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Resposta antecipada ou atrasada em relação à chuva: Efeito da precipitação sobre uma assembleia de artrópodes em um enclave de floresta perenifólia

Anticipated or delayed responses to rainfall: Effects of rainfall on arthropods assemblage in an enclave of evergreen forest

Respuesta anticipada o retrasada a la lluvia: efecto de la precipitación en un ensamblaje de artrópodos en un enclave de bosque siempre verde

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Abstract

In northeast Brazil, the most part of vegetation is a deciduous seasonally dry tropical forest called of “Caatinga”. Despite the semi-arid areas correspond to most of the caatinga vegetation, there are some areas 500 m above sea level with an annual rainfall up to 1200 mm forming evergreen forest enclaves. Macroarthropod abundance and fauna composition differences in Caatinga are related to seasonal rainfall effects but, this difference is unclear in the enclaves of evergreen forests. Thus, the aim of this study was to measure the effects of rainfall on insect, arachnid, and centipede assemblages in an enclave of evergreen forest within the Caatinga vegetation. We tested the following hypotheses: 1) rainfall changes arthropod abundance and species richness; 2) predator abundance correlate with prey, and 3) abundance arthropod abundance and species richness exhibit a delayed or anticipated response to rainfall. No effects of rainfall on insects and arachnids abudance were observed. There was a significant correlation between prey and predator abundance with changes in dominant species between the rainy and dry seasons. The insects and arachnids can show some anticipated responses to rainfall. The abundance and richness of centipedes were influenced by rainfall whith a delayed response. Our findings indicate that, in evergreen forest enclaves within Caatinga vegetation, the soil arthropods show different responses compared to rainfall than the most common areas of the Caatinga domain and an increase in the detection of insects and arachnids just before the beginning of the rainy season.

Keywords: Evergreen forest; Caatinga vegetation; Correlation; Soil arthropods; Seasonality.

Resumo

No nordeste do Brasil a maior parte da vegetação é uma formada por florestas tropicais sazonalmente secas cahamada de Caatinga. Apesar da maior parte da caatinga corresponder ao clima semi-árido, existem algumas áreas com altitudes acima dos 500 metros sobre o nível do mar que possui pluviometria anual acima dos 1500 milímetros formando enclaves de florestas perenifólias. A abundância de macroartrópodes e as diferenças na composição da fauna na Caatinga estão relacionadas aos efeitos sazonais das chuvas, mas essa diferença não é clara nos enclaves de florestas perenifólias. Assim, o objetivo deste estudo foi medir os

efeitos das chuvas sobre as assembléias de insetos, aracnídeos e miriápodes em um enclave de floresta perenifólia na Caatinga. Testamos as seguintes hipóteses: 1) a precipitação altera a abundância de artrópodes e a riqueza de espécies ao longo do ano; 2) a abundância de predadores se correlaciona com as presas, e 3) se a abundância de artrópodes e a riqueza de espécies apresentam uma resposta atrasada ou antecipada à chuva. Não foram observados efeitos das chuvas sobre a abundância de insetos e aracnídeos. Houve uma correlação significativa entre a abundância de presas e predadores com mudanças nas espécies dominantes entre as estações chuvosa e seca. Os insetos e aracnídeos podem apresentar algumas respostas antecipadas às chuvas. A abundância e riqueza de miriápodes foram influenciadas pelas chuvas com resposta tardia. Nossos resultados indicam que, em enclaves de floresta perenifólia dentro da vegetação da Caatinga, os artrópodes do solo apresentam respostas diferentes em relação a chuva do que as áreas mais comuns do domínio da Caatinga e um aumento na detecção de insetos e aracnídeos pouco antes do início da estação chuvosa.
Palavras-chave: Floresta perenifólia; Caatinga; Correlação; Artrópodes do solo; Sazonalidade.

Resumen

En el noreste de Brasil, la mayor parte de la vegetación es un bosque tropical caducifolio estacionalmente seco llamado “Caatinga”. A pesar de que las áreas semiáridas corresponden a la mayor parte de la vegetación de caatinga, existen algunas áreas a 500 m sobre el nivel del mar con una precipitación anual de hasta 1200 mm que forman enclaves de bosque siempre verde. La abundancia de macroartrópodos y las diferencias en la composición de la fauna en Caatinga están relacionadas con los efectos de las lluvias estacionales, pero esta diferencia no es clara en los enclaves de bosques siempreverdes. Por lo tanto, el objetivo de este estudio fue medir los efectos de la lluvia sobre conjuntos de insectos, arácnidos y ciempiés en un enclave de bosque siempre verde dentro de la vegetación de Caatinga. Probamos las siguientes hipótesis: 1) la lluvia cambia la abundancia de artrópodos y la riqueza de especies; 2) la abundancia de depredadores se correlaciona con la presa, y 3) la abundancia de artrópodos y la riqueza de especies exhiben una respuesta retrasada o anticipada a la lluvia. No se observaron efectos de la lluvia sobre insectos y abudancia de arácnidos. Hubo una correlación significativa entre la abundancia de presas y depredadores con cambios en las especies dominantes entre las estaciones lluviosa y seca. Los insectos y arácnidos pueden mostrar algunas respuestas anticipadas a la lluvia. La abundancia y riqueza de ciempiés se vio influenciada por las lluvias con una respuesta tardía. Nuestros hallazgos indican que, en enclaves de bosques siempreverdes dentro de la vegetación de Caatinga, los artrópodos del suelo muestran diferentes respuestas en comparación con las lluvias que las áreas más comunes del dominio Caatinga y un aumento en la detección de insectos y arácnidos justo antes del comienzo de la temporada de lluvias.

Palabras clave: Bosque siempre verde; Vegetación de caatinga; Correlación; Artrópodos del suelo; Estacionalidad.

1. Introduction

The literature reports that many tropical species show a distinct seasonal temporal distribution (Young, 1982). Water availability is recognized as important for invertebrate survival. Invertebrate mortality can increase with water loss (Danks, 2000; Addo-Bediako et al., 2001). To cope with varying water availability, invertebrates have developed strategies such as migration, hiding in soil, aestivation, shelter building, and development ofwater-repellant hairs (Willmer, 1982; Zalucki et al., 2002).

The Caatinga vegetation is known by peculiar characteristics as a mean annual temperature of 25 to 30°C and annual rainfall 600 and 1000 mm in 68,8% of the area (Silva et al., 2017) which is concentrated in three consecutive months (Andrade-Lima, 1981; Nimer 1972; Prado, 2003). The vegetation is xerophytic, woody, thorny, and deciduous with a seasonal herbaceous layer (Veloso et al., 1991; Pennington et al., 2000).

Although much of the caatinga has been poorly sampled (Correia et al., 2019), a relatively high number of plant and animal endemism is reported, and the degree of species richness is relatively high compared to other semiarid regions in the world (Silva et al., 2017). A greater number of vertebrate taxa (relative to invertebrate taxa) have been surveyed, including fishes (Lima et al., 2017), amphibians (Garda et al., 2017), birds (Araújo and Silva, 2017) and mammals (Carmignotto and Astúa, 2017). Efforts to survey invertebrate taxa resulted in a compilation of approximately 19 different taxa (Bravo and Calor, 2014).

In Caatinga vegetation, rainfall effects on macroarthropods include differences in abundance and fauna composition with season (rainy and dry) in the deciduous vegetation (Araújo et al., 2010). Rainy seasons have been associated with higher insect abundance (when sampled by Malaise traps, pitfall traps and beating trays) (Vasconcellos et al., 2010) and an increase in species richness of dung beetles (Liberal et al., 2011) and phytophagous insects (Creão-Duarte et al., 2016). For Arachnids, spider species respond to rainfall with a one- to two-month delay in abundance (Carvalho et al., 2015). For scorpions, habitat use varies with season (Lira et al., 2018).

Within the semiarid deciduous Caatinga vegetation evergreen forest enclaves (wet forests) occur at 500 m above sea level and with an annual rainfall up to 1200 mm allow the formation on the windward slopes of hills knowned as "Brejos de Altitude" (Prado 2003; Queiroz et al., 2017). In the states of Ceará, Rio Grande do Norte, Paraíba and Pernambuco there are 43 "Brejos de Altitude" (Tabarelli and Santos, 2004; Silva et al., 2017). The Araripe Plateau is considered a "Brejo de Altitude" in the south of Ceará (Andrade-Lima, 1982), with distinct flora and fauna relative to typical Caatinga (Werneck, 2011). To date, very few studies have evaluated the abiotic and biotic controls on arthropod assemblages in evergreen forest enclaves within semiarid areas of Brazil.

The aim of this study is to understand the effects of rainfall on insect, arachnid and centipede taxocenosis from enclave of evergreen forest into a semi-arid matrix. The following hypotheses are tested: 1) arthropod abundance and species richness are influenced by rainfall; 2) predator abundance (arachnids and centipedes) correlates with prey abundance (insects), and 3) arthropod abundance and richness exhibit a lag or anticipated response to rainfall.

2. Material and Methods

The present study sampled three locations (on trails) within the Araripe National Forest, in Crato, state of Ceara, Brazil. The coordinates obtained by GPS of these sites are: 1) Jatoba Trail - 07º16'47.6"S - 39º27'12.7" W, 2) Yellow trail - 07º16'46.3"S - 39º27'13.6"W, and 3) Belmonte Trail 07º16'42.2"S - 39º27'05.6"W.

Historical rainy and dry seasons were determined using the average monthly rainfall data from 1995 to 2015, based on Azevedo et al. (2018). The rainfall data were downloaded from Funceme (2019). The rainy season begins in December and finishes in April, while the dry season begins in June and finishes in November (Azevedo et al., 2018).Sampling was conducted twice a month between January 2018 and January 2019. Pitfall traps were constructed along lines perpendicular to each trail. From the trail border, each line ran 30 m into the woods with seven pitfall traps spaced five meters apart.

Each pitfall trap was installed at soil level and consisted of one glass bottle (15 cm depth x 6 cm diameter) inside a polyvinyl chloride (PVC) ring pipe (25 cm depth x 15 cm diameter). A plastic funnel (16 cm diameter tapering to 3cm diameter) was placed at the top of the ring pipe, so that sampled specimens could fall directly into the glass bottle. Above the pitfall trap, a roof was constructed using a plastic tray (25 cm x 45cm) supported by four 15 cm long wooden stakes with the roof height of 5 cm above soil level to allow access to the trap while protecting from excessive sun light. Specimens were preserved in 70% ethanol.

All specimens were sorted at Entomology Laboratory of Federal University of Cariri - UFCA. Spiders and scorpions were identified and deposited in the Arachnida and Myriapoda collection of the Instituto Butantan São Paulo (IBSP). Centipedes were identified and housed in the collection of the Universidade Federal do Mato Grosso (UFMT). Voucher specimens of insects were deposited in the reference collection of Laboratório de Entomologia of Federal University of Cariri (UFCA). Spiders, scorpions, and centipedes were identified through comparison with the material housed in their respective reference collections. The collection authorization was issued by the Chico Mendes Institute for Biodiversity Conservation (ICMBio - SISBIO 58732).

Relative frequency (F%) was calculated for each class (Insecta, Arachnida and Chilopoda) and ranked by species dominance and showed in the Table 1. To test the if the arthropod abundance and species richness are influenced by rainfall, we used generalized linear models (GLM), assuming normal error distributions.

Cross correlations were carried out to verify if the arthropod abundance and species richness exhibit a delayed or anticipated response to rainfall. In the cross-correlation test, negative values in x axis of the graphics indicates lag in the responses to variable (i.e rainfall), positive values inform possible anticipation responses and zero is the Pearson correlation in present time of collect. Pearson correlations between predators (Arachnids and Centipedes) and prey (Insects) were also assessed and Bonferroni corrections where applied to obtain p values. All statistics were performed using software R (Crawley, 2007).

3. Results and Discussion

In total, 6,870 arthropods were sampled, of which 3,638 were sampled in the rainy months and 3,232 in the dry months. A total of 108 species/morphospecies (Table 1) belonging to insects, spiders, scorpions and centipedes were collected.

Table 1. Species composition of insects, spiders, scorpions and centipedes from January 2018 to January 2019 collected at Araripe National Forest; Rainfall data (mm) and Relative frequency (F%) for taxa in function of all sample period.

	Observed Rainfall (mm)														
	109.4	234	162	290	33	6	0	0	0	3.2	77.3	236	157		
	2018												2019		
Taxon	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**I**	**Total**	**F%**
INSECTA															
Blattodea															
Blableridae															
Blableridae sp.1	0	3	7	0	3	0	0	0	0	10	3	1	0	**27**	**0%**
Blattidae															
Blattidae sp.1	0	2	7	8	16	6	4	21	7	9	20	19	5	**124**	**2%**
Pycnoscelus sp.	19	9	21	11	14	6	7	1	0	1	32	55	23	**199**	**3%**
Blattidae sp.3	0	0	2	8	7	2	1	2	0	0	4	0	0	**26**	**0%**
Blattidae sp.4	0	1	0	0	0	0	3	0	0	0	0	0	0	**4**	**0%**
Coleoptera															
Carabidae															
Carabidae sp.1	8	28	51	7	12	2	13	9	4	1	2	1	4	**142**	**2%**
Galerita sp.	4	1	2	0	3	19	6	14	2	0	16	3	1	**71**	**1%**
Carabidae sp.3	1	3	2	0	1	2	15	3	0	0	0	0	0	**27**	**0%**
Carabidae sp.4	1	0	0	0	2	0	0	17	0	0	0	0	0	**20**	**0%**
Carabidae sp.5	3	3	19	6	1	3	0	5	0	0	2	0	0	**42**	**1%**
Carabidae sp.6	3	1	1	0	0	0	0	2	0	3	0	0	0	**10**	**0%**
Scarites sp.	0	1	4	7	3	0	0	3	0	1	0	0	1	**20**	**0%**
Cerambycidae															
Chlorida sp.	0	6	10	5	14	5	4	25	5	12	11	10	18	**125**	**2%**
Eutrypanus dorsalis (Germar, 1824)	0	1	0	2	0	0	0	0	0	2	0	0	0	**5**	**0%**
Chrysoprasis sp.	0	0	0	3	16	0	5	11	5	9	11	0	0	**60**	**1%**
Chrysomelidae															
Percolaspsis sp.	0	0	0	0	0	0	0	0	0	3	0	0	0	**3**	**0%**
Curculionidae															
Conotrachellus sp.	529	32	84	56	10	11	12	2	5	5	12	15	11	**784**	**12%**
Heilipus sp.	3	0	0	0	5	3	0	0	0	3	1	0	5	**20**	**0%**
Elateridae															
Conodreus sp.	0	0	0	0	0	1	0	1	0	0	0	0	0	**2**	**0%**
Nitidulidae															
Nitidulidae sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**	**0%**
Scarabaeidae															
Dichotomius sp.	17	0	15	67	54	8	8	2	3	1	5	25	13	**218**	**3%**
Phileurus sp.	0	1	0	5	5	7	2	5	2	0	1	0	0	**28**	**0%**
Staphylinidae															
Pinophilus sp.	0	1	0	1	0	0	2	0	1	68	1	3	1	**78**	**1%**
Staphylindae sp.	0	0	0	0	0	0	0	0	0	78	0	0	0	**78**	**1%**
Tenebrionidae															
Phymatestes sp.	0	1	3	0	1	2	0	0	0	0	0	1	0	**8**	**0%**
Coleoptera sp.1	2	21	0	0	8	0	1	0	1	0	6	0	0	**39**	**1%**
Coleoptera sp.2	0	0	0	0	8	0	0	1	0	0	0	0	0	**9**	**0%**
Coleoptera sp.3	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**	**0%**
Coleoptera sp.4	0	0	0	0	0	0	1	0	0	0	0	0	0	**1**	**0%**
Dermaptera															
Forficulidae															
Forficula sp.	49	33	55	56	91	25	26	6	6	37	31	15	33	**463**	**7%**
Pygidicranidae															
Pygidicrana sp.	0	32	67	65	33	0	0	4	0	2	19	8	0	**230**	**3%**

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HEMIPTERA															
CYDNIDAE															
Canthophorus sp.	4	10	24	4	7	0	2	12	8	18	7	11	10	**117**	**2%**
Zelurus sp.	1	3	11	9	2	1	1	3	1	0	7	1	3	**43**	**1%**
REDUVIIDAE															
Pothea sp.	0	1	0	0	0	1	1	9	3	1	0	0	0	**16**	**0%**
Reduviidae sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	**1**	**0%**
Hemiptera sp.1	0	0	0	0	0	3	0	2	0	0	0	0	0	**5**	**0%**
Hemiptera sp.2	0	0	0	0	0	0	2	0	0	0	0	0	0	**2**	**0%**
HYMENOPTERA															
FORMICIDAE															
Dinoponera quadricepes Santschi 1921	110	125	143	82	140	93	116	156	116	155	186	173	103	**1698**	**26%**
Odontomachus sp.	13	22	14	59	23	10	17	17	20	5	18	2	5	**225**	**3%**
Formicidae sp.3	6	3	25	36	5	0	4	10	12	1	5	3	1	**111**	**2%**
Camponotus sp.	50	12	44	14	18	13	34	44	17	19	22	4	8	**299**	**5%**
Formicidae sp.5	1	3	0	1	1	0	0	3	0	1	7	0	1	**18**	**0%**
Formicidae sp.6	0	2	0	1	0	0	0	0	0	0	0	0	0	**3**	**0%**
Formicidae sp.7	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**	**0%**
POMPILIIDAE															
Fabriogenia sp.	1	1	4	3	6	2	1	0	0	0	1	0	0	**19**	**0%**
MUTILIDAE															
Traumatomutilla sp.	0	0	0	0	0	0	1	3	1	0	4	0	2	**11**	**0%**
ISOPTERA															
TERMITIDAE															
Syntermes sp.	59	29	16	27	56	24	62	86	29	57	41	42	12	**540**	**8%**
Isoptera sp.	2	0	0	0	0	0	0	0	0	0	11	0	0	**13**	**0%**
MANTODEA															
THESPIDAE															
Chloromiopteryx sp.	2	2	10	11	7	5	3	10	3	1	5	2	4	**65**	**1%**
ORTHOPTERA															
ACRIDAE															
Acridae sp.	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**	**0%**
ANOSTOSTOMATIDAE															
Lustosa sp.	14	0	0	15	3	0	4	0	0	0	0	0	0	**36**	**1%**
GRYLLIDAE															
Gryllidae sp.1	16	55	41	50	20	1	1	2	3	2	12	28	36	**267**	**4%**
Gryllidae sp.2	2	1	47	7	7	1	0	4	0	0	25	10	3	**107**	**2%**
Gryllidae sp.3	7	0	0	0	0	1	0	0	1	0	2	0	0	**11**	**0%**
ROMALEIDAE															
Romaleidae sp.1	1	0	0	0	0	12	17	46	42	7	3	0	1	**129**	**2%**
Total of individuals	**928**	**450**	**729**	**627**	**603**	**269**	**376**	**542**	**297**	**512**	**534**	**432**	**304**	**6603**	
ARACHNIDA															
ARANEAE															
ACTINOPODIDAE															
Actinopus sp.	1	0	0	0	0	0	0	0	0	0	0	1	0	**2**	**1%**
CAPONIIDAE															
Nops sp.	0	2	2	0	0	0	0	0	0	0	0	0	0	**4**	**2%**
CORINNIDAE															
Coriniidae sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**0%**
Corinna sp.1	1	0	2	1	3	0	1	0	0	0	0	0	0	**8**	**3%**
Corinna sp.2	0	0	0	0	0	0	0	0	0	0	0	1	0	**1**	**0%**
Creugas sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**	**0%**

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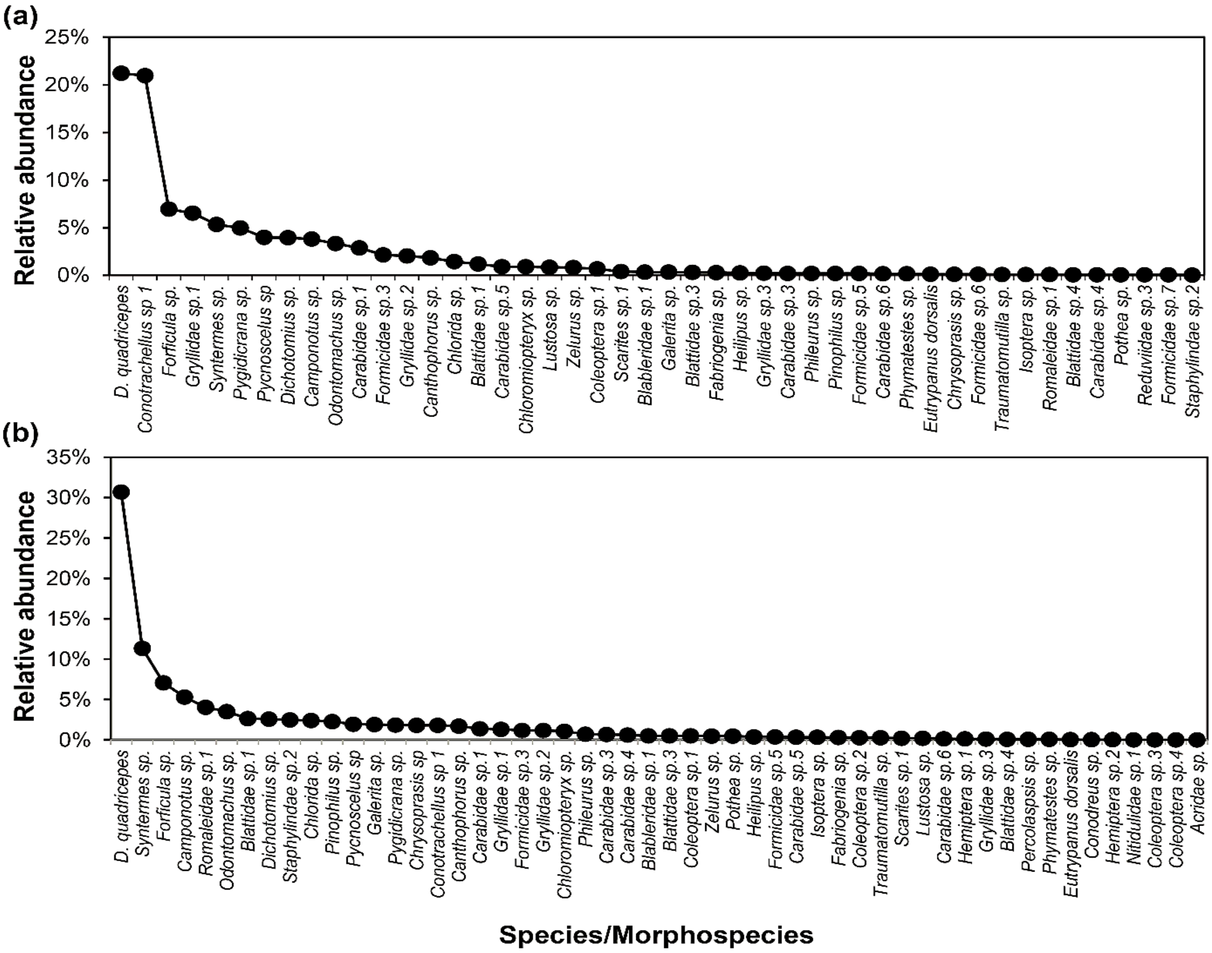
CTENIDAE															
Ctenus rectipes F. O. Pickard-Cambridge, 1897	0	0	0	0	0	0	1	2	1	4	0	0	0	**8**	**3%**
Isoctenus sp.1	2	0	0	2	0	0	0	0	0	1	1	0	2	**8**	**3%**
Isoctenus sp.2	0	0	0	0	0	0	0	3	0	0	0	0	0	**3**	**1%**
Nothroctenus sp.	0	0	0	0	0	0	1	0	0	0	0	0	0	**1**	**0%**
DIPLURIDAE															
Linothele sp.	0	0	0	0	1	0	0	0	0	3	0	2	0	**6**	**2%**
GNAPHOSIDAE															
Zimiromus sp.	0	0	0	0	0	0	0	0	0	6	0	0	0	**6**	**2%**
IDIOPIDAE															
Idiops sp.	2	0	0	0	0	0	0	0	0	0	0	0	0	**2**	**1%**
LINYPHIIDAE															
Linyphiidae sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**0%**
Meioneta sp.	1	1	1	0	0	0	1	0	0	0	0	0	0	**4**	**2%**
OONOPIDAE															
Neoxyphinus sp.	1	0	0	0	1	0	0	0	0	0	0	0	0	**2**	**1%**
Neotrops sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	**1**	**0%**
Oonopinae sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**	**0%**
PALPIMANIDAE															
Otiothops sp.1	0	8	1	0	0	2	1	0	0	0	0	0	0	**12**	**5%**
Fernandezina sp.	1	1	0	0	0	0	0	0	0	0	0	0	0	**2**	**1%**
SALTICIDAE															
gen.?1 sp.1	0	4	1	0	2	0	0	1	0	0	0	0	0	**8**	**3%**
gen.?2 sp.1	0	2	1	0	0	0	0	0	0	0	0	0	0	**3**	**1%**
gen.?3 sp.1	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0%**
gen.?4 sp.1	0	0	0	0	0	0	0	1	0	0	1	0	0	**2**	**1%**
Asaphobelis sp.	0	0	0	0	0	0	0	12	1	8	1	0	0	**22**	**9%**
Breda sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**	**0%**
Pensacola sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**	**0%**
Synemosyna sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**	**0%**
Soesilarischius sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**0%**
SEGESTRIIDAE															
Ariadna aff. *mollis*	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**0%**
SENOCULIDAE															
Senoculus sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	**1**	**0%**
SICARIIDAE															
Sicarius cariri Magalhaes, Brescovit& Santos, 2013	1	1	0	1	0	1	0	0	0	1	1	1	0	**7**	**3%**
SPARASSIDAE															
Olios sp.	0	0	0	0	0	1	0	1	0	0	0	0	0	**2**	**1%**
THERAPHOSIDAE															
Theraposidae sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**0%**
THERIDIIDAE															
Cryptachaea sp.	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**	**0%**
THOMISIDAE															
Bucranium taurifrons (O. Pickard-Cambridge, 1881)	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**	**0%**
TRACHELIDAE															
Orthobula sp.	1	2	0	0	0	0	0	0	0	0	0	0	0	**3**	**1%**
ZODARIIDAE															
Zodariidae sp.	2	0	0	0	0	0	0	0	0	0	0	0	0	**2**	**1%**

	Observed Rainfall (mm)														
	109.4	234	162	290	33	6	0	0	0	3.2	77.3	236	157		
	2018												**2019**		
Taxon	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**I**	**Total**	**F%**
Epicratinus sp.	9	4	0	0	0	0	0	0	0	1	0	0	1	**15**	**6%**
Tenedos sp.	23	12	1	0	0	1	0	0	0	2	0	0	0	**39**	**16%**
SCORPIONES															
BUTHIDAE															
Ananteris franckei Lourenço, 1982	15	3	3	2	2	2	0	0	0	0	0	0	0	**27**	**11%**
Ananteris aff. *franckei*	2	2	0	0	1	0	0	0	0	0	0	0	0	**5**	**2%**
Ananteris sp.	0	1	0	0	0	0	0	5	0	2	1	7	2	**18**	**7%**
Tytius serrulatus Lutz & Mello, 1922	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**	**0%**
Tytius stigmurus (Thorell, 1876)	0	0	0	0	0	0	0	0	0	0	0	1	0	**1**	**0%**
Tytius sp.	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**	**0%**
BOTHRIURIDAE															
Bothriurus asper Pocock, 1893	3	2	0	0	0	0	0	0	0	0	0	0	0	**5**	**2%**
Bothiurus sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**	**0%**
Total of individuals	**70**	**48**	**14**	**6**	**13**	**7**	**5**	**25**	**2**	**29**	**6**	**13**	**7**	**245**	
MYRIAPODA															
GEOPHILOMORPHA															
Geophilomorpha sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	**1**	**5%**
SCOLOPENDROMORPHA															
SCOLOPENDRIDAE															
Scolopendra viridicornis Newport, 1844	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**	**5%**
Otostigmus demelloi Verhoeff, 1937	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**5%**
CRYPTOPIDAE															
Cryptops (Trigonocryptops) sp.	0	1	0	1	0	0	0	0	0	0	0	0	0	**2**	**9%**
SCUTIGEROMORPHA															
PSELLIODIDAE															
Sphendononema guildingii Newport G., 1845	3	1	0	2	5	6	0	0	0	0	0	0	0	**17**	**77%**
Total of individuals	**4**	**2**	**1**	**3**	**6**	**6**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**22**	
Individuals (Insecta, Arachnida andMyriapoda)	1002	500	744	636	622	282	381	567	299	541	540	445	311	**6870**	
Species	50	53	38	36	46	34	36	42	26	38	40	28	29		

Legend: Rainy months: months painted as gray; Non rainy months: months not colored.
Source: Researcher data.

Eight orders of insects were collected. Coleoptera was the richest order, represented by 23 species/morphospecies. Hymenoptera was the most abundant order, represented by 2,385 individuals (Table 1). For Arachnida, Araneae was the richest order, represented by 40 species/morphospecies, followed by Scorpiones, which was represented by eight species/morphospecies. All Myriapoda collected in our study were chilopods represented by only five species/morphospecies. Insects demonstrated a general pattern of few dominant species in the rainy (Figure 1A) and dry (Figure 1B) months. The rainy months were dominated by *Dinoponera quadricepes* (Formicidae) and *Conotrachellus* sp. (Coleoptera), while during the dry months the dominant species were *D.* quadricepes, followed by *Forficula* sp. (Dermaptera).

Figure 1. Rank of Insecta species dominance for rainy (a) and dry (b) months.



Source: Researcher data.

In Brazil, *D. quadriceps* occurs in the Atlantic Forest, Caatinga, and Cerrado areas (Kempf, 1971, Paiva and Brandão, 1995) and is an omnivore ant (Araújo and Rodrigues, 2006). Medeiros et al. (2012) investigated temporal fluctuation in *D. quadriceps* abundance and found no correlation with rainfall. Specifically, the abundance peak between May and August identified by Medeiros et al. (2012) was not observed in our data. This may be attributed to differences in methodology or local environmental characteristics between

Atlantic forests (Mederios et al., 2012) and humid forest. For *Forficula* sp., a previous study within the National Araripe Forest by Azevedo et al. (2011), reported that the occurrence of Forficulidae reduced from the dry season to the rainy season. This is opposite to our results. However, our sample effort is different to those applied by Azevedo et al. (2011). We focused entirely in the humid forest for thirteen continuous months.

Our study presented the same general trends in species richness and abundance within taxa of macroarthropods as observed by Araújo et al. (2010). The rainy season presented greater species richness and an increase in abundance of taxa. The percentage of insects is also like data obtained by Araújo et al. (2010), however, in our study Formicidae was the most abundant taxa, followed by Coleoptera. The percentage of Arachnids and Myriapoda showed similar results.

Arthropods communities (mainly insects) exhibit increasing species richness and abundance from dry to rainy periods (Wolda 1978, 1980; Vasconcellos et al., 2010). This response is not uniform but may vary with habitat and taxa (Wolda and Broadhead, 1985), exhibit peaks throughout the year, vary with season (Wolda 1980; Wolda and Fisk 1981; Wolda 1988), or exhibit a delayed response to rainy months (Carvalho et al., 2015).

For spiders and scorpions, the dominant species during rainy months were the species/morphospecies *Tenedos* sp. (Araneae) and *Ananteris franckey* (Scorpiones) (Figure 2a). Other species exhibited relative frequencies lower than 10%. The dry months were dominated by the morphospecies *Asaphobellis* sp. (F% = 25%) (Araneae) (Figure 2b), while others species had relative frequencies less than 10%.

Except by the morphospecies *Tenedos* sp. (Table 1), both arachnids and centipedes did not exhibit relative frequency equal to or higher than 10%. Salticidae spiders were also abundant during the dry months, are one of the most abundant spiders in tropical soils because elevated temperatures favor spiders with elevated mobility (Jocqué, 1984). The use of pitfall traps is one of the most useful techniques to collect spiders, this technique is limited by the number of pitfall traps installed (Carvalho 2015). Pitfalls trap have been used for collecting both centipedes and scorpions in African Savanna (Druce et al., 2004), although it was recommended that a more successful qualitative technique for scorpions is the use of ultra-violet lights at night (Sissom et al., 1990).

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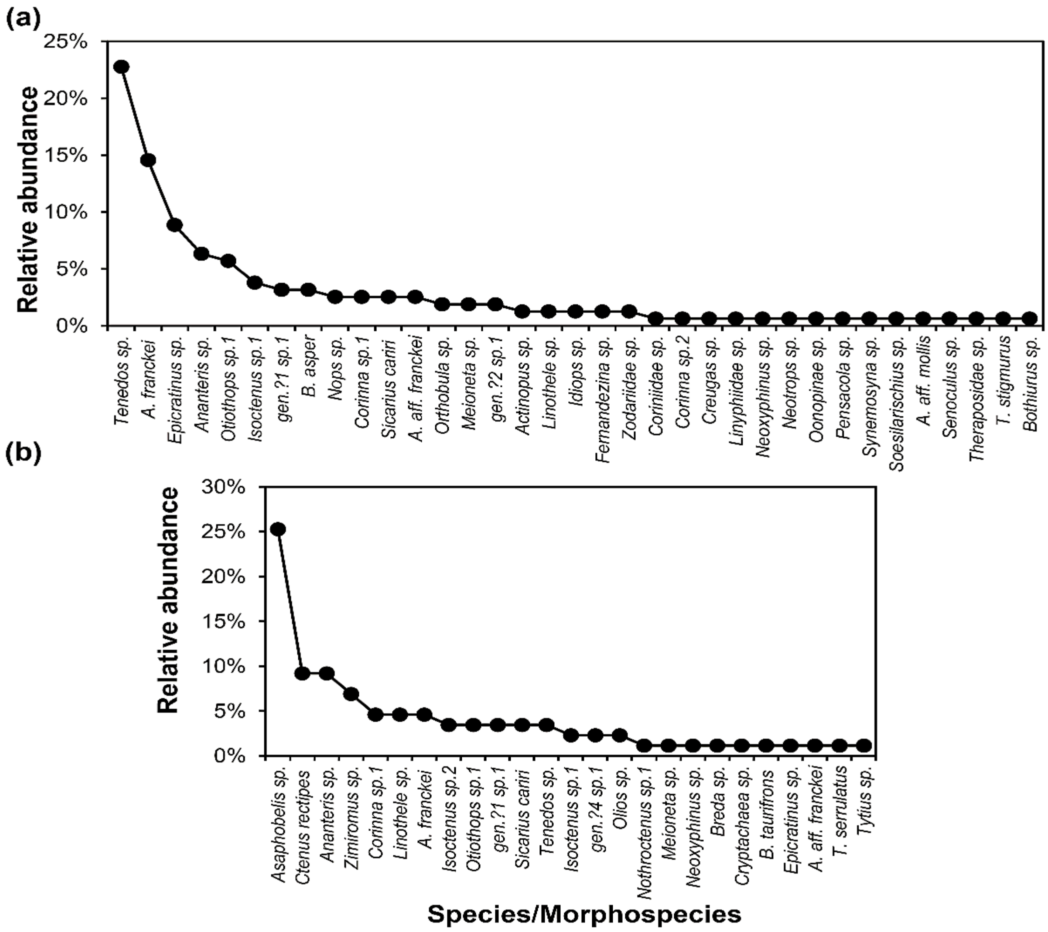
Figure 2. Rank of Arachnida species dominance for rainy (a) and dry (b) months.

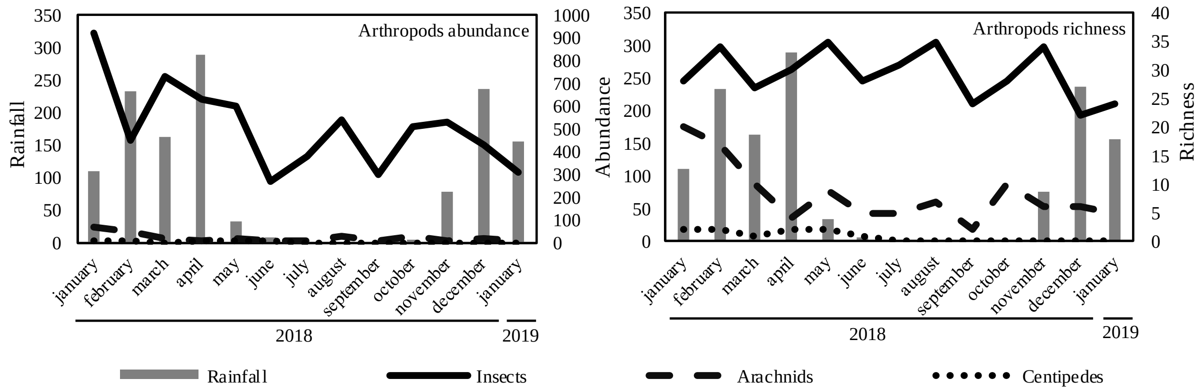


Source: Researcher data.

About the rainfall effects on arthropod abundance and richness, not significant are observed on insects, arachnids and all arthropods. The richness of insects, arachnids and artrhopods in general is not affected by rainfall (Figure 3).

However, the abundance and richness of centipedes was influenciated by precipitation (Table 2).

Figure 3. Variation of the rainfall, abundance and species richness of arachnids, insects and chilopods in Araripe National Forest.



Source: Researcher data.

Table 2. Summary of GLM results testing the effects of rainfall on abundance and richness of arachnids, insects and centipedes in Araripe National Forest.

Arthropods	Abundance		Richness	
	F	*P*	*F*	*P*
Insects	0.661	0.435	0.858	0.376
Arachnids	0.200	0.664	0.531	0.483
Centipedes	0.004	0.951	**9.031**	**0.013**
Total Arthropods	0.603	0.456	0.150	0.706

Source: Researcher data.

Throughout the sampling period there was a significant correlation between insect (prey) abundance and predator (Arachnida and Chilopoda) abundance (*r* = 0.626, p = 0.022). For non-social invertebrate predators in the tropics, there is a delayed population response to their prey (Richards and Coley, 2007), probably due to increased prey availability, reflecting the development time of the predators. On the other hand, generalist predators such ants can respond directly to prey density (without a delay) by shifting with available prey types or habitats (functional response) (Molleman et al., 2016). The dominant spider was *Tenedos* sp. this may be explained by the myrmecophagous behavior of the Zodariidae family (Pekar, 2004), and the dominance of the ant *D. quadriceps*, which spends 92.5% of its time searching for food (Araújo and Rodrigues, 2006), and thus, call attemption of *Tenedos* spiders.

There were no significant correlations between abundance and species richness of insects and arachnids with current rainfall. However, we observed that insect species abundance increased one-month before rainfall increased (Figure 4a), and arachnid abundance and richness increased up to two months prior to rainfall (Fig. 4c and 4d). Some groups of insect response to changes in barometric condition of atmosphere (Wellingt, 1946) changing their matting behavior (Pellegrino et al., 2013). The increased abundance and richness of insects before the rainy season observed in our study may be an evolutive vantage in semi-arid environments because the heavy rains in the begin of rainy season are potentially important mortality factor, mainly for immature stages (Tanner et al., 1991; Walker et al., 1984). Thus, reproducing before can be important to start the rainy season with the best-formed and competitively strong exoskeleton. For spiders, increased species richness has been correlated with simultaneous rainfall and one month after increased rainfall, one month before, and one month after the increase in humidity in arboreal areas of the Caatinga (Carvalho et al., 2015).

Spiders and scorpions and are predators (Foelix, 1996; Polis, 1990; Lewis, 2006) and respond to changes in prey abundance in a cascade effect. Our results show that species arachnid richness increased in the same month and one month before the abundance of potential prey for arachnids (i.e. insects) increased (Figure 4), like observed by Carvalho et al. (2015). Predation rates can increase with higher reproductive rates in predator populations. This increase in predator abundance would occur after a delay, therefore causing prey populations to fluctuate. In some cases, predators adapt their phenology to peak with prey abundance (Both et al., 2009).

Chilopods was positively when compared with rainfall three months after the sampling for abundance (Figure 4) and two and three to richness (Figure 4). The increase in centipede activity after the the rainy season starts was interesting because normally predators tend to have a delayed response to prey availability, which occurred after the rains started. In addition, the negative correlation of centipede richness in relation to the four- and five-month rains (i.e. at the end of the previous rainy season) may indicate that the number of myriapod species remains high until two months after the rains decrease. (Figure 4).

Centipedes respond to ecological factors such soil quality (Parisi et al., 2005) and fire (Trucchi et al., 2009). Chilopods are exclusive predators of soil invertebrates (Rosenberg, 2009; Minelli, 2011), with low dispersal capacity compared to other arthropods like winged insects. Although a low number of individuals were collected, our methodology is like previous studies but was conducted over a longer time. For example, the study of Tuf and Tufova (2008) involved five months of sampling while our work involved a continuous year of fortnightly sampling. Thus, our study indicated that there is an increase in the detection of the presence of centipedes after the beginning of the rainy season.

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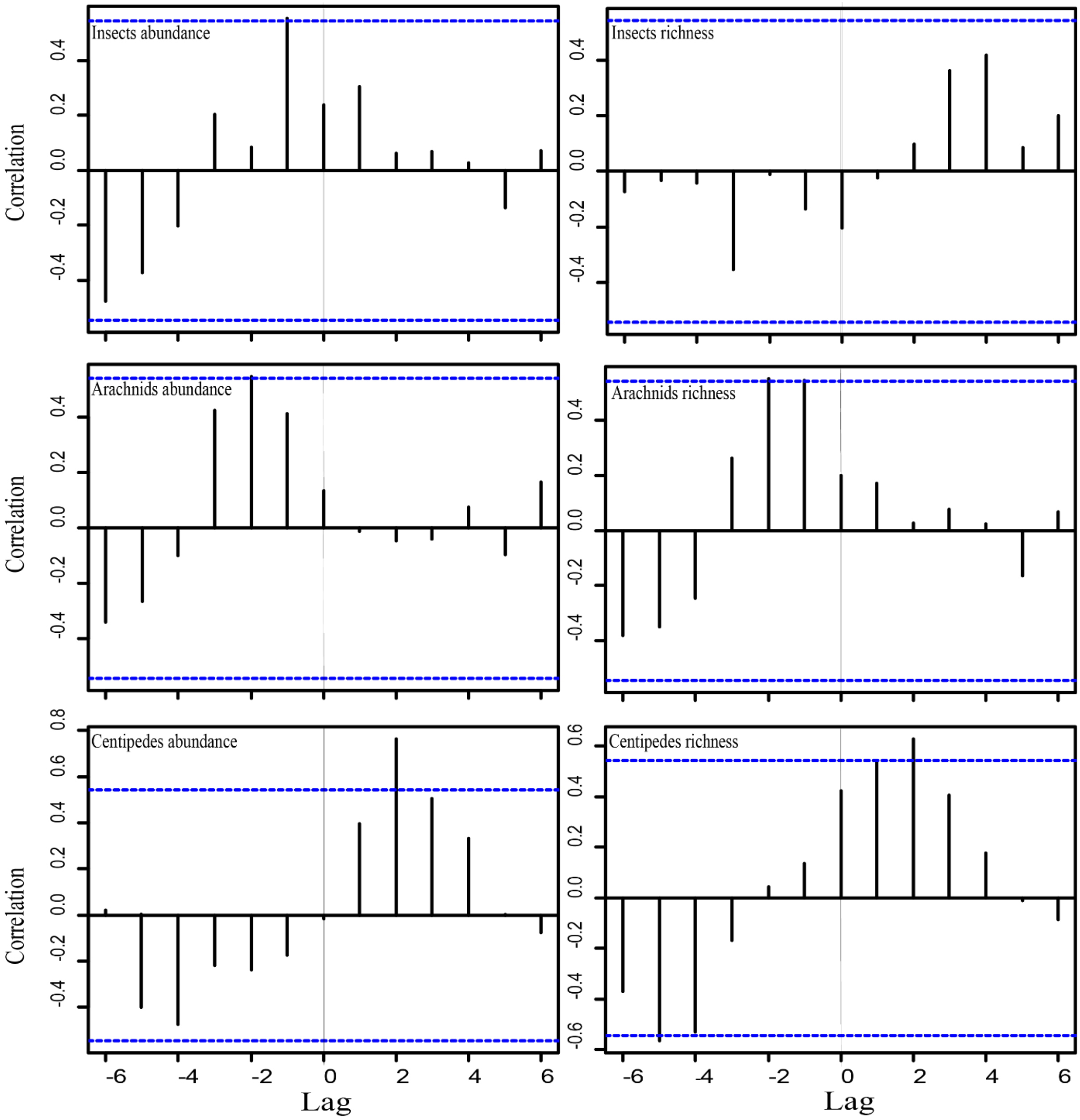
Figure 4. Cross correlation functions of arthropods richness and abundance with rainfall in Araripe National Forest. The dashed blue line indicates the significant correlation values.



Source: Researcher data.

4. Conclusions and Suggestions

Our study shows how rainfall influences the temporal variation of macrofauna in evergreen forest enclaves within semi-arid vegetation in Brazil (the Araripe National Forest). It is the first study to characterize rainfall effects on edaphic macrofauna and demonstrates how predators (arachnids and chilopods) respond to insect's fluctuations in evergreen enclaves.

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We expanded the database of insects, arachnids and centipedes for the area and increased the known geographic distribution of species.

Our work highlights than future research is required to understand why the behavior of the arachnids and insects changes just before the rainy season begins and how monitoring this behavior can help preserve the evergreen forest enclaves in Brazilian semi-arid regions.

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