Checklist of amphibians in a transitional area between the Caatinga and the Atlantic Forest, central-southern Bahia, Brazil

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ABSTRACT: We present a list of amphibian species from Serra do Brejo Novo, municipality of Jequié, state of Bahia in Brazil, a transition zone between the Caatinga and the Atlantic Forest that encompasses a great diversity of species and reproductive modes. Between November 2009 and April 2010 we surveyed the area using pitfall traps and between August 2010 and February 2012 data was collected using active search methodology. We recorded 32 species belonging to seven families. The unexpected composition of species and reproductive modes of this community highlight the importance of species inventories and also the need for exploring transitional areas to understand the ecological mechanisms responsible for changes in community structures between different zones.

INTRODUCTION
Bahia is a Brazilian state with a mosaic of vegetation formations, including areas of Cerrado, Caatinga and Atlantic Forest, as well as extensive zones of transitional vegetation between these biomes (SEMA 2007). The fauna of these domains and transition areas is still insufficiently sampled and anthropogenic changes that modify the structure of the landscape are a threat to the local taxa, especially those which have been poorly studied or are as yet unknown. The scarcity of studies in transitional environments is probably related to the fact that few transitional areas are protected and most of them have been and still are subject to impacts caused by human activities (Sabbag and Zina 2011).

Anurans are among the less studied vertebrate groups in the state. Although, recently, there has been an increase of studies in the region, such as several species inventories (Rodrigues 2003, Silvano and Pimenta 2003; Júnca 2006; Valdujo et al. 2009; Camurugi et al. 2010) and studies of population reproductive biology (Vilaça et al. 2011; Dias et al. 2011), the continuous increase in records extending known geographic distributions (Napoli et al. 2010; Dias et al. 2010), as well as the increase in the number of new species described from the state (Lugli and Haddad 2006a; 2006b; Cassimiro et al. 2008; Cruz et al. 2008; Pimenta et al., 2009; Napoli et al. 2011; Lourenço-de-Moraes et al. 2012), indicates that there are still areas, ecological aspects, species and communities that have yet to be explored in Bahia.

Only after increasing the knowledge about the anurans of the state it will be possible to establish a comprehensive list of species of Bahia, as has been done for the state of São Paulo (see Araújo et al. 2009), and at the same time identify the ecological patterns present and in need of being recognized for the establishment of conservation targets for the group.

Although of fundamental importance, species inventories, when they are not accompanied by biological information, such as reproduction, add little to our knowledge about the influence of abiotic factors, climate and vegetation on the life cycle of species and on modulating the composition and diversity of species existing in a given area. Still fewer is the number of studies that emphasize the importance of reproduction as a biological factor that can modulate communities in semi-arid environments such as the Caatinga (e.g. Arzabe 1999, Vieira et al. 2007, Vieira et al. 2009).

Thus, the aims of this study were: (1) register amphibian species in an area of Atlantic Forest-Caatinga ecotone located in central-southern Bahia, (2) identify the reproductive modes presented by the species, (3) establish the reproductive seasonal pattern of the species, and (4) verify if reproductive aspects of the species may explain their spatial distribution in the study area.

MATERIAL AND METHODS
Study area
This study was conducted in a forest fragment within the 74ha deciduous mountain forest (Macedo 2007), located in the Serra do Brejo Novo farm (13°56′41″ S and 40°06′33.9″ W; 617-755m asl), 12 km from the town of Jequié, state of Bahia, Brazil (Figure 1). The area is characterized as a transitional zone with rugged and mountainous environments and vegetation typical of the semi-deciduous Atlantic Rain Forest, surrounded by Caatinga xerophytic vegetation, with lakes and ponds in its lower section. Human activities such as logging, ranching and hunting take place in the fragment and its vicinities.

Data collection
Data collection using pitfall traps was carried out monthly, for seven consecutive days, from November 2009 to April 2010. Three sets of pitfall traps with drift fences (Cechin and Martins 2000; Calleffo 2002) were installed along the main 256m track in the forest interior. The traps were placed in a “Y” shape with four 60L buckets at each end and connected by five meters of 50cm high plastic sheeting. The first set of buckets was set at 131m from the beginning of the main track and each consecutive set was placed 60m away from the previous one along the main track, 25m from the track.

Additional data were collected by active search methodology at the reproductive site (Heyer et al. 1994) from August 2010 to February 2012, when fieldwork was carried out during the night weekly in the rainy season (October-March) and monthly in the dry season (April-September). Four types of environments were sampled over this period of time: (1) permanent lake: 10m in diameter and maximum depth of 1m, surrounded by cattails and grass; (2) temporary water bodies: (a) temporary pond in an open disturbed area, maximum length of 7m and maximum depth of 40cm surrounded by grasses and (b) temporary stream, maximum width of 1.20m and maximum depth of 40cm, also surrounded by grasses; (3) semi-permanent lake with a maximum length of 3m and maximum depth of 50cm, characterized by the presence of shrubs and grasses; and (4) fragment interior, where an area of 1.3ha was sampled by searches in the leaf litter, under fallen tree trunks, in burrows and in bromeliads. Data collection started just before sunset and ended around 24:00h.

Type specimens were collected, sacrificed with 5% xylocaïne, fixed in 10% formaldehyde and preserved in 70% ethanol. All species were collected under the permit of the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA / ICMBio - 20328-1) and the voucher specimens are deposited in theColeção de Zoologia of the Universidade Estadual do Sudoeste da Bahia (Museu de História Natural de Jequié Coleção Herpetológica - MHNJCH).

**RESULTS AND DISCUSSION**

A total of 32 amphibian species, divided into two orders (Anura and Gymnophiona) and seven families, was recorded (Table 1) (Figures 2 and 3). Most species (N = 17) belong to the family Hylidae, and this family also showed the largest number of reproductive modes (N = 4). Hylids are commonly predominant in studies of anuran communities in Neotropical regions (see Prado et al. 2005; Brasileiro et al. 2005; Zina et al. 2007) due to the diversity of species in the family and their arboreal habits, which allow them to explore various types of plants as breeding substrates (Zina et al. 2012). We observed the reproductive mode of approximately 52% of the all registered species, for the other species we consider the data available in the literature (Table 1).

The survey methods used in the present study to register the amphibian species richness (active search and pitfall traps) turned out to be complementary. However, active search was the most efficient method; only five species were registered using pitfall traps, being two of them (Chiasmocleis schubarti and Siphonops annulatus) collected exclusively by this method. Nevertheless, we need to consider the time during which both methods were performed (pitfall traps, 6 months; active search, one year and 6 months) that could interfere in the capture efficiency of them, as well as the limitations imposed by the methods to detect explosive breeders (active search) and arboricolous frogs (pitfall traps) (Cechin and Martins 2000).

The richness of species found in the Serra do Brejo Novo farm (N = 32) can be considered intermediate when compared to other localities of the Atlantic Forest, in which richness varies between 16 and 65 species (Heyer et al. 1990; Bertoluci and Rodrigues 2002; Silvano and Pimenta 2003; Prado et al. 2009). At the same time, the richness registered in the present study can be considered relatively high when compared to areas of Caatinga that have already been studied and that richness varied between 9 and 19 species (Arzabe 1999; Loebmann and Haddad 2010). Studies of Atlantic Forest- Caatinga ecotone in two other states (Sergipe - Carvalho, Villar and Oliveira 2005; Rio Grande do Norte - Magalhães et al. 2013) and at another locality in Bahia (Serra da Jibóia - Juncá 2006) reveals an amplitude of richness smaller than to the biomes separately; the species richness is ranging from 29 to 34 species and reinforce the pattern that transitional areas tend to present high richness.

There are four possibilities to explain the values of species richness in the region and that can possibly elucidate the richness in other ecotone zones in the same situation: (1) the area suffers from the effects of human disturbance and this has a negative effect on species richness when compared to areas under great influence of the Atlantic Forest; (2) human disturbance has a positive effect on richness, since it favors colonization by tolerant and widely distributed species (Morais et al. 2007) and, therefore, the number of species in the area is greater than would be expected in areas of Caatinga; (3) the area is typically transitional and, therefore, the diversity of microenvironments exceeds those available in other areas of Caatinga; and (4) a synergy of the above factors. Although we cannot exclude completely any of the above hypotheses, the presence of five species that belong to Atlantic forest domains and five others typically found in Caatinga, may corroborate the third hypothesis (Table 1).

Of the species for which the geographical distribution

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**Figure 1.** Geographic location of the study site (white circle), the Serra do Brejo Novo farm, municipality of Jequié, state of Bahia, Brazil.
is available in the literature, 33.3% are restricted to areas of Atlantic Forest or Caatinga (Table 1). The distribution of the species Scinax cf. auratus and Leptodactylus latrans has not been evaluated due to lack of more precise identification of the former and a recent taxonomic revision of the group to which the latter belongs (Lavilla et al. 2010).

By analyzing the geographical distribution, reproductive modes, and use of the environment for breeding activity, the only observable patterns in the community under study are that (1) for both widely distributed species and species of more restricted distribution, reproductive mode 1 (eggs and exotrophic tadpoles in lentic water) was the most common, as observed in other studies of Neotropical communities (Zimmerman and Simberloff 1996; Zina et al. 2007; Camurugi et al. 2010); (2) reproductive modes involving foam nests were typically observed in species that occupied temporary environments, as also observed for other anuran communities (Vieira et al. 2007; Kopp et al. 2010); and (3) the only species with direct development (Haddadus binotatus) was recorded in breeding activity only in the interior of the fragment, which also corroborates the data available in the literature (Canedo and Rickli 2006; Camurugi et al. 2010; Sabbag and Zina 2011). Thus, apparently, the reproductive modes did not determine the range of the geographical distributions but is strongly related to the occupation of a particular type of breeding site and may determine the spatial distribution of the species, as in the two cases mentioned above.

The spatial distribution of species in the visited water bodies, as well as their breeding pattern, can be summarized as follows:

1. Permanent pond (PP): 11 species were recorded in reproductive activity in this environment, and most of them had prolonged or continuous breeding patterns (Table 1). The use of the environment varied from cattail leaves (Dendropsophus spp., Scinax cf. auratus, and Scinax pachycrus), grasses (Dendropsophus spp.), soil near or in the water (Hypsiboas crepitans, Leptodactylus vastus, Physalaemus kroyeri, Rhinella granulosa, R. jimi, and Scinax x-signatus), and shrubs near the permanent pond (Hypsiboas crepitans, H. faber, and Phyllomedusa bahiana).

2. Temporary ponds in an open environment (TP): 21 species were recorded, most of which showed an explosive breeding pattern (Table 1). In this environment the species were observed using grasses (Dendropsophus spp., Phyllomedusa nordestina, Sphaenorhynchus prasinus), and soil near or in the water (Dermatotus muelleri, Leptodactylus spp., Physalaemus spp.) as calling sites.

3. Forest fragment (FF): four species of anurans and one of Gymnophiona were recorded in this habitat (Table 1), however, no species was observed in reproductive activity in the forest interior except for an individual of Hadaddus binotatus calling from a leaf approximately 1.5 m high.

Considering that reproductive mode is the set of features that include oviposition sites, ovum and clutch characteristics, rate and duration of larval development and parental care, if any (Salthe and Duellman 1973), it would not be surprising if the temporal and spatial distribution of species were somehow related to reproductive modes. Most species that uses temporary water bodies as oviposition site are expected to exhibit explosive breeding behavior. In this study, of the 28 species with observed reproductive mode and breeding patterns, 46.4% used temporary ponds as breeding sites and also had explosive breeding patterns (Table 1). Temporary environments are more likely to dry up and are, therefore, occupied by species with rapid development and those that build foam nests allowing the larvae to survive until the next rain (Zina 2006). Furthermore, near 64% of the recorded species showed an explosive breeding pattern, a fact that may be related to seasonal features of the study area.

Therefore, the reproductive mode and the spatial and temporal distribution of anuran species are co-dependent factors and cannot be considered in isolation. Moreover, the correlation between these processes should be viewed from a local perspective, considering the characteristics of the studied environments, and not from such broad perspectives as morphoclimatic classification or geographic location.

The Serra do Brejo Novo farm harbors a set of heterogeneous habitats, which provide a high variety of spatial and climatic features, also reflecting the heterogeneous composition of the species. These amphibian populations are under increasing pressure of fragmentiation in an area of transition between two vegetation domains, the Atlantic Rain Forest and the Caatinga. The continuity of studies with this amphibian community is important for understanding the dynamics of these populations. The richness of species in the area and the diversity of reproductive modes highlight the importance of the transition areas being investigated. Moreover, additional comparative studies should be performed in different domains to understand if the anuran diversity results from different vegetation/climatic types that permit the occurrence of species with different reproductive modes.

Moreover, the Caatinga and its transitional regions make up a unique environment in Brazil with high endemism and climate peculiarities, but they are still poorly studied (e.g. Tabarelli and Vincenete 2004). Inappropriate land use has caused environmental damage and acceleration of desertification (Leal et al. 2005) which makes this region a priority for biological studies (Camardelli and Napoli 2012).

Importance of inventories
Recently, studies of species inventories have received little attention from the scientific community, and the more specialized journals no longer publish this type of data. However, it is known that in order to determine ecological patterns of species occurrence or to determine anthropogenic effects on fauna and flora, data on the composition of communities are needed. Publication of species lists should be encouraged, in order to bring together information about temporal, spatial and reproductive aspects since they contribute to our understanding about the natural history of these species and provide insights into population differences that help in systematics, taxonomy and conservation.
| TAXON       | REPROD. MODE | REFERENCE                  | REPROD. PATTERN | SAMPLING METHOD | SPATIAL DISTRIBUTION | GEOGRAPHIC DISTRIBUTION | REFERENCE | VOUCHER |
|------------|--------------|----------------------------|-----------------|-----------------|----------------------|-------------------------|-----------|---------|
| **ANURA**  |              |                            |                 |                 |                      |                         |           |         |
| Rhinella jimii (Stevaux, 2002) | 1 OB         | P ACS                      | PP              | WIDE            | Loebmann and Haddad 2010 | MHNJCH 242 |
| Rhinella granulosa (Spix, 1824) | 1 OB         | E ACS                      | PP/TP           | WIDE            | Narvaes and Rodrigues 2009 | MHNJCH 066 |
| **BUFOIDAE** |              |                            |                 |                 |                      |                         |           |         |
| **CRAUGASTORIDAE** |              |                            |                 |                 |                      |                         |           |         |
| Haddadus binotatus (Spix, 1824) | 23 OB        | E PIT/ACS                  | FF              | WIDE            | IUCN 2012             | MHNJCH 073 |
| **ODONTOPHRYNIDAE** |              |                            |                 |                 |                      |                         |           |         |
| Odontophrynus carvalhoi (Savage and Cei, 1965) | 1 OB         | E ACS                      | PP/IF           | WIDE            | Lisboa et al. 2010 | MHNJCH 120 |
| **HYLIDAE** |              |                            |                 |                 |                      |                         |           |         |
| Dendropsophus bipunctatus (Spix, 1824) | 1 OB         | E ACS                      | TP              | AF              | IUCN 2012             | MHNJCH 449 |
| Dendropsophus brancoi (Cochran, 1948) | 1 OB         | P ACS                      | TP/PP           | WIDE            | IUCN 2012             | MHNJCH 127 |
| Dendropsophus elegans (Wied-Neuwied, 1824) | 1 OB         | P ACS                      | TP              | WIDE            | IUCN 2012             | MHNJCH 446 |
| Dendropsophus minutus (Peters, 1872) | 1 OB         | P ACS                      | TP              | WIDE            | IUCN 2012             | MHNJCH 450 |
| Dendropsophus novaisi (Bokermann, 1968) | -            | E ACS                      | TP              | WIDE            | Santos-Silva et al. 2012 | MHNJCH 322 |
| Dendropsophus olivaini (Bokermann, 1963) | 24 **        | NO ACS*                    | TP              | CA              | IUCN 2012             | MHNJCH 402 |
| Hyphioas carvalhoi (Wied-Neuwied, 1824) | 1 OB         | C ACS                      | PP              | WIDE            | IUCN 2012             | MHNJCH 029 |
| Hyphioas faber (Wied-Neuwied, 1821) | 4 OB         | E ACS                      | PP              | WIDE            | IUCN 2012             | Not Collected |
| Phyllomedusa bimaculata Lutz, 1925 | 24 OB        | E ACS                      | TP              | CA              | IUCN 2012             | MHNJCH 121 |
| Phyllomedusa nordestina Caramaschi, 2006 | 24 OB        | E ACS                      | TP              | CA              | IUCN 2012             | MHNJCH 121 |
| Scinax capoesebrasi (Boke mann, 1968) | 1 OB         | E ACS                      | TP              | WIDE            | Cândido et al. 2012 | MHNJCH 326 |
| Scinax eurydice (Bokermann, 1968) | 1 OB         | NO ACS                     | TP              | AF              | IUCN 2012             | MHNJCH 426 |
| Scinax cl. auratus (Wied-Neuwied, 1821) | 1 OB         | P ACS                      | PP              | - IUCN 2012    | MHNJCH 247 |
| Scinax poeyacae (Miranda-Ribeiro, 1937) | 1 OB         | E ACS                      | PP              | GA              | IUCN 2012             | MHNJCH 173 |
| Scinax xignatii (Spix, 1824) | 1 OB         | E ACS                      | PP              | WIDE            | IUCN 2012             | MHNJCH 136 |
| Sphaerodactylus parviceps Bokermann, 1973* | 1 OB         | E ACS                      | TP              | AF              | dos Santos and Moura 2009 | MHNJCH 182 |
| Trachycephalus atlased Bokermann, 1966 | 1 OB         | E ACS                      | TP              | AF              | Roberto et al. 2011 | MHNJCH 314 |
| **LEPTODACTYLIDAE** |              |                            |                 |                 |                      |                         |           |         |
| Physalaemus kroyeri (Reinhardt and Lütken, 1862) | 11 OB        | P ACS/PIT                  | PP/TP           | WIDE            | IUCN 2012             | MHNJCH 069 |
| Physalaemus cicalo Bokermann, 1966 | 11 OB        | E ACS                      | TP              | CA              | Linares and Mello 2011 | MHNJCH 090 |
| Pleurodema diplolister (Peters, 1870) | 11 OB        | E ACS                      | TP              | CA              | Andrade and Vaz-Silva 2012 | MHNJCH 101 |
| Leptodactylus mossicus (Schneider, 1799) | 30 OB        | P ACS                      | TP              | WIDE            | IUCN 2012             | MHNJCH 118 |
| Leptodactylus mystacinus (Burmeister, 1840) | 30 OB        | P ACS                      | TP              | WIDE            | IUCN 2012             | MHNJCH 105 |
| Leptodactylus tragodactylus Lutz, 1926 | 30 OB        | P ACS                      | TP              | WIDE            | Loebmann and Haddad 2010 | MHNJCH 106 |
| Leptodactylus vastus Lutz, 1930 | 13 OB        | E ACS                      | PP              | WIDE            | Loebmann and Haddad 2010 | MHNJCH 086 |
| Leptodactylus latrans (Steffen, 1815) | 11 OB        | E ACS                      | TP              | - IUCN 2012    | MHNJCH 035 |
| **MICROHYLIDAE** |              |                            |                 |                 |                      |                         |           |         |
| Dermatotus museleri (Boettger, 1875) | 1 OB         | E ACS                      | TP              | WIDE            | IUCN 2012             | MHNJCH 313 |
| Chiromantis schubarti Bokermann, 1952 | 1 OB         | NO PIT                     | FF              | AF              | Pimenta and Silva 2002 | MHNJCH 424 |
| **GYMNOPHIONA** |              |                            |                 |                 |                      |                         |           |         |
| **SIPHONOPIDAE** |              |                            |                 |                 |                      |                         |           |         |
| Siphonops annulatus (Mikan, 1820) | -            | -                         | PIT             | FF              | WIDE                  | IUCN 2012 | MHNJCH 414 |
Figure 2. Amphibians found at the Serra do Brejo Novo farm, municipality of Jequié, state of Bahia, from November 2009 to April 2010. Family Bufonidae: A- *Rhinella granulosa*, B- *Rhinella jimii*; Family Odontophrynidae: C- *Odontophrynus carvalhoi*; Family Craugastoridae: D- *Haddadus binotatus*; Family Hylidae: E- *Dendropsophus bipunctatus*, F- *Dendropsophus elegans*, G- *Dendropsophus minutus*, H- *Dendropsophus novaisii*, I- *Dendropsophus oliveirai*, J- *Hypsiboas crepitans*, K- *Hypsiboas faber*, L- *Phyllomedusa bahiana*, M- *Phyllomedusa nordestina*, N- *Scinax camposseabrai*, O- *Scinax eurydice*. 
**Figure 1.** Amphibians found at the Serra do Brejo Novo farm, municipality of Jequié, state of Bahia, from November 2009 to April 2010. Family Hylidae: A- *Scinax pachycrus*, B- *Scinax x-signatus*, C- *Trachycephalus atlas*; Family Leptodactylidae: D- *Physalaemus cicada*, E- *Physalaemus kroyeri*, F- *Pleurodema diplolister*, G- *Leptodactylus mystacinus*, H- *Leptodactylus vastus*, I- *Leptodactylus troglodytes*; Family Microhylidae: J- *Dermatonotus muelleri*; Family Siphonopidae: K- *Siphonops annulatus*.

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