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Anuran Species Richness, Composition, and Breeding Habitat Preferences: a Comparison between Forest Remnants and Agricultural Landscapes in Southern Brazil

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Fabrício Hiroiuki Oda, Vinicius Guerra Batista, Priscilla Guedes Gambale, Fabio Teruo Mise, Fagner de Souza, Sybelle Bellay, Jean Carlo G. Ortega, and Ricardo Massato Takemoto (2016) The expansion of agriculture causes habitat loss and fragmentation that negatively affects biodiversity. We analyzed the species richness, composition and habitat preferences of anuran species in aquatic habitats in mesophytic semideciduous Atlantic Forest remnants and surrounding agricultural landscapes in southern Brazil, between April 2011 and March 2013. Nineteen anuran species, belonging to 11 genera and 5 families, were recorded. Species richness was similar between the forest remnants and the agricultural landscapes (18 and 19 species, respectively). Anuran species composition was associated with habitat type and the number of vegetation types in breeding habitats. Most species preferred breeding habitats in the agricultural landscape. Our results suggest that the anuran species recorded have access to both forest remnants and agricultural landscapes, as species richness in the two areas was similar. Habitat type and the number of vegetation types may influence species composition, because vegetation provides shelter and calling sites for anurans, which breed mainly in lentic water bodies. Thus, to maintain anuran populations in fragmented landscapes, it is important to preserve artificially constructed bodies of water within the agricultural landscape and on the forest edge.

Key words: Agricultural ecosystems, Amphibians, Anthropic alterations, Atlantic Forest, Habitat loss.

BACKGROUND

Habitat loss and fragmentation due to the expansion of agriculture are among the main causes of global biodiversity loss (Tilman et al. 2001; Krauss et al. 2010; Rybicki and Hanski 2013). In Brazil, deforestation caused by agricultural expansion has created a fragmented landscape with forest patches within a crop and pasture matrix (Lira et al. 2012). The changes in the natural landscapes particularly threaten amphibian species (Storfer 2003; Stuart et al. 2004; Cushman 2006), which are susceptible to environmental changes, by altering their distribution and habitat use (Duellman and Trueb 1994). For example, the increase in temperature and decrease in soil moisture caused by deforestation render the area unsuitable for some anuran species, which have high rates of water loss by evaporation, leading to mortality due to desiccation or predation

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(deMaynadier and Hunter 1999; Rothermel and Semlitsch 2002).

Habitat fragmentation in the Atlantic Forest forces amphibians to migrate through a disturbed landscape in order to find breeding habitat that is suitable for their aquatic offspring (Becker et al. 2007, 2010). The forest remnants that exist within agricultural landscapes are important refuges for local anuran populations (da Silva and Rossa-Feres 2011; da Silva et al. 2011a). These forest patches can be used as migration corridors between breeding habitats, refuges, and feeding and aestivation areas (Knutson et al. 1999; Weyrauch and Gubb Jr 2004; da Silva and Rossa-Feres 2007). The forest vegetation structure creates microhabitats and provides favorable microclimatic conditions for contiguous aquatic habitats (Knutson et al. 1999), such as artificially constructed bodies of water on the edges of forest remnants in agricultural landscapes.

Water bodies are built in the agricultural landscape for various purposes (*e.g.*, to supply water to domestic animals, to irrigate crops, to enable fish production, to create recreational areas) (Jeffries 2011; Hartel and Von Wehrden 2013). These bodies of water are important to anurans, as they provide breeding habitats (Knutson et al. 2004; Peltzer et al. 2006; Santos et al. 2007; da Silva et al. 2011b, 2012; De Marco et al. 2014). However, the species richness and composition of anurans can be influenced by the environmental heterogeneity of breeding habitats (Vasconcelos et al. 2009). Some anurans are found in high abundance and demonstrate longer breeding periods in breeding habitats nearest to forest remnants (da Silva and Rossa-Feres 2011). Thus, the conservation of bodies of water in agricultural landscapes, especially near forest remnants, benefits these species (da Silva et al. 2012).

The Atlantic Forest, one of the world's 34 hotspots (Mittermeier et al. 2004), has high biodiversity and high endemism of plants and animals. Unfortunately, it has suffered many changes to its landscape (Ribeiro et al. 2009; Tabarelli et al. 2012). It is considered one of the most threatened forest ecosystems in the world, with only 11.73% of the original vegetation remaining (Ribeiro et al. 2009), which includes the mesophytic semideciduous Atlantic Forest (Morellato and Haddad 2000; Oliveira-Filho and Fontes 2000). Several ecological studies on anurans have been completed in this region in agricultural landscapes or forest remnants in the inland areas of São Paulo State, Brazil (*e.g.*, Toledo et al. 2003; Vasconcelos and Rossa-Feres 2005; Santos et al. 2007, 2009). In this region, most anuran species are considered habitat generalists and use artificially constructed bodies of water in agricultural landscapes as breeding habitats (Duellman 1999; Santos et al. 2007).

The northwestern region of Paraná State, southern Brazil, originally covered by extensive areas of mesophytic semideciduous Atlantic Forest, has suffered a massive loss of native vegetation (Campos 1999, 2004; Maack 2002). Less than 1% of the original vegetation remains, and this is comprised of small remnants scattered within the agricultural landscape (Campos 1999, 2004; Ribeiro et al. 2013). Artificial bodies of water in the agricultural landscapes provide breeding habitats for most anuran species (Affonso et al. 2013; Gambale et al. 2014; Oda et al. 2014a), but these species are threatened by the expansion of sugarcane crops used in ethanol production (Ribeiro et al. 2013). Little is known about which species depend on these water bodies, or which environmental factors influence the anuran species assemblage. Therefore, it is important to understand the structure of the anuran community and the factors affecting anurans' use of artificial bodies of water as breeding habitats, in order to develop strategies to maintain high biodiversity in these modified landscapes without sacrificing agricultural production (da Silva et al. 2012).

We surveyed anurans in aquatic habitats in forest remnants and surrounding agricultural landscapes in southern Brazil. Specifically, we sought to answer three questions: (1) Does the species richness in forest remnants differ from that in agricultural landscapes? (2) Which habitat features influence the species composition of anurans in different breeding habitats? and (3) Do anuran species in the study sites demonstrate fidelity to breeding habitats in agricultural land-scape?

Anurans from open areas are habitat generalists that use forest remnants as refuges only during the nonbreeding season, and as diurnal shelters and feeding areas during the breeding season (da Silva and Rossa-Feres 2007). We therefore expect to find similar species richness in forest remnants and agricultural landscapes. We also expected that vegetation cover (*e.g.*, forest vegetation contiguous to breeding habitats and vegetation in breeding habitats) would positively affect species composition because it provides shelters and calling sites for anurans (Vasconcelos et al. 2009). Finally, we expected that the majority of species would prefer breeding habitats in agricultural landscapes because anurans found in open areas are habitat generalists that are tolerant to anthropogenically modified environments (Duellman 1999; Vasconcelos and Rossa-Feres 2005; Santos et al. 2007).

MATERIALS AND METHODS

Study area

This study was conducted at the Estação Ecológica do Caiuá (EEC) and in surrounding agricultural landscapes (22°35' to 22°38'S, 52°49' to 52°53'W, 283 m asl), located at Diamante do Norte, in the northwestern region of Paraná State, in southern Brazil (Fig. 1). The EEC covers an area of approximately 15 km^2, composed of mesophytic semideciduous Atlantic Forest. The area surrounding the EEC is characterized by extensive pastures and manioc plantations that are being replaced by sugarcane (Ribeiro et al. 2013). The regional climate is classified as type Cfa in the Köppen Climate Classification system, a temperate climate with no dry season and with hot summers (Peel et al. 2007). The average annual temperature is 22°C (with an average minimum of 18°C in the winter and average maximum of 28°C in the summer) (Mendonça and Danni-Oliveira 2002), and the average annual rainfall is approximately 1,300 mm (Zandonadi et al. 2008).

Anuran sampling and heterogeneity of breeding habitats

We conducted 12 field sessions lasting 5 days each, including 4 sessions during the nonbreeding season (April, June, and August 2011 and April 2012), and 8 sessions during the breeding season (December 2011; February, October, November, and December 2012; and January, February, and March 2013), for a total of 60 sampling days and 252 hours. In the forest remnants (FR), we surveyed nine bodies of water, and in the agricultural landscapes (AL) we surveyed 12 bodies of water (Table 1, Fig. 2). We pooled the species occurrence in all the surveyed bodies of water across all sampling periods to preclude pseudoreplication. Surveys were performed using visual and auditory search methods to detect anuran species (Scott and Woodward 1994). Species that were not detected during these surveys were assumed absent. Each body of water was surveyed for 1 h by a single researcher during the night (from 18:00 to 00:00 h), for every field session. Voucher specimens were collected, and anesthetized with 5% lidocaine, fixed in 10% formalin, and preserved in 70% ethanol, and housed at the Zoological Collection of the Universidade Federal de Goiás (ZUFG, Brazil).

Structural (*i.e.*, hydroperiod and habitat type) and biological (*i.e.*, number of plant types) characteristics of the bodies of water were determined between October 2012 and March 2013. This time period was selected because it spans the breeding season of most anuran species in the region (Gambale et al. 2014). We visually recorded the characteristics of each breeding habitat as categorical variables: a) hydroperiod: 1 = permanent, 2 = temporary; b) habitat type: 1 = lentic, 2 = lotic; and c) number of different vegetation types: floating macrophytes (Fmc), emergent macrophytes (Emc), gramineous vegetation (Grm), herbaceous vegetation (Her), shrubby vegetation (Shb), and arboreal vegetation (Arb): 1 = 3-4 types of vegetation, 2 = 5-6 types of vegetation.

Data analysis

To evaluate sampling effort and compare species richness between FR and AL, we calculated individual rarefaction curves for each area (FR and AL), based on the presence or absence of anuran species at the breeding habitats. Each breeding habitat was considered a sampling unit. We also estimated richness using the Jackknife 2 estimator. Rarefaction curves and the estimations of richness were generated using EstimateS v.9.1.0 (Colwell 2013).

To assess the relative contribution of the habitat features to anuran species composition, we performed a permutational multivariate analysis of variance (PERMANOVA; Anderson 2001). The hydroperiod, habitat type, and number of vegetation types were included as predictor variables, and the response variables were taken from the species composition matrix. We calculated the PERMANOVA significance with 1,000 permutations. An analysis using the unweighted pair group method with arithmetic mean was performed to identify potential clusters of breeding habitats, using the factors analyzed using PERMANOVA. All multivariate analyses were performed using a dissimilarity matrix based on the Jaccard index (Wolda 1981). These analyses were performed using PRIMER version 6 (Clarke and Gorley 2006) and PERMANOVA+ for PRIMER (Anderson et al. 2008).

To determine breeding habitat preferences of the anuran species, we calculated Pearson's correlation coefficient (Φ) for habitat groups of unequal size (Chytrý et al. 2002) based on 10,000 randomizations of the presence/absence records of anuran species at the defined breeding habitats. This statistical measure of species preference equalizes the size of all groups in the dataset to a new value, since it depends on the size of the target site group (Tichý and Chytrý 2006). The value of Φ ranged from -1 to 1, where values equal or close to zero indicate that anuran species avoid or show no preference for the indicated breeding

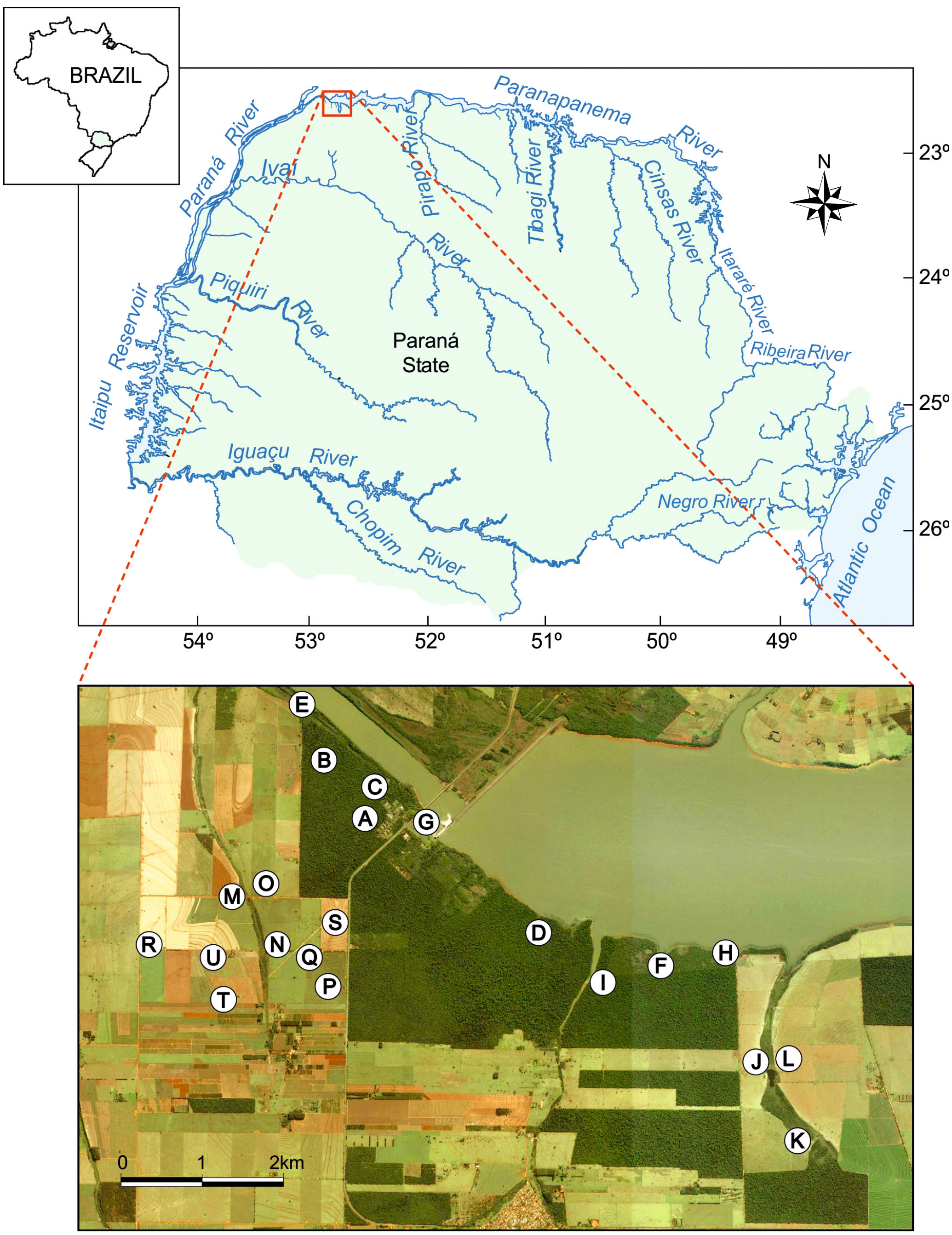

Fig. 1. Map of the study sites. Distribution of the breeding habitats in forest remnants and agricultural landscapes, Diamante do Norte, Paraná State, southern Brazil. See breeding habitat descriptions in table 1.

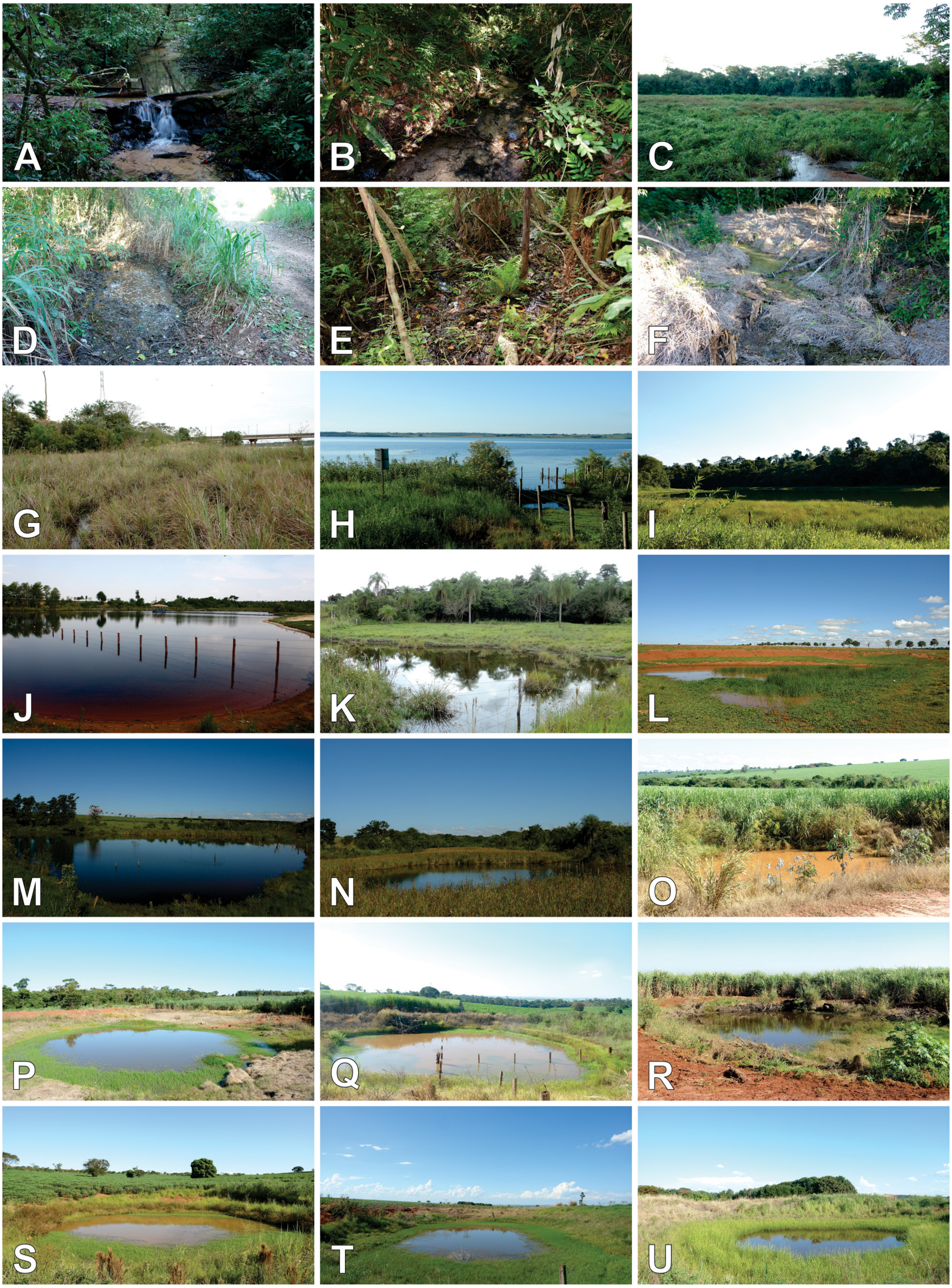

Fig. 2. General views of the breeding habitats in forest remnants and agricultural landscapes. Inside forest remnant (IFR): A, B, C, D; edge of forest remnant (EFR): E, F, G, H, I; pasture areas (PTA): J, K, L; sugarcane crops (SCC): M, N, O, P, Q, R; manioc crops (MNC): S, T, U.

Table 1. Description of the breeding habitats in forest remnants and agricultural landscapes

	Sampling points	Geographic coordinates	BH	Description	HT	HP	Vegetation in water body	
							Inside	Edge
Forest remnants								
IFR	Scherer stream	22°35'S 52°53'W	A	Small stream with sandy bed inside forest remnant	Lot	Pmt	-	Grm, Her, Shb, Arb
	Conceição stream	22°35'S 52°52'W	B	Small stream with sandy bed inside forest remnant	Lot	Pmt	-	Grm, Her, Shb, Arb
	Jacaré pond	22°36'S 52°52'W	C	Permanent artificially constructed pond inside forest remnant	Len	Pmt	Emc, Fmc, Grm, Her	Grm, Her, Shb, Arb
	Temporary ponds	22°36'S 52°52'W	D	Three small temporary ponds inside forest remnant	Len	Tmp	-	Grm, Her, Shb, Arb
EFR	Humid area	22°35'S 52°53'W	E	Riparian forest with soil that is flooded after heavy rains	Lot	Tmp	-	Grm, Her, Shb, Arb
	Flood area	22°37'S 52°50'W	F	Small watercourse with flooded area downstream	Lot	Tmp	Emc, Fmc, Grm, Her	Grm, Her, Shb, Arb
	Marsh	22°35'S 52°52'W	G	Marsh at the left margin of the Paranapanema River	Lot	Tmp	Fmc, Grm, Her, Shb	Grm, Her, Shb, Arb
	Paranapanema River	22°37'S 52°49'W	H	Left margin of the reservoir of the Rosana Hydroelectric Power Plant	Lot	Pmt	Emc, Fmc, Grm	Grm, Her, Shb, Arb
	Diamante River	22°37'S 52°50'W	I	Right margin of the Diamante River	Lot	Pmt	Emc, Fmc, Grm	Grm, Her, Shb, Arb
Agricultural landscapes								
PTA	Água Mole stream	22°38'S 52°49'W	J	Large dam in the midsection of the stream	Lot	Pmt	Emc, Fmc, Grm	Grm, Her, Shb, Arb
			K	Small dam near the spring that feeds the stream	Lot	Pmt	Grm, Her	Grm, Her, Shb
	Temporary pond	22°38'S 52°49'W	L	Pond in the pasture area near (26 m from) the gallery forest fed by the Água Mole stream	Len	Tmp	Emc, Grm, Her	Grm, Her
SCC	Maria Koss stream	22°37'S 52°53'W	M	Dam near the spring that feeds the stream	Lot	Pmt	-	Grm, Her, Shb, Arb
			N	Dam in the midsection of the stream	Lot	Pmt	Emc	Grm, Her, Shb, Arb
	Temporary ponds	22°36'S 52°53'W	O	Three temporary ponds at the edge of a sugarcane field	Len	Tmp	Grm	Grm, Her, Shb
	Permanent ponds	22°37'S 52°53'W	P, Q, R	Three permanent ponds within a sugarcane field	Len	Pmt	Grm	Grm, Her, Shb
MNC	Permanent ponds	22°36'S 52°53'W	S, T, U	Three permanent ponds within a manioc field	Len	Pmt	Grm	Grm, Her, Shb

BH: breeding habitats, HT: habitat type (Lot: lotic, Len: lentic), HP: hydroperiod (Pmt: permanent, Tmp: temporary), IFR: inside forest remnant, EFR: edge of forest remnant, PTA: pasture areas, SCC: sugarcane crops, MNC: manioc crops, Vegetation types (Fmc: fluctuant macrophytes, Emc: emergent macrophytes, Grm: gramineous vegetation, Her: herbaceous vegetation, Shb: shrubby vegetation, Arb: arboreal vegetation).

habitat. Lower values indicate that anuran species are under-represented in the indicated habitat, and higher values suggest that the anuran species are concentrated in the habitat. A value of 1 indicates that the anuran species occurs in all breeding habitats, and a value of -1 indicates that the anuran species is not present at any of the breeding habitats of the target group. This analysis was performed with the 'indicspecies' package (De Cáceres and Legendre 2009) for R version 2.1.5 (R Development Core Team 2012).

RESULTS

We identified 19 anuran species that belong to 11 genera and 5 families: Bufonidae (*n* = 1 species), Hylidae (*n* = 9), Leptodactylidae (*n* = 7), Microhylidae (*n* = 1), and Odontophrynidae (*n* = 1) (Table 2, Fig. 3). In the FR, the number of species in the breeding habitats ranged from 3 to 10 (mean ± standard deviation: 7.44 ± 2.74 species), and in the AL, the number of species ranged from 5 to 16 (10.67 ± 3.11 species; Table 2). According to rarefaction curves, the richness values were similar and did not differ between areas (Fig. 4). However, the species richness tended to stabilize with fewer samples in the AL than in the FR. The estimated species richness for the study area was 20 species, only one more than the observed richness.

The interaction between habitat type and number of different vegetation types was the main habitat feature related to species composition in breeding habitats (Pseudo-F = 3.44, p = 0.004), with approximately 38% of the total variation explained by this relationship (Table 3). The species composition based on habitat type and number of vegetation types in each breeding habitat was separated into three clusters: i) a small cluster formed by four lotic breeding habitats in the FR and AL with variable numbers of vegetation types; ii) a large cluster formed by eight lentic breeding habitats in the AL with 3-4 vegetation types, and iii) a medium cluster formed by five lotic breeding habitats in the FR and AL with 5-6 vegetation types (Fig. 5).

According to the habitat preference analysis, more species were positively associated with breeding habitats in the AL than in the FR (12 species vs. 7 species). *Leptodactylus chaquensis* and *Dendropsophus* aff. *minutus* showed significant preference values with occurrence concentrations in the set of breeding habitats in the AL. Meanwhile, *Rhinella schneideri*, *Leptodactylus mystacinus*, *Physalaemus cuvieri*, *Hypsiboas albopunctatus*, *Hypsiboas punctatus*, *Phyllomedusa tetraploidea*, and *Trachycephalus typhonius* occurred mainly in the breeding habitats in the FR (Table 4).

DISCUSSION

The EEC and surrounding agricultural landscape harbor lower anuran species richness than other localities within the mesophytic semideciduous Atlantic Forest domain, according to previous studies. These study locations include Parque Nacional da Serra da Bodoquena, MS (38 species; Uetanabaro et al. 2007), Parque Estadual Morro do Diabo, SP (28 species; Santos et al. 2009), Londrina, PR and Nova Itapirema, SP (27 species; Machado et al. 1999; Vasconcelos and Rossa-Feres 2005), Guararapes, SP (26 species; Bernarde and Kokubum 1999), Estação Ecológica dos Caetetus (24 species; Bertoluci et al. 2007), Três Barras do Paraná, PR and Mata São José, SP (23 species; Bernarde and Machado 2001; Zina et al. 2007), Reserva Biológica das Perobas, PR (22 species; Affonso and Gomes 2013), Floresta Estadual Edmundo Navarro de Andrade, SP and Maringá, PR (21 species; Toledo et al. 2003; Affonso et al. 2014). Similar species richness was recorded at Santa Fé do Sul, SP (20 species; Santos et al. 2007), Serra do Japi, SP (19 species; Ribeiro et al. 2005), and Porto Rico, PR (18 species; Affonso et al. 2013). The higher species richness values reported by these studies may be related to differences in sampling methods (*e.g.*, visual and acoustic search use of drift fences and pitfall traps) and sampling effort, as well as the area and type of habitat sampled. However, the lower species richness in the present study may also be a consequence of habitat loss and fragmentation caused by the intense logging, agricultural, and livestock activities that have occurred in the region since the early 1960s (Campos 1999).

A similar number of species were recorded in the FR and the AL, even though fewer breeding habitats were surveyed in the FR than in the AL. In addition, this study provided a robust estimate of the number of anuran species present. This sampling method was also the most successful methodology used to sample anuran species in other studies, including in areas that were natural remnants of native vegetation and in agricultural

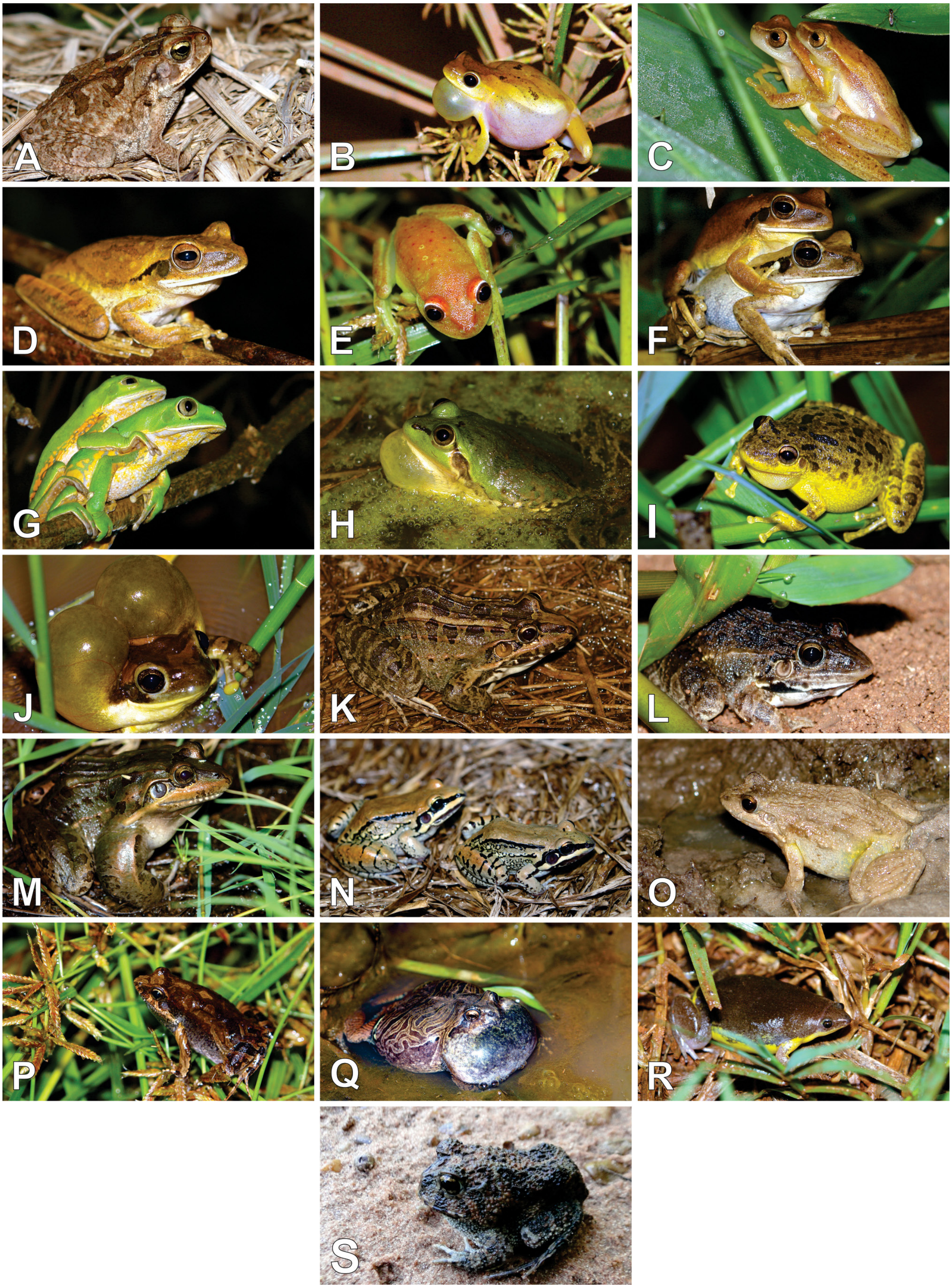

Fig. 3. Anuran species recorded in breeding habitats in forest remnants and agricultural landscapes. (A) *Rhinella schneideri*, (B) *Dendropsophus* aff. *minutus*, (C) *Dendropsophus nanus*, (D) *Hypsiboas albopunctatus*, (E) *Hypsiboas punctatus*, (F) *Hypsiboas raniceps*, (G) *Phyllomedusa tetraploidea*, (H) *Pseudis platensis*, (I) *Scinax fuscovarius*, (J) *Trachycephalus typhonius*, (K) *Leptodactylus chaquensis*, (L) *Leptodactylus fuscus*, (M) *Leptodactylus* aff. *latrans*, (N) *Leptodactylus mystacinus*, (O) *Leptodactylus podicipinus*, (P) *Physalaemus cuvieri*, (Q) *Physalaemus nattereri*, (R) *Elachistocleis bicolor*, (S) *Odontophrynus americanus.*

areas (Santos et al. 2009; Campos et al. 2013). Furthermore, the similar species richness observed in both areas seems to reflect the higher-amplitude use of resources by the anuran species (Heyer and Bellin 1973). These species utilize both forest remnants and agricultural landscapes as habitat (da Silva and Rossa-Feres 2007).

Although turnover can be one of the main factors determining the regional biodiversity of ponds, other factors, including habitat features, niche differentiation, and trophic conditions also determine pond assemblage structure (Vasconcelos et al. 2009; De Marco et al. 2014). In the present study, we found that habitat type was related to species composition and may be associated with the reproductive modes of all recorded species that breed mainly in lentic bodies of water (modes 1, 11, 13, 24, and 30; Haddad and Prado 2005; Crump 2015), such as those in agricultural landscapes. The number of vegetation types found in bodies of water in agricultural landscapes was also related to species composition, and a lower number of different vegetation types may affect anuran species composition in breeding habitats. Vegetation provides vocalization and oviposition sites (Vasconcelos et al. 2009; da Silva et al. 2012) and shelter against predators (F.H. Oda, personal communication), including several invertebrate species (Batista et al. 2013; Gambale et al. 2014; Oda et al. 2014b). Several studies have shown that high vegetation heterogeneity contributes to high species diversity, as species exploit the different microhabitats found in breeding habitats (Cardoso et al. 1989; Pombal Jr. 1997; Oda et al. 2009). However, the high species richness recorded in

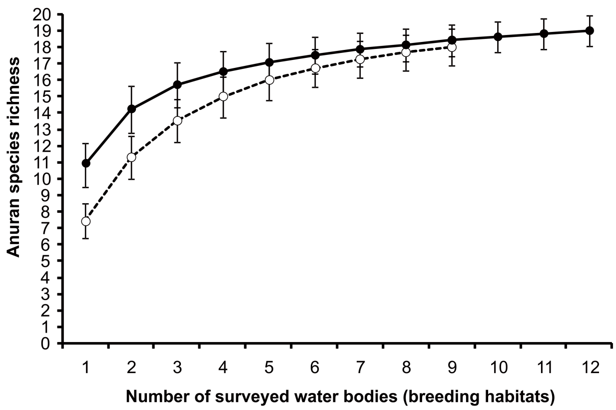

Fig. 4. Comparison of species richness between forest remnants and agricultural landscapes. Rarefaction curves were generated from 1,000 randomizations of the presence/absence records of anuran species in breeding habitats. Solid line with black circle: agricultural landscape, dashed line with white circle: forest remnant.

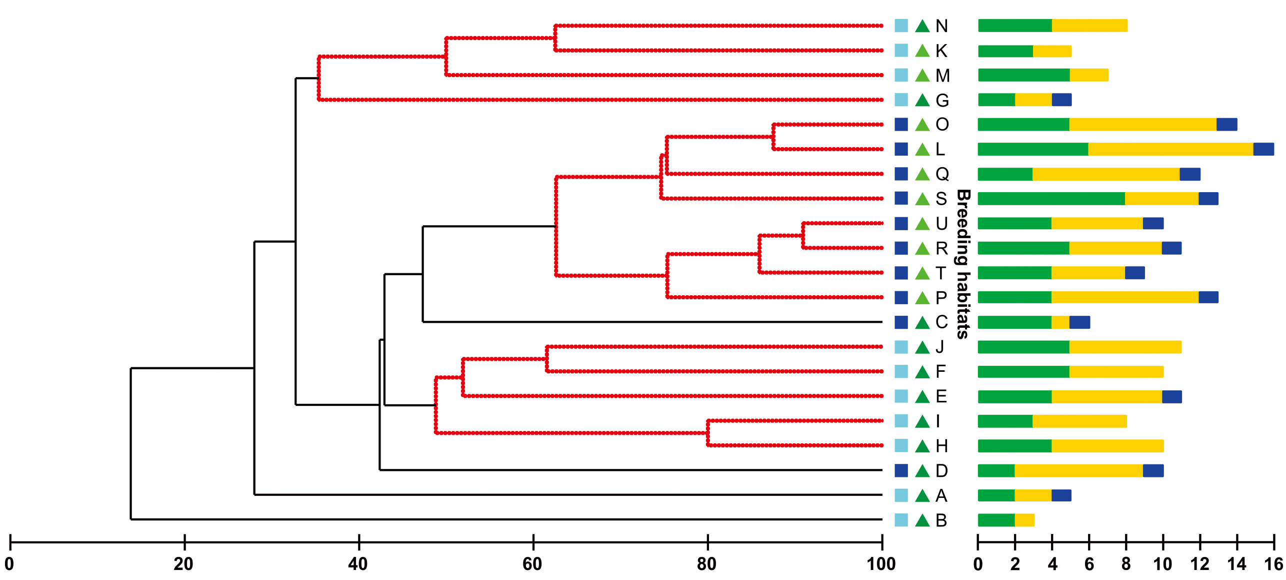

Fig. 5. Cluster analysis of anuran species composition in breeding habitats in forest remnants and agricultural landscapes. The red branches of the dendrogram represent the three breeding habitats clustered based on habitat type and number of plant vegetation types. Habitat descriptors: habitat type (dark blue squares: lentic water body, cyan squares: lotic water body); number of vegetation types (dark green triangles: habitats with 5-6 vegetation types, light green triangles: habitats with 3-4 vegetation types). Species composition (dark green bars: arboreal species, yellow bars: terrestrial species, blue bars: aquatic species). See breeding habitat descriptions in table 1.

bodies of water with a lower number of vegetation types (water bodies from the AL) might be a result of the anuran species in this region being associated with open environments (Duellman 1999).

In fact, the high species richness recorded in the breeding habitats in the agricultural landscape is consistent with the result of the Pearson's coefficient of association (Φ) analysis, which suggested that the majority of the anuran species prefer bodies of water in the agricultural landscape. The pattern recorded in this study is consistent with the results of other studies performed in homogeneous landscapes, which found that the same species reported here breed in bodies of water in modified areas or in natural remnants of

Table 2. Anuran species recorded in breeding habitats in forest remnants and agricultural landscapes. See breeding habitat descriptions in Table 1

Species	Forest remnant (FR)									Agricultural landscape (AL)											
	IFR			EFR						PTA				SCC				MNC			
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
Rhinella schneideri (Werner, 1894)	+	+		+	+	+		+	+	+		+			+		+		+		
Dendropsophus aff. *minutus*	+		+							+		+	+		+	+	+	+	+	+	+
Dendropsophus nanus (Boulenger, 1889)	+		+		+	+		+	+	+	+	+	+	+	+	+		+	+	+	+
Hypsiboas albopunctatus (Spix, 1824)		+			+	+	+			+	+		+	+							
Hypsiboas punctatus (Schneider, 1799)				+	+	+	+	+	+	+	+	+	+	+	+		+				
Hypsiboas raniceps Cope, 1862			+					+	+			+	+	+	+	+		+		+	+
Phyllomedusa tetraploidea Pombal & Haddad, 1992				+		+												+	+		
Pseudis platensis Gallardo, 1961	+		+	+			+					+			+	+	+	+	+	+	+
Scinax fuscovarius (A. Lutz, 1925)		+	+		+	+				+		+			+	+	+	+	+	+	+
Trachycephalus typhonius (Linnaeus, 1758)								+				+									
Leptodactylus chaquensis Cei, 1950				+						+	+	+		+	+	+	+	+	+	+	+
Leptodactylus fuscus (Schneider, 1799)				+		+		+		+		+		+	+		+	+	+		+
Leptodactylus aff. *latrans*						+		+	+	+		+		+	+	+	+		+		
Leptodactylus mystacinus (Burmeister, 1861)				+	+												+				
Leptodactylus podicipinus (Cope, 1862)			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Physalaemus cuvieri (Fitzinger, 1826)	+			+	+	+	+	+	+			+			+	+	+	+	+	+	+
Physalaemus nattereri (Steindachner, 1863)					+							+			+	+	+		+		
Elachistocleis bicolor (Valenciennes in Guérin-Menéville, 1838)				+	+			+	+	+		+	+		+	+	+	+	+	+	+
Odontophrynus americanus (Duméril & Bibron, 1841)												+									
Species richness by breeding habitat	5	3	6	10	10	10	5	10	8	11	5	16	7	8	14	11	13	11	13	9	10
Species richness by area	18									19											

IFR: inside forest remnant, EFR: edge of forest remnant, PTA: pasture areas, SCC: sugarcane crops, and MNC: manioc crops.

Table 3. PERMANOVA summary. Variation of anuran species composition in breeding habitats based on habitat descriptors

Descriptors	Pseudo-*F*	Variation components (%)	*p*
Number of different vegetation types (NV)	1.11	6.9	0.39
*Habitat type (HT)	2.69	26.4	0.007
*NV × HT	3.44	38.0	0.004
Residuals	-	30.8	-

p = probability. Single asterisk (*) indicate statistically significant values of $p \leq 0.05$.

original vegetation (Vasconcelos and Rossa-Feres 2005; Santos et al. 2007, 2009). On the other hand, the preference of some medium- and large-sized Hylidae species for breeding habitats in the FR may be related to the vegetation structure of these environments, which provide vocalization sites for these species (Santos and Rossa-Feres 2007; Vasconcelos and Rossa-Feres 2008).

Most of the species we recorded have a large geographic distribution (Valdujo et al. 2012; Toledo et al. 2014), and are found in several South American morphoclimatic domains (*e.g.*, *R. schneideri*, *Dendropsophus minutus*, *D. nanus*, *Hypsiboas albopunctatus*, *H. raniceps*, *H. punctatus*, *Leptodactylus fuscus*, *Leptodactylus* aff. *latrans*, *P. cuvieri*, *Scinax fuscovarius*, *T. typhonius*), whereas other species have distributions typically associated with the ecotonal zone of the Cerrado-Atlantic Forest (*Odontophrynus americanus*, *Phyllomedusa tetraploidea*, *L. mystacinus*), the Cerrado area (*Physalaemus nattereri*), or the Chaco area (*L. chaquensis*) (Duellman 1999; Valdujo et al. 2012; Batista and Bastos 2014; Frost 2015). Thus, our study showed that the anuran fauna of the northwestern region of Paraná State are mostly species associated with open areas that breed in bodies of water in forest remnants and agricultural landscapes.

CONCLUSIONS

This study presents important data on the anurans of a mesophytic semideciduous Atlantic Forest remnant and the surrounding agricultural landscape in southern Brazil, one of the most deforested, fragmented, and poorly studied regions of the Atlantic Forest in Paraná State. Species richness in the FR and the AL was similar, reflecting the ability of anuran species to exploit different habitat types. Habitat type and vegetation cover positively affected the species composition of the breeding habitats, most likely because vegetation provides shelter and calling sites for anurans. Finally, we found that the majority of species preferred breeding habitats in agricultural landscapes. Anurans from open areas are considered habitat generalists and are tolerant to environments that have been modified by anthropic activities. Therefore, to maintain anuran populations in these fragmented landscapes, it is

Table 4. Preference values (Φ) of anuran species for breeding habitats in forest remnants and agricultural landscapes

Species	Φ- values	*p* value	Preference for set of breeding habitats
**Leptodactylus chaquensis*	0.81	0.001	AL
**Dendropsophus* aff. *minutus*	0.61	0.009	AL
Elachistocleis bicolor	0.40	0.157	AL
Rhinella schneideri	0.37	0.183	FR
Leptodactylus podicipinus	0.35	0.172	AL
Physalaemus nattereri	0.35	0.183	AL
Hypsiboas raniceps	0.33	0.197	AL
Leptodactylus fuscus	0.33	0.195	AL
Scinax fuscovarius	0.31	0.204	AL
Dendropsophus nanus	0.31	0.278	AL
Leptodactylus aff. *latrans*	0.25	0.379	AL
Pseudis platensis	0.22	0.391	AL
Odontophrynus americanus	0.21	1.000	AL
Leptodactylus mystacinus	0.19	0.553	FR
Physalaemus cuvieri	0.12	0.662	FR
Hypsiboas albopunctatus	0.11	0.671	FR
Hypsiboas punctatus	0.09	1.000	FR
Phyllomedusa tetraploidea	0.07	1.000	FR
Trachycephalus typhonius	0.05	1.000	FR

Single asterisk (*) indicate statistically significant preference values of $p \leq 0.05$.

important to preserve artificially constructed bodies of water within the agricultural landscape and along the forest edge.

List of abbreviations

EEC: Estação Ecológica do Caiuá
FR: forest remnant
AL: agricultural landscape
IFR: inside forest remnant
EFR: edge of forest remnant
PTA: pasture areas
SCC: sugarcane crops
MNC, manioc crops
MS: Mato Grosso do Sul State
PR: Paraná State
SP: São Paulo State

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