiarid: the unexpected record of *Gonatodes humeralis* (squamata: sphaerodactylidae) for the Caatinga biome. Herpetol. Notes 7, 309–311.
Sá, F.P., Zina, J., Haddad, C.F.B., 2014. Reproductive dynamics of the neotropical treefrog *Hypsiboas albopunctatus* (Anura, Hylidae). J. Herpetol. 48, 181–185.
Santos, E.M., Carnaval, A.C.O.Q., 2002. Anfíbios anuros do Estado de Pernambuco. In: Tabarelli, M., Silva, J.M.C. (Eds.), Diagnóstico da Biodiversidade de Pernambuco Universidade Federal de Pernambuco, vol. 2, pp. 529–536.
Santos, T.G., Kopp, K., Spies, M.R., Trevisan, R., Cechin, Z.C., 2008. Distribuição temporal e espacial de anuros em área de Pampa, Santa Maria, RS. Iheringia Sér. Zool. 98, 244–253.
Silva, C.R.S., Moura, G.J.B., Andrade, E.V.E., Nogueira, E.M.S., 2011. Aspectos ecológicos da anurofauna dos municípios de Jatobá- PE e Paulo Afonso-BA, Nordeste do Brasil. In: Moura, G.J.B., Santos, E.M., Oliveira, M.A.B., Cabral, M.C.C. (Eds.), Herpetofauna do Estado de Pernambuco, Pernambuco. Ibama, pp. 177–185.
Silva, A.S.F.L., Siqueira Júnior, S., Zina, J., 2013. Checklist of amphibians in a transitional area between the Caatinga and the Atlantic forest, Central-southern Bahia, Brazil. CheckList 9, 725–732.
Taylor, C.M., Warren, M.M.J., 2001. Dynamics in species composition of stream fish assemblages: environmental variability and nested subsets. Ecology 82, 2320–2330.
Vasconcelos, T.S., Rossa-Feres, D.C., 2005. Diversidade, Distribuição Espacial e Temporal de Anfíbios Anuros (Amphibia, Anura) na Região Noroeste do Estado de São Paulo, Brasil. Biota Neotrop. 5, 1–14.
Vieira, W.L.S., Arzabe, C., Santana, G.G., 2007. Composição e distribuição espaço-temporal de anuros no Cariri Paraibano, nordeste do Brasil. Oecologia Bras. 11, 383–396.
Vieira, W.L.S., Santana, G.G., Arzabe, C., 2009. Diversity of reproductive modes in anurans communities in the Caatinga (dryland) of northeastern Brazil. Biodivers. Conserv. 18, 55–66.
Werneck, F.P., Colli, G.R., Vitt, L.J., 2009. Determinants of assemblage structure in Neotropical dry forest lizards. Austral Ecol. 34, 97–115.
Winck, G.R., Santos, T.G., Cechin, S.Z., 2011. Pampean lizard assemblage from subtropical Brazil: a temporal analysis. An. Acad. Bras. Ciênc. 83, 1345–1357.
Withers, P.C., Hillman, S.S., Drewes, R.C., 1984. Evaporative water loss and skin lipids of anuran amphibians. J. Exp. Zool. 232, 11–17.