A leap further: the Brazilian Amphibian Conservation Action Plan

Vanessa K. Verdade[a], Paula H. Valdujo[b], Ana Carolina Carnaval[c], Luis Schiesari[d], Luís Felipe Toledo[e], Tami Mott[f], Gilda V. Andrade[g], Paula C. Eterovick[h], Marcelo Menin[i], Bruno V. S. Pimenta[j], Cristiano Nogueira[k], Cybele S. Lisboa[l], Cátia D. de Paula[m] & Débora L. Silvano[n] [2],

[a] Centro de Ciências Naturais e Humanas, Universidade Federal do ABC, Av. dos Estados 5001, 09210-971, Santo André, SP, Brazil

[b] Departamento de Ecologia, Universidade de São Paulo, R. do Matão, trav. 14, 321, 05508-900, São Paulo, SP, Brazil

[c] Department of Biology, City University of New York, Marshak Science Building, 160 Convent Avenue, New York, NY 10031, USA

[d] Escola de Artes, Ciências e Humanidades, Universidade de São Paulo, Av. Arlindo Bétio 1000, 03828-080, São Paulo, SP, Brazil

[e] Museu de Zoologia "Prof. Adão José Cardoso", Universidade Estadual de Campinas, 13083-863, Campinas, SP, Brazil

[f] Departamento de Biologia e Zoologia, Universidade Federal de Mato Grosso, R. Fernando Corrêa da Costa 2367, 78060-900, Cuiabá, MT, Brazil

[g] Departamento de Biologia, Universidade Federal do Maranhão, Av. dos Portugueses s/n, 65085-580, São Luis, MA, Brazil

[h] Pontifícia Universidade Católica de Minas Gerais, Av. Dom José Gaspar 500, 30535-610, Belo Horizonte, MG, Brazil

[i] Instituto de Ciências Biológicas, Universidade Federal do Amazonas, Av. General Rodrigo Otávio Jordão Ramos 3000, 69077-000, Manaus, Amazonas, Brazil

[j] Bicho do Mato Meio Ambiente Ltda. /Bicho do Mato Instituto de Pesquisa, Rua Perdigão Malheiros 222, 30380234, Belo Horizonte, MG, Brazil

[k] Departamento de Zoologia, Universidade de Brasília, Campus Universitário Darcy Ribeiro, 70910-900, Brasília, DF, Brazil

[l] Fundação Parque Zoológico de São Paulo, Av. Miguel Stefano 4241, 04301-905, São Paulo, SP, Brazil

[m] Lapcom, Departamento de Patologia, Faculdade de Medicina Veterinária e Zootecnia, Universidade de São Paulo, Av. Prof. Dr. Orlando Marques de Paiva 87, 05508-270, São Paulo, SP, Brazil

[n] Laboratório de Zoologia, Universidade Católica de Brasília, Campus I, Q.S. 07 Lote 01 EPCT, 71966-700, Taguatinga, DF, Brazil; <deborasilvano@gmail.com>

Brazil has a fundamental role in amphibian conservation, harboring the highest amphibian species richness in the world and a large number of endemics. Here, we present an overview of the Brazilian Amphibian Conservation Action Plan (BACAP), which is still being developed by Brazilian herpetologists. Basic research – particularly species inventories, taxonomic revisions and the collection of field data – are urgently needed to guide amphibian conservation in the country. Documentation and monitoring of amphibian richness has improved, at least at regional scales. Lists of threatened species are regularly updated, efforts to standardize field work protocols are being attempted and captive breeding is being considered as a research and educational tool. We also present a short history of the BACAP, identify some of the challenges tied to its implementation, and review a few but important recent achievements.

[1] Corresponding author.

Introduction

Brazil has a fundamental role in amphibian conservation at regional and global scales. The country harbors the highest amphibian species richness in the world (almost 900 species described to date; Anonymous, 2010*a–b*), and is well-known for having more endemic species of amphibians than any country in the Neotropics (534 endemic species, representing 67 % of the total number of species recorded nationally; Anonymous, 2010*a*). Given the large number of species and the proportionally small, yet growing scientific community, it is not surprising that knowledge about the natural history and geographical range of Brazilian amphibians remains sparse. This information gap is reflected in the high percentage of Data Deficient (DD) Brazilian species (252 species, almost 30 % of all Brazilian amphibians), according to IUCN's criteria (Anonymous, 2010*a*). The most recent revision of the Brazilian list of threatened amphibians recognized 15 species under some degree of threat, 90 DD taxa, and one extinct species (Anonymous, 2003).

The first global initiative to assess the extinction risk and conservation status of amphibians, the Global Amphibian Assessment, communicated the urgent need to take conservation measures to protect amphibian species worldwide (Young et al., 2001, 2004). The Amphibian Conservation Action Plan (ACAP) was designed to address this need (Gascon et al., 2007). The elaboration of the global ACAP prompted Brazilian herpetologists to create a national plan, following the ACAP guidelines. Congregated at the Third Brazilian Congress of Herpetology in 2007, a group of herpetologists began the delineation of the Brazilian Amphibian Conservation Action Plan (BACAP). A first unpublished version, not yet concluded, was produced in 2010. Here we present a summary of the plan, its achievements, difficulties, opportunities, and prospects for future work. The final version of the BACAP is planned to be concluded and publicly available in 2012 through the Brazilian Society of Herpetology's (SBH) web page.

Primary data: assessment of amphibian diversity in Brazil

Comprehensive taxonomic revisions, geographical range assessments and demographic studies are the most fundamental science to assess species status, evaluate declines or extinctions, and define key priorities for establishing protected areas (Brooks et al., 2004; Eken et al., 2004). Brazilian specialists agree that local amphibian species richness, taxonomy, geographic ranges, natural history and population status are vastly understudied in our country (Pimenta et al., 2005; Silvano & Segalla, 2005; Verdade et al., in press).

The first step to inventory Brazilian amphibian species richness requires the compilation of an open-access national database that will synthesize available taxonomic, geographic, and natural history information about local species, following other worldwide initiatives (e.g., Global Biodiversity Information Facility; Namibian Biodiversity Database; Yukon Biodiversity Database). This is pivotal to support conservation policies and to define priorities for future biological research (Brooks et al., 2004; Funk et al., 2005). Three main categories of

data should feed this database: natural history and ecological data resulting from field work and supported by voucher specimens; data extracted directly from zoological collections following verification of species determination (GRAHAM et al., 2004); and literature data. This database must be constantly updated based on new inventories and research programs. A team of specialists coordinated by the SBH will be responsible for creating and updating the database.

The essential role of voucher specimens makes collection-bearing institutions central to this national database initiative. Brazil harbors important and representative zoological collections (PEIXOTO, 2003). Yet, several collection records are still to be explored, and most collections have yet to be digitized. Given the shortage of technical assistance, Brazilian collection managers are frequently overloaded by curatorial work. Keeping up with maintenance, requests and recent taxonomic updates has been a challenge in most institutions. Given the number of unidentified or misidentified specimens in Brazilian collections (see PIMENTA et al., 2008 for the impact of this situation in species range and conservation assessments), there is an urgent need to revise, organize, synthesize and update collection records, as well as update their facilities. We must invest in security procedures and infrastructure to avoid other tragedies such as the recent loss of the renowned herpetological collection of Instituto Butantan to a fire. This can only be achieved through collaborations among Brazilian collection managers, taxonomists and government.

Despite the large amount of information available in zoological collections and literature, a significant portion of the Brazilian territory remains unsampled or under-sampled. Species are still being described from areas that were well-inventoried in the past (e.g., ALVES et al., 2009; TARGINO et al., 2009; WEBER et al., 2011). Yet, when abundant enough, data from regions of reported declines reveal two major problems: (1) a few populations considered as "under decline" by previous studies are not, in fact, declining (e.g., PIMENTA et al., 2008); (2) several declines and local extinctions may have gone undetected so far (ETEROVICK et al., 2005).

In the case of persistent populations, data on natural demographic fluctuations in Brazil are limited to qualitative observations by local herpetologists and field notes, leading to a paucity of background data. Because fluctuations in population sizes are common in amphibians (GREEN, 2003; KEISER, 2008), monitoring surveys must be carried out for multiple years (ten or more) to differentiate drastic but natural fluctuations from real population declines (HAYES & STEIDL, 1997). In the case of declines, voucher specimens can be collected to enable further investigations such as pathogen presence or physiological syndromes (PELLET & SCHMIDT, 2005).

Although the methods employed to monitor amphibian assemblages and populations may be adapted according to particularities of bioregions, sites and taxa, it is desirable to standardize parameters across studies (SILVEIRA et al., 2010). Establishing well-defined and replicable monitoring methods will facilitate future analyses.

The establishment of long-term monitoring programs will focus on two targets: (1) amphibian assemblages at selected sites; and (2) rare, small-ranged and/or threatened species (GIBBONS et al., 1997). Ideally, the distribution of target sites should include both open and forest landscapes in all major phytogeographic domains. Unique landscapes and areas known to harbor a remarkable concentration of restricted-range species may also be covered by the

program. It is likewise important to establish monitoring programs for more abundant and widespread taxa, from which one may detect overlooked declines that did not change assessment status, extract general patterns as well as detect responses to factors believed to affect less tolerant species.

Potential causes of population declines and extinctions in Brazil

Habitat loss and deterioration

Habitat loss and deterioration are the first and most obvious factors associated to loss of biodiversity worldwide (e.g., Young et al., 2001; Cushman, 2006). Nevertheless, local extinctions of amphibians caused by habitat loss and fragmentation are poorly understood (Gardner et al., 2007).

Most of the data about the effects of habitat fragmentation on Brazilian amphibian richness comes from the Projeto Dinâmica Biológica de Fragmentos Florestais (PDBFF), in Central Amazon (Zimmerman & Simberloff, 1996; Tocher et al., 2001). More recently, similar studies have been carried out in the Atlantic Forest (e.g., Dixo & Martins, 2008; Dixo et al., 2009). The regional scope of these data does not allow for countrywide inferences, and the conclusions on how amphibians are affected by habitat fragmentation are not fully comprehended. The low capacity of dispersal of most species seems to be an important factor isolating subpopulations, but other factors are likewise important (e.g., habitat quality, size and availability of reproductive sites within fragments, habitat requirements of local species, reproductive modes, etc; Dixo et al., 2009; Dixo & Metzger, 2010). Data on recent habitat loss are now available throughout Brazilian biomes (Anonymous, 2010*c*), enabling quantitative assessments for Brazilian species. This can lead to the generation of standardized, comparable data for threat assessment and conservation planning in the near future, and will allow for a planned expansion of the number of conservation units in the country, particularly in high priority areas. Attention to priority areas is especially important because recent modifications in the Brazilian legislation (the Forest Act, which mandates preservation of native vegetation in riparian zones and in hilltops, as well as of a percentage of the total surface area, in every private land in the country) may jeopardize the national system of natural area protection, affecting amphibian populations negatively (see Toledo et al., 2010). Quantitative assessments on the effects of habitat loss on endemic amphibians that integrate range information and updated data on habitat fragmentation will be a basic priority for future mapping and research efforts.

Diseases

At least three major diseases have been related to amphibian population declines worldwide: ranaviruses of the family Iridoviridae (e.g., Docherty et al., 2003; Pearman et al., 2004), saprolegniasis (Romansic et al., 2009) and chytridiomycosis, caused by the fungus *Batrachochytrium dendrobatidis* (e.g., Lips et al., 2006). To date, the distribution of

B. dendrobatidis in Brazil is known from few histological and molecular studies (CARNAVAL et al., 2005, 2006; TOLEDO et al., 2006*a–b*; BECKER & ZAMUDIO, 2011). The chytrid fungus is widely distributed in the Atlantic forest, reaching a latitudinal transect that is 2700 km long, from sea level to 2400 m high. The oldest infection record dates from 1981. Other Brazilian biomes have been predicted as suitable for this fungus (RON, 2005) – including a few areas of the Amazon forest, Cerrado and wetlands of Pantanal. Preliminary (and few) screenings conducted so far failed to detect positive infection in these regions (T. MOTT & L. F. TOLEDO, unpublished data). It is nonetheless clear that we need to promote larger and coordinated efforts to determine the spatial and temporal distribution of amphibian chytrid in Brazil. In those communities where the fungus has been already detected, it will be crucial to investigate prevalence and loads throughout the years, as well as possible effects on particular species or group of species (e.g., stream dwellers vs. forest litter dwellers vs. arboreal taxa).

Little is known about the effects of the chytrid fungus in Brazilian amphibians. CARNAVAL et al. (2006) identified the fungus in moribund individuals collected in the field (GUERRA-FUENTES & DIXO, 2006). TOLEDO et al. (2006*a*) and CARNAVAL et al. (2006) recorded infected tadpoles bearing oral disc malformations, but apparently capable of feeding. Given the lack of long-term population monitoring and the small number of screenings, we are unable to link former declines in Brazil to chytrid outbreaks (HEYER et al., 1988; WEYGOLDT, 1989). There is a need to understand the potential factors leading to the wide distribution of the chytrid fungus in Brazil.

CLIMATE CHANGE

It is worth noting that the most reliable data on declines in Brazil come from protected areas (VERDADE et al., in press) and that most narrow endemics in the country are restricted to areas of sharp relief and difficult access that are frequently not disturbed by habitat loss. The most imminent threat for these species are thus those related to habitat deterioration or change driven by broader geographic scale factors, such as global warming and pollution.

Climate change has been frequently referred as a possible cause of the drastic amphibian declines reported in the Brazilian Atlantic Forest. The lack of long-term monitoring efforts again poses an obstacle to definitive inferences. HEYER et al. (1988) reported a severe frost in 1979 as a possible factor leading populations to decline at Estação Biológica de Boracéia and Teresópolis. WEYGOLDT (1989) suggested a severe drought as the elicit factor to declines observed in Santa Teresa. Climate projections based on data from the Intergovernmental Panel on Climate Change (IPCC) predict increasing temperatures throughout the country, along with decreasing precipitation in Caatinga and the northern Atlantic Forest, and increasing precipitation in the southern Atlantic Forest. The same projections predict that changes in sea level would alter the extent of lowland ecosystems along the Brazilian coast (MARENGO, 2006). Understanding how amphibian populations respond to environmental changes is thus crucial for their conservation in Brazil.

Table 1. – Main goals of the Brazilian Amphibian Conservation Action Plan.

Main goals of the Brazilian Amphibian Conservation Action Plan
• Creation of a national species database (support to systematics, inventory work, geo-referencing)
• Support to studies on the processes that mediate population fluctuations and declines
• Establishment of new protected areas and managing of the existing ones
• Capacity-building for ex-situ conservation
• Cooperation agreements between Academia, Government, Industries, Zoos and NGOs
• Education and outreach

Environmental contamination

Linking pollution to amphibian declines in Brazil is largely tentative due to the scarcity of data on levels and fate of various chemicals in the environment, as well as on their effects on local species. Only eight of the almost 900 species of amphibians in Brazil have been subject to ecotoxicological studies, none of them corresponding to taxa with reported declines (Schiesari et al., 2007). This pattern echoes a strong biogeographic bias in research, in which the vast majority of acquired knowledge derives from common, widely distributed species of the temperate northern hemisphere (Schiesari et al., 2007).

Nevertheless, environmental contamination is a strong candidate factor contributing to population declines in Reserva Biológica de Paranapiacaba, and a plausible candidate in Parque Nacional de Itatiaia (Verdade et al., in press). For decades, Paranapiacaba received atmospheric deposition of sulphate, ammonium, nitrate, calcium, magnesium, fluoride and eleven metals from Cubatão, one of the oldest industrial centers of Brazil. In turn, in protected high elevation areas of Itatiaia, a montane region nearby, one finds records of atmospheric deposition of sulphate, ammonium, nitrogen oxides, and accumulation of metals and persistent organic pollutants in the biota, possibly from nearby highways and industrial sites. Although data are sparse, the temporal occurrence of declines is consistent with periods of high emissions at both sites (Verdade et al., in press). Despite the lack of tradition in amphibian ecotoxicological research in Brazil, new research groups are starting to monitor residue loads of pesticides, fertilizers and metals, and to quantify estrogen levels in natural populations (L. Schiesari, G. Andrade & T. Mott, unpublished data).

Exploitation, native and invasive species

Limited information on animal trade in Brazil indicates that both native (e.g., dendrobatids and ceratophryids) and exotic (e.g., *Bombina* spp., *Xenopus laevis*, *Litoria* sp. and *Ambystoma mexicanum*) species are target of illegal commerce (Pistoni & Toledo, 2010).

Specific actions, including centralized regulation and enforcement of the law by governmental agencies, are required to prevent illegal trade (PISTONI & TOLEDO, 2010).

Although native species are not threatened by overexploitation, there are well-documented cases of invasive species established in the wild. *Lithobates catesbeianus* is now widespread in southern, southeastern and central Brazil. It acts as predator, competitor and vector of diseases to native amphibian populations (FICETOLA et al., 2007; PISTONI & TOLEDO, 2010). Bullfrogs were first introduced in Brazil through aquaculture projects in the 1930s and 1940s (SANTOS & CÂMARA, 2002), and individuals are still being released in the wild via pet trade (P. C. ETEROVICK, unpublished data) or after failed commercial attempts (G. ANDRADE, unpublished data).

CAPTIVE BREEDING

Faced with so many pervasive threats, it may be important to develop expertise in breeding amphibian species in captivity and initiate assurance captive colonies for target species. Reintroduction is not considered an immediate need or alternative in the country due to the lack of knowledge of the real population status for most Brazilian species. Ex-situ conservation can be applied to educational programs and research (GRIFFITHS & KUZMIN, 2011; PAVAJEAU et al., 2008). The Amphibian Ark (PAVAJEAU et al., 2008) held a workshop in 2009 to define priorities for ex-situ conservation, research needs and in-situ conservation of Brazilian species. This was followed by a course on amphibian management and ex-situ conservation, where zoo technicians and scientists from public and private institutions were able to exchange expertise and establish partnerships for future captive breeding programs. Some of these initiatives are already underway in the state of São Paulo (L. F. TOLEDO & C. S. LISBOA, unpublished data).

THE BRAZILIAN AMPHIBIAN CONSERVATION ACTION PLAN: SPECIFIC GOALS

The Brazilian Amphibian Conservation Action Plan includes direct and indirect conservation measures as summarized below (tab.1).

CREATION OF A UNIFIED, NATIONAL DATABASE OF AMPHIBIAN SPECIES

A unified national database of amphibian species should be created and updated periodically. It will gather, organize, and summarize all information available on amphibian species that are native to or introduced in Brazil. This digital, open-access database should include geo-referenced museum records, published biological data, conservation status, and pertinent information such as records of pathogen infections, data on sensitivity to chemical compounds, use in illegal trade, among others, followed by a comprehensive compilation of literature. The database should harmonize with other information systems such as those

provided by Sistema Nacional de Pesquisa em Biodiversidade (SISBIOTA), International Union for Conservation of Nature (IUCN), Global Biodiversity Information Facility (GBIF), Centro de Referência em Informação Ambiental (CRIA) and VERTNET (a global museum database of vertebrate natural history collections). In addition to the dissemination of information among specialists and the general public (see *Education and outreach* below), several by-products of the database will contribute to conservation planning. These include range maps of target species, maps of undersampled or understudied areas to guide future inventory work, identification of areas of high species richness and endemism to inform conservation priorities.

Investigation of mechanisms causing amphibian population fluctuations and declines

Studies of size, connectivity, structure and dynamics of Brazilian amphibian populations, and especially of the mechanisms that mediate them, should be encouraged. Two complementary lines of research are proposed. First, a set of localities should be selected for intensive, integrated research that couples cohesive research design and long-term population monitoring. This program may follow standardized techniques to ensure sampling sufficiency and power to discern between actual trends and demographic fluctuations. It should investigate the biotic and abiotic mechanisms that mediate current population dynamics, and (when possible) potential causes for previous recorded declines (predation, disease, competition, climatic extremes, land cover change and chemical contamination). It is advised that these localities include sites of trustworthy reports of amphibian population declines in Brazil. In addition, there should be a second group of case studies and/or studies in broader spatial contexts to help us understand the roles of particular factors regulating amphibian population dynamics. These would likely require different sampling and/or experimental designs than those proposed for more site-specific integrated research, and would profit from a comparative approach across populations along environmental gradients or gradients in environmental degradation. In both cases, the use of hypothesis-based, experimental and theoretical approaches is advised, as opposed to descriptive and observation-based methods. Projections of future climate change on amphibians should also be explored. We are now starting to understand the possible effects of future climate change on Brazilian amphibians. Studies in the two Brazilian hotspots (Cerrado and Atlantic Forest) predict changes in the availability of suitable areas for potential species occurrence, with direct implications to amphibian distribution (Haddad et al., 2008; D. L. Silvano, unpublished data). Species predicted to be most affected by climate change, such as those from coastal plains and high altitude areas, or range-restricted taxa, should have their populations monitored.

Establishment of new protected areas and managing of existing ones

Since the establishment of protected areas in Brazil has been historically based on opportunity rather than conservation value, future initiatives must be systematically planned in order to fill the current conservation gaps. This planning starts with the identification of species in higher need of conservation: threatened or restricted range species that have no

protected areas within their ranges. Areas where these high priority species occur are considered as Key Biodiversity Areas for amphibian conservation (sensu EKEN et al., 2004), and recommended as priorities for the establishment of future protected areas. Apart from the need for new protected areas, most of the currently established ones still lack specific management guidelines to efficiently protect the species within their limits.

DEVELOPMENT OF TECHNOLOGY FOR EX-SITU CONSERVATION

Ex-situ approaches are valuable tools in conservation biology in particular circumstances, and there are no currently identified needs for reintroduction or supplementation of amphibians in Brazil. Having said that, knowledge of amphibian captive maintenance and breeding is modest in Brazil, and several reasons justify an expansion of this capacity: (1) captive maintenance and breeding are an important source of biological data; (2) breeding techniques need to be developed in advance if we are to eventually rescue populations at imminent risk of extinction; (3) captive breeding could satisfy market demand for pets and laboratory demands for experimentation purposes; and (4) captive breeding programs can be tied to public education and outreach. Amphibian captive breeding programs should be promoted at institutions such as zoos and aquaria, or in specific centers to be created (see below).

FOSTERING COOPERATION BETWEEN ACADEMIA, GOVERNMENT, INDUSTRIES, ZOOS AND NGOS TOWARDS EFFECTIVE CONSERVATION MEASURES

The ACAP and the Brazilian Amphibian Conservation Action Plan have been designed by academics and conservation biologists. Yet, effective conservation measures require articulation of multiple partners, including the government, industries, zoos and NGOs. Amphibian conservation has to be part of a broader, national conservation effort. Otherwise, there is a high probability that the concerns and recommendations found in ACAP and the BACAP will have no practical implications.

Most importantly, there must be a strong articulation with the Brazilian Government. Several governmental institutions are already involved with the acquisition and monitoring of environmental data necessary for amphibian conservation. Many are responsible for setting environmental standards and implementing new protected areas. These include research centers that are devoted to investigate climate, climate change and atmospheric sciences (e.g., Instituto Nacional de Pesquisas Espaciais or INPE), research centers and regulatory agencies devoted to regulating, monitoring and controlling emissions of pollutants (e.g., Agência Nacional de Vigilância Sanitária or ANVISA, Companhia Ambiental do Estado de São Paulo or CETESB), and high level executive organs such as the Ministry of the Environment (MMA) and IBAMA/ICMBio (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais/Instituto Chico Mendes de Conservação da Biodiversidade), which keep records of wildlife trade, biodiversity conservation targets, and definition and implementation of biological preserves. Proper articulation with IBAMA/ICMBio offers the possibility of implementing biological preserves that could benefit target amphibian species or overlap with Key Areas for Amphibian Conservation.

Education and outreach

Effective conservation must view public awareness and outreach in a broad perspective, i.e., not strictly focused on amphibians, but rather on the overarching environmental questions of our days. Education and outreach should both include the provision of educational material such as booklets and web resources, and educational exhibits. Of primary importance in these goals is the role of natural history museums, zoos, and aquaria.

Last comments

One of the most important items still to be discussed in relation to the BACAP is that of estimated costs, and targets or actions in the short, medium and long terms. The responsibility to actually implement the plan will be shared by the academic and conservation biology community and government. The SBH will coordinate the access and updating process of large databases, and University consortia will coordinate more specific projects involving a collaborative network of researchers. Within the government, action is set to be coordinated by the Centro Nacional de Pesquisa e Conservação de Anfíbios e Répteis (RAN) from ICMBio. The scenario for implementation of collaborative networks is favorable, and several funding initiatives to improve knowledge about Brazilian biodiversity have been already implemented by organs such as the Conselho Nacional de Pesquisa e Desenvolvimento (CNPq) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). Part of the research costs associated with the BAAP will be covered by regional funding agencies (e.g. the Fundações de Amparo à Pesquisa or FAPs) and private institutions.

Brazil currently has still a relatively strict environmental legislation that mandates environmental compensation for new developments that impose significant environmental impacts — including land acquisition. Private companies operating in Brazil are also liable for environmental damage (e.g., oil spills) and have to invest into environmental preservation. Under this scenario, it may be plausible to use funds from the private sector to create and/or support existing regional research centers with the necessary facilities and personnel to implement amphibian captive breeding, chemical analyses for environmental monitoring, molecular analyses for incidence of diseases, etc.

Main achievements, great opportunities

Several achievements have already taken place since the 2004 Global Amphibian Assessment. Brazilian scientists intensified collaboration and interdisciplinary research, recruited and trained students, and acquired new research skills through various workshops and courses (tab. 2). A national list of amphibians was spearheaded by the Sociedade Brasileira de Herpetologia (Anonymous, 2010*b*). Regional lists of threatened species were updated (e.g., Anonymous, 2007, 2009), and the national list of threatened species is currently in the process of being revised based on the IUCN Red List Categories and Criteria (Anonymous, 2001), which are gradually becoming more broadly accepted amongst local scientists. Two new, national initiatives – the peer-reviewed, on-line journals *Checklist* and *Biota Neotropica* –

Table 2. – A few examples showing increasing collaborative and interdisciplinary research on amphibian conservation conducted by Brazilian scientists since the first discussions on the development of an Amphibian Conservation National Plan.

Herpetological meetings
• (From 2004 on). Brazilian Congress of Herpetology organized biannually by the Sociedade Brasileira de Herpetologia (SBH), with rapidly increasing number of participants.
• (2004). Workshop for the elaboration of the Brazilian list of species of amphibians. Organized by the Sociedade Brasileira de Herpetologia (SBH), State of Paraná, Brasil.
• (2009) First Workshop for the definition of priority Brazilian amphibian species for ex-situ conservation purposes. Organized by Amphibian Ark, Fundação Parque Zoológico de São Paulo, Asociación Latinoamericana de Parques Zoológicos y Acuarios (ALPZA) and International Union for Conservation of Nature (IUCN), State of São Paulo, Brasil.
Courses on amphibian conservation including Brazilian participants
• (2004). Advanced training on threatened amphibian population declines research. Organized by NatureServe, Rede de Análises sobre Anfíbios Neotropicais Ameaçados (RANA), and Host-Pathogen Biology and the Global Decline of Amphibians (IRCEB), Estación Biológica La Selva and Universidad de Costa Rica, Costa Rica.
• (2009). 1st Course on biology and ex-situ conservation of Brazilian amphibians. Organized by Amphibian Ark, Sociedade de Zoológicos Brasileiros, and World Association of Zoos and Aquariums (WAZA), State of São Paulo, Brasil.
• (2009) "Conservación de la Biodiversidad de Anfibios" course. Organized by Durrel Wildlife Conservation Trust and Museo de Historia Natural A. d`Orbigny, Copacabana, Bolívia.
• (2010) Amphibian Conservation, Biology and Management Course. Organized by Association of Zoo`s and Aquariums (AZA), Toledo, Ohio, USA.
Multi-institutional interdisciplinary projects
(2011–2013). Tadpoles from the Atlantic forest, Amazonia, Pantanal, Cerrado and transition zones: morphological description, spatial distribution, and diversity patterns. Edital MCT/CNPq/MEC/CAPES/FNDCT, Ação Transversal/FAPs Nº 47/2010Sistema Nacional de Pesquisa em Biodiversidade, SISBIOTA BRASIL. Coordinated by Dra. Denise de Cerqueira Rossa Feres, Universidade Estadual Paulista, campus de São José do Rio Preto, State of São Paulo, Brasil.

greatly facilitated the once problematic issue of publication of species range updates and inventories. Both are now obligatory literature for primary data information, and not only for Brazilian species.

There were also important regional initiatives. In the state of São Paulo, the Biota program, funded by Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), provided support for biodiversity assessments. The program's databasing system (known as SpeciesLink: <http://splink.cria.org.br>) now integrates primary data from several Brazilian scientific collections, including locality records – which are publicly available on the Web. Similarly, the Programa de Pesquisa em Biodiversidade (PPBio: <http://ppbio.inpa.gov.br>) (MCT/CNPq) implemented an online system to automate, review and invest in the mainte-

nance of biological collections in the Amazon and other regions. Similar initiatives are also being conducted elsewhere (e.g., the Biota Minas Program in the State of Minas Gerais), and most recently, a national initiative has been launched: SISBIOTA-Brasil (Sistema Nacional de Pesquisa em Biodiversidade).

The need for standardized methods to inventory, monitor, and analyze population trends has been incorporated into governmental regulatory protocols. In some cases, standardization resulted in an intensification of field work but no improvement in quality of data – leading to discussions on how to render protocols useful and adaptable (Silveira et al., 2010). Lastly, Brazil's recent initiative to create new public university campi throughout the country, particularly in poorly served areas, created emergent research centers that are now home to young amphibian specialists willing to establish strong laboratories and research groups.

Resumen

Brasil tiene un papel fundamental en la conservación de anfibios, presentando la mayor riqueza de especies en el mundo y un alto grado de endemismo. Presentamos aquí una descripción del Plan de Acción para la Conservación de Anfíbios de Brasil (BACAP, por sus siglas en inglés), el cual todavía está siendo discutido por herpetólogos del país. La investigación básica – particularmente inventarios de especies, revisiones taxonómicas, y colectas de datos en el campo – se muestra particularmente necesaria para guiar la conservación de anfibios en el país. La documentación y el monitoreo de especies han mejorado, por lo menos a escala regional. En resumen, las listas de especies amenazadas están siendo regularmente actualizadas, se están realizando esfuerzos para estandarizar protocolos de campo, y la manutención de especies en cautiverio está siendo considerada como una herramienta educativa y de investigación. También presentamos una breve historia del BACAP, identificamos algunos desafíos atados a su implementación, y repasamos algunos importantes logros recientes.

Resumo

Abrigando a maior riqueza de anfíbios anuros no mundo e com grande número de espécies endêmicas o Brasil apresenta papel fundamental para a conservação dos anfíbios. Precisamos investir imediatamente em pesquisa básica, particularmente inventários, revisões taxonômicas e coleta de dados em campo, para implementar efetivamente a conservação de anfíbios no país. A documentação da diversidade brasileira e o status em que se encontra do ponto de vista da conservação têm melhorado, pelo menos localmente. Listas de espécies ameaçadas têm sido regularmente atualizadas e tem havido esforços para padronizar protocolos de coleta. A manutenção e reprodução em cativeiro têm sido consideradas no país como uma importante ferramenta de pesquisa e educação. Apresentamos nesse trabalho uma breve história da elaboração do Plano de Ação Nacional para Conservação de Anfíbios (BACAP, correspondendo a "Brazilian Amphibian Conservation Action Plan" em inglês), uma visão

geral de seu conteúdo, os principais desafios, e nossas ainda pequenas, mas significativas conquistas.

ACKNOWLEDGEMENTS

We are thankful to all authors who contributed to the Brazilian Amphibian Conservation Action Plan: C. Canedo, C. A. Navas, D. Pavan, F. R. Gomes, H. R. Silva, I. Santos, J. E. Carvalho, L. B. Nascimento, L. O. M. Giasson, M. Segalla, M. Gordo, M. Martins, M. Dixo, M. T. Rodrigues, M. B. Sousa, R. P. Bastos, S. Neckel-Oliveira, S. Ziller, S. Z. Cechin and U. Caramaschi. The first outline for the Action Plan was defined during meetings funded by Conservation International and Probio/MMA. A. Carnaval acknowledges funding by NSF (DEB-1035184); L. F. Toledo thanks FAPESP for a grant and a scholarship; L. Schiesari acknowledges funding by FAPESP (2008/57939-9), CNPq (483801/2007-0, 563075/2010-4), and BACP/IFC/GEF (IPAM Grant 006); G. V. Andrade and M. Menin acknowledges funding by CNPq (304987/2009-3; 302374/2008-6; 563075/2010-4) and FAPESP (10/52321-7); P. C. Eterovick acknowledges a Research Productivity grant by CNPq (301077/2010-0); P. H. Valdujo acknowledges fellowship by FAPESP (2007/51956-6); V. K. Verdade acknowledges funding by FAPESP (2003/10335-8).

LITERATURE CITED

ANONYMOUS [IUCN], 2001. – *IUCN Red List Categories and Criteria. Version 3.1.* Gland, Switzerland & Cambridge, UK, IUCN Species Survival Commission: i–ii + 1–30.

ANONYMOUS [IBAMA], 2003. – *Lista nacional das espécies da fauna brasileira ameaçadas de extinção*. <http://www.mma.gov.br/port/sbf/fauna/index.cfm> [accessed 4 September 2010].

ANONYMOUS [Fundação Biodiversitas], 2007. – Revisão das listas vermelhas da flora e da fauna ameaçadas de extinção do Estado de Minas Gerais. Belo Horizonte, Fundação Biodiversitas. <http://www.biodiversitas.org.br/listas-mg/> [accessed 26 September 2010].

ANONYMOUS [Estado São Paulo], 2009. – Secretaria do Estado do Meio Ambiente. Fauna Ameaçada no Estado de São Paulo. *Diário oficial do Estado de São Paulo,* **118**: 187.

ANONYMOUS [IUCN], 2010*a*. – *IUCN Red List for threatened Species*. *Version 2010.4*. <http://www.iucnredlist.org/amphibians> [accessed 12 January 2011].

ANONYMOUS [SBH], 2010*b*. – *Brazilian Amphibians. List of species.* São Paulo, Brazil, Sociedade Brasileira de Herpetologia. <http://www.sbherpetologia.org.br> [accessed 26 September 2010].

ANONYMOUS [MMA], 2010*c*. – *Monitoramento do desmatamento nos biomas.* Brasília, Brasil, Ministério do Meio Ambiente. <http://www.mma.gov.br/sitio/index.php?ido=conteudo.monta&idEstrutura=72&idConteudo=7422&idMenu=7508> [accessed 26 September 2010].

ALVES, A. C. R., SAWAYA, R. J., REIS, S. F., & HADDAD, C. F. B., 2009. – A new species of *Brachycephalus* (Anura: Brachycephalidae) from the Atlantic Rain Forest in São Paulo state, Southeastern Brazil. *J. Herp.*, **43**: 212–219.

BECKER, C. G. & ZAMUDIO, K. R., 2011. – Tropical amphibian populations experience higher disease risk in natural habitats. *PNAS*, **108** (24): 9893–9898.

BROOKS, T., FONSECA, G. A. B. & RODRIGUES, A. S. L., 2004. – Species, data, and conservation planning. *Conserv. Biol.*, 18 (6): 1682–1688.

CARNAVAL, A. C. O. Q., TOLEDO, L. F., HADDAD, C. F. B. & BRITTO, F. B., 2005. – Chytrid fungus infects high-altitude stream-dwelling *Hylodes magalhaesi* (Leptodactylidae) in the Brazilian Atlantic Rainforest. *Froglog*, **70**: 3.

Carnaval, A. C. O. Q., Puschendorf, R., Peixoto, O. L., Verdade, V. K. & Rodrigues, M. T., 2006. – Amphibian chytrid fungus broadly distributed in the Brazilian Atlantic Rain forest. *Ecohealth* <published on line: DOI: 10.1007/s10393–005–0008–2>.

Cushman, S. A., 2006. – Effects of habitat loss and fragmentation on amphibians: a review and prospectus. *Biol. Conserv.*, **128**: 231–240.

Dixo, M. & Martins, M., 2008. – Are leaf-litter frogs and lizards affected by edge effects due to forest fragmentation in Brazilian Atlantic forest? *J. trop. Ecol.*, **24**: 551–554.

Dixo, M. & Metzger, J., 2010. – The matrix-tolerance hypothesis: an empirical test with frogs in the Atlantic Forest. *Biodiv. Conserv.*, **19**: 3059–3071.

Dixo, M., Metzger, J., Morgante, J., & Zamudio, K., 2009. – Habitat fragmentation reduces genetic diversity and connectivity among toad populations in the Brazilian Atlantic Coastal Forest. *Biol. Conserv.*, **142**: 1560–1569.

Docherty, D. E., Meteyer, C. U., Wang, J., Mao, J., Case, S. & Chinchar, V. G., 2003. – Diagnostic and molecular evaluation of three iridovirus associated salamander mortality events. *J. Wildl. Dis.*, **39**: 556–566.

Eken, G., Bennun, L., Brooks, T. M., Darwall, W., Fishpool, L. D. C., Foster, M., Knox, D., Langhammer, P., Matiku, P., Radford, E., Salaman, P., Sechrest, W., Smith, M. L., Spector, S. & Tordoff, A., 2004. – Key biodiversity areas as site conservation targets. *BioScience*, **54**: 1110–1118.

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. *Biotropica*, **37**: 166–179.

Ficetola, G. F., Thuiller, W. & Miaud, C., 2007. – Prediction and validation of the potential global distribution of a problematic alien invasive species – the American bullfrog. *Divers. Distrib.*, **13**: 476–485.

Funk, V. A., Richardson, K. & Ferrier, S., 2005. – Survey-gap analysis in expeditionary research: where do we go from here? *Biol. J. Linn. Soc.*, **85**: 549–567.

Gardner, T. A., Ribeiro-Júnior, M. A., Barlow, J., Ávila-Pires, T C. S., Hoogmoed, M. & Peres, C., 2007. – The value of primary, secondary, and plantation forests for a Neotropical Herpetofauna. *Conserv. Biol.*, **21**: 775–787.

Gascon, C., Collins, J. P., Moore, R. D., Church, D. R., McKay, J. E. & Mendelson, J. R. I., (ed.), 2007. – *Amphibian Conservation Action Plan*. Glands, Switzerland & Cambridge, UK, IUCN/SSC Amphibian Specialist Group: 1–68.

Gibbons, J. W., Burke, V. J., Lovich, J. E., Semlitsch, R. D., Tuberville, T. D., Bodie, J. R., Greene, J. L., Niewiarowski, P. H., Whiteman, H. H., Scott, D. E., Pechmann, J. H. K., Harrison, C. R., Bennett, S. H., Krenz, J. D., Mills, M. S., Buhlmann, K. A., Lee, J. R., Seigel, R. A., Tucker, A. D., Mills, T. M., Lamb, T., Dorcas, M. E., Congdon, J. D., Smith, M. H., Nelson, D. H., Dietsch, M. B., Hanlin, H. G., Ott, J. A. & Karapatakis, D. J., 1997. – Perceptions of species abundance, distribution, and diversity: lessons from four decades of sampling on a government-managed reserve. *Environ. Manag.*, **21** (2): 259–268.

Graham, C. H., Ferrier, S., Huettman, F., Moritz, C. & Peterson, A. T., 2004. – New developments in museum-based informatics and applications in biodiversity analysis. *Trends Ecol. & Evol.*, **19** (9): 497–503.

Green, D. M., 2003. – The ecology of extinction: population fluctuation and decline in amphibians. *Biol. Conserv.*, **111**: 331–343.

Griffiths, R. A. & Kuzmin, S. L., 2011. – Captive breeding of amphibians for conservation. *In*: H. Heatwole & J. W. Wilkinson (ed.), *Conservation and decline of amphibians: ecological aspects, effect of humans, and management*, vol. **10**, Baulkham Hills, Surrey Beatty & Sons Pty. Ltd.: 3687–3703.

Guerra-Fuentes, R. A. & Dixo, M., 2006. – *Crossodactylus caramaschii*: mortality. *Herp. Rev.*, **37**: 336.

Haddad, C. F. B., Giovanelli, J. G. R. & Alexandrino, J., 2008. – O aquecimento global e seus efeitos na distribuição e declínios dos anfíbios. *In*: M. S. Buckeridge (org.), *Biologia & mudanças climáticas no Brasil*, São Carlos, RiMa Ed.: 195–206.

Hayes, J. P. & Steidl, R. J., 1997. – Statistical power analysis and amphibian population trends. *Conserv. Biol.*, **11**: 273–275.

HEYER, W. R., RAND, A. S., CRUZ, C. A. G. & PEIXOTO, O. L., 1988. – Decimations, extinctions, and colonizations of frog populations in Southeast Brazil and their evolutionary implications. *Biotropica*, **20**: 230–235.

KEISER, K., 2008. – Evaluation of a long-term amphibian monitoring protocol in Central America. *J. Herp.*, **42** (1): 104–110.

LIPS, K. R., BURROWES, P. A., MENDELSON III, J. R. & PARRA-OLEA, G., 2005. – Amphibian declines in Latin America: a synthesis. *Biotropica*, **37**: 222–226.

LIPS, K. R., BREM, F., BRENES, R., REEVE, J. D., ALFORD, R. A., VOYLES, J., CAREY, C., LIVO, L., PRESSIER, A. P. & COLLINS, J. P., 2006. – Emerging infectious disease and the loss of biodiversity in a Neotropical amphibian community. *PNAS*, **103** (9): 3165–3170.

MARENGO, J. A., 2006. – *Mudanças climáticas globais e seus efeitos sobre a biodiversidade: caracterização do clima atual e definição das alterações climáticas para o território brasileiro ao longo do século XXI*. Brasília, MMA: 1–212.

PAVAJEAU, L., ZIPPEL, K. C., GIBSON, R. & JOHNSON, K., 2008. – Amphibian ark and the 2008 year of the frog campaign. *Int. Zoo Yearb.*, **42**: 24–29.

PEARMAN, P. B., GARNER, T. W. J., STRAUB, M. & GREBER, U. F., 2004. – Response of the Italian agile frog (*Rana latastei*) to a Ranavirus, frog virus 3: a model for viral emergence in naive populations. *J. Wildl. Dis.*, **40**: 660–669.

PEIXOTO, O. L., 2003. – Anfíbios em coleções científicas no Brasil: uma aproximação. *In*: A. L. PEIXOTO (org.), Coleções biológicas de apôio ao inventário, uso sustentável e conservação da biodiversidade, Rio de Janeiro, Instituto de Pesquisa do Jardim Botânico: 1–238.

PELLET, J. & SCHMIDT, B. R., 2005. – Monitoring distributions using call surveys: estimating site occupancy, detection probabilities and inferring absence. *Biol. Conserv.*, **123**: 27–35.

PIMENTA, B. V. S., HADDAD, C. F. B., NASCIMENTO, L. B., CRUZ, C. A. G. & POMBAL, J. P., 2005. – Comment on "Status and trends of amphibian declines and extinctions worldwide", *Science*, **309**: 1999.

PIMENTA, B. V. S., WACHLEVSKI, M. & CRUZ, C. A. G., 2008. – Morphological and acoustical variation, geographic distribution, and conservation status of the spinythumb frog *Crossodactylus bokermanni* Caramaschi and Sazima, 1985 (Anura, Hylodidae). *J. Herp.*, **42** (3): 481–492.

PISTONI, J. & TOLEDO, L. F., 2010. – Amphibian illegal trade in Brazil: what do we know? *South Am. J. Herp.*, **5** (1): 51–56.

ROMANSIC, J. M., DIEZ, K. A., HIGASHI, E. M., JOHNSON, J. E. & BLAUSTEIN, A. R., 2009. – Effects of the pathogenic water mold *Saprolegnia ferax* on survival of amphibian larvae. *Dis. aquat. Org.*, **83**: 187–193.

RON, S., 2005. – Predicting the distribution of the amphibian pathogen *Batrachochytrium dendrobatidis* in the New World. *Biotropica*, **37**: 209–221.

SANTOS, T. C. C. & CAMARA, J. B. D. (coord.), 2002. – *GeoBrasil 2002. Perspectivas do meio ambiente no Brasil.* Brasília, Edições IBAMA: 1–440.

SCHIESARI, L. C., GRILLITSCH, B. & GRILLITSCH, H., 2007. – Biogeographic biases in research and their consequences for linking amphibian declines to pollution. *Conserv. Biol.*, **21**: 465–471.

SILVANO, D. L. & SEGALLA, M. V., 2005. – Conservation of Brazilian amphibians. *Conserv. Biol.*, **19**: 653–658.

SILVEIRA, L. F., BEISIEGEL, B. M., CURCIO, F. F., VALDUJO, P. H., DIXO, M., VERDADE, V. K., MATTOX, G. M. T. & CUNNINGHAM, P. T. M., 2010. – Para que servem os inventários de fauna? *Estudos avançados*, **68**: 173–207.

TARGINO, M., COSTA, P. N., & CARVALHO-E-SILVA, S. P., 2009. – Two new species of the *Ischnocnema lactea* species series from Itatiaia highlands, Southeastern Brazil (Amphibia, Anura, Brachycephalidae). *South Am. J. Herp.*, 4 (2): 139–150.

TOCHER, M. D., GASCON, C. & MEYER, J. R., 2001. – Community composition and breeding sucesses of amazonian frogs in continuous forest and matrix aquatic sites. *In*: R. O. BIERREGAARD, C. GASCON, T. E. LOVEJOY & R. MESQUITA, (ed.), *Lessons from Amazonia: the ecology and conservation of a fragmented forest*, New Haven, Connecticut, Yale University Press: 235–247.

TOLEDO, L. F., BRITTO, F. B., ARAÚJO, O. G. S., GIASSON, L. M. O. & HADDAD, C. F. B., 2006*b*. – The occurrence of *Batrachochytrium dendrobatidis* in Brazil and the inclusion of 17 new cases of infection. *South Am. J. Herp.*, **1** (3): 185–191.

Toledo, L. F., Carvalho-e-Silva, S. P., Sánchez, C., Almeida, M. A. & Haddad, C. F. B., 2010. – A revisão do Código Florestal Brasileiro: impactos negativos para a conservação dos anfíbios. *Biota Neotrop.*, **10**: 1–4.

Toledo, L. F., Haddad, C. F. B., Carnaval, A. C. O. Q. & Brito, F. B., 2006*a*. – A Brazilian anuran (*Hylodes magalhaesi*: Leptodactylidae) infected by *Batrachochytrium dendrobatidis*: a conservation concern. *Amph. Rept. Conserv.*, **4**: 17–21.

Verdade, V. K., Carnaval, A. C., Rodrigues, M. T., Schiesari, L., Pavan, D. & Bertoluci, J., in press. – Decline of amphibians in Brazil. *In*: H. Heatwole & J. W. Wilkinson (ed.), *Amphibian conservation*. Baulkhlam Hills, Australia, Surrey Beatty & Sons PTY Limited.

Wake, D. B. & Vredemburg, V. T., 2008. – Are we in the midst of the sixth mass extinction? A view from the world of amphibians. *PNAS*, **105**: 11466–11473.

Weber, L. N., Verdade, V. K., Salles, R. O. L., Fouquet, A. & Carvalho-e-Silva, S. P., 2011. – An astonishing new frog genus (Anura: Cycloramphidae) from the highlands of Parque Nacional da Serra dos Órgãos, southeastern Brazil. *Zootaxa*, 2737: 19–33.

Weygoldt, P., 1989. – Changes in the composition of mountain stream frog communities in the Atlantic mountains of Brazil: frogs as indicators of environmental deteriorations? *Stud. Neotrop. Fauna Environ.*, **243** (4): 249–255.

Young, B. E., Lips, K. R., Reaser, J. K., Ibanez, R., Salas, A. W., Cedeno, J. R., Coloma, L. A., Ron, S., La Marca, E., Meyer, J. R., Munoz, A., Bolanos, F., Chaves, G. & Romo, D., 2001. – Population declines and priorities for amphibian conservation in Latin America. *Conserv. Biol.*, **15**: 1213–1223.

Young, B. E., Stuart, S. N., Chanson, J. S., Cox, N. A. & Boucher, T. M., 2004. – *Joyas que están desapareciendo. El estado de los anfibios en el Nuevo Mundo*. Arlington, Natureserve: 1–54.

Zimmerman, B. L. & Simberloff, D., 1996. – An historical interpretation of habitats use by frogs in a central Amazon forest. *J. Biogeogr.,* **23**: 27–46.

Corresponding editor: Ariadne Angulo.