Daniel Loebmann

Herpetofauna do Planalto da Ibiapaba, Ceará: composição, aspectos reprodutivos, distribuição espaço-temporal e conservação

Tese apresentada ao Intituto de Biociências do Campus de Rio Claro, Universiade Estadual Paulista —Júlio de Mesquita Filho, como parte dos requisitos para otenção do título de Doutor em Ciências Biológicas (Área de Concentração: Zoologia).

Orientador: Célio F. B. Haddad

Rio Claro

Julho / 2010

"O cérebro humano é uma grande criador de absurdos. Deus é o maior deles."

José Saramago.

Agradecimentos

Essa é uma ótima oportunidade de serem lembradas as pessoas e instituições que colaboraram de alguma forma para que a presente tese fosse construída. Em especial, àquelas pessoas que terão seus nomes suprimidos nas publicações em revistas científicas futuras, por razões óbvias de falta de espaço. Sendo assim, gostaria de manifestar meus sinceros agradecimentos as seguintes pessoas e instituições:

Aos meus pais, Marcelo e Leonice Loebmann, que sempre me ajudaram no que foi preciso durante toda minha trajetória acadêmica.

Ao meu orientador, Célio Haddad, por compartilhar seus conhecimentos científicos, pelos ensinamentos éticos e por sua ampla disponibilidade quando necessária, mesmo tendo sua agenda sempre repleta de compromissos.

Ao professor Augusto S. Abe por ter me aceitado como orientador no início da tese e pelas conversas sempre amigáveis e recheadas de conhecimento.

À Ana Cecília Giacometti Mai pelo companherismo, por toda ajuda e pela paciência e compreensão durante os últimos meses de tese.

Aos membros da banca examinadora Cynthia Almeida Peralta Prado, Cinthia Aguirre Brasileiro, Luis Olimpio Menta Giasson e Francisco Luis Franco pelas valiosas sugestões para o refinamento dessa tese.

A toda equipe do laboratório de Herpetologia que sempre estiveram disponíveis para me ajudar durante a tese, inclusive durante o período que residi no Ceará. Dentre eles, destaco os seguintes amigos:

Francisco Brusquetti, por compartilhar seu grande conhecimento sobre a herpetofauna paraguaia, pelas discussões relevantes sobre reprodução de anfíbios e pela crítica leitura e valiosas sugestões dessa tese.

João Gabriel Ribeiro Giovanelli, pela ampla ajuda na tese, em especial pelos ensinamentos sobre modelagem de nicho ecológico e modelos de previsão.

Juliana Zina Pereira Ramos, pela ajuda nas análises estatísticas, enriquecendo o conteúdo dessa tese, além de seu constante bom humor sempre bem-vindo no laboratório.

Luís Olímpio Menta Giasson, por compartilhar toda sua experiência e conhecimento sobre ecologia de anfíbios, além de sua constante paciência comigo e outras pessoas do laboratório.

Mariana L. Lyra, pela ampla ajuda na biologia molecular, fundamental para tese e inviável de ser realizada sem a sua colaboração.

Victor Goyannes Dill Orrico, meu amigo moderadamente robusto, pelos ensinamentos de bioacústica, taxonomia e sistemática, além das inúmeras discussões que contribuíram muito para essa tese.

Daniel do Nascimento Lima por toda ajuda durante o trabalho de campo.

Mario e seu avô "Santo Mano" por ter disponibilizado estrutura física para as expedições no sertão cearense, apesar de inicialmente ficarem contrariados quando falei que estava atrás de cobras e sapos.

Aos biólogos, Ciro Albano, Paulo Brito e, especialmente, Igor J. Roberto por disponibilizar conhecimento, material e dados fundamentais para essa tese.

Aos amigos Francisco Franco e Waldir Germano pelos valiosos ensinamentos sobre identificação de serpentes e por disponibilizar espaço e tempo

para tombar os répteis coletados na coleção do Butantan. Conte comigo para refaze-lá e torna-la grande e majestosa novamente.

Antonio Brescovit pela ajuda na identificação de quelicerados e por disponibilizar espaço para tombar os artrópodes coletados no Ceará. Conte comigo para reconstruir a coleção novamente.

Aos colegas de republica de Rio Claro, Gustavo, Alessandro, Sérgio e Gabriel.

À todos os editores do Check List que seguram a "bronca" nesses últimos meses e/ou colaboram com o crescimento do periódico, em especial Renato Silveira Bérnils, Paula Hanna Valdujo, Reginaldo Assêncio Machado, Leandro Bugoni e Cynthia Almeida Peralta Prado.

À Antonio Ivo de Araújo por toda sua ajuda em Ubajara, facilitando muito a execução do trabalho.

Aos funcionários do IBAMA de Ubajara.

À Hebert J. Klein pela ajuda durante o período que residi no Ceará e também por compartilhar seus conhecimentos adquiridos ao longo de todos dos mais de 30 anos que vive no Planalto da Ibiapaba.

Aos técnicos do jacarezário Marcelo e Carlos por estarem sempre disponíveis para ajudar.

As instituições financiadoras Fundação O Boticário de Proteção a Natureza, FAPESP e Conselho Nacional de Pesquisa e Desenvolvimento (CNPq).

Índice

Resumo 1

Abstract 2

Introdução geral 3

Capítulo 1 13

Amphibians and reptiles from a speciose area of the Caatinga domain: composition and conservation implications 13

Abstract 14

Introduction 15

Materials and Methods 16

Results 21

Discussion 55

Acknowledgments 60

References 60

Capítulo 2 72

Reproductive strategies and size-fecundity relationships of anurans in the Caatinga Domain, Northeastern Brazil 72

Abstract 73

Introduction 73

Materials and Methods 75

Results 78

Discussion 90

Acknowledgments 98

References 98

Capítulo 3.....106
Distribuição espacial e sazonalidade dos anfíbios do complexo Planalto da Ibiapaba, Ceará, Brasil.....106
Resumo.....107
Abstract.....107
Introdução.....108
Material e Métodos.....111
Resultados.....116
Discussão.....130
Referências.....136
Capítulo 4.....146
Good news for a Brazilian amphibian species threatened with extinction: discovery of new populations provide a new taxonomic and conservation status for Adelophryne baturitensis (Anura, Eleutherodactylidae, Phyzelaphryninae).....146
Introduction.....147
Material and Methods.....149
Results.....153
Discussion.....165
Acknowledgments.....175
References.....175
Capítulo 5.....183
Anexos.....184

Herpetofauna do Planalto da Ibiapaba, Ceará: composição, aspectos reprodutivos, distribuição espaço-temporal e conservação.

Resumo

O Planalto da Ibiapaba é um dos mais importantes fragmentos de floresta úmida do Ceará. Localizado do extremo noroeste do estado, essa região é privilegiada não somente pelas áreas de florestas úmidas, mas também por um mosáico de ambientes ao longo de sua extensão. Consequentemente, a fauna de anfíbios e répteis é extremamente rica se comparada as outras áreas do Bioma Caatinga. Durante dois anos a herpetofauna desse refúgio da vida silvestre foi estudada e os resultados obtidos são apresentados nessa tese. As 121 espécies (38 anfíbios e 83 répteis) encontradas no presente estudo revelam um resultado bastante expressivo, não só pelo fato de ser esta a região com maior riqueza de espécies para o Bioma Caatinga conhecidada até o momento, mas também pelo fato de que o Planalto da Ibiabapa abriga espécies consideradas raras e/ou ameaçadas. Padrões reprodutivos de machos e fêmeas em comunidades de anfíbios também foram investigados, tentando compreender melhor os mecanismos adaptativos das espécies para sobreviver às duras condições impostas pelo clima marcadamente sazonal da Caatinga. A presença no Planalto da Ibiapaba de *Adelophryne baturitensis*, uma espécie considerada ameaçada e até então conhecida somente para a localidade-tipo, foi também estudada em maior detalhe e dados inéditos de vocalização, descobertas de novas populações e dados moleculares são apresentados. Ampliações de distribuição e atualizações de distribuição de 14 espécies são também apresentadas nessa tese. Os resultados obtidos mostram a necessidade de preservar os fragmentos de floresta úmida e regiões adjacentes do Planalto da Ibiapaba, além do que são importantes para uma melhor compreensão da ecologia, biogeografia e taxonomia dos anfíbios e répteis de florestas úmidas do Nordeste e de áreas abertas do Brasil, em especial do Bioma Caatinga.

Abstract

The Planalto da Ibiapaba is one of the most important fragments of moist forests in the state of Ceará. Located at the Northwestern portion of the state, this region is not only privileged by the presence of moist forest areas, but also by the presence of a mosaic of environments along its extension. Consequently, the fauna of amphibians and reptiles present there is extremely rich if compared to other areas from the Caatinga Biome. During two years the herpetofauna of this wildlife refuge was studied and the results are presented in this thesis. The 121 species (38 amphibians and 83 reptiles) encountered in this study reveal a very expressive result, not only due to the fact that this is the region with the highest species richness for the Caatinga Biome known so far, but also because Planalto da Ibiabapa shelters species considered rare and threatened. Reproductive patterns for males and females in amphibian communities were also investigated, in order to try to understand adaptive mechanisms of the amphibian species to survive the harsh conditions imposed by marked seasonal climate of the Caatinga. The presence in Planalto da Ibiapaba of *Adelophryne baturitensis*, a species considered endangered and previously known only to its type locality, was also studied in more detail and data from vocalization, discoveries of new populations, and molecular data are here presented. Distribution extensions and upgrades of distribution from 14 species are also presented in this thesis. The results show the need to preserve the moist forest fragments and adjacent areas of the Planalto da Ibiapaba and are also important for the better understanding of ecology, biogeography, and taxonomy of amphibians and reptiles in the moist forests from Northeastern and open areas of Brazil, especially in the Caatinga Biome.

Introdução geral

O território brasileiro, devido a sua grande extensão continental dentro da América do Sul, possui um complexo de biomas, passando pelas formações de florestas úmidas tropicais da Amazônia e da Mata Atlântica e pelas formações abertas das planícies alagadas do Pantanal mato-grossense, das áreas predominantemente de savanas do Cerrado, das áreas subtropicais dos campos sulinos e das regiões semi-áridas da Caatinga. Do ponto de vista ecológico, cada um desses biomas possui características inerentes a si e podem ser considerados relativamente homogêneos ao longo de sua distribuição (AB'SABER, 1977). Contudo, é possível observar no interior desses biomas, áreas que destoam dessa relativa uniformidade, chegando a constituir um contraste com o seu entorno e, por essa razão, são denominadas paisagens de exceção (AB'SABER, 2003). Dentro desse contexto destacam-se os fragmentos de florestas úmidas do semi-árido brasileiro (CAVALCANTE, 2005a).

Os fragmentos de floresta tropical úmida do Nordeste do Brasil, também conhecidos como brejos-de-altitude, são florestas relictuais remanescentes das Florestas Atlântica e Amazônica, geralmente associadas a relevos de altitudes superiores a 600 m (COIMBRA-FILHO & CÂMARA, 1996). Essas florestas funcionam como verdadeiras ilhas para espécies de características ombrófilas, uma vez que estão isoladas pela Caatinga nas áreas de baixada.

O Ceará possui nove formações com fragmentos de florestas úmidas (CAVALCANTE, 2005b), sendo que as formações conhecidas como Serra dos Machados e Serra das Matas não apresentam, atualmente, fragmentos de floresta úmida e, por essa, razão, os anfíbios e/ou répteis típicos de florestas úmidas nunca

foram registrados para essas localidades (IJRoberto, comm. pess.). As sete principais áreas de florestas úmidas estão localizadas da seguinte maneira: Planalto da Ibiapaba (03°20'-5°00'S/ 40°42'-41°10'W) e Serra da Meruoca (03°31'S/ 40°28'W), localizadas a noroeste do Ceará; Serra da Uruburetama (03°36'S/ 39°34'W), localizada no norte do estado; Maciço de Baturité (04°15' S/ 38°54'W), Serra de Maranguape (03°54'S/ 38°42'W) e Serra da Aratanha (03°59'S/ 38°38'W), localizados a Nordeste do estado, nas proximidades de Fortaleza; Chapada do Araripe, localizada no extremo sul do estado (07°25' – 07°40' S/ 39°03' – 40°28' O) (Figura 1). Atualmente, a Serra da Meruoca e a Serra de Uruburetama são as áreas que mais sofrem com a pressão antrópica, sendo que os poucos fragmentos de florestas úmidas que ainda existem estão demasiadamente alterados.

Devido a importância dos fragmentos de florestas úmida para a preservação de muitas espécies (veja capítulo 1), as áreas de altitude no Ceará são consideradas prioritárias para conservação (TABARELLI & SILVA, 2003). Mesmo assim, diversos fatores vêm contribuindo para a perda de habitat e consequente diminuição da biodiversidade nessas áreas, em especial a agricultura de corte e queima, o corte de madeira para lenha, a caça de animais silvestres e a remoção da vegetação para a pecuária (LEAL et al., 2005).

As publicações disponíveis sobre a fauna de brejos de altitude do Ceará ainda são escassas e, em geral, não abordam aspectos ecológicos, limitando-se a descrição de novos táxons ou ampliação de limites geográficos para algumas espécies. Além disso, a maior parte das publicações limita-se ao Maciço de Baturité, dada a sua proximidade com a capital Fortaleza e facilidade de acesso. Os

principais trabalhos relacionados a fauna dos fragmentos de floresta úmida do Ceará até o presente momento foram feitos com invertebrados (LOPES, 1974; LOURENÇO, 1988; MAGALHÃES, et al. 2005), anfíbios e répteis (REBOUÇAS-SPIEKER, 1981; VANZOLINI, 1981; NASCIMENTO & LIMA-VERDE, 1989; CUNHA et al., 1991; HOOGMOED et al., 1994; RODRIGUES & BORGES, 1997; CARNAVAL & BATES, 2002, BORGES-NOJOSA & CARAMASCHI, 2003; BORGES-NOJOSA, 2007; PASSOS et al., 2007; RIBEIRO et al., 2008), aves (GIRÃO & SOUTO, 2005; OLMOS et al., 2005, ALBANO et al. 2007; GIRÃO et al. 2007) e mamíferos (THOMAS, 1910; PAIVA, 1973; MARES et al., 1981; CERQUEIRA et al., 1989; COIMBRA-FILHO et al., 1995; GUEDES et al., 2000a; GUEDES et al., 2000b; SILVA et al., 2001).

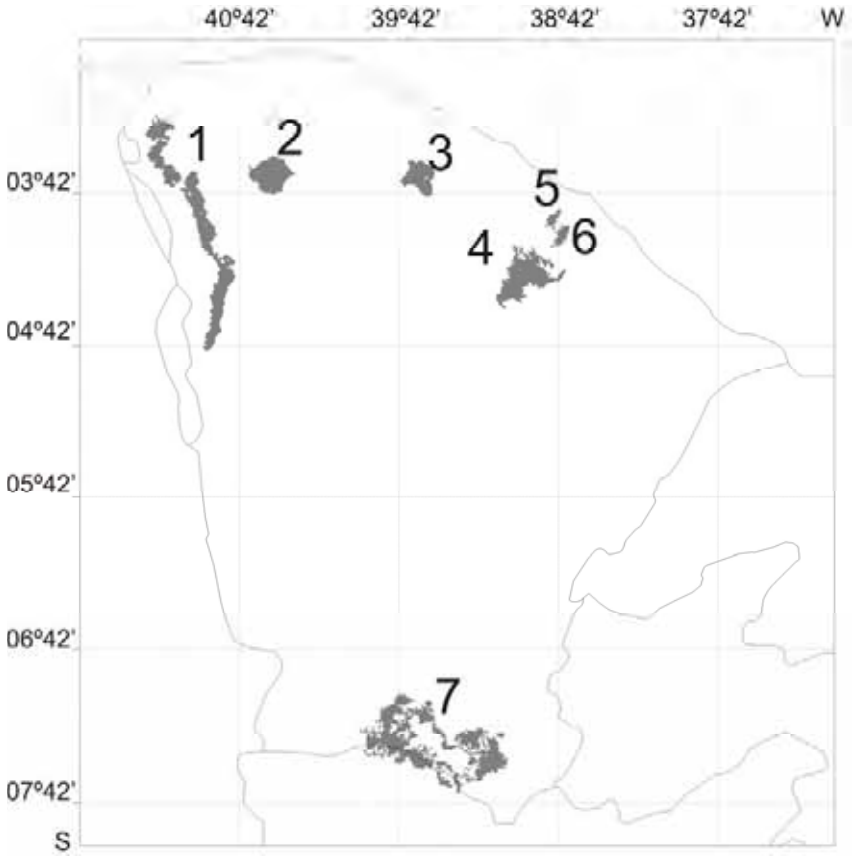


Figura 1 – Mapa do Ceará mostrando as principais áreas de florestas úmidas do estado. 1 – Planalto da Ibiapaba; 2 – Serra da Meruoca; 3 – Serra da Uruburetama; 4 – Maciço de Baturité; 5 – Serra de Maranguape; 6 – Serra da Aratanha; 7 – Chapada do Araripe.

Nos enclaves de florestas úmidas do semi-árido brasileiro a biodiversidade ainda é pouco conhecida, mas é bem provável que guardem boas surpresas, seja por seu longo isolamento, seja por pertencerem originalmente aos Biomas da Mata Atlântica e Amazônia, dois dos biomas mais diversificados da Terra (CAVALCANTE, 2005a). Sendo assim, a presente tese teve como principal objetivo gerar informações do ponto de vista biogeográfico, ecológico e de conservação da herpetofauna dos brejos de altitude do Ceará, em especial o Planalto da Ibiapaba. A tese foi estruturada em cinco capítulos. A seguir, uma sinopse de cada capítulo é apresentada.

CAPÍTULO 1. **A herpetofauna do complexo do Planalto da Ibiapaba, Ceará, Brasil: composição e implicações na conservação da área com maior riqueza de espécies do Bioma Caatinga.** Em decorrência de não se conhecer a herpetofauna do Planalto da Ibiapaba e áreas adjacentes, elaboramos esse capítulo para suprir essa carência de informação. Foram coletadas 38 espécies de anfíbios e 83 espécies de répteis, incluindo espécies raras, espécies consideradas ameaçadas e novos táxons. Além disso, os resultados indicam que o Planalto da Ibiapaba, até o presente momento, é a área do Bioma Caatinga com a maior riqueza de espécies conhecidas.

CAPÍTULO 2. **Estratégias reprodutivas e relações tamanho-fecundidade de anuros no Domínio Caatinga, Nordeste do Brasil.** Devido às duras condições climáticas impostas pela Caatinga as espécies de anfíbios apresentem adaptações para conseguir sobreviver nesse ambiente, incluindo estratégias reprodutivas.

Durante duas estações reprodutivas foram investigadas a composição de espécies, os modos reprodutivos, as relações tamanho-fecundidade e o investimento reprodutivo de fêmeas de 22 espécies de anuros. Este foi o primeiro estudo com essa ótica para o Bioma da Caatinga. Os resultados indicam um predomínio de anfíbios com reprodução explosiva, um padrão divergente ao encontrado em outras assembléias na América do Sul. Foram encontrados indícios de que fêmeas de algumas espécies podem sobreviver apenas uma estação reprodutiva. Houve forte correlação interespecífica entre número de ovos e tamanho de fêmeas, além do que detectou-se que existem diferenças significativas no investimento reprodutivo entre distintas famílias, diferentes estratégias reprodutivas e diferentes modos reprodutivos.

CAPÍTULO 3. **Distribuição espacial e sazonalidade dos anfíbios do complexo Planalto da Ibiapaba, Ceará, Brasil.** Durante dois anos monitoramos diversas áreas com o propósito de detectar padrões de distribuição ao longo do espaço e do tempo. Foram utilizadas armadilhas de interceptação e queda, transectos em duas áreas de gradiente altitudinal e monitoramento mensal de duas comunidades para atingir os resultados esperados. Mudanças na composição de espécies ao longo de um gradiente altitudinal e variação na abundância e número de espécies ao longo do ano foram os resultados mais expressivos encontrados desse capitulo.

CAPÍTULO 4. **Boas notícias sobre uma espécie de anfíbio brasileiro ameaçado de extinção: descoberta de novas populações evidencia um novo status taxonômico e de conservação para *Adelophryne baturitensis* (Anura,**

Eleutherodactylidae, Phyzelaphryninae). *Adelophryne baturitensis* e *Adelophryne maranguapensis* são duas espécies consideradas ameaçadas e endêmicas do Ceará. Foram investigados os principais fragmentos de floresta úmida do estado e foram descobertas novas populações de *Adelophryne*. Através de análises morfológicas, acústicas e moleculares foi possível concluir que *Adelophryne baturitensis* é uma espécie presente em pelo menos cinco das sete áreas estudadas no Ceará, além de uma localidade em Pernambuco. Os resultados indicam que *Adelophryne baturitensis* é uma espécie com populações disjuntas, mas com distribuição muito mais ampla do que se conhecia.

CAPÍTULO 5. **Anexos.** Nesse capítulo foram compilados dados de trabalhos publicados e/ou submetidos relacionados a essa tese, a maioria com enfoque de ampliações de distribuição geográfica. São apresentadas ampliações de distribuição de 15 espécies entre anfíbios e répteis. Esses registros são importantes para compreender a história biogeográfica do Ceará.

REFERENCIAS

AB'SÁBER, A. N. Os domínios morfoclimáticos na América do Sul. Primeira aproximação. **Geomorfologia,** São Paulo, v. 52, p. 1-21, 1977.

AB'SÁBER, A. N. **Os domínios da natureza do Brasil - Potencialidades paisagísticas.** São Paulo: Ateliê, 2003. 160 p.

ALBANO, C.; GIRÃO, W.; PINTO, T. Primeiro registro documentado do gavião-pega-macaco, Spizaetus *tyrannus*, para o estado do Ceará, Brasil. **Revista Brasileira de Ornitologia,** Brasília, v. 15, n. 1, p. 123-124, 2007.

BORGES-NOJOSA, D. M. Diversidade de Anfíbios e Répteis da Serra de Baturité, Ceará. In: OLIVEIRA, T. S.; ARAÚJO, F. S. (Eds.). **Diversidade e Conservação da Biota na Serra de Baturité, Ceará**. Fortaleza: Edições UFC, 2007. p. 225-247.

BORGES-NOJOSA, D. M.; CARAMASCHI, U. Composição e Análise Comparativa da Diversidade e das Afinidades Biogeográficas dos Lagartos e Anfisbenídeos (Squamata) dos Brejos Nordestinos. In: LEAL, I.; SILVA, J. M. C.; TABARELLI, M. (Eds.). **Ecologia e Conservação da Caatinga**. Recife: UFPE, 2003. p. 489-540.

CARNAVAL, A. C. O. Q.; BATES, J. M. Amphibian DNA shows marked genetic structure and tracks pleistocene climate change in northeastern Brazil. **Evolution**, Lancaster, v. 63, n. 12, p. 1-16, 2007.

CAVALCANTE, A. M. B. Jardins Suspensos do Sertão. **Scientific American**, São Paulo, v. 32, p. 66-73, 2005a.

CAVALCANTE, A. M. B. **A Serra de Baturité**. Fortaleza: Edições Livro Técnico, 2005b. 84 p.

CERQUEIRA, R.; VIEIRA, M. V.; SALLES, L. O. Habitat and reproduction of *Rhipidomys cearanus* at São Benedito, Ceará (Rodentia, Cricetidae). **Ciência & Cultura**, Campinas, v. 41, p. 1009-1013, 1989.

COIMBRA-FILHO, A. C.; CÂMARA, I. G. **Os limites originais do bioma Mata Atlântica na Região Nordeste do Brasil**. Rio de Janeiro: Fundação Brasileira para a Conservação da Natureza, 1996. 86 p.

COIMBRA-FILHO, A. C.; CÂMARA, I. G.; RYLANDS, A. B. On the geographic distribution of the red-handed howler monkey, *Alouatta belzebul*, in

Northeastern Brasil. **Neotropical Primates**, Belo Horizonte, v. 3, p. 176-179, 1995.

CUNHA, O. R.; LIMA-VERDE, J. S.; LIMA, A. C. M. Novo gênero e espécie de lagarto (*Colobosauroides cearensis*) no Estado do Ceará (Lacertilia: Teiidae). **Boletim do Museu Paranaense Emílio Goeldi**, Belém, v. 7, p. 163-176, 1991.

GIRÃO, W.; SOUTO, A. Breeding period of Araripe Manakin *Antilophia bokermanni* inferred from vocalization activity. **Cotinga**, Bedfordshire, v. 24, p. 35-37, 2005.

GIRÃO, W.; ALBANO, C.; PINTO, T.; SILVEIRA, L. F. Avifauna da Serra de Baturité: dos naturalistas à atualidade. In: OLIVEIRA, T. S.; ARAÚJO, F. S. (Eds.). **Diversidade e Conservação da Biota na Serra de Baturité, Ceará**. Fortaleza: Edições UFC, 2007. p. 187-224.

GUEDES, P. G.; BORGES-NOJOSA, D. M.; SILVA, J. A. G.; SALLES, L. O. Novos registros de *Alouatta* Lacépède, 1799 no estado do Ceará (Primates, Mammalia). **Neotropical Primates**, Belo Horizonte, v. 8, n. 1, p. 29-30, 2000 a.

GUEDES, P. G.; SILVA, S. S. P.; CAMARDELLA, A. R.; ABREU, M. F.; BORGES-NOJOSA, D. M.; SILVA, J. A. G.; SILVA, A. A. Diversidade de Mamíferos do Parque Nacional de Ubajara (Ceará, Brasil). **Mastozoologia Neotropical**, Tucumán, v. 7, n. 2, p. 95-100, 2000 b.

HOOGMOED, M. S.; BORGES, D. M.; CASCON, P. Three new species of the genus *Adelophryne* (Amphibia: Anura: Leptodactylidae) from northeastern Brazil, with remarks on the other species of the genus. **Zoologische Mededelingen**, Leiden, v. 68, p. 271-300, 1994.

LEAL, I. R.; SILVA, J. M. C.; TABARELLI, M.; LACHER JR., T. E. Mudando o curso da

conservação da biodiversidade na Caatinga do Nordeste do Brasil. **Megadiversidade**, Belo Horizonte, v. 1, n. 1, p. 139-146, 2005.

LOPES, H. S. Sarcophagid flies Diptera from Pacatuba, State of Ceará, Brazil. **Revista Brasileira de Biologia**, São Carlos, 34, p. 271-294, 1974.

LOURENÇO, W. R. Première evidence de la presence d'une faune scorpionique Amazonienne relictuelle dans les "brejos" de la Caatinga du Nordest du Bresil. **Bulletin de la Société scientifique de Bretagne,** Rennes, v. 59, p. 147-154, 1988.

MAGALHÃES, C.; ABRUNHOSA, F. A.; PEREIRA, M. O.; MELO, M. A. New records of *Fredius denticulatus* (H. Milne-Edwards, 1853) and *F. reflexifrons* (Ortmann, 1897), and the eastern limits of the distribution of pseudothelphusid crabs (Crustacea: Decapoda) in Brazil. **Acta Amazonica**, Manaus, v. 35, n. 1, p. 93-96, 2005.

MARES, M. A.; WILLIG, M. R.; STREIEIN, K. E.; LACHER JR., T. E. The mammals of Northeastern Brazil: a preliminary assessment. **Annals of Carnegie Museum**, Pittsburgh, v. 50, p. 81-137, 1981.

NASCIMENTO, F. P.; LIMA-VERDE, J. S. Ocorrência de ofídios de ambientes florestais em enclaves de matas úmidas do Ceará. (Ophidia: Colubridae). **Boletim do Museu Paraense Emílio Goeldi**, Belém, v. 5, p. 95-100, 1989.

OLMOS, F.; SILVA, W. A. G.; ALBANO, C. Grey-breasted Conure *Pyrrhura griseipectus*, an overlooked endangered species. **Cotinga**, Bedfordshire, v. 24, p. 77-83, 2005.

PAIVA, M. P. 1973. Distribuição e abundância de alguns mamíferos selvagens no Estado do Ceará. **Ciência e Cultura**, Campinas, v. 25, n. 5, 442-450, 1973.

PASSOS, P.; FERNANDES, D. S.; BORGES-NOJOSA, D. M. A new species of *Atractus* (Serpentes: Colubridae: Dipsadinae) from a relictual forest in Northeastern Brazil. **Copeia**, Lawrence, v. 2007, p. 788-797, 2007.

REBOUÇAS-SPIEKER, R. Sobre uma nova espécie de *Mabuya* do Nordeste do Brasil (Sauria, Scincidae). **Papéis Avulsos de Zoologia**, Rio de Janeiro, v. 34, n. 9, p. 121-123, 1981.

RIBEIRO, S. C.; FERREIRA, F. S.; BRITO, S. V.; SANTANA, G. G.; VIEIRA, W.L.S.; ALVES, R. R. N.; ALMEIDA, W. O. The Squamata Fauna of the Chapada do Araripe, Northeastern Brazil. **Cadernos de Cultura e Ciência**, Crato, v. 3, p. 1-14, 2008.

RODRIGUES, M. T.; BORGES, D. M. A new species of *Leposoma* (Squamata: Gymnophthalmidae) from a relictual forest in semiarid Northeastern Brazil. **Herpetologica**, Lafayette, v. 53, n. 1, p. 1-6, 1997.

SILVA, S. S. P.; GUEDES, P. G.; PERACCHI, A. L. Levantamento preliminar dos morcegos do Parque Nacional de Ubajara (Mammalia, Chiroptera), Ceará, Brasil. **Revista Brasileira de Zoologia**, Curitiba, v. 18, n. 1, p. 139-144, 2001.

TABARELLI, M.; SILVA, J. M. C. Áreas e ações prioritárias para a conservação da biodiversidade da Caatinga. In: LEAL, I.; SILVA, J. M. C.; TABARELLI, M. (Eds.). **Ecologia e conservação da Caatinga**. Recife: UFPE, 2003. p. 781-800.

THOMAS, O. On mammals collected in Ceará N.E. Brazil, by Fräulein Dr. Snethiage. **Annals and Magazine of Natural History**, Londres, v. 6, p. 500-503, 1910.

VANZOLINI, P. E. A quasi-historical approach to the natural history of differentiation of reptiles in the tropical geographic isolated**. Papéis Avulsos de Zoologia**, São Paulo, v. 34, n. 19, p. 189-204, 1981.

Capítulo 1

Amphibians and reptiles from the complex of Chapada da Ibiapaba, state of Ceará, northeastern Brazil: composition and conservation implications in the high species richness area of the Caatinga biome

Abstract: We surveyed the herpetofauna from the complex of Planalto da Ibiapaba (CPI), Ceará, Brazil, during two years, using five sampling methods and informations available in the literature. The amphibians are represented by 38 species distributed into nine families. The reptiles found summed 84 species, distributed into 25 families. Most amphibians collected exhibited wide occurrence along CPI, where we recorded 24 species (63.2%), which occurred at least in 60% of the sampled environments. Reptiles showed a different pattern, since 52 species (62.6%) had a restricted distribution (up to two environments). Sixteen species out of 25 considered as rare in CPI are restricted to relict moist forests. We also applied a rarity-vulnerability index to determine the most suceptible species. *Pristimantis* sp., *Adelophryne baturitensis* Hoogmoed, Borges, and Cascon, 1994, *Pseudopaludicola* sp. (aff. *saltica*), *Scinax fuscomarginatus* (A. Lutz, 1925), and *Odontophrynus carvalhoi* Savage & Cei, 1965 were the most vulnerable amphibians in CPI. Reptiles showed a more diverse range in the scale of rarity with 40 species considered vulnerable. Among the vulnerable reptiles *Leposoma baturitensis* Rodrigues & Borges, 1997, *Bothrops* sp. (gr. *atrox*), *Atractus ronnie* (Passos, Fernandes & Borges-Nojosa, 2007), *Apostolepis* sp. (gr. *pimy*), and *Mesoclemmys perplexa* Bour & Zaher, 2005 were the rarest species found in the whole complex of Ibiapaba mountain range. Results indicate that about 70% of the species found in Ceará are present in this complex. Also, CPI is the area of the Caatinga biome with the highest species richness, including rare and threatened species.

Key-words: Amphibia, Conservation, Herpetofauna, Rarity index; Reptilia; Ubajara National Park.

Introduction

The Brazilian territory comprises extensive areas named landscape domains such as the Atlantic Forest and the Caatinga (AB'SABER, 1977). These domains are formed by collections of ecossystems which are fairly ecologically homogeneous. However, it is possible to observe inside these domains contrasting areas which differs from their surroundings; and for this reason, these areas are known as exception landscapes (AB'SABER, 2003). In this context, we highlight the moist forests in the Brazilian semi-arid region, which form islands within the Caatinga (CAVALCANTE, 2005).

The fragments of moist forest in the state of Ceará, in Brazil known as "*brejos de altitude*", are relict forests that occur in altitudes over 600 m asl, and are considered remnants of the Atlantic and Amazon Forests (COIMBRA-FILHO & CÂMARA, 1996). Due to this peculiar condition, these fragments shelter several species from tropical forests which are incapable of inhabiting the semiarid/arid conditions in the adjacent Caatinga. Therefore, in the Caatinga region, species adapted to live in tropical moist forests have their distributions restricted to these fragments.

High altitude sites in Ceará are considered as priority areas for the conservation of Caatinga (TABARELLI & SILVA, 2003). However, several facts contribute to habitat loss and therefore to the decrease of biodiversity in these areas, in particular slash-and-burn agriculture, logging for firewood, hunting and cattle grazing (LEAL et al., 2005).

The state of Ceará still needs systematic species inventories in almost all its territory to advance the knowledge on its herpetofauna. The complex of Ibiapaba

mountain range (CPI), located in the northwest of the state, lacks a complete survey of amphibians and reptiles; there is only one inventory for amphisbaenians and lizards (BORGES-NOJOSA & CARAMASCHI, 2003) and some geographic distribution notes (e.g. LOEBMANN et al., 2007; LOEBMANN 2008 a,b,c, LOEBMANN 2009 a,b,c,d; ROBERTO & LOEBMANN, 2009). Therefore, the present study provides a list of amphibians and reptiles of the complex of Ibiapaba mountain range, and shows that this region is one of the most diverse of the Caatinga biome, presenting a mixed composition of fauna, with species from four Brazilian biomes.

Materials and Methods

Study area

The complex of the Planalto da Ibiapaba (Figure 1) represents the northwesternmost fragments of moist forest in the state of Ceará (3°20'-5°00'S/40°42'-41°10'W). This complex is located at the boundary with the state of Piauí and comprises the municipalities of Viçosa do Ceará, Tianguá, Ubajara, Ibiapina, São Benedito, Carnaubal, Guaraciaba do Norte, Croatá and Ipu. The stratigraphic formation is part of the sedimentary basin Maranhão-Piauí, with the lithology of the formation Serra Grande and soil with predominance of dystrophic marine quartzic sands, red-yellow latosols and dark-red latosols. The area is relatively close to the coast (73 km), and has the lowest average annual temperatures (22-26°C) and the highest average annual rainfall of the state (e.g. São Benedito with 2,062.8 mm, Ibiapina with 1,744.6 mm and Ubajara with 1,441.1 mm) (BEZERRA et al., 1997).

Five main phytophysiognomies occur along the complex (Figure 2). **Sub-evergreen Tropical Nebular Rainforest**; a relictual moist forest (RF) with a canopy higher than 20 m that extends along about 150 km, is between 400 and 950 m wide, and covers the eastern and northern regions of CPI. From the hilltop to the west the relict forest is gradually substituted for the **Thorny Deciduous Forest or High Altitude Caatinga** (HC). This is a short (canopy up to 4 m high) and dense forest, with intense leaf loss (over 70%) during the dry season (June-December). At the lower portion of the hill (120-450 m) is the **Sub-deciduous Tropical Rainforest or Arboreal Caatinga** (AC) (FIGUEIREDO, 1997). This forest exhibits high trees (up to 20 m) with straight trunks and an understory composed of small trees and short-lived bushes. In its superior part the AC touches the RF and below it touches the **Steppe Savanna or Low Altitude Caatinga** (LC). In this environment there are wax palm forests or vegetation similar to the HC. However, LC areas have lower shrub densities than HC areas, with wide areas of bare soils. Eventually, areas of high altitude, where relictual moist forest would be expected, are occupied for patches of **Cerrado** (CE), similar to the rock fields (*Campos rupestres*) found in highland areas in central and southeastern Brazil.

Parts of the CPI are protected areas, incorporated by Parque Nacional de Ubajara (National Park of Ubajara) with 563 ha, Reserva Particular do Patrimônio Natural Serra Grande ('RPPN'– Serra Grande Private Reserve of National Heritage) and Área de Proteção Ambiental Serra da Ibiapaba ('APA'- Environmental Protection Area of Ibiapaba Mountain Range) with 1,592,550 ha; the latter is considered the second largest 'APA' of Brazil.

We carried out collections from January 2007 to April 2009. The area sampled in this study has about 5,360 km^2 and a perimeter of about 520 km, and covered all phytophysiognomies previously described. We captured amphibians and reptiles using the following methods: 1) A total of 8,640 pitfall traps (number of traps x days x months) (CORN, 1994). For each pitfall we used a plastic bucket of 60 L. Six transects were set up for the whole duration of the samplings, each one comprising of six buckets 10 m apart from each other. 2) A total of 288 hours/person of time-limited search (CAMPBEL & CHRISTMAN, 1982), covering a distance of about 672 km. 3) Approximately 15,000 km of road sampling (FITCH, 1987). 4) Opportunistic encounters: specimens found by chance, not during searching or sampling activities, including specimens collected by local people. 5) Amphibians were also obtained during monthly monitoring of five reproduction sites (SCOTT JR. & WOODWARD, 1994). To complete the species list we included records available in the literature.

To classify the species according to their abundance we used a rarity model (RABINOWITZ, 1981) (Table 1). Rabinowitz's model focuses on three basic characteristics to categorize each species: 1) local abundance, (2) geographic distribution known for the species and (3) flexibility to use different kinds of habitats. Whenever one of these attributes is dichotomized, eight detailed categories are used to classify the species into different types of rarity or commonness (letters A-H). Seven out of eight categories contain rare species in some sense of the word. Only the species with a wide distribution range that occur in several habitats in high abundance are not considered as rare (RABINOWITZ, 1981). In the same diagram (see Table 1), it is possible to create a vulnerability

index (VU), considering the species rarity for each parameter analyzed, as follow: Non-rare species in any parameters (letter A; VU = 4), rare species in only one parameter (letters B, C, and E; VU = 3), rare species in two parameters (letters D, F, and G; VU = 2), and rare species in all parameters (letter H; VU = 1).

Collecting permits were issued by Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) (Processes 12545-1, 12545-2, 13571-1, 14130-1, 16381-1, and 17400-2). Voucher specimens were deposited in Coleção

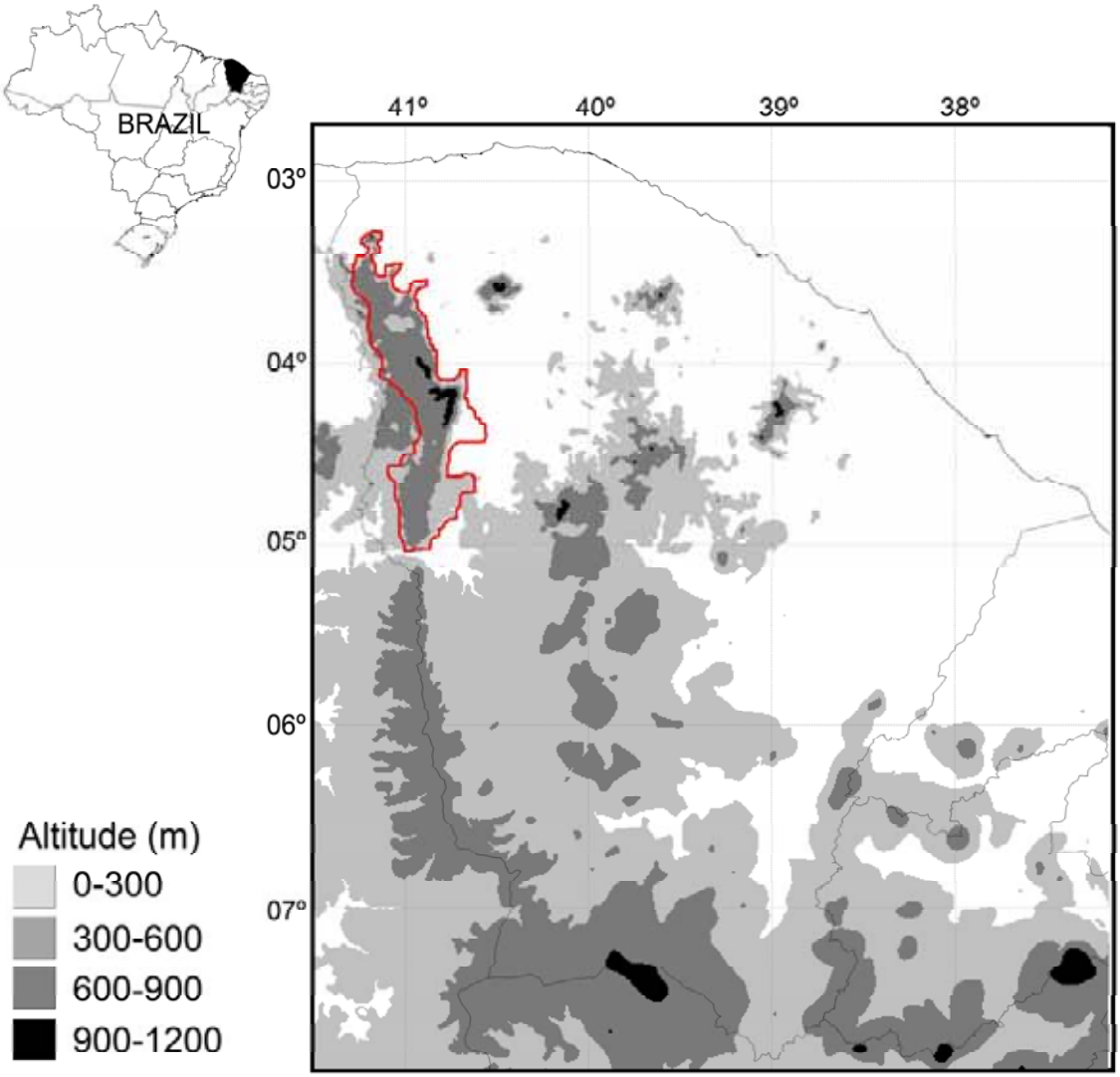


Figure 1 – Altitudinal map of state of Ceará. The redline delimits the Complex of Planalto da Ibiapaba.

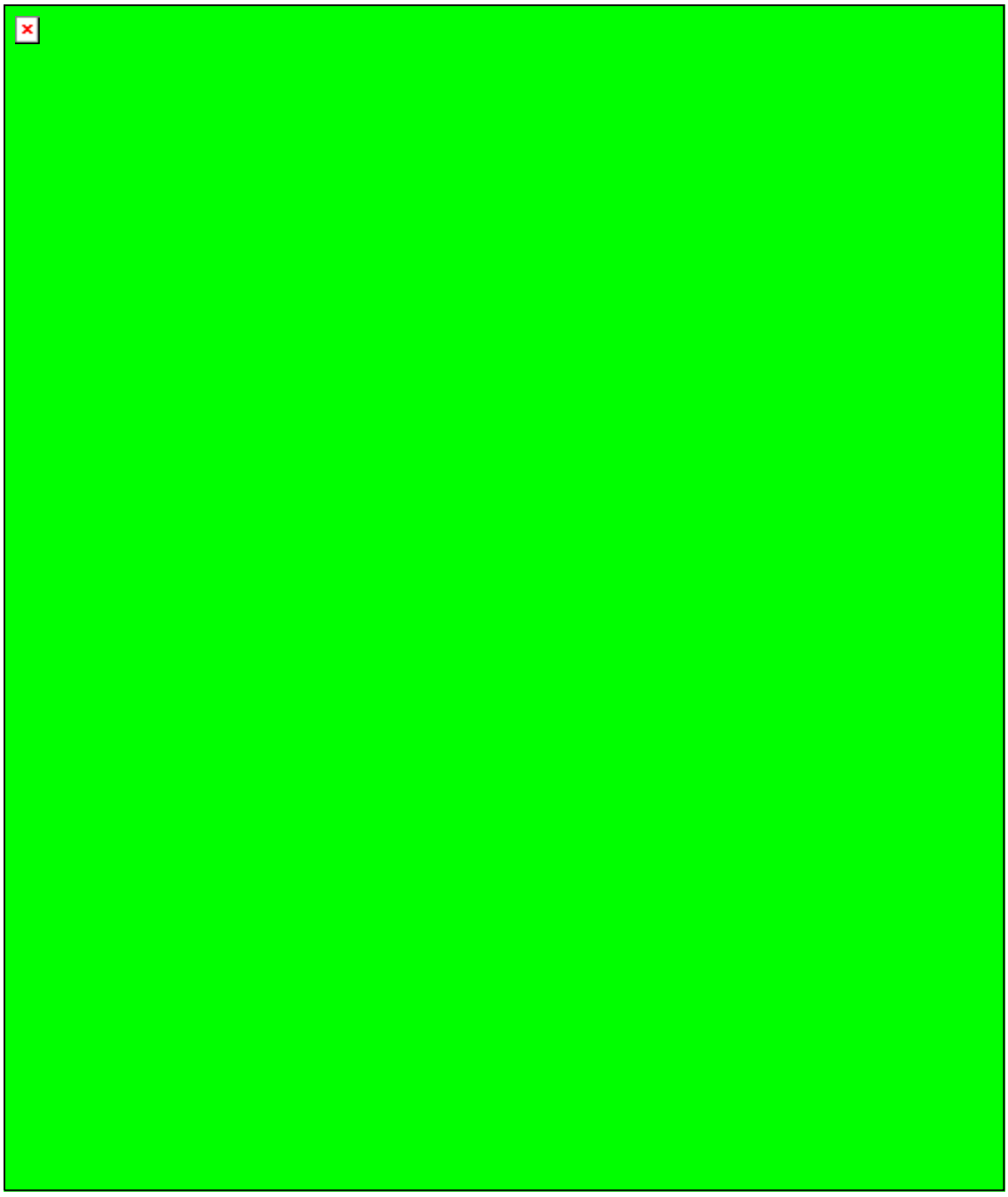


Figure 2 – Environments composing the CPI. A) Relictual Moist Forest; B) High Altitude Caatinga, C) Arboreal Caatinga; D) Low Altitude Caatinga; and E) Cerrado.

de anfíbios Célio F. B. Haddad (CFBH), Universidade Estadual Paulista "Julio de Mesquita Filho", campus de Rio Claro, São Paulo, Brasil; coleção de serpentes do Instituto Butantan (IBSP) and coleção de referência do Instituto Butantan (CRIB),

São Paulo, São Paulo, Brasil; coleção herpetológica da Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, Rio Grande do Sul, Brasil; Coleção Herpetológica da Universidade de Brasília (CHUNB), Brasília, Distrito Federal, Brasil; Museu de História Natural da Universidade de Campinas (ZUEC), Campinas, São Paulo, Brasil; and coleção herpetológica do Museu Nacional (MNRJ), Rio de Janeiro, Rio de Janeiro, Brasil. Species were taxonomically classified mainly based in Faivovich et al. (2005), Frost et al. (2006), Grant et al. (2006), Gamble et al. (2008), Hedges et al. (2008), Curcio et al. (2009), Fenwick et al. (2009), Hoser (2009), Mott & Vieites (2009), and Zaher et al. (2009).

Results

The amphibians found at the CPI are represented by 38 species distributed into two orders (37 Anura and 1 Gymnophiona), nine families (Brachycephalidae, Bufonidae, Cyclorhamphidae, Eleutherodactylidae, Hylidae, Leiuperidae, Leptodactylidae, Microhylidae, and Caeciliidae), and 18 genera (Table 2; Figures 3-7). The most representative families were Hylidae with 36.84 % of the species (N=14), followed by Leptodactylidae (21.05 %, N=8), and Leiuperidae (18.42 %, N=7). The species *Dendropsophus rubicundulus* and *Pseudopaludicola* sp. (gr. *saltica*) were recorded for the first time in the state.

We collected 80 reptile species during the present study. Other four species were not collected in this study, but were reported in the literature (BORGES-NOJOSA & CARAMASCHI, 2003). Therefore, reptiles were represented by 83 species, three orders (4 Testudines, 1 Crocodylia and 78 Squamata), 25 families and 62 genera (Table 3; Figures 8-18). The families exhibiting highest species

richness were Dipsadidae with 22 species (27.5%) and Colubridae with 10 species (12.5%). *Chelonoides carbonaria*, *Caiman crocodilus* and *Hemidactylus mabouia* are not native reptiles to the CPI.

Most amphibians occurred in a wide range of environments at the CPI: we recorded 24 species (63.2%) in at least three (60%) of the sampled environments. The reptiles, on the contrary, showed a different pattern, since 52 species (62.6%) had a restricted distribution (up to two environments); 38 species (45.8%) were restricted to only one environment. Only 29 species (34.9%) had a wide distribution within the complex.

Table 1. Representation of the rarity model proposed by Rabinowitz (1981) with the scores of vulnerability (in parentheses) used in this article. Geographical range is based on total species distribution known; habitat specificity is considered large for generalist species and narrow when the species has specialized habitat (*e.g.* bromeliads, bamboo, altitude); local population size is divided in rare and abundant based on our samples. Species with historical records only were considered rare. Scores of vulnerability values: Non-rare species in any parameters (letter A; VU = 4), rare species in only one parameter (letters B, C, and E; VU = 3), rare species in two parameters (letters D, F, and G; VU = 2), and rare species in all parameters (letter H; VU = 1).

Geographic range		Large		Small	
Habitat specificity		Wide	Narrow	Wide	Narrow
Size population (local)	Abundant	A (4)	B (3)	C (3)	D (2)
	Rare	E (3)	F (2)	G (2)	H (1)

Table 2. List of amphibians from the CPI, state of Ceará, Brazil, with their respective rarity level (*sensu* Rabinowitz 1981) and environments where they are found (AC = Arboreal Caatinga; CE = Cerrado; LC = Low Altitude Caatinga; RF = relictual moist forests and; HC = High Altitude Caatinga).

Taxon	Rarity level	Environment observed				
		AC	CE	LC	RF	HC
Class Amphibia Gray, 1825 (38 species)						
Order Anura Fischer von Waldheim, 1813 (37 species)						
Family Eleutherodactylidae Lutz, 1954 (1 species)						
Subfamily Phyzelaphryninae Hedges, Duellman, and Heinicke, 2008						
Genus *Adelophryne* Hoogmoed and Lescure, 1984						
1 *Adelophryne baturitensis* Hoogmoed, Borges, and Cascon, 1994	C				X	
Family Strabomantidae Hedges, Duellman, and Heinicke, 2008 (1 species)						
Genus *Pristimantis* Jiménez de la Espada, 1870						
2 *Pristimantis* sp.	B	X			X	X
Family Hylidae Rafinesque, 1815 (14 species)						
Subfamily Phyllomedusinae Günther, 1858						
Genus *Phyllomedusa* Wagler, 1830						
3 *Phyllomedusa nordestina* Caramaschi, 2006	A	X		X	X	X
Subfamily Hylinae Rafinesque, 1815						

Genus *Corythomantis* Boulenger, 1896							
4 *Corythomantis greeningi* Boulenger, 1896	A	X		X	X	X
Genus *Dendropsophus* Fitzinger, 1843							
5 *Dendropsophus* sp. (gr. *microcephalus*)	A			X	X	X
6 *Dendropsophus minutus* (Peters, 1872)	A			X	X	X
7 *Dendropsophus nanus* (Boulenger, 1889)	A			X	X	X
8 *Dendropsophus rubicundulus* (Reinhardt and Lütken, 1862)	A			X		
9 *Dendropsophus soaresi* (Caramaschi and Jim, 1983)	A			X	X	X
Genus *Hypsiboas* Wagler, 1830							
10 *Hypsiboas multifasciatus* (Günther, 1859)	A	X			X	
11 *Hypsiboas raniceps* Cope, 1862	A	X		X	X	X
Genus *Scinax* Wagler, 1830							
12 *Scinax fuscomarginatus* (A. Lutz, 1925)	E			X		
13 *Scinax nebulosus* (Spix, 1824)	A				X	X
14 *Scinax* sp. (gr. *ruber*)	A	X	X	X	X	X
15 *Scinax* cf. *x-signatus* (Spix, 1824)	A	X	X	X	X	X
Genus *Trachycephalus* Tschudi, 1838							
16 *Trachycephalus venulosus* (Laurenti, 1768)	A	X	X	X	X	X
Family Leiuperidae Bonaparte, 1850 (7 species)							
Genus *Physalaemus* Fitzinger, 1826							

17	*Physalaemus albifrons* (Spix, 1824)	A			X		X
18	*Physalaemus cicada* Bokermann, 1966	A			X		
19	*Physalaemus cuvieri* Fitzinger, 1826	A	X	X	X	X	X
Genus *Pleurodema* Tschudi, 1838							
20	*Pleurodema diplolister* (Peters, 1870)	A	X	X	X		X
Genus *Pseudopaludicola* Miranda-Ribeiro, 1926							
21	*Pseudopaludicola* sp. (gr. *falcipes*)	A			X	X	X
22	*Pseudopaludicola* sp. (gr. *mystacalis*)	A			X		
23	*Pseudopaludicola* sp. (aff. *saltica*)	C		X			
Family Leptodactylidae Werner, 1896 (8 species)							
Genus *Leptodactylus* Fitzinger, 1826							
24	*Leptodactylus* sp. (aff. *andreae*)	A	X	X		X	X
25	*Leptodactylus fuscus* (Schneider, 1799)	A	X		X	X	X
26	*Leptodactylus* sp. (aff. *hylaedactylus*)	A	X				
27	*Leptodactylus macrosternum* Miranda-Ribeiro, 1926	A	X	X	X	X	X
28	*Leptodactylus mystaceus* (Spix, 1824)	A	X		X	X	X
29	*Leptodactylus* sp. (aff. *syphax*)	A	X	X			
30	*Leptodactylus troglodytes* Lutz, 1926	A	X	X	X	X	X
31	*Leptodactylus vastus* (Lutz, 1930)	A	X	X	X	X	X
Family Cycloramphidae Bonaparte, 1850 (2 species)							

Subfamily Alsodinae Mivart, 1869							
Genus *Odontophrynus* Reinhardt and Lütken, 1862							
32 *Odontophrynus carvalhoi* Savage & Cei, 1965	E				X		
Genus *Proceratophrys* Miranda-Ribeiro, 1920							
33 *Proceratophrys cristiceps* (Müller, 1883)	A	X	X	X	X	X	
Family Bufonidae Gray, 1825 (2 species)							
Genus *Rhinella* Fitzinger, 1826							
34 *Rhinella granulosa* (Spix, 1824)	A	X	X	X	X	X	
35 *Rhinella jimi* (Stevaux, 2002)	A	X	X	X	X	X	
Family Microhylidae Günther, 1858 (2 species)							
Subfamily Gastrophryninae Fitzinger, 1843							
Genus *Dermatonotus* Méhely, 1904							
36 *Dermatonotus muelleri* (Boettger, 1885)	A			X	X	X	
Genus *Elachistocleis* Parker, 1927							
37 *Elachistocleis piauiensis* Caramaschi & Jim, 1983	A			X			
Order Gymnophiona Müller, 1832 (1 species)							
Family Caeciliidae Rafinesque, 1814 (1 species)							
Genus *Siphonops* Wagler, 1828							
38 *Siphonops* sp. (aff. *paulensis*)	A	X			X		

Table 3. List of reptiles from the CPI, state of Ceará, Brazil, with their respective rarity level (*sensu* Rabinowitz 1981) and environments where they were found (AC = Arboreal Caatinga; CE = Cerrado; LC = Low Altitude Caatinga; RF = relictual moist forests and; HC = High Altitude Caatinga).

Taxon	Rarity level	Environment observed				
		AC	CR	LC	RF	HC
Class Reptilia Laurenti, 1768 (83 species)						
Order Testudines Linnaeus, 1758 (4 species)						
Suborder Cryptodira Cope, 1869 (2 species)						
Family Testudinidae Batsch, 1788 (1 species)						
Genus *Chelonoidis* Fitzinger, 1835						
1 *Chelonoidis carbonaria* (Spix, 1824) (Intoduced)	E				X	
Family Kinosternidae Baur, 1893 (1 species)						
Genus *Kinosternon* Spix, 1824						
2 *Kinosternon scorpioides* (Linnaeus, 1766)	E			X		
Suborder Pleurodira Cope, 1869						
Family Chelidae Gray, 1825 (2 species)						
Genus *Mesoclemmys* Gray, 1863						
3 *Mesoclemmys perplexa* Bour & Zaher, 2005	H				X	
4 *Mesoclemmys tuberculata* (Lüderwaldt, 1926)	A	X		X	X	X

Order Crocodylia Gmelin, 1789 (1 species)							
Family Alligatoridae Cuvier, 1807 (1 species)							
Genus *Caiman* Spix, 1825							
5	*Caiman crocodilus* (Linnaeus, 1758) (Introduced)	E			X		
Order Squamata Oppel, 1811 (75 species)							
Suborder Amphisbaenia Gray, 1844							
Family Amphisbaenidae Gray, 1865 (5 species)							
Genus *Amphisbaena* Linnaeus, 1758							
6	*Amphisbaena alba* Linnaeus, 1758	A				X	X
7	*Amphisbaena pretrei* Duméril & Bibron, 1839	E				X	
8	*Amphisbaena vermicularis* Wagler, 1824	A			X	X	X
9	*Amphisbaena anomala* (Barbour, 1914)	A				X	X
10	*Amphisbaena polystegum* (Duméril, 1851)	A				X	
Suborder Sauria McCartney, 1802							
Infraorder Iguania Cope, 1864 (5 species)							
Family Iguanidae Oppel, 1811 (1 species)							
Genus *Iguana* Laurenti, 1768							
11	*Iguana iguana* (Linnaeus, 1758)	A	X		X	X	X
Family Polychrotidae Fitzinger, 1843 (3 species)							
Genus *Anolis* Daudin, 1802							
12	*Anolis fuscoauratus* D'Orbigny, 1837	A				X	

Genus *Polychrus* Cuvier, 1817						
13 *Polychrus acutirostris* Spix, 1825	A	X		X		X
14 *Polychrus marmoratus* (Linnaeus, 1758)	A				X	
Family Leiosauridae Frost, Etheridge, Janies, & Titus, 2001 (1 species)						
Subfamily Enyaliinae Frost, Etheridge, Janies, & Titus, 2001						
Genus *Enyalius* Wagler 1830						
15 *Enyalius bibronii* Boulenger, 1885	A				X	
Family Tropiduridae Bell, 1843 (3 species)						
Genus *Strobilurus* Wiegmann, 1834						
16 *Strobilurus torquatus* Wiegmann, 1834	E		Not observed*			
Genus *Tropidurus* Wied-Neuwied, 1824						
17 *Tropidurus hispidus* (Spix, 1825)	A	X	X	X	X	X
18 *Tropidurus semitaeniatus* (Spix, 1825)	A	X	X	X	X	X
Infraorder Gekkota Cuvier, 1817						
Family Gekkonidae Gray, 1825 (3 species)						
Genus *Hemidactylus* Gray, 1825						
19 *Hemidactylus brasilianus* (Amaral, 1935)	E		Not observed*			
20 *Hemidactylus agrius* Vanzolini, 1978	A	X	X	X	X	X
21 *Hemidactylus mabouia* (Moreau de Jonnès, 1818) (Alien)	A				X	
Family Phyllodactylidae Gamble, Bauer, Greenbaum & Jackman, 2008 (1 species)						
Genus *Phyllopezus* Peters, 1877						

22 *Phyllopezus pollicaris* (Spix, 1825)	A	X		X		X
Family Sphaerodactylidae Underwood, 1954 (1 species)						
Genus *Coleodactylus* Parker, 1926						
23 *Coleodactylus merionalis* (Boulenger, 1888)	A				X	
Infraorder Scincomorpha Camp, 1923 (12 species)						
Family Gymnophthalmidae Merrem, 1820 (7 species)						
Subfamily Cercosaurinae Gray 1838						
Genus *Cercosaura* Wagler, 1830						
24 *Cercosaura ocellata* Wagler, 1830	E				X	
Genus *Colobosaura* Boulenger, 1887						
25 *Colobosaura modesta* (Reinhardt & Lütken, 1862)	E		Not observed*			
Genus *Stenolepis* Boulenger, 1888						
26 *Stenolepis ridleyi* Boulenger, 1887	E		Not observed*			
Subfamily Ecpleopinae Fitzinger, 1843						
Genus Colobosauroides Cunha & Lima-Vende, 1991						
27 *Colobosauroides cearensis* Cunha, Lima-Verde & Lima, 1991	E	X			X	
Genus *Leposoma* (Spix, 1825)						
28 *Leposoma baturitensis* Rodrigues & Borges, 1997	G				X	
Subfamily Gymnophthalminae Merrem, 1820						
Genus *Micrablepharus* Dunn, 1932						
29 *Micrablepharus maximiliani* (Reinhardt & Lutker, 1862)	E	X	X	X	X	X

Genus *Vanzosaura* Rodrigues, 1991							
30 *Vanzosaura rubricauda* (Boulenger, 1902)	E			X			
Family Scincidae Gray, 1825 (3 species)							
Subfamily Lygosominae Greer, 1970							
Genus *Mabuya* Fitzinger, 1826							
31 *Mabuya arajara* Rebouças-Spieker, 1981	E	X					
32 *Mabuya heathi* Schmidt & Inger, 1951	A	X	X	X	X	X	
33 *Mabuya nigropunctata* (Spix, 1825)	A				X		
Family Teiidae Gray, 1827 (3 species)							
Subfamily Teiinae Merrem, 1820							
Genus *Ameiva* Meyer, 1795							
34 *Ameiva ameiva* (Linnaeus, 1758)	A	X	X	X	X	X	
Genus *Cnemidophorus* Wagler, 1830							
35 *Cnemidophorus ocellifer* (Spix, 1825)	A	X	X	X	X	X	
Subfamily Tupinambinae Daudin, 1802							
Genus *Tupinambis* Daudin, 1810							
36 *Tupinambis merianae* (Duméril & Bibron, 1839)	A	X			X	X	
Infraorder Diploglossa Cope, 1864							
Family Anguidae Gray, 1825 (2 species)							
Genus *Diploglossus* Wiegmann, 1834							
37 *Diploglossus lessonae* Peracca, 1890	E					X	

Genus *Ophiodes* Wagler, 1828						
38 *Ophiodes* sp. (aff. *striatus*)	C				X	
Suborder Serpentes Linnaeus, 1758 (44 species)						
Infraorder Scolecophidia Cope, 1864 (3 species)						
Family Anomalepididae Taylor, 1939 (1 species)						
Genus *Liotyphlops* Peters, 1881						
39 *Liotyphlops* sp. (cf. *ternetzi*) (Boulenger, 1896)	E	X				
Family Leptotyphlopidae Stejneger, 1892 (1 species)						
Genus *Leptotyphlops* Fitzinger, 1843						
40 *Leptotyphlops* sp. (aff. *brasiliensis*)	E				X	X
Family Typhlopidae Jan, 1863 (1 species)						
Genus *Typhlops* Oppel, 1811						
41 *Typhlops brongersmianus* Vanzolini, 1976	E				X	
Infraorder Henophidia Nopcsa, 1923 (3 species)						
Family Boidae Gray, 1842 (3 species)						
Subfamily Boinae Gray, 1825						
Genus *Boa* Linnaeus, 1758						
42 *Boa constrictor constrictor* Linnaeus, 1758	A	X		X	X	X
Genus *Corallus* Daudin, 1803						
43 *Corallus hortulanus* (Linnaeus, 1758)	A				X	
Genus *Epicrates* Wagler, 1830						

44	*Epicrates assisi* Machado, 1945	A	X		X	X	X
Infraorder Caenophidia Hoffstetter, 1939 (38 species)							
Family Viperidae Oppel 1811 (3 species)							
Genus *Bothrops* Wagler (in Spix), 1824							
45	*Bothrops* sp. (gr. *atrox*)	G				X	
Genus *Bothropoides* Fenwick, Gutberlet Jr, Evans, & Parkinson, 2009							
46	*Bothropoides lutzi* (Miranda-Ribeiro, 1915)	E					X
Genus *Caudisona* Laurenti, 1768							
47	*Caudisona durissa* (Linnaeus, 1758)	E	X		X	X	X
Family Elapidae Boie 1827 (3 species)							
Genus *Micrurus* Wagler (in Spix), 1824							
48	*Micrurus* sp. (aff. *ibiboboca*)	A	X	X	X	X	X
49	*Micrurus* cf. *lemniscatus ditius* Burger, 1955	A				X	
50	*Micrurus lemniscatus lemniscatus* Burger, 1955	E	X				
Superfamily Colubroidea Oppel, 1811 (32 species)							
Family Colubridae Oppel, 1811 (10 species)							
Genus *Chironius* Fitzinger, 1826							
51	*Chironius bicarinatus* (Wied, 1820)	E				X	
52	*Chironius flavolineatus* (Boettger, 1885)	A	X		X	X	X
Genus *Drymarchon* Fitzinger, 1843							
53	*Drymarchon corais corais* (Boie, 1827)	A	X		X	X	X

Genus *Drymoluber* Amaral, 1930						
54 *Drymoluber dichrous* (Peters, 1863)	E			X		
Genus *Leptophis* Bell, 1825;						
55 *Leptophis ahaetulla* (Linnaeus, 1758)	A	X		X	X	X
Genus *Mastigodryas* Amaral, 1934						
56 *Mastigodryas boddaerti boddaerti* (Sentzen, 1796)	E			X		
Genus *Oxybelis* Wagler, 1830						
57 *Oxybelis aeneus* (Wagler, 1824)	A	X		X	X	X
Genus *Pseustes* Fitzinger, 1843;						
58 *Pseustes sulphureus sulphureus* (Wagler, 1824)	E			X		
Genus *Spilotes* Wagler, 1830						
59 *Spilotes pullatus* (Linnaeus, 1758)	E	X		X	X	X
Genus *Tantilla* Girard (in Baird & Girard), 1853						
60 *Tantilla* sp. (aff. *melanocephala*)	A	X		X	X	X
Family Dipsadidae Bonaparte, 1838 (22 species)						
Genus *Xenopholis* Peters, 1869 (*incertae sedis*)						
61 *Xenopholis undulatus* (Jensen, 1900)	E			X		
Subfamily Dipsadinae Bonaparte, 1838						
Genus *Atractus* Wagler, 1828						
62 *Atractus ronnie* (Passos, Fernandes & Borges-Nojosa, 2007)	G			X		
Genus *Imantodes* Duméril, 1853						

63 *Imantodes cenchoa cenchoa* (Linnaeus, 1758)	F				X	
Genus *Leptodeira* Fitzinger, 1843						
64 *Leptodeira annulata pulchriceps* (Duellman, 1958)	A	X	X	X	X	X
Genus *Sibon* Fitzinger, 1826						
65 *Sibon nebulata nebulata* (Linnaeus, 1758)	A				X	X
Subfamily Xenodontinae Bonaparte, 1845						
Genus *Apostolepis* Cope, 1861						
66 *Apostolepis cearensis* Gomes, 1915	E	X		X	X	X
67 *Apostolepis* sp. (gr. *pimy*) Boulenger, 1903	G				X	
Genus *Boiruna* Zaher, 1996						
68 *Boiruna sertaneja* Zaher, 1996	E			X		X
Genus *Liophis* Wagler, 1830						
69 *Liophis poecilogyrus schotti* (Schlegel,1837)	A			X		X
70 *Liophis reginae semilineata* (Wagler, 1824)	A	X			X	
71 *Liophis taeniogaster* Jan, 1863	E				X	
72 *Liophis viridis* Günther, 1862	A			X		X
73 *Liophis dilepis* Cope, 1862	E			X		
Genus *Oxyrhopus* Wagler, 1830						
74 *Oxyrhopus melanogenys orientalis* Cunha & Nascimento, 1983	A				X	
75 *Oxyrhopus trigeminus* Duméril, Bibron & Duméril, 1854	A	X		X	X	X
Genus *Philodryas* Wagler, 1830						

76	*Philodryas nattereri* Steindachner, 1870	A	X	X	X	X
77	*Philodryas olfersii herbeus* (Wied, 1825)	A	X	X	X	X
Genus *Pseudoboa* Schneider, 1801						
78	*Pseudoboa nigra* (Duméril, Bibron & Duméril, 1854)	A	X	X	X	X
79	*Pseudoboa* sp.	A	X	X	X	X
Genus *Psomophis* Myers & Cadle, 1994						
80	*Psomophis joberti* (Sauvage, 1884)	E		X		
Genus *Taeniophallus* Cope, 1895						
81	*Taeniophalus affinis* (Günther, 1858)	E			X	
82	*Taeniophalus occipitalis* (Jan, 1863)	E	X			X
Genus *Thamnodynastes* Wagler, 1830						
83	*Thamnodynastes* sp.	A				X
Genus *Xenodon* Boie, 1826						
84	*Xenodon merremii* (Wagler, 1824)	A	X	X	X	X

* Species previously collected by Borges-Nojosa & Caramaschi (2003)

Some amphibians were restricted to only one environment: *Leptodactylus* sp. (aff. *hylaedactylus*) in the arboreal caatinga; *Pseudopaludicola* sp. (aff. *saltica*) in the cerrado; *Dendropsophus rubicundulus*, *Scinax fuscomarginatus*, *Physalaemus cicada*, *Pseudopaludicola* sp. (gr. *mystacalis*), *Elachistocleis piauiensis* in the low altitude caatinga; and *Adelophryne baturitensis* and *Odontophrynus carvalhoi* were restricted to the relict forest.

The reptiles collected in only one environment were mainly associated with relict forests: *Chelonoides carbonaria*, *Mesoclemmys perplexa*, *Amphisbaena pretrei*, *Amphisbaena polystegum*, *Anolis fuscoauratus*, *Polychrus marmoratus*, *Enyalius bibronii*, *Strobilurus torquatus*, *Cercosaura ocellata*, *Leposoma baturitensis*, *Mabuya nigropunctata*, *Ophiodes* sp. (aff. *striatus*), *Typhlops brongersmianus*, *Corallus hortulanus*, *Bothrops* sp. (gr. *atrox*), *Micrurus* cf. *lemniscatus ditius*, *Chironius bicarinatus*, *Drymoluber dichrous*, *Mastigodryas boddaerti boddaerti*, *Pseustes sulphureus*, *Xenopholis undulatus*, *Atractus ronnie*, *Imantodes cenchoa cenchoa*, *Apostolepis* sp. (gr. *pimy*), *Liophis taeniogaster*, *Oxyrhopus melanogenys*, and *Taeniophalus affinis*. Other reptiles were found only in the low altitude caatinga: *Kinosternon scorpioides*, *Caiman crocodilus*, *Vanzosaura rubricauda*, *Lygophis dilepis*, and *Psomophis joberti*; high altitude caatinga: *Diploglossus lessonae*, *Thamnodynastes* sp and *Bothropoides lutzi*; and arboreal caatinga: *Mabuya arajara*, *Liotyphlops* cf. *ternetzi*, and *Micrurus lemniscatus lemniscatus*.

Thirty-three (86.8%) species of amphibians were considered non-threatened. The other species *Pristimantis* sp., *Adelophryne baturitensis*, *Pseudopaludicola* sp. (aff. *saltica*), *Scinax fuscomarginatus*, and *Odontophrynus carvalhoi* showed only one parameter considered as rare (classified in the categories B, C, and E - see Tables 2 and 4).

Figure 3 – Amphibian species found in the region of CPI. A) *Adelophryne baturitensis*; B) *Pristimantis* sp.; C) *Phyllomedusa nordestina*; D) *Corythomantis greeningi*; E) *Dendropsophus* sp. (gr. *microcephalus*); F) *Dendropsophus minutus*; G) *Dendropsophus nanus*; and H) *Dendropsophus rubicundulus*.

Figure 4 – Amphibian species found in the region of CPI. A) *Dendropsophus soaresi*; B) *Hypsiboas multifasciatus*; C) *Hypsiboas raniceps* (juvenile); D) *Hypsiboas raniceps* (adult); E) *Scinax fuscomarginatus*; F) *Scinax nebulosus* G) *Scinax* sp. (gr. *ruber*); e H) *Scinax* cf. *x-signatus*.

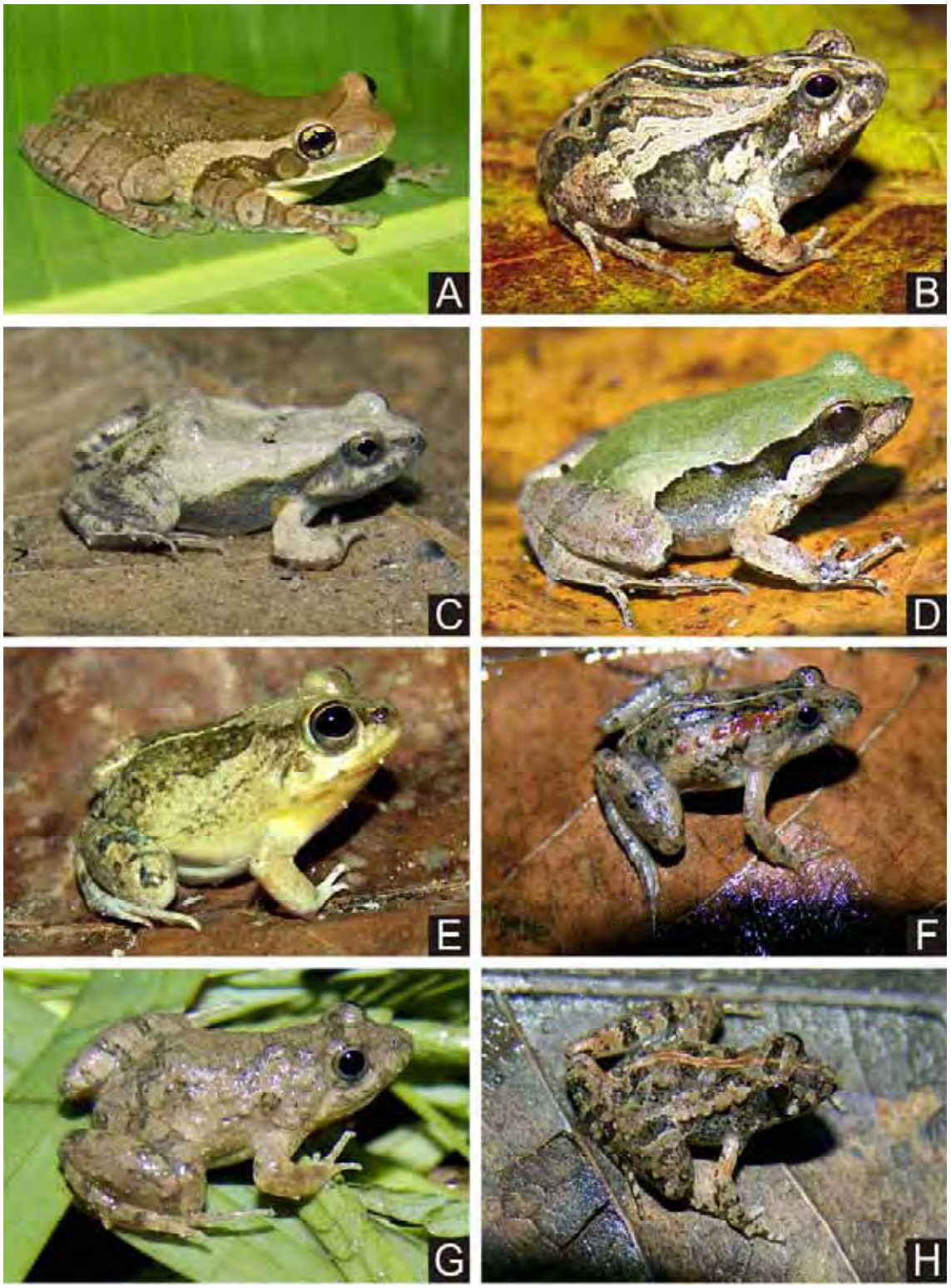


Figure 5 – Amphibian species found in the region of CPI. A) *Trachycephalus venulosus*; B) *Physalaemus albifrons*; C) *Physalaemus cicada*; D) *Physalaemus cuvieri*; E) *Pleurodema diplolister*; F) *Pseudopaludicola* sp. (gr. *falcipes*); G) *Pseudopaludicola* sp. (gr. *mystacalis*); and H) *Pseudopaludicola* sp. (aff. *saltica*).

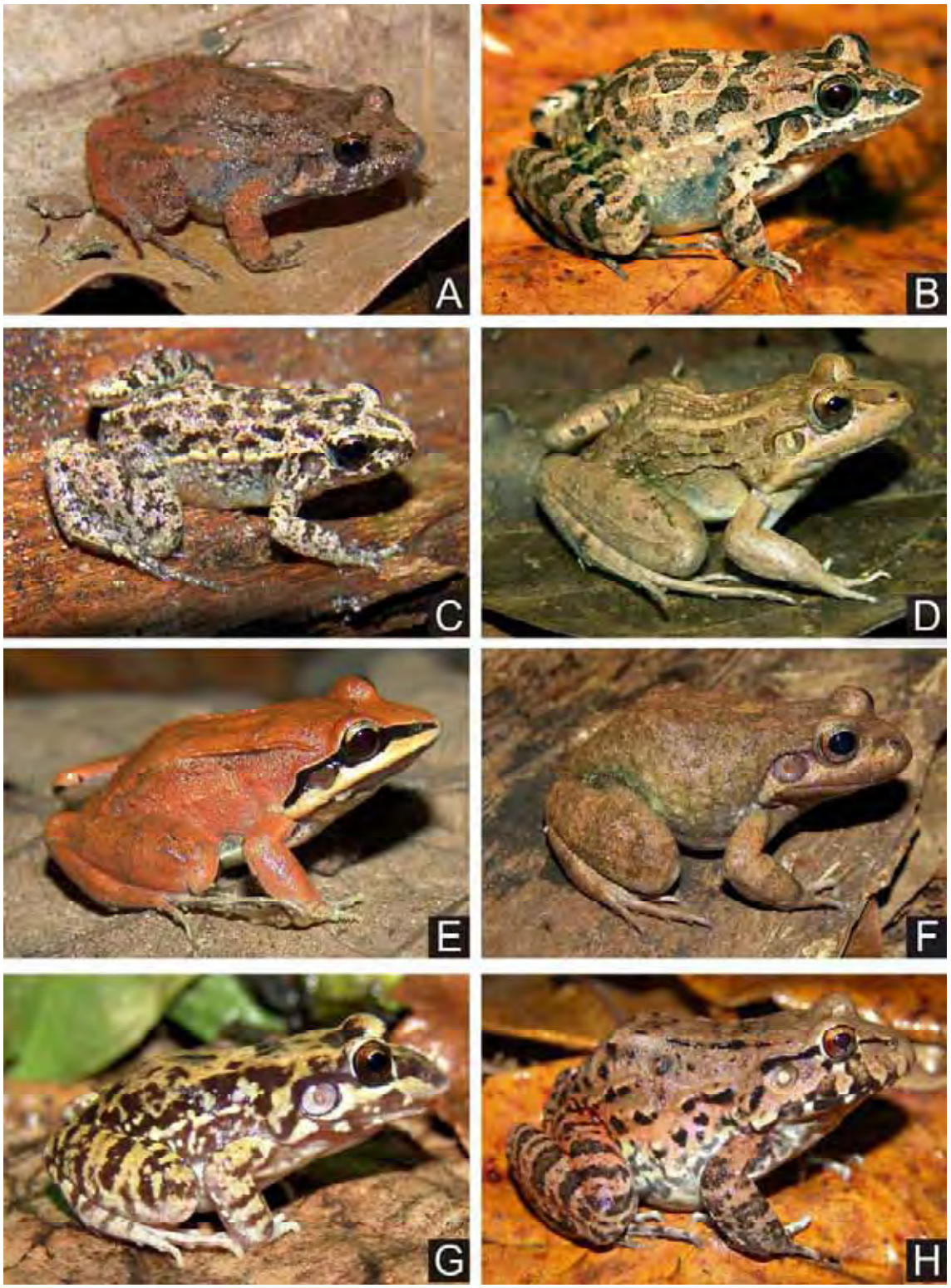


Figure 6 – Amphibian species found in the region of CPI. A) *Leptodactylus* sp. (aff. *andreae*); B) *Leptodactylus fuscus*; C) *Leptodactylus* sp. (aff. *hylaedactylus*); D) *Leptodactylus macrosternum*; E) *Leptodactylus mystaceus*; F) *Leptodactylus* sp. (aff. *syphax*); G) *Leptodactylus troglodytes*; and H) *Leptodactylus vastus*.

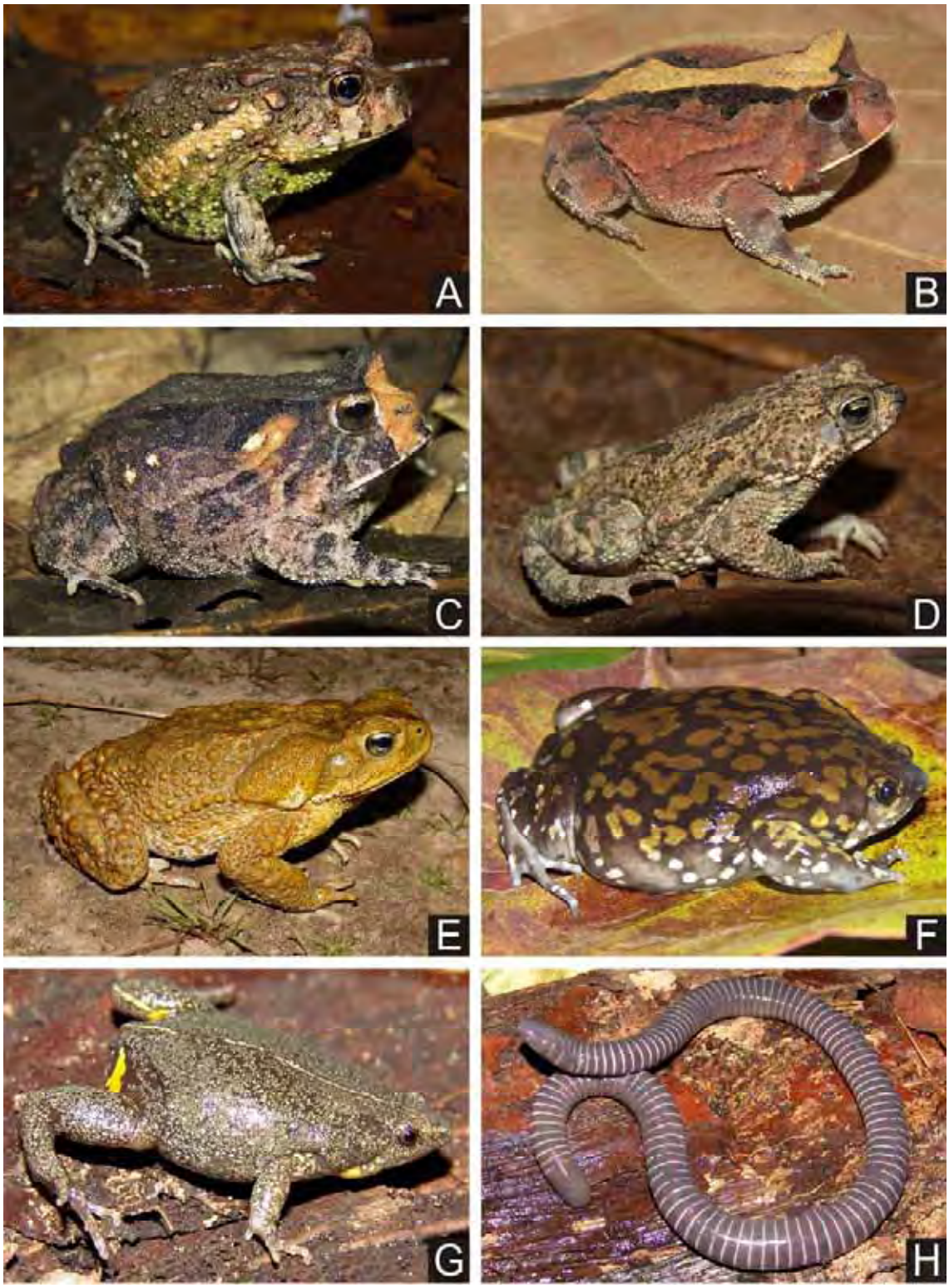


Figure 7 – Amphibian species found in the region of CPI. A) *Odontophrynus carvalhoi*; B) and C) *Proceratophrys cristiceps*; D) *Rhinella granulosa*; E) *Rhinella jimi*; F) *Dermatonotus muelleri*; G) *Elachistocleis piauiensis*; and H) *Siphonops* sp. (aff. *paulensis*).

Figure 8 – Reptile species found in the region of CPI. A) *Chelonoides carbonaria*; B) *Kinosternon scorpioides*; C) *Mesoclemmys perplexa*; D) *Mesoclemmys tuberculata*; E) *Caiman crocodilus*; F) *Amphisbaena alba*; G) *Amphisbaena pretrei*; and H) *Amphisbaena vermicularis*.

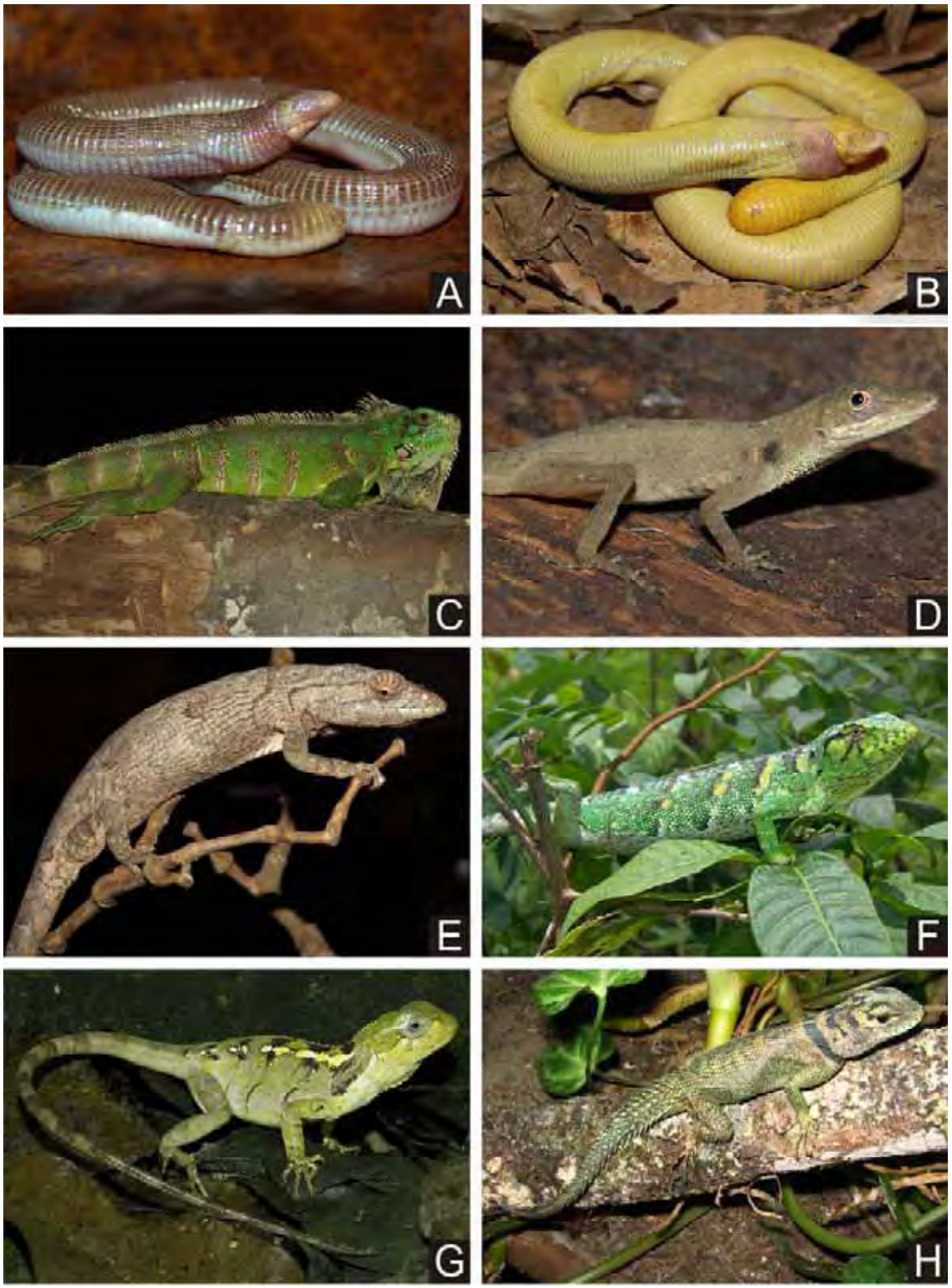


Figure 9 – Reptile species found in the region of CPI. A) *Amphisbaena anomala*; B) *Amphisbaena polystegum*; C) *Iguana iguana*; D) *Anolis fuscoauratus*; E) *Polychrus acutirostris*; F) *Polychrus marmoratus*; G) *Enyalius bibronii*; and H) *Strobilurus torquatus*.

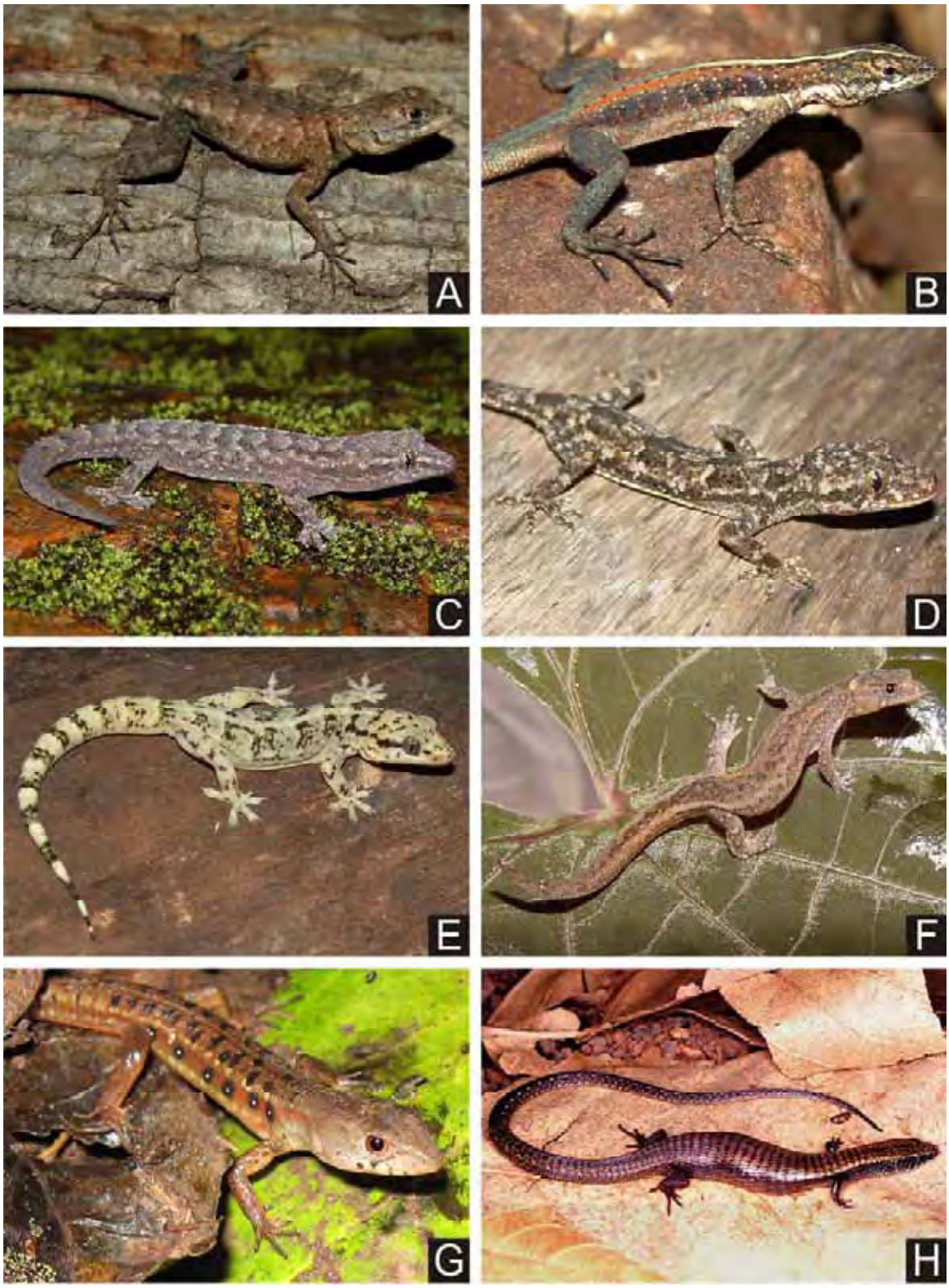


Figure 10 – Reptile species found in the region of CPI. A) *Tropidurus hispidus*; B) *Tropidurus semitaeniatus*; C) *Hemidactylus agrius*; D) *Hemidactylus mabouia*; E) *Phyllopezus pollicaris*; F) *Coleodactylus merionalis*; G) *Cercosaura ocellata*; and H) *Colobosaura modesta*.

Figure 11 – Reptile species found in the region of CPI. A) *Colobosauroides cearensis*; B) *Leposoma baturitensis*; C) *Micrablepharus maximiliani*; D) *Vanzosaura rubricauda*; E) *Mabuya arajara*; F) *Mabuya heathi*; G) *Mabuya nigropunctata*; and H) *Ameiva ameiva*.

Figure 12 – Reptile species found in the region of CPI. A) *Cnemidophorus ocellifer*; B) *Tupinambis merianae*; C) *Diploglossus lessonae* (juvenile); D) *Diploglossus lessonae* (adult); E) *Ophiodes* sp. (aff. *striatus*); F) *Liotyphlops* cf. *ternetzi*; G) *Leptotyphlops* sp. (aff. *brasiliensis*); and H) *Typhlops brongersmianus*.

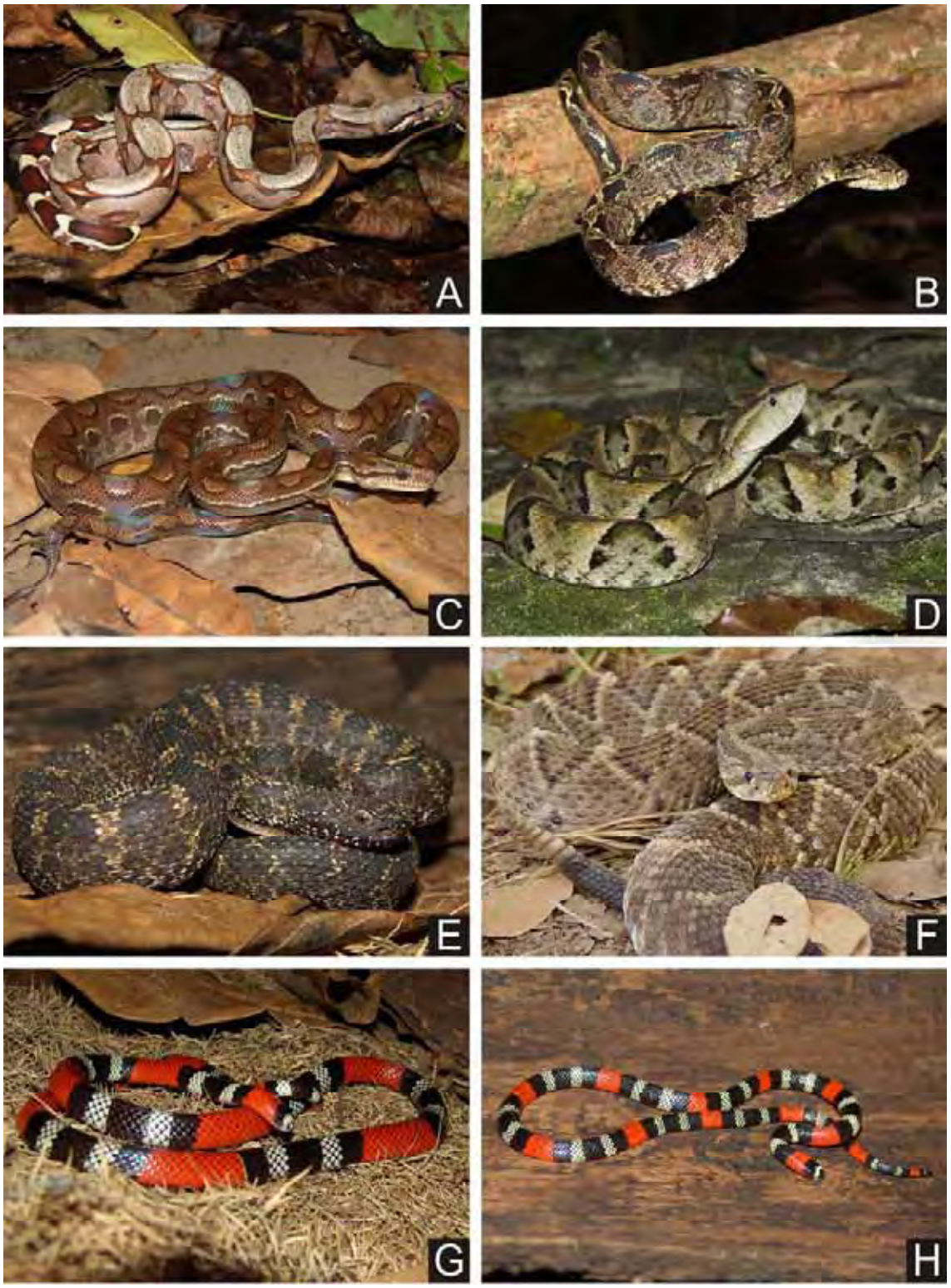


Figure 13 – Reptile species found in the region of CPI. A) *Boa constrictor constrictor*; B) *Corallus hortulanus*; C) *Epicrates assisi*; D) *Bothrops* sp. (gr. *atrox*); E) *Bothropoides lutzi*; F) *Caudisona durissus*; G) *Micrurus* sp. (aff. *ibiboboca*); and H) *Micrurus lemniscatus* cf. *ditius*.

Figure 14 – Reptile species found in the region of CPI. A) *Micrurus lemniscatus lemniscatus*; B) *Chironius bicarinatus*; C) *Chironius flavolineatus*; D) *Drymarchon corais corais*; E) *Drymoluber dichrous* (juvenile); F) *Drymoluber dichrous* (adult); G) *Leptophis ahaetulla*; and H) *Mastigodryas boddaerti boddaerti* (juvenile).

Figure 15 – Reptile species found in the region of CPI. A) *Mastigodryas boddaerti boddaerti* (adult); B) *Oxybelis aeneus*; C) *Pseustes sulphureus* (juvenile); D) *Pseustes sulphureus* (adult); E) *Spilotes pullatus*; F) *Tantilla* sp. (aff. *melanocephala*); G) *Xenopholis undulatus*; and H) *Atractus ronnie*.

Figure 16 – Reptile species found in the region of CPI. A) *Imantodes cenchoa cenchoa*; B) *Leptodeira annulata pulchriceps*; C) *Sibon nebulata nebulata*; D) *Apostolepis cearensis*; E) *Apostolepis* sp. gr *pimy*); F) *Boiruna sertaneja*; G) *Liophis poecilogyrus schotti* (juvenile); and H) *Liophis poecilogyrus schotti* (adult).

Figure 17 – Reptile species found in the region of CPI. A) *Liophis reginae semilineata*; B) *Liophis taeniogaster*; C) *Liophis viridis* (juvenile); D) *Liophis viridis* (adult); E) *Lygophis dilepis*; F) *Oxyrhopus melanogenys orientalis*; G) *Oxyrhopus trigeminus*; and H) *Philodryas nattereri*.

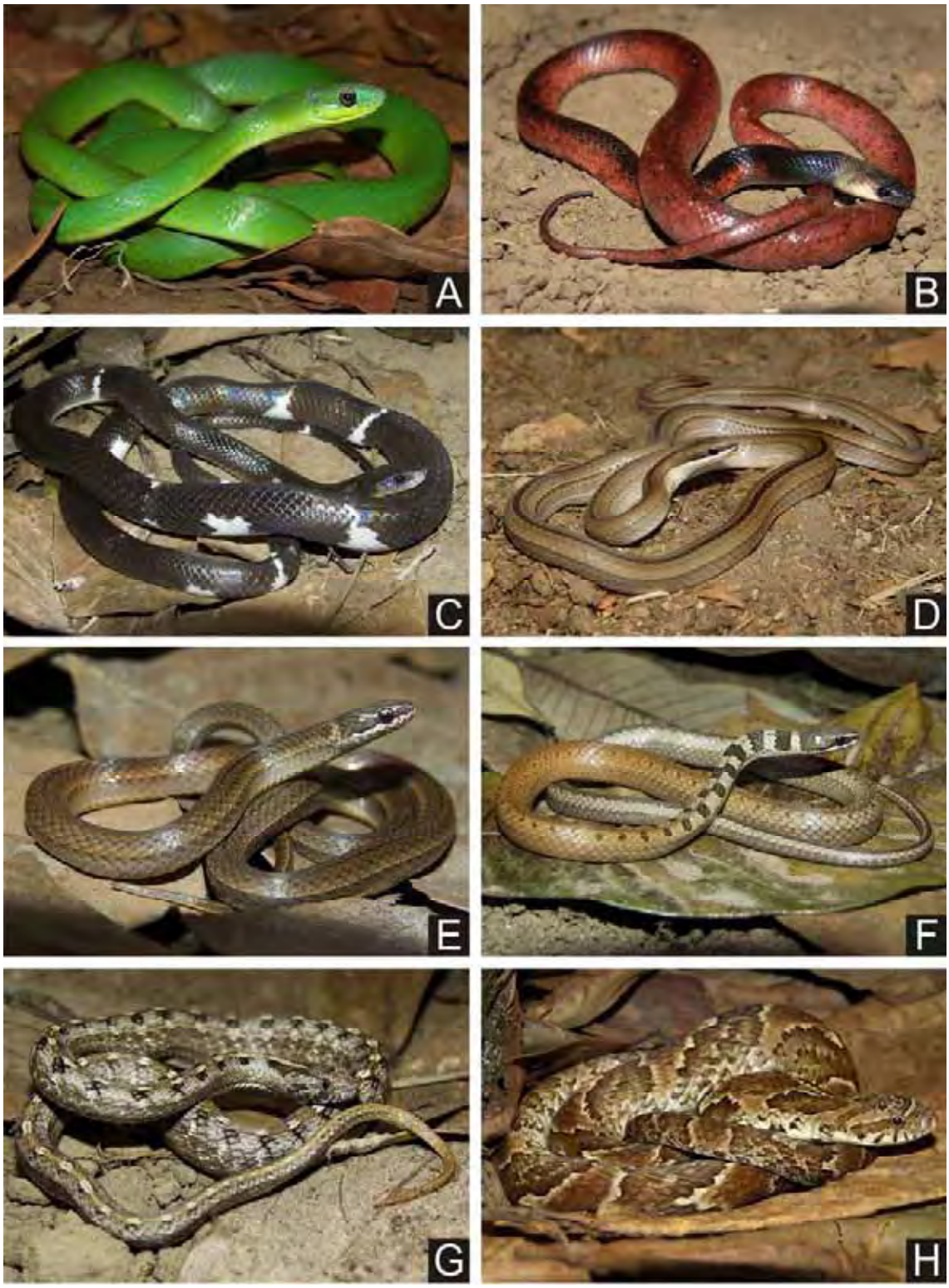


Figure 18 – Reptile species found in the region of CPI. A) *Philodryas olfersii herbeus*; B) *Pseudoboa nigra* (juvenile); C) *Pseudoboa* sp.; D) *Psomophis joberti*; E) *Taeniophalus affinis*; F) *Taeniophalus occipitalis*; G) *Thamnodynastes* sp.; and H) *Xenodon merremii*.

Reptiles showed a broader range in the scale of rarity (Tables 3 and 4). As the amphibians, most reptiles (43 species, 51.8%) were classified as not rare and not threatened. A total of 33 species (39.8%) were classified as E: locally rare species that have a wide distribution and are habitat-generalists. *Imantodes cenchoa cenchoa* was classified as F. *Leposoma baturitensis*, *Bothrops* sp. (gr. *atrox*), *Atractus ronnie*, *Apostolepis* sp. (gr. *pimy*) were classified as G and showed two parameters of rarity. *Mesoclemmys perplexa* was the only species included in the category H and, therefore, considered the rarest species in the whole complex of Ibiapaba mountain range.

Table 4. Distribution of amphibians (A) and reptiles (R) species among different categories of vulnerability, according to a combination of geographic distribution, habitat specificity, and population size.

		Geographic distribution							
		Nonendemic				Endemic			
		Habitat specificity				Habitat specificity			
Population size		Broad		Restricted		Broad		Restricted	
		A	R	A	R	A	R	A	R
Abundant	total no. species	33	44	1		2	1		
	Vulnerability index	4	4	3	3	3	3	2	2
Rare	total no. species	2	33		1		4		1
	Vulnerability index	3	3	2	2	2	2	1	1

Discussion

In the first species list for the state of Ceará there were 34 amphibians and 68 reptiles (LIMA-VERDE & CASCON, 1990). Since then, regional studies have been adding species and improving knowledge on the herpetofauna of Ceará. However, efforts were still not enough for a more complete knowledge of the herpetofauna, and those studies usually have added only the most common species. For example, Borges-Nojosa & Caramaschi (2003), who inventoried five areas of relict forests in Ceará, including CPI, concluded that the herpetofauna of all areas would sum up 115 species. In the present study we sampled 121 species of amphibians and reptiles only in CPI, evincing that those previous results were underestimates. Another evidence of the previous poor knowledge of the herpetofauna of Ceará is the high number of new occurrences and distribution extensions that have been recently published (*e.g.* LOEBMANN et al., 2007; LEITE JR. et al., 2008; LOEBMANN 2008 a,b,c; LOEBMANN & MAI, 2008 a; LOEBMANN 2009 a,b,c,d; LOEBMANN et al., 2009; ROBERTO & LOEBMANN, 2009).

Data for each relict forest available in the literature (see below) do not consider all groups of the herpetofauna, though it is already possible to find some comparable datasets and confirm the relevance of CPI. Borges-Nojosa (2007) found 88 species (30 amphibians and 58 reptiles) in Baturité mountain range: only 73% of the species richness found in CPI. For 'Chapada do Araripe', a relict forest located in the far southern Ceará, there are data only on Squamata reptiles (BORGES-NOJOSA & CARAMASCHI, 2003; VANZOLINI et al., 1980; VANZOLINI 1981; RIBEIRO et al., 2008): 55 species were recorded, 20 less than in CPI.

For the relict forests of Maranguape and Aratanha, only data on amphisbaenas and lizards are available in the literature (BORGES-NOJOSA &

CARAMASCHI, 2003). Maranguape with 20 species: 16 lizards and 4 amphisbaenas; and Aratanha with 16 species: 14 lizards and 2 amphisbaenas; they represent only 52.6 % and 42.1 %, respectively, of the number of species found in CPI.

The fauna of xeric environments in the Caatinga biome comprises 49 amphibians and 107 reptiles (RODRIGUES, 2003). Considering only the species found in xeric environments of CPI, i.e., all environments except for the relict forest, 28 out of 49 amphibian species and 51 out of 107 reptile species occur in CPI, which corresponds to 57.1% and 49.6%, respectively, of the known herpetofauna for the whole Caatinga. Besides, more six amphibian species were recorded in this domain: *Dendropsophus rubicundulus*, *Leptodactylus* sp. (aff. *hylaedactylus*), *Pristimantis* sp., *Pseudopaludicola* sp. (aff. *saltica*), *Scinax fuscomarginatus* and *Scinax nebulosus*.

Comparing our results with the ones found for a fragment of Atlantic Forest in the state of Paraíba (SANTANA et al., 2008), and putting aside the different sizes of these localities, we could again observe a remarkably higher species richness in CPI, since only 51 species were found in that region in Paraíba, corresponding to 42.15% of the total number of species found in the present study.

There are not enough data in the literature on coastal areas. Loebmann & Mai (2008b) reported the occurrence of 22 amphibian species in the coastal zone of Piauí, a neighbor state of Ceará and 70 km apart in a straight line from CPI, from which 21 species also occur in CPI.

Inventories of herpetofauna in Caatinga areas showed lower species richness when compared with our results. In Serra das Almas, an area located in western Ceará, a total of 45 species were recorded (18 amphibians and 27 reptiles)

(BORGES-NOJOSA & CASCON, 2005). In Parque Estadual da Pedra da Boca and Capivara farm, state of Paraíba, 52 species were recorded: 21 amphibians and 31 reptiles (ARZABE et al., 2005). In Reservas Particulares do Patrimônio Natural de Maurício Dantas and Cantidiano Valgueiro, state of Pernambuco, 41 species were recorded: 19 amphibians and 22 reptiles (BORGES-NOJOSA & SANTOS, 2005).

Borges-Nojosa & Caramaschi (2003) characterized the fauna of relict forests of Ceará as rainforest species, which are highly influenced by tree species typical of large Neotropical forests, occasionally including components from drier surrounding areas. Our results diverge from that characterization, as 94.7 % of amphibians and 65.1 % of reptiles are from open areas or have wide distribution, evidencing a strong influence of the open areas such Caatinga e Cerrado fauna on the relict forest.

The high species richness in CPI may be explained by a combination of factors: 1) the highest areas of the Planalto have the highest average annual rainfall and the lowest average annual temperature, which makes the climate of some areas milder and therefore favors the presence of species from higher latitudes, especially amphibians (*e. g.*, *O. carvalhoi*); 2) the strong altitudinal gradient, undoubtedly represents an important factor on species composition of CPI; 3) the region has the most heterogeneous environment mosaic of the state, hence, harbors components of the fauna from four different biomes; *e.g. P. cicada* and *P. pollicaris* from Caatinga biome, *A. anomala* and *O. melanogenys* from Amazon Forest biome, *T. affinis* from Atlantic Forest biome, *B. lutzi* and *M. perplexa* from Cerrado biome; 4) apart from this mixture, the area shelters species apparently endemic of Ceará such as: *A. baturitensis*, *L. baturitensis* and *A. ronnie*; 5) and the

area is partially protected by law favouring some species, in particular those that are habitat-specific.

Conservation Implications

The complex of Ibiapaba shelters a rich herpetofauna, which is highly representative of the state of Ceará. We estimate that about 70% of species found in Ceará occur in this complex. Colubrids are also very well-represented in the region, corresponding to almost 30% of the number of species recorded in Brazil (BÉRNILS, 2010).

The Catinga biome has about 735,000 km^2 (LEAL et al., 2005), what means that CPI comprises a little more than 0.7% of the area of this biome. However, over a half of the known fauna of this biome (ca. 51%; see RODRIGUES, 2003) is present in CPI. These results, associated with the high species richness in CPI, when compared with studies on similar areas, indicate that this region may be considered as the area with the highest herpetofauna richness known for the whole Caatinga biome, so far.

Agriculture and cattle raising are historically the main causes of habitat loss in CPI (BORGES-NOJOSA & CARAMASCHI, 2003). The complex has two priority areas for conservation of the biological diversity of the Caatinga: Planalto da Ibiapaba is classified as of extreme biological importance, and Serra das Flores is classified as of very high biological importance (TABARELLI & SILVA, 2003). Although the complex has protected areas, we do not consider that as a guarantee of full preservation of forest remnants and their associated fauna. Therein, two out of the six studied environments deserve more attention. The first environment is formed by relict forests and the second by Cerrado areas of CPI. The relict forests

in spite of constituting an almost continuous wall, forming a huge ecological corridor, are highly altered in the high areas of the plateau, without pristine forest fragments in the region. Therefore, it is likely that recent extinctions may have occurred in the area as a result of human activities in these forests. For example, it is possible that *Rhinella hoogmoedi*, a species of forest areas that reproduces in lentic environments, was once present in CPI, since there is a population in the Baturité massif (CARAMASCHI & POMBAL, 2006), a similar area in the same latitude, but with better preserved fragments in its plateau. The Cerrado areas of CPI represent the far northern distribution of this ecosystem in the Brazilian territory. Cerrado areas have low species richness when compared with other sampled environments. However, *Pseudopaludicola* aff. *saltica* seems to be restricted to this environment in CPI.

Species from relict forests that show habitat specificity are the most susceptible to environment loss. Sixteen species out of 25 considered rare in CPI (two amphibians and 14 reptiles) are restricted to this environment. Remarkably, we found well-established populations of *Adelophryne baturitensis* in several areas of CPI. This species is considered vulnerable in the Red List of Threatened Species of Brazil, and until now was believed to be restricted to the Baturité massif (HADDAD, 2008).

Liotyphlops cf. *ternetzi*, *Bothrops* sp. (gr. *atrox*), *Typhlops brongersmianus*, *Ophiodes* sp. (aff. *striatus*), and *Mesoclemmys perplexa* deserve special attention, since these species do not have records for other areas in Ceará. Therefore, 5.8% of the fauna in CPI is not apparently present in other areas of Ceará state.

Ultimately, we emphasize that high altitude caatingas are particular environments and have exclusive species, such as *Bothropoides lutzi* and

Diploglossus lessonae. We also consider that these areas have the most severe lack of data within the complex; therefore, there is a real need for more sampling. Certainly, studies on this environment will increase the number of species present in this complex, as well as the possibility of finding new taxa.

Acknowledgments

The authors are grateful to Ana C. G. Mai for the helpful suggestions during the manuscript preparation. Daniel do Nascimento Lima for helped during the field work. Francisco L. Franco, Luis Olimpio M. Giasson, Cynthia A. P. Prado, Cinthia Brasileiro and anonymous referees for helpful comments and suggestions. The pictures of *Cercosaura ocellata*, *Colobosaura modesta*, *Diploglossus lessonae* (juvenile), *Drymoluber dichrous* (adult), *Strobilurus torquatus*, and *Lygophis dilepis*, were courtesy from Paulo S. Bernarde, Mauro Teixeira Junior, Claúdio Sampaio, and Marco A. de Freitas (last three species). Fundação O Boticário de Proteção a Natureza. FAPESP (proc. 2008/50928-1) and CNPq, supported this research. Daniel Loebmann is supported by grant no. 140226/2006-0 from the Conselho Nacional de Pesquisa e Desenvolvimento (CNPq).

References

AB'SÁBER, A. N. Os domínios morfoclimáticos na América do Sul. Primeira aproximação. **Geomorfologia,** São Paulo, v. 52, p. 1-21, 1977.

AB'SÁBER, A. N. **Os domínios da natureza do Brasil - Potencialidades paisagísticas.** São Paulo: Ateliê, 2003. 160 p.

ARZABE, C.; SKUK, G.; SANTANA, G. G.; DELFIM, F. R.; LIMA, Y. C. C.; ABRANTES, S. H. F. Herpetofauna da Área de Curimataú, Paraíba. In: ARAÚJO, F. S.; RODAL, M. N. J.; BARBOSA, M. R. V. (Eds.). **Análise das Variações da**

Biodiversidade do Bioma Caatinga. Brasília: Ministério do Meio Ambiente, 2005. p. 259-274.

BÉRNILS, R. S. <http://www.sbherpetologia.org.br>. Acesso em 14 jan. 2010.

BEZERRA, E. C.; BEZERRA, J. E. G.; MENDES, M. F. S. Precipitações. In: Instituto de Planejamento do estado do Ceará (Ed.). **Atlas do Ceará**. Fortaleza: Secretaria do Planejamento - Governo do Estado do Ceará, 1997. p. 22-23.

BORGES-NOJOSA, D. M.; SANTOS, E. M. Herpetofauna da Área de Betânia e Floresta, Pernambuco. In: ARAÚJO, F. S.; RODAL, M. N. J.; BARBOSA, M. R. V. (Eds.). **Análise das variações da biodiversidade do bioma Caatinga.** Brasília: Ministério do Meio Ambiente, 2005. p. 277-291.

BORGES-NOJOSA, D. M. Diversidade de Anfíbios e Répteis da Serra de Baturité, Ceará. In: OLIVEIRA, T. S.; ARAÚJO, F. S. (Eds.). **Diversidade e Conservação da Biota na Serra de Baturité, Ceará**. Fortaleza: Edições UFC, 2007. p. 225-247.

BORGES-NOJOSA, D. M.; CARAMASCHI, U. Composição e Análise Comparativa da Diversidade e das Afinidades Biogeográficas dos Lagartos e Anfisbenídeos (Squamata) dos Brejos Nordestinos. In: LEAL, I.; SILVA, J. M. C.; TABARELLI, M. (Eds.). **Ecologia e Conservação da Caatinga**. Recife: UFPE, 2003. p. 489-540.

BORGES-NOJOSA, D. M.; CASCON, P. Herpetofauna da Área Reserva da Serra das Almas, Ceará. In: ARAÚJO, F. S.; RODAL, M. N. J.; BARBOSA, M. R. V. (Eds.). **Análise das Variações da Biodiversidade do Bioma Caatinga**. Brasília: Ministério do Meio Ambiente, 2005. p. 245-260.

CAMPBEL, H. W.; CHRISTMAN, S. P. Field techniques for herpetofaunal community analysis. In: SCOTT JR., N. J. (Ed.). **Herpetological Communities: a**

Symposium of the Society for the Study of Amphibians and Reptiles and Herpetologists' Leagle. Washington: Fish Wildlife Service, 1982. p. 193-200.

CARAMASCHI, U.; POMBAL JR., J. P. A new species of Rhinella Fitzinger, 1826 from the Atlantic Rain Forest, Eastern Brazil (Amphibia, Anura, Bufonidae). **Papéis Avulsos de Zoologia**, Rio de Janeiro, v. 46, n. 23, p. 251-259, 2006.

CAVALCANTE, A. M. B. Jardins Suspensos do Sertão. **Scientific American**, São Paulo, v. 32, p. 66-73, 2005.

COIMBRA-FILHO, A. C.; CÂMARA, I. G. **Os limites originais do bioma Mata Atlântica na Região Nordeste do Brasil**. Rio de Janeiro: Fundação Brasileira para a Conservação da Natureza, 1996. 86 p.

CORN, P. S. Straight–line drift fences and pitfall traps. In: (HEYER, W. R.; DONNELY, M. A.; MCDIARMID, R. W.; HAYEK, L. A. C.; FOSTER, M. S. (Eds.). **Measuring and monitoring biological diversity: Standard methods for amphibians.** Washington: Smithsonian Institution Press, 1994. p. 109-117.

CURCIO, F. F.; PIACENTINI, V. Q.; FERNANDES, D. S. On the status of the snake genera *Erythrolamprus* Boie, *Liophis* Wagler and *Lygophis* Fitzinger (Serpentes, Xenodontinae). **Zootaxa**, Auckland, v. 2173, p. 66-68, 2009.

FAIVOVICH, J.; HADDAD, C. F. B.; GARCIA, P. C. A.; FROST, D. R.; CAMPBELL, J. A.; WHEELER, W. C. Systematic review of the frog family Hylidae, with special reference to Hylinae: phylogenetic analysis and taxonomic revision. **Bulletin of the American Museum of Natural History**, New York, v. 294, p. 1-240, 2005.

FENWICK, A. M.; GUTBERLET JR., R. L.; EVANS J. A.; PARKINSON, C. L. Morphological and molecular evidence for phylogeny and classification of

South American pitvipers, genera *Bothrops*, *Bothriopsis*, and *Bothrocophias* (Serpentes: Viperidae). **Zoological Journal of the Linnean Society**, Londres, v. 156, p. 617-640, 2009.

FIGUEIREDO, M. A. Unidades Fitoecológicas. In: Instituto de Planejamento do estado do Ceará (Ed.). **Atlas do Ceará**. Fortaleza: Secretaria do Planejamento - Governo do Estado do Ceará, 1997. p. 28-29.

FITCH, H. S. Collecting and life-history techniques. In: SEIGEL, R. A.; COLLINS, J. T.; NOVAK, S. S. (Eds.). **Snakes. Ecology and Evolutionary Biology**. New York: MacMillan Publishing Company, 1987. p. 143-164.

FROST, D. R.; GRANT, T.; FAIVOVICH, J.; BAIN, R. H.; HAAS, A.; HADDAD, C. F. B.; DE SÁ, R. O.; CHANNING, A.; WILKISON, M.; DONNELAN, S. C.; RAXWORTHY, C. J.; CAMPBELL, J. A.; BLOTTO, B. L.; MOLER, P., DREWES, R. C.; NUSSBAUM, R. A.; LYNCH, J. D.; GREEN, D. M.; WHEELER, W. C. The Amphibian Tree of Life. **Bulletin of the American Museum of Natural History**, New York, v. 297, p. 1-370, 2006.

GAMBLE, T.; BAUER, A. M.; GREENBAUM, E.; JACKMAN, T. R. Out of the blue: a novel, trans-Atlantic clade of geckos (Gekkota, Squamata). **Zoologica Scripta**, Göteborg, v. 37, n. 4, p. 355-366, 2008.

GRANT, T.; FROST, D. R.; CALDWELL, J. P.; GAGLIARDO, R.; HADDAD, C. F. B.; KOK, P. J. R.;MEANS, D. B.; NOONAN, B. P.; SCHARGEL, W. E.; WHEELER, W. C. Phylogenetic Systematics of Dart-Poison Frogs and Their Relatives (Amphibia: Athesphatanura: Dendrobatidae). **Bulletin of the American Museum of Natural History**, New York, v. 299, p. 1-262, 2006.

HADDAD, C. F. B. Uma análise da lista brasileira de anfíbios ameaçados de extinção. In: MACHADO, A. B. M.; DRUMMOND, G. M.; PAGLIA, A. P. (Eds.). **Livro**

Vermelho da fauna brasileira ameaçada de extinção, volume II. Brasília: Ministério do Meio Ambiente/Fundação Biodiversitas, 2008. p. 287-295.

HEDGES, S. B.; DUELLMAN, W. E.; HEINICKE, M. P. New World direct-developing frogs (Anura: Terrarana): molecular phylogeny, classification, biogeography, and conservation. **Zootaxa**, Auckland, v. 1737, p. 1-182, 2008.

HOSER, R. A reclassification of the Rattlesnakes; species formerly exclusively referred to the Genera *Crotalus* and *Sistrurus*. Australasian Journal of Herpetology, Victoria, v. 6, p. 1-21, 2009.

LEAL, I. R.; SILVA, J. M. C.; TABARELLI, M.; LACHER JR., T. E. Mudando o curso da conservação da biodiversidade na Caatinga do Nordeste do Brasil. **Megadiversidade**, Belo Horizonte, v. 1, n. 1, p. 139-146, 2005.

LEITE JR., J. M. A.; SAMPAIO, J. M. S.; SILVA-LEITE, R. R.; TOLEDO, L. F.; LOEBMANN, D.; LEITE, J. R. S. A. Amphibia, Anura, Hylidae, *Scinax fuscomarginatus*: distribution extension. **Check List – Journal of species lists and distribution**, Campinas, v. 4, n. 4, p. 475-477, 2008.

LIMA-VERDE, J. S.; CASCON, P. Lista preliminar da Herpetofauna do estado do Ceará, Brasil. **Caatinga**, Mossoró, v. 7, n. 1, p. 158-163, 1990.

LOEBMANN, D.; MAI, A. C. G. Amphibia, Anura, Leiuperidae, *Physalaemus cicada*: distribution extension in the state of Ceará, Brazil. **Check List – Journal of species lists and distribution**, Campinas, v. 4, n. 4, p. 392-394, 2008a.

LOEBMANN, D.; MAI, A.C.G. Amphibia, Anura, Coastal Zone, Piauí state, Northeastern Brazil. **Check List – Journal of species lists and distribution**, Campinas, v. 4, n. 2, p. 161-170, 2008b.

LOEBMANN, D.; ROBERTO, I. J. Geographic distribution. *Oxyrhopus melanogenys orientalis* (Black-headed Calico Snake). Brazil: Ceará. **Herpetological Review**, Lawrence, v. 40, n. 3, p. 366, 2009.

LOEBMANN, D. Geographic distribution. *Echinanthera affinis*. Brazil: Ceará. **Herpetological Review**, Lawrence, v. 39, n. 2, p. 241, 2008a.

LOEBMANN, D. Geographic distribution. *Mesoclemmys perplexa*. Brazil: Ceará. **Herpetological Review**, Lawrence, v. 39, n. 2, p. 236, 2008b.

LOEBMANN, D. Geographic distribution. *Typhlops brongersmianus*. Brazil: Ceará. **Herpetological Review**, Lawrence, v. 39, n. 2, p. 244, 2008c.

LOEBMANN, D. Geographic distribution. *Micrurus lemniscatus lemniscatus* (Guiana s Ribbon Coral Snake). Distribution extension. Brazil: Ceará. **Herpetological Review**, Lawrence, v. 40, n. 3, p. 366, 2009a.

LOEBMANN, D. Geographic distribution. *Xenopholis undulatus*. Brazil: Ceará. **Herpetological Review**, Lawrence, v. 40, n. 1, p. 117, 2009b.

LOEBMANN, D. Reptilia, Squamata, Serpentes, Scolecophidia, Anomalepididae, *Liotyphlops* cf. *ternetzii* (Boulenger, 1896): first family record for the state of Ceará, Brazil. **Check List – Journal of species lists and distribution**, Campinas, v. 5, n. 2, p. 249-250, 2009c.

LOEBMANN, D. Reptilia, Squamata, Serpentes, Viperidae, *Bothrops lutzi*: distribution extension. **Check List – Journal of species lists and distribution**, Campinas, v. 5, n. 3, p. 375-377, 2009d.

LOEBMANN, D.; PRADO, C. A. P.; HADDAD, C. F. B.; BASTOS, R. F.; GUIMARÃES, L. D. Geographic distribution. *Hypsiboas multifasciatus*, Brazil: Ceará and Goiás. **Herpetological Review**, Lawrence, v. 38, n. 4, p. 476, 2007.

LOEBMANN, D.; RIBEIRO, S. C.; SALES, D. L.; ALMEIDA, W. O. New records for *Atractus ronnie* (Reptilia, Serpentes, Colubridae) with comments about meristic and morphometric data. **Biotemas**, Florianópolis, v. 22, n. 1, p. 169-173, 2009.

MOTT, T.; VIEITES, D. R. Molecular phylogenetics reveals extreme morphological homoplasy in Brazilian worm lizards challenging current taxonomy. **Molecular Phylogenetics and Evolution**, Amsterdam, v. 51, n. 2009, p. 190-200, 2009.

RABINOWITZ, D. Seven forms of rarity. In: SYNGE, H. (Ed.). **The biological aspects of rare plant conservation.** Chichester: John Wiley & Sons, 1981. p. 205-217.

RIBEIRO, S. C.; FERREIRA, F. S.; BRITO, S. V.; SANTANA, G. G.; VIEIRA, W.L.S.; ALVES, R. R. N.; ALMEIDA, W. O. The Squamata Fauna of the Chapada do Araripe, Northeastern Brazil. **Cadernos de Cultura e Ciência**, Crato, v. 3, p. 1-14, 2008.

RODRIGUES, M. T. Herpetofauna da Caatinga. In: LEAL, I. R.; TABARELLI, M.; SILVA, J. M. C. (Eds.). **Ecologia e Conservação da Caatinga.** Recife: Universidade Federal de Pernambuco, 2003. p. 181-236.

SANTANA, G. G.; VIEIRA, W. L. S.; PEREIRA-FILHO, G. A.; DELFIM, F. R.; LIMA, Y. C. C.; VIERIA, K. S. Herpetofauna em um fragmento de Floresta Atlântica no Estado da Paraíba, Região Nordeste do Brasil. **Biotemas**, Florianópolis, v. 21, n. 1, p. 75-84, 2008.

SCOTT JR., N. J.; WOODWARD, B. D. Técnicas estándar para inventarios e monitoreos. In: HEYER, W. R.; DONNELLY, M. A.; MCDIARMID, R.W.; HAYEK, L. A. C.; FOSTER, M. S. (Eds.). **Medición e monitoreo de la diversidad**

biológica: Métodos estandartizados para Anfibios. Chubut: Editora Universitária de la Patagonia, 1994. p.113-120.

TABARELLI, M.; SILVA, J. M. C. Áreas e ações prioritárias para a conservação da biodiversidade da Caatinga. In: LEAL, I.; SILVA, J. M. C.; TABARELLI, M. (Eds.). **Ecologia e conservação da Caatinga**. Recife: UFPE, 2003. p. 781-800.

VANZOLINI, P. E. A quasi-historical approach to the natural history of differentiation of reptiles in the tropical geographic isolated**. Papéis Avulsos de Zoologia**, São Paulo, v. 34, n. 19, p. 189-204, 1981.

VANZOLINI, P. E.; RAMOS-COSTA, A. M. M.; VITT, L. J. **Répteis das caatingas**. Rio de Janeiro: Academia Brasileira de Ciências, 1980. 161 p.

ZAHER, H.; GRAZZIOTIN, F. G.; CADLE, J. E.; MURPHY, R. W.; MOURA-LEITE, J. C.; BONATTO, S. L. Molecular phylogeny of advanced snakes (Serpentes, Caenophidia) with an emphasis on South American Xenodontines: a revised classification and descriptions of new taxa. **Papéis Avulsos de Zoologia**, São Paulo, v. 49, n. 11, p. 115-153, 2009.

Appendix 1 – Voucher list of specimens collected at the CPI.

Amphibians. *Adelophryne baturitensis* (CFBH 20431-20440); *Corythomantis greeningi* (CFBH 16115, 16129-16130, 20450, 20450-20454); *Dendropsophus* sp. (gr. *microcephalus*) (CFBH 15883-15885); *Dendropsophus minutus* (CFBH 15852-15854); *Dendropsophus nanus* (CFBH 15857-15858); *Dendropsophus rubicundulus* (CFBH 23464); *Dendropsophus soaresi* (CFBH 15864-15865, 15869-15873, 16172, 19296-19311, 23472-23475); *Dermatonotus muelleri* (CFBH 16104-16105, 16107-16108, 16127-16128, 16172, 23435-23444); *Elachistocleis piauiensis* (CFBH 15880, 15902-15903, 23465-23471); *Hypsiboas multifasciatus* (CFBH 16142, 16147-16149, 16151-16156); *Hypsiboas raniceps* (CFBH 15998-16006, 16124, 23766); *Pristimantis* sp. (CFBH 16165, 20304-20318); *Leptodactylus* sp. (aff. *andreae*) (CFBH 15898); *Leptodactylus* sp. (aff. *hylaedactylus*) (CFBH 15887-15890, 20456-20458); *Leptodactylus fuscus* (CFBH 16122-16123, 16150); *Leptodactylus macrosternum* (CFBH 16121); *Leptodactylus mystaceus* (CFBH 16101, 16103, 16117, 16132); *Leptodactylus* sp. (aff. *syphax*) (CFBH 20398, 23747-23755); *Leptodactylus troglodytes* (CFBH 16133); *Leptodactylus vastus* (CFBH 23445-23446, 23765); *Odontophrynus carvalhoi* (CFBH 20301-20302, 20415, 23764); *Phyllomedusa nordestina* (CFBH 15868, 23447); *Physalaemus albifrons* (CFBH 16137-16140, 16157-16164); *Physalaemus cicada* (CFBH 19389-19392, 19395); *Physalaemus cuvieri* (CFBH 16136, 16170-16172); *Pleurodema diplolister* (CFBH 16143-16145, 16166-16169, 23769-23770, 23771-23776); *Proceratophrys cristiceps* (CFBH 16102, 16112-16114, 16119-16120, 16125-16126, 16131, 23756, 23455-23462, 23758-23762); *Pseudopaludicola* sp. (gr. *falcipes*) (CFBH 20298-20300); *Pseudopaludicola* sp. (gr. *mystacalis*) (CFBH 20285-20287); *Pseudopaludicola* sp. (gr. *saltica*) (CFBH 20288-20297); *Rhinella granulosa* (CFBH

16106, 16110-16111); *Rhinella jimi* (CFBH 16007-16009, 23395-23400); *Scinax* cf. *x-signatus* (CFBH 15874-15875); *Scinax fuscomarginatus* (CFBH 19386); *Scinax* sp. (gr. *ruber*) (CFBH 15876-15878); *Scinax nebulosus* (CFBH 15859-15861); *Siphonops* sp. (aff. *paulensis*) (CFBH 16135, 20399-20411); *Trachycephalus venulosus* (CFBH 16116, 16118, 23448-23449).

Reptiles. *Ameiva ameiva* (UFRGS 4958, ZUEC 3419); *Amphisbaena alba* (CRIB 484-485, 611); *Amphisbaena anomala* (CRIB 288, ZUEC 3412); *Amphisbaena polystegum* (CRIB 489); *Amphisbaena pretrei* (ZUEC 3379, 3411); *Amphisbaena vermicularis* (CRIB 487-488, UFRGS 4945, ZUEC 3431); *Anolis fuscoauratus* (UFRGS 4946, 4959, 4960); *Apostolepis cearensis* (IBSP 76855, 77101, 77109, 77509); *Apostolepis* sp. (gr *pimy*) (ZUEC 3384); *Atractus ronnie* (MNRJ 17326); *Boa constrictor constrictor* (IBSP 77053); *Boiruna sertaneja* (IBSP 77514, ZUEC 3402); *Bothrops* sp. (gr. *atrox*) (IBSP 77064, 77067, 77070-77071); *Bothropoides lutzi* (UFPB 4506, ZUEC 3373-3376); *Cercosaura ocellata* (MNRJ 9914-9915); *Chironius bicarinatus* (IBSP 77076); *Chironius flavolineatus* (IBSP 77058-77059, 77113-77114, 77529-77531); *Cnemidophorus ocellifer* (ZUEC 3381-3383); *Coleodactylus merionalis* (ZUEC 3485-3400); *Colobosaura modesta* (MNRJ 9916-9917); *Colobosauroides cearensis* (CHUNB 57380, ZUEC 3413, 3429-3430); *Corallus hortulanus* (IBSP 77056); *Caudisona durissus* (IBSP 77241-77243); *Drymarchon corais corais* (IBSP 77237, 77553); *Drymoluber dichrous* (IBSP 77074, 77506, ZUEC 3424); *Enyalius bibronii* (CHUNB 57375-57379; CRIB 615-617); *Epicrates assisi* (IBSP 77062, 77086, 77105, 77107, 77235, 77523); *Hemidactylus agrius* (UFRGS 4953-4956); *Hemidactylus mabouia* (CHUNB 57374, ZUEC 3415); *Iguana iguana* (CHUNB 57364); *Imantodes cenchoa cenchoa* (IBSP 77072); *Kinosternon scorpioides* (ZUEC 3377); *Leposoma baturitensis* (UFRGS 4957); *Leptodeira*

annulata pulchriceps (IBSP 77054, 77060, 77525, 77526); *Leptophis ahaetulla* (IBSP 77075, 77240); *Leptotyphlops* sp. aff. *brasiliensis*) (ZUEC 3380); *Liophis poecilogyrus schotti* (IBSP 77099, 77104, 77238); *Liophis reginae semilineata* (IBSP 77051, 77097, 77100, 77233, 77551-77552); *Liophis taeniogaster* (IBSP 76850, 77050, 77084, 77098, ZUEC 3428); *Liophis viridis* (IBSP 77108); *Liotyphlops* cf. *ternetzi* (IBSP 76856); *Lygophis dilepis* (IBSP 77115); *Mabuya arajara* (CHUNB 57367, 57370, ZUEC 3407); *Mabuya heathi* (UFRGS 4947); *Mabuya nigropunctata* (UFRGS 4948); *Mastigodryas boddaerti boddaerti* (IBSP 76844, 77234, 77510, 77554-77555, ZUEC 3416); *Mesoclemmys perplexa* (CRIB 289); *Mesoclemmys tuberculata* (CRIB 618); *Micrablepharus maximiliani* (UFRGS 4949-4950); *Micrurus* sp. (aff. *ibiboboca*) (IBSP 76849, 77073, 77081, 77093, 77112; 77512); *Micrurus* cf. *lemniscatus ditius* (IBSP 77096); *Micrurus lemniscatus lemniscatus* (IBSP 77079); *Ophiodes* sp. (aff. *striatus*) (UFRGS 4898-4915, ZUEC 3420, 3427); *Oxybelis aeneus* (IBSP 77088, 77237, 77532); *Oxyrhopus melanogenys orientalis* (IBSP 76842, 77061, 77069, 77082, 77089, 77232); *Oxyrhopus trigeminus* (IBSP 76853, 77057, 77085, 77090, 77092, 77094, 77111, 77539-77540); *Philodryas nattereri* (IBSP 76840, 76854, 77083); *Philodryas olfersii herbeus* (IBSP 77077, 77535-77538); *Phyllopezus pollicaris* (CHUNB 57388-57436; 57515); *Polychrus acutirostris* (CRIB 612-614); *Polychrus marmoratus* (CHUNB57381-57386); *Pseudoboa nigra* (IBSP 77052, 77102, 77547-77549); *Pseudoboa* sp. (IBSP 77550); *Pseustes sulphureus* (IBSP 77504; 77505); *Psomophis joberti* (IBSP 76843); *Sibon nebulata nebulata* (IBSP 76848, 77063, 77065, 77068, 77087, 77096, 77527, 77528); *Spilotes pullatus* (IBSP 77503, ZUEC 3401); *Taeniophalus affinis* (IBSP 76363, 76364); *Taeniophalus occipitalis* (IBSP 76852, 77508, ZUEC 3405); *Tantilla* sp. (aff. *melanocephala*) (IBSP 76841, MNRJ 17331-17336, ZUEC 3409); *Thamnodynastes* sp. (IBSP 77507);

Tropidurus hispidus (UFRGS 4952); *Tropidurus semitaeniatus* (UFRGS 4951); *Tupinambis merianae* (ZUEC 3372); *Typhlops brongersmianus* (IBSP 76365, 76845-76847); *Vanzosaura rubricauda* (CHUNB 57373); *Xenodon merremii* (IBSP 77066, 77533, 77534); *Xenopholis undulatus* (IBSP 76832, 77110).

Capítulo 2

Reproductive strategies and size-fecundity relationships of anurans in the Caatinga Domain, Northeastern Brazil

Abstract: The Caatinga Domain is a peculiar ecosystem in Brazil – it presents the most marked variation between rainy and dry seasons. Consequently, amphibian species inhabiting the Caatinga have developed adaptations to survive in the rough conditions of this ecosystem. During two reproductive seasons, we investigated the species composition, reproductive modes, size-fecundity relationships, and reproductive investment of females in a Neotropical assemblage in an area of Caatinga. The anuran assemblage composition in the studied semi-permanent pond is composed of 23 species. Explosive breeders represented 47.8 % of frog species while prolonged breeders, 39.1%. This reproductive pattern differs from the reported in other anuran assemblages in the Neotropical region. Interspecific size-fecundity relationships for the studied species revealed that large females tend to produce more eggs and species with aquatic eggs present a strong correlation between female size and egg diameter. The reproductive investment is mainly characterized by the combination of the following patterns: Ovarian mass tend to increase proportionally to female mass; ovary mass/body mass ratio is highly variable and poorly correlated with female mass; the strategies of reproductive investment differs among families, between explosive and prolonged breeders, as well as among reproductive modes. This is the first study about reproductive strategies in the Caatinga and presents new insights for Neotropical anurans.

Key words: Anurans, Caatinga domain, clutch size, reproductive effort.

Introduction

Maintenance requirements for males and females probably do not differ dramatically among most amphibians, but the energetic demands of reproduction

on the two sexes differ both qualitatively and quantitatively (WELLS, 2007). The amount of resources available to an organism that is invested in reproduction during a given period of time has been defined as reproductive investment or reproductive effort (GADGIL & BOSSERT, 1970). For most species, the major cost of reproduction for females almost certainly is the production of eggs (WELLS, 2007). For this reason, the most common method used to determine the reproductive investment is to calculate the ratio between gonad mass and body mass or between clutch volume and body volume (e.g. CRUMP, 1974; LEMCKERT & SHINE, 1993; PEROTTI, 1997; PRADO & HADDAD, 2005). However, other activities, such as searching for mates, nest building, brooding of the eggs, and feeding tadpoles, also add to the reproductive costs (WELLS, 2007).

In general, large species are expected to produce relatively more eggs than smaller ones, and species that exhibit general reproductive modes produce larger clutches than those with specialized modes. Furthermore, within a given reproductive mode there is a positive correlation between female body size and clutch size, and a negative correlation between clutch size and ovum size (DUELLMAN, 1989). Size-fecundity relationships for anurans have been examined by Salthe & Duellman (1973), Crump (1974), and Lang (1995). For open areas of South America, the main studies were conducted by Perotti (1997) in the Argentinean Chaco, and by Prado & Haddad (2005) in the Pantanal floodplain in Brazil.

The Caatinga Domain (*sensu* AB´SABER, 1977) is an ecosystem located between the latitudes 03° and 15° S, and the longitudes 34° and 45° W. Due to the marked seasonal climate, with a long dry period and a rainy season restrict to few months, the Caatinga is a singular ecosystem in Brazil. The Caatinga is basically characterized by the presence of heterogeneous arid and semi-arid environments surrounded by mesic phytogeographic formations. The vegetation is xerophytic and summer deciduous, morphologically and physiologically drought-adapted (ARZABE, 1999). However, inside of this morphoclimatic zone, it is possible to

observe wet tropical forest enclaves, known as "*brejos de altitude*" (highland marshes). This term can be applied to hills exposed at certain angles to moist winds and their elevation cause condensation and precipitation, with consequent formation of forests (ANDRADE-LIMA, 1982).

Specific studies on amphibian assemblages of Caatinga ecosystems are scarce, and only monthly variations in calling activity have been reported (ARZABE, 1999; SILVA et al. 2007; VIEIRA et al., 2007). No studies on reproductive investment and fecundity of anuran assemblages of the Caatinga have been conducted.

Therefore, in this study we investigated some reproductive aspects of an anuran assemblage in an area of the Caatinga Domain, northeastern Brazil during two breeding seasons. The following hypotheses were investigated : 1) Is the relative number of explosive breeders (*sensu* WELLS, 1977) higher in the Caatinga of northeastern Brazil than that of anuran assemblages in other domains? 2) Is size-fecundity relationships and reproductive investment of frogs in Caatinga distinct from that of other Neotropical anuran assemblages? 3) Are there differences in reproductive investment among distinct reproductive modes, distinct reproductive strategies, and distinct phyllogenetic groups (among families)?

Materials and Methods

STUDY AREA DESCRIPTION AND FIELD WORK

The Planalto da Ibiapaba complex is a plateau where the westernmost fragments of wet tropical forest in the state of Ceará, Brazil are located (3°20'-5°00'S/40°42'-41°10'W). This complex borders the state of Piauí and comprises approximately 5,071 km^2 in the municipalities of Viçosa do Ceará, Tianguá, Ubajara, Ibiapina, São Benedito, Carnaubal, Guaraciaba do Norte, Croatá, and Ipu. The

stratigraphic formation is part of the sedimentary basin Maranhão-Piauí, with the lithology of the formation Serra Grande and soil with predominance of dystrophic marine quartz sands, red-yellow latosol, and dark-red latosol. The area is relatively close to the coast (73 km), has the lowest average annual temperatures (22-26°C), and the highest average annual rainfall of the state (São Benedito with 2,062.8 mm, Ibiapina with 1,744.6 mm and Ubajara with 1,441.1 mm) (BEZERRA et al., 1997).

The field work in the municipality of Ubajara was carried out during two reproductive seasons (2008/2009) in a semi-permanent pond located in the coordinates 03º50'46" S, 40º 53' 40" W, 850 m above sea level. The vegetation of this man-altered area consists of a sub-evergreen tropical cloud forest. Collections were carried out monthly throughout the year, and during the rainy season, the effort to find gravid females was increased with collections conducted at least two nights per week.

Clutches were obtained from amplexed pairs or estimated based on the number and size of mature ovarian eggs from gravid females caught in the field. Eggs in each clutch were counted (= clutch size) and the diameter of individual egg (up to 10 from each female) was measured to the nearest 0.1 mm with an ocular micrometer in a stereomicroscope Zeiss® Stemi SV 11 (0.6x to 6.6x zoom range). Snout-vent length (SVL) of gravid females was measured with a Starrett® 727 series digital caliper (scale graduation = 0.01 mm), body mass was obtained with a Bel Engineering® SSR-600 digital dynamometer (scale graduation = 0.01 g), and ovarian and body fat mass were obtained with an OHAUS® TS200 digital dynamometer (scale graduation = 0.001 g), after being blotted to remove excess liquid.

Collecting permits were issued by the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) (Processes 12545-1, 12545-2, and 13571-1). Specimens were deposited in the Célio F. B. Haddad amphibian collection (CFBH), Universidade Estadual Paulista "Julio de Mesquita Filho", Rio Claro campus, São Paulo, Brazil.

DATA ANALYSIS

In order to determine intra/interspecific size-fecundity relationships, data on gravid females were compared with a linear regression analysis (ZAR, 1999). The data used to calculate linear regressions and correlations were log-transformed. Intraspecific relationships between clutch size and female SVL, and clutch size and female body mass (body mass/ovary mass) were determined for the species with enough sample size ($n \geq 6$). Interspecific relationships between clutch size and female SVL, egg size and female SVL, ovary mass and female mass, and reproductive investment and female mass were compared among all species collected. We used ANOVA to determine if there were significant differences among the observed means in these relationships. Results were considered statistically significant at the level of $P<0.05$.

The reproductive investment (RI) was calculated based on the percentage of mature ovarian mass relative to body mass ($\sum \frac{xipi}{pi} \times \text{ovary mass}$). In order to try to refine the results of RI we categorized RI by family, reproductive period, and reproductive mode (aquatic eggs, aquatic foam nests, leaf tree eggs and leaf litter eggs, only). Due to the non-identical number of the samples among variables and the data not distributed normally, we performed a nonparametric variance

analysis (Kruskal-Wallis test) to compare our results, which were considered statistically significant at the level of $P<0.05$.

Results

SPECIES COMPOSITION, REPRODUCTIVE MODES, AND SIZE-FECUNDITY RELATIONSHIPS

The composition of the studied assemblage is represented by 23 species distributed into 15 genera and seven families, with eight different reproductive modes (*sensu* HADDAD & PRADO, 2005) (Table 1). However, to perform the analyses, we regrouped the species into four categories: 1) Aquatic eggs - species that lay their eggs in the bottom, columns or surface of the water without producing foam nests (modes 1 and 2 according to Haddad & Prado 2005). This category was represented by 60.9% of the species (*Dermatonotus muelleri*, *Pseudopaludicola* sp. (gr. *falcipes*), *Rhinella granulosa*, *Rhinella jimi*, *Odontophrynus carvalhoi*, *Proceratophrys cristiceps*, *Corythomanthis greeningi*, *Dendropsophus soaresi*, *Dendropsophus* sp. (gr. *microcephalus*), *Dendropsophus minutus*, *Dendropsophus nanus*, *Hypsiboas raniceps*, *Scinax* sp. (gr. *ruber*), and *Trachycephalus venulosus*); 2) Aquatic foam nests - species that deposited their eggs into foam nests on the surface of the water (modes 11 and 13 according to Haddad & Prado 2005), represented by 17.4% of the species (*Physalaemus cuvieri*, *Pleurodema diplolister*, *Leptodactylus macrosternum*, and *Leptodactylus vastus*); 3) Terrestrial eggs – species with direct or indirect development, with clutches deposited in burrows or leaf litter, and with eggs deposited in foam nests or not, but in contact with the forest floor in part or during the entire development (modes 23, 30, and 32 accordingly Haddad & Prado 2005), represented by 17.4%

of the species (*Pristimantis* sp., *Leptodactylus* sp. (aff. *andreae*), *Leptodactylus mystaceus*, *Leptodactylus troglodytes*); and 4) Arboreal eggs – species that deposit their eggs on the leaves of shrubs overhanging temporary or permanent ponds (mode 24 according to HADDAD & PRADO, 2005), represented by 4.35% of the species (*Phyllomedusa nordestina*). For the species with two reproductive modes, we considered the most frequently observed mode.

Based on the definition proposed by Crump (1974) and Wells (1977), explosive, prolonged, and continuous breeders were identified in the studied assemblage (Table 1). However, only *Odontophrynus carvalhoi* was considered a continuous breeder. Nonetheless, the relative abundance of *O. carvalhoi* producing advertisement calls was higher during the rainy season, especially from February to April. Twelve species (52.2%) were classified as explosive breeders and 10 (43.5%) were considered prolonged breeders (Table 1).

We obtained data on clutch and egg size for 180 females. Except for *Hypsiboas raniceps,* all species had at least one female collected and analyzed (see data in Table 2). Nevertheless, considering that the sample size for some species was small, intraspecific relationships between clutch size and female SVL and between clutch size and female body mass could only be determined for 11 species (see Table 3 and Fig. 1). For the species *Pristimantis* sp., *Dendropsophus soaresi*, *Dendropsophus* sp. (gr*. microcephalus*), *Trachycephalus venulosus*, *Pseudopaludicola* sp. (gr*. falcipes*), and *Leptodactylus mystaceus,* neither SVL nor body mass were significantly associated with clutch size. Body size and body mass was positively correlated with clutch size in *Rhinella granulosa*, *Phyllomedusa nordestina*, *Scinax* sp. (gr*. ruber*), and *Dermatonotus muelleri*. In *Physalaemus cuvieri*, SVL was not significantly associated with clutch size.

Interspecific size-fecundity relationships were also examined for all species sampled. Clutch size was positively correlated with female SVL for the compared species (r^2=0.67; P<0.001; n=22). *Phyllomedusa nordestina*, *Pristimantis* sp., *Leptodactylus mystaceus*, and *Leptodactylus troglodytes* exhibited smaller clutches than expected, while the species *Pleurodema diplolister*, *Scinax* sp. (gr. *ruber)*, *Rhinella granulosa*, and *Dermatonotus muelleri* exhibited larger clutches compared to the remaining species (Fig. 2).

Egg diameter also correlated positively with female SVL (r^2=0.19; P<0.043; n= 22). However, due to the large egg diameter of *P. nordestina* and *Pristimantis* sp., the correlation was not so strong. *Corythomanthis greeningi*, *Leptodactylus mystaceus*, and *Leptodactylus troglodytes* also presented eggs larger than expected and *Leptodactylus* sp. (aff. *andreae*) exhibited smaller egg sizes compared to the remaining species (Fig. 3).

REPRODUCTIVE INVESTMENT

We found a strong and positive correlation between ovary mass and female mass (r^2=0.88; n=22; p=0.000; Fig. 4), as most species had values within or close to the expected ones, except for *Leptodactylus vastus* and *Dermatonotus muelleri* (Fig. 4). The mean reproductive investment (RI = ovary mass/body mass %), including all species and reproductive modes, was 20.10±11.18 % (n=22), ranging from 1.15 % in *Leptodactylus vastus* to 51.56 % in *Dermatonotus muelleri* (Table 2). The linear regression analysis revealed a negative, but weak correlation between RI and female mass (r^2=0.04; n=22; Fig. 5). This result was strongly influenced by *Dendropsophus* sp. (gr*. microcephalus*), *P. nordestina*, *D. muelleri*, and *R. granulosa,*

which had RI much higher than expected, while *Leptodactylus* sp. (aff. *andreae*) and *L. vastus* had much lower RI values than expected (Fig. 5).

The reproductive investment was highly significant different for the seven families tested (Kruskal-Wallis, Chi-Square=62.15; df=6; p=0.000; n=177). Hylidae (21.8±9.9%), Bufonidae (23.9±6.3%), and Microhylidae (33.9±12.6%) were the families with the highest median values, while Leptodactylidae (8.0±5.2%), Leiuperidae (15.2±5.7%), and Strabomantidae (10.0±3.3%) were the families with the lowest values (Fig. 6a).

The mean values for species that have distinct reproductive periods were also highly significant among the three reproductive periods tested (Kruskal-Wallis, Chi-Square=32.99; df=2; p=0.000; n=177). For species that exhibit continuous reproductive modes, the mean RI was 25.3±19.5% (range=3.12-44.69%; n=4), for species with explosive reproductive modes, the mean RI was 22.7±10.4% (range=3.75-51.56%; n=115), and for species with prolonged reproductive modes, the mean RI was 14.62±10.1% (range=1.15-43.53%; n=58) (Fig. 6b).

Similarly to the previous categorizations, mean values for species that have distinct reproductive modes were also highly significant among the four reproductive modes tested (Kruskal-Wallis, Chi-Square=39.89; df=3; p=0.000; n=177). For species with aquatic eggs, the mean RI was 22.6±10.8% (range=3.12-51.56%; n=120), for species with aquatic foam nests, the mean RI was 13.6±6.5% (range=1.15-34.31%; n=28), for species that lay eggs on the leaf litter, the mean RI was 8.4±4.5% (range=1.53-15.6%; n=18), and for species that lay eggs on leaves of trees, the mean RI was 20.1±11.2% (range=11.63-43.53%; n=11) (Fig. 6c).

TABLE 1 – Reproductive modes, type of reproductive pattern (see further details in PRADO et al., 2005), and annual period of vocal activity from the 23 species of anurans recorded from Planalto da Ibiapaba, Ceará, Brazil. Reproductive modes *sensu* Haddad & Prado (2005).

Family/Species	Mode	Reproductive pattern	Months of vocal activity
STRABOMANTIDAE			
Pristimantis sp.	23	Prolonged	Dec-Apr
BUFONIDAE			
Rhinella granulosa	1	Explosive	Feb-Apr
Rhinella jimi	1	Prolonged	Oct-Nov
CYCLORAMPHIDAE			
Odontophrynus carvalhoi	1; 2	Continuous	Jan-Dec
Proceratophrys cristiceps	1; 2	Explosive	Feb-Apr
HYLIDAE			
Corythomanthis greeningi	1; 2	Prolonged	Feb-Apr
Dendropsophus soaresi	1	Explosive	Feb-Apr
Dendropsophus sp. (gr. *microcephalus*)	1; 24	Explosive *	Jan-Dec
Dendropsophus minutus	1	Explosive *	Jan-Dec
Dendropsophus nanus	1	Explosive *	Jan-Dec
Hypsiboas raniceps	1	Prolonged	Dec-Aug
Phyllomedusa nordestina	24	Prolonged	Jan-Apr
Scinax sp. (gr. *ruber*)	1	Explosive	Feb-Apr
Trachycephalus venulosus	1	Explosive	Feb-Mar
LEIUPERIDAE			
Physalaemus cuvieri	11	Prolonged	Jan-Jun
Pleurodema diplolister	11	Explosive	Feb-Mar
Pseudopaludicola sp. (gr. *falcipes*)	1	Explosive *	Jan-Dec
LEPTODACTYLIDAE			
Leptodactylus sp. (aff. *andreae*)	32	Prolonged	Feb-May
Leptodactylus macrosternum	11	Explosive	Feb-Apr
Leptodactylus mystaceus	30	Prolonged	Feb-Apr
Leptodactylus troglodytes	30	Prolonged	Jan-May
Leptodactylus vastus	11; 13	Prolonged	Nov-Jan
MICROHYLIDAE			
Dermatonotus muelleri	1	Explosive	Feb-Mar

* Species were considered explosive due to the fact that female with eggs are found in a restricted period of the year. However, males called during entire year.

TABLE 2. Mean±SD and range (in parenthesis) of the following parameters analyzed: female SVL and mass, ovary mass, clutch size (number of eggs per clutch), body fat mass, reproductive investment (RI), and egg diameter, for the anurans studied from the Planalto da Ibiapaba, state of Ceará, Brazil.

Family/Species	N	Female SVL (mm)	Female mass (g)	Ovary mass (g)	Clutch size	Body fat (g)	RI (%ovary/body)	Egg diameter (mm)
STRABOMANTIDAE								
Pristimantis sp.	13	31.15 ± 1.21	2.43 ± 0.48	0.25 ± 0.11	35 ± 9.4	0	10.0 ± 3.34	2.17 ± 0.33
		(28.0 - 33.0)	(1.45 - 3.27)	(0.08 – 0.44)	(21 - 53)		(4.82 – 15.65)	(1.0 – 2.9)
BUFONIDAE								
Rhinella granulosa	19	63.53 ± 5.21	35.26 ± 10.10	9.18 ± 2.79	11,473 ± 3,653	0.17 ± 0.3	25.97 ± 3.64	1.03 ± 0.1
		(53.0 – 71.0)	(21.08 – 62.59)	(4.01 – 14.44)	(5,034 – 17,828)	(0 – 0.82)	(16.91 – 32.88)	(0.8 – 1.3)
Rhinella jimi	5	182.96 ± 18.29	729.41 ± 266.29	76.69 ± 24.46	32,123 ± 7,503	24.15 ± 19.66	10.64 ± 0.57	1.65 ± 0.12
		165.0 – 201.6	(456.00 – 988.00)	(50.39 – 98.74)	(24,495 – 39,496)	(4.92 – 44.22)	(9.99 – 11.05)	(1.4 – 1.8)
CYCLORAMPHIDAE								
Odontophrynus carvalhoi	4	58.50 ± 2.65	29.04 ± 5.60	8.16 ± 7.02	2,628 ± 1681	0.18 ± 0.01	25.30 ± 19.52	1.34 ± 0.34
		(55.0-61.0)	(23.30 – 34.60)	(0.73 – 15.46)	(628 – 4695)	(0.17 – 0.19)	(3.12 – 44.69)	(0.5 – 2.0)
Proceratophrys cristiceps	4	56.85 ± 4.40	33.65 ± 10.20	4.41 ± 3.62	2,243 ± 1,402	0.33 ± 0.36	11.73 ± 6.50	1.26 ± 0.63
		(54.0 – 63.4)	(24.79 – 48.36)	(0.93 – 9.50)	(1227 – 4318)	(0 – 0.83)	(3.75 – 19.64)	(0.1 – 1.9)
HYLIDAE								
Corythomanthis greeningi	3	77.02 ± 6.59	29.96 ± 1.46	4.62 ± 1.15	1,458 ± 150	0	15.38 ± 3.35	1.93 ± 0.08
		(71.0 – 84.1)	(28.4 - 31.29)	(3.67 - 5.90)	(1310 – 1609)		(12.15 - 18.84)	(1.8- 2.0)
Dendropsophus soaresi	10	27.07 ± 1.49	2.01 ± 0.38	0.35 ± 0.17	465 ± 123	0.01 ± 0.01	16.77 ± 5.83	0.92 ± 0.15
		(29.8 – 33.0)	(1.43 – 2.63)	(0.13 – 0.67)	(206 – 581)	(0 - 0.03)	(8.87 – 25.48)	(0.4 – 1.2)
Dendropsophus sp. (gr. *microcephalus*)	9	20.49 ± 0.58	0.60 ±0.12	0.21 ± 0.002	256 ± 68	0	36.31 ± 6.93	0.92 ± 0.11
		(19.6 – 21.3)	(0.44-0.79)	(0.207 – 0.213)	(136 – 385)		(26.97 – 48.50)	(0.7 – 1.2)
Dendropsophus minutus	4	22.13 ± 1.84	1.06 ± 0.20	0.22 ± 0.06	290 ± 91	0	20.34 ± 2.52	1.02 ± 0.1
		(20.0 – 24.5)	(0.89 – 1.32)	(0.16 – 0.29)	(225 – 424)		(17.63 – 22.70)	(0.9 – 1.4)

Dendropsophus nanus	1	24.90	1.07	0.22	402	0	20.58	
Phyllomedusa nordestina	11	37.50 ± 1.91	4.57 ± 1.00	1.15 ± 0.46	105 ± 43	0.04 ± 0.1	14.54 ± 2.61	2.57 ± 0.49
		(36.0 – 40.0)	3.75 – 5.89	(0.49 – 1.72)	(66-228)	(0 – 0.2)	(11.64 – 16.90)	(1.5 – 3.2)
Scinax sp. (gr. *ruber*)	23	37.16 ± 2.38	5.16 ± 1.20	1.17 ± 0.5	1,596 ± 448	0.05 ± 0.04	21.80 ± 5.65	1.01 ± 0.1
		(33.0 – 42.0)	(3.17 – 7.55)	(0.39 – 2.16)	(807 – 2410)	(0 - 0.15)	(10.67 – 29.60)	(0.8 – 1.3)
Trachycephalus venulosus	14	77.50 ± 6.44	40.67 ± 9.61	5.24 ± 2.78	3,802 ± 1,892	0.18 ± 0.19	12.61 ± 4.76	1.18 ± 0.21
		(64.0 – 88.0)	(24.80 – 61.89)	(2.43 – 11.45)	(1,230 – 7,253)	(0.03 – 0.8)	(6.13 – 24.68)	(0.7 – 1.7)
LEIUPERIDAE								
Physalaemus cuvieri	14	29.92 ± 1.73	2.53 ± 0.29	0.40 ± 0.21	662 ± 258	0.01 ± 0.01	15.58 ± 6.72	0.96 ± 0.13
		(28.0 – 33.0)	(2.21 – 2.99)	(0.18 – 0.95)	(282 - 1110)	(0 - 0.04)	(7.93 – 34.31)	(0.4 – 1.2)
Pleurodema diplolister	3	32.00 ± 1.73	5.74 ± 1.24	1.07 ± 0.3	967 ± 395	0	18.73 ± 4.11	1.06 ± 0.1
		(31.0 – 34.0)	(4.40 – 6.83)	(0.79 – 1.39)	(556 – 1344)		(15.07 – 23.17)	(0.8 – 1.2)
Pseudopaludicola sp. (gr. *falcipes*)	8	14.56 ± 0.50	0.26 ± 0.02	0.035 ± 0.010	97 ± 24	0	13.15 ± 3.58	0.72 ± 0.15
		(14.0-15.0)	(0.22 – 0.30)	(0.011 – 0.044)	(48 – 131)		(4.64 – 15.53)	(0.3 – 1.0)
LEPTODACTYLIDAE								
Leptodactylus sp. (aff. *andreae*)	4	20.00 ± 1.83	0.86 ± 0.20	0.02 ± 0.00	81 ± 17	0	2.17 ± 0.71	0.41 ± 0.22
		(18.0 – 22.0)	(0.67 – 1.05)	(0.01 – 0.02)	(60 – 98)		(1.53 – 3.13)	(0.1 – 0.9)
Leptodactylus macrosternum	3	81.50 ± 3.54	57.97 ± 10.35	5.99 ± 0.61	5,219 ± 698	0.83 ± 1.17	10.40 ± 0.80	1.30 ± 0.1
		(79.0 - 84.0)	(50.65 – 65.29)	(5.55 – 6.42)	(4,725 – 5,714)	(0 - 1.66)	(9.83 – 10.96)	(1.1 – 1.4)
Leptodactylus mystaceus	6	47.67 ± 1.37	12.11 ± 2.24	1.47 ± 0.22	351 ± 62	0.16 ± 0.14	12.47 ± 2.80	2.04 ± 0.37
		46.0 – 50.0)	(10.34 – 16.11)	(1.28 – 1.90)	(284 – 431)	(0 – 0.45)	(7.92 – 15.27)	(1.0 – 2.9)
Leptodactylus troglodytes	1	48	15.70	2.09	479	0.88	13.30	1.98 ± 0.04
								(1.9 – 2.0)
Leptodactylus vastus	3	126.0 ± 19.57	204.85 ± 164.21	4.95 ± 2.19	2,439 ± 754	0.96 ± 1.66	3.44 ± 2.63	1.29 ± 0.39
		(114.4 – 148.6)	(104.4 – 394.35)	(2.99 – 7.31)	(1595 - 3045)	(0 – 2.87)	(1.15 – 6.31)	(0.4 – 1.9)
MICROHYLIDAE								
Dermatonotus muelleri	18	69.74 ± 6.64	51.14 ± 13.35	17.65 ± 8.79	7,727 ± 2,445	0.58 ± 0.58	33.97 ± 12.57	1.15 ± 0.1
		(59.6 – 80.3)	(28.38 - 78.85)	(4.21 – 32.44)	(3,597 – 11,702)	(0 – 2.17)	(14.62 – 51.56)	(0.8 – 1.4)

TABLE 3. Linear regression analysis between female SVL and clutch size and female body mass and clutch size for the anurans studied from the Planalto da Ibiapaba, state of Ceará, Brazil. Significant results in bold.

Family/Species	**N**	**Log SLV +1 (mm) vs Log Clutch size +1**	**Log body mass +1 (g) vs Log Clutch size +1**
STRABOMANTIDAE			
Pristimantis sp.	13	r^2 = 0.0044; p = 0.8298; y = 1.4914 + 0.0101*x	r^2 = 0.1807; p = 0.1476; y = 0.1468 + 0.2488*x
BUFONIDAE			
Rhinella granulosa	19	**r^2 = 0.4336; p = 0.0022; y = 1.1495 + 0.1632*x**	**r^2 = 0.5812; p = 0.0001; y = -0.9696 + 0.6225*x**
HYLIDAE			
Dendropsophus soaresi	10	r^2 = 0.0324; p = 0.6189; y = 1.4194 + 0.0256*x	r^2 = 0.3488; p = 0.0722; y = -0.1011 + 0.2178*x
Dendropsophus sp. (gr. *microcephalus*)	9	r^2 = 0.2774; p = 0.1452; y = 1.2122 + 0.05*x	r^2 = 0.1607; p = 0.2850; y = -0.0384 + 0.1008*x
Phyllomedusa nordestina	11	**r^2 = 0.6876; p = 0.0016; y = 1.3762 + 0.1025*x**	**r^2 = 0.7210; p = 0.0009; y = 0.0912 + 0.3068*x**
Scinax sp. (gr. *ruber*)	23	**r^2 = 0.4788; p = 0.0003; y = 1.1283 + 0.1421*x**	**r^2 = 0.6659; p = 0.00002; y = -0.9238 + 0.5353*x**
Trachycephalus venulosus	14	r^2 = 0.0185; p = 0.6428; y = 1.8211 + 0.0206*x	r^2 = 0.1017; p = 0.2665; y = 1.1401 + 0.1331*x
LEIUPERIDAE			
Physalaemus cuvieri	14	r^2 = 0.1428; p = 0.1829; y = 1.3526 + 0.0492*x	**r^2 = 0.3101; p = 0.0386; y = 0.2481 + 0.1068*x**
Pseudopaludicola sp. (gr. *falcipes*)	8	r^2 = 0.1554; p = 0.3338; y = 1.2774 - 0.0432*x	r^2 = 0.2826; p = 0.1751; y = 0.0313 + 0.0355*x
LEPTODACTYLIDAE			
Leptodactylus mystaceus	6	r^2 = 0.1910; p = 0.3861; y = 1.5109 + 0.0693*x	r^2 = 0.0554; p = 0.6534; y = 0.5626 + 0.2166*x
MICROHYLIDAE			
Dermatonotus muelleri	18	**r^2 = 0.3593; p = 0.0086; y = 1.2063 + 0.166*x**	**r^2 = 0.5444; p = 0.0005; y = -0.5849 + 0.5918*x**

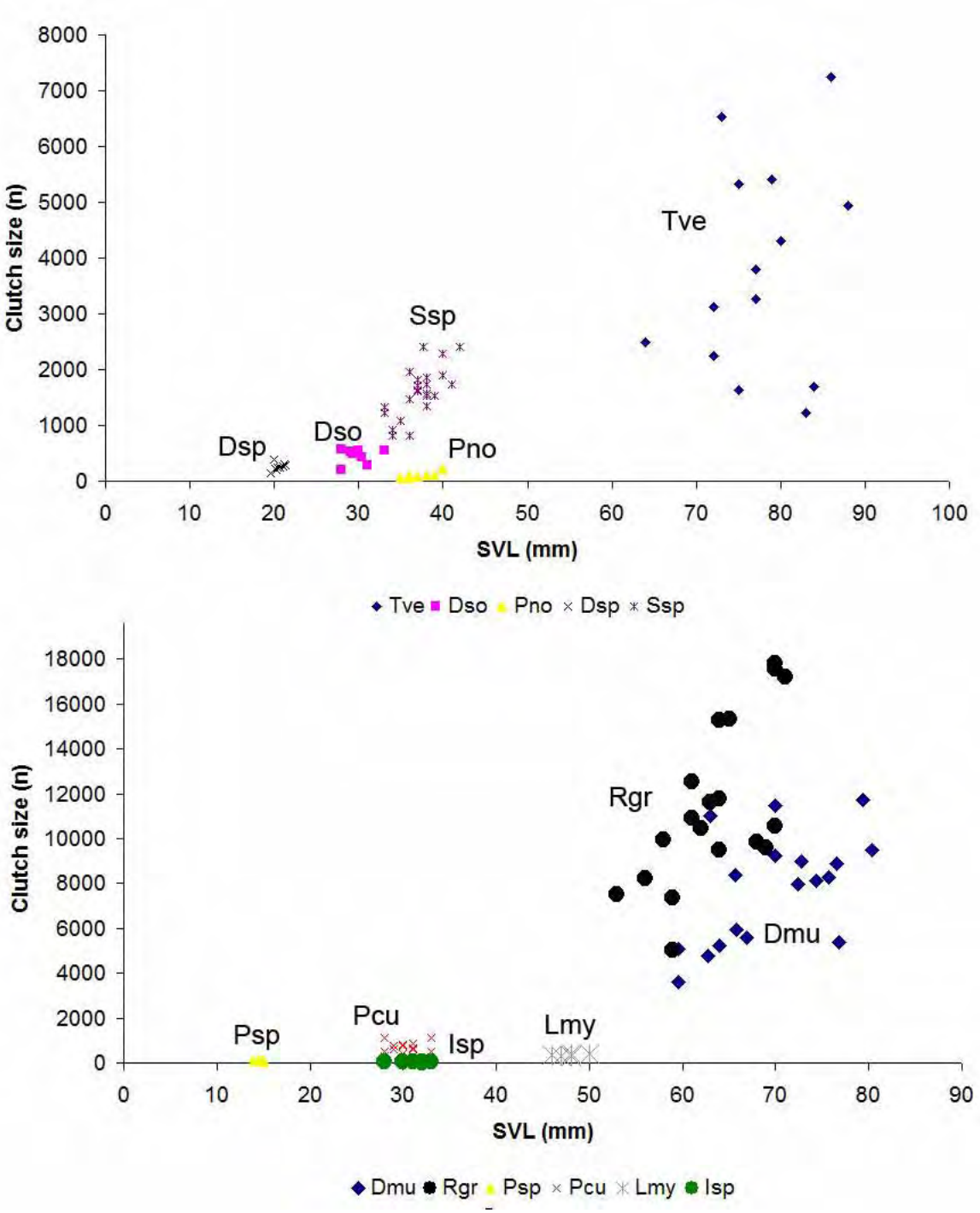


FIGURE 1 - Relationship between clutch size and female SVL for the 11 most abundant anuran species in the Planalto da Ibiapaba. Species: (Dso) *Dendropsophus soaresi*; (Dsp) *Dendropsophus* sp. (gr. *microcephalus*); (Dmu) *Dermatonotus muelleri*; (Isp) *Pristimantis* sp.; (Lmy) *Leptodactylus mystaceus*; (Pno) *Phyllomedusa nordestina*; (Pcu) *Physalaemus cuvieri*; (Psp) *Pseudopaludicola* sp. (gr. *falcipes*); (Rgr) *Rhinella granulosa*; (Ssp) *Scinax* sp. (gr. *ruber*); and (TVe) *Trachycephalus venulosus*. Note that correlation for the species with less than 35 mm of maximum SVL is low (see Table 3).

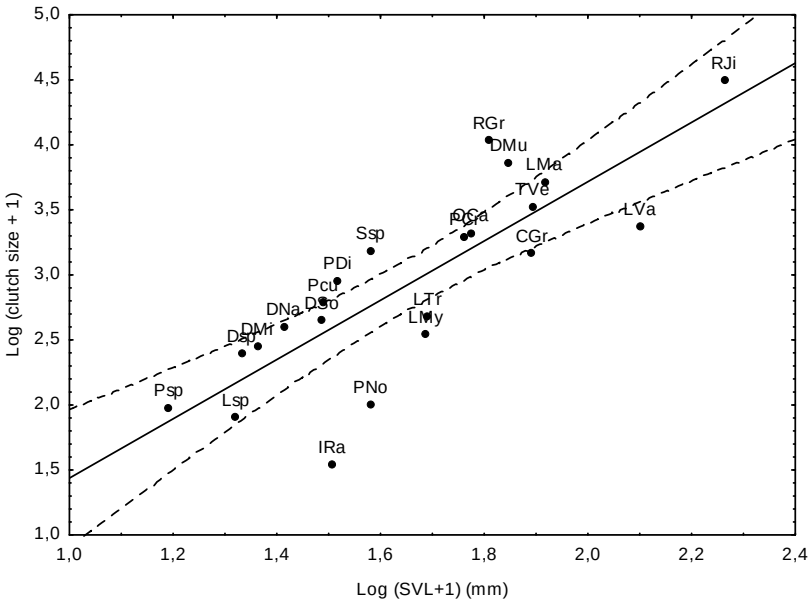


FIGURE 2. Relationship between mean log female SVL +1 and mean log clutch size +1 for 22 anuran species in the Planalto da Ibiapaba (log y = -0.8422 + 2.2794 log x). Species: (CGr) *Corythomanthis greeningi*; (DSo) *Dendropsophus soaresi*; (Dsp) *Dendropsophus* sp. (gr*. microcephalus*); (DMi) *Dendropsophus minutus*; (DNa) *Dendropsophus nanus*; (DMu) *Dermatonotus muelleri*; (IRa) *Pristimantis* sp.; (Lsp) *Leptodactylus* sp. (aff. *andreae*); (LMa) *Leptodactylus macrosternum*; (LMy) *Leptodactylus mystaceus*; (LTr) *Leptodactylus troglodytes*; (LVa) *Leptodactylus vastus*; (OCa) *Odontophrynus carvalhoi*; (PCr) *Proceratophrys cristiceps*; (PNo) *Phyllomedusa nordestina*; (Pcu) *Physalaemus cuvieri*; (PDi) *Pleurodema diplolister*; (Psp) *Pseudopaludicola* sp. (gr. *falcipes*); (RGr) *Rhinella granulosa*; (RJi) *Rhinella jimi*; (Ssp) *Scinax* sp. (gr. *ruber*); and (TVe) *Trachycephalus venulosus*. Curved lines represent 95% confidence interval.

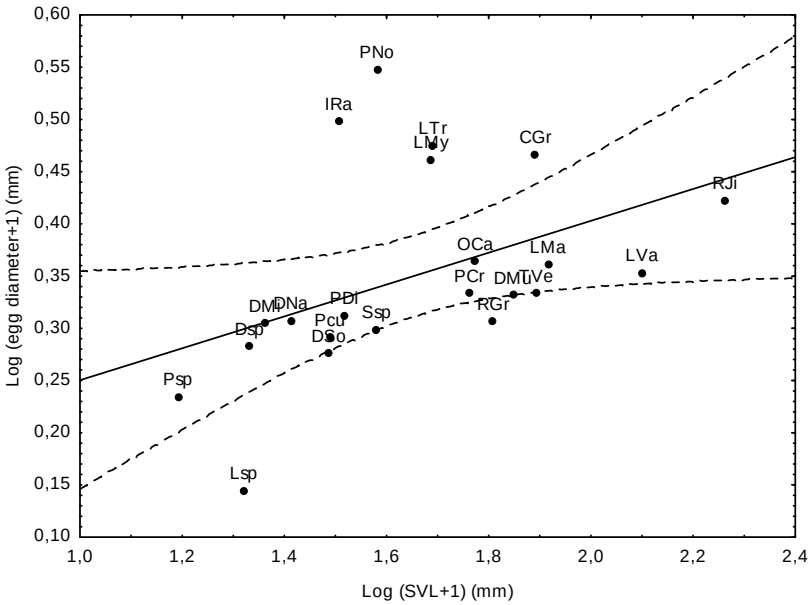


FIGURE 3. Relationship between mean log female SVL +1 and mean log egg diameter +1 for 22 anuran species in the Planalto da Ibiapaba (log y = 0.0978 + 0.1525 log x). Species: (CGr) *Corythomanthis greeningi*; (DSo) *Dendropsophus soaresi*; (Dsp) *Dendropsophus* sp. (gr. *microcephalus*); (DMi) *Dendropsophus minutus*; (DNa) *Dendropsophus nanus*; (DMu) *Dermatonotus muelleri*; (IRa) *Pristimantis* sp.; (Lsp) *Leptodactylus* sp. (aff. *andreae*); (LMa) *Leptodactylus macrosternum*; (LMy) *Leptodactylus mystaceus*; (LTr) *Leptodactylus troglodytes*; (LVa) *Leptodactylus vastus*; (OCa) *Odontophrynus carvalhoi*; (PCr) *Proceratophrys cristiceps*; (PNo) *Phyllomedusa nordestina*; (Pcu) *Physalaemus cuvieri*; (PDi) *Pleurodema diplolister*; (Psp) *Pseudopaludicola* sp. (gr. *falcipes*); (RGr) *Rhinella granulosa*; (RJi) *Rhinella jimi*; (Ssp) *Scinax* sp. (gr. *ruber*); and (TVe) *Trachycephalus venulosus*. Curved lines represent 95% confidence interval.

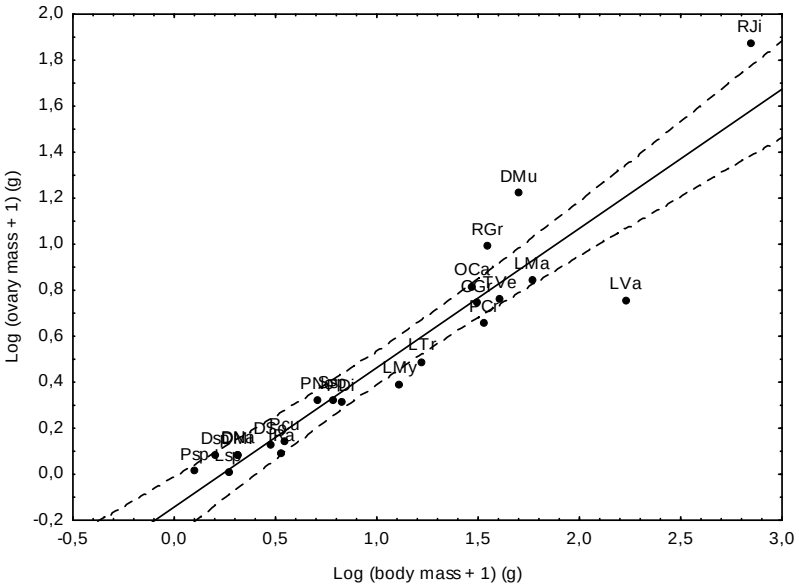


FIGURE 4. Relationship between mean log female body mass +1 and mean log ovary mass +1 for 22 anuran species in the Planalto da Ibiapaba (log y = -0.142 + 0.6053 log x). Species: (CGr) *Corythomanthis greeningi*; (DSo) *Dendropsophus soaresi*; (Dsp) *Dendropsophus* sp. (gr. *microcephalus*); (DMi) *Dendropsophus minutus*; (DNa) *Dendropsophus nanus*; (DMu) *Dermatonotus muelleri*; (IRa) *Pristimantis* sp.; (Lsp) *Leptodactylus* sp. (aff. *andreae*); (LMa) *Leptodactylus macrosternum*; (LMy) *Leptodactylus mystaceus*; (LTr) *Leptodactylus troglodytes*; (LVa) *Leptodactylus vastus*; (OCa) *Odontophrynus carvalhoi*; (PCr) *Proceratophrys cristiceps*; (PNo) *Phyllomedusa nordestina*; (Pcu) *Physalaemus cuvieri*; (PDi) *Pleurodema diplolister*; (Psp) *Pseudopaludicola* sp. (gr. *falcipes*); (RGr) *Rhinella granulosa*; (RJi) *Rhinella jimi*; (Ssp) *Scinax* sp. (gr. *ruber*); and (TVe) *Trachycephalus venulosus*. Curved lines represent 95% confidence interval.

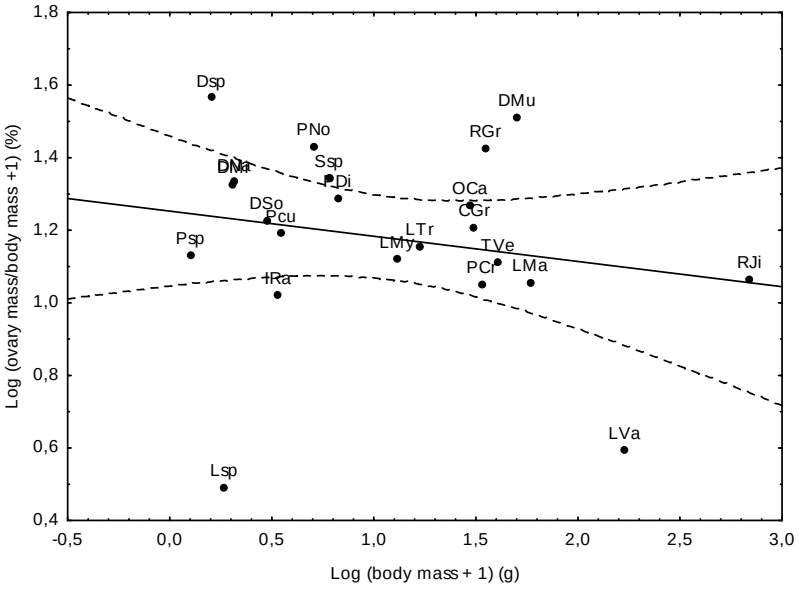


FIGURE 5. Relationship between mean log female body mass +1 and mean log ovary mass/body mass +1 (reproductive investment) for 22 anuran species in the Planalto da Ibiapaba (log y = 1.2528 - 0.0694 log x). Species: (CGr) *Corythomanthis greeningi*; (DSo) *Dendropsophus soaresi*; (Dsp) *Dendropsophus* sp. (gr. *microcephalus*); (DMi) *Dendropsophus minutus*; (DNa) *Dendropsophus nanus*; (DMu) *Dermatonotus muelleri*; (IRa) *Pristimantis* sp.; (Lsp) *Leptodactylus* sp. (aff. *andreae*); (LMa) *Leptodactylus macrosternum*; (LMy) *Leptodactylus mystaceus*; (LTr) *Leptodactylus troglodytes*; (LVa) *Leptodactylus vastus*; (OCa) *Odontophrynus carvalhoi*; (PCr) *Proceratophrys cristiceps*; (PNo) *Phyllomedusa nordestina*; (Pcu) *Physalaemus cuvieri*; (PDi) *Pleurodema diplolister*; (Psp) *Pseudopaludicola* sp. (gr. *falcipes*); (RGr) *Rhinella granulosa*; (RJi) *Rhinella jimi*; (Ssp) *Scinax* sp. (gr. *ruber*); and (TVe) *Trachycephalus venulosus*. Curved lines represent 95% confidence interval.

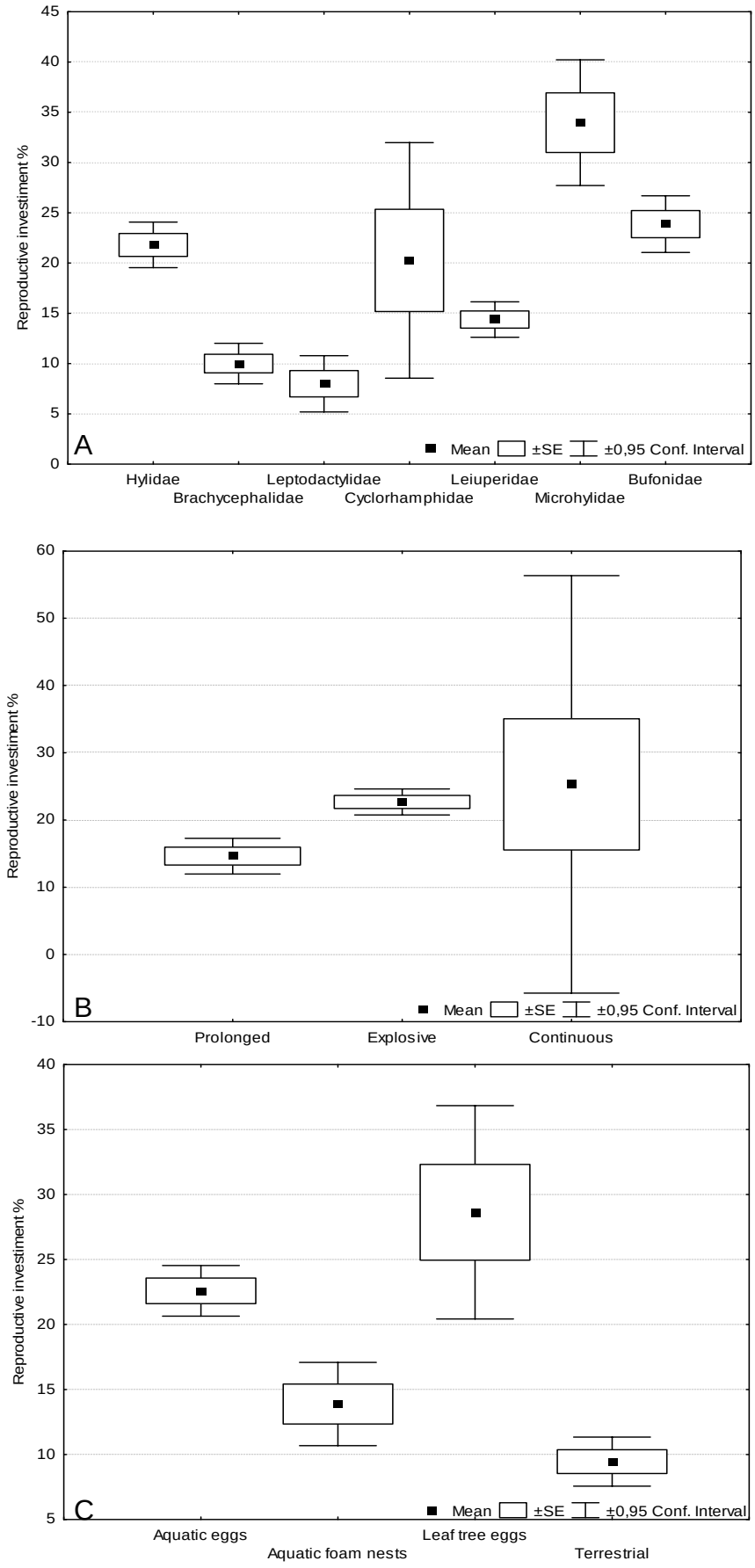


FIGURE 6 – Reproductive investment categorized by box plots. A) Families, B) Reproductive periods, and C) Reproductive modes. Planalto da Ibiapaba, state of Ceará, Brazil.

Discussion

SPECIES COMPOSITION, REPRODUCTIVE MODES, AND SIZE-FECUNDITY RELATIONSHIPS

The composition of the anuran assemblage in the permanent pond studied is composed of 23 of the 35 species of amphibians inhabiting the Planalto da Ibiapaba complex, and representing 65.7% of amphibians in the region and approximately 45.1% of the amphibians found in Ceará state (LOEBMANN & HADDAD, 2010). Except for *Pristimantis* sp., all species are typical of open areas and most of them is widely distributed in the Caatinga domain. In addition, seven of the eight anuran families found in Ceará state are represented in this assemblage (only Pipidae was not recorded). Considering that Ceará is entirely inserted in the Caatinga, we believe that the results presented here are a good representation of the reproductive strategies of the anurans inhabiting this ecosystem.

The reproductive season of anurans has been studied in several communities in the Neotropical region (e.g. CRUMP, 1974; PEROTTI, 1997; POMBAL, 1997; ARZABE et al., 1998; ARZABE, 1999; BERNARDE & MACHADO, 2001; BERTOLUCCI & RODRIGUES, 2002; TOLEDO et al., 2003; GRANDINETTI & JACOBI, 2005; POMBAL & HADDAD, 2005; PRADO & HADDAD, 2005; PRADO et al., 2005; VASCONCELOS & ROSSA-FERES, 2005; BERNARDE, 2007; VIEIRA et al., 2007; ZINA et al., 2007). According to Wells (1977), prolonged breeding is the most common pattern observed in anurans. In fact, the literature shows a strong bias toward prolonged reproductive activity in amphibian assemblages, indicating that this is the most common pattern, specially in tropical rainforests (see BERTOLUCCI & RODRIGUES, 2002; GOTTSBERGER & GRUBER, 2004; POMBAL & HADDAD, 2005; BERNARDE 2007). Even in open areas of higher latitudes with

markedly seasonal rainfall, the number of explosive breeders is lower than that of prolonged breeders ranging from 33 to 37% (PEROTTI, 1997; PRADO & HADDAD, 2005). Therefore, the studied assemblage, with 52.2% of explosive breeders and 43.5% of prolonged breeders, has a distinct pattern of reproduction compared with that of other anuran assemblages in the Neotropical region. This result supports our first hypothesis that in the Caatinga, the number of explosive breeders is higher than that of prolonged breeders.

On the other hand, other studies in the Caatinga domain have reported a predominance of prolonged breeders over explosive breeders (ARZABE, 1999; VIEIRA et al., 2007). There are some explanations for this divergence of results: 1) Like the majority of studies reported in the literature, Arzabe (1999) and Vieira et al. (2007) considered that the reproductive period of a species is the period when males are calling. Undoubtedly this is the easiest method to determine the reproductive season. However, in some species that reproduce during a short period of the year in the Caatinga - usually in the first heavy rains of the rainfall season (LOEBMANN & HADDAD, *in prep*) – males call for several months. 2) Some species have the plasticity to change their reproductive strategies according to the environmental conditions. Whereas some species are typically explosive breeders (e.g. *Dermatonotus muelleri*, *Trachycephalus venulosus*, and *Rhinella granulosa*), others can change their reproductive strategies. *Pleurodema diplolister*, for example, has been considered an explosive breeder (CARDOSO & ARZABE, 1993; VIEIRA et al., 2007). However, in years with precipitation levels higher than expected, this species is able to reproduce during three consecutive months (LOEBMANN & HADDAD, *in prep*). 3 – Insufficient sampling effort. The probability to find explosive breeders in the field is lower than that of prolonged breeders,

especially those with fossorial behavior. Therefore, if the experimental design is inadequate to find species with a short reproductive season, which is a common pattern for species in the Caatinga (e.g. *Ceratophrys joazeirensis*, *Dendropsophus soaresi*, *Physalaemus albifrons*, *Trachycephalus venulosus*), some of these species might not be observed. Consequently, the percentage of prolonged breeders tend to be higher than it is in a given sampled assemblage.

Continuous breeders (*sensu* CRUMP, 1974), nevertheless, seem to have a similar pattern regardless of the environment and/or latitude studied, i.e., in all cases reported in the literature this strategy is rare or nonexistent in anuran assemblages. In fact, this is unexpected for most species, given the seasonal changes in the environment regarding food availability (CRUMP, 1982; GALATTI, 1992), rainy season and annual temperature (e.g. BLAIR, 1961; AICHINGER, 1987; CARDOSO & MARTINS, 1987; CRUMP & PONDS, 1989; DONNELLY & GUYERR, 1994), partition of space acoustic, male calling sites, microhabitats, and oviposition sites (LITTLEJOHN, 1959; CRUMP, 1974; CRUMP, 1982; DUELLMAN & PYLES 1983; ROSSA-FERES & JIM, 2001, BERTOLUCCI & RODRIGUES, 2002; SILVA et al., 2008), and the energy allocated to reproduction (reproductive investment) among egg and sperm production, courtship, searching, attraction, vocalization, territoriality, fighting, parental care, frequency of breeding, and nest-building (CRUMP, 1974; WELLS, 2007).

Interspecific size-fecundity relationships for the species found in the Caatinga can be characterized by the combination of the following patterns: 1) Species with large females tend to produce more eggs (less evident in some species with explosive behavior and with non-aquatic eggs); 2) In species with aquatic

eggs, there is a high correlation between female size and eggs diameter, while in species with terrestrial eggs, this correlation in unclear.

A positive correlation between fecundity and female size is expected for cold-blooded vertebrates (RENSCH, 1960), including amphibians (DUELLMAN, 1989). This trend seems to occur regardless of the type of environment. In South America, for example, similar results have been found for amphibians in the Ecuadorian Amazon rainforest (CRUMP, 1974), Argentinian Chaco (PEROTTI, 1997), and Pantanal floodplain in Brazil (PRADO & HADDAD, 2005). Therefore, our findings corroborate previous studies. However, although interspecific size-fecundity relationships show expected values for most of the study species, intraspecific size-fecundity relationships for the 11 species with larger sample size exhibited an unexpected pattern compared to those of other studies (e.g. BERVEN, 1988; LEMCKERT & SHINE, 1993; LÜDDECKE, 2002; PRADO & HADDAD, 2005): six of the 11 species have significant correlations between SVL and body mass with clutch size. Furthermore, even species with significant differences among means had low correlation coefficients of size-fecundity. A possible explanation is the life expectancy for most species. Smaller species (up to 35 mm SVL), such *Pristimantis* sp., *Dendropsophus soaresi*, *Dendropsophus* sp. (gr. *microcephalus*), *Physalaemus cuvieri*, and *Pseudopaludicola* sp. (gr. *Falcipes*), might live one year or at least are able to reproduce once. Therefore, when females are sexually mature to reproduce, size and weight are relatively constant among them and both variables do not explain much of the variation in clutch size. Larger species, such as *Rhinella granulosa*, *Phyllomedusa nordestina*, *Scinax* sp. (gr. *ruber*), and *Dermatonotus muelleri*, on the other hand, are able to reproduce for some years and, consequently, younger females tend to produce smaller clutches than older ones.

Nonetheless, this assumption does not support the non-significant results found for *Trachycephalus venulosus* and *Leptodactylus mystaceus*.

Estimates of anuran lifespan, especially in natural conditions and for tropical species, are still needed and the factors involved should be carefully investigated Although the data available in the literature for Neotropical species are scarce, there are some evidences that even relatively large tropical anurans have high rates of mortality due to predation (WELLS, 2007). For instance, a mark-recapture study conducted with *Hypsiboas rosenbergi* reported that the frogs probably die few months after males enter the breeding chorus (KLUGE, 1981). Galatti (1992) demonstrated that approximately 80% of juveniles of *Leptodactylus pentadactylus* die before completing the age of one year in Central Amazonia. Physical factors can influence the survival rates in anurans. In tropical savannas, adults of some small species have difficulty surviving during the severe dry season (GEISE & LISENMAIR, 1986; RÖDEL, 1996).

Within a given reproductive mode, a positive correlation is expected between clutch size and egg size (DUELLMAN & TRUEB, 1986). However, the number of laid eggs tends to decrease while egg size increases when all reproductive modes are included, from the most general aquatic to the most terrestrial mode (SALTHE & DUELLMAN, 1973; CRUMP, 1974; DUELLMAN & TRUEB, 1986). In the present study, the correlation found between egg diameter and female SVL was lower in comparison with those of other studies (CRUMP, 1974; PEROTTI, 1997; PRADO & HADDAD, 2005). Undoubtedly, this result was influenced by the high proportion of terrestrial breeders (which have usually larger eggs as mentioned above) in comparison with previous studies. Also, the regression analysis performed in the present study did not distinguished

terrestrial from aquatic breeders as earlier studies did (CRUMP, 1974; PEROTTI, 1997). *Corythomanthis greeningi* was the only species with aquatic eggs larger than expected. A possible explanation is the behavior of the species that lays eggs frequently in flowing water. A similar result was found by Lang (1995) that studied stream-breeding hylids and found that all stream-breeding species had relatively large eggs, probably associated with the flowing water in these habitats. According to Prado & Haddad (2005), *Phyllomedusa azurea*, *Leptodactylus* cf. *diptyx*, and *Leptodactylus fuscus* have smaller clutches and larger eggs compared to species with more aquatic modes (aquatic eggs and aquatic foam nests). We found similar results for species in the same taxonomic group in Caatinga (*Phyllomedusa nordestina*, *Leptodactylus mystaceus*, and *Leptodactylus troglodytes*).

REPRODUCTIVE INVESTMENT

The reproductive investment for the studied species can be characterized by the combination of the following patterns: 1) Ovarian mass tends to increase proportionally with females mass; 2) the ovary mass/body mass ratio is highly variable and poorly correlated with female mass; 3) each anuran family has different strategies of reproductive investment; 4) reproductive investment in explosive breeders is higher than in prolonged breeders and highly variable in continuous breeders; and 5) the strategies to invest in reproduction are also significantly different for the main reproductive modes.

Considering all size-fecundity relationships analyzed in this study, the relationship between ovarian mass and females mass is the most highly correlated and, therefore, is the best indirect method to determine clutch size. This was also

found for other anuran assemblages (e.g. CRUMP, 1974; LANG, 1995; PRADO et al., 2000).

Reproductive investment was highly variable ranging from 1.15 to 51.56 % but it was poorly correlated with female mass, regardless of the reproductive period or reproductive mode. The range of RI values found in the present study is wider when compared with those found for anurans of the Amazon rainforest (RI = 3.1 to 18.2%; Crump, 1974) and Pantanal flood plain (RI = 5.5 to 18%; PRADO & HADDAD, 2005).

According to Wells (2007), the type of reproductive mode does not appear to have much effect on the energetic investment that females make in each clutch of eggs, rather it alters the way in which energy is partitioned. In fact, studies have demonstrated this tendency (CRUMP, 1974; PRADO & HADDAD, 2005). However, our results do not support this hypothesis since significant differences were found among reproductive investment strategies and reproductive modes, i.e., species that deposit their eggs directly in the water or on leaves of shrubs (only *Phyllomedusa nordestina* in our case) invest more in ovaries than species that produce aquatic foam nests as well as species that lay their eggs in the leaf litter.

Significant differences among prolonged, continuous, and explosive breeders were also identified. Explosive breeders invest more in ovaries than prolonged breeders, this was the case of *Dendropsophus* sp. (gr. *microcephalus*), *Rhinella granulosa*, and *Dermatonotus muelleri*. Continuous breeders, represented only by *Odontophrynus carvalhoi*, had high variable RI values, which could be due to two reasons: First, the number of samples was low and certainly influenced the results. On the other hand, a range of RI values among continuous breeders is

expected, because species might breed several times a year (WELLS, 2007). Thus, for this type of strategy, the annual RI is difficult to be estimated.

Several authors have pointed out that simultaneous occurrence of more than one size of oocyte in the ovaries of females frogs is an indication of prolonged breeding (e.g. CHURCH, 1960; CRUMP, 1974; BARBAULT & RODRIGUES 1978a; b; BARBAULT & RODRIGUES, 1979 a; b; BARBAULT & PILORGE, 1980; DONNELLY, 1989; KYRIAKOPOULOU-SKLAVOUNOU & LOUMBOURDIS, 1990; SILVERIN & ANDREN, 1992). While this generalization is reasonable, it should be carefully interpreted. For instance, we examined six clutches of *Phyllomedusa nordestina* and all of then contained large fertilized eggs and small eggs unfertilized at a ratio of approximately 1:5. Females might lay unfertilized eggs so that tadpoles can eat them after hatching. Oophagy has not been in Phylomedusinae, but it occurs in other species such *Leptodactylus fallax* (GIBSON & BULEY, 2004). This might be a strategy of the species to survive the extreme environmental conditions of the Caatinga.

FINAL REMARKS

This is the first study on reproductive strategies in the Caatinga Domain and presents new approaches for Neotropical anurans. The composition of an anuran assemblage in an ephemeral pond was composed of 23 species, mostly explosive breeders. This is an unexpected pattern if compared with other anuran assemblages observed in the Neotropical region.

Interspecific size-fecundity relationships for the studied species show that large females tend to produce more eggs and species with aquatic eggs present a strong correlation between female size and eggs diameter. Species with terrestrial

reproductive modes tend to produce larger eggs and smaller clutches than species with aquatic reproductive modes.

The reproductive investment can be mainly characterized by the combination of the following patterns: 1) Ovarian mass tend to increase proportionally with female mass; 2) ovary mass/body mass ratio is highly variable and poorly correlated with female mass; 3) the strategies to invest in reproduction are different among families, between explosive and prolonged breeders, as well as among reproductive modes.

Acknowledgments

The authors are grateful to Daniel do Nascimento Lima for helping during the field work. Fundação O Boticário de Proteção a Natureza (proc. 0776_20081), FAPESP (proc. 2008/50928-1) and CNPq, supported this research. Daniel Loebmann was supported by grant no. 140226/2006-0 from CNPq.

References

AB'SABER A. N. Os domínios morfoclimáticos na América do Sul. Primeira aproximação. **Geomorfologia**, São Paulo, v. 52, p. 1-21, 1977.

AICHINGER, M. Annual activity patterns of anurans in a seasonal Neotropical environment. **Oecologia**, Berlim, v. 71, p. 583-592, 1987.

ANDRADE-LIMA, D. Present-day forest refuges in Northeastern Brazil, In: PRANCE, G. T. (Ed.). **Biological diversification in the Tropics.** New York: Columbia Univ. Press, 1982. p. 245-251.

ARZABE, C. Reproductive activity patterns of anurans in two different altitudinal sites within the Brazilian Caatinga. **Revista Brasileira de Zoologia**, Curitiba, v. 16, n. 3, p. 851-864, 1999.

ARZABE, C.; CARVALHO, C. X.; COSTA M. A. G. Anurans assemblages in Crasto Forest ponds (Sergipe, State, Brazil): comparative, structure and calling activity patterns. **Journal of Herpetology**, Lawrence, v. 3, p. 111-113, 1998.

BARBAULT, R.; RODRIGUES, M. T. Observations sur la reproduction et la dynamique des populations de quelques anoures tropicaux. I. *Ptychadena maccarthyensis* et *Ptychadena oxyrhynchus*. **La Terre et la vie**, Paris, v. 32, p. 441-452, 1978a.

BARBAULT, R.; RODRIGUES, M. T. Observations sur la reproduction et la dynamique des populations de quelques anoures tropicaux. II. *Phrynobathrachus plicatus* (Gunther). **Géologie et Ecologie Tropicale**, Paris, v. 2, n. 4, p. 455-466, 1978b.

BARBAULT, R.; RODRIGUES, M. T. Observations sur la reproduction et la dynamique des populations de quelques anoures tropicaux. III. *Arthroleptis poecilonotus*. **Tropical Ecology**, Paris, v. 20, n. 1, p. 64-77, 1979a.

BARBAULT, R.; RODRIGUES, M. T. Observations sur la reproduction et la dynamique des populations de quelques anoures tropicaux. IV. *Phrynobathrachus acraensis*. **Bulletin de l'Institut fondamental d'Afrique noire**, Dakar, v. 41, série A, n. 2, p. 417-428, 1979b.

BARBAULT, R.; PILORGE, T. Observations sur la reproduction et la dynamique des populations de quelques anoures tropicaux V. *Phrynobatrachus calcaratus*. **Acta Oecologica**, Paris, v. 1980, p. 373-382, 2001.

BERNARDE, P. S.; MACHADO, R. A. Riqueza de espécies, ambientes de reprodução e temporada de vocalização da anurofauna em Três Barras do Paraná, Brasil (Amphibia: Anura). **Cuadernos de Herpetologia**, Tucuman, v. 14, n. 2, p. 93-194, 2001.

BERNARDE, P. S. Ambientes e temporada de vocalização da anurofauna no Município de Espigão do Oeste, Rondônia, Sudoeste da Amazônia - Brasil (Amphibia: Anura). **Biota Neotropica**, Campinas, v. 7, n. 2, p. 87-92, 2007.

BERTOLUCCI, J.; RODRIGUES, M. T. Seasonal patterns of breeding activity of Atlantic rainforest anurans at Boracéia, southeastern Brazil. **Amphibia-Reptilia**, Leiden, v. 23, p. 161-167, 2002.

BERVEN, K. A. Factors affecting variation in reproductive traits within a population of wood frogs (*Rana sylvatica*). **Copeia**, Lawrence, v. 1988, p. 605-615, 1988.

BEZERRA, E. C.; BEZERRA, J. E. G.; MENDES, M. F. S. Precipitações. In: Instituto de Planejamento do estado do Ceará (Ed.). **Atlas do Ceará.** Fortaleza: Secretaria do Planejamento - Governo do Estado do Ceará, 1997. p. 22-23.

BLAIR, W. F. Calling and spawning seasons in a mixed population of anurans. **Ecology**, Davis, v. 42, n. 1, p. 99-110, 1961.

CARDOSO, A. J.; ARZABE, C. Corte e desenvolvimento larvário de *Pleurodema diplolistris* (Anura: Leptodactylidae). **Revista Brasileira de Biologia**, São Carlos, v. 53, n. 4, p. 561-570, 1993.

CARDOSO, A. J.; MARTINS, J. E. Diversidade de anuros durante o turno de vocalizações, em comunidade neotropical. **Papéis Avulsos de Zoologia**, Rio de Janeiro, v. 36, n. 23, p. 279-285, 1987.

CHURCH, G. The effects of seasonal and lunar changes on the breeding pattern of the edible Javanese frog, *Rana cancrivora* (Gravenhurst). **Treubia**, Batavia, v. 25, p. 215-233, 1960.

CRUMP, M. L.; POUNDS, J. A. Temporal variation in the dispersion of a tropical anuran. **Copeia**, Lawrence, v. 1989, p. 209-211, 1989.

CRUMP, M. L. Reproductive strategies in a tropical anuran community. **Miscellaneous Publication of the Museum of Natural History**, Lawrence v. 61, 1-68, 1974.

CRUMP, M. L. Amphibian reproductive ecology on the community level. In: SCOTT JR., N. J. (Ed.). **Herpetological Communities.** Washington: Wildlife Research Report 13, 1982. p. 21-36.

DONNELLY, M. A. Reproductive phenology and age structure of *Dendrobates pumilio* in northeastern Costa Rica. **Journal of Herpetology**, Laurence, v. 23, p. 362-367, 1989.

DONNELLY, M. A.; GUYER, C. Patterns of reproduction and habitat use in an assemblage of Neotropical hylid frogs. **Oecologia**, Berlim, v. 98, n. 3-4, p. 291-302, 1994.

DUELLMAN, W. E.; PYLES, R. A. Acoustic resource partitioning in anuran communities. **Copeia**, Lawrence, v. 1983, p. 639-649, 1983.

DUELLMAN, W. E. Courtship isolating mechanisms in Costa Rica hylids frogs. **Herpetologica**, Louisiana, v. 23, n. 3, 169-183, 1967.

DUELLMAN, W. E. Alternative life-history styles in anuran amphibians: evolutionary and ecological implications. In: BRUTON, M. N. (Ed.). **Alternative life-history styles of animals**. Dordrecht: Kluwer Academic Publishers, 1989. p. 101-126.

DUELLMAN, W.E.; TRUEB, L. **Biology of amphibians.** New York: McGraw-Hill, 1986. 670 p.

FIGUEIREDO, M. A. Unidades Fitoecológicas. In: Instituto de Planejamento do estado do Ceará (Ed.). **Atlas do Ceará.** Fortaleza: Secretaria do Planejamento - Governo do Estado do Ceará, 1997. p. 28-29.

GADGIL, M; BOSSERT W. H. Life historical consequences of natural selection. **The American Naturalist**, Chicago, v. 104, p. 1-24, 1970.

GALATTI, U. Population Biology of the Frog *Leptodactylus pentadactylus* in a Central Amazonia Rainforest. **Journal of Herpetology**, Lawrence, v. 26, n. 1, p. 23-31, 1992.

GEISE, W.; LINSENMAIR, K. E. Adaptations of the Reed Frog *Hyperolius viridiflavus* (Amphibia: Anura: Hyperoliidae) to its arid environment, II. Some aspects of the water economy of *Hyperolius viridiflavus nitidulus* under wet and dry season conditions. **Oecologia**, Berlim, v. 68, p. 542-548, 1986.

GIBSON, R. C.; BULEY, K. R. Maternal care and obligatory oophagy in *Leptodactylus fallax*: a new reproductive mode in frogs. **Copeia**, Lawrence, v. 2004, n. 1, p. 128-135, 2004.

GOTTSBERGER, B.; GRUBER, E. Temporal partitioning of reproductive activity in a neotropical anuran community. **Journal of Tropical Ecology,** Cambridge, v. 20, n. 3, p. 271-280, 2004.

GRANDINETTI, L.; JACOBI, C. M. Distribuição estacional e espacial de uma taxocenose de anuros (Amphibia) em uma área antropizada em Rio Acima - MG. **Lundiana**, Belo Horizonte, v. 6, n. 1, p. 21-28, 2005.

HADDAD, C. F. B.; PRADO, C. P. A. Reproductive modes in frogs and their unexpected diversity in the Atlantic forest of Brazil. **Bioscience**, Uberlândia, v. 55, n. 3, p. 207-217, 2005.

KLUGE, A. G. The life history, social organization, and parental behavior of *Hyla rosenbergi* Boulenger, a nest-buildling Gladiator frog. **Miscellaneous Publications**, Museum of Zoology, Michigan, v. 160, p. 1-170, 1981.

KYRIAKOPOULOU-SKLAVOUNOU P.; LOUMBOURDIS, N. S. Annual ovarian cycle in the frog *Rana ridibunda* in Northern Greece. **Journal of Herpetology**, Lawrence, v. 24, n. 2, p. 185-191, 1990.

LANG, C. Size-fecundity relationships among stream-breeding hylid frogs. **Herpetological Natural History**, Phoenix, v. 3, p. 193-197, 1995.

LEMCKERT, F. L.; SHINE, R. Costs of reproduction in a population of the frog *Crinia signifera* (Anura: Myobatrachidae) from Southeastern Australia. **Journal of Herpetology**, Lawrence, v. 27, p. 420-425, 1993.

LITTLEJOHN, M. J. Call differentiation in a complex of seven species of *Crinia* (Anura: Leptodactylidae). **Evolution**, Lawrence, v. 13, p. 452-468, 1959.

LÜDDECKE, H. Variation and trade-off in reproductive output of the Andean frog *Hyla labialis*. **Oecologia**, Berlim, v. 130, p. 403-410, 2002.

PEROTTI, M. G. Reproductive modes and quantitative reproductive parameters of an anuran assemblage from the semiarid Chaco, Salta, Argentina. **Revista Chilena de Historia Natural**, Santiago, v. 70, p. 277-288. 1997.

POMBAL JR., J. P. Distribuição espacial e temporal de anuros (Amphibia) em uma poça permanente na Serra de Paranapiacaba, sudeste do Brasil. **Revista Brasileira de Biologia**, São Carlos, v. 57, n. 4, p. 583-594, 1997.

POMBAL JR., J. P.; HADDAD, C F B. Estratégias e modos reprodutivos de anuros (Amphibia) em uma poça permanente na Serra de Paranapiacaba, Sudeste do Brasil. **Papéis Avulsos de Zoologia**, São Paulo, v. 45, n. 15, p. 201-213, 2005.

PRADO, C. P. A.; HADDAD, C. F. B. Size-fecundity relationships and reproductive investment in female frogs in the Pantanal, southwestern Brazil. **Herpetological Journal**, London, v. 15, n. 4, p. 181-189, 2005.

PRADO, C. P. A.; UETANABARO, M.; LOPES, F. S. Reproductive strategies of *Leptodactylus chaquensis* and *L. podicipinus* in the Pantanal, Brazil. **Journal of Herpetology**, Lawrence, v. 34, p. 135-139, 2000.

PRADO, C. P. A.; UETANABARO, M.; HADDAD, C. F. B. Breeding activity patterns, reproductive modes, and habitat use by anurans (Amphibia) in a seasonal environment in the Pantanal, Brazil. **Amphibia-Reptilia**, Leiden, v. 26, n. 2, p. 211-221, 2005.

RENSCH, B. **Evolution above the species level.** New York: Columbia University Press, 1960. 419 p.

RÖDEL, M-O. **Amphibien der westafrikanischen Savanne.** Frankfurt: Edition Chimaira, 1996. 295 p.

ROSSA-FERES, D. C.; JIM, J. Similaridade no sítio de vocalização em uma comunidade de anfíbios anuros na região noroeste do Estado de São Paulo, Brasil. **Revista Brasileira de Zoologia**, Curitiba, v. 18, n. 2, p. 439-454, 2001.

SALTHE, S. N.; DUELLMAN, W. E. Quantitative constraints associated with reproductive mode in anurans. In: VIAL, J. L. (Ed.). **Evolutionary Biology of the Anurans.** Columbia: University of Missouri Press, 1973. ??? p. 229-249.

SILVA, G. R.; ALVES, M. R.; SANTOS, C. L.; SOUZA, S. D. V.; ANNUNZIATA, B. B. Anfíbios das dunas litorâneas do extremo norte do Estado do Piauí, Brasil. **Sitientibus.** Série Ciências Biológicas, Feira de Santana, v. 7, p. 334-340, 2007.

SILVA, R. A.; MARTINS, I. A.; ROSSA-FERES, D. C. Bioacústica e sítio de vocalização em taxocenoses de anuros de área aberta no noroeste paulista. **Biota Neotropica**, Campinas, v. 8, n. 3, p. 1-12, 2008.

SILVERIN, B.; ANDREN C. The ovarian cycle in the natterjack toad, *Bufo calamita*, and its relation to breeding behaviour. **Amphibia-Reptilia**, Leiden, v. 13, p. 177-192, 1992.

TOLEDO, L. F.; ZINA, J.; HADDAD, C. F. B. Distribuição espacial e temporal de uma comunidade de anfíbios anuros do município de Rio Claro, São Paulo. **Holos Environment**, Rio Claro, v. 3, n. 2, p. 136-149, 2003.

VASCONCELOS, T. S.; ROSSA-FERES, D. C. Diversidade, distribuição espacial e temporal de anfíbios anuros (Amphibia, Anura) na região noroeste do estado de São Paulo, Brasil. **Biota Neotropica**, Campinas, v. 5, n. 2, p. 1-14, 2005.

VIEIRA, W. L. S.; ARZABE, C.; SANTANA, G. G. Composição e distribuição espaço-temporal de anuros no Cariri paraibano, Nordeste do Brasil. **Oecologia Brasiliensis**, Rio de Janeiro, v. 11, p. 383-396. 2007.

WELLS, K. D. The social behaviour of anuran amphibians. **Animal Behaviour**, London, v. 25, p. 666-693, 1977.

WELLS, K. D. The ecology and behavior of amphibians. Chicago: University of Chicago Press, 2007. 1148 p.

ZAR, J. Biostatistical analysis, 4th ed. New Jersey: Prentice Hall, 1999. 663 p.

ZINA, J.; ENNSER, J.; PINHEIRO, S. C. P.; HADDAD, C. F. B.; TOLEDO, L. F. Taxocenose de anuros de uma mata semidecídua do interior do Estado de São Paulo e comparações com outras taxocenoses do Estado, sudeste do Brasil. **Biota Neotropica**, Campinas, v. 7, p. 49-58, 2007.

Capítulo 3

Distribuição espacial e sazonalidade dos anfíbios do complexo Chapada da Ibiapaba, Ceará, Brasil

Resumo: Durante o período de abril de 2007 e abril de 2009 foram investigados padrões de distribuição altitudinal, sazonalidade, turnos de vocalização, composição e abundância de anfíbios do Planalto da Ibiapaba, Ceará, Brasil. Coletas foram realizadas através do monitoramento em sítios de vocalização, procura ativa em dois transectos altitudinais e uso de armadilhas de interceptação e queda. A riqueza de espécies obtidas pela soma dos três métodos empregados foi de 35 espécies distribuídas em nove famílias (Bufonidae, Cycloramphidae, Eleutherodactylidae, Hylidae, Leiuperidae, Leptodactylidae, Microhylidae, Strabomantidae e Caeciliidae). A análise das capturas através do uso de armadilhas de interceptação e queda revelou que *Physalaemus cuvieri* é o anfíbio dominante na serapilheira dos fragmentos de floresta úmida, representando 93,55% da abundância total de anfíbios coletados. Dados obtidos através dos transectos altitudinais mostraram que o número de espécies, assim como sua composição, nas áreas de altitude e de baixada é semelhante, embora exista substituição de algumas espécies. Sazonalidade reprodutiva foi observada para as duas áreas estudadas. Houve correlação entre número de espécies e precipitação, todavia, foi demonstrado que a reprodução está fortemente condicionada às primeiras chuvas. A maioria das espécies não apresentou flutuações de abundância pronunciadas ao longo do turno de vocalização.

Palavras-chave: anfíbios, caatinga, sazonalidade, reprodução.

Abstract: During the period of April 2007 to April 2009 we investigated altitudinal and seasonal distribution patterns, vocalization activity, composition, and abundance of amphibians in the Planalto da Ibiapaba, Ceará, Brazil. Samples were

obtained by the monitoring of the call sites, active searching in two altitudinal transects, and use of pitfall traps with drift fences. Species richness obtained by compilation of the three methods was 35 distributed into nine families (Bufonidae, Cycloramphidae, Eleutherodactylidae, Hylidae, Leiuperidae, Leptodactylidae, Microhylidae, Strabomantidae, and Caeciliidae). The analysis of catches through the use of pitfall traps revealed that *Physalaemus cuvieri* is the dominant species in the leaf litter of the moist forest fragments, representing 93.55% of total abundance of amphibians collected. Data from altitudinal transects showed that the number of species and their composition in the areas of altitude and lowland is similar, although some species are replaced along the transect. Reproductive seasonality was observed for both monitored areas. Although we found a correlation between number of calling males and rainfall, the reproduction of most species of frogs are mainly correlated with the first storms of rainy season. Analysis of daily vocalization activity did not detect any pattern of segregation of the acoustic space in the monitored sites.

Key words: amphibians, Caatinga, sazonality, reproduction.

Introdução

O continente sul-americano apesar de ser predominantemente úmido, possui formações áridas e semi-áridas em províncias geológicas e condições térmicas distintas entre si (ARAÚJO et al., 2005). Dentre elas, as mais importantes estão localizadas da seguinte maneira: 1) o semi-árido de Guajira, localizado no extremo setentrional da América do Sul, na face caribenha da Venezuela e Colômbia a 12º N de latitude; 2) uma faixa a oeste do continente, estendendo-se

desde o golfo de Guayaquil, nas proximidades da linha do equador, até o Estreito de Magalhães, acima dos 52º S de latitude; 3) o domínio da Caatinga no Brasil (AB'SÁBER, 1974; AB'SÁBER, 1977; ARAÚJO et al., 2005).

Com seus mais de 800.000 km² a Caatinga é o único ecossistema exclusivamente brasileiro, ocorrendo nos estados do Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, Bahia e Minas Gerais (AB'SÁBER, 1977; TABARELLI & SILVA, 2003). Embora a Caatinga apresente-se ao longo de quase toda sua extensão como uma vegetação adaptada as condições impostas pelo clima semi-árido, algumas áreas podem apresentar outras fitofisionomias como manchas de cerrados e fragmentos de floresta úmida, em decorrência da presença de climas mais amenos e maior umidade.

Os fragmentos de floresta úmida do Ceará, também conhecidos como brejos-nordestinos, brejos-de-altitude, serras-úmidas e enclaves, são normalmente relevos residuais de altitudes superiores a 600 m, recobertos por vegetação remanescente da Floresta Amazônica e da Mata Atlântica (COIMBRA-FILHO & CÂMARA, 1996). São essenciais para diversas espécies de característica ombrófila que possuem forte afinidade com a fauna típica dos grandes corpos florestados neotropicais (BORGES-NOJOSA & CARAMASCHI, 2003), além de serem ocupadas por diversas espécies típicas da Caatinga circundante (veja capítulo 1).

A predação e a competição são duas interações usualmente consideradas como de importância primária na estruturação das comunidades (CRUMP, 1982). Essas interações relacionadas com estratégias na utilização de recursos, como sítios de reprodução, temporada reprodutiva (ao longo do ano), turno de atividade reprodutiva (diário) e espaço acústico, através das vocalizações possibilita a coexistência das espécies em um mesmo hábitat (DUELLMAN & PYLES, 1983;

HEYER et al., 1990; CARDOSO & HADDAD, 1992; HADDAD & SAZIMA, 1992; ROSSA-FERES & JIM, 1994; 2001; POMBAL JR., 1997; ARZABE et al., 1998; BERTOLUCI, 1998; BERNARDE & MACHADO, 2001; CONTE & MACHADO, 2005; CONTE & ROSSA-FERES, 2006; entre outros).

Os fatores abióticos estabelecem uma sazonalidade reprodutiva, condicionada principalmente pelas chuvas em climas tropicais e pela temperatura em climas temperados (CARDOSO & MARTINS, 1987), sendo também uma função chave nas interações ecológicas em uma comunidade (BARBAULT, 1991). Além dessas duas variáveis abióticas, estudos vêm demonstrando que a umidade relativa do ar, a direção e intensidade do vento, a pressão atmosférica e a luminosidade atuam em segundo plano na atividade reprodutiva dos anfíbios anuros (e.g. BLAIR, 1961; BELLIS, 1962; BALINSKY, 1969; WIEST, 1982; AICHINGER, 1987; POMBAL JR., et al. 1994; POMBAL JR., 1997).

Embora muitos trabalhos com enfoque em ecologia de comunidades de anfíbios tenham sido conduzidos no Brasil, em especial nas últimas décadas (POMBAL JR., 1997; BERNARDE & MACHADO, 2001; BERTOLUCI & RODRIGUES, 2002; GRANDINETTI & JACOBI, 2005; POMBAL JR. & HADDAD, 2005; PRADO & HADDAD, 2005; PRADO et al., 2005; VASCONCELOS & ROSSA-FERES, 2005; BERNARDE, 2007; ZINA et al., 2007; BRASSALOTI et al., 2010 e outros), o Bioma Caatinga ainda é bastante deficiente em informações sobre esse tema (ARZABE et al., 1998; ARZABE, 1999; VIEIRA et al., 2007) e, especificamente para o Ceará, não existe nenhum trabalho nesta ótica.

Nesse capítulo, serão apresentados dados sobre a distribuição espacial e sazonalidade de comunidades de anfíbios de áreas de altitude e Caatinga circundante do Planalto da Ibiapaba, Ceará, Nordeste do Brasil.

Material e Métodos

Área de estudo

O Ceará apresenta em sua face sul e oeste uma cadeia de montanhas que atingem cotas altimétricas de até 1000 metros e percorrem a fronteira do Ceará com os estados de Pernambuco e Piauí. Os principais relevos que compõem essa cadeia são a Chapada do Araripe, localizada ao sul do estado (7º25' – 7º40' S/ 39º03' – 40º28' O), a formação Serra das Almas, localizada a sudoeste do estado (7º08' - 5º03' S/ 41º01' O) e o Planalto da Ibiapaba, localizada a noroeste do Ceará (3°20'-5°00'S/ 40°42'-41°10'W). Apenas uma formação fluvial de grande porte, o Rio Poti (5°02'11" S, 41°00'51" W, 230 m alt, 90 m de largura), que origina-se no Piauí e adentra o Ceará interrompe essa cadeia de montanhas, ao longo de seus aproximadamente 650 km de extensão.

O presente estudo foi realizado em diversas áreas do Planalto da Ibiapaba e áreas de baixada adjacentes (Figura 1). Embora esteja completamente inserida no Bioma Caatinga, a área de estudo é composta por um mosaico de fitofisionomias distintas, distribuídas em função das características de clima, relevo e tipo de solo. Uma descrição breve dos principais ambientes que compõem o Planalto da Ibiapaba está presente no capítulo 1.

De acordo com a classificação proposta por Köppen, modificada (KOTTEK et al., 2006), a região é do tipo Savana Equatorial com verão seco (As), ou seja, apresenta temperaturas médias mínimas superiores a 18ºC e baixa taxa de precipitação durante o verão (< 60 mm). Devido às áreas de altitude na região que acumula a umidade vinda do oceano, a região apresenta as maiores médias históricas de precipitação do estado (São Benedito com 2.062 mm, Ibiapina com 1.744 mm e Ubajara com 1.441 mm) (BEZERRA et al., 1997).

Coleta de dados e método amostral

Durante os meses de abril de 2007 e abril de 2009, obtiveram-se dados sobre composição e abundância de anuros do Planalto da Ibiapaba e áreas adjacentes. Foram usados três métodos para coleta de dados, dos quais foram independentemente analisados.

Estabeleceram-se dois transectos (perfis altitudinais) que foram mensalmente percorridos e monitorados. Cada transecto tinha aproximadamente 7 km de extensão e uma variação altitudinal aproximada de 600 metros. O primeiro transecto compreendeu a trilha que atravessa do Parque Nacional de Ubajara (Parna Ubajara), começando na entrada do Parque pelo Portão Neblina (03°50'31,57"S, 40°53'56,00"W, 850 m alt.) e indo até o Portão Araticum (03°49'25,83"S, 40°53'29,22"W, 260 m alt.). Duas fitofisionomias predominavam ao longo do transecto. Na parte superior, entre 550 e 850 metros de altitude, uma área de floresta úmida com dossel superior a 20 metros, sob uma matriz arenítica. Na parte inferior, entre 290 e 540 metros de altitude, a floresta úmida é substituída por uma área de Caatinga Arboréa, com vegetação relativamente espaçada e dossel de até 20 metros de altura, sob uma matriz calcária. O segundo transecto foi realizado na Serra das Flores, uma formação montanhosa separada por um vale do Planalto da Ibiapaba, partindo da propriedade denominada Santo Mano (03°24'27,22"S; 41°08'10.87" W, 105 m alt.) e indo até o topo da serra (03°23'03,21"S, 41°09'40.23"W, 710 m alt.). Nesse segundo transecto quatro principais fitofisionomias podem ser identificadas. No primeiro trecho, entre os 110 e 200 metros de altitude predomina a savana estépica, com predominância de arbustos e vegetação fechada, além de áreas de carnau+bais (*Copernicia prunifera*)

Figura 1 – Alguns dos ambientes amostrados durante o período de estudo do Planalto da Ibiapaba e áreas adjacentes, Ceará, Brasil. A – Vista geral da Serra das Flores; B e C – Açude da localidade Santo Mano – Notar que o espelho d'água de 1,5 km de perímetro, com coluna d'água de 4 metros no pico da estação chuvosa, desaparece na estação seca; D - Banhado do Trapiche, Parna Ubajara; E – Área encharcada presente na mancha de Cerrado da Serra das Flores; F – Área parcial do Sítio Luis Gonzaga.

nas regiões mais úmidas. Entre os 200 e 400 metros a savana estépica é substituída pela Caatinga arbórea, similar ao outro transecto. Dos 400 aos 700 metros de altitude, sob uma matriz predominantemente quartzosa, encontra-se uma mancha de Cerrado (campos rupestres). Por fim, no último trecho (700-750 m), pequenos fragmentos de floresta úmida preenchem parte do topo da serra. Os transectos foram divididos em cotas altimétricas de 100 m e foram percorridos entre 18:00 h e 22:00 h. Para esse método as espécies foram registradas qualitativamente e foram considerados todos os registros encontrados (machos vocalizando, indivíduos forrageando, girinos e desovas).

Para a estimativa da abundância de anfíbios de serapilheira dos fragmentos de floresta úmida do Planalto da Ibiapaba foram utilizadas armadilhas de interceptação e queda (CORN, 1994). As armadilhas foram dispostas em linha, cada uma com 6 baldes de 60 litros distantes 10 metros um do outro e cerca-guia de 50 cm de altura em relação ao solo. Foram instalados dois conjuntos de três linhas cada sendo um nas proximidades do Rio Samambaia (03°50'25,41"S, 40°54'27,12"W, 830 m alt.) e outro no Rio Cafundó (03°50'15,80"S, 40°54'37,64"W, 821 m alt.). A distância entre cada conjunto era de 2 km e foram tratados como amostras independentes. Os baldes ficaram abertos 10 dias por mês durante o período de 24 meses, totalizando 5760 horas de esforço amostral. Embora o foco de captura estivesse concentrado em anfíbios, todos os espécimes que caíram nas armadilhas foram registrados e identificados ao menor nível taxonômico possível, exceto pelos insetos que foram descartados.

Por último, foram efetuados monitoramentos em sítios de vocalização (SCOTT JR. & WOODWARD, 1994) em dois pontos fixos ao longo da área de estudo. Os pontos escolhidos foram: 1) Sitio Luis Gonzaga – compreende uma área com

três ambientes lênticos sucessivos com vegetação predominante de gramíneas e bordeado por pequenos fragmentos de floresta úmida (03°49'33,93"S, 40°55'10,81"W, 870 m alt.), localizado no município de Ubajara; 2) Santo mano - um açude de 1,5 km de perímetro e profundidade máxima de 4 metros, que seca por completo na estação de seca, localizado em meio a Caatinga (03°24'30,19"S, 41°08'15,81"W; 104 m alt.) no município de Viçosa do Ceará. Os dados referentes ao monitoramente de sítio de vocalização eram recolhidos mensalmente, entre as 18:00 h e 23:00 h, sempre por duas pessoas.

Autorizações de coletas foram aprovadas através de projetos de pesquisa submetidos ao Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) (Processos 12545-1, 12545-2, 13571-1 e 14130-1). Espécimes testemunho foram fixados em formalina 10%, preservados em álcool 70% e encontram-se depositado na coleção de anfíbios Célio F. B. Haddad (CFBH), Universidade Estadual Paulista "Julio de Mesquita Filho", campus de Rio Claro, São Paulo, Brasil.

Análise de dados

Para avaliar a eficiência da amostragem foi utilizado o método da curva de acumulação de espécies (GOTELLI & COLWELL, 2001; COLWELL et al., 2004), a partir dos dados mensais de presença/ausência das espécies registradas pelo método de monitoramentos em sítio de vocalização. Foram utilizadas 1000 aleatorizações e reposição de amostras. As curvas foram efetuadas no Programa EstimateS, versão 7.5.2 (COLWELL, 2005).

Comparações entre as abundâncias de indivíduos capturados nas armadilhas de interceptação e queda, abundância de machos vocalizando em

diferente locais de monitoramento e riqueza de espécies foram testados através do T de Student ($p<0,05$) ou ANOVA paramétrica ($p<0,05$) (ZAR, 1999).

Para testar se havia sazonalidade nos ambientes em que os machos foram monitorados em atividade de vocalização, foi utilizada uma estatística circular com aplicação do teste de Rayleigh (z) (ZAR, 1999). Para que a análise seja processada faz-se necessário converter os meses em graus (0^o para janeiro até 330^o para dezembro) e os vetores gerados correspondem ao número de espécies encontradas em atividade de vocalização para seu mês correspondente. As localidades foram analisadas independentemente, todavia, os dois anos de amostragem foram agrupados, sendo que cada intervalo de 30^o corresponde a soma de espécies encontradas no seu respectivo mês, independente do ano em que foram amostradas. Para rodar as análises foi utilizado o programa Oriana 3.11 (KOVACH, 2009).

Dados diários de precipitação foram obtidos através da estação metereológica do Instituto Chico Mendes de Conservação da Biodiversidade, estação de Ubajara, Ceará. Foram verificadas possíveis correlações entre a quantidade acumulada mensal de chuva e o número de espécies vocalizando e a quantidade acumulada mensal de chuva e o número estimado de machos vocalizando.

Resultados

Padrões de distribuição altitudinal e fitofisionomia

Durante o período amostrado foi realizado 24 transectos em cada perfil monitorado. No perfil 1 (Parna Ubajara) foram registradas 19 espécies enquanto que para o perfil 2 (Serra das Flores) foram encontradas 31 espécies (Tabelas 1 e

2). O número total de espécies encontradas nos transectos foi 34, sendo que 16 ocorreram em ambos os perfis.

Em geral, as espécies apresentaram ampla distribuição ao longo dos transectos ocorrendo em diversas altitudes. *Odontophrynus carvalhoi*, *Pseudopaludicola* sp. (aff. *saltica*) e *Scinax nebulosus*, todavia, foram restritas aos ambientes superiores a 650 metros de altitude enquanto que *Elachistocleis piauiensis*, *Dendropsophus rubicundulus* foram exclusivas de áreas de baixada. *Dendropsophus nanus*, *Dendropsophus soaresi*, *Dendropsophus* sp. (gr. *microcephalus*), *Dermatonotus muelleri*, *Leptodactylus fuscus*, *Phyllomedusa nordestina* e *Physalaemus albifrons*, embora tenham sido encontradas somente em áreas de baixadas no perfil da Serra das Flores, são espécies que ocorrem também em áreas de altitude.

Tabela 1 – Relação das espécies de anfíbios anuros registradas no transecto do Parna Ubajara em cada fitofisionomia e ao longo do gradiente altitudinal.

Fitofisionomia	**Caatinga arbórea**			**Floresta úmida**			
Perfil 1 – Parna Ubajara	200-300	300-400	400-500	500-600	600-700	700-800	800-900
Adelophryne baturitensis				X	X	X	X
Corythomantis greeningi			X	X			X
Dendropsophus minutus							X
Hypsiboas multifasciatus				X	X		X
Hypsiboas raniceps				X			X
Pristimantis sp.		X	X	X	X	X	X
Leptodactylus macrosternum	X	X		X			
Leptodactylus mystaceus			X			X	
Leptodactylus sp. (aff. *andreae*)		X		X			
Leptodactylus sp. (aff. *syphax*)	X		X	X			
Leptodactylus troglodytes							X
Leptodactylus vastus	X	X	X	X			X
Odontophrynus carvalhoi							X
Physalaemus cuvieri	X		X			X	X
Proceratophrys cristiceps						X	X
Rhinella granulosa	X	X	X	X			
Rhinella jimi	X		X			X	X
Scinax nebulosus							X
Scinax x-signatus			X	X			
Numero total de espécies	6	5	9	11	3	6	13

Tabela 2 – Relação das espécies de anfíbios anuros registradas no transecto da Serra das Flores em cada fitofisionomia e ao longo do gradiente altitudinal.

Fitofisionomia	**Savana estépica**	**Caatinga árborea**		**Cerrado**			**Floresta úmida**
Perfil 1 – Serra das Flores	100-200	200-300	300-400	400-500	500-600	600-700	700-800
Adelophryne baturitensis							X
Corythomantis greeningi	X	X	X	X	X	X	X
Dendropsophus minutus	X						
*Dendropsophus nanus**	X						
Dendropsophus rubicundulus	X						
*Dendropsophus soaresi**	X						
Dendropsophus sp. (gr. *microcephalus*)*	X						
*Dermatonotus mullieri**	X						
Elachistocleis piauiensis	X						
Hypsiboas raniceps	X	X	X				X
Pristimantis sp.		X	X				X
*Leptodactylus fuscus**	X						
Leptodactylus macrosternum	X					X	X
Leptodactylus mystaceus	X	X	X				
Leptodactylus sp. (aff. *andreae*)		X	X	X	X	X	X
Leptodactylus sp. (aff. *hylaedactylus*)	X	X					
Leptodactylus sp. (aff. *syphax*)	X	X	X	X	X		
Leptodactylus troglodytes	X	X	X		X	X	X
Leptodactylus vastus	X	X			X	X	X
*Phyllomedusa nordestina**	X						
*Physalaemus albifrons**	X						
Physalaemus cuvieri	X	X			X	X	X
Pleurodema diplolister	X	X					X
Proceratophrys cristiceps	X	X	X			X	X
Pseudopaludicola sp. (aff. *mystacalis*)	X	X					
Pseudopaludicola sp. (aff. *saltica*)						X	
Rhinella granulosa	X	X	X	X			
Rhinella jimi	X	X					X
Scinax sp. (gr. *ruber*)	X	X	X			X	X
Scinax x-signatus	X	X	X				
Trachycephalus venulosus	X					X	X
Número total de espécies	27	17	11	4	6	10	14

Com relação à ocorrência de espécies dentro de cada fitofisionomia, também foi observado que a maioria das espécies ocorre em mais de um tipo de ambiente. Foram restritos a uma única fitofisionomia *Odontophrynus carvalhoi*, *Adelophryne baturitensis*, *Hypsiboas multifasciatus* e *Scinax nebulosus*, restritas a áreas de florestas úmidas; *Pseudopaludicola* sp. (aff. *saltica*), restrita a manchas de Cerrado; *Elachistocleis piauiensis* e *Dendropsophus rubicundulus* restritas as áreas de savana estépica.

Avaliação das capturas por armadilhas de interceptação e queda

Durante os 24 meses de amostragem no Parque Nacional de Ubajara, as armadilhas de interceptação e queda permaneceram abertas por 5760 horas, sendo verificadas diariamente durante 10 dias/mês. Das 19 espécies presentes nas áreas de floresta úmida do Parna Ubajara (vide tabela 1), um total de 13 espécies distribuídas em 2 ordens (Anura e Gymnophiona) e 8 famílias (Bufonidae, Cycloramphidae, Eleutherodactylidae, Hylidae, Leiuperidae, Leptodactylidae, Strabomantidae e Caeciliidae) foram coletadas através das armadilhas de interceptação e queda o que corresponde a 68,4% do número de espécies encontradas para essa fitofisionomia (Tabela 3). Todas as espécies presentes nas armadilhas foram também registradas através de outros métodos, exceto por *Siphonops* sp. (aff. *paulensis*) que só foi amostrado nas armadilhas.

A comparação entre as abundâncias médias de anuros em armadilhas entre os setores 1 e 2 através do test t de Student mostrou que ambos os setores não apresentam diferenças significativas (p=0,39). Por essa razão, os dados foram analisados em conjunto.

Considerando todos os táxons registrados observa-se que *Physalaemus cuvieri* é a espécie mais abundante no folhiço dentro da área do Parna Ubajara e representa 62,65% do número total de exemplares capturados nas armadilhas e 93,55% do número total de anfíbios capturados. *Leptodactylus mystaceus* e *Adelophryne baturitensis* foram a segunda e terceira espécies de anfíbios mais abundantes, com 2,35% e 1,68% do total de anfíbios capturados, respectivamente. Através da análise de variância foi possível detectar diferenças significativas entre as médias mensais de captura de *Physalaemus cuvieri* (g.l. = 11, F = 7,58, p < 0,0001; Figura 2).

Tabela 3 – Relação dos anfíbios capturados em armadilhas de interceptação e queda. N = número de indivíduos capturados, PN = abundância relativa de cada táxon, FO = frequência ocorrência percentual, MAX = número máximo de indivíduos registrados em um único balde, MED = número médio de indivíduos por armadilha.

Táxon	N	PN	FO	MAX	MED	DP
Adelophryne baturitensis	72	1.677	9,79	5	1,53	0,91
Corythomantis greeningi	1	0.023	0,21	1	1,00	0,00
Pristimantis sp.	13	0.303	2,71	1	1,00	0,00
Leptodactylus mystaceus	101	2.352	12,71	8	1,66	1,50
Leptodactylus sp. (aff. *andreae*)	1	0.023	0,21	1	1,00	0,00
Leptodactylus vastus	25	0.582	4,58	3	1,14	0,47
Odontophrynus carvalhoi	1	0.023	0,21	1	1,00	0,00
Phyllomedusa nordestina	1	0.023	0,21	1	1,00	0,00
Physalaemus cuvieri	4017	93.55	81,88	82	10,22	11,69
Proceratophrys cristiceps	39	0.908	6,04	5	1,34	0,94
Rhinella granulosa	1	0.023	0,21	1	1,00	0,00
Rhinella jimi	20	0.466	3,96	2	1,05	0,23
Siphonops sp. (aff. *paulensis*)	2	0.047	0,42	1	1,00	0,00
Total geral	4294	100,00	326,04	82	4,10	7,04

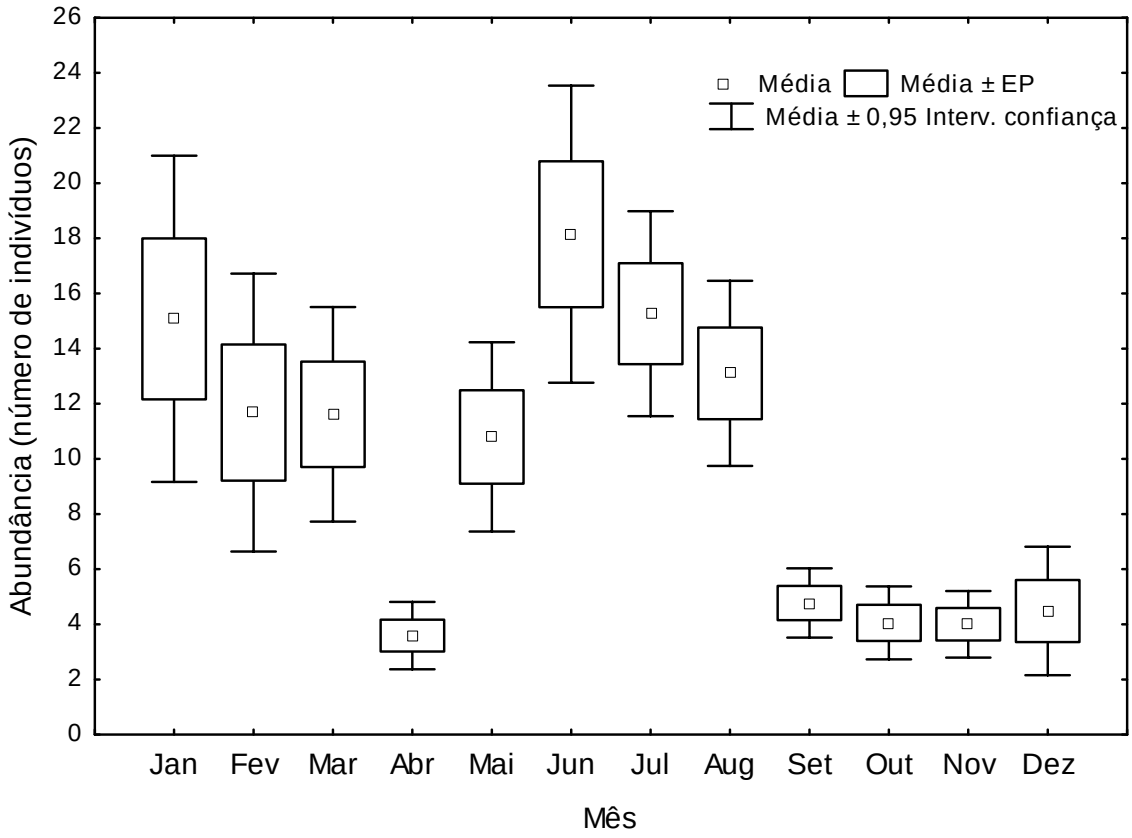


Figura 2 – Variação na abundância de indivíduos *Physalaemus cuvieri* obtidos através das capturas em armadilhas e interceptação e queda nas áreas de floresta úmida do Parque Nacional de Ubajara, Ceará, Brasil.

Sazonalidade

Os monitoramentos nas localidades Luis Gonzaga (floresta umidade de altitude) e Santo Mano (Caatinga de baixada) ocorreram sistematicamente entre as 18:00 h e 0:00 h. Apesar de algumas espécies vocalizarem fora dessa amplitude de horário, foi possível detectar parte da atividade de vocalização de todas as espécies presentes nessas localidades, durante o período de monitoramento.

A análise da curva acumulada de espécies para ambas as localidades indica uma estabilização de ambas as curvas (Figuras 3 e 4), sugerindo que o esforço empregado foi adequado para contemplar todas as espécies de cada uma das comunidades estudadas. De fato, todas as espécies foram registradas próximas a metade do período amostral, sendo que para a localidade de floresta úmida de altitude a última espécie registrada ocorreu na 13ª expedição e na Caatinga de baixada ocorreu na 11ª expedição.

O maior número de espécies vocalizando ocorreu durante o início das estações chuvosas que variou de janeiro a abril, tanto para a localidade Luis Gonzaga como para localidade Santo Mano (Figura 5). O mês de janeiro de 2008 foi o mês com maior número de espécies em atividade de reprodução, com 17 espécies para cada localidade. Na localidade Luis Gonzaga o registro de machos vocalizando foi mais constante ao longo do ano e diferiu significativamente da localidade Santo Mano (t de Student, valor de $t = 5,52$; $gl = 48$; $p < 0,000$).

A abundância de machos vocalizando também apresentou padrão similar ao encontrado para o número de espécies (Figura 6), mas os picos de abundância foram mais pronunciados, especialmente para a Caatinga nos meses de Abril de 2007 e Janeiro de 2008. Todavia, a comparação das abundâncias registradas entre

as localidades não diferiu significativamente no período de estudo (T de Student, valor de t =-0,84; gl=48; p=0.406, N.S.).

Em outras palavras, para ambas as localidades monitoradas, em especial para a localidade de Caatinga de baixada (Santo Mano) observou-se uma queda abrupta no número de espécies e número estimado de machos vocalizando após a explosão reprodutiva ocorrida após as primeiras chuvas do ano.

Para ambas as localidades foram encontradas correlações positivas entre o número de espécies e o volume acumulado mensal de chuva $r^2 = 0.23$ (n = 25; p = 0,016; Figura 7) para floresta úmida de altitude e $r^2 = 0.18$ (n = 25; p = 0,032; Figura 8) para a Caatinga. A análise da estatística circular (teste de uniformidade de Rayleigh) (Figura 9) demonstrou que foram significativamente sazonais as áreas de floresta úmida de altitude (n = 140; vetor médio = 33,26º; p = 0,018) e de caatinga de baixada (n = 64; vetor médio = 58,27 º; p<0,000)

Turnos de vocalização

As variações interespecíficas na abundância estimada de machos em atividade de vocalização podem ser encontradas na Tabela 5 para área de floresta úmida de altitude e na Tabela 6 para a área de Caatinga de baixada. Em decorrência que para cada hora foram compilados os dados de todas as amostragens e nos picos reprodutivos as espécies vocalizam durante todo o período amostrado, não foi possível detectar padrões marcantes de flutuação ao longo dos horários monitorados, exceto por *Pseudopaludicola* sp. (aff. *falcipes*) na área de floresta úmida de altitude que durante todos os meses do ano tiveram machos vocalizando nas primeiras horas da noite com abrupta redução de machos em atividade de vocalização a partir das 20 h.

A relação entre a abundância total estimada de machos vocalizando ao longo das horas de monitoramento, todavia, foram bastante divergentes entre as áreas amostradas. Para a floresta úmida de altitude uma correlação negativa muito forte e significativamente diferente foi identificada (r^2=0.99, p < 0.000; Figura 10), enquanto que para a área de Caatinga de baixada essa correlação positiva e não significativa (r^2=0.30, p = 0.26; Figura 11).

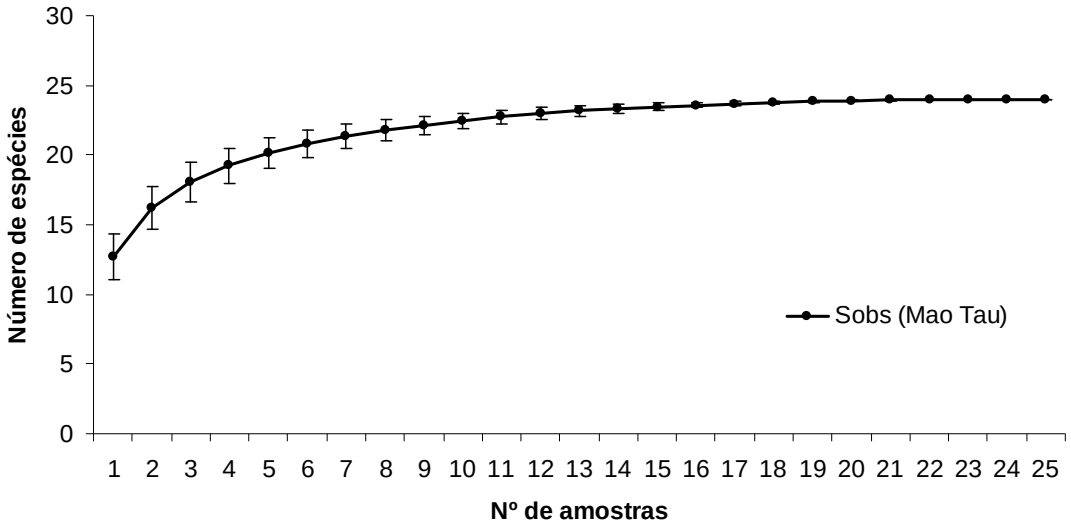


Figura 3 – Curva de acumulação de espécies confeccionada a partir de 1000 aleatorizações e com seus respectivos intervalos de desvio padrão para a área de floresta úmida de altitude (Luis Gonzaga), município de Ubajara, Ceará, Brasil.

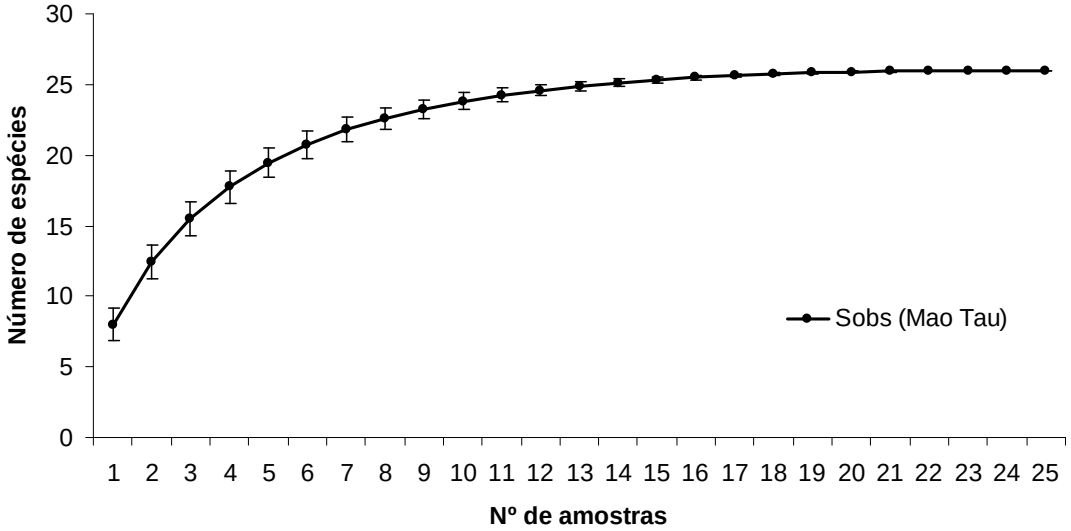


Figura 4 – Curva de acumulação de espécies confeccionada a partir de 1000 aleatorizações e com seus respectivos intervalos de desvio padrão para a área de Caatinga de baixada (Santo Mano), município de Viçosa do Ceará, Ceará, Brasil.

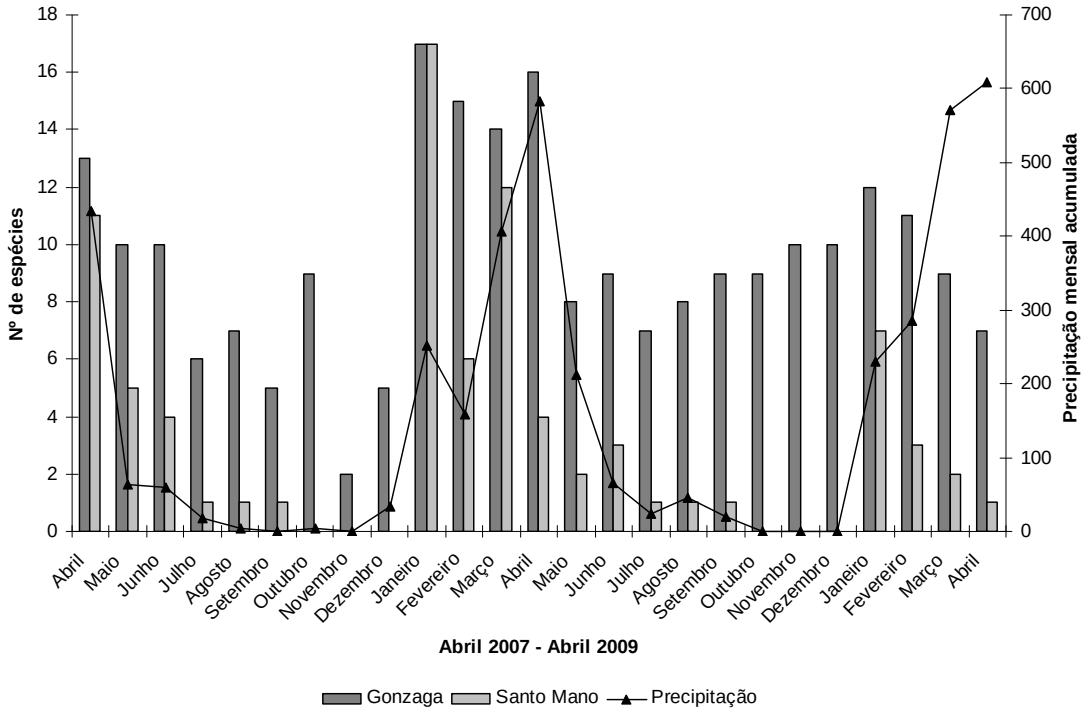


Figura 5 – Número de espécies em atividade de vocalização (barras) e precipitação mensal acumulada para ambas as localidades monitoradas durante o período de estudo.

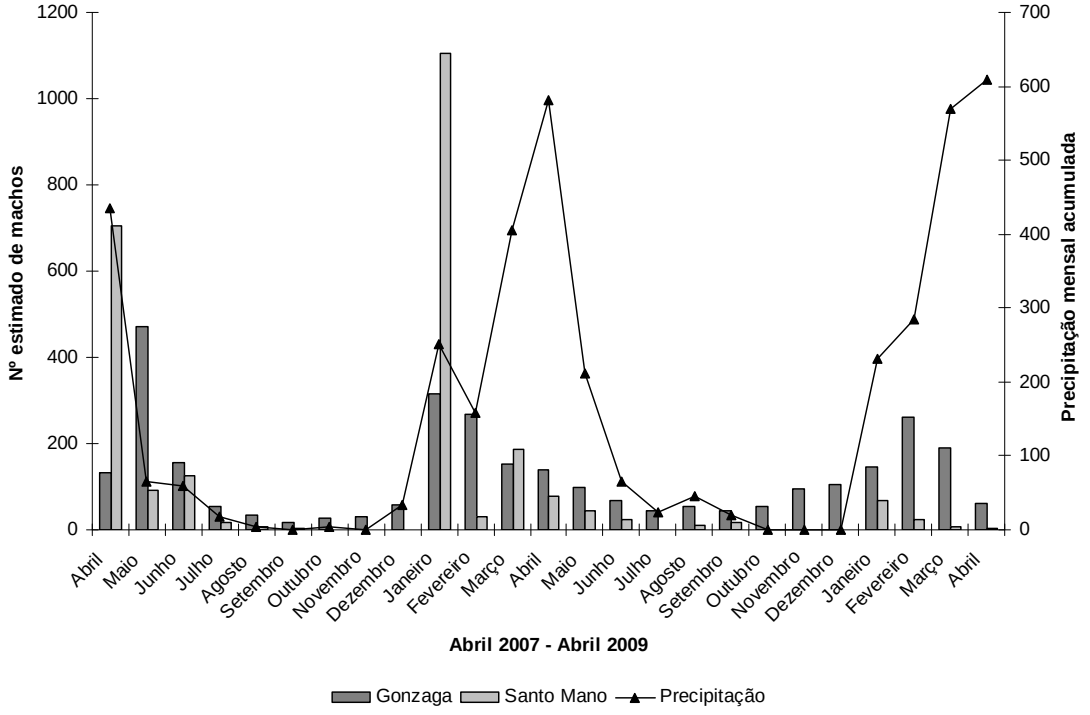


Figura 6 – Abundância de machos em atividade de vocalização (barras) e precipitação mensal acumulada para ambas as localidades monitoradas durante o período de estudo.

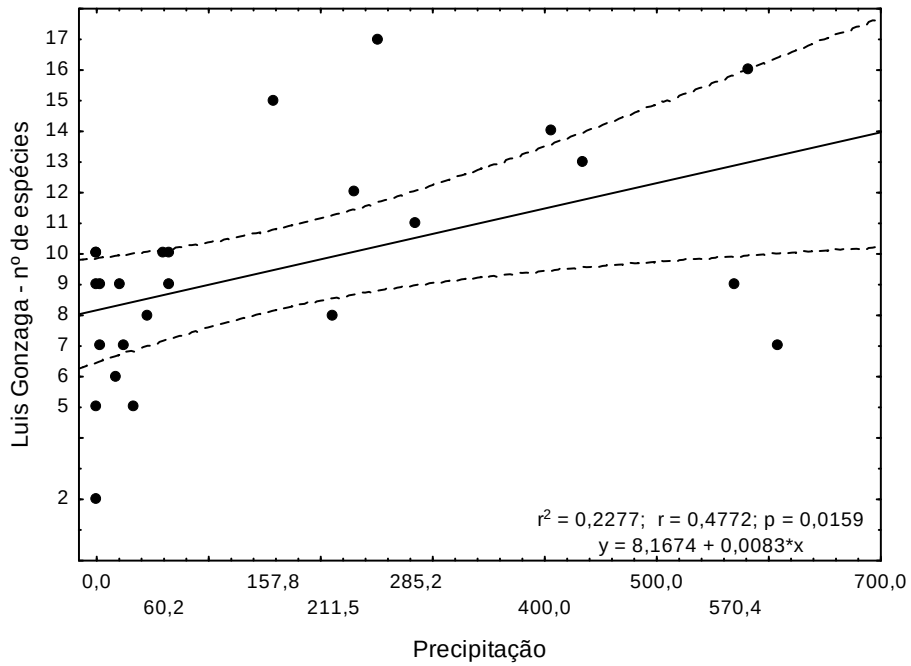


Figura 7 – Relação entre o número de espécies e a quantidade acumulada mensal de chuva entre abril de 2007 e abril de 2009 para a localidade Luis Gonzaga (floresta úmida de altitude), Ubajara, Ceará, Brasil. Linhas pontilhadas representam o intervalo de confiança ($p<0,05$).

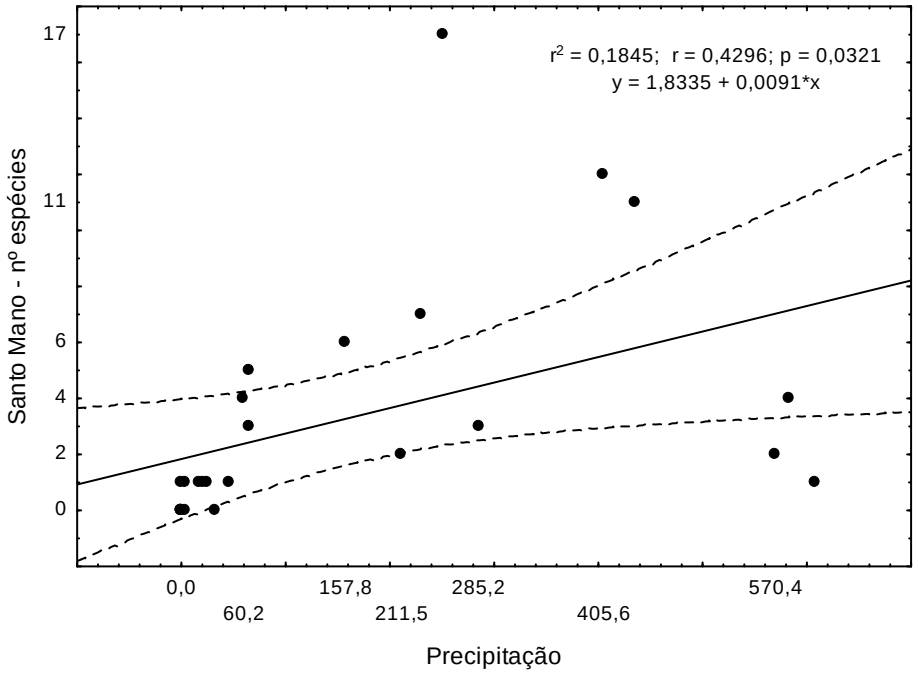


Figura 8 - Relação entre o número de espécies e a quantidade acumulada mensal de chuva entre abril de 2007 e abril de 2009 para a localidade Santo Mano (Caatinga de baixada), Ubajara, Ceará, Brasil. Linhas pontilhadas representam o intervalo de confiança ($p<0,05$).

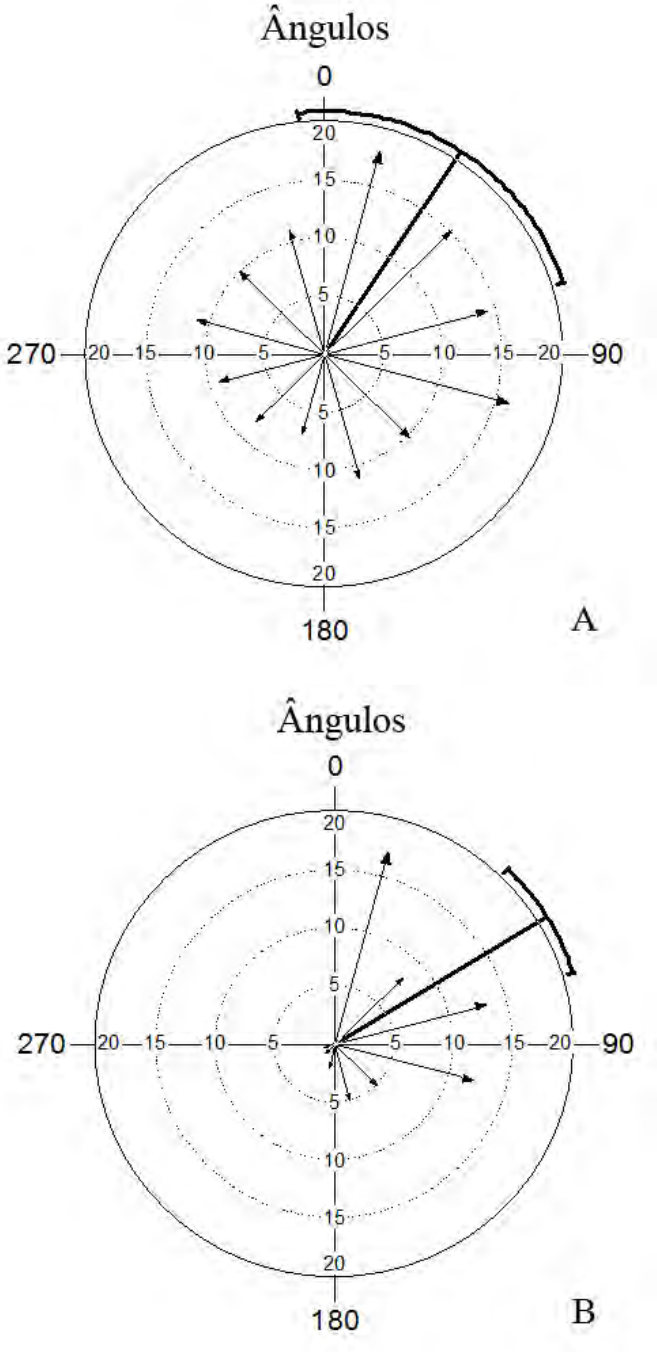


Figura 9 – Estatística circular aplicada para testar a sazonalidade de machos vocalizando para as duas comunidades com sítios de reprodução monitorados, planalto da Ibiapaba, Ceará, Brasil. A – Área de floresta úmida de altitude (Luis Gonzaga) e B – Área de Caatinga de baixada (Santo Mano). Vetores representam o número de espécies em atividade de vocalização para cada mês de monitoramento. O eixo inclinado que corta o círculo formando um ângulo representa a medida da concentração dos dados (número de espécies em atividade de vocalização) ao longo do ciclo anual e seu respectivo desvio padrão ($p<0,05$).

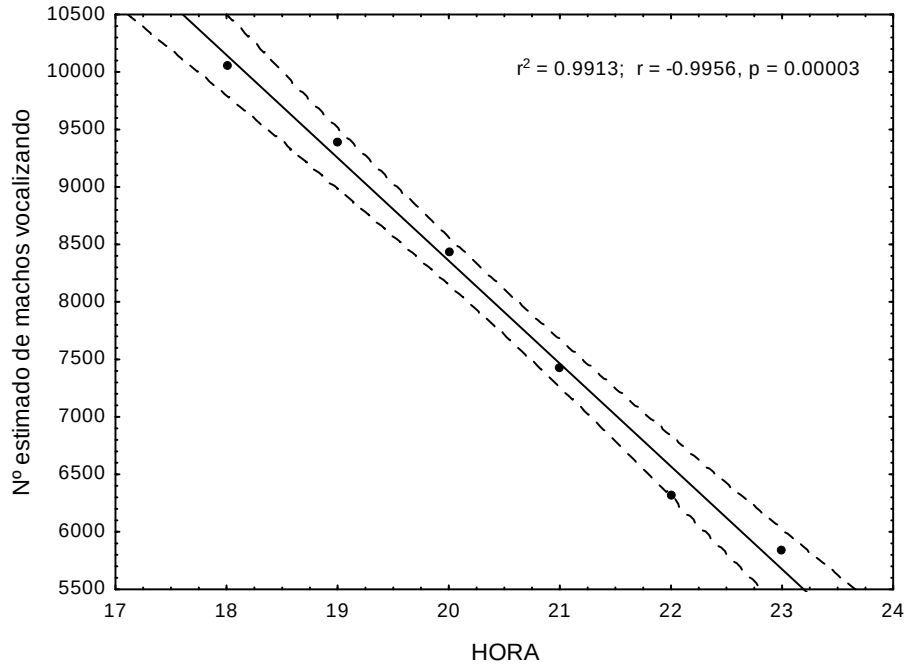


Figura 10 - Relação entre a abundância total estimada de machos vocalizando ao longo das horas de monitoramento, entre Abril de 2007 e Abril de 2009, para a localidade Luis Gonzaga (floresta úmida de altitude), Ubajara, Ceará, Brasil. Linhas pontilhadas representam o intervalo de confiança (p<0,05).

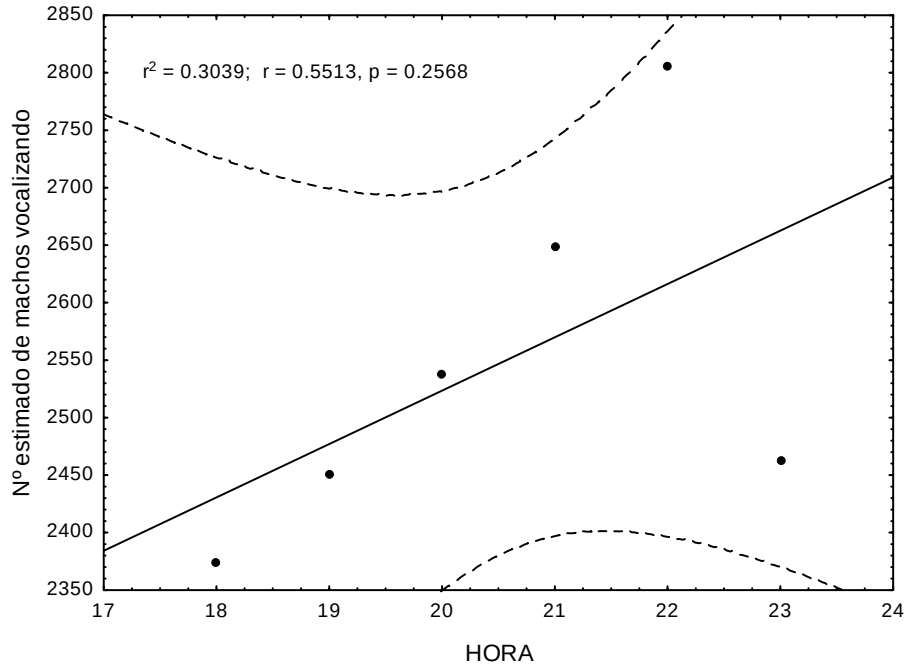


Figura 11 - Relação entre a abundância total estimada de machos vocalizando ao longo das horas de monitoramento, entre abril de 2007 e abril de 2009, para a localidade Santo Mano (Caatinga de baixada), Ubajara, Ceará, Brasil. Linhas pontilhadas representam o intervalo de confiança (p<0,05).

Tabela 5 – Média ± Desvio padrão e número máximo de machos vocalizando (entre parênteses) para cada hora de monitoramento dos anuros da localidade Luís Gonzaga, Ceará, Brasil.

Táxon	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
D. minutus	5,8 ± 5,79 (16)	10,32 ± 6,28 (20)	18,52 ± 9,07 (40)	19,84 ± 10,65 (50)	19 ± 11,20 (50)	17,68 ± 11,60 (50)
D. nanus	14,6 ± 25,44 (100)	14,48 ± 25,52 (100)	12,52 ± 18,23 (60)	8,28 ± 11,20 (30)	6,04 ± 9,56 (30)	5,16 ± 9,77 (30)
D. soaresi	0,8 ± 0 (20)	0,8 ± 0 (20)	0,8 ± 0 (20)	0,8 ± 0 (20)	0,8 ± 0 (20)	0,8 ± 0 (20)
D. sp. (gr. *microcephalus*)	40,76 ± 21,74 (100)	41,88 ± 24,54 (100)	41,88 ± 24,54 (100)	39,4 ± 28,21 (100)	34,88 ± 29,71 (100)	31,6 ± 28,61 (100)
H. multifasciatus	13,48 ± 10,40 (50)	13,76 ± 10,42 (50)	13,04 ± 9,94 (50)	12,08 ± 10,22 (50)	10,28 ± 9,22 (50)	9,6 ± 9,25 (50)
H. raniceps	8,8 ± 4,34 (15)	8,4 ± 4,12 (15)	9,44 ± 9,20 (50)	8,6 ± 9,62 (50)	6,56 ± 5,93 (20)	6,28 ± 5,99 (20)
Pristimantis sp.	2,28 ± 10,76 (30)	2,2 ± 11,10 (30)	1,8 ± 11,66 (30)	1,68 ± 11,59 (30)	0,6 ± 2,43 (5)	0,36 ± 2,34 (5)
L. macrosternum	1,6 ± 7,23 (20)	1,6 ± 7,23 (20)	1,56 ± 7,40 (20)	0,76 ± 1,83 (5)	0,56 ± 1,97 (5)	0,32 ± 2,16 (5)
L. mystaceus	0,28 ± 0 (7)	0,28 ± 0 (7)	0,28 ± 0 (7)	0,28 ± 0 (7)	0,28 ± 0 (7)	0,28 ± 0 (7)
L. sp. (aff. *andreae*)	0,28 ± 2,31 (5)	0,24 ± 2,64 (5)	0,2 ± 2,89 (5)	-	-	-
L. troglodytes	1,68 ± 14,42 (30)	1,68 ± 14,42 (30)	1 ± 7,64 (15)	0,6 ± 8,67 (15)	-	-
L. vastus	5,04 ± 6,01 (25)	4,48 ± 6,49 (25)	3,44 ± 6,80 (25)	3,4 ± 6,85 (25)	2,88 ± 6,21 (25)	2,72 ± 6,29 (25)
O. carvalhoi	1,52 ± 3,25 (12)	1,72 ± 3,30 (12)	1,72 ± 3,30 (12)	1,36 ± 2,14 (6)	1,4 ± 2,06 (6)	1,32 ± 2,02 (6)
P. nordestina	0,24 ± 1 (2)	0,24 ± 1 (2)	0,24 ± 1 (2)	0,28 ± 0,5 (2)	0,24 ± 0,58 (2)	0,24 ± 0,58 (2)
P. cuvieri	33,76 ± 51,58 (200)	32,56 ± 51,71 (200)	32,88 ± 51,91 (200)	33,04 ± 54,46 (200)	30,04 ± 54,33 (200)	29,24 ± 53,72 (200)
P. cristiceps	4,44 ± 13,30 (30)	4,2 ± 11,50 (30)	3,44 ± 10,17 (30)	1,36 ± 7,08 (20)	0,32 ± 1,95 (4)	0,16 ± 1,51 (4)
P. sp. (aff. *falcipes*)	49,68 ± 30,34 (100)	31,88 ± 27,51 (100)	8,12 ± 12,80 (50)	1,2 ± 4,24 (20)	0,24 ± 1,15 (6)	-
R. jimi	2,8 ± 3,98 (12)	2,8 ± 3,98 (12)	2,76 ± 4,12 (12)	2,16 ± 4,01 (12)	1,64 ± 3,00 (10)	1,6 ± 3,01 (10)
S. nebulosus	10,84 ± 10,18 (50)	11,84 ± 10,37 (50)	12,52 ± 13,42 (70)	11,12 ± 14,00 (70)	8,76 ± 7,59 (30)	7,84 ± 7,40 (30)
S. sp. (gr. *ruber*)	1,88 ± 9,58 (20)	1,88 ± 9,58 (20)	1,88 ± 9,58 (20)	1,8 ± 9,79 (20)	1,24 ± 8,26 (20)	0,84 ± 5,05 (10)
S. x-signatus	0,48 ± 2,45 (6)	0,64 ± 2,83 (6)	0,64 ± 2,83 (6)	0,64 ± 4,90 (10)	0,64 ± 4,90 (10)	0,64 ± 4,90 (10)

Tabela 6 – Média ± Desvio padrão e número máximo de machos vocalizando (entre parênteses) para cada hora de monitoramento dos anuros da localidade Santo Mano, Ceará, Brasil.

Táxon	18:00	19:00	20:00	21:00	22:00	23:00
D. minutus	-	-	0,12 ± 0 (3)	0,12 ± 0 (3)	0,12 ± 0 (3)	0,12 ± 0 (3)
D. nanus	4,88 ± 52,16 (100)	5,6 ± 46,19 (100)	6,4 ± 41,63 (100)	2,4 ± 17,32 (40)	2 ± 20,82 (40)	2 ± 20,82 (40)
D. rubicundulus	0,04 ± 0 (1)	0,04 ± 0 (1)	0,04 ± 0 (1)	-	-	-
D. soaresi	1,52 ± 15,01 (30)	1,96 ± 13,05 (30)	2,96 ± 23,35 (50)	1,2 ± 10 (20)	12,8 ± 167,73 (300)	12,8 ± 167,73 (300)
D. sp. (gr. *microcephalus*)	17,04 ± 37,94 (150)	17,84 ± 37,15 (150)	17,44 ± 37,68 (150)	11,44 ± 26,87 (100)	7,52 ± 17,88 (50)	6,72 ± 17,35 (50)
D. mullieri	20,36 ± 248,50 (500)	20,36 ± 248,50 (500)	20,36 ± 248,50 (500)	20,32 ± 248,67 (500)	20,12 ± 249,50 (500)	20,12 ± 249,50 (500)
E. piauiensis	4,6 ± 36,86 (80)	4,6 ± 36,86 (80)	4,6 ± 36,85 (80)	4,6 ± 36,86 (80)	4,4 ± 37,86 (80)	2,8 ± 15,27 (40)
H. raniceps	3 ± 5,17 (20)	3,12 ± 4,96 (20)	3,12 ± 4,96 (20)	3,12 ± 4,96 (20)	3,12 ± 4,96 (20)	3,12 ± 4,96 (20)
L. fuscus	2,28 ± 19,31 (40)	2,28 ± 19,31 (40)	2,28 ± 19,31 (40)	2,2 ± 20,21 (40)	2,2 ± 20,21 (40)	1,4 ± 10,41 (20)
L. macrosternum	1,24 ± 20,50 (30)	1,24 ± 20,50 (30)	3,2 ± 56,57 (80)	3,2 ± 56,57 (80)	3,2 ± 56,57 (80)	3,2 ± 56,57 (80)
L. mystaceus	1,2 ± 0 (15)	1,2 ± 0 (15)	1,2 ± 0 (15)	0,6 ± 10,61 (15)	0,6 ± 10,61 (15)	0,6 ± 10,61 (15)
L. troglodytes	1,24 ± 6,81 (18)	1,24 ± 6,81 (18)	1,24 ± 6,81 (18)	1,04 ± 9,02 (18)	0,56 ± 4,16 (8)	0,56 ± 4,16 (8)
L. vastus	0,56 ± 3,32 (8)	0,56 ± 3,31 (8)	0,48 ± 3,83 (8)	0,16 ± 2 (4)	0,24 ± 1,91 (4)	0,24 ± 1,91 (4)
P. nordestina	3,28 ± 9,10 (30)	3,28 ± 9,10 (30)	3,28 ± 9,10 (30)	6,8 ± 37,92 (100)	6,8 ± 37,92 (100)	6,8 ± 37,92 (100)
P. albifrons	5,2 ± 49,33 (100)	5,2 ± 49,33 (100)	5,2 ± 49,33 (100)	5,2 ± 49,33 (100)	5,2 ± 49,33 (100)	5,2 ± 49,33 (100)
P. cuvieri	3,24 ± 14,91 (40)	3,24 ± 14,90 (40)	3,2 ± 15,16 (40)	3,2 ± 15,16 (40)	3,2 ± 15,16 (40)	3,04 ± 15,66 (40)
P. cristiceps	0,64 ± 4,51 (10)	0,64 ± 4,51 (10)	0,4 ± 5,77 (10)	0,16 ± 2,31 (4)	-	-
P. sp. (aff. *falcipes*)	6,88 ± 42,85 (100)	6 ± 47,87 (100)	4 ± 37,86 (80)	3,2 ± 40 (80)	3,2 ± 40 (80)	3,2 ± 40 (80)
R. granulosa	0,2 ± 2,12 (4)	0,2 ± 2,12 (4)	0,2 ± 2,12 (4)	0,2 ± 2,12 (4)	0,16 ± 2,83 (4)	0,16 ± 2,83 (4)
R. jimi	0,24 ± 1,41 (4)	0,24 ± 1,41 (4)	0,24 ± 1,41 (4)	0,24 ± 1,4 (4)	0,24 ± 1,41 (4)	0,24 ± 1,41 (4)
S. sp. (gr. *ruber*)	17 ± 176,17 (400)	16,96 ± 176,28 (400)	16,96 ± 176,29 (400)	24,56 ± 176,63 (400)	24,56 ± 176,63 (400)	14,2 ± 96,60 (200)
S. x-signatus	0,16 ± 0 (4)	0,6 ± 0 (15)	0,6 ± 0 (15)	8 ± 0 (200)	8 ± 0 (200)	8 ± 0 (200)
T. venulosus	0,16 ± 0 (4)	1,6 ± 0 (40)	4 ± 0 (100)	4 ± 0 (100)	4 ± 0 (100)	4 ± 0 (100)

Discussão

A análise dos dados apresentados nesse trabalho permitiu identificar os seguintes padrões para a área estudada: 1) O número de espécies nas áreas de altitude e de baixada é semelhante, assim como a composição de espécies, embora exista substituição de algumas espécies ao longo do gradiente; 2) a assembléia de anfíbios de serapilheira dos fragmentos de floresta úmida é dominada, em número, por *Physalemus cuvieri*; 3) as áreas de altitude e baixada apresentam marcada sazonalidade reprodutiva; 4) o número de espécies em atividade de vocalização apresenta correlação positiva com a chuva, embora para a maioria das espécies o gatilho reprodutivo ocorra simultaneamente nas primeiras tempestades da estação chuvosa; 5) a abundância de manchos vocalizando não apresentou flutuações pronunciadas ao longo dos turnos de vocalização monitorados.

Considerando todos os métodos empregados foi coletado um total de 35 espécies, um número bastante próximo das 38 espécies conhecidas para a região (veja Capítulo 1). Apenas *Pseudopaludicola* sp. (gr*. mystacalis*), *Physalaemus cicada* e *Scinax fuscomarginatus* não foram encontradas no presente estudo. Aparentemente a não captura dessas espécies para a área amostrada parece não estar associada aos métodos empregados e sim a não existência das mesmas para a região estudada, uma vez que essas espécies foram coletadas com os mesmos métodos aqui empregados em outras localidades do Planalto da Ibiapaba (LOEBMANN & MAI 2008a; LEITE JR, 2008, Capítulo 1).

A composição de espécies encontrada mostra forte influência da fauna de Caatinga na região de estudo, sendo relativamente semelhante às áreas circundantes (e.g. BORGES-NOJOSA & CASCON, 2005; ARZABE et al., 2005; BORGES-NOJOSA & SANTOS, 2005; LOEBMANN & MAI, 2008b). De fato, a maioria

das espécies é típica de áreas abertas, exceto por *Adelophryne baturitensis* e *Pristimantis* sp., *Odontophrynus carvalhoi* tem sido considerada uma espécie de áreas abertas da Caatinga (SKUK et al. 2004); todavia, os registros da espécie para o Ceará estão restritos e associados aos fragmentos de floresta úmida do Maciço de Baturité (BORGES-NOJOSA, 2007) e Planalto da Ibiapaba. *Scinax nebulosus* e *Hypsiboas multifasciatus*, espécies associadas às áreas de baixada do Cerrado, Amazônia e nordeste da Mata Atlântica (LA MARCA et al., 2004; LOEBMANN et al., 2007; SANTANA et al., 2008), ocorrem somente em áreas de altitude do Planalto da Ibiapaba no Ceará.

Trabalhos com informação sobre abundância e composição seguindo um gradiente altitudinal ainda são escassos no Brasil, sendo que em todos eles foram utilizados o métodos de parcelas para coleta de dados (GIARETTA et al., 1999; SAWAYA, 1999; PINHEIRO, 2009). Por essa razão, comparações entre as diferenças observadas ao longo do gradiente altitudinal no presente estudo necessitam ser cuidadosamente interpretadas. Além disso, dois importantes fatores presentes em nossos transectos devem ser considerados: 1) o fato de ter diferentes fitofisionomias não permite afirmar que diferenças na composição de espécies são reflexos da variação altitudinal; 2) a presença de ambientes lênticos somente nos extremos dos transectos limita a presença da maioria das espécies durante a maior parte dos dois transectos monitorados, já que somente as espécies *Adelophryne baturitensis*, *Pristimantis* sp., *Odontophrynus carvalhoi*, *Leptodactylus* sp. (aff. *syphax*), *Leptodactylus* sp. (aff. *andreae*) e *Leptodactylus* sp. (aff. *hylaedactylus*) não dependem de corpos d'água lênticos para reprodução.

Por outro lado, dois padrões marcantes podem ser observados dentro dos gradientes altitudinais. O primeiro é que enquanto *Leptodactylus* sp. (aff.

hylaedactylus) ocorre em áreas de baixadas até 250 m de altitude, *Leptodactylus* sp. (aff. *andreae*) está distribuída entre 250 até o 950 metros de altitude, sendo que as espécies co-existem em apenas uma pequena faixa inferior a 50 metros de altitude. A co-existência dessas espécies similares parece não ser um problema para elas, pois elas desenvolveram cantos de anúncio bem distintos que facilitam a segregação entre elas. O segundo padrão relacionado com a altitude é a presença de *Leptodactylus* sp. (aff. *syphax*) que ocorre entre a faixa altitudinal de 150 a 600 m. Esse padrão encontrado para *L. syphax*, entretanto, deve-se ao fato da espécie está fortemente associada à presença de riachos temporários, com fundo rochoso e em declive acentuado, presente principalmente nessa faixa altitudinal.

Não existem dados sobre abundância de anfíbios de serapilheira para Brejos de Altitude do nordeste do Brasil. Para formações de Mata Atlântica do Sudeste, todavia, existem informações disponíveis na literatura. A maioria dos trabalhos destaca que, em geral, apenas uma espécie domina em número as assembléias de anuros de serapilheira, embora a substituição de dominância das espécies mude entre diferentes áreas ou altitudes, conforme alguns exemplos a seguir. Giaretta et al. (1997) descrevem para uma área do Serra do Japi, São Paulo, Brasil, uma dominância de *Ischnocnema guentheri* para a altitude de 1000 metros, correspondendo a 85% do total capturado e uma dominância de *Ischnocnema juipoca* para a altitude de 850 metros, correspondendo a 67% do total capturado. Giaretta et al. (1999) demonstraram que para Atibaia, São Paulo, Brasil, *Brachycephalus ephippium* é a espécie dominante com 78,6% do total capturado. Pinheiro (2009) encontrou para a Ilha do Cardoso, São Paulo, Brasil, que *Leptodactylus bokermanni* é a espécie mais abundante, com 55,6% do total capturado. Dixo & Verdade (2006) encontraram para Morro Grande, Cotia, São

Paulo, Brasil, uma dominância de *Rhinella ornata*, perfazendo 60% do total capturado, em número. Vasconcelos (2009), estudando uma área de Mata Atlântica no interior do estado de São Paulo, Brasil, mostrou que *Physalaemus cuvieri*, assim como no presente estudo, é a espécie dominante, sendo representada por 73,7% do total de indivíduos capturados. Todavia, nenhum dos estudos mencionados teve dominância de uma espécie com valores de abundância superior a 90%, como no presente estudo. Certamente a abundância de *Pristimantis* sp. é muito superior ao registrado nas capturas nas armadilhas, e provavelmente esta é a segunda espécie mais abundante na serapilheira de fragmentos úmidos do Ceará, sendo os resultados encontrados uma limitação do método de armadilhas de interceptação e queda.

A composição de espécies e abundância de anfíbios é influenciada por fatores ambientais locais como a altitude e o clima (SCOTT, 1976; TOFT, 1980). A chuva tem sido apontada como principal fator abiótico que regula a atividade reprodutiva da maioria das espécies das regiões equatoriais e tropicais do planeta (CARDOSO & MARTINS, 1987). De fato, estudos têm confirmado sazonalidade reprodutiva condicionada pela temporada de chuvas (e.g., AICHINGER, 1987; DONNELLY & GUYER, 1994, BERTOLUCI & RODRIGUES, 2002, TOLEDO et al., 2003; BRASILEIRO et al., 2005; PRADO et al., 2005; ZINA et al., 2007). Os resultados apresentados aqui também mostram essa correlação para a região de estudo. Todavia, apesar dessa correlação existir, fica evidente que a atividade reprodutiva dos anuros é fortemente influenciada pelas primeiras chuvas, pois os picos reprodutivos ocorrem entre 200 e 500 mm do acumulado anual. Ou seja, a quantidade de chuva após esse período não impedirá que o número de espécies em atividade de reprodução diminua drasticamente. A variação de total acumulado de

chuva entre os anos de 2007 e 2009 foi bastante pronunciada (2007 = 1185 mm, 2008 = 1797 mm e 2009 = 2300), sendo que em todos os casos observou o padrão de queda abrupta de espécies em atividade de vocalização. É possível que a quantidade total de chuvas do ano influenciará na sobrevivência dos girinos e juvenis, mas isso não foi testado nesse trabalho e essa questão permanece em aberto.

Exceto por *Pseudopaludicola* sp. (gr. *falcipes*), o turno de vocalização para o restante das espécies iniciou durante o crepúsculo para ambas as áreas monitoradas, corroborando com resultados encontrados em outros trabalhos (e.g. CARDOSO & HADDAD, 1992; POMBAL JR., 1997, PRADO & POMBAL JR. 2005). A grande sobreposição de machos vocalizando evidencia que a temporada de vocalização apresenta importância secundária para o isolamento reprodutivo das espécies.

A segregação espacial em microhabitats também ocorre de maneira limitada para os anfíbios de Caatinga, pois a maioria das espécies divide seus sítios de reprodução com outras espécies durante a explosão reprodutiva. Por exemplo, arbustos e juncais são compartilhados pelas espécies *Scinax* sp. (gr. *ruber*), *Scinax x-signatus*, *Dendropsophus soaresi*, *Dendropsophus nanus*, *Dendropsophus* sp. (gr. *microcephalus*) e *Phyllomedusa nordestina*, enquanto que as espécies *Dermatonotus mullieri*, *Physalaemus albifrons*, *Physalaemus cuvieri*, *Rhinella granulosa*, *Elachistocleis piauiensis*, *Leptodactylus macrosternum* e *Leptodactylus vastus* compartilham simultaneamente áreas de borda de corpos d'água lênticos. O menor número de microhabitats disponíveis quando comparados as área de florestas tropicais (e.g. BERTOLUCI, 1998; BERTOLUCI & RODRIGUES, 2002; CRUMP, 1974), resultando em uma menor diversidade de modos reprodutivos (POMBAL JR &

HADDAD, 2005; HADDAD & PRADO, 2005) e a necessidade da maioria das espécies de se reproduzirem nas primeiras chuvas da estação, parecem atuar como fatores intensificadores na sobreposição de espécies reproduzindo-se simultaneamente na Caatinga.

Apesar de ser constada sazonalidade significativa para ambas as áreas monitoradas, a área de Caatinga de baixada teve sazonalidade muito mais acentuada que na área de floresta úmida de altitude. De fato, é possível observar algumas espécies vocalizando durante quase todos os meses do ano nas áreas de floresta úmida de altitude. Sazonalidade é um resultado esperado e padrão semelhante foi encontrado em outras áreas de Caatinga (ARZABE et al., 1998; ARZABE, 1999; VIEIRA et al., 2007). Todavia, a abundância de machos vocalizando nas florestas úmidas diminui gradativamente com a passagem do pico reprodutivo. Além disso, durante o pico reprodutivo é frequente o encontro de casais em amplexo e/ou desovando, mas passado esse ciclo isto não é mais observado. Portanto, se fosse considerado somente o período onde é possível registrar espécies em amplexo a sazonalidade seria mais acentuada para ambas as áreas estudadas. Uma possível hipótese para explicar esse fato é que a maior parte das espécies está adaptada às marcadas condições sazonais presente na Caatinga e, por essa razão, estão condicionadas a terem explosões reprodutivas, mesmo que o ambiente proporcione condições ideais para reprodução durante um período mais prolongado.

A atividade de vocalização de machos tem sido amplamente correlacionada na literatura como uma medida direta de reprodução para anuros, inclusive em parte no presente trabalho. De fato, isso é um raciocínio lógico considerando que a maioria das espécies de anuros necessita da vocalização para encontro de machos

e fêmeas durante a reprodução (CARDOSO & MARTINS, 1987), além do que existe um custo enérgico para machos durante a vocalização (veja WELLS, 2007). Entretanto, os dados presentes nesse trabalho sugerem que para os anuros do Bioma Caatinga, passado o período de explosão reprodutiva, tem sua atividade reprodutiva praticamente encerrada para a maioria das espécies, ainda que exista machos vocalizando. É provável que isso também ocorra para outros biomas, talvez em menor proporção, considerando que outros biomas tendem a ter menor número de espécies explosivas (veja capitulo 2). Futuros estudos testando essa hipótese serão necessários para esclarecer essa questão em aberto.

Referências

AB'SÁBER, A. N. **O domínio morfoclimático semi-árido das caatingas brasileiras.** São Paulo: Instituto de Geografia da USP, 1974.

AB'SÁBER, A. N. Os domínios morfoclimáticos na América do Sul. Primeira aproximação. **Geomorfologia,** São Paulo, v. 52, p. 1-21, 1977.

AICHINGER, M. Annual activity patterns of anurans in a seasonal Neotropical environment. **Oecologia**, Berlim, v. 71, p. 583-592, 1987.

ARAÚJO, F. S.; RODAL, M. J. N.; BARBOSA, M. R. V (orgs). **Análise das variações da biodiversidade do bioma Caatinga: suporte a estratégias regionais de conservação.** Brasília: Ministério do Meio Ambiente, 2005. 446 p.

ARZABE, C. Reproductive activity patterns of anurans in two different altitudinal sites within the Brazilian Caatinga. **Revista Brasileira de Zoologia**, Curitiba, v. 16, n. 3, p. 851-864, 1999.

ARZABE, C.; CARVALHO, C. X.; COSTA, M. A. G. Anurans assemblages in Crasto Forest ponds (Sergipe, State, Brazil): comparative, structure and calling activity patterns. **Journal of Herpetology**, Lawrence, v. 3, p. 111-113, 1998.

ARZABE, C.; SKUK, G.; SANTANA, G. G.; DELFIM, F. R.; LIMA, Y. C. C.; ABRANTES, S. H. F. Herpetofauna da Área de Curimataú, Paraíba. In: ARAÚJO, F. S.; RODAL, M. N. J.; BARBOSA, M. R. V. (Eds.). **Análise das Variações da Biodiversidade do Bioma Caatinga**. Brasília: Ministério do Meio Ambiente, 2005. p. 259-274.

BALINSKY, B. I. The reproductive ecology of amphibians of the Transvaal Highveld. **Zoologica Africana**, Cidade do Cabo, v. 4, n. 1, p. 37-93, 1969.

BARBAULT, R. Ecological constraints and community dynamics*:* linking community patterns to organismal ecology. The case of tropical herpetofaunas. **Acta Oecologia**, Paris, v. 12, p. 139-163, 1991.

BELLIS, E. D. The influence of humidity on wood frog activity. **The American Midland Naturalist**, Notre Dame, v. 68, n. 1, p. 139-148, 1962.

BERNARDE, P. S. Ambientes e temporada de vocalização da anurofauna no Município de Espigão do Oeste, Rondônia, Sudoeste da Amazônia - Brasil (Amphibia: Anura). **Biota Neotropica**, Campinas, v. 7, n. 2, p. 87-92, 2007.

BERNARDE, P. S.; MACHADO, R. A. Riqueza de espécies, ambientes de reprodução e temporada de vocalização da anurofauna em Três Barras do Paraná, Brasil (Amphibia: Anura). **Cuadernos de Herpetologia**, Tucuman, v. 14, n. 2, p. 93-194, 2001.

BERTOLUCI, J.; RODRIGUES, M. T. Seasonal patterns of breeding activity of Atlantic rainforest anurans at Boracéia, southeastern Brazil. **Amphibia-Reptilia**, Leiden, v. 23, p. 161-167, 2002.

BERTOLUCI, J. Annual patterns of breeding activity in Atlantic Rainforest anurans. **Journal of Herpetology**, Lawrence, v. 32, n. 4, p. 607-611, 1998.

BEZERRA, E. C.; BEZERRA, J. E. G.; MENDES, M. F. S. Precipitações. In: Instituto de Planejamento do estado do Ceará (Ed.). **Atlas do Ceará**. Fortaleza: Secretaria do Planejamento - Governo do Estado do Ceará, 1997. p. 22-23.

BLAIR, W. F. Calling and spawning seasons in a mixed population of anurans. **Ecology**, Davis, v. 42, n. 1, p. 99-110, 1961.

BORGES-NOJOSA, D. M. Diversidade de Anfíbios e Répteis da Serra de Baturité, Ceará. In: OLIVEIRA, T. S.; ARAÚJO, F. S. (Eds.). **Diversidade e Conservação da Biota na Serra de Baturité, Ceará**. Fortaleza: Edições UFC, 2007. p. 225-247.

BORGES-NOJOSA, D. M.; CARAMASCHI, U. Composição e Análise Comparativa da Diversidade e das Afinidades Biogeográficas dos Lagartos e Anfisbenídeos (Squamata) dos Brejos Nordestinos. In: LEAL, I.; SILVA, J. M. C.; TABARELLI, M. (Eds.). **Ecologia e Conservação da Caatinga**. Recife: UFPE, 2003. p. 489-540.

BORGES-NOJOSA, D. M.; CASCON, P. Herpetofauna da Área Reserva da Serra das Almas, Ceará. In: ARAÚJO, F. S.; RODAL, M. N. J.; BARBOSA, M. R. V. (Eds.). **Análise das Variações da Biodiversidade do Bioma Caatinga**. Brasília: Ministério do Meio Ambiente, 2005. p. 245-260.

BORGES-NOJOSA, D. M.; SANTOS, E. M. Herpetofauna da Área de Betânia e Floresta, Pernambuco. In: ARAÚJO, F. S.; RODAL, M. N. J.; BARBOSA, M. R. V. (Eds.). **Análise das variações da biodiversidade do bioma Caatinga.** Brasília: Ministério do Meio Ambiente, 2005. p. 277-291.

BRASILEIRO, C. A.; SAWAYA, R. J.; KIEFER, M. C.; MARTINS, M. Amphibians of an open Cerrado fragment in southeastern Brazil. **Biota Neotropica**, Campinas, v. 5, n. 2, p. 1-17, 2005.

BRASSALOTI, R. A.; ROSSA-FERES, D. C.; BERTOLUCI, J. Anuran fauna of the Semi-deciduous Forest of the Estação Ecológica dos Caetetus, southeastern Brazil. **Biota Neotropica**, Campinas, v. 10, n. 1, p. 1-17, 2010.

CARDOSO, A. J.; HADDAD, C. F. B. Diversidade e turno de vocalizações de Anuros em comunidade neotropical. **Acta Zoologica Lilloana**, Tucumán, v. 41, p. 93-105, 1992.

CARDOSO, A. J.; MARTINS, J. E. Diversidade de anuros durante o turno de vocalizações, em comunidade neotropical. **Papéis Avulsos de Zoologia**, Rio de Janeiro, v. 36, n. 23, p. 279-285, 1987.

COIMBRA-FILHO, A. C.; CÂMARA, I. G. **Os limites originais do bioma Mata Atlântica na Região Nordeste do Brasil**. Rio de Janeiro: Fundação Brasileira para a Conservação da Natureza, 1996. 86 p.

COLWELL, R. K. 2005. EstimateS: statistical estimation of species richness and shared species from samples. Versão 7.5.2. University of Connecticut, Storrs. http://viceroy.eeb.uconn.edu/estimates (último acesso em 1/09/2009).

COLWELL, R. K.; MAO, C. X.; CHANG, J. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. **Ecology**, Davis, v. 85, n. 10, p. 2717-2727, 2004.

CONTE, C. E.; MACHADO, R. A. Riqueza de espécies e distribuição espacial e temporal em comunidade de anfíbios anuros (Amphibia, Anura) em uma localidade do Município de Tijucas do Sul, Paraná, Brasil. **Revista Brasileira de Zoologia**, Curitiba, v. 22, n. 4, p. 940-948, 2005.

CONTE, C. E.; ROSSA-FERES, D. C. Diversidade e ocorrência temporal da anurofauna (Amphibia, Anura) em São José dos Pinhais, Paraná, Sul do Brasil. **Revista Brasileira de Zoologia**, Curitiba, v. 23, n.1, p. 162-175, 2006.

CORN, P. S. Straight–line drift fences and pitfall traps. In: HEYER, W. R.; DONNELY, M. A.; MCDIARMID, R. W.; HAYEK, L. A. C.; FOSTER, M. S. (Eds.). **Measuring and monitoring biological diversity: Standard methods for amphibians.** Washington: Smithsonian Institution Press, 1994. p. 109-117.

CRUMP, M. L. Reproductive strategies in a tropical anuran community. **Miscellaneous Publication of the Museum of Natural History**, Lawrence v. 61, 1-68, 1974.

CRUMP, M. L. Amphibian reproductive ecology on the community level. In: SCOTT JR., N. J. (Ed.). **Herpetological communities**. Washington, USDI Fish and Wildlife Service, 1982. p. 21-36.

LA MARCA, E.; REYNOLDS, R.; AZEVEDO-RAMOS, C. 2004. *Scinax nebulosus*. In: IUCN 2010. **IUCN Red List of Threatened Species.** Version 2010.1. <www.iucnredlist.org>. Acessado em 03 de Maio de 2010.

DIXO, M.; VERDADE, V. K. Herpetofauna de serrapilheira da Reserva Florestal de Morro Grande, Cotia (SP). **Biota Neotropica**, São Paulo, v. 6, n. 2, p. 1-20, 2006.

DONNELLY, M. A.; GUYER, C. Patterns of reproduction and habitat use in an assemblage of Neotropical hylid frogs. **Oecologia,** Berlim, v. 98, p. 291-302, 1994.

DUELLMAN, W. E.; PYLES, R. A. Acoustic resource partitioning in anuran communities. **Copeia**, Lawrence, v. 1983, p. 639-649, 1983.

GOTELLI, N. J.; COLWELL, R. K. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. **Ecology Letters**, Singapura, v. 4, p. 379-391, 2001.

GIARETTA, A. A.; SAWAYA, R. J.; MACHADO, G.; ARAÚJO, M. S.; FACURE, K. G.; MEDEIROS, H. F.; NUNES, R. Diversity and abundance of litter frogs at altitudinal sites at Serra do Japi, Southeastern Brazil. **Revista Brasileira de Zoologia**, Brasil, v. 14, n. 2, p. 341-346, 1997.

GIARETTA, A. A.; FACURE, K. G.; SAWAYA, R. J.; MEYER, J. H. M.; CHEMIN, N. Diversity and abundance of litter frogs of a montane forest in southeastern Brazil: seasonal and altitudinal changes. **Biotropica**, Zurique, v. 31, n. 4, p. 669-674, 1999.

GRANDINETTI, L.; JACOBI, C. M. Distribuição estacional e espacial de uma taxocenose de anuros (Amphibia) em uma área antropizada em Rio Acima - MG. **Lundiana**, Belo Horizonte, v. 6, n. 1, p. 21-28, 2005.

HADDAD, C. F. B.; SAZIMA, I. Anfibios Anuros da Serra do Japi. In: Morellato, L. P. C. (Org.). **Historia natural da Serra do Japi**: ecologia e preservação de uma área florestal no sudeste do Brasil. 1 ed. Campinas: UNICAMP/FAPESP, v. 1, p. 188-211, 1992.

HADDAD, C. F. B.; PRADO, C. P. A. Reproductive modes in frogs and their unexpected diversity in the Atlantic forest of Brazil. **Bioscience**, Washington, v. 55, n. 3, p. 207-217, 2005.

HEYER, W. R.; RAND, A. S.; CRUZ, C. A. G. D.; PEIXOTO, O. L.; NELSON, C. E. Frogs of Boracéia. **Arquivos de Zoologia**, São Paulo, v. 31, p. 231-410, 1990.

KOTTEK, M.; GRIESER, J.; BECK, C.; RUDOLF, B.; RUBEL, F. World Map of the Köppen-Geiger climate classification updated. **Meteorologische Zeitschrift**, Stuttgart, v. 15, n. 3, p. 259-263, 2006.

KOVACH, W. L. **Oriana para Windows**, versão 3.11. Pentraeth: Kovach Computer Services, 2009.

LEITE JR., J. M. A.; SAMPAIO, J. M. S.; SILVA-LEITE, R. R.; TOLEDO, L. F.; LOEBMANN, D.; LEITE, J. R. S. A. Amphibia, Anura, Hylidae, *Scinax fuscomarginatus*: distribution extension. **Check List – Journal of species lists and distribution**, Campinas, v. 4, n. 4, p. 475-477, 2008.

LOEBMANN, D.; MAI, A. C. G. Amphibia, Anura, Leiuperidae, *Physalaemus cicada*: distribution extension in the state of Ceará, Brazil. **Check List – Journal of species lists and distribution**, Campinas, v. 4, n. 4, p. 392-394, 2008a.

LOEBMANN, D.; MAI, A. C. G. Amphibia, Anura, Coastal Zone, Piauí state, Northeastern Brazil. **Check List**, Campinas, v. 4, n. 2, p. 161-170, 2008b.

LOEBMANN, D.; PRADO, C. A. P.; HADDAD, C. F. B.; BASTOS, R. F.; GUIMARAES, L. D. Geographic distribution. *Hypsiboas multifasciatus*, Brazil: Ceará and Goiás. Herpetological Review, Lawrence, v. 38, n. 4, p. 476, 2007.

PINHEIRO, S. C. P. Anurofauna de serapilheira de diferentes formações vegetais ao longo de um gradiente altitudinal no Parque Estadual da Ilha do Cardoso, município de Cananéia, SP. **Dissertação de Mestrado**, Escola Superior de Agricultura "Luiz de Queiroz", Piracicaba, 2009. 110 p.

POMBAL JR., J. P. Distribuição espacial e temporal de anuros (Amphibia) em uma poça permanente na Serra de Paranapiacaba, sudeste do Brasil. **Revista Brasileira de Biologia**, São Carlos, v. 57, n. 4, p. 583-594, 1997.

POMBAL JR., J. P.; HADDAD, C F B. Estratégias e modos reprodutivos de anuros (Amphibia) em uma poça permanente na Serra de Paranapiacaba, Sudeste do Brasil. **Papéis Avulsos de Zoologia**, São Paulo, v. 45, n. 15, p. 201-213, 2005.

POMBAL JR., J. P.; SAZIMA, I.; HADDAD, C. F. B. Breeding behavior of the pumpkin toadlet, *Brachycephalus ephippium* (Brachycephalidae). **Journal of Herpetology**, Lawrence, v. 28, n. 4, p. 516-519, 1994.

PRADO, C. P. A.; HADDAD, C. F. B. Size-fecundity relationships and reproductive investment in female frogs in the Pantanal, southwestern Brazil. **Herpetological Journal**, London, v. 15, n. 4, p. 181-189, 2005.

PRADO, C. P. A.; UETANABARO, M.; HADDAD, C. F. B. Breeding activity patterns, reproductive modes, and habitat use by anurans (Amphibia) in a seasonal environment in the Pantanal, Brazil. **Amphibia-Reptilia**, Leiden, v. 26, n. 2, p. 211-221, 2005.

PRADO, G. M.; POMBAL JR. J. P. Distribuição espacial e temporal dos anuros em um brejo de Reserva Biológica de duas bocas, Sudeste do Brasil. **Arquivos do Museu Nacional**, Rio de Janeiro, v. 63, n. 4, p. 685-705, 2005.

ROSSA-FERES, D. C.; JIM, J. Distribuição sazonal em comunidades de anfíbios anuros na região de Botucatu, São Paulo. **Revista Brasileira de Biologia**, São Carlos, v. 54, n. 4, p. 323-334, 1994.

ROSSA-FERES, D. C.; JIM, J. Similaridade do sítio de vocalização em uma comunidade de anfíbios anuros na região noroeste do Estado de São Paulo, Brasil. **Revista Brasileira de Zoologia**, Curitiba, v. 18, n. 2, p. 439-454, 2001.

SANTANA, G. G.; VIEIRA, W. L. S.; PEREIRA-FILHO, G. A.; DELFIM, F. R.; LIMA, Y. C. C.; VIERIA, K. S. Herpetofauna em um fragmento de Floresta Atlântica no Estado da Paraíba, Região Nordeste do Brasil. **Biotemas**, Florianópolis, v. 21, n. 1, p. 75-84, 2008.

SAWAYA, R. J. 1999. Diversidade, densidade e distribuição altitudinal da anurofauna de serapilheira da Ilha de São Sebastião, SP. **Dissertação de Mestrado**, Universidade de São Paulo, São Paulo. 65p.

SCOTT, N. J. The abundance and diversity of herpetofaunas of tropical Forest litter. **Biotropica**, Zurique, v. 8, p. 41-58, 1976.

SCOTT JR., N. J.; WOODWARD, B. D. Técnicas estándar para inventarios e monitoreos. In: HEYER, W. R.; DONNELLY, M. A.; MCDIARMID, R.W.; HAYEK, L. A. C.; FOSTER, M. S. (Eds.). **Medición e monitoreo de la diversidad biológica: Métodos estandartizados para Anfibios**. Chubut: Editora Universitária de la Patagonia, 1994. p. 113-120.

SKUK, A.; BORGES-NOJOSA, D. M.; PAVAN, D. *Odontophrynus carvalhoi*. In: IUCN 2010. **IUCN Red List of Threatened Species.** 2004. Version 2010.1. <www.iucnredlist.org>. Acesso em 02 de Maio de 2010.

TABARELLI, M.; SILVA, J. M. C. Áreas e ações prioritárias para a conservação da biodiversidade da Caatinga. In: LEAL, I.; SILVA, J. M. C.; TABARELLI, M. (Eds.). **Ecologia e conservação da Caatinga**. Recife: UFPE, 2003. p. 781-800.

TOFT, C. A. Feeding ecology of thirteen syntopic species of anurans in a sazonal tropical rain forest. **Oecologia**, Berlin, v. 45, p. 131-141, 1980.

TOLEDO, L. F.; ZINA, J.; HADDAD, C. F. B. Distribuição espacial e temporal de uma comunidade de anfíbios do Município de Rio Claro, São Paulo, Brasil. **Holos Environment**, Rio Claro, v. 3, n. 2, p. 136-149, 2003.

VASCONCELOS, T. S. Diversidade, padrões espaciais e temporais de anfíbios anuros em uma Floresta Estacional Semidecidual Atlântica, Parque Estadual do Morro do Diabo (PEMD), **Tese de Doutorado**, Universidade Estadual Paulista, Rio Claro, 2009. 137 p.

VASCONCELOS, T. S.; ROSSA-FERES, D. C. Diversidade, distribuição espacial e temporal de anfíbios anuros (Amphibia, Anura) na região noroeste do estado de São Paulo, Brasil. **Biota Neotropica**, Campinas, v. 5, n. 2, p. 1-14, 2005.

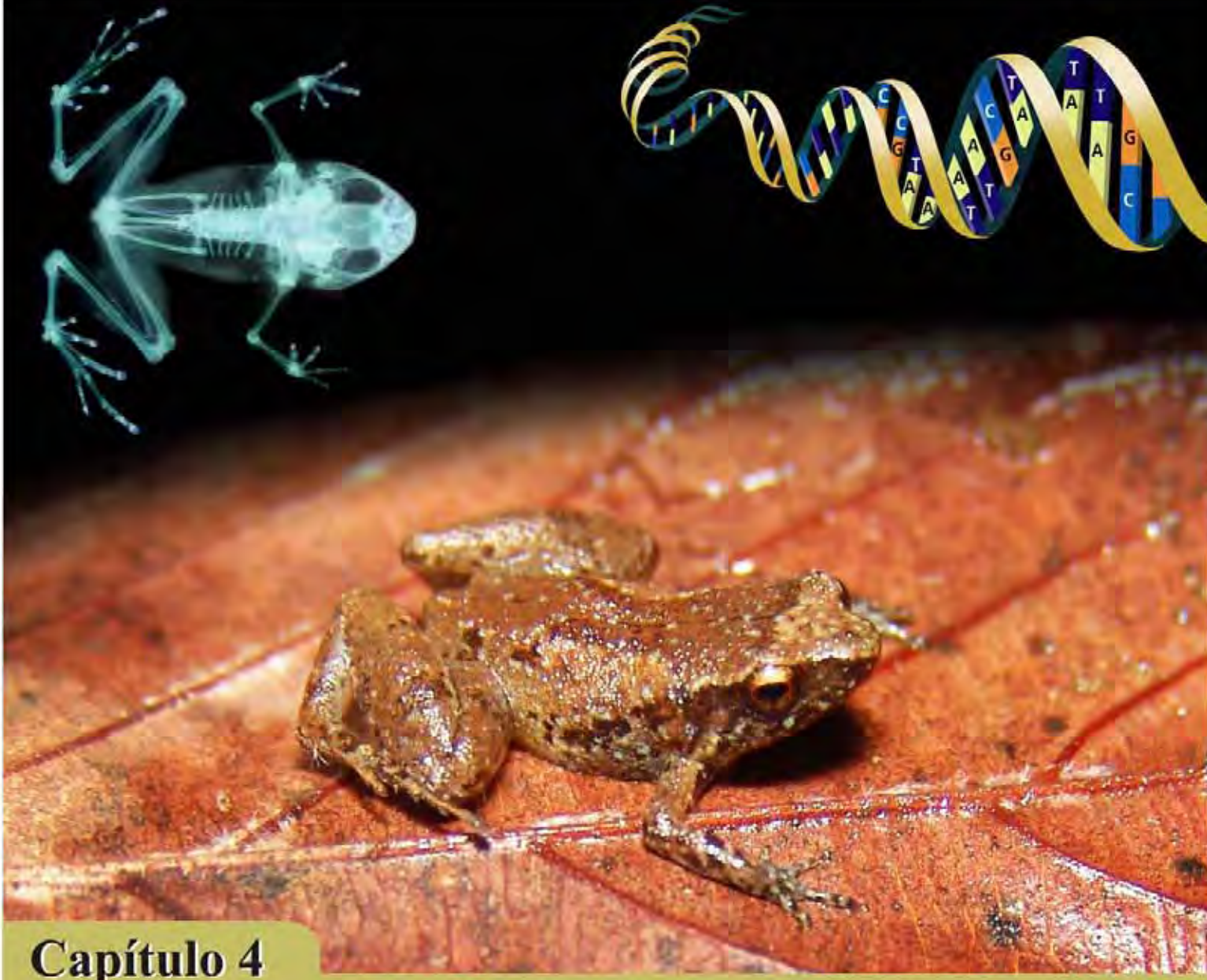
VIEIRA, W. L. S.; ARZABE, C.; SANTANA, G. G. Composição e distribuição espaço-temporal de anuros no Cariri paraibano, Nordeste do Brasil. **Oecologia Brasiliensis**, Rio de Janeiro, v. 11, p. 383-396, 2007.

WELLS, K. D. **The ecology and behavior of amphibians**. Chicago: University of Chicago Press, 2007. 1148 p.

WIEST JR., J. A. Anuran succession at temporary ponds in a post oak-savanna region of Texas. p. 39-47. In: SCOTT JR., N. J. (Ed.). **Herpetological Communites.** Washington: USDI Fish and Wildlife Service, 1982. 239 p.

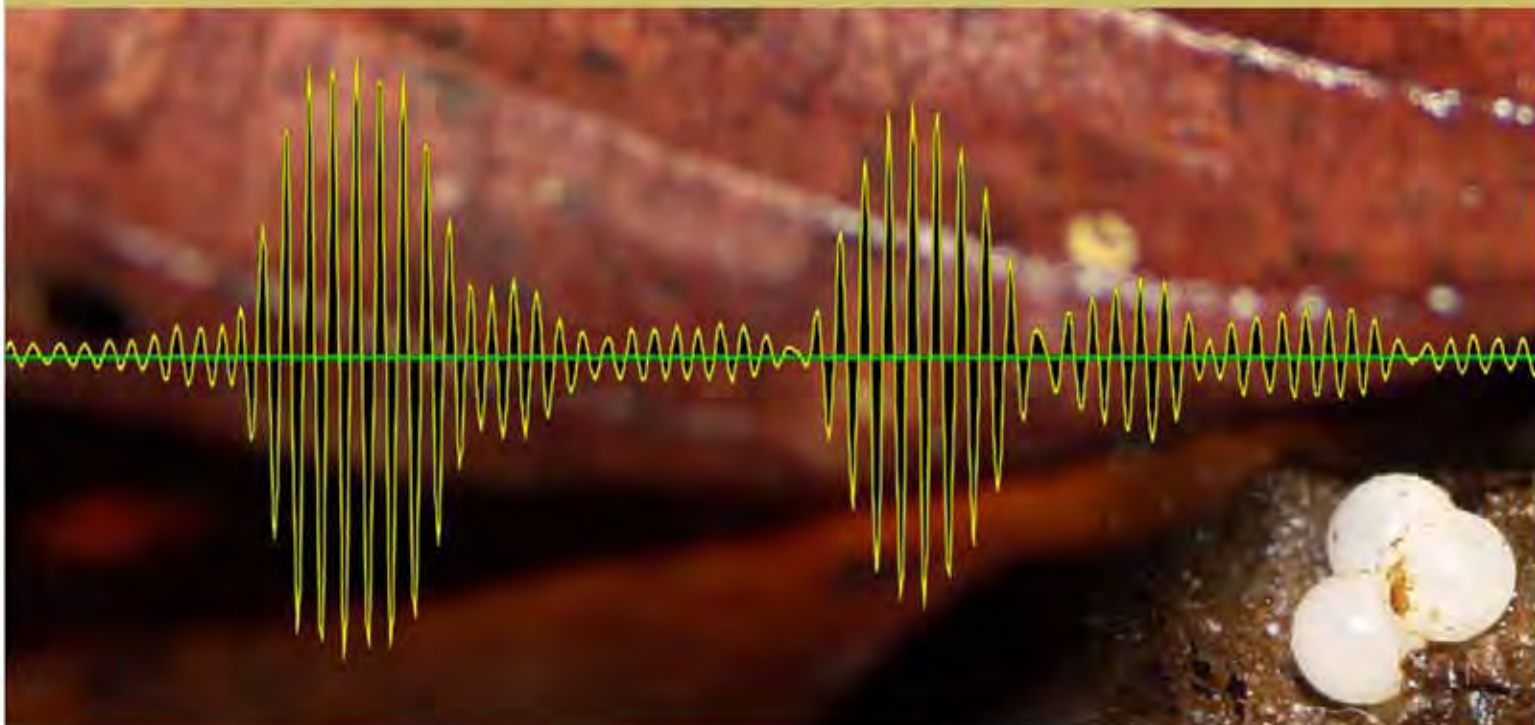
ZAR, J. **Biostatistical analysis**, 4th ed. New Jersey: Prentice Hall, 1999. 663 p.

ZINA, J.; ENNSER, J.; PINHEIRO, S. C. P.; HADDAD, C. F. B.; TOLEDO, L. F. Taxocenose de anuros de uma mata semidecídua do interior do Estado de São Paulo e comparações com outras taxocenoses do Estado, sudeste do Brasil. **Biota Neotropica**, Campinas, v. 7, p. 49-58, 2007.



Capítulo 4

Good news for a Brazilian amphibian species threatened with extinction: discovery of new populations provide a new taxonomic and conservation status for *Adelophryne baturitensis* (Anura, Eleutherodactylidae, Phyzelaphryninae)



Abstract: The state of Ceará shelters two species of tiny frogs, *Adelophryne baturitensis* and *Adelophryne maranguapensis*, which are currently considered threatened with extinction. These species have been regarded as endemic from their type localities, occurring in restricted highland areas (up to 1110 m above sea level) of tropical moist forest enclaves. During two years, we investigated seven forest enclaves in the state of Ceará in order to find other populations of these species. We discovered new populations in other areas, including a very well established population within a protected area. Due to the high similarities between species, a taxonomic review for all populations was performed. We examined morphological characters from 148 specimens, along with other techniques (advertisement calls description and molecular analyzes), and we concluded that *Adelophryne baturitensis* is present in all localities, including in the type locality of *Adelophryne maranguapensis*. Therefore, *Adelophryne baturitensis* distribution is not restricted to its type locality as formerly believed. These results bring a new insight on the conservation status of *Adelophryne baturitensis*.

Key words: *Adelophryne baturitensis*, conservation, tropical moist forest enclaves, taxonomic review, call description.

Introduction

The subfamily Phyzelaphryninae is currently composed by terrestrial leaf litter frogs from the genera *Phyzelaphryne* Heyer, 1977 and *Adelophryne* Hoogmoed and Lescure, 1984, both represented by tiny frogs, none of them exceeding 23 mm in snout-vent length (SVL) (HEGDES et al., 2008; MACCULLOCH

et al., 2008). While *Phyzelaphryne* has been considered a monospecific genus, *Adelophryne* comprises a total of six described species (MACCULLOCH et al., 2008; FROST, 2009) which occurs in moist/humid forests, in the Amazon rainforest (*Adelophryne adiastola* Hoogmoed and Lescure, 1984, *Adelophryne gutturosa* Hoogmoed and Lescure, 1984, *Adelophryne patamona* MacCulloch, Lathrop, Kok, Minter, Khan, and Barrio-Amoros, 2008), in the Atlantic rainforest (*Adelophryne pachydactyla* Hoogmoed, Borges, and Cascon, 1994), and in enclaves of moist forests in Caatinga (*Adelophryne baturitensis* Hoogmoed, Borges, and Cascon, 1994, and *Adelophryne maranguapensis* Hoogmoed, Borges, and Cascon, 1994).

Due to *Adelophryne* life cycle – these frogs have direct development – the species are strictly dependent on forest environments with high humidity to survive. Considering the Caatinga has a predominance of arid and semi-arid formations, resulted from a pronounced seasonal climate with a long dry period, the presence of *Adelophryne baturitensis* and *A*. *maranguapensis* are unsuitable in almost all areas of the state. Therefore, their distributions are restricted to highland areas up to 1110 m above sea level, in small enclaves of tropical moist forests.

This peculiar condition of both species inhabiting the Caatinga, associated with their restricted distributions to their type-localities and surroundings (Maciço de Baturité for *A. baturitensis,* and Serra de Maranguape for *A. maranguapensis*) (HOOGMOED et al., 1994), and the supposed decreasing of their populations (ETEROVICK et al., 2005) have maintained *Adelophryne baturitensis* and *A*. *maranguapensis* status as Vulnerable and Endangered, respectively, according to the Red List of Threatened Species of Brazil (HADDAD, 2008) and the Red List of

Threatened Species of International Union for Conservation of Nature (IUCN, 2008).

Theoretically, each tropical rainforest enclave in the state of Ceará would have their own set of endemic species (VANZOLINI, 1981, 1992, HOOGMOED et al., 1994; BORGES-NOJOSA & CARAMASCHI, 2003); however, this paradigm has recently become questionable (e.g. LOEBMANN et al., 2009, Annex 12; LOEBMANN & HADDAD, submitted, Chapter 1; ROBERTO & LOEBMANN, Annex 13). During two years, we investigated the main areas of tropical rainforests enclaves in the state of Ceará and we found other populations of *Adelophryne*. In this work, we tested the relationships of these species using morphological, acoustic, and molecular techniques. Based on the results, we discuss the conservation status for both species based on IUCN criteria.

Material and Methods

STUDY AREA

During January 2007 to April 2009, we conducted several expeditions in the main physiognomies of tropical rainforest enclaves in the state of Ceará. Since *Adelophryne* is not adapted to inhabiting open areas of Caatinga Biome, we can assure the specimens sampled were restricted to enclave areas. The sampled areas were Chapada do Araripe (03°33'-03°34' S/40°46'-39°05' W), Planalto da Ibiapaba (03°20'-05°00' S/40°42'-41°10' W), Serra de Baturité (07°08'-07°41' S/ 38°51'-38°59' W), Serra de Maranguape (03°52'-3°54' S/ 38°43' W), Serra da Meruoca (03°30'-03°34' S/40°21'-40°35' W), Serra da Uruburetama (03°33'-03°39' S/39°36'-39°31' W), and Serra da Aratanha (03°56'-04°04' S/38°40'- 38°37 W).

FIELD WORK

We collected and/or monitored *Adelophryne* populations using the following methods: 1) opportunistic encounters; 2) vocalizations; and 3) a pitfall sampling effort of 8,640 (number of traps x days x months). For each pitfall, we used a plastic bucket of 60 l. Six transects were set up, each one comprising six buckets set at a distance of 10 m apart from each other. Pit fall traps were used only in Planalto da Ibiapaba (Parque Nacional de Ubajara). Collecting permits were granted by Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) (Process #14130-1). Voucher specimens were deposited in Célio F. B. Haddad Amphibian Collection (CFBH), Universidade Estadual Paulista "Julio de Mesquita Filho", Rio Claro, São Paulo, Brazil.

DISTRIBUTION MAP OF *ADELOPHRYNE*

To create a map of distribution for *Adelophryne*, we compiled our data with data available in the literature. The map was constructed using DIVA-GIS software (http://www.diva-gis.org) (HIJMANS et al., 2002). Geographical coordinates and altitude were obtained with a Garmin® Etrex Legend portable GPS. To estimate the potential area of occurrence of each population, we used layers of forest remnants available at http://mapas.mma.gov.br/mapas/aplic/probio/datadownload.htm?/ (MMA, 2009). The area of each layer was estimated using UTHSCSA ImageTool software (http://ddsdx.uthscsa.edu/dig/download.html). The minimum home range for the

populations was determined based on the smaller forest remnants in which *Adelophryne* was found.

ACOUSTIC PARAMETERS

To record the advertisement calls, we used a ®Sony cassette tape recorder (TCM-150) equipped with an external directional microphone ®Yoga (HT 81 Boom) positioned at least 3 m distance of the calling males. Magnetic tapes of iron were used and calls were recorded only at one side of the tape. Calls were digitalized at a PC-Desktop equipped with a PCI Soundboard ®Creative Sound Blaster Audigy SE 7.1 with 24-bit of resolution.

Call analyses were performed using the software Raven 1.2.1 with 44.1 kHz and 16 bits of resolution. The audio spectrograms were produced with FFT of 256 points, 87% overlap, and window flat top. Eight acoustic variables were measured: duration of each call, interval between calls, duration of each note, interval between two consecutive notes, dominant, maximum and minimum frequencies, and number of pulses per note. Acoustic and mechanistic call parameters followed designations proposed by Robillard et al. (2006).

We examined variation on internal and external morphological diagnostic characters for both valid species of *Adelophryne* from Ceará (see Table 2). The external characters analyzed were snout vent length, dorsal and ventral pattern color, pigmentation in the temporal and flanks regions, dorsal texture, and presence of tubercles or pads in the solar surface of the foot. Body measurements were taken with the aid of a Starrett® 727 series digital calliper (scale graduation

= 0.01 mm). At least one specimen from each population was cleared and stained following the method proposed by Taylor & Van Dyke (1985).

MOLECULAR DATA

Specimens of *Adelophryne* sp. (gr. *baturitensis*) were obtained from six municipalities in Ceará state and one locality in Pernambuco state (Appendix 1). Muscle tissue samples were taken from legs and stored in 95% ethanol for DNA extraction.

Total DNA was extracted from individuals with DNeasy Tissue Kit (Qiagen, Hilden, Germany). A fragment of mitochondrial 16S rRNA (16S) was amplified with primers An16S-F and An16S-R (LYRA et al., *in prep.*) using reaction conditions described in Lyra et al. (*in prep.*). PCR products were purified using the Invisorb® fragment cleanup kit (Invitek, Berlin, Germany) and were sequenced using BigDye terminator sequencing kit in an ABI3077 automated sequencer (Applied Biosystems). Products were sequenced in both directions using amplification primers.

Sequences were assembled in a contig for each individual with CAP3 software (HUANG & MADAN, 1999). Alignment of sequences was performed with Clustal X (THOMPSON et al., 1997) and it was verified by eye. Sequence divergences were quantified by Kimura-2-Parameter distance model (K2P) and graphically displayed in a neighbor-joining (NJ) tree, using MEGA4 software (TAMURA et al., 2007).

In addition to the specimens sampled, we included in the analyses sequences of *Adelophryne pachydactyla* (Appendix 1), *Adelophryne gutturosa* and *Phyzelaphryne miriamae* (Accession numbers EU 186679 and EU186689,

respectively) as the closest out-groups for quantification of interspecies divergences.

Results

RECORDS OF *ADELOPHRYNE* POPULATIONS AND ESTIMATES OF THEIR POTENTIAL AREA OF OCCURRENCE

We sampled seven main physiognomies of tropical moist forests enclaves in the state of Ceará (Figure 1). It was possible to identify well established populations of *Adelophryne baturitensis* in four areas (Planalto da Ibiapaba, Maciço de Baturité, Serra de Maranguape, and Serra da Aratanha; Figure 1). In these four areas, we were able to find specimens of *Adelophryne baturitensis* in every expedition. Besides this, we included in the distribution map a recent record of *Adelophryne baturitensis* for Brejo dos Cavalos, located in the municipality of Caruaru, state of Pernambuco (08°22'23.98" S, 36°02'00.20" O; ca. 900 m above sea level) (Loebmann et al. submitted, Annex 14). The estimate of the potential area of occurrence for the species, i.e. the size in square kilometers of tropical moist forest remnants (database available at MMA 2009) is ca. 2,800 km^2, distributed as the following: ca. 1,650 km^2 in the Planalto da Ibiapaba, ca. 915 km^2 in the Maciço de Baturité, ca. 60 km^2 in the Serra da Aratanha, ca. 72 km^2 in the Serra de Maranguape, and ca. 106 km^2 in the Brejo dos Cavalos.

The smaller area where the species was found comprises 0.5 km^2. This area is a small and isolated forest remnant in the extreme Northern section of the Planalto da Ibiapaba mountain range (03°22'59" S and 41°09'38" W); 710 m above sea level.

MORPHOLOGICAL COMPARISONS AMONG *ADELOPHRYNE* POPULATIONS

We examined a total of 148 individuals from four distinct areas, a larger series of specimens compared with the original description (HOOGMOED et al., 1994). The main characters that distinguish both recognized species for the state of Ceará were found in all populations. Specimens presented a high intraspecific polymorphism in the dorsal coloration pattern (see Figures 2 and 3). The ventral region of all specimens analyzed was relatively similar, with throat, chest and belly light brown colored, and with high density of dark brown flecks (Figure 4). In all analyzed individuals, the skin texture was pustulous.

In figure 5, it is possible to observe the plantar surface of hands and solar surface of feet of *Adelophryne* specimens from Serra de Maranguape, Maciço de Baturité, and Planalto da Ibiapaba, respectively. It was not possible to identify a variation in tubercles or pads, i.e. all specimens analyzed had tubercles in the toes. We assume that all specimens examined have tubercles by comparison with *Adelophryne pachydactyla*, a species with pads in the foot (see further details in Figure 6). Cleared and stained individuals showed that all populations from Ceará have finger phalangeal formula 2-2-3-3 (Figure 7). Snout vent length highly overlapped among populations (Planalto da Ibiapaba population SVL ranging from 9.35 to 17.63 mm, n = 44; Serra de Baturité population SVL ranging from 10.45 to 13.05 mm, n = 8; Serra de Maranguape population SVL ranging from 10.90 to 15.06 mm, n = 14).

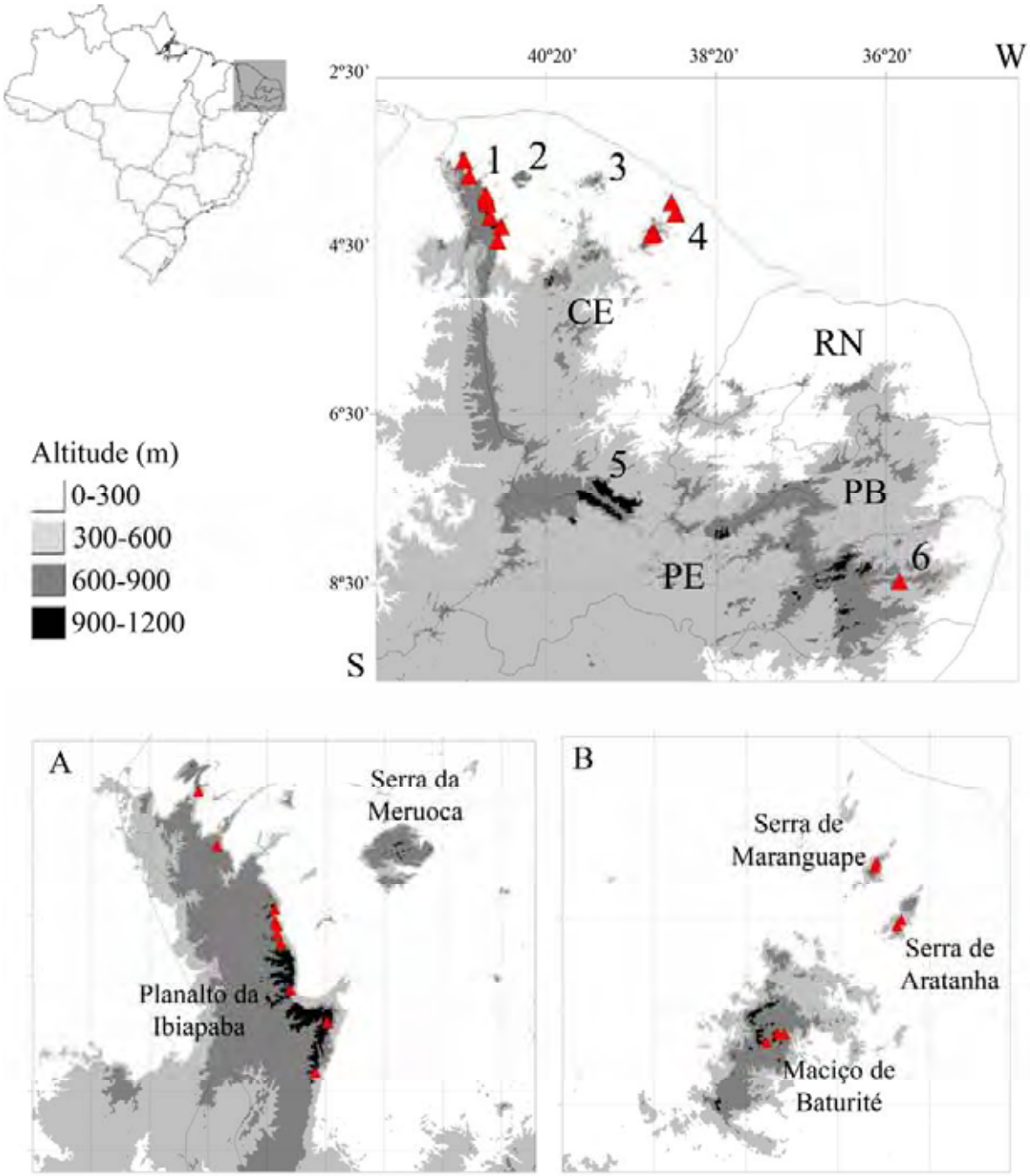


Figure 1 – Sampled areas and populations of *Adelopryne baturitensis* found (red triangles) in the state of Ceará (CE) and Pernambuco (PE). 1 - Planalto da Ibiapaba (see detailed map bellow in A), 2 - Serra da Meruoca, 3 - Serra da Uruburetama, 4 Maciço de Baturité, Serra de Maranguape, and Serra da Aratanha (see detailed map bellow B), 5 – Chapada do Araripe, and 6 – Brejo dos Cavalos. RN and PB – states of Rio Grande do Norte and Paraíba, respectively.

Figure 2 – *Adelophryne baturitensis* in life. A-F) Some reproductive aspects of the species. A) Adult male on the leaf litter in normal position. B) Adult male uttering an advertisement call. C and D) Comparison of size between male (left) and female (right). E) A pair in axillar amplexus. F) Eggs of *Adelophryne baturitensis* deposited on the ground amidst the leaves. Municipality of Ubajara, Planalto da Ibiapaba, state of Ceará, Brazil.

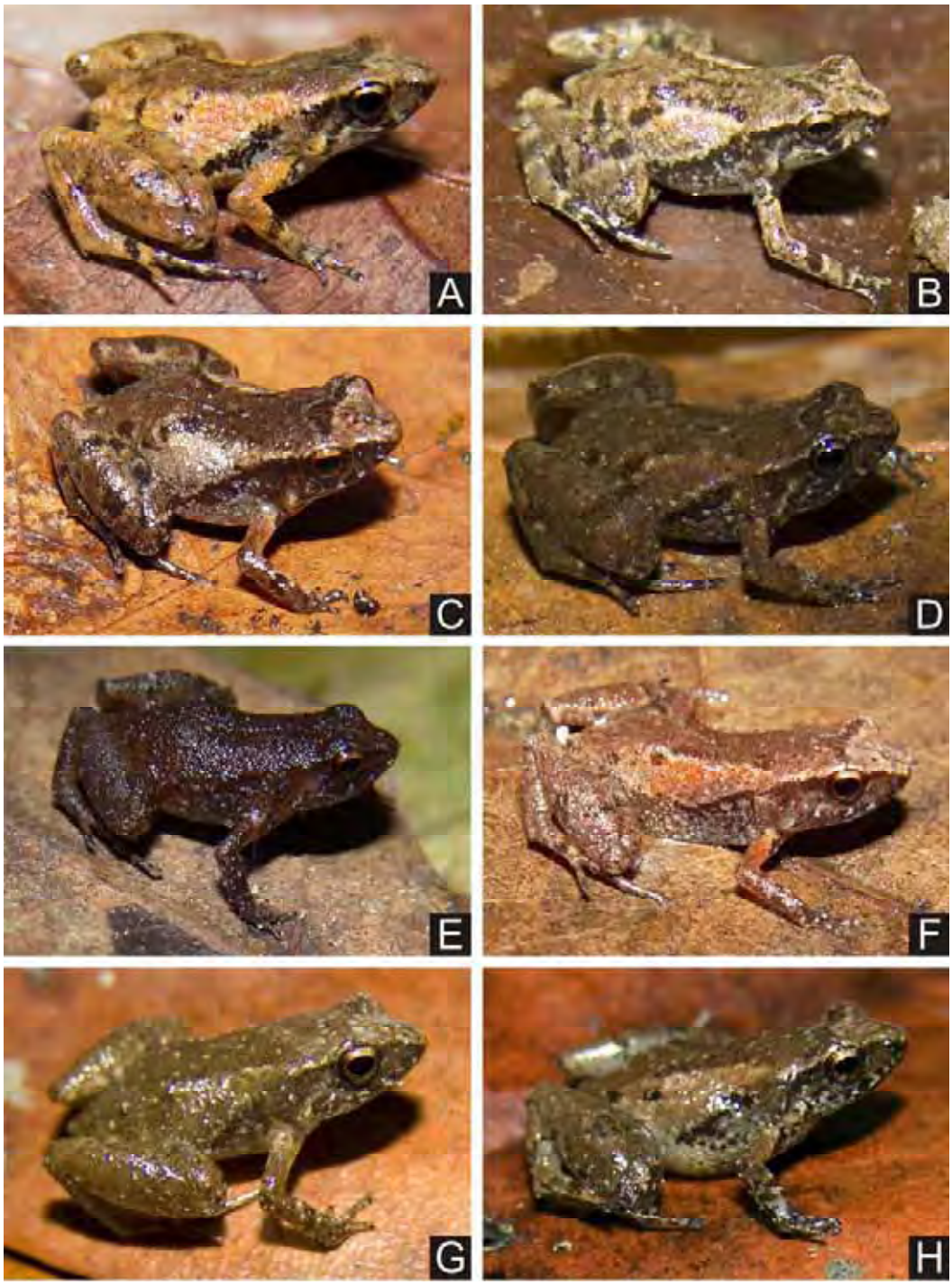


Figure 3 – *Adelophryne baturitensis* in life, showing polymorphism . A) Adult male from the municipality of Tianguá, Planalto da Ibiapaba. B) Adult male from the municipality of Maranguape, Serra de Maranguape. C) Adult male from the municipality of Guaramiranga, Maciço de Baturité. D) Adult male from the municipality of Tianguá, Planalto da Ibiapaba. E) and F) Adult females from the municipality of Ubajara, Planalto da Ibiapaba. G) and H) Adult male from the municipality of Tianguá, Planalto da Ibiapaba. All localities in the state of Ceará, Brazil.

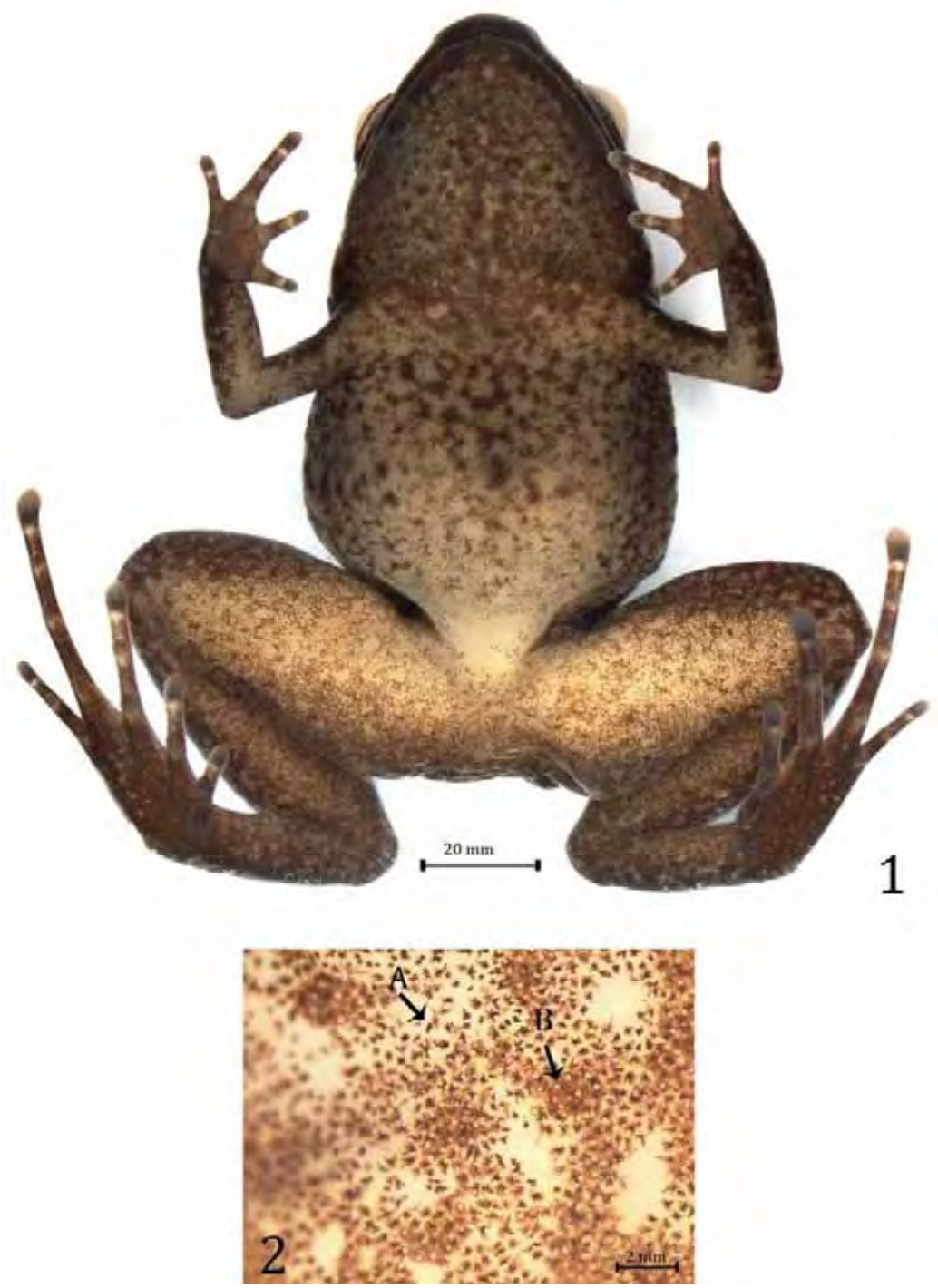


Figure 4 – 1) Ventral view of a specimen of *Adelophryne baturitensis* from the municipality of Ubajara, state of Ceará, Brazil. 2) Skin pigmentation detail (throat region) of the same specimen showing the melanophores (A) and glands (B). Both structures are present in the skin surface. Note that ventral coloration is yellowish with brown spots instead of purplish with lighter spots as mentioned in the original description.

Figure 5. Palmar view (right hand) and plantar view (left foot) of distinct *Adelophryne* populations evidencing the high similarities among diagnostic structures. A and B) Specimen from Serra de Maranguape, C and D) Specimen from Maciço de Baturité, and E and F) Specimen from Planalto da Ibiapaba.

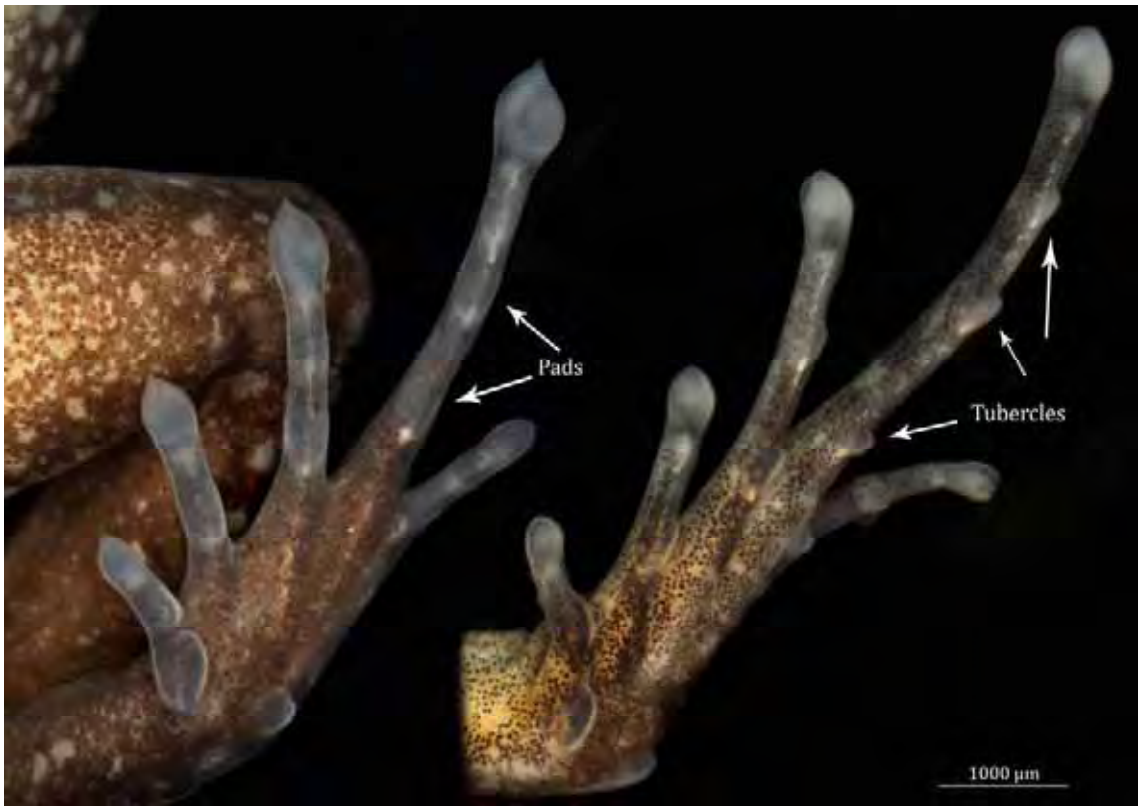


Figure 6 – Comparison of foot structures between *Adelophryne pachydactyla* (left) from municipality of UNA, state of Bahia, Brazil, and *Adelophryne* sp. (cf. *baturitensis*) from Maranguape, showing the presence of pads (less evident in the toes) in *A. Pachydactyla,* and tubercles (more conspicuous in the toes) in *Adelophryne* sp. (cf. *baturitensis*) from Maranguape, state of Ceará, Brazil.

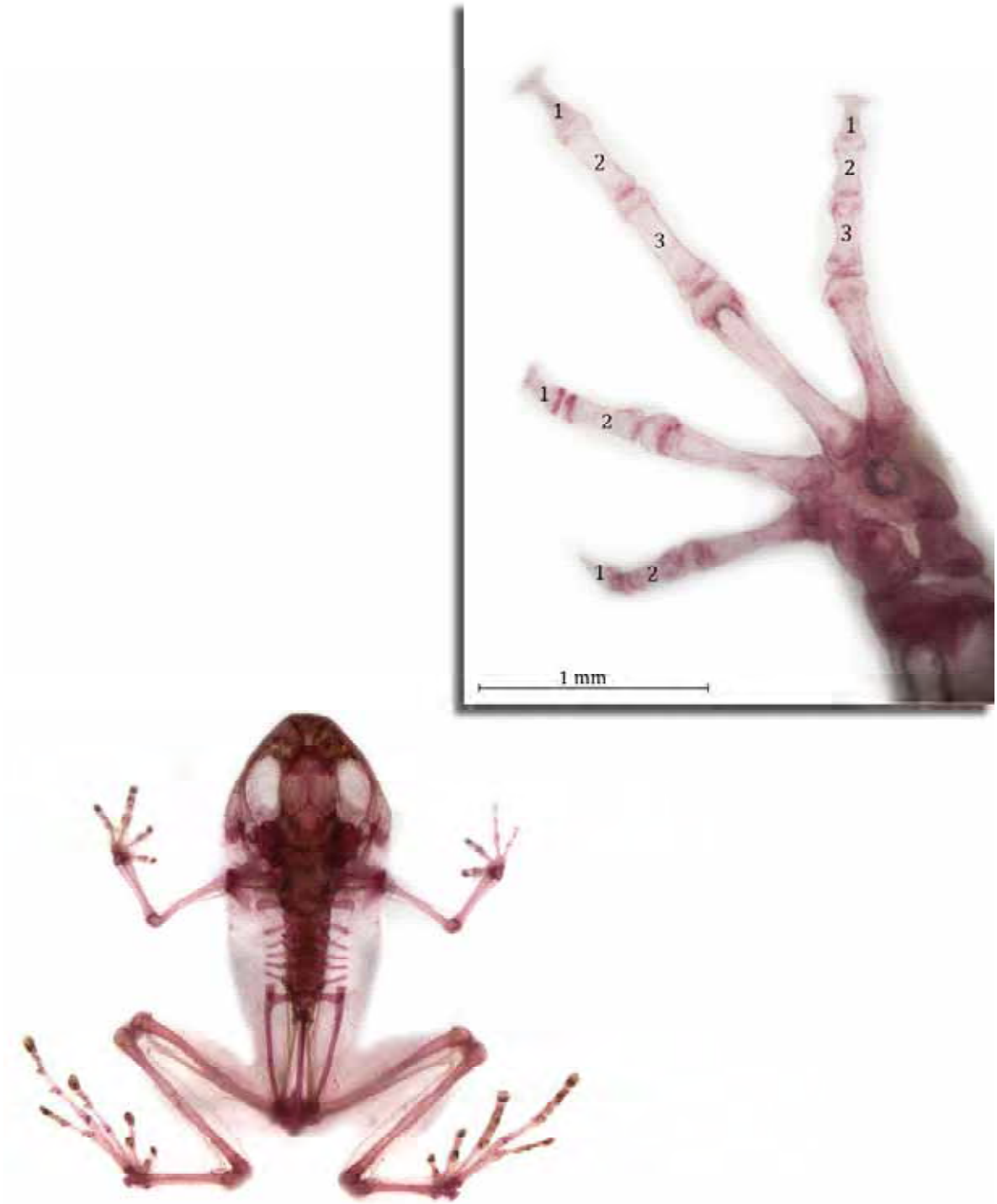


Figure 7 - Cleared and stained specimen of *Adelophyne baturitensis* (CFBH 24559) showing a detail of the hand (finger phalangeal formula = 2-2-3-3). Note the T-shaped of the terminal phalange, a character of Phyzelaphryninae.

ADVERTISEMENT CALL DESCRIPTION

We analyzed 23 advertisement calls from eight males (n = 23/8) of distinct populations of *Adelophryne* from the state of Ceará. Usually, males called from the leaf litter, however, it was possible to observe males calling above ground (ca. 30 cm), in the base of the leaves of *Orbignya*, a very abundant palm tree in the area. Males were found calling in almost all hours of the day, but the density of calling males was higher during daylight, especially in the first hours near sunset and sunrise. Although it was not possible to observe aggressive interactions between males, we believe that they are territorial since males called at least 5 meters apart. Neighbor males call sequentially, i.e. they perform an antiphonal chorus in which individuals synchronize their calls to distinguish themselves from others. Thus, there is no overlap of advertisement calls.

The analysis of acoustic and mechanistic call parameters among distinct populations of *Adelophryne* showed a high overlap of them (Table 2, Figure 8). The advertisement call (Figure 9) can be described by the combination of the follow characteristics: call duration (s) ranging from 0.61 to 1.24 (0.87 ± 0.17; n= 23); interval between calls (s) ranging from 3.38 to 30.28 (14.29 ± 6.75; n= 23); number of notes per call ranging from 4 to 8 (6 ± 1.04; n = 139); notes with 2 to 3 pulses (2.47 ± 0.50; n = 139) with a single harmonic; note duration (s) varying from 0.02 to 0.07 (0.04 ± 0.01; n = 139) and note interval (s) 0.09 – 0.18 (0.12 ± 0.02; n = 139); minimum frequency (Hz) ranging from 900.9 to 2560.6 (1767.6 ± 400.0; n = 139); maximum frequency (Hz) ranging from 9776.4 to 12743.4 (10940.5 ± 550.1; n = 139); and dominant frequency (Hz) ranging from 4392.8 to 5684.8 (4882.9 ± 418.5; n = 139). Other spectral and temporal characteristics are presented in Table 2.

Table 2 - Physical characteristics of the advertisement calls of adult males of *Adelophryne* populations from the state of Ceará. Values are expressed as mean ± standard error (amplitude).

	Municipality/ Locality	**Guaramiranga (Maciço de Baturité)**	**Pacoti (Maciço de Baturité)**	**Maranguape (Serra de Maranguape)**	**Ubajara (Planalto da Ibiapaba)**	**Viçosa do Ceará (Planalto da Ibiapaba)**
	Calls analyzed/ Number of males	5/1	8/1	3/1	4/3	3/2
	Call duration (s)	0.76 ± 0.08 (0.63 – 0.85)	1.02 ± 0.16 (0.78 – 1.24)	0.90 ± 0.11 (0.80 – 1.03)	0.78 ± 0.03 (0.76 - 0.82)	0.73 ± 0.10 (0.61 – 0.83)
	Call interval (s)	13.43 ± 2.54 (10.95 – 15.80)	20.01 ± 4.99 (14.50 – 30.28)	16.37 ± 1.78 (15.11 – 17.63)	3.44 ± 0.09 (3.38 - 3.51)	7.97 ± 1.94 (5.97 – 9.85)
	Notes analyzed	27	56	19	18	19
	Number of Notes	5.40 ± 0.55 (5 – 6)	6.88 ± 0.83 (6 - 8)	6.33 ± 0.58 (6 - 7)	6 ± 0 (6)	4.75 ± 0.96 (4 - 6)
	Note duration (s)	0.05 ± 0.01 (0.03 – 0.06)	0.04 ± 0.01 (0.03 – 0.05)	0.04 ± 0.01 (0.03 – 0.06)	0.02 ± 0 (0.02)	0.06 ± 0.01 (0.05 – 0.07)
	Note interval (s)	0.11 ± 0.01 (0.09 – 0.14)	0.12 ± 0.02 (0.09 – 0.16)	0.12 ± 0.02 (0.10 – 0.17)	0.13 ± 0.02 (0.10 – 0.18)	0.12 ± 0.03 (0.09 – 0.18)
Frequency (Hz)	Dominant	4488.5 ± 55.1 (4392.8 – 4565.0)	4671.2 ± 121.8 (4392.8 – 4823.4)	4782.6 ± 52.7 (4651.2 – 4823.4)	5483.8 ± 51.2 (5426.4 – 55.98)	5598.6 ± 49.7 (5512.5 – 5684.8)
	Minimum	1431.4 ± 194.1 (1073.1 – 1762.1)	2181.7 ± 121.8 (1842.7 – 2560.6)	1443.2 ± 190.1 (986.8 – 1832.7)	1740.6 ± 256.9 (1208.7 – 2272.6)	1375.0 ± 225.4 (900.9 – 1663.1)
	Maximum	10529.6 ± 181.7 (9776.4 – 10740.9)	10647.8 ± 48.0 (10558.7 – 10737.8)	10865.5 ± 361.5 (10197.2 – 11278.0)	11359.7 ± 217.9 (11057.0 – 12105.9)	12064.9 ± 232.0 (11711.1 – 12743.4)
	Number of pulses	2 ± 0 (2)	3 ± 0 (3)	2.53 ± 0.51 (2 – 3)	2 ± 0 (2)	2 ± 0 (2)

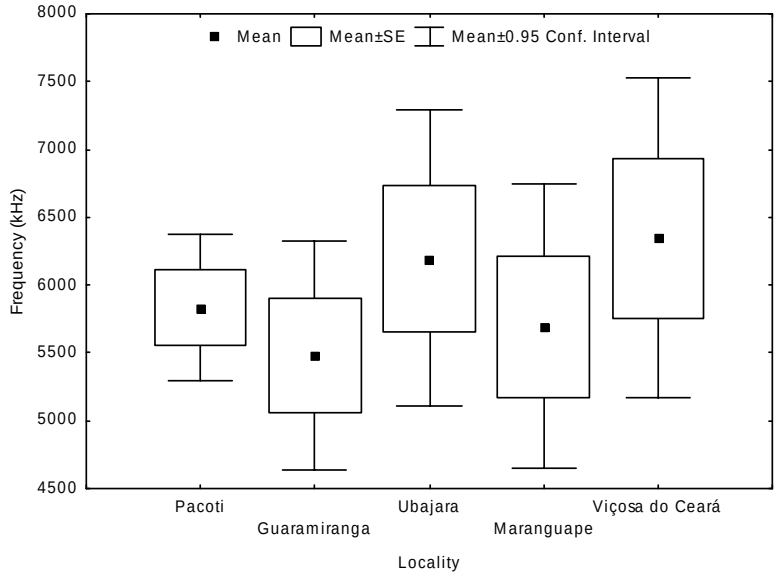


Figure 8 – Box plot of the frequency amplitude (kHz) of the advertisement calls of adult males of *Adelophryne* populations from the state of Ceará showing frequency overlap among populations.

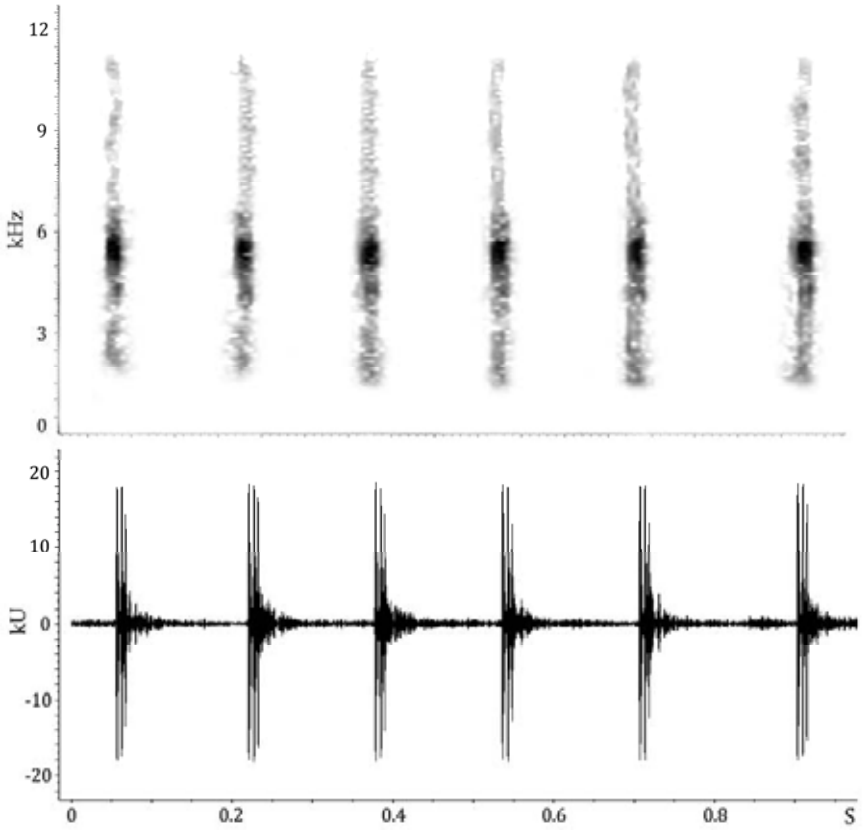


Figure 9 - Advertisement call of *Adelophryne baturitensis* (spectrogram above and waveform below) recorded at the municipality of Ubajara, state of Ceará, Brazil.

MOLECULAR DATA

We obtained 19 sequences (410-430bp) of 16S from *Adelophryne* sp. and a total of seven different haplotypes were defined for the analyzed specimens (Appendix 1). Haplotype sequences were deposited in GenBank.

Two different clades were found within this specimens, one formed by individuals of *Adelophryne baturitensis* from all localities sampled (Clade I, Figure 10), and another formed by two (out of four) individuals from the municipality of Maranguape (Clade II, Figure 10). Samples from the municipality of Viçosa do Ceará clustered together within Clade I (sub-clade B, Figure 10), suggesting that this population is disrupted from other populations from Planalto da Ibiapaba, but no other geographic structure differentiating samples from other tropical moist forests enclaves studied was observed.

Mean sequence divergence (K2P) was 1.5% within Clade I, and 0.3% within Clade II. Sequence divergence between Clades I and II was surprisingly high (15.9%) and was similar to the divergence found between *A. gutturosa* and *A. pachydactyla* (16.3%). Divergence between *Adelophryne* specimens from state of Ceará and out-groups (*A. gutturosa*, *A. pachydactyla*, and *P. miriamae*) ranged from 20.7% to 31.9%.

Discussion

ADVERTISEMENT CALL COMPARISON WITH OTHERS *ADELOPHYNE* SPECIES

Data on advertisement calls of *Adelophryne* are available in the literature only for *A. adiastola* (HEYER, 1977; originally published as *Phyzelaphryne miriamae*), and for *A. gutturosa* and *A. patamona* (MACCULLOCH et al., 2008). While *Adelophryne* populations of the state of Ceará have notes composed by a

single harmonic, other species have multi-harmonic notes as follow: three in *A. patamona*, three-four in *A. gutturosa*, and two in *A. miriamae* (HEYER, 1977, MACCULLOCH et al., 2008). Except to *A. patamona*, other species have pulsed notes (MACCULLOCH et al., 2008, present study). Orrico et al. (2006) compared the number of harmonics from five species of *Aplastodiscus* (*A. perviridis* and four species of *A. albofrenatus* group) and demonstrated that modal values of the number of harmonics per note are specific, ranging from two in *Aplastodiscus ehrhardti* to seven in *A. weygoldti* (CONTE et al., 2005, ORRICO et al., 2006).

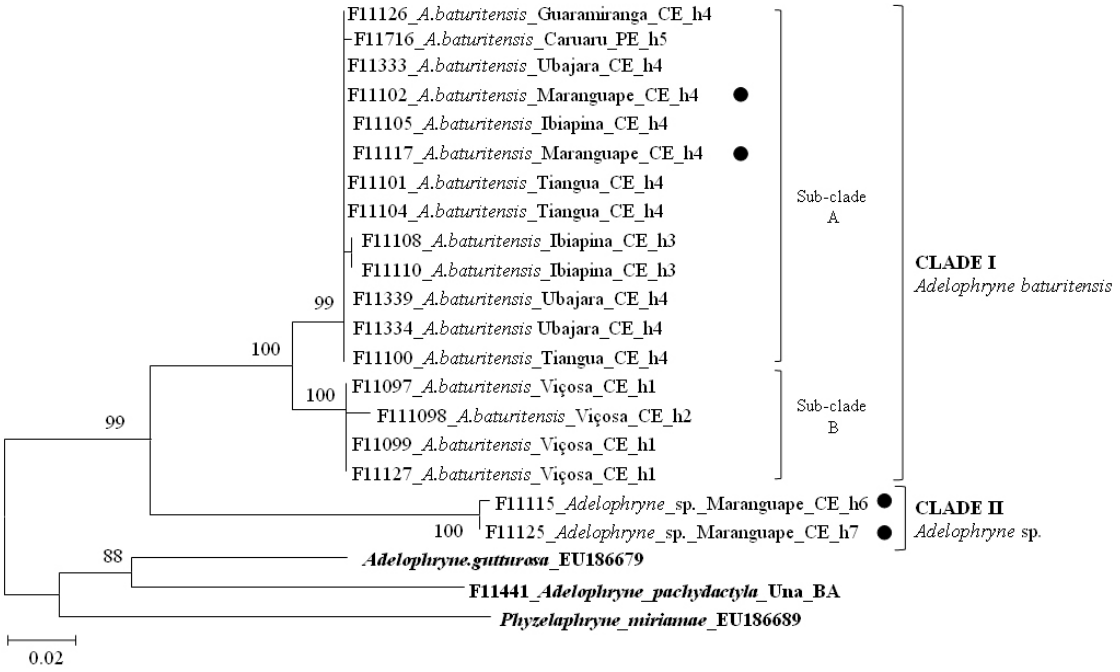


Figure 10 - 16S Neighbor-joining tree of analyzed *Adelophryne* spp. Clade I represent *Adelophryne baturitensis* lineage and Clade II *Adelophryne* sp. (cf. *baturitensis*) lineage (potential cryptic species). Sub-clade B represents structured population of *A. baturitensis* from Serra das Flores, municipality of Viçosa do Ceará, state of Ceará, Brazil. Black circles represent samples of *Adelophryne* specimens sampled in Serra de Maranguape, Ceará, Brazil. Out-groups are in bold.

The structure of the advertisement calls of *A. baturitensis*, *A. adiastola*, and *A. gutturosa* is very similar, consisting of a group of short notes produced in quick succession. However, the range in number of notes is shorter in *A. baturitensis* (4-8) compared to *A. adiastola* (1-10; HEYER, 1977) and *A. gutturosa* (2-15; MACCULLOCH et al., 2008). Dominant frequency is higher in *A. baturitensis* (4,392.8 – 5,684.8 Hz) when compared with the other species (see MACCULLOCH et al., 2008), but it is partially overlapped with *A. gutturosa*.

MOLECULAR DATA

Our sequencing results support our morphological and bioacustic results suggesting that *Adelophryne baturitensis* (Clade I, Figure 10) has disjunct distribution, with isolated populations in highland areas with moist forests fragments in the states of Ceará and Pernambuco.

Adelophryne baturitensis lineage was distributed in all analyzed localities and the other lineage was restricted to Serra de Maranguape. We did not find variation in morphology or in advertisement call structure between the two lineages, but the genetic divergence found between them was similar to the divergence found between *A. gutturora* and *A. pachydactyla.* This result may suggest the presence of a cryptic species in Maranguape. The existence of a morphologically cryptic species living in sympatry has been described in recent works for other anurans species (e.g. STUART et al., 2006, ELMER et al., 2007). However, the possibility that the pattern observed may be due to inherent characteristics of mitochondrial DNA, as introgression, cannot be ruled out (BAILLARD & WHITLOCK, 2004).

Another point is that we found a well established population of *A. baturitensis* geographically structured in the municipality of Viçosa do Ceará. This observation may be a result of a founder effect and/or a smaller effective population size (AVISE et al., 1987), but further analysis are being conducted in order to understand the pattern observed. In any case, this outcome is indicative that the extent of observed variation in *A. baturitensis* needs to be further investigated for a better understanding of the historical distribution of this species.

TAXONOMIC COMMENTS

In the original description of *A. baturitensis* and *A. maranguapensis* the authors made the following comment "*Recently some Adelophryne became available from the Serra de Maranguape. They show differences with the specimens from the Maciço de Baturité, although specimens in the sample are rather variable in several characters. We want to name this species"* (HOOGMOED et al., 1994, p. 289). In fact, Hoogmoed and collaborators had the chance to examine a very small sample from the population of Maranguape, with only six specimens available in the type series (four adults only). Besides this, neither advertisement calls nor molecular techniques were applied for the original description to support their conclusions.

According to the original descriptions (HOOGMOED et al., 1994), the most conspicuous morphological trait which distinguish both species is the presence of pads instead of tubercles in the toes of *A. maranguapensis*, while in *A. baturitensis* the tubercles are well defined. Our analyzed series had no specimens with pads in the foot, including the specimens collected in the type locality of *Adelophryne maranguapensis*.

In the original descriptions, the authors also found differences in the color patterns of dorsum, temporal area, and flanks, as well as in the dorsum texture and in the relation between eye diameter and the distance from the tympanum to the eye. However, we observed variations in these morphological characters in *A. baturitensis* topotypes. For instance, in the original description, the dorsal pattern X-shaped is attributed to *Adelophryne maranguapensis*; however, this is a character found in all populations analyzed in the present work. The relation between eye diameter and distance from the tympanum to the eye, considered equal in *A. maranguapensis* and from half to equal in *A. baturitensis*, is another unreliable character, because some individuals can show both proportions (one on each side of the head). Skin texture was also a variable character in all populations, being impossible to attribute a smooth texture to *A. baturitensis* and a slightly pustulous one to *A. maranguapensis*. Likewise, our results for the advertisement calls and molecular data (16S sequences) support our hypothesis that *Adelophryne baturitensis* is present in all areas of occurrence of the genus in the state of Ceará, including Serra de Maranguape, the type-locality of *Adelophryne maranguapensis*.

Results obtained with 16S sequencing of samples from Serra de Maranguape indicate a possible presence of two sympatric species for this area (see discussion above). However, the Maranguape specimens used in this analysis did not present pads in the foot as indicated in the original description as a diagnostic character of *A. maranguapensis*. No morphological differences were detected among the specimens analyzed from Serra de Maranguape, i.e. all specimens had X-shaped dorsal pattern and tubercles in the foot.

We have at least two main hypotheses to explain what we observed. First, it is possible that we did not collect specimens of *Adelophryne maranguapensis* even

though our specimens are from the same locality as the holotype. Thus, it is possible that three species of *Adelophryne* (*A. baturitensis*, *A. maranguapensis*, and *Adelophryne* sp.) occur in sympatry in the Serra de Maranguape. Second, the variation found in the molecular data could be the result of an introgression of mitochondrial DNA of the ancestral species. If this possibility is to be confirmed, *A. maranguapensis* should be considered a synonym of *A. baturitensis*.

Natural history and external morphology of *Adelophryne* species is very similar. Consequently, the relationships among the species will continue unclear and probably will be solved only with molecular studies. However, considering that *Adelophryne pachydactyla* is the most distinctive species of the genus because of its pudgy, depressed fingers and toes, and its two phalanges in the fourth finger – this second characteristic is shared only with *A. adiastola* (HOOGMOED & LESCURE, 1984, HOOGMOED et al, 1994), and considering that *A. baturitensis*, as here defined, i.e. a species with tubercles in the toes, three phalanges in the fourth finger, and call structure similar to two Amazonian species (*A. adiastola* and *A. gutturosa*), we suggest that *A. baturitensis* may be closely related to the Amazonian species.

BIOGEOGRAPHICAL APPROACH

Recent studies demonstrated that 12 cycles of pluvial phases occurred in the Caatinga during the Quaternary (ca. last 210 kyr) (AULER et al., 2004; WANG et al., 2004). Therefore, the xeric Caatinga and the Tropical rainforests had their area of occupancy alternately expanded and retracted several times during the Quaternary as previously reported by AB'SABER (1977). During these periods, with a higher amount of rainfall in Northeastern Brazil, Amazon and Atlantic

rainforests had a connection forming a widespread and continuum belt of tropical forest in the area where the Caatinga occurs today (BIGARELLA & ANDRADE-LIMA, 1982). Living mammals (DE VIVO, 1997) and botanical fossil data (BIGARELLA & ANDRADE-LIMA, 1982) have corroborated these theories. Besides this, many reptile and amphibian species from forest environments (sister or same species) have evidenced a past connection between Amazon and Atlantic rainforests (e.g. *Rhinella hoogmoedi* versus *Rhinella margaritifer*, *Lithobates palmipes*, *Hypsiboas geographicus* versus *Hypsiboas semilineatus*, *Scinax nebulosus*, *Polychrus marmoratus*, *Xenopholis scalaris*, *Bothriopsis bilineatus*, *Lachesis muta*, and others).

According to Auler et al. (2004) and Wang et al. (2004), the last pluvial cycle in the Caatinga Biome occurred in the Quaternary between 14,670 – 16,100 years ago. Palinological data from the middle São Francisco Basin (10°24'S, 43°13'W) suggested that the tropical moist forest from Northeastern Brazil began its decline in the Holocene, 8,910 – 6,790 years ago (DE OLIVEIRA et al., 1999). Therefore, this was the last period that *Adelophryne baturitensis* populations had a possibility of being interconnected.

Considering the current distribution presented in this work for *Adelophryne baturitensis*, this species seems to be unique in the genus since it presents populations with disjunct distribution. A similar pattern can be found by interspecific comparison, except to *A. gutturosa* and *A. patamona* that are sympatric (MACCULLOCH et al., 2008). Like other species of the genus, *A. baturitensis* has never been found in open areas (HOOGMOED et al., 1994, MACCULLOCH et al., 2008, present study). Thus, considering the actual pattern of distribution of all *Adelophryne* species and the evidences that Amazon and Atlantic

rainforests had a connection in the past, it is possible that in a preterit situation the genus had a larger distribution, from Northern South America (surroundings of Ecuadorian Andes and Guiana shield) to the Brazilian Atlantic coast in Southern Bahia.

In the past 30 years, the tropical rainforest remnants of the state of Ceará have been considered areas with high occurrence of endemism, including species restricted to a single remnant (VANZOLINI, 1981, 1992, HOOGMOED et al., 1994; RODRIGUES & BORGES, 1997, BORGES-NOJOSA & CARAMASCHI, 2003, PASSOS et al., 2007). However, all herpetofauna species previously known only for the type locality had their distributions recently extended for at least one more forest remnant. For instance, *Atractus ronnie*, a dipsadid snake known only for Maciço de Baturité had its distribution extended to Chapada do Araripe (LOEBMANN et al. 2009, ANNEX 12). Carnaval & Bates (2007) demonstrated that *Pristimantis* sp. is a single species occurring in Maciço do Baturité, Serra de Maranguape, and Planalto da Ibiapaba. *Mabuya araraja*, until now considered endemic to Chapada do Araripe, had its distribution extended for other three localities (ROBERTO & LOEBMANN, submitted, ANNEX 13). *Leposoma baturitensis*, considered endemic to Maciço de Baturité, have been recorded for Planalto da Ibiapaba (BORGES-NOJOSA & CARAMASCHI, 2003, LOEBMANN & HADDAD, submitted; CHAPTER 1) and Serra da Aratanha (I.J. Roberto, pers. comm.). Therefore, our new records for *Adelophryne baturitensis* in this study also shows that this species is not endemic to Maciço de Baturité as formerly believed (HOOGMOED et al., 1994, ETEROVICK et al., 2005, BORGES-NOJOSA, 2007).

So, how to explain this distribution? Our hypotheses is that although the state of Ceará had a connection with the Amazon and Atlantic rainforests as

mentioned above, this connection probably did not occur in the last glacial period. The moist forest remnants of the state, however, kept interconnected until early Holocene. Consequently, the tropical moist forests currently shelter several cases of endemic species for the state, but there is no case of endemic species restricted to a single fragment of moist forest as previously believed.

CONSERVATION STATUS

According to the Red List of Threatened Species of Brazil and IUCN Red List (SILVANO & BORGES-NOJOSA, 2004a, b, HADDAD, 2008), *Adelophryne maranguapensis* and *Adelophryne baturitensis* were considered as Endangered and Vulnerable, respectively. The two main reasons for both species to be considered threatened are the fact that their areas of occurrence comprise less than 20,000 km^2, and that they are known only for their type localities and respective surrounding areas (IUCN, 2001). Our findings of other populations of *Adelophryne baturitensis*, including some in protected areas, bring a new conservation approach for the species.

Applying the minimum convex polygon proposed by the International Union for Conservation of Nature (IUCN, 2001), the current distribution of *Adelophryne baturitensis* is ca. 74,060 km^2. The sum of theses areas is much larger than previously reported. Considering the fact that the species is the third most common in the leaf litter of the forest remnants, the fact that the species have been recorded reproducing every year, and due to the presence of the species in protected areas, we consider that *A. baturitensis* fulfill the requirements of Least Concern status by IUCN Red List criteria.

On the other hand, it is clear that habitat loss is a risk to the species. For instance, in two mountain ranges in which we conducted expeditions (Serra da Uruburetama and Serra de Meruoca), both located between Serra de Baturité and Planalto da Ibiapaba, *Adelophryne* populations might had occur in a recent past. However, the forest remnants of both places are replaced by banana and coffee plantations, eliminating the microhabitats necessary for the survival of *A. baturitensis*. Currently, there is no evidence of *A. baturitensis* inhabiting these areas. Besides this, our estimate of potential areas of occurrence for the species is ca. 2,800 km^2, i.e. much more restricted than ca. 74,060 km^2 following the criteria proposed by IUCN.

Another point, based on our observations at Serra das Flores, a disjunct hill from Planalto da Ibiapaba, is that *Adelophryne* populations seem to need just a small area to be established (ca. 0.5 km^2). However, the presence of water during the entire year should be a crucial condition for the species. We have drawn this conclusion based on a 24 months monitoring of two forest remnants with similar characteristics (similar area, same altitude, and same regeneration state), but only one had available water during all months. We never found specimens of *Adelophryne* in the fragment lacking temporary streams. The same occurred in larger forest remnants visited sporadically without available water in the dry season.

FUTURE PERSPECTIVES

In the seven areas of relictual forests sampled we detected stable populations of *Adelophryne baturitensis* in four of them. This result is very positive comparing the knowledge we have so far of the species situation. The conservation

of this species seems to depend only on the preservation of forest remnants, especially those with availability of water during the entire year. If an effective plan of conservation is to be implemented in order to preserve these forest remnants, *Adelophryne baturitensis* probably will not be at risk of extinction, as well as several endemic amphibians and reptiles that live in the tropical rainforests fragments of Ceará.

Acknowledgments

The authors are grateful to Ana C. G. Mai, Francisco Brusquetti, and Victor G. Dill Orrico for the helpful suggestions during the manuscript preparation. Thieres Pinto, Ciro Albano and Daniel do Nascimento Lima helping during the field work. Victor G. Dill Orrico provided a sample tissue of *A. pachydactyla* for molecular analysis. Ciro Albano provided some of the call recordings of *Adelophryne* from Guaramiranga and Maranguape. Fundação O Boticário de Proteção a Natureza (proc. 0776_20081), FAPESP (proc. 2008/50928-1) and CNPq, supported this research. Daniel Loebmann was supported by grant no. 140226/2006-0 from CNPq.

References

AB'SABER A. N. Os domínios morfoclimáticos na América do Sul. Primeira aproximação. **Geomorfologia**, São Paulo, v. 52, p. 1-21, 1977.

AULER, A. S.; SMART, P. L. Late quaternary paleoclimate in semiarid northeastern Brazil from U-Series dating of travertine and water-table speleothems. **Quaternary Research**, Washington, v. 55, p. 159-167, 2001.

AVISE, J. C.; ARNOLD, J.; BALL, R. M.; BERMINGHAM, E.; LAMB, T.; NEIGEL, J. E.; REED, C. A.; SAUNDERS, N. C. Intraspecific phylogeography: the mitochondrial DNA bridge between population genetics and systematic. **Annual Review of Ecology and Systematics**, Palo Alto, v. 18, 489-522, 1987.

BALLARD, J. W. O & WHITLOCK, M. C. The incomplete natural history of mitochondria. **Molecular Ecology**, Vancouver, v. 13, n. 4, p. 729–744, 2004.

BIGARELLA, J. J.; ANDRADE-LIMA, D. Paleoenvironmental changes in Brazil. In: PRANCE, G. T. (Ed.). **Biological diversification in the tropics.** New York: Columbia University press, 1982. p. 27-40.

BORGES-NOJOSA, D. M. Diversidade de Anfíbios e Répteis da Serra de Baturité, Ceará. In: OLIVEIRA, T. S.; ARAÚJO, F. S. (Org.). Diversidade e Conservação da Biota na Serra de Baturité, Ceará. 1a. ed. Fortaleza: Edições UFC, 2007, v. 1. p. 225-247.

BORGES-NOJOSA, D. M.; CARAMASCHI, U. Composição e Análise Comparativa da Diversidade e das Afinidades Biogeográficas dos Lagartos e Anfisbenídeos (Squamata) dos Brejos Nordestinos. In: LEAL, I.; SILVA, J. M. C.; TABARELLI, M. (Eds). **Ecologia e Conservação da Caatinga.** Recife: Universidade Federal de Pernambuco, 2003. p. 489-540.

CARNAVAL, A. C. O. Q.; BATES, J. M. Amphibian DNA shows marked genetic structure and tracks pleistocene climate change in northeastern Brazil. **Evolution**, Lancaster, v. 63, n. 12, p. 1-16, 2007.

DE OLIVEIRA, P. E.; BARRETO, A. M. F.; SUGUIO, K. Late Pleistocene=Holocene climatic and vegetational history of the Brazilian Caatinga: the fossil dunes of the middle São Francisco River. **Palaeogeography, Palaeoclimatology, Palaeoecology**, Amsterdam, v. 152, p. 319-337, 1999.

DE VIVO, M. Mammalian evidence of historical ecological change in the Caatinga semiarid vegetation of northeastern Brazil. **Journal of Comparative Biology**, Ribeirão Preto, v. 2, n. 1, p. 65-73, 1997.

ELMER, K. R.; D'ÁVILA, J. A.; LOUGHEED, S. C. Cryptic diversity and deep divergence in an upper Amazonian leaflitter frog, *Eleutherodactylus ockendeni*. **BMC Evolutionary Biology**, v. 7, p. 247-260, 2007.

ETEROVICK, P. C.; CARNAVAL, A. C. O. Q.; BORGES-NOJOSA, D. M.; SILVANO D. L.; SEGALLA, M. V.; SAZIMA, I. Amphibian declines in Brazil: an overview. **Biotropica**, Saint Louis, v. 37, n. 2, p. 166-179, 2005.

FROST, D. R. **Amphibian species of the world: an online reference. Version 5.3**. Available at http://research.amnh.org/herpetology/amphibia/. American Museum of Natural History, New York, USA. Acesso em 03 jan. 2010.

HADDAD, C. F. B. Anfíbios. In: MACHADO, A. B. M., DRUMMOND, G. M.; PAGLIA, A. P. (Eds.). **Livro vermelho da fauna brasileira ameaçada de extinção** (série Biodiversidade 19, vol. 2,). Brasília, DF: MMA; Belo Horizonte, MG: Fundação Biodiversitas, 2008. p. 59-63.

HEDGES, S. B.; DUELLMAN, W.E.; HEINICKE, M. P. New World direct-developing frogs (Anura: Terrarana): molecular phylogeny, classification, biogeography, and conservation. **Zootaxa**, Auckland, v. 1737, p. 1-182, 2008.

HEYER, W. R. Taxonomic notes on frogs from the Madeira and Purus Rivers, Brazil. **Papéis Avulsos de Zoologia**, São Paulo, v. 31, n. 8, p. 141-162, 1977.

HIJMANS, R. J.; GUARINO, L.; ROJAS, E. DIVA-GIS. **A Geographic Information System for the Analysis of Biodiversity Data-Manual**. Lima: International Potato Center, 2002. 73 p.

HOOGMOED, M. S.; LESCURE, J. A new genus and two new species of minute leptodactylid frogs from northern South America, with comments upon *Phyzelaphryne* (Amphibia: Anura: Leptodactylidae). **Zoologische Mededelingen**, Leiden, v. 58, p. 85-115, 1984.

HOOGMOED, M. S.; BORGES, D. M.; CASCON, P. Three new species of the genus *Adelophryne* (Amphibia: Anura: Leptodactylidae) from northeastern Brazil, with remarks on the other species of the genus. **Zoologische Mededelingen**, Leiden, v. 68, p. 271-300, 1994.

HUANG, X.; MADAN, A. CAP3: A DNA sequence assembly program. **Genome Research**, Cold spring Harbor, v.9, p. 868-877, 1999.

ICZN (International Commission on Zoological Nomenclature). **International Code of Zoological Nomenclature**. London: International Trust for Zoological Nomenclature. 1999.

IUCN. **IUCN Red List Categories and Criteria**: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK. Vol. 2, 30 pp.

LYRA, M. L.; HADDAD, C. F. B; AZEREDO-ESPIN, A. M. L. Taking the challenge of Barcoding Anurans from Brazilian Atlantic Forest: implications for amphibians conservation. In progress.

LOEBMANN, D.; HADDAD, C. F. B. Amphibians and reptiles from the complex of Planalto da Ibiapaba, state of Ceará, northeastern Brazil: composition and conservation implications in the high species richness area of the Caatinga biome (submitted). **Biota Neotropica**, Campinas, submetido, 2010.

LOEBMANN, D.; RIBEIRO, S. C.; SALES, D. L.; ALMEIDA, W. O. New records for *Atractus ronnie* (Reptilia, Serpentes, Colubridae) with comments about

meristic and morphometric data. **Biotemas**, Florianopolis, v. 22, n. 1, p. 169-173, 2009.

MACCULLOCH, R. D.; LATHROP, A.; KOK, P. J. R.; MINTER, L. R.; KHAN, S. Z.; BARRIO-AMORÓS, C. L. A new species of *Adelophryne* (Anura: Eleutherodactylidae) from Guyana, with additional data on *A. gutturosa*. **Zootaxa**, Auckland, v. 1884, p. 36-50, 2008.

MMA (MINISTÉRIO DO MEIO AMBIENTE) 2003. Instrução Normativa nº 3, de 27 de maio de 2003. Lista das espécies da fauna brasileira ameaçadas de extinção. **Diário Oficial da República Federativa do Brasil**, Brasília, DF, 28 mai. 2003.

MMA (MINISTÉRIO DO MEIO AMBIENTE) 2009. **Mapas de Cobertura Vegetal dos Biomas Brasileiros**. Electronic resource available at http://mapas.mma.gov.br/mapas/aplic/probio/datadownload.htm?. Acesso em 20 nov. 2009.

ORRICO, V. G. D.; CARVALHO-E-SILVA, A. M. P. T.; CARVALHO-E-SILVA, S. P. Redescription of the advertisement call of *Aplastodiscus arildae* (Cruz & Peixoto) and description of the call of *Aplastodiscus weygoldti* (Cruz & Peixoto) with general notes about the genus in Southeastern Brazil (Anura, Hylidae). **Revista Brasileira de Zoologia**, Curitiba, v. 23, n. 4, p. 994-1001, 2006.

PASSOS, P.; FERNANDES, D. S.; BORGES-NOJOSA, D. M. A new species of *Atractus* (Serpentes: Colubridae: Dipsadinae) from a relictual forest in Northeastern Brazil. **Copeia**, Lawrence, v. 2007, p. 788-797, 2007.

ROBERTO, I. J.; LOEBMANN, D. Geographic distribution map and parturition aspects of the poorly known viviparous lizard *Mabuya arajara* Rebouças-

Spieker, 1981 (Squamata, Sauria, Scincidae) from the state of Ceará, northeastern Brazil. **The Herpetological Bulletin**, Montrose. 2010.

ROBILLARD, T.; HÖBEL, G.; GERHARDT, H. C. Evolution of advertisement signals in North American hylid frogs: vocalizations as end-products of calling behavior. **Cladistics**, New York, v. 22, n. 6, p. 533–545, 2006.

RODRIGUES, M. T.; BORGES, D. M. A new species of *Leposoma* (Squamata: Gymnophthalmidae) from a relictual forest in semiarid Northeastern Brazil. **Herpetologica**, Austin, v. 53, n. 1, p. 1-6, 1997.

SILVANO, D. L.; BORGES-NOJOSA, D. ***Adelophryne baturitensis***. In: IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2. Available at http://www.iucnredlist.org. Acesso em: 30 nov. 2009.

SILVANO, D. L.; BORGES-NOJOSA, D. ***Adelophryne maranguapensis***. In: IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2. Available at http://www.iucnredlist.org. Acesso em: 30 nov. 2009.

STUART, B. L.; INGER, R. F.; VORIS, H. K. High level of cryptic species diversity revealed by sympatric lineages of Southeast Asian forest frogs. **Biological Letters** v.2, p.470–474, 2006.

TAMURA, K.; DUDLEY, J.; NEI, M.; KUMAR, S. MEGA4: Molecular Evolutionary Genetics Analysis (MEGA) software version 4.0. **Molecular Biology and Evolution**, Oxford, v. 24, p. 1596-1599, 2007.

TAYLOR, R.; VAN DYKE, C. C. Revised procedures for staining and clearing small fishes and other vertebrates for bone and cartilage study. **Cybium**, Paris, v. 9, n. 2, p. 107-119, 1985.

THOMPSON, J. D.; GIBSON, T.J.; PLEWNIAK, F.; JEANMOUGIN, F.; HIGGINS, D. The CLUSTAL_X windows interface: flexible strategies for multiple sequence

alignment aided by quality analysis tools. **Nucleic Acids Research,** Oxford, v. 25, p. 4876-4882, 1997.

UTHSCSA ImageTool. Version 3.0 [S.I]: The University of Texas Health Science Center at San Antonio. Available at http://ddsdx.uthscsa.edu/dig/itdesc.html. Acesso em 10 out. 2009.

VANZOLINI, P. E.; WILLIAMS, K. R. The vanishing refuge: a mechanism for ecogeographical speciation. **Papéis Avulsos de Zoologia**, São Paulo, v. 34, n. 23, p. 251-255, 1981.

VANZOLINI, P. E. Paleoclimas e especiação em animais da América do Sul tropical. **Estudos Avançados**, São Paulo, v. 6, n. 15, p. 41-65, 1992.

VANZOLINI, P. E. A quasi-historical approach to the natural history of the differentiation of reptiles in tropical geographic isolates. **Papéis Avulsos de Zoologia**, São Paulo, v. 34, n. 19, p. 189-204, 1981.

WANG, X. F.; AULER, A. S.; EDWARDS, R. L.; CHENG, H.; CRISTALLI, P. S.; SMART, P. L.; RICHARDS, D. A.; SHEN, C. C. Wet periods in northeastern Brazil over the past 210 kyr linked to distant climate anomalies. **Nature**, Londres, v. 432, p. 740-743, 2004.

Material examined

Adelophryne baturitensis: state of Ceará, municipality of Guaramiranga (CFBH 20469-20476). *Adelophryne "maranguapensis"*: state of Ceará, municipality of Maranguape (CFBH 20468; CFBH 24515-23). *Adelophryne baturitensis*: state of Ceará, municipality of Ibiapina (CFBH 23577-23586), Tianguá (CFBH 24554-24563), Ubajara (CFBH 20433-20442), and Viçosa do Ceará (CFBH 20453-20463). *Adelophryne pachydactyla*: state of Bahia, municipality of Una (CFBH 23672).

Appendix 1: Individuals of *Adelophryne* spp. analyzed for 16S mitochondrial DNA fragment and sample sites with respectively geographical location. CFBH: Voucher number in Célio F. B. Haddad Amphibian Collection (CFBH), Universidade Estadual Paulista "Julio de Mesquita Filho", Rio Claro, São Paulo, Brazil. 16S hap: haplotype definition for 16S fragment for each sample.

Specimen	CFBH	**Locality**	**Lat. (S)**	**Long. (W)**	**16S hap**
Adelophryne baturitensis	11097	Viçosa do Ceará, CE	03º21'56"	41º09'20"	h1
Adelophryne baturitensis	11098	Viçosa do Ceará, CE	03º21'56"	41º09'20"	h2
Adelophryne baturitensis	11099	Viçosa do Ceará, CE	03º21'56"	41º09'20"	h1
Adelophryne baturitensis	11127	Viçosa do Ceará, CE	03º21'56"	41º09'20"	h1
Adelophryne baturitensis	11100	Tianguá, Gameleira, CE	03º43'07"	40º55'54"	h4
Adelophryne baturitensis	11101	Tianguá, Gameleira, CE	03º43'07"	40º55'54"	h4
Adelophryne baturitensis	11104	Tianguá, Gameleira, CE	03º43'07"	40º55'54"	h4
Adelophryne baturitensis	11105	Ibiapina,CE	03º53'60"	40º52'21"	h4
Adelophryne baturitensis	11108	Ibiapina, CE	03º53'60"	40º52'21"	h3
Adelophryne baturitensis	11110	Ibiapina, CE	03º53'60"	40º52'21"	h3
Adelophryne baturitensis	11333	Ubajara, CE	03º51'44"	40º53'11"	h4
Adelophryne baturitensis	11334	Ubajara, CE	03º51'44"	40º53'11"	h4
Adelophryne baturitensis	11339	Ubajara, CE	03º51'44"	40º53'11"	h4
Adelophryne baturitensis	11126	Guaramiranga, CE	04º15'60"	38º56'50"	h4
Adelophryne baturitensis	11117	Maranguape, CE	03º53'40"	38º43'17"	h4
Adelophryne baturitensis	11102	Maranguape, CE	03º53'40"	38º43'17"	h4
Adelophryne sp. (cf. *baturitensis*)	11115	Maranguape, CE	03º53'40"	38º43'17"	h7
Adelophryne sp. (cf. *baturitensis*)	11125	Maranguape, CE	03º53'40"	38º43'17"	h6
Adelophryne baturitensis	11716	Caruaru, PE	08°22'2"	36°02'00"	h5
Adelophryne pachydactyla	11441	Una, BA	15º16'12"	39º03'02"	

Capítulo 5

ANEXOS

Anexos

[1] LOEBMANN, D.; PRADO, C. A. P.; HADDAD, C. F. B.; BASTOS, R. F.; GUIMARÃES, L. D. Geographic distribution. *Hypsiboas multifasciatus*, Brazil: Ceará and Goiás. **Herpetological Review**, Lawrence, v. 38, n. 4, p. 476, 2007.

[2] LOEBMANN, D. Geographic distribution. *Echinanthera affinis*. Brazil: Ceará. **Herpetological Review**, Lawrence, v. 39, n. 2, p. 241, 2008.

[3] LOEBMANN, D. Geographic distribution. *Mesoclemmys perplexa*. Brazil: Ceará. **Herpetological Review**, Lawrence, v. 39, n. 2, p. 236, 2008.

[4] LOEBMANN, D. Geographic distribution. *Typhlops brongersmianus*. Brazil: Ceará. **Herpetological Review**, Lawrence, v. 39, n. 2, p. 244, 2008.

[5] LOEBMANN, D. Geographic distribution. *Micrurus lemniscatus lemniscatus* (Guiana s Ribbon Coral Snake). Distribution extension. Brazil: Ceará. **Herpetological Review**, Lawrence, v. 40, n. 3, p. 366, 2009.

[6] LOEBMANN, D. Geographic distribution. *Xenopholis undulatus*. Brazil: Ceará. **Herpetological Review**, Lawrence, v. 40, n. 1, p. 117, 2009.

[7] LOEBMANN, D. Reptilia, Squamata, Serpentes, Scolecophidia, Anomalepididae, *Liotyphlops* cf. *ternetzii* (Boulenger, 1896): first family record for the state of Ceará, Brazil. **Check List**, Campinas, v. 5, n. 2, p. 249-250, 2009.

[8] LOEBMANN, D. Reptilia, Squamata, Serpentes, Viperidae, *Bothrops lutzi*: distribution extension. **Check List**, Campinas, v. 5, n. 3, p. 375-377, 2009.

[9] LOEBMANN, D.; ROBERTO, I. J. Geographic distribution. *Oxyrhopus melanogenys orientalis* (Black-headed Calico Snake). Brazil: Ceará. **Herpetological Review**, Lawrence, v. 40, n. 3, p. 366, 2009.

[10] LEITE JR., J. M. A., SAMPAIO, J. M. S., SILVA-LEITE, R. R., TOLEDO, L. F., LOEBMANN, D.; LEITE, J. R. S. A. Amphibia, Anura, Hylidae, *Scinax fuscomarginatus*: distribution extension. **Check List**, Campinas, v. 4, n. 4, p. 475-477, 2008.

[11] LOEBMANN, D.; MAI, A. C. G. Amphibia, Anura, Leiuperidae, *Physalaemus cicada*: distribution extension in the state of Ceará, Brazil. **Check List**, Campinas, v. 4, n. 4, 392-394, 2008.

[12] LOEBMANN, D.; RIBEIRO, S. C.; SALES, D. L.; ALMEIDA, W. O. New records for *Atractus ronnie* (Reptilia, Serpentes, Colubridae) with comments about meristic and morphometric data. **Biotemas (UFSC)**, Florianópolis, v. 22, n. 1, p. 169-173, 2009.

[13] ROBERTO, I. J.; LOEBMANN, D. Geographic distribution map and parturition aspects of the poorly known viviparous lizard *Mabuya arajara* Rebouças-Spieker, 1981 (Squamata, Sauria, Scincidae) from the state of Ceará, northeastern Brazil. **The Herpetological Bulletin**, submetido, 2009.

[14] LOEBMANN, D.; ORRICO, V. G. D.; HADDAD, C. F. B. First record of the threatened species *Adelophryne baturitensis* Hoogmoed, Borges and Cascon, 1994 for the state of Pernambuco, Northeastern Brazil (Anura, Eleutherodactylidae, Phyzelaphryninae). **Herpetology Notes**, submetido, 2010.

ANEXO 1

HYPSIBOAS MULTIFASCIATUS. Many-Banded Treefrog. BRAZIL: CEARÁ: Ubajara (03°49'36"S; 40°55'02"W; 857 masl). 04 April 2007. D. Loebmann. Coleção de anuros Célio F. B. Haddad, Departamento de Zoologia, Instituto de Biociências, Universidade Estadual Paulista, Rio Claro, São Paulo, Brazil (CFBH 16142; 16147-16149; 16151-16156). Verified by Julian Faivovich. GOIÁS: Aruanã (14°55'13" S; 51°04'59" W; 254 masl). Coleção Zoológica da Universidade Federal de Goiás, Goiânia, Brazil (ZUFG 1835); Caiapônia (16°57'24" S; 51°48'37" W; 593 masl) (ZUFG 1347-1948); Cidade de Goiás (15°56'04" S; 50°08'25" W; 329 masl) (ZUFG 2772); Guapó (16°49'50" S, 49°31'55" W; 771 masl) (ZUFG 1029-1930); Iporá (16°26'31" S; 51°07'04" W; 561 masl) (ZUFG 2439); Jussara (15°51'54" S; 50°52'05" W; 329 masl) (ZUFG 1184-1185); Mossâmedes (16°07'36" S; 50°12'54" W; 518 masl) (ZUFG 273-277, 430-431, 641, 834, 844, 851-852); Palmeiras de Goiás (16°48'18" S; 49°55'33" W; 615 masl) (ZUFG 968, 970); Santa Rita do Novo Destino (15°08'07" S; 49°07'13" W; 737 masl) (ZUFG 2638); São Miguel do Araguaia (13°16'30" S; 50°09'46" W; 352 masl) (ZUFG 1814, 2038); and Serranópolis (18°18'22"; 51°57'44"; 679 masl) (ZUFG 2494-95). All specimens from Goiás collected by R. P. Bastos and L. D. Guimarães and verified by José Perez Pombal Júnior. Species previously reported from eastern Venezuela, through the Guianas to northern Brazil in Amapá, Pará, Maranhão and Piauí (de Sá 1996. Catalogue of American Amphibians and Reptiles. Society for the Study of Amphibians and Reptiles, 624:1-4; Barreto 2007. Cerrado Norte do Brasil = North Cerrado of Brazil. União Sul Americana de Estudos da Biodiversidade, Pelotas, Brazil, 378p.). First state records, extend distribution ca. 560 km eastern from the

city of Uruçui, Piauí state, Brazil, and ca. 786 km southern from the city of Balsas, Maranhão state, Brazil (Barreto *op. cit.*).

Submitted by **Daniel Loebmann**, **Cynthia Peralta de Almeida Prado**, **Célio Fernando Baptista Haddad**. Universidade Estadual Paulista, Instituto de Biociências, Departamento de Zoologia, Rio Claro, Caixa Postal 199, CEP 13506-970, São Paulo, Brasil; **Rogério Pereira Bastos**, and **Lorena Dall'ara Guimarães**. Universidade Federal de Goiás, Instituto de Ciências Biológicas, Departamento de Biologia Geral, Laboratório de Comportamento Animal, Goiânia, Caixa postal 131, CEP 74001-970, Goiás, Brasil. E-mail: contato@danielloebmann.com

ANEXO 2

ECHINANTHERA AFFINIS. Günther's Forest Snake. BRAZIL: CEARÁ: Ubajara (03º50'25.7" S; 40º54'27.5" W; 896 m above sea level). 02 jul 2007. D. Loebmann; and Ubajara (03º50'51.1" S; 40º53'20.7" W; 884 m above sea level). 05 sep 2007. H. Klein. Coleção Instituto Butantan, São Paulo, Brazil (IBSP 76363-76364). Verified by M. Trefaut Rodrigues. The species was known from the states of Rio Grande do Sul, Santa Catarina, Paraná, São Paulo, Rio de Janeiro, Minas Gerais, Espírito Santo, and Bahia (Di-Bernardo & De Lema 1988. Acta Biol. Leopol. 10(2): 223-252; Argôlo 1998. Herpetol. Rev. 29(3): 176). This finding represents an isolated population in the rain forests of Ibiapaba's plateau and also is the first record for the Ceará state, extends distribution ca. 1230 km N from Vitória da Conquista, Bahia state, Brazil (Argôlo op. cit.).

Submitted by **Daniel Loebmann**, Departamento de Zoologia, Instituto de Biociências, Universidade Estadual Paulista, Rio Claro, São Paulo, Brasil. Caixa Postal 199, CEP 13506-970. E-mail: contato@danielloebmann.com

ANEXO 3

MESOCLEMMYS PERPLEXA. BRAZIL: CEARÁ: Viçosa do Ceará (03º21'55.9" S; 41º09'20.1" W; 707 m above sea level). 29 may 2007. D. Loebmann. Verified by M. Trefaut Rodrigues. Coleção de referência do Instituto Butantan, São Paulo, Brazil (CRIB 289). Previously reported only for type-locality, (Serra das Confusões National Park, Piauí state (09°16' S, 43°51' W) by Bour and Zaher 2005. Papeis Avulsos Zool. 45(24): 295-311). First state record extends the species distribution nearly 780 km N from the type-locality.

Submitted by **Daniel Loebmann**, Departamento de Zoologia, Instituto de Biociências, Universidade Estadual Paulista, Rio Claro, São Paulo, Brasil. Caixa Postal 199, CEP 13506-970. E-mail: contato@danielloebmann.com

ANEXO 4

***TYPHLOPS BRONGERSMIANUS*.** Brongersma's Worm Snake. CEARÁ: Ubajara (03º51'43" S; 40º55'02" W; 834 m above sea level). 06 apr 2007. D. Loebmann. Coleção Instituto Butantan de São Paulo (IBSP 76365). Verified by Miguel Trefaut Rodrigues. Species widely distributed with recognized records for the countries of Central America (Trinidad) and South America (Peru, Ecuador, Colombia, Venezuela, Guiana, French Guiana, Suriname, Brazil, Bolivia, Paraguay, and Argentina) (Dixon & Hendricks 1979. Zool. Verh. Leiden. 173:1-39; McDiarmid et al. 1999. Snake Species of the World: A Taxonomic and Geographic Reference, vol. 1. Herpetologists' League, Washington, USA, xii + 511 p). Therefore, this is the first record for the state of Ceará, extending the distribution previously known for this species as follow: ca. 760 km towards northwestern from the João Pessoa city, Paraíba state, Brazil (Santana et al. 2008. Biotemas. 21(1): 75-84); ca. 700 km towards northern from the Ecological station of Uruçui-Una, Piauí state, Brazil and ca. 700 km towards northeastern from the Balsas city, Maranhão state, Brazil (Barreto 2007. Cerrado Norte do Brasil = North Cerrado of Brazil. União Sul Americana de Estudos da Biodiversidade, Pelotas, Brazil, 378p.); and ca. 620 km towards eastern from the Junco do Maranhão city, state of Maranhão, Brazil (Cunha and Nascimento 1993. Bol. Mus. Para. Emílio Goeldi, sér. Zool. 9(1): 1-191). Submitted by DANIEL LOEBMANN, Departamento de Zoologia, Instituto de Biociências, Universidade Estadual Paulista, Rio Claro, São Paulo, Brasil. Caixa Postal 199, CEP 13506-970. E-mail: contato@danielloebmann.com

ANEXO 5

MICRURUS LEMNISCATUS LEMNISCATUS (Guiana's Ribbon Coralsnake). Brazil: Ceará: Municipality of Ubajara: Ubajara National Park (03.830417°S, 40.900278°W; datum WGS84), 445 m elev. 13 November 2008. D. Loebmann. Verified by F. L. Franco. Coleção Instituto Butantan, São Paulo, Brazil (IBSP 77079). Species recorded for the Amazon Rainforest Biome with distribution in Guyana, Suriname, French Guyana, Colombia, Bolivia, Ecuador, Peru, Venezuela, and Brazilian states of Acre, Amapá, Amazonas, Pará, Maranhão, Rondônia, and Roraima (Cunha and Nascimento 1993. Bol. Mus. Para. Emílio Goeldi, sér. Zool. 9[1]:1–191; Roze 1996. Coral Snakes of the Americas: Biology, Identification, and Venoms. Krieger Publishing Company, Malabar, Florida. 328 pp.; Campbell and Lamar 2004. The Venomous Reptiles of the Western Hemisphere. Cornell University Press, Ithaca, New York. 1032 pp.; Feitosa 2006. Morfologia hemipeniana de 11 espécies do gênero *Micrurus* Wagler, 1824 na amazônia brasileira, com redescrição de *Micrurus filiformis* (günther, 1859) e *Micrurus paraensis* Cunha & Nascimento, 1973 (Serpentes, Elapidae. Unpublished Thesis. 170 pp.). First record for Ceará state and Biome of Caatinga, extends distribution ca. 350 km E from state of Maranhão, in surroundings of municipality of Coroatá, Brazil (Campbell and Lamar 2004 *op cit.*).

Submitted by **Daniel Loebmann**, Departamento de Zoologia, Instituto de Biociências, Universidade Estadual Paulista, Rio Claro, São Paulo, Brazil, Caixa Postal 199, CEP 13506-970; e-mail: contato@danielloebmann.com.

ANEXO 6

XENOPHOLIS UNDULATUS (Jensen's Ground Snake). BRAZIL: CEARÁ: Municipality of Ubajara, Ubajara National Park (3.840278°S, 40.907500°W; DATUM WGS84), 896 m above sea level. 09 september 2008. D. N. Lima; and Municipality of Ubajara, Ubajara National Park (3.838346°S, 40.911467°W; DATUM WGS84), 829 m above sea level. 07 november 2008. D. N. Lima. Verified by Francisco L. Franco. Coleção Instituto Butantan, São Paulo, Brazil (IBSP 76832 and IBSP 77110). The species was recorded for Paraguay and Brazilian states of Goiás, Maranhão, Mato Grosso do Sul, Minas Gerais, Pará, Paraná, São Paulo, and Tocantins (Cunha and Nascimento 1993. Bol. Mus. Para. Emílio Goeldi, sér. Zool. 9(1): 1-191, França et al. 2006. SNOMNH Occasional Papers (17): 1-13). This finding represents an isolated population in the rain forests of Ibiapaba's plateau and also is the first record for the genus in Ceará state and Biome of Caatinga, extends distribution ca. 770 km NE from Porto Franco municipality, Maranhão state, Brazil and ca. 1,220 km E from Carajás municipality, Pará state, Brazil (Cunha et al. 1985. Publ. Avul. Mus. Para. Emílio Goeldi. 40:9-85).

Submitted by **Daniel Loebmann**, Departamento de Zoologia, Instituto de Biociências, Universidade Estadual Paulista, Rio Claro, São Paulo, Brasil. Caixa Postal 199, CEP 13506-970. E-mail: contato@danielloebmann.com.

ANEXO 7

Reptilia, Squamata, Serpentes, Scolecophidia, Anomalepididae, *Liotyphlops* cf. *ternetzii* (Boulenger, 1896): first family record for the state of Ceará, Brazil

Daniel Loebmann[1]

[1] *Laboratório de Herpetologia, Programa de Pós-Graduação em Ciências Biológicas (Zoologia), Instituto de Biociências, Universidade Estadual Paulista, Av. 24 A, 1515, Bairro Bela Vista, CEP 13506-900 Rio Claro-SP, Brasil. E-mail: contato@danielloebmann.com*

The Scolecophidia is a basal group in the phylogeny of snakes which includes three families of very odd creatures, collectively called Blind Snakes (Greene 1997). The family Anomalepididae (Dawn Blind Snakes) is considered the world's smallest snakes and they are represented currently by four genera comprising 17 species (*Anomalepis* Jan, 1860 ((4 ssp.), *Helminthophis* Peters, 1860 (3 ssp.), *Liotyphlops* Peters, 1860 (8 ssp.), and *Typhlophis* Fitzinger, 1843 (2 ssp.)) (Uetz et al. 2008), ranging from southern Middle America (Nicaragua, Costa Rica, and Panama) to South America (Argentina, Brazil, Colombia, Ecuador, Paraguay, Peru, and Uruguay) (Carreira 2004; Freire et al. 2007). *Liotyphlops* is the richest genus in the family with eight species currently recognized: *L. albirostris* (Peters, 1857), *L. anops* (Cope, 1899), *L. argaleus* Dixon and Kofron, 1984, *L. beui* (Amaral, 1924), *L. schubarti* Vanzolini, 1948, *L. ternetzii* (Boulenger, 1896), *L. wilderi* (Garman, 1883), and *L. trefauti* (Freire, Caramaschi and Argôlo, 2007) (Freire et al. op cit.).

During a field survey conducted on 10th July 2008 in the Ubajara National Park a juvenile specimen (total length = 121 mm) of *Liotyphlops* cf. *ternetzii* was collected. The specimens were found in the surroundings of Minas River (03°50'01.9" S, 40°54'15.6" W; 519 m above sea level), an area with a physiognomy of Caatinga (*sensu* Ab'Saber 1977). Although the external diagnostic characters analyzed combined with *Liotyphlops ternetzii* (see Dixon and Kofron 1984), I prefer to leave as confer status due to the fact that anomalepidids has a complex taxonomy and it is very difficult to determine precisely the species identification, such as in this case with a single juvenile found over a two years of expedition in the Plateau of Ibiapaba. The specimen was deposited in the snakes collection of Institute Butantan, São Paulo, Brazil (IBSP 76856). Collecting permits was autorized by Ibama (Lic. Number 13571-1).

Liotyphlops ternetzii was known from the Brazilian states of Minas Gerais, Mato Grosso, Pará, São Paulo, and also for the countries of Argentina, Paraguay, and Uruguay (Cunha and Nascimento 1993; Carreira 2004; Recorder and Nogueira 2007). This finding represents the first record for the family Anomalepididae in state of Ceará and also the extension of the genus distribution as follows: ca. 720 km E from municipality of Capitão Poço, state of Pará, Brazil (*L. ternetzii*; Cunha and Nascimento 1993), 1,375 km N from the Grande Sertão Veredas National Park, state of Minas Gerais, Brazil (*L. ternetzii*; Recoder and Nogueira 2007), and ca. 780 km NW from municipality of São José da Lage, State of Alagoas, Brazil (*L. trefauti*; Freire et al. 2007).

Two hypotheses should be considered about the wide and fragmented distribution of *L. ternetzii*, based on available literature. Firstly, it is possible that *L. ternetzii* is, in fact, a complex of species. Second, the fossorial behavior of the

species associated with its apparent low density becomes very difficult find these snakes to in the wild and, perhaps, the distribution of the species is not so fragmented as actually considered. Therefore, the best way to try to solve this dilemma definitively is to conduct a taxonomic review for the currently recognized populations of *L. ternetzii*.

Figure 1 – A juvenile of *Liotyphlops ternetzii* (IBSP 76856) collected at Ubajara National Park, municipality of Ubajara, state of Ceará.

Acknowledgements

I am grateful to Valdir Germano (Instituto Butantan) for help in the specimen identification. Maria Cristina Oddone (Secretaria Especial de Aquicultura e Pesca) for reviewed the English grammar and style of the manuscript.

Literature cited

Ab'Saber, A. N. 1977. Os Domínios Morfoclimáticos na América do Sul. Primeira aproximação. Geomorfologia 52: 1-159.

Carreira, S. 2004. Geographic distribution: *Liotyphlops ternetzii*. Herpetological Review 35(4): 411-412.

Cunha, O. R. and F. P. Nascimento. 1993. Ofídios da Amazônia. As cobras da região leste do Pará. Boletim do Museu Paraense Emílio Goeldi (Série Zoologia) 9(1): 1-191.

Dixon, J. R. and Kofron, C. P. 1984. The Central and South American anomalepid snakes of the genus *Liotyphlops*. Amphibia-Reptilia 4(2-4): 241–264.

Freire, E. M. X., U. Caramaschi, and A. J. S. Argolo. 2007. A new species of *Liotyphlops* (Serpentes: Anomalepididae) from the Atlantic Rain Forest of Northeastern Brazil. Zootaxa 1393: 19–26.

Greene, H. W. 1997. Snakes*:* the evolution of mystery in nature. Berkeley: University of California Press. 351p.

Recorder, R. and C. Nogueira 2007. Composição e diversidade de répteis na região sul do Parque Nacional Grande Sertão Veredas, Brasil Central. Biota Neotropica 7(3): 267-278.

Uetz, P. 2008. TIGR. Reptile database. Electronic Database accessible at http://www.reptile-database.org. Captured on March 2008.

ANEXO 8

Reptilia, Squamata, Serpentes, Viperidae, *Bothrops lutzi*: distribution extension

Daniel Loebmann [1, 2]

[1] Laboratório de Herpetologia, Programa de Pós-Graduação em Ciências Biológicas (Zoologia), Instituto de Biociências, Universidade Estadual Paulista, Av. 24 A, 1515, Bairro Bela Vista, CEP 13506-900, Rio Claro-SP, Brasil.

[2] Corresponding author: contato@danielloebmann.com

The family Viperidae comprises 28 species in Brazilian territory, with 23 of them belonging to the genus *Bothrops* Wagler, 1824 (Bérnils 2009). The *Bothrops neuwiedi* complex presents an ambiguous taxonomic status and seven species *B. diporus*, *B. lutzi*, *B. mattogrossensis*, *B. neuwiedi*, *B. pauloensis*, *B. pubescens*, and *Bothrops marmoratus* have been formerly recognized so far (Silva 2004; Silva and Rodrigues 2008).

The distribution of *B. lutzi* is known to central eastern Brazil, which includes Minas Gerais, Bahia, Goiás, Tocantins, Piauí, and Ceará states (Lira-da-Silva et al. 2003; Silva 2004; Borges-Nojosa and Cascon 2005; Freitas and Silva 2007). Here, I present a new record for *B. lutzi* in the Ceará state.

Between February 2007 to November 2007, I found 5 specimens (four females, one male) of *B. lutzi* (Figure 1) in the Chapada da Ibiapaba (Plateau of Ibiapaba) between Ubajara and Tianguá municipalities (03º53'29.4" S, 41º04'30.7" O; 796 m above sea level). The Ibiapaba's plateau is a rocky arenitic formation in

the frontier of Piauí and Ceará states, belonging to the *Caatinga* Biome (*sensu* Ab'Saber, 1977). The physiognomy where the specimens were found is classified as Dry Dense Bush Forest,

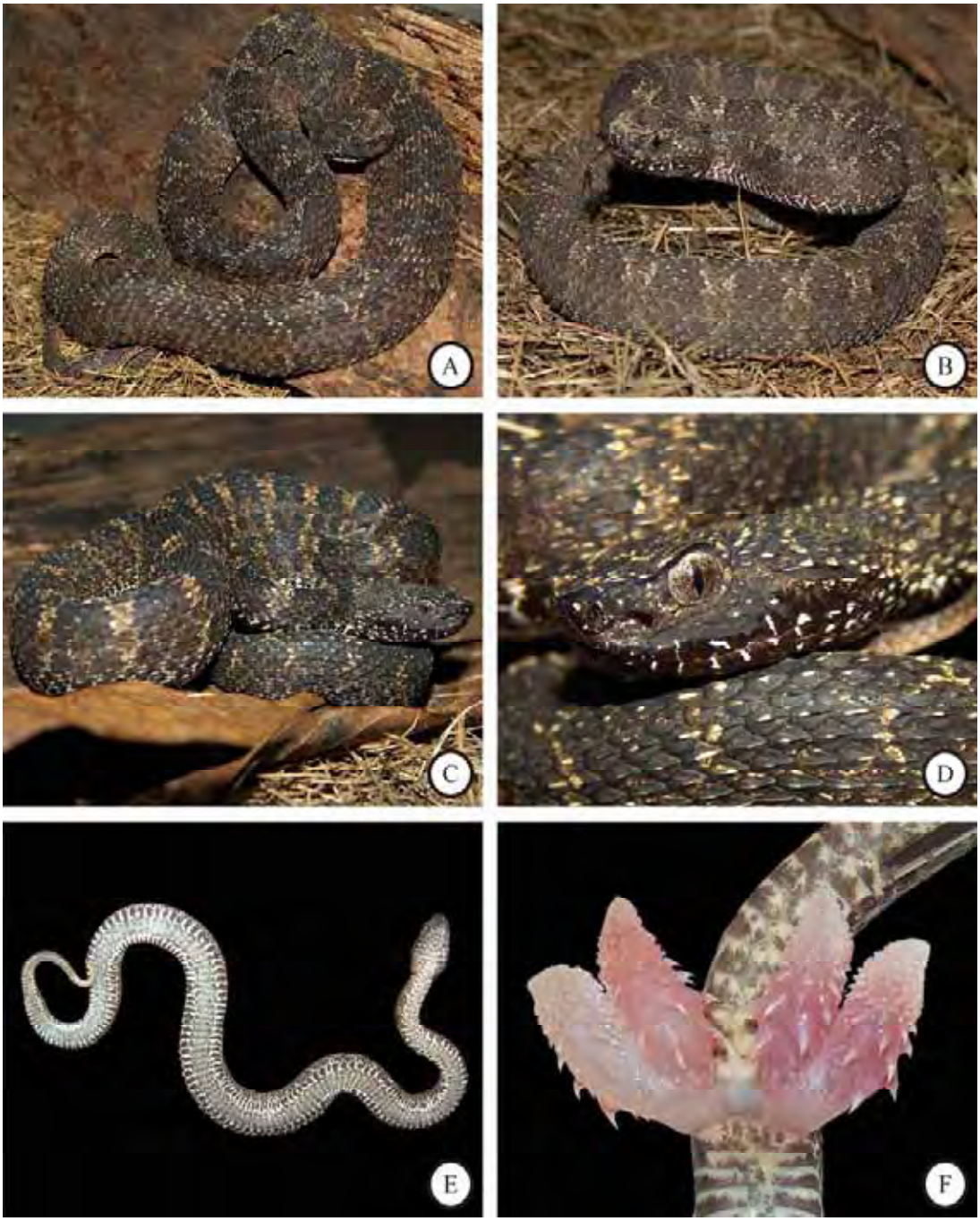


Figure 1 –Specimens of *Bothrops lutzi* found at the present study with their main color patterns and some diagnostics characters. A-C) General view of female adults with snout-vent length of 72.0, 45.2, and 59.0 cm respectively; D) Head detail; E) Ventral color pattern of a juvenile female (SVL = 34 cm); and F) Hemipenis of an adult male SVL = 52,8 cm).

locally known as *Carrasco*, and can be basically characterized as a Forest zone with trees of the medium size (up to 4 meters high), where the loss of leaves is higher than 70% during the dry season (June-December). The snout-vent length of the individuals varied from 34 to 72 cm. A voucher specimen was deposited in the Herpetological Collection of the Paraíba Federal University (UFPB4506). Collecting permits were granted by *Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis* - IBAMA (number 267/2006).

This finding is the first record for the species in the Ibiapaba's plateau, extending the species' range in ca. 140 km north, in a straight line from the previous report at Brejo Santo municipality, in Southern Ceará (Borges-Nojosa and Cascon 2005). Considering that in Ceará this species is registered only in dry forests located in high altitudes (700 m above sea level) in the border with Piauí, it is likely that Ibiapaba's plateau represents the northern limit in the distribution of *B. lutzi* in Brazilian's territory. Therefore, the current distribution knowledge for *B. lutzi* should be considered as presented in figure 2.

Acknowledgments

I am grateful to the Vinícius Xavier Silva to confirm the species identification. To Conselho Nacional de Pesquisa e Desenvolvimento (CNPq) to provide a doctoral scholarship (grant no. 140226/2006-0).

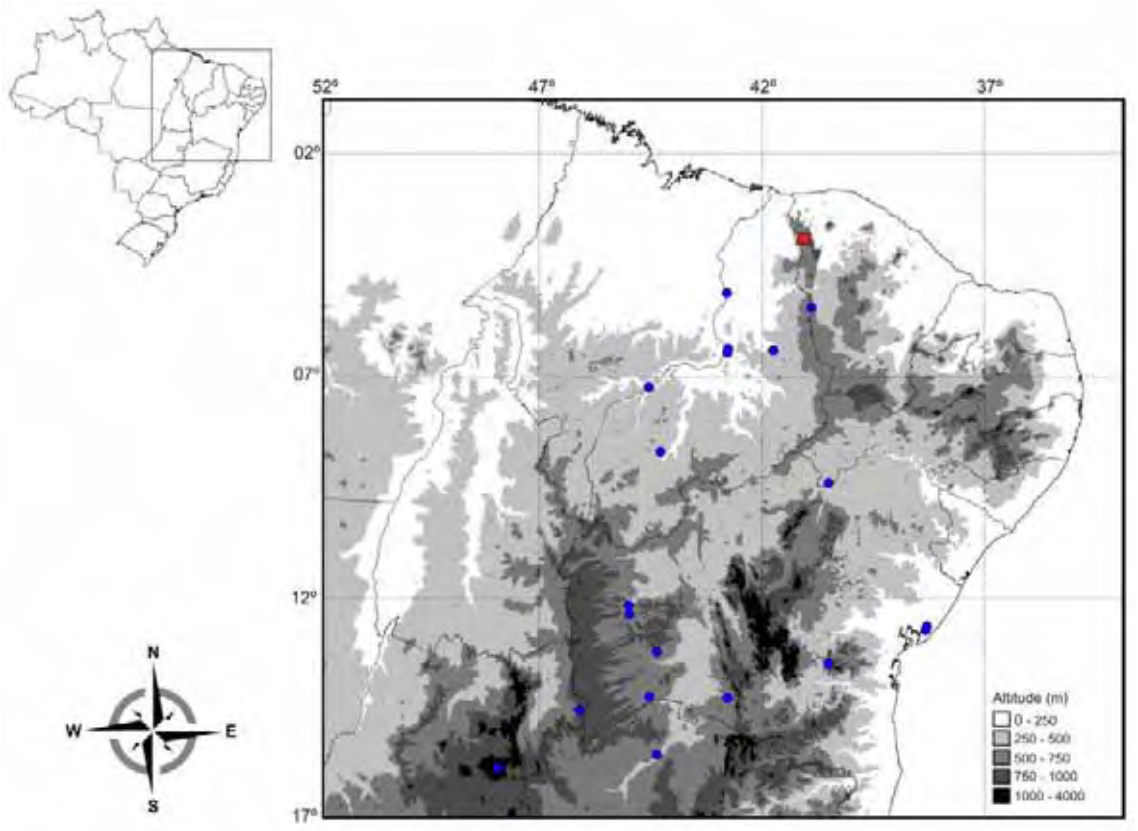


Figure 2 – Altitudinal distribution map of *Bothrops lutzi* indicating the previous knowledge localities (blue circles) adapted from Silva and Rodrigues (2008) and the present record (red square).

References

Ab'Saber, A. N. 1977. Os Domínios Morfoclimáticos na América do Sul. Primeira aproximação. Geomorfologia 52: 1-159.

Bérnils, R. S. 2009. Brazilian reptiles – List of species. Electronic Database accessible at http://www.sbherpetologia.org.br. Brazilian Society of Herpetology, Brazil. Captured on 6 May 2009.

Borges-Nojosa, D. M. and P. Cascon. 2005. Herpetofauna da Área Reserva da Serra das Almas, Ceará. Pp. 243-258. In: F. S. Araújo, M. J. N. Rodal, and M. R. V.

Barbosa (eds.), Análise das Variações da Biodiversidade do Bioma Caatinga. Brasília, Ministério do Meio Ambiente.

Freitas, M. A. and T. F. S. Silva. 2007. A Herpetofauna das Caatingas e áreas de altitude do Nordeste Brasileiro. Pelotas. União Sul-Americana de estudos a Biodiversidade. 388 p.

Lira-da-Silva, R. M., Y. F. Mise, G. Puorto, and V. X. Silva. 2003. Geographic distribution. *Bothrops neuwiedi lutzi* (Neuwiedi's Lancehead): Bahia. Herpetological Review 34(4): 386.

Silva, V. X. 2004. The *Bothrops neuwiedi* complex. Pp. 410-422. In: J. A. Campbell and W. W. Lamar (eds.), The Venomous Reptiles of the Western Hemisphere. Ithaca. Cornell University Press.

Silva, V. X. and M. T. Rodrigues. 2008. Taxonomic revision of the *Bothrops neuwiedi* complex (Serpentes, Viperidae) with description of a new species. Phyllomedusa 7(1): 45-90.

ANEXO 9

OXYRHOPUS MELANOGENYS ORIENTALIS (Black-headed Calico Snake). BRAZIL: CEARÁ: Municipality of Ubajara (3.8450°S, 40.9344°W; DATUM WGS84), 857 m above sea level. 10 February 2008. D. Loebmann. Coleção Instituto Butantan, São Paulo, Brazil (IBSP 77061); Municipality of Guaramiranga (4.2723°S, 38.9492°W; DATUM WGS84), 844 m above sea level. 10 December 2006. T. Pinto, C. Albano and I. J. Roberto (IBSP 76979); Municipality of Pacoti (4.2208°S, 38.9259°W; DATUM WGS84), 758 m above sea level. 15 April 2006. C. Albano and I. J. Roberto. (IBSP 77980). All verified by F. L. Franco. Subspecies distributed in the Brazilian states of Pará and Maranhão (Cunha and Nascimento 1993. Bol. Mus. Para. Emílio Goeldi, sér. Zool. 9(1): 1-191). First state records represented by two isolated populations in the relictual rain forests of plateau of Ibiapaba and Baturité Hills. Also are the first records in the Biome of Caatinga, extending range distribution ca. 480 km E (plateau of Ibiapaba) and ca. 710 km E (Baturité Hills) from municipality of Santa Inês, state of Maranhão, Brazil (Cunha and Nascimento 1983. Bol. Mus. Para. Emílio Goeldi, sér. Zool. (122): 1-42).

Submitted by **Daniel Loebmann**, Departamento de Zoologia, Instituto de Biociências, Universidade Estadual Paulista, Rio Claro, São Paulo, Brasil. Caixa Postal 199, CEP 13506-970; **Igor Joventino Roberto**, Aquasis - Associação de Pesquisa e Preservação de Ecossistemas Aquáticos, Programa Biodiversidade. Praia de Iparana s/n, SESC Iparana, Caucaia, Ceará, Brasil, CEP 61627-010. E-mail: contato@danielloebmann.com.

ANEXO 10

Amphibia, Anura, Hylidae, *Scinax fuscomarginatus*: distribution extension

João Manoel A. Leite Jr[1], Johnny M. S. Sampaio[1,2], Roberta Rocha Silva-Leite[1,3], Luís Felipe Toledo[4], Daniel Loebmann[5], José Roberto S. A. Leite[1*]

[1]Projeto Biodiversidade do Delta - PROBID, *Campus* Ministro Reis Velloso - CMRV, Universidade Federal do Piauí - UFPI, Parnaíba, Piauí, 64202-020, Brazil.

[2]*Campus* Professor Alexandre Alves de Oliveira, Universidade Estadual do Piauí - UESPI, Avenida Na. Senhora de Fátima, s/n - Bairro de Fátima Parnaíba, PI 64202-220, Brazil.

[3]Programa de Pós-graduação em Desenvolvimento e Meio Ambiente, Núcleo de Referência em Ciências Ambientais do Trópico Ecotonal do Nordeste -TROPEN, Universidade Federal do Piauí – UFPI.

[4]Universidade Federal do Paraná, Pós Graduação em Ecologia e Conservação, Setor de Ciências Biológicas, Centro Politécnico, Curitiba, Paraná, Brasil, Caixa Postal 19031, CEP 81531-980; E-mail: toledolf2@yahoo.com.

[5]Laboratório de Herpetologia, Programa de Pós-Graduação em Ciências Biológicas (Zoologia), Instituto de Biociências, Universidade Estadual Paulista, Av. 24 A, 1515, Bairro Bela Vista, CEP 13506-900 Rio Claro-SP, Brasil: E-mail contato@danielloebmann.com; Webpage: www.danielloebmann.com.

[*]Corresponding Author: Leite, J.R.S.A. (jrleite@ufpi.br).

Address: *Campus* Ministro Reis Velloso, Universidade Federal do Piauí - UFPI, Parnaíba, PI, 64202-020, Brazil.

There are currently 73 species of *Scinax* described for Brazil, among them there is *Scinax fuscomarginatus*, a small species in the *Scinax ruber* clade (Faivovich 2002; Faivovich et al. 2005), with about 2 cm of snout-vent length (Figure 1). Treefrogs of the *S. ruber* clade occur from Mexico to Argentina and may have originated in South America (Léon, 1969). *Scinax fuscomarginatus* is typical from open areas such as those of Pantanal and Cerrado (Brasileiro et al. 2005; Toledo & Haddad 2005a; b), occurring in the central portion of Brazil (Haddad et al. 2008), but also occurring in the eastern of Bolivia, Paraguay, and Argentina (Frost 2007). In spite of this wide distribution, its geographic range is still unclear, and some populations can be found in open areas of unexpected biomes, such as the Atlantic Rainforest (Freitas and Silva, 2007). Besides this, its austral boundaries of distribution remain obscure. Therefore, we provide here data on its northernmost distribution known up today.

We registered new occurrences of populations of *S. fuscomarginatus* in several localities in states of the northeastern Brazil. In the state of Alagoas a population was registered in the municipality of Passo de Camarajibe (09º17'04" S, 35º23'23" W; individuals deposited at the Célio F. B. Haddad amphibian collection, CFBH 7324; 7327-28; 7349-52; 7402-05); three populations were registered in the state of Maranhão; in Ilha das Canárias, municipality of Araioses (02º47'48.9" S 41º52'12.1" W, animals deposited in the Coleção Herpetológica Delta do Parnaíba, CHDP 0027; 0094; 0097); in the municipality of Alcântara (02º15'27" S 44º25'36" W), and in the municipality of Timbiras (04º15'25" S 43º56'56" W) (license number 12180-1/SISBIO). The population of the state of Piauí was observed in Ilha Grande de Santa Isabel, municipalities of Ilha Grande do Piauí and Parnaíba (02°51'48" S 41°49'57" W) (Figure 2). In the state of Ceará, we registered a

population in the municipality of Viçosa do Ceará (03º24'10" S 41º07'26" W) (CFBH 19386).

Figure 1. (**A**) Adult male of *Scinax fuscomarginatus* collected in the municipality of Viçosa do Ceará, state of Ceará, Brazil (CFBH 19386) (Photo: Daniel Loebmann). (**B**) Temporary ponds (arrows) where the species was found in the Ilha das Canárias, Delta do Parnaíba, state of Maranhão, Brazil (Photo: Palê Zuppani).

The records to the municipality of Viçosa do Ceará extends the distribution of *S. fuscomarginatus* in about 760 km towards northeastern from the municipality of Ribamar Fiquene, state of Maranhão (Brasileiro et al. 2008). Therefore, these are also the first records of this species for the coastal islands and for the states of Ceará and Piauí. These findings in areas of transition and estuaries, as the region of Parnaíba's Delta and Alagoas state, indicate that the species is not restrict to the Cerrado and Pantanal, as formerly believed (Araujo and Colli 1998), but actually to every open formations from Argentina to the Amazon basin.

Figure 2 – (**A**) Occurrence and distribution of *S. fuscomarginatus* on the islands of the Parnaíba's Delta. (**B**) Geographic distribution of *Scinax fuscomarginatus*. The dashed area was based and modified from GAA (Conservation International, and NatureServe), and the dots indicate the new records presented by the present study.

Acknowledgements

The authors are grateful to Pedro da Costa e Silva during field expeditions, Etielle Barroso de Andrade for line drawings of Delta do Parnaíba and Wennys Dean Sousa da Silva for the construction of the map of distribution. Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA – Parnaíba) for the logistical support, Instituto Chico Mendes for provided the collecting permits, Instituto Ilha do Caju Ecodesenvolvimento e Pesquisa (ICEP) and Projeto Biodiversidade do Delta / Conservação e Pesquisa (PROBID) for partial economical support. To Programa Petrobrás Ambiental and Universidade Federal do Piauí (UFPI) granted part of the work. LFT acknowledges CAPES (PRODOC) for grants provided.

References

Brasileiro, C. A., R. J. Sawaya, M. C. Kiefer and M. Martins. 2005. Amphibians of a open cerrado fragment in southeastern Brazil. Biota Neotropica, 5(2): http://www.biotaneotropica.org.br/v5n2/pt/abstract?article+BN00405022005.

Brasileiro, C. A., E. M. Lucas, H. M. Oyamaguchi, M. T. C. Thomé and M. Dixo. Anurans, Northern Tocantins River Basin, Tocantins and Maranhão States, Northern Brazil. Check List, 4(2): 185-197.

Faivovich, J. 2002. A cladistic analysis of *Scinax* (Anura: Hylidae). Cladistics 18: 367–393.

Faivovich, J., C. F. B. Haddad, P. C. A. García, D. R. Frost, and J. A. Campbell. 2005. Systematic review of the frog family Hylidae, with special reference to

Hylinae: phylogenetic analysis and taxonomic revision. Bulletin of the American Museum of Natural History 294:1-240.

Frost, D. R. 2007. Amphibian Species of the World: an online reference. Version 5.1. Electronic Database accessible at http://research.amnh.org/herpetology/amphibia/index.html. American Museum of Natural History, New York, USA. Captured on 25 April 2008.

Haddad, C. F. B., L. F. Toledo, and C. P. A. Prado. 2008. Anfíbios da Mata Atlântica: guia dos anfíbios anuros da Mata Atlântica. Editora Neotropica 244 p.

Léon, J. R. 1969. The systematic of the frogs of the *Hyla rubra* group in Middle America. Museum of Natural History 18:505–545.

Pavan, D. and M. Dixo. 2002. A Herpetofauna da área de influência do reservatório da Usina Hidrelétrica Luís Eduardo Magalhães, Palmas, TO. Humanitas 4(6):13-30.

Freitas, M. A. and T. F. S. Silva. 2007. A Herpetofauna das Caatingas e Áreas de Altitude do Nordeste Brasileiro. Pelotas, ed. USEB. In press, 388p.

Toledo, L. F. and C. F. B. Haddad. 2005a. Acoustic repertoire and calling site of *Scinax fuscomarginatus* (Anura, Hylidae). Journal of Herpetology 39(3):455-464.

Toledo, L. F. and C. F. B. Haddad. 2005b. Reproductive biology of *Scinax fuscomarginatus* (Anura, Hylidae) in south-eastern Brazil. Journal of Natural History 39(32):3029-3037.

ANEXO 11

Amphibia, Anura, Leiuperidae, *Physalaemus cicada*: distribution extension in the state of Ceará, Brazil

Daniel Loebmann [1,3] and Ana Cecília Giacometti Mai [2]

[1] *Laboratório de Herpetologia, Programa de Pós-Graduação em Ciências Biológicas (Zoologia), Instituto de Biociências, Universidade Estadual Paulista, Av. 24 A, 1515, Bairro Bela Vista, CEP 13506-900 Rio Claro-SP, Brasil. Webpage:* http://ns.rc.unesp.br/ib/zoologia/anuros*.*

[2] *Departamento de Sistemática e Ecologia, Programa de Pós-graduação em Ciências Biológicas (Zoologia), Universidade Federal da Paraíba, CEP 58059-900, João Pessoa, Paraíba, Brasil.*

[3] Corresponding author: contato@danielloebmann.com

The genus *Physalaemus* comprises 41 recognized species (Frost 2007) distributed from northern to southern South America, east of the Andes (Nascimento et al. 2005). *Physalaemus cicada* is typically found in lowland open areas (around 200 m ASL) of the Caatinga and Cerrado Biomes (IUCN et al. 2006) in the Brazilian states of northeastern (Ceará, Paraíba, Pernambuco, Bahia), and southeastern (Minas Gerais) (see Table 1 and references therein).

On 17 April 2008, we observed five adult males (mean snout-vent length ± Standard deviation = 22.83 ± 1.04) (Figure 1A) and three foam nests (Figure 1B) of *P. cicada* in the municipality of Nova Russas, state of Ceará (04º41'07.5" S 40º33'56.7" W; 270 m ASL). Individuals were calling in a temporary pond (6 m

maximum length and 0.3 m maximum depth) formed after a storm on the day before, located near to the road CE-187. Other six species of anurans were also registered in the same pond: *Phyllomedusa nordestina*, *Pleurodema diplolister*, *Elachistocleis* cf. *piauiensis*, *Pseudopaludicola* gr. *falcipes*, *Physalaemus albifrons*, and *Leptodactylus fuscus*. Voucher specimens are deposited at the amphibian collection Célio F. B. Haddad (CFBH 19389-19392; 19385), at Laboratório de Herpetologia, Departamento de Zoologia, Universidade Estadual Paulista, Rio Claro, São Paulo, Brazil. Collecting permits was authorized by Brazilian Institute of Environment and Renewable Natural Resources (*Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis* - IBAMA) (Proc. number - SISBIO/14130-1).

Table 1. Localities with records of *Physalaemus cicada* and their respective literature references.

Municipality	**State**	**Latitude**	**Longitude**	**Source**
Araruna	Paraíba	06º27'13" S	35º40'49" W	Arzabe et al. 2005
Betânia	Pernambuco	08º16'29" S	38º02'03" W	Borges-Nojosa and Santos 2005
Floresta	Pernambuco	08º36'04" S	38º34'07" W	Borges-Nojosa and Santos 2005
Lençóis	Bahia	12º33'47" S	41º23'18" W	Santana and Juncá 2007
Maracás	Bahia	13º26'28" S	40º25'51" W	Bokermann 1966
Juazeiro	Bahia	09º24'42" S	40º29'55" W	Nascimento et al. 2005
Carnaíba	Bahia	09º27'06" S	41º52'43" W	Nascimento et al. 2005
João Pinheiro	Minas Gerais	17º43'59" S	46º10'00" W	Silveira 2006
Pedra Azul	Minas Gerais	16º00'19" S	41º17'50" W	Nascimento et al. 2005
Matias Cardoso	Minas Gerais	14º51'17" S	43º55'19" W	Nascimento et al. 2005
Brejo Santo	Ceará	07º29'36" S	38º59'14" W	Nascimento et al. 2005
Nova Russas	Ceará	04º41'07" S	40º33'56" W	New Record

Figure 1. *Physalaemus cicada* found in the municipality of Nova Russas, state of Ceará. A) Male adult; B) Nest.

Figure 2. Geographic distribution of *Physalaemus cicada.* Red circles represent bibliographic data (see Table 1) and red square represents the new record for the species (present study). The Brazilian states with species records are shown in gray.

This finding extends species' range in ca. 360 km northwest from the previous report at the municipality of Brejo Santo, southern region of the Ceará state. Moreover, based on the known records for this species (Table 1) it was

possible to create a map of the distribution of *P. cicada* (Figure 2). Considering that *P. cicada* does not occur in other nearby areas such Almas' hills (*Serra das Almas*) (Borges-Nojosa and Cascon 2005), Ibiapaba' hills (*Serra da Ibiapaba*) (DL pers. obs.), and areas from the coastal zone of Piauí and Ceará states (Cascon and Borges-Nojosa 2003; Silva et al. 2007; Loebmann and Mai 2008), the present record probably pointed out the northwest limit in the distribution of this species.

Literature cited

Arzabe, C., G. Skuk, G. G. Santana, F. R. Delfim, Y. C. C. Lima, and S. H. F Abrantes. 2005. Herpetofauna da Área de Curimataú, Paraíba. Pp. 259-274. In F. S. Araújo, M. J. N. Rodal, and M. R. V. Barbosa (eds.), Análise das variações da biodiversidade do bioma Caatinga. Brasília, Ministério do Meio Ambiente.

Bokermann, W. C. A. 1966. Notas sobre três espécies de *Physalaemus* de Maracás, Bahia (Amphibia, Leptodactylidae). Revista Brasileira de Biologia 26(3): 253-259.

Borges-Nojosa, D. M. and C. Arzabe. 2005. Diversidade de anfíbios e répteis em áreas prioritárias para a conservação da Caatinga. Pp. 227-241. In F. S. Araújo, M. J. N. Rodal, and M. R. V. Barbosa (eds.), Análise das variações da biodiversidade do bioma Caatinga. Brasília, Ministério do Meio Ambiente.

Borges-Nojosa, D. M. and E. M. Santos. 2005. Herpetofauna da área de Betânia e Floresta, Pernambuco. Pp. 275-289. In F. S. Araújo, M. J. N. Rodal, and M. R. V. Barbosa (eds.), Análise das variações da biodiversidade do bioma Caatinga. Brasília, Ministério do Meio Ambiente.

Borges-Nojosa, D. M. and P. Cascon. 2005. Herpetofauna da Área Reserva da Serra das Almas, Ceará. Pp. 243-258. In: F. S. Araújo, M. J. N. Rodal, and M. R. V.

Barbosa (eds.), Análise das Variações da Biodiversidade do Bioma Caatinga. Brasília, Ministério do Meio Ambiente

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

Frost, D. R. 2007. Amphibian Species of the World: an online reference. Version 5.0. Electronic Database accessible at http://research.amnh.org/herpetology/amphibia/index.html. New York: American Museum of Natural History. Captured on 14 May 2008.

IUCN, Conservation International, and NatureServe. 2007. Global Amphibian Assessment. Eletronic database accessible at http://www.globalamphibians.org. Captured on 14 May 2008.

Loebmann, D. and A. C. G. Mai. 2008. Amphibia, Anura, Coastal Zone, State of Piauí, Northeastern Brazil. Check List 4(2): 161-170.

Nascimento, L. B.; U. Caramaschi, and C. A. G. Cruz. 2005. Taxonomic review of the species groups of the genus *Physalaemus* Fitzinger, 1826. Arquivos do Museu Nacional 63(2): 297-320.

Silva, G. R., C. L. Santos, M. R. Alves, S. D. V. Souza, and B. B. Annunziata. 2007. Anfíbios das dunas litorâneas do extremo norte do Piauí, Brasil. Sitientibus. Série Ciências Biológicas 7(4): 334-340.

Silveira, A. L. 2006. Anfíbios do município de João Pinheiro, uma área de cerrado no noroeste de Minas Gerais, Brasil. Arquivos do Museu Nacional 64(2): 131-139.

Santana, A. S. and F. A. Juncá. 2007. Diet of *Physalaemus* cf. *cicada* (Leptodactylidae) and *Bufo granulosus* (Bufonidae) in a semideciduous forest. Brazilian Journal of Biology 67(1): 125-131.

ANEXO 12

New records of *Atractus ronnie* (Serpentes, Colubridae) in relictual forests from the state of Ceará, Brazil and comments on meristic and morphometric data

Daniel Loebmann[1]*, Samuel Cardozo Ribeiro[2], Débora Lima Sales[2] and Waltécio de Oliveira Almeida[2]

[1]PPG em Zoologia, Instituto de Biociências, Universidade Estadual Paulista Av. 24 A, 1515, Bairro Bela Vista, CEP 13506-900, Rio Claro – SP, Brasil.

[2]Laboratório de Zoologia, Departamento de Ciências Físicas e Biológicas. Universidade Regional do Cariri, Crato – CE, Brasil.

*Author for correspondence: contato@danielloebmann.com

Abstract

Atractus ronnie was recently described from Serra de Baturité, a mountainous relictual forest enclave in the semiarid Caatinga, state of Ceará, northeastern Brazil. Here we report new records of *A. ronnie* in others two areas of relictual forests and provide additional data on pholidosis variation. The results presented herein reinforces the need of systematic inventory surveys in the relictual forests of Ceará, since the herpetofauna remains poorly known.

Key words: *Atractus ronnie*, Colubridae, northeastern Brazil, relictual forests, Ceará state.

Resumo: Novos registros de *Atractus ronnie* (Reptilia, Serpentes, Colubridae) em florestas relictuais do estado do Ceará e comentários sobre dados merísticos e morfométricos. *Atractus ronnie* foi recentemente descrita para Serra de Baturité, uma área montanhosa de enclave de floresta relictual na Caatinga semi-árida, estado do Ceará, nordeste do Brasil. Apresentamos aqui novos registros de *A. ronnie* em duas novas áreas de floresta relictual e apresentamos dados adicionais de variação de sua folidose. Os resultados apresentados aqui reforçam a necessidade de inventários sistemáticos em florestas relictuais do Ceará, uma vez o conhecimento sobre a herpetofauna das florestas relictuais permanece pobremente conhecido.

Unitermos: *Atractus ronnie*, Colubridae, nordeste do Brasil, florestas relictuais, estado do Ceará

The genus *Atractus* currently comprises about 100 species of semi-fossorial or fossorial snakes (Fernandes et al., 2000; Passos et al., 2005) widely distributed in South and Central America, occurring from the southern of Panama to Argentina (Giraudo and Scrocchi, 2000; Myers, 2003). A total of 29 species of *Atractus* are recognized for Brazil (SBH, 2008), with only *Atractus guentheri* (Wucherer, 1861), *Atractus maculatus* Günther, 1858, *Atractus potschi* Fernandes, 1995, and the recently described *Atractus ronnie* Passos, Fernandes & Borges-Nojosa, 2007 occurring in northeastern Brazil (Fernandes, 1995; Fernandes, 1996; Passos et al., 2007).

Atractus ronnie (Figure 1) was recently described based on individuals from Serra de Baturité (Baturité hills), a mountainous humid forest in the semiarid Caatinga domain, state of Ceará, Brazil (Passos et al., 2007). Here we report two

new records of *A. ronnie* in the state of Ceará and provide additional data on pholidosis variation of this taxon.

The first record was a single specimen from the Plateau of Ibiabapa, municipality of Tianguá (03°43'7.02"S, 40°55'53.71'W, 871m above sea level). The second record were specimens from the Plateau of Araripe, municipality of Crato (07°15'19"S, 39°28'12"W, at 729m above sea level). Vouchers specimens were deposited at the Laboratory of Zoology, Universidade Regional do Cariri (LZ-URCA 460-465; 489-491) and Museu Nacional, Universidade Federal do Rio de Janeiro (MNRJ 17326).

Figure 1 – General view of the adult female of *Atractus ronnie* in life collected in the municipality of Tianguá, Plateau of Ibiapaba. Picture by Daniel Loebmann.

Both areas are relictual forests and represent exceptionally humid habitat islands within the semiarid *Caatinga* Domain (*sensu* Ab'Saber, 1977). Localized orographic rains and fog condensation favor the persistence of these relictual

forests, and they experience significantly milder temperatures and increased levels of rainfall compared to the surrounding *Caatinga* lowlands (Vanzolini, 1981; Andrade-Lima, 1982; Carnaval and Bates, 2007). The main difference between both areas is the location of the relictual forest. This happen because the chemical morphogenesis which contributes to the formation of the humid forest occurs in the top and slope of the hills in the Plateau of Ibiapaba, while in the Plateau of Araripe this phenomenon occurs only in the slope of the hills (Fernandes, 1990).

Meristic data from the collected specimens agree in most aspects with the original description, although it was possible to identify certain differences (Table 1). The maximum snout vent lengths attained by specimens, especially among females, were greater (223mm in males; 391mm in females) than those seen among individuals from Serra de Baturité (220mm in males; 312mm in females). Although the ventral color pattern is uniformly creamish white in most of the specimens analyzed, as depicted in the original description, the largest specimen had small dark brown spots concentrated in the distal half of its body.

Scale counts also revealed certain differences. Ventral scales varied from 146 to 163 among females (n= 7), and from 129 to 132 among males (n = 3); against 154-160 among females and 134-144 among males in the original description. Subcaudals were very similar to the original description, although one female had 16 subcaudals, one less than the minimum observed in the population of Serra de Baturité.

Although some of the meristic data differs from the original description we believe these must be interpreted as intraspecific variation rather than to consider these populations as a distinct taxon.

The presence of *A. ronnie* in others areas of relictual forest in Ceará demonstrates that the species is not restricted to Serra de Baturité. The new records presented here extends the species distribution in ca. 230 km east and ca. 350 km south from the type locality, the municipality of Pacoti, state of Ceará (Figure 2).

These results provide additional evidence for the need of systematic inventory surveys in order to study the diversity of the herpetofauna of the relictual forests of the Ceará state, since new distribution records and new taxa are still being published in the last few years (e.g. Loebmann et al., 2007; Passos et al., 2007; Loebmann, 2008a; 2008b; 2008c; Ribeiro et al., 2008).

TABLE 1: Measurements and scale counts from all individuals of *Atractus ronnie* examined in this study. PAHF = Plateau of Araripe (humid forest); PIHF = Plateau of Ibiapaba (humid forest); SVL = Snout Vent Length; CL = Caudal Length; VSN = Ventral scale number; SSN = Subcaudal scale number.

Local	**Sex**	**SVL (mm)**	**CL (mm)**	**VSN**	**SSN**	**Sample method**	**Voucher number**
PAHF	Male	223	30	132	22	Pitfall	LZ-URCA 465
PAHF	Male	204	28	129	23	Pitfall	LZ-URCA 462
PAHF	Male	203	27	132	24	Pitfall	LZ-URCA 463
PAHF	Female	284	29	151	20	Pitfall	LZ-URCA 464
PAHF	Female	247	26	152	20	Pitfall	LZ-URCA 460
PAHF	Female	247	25	146	17	Pitfall	LZ-URCA 489
PAHF	Female	241	21	149	19	Pitfall	LZ-URCA 491
PAHF	Female	234	20	149	16	Pitfall	LZ-URCA 490
PAHF	Female	217	19	146	18	Pitfall	LZ-URCA 461
PIHF	Female	391	33	163	23	Visual search	MNRJ 17326

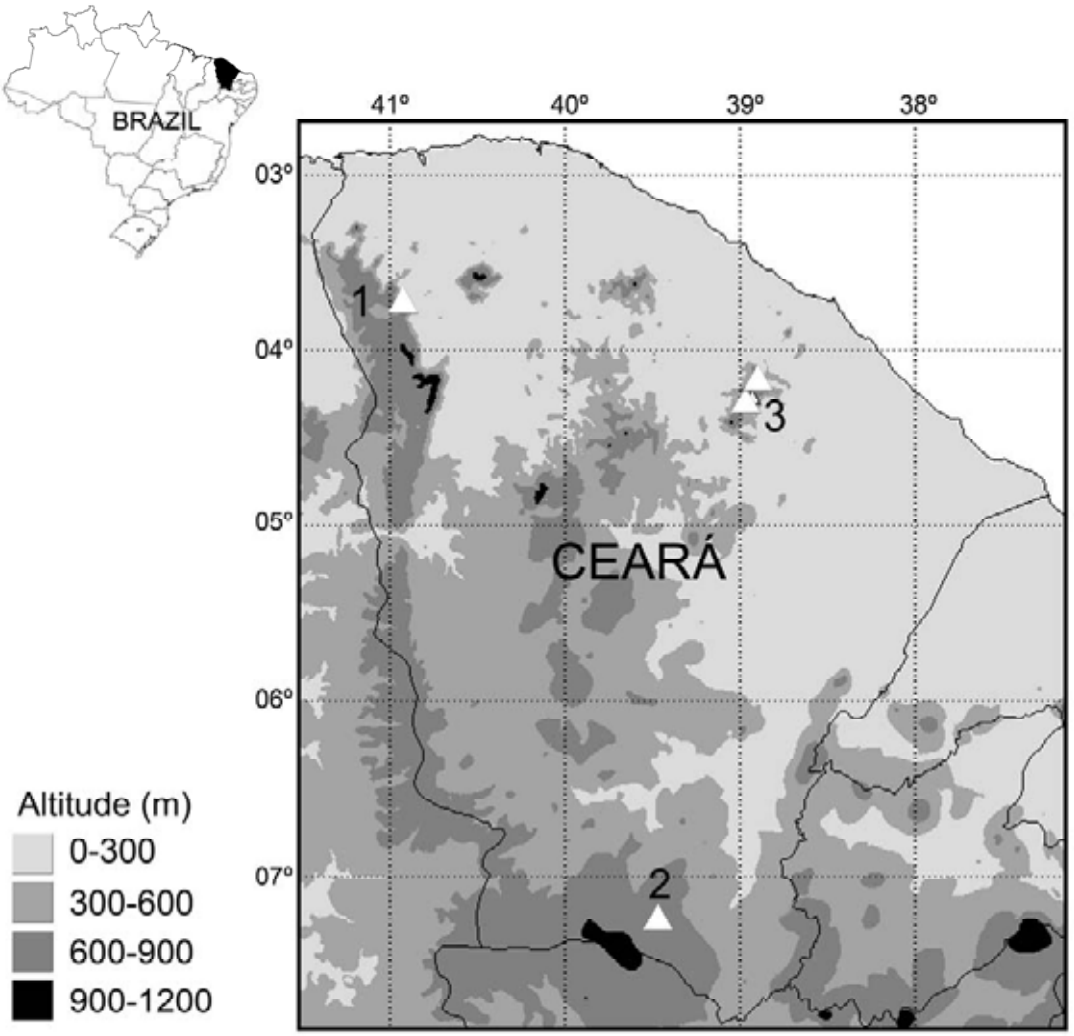


Figure 2: Geographic distribution of *Atractus ronnie* (white triangles). 1- Plateau of Ibiapaba; 2- Plateau of Araripe and; 3- Serra de Baturité.

Acknowledgments

The authors are grateful to the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) for the permission to collect specimens (Processes 14130-1 and 267/2006). We also thank to Raimundo M. de Almeida and his family for logistical support during the field work in the municipality of Crato. Adaílton D. da Silva and Igor Joventino Roberto helped us in the field work. DL is supported by grant no. 140226/2006-0 from the Conselho Nacional de Pesquisa e Desenvolvimento (CNPq). We are grateful to the Fundação Cearense de

Apoio ao Desenvolvimento Científico e Tecnológico – FUNCAP, for our research grant (Process number 9913/06 – Contract 0006-00/ 2006), the scholarship awarded to SCR and the productivity fellowship of WOA (02/2008-BPI); to Brazilian National Research Council – CNPq, for its support through a scholarship PIBIC to DLS.

References

Ab' Saber, A. N. 1977. Os domínios morfoclimáticos na América do Sul. Primeira aproximação. **Geomorfologia, 52**: 1-21.

Andrade-Lima, D. 1982. Present-day refuges in northeastern Brazil. In: Prance, G. T. (Ed.). **Biological diversification in the tropics.** Columbia University Press, New York, USA, p.245-251.

Carnaval, A. C.; Bates, J. M. 2007. Amphibian DNA Shows Marked Genetic Structure and Tracks Pleistocene Climate Change in Northeastern Brazil. **Evolution, 61** (12): 2942-2957.

Fernandes, A. 1990. **Temas Fitogeográficos.** Editora Stylus Comunicações, Fortaleza, Brazil, 116pp.

Fernandes, R. 1995. A new species of snake in the genus *Atractus* (Colubridae: Xenodontinae) from northeastern Brazil. **Journal of Herpetology, 29**: 416-419.

Fernandes, R. 1996. Variation and taxonomy of *Atractus reticulatus* complex (Serpentes: Colubridae). **Comunicações do Museu de Ciências e Tecnologia da PUCRS (Série Zoologia)**, **8**: 37-53.

Fernandes, R.; Freire, E. M. X.; Puorto, G. 2000. Geographic variation of the Brazilian Atlantic Rainforest snake *Atractus maculatus* (Günther, 1858), with revalidation of *Rhabdosoma zebrinum* Jan, 1862 (Serpentes: Colubridae). **Boletim do Museu Nacional, Nova Série, Zoologia, 419**: 1-8.

Giraudo, A. R.; Scrocchi, G. J. 2000. The genus *Atractus* (Serpentes: Colubridae) in Northeastern Argentina. **Herpetological Journal, 10**: 81-90.

Loebmann, D. 2008a. Geographic distribution. *Echinanthera affinis*. Brazil: Ceará. **Herpetological Review, 39** (2): 241.

Loebmann, D. 2008b. Geographic distribution. *Mesoclemmys perplexa*. Brazil: Ceará. **Herpetological Review, 39** (2): 236.

Loebmann, D. 2008c. Geographic distribution. *Typhlops brongersmianus*. Brazil: Ceará. **Herpetological Review, 39** (2): 244.

Loebmann, D.; Prado, C. A. P.; Haddad, C. F. B.; Bastos, R. F. Guimarães, L. D. 2007. Geographic distribution. *Hypsiboas multifasciatus*, Brazil: Ceará and Goiás. **Herpetological Review, 38**: 476.

Myers, C. W. 2003. Rare snakes — five new species from eastern Panama: Reviews of Northern *Atractus* and Southern *Geophis* (Colubridae: Dipsadinae). **American Museum Novitates, 3391**: 1-47.

Passos, P.; Fernandes, R.; Zanella, N. 2005. A new species of *Atractus* (Serpentes: Colubridae) from Southern Brazil. **Herpetologica, 61**: 209-218.

Passos, P.; Fernandes, D. S.; Borges-Nojosa, D. M. 2007. A new species of *Atractus* (Serpentes: Colubridae: Dipsadinae) from a relictual forest in Northeastern Brazil. **Copeia, 2007**: 788-797.

Ribeiro, S. C.; Ferreira, F. S.; Brito, S. V.; Santana, G. G.; Vieira, W. L. S.; Alves, R. R. N.; Almeida, W. O. 2008**.** Inventory of the Squamata fauna of the Chapada do Araripe, Northeastern Brazil. **Cadernos de Cultura e Ciências,** in press.

SBH. 2008. **Brazilian reptiles/List of species - an on line reference***.* Accessible at <http://www.sbherpetologia.org.br>. Access on 30 May 2008.

Vanzolini, P. E. 1981. A quasi-historical approach to the natural history of the differentiation of reptiles in tropical geographic isolates. **Papéis Avulsos de Zoologia, 34**: 189-204.

ANEXO 13

Geographic distribution map and parturition aspects of the poorly known viviparous lizard *Mabuya arajara* Rebouças-Spieker, 1981 (Squamata, Sauria, Scincidae) from the state of Ceará, northeastern Brazil

Igor Joventino Roberto[1] and Daniel Loebmann[2]

[1]AQUASIS - Associação de Pesquisa e Preservação de Ecossistemas Aquáticos, Programa de Conservação da Biodiversidade, Praia de Iparana s/n, SESC Iparana, 61627-010, Caucaia, CE. Webpage: http://www.aquasis.org. E-mail: igorjoventino@yahoo.com.br

[2]Programa de Pós-Graduação em Ciências Biológicas (Zoologia), Instituto de Biociências, Universidade Estadual Paulista, Laboratório de Herpetologia. Av. 24 A, 1515, Bairro Bela Vista, CEP 13506-900 Rio Claro-SP, Brasil. Webpage: http://ns.rc.unesp.br/ib/zoologia/anuros. E-mail: contato@danielloebmann.com

ABSTRACT: *Mabuya arajara* Rebouças-Spieker, 1981 has been considered an endemic species from the southern of state of Ceará, restricted to the Deciduous Dry Forests in the slopes of Plateau of Araripe (Chapada do Araripe). Here, we present an updated distributional map for the species and demonstrate that the species range is not restricted as formerly believed. In addition, we had an opportunity to observe a pregnant female and we describe aspects regarding parturition process and number of offspring for the species.

KEY-WORDS: Reproductive aspects, Biogeography, Scincidae, *Mabuya*.

1. INTRODUCTION

The skinks of genus *Mabuya* Fitzinger, 1826 comprise 33 species (Uetz et al. 2009), 13 of them distributed within Brazilian territory (Bérnils, 2009). In northeastern Brazil, five species *Mabuya agmostincha* Rodrigues, 2000, *Mabuya arajara* Rebouças-Spieker, 1981, *Mabuya heathi* Schmidt & Inger, 1951, *Mabuya macrohryncha* Hoge, 1947, and *Mabuya nigropunctata* (Spix, 1825) are recorded in the Caatinga and/or Atlantic Rain Forest Biomes (Rodrigues, 2000). The taxonomy of the genus is poorly known and sometimes ambiguous and there is a high necessity for a major taxonomic revision (Avila-Pires, 1995; Rodrigues, 2000).

The South and Central American species of *Mabuya* present interesting aspects regarding its reproductive biology; they are lecithotrophic viviparous lizards that present certain similarities to therian mammals in terms of placental structure and function (Blackburn & Vitt, 1992). Studies about the reproductive biology of a few Brazilian species of *Mabuya* have been conducted in the last four decades, and information is available for *Mabuya agilis* (Rocha & Vrcibradic, 1999; Rocha et al. 2002), *Mabuya caissara* (Vanzolini & Rebouças-Spieker, 1976), *Mabuya dorsivittata* (Vrcibradic, 2001), *Mabuya frenata* (Vrcibradic & Rocha, 1998), *Mabuya heathi* (Vitt & Blackburn, 1983; Blackburn & Vitt, 1992; 2002), *Mabuya macrorhyncha* (Rocha et al. 2002), and *Mabuya nigropunctata* (Vitt & Blackburn, 1991; Blackburn & Vitt, 1992).

Mabuya arajara is placed in the large species group with normal snout, paired frontoparientals, and no vertebral stripes on the body (Rodrigues, 2000). It is considered closely related to *M. nigropunctata* (*sensu* Avila-Pires, 1995), and the main difference between them is the colour pattern. In *Mabuya arajara*, the dark lateral stripe begins in the loreal region and starts to fade away in the middle of the

body. The white dorsolateral stripe, which begins in the superciliaries, dwindles behind the arm. In *M. nigropunctata*, both stripes are well defined and marked all over the body, reaching the tail (Rebouças-Spieker, 1981).

Mabuya arajara is the least known species of the group; it was described based on specimens collected from a single locality, the district of Arajara, municipality of Barbalha, southern of state of Ceará. No ecological data or new distributional records are known for the species that is still considered endemic to the locality of description. Therefore, in order to cover these gaps of information we present in this article an updated map of distribution for *Mabuya arajara,* and we describe the parturition process and offspring size for the first time.

2. MATERIAL AND METHODS

During October 2005 and May 2009, we carried out fieldtrips in several localities in the state of Ceará in order to find new records of occurrence for *M. arajara*. Specimens were obtained through the methods of person-hour of time constrained search (Campbel & Christman, 1982) and opportunistic encounters. Effort was concentrated on mountainous areas (120-950 m above sea level) once there is no indication that this species occurs in open areas from lowlands. To create a map of distribution for *M. arajara* we compiled our data with data available in literature. The map was constructed using the DIVA-GIS software (http://www.diva-gis.org) (Hijmans et al. 2002). In order to find possible relationships between the occurrences of the species and altitude, we incorporated a layer of altitude of 2.5 min (ca. 5 km) of spatial resolution in the final map. For each specimen we recorded data on type of substrate, physiognomy, geographical

coordinates and altitude. Geographical coordinates and altitude were obtained with a Garmin® Etrex Legend portable GPS.

Parturition events were observed from a pregnant female found in a field trip and kept in a terrarium covered with a layer of sediment and leaf litter in order to simulate natural conditions. The air temperature was not controlled. The female was fed with crickets and mealworms, and daily monitored until the newborns' birth. Body measurements of the pregnant female and their newborns were taken with aid of a Starrett® 727 series digital calliper (scale graduation = 0.01 mm), and body weight was obtained with a Bel Engineering® SSR-600 digital dynamometer (scale graduation = 0.01 g).

Collecting permits were authorized by Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) (Processes 16381-1 and 17400-2). Voucher specimens were deposited in Universidade Federal de Brasília Herpetological collection (CHUNB 57367, 57370), Brasília, Distrito Federal, Brazil; Universidade de Campinas Natural History Museum (ZUEC 3407), Campinas, São Paulo, Brazil.

3. RESULTS AND DISCUSSION

3.1 Geographic Distribution

Several expeditions were conducted in the main mountainous areas of Ceará state. The new records of occurrence for *M. arajara* were exclusively located in the northern and southern parts of Ceará state (Figure 1). Descriptions for each area and for *M. arajara* records are as follow.

Four specimens of *M. arajara* were recorded in the Ubajara's National Park located at the municipality of Ubajara (03°49'50"S; 40°53'16"W; 390 m ASL) as

follow: a adult pregnant female (SVL = 91.89 mm; tail length 123.72 mm) on 25th October 2008, kept in a terrarium to observe parturition aspects described in this study, and three adult specimens between November and December 2008. Two main physiognomies were observed in this area. The first one is the Sub-evergreen Tropical Nebular Rainforest, a relictual wet forest with a canopy more than 20 m high, extending about 150 km of length, between 400 and 950 m wide, covering the eastern and northern regions of Plateau of Ibiapaba (*Chapada da Ibiapaba*). The second is the Deciduous Dry Forest, a forest located at low altitudes (120-450 m), exhibiting trees up to 20 m high with straight trunks and an understory composed of small trees and short-lived bushes. All individuals were found foraging in the leaf litter in the areas of the Deciduous Dry Forest.

Two other specimens of *Mabuya arajara* were collected in 2nd December 2005 in an expedition to Ubatuba hills (*Serra da Ubatuba*), municipality of Granja, state of Ceará (03º18'04"S; 41º08'37"W; 645 m ASL). The vegetation of the area is characterized by Deciduous Dry Forest on the slopes, with gallery forest and savannah vegetation (cerrado) in the rocky outcrops of the plateau. Individuals were found basking on the leaf litter of the Deciduous Dry Forest.

Two new distributional records were obtained in the slopes of Plateau of Araripe (*Chapada do Araripe*). Individuals of *Mabuya arajara* were observed in the leaf litter at the border of the Sub-evergreen Tropical Nebular Rainforest near a stream in the locality of Granjeiro, municipality of Crato (07°16'50"S; 39°26'19"W; 708 m ASL), and in the municipality of Missão Velha in the locality of Arajara Park (07°36'17"S; 39°24'43"W; 751 m ASL). The specimens were found in the border of the relictual forest, in the leaf litter and under fallen logs.

Mabuya arajara has been considered to be endemic to a very restrict distribution in the Plateau of Araripe mountain, municipality of Barbalha (Rebouças-Spieker, 1981; Borges-Nojosa & Caramaschi, 2003; Ribeiro et al. 2008). Borges-Nojosa and & Cascon (2005) mentioned the presence of a similar species (*Mabuya* sp. (aff. *arajara*)) outside its known range, in the municipality of Crateús, in a Deciduous Dry Forest of the Almas hills complex (complexo *Serra das Almas*) (05°16'04"S; 40°54'13"W; 681 m ASL). However, based on the photograph of the individual from Almas hills (see Borges-Nojosa & Cascon 2005, p. 242), which clearly show the typical coloration pattern of *M. arajara* and, based on our records of lower latitudes, we can confirm the presence of the species in the area.

Therefore, considering the species presence confirmed for Almas hills and the new records for Ibiapaba Plateau complex (municipalities of Ubajara and Granja) we demonstrate *Mabuya arajara* is not endemic to Araripe Plateau. In addition, we believe the species has a high probability to occur in the neighbouring states of Piauí and Pernambuco considering the current knowledge of its range (altitudinal and geographical) (see Figure 1).

Taking into consideration the physiognomy of the study area and the other species of *Mabuya* from the region it is possible to observe a preference in habitat among them. *Mabuya arajara* presents a high preference to inhabiting the Deciduous Dry Forests among ca. 350 to 700 m above sea level, although the species can be found eventually in the border of the Sub-evergreen Tropical Nebular Rainforest. *Mabuya heathi* should be considered the most habitat flexible species but it is more frequently found in the steppe savannah (low altitude Caatinga). *Mabuya nigropunctata* is mainly associated with the Sub-evergreen Tropical Nebular Rainforest.

The Deciduous Dry Forests in the state of Ceará are exclusively located in areas with irregular topography, characterized by presenting elevated humidity, low temperatures and high degree of rainfall when compared to "caatinga *sensu strictu*" areas. These abiotic conditions seem to occur along all of *M. arajara*'s distribution: the Araripe Plateau, Almas hills, and Ibiapaba Plateau complexes. In fact, these complexes are relatively interconnected, and the Poti River is the major altitudinal/fluvial barrier found in the area. Even so, there is no evidence that Poti River should be considered a barrier for any reptile species inhabiting the mountain complexes.

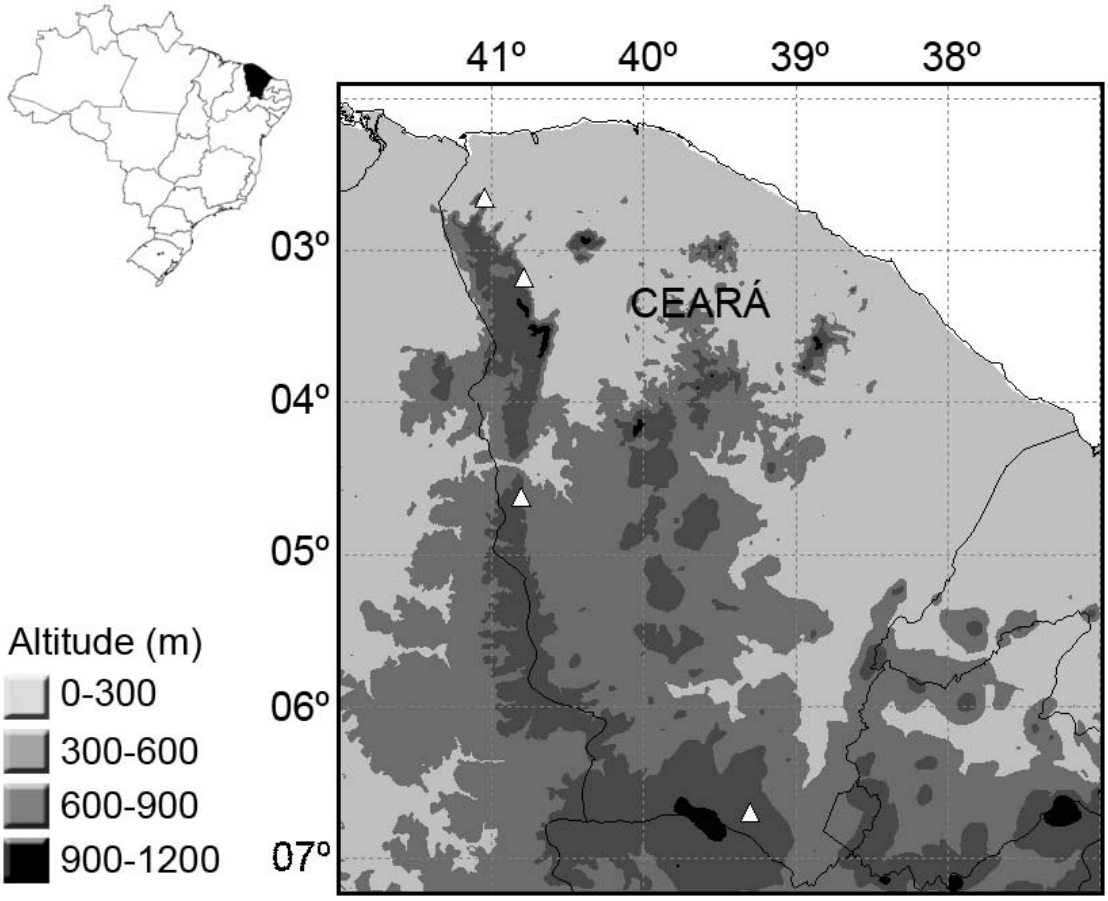


Figure 1 – Altitudinal distribution map of *Mabuya arajara* indicating the previous knowledge localities and the present records.

On the other hand, there is no indication (Borges-Nojosa & Caramaschi, 2003; present study) that *M. arajara* inhabits other mountainous areas of the state of Ceará with similar altitude and physiognomy such as Maranguape hills (03°53'36"S; 38°43'26"W), Baturité hills (04°16'55"S; 38°56'46"W), Pacatuba hills (03°58'02"S; 38°38'06"W), and Uruburetama hills (03°36'25"S; 39°34'58"W). The wide track of steppe savannah (low altitude Caatinga) formation (> 100 km of extension) amidst these mountain chains (Araripe Plateau, Almas hills, and Ibiapaba Plateau) seems to be the reason for the species not to occur on these mountains.

According to the Vanishing Refuge theory (Vanzolini & Williams, 1981) during the dry periods of climate cycle events in Holocene, species from forested areas pre-adapted to live in open formations could have endured a speciation process in forest refuges, and be adapted to live in open formations. In order to corroborate this theory the authors focused mainly in *M. arajara* once the species seems to have originated from *M. nigropunctata*, a species specialized to live in forested areas.

Mabuya nigropunctata occurs throughout Brazilian Amazonia, in the gallery forests of cerrado areas (Blackburn & Vitt, 1992) and in the Atlantic rain forest of northeastern Brazil, in the states of Pernambuco, Alagoas, and Ceará (Vanzolini, 1981; Borges-Nojosa & Caramaschi, 2003). This species is well adapted to live outside forested areas, occupying open spots at the edge of the forest (Vanzolini, 1992; Vitt & Blackburn, 1991; Avila-Pires, 1995). Therefore, its ecology is very similar to *M. arajara* which may have experienced an ecological reversal from the forest adapted life of its origin to life in open environments (Vanzolini, 1992) such as the Dry Deciduous Forests in the plateaus of Ibiapaba and Araripe.

3.2 Reproductive Aspects

The pregnant female of *M. arajara* (SVL = 91.89 mm; tail length 123.72 mm) kept in the terrarium gave birth to a total of four newborns on 19th November 2008 (see Table 1 for body measurement). It was possible to observe the third born event which occurred at 05:21p.m. The female did not eat the extraembryonic membranes neither helped the newborns to be freed from the fetal membranes (Figure 2).

A brood size of four newborns documented by *M. arajara* seems to be very common among the South American viviparous species of *Mabuya* which can vary from 1-9 (Vanzolini & Rebouças-Spieker, 1976; Vitt & Blackburn, 1983; Vitt & Blackburn, 1991; Blackburn & Vitt, 1992; Vrcibradic & Rocha, 1998; Rocha & Vrcibradic, 1999; Vrcibradic, 2001; Rocha et al. 2002; Blackburn & Vitt, 2002). *Mabuya nigropunctata,* a closely related species to *M. arajara*, was documented to have a brood size of 2-9 embryos, with a gestation period of 10 to 12 months, and number of embryos was positively correlated with female size (Vitt & Blackburn, 1991). *Mabuya heathi*, a sympatric species to *M. arajara*, also has a brood size of 2-9, and gestation period of 8 to 12 months with parturition occurring in the end of the dry season (Vitt & Blackburn, 1983). It is the same with the parturition of *M. arajara* in the municipality of Ubajara.

One interesting aspect of the newborns is the presence of a well defined dark stripe from the snout to the tail, just like the adults of *M. nigropunctata*. Probably the coloration pattern shifts during ontogeny process, and started to fade away in adults. This reinforces the possible speciation process that *M. nigropunctata* may have suffered to originate *M. arajara* as proposed by Vanzolini & Williams (1981).

Figure 2 – *Mabuya arajara* in life and some reproductive aspects about the female pregnant and their respective newborns. A) Adult female pregnant (SVL = 91,89 mm ; Tail length = 123,72 mm) collected on 25th October 2008. B) Head detail from the same specimen; C-D) Third born event on 19th November 2008, 05h:21min p.m.; E) Newborns and female during the next day; F) General view of a newborn (SVL = 32,02 mm ; Tail length = 40,36 mm ; Weight=0,81g). Pictures by Daniel Loebmann.

Vanzolini & Rebouças-Spieker (1976) described maternal care by a female in *M. macrorhyncha* what was not observed for *M. arajara*. There are two possibilities to explain the difference. First, it is possible that the confined conditions in a terrarium caused enough stress for the female to left their offspring without maternal care after parturition. Second, maternal care pattern does not constitute a characteristic in the Scincomorpha as proposed by Vanzolini & Rebouças-Spieker (1976). There is still little information about *M. arajara* ecology and future studies are necessary to better understand the reproductive biology of the species.

Table 1. Weight, snout-vent length and tail length in mm, of the four younglings of *Mabuya arajara*, collected in the Ubajara National Park, municipality of Ubajara, state of Ceará.

Newborn	Weight (g)	SVL (mm)	TL (mm)
1	0.80	33.58	39.45
2	0.79	32.85	39.54
3	0.71	32.43	40.18
4	0.82	32.02	40.36

References

Ávila-pires, T.C. (1995). Lizards of Brazilian Amazonia (Reptilia: Squamata). Zool. Verh, **Leiden 299**, 1-706.

Bérnils, R.S. (2009). *Brazilian reptiles – List of species*. Sociedade Brasileira de Herpetologia. Available at http://www.sbherpetologia.org.br/. Accessed April 10th 2009).

Blackburn, D.G. & Vitt, L.J. (2002). Specialization of the chorioallantoic placenta in the Brazilian Scincid lizard *Mabuya heathi* a new placental morphotype for reptiles. *J. Morphol*. **254**, 121-131.

Blackburn, D.G. & Vitt, L.J. (1992). Reproduction in viviparous South American lizards of the genus *Mabuya*. In *Reproductive Biology of South American Vertebrates*, pp. 150-164. Hamlett, W.C. (ed.). New York: Springer-Verlag.

Borges-Nojosa, D.M. & Caramaschi, U. (2003). Composição e análise comparativa da diversidade e das afinidades biogeográficas dos lagartos e anfisbenídeos (Squamata) dos brejos nordestinos. In *Ecologia e Conservação da Caatinga*, pp. 489-540. Leal, I. Silva, J.M.C. & Tabarelli, M.. (Eds.). Recife UFPE.

Borges-Nojosa, D.M. & Cascon, P. (2005). Herpetofauna da área Reserva da Serra das Almas, Ceará. In *Análise das Variações da Biodiversidade do Bioma Caatinga*, pp. 245-260. Araújo, F.S. Rodal, M.N.J. & Barbosa, M.R.V. (Eds.). Brasília: Ministério do Meio Ambiente.

Campbel, H.W. & Christman, S.P. (1982). Field techniques for herpetofaunal community analysis. In: *Herpetological Communities: a Symposium of the Society for the Study of Amphibians and Reptiles and Herpetologists' Leagle.* pp. 193-200. Scott Jr, N.J. (Ed.). Fish Washington: Wildlife Service.

Hijmans, R.J. Guarino, L. & Rojas, E. (2002). DIVA-GIS. A geographic information system for the analysis of biodiversity data. Manual. Lima: International Potato Center, 73 p.

Rebouças-Spieker, R. (1981). Sobre uma nova espécie de Mabuya do Nordeste do Brasil (Sauria, Scincidae). *Pap. Avulsos Zool. São Paulo* **34**(9), 1-123.

Ribeiro, S.C. Ferreira, F.S. Brito, S.V. Santana, G.G. Vieira, W.L.S. Alves, R.R.N. & Almeida, W.O. (2008). The squamata fauna of the Chapada do Araripe, northeastern Brazil. *Cadernos de Cultura e Ciência* **3**, 1-14.

Rocha, C.F.D. & Vrcibradic, D. (1999). Reproductive traits of two sympatric viviparous skinks (*Mabuya macrorhyncha* and *Mabuya agilis*) in a Brazilian restinga habitat. *Herpetol. J.* **9**, 43-53.

Rocha, C.F.D. Vrcibradic, D. Teixeira, R.L. & Cuzzuol, M.G.T. (2002). Interpopulational variation in litter size of the skink *Mabuya agilis* in southeastern Brazil. *Copeia* **2002**(3), 857-864.

Rodrigues, M.T. (2000). A new species of *Mabuya* (Squamata: Scincidae) from the semiarid caatingas of northeastern Brazil. *Pap. Avulsos Zool. São Paulo* **41**(21), 313-328.

Uetz, P. et al. (2009). The Reptile Database. http://www.reptile-database.org. Accessed July 18, 2009.

Vanzolini, P.E. & Rebouças-Spieker, R. (1976). Distribution and differentiation of animals along the coast and in continental islands of the state of São Paulo, Brazil. 3. Reproductive differences between *Mabuya caissara* and *Mabuya macrorhyncha* (Sauria, Scincidae). *Pap. Avulsos Zool. São Paulo* **29** (15), 95-109.

Vanzolini, P.E. (1981). A quasi-historical approach to the natural history of differentiation of reptiles in the tropical geographic isolated. *Pap. Avulsos Zool. São Paulo* **34**(19), 189-204.

Vanzolini, P.E. & Williams, E.E. (1981). The vanishing refuge: a mechanism for ecogeographic speciation. *Pap. Avulsos Zool. São Paulo* **34** (23), 251-255.

Vanzolini, P.E. 1992. Paleoclimas e especiação em animais da América do Sul tropical. *Estudos Avançados* **6** (15):41-65.

Vitt, L.J. & Blackburn, D.G. (1983). Reproduction in the lizard *Mabuya heathi* (Scincidae): a commentary on viviparity in new world *Mabuya*. *Can. J. Zool.* **61**, 2798-2806.

Vitt, L.J. & Blackburn, D.G. (1991). Ecology and life history of the viviparous lizard *Mabuya bistriata* (Scincidae) in the Brazilian Amazon. *Copeia* **1991**, 918-927.

Vrcibradic, D. (2001). Ecologia de cinco espécies de *Mabuya* (Lacertilia; Scincidae) no Sudeste do Brasil: padrões reprodutivos, térmicos, tróficos e comunidades de nematódeos parasitas associados. Tese de doutorado. Universidade Estadual de Campinas. 210 p.

Vrcibradic, D. & Rocha, C.F.D. (1998). Reproductive cycle and life-history traits of the viviparous skink *Mabuya frenata* in southeastern Brazil. *Copeia* **1998** (3), 612–619.

ANEXO 14

First record of the threatened species *Adelophryne baturitensis* Hoogmoed, Borges and Cascon, 1994 for the state of Pernambuco, Northeastern Brazil (Anura, Eleutherodactylidae, Phyzelaphryninae)

Daniel Loebmann [1,2], Victor G. Dill Orrico [1,3] and Célio F. B. Haddad [4]

[1]*Programa de Pós-Graduação em Ciências Biológicas (Zoologia), Universidade Estadual Paulista, Instituto de Biociências, Departamento de Zoologia, Laboratório de Herpetologia. Av. 24 A, 1515, Bairro Bela Vista, CEP 13506-970, Rio Claro, SP, Brasil.*

[4]*Universidade Estadual Paulista, Instituto de Biociências, Departamento de Zoologia, Laboratório de Herpetologia. Av. 24 A, 1515, Bairro Bela Vista, CEP 13506-970, Rio Claro, SP, Brasil.*

[2]*E-mail: contato@danielloebmann.com*

[3]*E-mail: victordill@gmail.com*

The genus *Adelophryne* Hoogmoed and Lescure, 1984 currently comprises six species as follow: *Adelophryne adiastola* Hoogmoed and Lescure, 1984, *A. gutturosa* Hoogmoed and Lescure, 1984, and *A. patamona* MacCulloch, Lathrop, Kok, Minter, Khan, and Barrio-Amoros, 2008 for Amazon Rainforest Biome; *A. baturitensis* Hoogmoed, Borges, and Cascon, 1994 and *A. maranguapensis* Hoogmoed, Borges, and Cascon, 1994 for Caatinga Biome; and *A. pachydactyla* Hoogmoed, Borges, and Cascon, 1994 for Atlantic Rainforest Biome (Hegdes et al., 2008; Macculloch et al., 2008). *Adelophryne baturitensis* has been considered an endemic species from the Maciço de Baturité, a restrict area of high altitude moist forest remnants in the state of Ceará, Brazil (Hoogmoed et al., 1994; Eterovick et

al., 2005). For that reason, this species has been considered as “vulnerable” in the Red List of Threatened Species of Brazil (Haddad, 2008) and Red List of Threatened Species of International Union for Conservation of Nature (Silvano and Borges-Nojosa, 2004).

On December 2009, in a highland area of Atlantic Rainforest remnants known as Brejo dos Cavalos, located in the municipality of Caruaru, state of Pernambuco (08°22’23.98” S, 36°02’00.20” O; ca. 900 m above sea level) one specimen of *A. baturitensis* was collected (Figure 1). The specimen was deposited in Célio F. B. Haddad Amphibian Collection (CFBH 24627), Universidade Estadual Paulista “Júlio de Mesquita Filho”, Rio Claro, São Paulo, Brasil.

Due to the small size (all species of the genus do not reach 20 mm in SVL) and to the fact that species within the genus are morphologically very similar, the taxonomy of *Adelophryne* is considered difficulty. However, regarding that *Adelophryne baturitensis* is the unique species of the genus with tubercles instead pads in the feet (Hoogmoed et al., 1994), and all other diagnostic characters are present in the specimen examined, i.e., size; ventral and dorsal color pattern; number and position of tubercles in the hands and feet; and relation between eye diameter and distance from the tympanum to the eye, we can attribute that specimen of Brejo dos Cavalos to *A. baturitensis*. We also compared the specimen with seven voucher specimens from the type-locality (Maciço de Baturité) (CFBH 20469-20472; 20474-20476) and did not find any character which distinguished the topotypes of *A. baturitensis* from the specimen of Pernambuco.

This is the first record for the species outside from its type-locality, extending the species distribution ca. 550 km towards southeastern (Figure 2). Also, this is the first record of the species for the Atlantic Rainforest Biome. The

record of this threatened species for other locality is extremely relevant for its conservation status and highlights the importance of preservation of Brejos dos Cavalos which has suffered intense degradation process due to agriculture activities and clay exploration (Braga et al., 2002).

Figure 1 – A) Dorsal and ventral view of the specimen collected (SVL=13.2 mm) at Brejo dos Cavalos, municipality of Caruaru, state of Pernambuco. B) Adult male of *Adelophryne baturitensis* from the type-locality the Maciço de Baturité, municipality of Pacoti, state of Ceará.

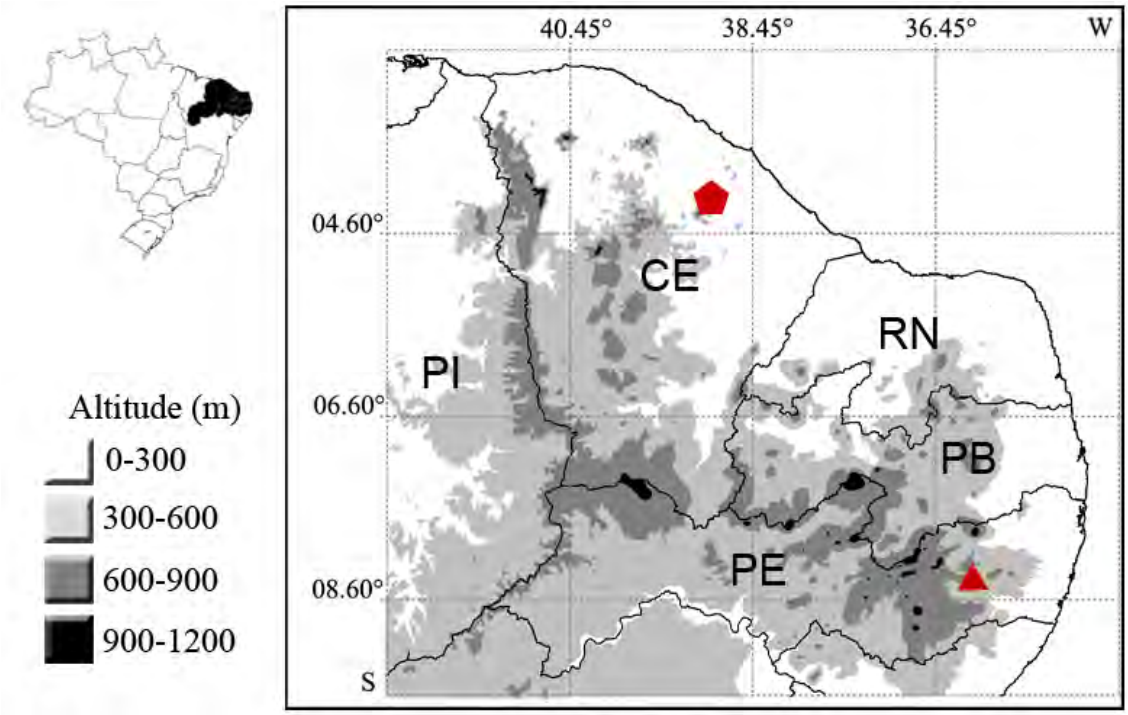


Figure 2 – Altitudinal map showing the recognized records of *Adelopryne baturitensis* (red pentagon) in the state of Ceará (Maciço de Baturité, type-locality) and the new record in the state of Pernambuco (Brejo dos Cavalos) (red triangle). Map created by the using of Diva-GIS software (Hijmans et al., 2002).

Acknowledgements. The authors are grateful to Cristiano Sampaio, Alessandro Giupponi and Amazonas Chagas Junior to have provided the specimen of *Adelophryne baturitensis* recorded in this study. Julian Faivovich for making useful comments on a draft version of the manuscript. Daniel Loebmann was supported by grant nº. 140226/2006-0 from CNPq. Victor G. Dill Orrico was supported by grant nº.2007-57067-9 from FAPESP. Specimen was collected under ICMBio/ SISBIO license nº.12920-4. Célio F. B. Haddad thanks FAPESP and CNPq for financial support.

References

Braga, R.A.P., Cabral, J.J.S.P., Montenegro, S.M.G.L., Perrier Jr, G.S. (2002): Conservação dos recursos hídricos em brejos de altitude - O caso de Brejo dos Cavalos, Caruaru, PE. Rev. Bras. Eng. Agric. Amb. **6**: 539-546.

Eterovick, P.C., Carnaval, A.C.O.Q., Borges-Nojosa, D.M., Silvano D.L., Segalla, M.V., Sazima, I. (2005): Amphibian declines in Brazil: an overview. Biotrop. **37**: 166-179.

Haddad, C.F.B. (2008): Anfíbios. In: Livro vermelho da fauna brasileira ameaçada de extinção (série Biodiversidade 19, vol. 2,), p. 286-325. Machado, A.B.M., Drummond, G.M., Paglia, A.P., Ed., Brasília, Ministério do Meio Ambiente.

Hedges, S.B., Duellman, W.E., Heinicke, M.P. (2008): New World direct-developing frogs (Anura: Terrarana): molecular phylogeny, classification, biogeography, and conservation. Zootaxa. **1737**: 1-182.

Hijmans, R.J., Guarino, L., Rojas, E. (2002): DIVA-GIS. A Geographic Information System for the Analysis of Biodiversity Data—Manual. International Potato Center, Lima, Peru, 73 pp.

Hoogmoed, M.S. & Lescure, J. (1984): A new genus and two new species of minute leptodactylid frogs from northern South America, with comments upon *Phyzelaphryne* (Amphibia: Anura: Leptodactylidae). Zool. Meded. **58**: 85–115.

Hoogmoed, M.S., Borges, D.M., Cascon, P. (1994): Three new species of the genus *Adelophryne* (Amphibia: Anura: Leptodactylidae) from northeastern Brazil, with remarks on the other species of the genus. Zool. Meded. **68**: 271–300.

Macculloch, R.D., Lathrop, A., Kok, P.J.R., Minter, L.R., Khan, S.Z., Barrio-Amorós, C.L. (2008): A new species of *Adelophryne* (Anura: Eleutherodactylidae) from Guyana, with additional data on *A. gutturosa*. Zootaxa. **1884**: 36–50.

Silvano, D.L., Borges-Nojosa, D. (2004): *Adelophryne baturitensis*. In: IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2. Available at: http://www.iucnredlist.org. Downloaded on 30 January 2010.