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Anuran community of a cocoa agroecosystem in southeastern Brazil

Rogério L. Teixeira[1,2], Rodrigo B. Ferreira[1,3], Thiago Silva-Soares[4], Marcio M. Mageski[5], Weslei Pertel[6], Dennis Rödder[7], Eduardo Hoffman de Barros[1] & Jan O. Engler[7]

1) Ello Ambiental, Av. Getúlio Vargas, 500, Colatina, Espirito Santo, Brazil, CEP 29700-010

2) Laboratorio de Ecologia de Populações e Conservação, Universidade Vila Velha. Rua Comissário José Dantas de Melo, 21, Boa Vista, Vila Velha, ES, Brasil. CEP 29102-920

3) Instituto Nacional da Mata Atlântica, Laboratório de Zoologia, Avenida José Ruschi, no 04, Centro, CEP 29.650-000, Santa Teresa, Espírito Santo, Brazil

4) Universidade Federal do Rio de Janeiro, Museu Nacional, Dept. Vertebrados, Lab. de Herpetologia, Rio de Janeiro, 20940-040, Rio de Janeiro, Brazil

5) Universidade Vila Velha, Programa de Pós-Graduação em Ecologia de Ecossistemas, Rua Comissário José Dantas de Melo, 21, Vila Velha, 29102-770, Espírito Santo, Brazil

6) Instituto Estadual de Meio Ambiente e Recursos Hídricos – IEMA, Rodovia BR 262, Cariacica, 29140-500, Espírito Santo, Brazil

7) Zoologisches Forschungsmuseum Alexander Koenig, Division of Herpetology, Adenauerallee 160, 53113, Bonn, Germany

Correspondence: Rodrigo B. Ferreira, e-mail: rodrigoecologia@yahoo.com.br

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Brazil's Atlantic Forest is considered a biodiversity "hotspot" (Myers et al. 2000). Originally, this biome covered ca. 1,350,000 km² along the east coast of Brazil (IBGE 1993). Intense deforestation during the last decades has greatly reduced the amount of primary forest to 11.73% of its original extent, consequently threatening the conservation of native biodiversity (Ribeiro et al. 2009, Tabarelli et al. 2010). Out of the 1027 amphibian species in Brazil, approximately 540 are found at Atlantic Forest, and new taxa are frequently discovered (Haddad et al. 2013, Lourenço-de-Moraes et al. 2014, Segalla et al. 2014).

The cocoa agroecosystem (known as 'cabruca') is one of the most common agricultural matrices in southern Bahia and northern Espírito Santo (Franzen & Baumgarten 2007, Faria et al. 2007). It is characterized by an understorey of cocoa trees and an overstorey of native trees. The cocoa agroecosystem still holds important characteristics of primary forest that facilitate ecological processes, but the presence of true primary forest remnants in the landscape is nevertheless essential to the conservation of biodiversity (Faria et al. 2007). However, the frog composition of most cabrucas is still poorly understood.

In this study we assess the diversity of an anuran community inhabiting a cocoa agroecosystem in southeastern Brazil. Fieldwork was carried out on approximately 2,500 m² at the Fazenda José Pascoal (19°28' S, 39°54' W), district of Regência, municipality of Linhares, state of Espírito Santo, southeastern Brazil (Fig. 1). Cocoa agroecosystems dominate the landscape in this region. During the rainy season (November to March), continuous rains will soak the soil-filled depressions in the cocoa plantations and create temporary ponds. The shade cast by the native trees reduces water evaporation, which in turn increases the longevity of temporary ponds (unpublished data). Additional pools will form in the ruts left by tractor, which are used to collect the cocoa fruits during daylight hours. The climate at the study site can be classified as Tropical monsoon climate (Am) according to the updated Köppen-Geiger classification (Peel et al. 2007), marked by high temperatures, rainy summers, and dry winters. Average precipitation, maximum and minimum temperatures per month from 1950 to 2000 were obtained from the Worldclim database (Hijmans et al. 2005, Fig. 2).

Amphibians were recorded monthly from 19:00–23:00 h from November 2000 through March 2001 by means of visual and acoustic surveys. The individuals were hand-captured and stored in plastic bags for identification and released during the same night and at the original sites. It is possible that some individuals were counted more than once on different sampling occasions. Data on population trends and threat status of the species were obtained from the International Union for Conservation of Nature and Natural Resources, IUCN RedList of Threatened Species (http://www.iucnredlist.org; last viewed on 8 August 2014), Convention on International Trade in Endangered Species of Wild Fauna and Flora, CITES (http://www.cites.org; last viewed on 8 August 2014), Brazilian national RedList (MMA 2000), and Espírito Santo's state RedList (Gasparini et al. 2007). Moreover, the species were categorized as per their habitat requirements into the following categories: "forest-dependent", "open area-dweller" and "generalist" (preferring both forested and open sites) (see Haddad et al. 2013). The Shannon-Weaver Index was computed based on abundance and species richness.

We recorded 37 species belonging to seven families (Table 1). The Hylidae had the highest species richness and relative abundance. Three species could not be identified at species level and their population trend was characterized as "no data". The overall species diversity within this cocoa agroecosystem was H' = 2.27. Most species have stable population trends (N = 26; 72%), but some exhibit decreasing population trends (N = 8; 22%, Table 1). The evaluated species are listed as Least Concern on a global level (LC; IUCN 2014; Table 1) and are not listed in any threat category in the state and national red lists either.

The recorded number of species found at our study site is similar to other amphibian communities in Espírito Santo lowlands. For instance, 26 species were found in a nearby permanent pond (Teixeira et al. 2008) and 34 were recorded in the municipality of Vitória (Ferreira et al. 2010). Proportional habitat preferences differed across these communities, however. At our study site, 49% of the species were forest-dependent, 35% preferred open habitat, and 16% were habitat generalists. In the nearby permanent pond, 31% were forest-dependent, 46% were of the open habitat type, and 23% were habitat generalists (Teixeira et al. 2008). In Vitória, 27% were forest-dependent, 37% inhabited open habitat, and 37% were habitat generalists (Ferreira et al. 2010). Habitat differences across these sites may be responsible for these discrepancies in species richness. The higher proportion of forest-dependent species at our study site may be indicative of the cocoa agroecosystem value for amphibian conservation.

Our results highlight the substantial value of cabrucas for maintaining amphibian communities, including those with decreasing population trends. Even for a monoculture sustained by secondary forest, cocoa agroecosystems retain a wide variety of breeding habitats such as temporary and permanent ponds, bromeliads, and deep leaf litter. This heterogeneity of habitats preserves particular characteristics, which are essential for sustaining amphibian life cycles. Pardini et al. (2009) demonstrated that the cocoa agroecosystem can maintain the diversity of "forest specialist" species. However, the capability of this agroecosystem to maintain high amphibian diversity may not necessarily be stable over time (Pardini et al. 2009) and responses of the overall diversity to habitat fragmentation may be delayed (Metzger et al. 2009).

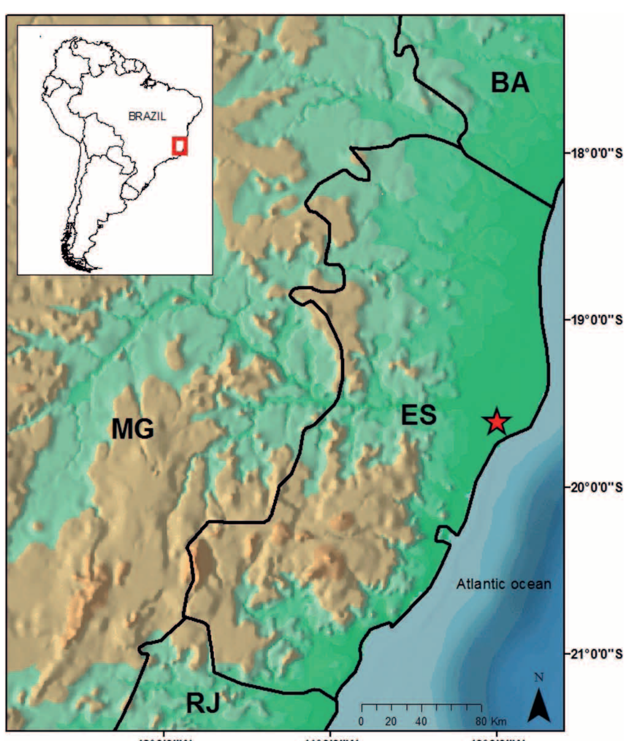

Figure 1. Location of study site: district of Regência, municipality of Linhares, state of Espírito Santo, southeastern Brazil.

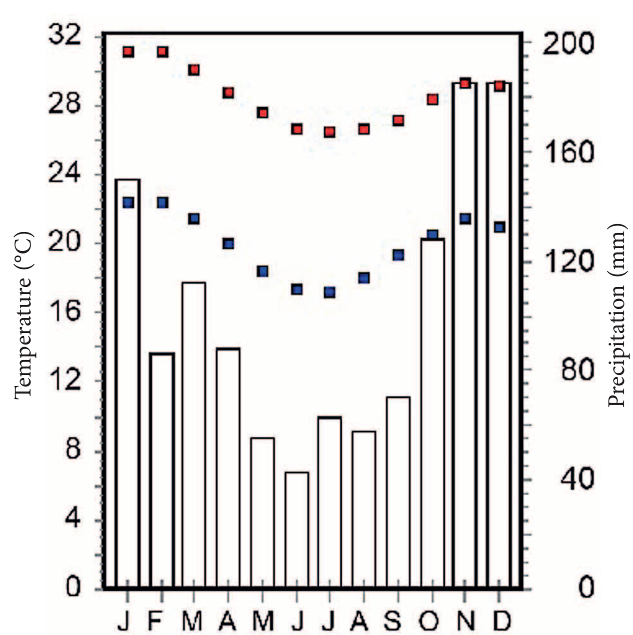

Figure 2. Monthly precipitation and temperature in the study region. Blue – minimum temperature; red – maximum temperature; and vertical bars – precipitation. Source: Hijmans et al. (2005).

Table 1. Amphibian diversity from a cocoa agroecosystem (cabruca) in the district of Regência, municipality of Linhares, state of Espírito Santo, southeastern Brazil. Conservation status: LC – Least Concern; Habitat: F – forest-dependent; O – open areas dweller; G – habitat generalist. N (%) – number of individuals recorded (percentage).

Family Species	Conservation status	Population trend	N	N (%)	Habitat
Bufonidae					
Rhinella crucifer (Wied-Neuwied, 1821)	LC	decreasing	4	0.9	G
Rhinella granulosa (Spix, 1824)	LC	stable	14	3.1	G
Rhinella schneideri (Werner, 1894)	LC	increasing	1	0.2	O
Ceratophryidae					
Ceratophrys aurita (Raddi, 1823)	LC	decreasing	2	0.4	F
Craugastoridae					
Haddadus binotatus (Spix, 1824)	LC	stable	5	1.1	F
Hemiphractidae					
Gastrotheca cf. *megacephala*	no data	no data	1	0.2	F
Hylidae					
Aparasphenodon brunoi Miranda-Ribeiro, 1920	LC	decreasing	14	3.1	F
Bokermannohyla aff. *circumdata*	no data	no data	1	0.2	F
Dendropsophus anceps (Lutz, 1929)	LC	stable	3	0.7	O
Dendropsophus berthalutzae (Bokermann, 1962)	LC	stable	2	–	F
Dendropsophus bipunctatus (Spix, 1824)	LC	stable	24	5.2	O
Dendropsophus branneri (Cochran, 1948)	LC	stable	11	2.4	O
Dendropsophus decipiens (Lutz, 1925)	LC	stable	28	6.1	G
Dendropsophus elegans (Wied-Neuwied, 1824)	LC	stable	17	3.7	O
Dendropsophus minutus (Peters, 1872)	LC	stable	11	2.4	O
Hypsiboas albomarginatus (Spix, 1824)	LC	stable	26	5.7	O
Hypsiboas albopunctatus (Spix, 1824)	LC	stable	23	5	O
Hypsiboas faber (Wied-Neuwied, 1821)	LC	stable	8	1.7	G
Hypsiboas pardalis (Spix, 1824)	LC	stable	2	0.4	G
Hypsiboas semilineatus (Spix, 1824)	LC	stable	14	3.1	F
Itapotihyla langsdorffii (Duméril & Bibron, 1841)	LC	decreasing	33	7.2	F
Phyllomedusa burmeisteri Boulenger, 1882	LC	stable	1	0.2	G
Phyllomedusa rohdei Mertens, 1926	LC	stable	3	0.7	F
Scinax alter (B. Lutz, 1973)	LC	stable	15	3.3	O
Scinax argyreornatus (Miranda-Ribeiro, 1926)	LC	stable	146	31.9	F
Scinax fuscovarius (A. Lutz, 1925)	LC	stable	6	1.3	O
Scinax similis (Cochran, 1952)	LC	stable	1	0.2	O
Scinax gr. *catharinae*	no data	no data	1	0.2	F
Trachycephalus mesophaeus (Hensel, 1867)	LC	decreasing	4	0.9	F
Trachycephalus nigromaculatus Tschudi, 1838	LC	stable	1	0.2	F
Leptodactylidae					
Leptodactylus spixi Heyer, 1983	LC	stable	1	0.2	O
Leptodactylus latrans (Steffen, 1815)	LC	stable	7	1.5	O
Physalaemus aguirrei Bokermann, 1966	LC	decreasing	16	3.5	F
Adenomera thomei (Almeida & Angulo, 2006)	LC	stable	1	0.2	F
Microhylidae					
Chiasmocleis schubarti Bokermann, 1952	LC	decreasing	3	0.7	F
Stereocyclops incrassatus Cope, 1870	LC	stable	7	1.5	F
Odontophrynidae					
Macrogenioglottus alipioi Carvalho, 1946	LC	stable	3	0.7	F

Long-term monitoring should be conducted to understand population dynamics and amphibian sustainability in this agroecosystem. It is likely that our sampling period and the omission of sampling in some habitats (i.e., bromeliads, canopy and streams) may have caused the amphibian richness occurring at this site to be underestimated.

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