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Inventory

Anurans from preserved and disturbed areas of Atlantic Forest in the region of Etá Farm, municipality of Sete Barras, state of São Paulo, Brazil

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Abstract: We provide information on the diversity and natural history of anurans from preserved and disturbed habitats in the region of Etá Farm, municipality of Sete Barras, state of São Paulo, Brazil. The region is covered by rainforest and plantations of banana and peach palm. From April, 2013 to March, 2014 we sampled amphibians mainly with pitfall traps with drift fences and visual and auditory surveys. A total of 9813 individuals of 36 species of anurans from nine families were recorded in this study. A larger number of species was found in forests (29 species), followed by peach palm plantations (21 species), and banana plantations (17 species). The areas of peach palm plantation and forests showed the greatest similarity in species composition. The vegetation type with the highest number of exclusive species was the forest, whereas only four species were exclusive of the peach palm plantation, and none was exclusive of the banana plantation. Species accumulation curves indicated that our sampling effort was not enough to sample all the species that occur in the region. Our results reinforce the importance of forested habitats for the maintenance of anuran diversity in the Atlantic forest. The preservation of large fragments of forest in the region of Etá Farm is necessary to preserve the diverse amphibian fauna of this region.
Keywords: *rainforest, banana plantation, peach palm plantation, reproductive phenology, reproductive mode, conservation.*

Anuros de áreas preservadas e perturbadas de Mata Atlântica na região da Fazenda Etá, município de Sete Barras, Estado de São Paulo, Brasil

Resumo: Neste estudo são apresentadas informações sobre diversidade e história natural de anuros de área preservadas e perturbadas na região da Fezenda Etá, município de Sete Barras, estado de São Paulo, Brasil. A região é coberta por florestas e plantações de pupunha e banana. De abril de 2013 a março de 2014 nós amostramos anuros principalmente com armadilhas de queda com cercas-guia e por meio de procura visual e auditiva. Um total de 9.813 indivíduos de 36 espécies de nove famílias foram registrados. Um número maior de espécies foi encontrado nas florestas (29 espécies), seguidas pelas plantações de pupunha (21 espécies) e de banana (17 espécies). As áreas de plantação de pupunha e as florestas tiveram a maior similaridade em composição de espécies. O tipo de vegetação com o maior número de espécies exclusivas foi a floresta, ao passo que somente quatro espécies foram encontradas exclusivamente na plantação de pupunha e nenhuma foi exclusiva de bananais. As curvas de acumulação de espécies indicaram que nosso esforço amostral não foi suficiente para amostrar todas as espécies que ocorrem na região. Nossos estudos reforçam a importância de ambientes florestados para a manutenção da diversidade de anfíbios na Mata Atlântica. A preservação de grandes fragmentos de floresta é imprescindível para a conservação da rica fauna de anfíbios da região da Fazenda Etá.
Palavras-chave: *floresta, bananal, plantação de pupunha, fenologia reprodutiva, modo reprodutivo, conservação.*

Introduction

Currently, about 1,100 amphibian species are known to occur in Brazil (Segalla et al. 2016), of which, 543 are found in the Atlantic Forest (Haddad et al. 2013), most of them endemic of this formation (Haddad et al. 2013). This high richness and endemism resulted from the isolation of populations by geographical barriers throughout the Atlantic Forest (Haddad 1998, Araújo et al. 2009). Furthermore, the high amount of rainfall, high humidity and high habitat complexity favour the occurrence of this rich and unique amphibian fauna (Haddad 1998, Haddad & Prado 2005).

The Atlantic Forest has been recognized as "hotspot" for studying and conserving the world's biodiversity (Mittermeier et al. 2004). The greatest threats to Brazilian amphibians are mainly the result from habitat loss and degradation (Becker et al. 2007). Studies on the diversity, geographic distribution, and ecology of amphibians (e.g., Haddad & Sazima 1992, Pombal Jr. & Gordo, 2004, Moraes et al. 2007, Serafim et al. 2008, Silva et al. 2008, Araújo et al. 2009, Forlani et al. 2010, Haddad et al. 2013) have provided valuable data for conservation strategies directed to this group. Faunal inventories provide the most direct means of accessing the diversity of a given locality at a given time (Silveira et al. 2010). At the same time, they provide useful natural history data that can be used in different kinds of research like evolutionary biology and conservation (Greene 1986).

The Atlantic Forest in the southern portion of the state of São Paulo, southeastern Brazil, is relatively well protected by a series of well-preserved protected areas such as the Carlos Botelho and Intervales State Parks. However, the remaining forests outside these protected areas are under threat by human activities. The regional economy is largely based on tea and banana agriculture (both in sharp decline) and on mining (mainly limestone). A large part of the population lives in rural areas and lives on subsistence agriculture and extraction of natural products from unprotected forest fragments (Alves 2004). These types of activities have changed the local landscape and several areas of the region are composed of secondary forests and areas of cultivation adjacent to the forest fragments. Although the amphibian communities occurring in the protected areas of this region have been previously studied (e.g., Forlani et al. 2010), our knowledge on communities from areas under human disturbance is still scant.

The aim of the present study was to make an inventory and provide information on the diversity and natural history of anurans from preserved and disturbed habitats in an area of Atlantic Forest in the municipality of Sete Barras, located in the southern portion of the state of São Paulo, southeastern Brazil. By providing information on anuran diversity in relatively well-preserved forests and in two types of anthropogenic habitats (peach palm and banana plantations), we contribute to the knowledge on the biology of amphibians of this portion of the Atlantic Forest and thus contributing with important information for conservation of the group in this domain.

Material and methods

1. *Study area*

Our study was carried out in the region of the Etá Farm, municipality of Sete Barras, state of São Paulo, southeastern Brazil (24°19'13" S and 48°7'3" W). The region is a transition between coastal lowlands and the Serra do Mar slopes, covered by Atlantic Forest (Joly et al. 1991), ranging from 45 to 800 m a.s.l. (Forlani et al. 2010). The present study was restricted to the lowlands of this region, from 45 to 80 m a.s.l. (Figure 1). Most of the region is covered by diverse rainforests (Mantovani 1993) and well-preserved forests in lowlands are interspersed by secondary forests and banana and peach palm plantations. The climate of the region is characterized by a high amount of annual rainfall (mean 1542 mm for the period of 2005 to 2014), high monthly maximum temperatures (mean 27.5 ºC), and moderate minimum monthly temperatures (mean 18.6 ºC). A warmer and wetter season occurs from October to March (mean monthly maximum temperature 30.0 ºC, mean monthly minimum temperature 21.0 ºC, 1030 mm of rainfall) and a colder and drier season from April to September (mean monthly maximum temperature 25.2 ºC, mean monthly minimum temperature 15.2 ºC, 512 mm of rainfall).

2. *Data collection*

Data were collected by two researchers along 14 days per month, from April, 2013 to March, 2014, for a total sample time of 168 days. Anurans were sampled with pitfall traps with drift fences (Greenberg et al. 1994, Cechin & Martins 2000), visual and auditory surveys (Scott & Woodward 1994, Martins & Oliveira 1998), as well as during accidental encounters (Martins & Oliveira 1998). Three main vegetation types (banana plantation, peach palm plantation, and secondary forest; Figure 2) were sampled with pitfall traps with drift fences. Our sampling design for pitfall traps included two sampling units per vegetation type, each sampling unit comprising three Y sets (with 12 m-long branches), located 100 m from each other. Thus, we installed a total of six sampling units with a total of 18 Y sets and 72 buckets. Sampling units were located at least 500 m from each other. Each Y set had four 100 L plastic buckets (three at each branch end and one in the center) connected by a 60 cm-high plastic fence. The buckets were perforated on the bottom to avoid accumulation of rain water.

Visual and auditory surveys were made in all vegetation types, including sporadic searches in an area of primary forest. These surveys were made at night, especially during the first hours after sunset and lasted two to four hours (total sampling effort of 558 person-hours of visual search). Searches were made along trails and streams in forests, and around ponds and marshes in open areas (banana and peach palm plantation). During these searches, we recorded reproductive activity (amplexus, number of calling males or presence of egg clutches), reproductive mode (based on Salthe & Duellman 1973, Haddad & Prado 2005, Pombal & Haddad 2005,; Haddad et al. 2013, Mariotto 2014), vegetation type and substrate used (e.g., ground, leaves, branches).

We collected a maximum of 40 specimens of each species and all specimens that were collected were measured (snout-vent length) with a caliper (0.01 mm) and weighed with spring scales (0.1 g). Field or collection numbers are listed in Appendix. Body size measurements are presented as mean snout-vent length (SVL) ± standard deviation. Voucher specimens were deposited in the herpetological collection of the Museu de Zoologia da Universidade de São Paulo (MZUSP). Specimen collecting was authorized by the Instituto Chico Mendes de Conservação da Biodiversidade (SISBIO permits 37820-3/2013 and 16593-1).

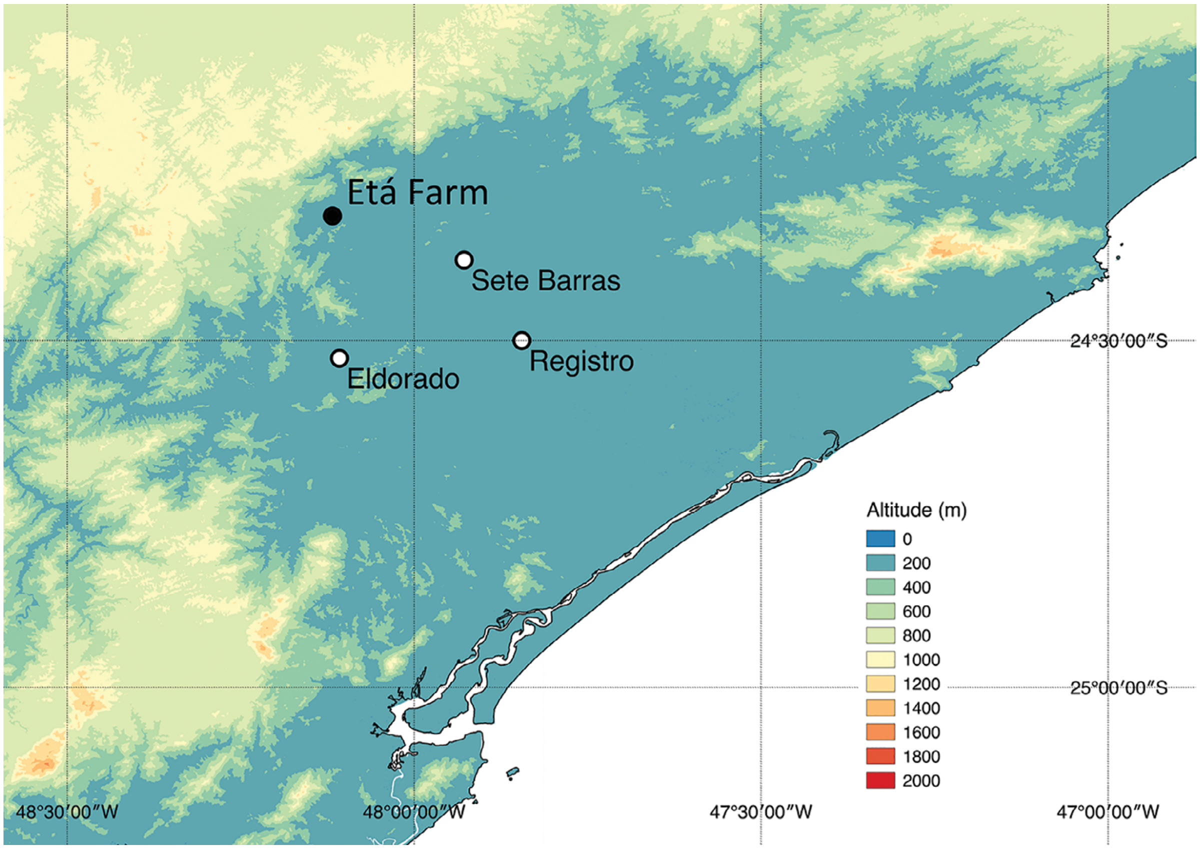

Figure 1. Altitudinal map of the southern portion of São Paulo state, Brazil, showing the location of the Etá farm as well as of the main cities in the region of the farm.

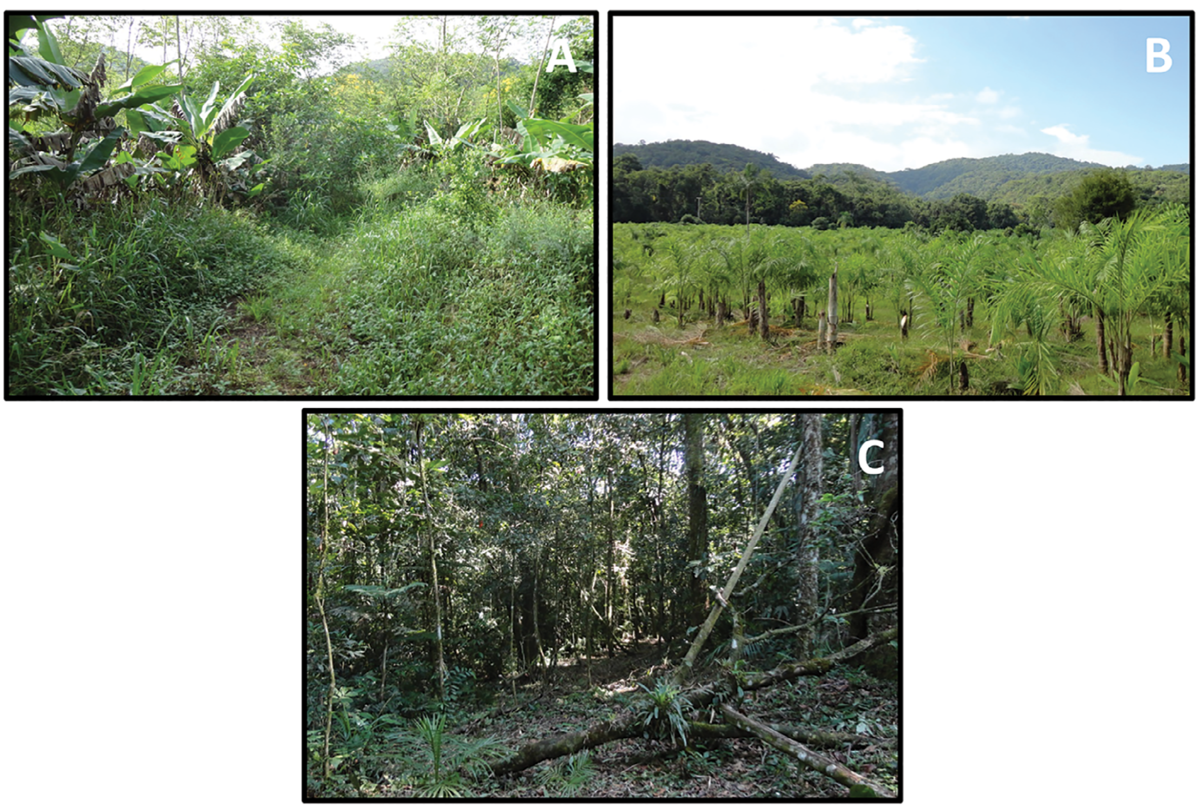

Figure 2. Main vegetation types sampled at Etá farm, municipality of Sete Barras, southern São Paulo state, Brazil. (A) Banana plantation, (B) Peach palm plantation, and (C) secondary forest.

3. *Data Analysis*

Sampling sufficiency was estimated visually with species accumulation curves (Magurran 2004) for the three main vegetation types (forest, banana plantation and peach palm plantation), together and separately. Using EstimateS v. 8.20 (Colwell 2012), we generated 1000 randomizations using our data matrix containing monthly abundance data for each vegetation type. A Bootstrap equation was used to estimate species richness (with 95% confidence limits). Our abundance data is based on different methods (see Table 1), some of them (visual/auditory survey and accidental encounters) not adequate to estimate abundances. Thus, we consider the Bootstrap equation more appropriate to our dataset because it estimates total richness using data for all species, not being restricted to the rare ones. The similarity between the vegetation types was achieved through the Bray-Curtis similarity index (Magurran 2004). Diversity was estimated using four different indices: Margalef's index (DMg), which expresses richness weighted by the range of sample size; Simpson's index (1/D), which measures dominance influenced by the most common species; Shannon's index (H'), which places a value on the proportional abundance of species, emphasizing richness and homogeneity; and Pielou's equitability index (J).

To provide the species composition and abundance distribution in all vegetation types we constructed a Venn diagram and abundance diagram (containing the total number of individuals observed in the field). A modification was made in the abundance diagram to include the total number of individuals captured of the species *Physalaemus spiniger* (which presented a much larger number of individuals than the other species).

To synthetize ecological patterns for the assemblage as a whole, a cluster analysis was performed using natural history data: habits (aquatic, arboreal, cryptozoic, fossorial, rheophilic, terrestrial), microhabitat (bromeliad, leaf litter, soil, soil at margins of water body, water body, trunk, emergent vegetation, vegetation), habitat (banana plantation, peach palm plantation, primary forest, secondary forest, disturbed areas), and parameters related to reproductive mode [aquatic, terrestrial, arboreal, endotrophic or exotrophic larvae, development mode (direct or indirect), egg deposition site (lentic or lotic environments), foam or free egg nests, parental care (if any)]. Euclidean distances were calculated on a presence/absence matrix and the unweighted pair-group average method (UPGMA, Romesburg 1984) was used for amalgamation in the software PAST (Hammer et al. 2001). We arbitrarily considered clusters with linkage distances greater than 2.75 as guilds, because clusters delimited by this value were ecologically coherent.

Results

A total of 9813 individuals of 36 species of anurans from nine families were recorded in this study (Figures 3-7). Most species were found in forests, followed by peach palm plantations (about two thirds of the species), and the banana plantations (about half of the species; Table 1, Figure 8). The areas of peach palm plantation and forests showed the greatest similarity in composition (BC = 0.57; Table 2). The banana plantation showed the same number of species in common with forest and with peach palm plantation (11 species). Only eleven species (30.5% of all species found) were found in all three vegetation types. The vegetation type with the highest number of exclusive species was the forest (primary and secondary), whereas only four species were exclusive of the peach palm plantation and none was exclusive of the banana plantation (Figure 8). Some species were found in a single vegetation type. Among the latter, twelve (33.3%;*Boana bischoffi*, *B. faber*, *Bokermannohyla hylax*, *Cycloramphus acangatan*, *C. lutzorum*, *Dendropsophus* cf. *brevipollicatus*, *Fritziana* cf. *ulei*, *Hylodes phyllodes*, *Ischnocnema* sp., *Ololygon rizibilis*, *Proceratophrys boiei*, and *Physalaemus lateristriga*) were found only in forests (primary and secondary), and four (11.1%; *Boana* cf. *raniceps*, *Dendropsophus elegans*, *D. seniculus*, and *Scinax imbegue*) only in peach palm plantations. No species was found exclusively in banana plantations (Figure 8).

Species accumulation curves for each of the three vegetation types as well as for all three vegetation types combined indicate that our sampling effort was not enough to sample all species that occur in the region (Figure 9). The estimated species richness was 39.4 species for the entire Etá Farm anuran assemblage. The estimates for each vegetation type separately were 32.8 species for the forest (primary and secondary), 23.8 for the peach palm plantation, and 19.7 for the banana plantation. The species most frequently found in this study was *Physalaemus spiniger*, with about 5500 individuals (Figure 10). Eight other species contributed with more than 100 individuals in our sample: *Leptodactylus latrans, Rhinella ornata, R. hoogmoedi, Leptodactylus notoaktites, Scinax imbegue, Rhinella icterica, Dendropsophus werneri*, and *Boana albomarginata* (Figure 10). In the other extreme, seven species contributed with a single individual: *Cycloramphus acangatan*, *C. lutzorum*, *Hylodes phyllodes*, *Ischnocnema* sp., *O. rizibilis*, *P roceratophrys boiei* and *P. lateristriga* (Figure 10). The areas that had the highest diversity according to the three indices were the forest (primary and secondary) and peach palm plantation (Table 3).

Nine of the species sampled (25%) are exclusively arboreal (using low or high vegetation), four (11.1%) are cryptozoic, one (2.7%) is bromeligenous, one is fossorial (2.7%), and one (2.7%) is rheophilic. Ten species (27.7%) use two types of substrate and ten (27.7%) use three or more types (Table 1).

During our study, the months with the largest number of calling species were November and December, while March, April, and May were the months with the smallest number of calling species (Table 4). No reproductive activity was recorded for seven species: *Ischnocnema* sp., *Cycloramphus lutzorum*, *Itapotihyla langsdorffii, Ololygon rizibilis*, *Hylodes phyllodes*, *Physalaemus lateristriga*, and *Proceratophrys boiei* (Table 4). During the study, monthly temperatures were relatively typical for the region while the amount of rainfall was atypical (Figure 11A). Rainfall was lower than expected in April, May, and December and higher than expected in June and July (compare months in Figure 11A and 11B). A total of 11 reproductive modes were identified in the assemblage studied, of which only three were observed in the field (Table 4). The most frequent modes were mode 1, occurring in 20 species (55.6%), modes 2 and 11, occurring in four species (11.1%) each, followed by mode 24, occurring in three species (8.3%), and by modes 4 and 23, in two species (5.6%) each. Eight species (22.2%) presented more than one reproductive mode, being mode 1 present in 7 of these species. Only one species (2.8%) showed three reproductive modes (Table 4).

The cluster analysis based on natural history data (vegetation type, substrate, and parameters related to reproductive mode; phenetic correlation coefficient 0.863) indicated an ecological structuring with six

Table 1. List of species of anurans found at Etá Farm and surroundings, including data on body size, habitat, substrate, and method of capture. Habitat: A = altered habitat (near buildings); B = Banana plantation; Fb = Forest border; P = Peach palm plantation; Pf = Primary forest; Sf = Secondary forest. For substrate: Br = Bromeliad; Fo = fossorial; Ll = Leaf litter; Ln = lentic water bodies (e. g., permanent or temporary ponds or natural or artificial lakes); Lo = lotic water bodies (rivers or streams); Lv = low vegetation (below 1.5 m); Hv = high vegetation (above 1.5 m); S = soil; T = Trunk. For method of capture: C = accidental encounter; P = pitfall trap; V/A visual/auditory search.

Species/Family	SVL ± SD (mm)	Habitat	Substrate	Capture Method
Brachycephalidae				
Ischnocnema sp.	31.1 ± 0.5 (*N* = 2)	Sf	Ll	V/A
Bufonidae				
Dendrophryniscus cf. *brevipollicatus* Jimenez de la Espada, 1870	17.6 ± 2.2 (*N* = 17)	Sf	Br, Ll	V/A, C
Rhinella hoogmoedi Caramaschi & Pombal, 2006	42.5 ± 10.3 (*N* = 23)	B, Fb, P, Sf	Ll, Lv, S	V/A, P, C
Rhinella icterica (Spix, 1824)	50.1 ± 19.3 (*N* = 8)	A, B, Fb, P, Sf	Ll, Ln, Lo, S	V/A, P, C
Rhinella ornata (Spix, 1824)	62.3 ± 16.8 (*N* = 22)	B, P, Sf	Ll, Ln, S	V/A, P, C
Cycloramphidae				
Cycloramphus acangatan Verdade & Rodrigues, 2003	37.0 (*N* = 1)	Sf	Fo	V/A
Cycloramphus lutzorum Heyer, 1983	48.8 (*N* = 1)	Pf	Lo	V/A
Craugastoridae				
Haddadus binotatus (Spix, 1824)	46.3 ± 9.8 (*N* = 19)	P, Sf	Ll	P
Hemiphractidae				
Fritziana cf. *ulei* Miranda-Ribeiro, 1926	25.0 ± 0.7 (*N* = 4)	Sf	Br	V/A, C
Hylidae				
Boana albomarginata (Spix, 1824)	52.3 ± 9.1 (*N* = 9)	B, Fb, P	Hv	V/A, C
Boana bischoffi (Boulenger, 1887)	47.6 ± 1.3 (*N* = 5)	Fb	Lv	V/A
Boana faber (Wied-Neuwied, 1821)	97.3 ± 5.9 (*N* = 11)	Fb, Sf	Ln, Lv, Hv, S	V/A
Boana cf. *raniceps* (Cope, 1862)	57.6 ± 7.9 (*N* = 7)	A, P	Ln, Lo, Lv, Hv	V/A
Boana semilineata (Spix, 1824)	48.4 ± 6.2 (*N* = 20)	A, B, P, Sf	Lv, S	V/A, C
Bokermannohyla hylax (Heyer, 1985)	60.4 ± 1.6 (*N* = 3)	Sf	Lv	V/A
Dendropsophus berthalutzae (Bokermann, 1962)	22.2 ± 2.2 (*N* = 13)	Fb, P	Lv	V/A, C
Dendropsophus elegans (Wied-Neuwied, 1824)	27.4 ± 3.1 (*N* = 16)	A, P	Ln, Lv, S	V/A, C
Dendropsophus minutus (Peters, 1872)	22.2 ± 1.5 (*N* = 8)	A, B, P	Ln, Lv	V/A, C
Dendropsophus seniculus (Cope, 1868)	36.1 ± 5.0 (*N* = 4)	P	Lv	V/A
Dendropsophus werneri (Cochran, 1952)	18.0 ± 1.9 (*N* = 19)	A, B, P	Ln, Lv	V/A, C
Itapotihyla langsdorffii (Duméril & Bibron, 1841)	95.0 ± 14.5 (*N* = 6)	Fb, P	Lo, Lv, T	V/A, C
Phyllomedusa distincta Lutz, 1950	57.2 ± 8.9 mm (*N* = 15)	A, B, Fb, Sf	Ln, Lv	V/A, C
Ololygon argyreornata (Miranda-Ribeiro, 1926)	16.8 ± 2.3 (*N* = 6)	A, B, Fb, Sf	Lv	V/A, C
Ololygon littoralis (Pombal & Gordo, 1991)	27.9 ± 6.3 (*N* = 10)	B, Fb, P, Sf	Lv	V/A, C
Ololygon rizibilis (Bokermann, 1964)	27.5 (*N* = 1)	Sf	Lv	V/A
Scinax fuscovarius (Lutz, 1925)	40.3 ± 3.6 (*N* = 13)	A, B, Fb, P	Lv	V/A, C
Scinax imbegue Nunes, Kwet & Pombal, 2012	30.3 ± 2.1 (*N* = 16)	A, P	Ln, Lv, S	V/A, C
Sphaenorhynchus caramaschii Toledo, Garcia, Lingnau & Haddad, 2007	24.6 ± 0.5 (*N* = 3)	Sf, B	Ln, Lv	V/A
Trachycephalus mesophaeus (Hensel, 1867)	67.6 ± 9.1 (*N* = 10)	B, Fb, P, Sf	Ln, Lv, Hv	V/A
Hylodidae				
Hylodes phyllodes Heyer & Cocroft, 1986	22.1 (*N* = 1)	Sf	Ll, Lo	C
Leptodactylidae				
Adenomera marmorata Steindachner, 1867	18.2 ± 1.8 (*N* = 26)	B, P, Sf	Ll, S	P
Leptodactylus latrans (Steffen, 1815)	88.1 ± 26.3 (*N* = 21)	A, B, Sf, P	Ln, Lo, S	P, C
Leptodactylus notoaktites Heyer, 1978	44.6 ± 7.6 (*N* = 49)	B, Fb, P, Sf	Fo, S	V/A, P, C
Physalaemus lateristriga (Steindachner, 1864)	34.3 (*N* = 1)	Sf	Ll	P
Physalaemus spiniger (Miranda-Ribeiro, 1926)	19.0 ± 1.8 (*N* = 41)	A, B, P, Sf	Ll, Ln	V/A, P, C
Odontophrynidae				
Proceratophrys boiei (Wied-Neuwied, 1824)	15.95 (*N* = 1)	Pf	Ll	V/A

Figure 3. Anurans recorded at Etá farm, municipality of Sete Barras, southern São Paulo state, Brazil. (A) *Ischnocnema* sp.; (B) *Dendrophryniscus* cf. *brevipollicatus*; (C) *Rhinella hoogmoedi*; (D) *R. icterica*; (E) *R. ornata*; (F) *Cycloramphus acangatan*; (G) *C. lutzorum*; (H) *Haddadus binotatus*. Photos: B. F. Fiorillo.

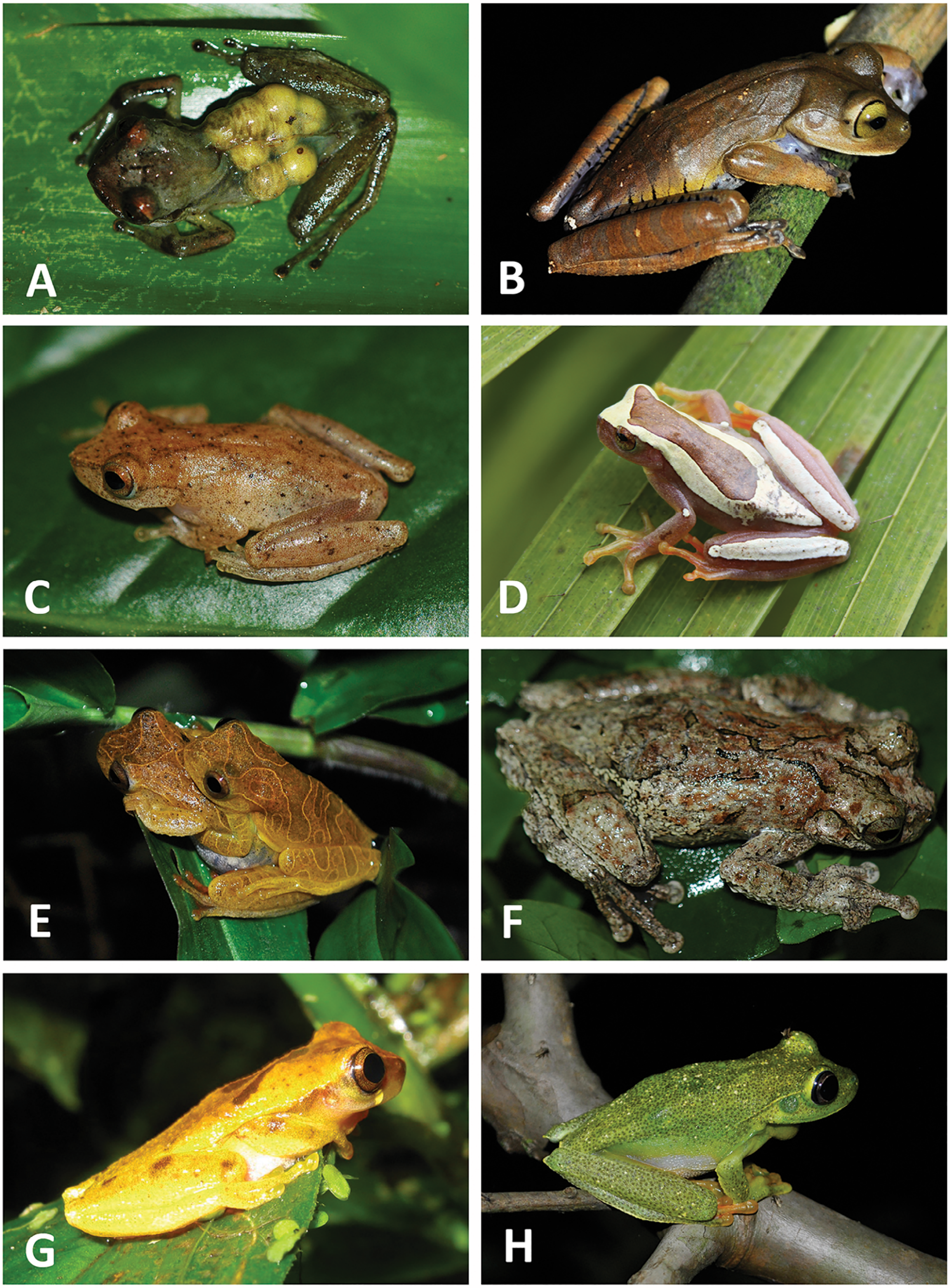

Figure 4. Anurans recorded at Etá farm, municipality of Sete Barras, southern São Paulo state, Brazil. (A) *Fritziana* cf. *ulei*; (B) *Bokermannohyla hylax*; (C) *Dendropsophus berthalutzae*; (D) *D. elegans*; (E) *D. minutus*; (F) *D. seniculus*; (G) *D. werneri*; (H) *Boana albomarginata*. Photos: B. F. Fiorillo.

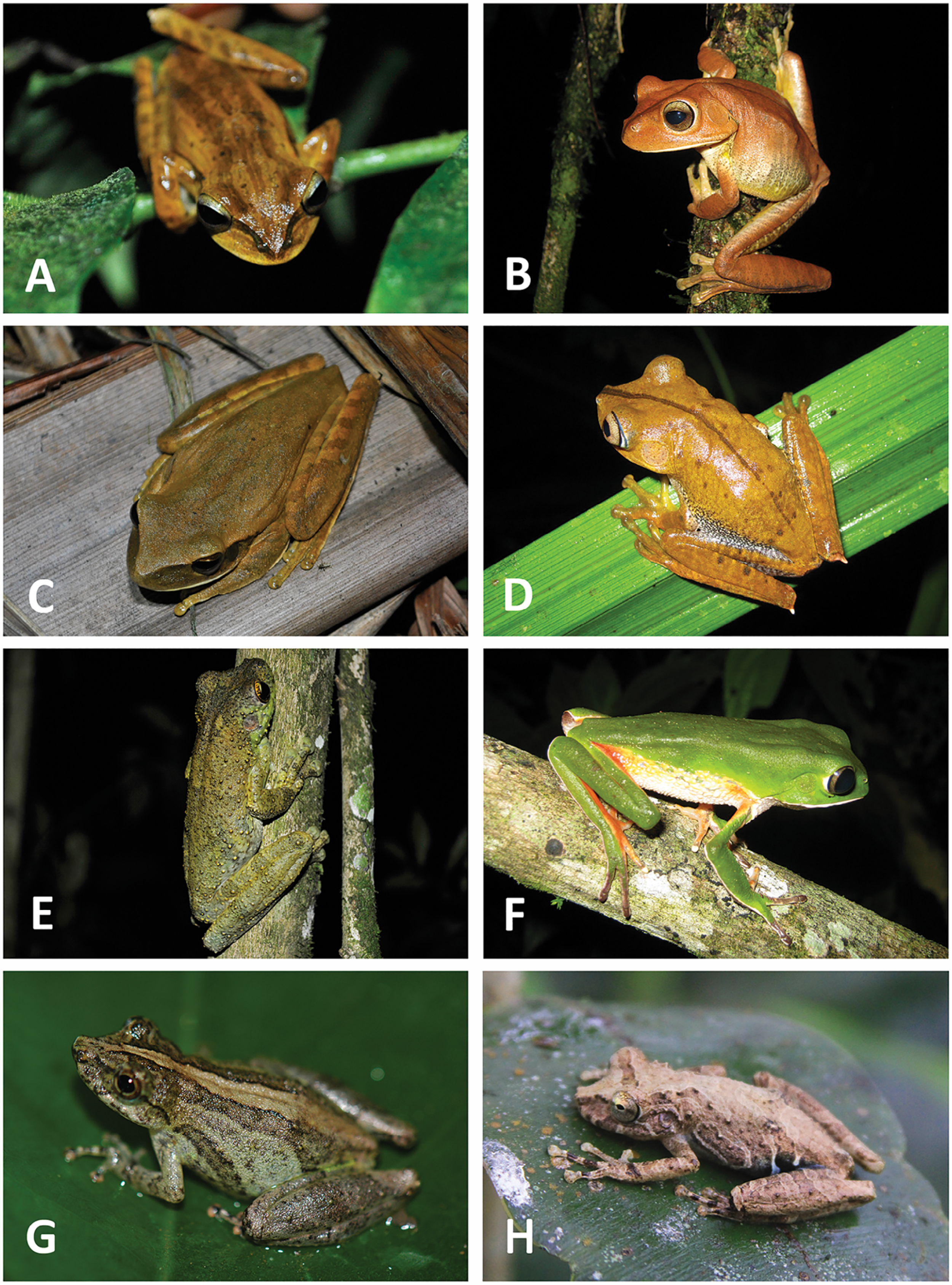

Figure 5. Anurans recorded at Etá farm, municipality of Sete Barras, southern São Paulo state, Brazil. (A) *Boana bischoffi*; (B) *B. faber*; (C) *B.* cf. *raniceps*; (D) *B. semilineata*; (E) *Itapotihyla langsdorffii*; (F) *Phyllomedusa distincta*; (G) *Ololygon argyreornata*; (H) *Ololygon. littoralis*. Photos: B. F. Fiorillo.

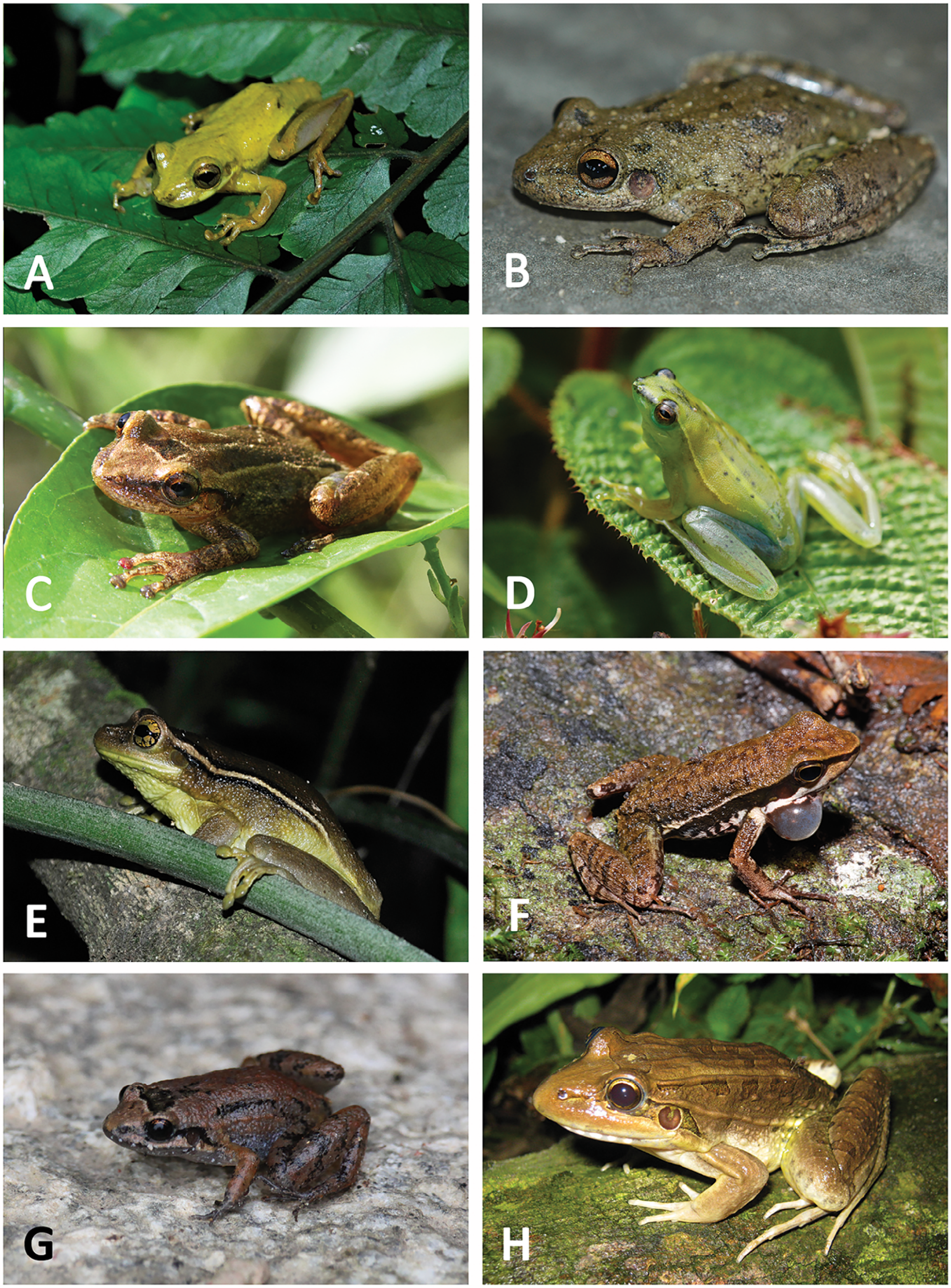

Figure 6. Anurans recorded at Etá farm, municipality of Sete Barras, southern São Paulo state, Brazil. (A) *Ololygon rizibilis*; (B) *Scinax fuscovarius*; (C) *Scinax imbegue*; (D) *Sphaenorhynchus caramaschii*; (E) *Trachycephalus mesophaeus*; (F) *Hylodes phyllodes* (Photo: M. Martins, municipality of Ubatuba, SPstate of São Paulo, Brazil);. (G) Adenomera marmorata; (H) Leptodactylus latrans. Remaining photos: B. F. Fiorillo.

Figure 7. Anurans recorded at Etá farm, municipality of Sete Barras, southern São Paulo state, Brazil. (A) *Leptodactylus notoaktites*; B) *Physalaemus lateristriga* (Photo: G. L. Oliveira, municipality of Tijuco do Sul, state of Paraná, Brazil); (C) *P. spiniger*; (D) *Proceratophrys boiei* (Photo: M. Denoel, municipality of São Miguel Arcanjo, state of São Paulo, Brazil). Remaining photos: B. F. Fiorillo.

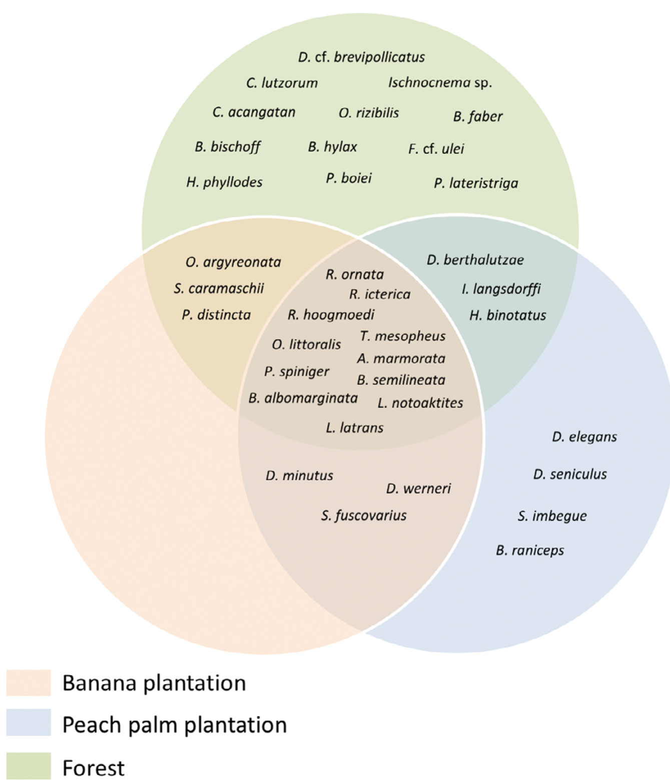

Figure 8. Venn diagram of the intersections between the composition of each of the three vegetation types sampled (banana plantation, peach palm plantation, and forests)

Table 2. Similarity (Bray-Curtis index) of anuran abundances between vegetation types sampled at Etá farm, municipality of Sete Barras, state of São Paulo, Brazil.

	Banana plantation	Peach palm plantation	Forest
Banana plantation	-	0.40	0.18
Peach palm plantation	0.40	-	0.57
Forest	0.18	0.57	-

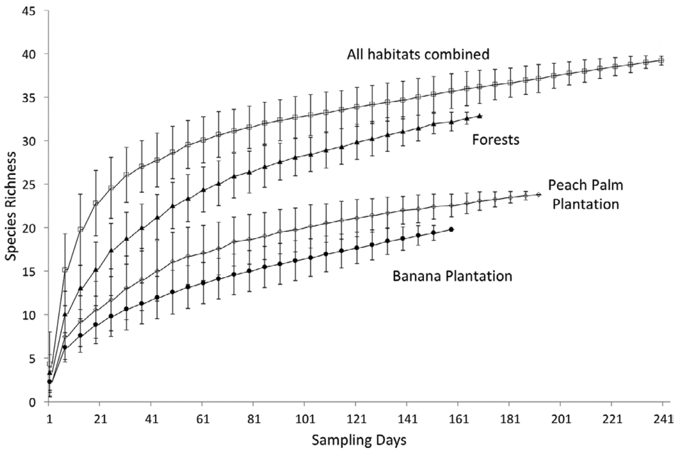

Figure 9. Bootstrap mean species accumulation curves and respective standard deviations (1000 randomizations of samplings) for all vegetation types combined, for forest, for peach palm plantation, and for banana plantation. Samplings were made at Etá farm, municipality of Sete Barras, southern São Paulo state, Brazil.

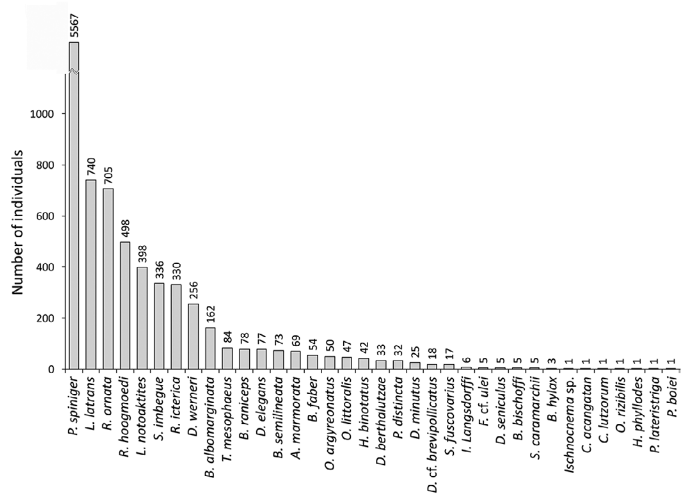

Figure 10. Distribution of abundances of anurans sampled at Etá farm, municipality of Sete Barras, southern São Paulo state, Brazil. Values are shown above each bar. Note that the bar for *Physalaemus spiniger* is broken.

Table 3. Richness, diversity, and equitability of anurans in the vegetation types studied at Etá farm, municipality of Sete Barras, São Paulo state, Brazil.

	Banana plantation	Peach palm plantation	Forest
Total number of species	17	21	29
Number of exclusive species	0	4	12
Margalef diversity (Dmg)	2.34	2.53	3.35
Simpson diversity (1/D)	0.79	0.58	0.42
Shannon diversity (H’)	1.80	1.41	1.08
Pielou’s equitability (J)	0.63	0.46	0.32

guilds (Figure 12), one composed of related species (guild a, comprising exclusively hylids) and the remaining composed by species from different lineages (e.g., guild b, comprising species from three different families). Guild a is composed by all hylids (except for *Boana faber* that was not included in this cluster), all of them using arboreal substrates and laying eggs in lentic habitats or on vegetation; guild b is composed by *Cycloramphus lutzorum*, *Hylodes phyllodes*, *Proceratophrys boiei*, and *Boana faber*, species that are always associated to forests forests and lay eggs in the water or in the soil; guild c is composed by the species of the family Bufonidae and *Leptodactylus latrans* (Leptodactylidae), which use terrestrial substrates and were found in water bodies in all vegetation types sampled; guild d is composed of *Dendrophryniscus* cf. *brevipollicatus* and *Fritziana* cf. *ulei*, which are closely associated to bromeliads; guild e is composed of *Leptodactylus notoaktites*, *Physalaemus lateristriga*, *P. spiniger*, and *Adenomera marmorata*, which are cryptozoic, all of them found in forests and deposit eggs in foam nests; and guild f which includes *Cycloramphus acangatan*, *Haddadus binotatus*, and *Ischnocnema* sp., species that use non-arboreal substrates and lay eggs on the ground (Figure 12).

Discussion

The anuran species richness found in the region of Etá Farm (36 species) and the estimated species richness based on our sample (ca. 40 species) are smaller than those obtained in some studies conducted at Atlantic Forest sites in southern São Paulo state. For instance, Araujo et al. (2010) found 60 species at Parque Estadual Turístico do Alto do Ribeira, located about 50 km far from our study area, and Forlani et al. (2010) found 65 species at a Parque Estadual Carlos Botelho, located about 25 km far from Etá Farm. However, both studies included sampling sites with different forest types within a wide altitudinal range (e.g., 30–1000 m above sea level in the study of Araujo et al. 2010). Possibly, the limited area and altitudinal range of our forest site may have limited the number of species that we could potentially find. The smaller species richness found may also reflect the frequent sampling in disturbed areas in our study.

Indeed, Pombal & Haddad (2005) found 45 anuran species in a mosaic of forests and disturbed areas in the region of Ribeirão Branco, located about 70 km from our study site. Zina et al. (2012) found 17

Table 4. Reproductive mode and phenology of anuran species found at Etá Farm, municipality of Sete Barras, state of São Paulo, Brazil, from April 2013 to March 2014. Abbreviations are: a = amplexus; c = calling males; e = egg clutches; f = females bearing eggs; RM = reproductive mode (based on Salthe & Duellman 1973, Pombal & Haddad 2005, Haddad & Prado 2005; Haddad et al. 2013; Mariotto 2014).

Family/Species	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	RM
Brachycephalidae													
Ischnocnema sp.													23**
Bufonidae													
Dendrophryniscus cf. *brevipollicatus*			c e										8*
Rhinella hoogmoedi				f				c	f a				1**
Rhinella icterica				c	c			c	a e				1** 2*
Rhinella ornata	a	c f	c a	c	c a								1* 2**
Cycloramphidae													
Cycloramphus acangatan					c								21**
Cycloramphus lutzorum													19**
Craugastoridae													
Haddadus binotatus					f	f		f					23**
Hemiphractidae													
Fritziana cf. *ulei*						f					f		36*
Hylidae													
Bokermannohyla hylax					f								4**
Boana albomarginata				c			c	c f	c				1**
Boana bischoffi					c						c		1**
Boana faber	c						c	c	c	c		c	1** 4**
Boana cf. *raniceps*						c	c	c	c				1**
Boana semilineata	c	c	c	c								c	1** 2**
Dendropsophus berthalutzae										f	c	c	24**
Dendropsophus elegans							c	c f	c		c	c	1**
Dendropsophus minutus					c a		c	c				c	1*
Dendropsophus seniculus											c f a		1**
Dendropsophus werneri					c	c	c	c	c			c	1** 24**
Itapotihyla langsdorffii													1**
Ololygon argyreornata					f a						c f a		1**
Ololygon littoralis				c	f		c		f a		c		1** 6**
Ololygon rizibilis													11**
Phyllomedusa distincta					f		c		c	c	c a		24**
Scinax fuscovarius	c		c										1**
Scinax imbegue				c	c	c	c	c	c		f a	c	1*
Sphaenorhynchus caramaschii							c	c					1*
Trachycephalus mesophaeus								c f a			c		1*
Hylodes phyllodes													3**
Leptodactylidae													
Adenomera marmorata				f	f	f	f	f					32**
Leptodactylus latrans				f			c	c					11**
Leptodactylus notoaktites					c	c f		c f	c f	c f			30*
Physalaemus lateristriga													11**
Physalaemus spiniger	c		a	a	a		c						11* 14** 28*
Odontophrynidae													
Proceratophrys boiei													1** 2**

* Reproductive mode observed in the field; ** Reproductive mode based on literature information.

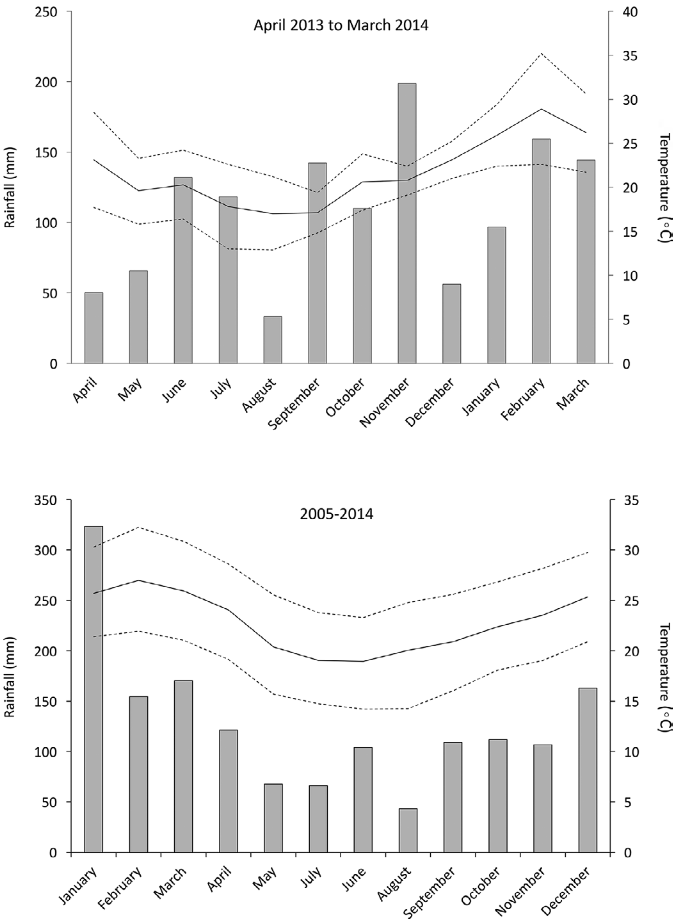

Figure 11. (A) Climatic data for the period of study (April 2013 to March 2014) and (B) for 10 years (2005 to 2014) for municipality of Sete Barras (ca. 35 m a.s.l.), southern São Paulo state, Brazil, located ca. 20 km from the study area. The continuous line represents monthly mean temperature and interrupted lines above and below represent monthly means of maximum and minimum temperatures, respectively. Bars represent monthly amount of rainfall. Data from CIIAGRO (2015).

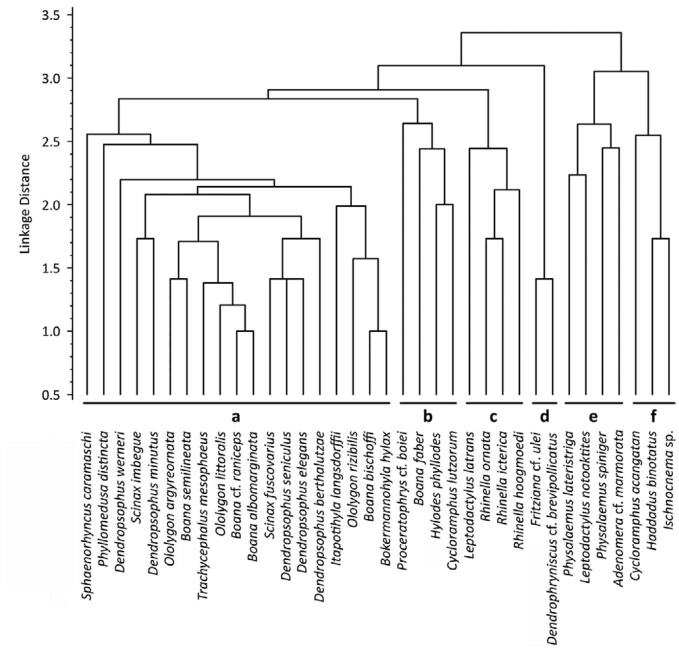

Figure 12. Dendrogram of a cluster analysis based on natural history data (vegetation type, substrate, and characters related to reproductive mode). Euclidean distances were calculated on a presence/absence matrix and the unweighted pair-group average method was used for amalgamation. Bars with lowercase letters indicate guilds. See text for details.

to 27 species in anuran communities of sandy coastal plains of the Lagamar Paulista, which comprises the municipalities of Cananéia, Ilha Comprida, Iguape, and Pariquera-Açu (located 35 to 70 km from our study site).

We found a higher species richness of anurans in forests (N = 29) than in plantations (N = 21 in peach palm plantation and 17 in banana plantation). Furthermore, forests showed more exclusive species (N = 12) than plantations (zero and four species in peach palm plantation and banana plantation, respectively). These results indicate that the preservation of forest fragments is fundamental for most of the species found in the region of Etá Farm. The higher species richness in peach palm plantations (N = 21) in relation to banana plantations (N = 17) may be related to the frequent occurrence of temporary ponds in the former. The lower species richness of the banana plantation, combined with the fact that this vegetation type does not have any exclusive species, may be related to some difficulty of the species to colonize and/or settle in this vegetation type. Gardner et al. (2007) analysed data for different forest types (primary, secondary, and *Eucalyptus* forests) and concluded that primary rainforest harbours significantly more species, but support a similar abundance of amphibians and lizards compared with adjacent areas of second-growth forest or plantations.

Three of the commonest species in our study site, *Physalaemus spiniger*, *Leptodactylus latrans*, and *Rhinella ornata*, are habitat generalists and seem to tolerate a relatively high intensity of human disturbance in their habitats (Haddad 1998, Carvalho-e-Silva et al. 2008, Serafim et al. 2008, Ferreira & Tonini 2010, Forlani et al. 2010), what may explain their high abundance. Despite the tolerance to disturbed habitats, the high number of individuals of *P. spiniger* (5567) possibly reflects the diversity of reproductive modes used by this species as well as the relatively high diversity of vegetation types it used. Other species of *Physalaemus* may also show a high abundances (e.g., Brasileiro et al. 2005, Araujo & Almeida-Santos 2011).

Only three anuran species (8.3%), *Boana faber*, *Dendropsophus werneri*, and *Scinax imbegue*, showed reproductive activity (indicated by amplexus, vocalizations, gravid females, and egg clutches) for six or more months during our study. In spite of being observed breeding throughout the year in other studies (Pombal 1997, Forti 2009, Santos & Conte 2014), *Boana bischoffi* and *Dendropsophus minutus* were reproductively active for few months at the Etá Farm region.

The cluster analysis based on natural history data revealed an ecological structuring with six arbitrarily defined guilds (Figure 12). These groups can be explained, in part, by convergent traits related to locomotion in closely related species (Gomes et al. 2009). Zug (1978) suggested that habitat use is related to amphibian morphology (e.g., jumping performance relative to snout-vent length). For instance, the larger group (group a) is formed essentially by hylids, that use arboreal substrates. The groups c and e are formed almost completely by bufonids (with exception of *Leptodactylus latrans*) and leptodactylids, respectively, which use terrestrial substrates. As for habitat use, in group c, all species use all types of vegetation cover, while in the group e species are more restricted to forests. Bastazini et al. (2007) investigated which environmental variables would predict the main changes in anuran community composition in a shrub-to-forest restinga gradient and their analysis suggested that plant communities are the most important environmental factor acting on the structure of the anuran community studied. This also seems to be the case of group d, formed by *Dendrophryniscus* cf. *brevipollicatus* and *Fritziana* cf. *ulei*, species highly dependent on bromeliads (shelter and reproduction site). The groups b and f appear to differ in their need for water bodies for breeding. Although both are restricted to forests, they include species that present different preferences in substrate use (e.g., group b includes one cryptozoic, one arboreal, and two rheophilic species). As stated by Duellman & Trueb (1994), spatial heterogeneity lead to a higher number of substrates, thereby increasing the number of anuran species in communities, because they could occupy different parts of the mosaic. Thus, guilds can be formed by species that occupy the same vegetation cover and different substrates.

In conclusion, we found less species in disturbed areas than in forests, no species was exclusive to banana plantation, and just a few species were exclusive to peach palm plantation. These results reinforce the importance of forested habitats for the maintenance of anuran diversity in the Atlantic Forest. Therefore,, the preservation of large fragments of forest in the region of Etá Farm is necessary to preserve the diverse amphibian fauna of this region.

Supplementary material

The following online material is available for this article:
Appendix

Acknowledgements

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Author Contributions

Bruno Ferreto Fiorillo: Provided substantial contribution in the concept and design of the study. Sconfienza contributed to data collection. Contributed to data analysis and interpretation, manuscript preparation, and to critical revision, adding intellectual content.

Carolina Sconfienza Faria: To data collection. Contributed to data analysis and interpretation, manuscript preparation, and to critical revision, adding intellectual content.

Bruno Rocha Silva: Contributed to data collection.

Marcio Martins: Provided substantial contribution in the concept and design of the study. Contributed to data analysis and interpretation, manuscript preparation, and to critical revision, adding intellectual content.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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