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Amphibian Declines in Brazil: An Overview[1]

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ABSTRACT

Population declines have previously been reported for at least 31 amphibian species in Brazil, in the families Leptodactylidae (19), Hylidae (7), Centrolenidae (2), Dendrobatidae (2), and Bufonidae (1). In five Brazilian museum collections, we found no entries of new records dating back to at least 15 yr ago for 13 of these species. We suggest that these taxa be studied in more detail to verify their status and to generate basic ecological data. Museum data indicate that the remaining species have been recently found in areas of reported crashes, or elsewhere. Several apparent declines in Brazil can be associated with habitat loss, interspecific interactions, natural fluctuations, or lack of intensive sampling. Personal observations and field data also indicate possible declines in the states of Paraná and Ceará as well as in highlands within the Cerrado biome, in the state of Minas Gerais. Records suggest declines of montane and stream-associated populations of Brazilian amphibians in apparently pristine habitats. Field work is necessary to confirm these cases and to examine whether factors associated with similar extinctions in other parts of the globe—such as pathogens and climate change—are also related to local disappearances. To clarify pending questions and perhaps circumvent new cases, it is important to invest in short- and long-term field studies, and in the maintenance and expansion of museum collections.

RESUMO

Uma revisão bibliográfica indica a existência de 31 registros de declínios de populações de anfíbios no Brasil, abrangendo as famílias Leptodactylidae (19), Hylidae (7), Centrolenidae (2), Dendrobatidae (2) e Bufonidae (1). Em cinco coleções brasileiras, nenhum registro foi encontrado nos últimos 15 anos para 13 destas espécies. Sugerimos que as mesmas sejam estudadas em maior detalhe, de modo a verificar seu status e gerar dados ecológicos necessários para conservação. Levantamentos em coleções indicam que as demais espécies têm sido recentemente encontradas nas localidades do proposto declínio, ou em outras regiões. Vários registros de declínios no país estão associados a perda de habitat, interações entre espécies, flutuações populacionais, ou amostragem insuficiente. Com base em observações pessoais e dados de campo, levantamos a possibilidade de novos casos de declínios nos estados do Paraná e Ceará, e em áreas de altitude no bioma do Cerrado, em Minas Gerais. Vários casos de declínios populacionais sugeridos para anfíbios brasileiros referem-se a espécies de altitude que se reproduzem em riachos, em áreas aparentemente bem conservadas. Será interessante confirmar tais casos e avaliar se fatores associados a padrões semelhantes de extinções em outras partes do mundo—tais como patógenos ou mudanças climáticas— estão também relacionados a desaparecimentos ou declínios no país. Para esclarecer questões pendentes, é importante investir em estudos de campo a curto e longo prazo, bem como na manutenção e expansão das coleções herpetológicas do país.

Key words: Amphibia; Atlantic Forest; Brazil; Cerrado; Latin America; population declines; Serra do Cipó.

ALTHOUGH GLOBAL AMPHIBIAN DECLINES HAVE BEEN REPORTED SINCE THE 1980S, relatively little is known about the status of amphibian populations in South American countries due to insufficient data on species distribution and population dynamics, combined with high levels of species diversity (Myers *et al.* 2000, Young *et al.* 2001). While many known examples of species declines can be attributed to direct causes such as habitat destruction, subtle factors have been shown to act on amphibian populations worldwide, leading to local and regional extinctions in pristine habitats (Young *et al.* 2001). Species dwelling at higher elevations seem to be at greater risk, given the relatively high number

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of declines recorded above 500 m of altitude in Central America, and above 1000 m in Andean areas (Young *et al.* 2001). In the Neotropics, species extinctions and changes in population size have been described from upland regions of Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Guatemala, Mexico, Panama, Puerto Rico, and Venezuela (see Young *et al.* 2001 for a comprehensive review).

A common criticism of reports of amphibian population declines is that populations are known to fluctuate naturally, making it difficult to pinpoint actual extinctions (Green 2003). Metapopulation dynamics can lead to temporary or permanent disappearances of populations undergoing local extinction and recolonization (Gulve 1994). Populations may also suffer successive reduction and expansion events, depending on extrinsic factors that influence recruitment (Alford & Richards 1999). Nonetheless, data suggest that amphibian populations have been decreasing worldwide, with declines generally outnumbering increases (Green 2003).

Relatively few papers have addressed amphibian population declines in Brazil (Heyer *et al.* 1988, Weygoldt 1989, Bertoluci & Heyer 1995, Guix *et al.* 1998, Pombal & Haddad 1999, Izecksohn & Carvalho-e-Silva 2001), notwithstanding the fact that herpetologists have noticed that many formerly abundant species appear to be presently absent from selected study sites, as brought up during the 2003 Meeting of the Research and Analysis Network for Neotropical Amphibians (RANA) in Rio de Janeiro. Given the large geographic scale of the country, the diverse ecosystems represented, and the great number of amphibian species, very little is actually known about population declines in Brazil. Several factors contribute to this scenario, including an incomplete knowledge of the biology of local species, unequal sampling across regions, scarcity of long-term and monitoring studies, large number of unpublished observations, and the fact that field data have been frequently collected in relation to taxonomic studies aimed at selected species (as opposed to exhaustive inventories).

Brazil is home to 770 of the nearly 6000 known living species of amphibians (Young *et al.* 2004, SBH 2005); many of these are endemic. One of its most diverse ecosystems, the Atlantic Rainforest, has been recently listed among the five top hotspots for conservation priority in the world (Myers *et al.* 2000). Today, remnants of the Atlantic Forest cover less than 8 percent of the original forested area (Myers *et al.* 2000). Most remnant patches are found in the highlands of the Serra do Mar and Serra da Mantiqueira in Southeastern Brazil. These mountain ranges harbor a great percentage of the endemic Brazilian amphibian fauna (Câmara 1992). The overwhelming majority of reports of amphibian declines in Brazil come from this area.

The Brazilian Cerrado, also considered to be a biodiversity hotspot (Myers *et al.* 2000), is a gradient-like mosaic of several vegetation types determined primarily by soil conditions. It consists of savanna, woodland/savanna, and dry forest ecosystems, also containing a rich montane meadow vegetation found at higher portions of some of the mountain ranges in Southeastern Brazil, such as the Serra do Espinhaço. Its core area occupies the central Brazilian plateau (Mittermeier *et al.* 1999). Annual rainfall typically ranges between 1100 and 1600 mm, with higher precipitation between October and April. Its grassy and shrubby-like vegetation includes many drought-adapted species (Mittermeier *et al.* 1999). The first records of frog population declines in this biome are reported here.

In an attempt to contribute to the discussion about amphibian declines in Brazil and motivate further studies, we review what has been published about the status of populations of Brazilian frogs and discuss the data based on analyses of museum specimens and field work carried out in the states of Ceará, Minas Gerais, and Paraná.

PUBLISHED RECORDS OF AMPHIBIAN DECLINES IN BRAZIL

Although little effort has been dedicated to this subject to date, the number of reports of amphibian population declines and species extinctions in Southeastern Brazil is worthy of attention. Records exist for the highlands of Serra do Mar at Boracéia, in the state of São Paulo (Heyer *et al.* 1988, Bertoluci & Heyer 1995), Santa Teresa and Linhares, state of Espírito Santo (Weygoldt 1989, Papp & Papp 2000), Maciço da Tijuca and Teresópolis, state of Rio de Janeiro (Heyer *et al.* 1988, Weygoldt 1989, Izecksohn & Carvalho-e-Silva 2001), as well as for the Parque Nacional do Itatiaia, at Serra da Mantiqueira (Heyer *et al.* 1988, Guix *et al.* 1998, Pombal & Haddad 1999; Appendix). When compiled, the above-listed records yield reports for at least 31 species of Brazilian anurans (depending on taxonomic issues), involving representatives of five families: Leptodactylidae (19 species), Hylidae (7 species), Centrolenidae (2 species), Dendrobatidae (2 species), and Bufonidae (1 species). Several modes of reproduction are represented in this compilation, which includes not only stream-associated taxa, but also species that breed in lentic environments.

A closer look at the list of species with reported declines reveals its highly heterogeneous nature—cases of declines and disappearances at mid- and high-altitude areas ($\geq$500 m above sea level) have been tied to many different causes (Appendix). A few observations are linked to habitat loss, such as the decline of *Flectonotus ohausi* in response to bamboo die-offs in Boracéia (Appendix). Landscape changes are known to affect amphibian populations in Brazil, as shown by records of population decline of *Phyllodytes luteolus* in response to fire at an open site surrounded by Atlantic Forest in the state of Espírito Santo (Papp & Papp 2000). Given the rapid rate of destruction of Brazil's natural ecosystems, habitat loss and habitat modification might represent much larger problems than documented thus far. In addition, there are suggestions that ecological processes—such as competition among species—might have led populations to decline, as in the case of *Hyla prasina* and *H. albopunctata* in open areas of Boracéia (Heyer *et al.* 1988).

A detailed examination of the list of Brazilian species with reported declines in apparently pristine areas calls for a review (Appendix). Taxonomic problems, for instance, may be an issue of concern. When discussing the absence of records of *Colostethus carioca* in the township of Rio de Janeiro, Izecksohn and Carvalho-e-Silva (2001) mentioned the possibility that this is, in fact, a synonym of *C. olfersioides* (Appendix). In addition, long-term monitoring and increased sampling in selected areas have shown that many populations formerly seen as declining or extinct have in fact recovered and persevered. For example, continuing field work in Boracéia showed that apparent decreases of *Scinax perpusillus*, *Adenomera marmorata*, and *Eleutherodactylus guentheri* were followed by rebounds (Appendix). The use of pit-fall traps also resulted in the "rediscovery" of *Hylodes asper*, a species once thought to be locally extinct

(Lange 2004). Given the absence of long-term monitoring studies and intense sampling effort in most areas where declines have been reported in Brazil, it is likely that the records compiled herein include taxa whose populations actually presently persist. On the other hand, because there are many more "at risk" areas in Brazil that require monitoring studies, it is also possible that other species declines and disappearances have been overlooked. Hence, this list should be seen as preliminary and incomplete, requiring revisions and updates.

Even after acknowledging all the above-mentioned factors, the list of amphibians with published records of declines or disappearances in the country includes several species in apparently undisturbed areas at mid- or high-elevations, a pattern reminiscent of those seen in other areas of the world. In an attempt to explain patterns seen throughout the mountains of southeastern and southern Brazil, Heyer *et al.* (1988) identified the unusually heavy frost of 1979, which included 4 d of zero or subzero temperatures, as likely responsible for the declines and extinctions observed. Based on records for the state of Espírito Santo, Weygoldt (1989) dismissed the hypothesis that a severe frost led to the patterns observed in Santa Teresa, and discussed other possible causes. Pollution and acid rain were listed as likely associated with the low pH of the water detected in some streams in 1989. Climatic changes and prolonged droughts were also discussed, as parts of the streams in Santa Teresa dried completely in 1987. Because larvae of stream-breeding species are known to take long to metamorphose (*Hylodes* tadpoles may take at least 1 yr to complete the process), Weygoldt (1989) discussed the possibility that extended dry periods could be leading to changes in population size, eventually resulting in local extinction. Weygoldt (1989) also mentioned the possibility of an epidemic disease. Tadpoles of *Hylodes babax* collected in the field in 1975 were successfully raised in the laboratory, but most of those collected in 1987 died during metamorphosis. The remaining individuals were raised through metamorphosis only after treating the larvae with an antibiotic and a nematicide.

THE CONTRIBUTION OF MUSEUM COLLECTIONS

As pointed out by Heyer (1988), we still have much to learn about the distributional range of Brazilian amphibian species. Data on species occurrence are limited not only because large portions of the country remain to be surveyed, but also due to the fact that many sites have been poorly sampled to date. Sites reported to shelter great species diversity usually correspond to conservation units that have been studied for many years, some of them going through periodic inventories, a pattern reflected by museum records.

Museum records can provide invaluable data on the spatial and temporal distribution of local taxa, documenting diversity and guiding conservation strategies (Kress *et al.* 1998, Heyer *et al.* 1999, Peixoto 2003a). Moreover, because knowledge of the former status of any species is needed to detect and analyze population declines, taxonomic museum collections turn into a valuable tool for studies of this nature (Shaffer *et al.* 1998), especially when monitoring data are lacking. Although collection data neither account for natural fluctuations in population size nor provide estimates of species abundances, there are several reasons why they help in the assessment of Brazilian amphibian declines. First, many field studies in Brazil are site specific, with several visits being made to a small set of areas. Second, many inventories conducted in Brazil have not been published to date or have been published in journals or technical reports of limited circulation. In instances such as these, museum specimens constitute an important source of information about species ranges and presence/absence data. Although the publication of descriptive species inventories is often discouraged by scientific journals, species lists are essential for conservation purposes in Brazil (Haddad 1998).

Based on data from selected Brazilian museum collections, we examined the information available about amphibian species with reported declines in the Brazilian Atlantic Forest. The results presented here are part of a data set gathered for Conservation International, available for the study of endemic amphibians in Brazil. Five herpetological collections were visited: Museu Nacional do Rio de Janeiro (MNRJ), Museu de Zoologia da Universidade Federal de São Paulo (MZUSP), Museu de Zoologia Mello Leitão, Espírito Santo (MBML), Museu de História Natural Capão da Imbuia, Paraná (MHNCI), and Universidade Federal do Ceará (UFC).

We were able to obtain 627 records in 122 townships from nine Brazilian states, dated from 1893 to 2003, which represent 29 of the species cited in the literature as having suffered population declines or extinctions in apparently pristine areas of the Atlantic Forest. Each record corresponds to presence at a given locality and specific time recorded in a given collection, notwithstanding the number of individuals collected.

Thirteen out of the 31 species with reported declines or apparent disappearances in Brazil have not been deposited in any of the above-mentioned herpetological collections for at least 15 yr: *Colostethus carioca, C. olfersioides*, *Crossodactylus dispar*, *C. gaudichaudii*, *Cycloramphus boraceiensis, C. duseni*, *C. eleutherodactylus*, *C. granulosus*, *C. semipalmatus, Hylodes babax, Paratelmatobius lutzii, Thoropa lutzi*, and *T. petropolitana*. Given the existing field observations associated with these taxa and the lack of recently collected specimens, we suggest that these species be studied in further detail with the aim of confirming if local populations are in fact extinct, or if the absence of records is due to insufficient or inappropriate sampling. Management and conservation activities can be then proposed.

With respect to the discussion of risk categories, several species with reported declines in Brazil have broad distributions and still occur in places other than those where population crashes were recorded (*e.g., Hyalinobatrachium eurygnathum*, *H. uranoscopum*, *Hyla circumdata*, *H. prasina, Phyllodytes luteolus, Scinax perpusillus, Adenomera marmorata*, *Cycloramphus fuliginosus*, *Eleutherodactylus guentheri*, *E. parvus*, *Hylodes asper*, *H. lateristrigatus*, *H. phyllodes*). Although *Thoropa miliaris* was observed to decline in Boracéia, São Paulo (Appendix), it was found in several localities in the state of Minas Gerais from 2000 to 2004 (P. C. Eterovick, pers. obs.). Given that such presumed declines may represent local phenomena, these species should not be seen as endangered without further evidence. It is nonetheless important to keep in mind that some of the taxa listed above might actually be complexes of species—in which case a thorough systematic review will be crucial before any statement can be made about local extinction risks. Ecological and monitoring studies will be particularly important to provide information and to guide future management practices concerning species recorded only near to or from the same locality where declines have been reported, such as *Melanophryniscus moreirae*, *Cycloramphus duseni*, *C. semipalmatus*, *Hylodes babax*, and *Paratelmatobius lutzii*.

Museum data should be analyzed with due caution given that collections may contain misidentified specimens. Institutions may house species that have been put in synonymy, or reallocated to other genera, requiring literature review and taxonomic updates. Many contain a proportion of preserved specimens that are yet to be deposited. As pointed out by Kress *et al.* (1998), biological collections can be a powerful tool for conservation—but efforts to increase their distribution, number, and organization are necessary to use the information more effectively. Brazil's Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) has been supporting a multi-institutional program in the last few years with the explicit goal to conserve, promote, and expand the value of biological collections in the country (Peixoto 2003a). A comprehensive review of the status, use, and needs of Brazilian amphibian collections resulted from that effort (Peixoto 2003b). By meeting these needs, local museums and institutions will not only document and preserve the diversity of the local fauna, but also contribute to the discussion of amphibian declines in the country.

DISAPPEARANCES OF ATLANTIC FOREST SPECIES IN PARANÁ HIGHLANDS?

Although quantitative data are lacking, one should consider the possibility that other amphibian species may have declined or are declining in the Brazilian Atlantic Forest. In the state of Paraná, in addition to *Cycloramphus duseni*, three species endemic to the Atlantic Forest are worth mentioning based on the low number of specimens collected and given the long-time interval with no records in spite of frequent searches (M. Segalla, pers. obs.). *Hyla langei*, a species associated with streams, is known only from two specimens collected at the Rio Taquaral, in the township of Morretes, in 1946 (this species has been unsuccessfully searched for since 1986). *Cycloramphus mirandaribeiroi*, a rare species associated with streams, is only known from São João da Graciosa and Marumbi, also in the township of Morretes. Only 20 individuals have ever been collected (Heyer 1983), and unsuccessful attempts to find this species have taken place since 1986. *Eleutherodactylus paranaensis*, a species associated with high elevation grasslands in the Atlantic Forest biome, is known from a single specimen collected in 1988 at the Pico Paraná, Campina Grande do Sul. Searches for this species in 1999, 2001, and 2003 were unsuccessful.

FOREST ENCLAVES ("BREJOS") IN HIGHLANDS OF NORTHEASTERN BRAZIL: DECLINE OF AN ENDEMIC SPECIES?

In the northeastern state of Ceará, the Atlantic Forest occurs as small relictual patches surrounded by the drier Caatinga vegetation. Such isolated fragments are known as forest enclaves or "brejos de altitude." Maciço de Baturité (4°05′–4°40′S, 38°30′–39°10′W) and Serra de Maranguape (3°54′–4°03′S, 38°32′–38°40′W) are examples of the "brejos." These highlands are crystalline formations with mean elevation in excess of 600 m above sea level. Their proximity to the coast, elevation, and orographic rains result in high humidity and mild temperatures. Amphibians from these highlands have been studied by Borges-Nojosa and collaborators since 1988 (*e.g.*, Borges 1991, Hoogmoed *et al.* 1994), revealing a fauna rich in endemic species and threatened by human-driven habitat change.

In 1994, Hoogmoed and collaborators described two new toadlet species from the highlands of Baturité and Maranguape: *Adelophryne baturitensis* and *A. maranguapensis*, respectively. Both are diurnally active and have direct development. Since 1992, *A. maranguapensis* has been continuously found at 10 localities in the township of Maranguape, being found in 26 out of 65 field trips, with specimens collected in 18 such occasions. Notwithstanding the smaller range of the Serra de Maranguape and the greater local human impact (with most native vegetation replaced by banana plantations), *A. maranguapensis* has been recorded frequently in the region, in banana and bamboo plantations, as well as in forest fragments. *Adelophryne baturitensis*, on the other hand, has a different record. This species is found among leaf litter, in bromeliads, and stream margins in areas of primary and secondary forest. Although it has not been recorded hitherto in areas occupied by coffee, banana, and chayote plantations, it can be found among leaf litter in bamboo plantations. From 1989 to 1993, *A. baturitensis* was found in 10 out of 30 field trips conducted in Baturité (Table 1), and found at nine sites located 600–900 m above sea level. However, from 1994 to 2003, 34 field trips in the same sites yielded no record of the species. During a recent (July 2004) visit to its type locality, Borges-Nojosa was able to find only three individuals. Ongoing monitoring studies should provide insight into natural fluctuations in these species.

FROGS FROM THE SERRA DO CIPÓ—A NEW CASE STUDY

The Espinhaço mountain range in Southeastern Brazil is a noteworthy area with watersheds of some important Brazilian river systems, unique geological and floristic formations, many endemic species of animals and plants, and high species richness (Costa *et al.* 1998). Anuran amphibians from the southern part of this range, including the highest portions of the Parque Nacional da Serra do Cipó and its vicinities (19°12′–19°20′S, 43°30′–43°40′W, 1095–1485 m above sea level) are relatively well studied. Several species descriptions and naturalistic observations resulted from the studies of Ivan Sazima and collaborators from 1971 to 1974 (*e.g.*, Bokermann & Sazima 1973a,b, 1978; Caramaschi & Sazima 1984; Caramaschi, 1985; Eterovick & Sazima 1998; Sazima & Bokerman 1977; Sazima, 1978, 1982; Sazima & Caramaschi 1986). About 25 yr later (1996–2000), Paula C. Eterovick and collaborators studied ecological aspects of anuran community ecology and tadpoles in the same area (Eterovick & Sazima 1999; Eterovick, 2000, 2001, 2004; Eterovick & Brandão 2001; Eterovick & Fernandes 2001; Eterovick, 2002; Eterovick *et al.* 2002; Eterovick 2003; Eterovick & Barros 2003). These studies provided a long-term survey of tadpoles and adult frogs from the area, with many sampling points in common, creating the opportunity to compare data on species' occurrences for two periods almost a quarter of a century apart—a situation never before analyzed for amphibians in Brazil.

TABLE 1. *Sampling effort, number of records, and sampling sites of* Adelophryne baturitensis *and* A. maranguapensis *in the "brejos de altitude" of Ceará, Brazil.*

Species	Period	Trips (*N*)	Trips with records (*N*)	Sites visited	Individuals (*N*)	Townships
Adelophryne baturitensis	1989–1993	30	10	Sítio Sinimbú	02	Baturité
				Remanso, Sítio Monte Belo, Sítio Riacho Fundo	15	Guaramiranga
				Povoado Santana, Sítio Barbosa, Sítio Floresta, Sítio São Luís, Sítio São Pedro, Sítio Timbaúba	16	Pacoti
	1994–2004	35	1	Same sites listed for 1989–1993, specimens recorded at the township of Pacoti	3	Same municipalities listed for 1989–1993
Adelophryne maranguapensis	1992–2004	65	26	Four sites along Trilha do Derretido, six sites along Trilha do Pico da Rajada	52	Maranguape

Sampling effort was about 3000 person/h in the 1971–1974 study period, summing 125 field work days and 36 frog species recorded, represented by 2161 tadpoles and 1047 adults. In the 1996–2000 period, sampling effort was about 2500 person/h, summing 80 field work days and 31 species recorded, represented by 1972 tadpoles and 585 adults. The data were compiled directly from original field sheets. To account for differences in sampling effort and species abundance between sampling periods, species richness was compared through rarefaction curves based on the number of individuals (adults and tadpoles) recorded in all sampling sites. In this analysis, we included some additional individuals that were collected on occasional visits and could not be included in the quantified sampling effort, so we had a total of 3230 individuals for the 1971–1974 sampling period and 2564 individuals for the 1996–2000 sampling period. Rarefaction curves were calculated using EcoSim software (Gotelli & Entsminger 2001).

In 1971–1974, 21 different sites were sampled (including streams and swamps), some of them just a few times. In 1996–2000, 16 streams (some with marginal swamps) and six ponds were sampled regularly. Analyses of species accumulation over time show a decrease in the number of additional species records throughout both the sampling periods, which indicate that sampling effort was intensive and that the surveys conducted at both periods are representative of the local anuran fauna (Figs. 1 and 2). Specific sites sampled during each sampling period could not always be matched with complete certainty, and some of them are known to be different. We have taken the possible influences of differences in sampling sites between both sampling periods into account to interpret and discuss the results. For instance, a larger number of swamps and ponds was monitored in 1970–1974, thus conclusions about population status of species inhabiting such water bodies cannot be drawn. Four particular areas, called herein Sites 1, 2, 3, and 4, were monitored during both sampling periods and thus can be directly compared regarding the number of tadpoles and adult frogs recorded (Table 2).

It is worth noticing that the difference between zero records and one record is much more significant than that between one and two records, and so on. This is due to the fact that, in some instances, the actual number of individuals was not recorded: either their presence was registered, or a qualitative abundance description such as "a lot of individuals" or "a few individuals" was used. In all such instances, the number summed (as those in Table 2) is a conservative estimate: "presence" was counted as one individual, "a few individuals" were counted as three, and "a lot of individuals" were counted as five. Therefore, the number of individuals recorded may be underestimated, but the lack of records really means that no tadpole or adult of a given species was ever found at the site during the whole sampling period. The results are interpreted with caution,

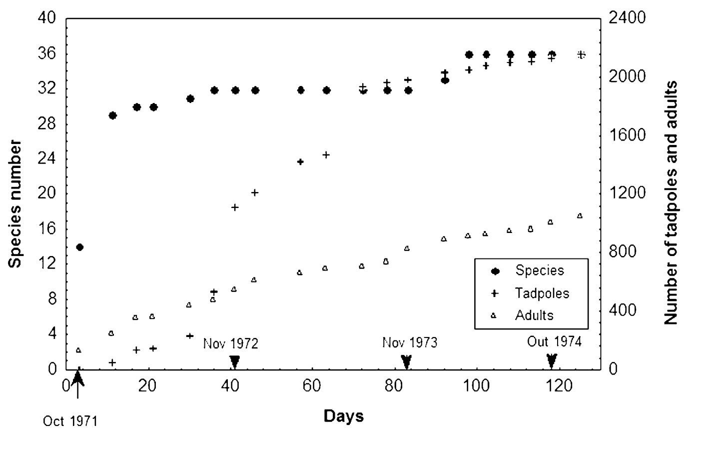

FIGURE 1. Cumulative number of species, tadpoles, and adult frogs recorded for all sites sampled at the Serra do Cipó from October 1971 to December 1974 (125 d of field work). Arrows indicate samplings that coincided with the onset of the rainy season, when most species would be reproductively active.

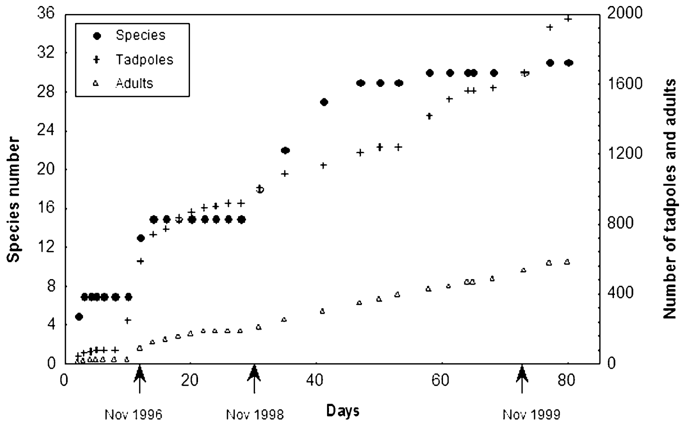

FIGURE 2. Cumulative number of species, tadpoles, and adult frogs recorded for all sites sampled at the Serra do Cipó from February 1996 to February 2002 (80 d of field work). Arrows indicate samplings that coincided with the onset of the rainy season, when most species would be reproductively active.

considering that the data set provides information on species' relative abundance rather than being an actual population estimator.

RESULTS

The most striking change in anuran assemblages at the four sites sampled both by Sazima (1971–76) and by Eterovick (1996–2000) is the disappearance of two species: *Epipedobates flavopictus* and *Crossodactylus bokermanni*. Although these taxa were very common in 1971–1974, they were not found in 1996–2000 (Table 2). During the 1996–2000 study, only two tadpoles of *E. flavopictus* were collected in a stream presently polluted by human domestic waste and crossed by the new road BR 161 (paved in 2002). *Epipedobates flavopictus* and *C. bokermanni* reproduce in streams and are diurnal, calling frequently at stream margins in montane meadows (Caramaschi & Sazima 1985, Haddad *et al.* 1988, Haddad & Martins 1994). *Epipedobates flavopictus* calls from October to December at the Serra do Cipó, whereas *C. bokermanni* calls almost year-round (Eterovick & Sazima 2004). These features render both species easy to detect under sampling conditions employed by Sazima and Eterovick, which indicates that the absence of records in 1996–2000 is worthy of concern, especially when taking into account that 16 unconnected streams were systematically sampled throughout this period.

Four other species were recorded in 1971–1974 but not in 1996–2000: *Phrynohyas venulosa*, *Adenomera bokermanni*, *Eleutherodactylus juipoca*, and *Elachistocleis ovalis*. Given that only three individuals of *P. venulosa* were recorded during the 1971–1974 study period, and that both *A. bokermanni* and *E. juipoca* were already very rare at the Serra do Cipó in 1971–1974 (I. Sazima, pers. obs.), their absence in 1996–2000 does not mean their disappearance from the area. *Elachistocleis ovalis* was recorded at Sites 1 and 3 (among other localities) in several instances in 1971–1974, but was not recorded at any site in 1996–2000. However, given that this is an explosive breeder which uses temporary swamps for reproduction (Eterovick & Sazima 2004), its occurrence and abundance

TABLE 2. *Number of adults and tadpoles recorded at four sites at the Serra do Cipó, MG. Site 1 (19° 17′ 23″ S, 43° 35′ 38″ W) is composed by two temporary streams with rocky and silty bottom, a temporary pond, and a temporary swamp. Site 2 (Riacho Vitalino: 19° 16′ 52″ S, 43° 34′ 58″ W) is a third-order permanent stream. Site 3 (19° 17′ 41″ S, 43° 34′ 05″ W) is composed by two streams that dry almost completely by the end of the dry season, with rocky and silty bottom. Site 4 (19° 15′ 26″ S, 43° 32′ 37″ W) is composed by two interconnected permanent streams bordered by gallery forests and a temporary pond. Estimated sampling effort (person-hours: p/h) is presented below the totals for each site. Species noticed to disappear in the second sampling period are in boldface.*

	Number of tadpoles		Number of adults	
Site/Species	1971–1974	1996–2000	1971—1974	1996–2000
Site 1				
Bufo rubescens	—	—	3	1
Epipedobates flavopictus	**11**	—	**13**	—
Hyla albopunctata	—	—	1	9
H. alvarengai	35	83	20	14
H. cipoensis	2	—	1	1
H. saxicola	1	206	1	22
Phyllomedusa megacephala	9	32	18	8
S. curicica	31	203	19	71
S. fuscovarius	—	—	1	—
S. machadoi	1	—	—	—
Crossodactylus bokermanni	**9**	—	**6**	—
Leptodactylus camaquara	3	2	6	—
L. cunicularius	6	22	14	13
L. furnarius	2	4	5	7
L. jolyi	1	2	11	4
L. labyrinthicus	4	2	5	1
L. syphax	2	45	7	9
Odontophrynus americanus	18	449	5	23
Physalaemus cuvieri	7	1	7	13
Proceratophrys cururu	1	29	1	6
Pseudopaludicola mineira	12	—	49	35
Thoropa megatympanum	3	3	9	17
Elachistocleis ovalis	6	—	4	—
Total	164	1083	206	254
1971–1974: 600 p/h				
1996–2000: 965 p/h				
Site 2				
Bufo rubescens	339	234	10	5
Epipedobates flavopictus	—	—	**4**	—
H .albopunctata	—	10	8	11
H. lundii	—	—	5	—
H. saxicola	3	23	6	8
Leptodactylus cunicularius	Foam nest	—	—	1
L. labyrinthicus	—	—	1	—
Total	342	267	34	25
1971–1974: 270 p/h				
1996–2000: 157 p/h				

TABLE 2. *Continued.*

Site/Species	Number of tadpoles 1971–1974	Number of tadpoles 1996–2000	Number of adults 1971—1974	Number of adults 1996–2000
Site 3				
Bufo rubescens	—	—	—	1
Hyla albopunctata	29	—	21	5
H. alvarengai	—	—	1	—
H. cipoensis	289	1	32	16
H. lundii	—	—	—	1
H. saxicola	6	6	2	9
Phyllomedusa megacephala	1	21	1	—
Scinax curicica	426	19	14	2
S. machadoi	268	24	15	2
Crossodactylus bokermanni	**35**	**—**	**22**	**—**
L. camaquara	—	7	—	—
L. cunicularius	—	27	—	—
L. furnarius	1	2	2	—
L. jolyi	—	—	11	1
L. labyrinthicus	4	—	1	—
L. cf. *ocellatus*	—	—	10	1
L. syphax	—	22	—	—
Odontophrynus americanus	1	3	11	—
Physalaemus cuvieri	69	—	10	3
Proceratophrys cururu	8	11	2	1
Pseudopaludicola mineira	—	—	7	14
Elachistocleis ovalis	—	—	11	—
Total	1137	143	173	56
1971–1974: 496 p/h				
1996–2000: 232 p/h				
Site 4				
Hyalinobatrachium sp.	—	—	21	4
Hyla albopunctata	—	—	—	6
H. alvarengai	—	—	2	—
H. cipoensis	9	1	5	13
H. cf. *circumdata*	—	—	—	1
H. nanuzae	59	1	19	1
H. saxicola	92	—	26	6
Phasmahyla jandaia	8	8	15	4
Phrynohyas venulosa	—	—	3	—
Scinax cf. *duartei*	1	1	1	3
S. machadoi	145	—	50	1
S. squalirostris	—	—	—	5
Adenomera bokermanni	—	—	6	—
Crossodactylus bokermanni	**23**	**—**	**16**	**—**
Eleutherodactylus juipoca	—	—	2	—
Hylodes otavioi	2	1	9	—
Leptodactylus cunicularius	—	—	2	3
L. furnarius	—	1	—	1
L. jolyi	—	—	—	5
Odontophrynus americanus	—	2	—	2
Physalaemus cuvieri	—	—	—	4
Proceratophrys cururu	8	—	7	—
Thoropa megatympanum	—	—	1	—
Total	347	15	185	59
1971–1974: 400 p/h				
1996–2000: 222 p/h				

at any site may vary greatly from year to year. The fact that higher sampling efforts were applied to lotic habitats in 1996–2000 could also have caused this species to be overlooked given its reproductive patterns.

When comparing Sites 1–4, it is noticeable that tadpoles and/or adults of several species were found only in 1971–1974 or 1996–2000: *Scinax fuscovarius* and *S. machadoi* at Site 1, *Hyla lundii* and *Leptodactylus labyrinthicus* at Site 2, *Bufo rubescens, Hyla alvarengai, H. lundii, Leptodactylus camaquara, L. cunicularius, L. labyrinthicus*, and *L. syphax* at Site 3, *Hyla albopunctata, H. alvarengai, Hyla* cf. *circumdata, Scinax squalirostris*, *L. furnarius, L. jolyi, Odontophrynus americanus, Physalaemus cuvieri, Proceratophrys cururu,* and *Thoropa megatympanum* at Site 4 (Table 2). However, an analysis across all sampled sites shows that these species have been recorded during both sampling periods in other areas, except for *Hyla* cf. *circumdata* at Site 4, represented by a single individual in 1996–2000. This indicates that species' absence or presence at a given locality at a given time may be an effect of local metapopulation dynamics (Gulve 1994). Random local extinctions and re-colonizations may be producing presence/absence patterns of some amphibian species across breeding sites at the Serra do Cipó.

In several instances, some species were represented by few adults at a given sampling site—*Scinax fuscovarius* at Site 1, *Leptodactylus labyrinthicus* at Site 2, *Bufo rubescens*, *Hyla alvarengai*, and *H. lundii* at Site 3, and *H. alvarengai*, *Hyla* cf. *circumdata* and *Thoropa megatympanum* at Site 4 (Table 2). Given that no reproductive activity was recorded locally, and that no tadpoles were recorded later in the season, it is possible that the recorded individuals were vagrant adults. No noticeable differences could be detected among the remaining species, which include *Hyalinobatrachium* sp., *Hyla cipoensis, H. nanuzae, H. saxicola, Phasmahyla jandaia, Phyllomedusa megacephala, Scinax curicica, Hylodes otavioi, Leptodactylus* cf. *ocellatus,* and *Pseudopaludicola mineira*.

Individual-based rarefaction curves (Fig. 3) show that species richness tended to be lower in the second sampling period, even after correcting for different number of individuals sampled in each sampling period. If a subsample of 2564 individuals were taken from the sample from 1970 to 1974, the mean species richness would be 36, with a variance

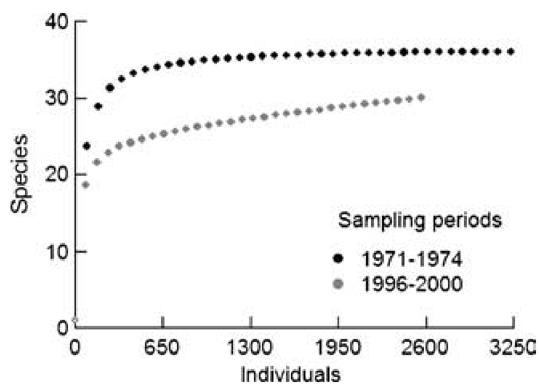

FIGURE 3. Individual-based rarefaction curves for the two periods of frog sampling at the Serra do Cipó, Southeastern Brazil.

of 0.039, based on 1000 iterations—while 31 species were recorded in the 1996–2000 sampling period. This result may be due both to species' declines and to less intensive sampling effort applied to lentic habitats during the second sampling period. It would be instructive to compare variations in the number of individuals and species richness within and between both sampling periods to distinguish between natural fluctuations and population declines. Nevertheless, field work was not uniformly distributed among years within sampling periods, restricting our ability to reveal fluctuation patterns.

DISCUSSION

Epipedobates flavopictus is a widespread species, whose distribution includes southeastern, northern, and northeastern Brazil (states of Minas Gerais, Goiás, Tocantins, Pará, and Maranhão), and eastern Bolivian mountain ranges (IUCN *et al.* 2004). Populations of this species are thought to be threatened by habitat loss due to deforestation, human settlement, cattle breeding, fire, logging and mining (data revised at the 2003 Workshop for Global Amphibian Assessment, Belo Horizonte, Brazil). Some sites where *E. flavopictus* disappeared at the Serra do Cipó may have been affected by fire and human settlement. Fires, which are common in this region, may occasionally cause extinction of local populations. Migration of new colonizers is therefore essential to maintain local populations. Although local streams are apparently intact, human settlement is potentially changing the whole landscape in a way that may affect anuran migration and recolonization. *Epipedobates flavopictus* may also be declining due to habitat fragmentation. All populations recorded in the 1971–1974 study, which were found along the edges or outside the national park, are currently missing.

Crossodactylus bokermanni, on the other hand, is known only from the Serra do Cipó (IUCN *et al.* 2004). Only a few adult individuals were recorded in 2001 (P. C. Eterovick, pers. obs.), at a stream in the Parque Nacional da Serra do Cipó (Riacho Água Escura, 19°16′27″S, 43°31′12″W; 1450 m). Populations from areas surrounding the park seem to have all disappeared, even from the apparently undisturbed streams where they were common in the 1971–1974 study (present paper). It is still possible, however, that this species persists in some streams within the park.

Amphibian species living in changeable environments such as small ponds and streams may be especially susceptible to habitat reduction and fragmentation, as these factors affect their dispersal (Green 2003). Declines in species of the genus *Crossodactylus* were also described by Heyer *et al.* (1988) at Boracéia, and by Weygoldt (1989) at Santa Teresa, southeastern Brazil. Populations from small streams are relatively stable when compared with populations from large streams and ponds, but stability is not related to population persistence, and dispersal abilities may aid to the understanding of a given species' susceptibility to habitat fragmentation (Green 2003).

As tourism and human settlement increase in the vicinities of the Parque Nacional da Serra do Cipó, new barriers may appear for the migration of species susceptible to disturbances in the area as a whole. This may be an explanation for the apparent restriction of *C. bokermanni* to the less accessible sites within the park, where direct human influence is minimized and probably does not disturb local population dynamics. Currently, tourist visitation in the highlands of the park is infrequent and thus would not inhibit reproductive activities of this diurnal species in small streams. Unfortunately, very little is known about migration abilities and gene flow of Brazilian frogs at this small geographic scale. Knowledge of these features is essential for understanding population dynamics and the influence of habitat fragmentation on local extinctions (Avise 1994, Meffe & Carroll 1997). Indeed, for amphibians, local population dynamics and metapopulation connectivity are essential components of effective conservation plans (Semlitsch 2002). Studies on genetic variability are thus needed to infer the amount of inbreeding within the remaining populations of *C. bokermanni* and to estimate migration rates among them. Additionally, surveys should be conducted in other areas within the distribution of *E. flavopictus* to examine whether the decline recorded at the Serra do Cipó is a local event or a widespread phenomenon.

It is noteworthy that both *C. bokermanni* and *E. flavopictus* are diurnal stream inhabitants that occur at high elevations (>1000 m above sea level) at the Serra do Cipó. These features mirror those of several amphibian taxa reported to decline around the globe (Young *et al.* 2001, Lips *et al.* 2003). Presently, we cannot rule out the possibility that some of the causes underlying the declines recorded at the Serra do Cipó are related to causes of amphibian extinctions in several pristine areas of the world.

CONCLUSIONS

Based on combined data from literature, museum collections, and field observations, at least 20 Brazilian anuran species merit attention regarding population declines—be it in the form of research priority to verify their status, or in the form of conservation and management practices. *Epipedobates flavopictus* and *Crossodactylus bokermanni* are declining at a site in the Cerrado biome, the latter species with no records elsewhere. Both species are stream dwellers that occur above 400 and 800 m, respectively (IUCN *et al.* 2004). All other suspected cases are related to the Atlantic Forest, from variable altitudinal ranges. Most species are recorded at elevations up to 1000 m, some of them associated with streams (*Colostethus olfersioides, Hyla langei, Crossodactylus dispar, C. gaudichaudii, Hylodes babax, Cycloramphus boraceiensis, C. mirandaribeiroi, C. semipalmatus*, *Hyalinobatrachium uranoscopum*), whereas others use cliffs dripping with water for tadpole development (*Cycloramphus duseni, Thoropa lutzi, T. petropolitana*), are direct developers (*Adelophryne baturitensis*), or remain unknown regarding reproductive mode (*Colostethus carioca, Cycloramphus eleutherodactylus*). A few species are recorded only above 1500 m (*Eleutherodactylus paranaensis, Cycloramphus granulosus, Paratelmatobius lutzii*). Among these cases, there are no clear causes to explain observed declines, although severe winters (Heyer *et al.* 1988), pollution and acid rain, extended dry periods and diseases (Weygoldt 1989), habitat change, and fragmentation are some possible causing factors that have been associated with population crashes. Such factors have already been pointed as responsible for amphibian declines in several sites worldwide, though information is still incipient for most areas in Latin America (Young *et al.* 2001).

In the Neotropics, several cases of amphibian declines have been tied to climate change (*e.g.*, Pounds & Crump 1994, Pounds *et al.* 1999) and chytridiomycosis (*e.g.*, Berger *et al.* 1998, Lips 1998). Global warming alters temperature and patterns of cloud formation, forcing amphibian species to move upward beyond their original distributions, so that species already living in highlands may have nowhere to go (Pounds & Puschendorf 2004). Altered climate may also provide conditions for the proliferation of amphibian diseases such as chytridiomycosis (Ron *et al.* 2003), and influence pollutant deposition (Lips 1998), besides affecting amphibian reproductive success (Donnelly & Crump 1998). Several Brazilian anuran species are endemic to altitudes above 1000 m and may be suffering declines due to unsuitable climatic conditions, among other factors (*e.g.*, *Crossodactylus bokermanni, Eleutherodactylus paranaensis, Cycloramphus granulosus, Paratelmatobius lutzii*). Ron *et al.* (2003) associated the decline of *Atelopus ignescens* in the Andes of Ecuador to unusual climatic conditions and their interaction with chytridiomycosis. Burrowes *et al.* (2004) also reported the disappearance of three and the decline of six *Eleutherodactylus* species in Puerto Rico, supposedly caused by climate change (severe droughts) and disease interaction. Infectious diseases known to cause amphibian declines worldwide have not been reported for amphibians in Brazil, and related studies remain to be done.

Riparian species from highlands (above 600 m elevation) have been noticed to decline at many sites in South and Central Americas and Mexico (Young *et al.* 2001, Lips *et al.* 2004). In Brazil, even species with known altitudinal distribution from 100 to 600 m seem to be disappearing from apparently undisturbed sites (*e.g.*, *Hyla langei, Cycloramphus mirandaribeiroi*). In Latin America, studies of the effects of contaminants on amphibians are just beginning (Young *et al.* 2004); however, no studies have been done in Brazil. Other factors related to amphibian declines worldwide, such as species introduction, trade, and synergistic interactions among known causes of population crashes (Young *et al.* 2004) also deserve further attention since their impacts on our native amphibian fauna are unknown.

Much work remains to be done to clarify some of the pending questions and to mitigate amphibian declines in Brazil. As discussed throughout this paper, acquisition of new field data via short- and long-term studies is crucial. Only through detailed field studies will we be able to assess metapopulation dynamics, examine persistence of target populations in areas insofar unsampled or poorly sampled, and generate basic ecological data about taxa at risk. Investments to maintain and increase museum herpetological collections and to clarify systematic relationships and taxonomic issues are key efforts for the establishment of baseline data. Provided that many literature records suggest declines of montane and stream-associated populations of Brazilian amphibians in apparently pristine habitats, a high priority is to verify these cases and to investigate whether factors associated with similar extinctions in other parts of the globe—such as pathogens and climate change—can also be linked to local disappearances.

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Appendix. *Published records of amphibian declines and species extinctions in Brazil. ES = State of Espírito Santo, MG = State of Minas Gerais, PR = State of Paraná, RJ = State of Rio de Janeiro, and SP = State of São Paulo.*

Species	Natural history	Locality	Changes detected	References
Family Bufonidae				
Melanophryniscus moreirae	Diurnal, open vegetation >2000 m; uses shallow temporary pools after intense rains	Parque Nacional do Itatiaia, Serra da Mantiqueira (RJ, SP, MG)	1970's–1990's vs. 1950–1975: Decreased elevational range, smaller population. 1967: 3–8 frogs/m^2 (estimated 1000 indiv.) when breeding. 1981–1994: 11 total individuals observed.	Bokermann (1967), Guix *et al.* (1998)
Family Centrolenidae				
Hyalinobatrachium eurygnathum	Eggs on leaves over streams	Estação Biológica de Boracéia, SP	Late 1979:1–2 calling males/linear m of stream. After 1979: 2 males total among all streams.	Heyer *et al.* (1988)
		Santa Teresa, ES	Until 1981: males found every 2–10 m along stream, larvae common. 1987–88: No adults or larvae.	Weygoldt (1989)
		São Conrado, Maciço da Tijuca, Rio de Janeiro, RJ	1989, 2001: absent.	Weygoldt (1989), Izecksohn and Carvalho-e-Silva (2001)
Hyalinobatrachium uranoscopum	As above	Maciço da Tijuca, Rio de Janeiro, RJ	Not found for some (unspecified) years. Previously common.	Izecksohn and Carvalho-e-Silva (2001)
Family Dendrobatidae				
Colostethus carioca	Leaf litter	Represa Rio Grande, RJ	Not found since 1967 description. May be synonymous with *C. olfersioides*.	Izecksohn and Carvalho-e-Silva (2001)
Colostethus olfersioides	Diurnal, leaf litter; eggs in water-filled depressions, larvae in streams	Maciço da Tijuca, Rio de Janeiro, RJ	Not found for some (unspecified) years. Previously common.	Izecksohn and Carvalho-e-Silva (2001)
Colostethus cf. *olfersioides*	As above	Santa Teresa, ES	Prior to 1981 vs. 1988: Decreased numbers of calling males	Weygoldt (1989)

Appendix. *Continued.*

Species	Natural history	Locality	Changes detected	References
Family Hylidae				
Subfamily Hemiphractinae				
Flectonotus ohausi	Calls from cut-off bamboo ends	Estação Biológica de Boracéia, SP	Prior to 1970s vs. 1970s–1988: Decreased number of indiv. seen and heard. Bamboos flowered and died in the 1970s. Species possibly persisted at lower density, calling from tree holes.	Heyer *et al.* (1988)
Subfamily Hylinae				
Hyla circumdata	Along streams; eggs and larvae in flowing water	Parque Nacional da Tijuca, Rio de Janeiro, RJ	Not found for several (unspecified) years. Common in other highlands in RJ, SP, ES, MG.	Izecksohn and Carvalho-e-Silva (2001)
Hyla prasina	Calls from open areas and man-made lakes	Estação Biológica de Boracéia, SP	1948, 1963, 1965 vs. 1982–1984, 1990's: Decreased number of males heard, none collected from 1965–1988. Decline tied to higher abundance of *H. albopunctata*.	Heyer *et al.* (1988), Bertoluci and Heyer (1995)
Phyllodytes luteolus	Coastal areas, restinga; eggs and larvae in axils of bromeliad leaf	"Nativo Parajú", Linhares, ES	1993 vs. 1995: Declined after fire. 1996: Breeding activity detected at local ornamental garden. Declines not observed in other areas.	Eterovick (1999), Papp and Papp (2000)
Scinax perpusillus	Larvae in bromeliads	Estação Biológica de Boracéia, SP	Prior to 1979 vs. 1983: Decreased number of calling males. Prior to 1979: One male for every 2–3 bromeliads. 1983: 1–2 heard on any night. Slight recover in 1984. Abundant in early 1990's.	Heyer *et al.* (1988), Bertoluci and Heyer (1995)
Subfamily Phyllomedusinae				
Phasmahyla exilis	Eggs on leaves hanging over water, larvae in streams	Santa Teresa, ES	Prior to 1981 vs. late 1980's: Decreased number of tadpoles and adults. Until 1981: Thousands of tadpoles seen, adults common. 1987, 1988: Smaller groups of tadpoles (100–200), fewer streams with tadpoles, no frogs seen.	Weygoldt (1989)
Phasmahyla guttata	As above	Teresópolis, RJ	No records since 1979. Larvae abundant until then.	Heyer *et al.* (1988)
		Maciço da Tijuca, Rio de Janeiro, RJ	Declines inferred for last decades. 1989: Reported missing from most streams in São Conrado. Disappeared from some highland sites in RJ (no details provided).	Weygoldt (1989), Izecksohn and Carvalho-e-Silva (2001)
Family Leptodactylidae				
Subfamily Cycloramphinae				
Crossodactylus dispar	Diurnal, small streams or marshy areas with slow-moving waters	Estação Biológica de Boracéia, SP	Prior to 1979: Seen at two spots. 1982–1984, 1991, 1993–1994: Not found. Listed as locally extinct.	Heyer *et al.* (1988), Bertoluci and Heyer (1995)

Appendix. *Continued.*

Species	Natural history	Locality	Changes detected	References
		Santa Teresa, ES	Prior to 1981: Found in small numbers. 1987, 1988: Not seen.	Weygoldt (1989)
Crossodactylus gaudichaudii	In rocks along brooks, tadpoles in flowing water	Estação Biológica de Boracéia, SP	Not seen since 1979. 1989: *C. gaudichaudii* abundant in Maciço da Tijuca, RJ.	Heyer *et al.* (1988), Bertoluci and Heyer (1995)
Crossodactylus cf. *gaudichaudii*	As above	Santa Teresa, ES	Prior to 1981 vs. late 1980's: No new records of adults or larvae. Until 1981: Calling males spaced by 2 m, non-calling indiv. every 50–100 m, larvae abundant. 1987, 1988: No frogs or larvae seen.	Weygoldt (1989)
Cycloramphus boraceiensis	Larvae on quarry walls	Estação Biológica de Boracéia, SP	Prior to 1979 vs. 1982–1984, 1991, 1993–1994: No new records of previously abundant juveniles, no records of adults or larvae. 1988: Listed as locally extinct.	Heyer *et al.* (1988), Bertoluci and Heyer (1995)
Cycloramphus duseni	Vertical cliffs, dripping water	Near Casa Ipiranga, railway line Curitiba–Paranaguá, PR	Individuals unsuccessfully searched for since 1982. Known only from type series.	Heyer *et al.* (1988), Heyer (1983), M. Segalla (pers. obs.)
Cycloramphus eleutherodactylus	Forest-restricted, larvae believed terrestrial	Rio de Janeiro, RJ	Never found in township of Rio de Janeiro, where is registered to occur.	Izecksohn and Carvalho-e-Silva (2001)
Cycloramphus fuliginosus	Nocturnal; calls from rocks along forest streams	Santa Teresa, ES	Prior to 1981 vs. 1987, 1988: Decreased numbers of calling males. Prior to 1981: Distances between calling males 10–50 m. 1987, 1988: None heard.	Weygoldt (1989)
		Maciço da Tijuca, Rio de Janeiro, RJ	Not found for some (unspecified) years. 1989: Reported missing from most streams in São Conrado. Previously common.	Weygoldt (1989), Izecksohn and Carvalho-e-Silva (2001)
Cycloramphus granulosus		Brejo da Lapa, Parque Nacional de Itatiaia, MG	Searched for in 1982 and 1983, not found.	Heyer *et al.* (1988)
Cycloramphus semipalmatus	Calls along small brooks in forest	Estação Biológica de Boracéia, SP	Prior to 1979 vs. 1982–1984, 1991, 1993–1994: No new records of once common species. 1988: Listed as locally extinct.	Heyer *et al.* (1988), Bertoluci and Heyer (1995)
Hylodes asper	Diurnal; calls from rocks along streams	Estação Biológica de Boracéia, SP	Prior to 1979 vs. 1983, 1991, 1993–1994: No new records of once common species. 1988: Listed as locally extinct. Recently captured with help of pit-fall traps.	Heyer *et al.* (1988), Bertoluci and Heyer (1995), Lange (2004)
Hylodes babax	Diurnal, along forest streams	Santa Teresa, ES	Prior to 1981 vs. 1987: No new records of adults. 1988: Neither adults nor larvae found.	Weygoldt (1989)
Hylodes lateristrigatus	As above	Santa Teresa, ES	Prior to late 1970's vs. 1987, 1988: No new records of adults or larvae.	Weygoldt (1989)

Appendix. *Continued.*

Species	Natural history	Locality	Changes detected	References
Hylodes phyllodes	As above	Estação Biológica de Boracéia, SP	1979: Decreased number of calling males. Prior to 1979: 2–4 indiv. heard at any point. After 1979: 4 males heard in total. 1982–1984: Slight recovery. Early 1990's: Few indiv. heard in 3 streams.	Heyer *et al.* (1988), Bertoluci and Heyer (1995)
Paratelmatobius lutzii	Adults under rocks, amid mosses.	Brejo da Lapa, Parque Nacional de Itatiaia, MG	1957–1974, 1976, 1978 vs. after 1978: No new records of once easily collected species, several attempts made to find specimens.	Pombal and Haddad (1999)
Thoropa lutzi	Forest habitat; Larvae adhere to wet rocks	Rio de Janeiro, RJ	Not found for several (unspecified) years.	Izecksohn and Carvalho-e-Silva (2001)
Thoropa miliaris	Sub aerial larvae on quarry walls	Estação Biológica de Boracéia, SP	Prior to 1979 vs. 1982–1984: No new records of once common adults and larvae. 1988: Listed as locally extinct. Species still found elsewhere in SP and other states.	Heyer *et al.* (1988), Bertoluci and Heyer (1995), P. C. Eterovick (pers. obs.)
Thoropa petropolitana	Adults and larvae on wet, rocky walls along roads	Teresópolis, Serra dos Órgãos, RJ	No records since 1979. Species abundant and easily found until then.	Heyer *et al.* (1988)
Subfamily Eleutherodactylinae				
Eleutherodactylus guentheri	Ground dweller	Estação Biológica de Boracéia, SP	1979 vs. 1983, 1984: Decreased abundance. Abundent in 2004.	Heyer *et al.* (1988), Lange (2004)
Eleutherodactylus parvus	As above	Estação Biológica de Boracéia, SP	1979 vs. 1983, 1984: Decreased abundance.	Heyer *et al.* (1988)
Subfamily Leptodactylinae				
Adenomera marmorata	As above	Estação Biológica de Boracéia, SP	1979 vs. 1983, 1984: Decreased abundance. Abundant in 2004.	Heyer *et al.* (1988), Lange (2004)