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A checklist of the amphibians and reptiles of Río Macho Biological Station, Provincia de Cartago, Costa Rica

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Abstract: We provide a checklist of the amphibians and reptiles of Río Macho Biological Station (RMBS), Costa Rica. During a period of a year (2012–2013) we conducted visual and acoustic surveys in a natural mature forest plot (>50 years old) (MF), secondary forest plot (~17 years old) (SF), in open areas and riparian forest at RMBS. We found a total of 11 species of amphibians and 15 species of reptiles belonging to 11 taxonomic families. We also compared the diversity of the MF against the SF. The MF contained 10 species (five amphibians and five reptiles) and the SF seven (three amphibians and four reptiles), with similar dominance between sites. Unfortunately, some forest and riparian species have vanished at this elevation after an enigmatic decline; according to historical literature pristine areas should contain higher species richness. Perhaps, the secondary forest will provide an available habitat for an important percentage of the remaining forest species.

Key words: amphibians, lower montane tropical forest, Orosi Valley, reptiles, secondary forest.

INTRODUCTION

Due to the small size and extensive herpetological sampling conducted in the country during the twentieth century, Costa Rican amphibian and reptile diversity is considered among the best known when compared to other Neotropical countries (Savage 2002). However, scarce ecological information on the herpetofauna of lower tropical montane forest (1500–2500 m.a.s.l) is available in contrast to other elevational belts in the country, such as humid lowlands or premontane tropical forest (Bolaños and Emcke 1996; Whitfield et al. 2007; Abarca 2012b).

Coincidently this elevational belt has been one of the most affected by the amphibian population decline, a phenomenon documented since the 1980's and mainly attributed by some authors to the chytrid fungus, *Batrachochitrium dendrobatidis* (Lips 1998, Lips et al. 2003), and climate change (Pounds and Puschendorf 2004). Examples of highly diverse locations with reported extirpations of amphibian species at this elevational range include: Las Tablas Protected Area in southeastern Costa Rica (Lips 1998), Monteverde on the Tilarán Mountain Range (Pounds and Crump 1994), Volcanic Central Cordillera (Abarca 2012a), and Tapantí National Park and surrounding areas (Bolaños and Chaves, unpubl. data), where we carried out our study. Despite this disturbing scenario, several critically endangered species have been found in recent years in regions at identical elevations after decades of apparent disappearance (Abarca 2012a, Hertz et al. 2012b). An increase of sampling effort in clouded forests is a basic step to understand the dynamics of local extinction, or even species recolonization, in areas that suffered biodiversity decline due to climatic change (Bickford et al. 2010). Also, because forested areas are no longer dominant in the Mesoamerican landscape, fragmented areas such as Río Macho can play an important role in species conservation (Dent and Wright 2009).

Therefore, this manuscript provides the first checklist of herpetofauna for Río Macho Biological Station (RMBS), Province of Cartago, Costa Rica. Here we tested for differences between two forest patched with different regeneration ages, to further explore the current role of secondary forest as a reservoir for herpetofauna at this location and elevation.

MATERIALS AND METHODS

Study site

Río Macho Biological Station (RMBS) is located in Orosi Valley (09°46′ N, 083°51′ W, WGS84) (Figure 1). The area ranges from 1,550–1,900 m in elevation and is classified as a Lower Pluvial Montane Tropical Forest according to Holdridge's Life Zones (Acosta-Chaves et

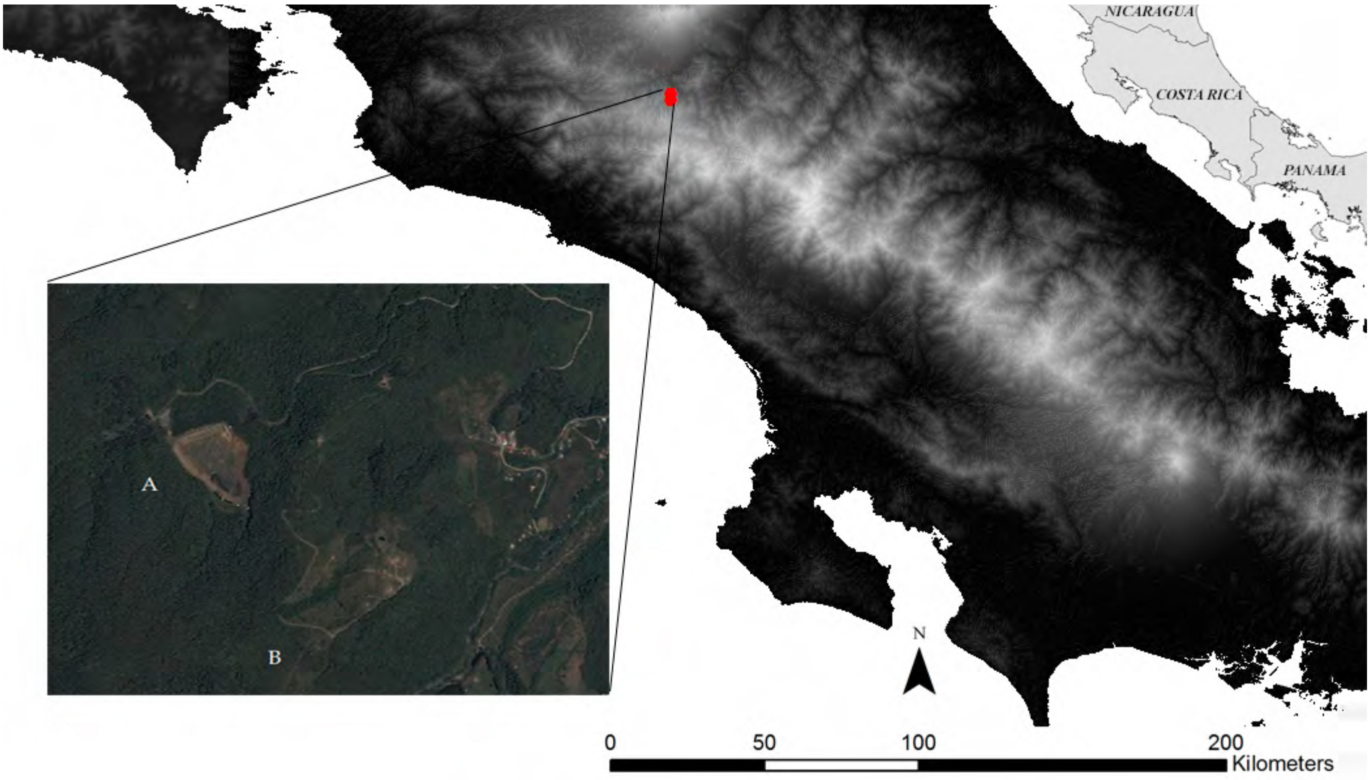

Figure 1. Study site in RMBS: **A**) natural old forest plot, **B**) secondary forest plot.

al. 2012, Guzmán and Rodríguez–Corrales 2014). Annual average precipitation in this area is 3400 ± 400 mm, with a temperature variation between 14–26 °C (Acosta-Chaves et al. 2012). RMBS and surrounding areas comprise an admixture of habitats including primary forests (above 1,850 m above sea level [a.s.l.]), natural old secondary forest, young secondary forest, riparian forest and open areas primarily constituted of rush-dominated marshes (*Juncus* sp.) and roads (Figure 2).

We compared diversity between a natural old forest (>50 years old) (09°46′ N, 083°51′ W, WGS84; 1,750 m a.s.l., 21.26 ha) and a young secondary forest (ca. 17 years old) (09°45′ N, 083°51′ W, WGS84; 1,715 m a.s.l., 11.62 ha) (Figures 1 and 2). Both sites have significantly different forest structure, phenology, tree composition and light patterns; the old forest is a product of natural regeneration while the secondary forest is a pasture dominated by a previous plantation of rose apple trees (*Syzygium jambos*) (Guzmán and Rodríguez-Corrales 2014) (Figure 2).

Data collection

We made monthly visits to each site between January 2012 and January 2013 to conduct both diurnal (9–12h) and nocturnal surveys (20–23h). We sampled two areas of 0.5 ha at each site, divided into subplots of 10 × 10 m. Seven of these plots were randomly selected at each site in survey sessions. We recorded richness and abundance of herpetofauna found in leaf litter and shrubs using visual and acoustic surveys (Marsh and Haywood 2009). Each plot was sampled by four people with one person located in each corner doing a parallel zigzag in the leaf litter; a fifth researcher sampled the shrubs inside the plots.

We complemented our species list with observations made in old and riparian forests, open areas, marshes and secondary forest, anecdotally complimenting the species list while walking to plots or exploring the station grounds. We identified species observed in the field using dichotomous keys (Savage 2002) and personal experience. Anurans that inhabit high canopy (e.g. *Ishtmohyla zeteki*) were recorded using a microphone and spectrograms were compared with available call descriptions (e.g., Hertz et al. 2012a). When required, specimens were collected and deposited in Museo de Zoología, Universidad de Costa Rica (MZUCR). We carried out the study under a permit issued by La Amistad–Pacific Conservation Area, 059-12-ACLAP.

Data analysis

We determined if the detected species were endangered according to the Red List of Threatened Species (IUCN 2015). We estimated alpha diversity with the dominance Simpson index (λ) for natural old forest plot and young secondary forest plot; and beta diversity between sites using the Wilson and Smidha index (β_T). Additionally, we tested the probability of similarity between both alpha diversities of different plots using a randomization test with Species Diversity and Richness v.2.4 software (Henderson and Seaby 1998).

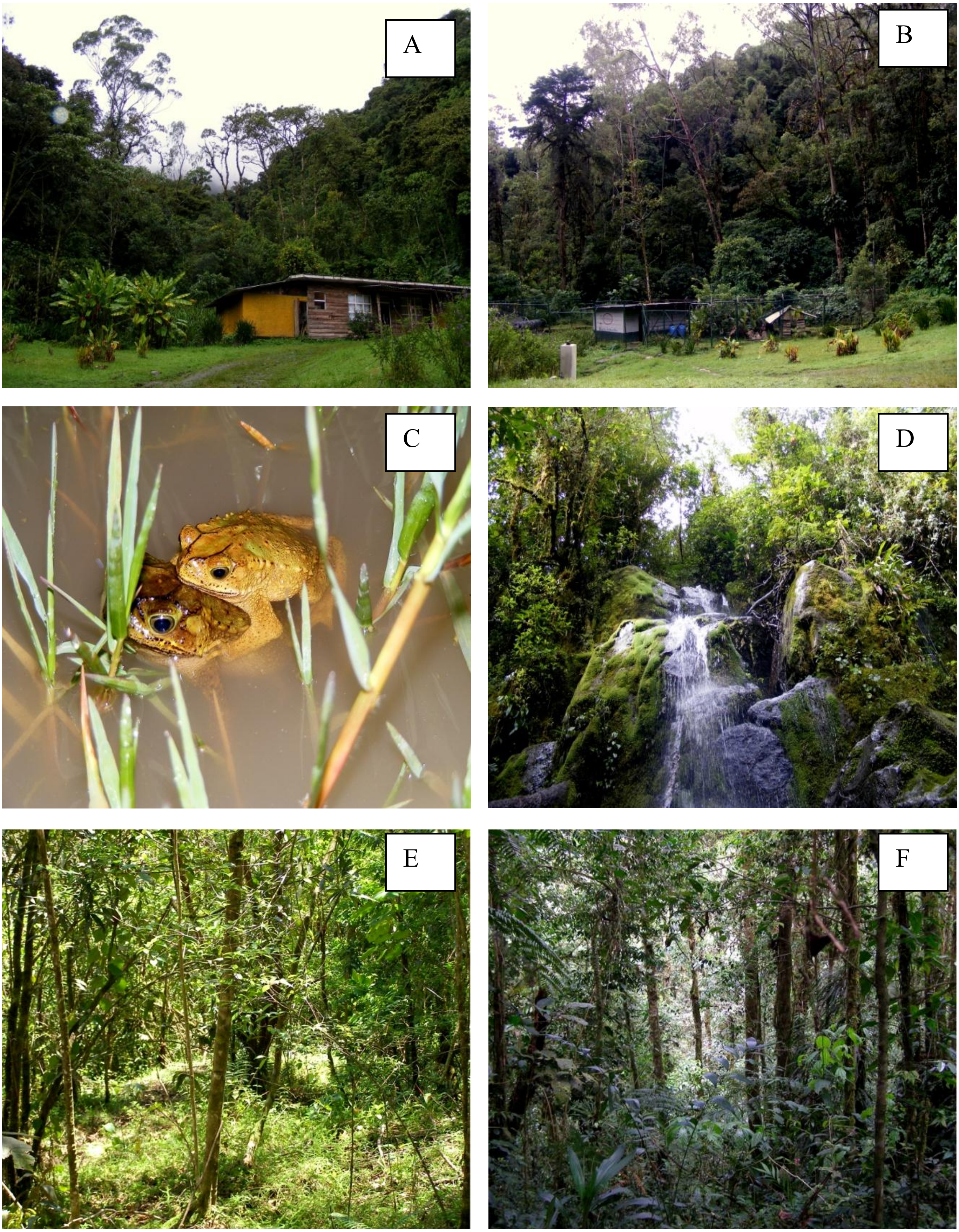

Figure 2. Habitat for herpetofauna in RMBS. **A**) Station building with old secondary forest and primary forests behind. **B**) Open areas and rainbow trout ponds. C) Seasonal pond in open areas. **D**) Waterfall and riparian forest. **E**) Secondary forest plot. **F**) Old natural forest plot.

RESULTS

The total species richness for RMBS was composed of two orders, 11 families, 19 genera and 26 species (15 reptiles and 11 amphibians) (Table 1; Figure 3). All species were listed as Least Concern. When the plots (mature and secondary forest) were compared, we found 614 individuals distributed into 12 species, six genera, five families and two orders (Table 2). A major representation of the herpetofauna occurring inside the plots was obtained, with no new species records after seven samplings (Figure 4). In the natural mature forest plot ten species were found, while just seven species were observed in the secondary forest plot (Table 2). Some species were restricted to riparian forests, open areas, marshes and primary forest (over 1,850 m) (Table 2).

The dominance of the community in the natural mature forest (λ=2.21) and secondary forest (λ=2.11) was low and similar (p=0.60). The shared diversity was intermediate (β_T=0.41). The principal shared amphibian species were *Craugastor underwoodi*, *Diasporus diastema* and *Isthmohyla zeteki*, while *Anolis capito*, *A. altae* and *A. humilis* were the most abundant shared reptile species. The total number of individuals was three times higher in the natural old forest than in the secondary forest (Table 2).

Table 1. List of herpetofauna found in Río Macho Biological Station. Sites where species were detected: MF=mature forest plot, SF=secondary forest plot, OF=other mature forest, RF=riparian forest and OA=open areas.

Taxon	MF	SF	OF	RF	OA	Voucher number
CLASS AMPHIBIA Linné, 1758						
Order Anura Hogg, 1939						
Family Bufonidae J. E. Gray, 1825						
Incilius coniferus (Cope, 1862)					X	photo only
Incilius epioticus (Cope 1875)			X			UCR20080
Family Centrolenidae Taylor, 1951						
Espadarana prosoblepon (Boettger, 1892)				X		photo only
Family Craugastoridae Hedges, Duellman & Heinicke, 2008						
Craugastor podiciferus (Cope, 1875)			X	X		UCR2708
Craugastor underwoodi (Boulenger, 1896)	X	X	X	X	X	photo only
Pristimantis caryophyllaceus (Barbour, 1928)	X		X	X		UCR21508
Pristimantis cruentus (W. Peters, 1873)	X		X	X		photo only
Family Eleutherodactylidae Lutz, 1954						
Diasporus diastema (Cope, 1875)	X	X	X	X	X	photo only
Family Hylidae Rafinesque, 1815						
Isthmohyla pseudopuma (Günther, 1901)		X	X	X	X	photo only
Isthmohyla zeteki (Gaige, 1929)	X	X	X	X	X	audio only
Family Ranidae Rafinesque, 1814						
Lithobates taylori (H. M. Smith, 1959)					X	photo only
CLASS REPTILIA Laurenti, 1768						
Order Squamata Oppel, 1811						
Suborder Sauria Macartney, 1802						
Family Phrynosomatidae Fitzinger, 1843						
Sceloporus malachiticus Cope, 1864					X	photo only
Family Dactyloidae Nichols, Crother, Guyer and Savage, 2012						
Anolis altae (Dunn, 1930)	X	X	X	X	X	UCR21509
Anolis capito (W. Peters, 1863)	X	X	X	X		photo only
Anolis humilis (W. Peters, 1863)	X	X	X			photo only
Anolis intermedius (W. Peters, 1863)	X				X	photo only
Anolis tropidolepis (Boulenger, 1885)	X		X	X		photo only
Anolis woodi (Dunn, 1940)		X				photo only
Suborder Serpentes Linné, 1758						
Family Colubridae Oppel, "1810", 1811						
Chironius exoletus (Linné, 1758)*					X	photo only
Dendrophidion paucicarinatum (Cope, 1894)	X	X	X		X	photo only
Lampropeltis micropholis Cope, 1860			X			photo only
Family Dipsadidae Bonaparte, 1838						
Geophis brachycephalus (Cope, 1871)			X		X	photo only
Imantodes cenchoa (Linné, 1758)			X		X	photo only
Rhadinaea serperaster (Günther, 1858)			X		X	photo only
Erythrolamprus epinephelus Cope, 1862				X	X	road kill
Family Viperidae Oppel, "1810", 1811						
Bothriechis lateralis W. Peters, 1862			X	X	X	photo only

DISCUSSION

The presented checklist provides evidence that RMBS has not rebounded from decline of forest amphibian species previously distributed in that elevation according to the literature (Savage 2002). Due to amphibian population recoveries reported to date in similar elevations, as Cerro Chompipe (Abarca 2012a), Monteverde (unpubl. data) or Southern Talamanca Cordillera (Hertz et al. 2012b), at least we conclude that RMBS and surrounded areas were not experiencing a similar recovery during our sampling period. For example, although the Tapantí area was a historically rich place for caudates (Wake 1987; Savage 2002), we did not find any salamander species in Río Macho. If salamanders were present still in the area, possibly our sampling methods were not inclusive enough to capture individuals with their representative low densities (Rovito et al. 2009). Nevertheless, we obtained a good representation of ground and semi-arboreal species potentially occurring at this elevation, according with Savage (2002) (e.g., *Anolis* sp.) Although,

Table 2. Number of detected individuals in the mature forest plot (MF), and secondary forest plot (SF), during samplings at day and night.

	MF			SF		
Taxon	**Day**	**Night**	**Total**	**Day**	**Night**	**Total**
AMPHIBIA	**54**	**376**	**430**	**20**	**135**	**155**
Craugastoridae	**41**	**29**	**70**	**20**	**16**	**36**
Craugastor underwoodi	40	13	53	20	16	36
Pristimantis caryophyllaceus	1	5	6			
Pristimantis cruentus		11	11			
Eleutherodactylidae	**11**	**272**	**283**		**112**	**112**
Diasporus diastema	11	272	283		112	112
Hylidae	**2**	**75**	**77**		**7**	**7**
Isthmohyla zeteki	2	75	77		7	7
REPTILIA	**2**	**11**	**13**	**9**	**7**	**16**
Colubridae		**1**	**1**			
Dendrophidion paucicarinatum		1	1			
Dactyloidae	**2**	**10**	**12**	**9**	**7**	**16**
Anolis altae				1	2	3
Anolis capito	1	3	4	4	3	7
Anolis humilis	1	1	2	4	1	5
Anolis intermedius		3	3			
Anolis tropidolepis		3	3			
Anolis woodi					1	1
Total	56	387	443	29	142	171

Figure 3. Species of amphibians and reptiles occurring in RMBS. 1) *Incilius epioticus*, 2) *Incilius coniferus*, 3) *Espadarana prosoblepon*, 4) *Craugastor underwoodi*, 5) *Craugastor podiciferus*, 6) *Pristimantis caryophyllaceus*. Photos by V. Acosta, RMBS. (*Figure continued on following page.*)

Figure 3, *continued*. Species of amphibians and reptiles occurring in RMBS. 7) *Pristimantis cruentus*, 8) *Diasporus diastema*, 9) *Isthmohyla pseudopuma*, 10) *Lithobates taylori*, 11) *Ishtmohyla zeteki*, 12) *Sceloporus malachiticus*. Photos 7–10 and 12 by V. Acosta, RMBS; 11 by R. Puschendorf, Turrialba, Cartago. (*Figure continued on following page.*)

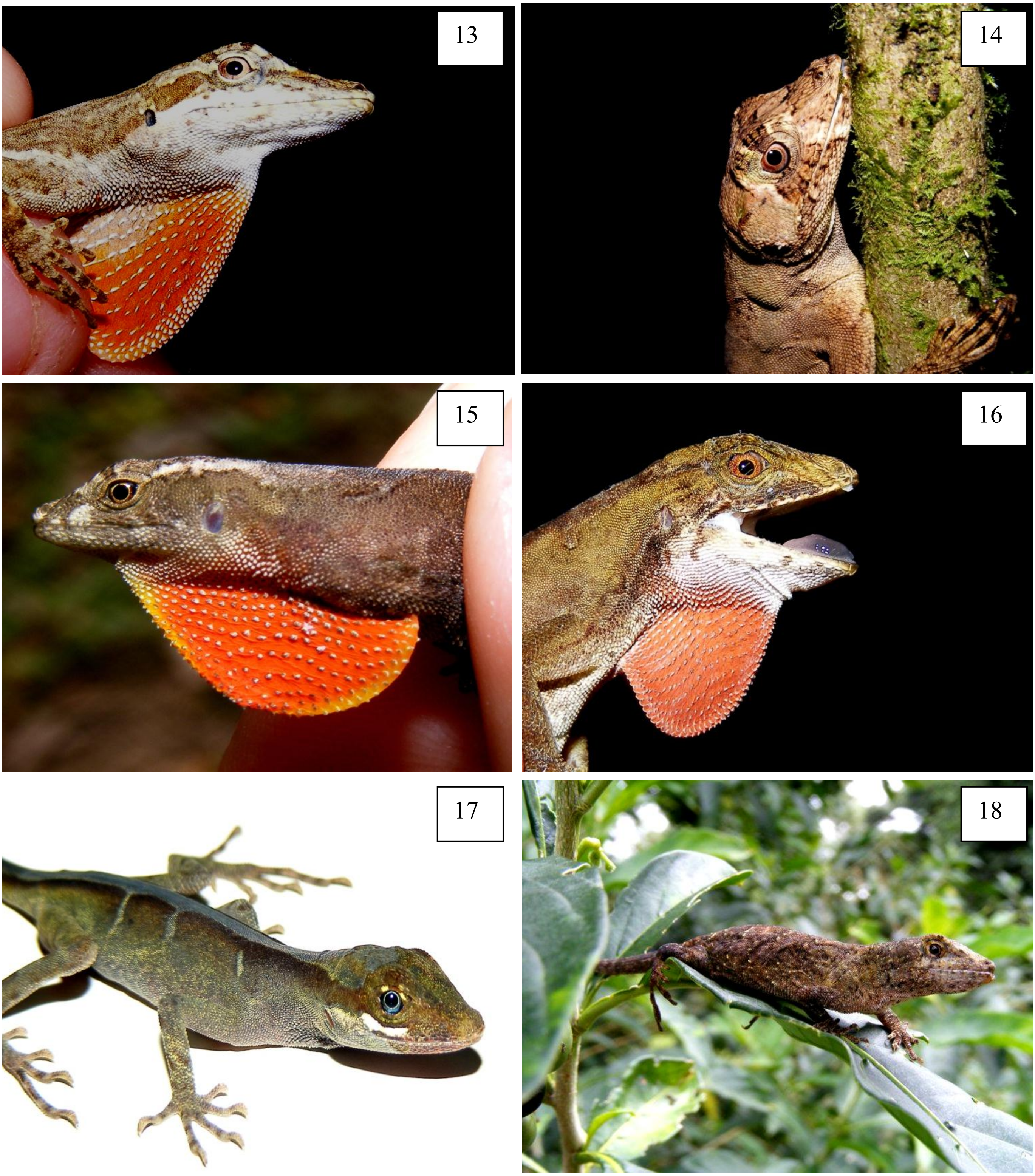

Figure 3, *continued*. Species of amphibians and reptiles occurring in RMBS. 13) *Anolis altae*, 14) *Anolis capito*, 15) *Anolis humilis*, 16) *Anolis tropidolepis*, 17) *Anolis woodi*, 18) *Anolis intermedius*. Photos by V. Acosta, RMBS. (*Figure continued on following page.*)

Figure 3, *continued*. Species of amphibians and reptiles occurring in RMBS. 19) *Geophys brachicephalus*, 20) *Rhadinaea serperaster*, 21) *Imantodes cenchoa*, 22) *Chironius exoletus*, 23) *Dendrophidion paucicarinatum,* 24) *Erythrolamprus epinephelus*. Photos 19–21 and 23 by V. Acosta, RMBS; 24 by T. Lenders, Rara Avis Rainforest Lodge, Heredia. (*Figure continued on following page.*)

Figure 3, *continued*. Species of amphibians and reptiles occurring in RMBS. 25) *Lampropeltis micropholis,* 26) *Bothriechis lateralis*. Photos 25 by J.G. Abarca, RMBS; 26 by V. Acosta, RMBS.

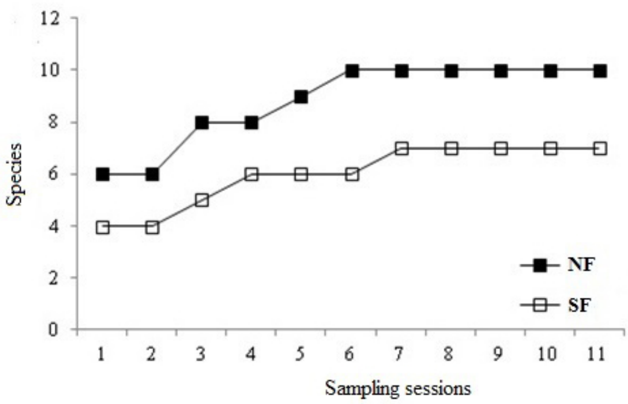

Figure 4. Species accumulation curve for quadratic plot sampling (mature forest plot = MF, secondary forest plot = SF).

we expect that other arboreal and secretive squamates will be found in future surveys, because these are difficult groups to detect using quadratic sampling (Doan 2003). Further canopy exploration is recommended to capture the missing expected herpetofauna species that demonstrated low detection using our methods.

Additionally, our results show that amphibian and reptile diversity in the natural old forest was not significantly different from that of the secondary forest, mainly in species number. This is a phenomenon observed by some authors in fragmented areas (e.g., Laurance et al. 2002; Urbina and Londoño 2003), but not consistent with patterns observed among other tropical lowlands, where older forests show a much higher diversity than secondary forests (Gardner et al. 2006, 2007). We concluded that the synergy of two process are producing our observations in species richness: 1) a significant number of potential forest amphibian species have vanished from nearby pristine areas (Savage 2002; Lips et al. 2003); and 2) the secondary forest specialists colonized pristine areas because of the deleterious effect of pristine forest species by fragmentation or population decline (Urbina and Londoño 2003). Thus, a rapid species decline, in collaboration with climate change effects and habitat fragmentation, produces transformations and decay of tropical forest ecosystems as RMBS (Laurance et al. 2002; Lips et al. 2003; Whitfield et al. 2007; Bickford et al. 2010).

Even when a high percentage of total species richness was found in the secondary forest, it is not a substitute for a pristine forest (Gardner et al. 2007). The relatively higher number of organisms in the old mature forest might be explained by a higher number of available microhabitats, and because some species apparently prefer old forests (e.g., *Isthmohyla zeteki*, *Anolis capito*) (Savage 2002), excluding the secondary forest specialists (e.g., *A. humilis*) (Whitfield et al. 2007). However, due to the important role of secondary forest (Dent and Wright 2009), we expect that young forests might function as species reservoirs at this elevation, which help populations recover across time, as has been documented in the Costa Rican Caribbean lowlands (Hilje and Aide 2012). We suggest that the next step is the implementation of further research to understand the factors driving habitat selection of the amphibian and reptile species inhabiting this cloud forest.

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