

Anuran hotspots: the municipality of Santa Teresa, Espírito Santo, southeastern Brazil

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Abstract. A total amount of 102 anuran species has been recorded for the municipality of Santa Teresa, Espírito Santo, southeastern Brazil. Santa Teresa is type locality to 14 anuran species and the area is characterised by a high degree of endemism. The anuran fauna is dominated by Hylidae (48.5%), followed by Cycloramphidae (17.8%), Brachycephalidae (9.9%) and Leptodactylidae (8.9%). Other families found represented in smaller percentages are Aromobatidae, Bufonidae, Centrolenidae, Ceratophryidae, Microhylidae, Pipidae and Thoropidae. Macrogeographical comparisons using species lists for other areas showed greatest similarities with nearby locations situated in the Atlantic forest and greatest differences when compared with communities in Cerrado-Caatinga formations. Furthermore, a shift in family composition was observed from north to south. Microgeographical variations in species composition were observed within five areas sampled in the municipality of Santa Teresa. As a consequence, we recommend that multiple sites be analysed to get a more comprehensive picture of species inhabiting an area. From the species found at Santa Teresa, 10.8 % are considered as Data Deficient, 4.9 % as Nearly Threatened, 2.0 % as Vulnerable and 1.0 % as Endangered under the current IUCN Red List. A total of 13 species (12.7 %) have not been considered for Red List status. Further investigation is necessary to get a better basis for the establishment of conservation measures.

Key words. Amphibia, Anura, species richness, endemism, biogeography, conservation, Red List status.

Introduction

Generally speaking, the amphibian fauna of South America remains poorly known and new species are often found, particularly in recent decades, due to the discovery of cryptic species with modern methods (e.g. KÖHLER et al. 2005). This situation is related to the great diversity in the number of species that make up Neotropical communities. Brazil is the world leader in amphibian diversity in terms of species richness. Currently 751 species are known to occur and 489 are endemic (IUCN et al. 2006). SILVANO & SEGELLA (2005) referred to about 765 amphibian species in Brazil, which were listed by the Sociedade Brasileira de Herpetologia in 2004.

The highest amphibian species densities in Brazil can be found in two major areas: the Amazon basin (Amazonia-Guiana: 335 species) and the Atlantic forest (334 spe-

cies) (DUELLMAN 1999). Many models have been postulated to explain the high diversity found in rainforests. Among the most common are the refugia, the riverine and the gradient theories (MORITZ et al. 2000). The Amazon basin and the Atlantic forest were found to be the earliest areas separated by analysing amphibian distribution patterns (RON 2000). Xeric formations (Caatinga/Cerrado/Chaco) spatially separate species occurring in the Amazon basin from those of the Atlantic forest and, together with high habitat diversity due to elevation gradients and temperature changes during the Pleistocene, it is suggested that this has resulted in the high degree of speciation in the Atlantic forest. The latter is one of the biodiversity hotspots of the world (MYERS et al. 2000) containing high percentages of endemic amphibians (300 out of 322 species) (DUELLMAN 1999), but at the same time one of the most threatened due to mas-

sive logging and extensive agricultural use (MORELLATO & HADDAD 2000).

Anuran species richness per locality can be remarkable. Mt. Nlonako, Cameroon, is among the most species-rich areas for anurans in the world with 91 species (HERRMANN et al. 2005). According to DUELLMAN (1990), Santa Cecilia, Ecuador, has 86 species. For Brazil, the Estação Biológica de Boracéia, situated in the Atlantic Forest, is one of these areas situated in the Atlantic Forest (68 species) (HEYER et al. 1990, BERTOLUCI & HEYER 1995, BERTOLUCI & RODRIGUES 2002). The area around Santa Teresa, Espírito Santo, has been repeatedly studied during the last decades, but no summary of species found is currently available, although the area is known for its high degree of diversity and endemism (POMBAL et al. 2003).

We provide here information on species diversity in the municipality of Santa Teresa, compare it with information available for different species assemblages along the Atlantic forest and analyse biogeographic relationships. Our data suggest that for anurans Santa Teresa is one of the species richest areas of the world.

Materials and methods

Study sites

The anuran fauna was recorded in different areas in the municipality of Santa Teresa (Fig. 1). The best sampled area is the Biological Reserve of Santa Lúcia (EBSL). General information on EBSL (19°58.000 S, 40°32.150 W; 812 m above sea level) can be found in MENDES & PADOVAN (2000). The reserve has approximately 440 ha comprising well preserved remnants of the Atlantic Rainforest. The climate is categorized as tropical super wet with a sub dry season. During the day, the minimal mean temperature is 14.3 °C, whereas the maximal is 26.2 °C. According to the KÖPPEN's classification, the climate is a Cwa one, a mesotermic type, characterised by having a dry season during the winter (June to August) and a heavy rainy season

during the summer (December to February) (THOMAZ & MONTEIRO 1997). Records from the last 40 years revealed that the smallest lowest mean precipitation occurred in July (58.9 mm), while the highest occurred in November (268.8 mm) (MENDES & PADOVAN 2000). Further information about the general climate in the highlands of Espírito Santo is provided in Figure 2 (INCAPER 2006).

Additional data on anuran compositions was obtained from three areas around Santa Teresa in order to estimate microgeographical variations. The species compositions of 10 ponds, two small streams and one swamp were studied between March and May 2006. The three areas sampled were: Vargem Alta (VA) (19°55.408' S, 40°38.838' W, 862 m above sea level) with two ponds and a small swamp characterised as an ecosystem almost completely anthropogenically undisturbed; Pousada Paradiso (PP) (19°55.558' S, 40°35.416' W, 684 m above sea level) as a moderately human-modified system and one small stream; and Nova Lombardia (NL) (19°54.053' S, 40°29.897' W, 512 m above sea level) as a heavily degraded area characterised by extensive agriculture and pesticide use.

Samples

Sampling methods used included visual encounter surveys, audio stripe transects (HEYER et al. 1994) and opportunistic searching during the day and at night (from 16 to 24 hrs) at random transects. The number of persons surveying varied, but was usually two or three. These methods yielded the best success and were carried out throughout all the study periods. The EBSL was regularly visited during the last 10 years by RLT, RBE, RBD, and WP and from 2002 to 2004 more frequently than in the years before 2002 to 2004. A total amount of 24 surveys was conducted by RLT and GJG at Pousada Paradiso and 21 at Vargem Alta between March and May 2006. During the same period, Nova Lombardia was sampled on 11 days. Our data was complemented by donated specimens, which

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Fig. 1. Location of Santa Teresa in Espírito Santo (A) and the study sites in the municipality of Santa Teresa (B). BA = Bahia; MG = Minas Gerais, RJ = Rio de Janeiro. Definitions of further abbreviations are provided in Table 1.

were found by local people.

Specimens which could not be immediately determined were collected alive for comparison with preserved specimens housed in the zoological collection of the Museu de Biologia Prof. MELLO-LEITÃO (MBML), Santa Teresa, and were released afterwards at the study site.

Supplemental data

Species records for the area from the literature are included in the species list for completeness. Sources are given in the species accounts. Several species lists are available for reserves or municipalities throughout the Atlantic forest. However, comparisons are dif-

Tab. 1. Area characteristics for study sites. Abbreviations and sources: PNEV = Patrimônio Natural Estação Veracruz (B. V. S. Pimenta unpubl. data.); MST = Municipality of Santa Teresa; EBSL = Estação Biológica de Santa Lúcia; PP = Pousada Paradiso; NL = Nova Lombardia; VA = Vargem Alta; G-A = Goiababa-Açu. PERD = Parque Estadual do Rio Doce; SC = Parque Serra do Cipó; SJP = Parque São Jose dos Pinhais; MRJ = Municipality of Rio de Janeiro; PM = Reserva Pró-Mata; B = Estação Biológica de Boracéia; MG = Municipality of Guararapes.

Place	State	time sampled	area analysed	No. anuran species	References
PNEV	Bahia	24 months	60.69 km ²	53	B.V.S. PIMENTA (pers. comm.)
MST	Espírito Santo	> 5 y	711 km ²	102	this study
EBSL	Espírito Santo	> 2 y	25000 m ²	54	this study
PP	Espírito Santo	3 months	2000 m ²	21	this study
NL	Espírito Santo	3 months	10000 m ²	30	this study
VA	Espírito Santo	3 months	10000 m ²	23	this study
G-A	Espírito Santo	24 months	37.4 km ²	41	RAMOS & GASPARINI (2004)
PERD	Minas Gerais	> 5 y	360 km ²	38	FEIO et al. (1998)
SC	Minas Gerais	> 5 y	/	42	ETEROVICK & SAZIMA (2004)
SJP	Paraná	16 months	2.15 km ²	32	CONTE & ROSSA-FERES (2006)
MRJ	Rio de Janeiro	> 5 y	1356 km ²	68	IZECKSOHN & CARVALHO-E-SILVA (2001)
PM	Rio Grande do Sul	> 3 y	45 km ²	45	KWET (2001)
B	São Paulo	> 5 y	164.5 km ²	68	HEYER et al. (1990)
MG	São Paulo	> 2 y	4 km ²	22	BERNARDE & KOKUBUM (1999)

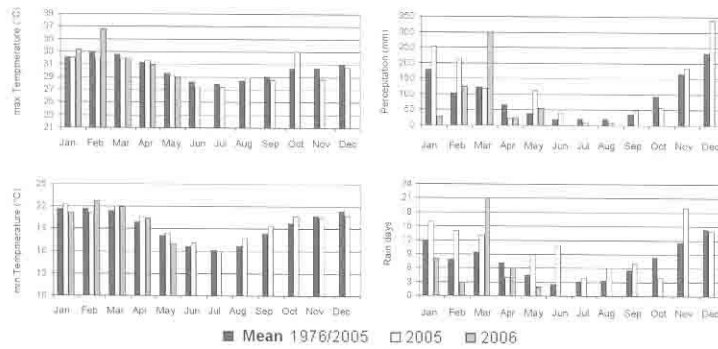


Fig. 2. Climatic characterisation of Itarana, circa 30 km westward from Santa Teresa (19.867S 40.883W, 245 m above sea level). Mean maximum and minimum temperature from 1976 to 2005 and values in 2005 and 2006. Mean precipitation and mean days of rain from 1976 to 2005 and values recorded in 2005 and 2006. Source: Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural (Incaper), modified.

ficult due to different sampling methods and durations, but they do provide a general idea of relationships and distribution patterns. To estimate similarities between well known areas and the species composition found at San-

ta Teresa we chose species lists from different states (Table 1). A map of all sites is provided in Figure 3. For comparisons at a smaller scale, we added a list for the nearest area with an available species list, Goiapaba-Açu (G-



Fig. 3. Location of the study site and origin of the species lists taken from literature. Areas once covered with Atlantic forest are grey indicated. Abbreviations: MST = Municipality of Santa Teresa, Espírito Santo; PNEV = Partrimônio Natural Estação Veracruz, Bahia; B = Boracéia, São Paulo; PM = Reserva Pró-Mata, Rio Grande do Sul; SC = Serra do Cipó, Minas Gerais; SJP = São Jose dos Pinhais, Paraná; PERD = Parque Estadual do Rio Dolce, Minas Gerais; MG = Municipality of Guararapes, São Paulo; MRJ = Municipality of Rio de Janeiro.

A), provided by RAMOS & GASPARINI (2004). This reserve is located between the municipalities of Santa Teresa and Fundão. Two species, *Aparasphenodon bruno*i and *Chiasmocleis schubarti*, have been recorded for this reserve, but not for other parts of Santa Teresa. We included these two species because parts of the reserve are located in the municipality of Santa Teresa, it is very close by and we expect the two species to occur in the municipality of Santa Teresa. Specimens housed in several zoological collections which were collected by several parties in Santa Teresa were added. Museum acronyms are listed in Appendix 1.

To estimate conservation priorities and to give further recommendations we use percentages per IUCN Red List category [Least Concern (LC), Nearly Threatened (NT), Endangered (EN), Vulnerable (VU) and Data Deficient (DD)] of each species (IUCN et al. 2006). For species found at MST, categories are provided in the species accounts. If available, information on the predominant way of life for each species is presented. Abbreviations in Habitat comments mean: A = arboreal, T = terrestrial, Aq = aquatic, N = nocturnal, D = diurnal.

Biogeographic analysis

To compare the species composition of the municipality of Santa Teresa with other well sampled areas situated in the Atlantic Forest and connected areas we calculated the "coefficient of biogeographic resemblance" CBR (DUELLMAN 1990)

$$CBR = \frac{2C}{(N_1 + N_2)}$$

where C is the number of shared taxa in two compared areas, N₁ is the number of taxa in area 1 and N₂ the number of taxa in area 2. CBR = 0 means no common species among the two areas whereas CBR = 1 means that the two areas have all species in common. By calculating CBR values we used all species known from each locality. In order to deter-

mine the species making up the greatest parts of overall similarities we provide a list of species recorded at more than five sites.

Results

Species occurring in Santa Teresa

A total amount of 102 anuran species was found to occur in the municipality of Santa Teresa. During our surveys, we recorded 63 species. Additional 39 species were found by searching in literature and collections. This area is type locality for 14 (13%) species.

Species account

In the following, we present a systematic list of anuran species occurring in the municipality of Santa Teresa. We list localities, voucher specimens, and IUCN Red List status for each taxon. For a few species cited in literature no voucher numbers are available. Nomenclature follows FAIVOVICH et al. (2005), FROST et al. (2006) and GRANT et al. (2006), and species found in literature (noted in remarks) are updated using these references and FROST (2006). Locality abbreviations are explained in Tab. 1.

Pipidae

Pipa carvalhoi (MIRANDA-RIBEIRO, 1937)
Locality: PP. Voucher specimens: MBML 4518, 4519. Habitat: Aq + N. IUCN: LC.

Brachycephalidae

Eleutherodactylus binotatus (SPIX, 1824)
Locality: PP, NL, VA, EBSL, G-A. Voucher specimens: MBML 4485, 4534, 4535, 4694, 4698, 4700. Habitat: T + N. IUCN: LC.

Eleutherodactylus epipedus HEYER, 1984
Locality: Santa Teresa, near Parque Lombardia. Voucher specimens: AL 1253, 1253a, 1253c, EI 7294-7302. Habitat: N. IUCN: NT. Remarks: Type locality Santa Teresa according to original description (HEYER 1984), no further populations known.

Eleutherodactylus guentheri (STEINDACHNER, 1864)

Locality: NL, VA, G-A. Voucher specimens: EI 7322, 7324-7325, MBML 3731, 3911, 3919, 4545. Habitat: T + N. IUCN: LC. Source: HEYER (1984).

Eleutherodactylus cf. juipoca SAZIMA & CARDOSO, 1978

Locality: EBSL. Voucher specimen: MBML 5737. Habitat: T + N. IUCN: LC. Remarks: first record for Espírito Santo.

Eleutherodactylus lacteus (MIRANDA-RIBEIRO, 1923)

Locality: EBSL. Voucher specimen: MBML 1143. Habitat: T + N. IUCN: LC.

Eleutherodactylus nasutus LUTZ, 1925

Locality: NL, VA. Voucher specimens: EI 7303, 7313, MBML 4667, 4690, 4691. Habitat: T + N. IUCN: LC. Source: HEYER (1984).

Eleutherodactylus oeus HEYER, 1984

Locality: Santa Teresa, EBSL. Voucher specimens: MBML 634, 3869, 3873, 3964, MNRJ 1244. Habitat: T + N. IUCN: NT. Remarks: Type locality in Santa Teresa (HEYER 1984), no further populations known.

Eleutherodactylus parvus (GIRARD, 1853)

Locality: VA, EBSL. Voucher specimens: MBML 634, 4117. Habitat: T + N. IUCN: LC.

Eleutherodactylus sp.

Locality: VA, NL. Voucher specimens: MBML 4703, 4709. Habitat: T + N. IUCN: not listed.

Eleutherodactylus verrucosus (REINHARDT & LÜTKEN, 1862 "1861")

Locality: Santa Teresa, Nova Valsuganga, G-A. Voucher specimen: MBML 3709. Habitat: -. IUCN: DD.

Euparkerella tridactyla IZECKSOHN, 1988

Locality: Santa Teresa. Voucher specimen: EI 7257. Habitat: -. IUCN: VU. Remarks: Type locality in Santa Teresa (IZECKSOHN 1988).

Hylidae

Phyllomedusinae

Phasmahyla exilis (CRUZ, 1980)

Locality: Santa Teresa, 19°55'S, 30°40'W.

Voucher specimens: EI 5584, SMNS 7907-1-9, ZFMK 54406-54412. Habitat: A + N. IUCN: LC. Source: Type locality in Santa Teresa. Known distribution: Santa Teresa and 555 km to the north at Jussari Municipality, Bahia, Brazil (FROST 2006) The SMNS and ZFMK material was collected by P. WEYGOLDT between 1975 and 1990.

Phrynomedusa marginata (IZECKSOHN & CRUZ, 1976)

Locality: Santa Teresa, 19°55'S, 30°40'W. Voucher specimens: EI 5177, SMNS 7909-1-15, ZFMK 54364-54368, 54413, 54414. Habitat: A + N. IUCN: LC. Remarks: Type locality in Santa Teresa (IZECKSOHN & CRUZ 1976). No further distribution records. The SMNS and ZFMK material was collected by P. WEYGOLDT between 1975 and 1990.

Phyllomedusa burmeisteri BOULENGER, 1882

Locality: G-A, Santa Teresa. Voucher specimen: MBML 171. Habitat: A + N. IUCN: LC. Remarks: one specimen was collected in 1970, its identity doubtful. Listed for G-A (RAMOS & GASPARINI 2004).

Phyllomedusa rohdei MERTENS, 1926

Locality: EBSL, Alto Rio Saltinho. Voucher specimens: MBML 506, 642, 3949, 4096. Habitat: A + N. IUCN: LC.

Hylinae

Aparasphenodon brunoi MIRANDA-RIBEIRO, 1920

Locality: G-A. Voucher specimens: -. Habitat: A + N. IUCN: LC. Remarks: Listed for G-A by RAMOS & GASPARINI (2004).

Aplastodiscus cavicola (CRUZ & PEIXOTO, 1985)

Locality: PP, NA, VA, G-A. Voucher specimens: EI 7341, MBML 4530, 4547. Habitat: A + N. IUCN: NT. Remarks: Type locality in Santa Teresa (CRUZ & PEIXOTO 1984).

Aplastodiscus weygoldti (CRUZ & PEIXOTO, 1987 "1985")

Locality: Santa Teresa according to original description. Voucher specimens: EI 7697, SMNS 7880-1-3, ZFMK 54419-54422. Habitat: A + N. IUCN: NT. Remarks: Type local-

ity in Santa Teresa (CRUZ & PEIXOTO 1985), one further population known at Itapebi, Bahia (IUCN 2006). The SMNS and ZFMK material was collected by P. WEYGOLDT between 1975 and 1990.

Bokermannohyla caramaschii (NAPOLI, 2005)

Locality: EBSL, VA, G-A. Voucher specimen: MBML 4668. Habitat: A + N. IUCN: not listed. Remarks: Type locality in Santa Teresa (NAPOLI 2005).

Bokermannohyla aff. *nanuzae* (BOKERMANN & SAZIMA, 1973)

Locality: VA. Voucher specimen: MBML 4528. Habitat: A + N. IUCN: not listed. Remarks: probably a new species.

Dendropsophus berthaltutzae (BOKERMANN, 1962)

Locality: NL. Voucher specimens: MBML 50-52, 65-68. Habitat: A + N. IUCN: LC.

Dendropsophus bipunctatus (SPIX, 1824)

Locality: PP, EBSL, G-A. Voucher specimens: MBML 1217, 2445, 5415. Habitat: A + N. IUCN: LC.

Dendropsophus branneri (COCHRAN, 1948)

Locality: PP, VA, NL, EBSL, G-A. Voucher specimens: MBML 4520, 4618, 4619, 4634, 4635, 4699, 4494. Habitat: A + N. IUCN: LC. Remarks: very common throughout Santa Teresa.

Dendropsophus decipiens (A. LUTZ, 1925)

Locality: VA, EBSL. Voucher specimens: MBML 4581-4583. Habitat: A + N. IUCN: LC.

Dendropsophus elegans (WIED-NEUWIED, 1824)

Locality: PP, VA, EBSL, G-A. Voucher specimens: MBML 4527, 4529, 4487-4490. Habitat: A + N. IUCN: LC.

Dendropsophus giesleri (MERTENS, 1950)

Locality: EBSL, NL. Voucher specimens: MBML 4067, 4075, 4314. Habitat: A + N. IUCN: LC.

Dendropsophus haddadi (BASTOS & POMBAL, 1996)

Locality: "Municipality of Santa Teresa", according to the original description. Voucher specimens: MNRJ 17078-17082. Habitat: A + N. IUCN: LC. Remarks: Listed as paratypes by BASTOS & POMBAL (1996).

Dendropsophus microps (PETERS, 1872)

Locality: "Santa Teresa", 19°55'S, 30°40'W. Voucher specimens: MBML 2584, 2585. Habitat: A + N. IUCN: LC. Remarks: Source: WEYGOLDT (1986).

Dendropsophus minutus (PETERS, 1872)

Locality: PP, NL, VA, EBSL, G-A. Voucher specimens: MBML 4508-4514, 4523. Habitat: A + N. IUCN: LC.

Dendropsophus gr. *parviceps* (BOULENGER, 1882)

Locality: EBSL. Voucher specimen: MBML 2446. Habitat: A + N. IUCN: not listed.

Dendropsophus ruschii (WEYGOLDT & PEIXOTO, 1987)

Locality: "Santa Teresa" according to the original description. Voucher specimens: SMNS 7897-1-4, MZUSP 63322, 63223. Habitat: A + N. IUCN: DD. Remarks: Paratype locality in Santa Teresa (WEYGOLDT & PEIXOTO 1987). The SMNS material was collected by P. WEYGOLDT between 1975 and 1990.

Dendropsophus seniculus (COPE, 1868)

Locality: EBSL, NL. Voucher specimens: MBML 2810, 2811, 3331. Habitat: A + N. IUCN: LC.

Dendropsophus sp.

Locality: EBSL, NL. Voucher specimens: MBML 3112-3116. Habitat: A + N. IUCN: not listed. Remarks: A species tentatively associated with the *D. microcephalus* group.

Flectonotus fissilis (MIRANDA-RIBEIRO, 1920)

Locality: EBSL, Santa Teresa, 19°56'S, 40°35'W. Voucher specimen: MBML 46. Habitat: A + N. IUCN: LC.

Flectonotus goeldii (BOULENGER, 1895 "1894")

Locality: EBSL, G-A, Voucher specimens: MBML 500, 848-851, 2821, 2822. Habitat: A + N. IUCN: LC.

- Hypsiboas albomarginatus* (SPIX, 1824)
Locality: PP, EBSL, G-A. Voucher specimens: MBML 54, 472, 875, 1208, 1225, 1283, 1285, 1307. Habitat: A + N. IUCN: LC.
- Hypsiboas albopunctatus* (SPIX, 1824)
Locality: PP, NL, VA, EBSL, G-A. Voucher specimens: MBML 4466, 4468, 4469, 4526, 4629. Habitat: A + N. IUCN: LC.
- Hypsiboas crepitans* (WIED-NEUWIED, 1824)
Locality: PP, G-A, Aparecidinha. Voucher specimens: MBML 2873-2875. Habitat: A + N. IUCN: LC.
- Hypsiboas faber* (WIED-NEUWIED, 1821)
Locality: PP, NL, VA, EBSL, G-A. Voucher specimens: MBML 3218, 3219, 4516, 4517, 4683. Habitat: A + N. IUCN: LC.
- Hypsiboas pardalis* (SPIX, 1824)
Locality: PP, NL, EBSL, G-A. Voucher specimens: MBML 4462, 4463, 4532, 4536, 4537. Habitat: A + N. IUCN: LC.
- Hypsiboas pombali* (CARAMASCHI, PIMENTA & FEIO, 2004)
Locality: PP, NL, VA. Voucher specimens: MBML 4533, 4636-4639. Habitat: A + N. IUCN: not listed.
- Hypsiboas semilineatus* (SPIX, 1824)
Locality: PP, NL, VA, EBSL, G-A. Voucher specimens: MBML 4265-4267, 4465, 4467, 4688. Habitat: A + N. IUCN: LC.
- Itapotihyla langsdorffii* (DUMÉRIL & BIBRON, 1841)
Locality: EBSL, G-A. Voucher specimens: MBML 96-101, 202, 1215, 1220, 2963-2973. Habitat: A + N. IUCN: LC.
- Phyllodytes luteolus* WIED-NEUWIED, 1824
Locality: G-A. Voucher specimens: MBML 740-748. Habitat: A + N. IUCN: LC.
- Scinax alter* (B. LUTZ, 1973)
Locality: PP, NL, VA, EBSL, G-A. Voucher specimens: MBML 2440-2444, 4475-4478, 4524. Habitat: A + N. IUCN: LC.
- Scinax arduous* PEIXOTO, 2002
Locality: NL, EBSL, Santa Teresa. Voucher specimens: MBML 4201, 4630, 4631, WCAB 44833, 44834. Habitat: A + N. IUCN: DD. Remarks: Type locality in Santa Teresa (PEIXOTO 2002), W. PERTEL and R. L. TEIXEIRA found it in Três Pontões (20°04'S, 41°02'W), located in the municipality of Afonso Cláudio, Espírito Santo and extended its range ca. 150 km southward.
- Scinax argyreornatus* (MIRANDA-RIBEIRO, 1926)
Locality: NL, EBSL, G-A. Voucher specimens: MBML 2471-2489, 4689, 4695. Habitat: A + N. IUCN: LC.
- Scinax* gr. *catharinae* (BOULENGER, 1888)
Locality: EBSL, G-A. Voucher specimens: MBML 3587-3589. Habitat: A + N. IUCN: LC. Source: RAMOS & GASPARINI (2004).
- Scinax cuspidatus* (A. LUTZ, 1925)
Locality: EBSL, near Banestes, G-A. Voucher specimens: MBML 755, 765, 766, 3594, 3595. Habitat: A + N. IUCN: LC.
- Scinax* cf. *eurydice* (BOKERMANN, 1968)
Locality: EBSL. Voucher specimens: MBML 1126, 1128. Habitat: A + N. IUCN: LC.
- Scinax fuscovarius* (A. LUTZ, 1925)
Locality: NL, EBSL. Voucher specimen: MBML 4632. Habitat: A + N. IUCN: LC.
- Scinax* cf. *hayii* (BARBOUR, 1909)
Locality: PP, VA, EBSL. Voucher specimens: MBML 4479, 4480, 4663-4666. Habitat: A + N. IUCN: LC.
- Scinax heyeri* (PEIXOTO & WEYGOLDT, 1986)
Locality: Santa Teresa, EBSL. Voucher specimens: EI 7558, MBML 206, MZUSP 61094, SMF 73244, SMNS 7893-1-3, 8722, USNM 255230, ZFMK 54415-54418. Habitat: A + N. IUCN: DD. Remarks: Type locality in Santa Teresa (PEIXOTO & WEYGOLDT 1987), known distribution at two locations, the municipalities of Santa Teresa and Domingos Martins. The SMF, SMNS, and ZFMK material was collected by P. WEYGOLDT between 1975 and 1990.
- Scinax kautskyi* (CARVALHO-E-SILVA & PEIXOTO, 1991)
Locality: "Bergbach", Santa Teresa. Vouch-

er specimen: SMNS 12360. Habitat: A + N. IUCN: DD. Remarks: Collected by WEYGOLDT between 1975 and 1990. It is not absolutely sure if the label on the voucher specimen is correct, but the majority of WEYGOLDT's material was collected at Santa Teresa (WEYGOLDT 1989).

Scinax perpusillus (A. LUTZ & B. LUTZ, 1939)
Locality: EBSL, G-A. Voucher specimens: MBML 2943, 3974. Habitat: A + N. IUCN: LC.

Scinax similis (COCHRAN, 1952)
Locality: PP. Voucher specimens: MBML 4482, 4483. Habitat: A + N. IUCN: LC. Remarks: First record for Espírito Santo.

Scinax v-signatus (B. LUTZ, 1968)
Locality: Santa Teresa. Voucher specimens: EI 7600, 7595, 7596, 7603, 7607, WCAB 44838. Habitat: A + N. IUCN: LC. Source: PEIXOTO 2002.

Scinax cf. *x-signatus* (SPIX, 1824)
Locality: PP, NL, VA, Alto Rio Saltinho. Voucher specimens: MBML 3815, 3830, 4541, 4542. Habitat: A + N. IUCN: LC.

Scinax sp.
Locality: VA. Voucher specimen: MBML 4708. Habitat: A + N. IUCN: not listed.

Trachycephalus mesophaeus (HENSEL, 1867)
Locality: NL, EBSL, G-A. Voucher specimens: MBML 2802, 2955-2962, 4084. Habitat: A + N. IUCN: LC.

Trachycephalus nigromaculatus TSCHUDI, 1838
Locality: G-A. Voucher specimens: MBML 1271, 1272. Habitat: A + N. IUCN: LC.

Centrolenidae

Hyalinobatrachium eurygnathum (A. LUTZ, 1925)
Locality: Parque Natural Municipal de São Lourenço. Voucher specimen: MBML 4113. Habitat: A + N. IUCN: LC. Remarks: Listed by WEYGOLDT (1986).

Hyalinobatrachium uranoscopum (MÜLLER, 1924)

Locality: Santa Teresa, 19°55'S, 30°40'W. Voucher specimen: -. Habitat: A + N. IUCN: LC. Remarks: Listed by WEYGOLDT (1986) and WEYGOLDT (1989). Information on the distribution of this species obtained from IUCN (2006) support the hypothesis that WEYGOLDT found this species.

Leptodactylidae

Leptodactylus fuscus (SCHNEIDER, 1799)
Locality: Santa Teresa, Loteamento Jardim da Montanha, EBSL, G-A. Voucher specimens: MBML 778-780, 3058. Habitat: T + N. IUCN: LC.

Leptodactylus cf. *mystacinus* (BURMEISTER, 1861)

Locality: EBSL. Voucher specimen: MBML 874. Habitat: T + N. IUCN: LC.

Leptodactylus natalensis A. LUTZ, 1930
Locality: EBSL. Voucher specimens: MBML 3909, 3910. Habitat: T + N. IUCN: LC.

Leptodactylus ocellatus (LINNAEUS, 1758)
Locality: PP, NL, VA, EBSL, G-A. Voucher specimens: MBML 4645, 4653, 4701, 2077. Habitat: T + N. IUCN: LC.

Leptodactylus spixi HEYER, 1983
Locality: EBSL. Voucher specimens: MBML 2439, 4097, 4287, 4414. Remarks: T + N. IUCN: LC.

Physalaemus aguirrei BOKERMANN, 1966
Locality: EBSL. Voucher specimens: MBML 2803, 2804. Habitat: T + N. IUCN: LC.

Physalaemus crombiei HEYER & WOLF, 1989
Locality: Santa Teresa, near Reserva de Lombardia (19°55'S, 40°36'W), EBSL, Aparecidinha, G-A. Voucher specimens: MZUSP 66252, MBML 1150, 1697, 1699, 1835, 2878. Habitat: T + N. IUCN: LC. Remarks: Type locality in Santa Teresa (HEYER & WOLF 1989).

Physalaemus cuvieri FITZINGER, 1826
Locality: Santa Teresa, PP, Alto Rio Saltinho, G-A. Voucher specimens: MBML 4486, 3831. Habitat: T + N. IUCN: LC.

Physalaemus olfersii (LICHTENSTEIN & MARTENS, 1856)

Locality: Santa Teresa. Voucher specimens: SMNS 7908-1-2. Habitat: T + N. IUCN: LC. Remarks: Collected by P. WEYGOLDT between 1975 and 1990. Although it may be possible that the labels attached to the vouchers collected by WEYGOLDT are not correct, vouchers from other areas northwards and eastwards from Santa Teresa are available (Aracruz, MBML 606, 920; Linhares, MBML 1106), making its occurrence high likely, because this species has its main distribution from the states of Rio de Janeiro to Santa Catarina (IUCN 2006).

Ceratophryidae

Ceratophrys cf. *aurita* (RADDI, 1823)

Locality: EBSL, G-A, and 8 km NE of Santa Teresa (city). Voucher specimens: MBML 591, 609, 623. Habitat: T. IUCN: LC.

Cycloramphidae

Crossodactylodes bokermanni PEIXOTO, 1983

Locality: Santa Teresa, 19°56'S, 40°36'W. Voucher specimen: EI 7173. Habitat: T + D. IUCN: NT. Remarks: Type locality according to original description (PEIXOTO 1982), another population was found at Castelo, Espírito Santo (IUCN 2006).

Crossodactylodes izecksohni PEIXOTO 1983

Locality: EBSL, G-A, Lombardia, Santa Teresa. Voucher specimens: MBML 768, 3832-3840, 3953-3961. Habitat: A/T + D. IUCN: NT. Remarks: Type locality in Santa Teresa (PEIXOTO 1982), no further populations known.

Crossodactylus cf. *dispar* A. LUTZ, 1925

Locality: NL, Rio Lombardia. Voucher specimens: MBML 3691, 4692, 4693, 4697, SMNS 8708-1-7. Habitat: T + D. IUCN: DD. Remarks: The SMNS material was collected by P. WEYGOLDT between 1975 and 1990. This species is considered to be a new species (B. V. S. PIMENTA, pers. comm.).

Crossodactylus cf. *gaudichaudii* DUMÉRIL & BIBRON, 1841

Locality: Santa Teresa, Estrada Santa Teresa - Lombardia. Voucher specimens: MBML 3701, 4572-4575, SMNS 8700-1-4, 8701-1-

3, 8702-1-11. Habitat: T + D. IUCN: LC. Remarks: The SMNS material was collected by P. WEYGOLDT between 1975 and 1990.

Cycloramphus fuliginosus TSCHUDI, 1838

Locality: Santa Teresa, 19°55'S, 30°40'W. Voucher specimen: SMNS 7919. Habitat: T + N. IUCN: LC. Remarks: Collected by P. WEYGOLDT between 1975 and 1990, Santa Teresa as locality mentioned in WEYGOLDT (1989).

Hylodes babax HEYER, 1982

Locality: Santa Teresa, 19°55'S, 30°40'W. Voucher specimens: SMNS 7927-1-21. Habitat: T + D. IUCN: DD. Remarks: Collected by P. WEYGOLDT between 1975 and 1990. Occurrence in Santa Teresa confirmed in WEYGOLDT (1989).

Hylodes lateristrigatus (BAUMANN, 1912)

Locality: G-A, Santa Teresa, 19°55'S, 30°40'W. Voucher specimens: MBML 1850. Habitat: T + N. IUCN: LC. Source: WEYGOLDT (1986, 1989). WEYGOLDT (1989) mentioned three voucher specimens housed in the MBML collection, of which two could not be found during our investigations at the museum.

Macrogenioglottus alipioi CARVALHO, 1946

Locality: Santa Teresa, Reserva Biológica de Nova Lombardia. Voucher specimens: MBML 1170, 1232. Habitat: T. IUCN: LC.

Megaelosia sp.

Locality: Santa Teresa. Voucher specimen: MZUSP 27717. Habitat: -. IUCN: not listed. Source: POMBAL et al. (2003).

Proceratophrys appendiculata (GÜNTHER, 1873)

Locality: EBSL. Voucher specimen: MBML 1154. Habitat: T + N. IUCN: LC.

Proceratophrys boiei (WIED-NEUWIED, 1825)

Locality: EBSL, Santa Teresa, NL. Voucher specimen: MBML 4661. Habitat: T + N. IUCN: LC.

Proceratophrys paviotii CRUZ, PRADO & IZECKSOHN 2005

Locality: PP, VA, NL, EBSL. Voucher specimens: MBML 4473, 4474, MNRJ 34935, 34936, 30888-30890. Habitat: T + N. IUCN:

not listed. Remarks: Type locality in Santa Teresa (CRUZ et al. 2005).

Proceratophrys laticeps IZECKSOHN & PEIXOTO, 1981

Locality: EBSL, G-A. Voucher specimens: MBML 1695, 3889, 3899, 3905, 3963. Habitat: T + N. IUCN: LC.

Proceratophrys moehringi WEYGOLDT & PEIXOTO, 1985

Locality: Santa Teresa. Voucher specimens: MZUSP 59685, SMF 72416, SMNS 7894-1-3, 8711-1-3, USNM 239919-239947, ZFMK 54359, 54928. Habitat: T + N. IUCN: DD. Remarks: Type locality in Santa Teresa (WEYGOLDT & PEIXOTO 1985). The SMF, SMNS and ZFMK material was collected by P. WEYGOLDT between 1975 and 1990.

Proceratophrys phyllostomus IZECKSOHN, CRUZ & PEIXOTO 1999

Locality: Santa Teresa, Valsugana Velha. Voucher specimen: MBML 1326. Habitat: T + N. IUCN: DD. Remarks: GASPARINI (2002) extended its range to Santa Teresa.

Proceratophrys schirchi (MIRANDA-RIBEIRO, 1937)

Locality: EBSL. Voucher specimens: MBML 1309, 3624. Habitat: T + N. IUCN: LC.

Zachaenus carvalhoi IZECKSOHN, 1983

Locality: Santa Teresa. Voucher specimen: EI 7243. Habitat: -. IUCN: LC. Remarks: Type locality in Santa Teresa (IZECKSOHN 1982), no further population known.

Thoropidae

Thoropa miliaris (SPIX, 1824)

Locality: NL, EBSL, G-A. Voucher specimens: MBML 4625-4628, 4683, 4687. Habitat: T + N. IUCN: LC.

Aromobatidae

Allobates cf. *olfersioides* (A. LUTZ, 1925)/*Allobates* cf. *capixaba* (BOKERMANN, 1967)

Locality: Santa Teresa, 19°55'S, 30°40'W. Voucher specimens: EI 10961, 10964-10966 (as *A. cf. capixaba*). Habitat: T + D. IUCN: VU. Remarks: Listed in WEYGOLDT (1986) and WEYGOLDT (1989) as *Colostethus* cf. *olfer-*

sioides. According to V. VERDADE *A. capixaba* is a synonym of *A. olfersioides* (mentioned on the IUCN 2006 site of *C. capixaba*). Voucher numbers were taken from CARNAVAL et al. (2006).

Bufonidae

Chaunus crucifer (WIED-NEUWIED, 1821)

Locality: EBSL, PP, VA, NL, G-A. Voucher specimens: MBML 4546, 4650, 4651, 4581, 4582. Habitat: T + N. IUCN: LC.

Chaunus granulatus (SPIX, 1824)

Locality: NL, G-A. Voucher specimen: MBML 4662. Habitat: T + N. IUCN: LC.

Chaunus pombali (BALDISSERA, CARAMASCHI & HADDAD, 2004)

Locality: EBSL, VA, NL. Voucher specimens: MBML 4546-4549. Habitat: T + N. IUCN: not listed. Remarks: Separated from *Chaunus crucifer* by BALDISSERA et al. (2004). First record for Espírito Santo.

Chaunus schneideri (WERNER, 1894)

Locality: G-A, Vila Nova. Voucher specimen: MBML 687. Habitat: T. IUCN: LC. Remarks: Formerly known as *Bufo paracnemis* (LUTZ, 1925).

Dendrophryniscus carvalhoi IZECKSOHN, 1994 "1993"

Locality: EBSL, G-A. Voucher specimens: EI 4127, MBML 632, 846, 847. Habitat: A/T. IUCN: EN. Remarks: Type locality in Santa Teresa (IZECKSOHN 1993), one further population known at Fundão.

Dendrophryniscus sp.

Locality: EBSL. Voucher specimens: MBML 3841, 4202. Habitat: A.

Rhinella gr. *margaritifera* (LAURENTI, 1768)

Locality: Santa Teresa. Voucher specimen: SMNS 12345. Habitat: T + N. Remarks: Collected by P. WEYGOLDT. It is not completely sure that the locality on the label attached to the voucher is correct, but it is highly likely.

Microhylidae

Chiasmocleis schubarti BOKERMANN, 1952

Locality: G-A. Voucher specimen: -. Habi-

tat: T + N. IUCN: LC. Source: RAMOS & GASPARINI (2004).

Myersiella microps (DUMERIL & BIBRON, 1841)

Locality: Santa Teresa, forest of Atlantic Veneer do Brazil. Voucher specimen: SMNS 8725. IUCN: LC. Remarks: Collected by P. WEYGOLDT 1979. It is not completely sure that the locality on the label attached to the voucher is correct, but it is highly likely.

Biogeography

Looking at species numbers per family as a total from the sites examined, these differed with Hylidae being the most diverse (N = 126), followed by Leptodactylidae (N = 43), Cycloramphidae (N = 39), Brachycephalidae (N = 23), Bufonidae (N = 19), Microhylidae (N = 12), Aromobatidae (N = 5), Thoropidae (N = 4), Centrolenidae (N = 3), Ceratophryidae and Pipidae (both N = 1).

Species compositions at the four study sites in Santa Teresa and Goiapaba-Açu (G-A) were different. The highest species richness was found in EBSL (N = 54), followed by G-A (N = 41), NL (N = 31), PP (N = 24) and VA (N = 23). Highest CBR values were found for VA/PP, followed by VA/NL. The lowest values were observed between G-A/VA and EBSL/VA. All results are presented in Table 2.

The results of comparisons on a greater scale between assemblages described in literature and Santa Teresa are presented in Table 3. Highest CBR values were found for PNEV/PERD, followed by MRJ/MST. The lowest CBR values were observed for MRJ/SC followed by MRJ/PM, MRJ/MG, PM/PERD, PNEV/SC, SC/B, and MG/B. For the municipality of Santa Teresa the highest degree of similarity was observed between MST and MRJ, followed by MST/PNEV and MST/B, whereas the lowest observed were MST/PM, and MST/SC. That means that the highest similarities occurred between MST and the closest analysed sites situated in Atlantic for-

est, whereas the highest dissimilarities were found comparing MST with the site furthest away. Furthermore the highest dissimilarities were observed between MST situated in Atlantic forest and PM and SC, situated in a drier biome. The closest analysed areas (PERD and SC), both situated in different biomes (Atlantic forest and Cerrado), have a low CBR value.

Hylidae predominated at all sites as the most represented family (Table 4). The second most frequently found family differed according to site, Cycloramphidae being important at MST and B, but Leptodactylidae predominating at MG, SC, and PM. The site dominated by Brachycephalidae as second most important family was B. The other families were represented only by small percentages at every site.

Looking at the distribution of the families between the sites (Table 5), the greatest percentages of Cycloramphidae, Brachycephalidae, Hylidae, and Bufonidae can be found at MST, whereas the greatest percentages of Aromobatidae occur at MRJ and of Microhylidae at MRJ and PNEV. Most Leptodactylidae are reported for SC.

The following species were recorded at more than five sites and contribute a significant amount of similarity values (number of sites in parentheses): *Dendropsophus minutus*, *Leptodactylus ocellatus* (9-10); *Hypsiboas albopunctatus*, *Hypsiboas faber*, *Leptodactylus fuscus*, *Physalaemus cuvieri* (7-9); *Ceratophrys aurita*, *Chaunus schneideri*, *Eleutherodactylus binotatus*, *Eleutherodactylus guentheri*, *Dendropsophus elegans*, *Dendropsophus microps*, *Dendropsophus seniculus*, *Hypsiboas albomarginatus*, *Hypsiboas semilineatus*, *Itapotihyla langsdorffii*, *Scinax argyreornatus*, *Scinax cf. x-signatus*, *Scinax fuscovarius* (5-6).

An analysis of the family composition in Santa Teresa is illustrated in Table 6. The anuran communities at all the sites are dominated by hylids, followed by Leptodactylidae and Cycloramphidae at EBSL. GA displays equal percentages of bufonids, cycloram-

Tab. 2. Species composition similarities between study sites. Diagonal row in bold: number of species at site; below diagonal row: CBR values; above diagonal row: number of species sharing two sites. For abbreviations see Table 1.

	EBSL	PP	NL	VA	G-A
EBSL	54	16	21	14	26
PP	0.461	24	15	15	17
NL	0.500	0.545	31	17	17
VA	0.368	0.638	0.630	23	12
G-A	0.553	0.523	0.472	0.375	41

phids and leptodactylids (N = 4; 9.5%) as the second most important families. NL and VA are different, Brachycephalidae being much more important. PP shows the highest percentage of hylids (70.8 %) followed by leptodactylids (8.3 %).

A comparison between percentages of IUCN Red List categories found for the sites is presented in Table 7.

Discussion

A total amount of 102 anuran species inhabiting an area of 711 km² (entire area of the municipality of Santa Teresa) was recorded. Most species (66, including records from other sources) were found at our four study sites covering a total area sampled of approximately 0.047 km². The area containing all studied sites is approximately about 53.2 km². The municipality of Santa Teresa is type locality for 14 (14.1%) anuran species, maybe due to the fact that it is one of the best sampled areas in Espírito Santo and the anuran fauna of many other large areas is poorly known.

Micro-geographic comparisons

Diversity and density of frogs depend on abiotic factors like temperature and humidity which are correlated with altitude and, especially at small scales, habitat features (DUELLMAN 1999). Highest similarity values were found for PP and NL. These areas both are human-modified. The main differences can be found in the percentages of Brachycephalidae and Cycloramphidae. These ground-dwelling species seem to replace each other at these sites, probably due to differences arising from available humidity which is necessary for the egg development of many members of these families. Lower vegetation density in NL indicates drier conditions in comparison can be expected to be much drier than VA., because of lower vegetation density. Species richness at these sites is lower than in the two reserves.

EBSL and G-A are characterised by the third highest CBR value, both containing highest species richness. Differences at family level between these sites are only small, mainly characterised by Leptodactylidae be-

Tab. 3. Species composition similarities at different sites along the Atlantic forest. Diagonal row in bold: number of species at study site; below diagonal row: CBR values; above diagonal row: number of species sharing two sites.

	MST	PNEV	B	PM	SC	SJP	PERD	MG	MRJ
MST	102	32	27	9	9	11	24	9	37
PNEV	0.410	53	10	6	5	5	20	6	23
B	0.316	0.165	68	8	6	15	11	5	25
PM	0.122	0.122	0.142	45	7	13	4	7	5
SC	0.138	0.105	0.109	0.161	42	5	7	8	3
SJP	0.162	0.116	0.297	0.333	0.133	33	5	6	8
PERD	0.345	0.449	0.212	0.099	0.179	0.145	36	8	18
MG	0.144	0.160	0.111	0.209	0.250	0.218	0.276	22	4
MRJ	0.435	0.383	0.370	0.089	0.055	0.160	0.350	0.09	67

Tab. 4. Family composition among analysed sites along the Atlantic forest. Left side = total number of species per family per site; right side = percentage represented by family per site characterising each community. For abbreviations see Table 1.

Family	PNEV	MST	MRJ	B	SJP	PM	PERD	MG	SC
Brachycephalidae	3	11	6	10	2	1	1		1
Bufonidae	4	7	4	3	2	6	2	1	2
Centrolenidae		2	2	2					1
Ceratophrynidae	1	1	1	1					
Cycloramphidae	1	18	7	10	3	6			4
Dendrobatidae	1	1	2				1		1
Hylidae	34	49	32	29	17	20	21	10	17
Leptodactylidae	5	9	7	9	7	11	7	8	14
Microhylidae	4	2	4	3	1		3	2	1
Pipidae		1							
Ranidae					1				
Thoropidae		1	2	1		1			1
Sum	53	102	67	68	33	45	35	21	42

ing a little better represented at EBSL. The forest-covered, undisturbed habitats EBSL and G-A display slightly lower percentages of hylids than the other three areas. Hylids seem to be less sensitive to disturbances due to agriculture and logging than on forest dependent species such as brachycephalids. Maybe that is one reason for their evolutionary success.

Sampling in these nearby localities gives different results for each site, even at EBSL and G-A which have been sampled for a long time. Small scale variations in community composition were also observed in Peru (DOAN & ARRIAGA 2002). As a consequence,

species inventories for one area should be conducted at different sites and not only within protected areas to give a real picture of species inhabiting an area.

Macro-geographic comparisons

The species richest areas (MST > B > MRJ > PNEV) are located in the Atlantic forest and close to one another along the coast, whereas species richness increases southwards and westwards. Lower species numbers in the south can be explained by lower humidity and lower temperatures over the year (DU-

Tab. 5. Species composition in macro-geographical scale per family. Percentages represent the part of each family compared with all other sites. For abbreviations see Table 1.

Family	PNEV (%)	MST (%)	MRJ (%)	B (%)	SJP (%)	PM (%)	PERD (%)	MG (%)	SC (%)	Sum (%)
Brachycephalidae	8.6	31.4	17.1	28.6	5.7	2.9	2.9		2.9	100.0
Bufonidae	12.9	22.6	12.9	9.7	6.5	19.4	6.5	3.2	6.5	100.0
Centrolenidae		28.6	28.6	28.6					14.3	100.0
Ceratophrynidae	25.0	25.0	25.0	25.0						100.0
Cycloramphidae	2.0	36.7	14.3	20.4	6.1	12.2			8.2	100.0
Dendrobatidae	16.7	16.7	33.3				16.7		16.7	100.0
Hylidae	14.8	21.4	14.0	12.7	7.4	8.7	9.2	4.4	7.4	100.0
Leptodactylidae	6.5	11.7	9.1	11.7	9.1	14.3	9.1	10.4	18.2	100.0
Microhylidae	20.0	10.0	20.0	15.0	5.0		15.0	10.0	5.0	100.0
Pipidae		100.0								100.0
Ranidae					100.0					100.0
Thoropidae		16.7	33.3	16.7		16.7			16.7	100.0

Anuran hotspots: the municipality of Santa Teresa, Brazil

PNEV (%)	MST (%)	MRJ (%)	B (%)	SJP (%)	PM (%)	PERD (%)	MG (%)	SC (%)
5.7	9.9	9.0	14.7	6.1	2.2	2.9		2.4
7.5	6.9	6.0	4.4	6.1	13.3	5.7	4.8	4.8
	2.0	3.0	2.9					2.4
1.9	1.0	1.5	1.5					
1.9	17.8	10.4	14.7	9.1	13.3			9.5
1.9	1.0	3.0				2.9		2.4
64.2	48.5	47.8	42.6	51.5	44.4	60.0	47.6	40.5
9.4	8.9	10.4	13.2	21.2	24.4	20.0	38.1	33.3
7.5	2.0	6.0	4.4	3.0		8.6	9.5	2.4
	1.0			3.0				
	1.0	3.0	1.5		2.2			2.4
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

ELLMAN 1999), whereas mean temperatures westwards from our study site can be expected to be similar. The Cerrado-Caatinga-Chaco biome can be found to the west directly behind the mountain range covered with Atlantic forest vegetation and is characterised by lower precipitation and relative humidity. The contrast between the two biomes is accompanied by a change in the composition of the anuran fauna inhabiting them. Species numbers at the areas located close to each other, SC and PERD, are nearly equal, but the species composition is totally different (0.179), Leptodactylidae being better represented in SC than in PERD. Our analysis allows for the hypothesis, in congruence with DUELLMAN (1999), that similarities between

anuran communities depend on (1) geographic distance, (2) topography, (3) structure and composition of vegetation and (4) climate. Similar results were presented by BASTOS et al. (2003): two sites analysed in Espírito Santo clustered close or adjacent to sites situated in the Atlantic forest in São Paulo and were clearly separated from sites in Minas Gerais, Goiás and areas further west in Brazil.

The Atlantic forest communities are characterised by high percentages of hylids and cycloramphids whereas the two drier sites, MG and SC, display the highest percentages of leptodactylids of all the sites. Many Brachycephalidae seem to be restricted to the Atlantic forest, with the highest percentages found at Boracéia followed by MST, both

Tab. 6. Family composition among analysed sites in Santa Teresa. Left = number of species per family per site; right = percentage represented by family per site. For abbreviations see Table 1.

Family	EBSL	VA	NL	PP	G-A	EBSL (%)	VA (%)	NL (%)	PP (%)	G-A (%)
Brachycephalidae	4	5	4	1	3	7.4	21.7	12.9	4.2	7.1
Bufo	4	2	3	1	4	7.4	8.7	9.7	4.2	9.5
Ceratophryidae	1				1	1.9				2.4
Cycloramphidae	6	1	3	1	4	11.1	4.3	9.7	4.2	9.5
Hylidae	29	14	19	17	24	53.7	60.9	61.3	70.8	57.1
Leptodactylidae	8	1	1	2	4	14.8	4.3	3.2	8.3	9.5
Microhylidae	1				1	1.8				2.4
Thoropidae	1		1	1	1	1.8		3.2	4.2	2.4
Pipidae				1					4.2	
Sum	54	23	31	24	42	100	100	100	100	100

Tab. 7. IUCN Red List status of species at compared sites. For locality abbreviations see Tab. 1, for Red List abbreviations see Material and Methods. Not listed = no category allocated by IUCN et al. (2006).

Study site	No. Species	LC	LC %	DD	DD %	NT	NT %	VU	VU %	Not listed	Not listed %	EN	EN %
MST	102	67	65.7	11	10.8	5	4.9	2	2.0	13	12.7	1	1.0
PNEV	53	43	81.1	1	1.9					7	13.2	1	1.9
B	68	54	79.4	10	14.7	2	2.9			1	1.5	1	1.5
PM	45	35	77.8	3	6.7	3	6.7			4	8.9		
SC	42	27	64.3	8	19.0	1	2.4			6	14.3		
SJP	33	29	87.9	3	9.1					1	3.0		
PERD	36	31	86.1	1	2.8					3	8.3		
MG	22	22	100										
MRJ	67	58	86.6	2	3.0	2	3.0	1	1.5	2	3.0	2	3.0

situated in mountain ranges. GIARETTA et al. (1999) found that densities of litter frogs in the Parque Florestal do Itapetininga, São Paulo, were positively correlated with altitude and suggested a correlation with higher relative humidity due to the greater presence of mist. Probably brachycephalids depend more than other families on humidity due to terrestrial directly developing eggs which are the most common reproductive mode in this family. On a smaller scale, results are reflected in the comparison of brachycephalid percentages between VA and NL (Table 6).

A total amount of 272 species were recorded for all the sites compared in this thesis paper, whereas 176 were found only at one site. Maybe one reason is the high degree of local endemism. The majority of similarities found are due to 19 species, which show an apparently high degree of ecological plasticity by occurring at more than five sites. Most often found were *Leptodactylus ocellatus* and *Dendropsophus minutus* (9 and 10 sites). Both species are considered to be complexes of several species, so interpretations must be made carefully.

Recommendations for conservation and outlook

A major part of the anuran fauna found in the municipality of Santa Teresa is unique and the high degree of endemism in Santa

Teresa, and within the state of Espírito Santo, is remarkable. Six species described at MST are only known from the type localities (*Phrynomedusa marginata*, *Scinax arduous*, *Crossodactylodes izecksohni*, *Eleutherodactylus epipedus*, *Eleutherodactylus oeus* and *Zachaenus carvalhoi*). Data to estimate the population status about of 11 of the 102 species is lacking (DD), a further six (5.0%) are considered Nearly Threatened, and one (1.0%) is considered Endangered. Thirteen species (12.9%) are not listed, some due to the fact that they were recently described or that their taxonomic status is unclear. The same is true for seven (13.2%) species found in PNEV, six (14.3%) in Boracéia, and all the other analysed sites except MG (Table 7). Further investigations should focus on the distribution and ecology of these species. In particular, without established knowledge of the natural history of these species conservation measurements are only tentative and cannot be that successful.

The massive amphibian population declines observed during the last few years are forcing us to reconsider conservation strategies. The Research and Analyse Network for Amphibians (RANA) has been established as an open platform for scientists to simplify research and to make knowledge available. Currently, an Amphibian Conservation Action Plan (ACAP) has been released containing advice for further steps including more research, especially inventories in poorly

known areas, and the establishment of protected areas (MENDELSON III et al. 2006). The establishment of reserves is in progress, but as pointed out by COLLINS (2006), amphibian declines have also been observed in reserves, showing that biodiversity cannot only be protected by establishing places of refuge. Because reserves are often too small and isolate populations, we recommend linking protected areas and thus metapopulations, and allowing free gene flow. To determine the minimum corridor size is difficult and depends on the target species since MARSH & PEARMAN (1997) showed for *Eleutherodactylus* species a density decline at a distance of several hundred metres toward forest edges. On the other hand, PEARMAN (1997) showed that frog diversity changes at forest margins. Some species (Hylidae) seem to prefer more open habitats whereas others (e. g. some Eleutherodactylids) avoid them. Thus, species richness by itself is not a good indicator of habitat quality and specific taxa must be chosen to avoid misinterpretations.

However, the Atlantic forest in Espírito Santo is highly endangered due to massive logging and extensive agriculture. A decline in the populations of eight species in Santa Teresa was observed by WEYGOLDT (1989). Fortunately, one species (*Crossodactylus* cf. *gaudichaudii*) was found in higher numbers during our investigation and another, *Hylodes lateristrigatus*, has recently been found in the São Lourenço reserve. The status of the other species affected is unclear. Recently was shown that the declines observed by WEYGOLDT (1989) may be related to the occurrence of the epizootic amphibian fungus *Batrachochytrium dendrobatidis* at Santa Teresa (CARNAVAL et al. 2006). Without further research and establishment of conservation measures many species inhabiting this unique habitat will be lost.

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Appendix 1

Voucher specimens are housed in the herpetological collections of the following institutions: Adolpho Lutz collection (AL), now in MNRJ; Eugenio Izecksohn collection (IE), Universidade Federal Rural do Rio de Janeiro, Itaguaí, Brazil; Museu de Biologia Prof. Mello-Leitão (MBML), Santa Teresa, Brazil; Museu Nacional do Rio de Janeiro (MNRJ), Rio de Janeiro, Brazil; Universidade de São Paulo, Museu de Zoologia (MZUSP), São Paulo, Brazil; Forschungsinstitut und Natur-Museum Senckenberg (SMF), Frankfurt a. M., Germany; Staatliches Museum für Naturkunde Stuttgart (SMNS), Stuttgart, Germany; National Museum of Natural History, Division of Amphibians and Reptiles (USNM), Washington, D.C., USA; Werner C. A. Bokermann collection (WCAB), now transferred to MZUSP; Zoologisches Forschungsmuseum Alexander Koenig (ZFMK), Bonn.

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