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## NATURAL HISTORY AND CONSERVATION OF BUFONIDS IN FOUR ATLANTIC RAINFOREST AREAS OF SOUTHEASTERN BRAZIL

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**Abstract.** The distribution, habitat use, and pattern of activity of six bufonid species were studied in a 450 km section, from the southern part of the State of Rio de Janeiro through the southern State of São Paulo, in the coastal Atlantic Chain mountains of Brazil. The occurrence of each species was characterized at different spatial scales: macroecological (elevation), mesoecological (vegetation type), and microecological (water availability at ground level and ground slope). *Bufo crucifer* and *B. ictericus* occur at wide elevational ranges (0–940 m and 30–1870 m, respectively) and occupy a great diversity of environments. Conversely, the other species (*Bufo* aff. *margaritifera*, *Dendrophryniscus brevipollicatus*, *D. leucomystax* and *Melanophryniscus moreirae*) are restricted to narrow elevation ranges that are covered only by one or two types of vegetation, and to areas with a limited biotope variability. In the lowland Atlantic rainforest (0–50/150 m), four species of Bufonidae live in syntopy: *B. crucifer*, *B. ictericus*, *B. aff. margaritifera*, and *D. brevipollicatus*. Although all of them are ground-dwelling species, *Dendrophryniscus brevipollicatus* and *D. leucomystax* climb into the low vegetation. Adult *B. crucifer* and *B. ictericus* are mainly nocturnal, whereas adult *D. brevipollicatus* and *B. aff. margaritifera* are diurnal. *Dendrophryniscus brevipollicatus* is the only species occurring exclusively in biotopes lacking both permanent and temporary ground water points. Additional information on other syntopic anurans is given, and the inclusion of *M. moreirae* in the IUCN threatened species lists in the *Endangered/B1* category is proposed.

**Resumo.** História natural e conservação de bufonídeos em quatro áreas de Floresta Pluvial Atlântica do sudeste do Brasil. Analisou-se a distribuição, o uso de hábitat e o padrão de atividade de seis espécies de Bufonidae em um trecho de 450 km da cordilheira atlântica brasileira, situado entre o sul do estado do Rio de Janeiro e sul do estado de São Paulo. A presença de cada espécie foi caracterizada de acordo com diferentes escalas espaciais: nível macroecológico (altitude), mesoecológico (tipo de vegetação) e microecológico (disponibilidade de água ao nível do solo e inclinação do terreno). *Bufo crucifer* e *B. ictericus* ocorrem em intervalos de altitude amplos (0–940 e 30–1870 m, respectivamente), ocupando uma grande diversidade de ambientes. As outras espécies (*Bufo* aff. *margaritifera*, *Dendrophryniscus brevipollicatus*, *D. leucomystax* e *Melanophryniscus moreirae*) ocupam intervalos de altitude mais restritos, com um ou dois tipos de formações vegetais e em áreas com uma variedade de biótopos limitada. Na floresta pluvial atlântica da planície costeira (0–50/150 m), quatro espécies de Bufonidae convivem em sintopia: *B. crucifer*, *B. ictericus*, *B. aff. margaritifera* y *D. brevipollicatus*. Apesar de todas as espécies estudadas deambularem pela superfície do solo, *D. brevipollicatus* e *D. leucomystax* costumam trepar na vegetação baixa. Os adultos de *Bufo crucifer* e *B. ictericus* são principalmente noturnos enquanto que *D. brevipollicatus* y *B. aff. margaritifera* são diurnos. *Dendrophryniscus brevipollicatus* foi a única espécie encontrada exclusivamente em biótopos sem

pontos de acúmulo de água na superfície do solo, nem permanentes nem temporários. Apresenta-se informações adicionais sobre outras espécies sintópicas de anuros e propõe-se incluir *Melanophryniscus moreirae* nas listas de espécies em risco de extinção da IUCN, dentro da categoria de *ameaçada/B1*.

**Resumen.** *Historia natural y conservación de bufónidos en cuatro áreas de bosque pluvial atlántico del sudeste de Brasil.* Se analizaron la distribución, uso del hábitat y patrón de actividad de seis especies de Bufonidae en un tramo de 450 km de la Cordillera Atlántica brasileña, entre el sur del estado de Rio de Janeiro y el sur del de São Paulo. La presencia de cada especie se caracterizó a diferentes escalas espaciales: niveles macroecológico (altitud), mesoecológico (tipo de vegetación) y microecológico (disponibilidad de agua a nivel del suelo y pendiente). *Bufo crucifer* y *B. ictericus* se localizan en intervalos de altitud amplios (0–940 m y 30–1870 m, respectivamente), ocupando una gran diversidad de ambientes. Las demás especies (*Bufo* aff. *margaritifera*, *Dendrophryniscus brevipollicatus*, *D. leucomystax* y *Melanophryniscus moreirae*) ocupan rangos de altitud más restringidos, con uno o dos tipos de vegetación, y áreas con una variedad de biotopos limitada. En el bosque pluvial atlántico de llanuras (0–50/150 m), cuatro especies de Bufonidae conviven en sintopía: *B. crucifer*, *B. ictericus*, *B. aff. margaritifera* y *D. brevipollicatus*. Aunque todas son especies de suelo, *D. brevipollicatus* y *D. leucomystax* se encaraman en la vegetación baja. Los adultos de *Bufo crucifer* y *B. ictericus* son principalmente nocturnos en tanto que *D. brevipollicatus* y *B. aff. margaritifera* son diurnos. *Dendrophryniscus brevipollicatus* es la única especie hallada exclusivamente en biotopos sin puntos de agua en el suelo, ni permanentes ni temporales. Se presenta información adicional sobre otras especies sintópicas de anuros y se propone incluir *Melanophryniscus moreirae* en las listas de especies susceptibles de extinción de la IUCN, dentro de la categoría de *amenazada/B1*.

**Key words.** Brazilian Atlantic Rainforest; Bufonidae; Natural history; Conservation status; *Bufo margaritifera*; *Melanophryniscus moreirae*.

Little is known about the ecology of South American bufonids, especially with respect to their habitat requirements (Duellman 1978; Duellman and Trueb 1986). In fact, several species are often found living in sympatry in tropical ecosystems. Usually, two or three species of *Bufo*, varying greatly in size, occur in the same area and share the same habitat (but see Duellman and Mendelson 1995). When living syntopically, these species frequently breed side by side at the same water bodies (e.g. pools, lagoons, rivers; see Guix et al. 1994; Heyer et al. 1990; Toft 1985). If ecological resources are limited, syntopy may involve resource partitioning, including space (terrestrial and aquatic habitats of adults, breeding sites), time, and food. The number of species living together seems to be determined by the complexity of the environment (Toft 1985).

At least 12 species of Bufonidae occur in southeastern Brazil (Frost 1985; Hass et al. 1995). Of these species, five live in the coastal Atlantic forests between the cities of São Paulo

and Rio de Janeiro: three in the Atlantic rainforest (*Bufo ictericus*, *B. aff. margaritifera*, *Dendrophryniscus brevipollicatus*); one (*B. crucifer*) in the Atlantic rainforest and in the restinga (scrubland and forest; sensu Hueck 1972a,b), and one (*D. leucomystax*) in the restinga forest. Another species (*Melanophryniscus moreirae*) lives in the high mountains above the forest limits (Frost 1985). Finally, *B. pygmaeus* is found in the restingas of the State of Rio de Janeiro, and *B. paracnemis*, an inland species, is absent from all of the former ecosystems. Data concerning habitat use by these species are scarce and are restricted to breeding sites or small areas with respect to their geographic distribution (Bokermann 1967; Carvalho 1949; Guix 1993; Guix et al. 1994; Haddad and Sazima 1992; Heyer et al. 1990). This paper describes habitat use by sympatric and allopatric species of Bufonidae which inhabit a 450 km section of the Serra do Mar mountain chain (including the adjacent Serra da Mantiqueira), which is mainly covered by native forest.

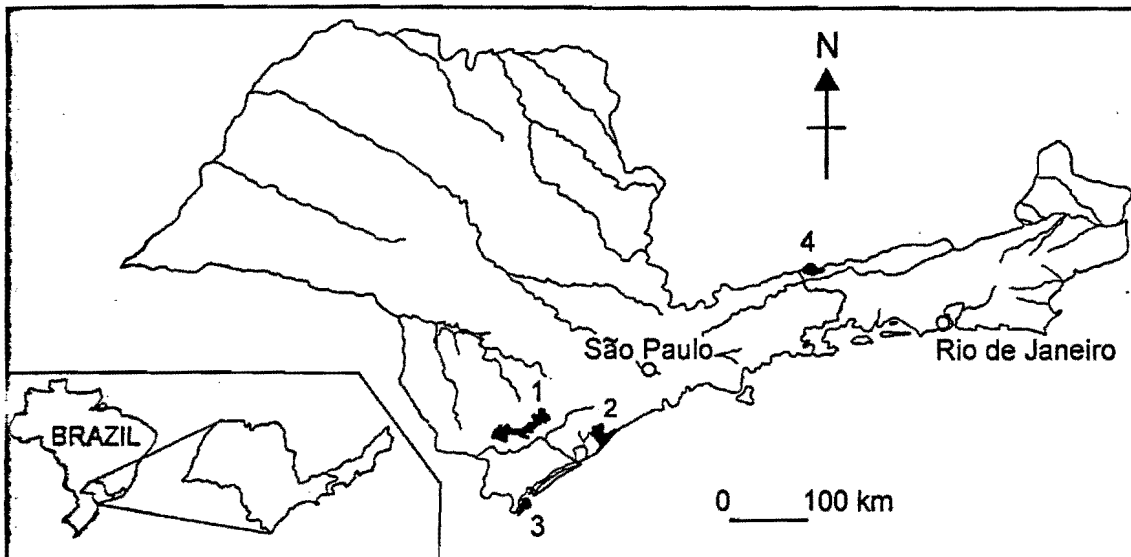


Figure 1. Location of the study areas in the States of São Paulo and Rio de Janeiro. 1—Paranapiacaba; 2—Estação Ecológica de Juréia e Itatins; 3—Parque Estadual da Ilha do Cardoso; 4—Parque Nacional de Itatiaia.

## MATERIALS AND METHODS

### Study Areas

Three main geographic units can be distinguished from east to west in the 450 km coastal section studied (Fig. 1): the coastal plain, the Atlantic mountain chain, and the high plateau. The coastal plain (< 3 m elevation), composed of sandy soils of Quaternary origin, is situated between the Atlantic Ocean and the Atlantic Chain. The Atlantic Chain, locally called Serra do Mar, is a Pre-Cambrian mountain complex nearly 900 km in length, running parallel to the coast. In the State of São Paulo, this coastal chain reaches an elevation of 2058 m. The plateau (400–900 m) is located west of the Atlantic Chain and includes the Serra da Mantiqueira Chain which reaches an elevation of 2787 m.

**Paranapiacaba** (State of São Paulo). This area is composed of four contiguous protected reserves and several private properties located at Serra de Paranapiacaba in the Atlantic Chain. Data were collected at Parque Estadual de Carlos Botelho (37,644 ha; 24°10' S, 47°55' W) and Parque Estadual Intervales (38,356 ha; 24°20' S, 48°15' W), both mainly covered by mature and old secondary Atlantic rainforest with an elevational range from 20–1095 m.

**Estação Ecológica de Juréia e Itatins** (State of São Paulo). This area is located between the cities of Peruibe and Cananéia in the Maciço da Juréia and Serra dos Itatins (79,830 ha; 24° 32' S, 47° 15' W), also in the Atlantic Chain. It is covered by mature and secondary Atlantic rainforest, mangroves, bushy restinga, forest restinga, and mountain steppes and has an elevational range of 0–870 m (Maciço da Juréia).

**Parque Estadual da Ilha do Cardoso** (State of São Paulo). This site is located on the continental island of Cardoso (22,500 ha; 25°10' S, 48°00' W) and is covered by mature and secondary forests, mangroves, and bushy and forest restinga. Its elevational range is 0–890 m.

**Parque Nacional de Itatiaia** (State of Rio de Janeiro). This park is located in the Serra da Mantiqueira on the border of the States of São Paulo, Rio de Janeiro, and Minas Gerais (11,943 ha; 22°37' S, 44°45' W). It is covered by old secondary Atlantic rainforest, cloud forest, and elevational steppes with bushes. The elevational range is 816–2787 m.

### Field Methods

Between November 1981 and August 1994, these areas were surveyed in search of bufonid frogs (adults, juveniles, larvae, egg clutches).

Throughout this period, field campaigns were carried out depending on logistical support and access conditions. Nevertheless, because the period of study was so long, all seasons, hours, vegetation types, and elevations were covered. Thus, it is assumed that the sampling effort was uniform with respect to these variables at the scale levels of the study. When necessary, eggs and tadpoles were carried to the laboratory in order to enable species identification of dubious specimens. Voucher specimens (tadpoles, juveniles, adults) were deposited in the Werner C.A. Bokermann collection (now in the Museu de Zoologia of Universidade de São Paulo—MZUSP) and in Departamento de Zoologia of Instituto de Biologia, Universidade de Campinas (ZUEC).

For each observation, data on five ecological variables representing different spatial scales were considered (Blondel 1986; concerning bufonids see Guix 1983, 1993, and Guix et al. 1994): macroecological (elevation), mesoecological (vegetation type), microecological (water availability and ground slope).

**Elevation.** Data were recorded by altimeter and confirmed by isoclines in 1:50,000 maps.

**Vegetation type.** Typing was done according to the classification of Hueck (1972a,b; see Table 1).

**Water availability.** Several categories based on water availability at ground level were registered in accordance with our observations of bufonids (see Table 2).

**Ground slope.** Slopes were measured with a geological clinometer (10 m line) at sites where

active adult specimens were found.

**Activity.** Seasonal and daily activities of toads were recorded. Seasonal activity was divided into two periods: winter (June–September), and the rest of the year. Daily activity was categorized as diurnal (0700–1700h) and crepuscular/nocturnal (1700–0700h). Additional data on activity patterns and biotope characteristics of other syntopic ground-dwelling anurans (mainly leptodactylids) were collected in the same study areas in order to complete the analysis of the amphibian community.

## RESULTS

Six species of Bufonidae were documented in the coastal section; no specimens of *Bufo pygmaeus* were found. Two species (*B. ictericus* and *B. crucifer*) were found at the widest range of elevations covered by different vegetation types (Fig. 2; Table 1). *Bufo crucifer* was found from sea level to 940 m (in scrubland and forest restinga, and in Atlantic rainforest) and *B. ictericus* occurred at altitudes between 30–1870 m (mainly in Atlantic rainforest).

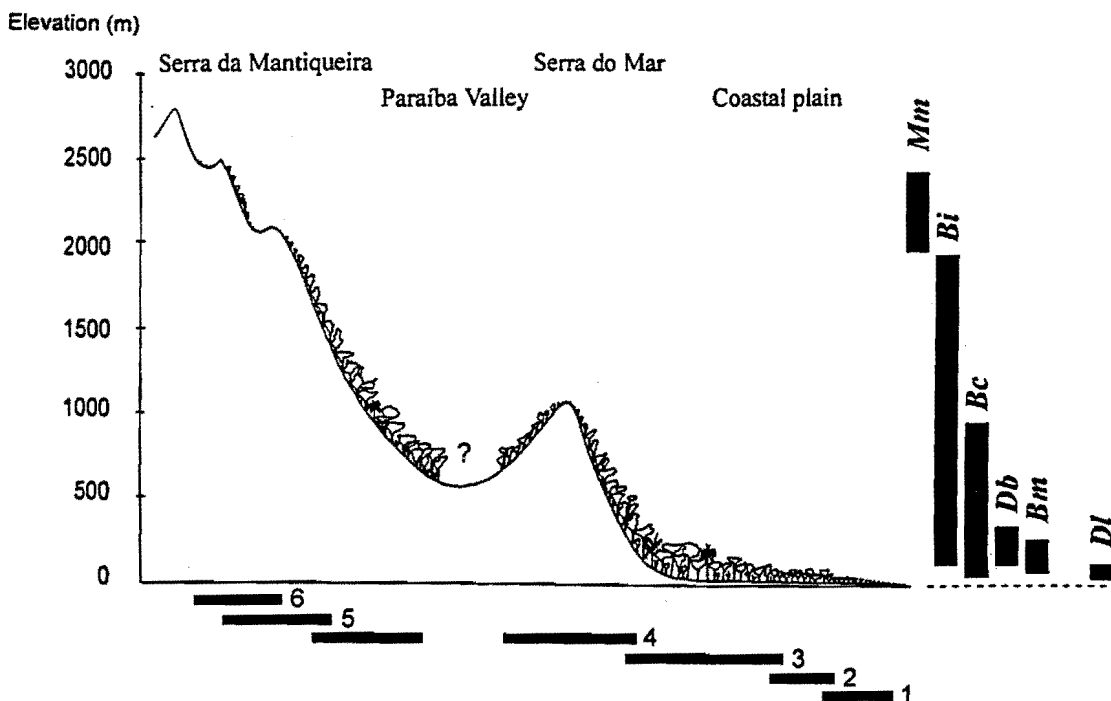
Conversely, *Bufo* aff. *margaritifera*, *Dendrophryniscus leucomystax*, *D. brevipollicatus*, and *Melanophryniscus moreirae* were restricted to narrow elevational ranges and to only one or two vegetation types (Fig. 2; Table 1). *Bufo* aff. *margaritifera*, *D. brevipollicatus*, and *D. leucomystax* were present only in the lowlands (below 300 m), and *M. moreirae* only in the highlands (1940–2350 m).

**TABLE 1.** Occurrence (×) of bufonid species in the vegetation types of the study areas. Forest types and elevational distribution of the vegetation based in Hueck (1972a,b). (\*) = only tadpoles (Guix and Lopes 1989). Mm—*Melanophryniscus moreirae*, Bi—*Bufo ictericus*, Bc—*B. crucifer*, Bm—*B. aff. margaritifera*, Db—*Dendrophryniscus brevipollicatus*, Dl—*D. leucomystax*.

Vegetation types	Elevation (m)	Species					
		Mm	Bi	Bc	Bm	Db	Dl
Elevational steppes	2000–2500	×	-	-	-	-	-
Cloud Atlantic forest	1200–2300	-	×	-	-	-	-
Hillside Atlantic rainforest	50–1600	-	×	×	-	×	-
Lowland Atlantic rainforest	3–150	-	×	×	×	×	-
Forest Restinga	1–3	-	-	×	-	-	×
Scrubland "Restinga"	1–3	-	-	×	-	-	×
Mangroves	<1	-	-	*	-	-	-

**TABLE 2.** Occurrence (×) of Bufonidae species in eleven categories based on water availability in the study areas. (a) rivers, streams and brooks surrounded by native forest (mature or old secondary); (b) permanent artificial lagoons or lakes surrounded by *Typha* sp. vegetation and native forest; (c) permanent artificial lagoons or lakes surrounded by *Typha* sp. vegetation, pioneering herbaceous vegetation and artificial forest of *Araucaria angustifolia* + pioneering bush; (d) temporary artificial lagoons surrounded by native forest; (e) temporary pools surrounded by pioneering herbaceous vegetation and secondary forests along unpaved roads; (f) native forests outside the zone of permanent water sources (lakes, lagoons, rivers, streams and brooks), and temporary lagoons or pools; (g) clearings in mature and secondary forests, outside the zone of permanent water sources, and temporary lagoons or pools; (h) clearings in mature and secondary forests, inside the zone of permanent water sources, temporary lagoons or pools; (i) scrub (restinga scrubland) partially flooded; (j) forest (restinga) partially flooded; (k) elevational steppe + bushes with brooks, small lakes and temporary lagoons or pools.

Species	Categories										
	a	b	c	d	e	f	g	h	i	j	k
<i>Bufo crucifer</i>	×	×	-	×	×	-	-	×	-	-	-
<i>B. ictericus</i>	×	×	×	-	×	×	-	×	-	-	-
<i>B. aff. margaritifera</i>	×	-	-	-	-	-	-	-	-	-	-
<i>Dendrophryniscus brevipollicatus</i>	-	-	-	-	-	×	×	-	-	-	-
<i>D. leucomystax</i>	-	-	-	-	-	-	-	-	×	×	-
<i>Melanophryniscus moreirae</i>	-	-	-	-	-	-	-	-	-	-	×



**Figure 2.** Elevational distribution of six bufonid species in relation to vegetation type in the study areas. Localities are listed from east to west as follows: the coastal plain (CP), the “Serra do Mar” Atlantic Chain (AC), the Paraiba Valley in the plateau (PV), and the “Serra da Mantiqueira” (SM). Vegetation types: 1—Restinga scrubland; 2—Restinga forest; 3—Lowland Atlantic rainforest; 4—Hillsides Atlantic rainforest; 5—Cloud Atlantic forest; 6—Elevational steppe; ?—Unknown forest type completely destroyed by early colonization (according to Hueck 1972a).

**TABLE 3.** Occurrence of adult bufonids ( $n = 253$ ) observed on the ground according to ground slope categories.

Species	Slope			
	0-10°	11-30°	31-45°	total
<i>Bufo crucifer</i>	26	22	1	49
<i>B. ictericus</i>	66	64	2	132
<i>B. aff. margaritifera</i>	32	1	0	33
<i>Dendrophryniscus brevipollicatus</i>	5	7	1	13
<i>D. leucomystax</i>	9	0	0	9
<i>Melanophryniscus moreirae</i>	12	5	0	17

Observations of bufonids were also made in different categories of water availability (Table 2). *Bufo ictericus* and *B. crucifer* again occupied the highest diversity, whereas the other species were found in only one or two categories. Biotopes characterized by the absence of water at the ground level were used only by *D. brevipollicatus* (categories f and g), and by female *B. ictericus* (category f). However, male *B. ictericus* were absent in such places.

With regard to ground slope (Table 3), the general pattern was a decrease in the number of observations as slope increased. *Bufo ictericus*, *B. crucifer*, and *Dendrophryniscus brevipollicatus* used the highest diversity of slopes. Only the three *Bufo* species were compared because the samples of the others were too small. No significant differences were found in the effect of ground slope on the

presence of *B. crucifer* and *B. ictericus* ( $\chi^2 = 0.222$ , 2 *df*,  $P = 0.89$ ). However, ground slope use was significantly different between *B. aff. margaritifera* and *B. crucifer* ( $\chi^2 = 18.372$ , 2 *df*,  $P < 0.001$ ) and *B. aff. margaritifera* and *B. ictericus* ( $\chi^2 = 24.152$ , 2 *df*,  $P < 0.00001$ ).

In the lowlands (below 300 m), *Bufo crucifer*, *B. ictericus*, *B. aff. margaritifera*, and *D. brevipollicatus* were simultaneously active during winter (June–September). Other ground-dwelling anurans, such as *Adenomera marmorata* and *Eleutherodactylus binotatus* (Leptodactylidae), were also found syntopically in the winter. In the mountains (above 300 m) *B. crucifer* and *B. ictericus*, as well as syntopic leptodactylids (*A. marmorata* and *E. binotatus*), were observed to be active during winter. Occasionally, winter breeding activity by *B. crucifer* and *B. ictericus* was detected (advertising

**TABLE 4.** General patterns of daily activity in bufonids ( $n = 581$ ). Numbers indicate the active specimens observed.

Species	Diurnal		Crepuscular- Nocturnal adults
	adults	recently metamorphosed and juveniles	
<i>Bufo crucifer</i>	3	64	62
<i>B. ictericus</i>	81	102	228
<i>B. aff. margaritifera</i>	39	37	2
<i>Dendrophryniscus brevipollicatus</i>	14	-	2
<i>D. leucomystax</i>	9	-	-
<i>Melanophryniscus moreirae</i>	11	-	-

<sup>1</sup>all females inside forests.

**TABLE 5.** Daily activity of bufonids and other syntopic anurans (ground-dwelling, sit-and-wait species) in three regions of Serra de Paranapiacaba with the same category of water availability ("a" in Table 2: rivers, streams and brooks surrounded by native forest; mature or old secondary) and different elevation: A—Riacho da Ponte 600–800 m (Parque Estadual de Carlos Botelho), B—São Pedro 350–500 (P.E. Intervales), C—Funil 40–150 (P.E. Intervales).

Family/Species	Nocturnal	Diurnal	Localities		
			A	B	C
<b>Bufonidae</b>					
<i>Bufo crucifer</i>	×		×	×	×
<i>Bufo ictericus</i>	×		×	×	×
<i>Bufo</i> aff. <i>margaritifera</i>	×?	×			×
<b>Leptodactylidae</b>					
<i>Eleutherodactylus binotatus</i>	×	×		×	×
<i>Eleutherodactylus guentheri</i>	×		×		
<i>Physalaemus olfersi</i>	×		×		
<i>Physalaemus moreirae</i> (= <i>P. franciscae</i> )	×			×	×
<i>Crossodactylus dispar</i>		×	×		
<i>Adenomera marmorata</i>		×	×		×
<b>Ceratophryidae</b>					
<i>Proceratophrys boiei</i>		×	×		

calls, amplexus, clutches recently laid). *Melanophryniscus moreirae* activity was observed from October–March. More sampling effort is needed during winter in the highlands.

Patterns of daily activity among the sampled bufonid species were varied (Table 4). Adult *Bufo crucifer* and *B. ictericus* are mainly nocturnal, whereas the rest of the sampled bufonids, including the juveniles of the former species, are diurnal. More detailed observations on these anurans in three different elevational sites belonging to the same category of water availability (Table 5) show that in all localities, several ground-dwelling, non-bufonid species were found to be active together with *Bufo* spp. both by day and by night.

## DISCUSSION

The zone of the highest syntopy of bufonids in the study areas was found in the foothills of the Serra de Paranapiacaba (Fig. 1), where lowland and hillside Atlantic rainforest meet. In P.E. Intervales (Funil region, 40–150 m), four bufonids were found in syntopy: *Bufo ictericus*, *B. crucifer*, *B. aff. margaritifera*, and *Dendrophryniscus brevipollicatus*.

*us*. In P.E. Carlos Botelho (Sete Barras region, 40–150 m), a preliminary study detected the same species of *Bufo*, and also *D. brevipollicatus* (Guix et al. 1994; see Table 1, Fig. 2).

The foothills of the Serra de Paranapiacaba (20–150 m) have a great richness of forest anuran species (see Guix et al. 1994). This diversity may be related to both historical and ecological factors. On one hand, past climatic and vegetational changes during the Pleistocene led to the wet forest becoming isolated among open and semi-open formations in the so-called Pleistocene refugia along the Atlantic Chain (Haffer 1979; Lynch 1979). On the other hand, there are alternative explanations for diversity, including climatic stability (Klopfer 1959), habitat heterogeneity (Pianka 1966), and energy (Hutchinson 1959) and productivity hypotheses (Tilman 1982). The scale of this study should also be taken into account. Thus, the influences on ecotone effect in the medium elevation areas could explain the simultaneous presence of lowland and highland bufonids.

The present distribution of *Melanophryniscus moreirae*, restricted to the highest elevations of southeastern Brazil surrounded by rainforests

(Bokermann 1967; J.P. Pombal Jr., in litt., 1997), may be the result of climate alternations in the Pleistocene (see Haffer 1979; Simpson 1979). During dry, cold periods, the range of the genus *Melanophryniscus* was probably more extensive than present. But during interglacial periods like the present the climate became warmer and more humid, allowing the expansion of tropical wet forest upwards at the expense of the open and semi-open vegetation now present at high elevations in the Itatiaia National Park. The populations of the genus *Melanophryniscus* would follow the same dynamics of open vegetation and, consequently, became isolated in highlands. At present, steppes cover several high elevations of the Atlantic chain, but *M. moreirae* has been found only in Itatiaia. It remains unclear if this is due to historical causes or to the scarcity of water bodies suitable for breeding in the other localities.

The abundance and type of water bodies available probably determine which the most abundant species are in each area. In the zone of elevational overlap between *Bufo crucifer* and *B. ictericus* (30–940 m), these species use the same breeding sites (e.g. pools, lagoons) at the same time (Haddad and Sazima 1992; Haddad et al. 1990; Heyer et al. 1990).

*Bufo* aff. *margaritifera* has often been found inactive at night on vegetation in the Upper Amazon (Duellman 1978; Duellman and Mendelson 1995). However, in the study areas, only *Dendrophryniscus brevipollicatus* and *D. leucomystax* were observed climbing in vegetation and trunks which have fallen over in the forest (< 1.7 m high). The ability to use the vertical dimension of habitat enables *D. brevipollicatus* not only to breed on the ground, as do other members of the family, but also to use epiphytic bromeliads (thus not depending exclusively on ground water; Carvalho 1949). *Dendrophryniscus leucomystax* uses temporary flooded forests, such as the restinga vegetation during the period of major rainfalls (December–February).

Although *Dendrophryniscus brevipollicatus* has been considered a forest species (Guix et al. 1994; Heyer et al. 1990), it was also found in small clearings surrounded by forest, in places where there was dense vegetation (herbaceous plants, bushes and epiphytic bromeliads on fallen trunks).

In terms of elevational distribution, *Bufo crucifer* was found up to an altitude of 900 m in the Atlantic Chain. However, the maximum elevation could be higher at Serra da Mantiqueira because in this area (P.N. Itatiaia) the hillside Atlantic rainforest rises to higher elevations than in the Atlantic Chain (Hueck 1972b). On the other hand, despite of the fact that *Dendrophryniscus brevipollicatus* was found only at elevation from 40–290 m, the species has been reported at higher elevations, but without precise elevation data given (Carvalho 1949; Heyer et al. 1990; Jimenez de la Espada 1875).

Concordance between the use of slopes and elevational level was found. Differences in the use of slopes by *Bufo* spp. were evident: most adult *B. crucifer* and *B. ictericus* were found on flat to moderate slopes, whereas adult *B. aff. margaritifera* were usually found in flat areas (Table 3). This suggests a preference by the latter species for gently sloping areas, which determines the distribution at a larger scale. In fact, *B. aff. margaritifera*, along with *Dendrophryniscus* spp., occur only at the lowest elevations and plains whereas the other *Bufo* species reach higher elevations (Fig. 2; Table 3).

Although the species studied are tropical, they show great variation in seasonal activity; sharp temperature drops, due to the penetration of southern polar air masses, often affect the mountainous areas (>200 m) of southeastern Brazil (Bigarella 1978; Nimer 1979). Air temperature may fall below 0°C during the winter (e.g. –4°C on 29 July 1994). None of the species were seen active when air temperature was below 12.5°C (Guix 1996). Thus, these wide variations in winter temperatures are the most probable factors inducing winter “intermittent activity” in these bufonids (and other anurans) living in the mountains. Conversely, in the lowland sedimentary valleys, the minimum temperatures do not drop to such low levels, rainfall is more uniform throughout the year, and anurans remain active almost all year (Guix 1996).

Concerning daily activity, intraspecific differences were evident. *Dendrophryniscus* sp. and *Melanophryniscus moreirae* are diurnal. Adult *Bufo* aff. *margaritifera* are also mainly diurnal while the adults of the other *Bufo* spp. are nocturnal. Moreover, recently metamorphosed animals and juveniles belonging to all three *Bufo* species were found only by day. Consequently, *B. ictericus*



and *B. crucifer* (but not *B. aff. margaritifera*) show size differences in daily activity. As in other nocturnal species of *Bufo* (de la Riva 1993; Guix 1983), some adults were also detected by day but these seem to be rare events. *Bufo aff. margaritifera* from southeastern Brazil seems to be considered a diurnal species. However, de la Riva (1993) pointed out that Amazonian species of the *Bufo margaritifera* complex (see Hoogmoed 1995) have diurnal feeding activity and breed by night (see also Escure and Gasc 1986).

Nocturnal/crepuscular species were found to occur in more vegetation types and categories of water availability than diurnal species (Table 2). Nocturnality gives dispersal, and possibly survival, advantage to butterflies, beetles, birds, and bats living in tropical forests under anthropogenic disturbance (Daily and Ehrlich 1996). This may mean that diurnal bufonids have a poorer environmental tolerance, and fewer dispersal and colonization possibilities than nocturnal bufonids when faced with human interferences. This is not only due to the increase of isolation in deforested areas but also to indirect causes, such as lower humidity or higher vulnerability to predators. Although it has been assumed that dispersal by *Bufo* spp. is greater during the larval stage (e.g., when eggs are laid in streams and rivers; Guix 1993), adults also seem to play an important role in dispersal and colonization (Blair 1953; Dodd 1994; Gittins et al. 1980). Juvenile *B. ictericus* and *B. crucifer* were observed active by day. However, no data are available on their dispersal ability in comparison with adults.

#### Conservation Status

The conservation status of many amphibians from southeastern Brazil is virtually unknown. Little information on distribution, natural history and ecology of the endemic species is available and there are no published data on their past and present densities.

Among the bufonids studied, both *Bufo ictericus* and *B. crucifer* are widely distributed (*B. ictericus*: from southeastern Brazil to eastern Paraguay; *B. crucifer*: from northeastern, eastern, and southeastern Brazil to eastern Paraguay, northern Argentina and Uruguay; Frost 1985). These species tolerate deforestation and other anthropogenic

interference in their habitats (e.g., agriculture) and sometimes are even favored by the proximity of human settlements (e.g., elimination of local predators, creation of new breeding sites).

*Dendrophryniscus brevipollicatus* and *D. leucomystax* are endemic to southeastern coastal forests of Brazil. Their distributions are wide (*D. brevipollicatus* from Espírito Santo to Rio Grande do Sul; *D. leucomystax* in Rio de Janeiro and São Paulo; Frost 1985; Izecksohn 1968), but both species have lost great portions of their original habitats in the last 30 years. As a forest species using ground bromelias, *D. brevipollicatus* may be more sensitive to deforestation than *D. leucomystax*.

An evaluation of the conservation status of the populations of *Bufo aff. margaritifera* in southeastern Brazil is only possible after a wide re-evaluation of their taxonomic status. The name *B. "margaritifera"* (formerly *B. typhonius*) includes many species in Central and South America (Hass et al. 1995; Hoogmoed 1989, 1990). In the study areas, *B. aff. margaritifera* lives in mature and old secondary lowland Atlantic forest in a narrow elevational range (5–150 m). During the last few decades, this forest has been intensely deforested and disturbed. *Bufo aff. margaritifera* from the Atlantic rainforest (as with other members of the complex in Amazonia; de la Riva 1993; Heyer 1976) does not seem to tolerate deforestation and agriculture and is not found close to buildings in the areas where extensive forests remain. Thus, these populations could decrease in the near future. While the taxonomic re-evaluation of *B. aff. margaritifera* has not been completed, it would be appropriate to include the southeastern Brazil populations in the *Data Deficient* category, according to IUCN's reviewed criteria (IUCN 1994, 1996; Mace and Stuart 1994).

In the past, *Melanophryniscus moreirae* was also assigned to Amazonian (Cochran 1948, in Frost 1985) and Guianan Regions (Hoogmoed 1979), and even to other areas dominated by Atlantic rainforest (Lutz 1954). However, at present, the species is considered to be endemic at the highest elevations of the Itatiaia National Park in southeastern Brazil (1800–2400 m; Bokermann 1966, 1967; J. P. Pombal, in litt., 1997). During the last two decades, both population and elevational range decrease in comparison with the 1950–75

period have been suggested (W.C.A. Bokermann, pers. comm., 1994; see also Bokermann 1967 in relation with previous periods). This species was not included in either Brazilian or international lists of threatened species of amphibians (Anonymous 1989; Bernardes et al. 1990; IUCN 1996; M. Gimenez Dixon, pers. comm., 1996). Because the habitat of *M. moreirae* falls within a protected area, and no evident anthropogenic alterations in the vegetation were detected during the last few decades, the possibility of a *M. moreirae* decline due to ultraviolet radiation, infectious diseases, or other such causes should not be discarded, as has been suggested for other high mountain amphibian species (e.g., Blaustein and Wake 1995; White 1995). No more precise data on the distribution of *M. moreirae* are available. However, the range of distribution of this species was estimated to be less than 2000 km<sup>2</sup> (mainly in Vale do Rio Maromba; Bokermann 1967; JCG, pers. obs., 1990). Thus, considering this restricted distribution and the possibility of population decline (see above), the inclusion in the *Endangered/B1* category, according to IUCN's criteria (IUCN 1994, 1996) is proposed.

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