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Endemism on a threatened sky island: new and rare species of herpetofauna from Cerro Chucantí, Eastern Panama

[1,2,3]Abel Batista, [2,4,*]Konrad Mebert, [2]Madian Miranda, [2]Orlando Garcés, [2]Rogemif Fuentes, and [5]Marcos Ponce

[1]ADOPTA El Bosque PANAMÁ [2]Los Naturalistas, P.O. Box 0426-01459 David, Chiriquí, PANAMÁ [3]Universidad Autónoma de Chiriquí, Ciudad Universitaria El Cabrero David, Chiriquí, 427, PANAMÁ [4]Programa de Pós-graduação em Zoologia, Universidade Estadual de Santa Cruz, Rodovia Jorge Amado, Km 16, 45662-900, Ilhéus, Bahia, BRAZIL [5]Museo Herpetológico de Chiriquí, PANAMÁ

***Abstract.*—Cerro Chucantí in the Darién province is the highest peak in the Majé Mountains, an isolated massif in Eastern Panama. In addition to common herpetological species such as the Terraranas, *Pristimantis cruentus*, and *P. caryophyllaceus*, rare species such as *Pristimantis moro* and *Strabomantis bufoniformis* occur as well. Recent expeditions to Cerro Chucantí revealed a remarkably rich diversity of 41 amphibian (19% of the total in Panama) and 35 reptile (13% of the total in Panama) species, including new and endemic species such as a salamander, *Bolitoglossa chucantiensis*, a frog *Diasporus majeensis,* and a snake, *Tantilla berguidoi*. Here, an up-to-date summary is presented on the herpetological species observed on this sky island (an isolated mountain habitat with endemic species), including several species without definitive taxonomic allocation, new elevation records, and an analysis of species diversity.**

Keywords. Amphibians, community, diversity, evaluation, integrative taxonomy, premontane, reptiles, surveys

***Resumen.*—El Cerro Chucantí en la provincia de Darién es el pico más alto de las montañas de la serranía de Majé, un macizo aislado en el este de Panamá. Además de las especies herpetológicas comunes como las ranas, *Pristimantis cruentus*, y *P. caryophyllaceus*, también ocurren especies raras, p. ej. *Pristimantis moro* y *Strabomantis bufoniformis*. Las recientes expediciones al Cerro Chucanti revelaron una gran diversidad de 41 especies de anfibios (19% del total en Panamá) y 35 especies de reptiles (13% del total en Panamá), incluidas especies nuevas y endémicas, como la salamandra, *Bolitoglossa chucantiensis*, la rana *Diasporus majeensis* y la serpiente, *Tantilla berguidoi*. Presentamos un resumen actualizado de las especies herpetológicas observadas en esta "sky island" (un hábitat de montaña aislado con especies endémicas), que incluye una multitud de especies sin asignación taxonómica definida, nuevos registros de elevación y un análisis de la diversidad de especies.**

Palabras clave. Anfibios, comunidad, diversidad, evaluación, integrativa, premontano, reptiles, taxonomía

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Introduction

For the last few decades, the knowledge on the herpetofauna of Panamá has experienced a rapid increase, revealing a high species richness with 219 species of amphibians (Batista et al. 2016; Hertz 2015) and 263 of reptiles (Lotzkat 2015). Most herpetological studies have been concentrated in Central Panama and more recently in Western Panama (Hertz 2015; Lotzkat 2015). Many areas remain poorly explored, and several remote sites are threatened and urgently need an evaluation of their species diversity and population status. The focus of recent studies has shifted to the herpetofauna of the far less known eastern half of Panama (Batista et al. 2014a,c, 2015, 2016a,b), with most distinctive areas lacking representative species check lists. The Chucantí Private Nature Reserve (CPNR) is one such area without any comprehensive inventory. The reserve is part of the Eastern Panamanian montane forests (World Wildlife Fund 2014) and lies within the Serrania de Majé (hereafter, Majé Mountains). These mountains contain many peaks between 800–1,200 m asl, but only Cerro (or Mount) Chucantí reaches an elevation of >1,400 m asl (Samudio 2001).

Correspondence. *abelbatista@hotmail.com* (AB); **konradmebert@gmail.com* (KM); *mpamela0305@gmail.com* (MM); *orlgarces21@gmail.com* (OG); *rogemifdaniel@gmail.com* (RF); *marcosponce27@gmail.com* (MP)

Cerro Chucantí represents a sky island (Doge 1943; Heald 1967, pp. 114–126), a concept widely used in the study of island biogeography that describes mountains as "islands of habitat" (e.g., Quammen 2004, pp. 436–447; Warshall 1994). Indeed, because of its higher elevation, Cerro Chucantí is the only area within the Majé Mountains covered predominantly by cloud forest, and it is isolated from the nearest equivalent cloud forest of the Cerro Pirre range by a stretch of 120 km which consists of completely different lowland terrain. More than a dozen new species of fungi, plants, invertebrates, and vertebrates have recently been described which are known only from Cerro Chucantí (see articles listed at: http://adoptabosque.org/chucanti/newspecies/). Unfortunately, as much as tropical sky islands have promoted the evolution of endemic species, and thus, harbor a disproportionately high diversity, they are under increasing threat from global warming, causing the redistribution of biodiversity patterns (Pecl et al. 2017), and from drastic habitat loss due to upward displacement of species (Kok et al. 2016; Haines et al. 2017; Mizsei et al. 2020) where the local topography allows this (Şekercioğlu et al. 2008). In addition, the montane rainforest of Cerro Chucantí is significantly threatened by slash-and-burn agriculture, as well as logging and cattle ranching on all but the steepest slopes (http://www.rainforesttrust.org/expansion-of-the-cerro-chucanti-nature-reserve/). Species restricted to sky islands like Cerro Chucantí are thus clearly at risk of extinction, so protecting pristine land becomes a priority. To address this, Rainforest Trust has partnered with ADOPTA (http://www.adoptabosque.org) to purchase land with the long-term aim of creating a broader government-protected area.

Furthermore, there is an urgent need to evaluate the exact species composition and status of the amphibians and reptiles of the Cerro Chucantí sky island, because high altitude ectothermic animals are particularly vulnerable to climate change due to their low dispersal ability, a high level of habitat specialization, and fragmented distributions (Davies et al. 2004; Sinervo et al. 2010). A few herpetological studies have been conducted in the Majé Mountains; including the first amphibian diversity study in 2007 by Medina et al. (2019), and some effort focusing on the entire herpetofauna of the Cerro Chucantí by the current authors since 2012 (e.g., Batista et al. 2014b), resulting in one new species of salamander and a snake described for this peak area (Batista et al. 2014a, 2016b). This article presents the first check list on the herpetofauna of CPNR, including the recently described species and those in anticipation of a formal description. Furthermore, analyses of abundance and diversity are presented.

Methods

Located in the southeastern part of the Majé Mountains, the higher elevation Cerro Chucantí (1,439 m asl, 8.8046°N, 78.4595°W; Fig. 1A,B) is part of the eco-region "Eastern Panamanian Montane Forests" (World Wildlife Fund 2014). There is no particular climatic information available for this mountain range (Samudio 2001), but according to the eco-region, the precipitation varies between 3,000 and 4,000 mm/year, and the temperature between 20 and 27 °C (World Wildlife Fund 2014). The vegetation belts of Cerro Chucantí are Tropical Lowland Wet/Moist Forest (0–600 m asl), Premontane Moist Forest (500–1,000 m asl), and a small area of Premontane Wet Forest above 1,000 m asl (Holdridge 1967; with modifications from ANAM 2010; Ramírez 2003). In this region, rainfall occurs mostly during April–December (Rio Majé Meteorological Station, 70 m asl; http://www.hidromet.com.pa/, accessed on 19 Sep 2015). To evaluate the status of the CPNR herpetofauna, surveyors walked along transects with 1–2 m width by applying VES (Visual Encounter Survey) and some voice recording of the anurans. Only post-metamorphic life stages of anurans were sampled. The two investigated areas within the reserve are described below.

Premontane Moist Forest (PMF, Fig. 2). PMF is the area surrounding the Chucantí Biological Station (~800 m asl), with the forest continuing along a trial above the station up to ~950 m asl. The forest is pristine with an open understory and variably-sized boulders scattered across the floor, which provide many holes and crevices that can be used as shelter for amphibians and reptiles. The leaf litter is scarce, mainly due to the inclination of the terrain (with some slopes > 40°). The area below the biological station is structured by two trails and the Chucantí Creek. The main trail, labeled "Entrance" in Fig. 1B, leads after a few hundred meters downward to the exit of the reserve, and into an open pasture land. This area consists mainly of secondary forest (~15 years old). The second trail continues along "Helicopteros trail" into a loop to the top of Cerro Chucantí and back along "Chucantí" and "Escalera trails" to the biological station. Most areas below 900 m asl are covered by old growth secondary forest. The PMF zones of both trails, including the short trail labeled Cascada (Fig. 1B), and Chucantí Creek were sampled along eight transects during three visits to the reserve on 1–5 December 2012, 2–5 April 2015, and 8–16 October 2016 (Table 1).

Premontane Wet Forest (PWF, Fig. 2). This forest begins as low as 950 m asl, where the PMF changes gradually into the PWF as one ascends. It is a cloud forest that covers the mountain ridges and several smaller peaks around Cerro Chucantí. The understory is filled with palm trees, ferns, and plenty of epiphytes, whereas tree bark and branches are copiously covered by moss. The trail up the slope from the biological station passes by two helicopter wreckages (which crashed decades ago) and leads to Camp Site 1 at 1,200 m asl. The understory and forest floor of the highest areas surrounding Cerro Chucantí (1,350–1,439 m asl) and the ridge following east to a second peak (1,290 m asl) are extensively

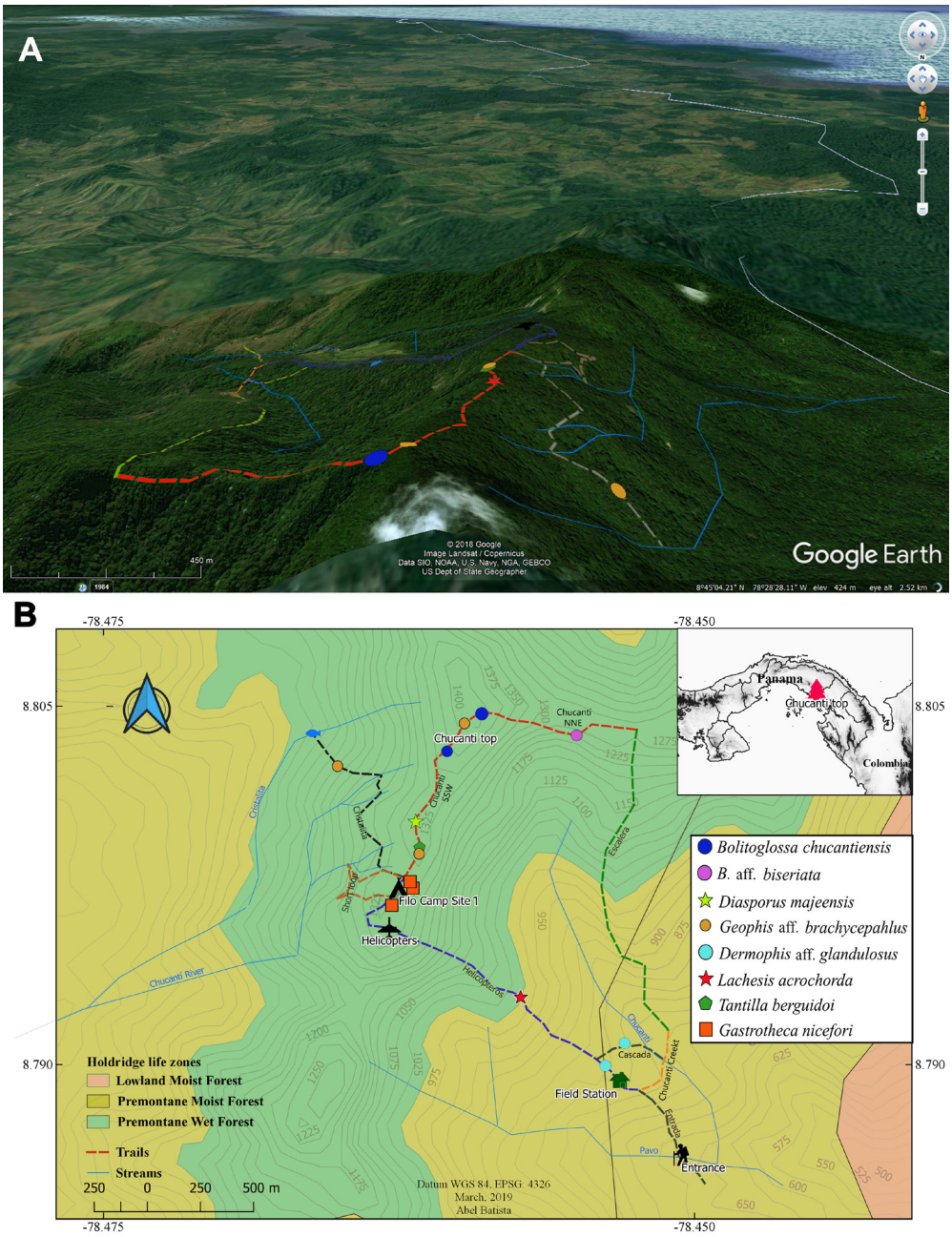

Fig. 1. (A) Satellite map and **(B)** abstract digital map showing the trails used on Cerro Chucantí for transects in the PWF (beige, black, partly blue, and red dashed trails) and PMF (orange, dark-grey, and green dashed trails). Records of some species are also shown (see **Materials and Methods** for details).

covered with bromeliads and moss (Fig. 2). Twelve transects were laid out in this forest, some of which were sampled repeatedly during 2012–2016, whereas others were visited only once (Table 1). Transects all started or ended at Camp Site 1 and were set up along the following five trails/areas (Fig. 1B): (1) Chucantí top: covers the peak; (2) Helicopteros trail: expands along the main trail down to the biological field station; (3) Chucantí SSW trail: follows the ridge south-south-west; (4) Chucantí NNE trail: follows the ridge north-north-east; and (5) Short Loop and Cristalita: includes two transects on slopes down to 1,200 m asl and 1,040 m asl, respectively, which lead to the "Cristalita" stream (Spanish for little glass), so-named during our surveys because of the loud choir of calling glass frogs when we arrived there the first time (see details in Fig. 1 and Table 1). Georeference points were recorded using a Garmin GPSmap 60CSx in the WGS 1984 datum format, changed into decimal degrees, and maps created in QGIS 2.18.0.

Species identification mainly used the keys by Köhler (2008, 2011), augmented by specialized publications on the amphibians and reptiles of Eastern Panamá. Specimens that could not be positively identified in the field, or for which taxonomic allocation was doubtful, were collected with the permission of the Ministerio de Ambiente (permits for 2012: SC/A-33-12; for

Table 1. Details of transects sampled at the CPNR from 2012 to 2016. Distance: walking distance in meters; man/hr: number of hours invested searching a transect by one surveyor multiplied by the number of field surveyors involved.

Transect	Location, year sampled	Forest type	Start coordinates		End coordinates		Elevation	Distance	man/hrs
			N	W	N	W	(m asl)	(m)	
T1	Chucanti creek, 2012	Premontane Moist	8.79051	78.45095	8.79075	78.45130	746-764	200	10
T2	Cloud forest camp site 1, 2012	Premontane Wet	8.79768	78.46229	8.47450	78.27470	1,274–1,327	300	10
T3	Cloud forest Chucantí top 1, 2012	Premontane Wet	8.79768	78.46229	8.80476	78.45896	1,300–1,429	500	6
T4	Cloud forest camp site 1 diurnal search, 2012	Premontane Wet	8.79768	78.46229	8.47450	78.27470	1,274–1,327	300	8
T5	Cloud forest Chucantí top 1, 2015	Premontane Wet	8.79768	78.46229	8.80476	78.45896	1,300–1,429	500	12
T6	Chucanti creek, 2015	Premontane Moist	8.79051	78.45095	8.79075	78.45130	746–764	200	9
T7	Cloud forest camp site 1, 2015	Premontane Wet	8.79768	78.46229	8.47450	78.27470	1,274–1,327	300	9
T8	Chucanti creek, 2016	Premontane Moist	8.79051	78.45095	8.79075	78.45130	746–764	200	6
T9	Above field station, 2015	Premontane Moist	8.78923	78.45216	8.79572	78.46290	900–1,300	1,200	6
T10	Cloud forest Chucantí top 1, 2016	Premontane Wet	8.79768	78.46229	8.80476	78.45896	1,300–1,429	500	8
T11	Camp site 1 down southwest	Premontane Wet	8.79768	78.46229	8.79699	78.46508	1,300–1,274	942	10
T12	Cristalita stream	Premontane Wet	8.80388	78.46613	8.80412	78.46526	1,052–1,080	100	4
T13	Cristalita to camp site 1	Premontane Wet	8.80388	78.46613	8.79768	78.46229	1,052–1,274	1,800	20
T14	Cloud forest Chucantí top 1, 2016	Premontane Wet	8.79768	78.46229	8.80476	78.45896	1,300–1,429	1,600	28
T15	Cloud forest camp site 1 to helicopters, 2016	Premontane Wet	8.79051	78.45095	8.79572	78.46290	1,274–1,336	300	24
T16	Camp site 1 down northwest	Premontane Wet	8.79051	78.45095	8.80040	78.46420	1,200–1,078	300	8
T17	Field station, loop to Chucanti creek, 2016	Premontane Moist	8.78923	78.45216	8.79104	78. 45366	800–850	400	6
T18	Entrance to the reserve's field station	Premontane Moist	8.78923	78.45216	8.78730	78.45237	800–740	400	2
T19	Above field station, 2015	Premontane Moist	8.78923	78.45216	8.79572	78.46290	900–1,300	1,200	4
T20	Chucanti creek, 2016	Premontane Moist	8.79051	78.45095	8.790753	78.45130	746–764	200	8
						Total		**11,442**	**198**

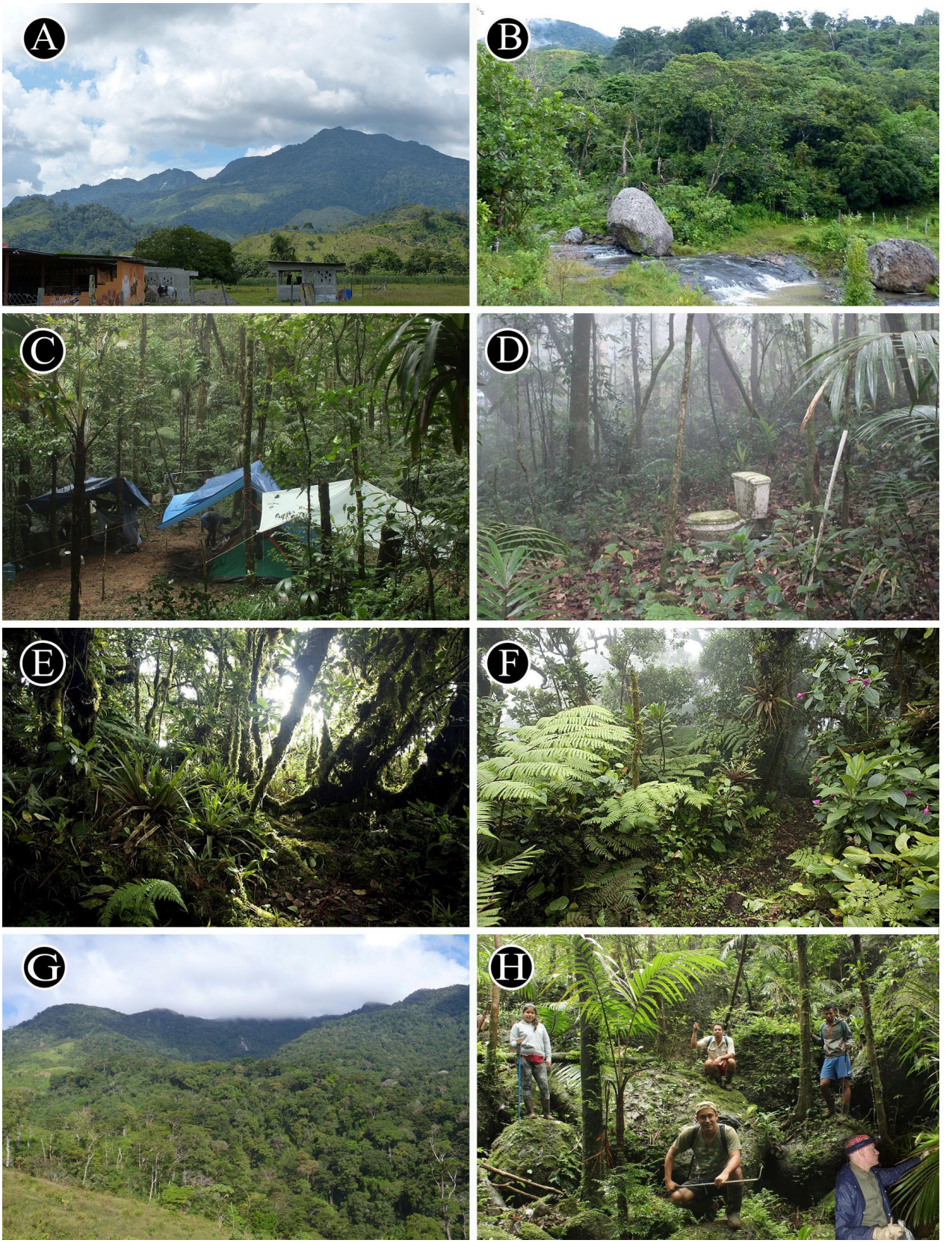

Fig. 2. Study area at CPNR. **(A)** Cerro Chucantí; **(B)** entrance to the reserve; **(C)** Camp Site 1, on 2016; **(D)** modern toilet at Camp Site 1; **(E–F)** forest above 1,300 m asl; **(G)** view of the secondary forest around the biological station up to the cloud forest on the ridge; **(H)** the field team, at 1,200 m asl from left: Madian Miranda, above Rogemif Fuentes, Orlando Gárces, below Abel Batista, and lower right Konrad Mebert.

2013: SEX/A-7-13; for 2016: SE/A-60-16). Collected specimens were euthanized by applying T61 solution, preserved with 5 ml formalin (36%) in 1 L ethanol (94%), and subsequently stored in ethanol (70%). Specimens were deposited in the Senckenberg Museum of Frankfurt (SMF), Museo Herpetológico de Chiriquí (MHCH), or Museo de Vertebrados de la Universidad de Panama (MVUP). The nomenclature used to make the check lists corresponds to the taxonomy obtained from AmphibiaWeb (http://amphibiaweb.org/) and The Reptile Database (http://reptile-database.org/).

To evaluate the abundance and diversity status of amphibians and reptiles in the CPNR, diversity analyses were performed using PAST software (Hammer et al. 2001). Dominance (D), Shannon (H') and Equitability (J) were used as metrics for community evenness inferences. Relative richness was calculated dividing the number of taxa per hour of survey time in a transect. To predict the maximum number of reptile and amphibian species by forest type, we applied ESTIMATES (Colwell 2006), using the sample-based estimation with 100 runs of randomization and extrapolated to a factor of doubling the effort made.

Results

The surveys accumulated a sampling effort of 198 man/hr and covered 11,793 m of trails (Table 1). A total of 41 amphibian and 35 reptile species were found for the CPNR (Figs. 3–5; Appendix 1). These numbers consist of: total of observed species, including those newly described since 2014 (29 amphibians, 24 reptiles); potentially new species (nine amphibians, three reptiles); species likely to occur on Cerro Chucantí, but found in similar habitats and elevations of an adjacent area within the Majé Mountains (two amphibians, eight reptiles); and one non-collected species of a Marsupial Frog heard from the canopy tree at Camp Site 1 during the 2012 survey. A video-recording captured the brief calls of at least three specimens, with identifications that they most likely refer to *Gastrotheca nicefori* corroborated among experts (including W.E. Duellman and U. Sinsch).

Among the transects, amphibians were more diverse at lower elevations with 27 species in the PMF versus 20 species higher up in the cloud forest or PWF (Fig. 6; Appendices 2–3). This diversity is also reflected in the higher relative species richness index in the PMF versus PWF for amphibians (average richness index across transects per forest type: 1.42 versus 0.84). According to the estimations, a slight increase in the number of species may occur if the hourly effort made were doubled, with three more species in the PMF and one in the PWF. Reptiles showed a comparatively smaller general species richness (Fig. 6; Appendices 2–3), but a much greater increase would be expected than in amphibians if the sampling effort were doubled, with nine more species in the PMF and seven in the PWF (Fig. 6). The relative richness in reptiles was also greater in the PMF than in PWF (average richness index across transects per forest type: 0.46 versus 0.24). The PMF showed also a more evenly distributed community for both taxonomic groups and most transects (Fig. 6; Appendices 2–3). The amphibian community in the PWF was dominated by three species with the highest relative abundance (*Pristimantis caryophyllaceus*, *Diasporus majeensis,* and *Pristimantis cruentus*), which together contributed 75% of all amphibian individuals seen in that forest (Figs. 7–8). Among reptiles, a potentially new lizard, *Ptychoglossus* aff. *plicatus*, and snake, *Geophis* aff. *brachycephalus*, were the species with the highest relative abundance in the PWF, contributing 62% of all reptiles (Figs. 9–10). Across both forest types, amphibian and reptile species numbers were higher in aquatic than terrestrial habitats (Fig. 11).

Of the defined species from the CPNR, only one is listed in any threat category of the IUCN, *Pristimantis pardalis*, which is listed as "Near Threatened." Most of the remaining species are listed in the "Least Concern" category or have not been evaluated yet (see Appendix 1). However, according to the environmental vulnerability score (EVS), three amphibian and 12 reptile species are listed in the "high" EVS category (Johnson et al. 2015), although most amphibians scored in the "low" EVS category and most reptiles in the "medium" EVS category (see Appendix 1).

Discussion

The high endemism of Cerrro Chucanti, and Eastern Panama (EP) in general, is a consequence of the complex geological history of the Isthmus of Panama, with EP representing the northernmost block of the Chocó biogeographical region (Duque-Caro 1990). This block began with a widespread uplift as a result of the collision of the Panama Arc with South America around 20 Mya (Montes et al. 2012). The uplift continued and formed regional mountain ranges, including Cerro Chucanti in the Majé Mountains, that became isolated through eustatic fluctuations during the middle and late Miocene (as early as 11 Mya), such as the flooding of the Atrato and Chucunaque Basins (Duque-Caro 1990; Coates et al. 2004). This isolation promoted speciation events and an increased species diversity in this region from 5–8 Mya (Batista et al. 2014a,b, 2016a; Coates et al. 2004).

Currently, the Majé Mountains are separated by at least 100 km from the nearest mountain ranges with elevations reaching > 1,000 m asl (Cerro Pirre, Cerro Darien). Cerro Chucantí is situated at the easternmost portion of the Majé Mountains and represents a sky island, as it is the only site in the region with elevations of more than 1,200 m, providing the topographic and climatic conditions for a largely isolated cloud forest. This restricted habitat is home to several endemic species (e.g., *Bolitoglossa chucantiensis*, *Bolitoglossa* aff. *biseriata*, *Diasporus*

Fig. 3. Selected amphibian species found during the 2012–2016 surveys on Cerro Chucantí. **(A)** *Dermophis* aff. *glandulosus*; **(B)** second known specimen of *Bolitoglossa chucantiensis*, recently described and endemic (Batista et al. 2014a); **(C)** *Bolitoglossa* aff. *biseriata*; **(D)** *Oedipina* aff. *complex*; **(E)** *Strabomantis bufoniformis*; **(F)** *Diasporus majeensis,* recently described and endemic (Batista et al. 2016a); **(G)** *Pristimantis gaigei*; **(H)** *Pristimantis moro*.

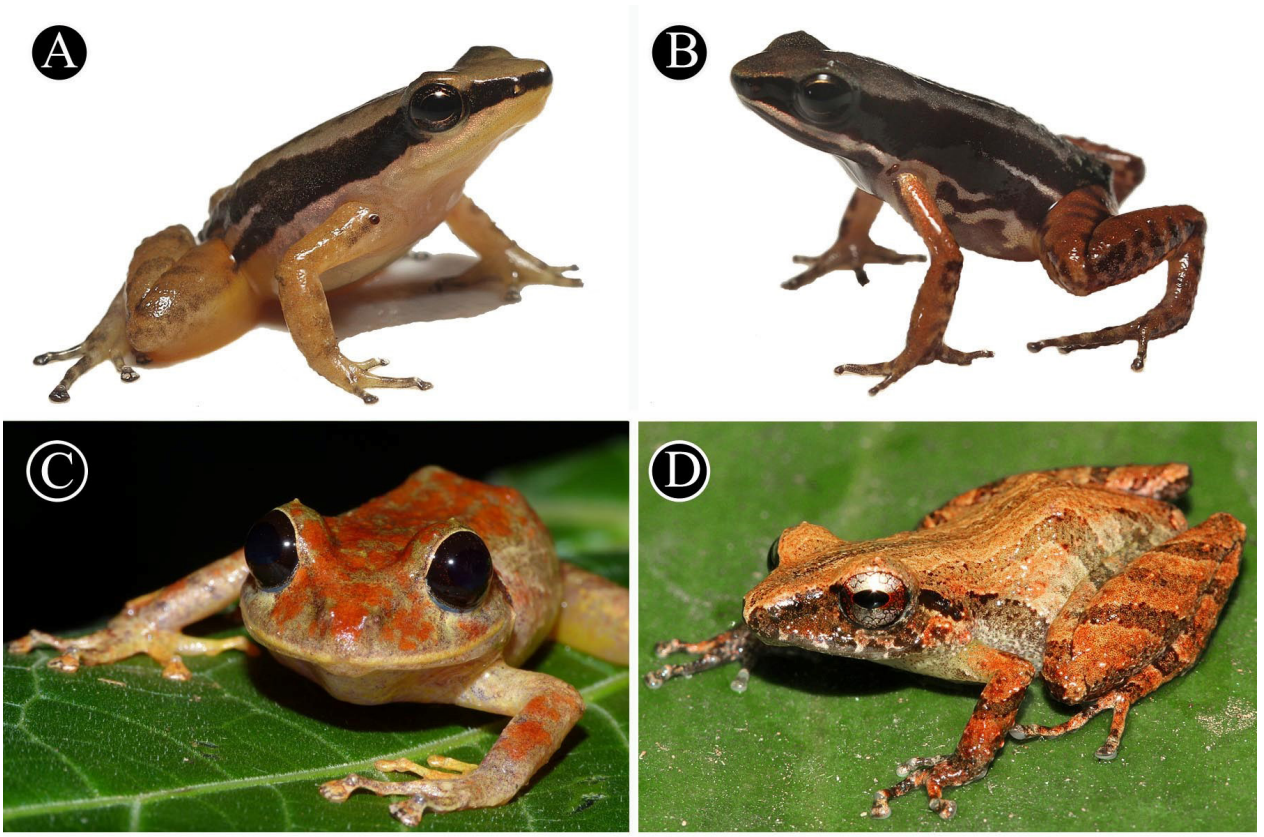

Fig. 4. Selected amphibian species found during the 2012–2016 surveys on Cerro Chucantí that await formal description or clarification of relationships. **(A)** *Colostethus* aff. *pratti*; **(B)** *Silverstoneia* sp.; **(C)** *Pristimantis* aff. *latidiscus*; **(D)** *Pristimantis* aff. *ridens*.

majeensis, Geophis aff. *brachycephalus,* and *Tantilla berguidoi*), that have only been found within this area of about 3 km^2 calculated with Google Earth (Batista et al. 2014a,b, 2016a). Its high diversity and endemism are surprising, generally comparable with other highlands in the Neotropics, yet slightly higher than the average for either Central America (Batista and Ponce 2002; Chávez and Morales 2014; Duellman 1988; Veith et al. 2004; http://www.somaspa.org/) or the tepuis in South America (Aubrecht et al. 2012).

In general, amphibians are easier to detect than reptiles (Myers 2003; Savage 2002; Yeo and Peterson 1998), which is consistent with our results (Fig. 6). The observed species richness at Cerro Chucantí, at least in the cloud forest (see potential species in Appendix 1, Fig. 6), appears to approach its current maximum, although its canopy was not explored. Furthermore, additional reptile species are expected to be discovered in the future, because reptiles usually yield lower detection probabilities (see Fig. 6 for estimating richness). The species richness in the PMF was consistently larger than in the higher-altitude PWF (Premontane Wet Forest or cloud forest) for both amphibians and reptiles, even though a greater effort was invested in the PWF. This confirms the general rule of diversity patterns in the American tropics (Wilson et al. 2010), with decreasing diversity from intermediate elevations where diversity is highest (Whitfield et al. 2016), to higher altitudes where cooler temperatures physiologically restrict ectothermic animals. Medina et al. (2019) suggested that the reduced number of observed species at the highland site on Cerro Chucanti may reflect the absence of streams and ponds, and the reduced patch size of the cloud forest. However, the altitude range at the CPNR was too small to experience large climatic differences, and the area available for the cloud forest (PWF) is very limited, roughly estimated at only 1.8 km^2 above 1,200 m asl (Batista et al. 2016; Medina et al. 2019). These factors may possibly dampen the effect of altitudinal zonation due to overlap between the two forest types. However, the J evenness index for PWF versus PMF (see Appendices 2–3) indicates that the zonation is sufficiently accentuated so that a few species dominate, or have been recorded only, which are particularly well-adapted to the cooler environment in the PWF. For example, *Pristimantis cruentus*, *P. caryophyllaceus,* and *Diasporus majeensis,* accounted for 75% (according to recorded advertisement calls) of the total relative species abundance in the PWF. Similarly, only one lizard, *Ptychoglossus* sp., dominates the reptilian composition with a relative abundance of 42% among all species.

Amphibian species richness in Cerro Chucanti was higher in this study (combined 15 days survey for the three years) than in a 10-day survey conducted in 2007 (95% CI, see Table 2 in Medina et al. 2019). The observed/

Fig. 5. Selected reptile species found during the 2012–2016 surveys on Cerro Chucantí. **(A)** *Echinosaura* aff. *palmeri*; **(B)** *Ptychoglossus* aff. *plicatus*; **(C)** *Anolis* aff. *fuscoauratus*; **(D)** *Geophis* aff. *brachycephalus*; **(E)** *Corallus annulatus*, highest elevation record; **(F)** *Tantilla berguidoi*, recently described and endemic (Batista et al. 2016b); **(G)** *Bothrops asper*, 1,273 m asl, highest elevation record for Panama; **(H)** *Lachesis acrochorda* juvenile, 1,011 m asl, highest elevation for this species in Panama.

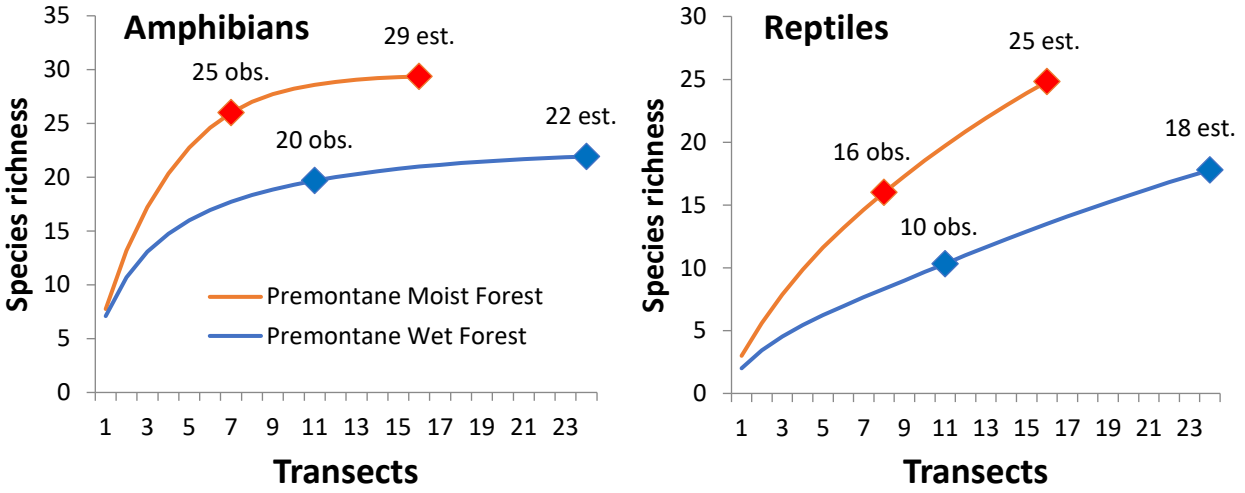

Fig. 6. Species accumulation curves for amphibians (left) and reptiles (right) for transects in the PMF and PWF on Cerro Chucantí. obs: observed species on transects; est: estimated species if the sampling effort is doubled. Details on the transects are shown in Table 1.

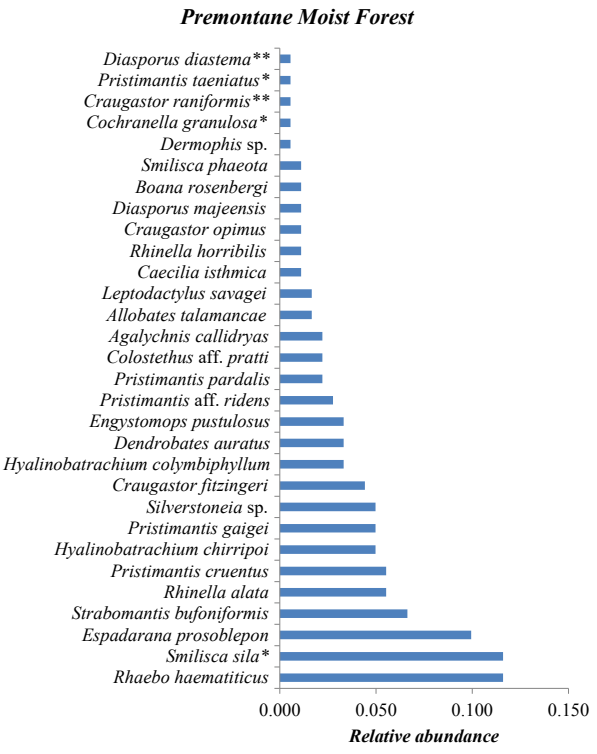

Fig. 7. Relative abundance of amphibians found during surveys from 2012–2016 in the Premontane Moist Forest (PMF) on Cerro Chucantí. * Species observed in PWF and PMF on Cerrro Chucanti, but outside a transect; ** Species of likely occurrence that have been found in similar habitat and elevations in adjacent peaks of Majé Mountains.

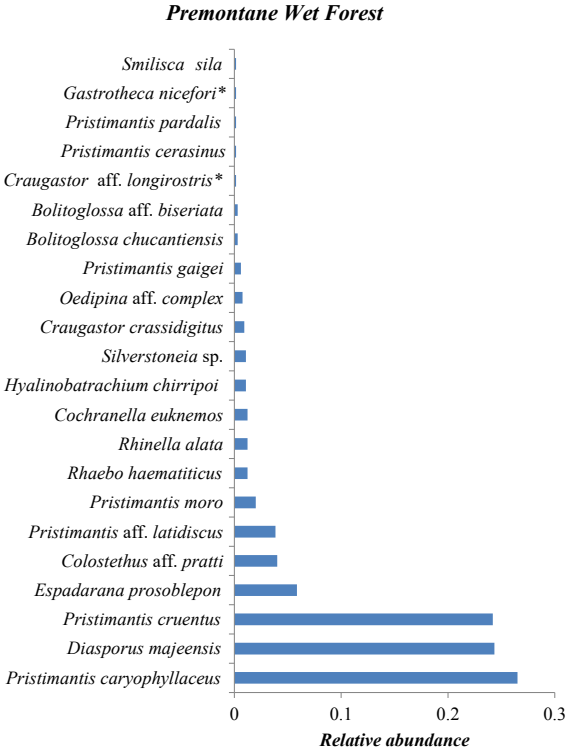

Fig. 8. Relative abundance of amphibians found during surveys from 2012–2016 in the Premontane Wet Forest (PWF) on Cerro Chucantí. * Species observed in PWF and PMF on Cerrro Chucanti, but outside a transect.

maximum-estimated species richness in 2007 was 21-obs/26-est (PMF) and 13-obs/17-est (PWF) species, which is 6–7 fewer observed species than were reported for the same elevation herein (25-obs/29-est, respectively 20-obs/22-est species). The difference may be attributed to the 30% greater survey time in this study, or to the erratic (although not recorded) weather fluctuations affecting amphibian activity in the respective study periods. No comparative data are available for reptiles in the 2007 survey (Medina et al. 2019), however, we would expect an increase of nine and seven species for the PMF and PWF, respectively.

As a result, from the first expedition to Cerro Chucantí in 2012, we have described *Diasporus majeensis, Bolitoglossa chucantiensis*, and *Tantilla berguidoi*. In addition, several collected specimens represent potentially

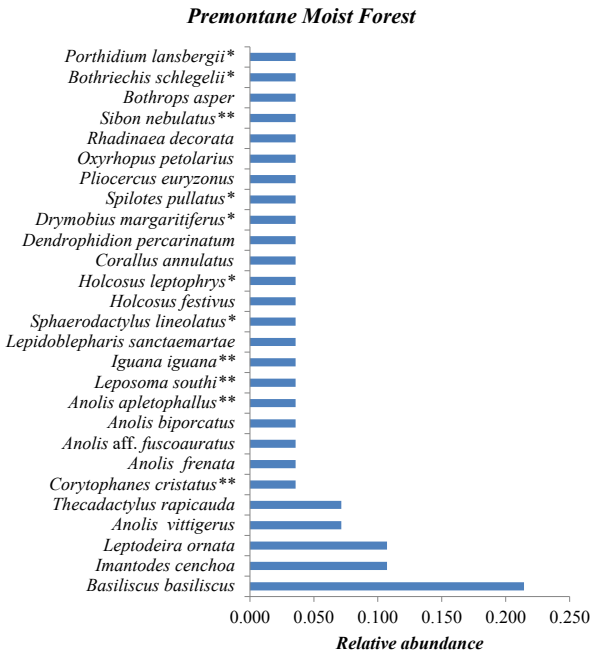

Fig. 9. Relative abundance of the reptiles found during surveys from 2012–2016 in the Premontane Moist Forest (PMF) on Cerro Chucantí. * Species observed in PWF and PMF on Cerrro Chucanti, but outside a transect; ** Species of likely occurrence that have been found in similar habitat and elevations in adjacent peaks of Majé Mountains.

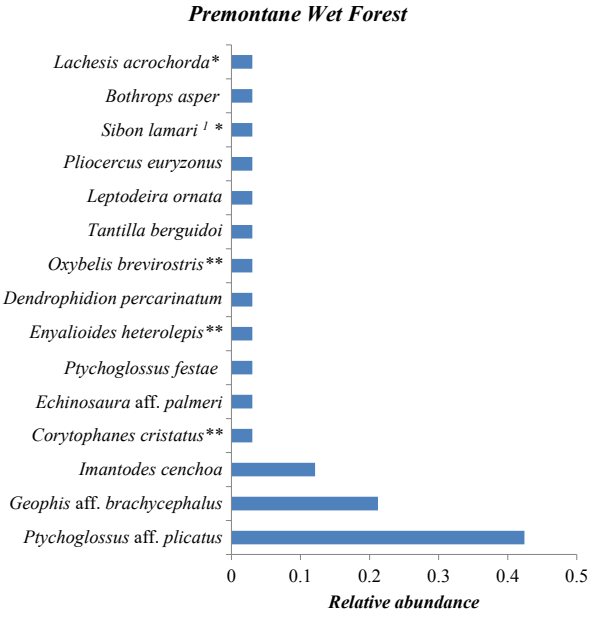

Fig. 10. Relative abundance of the reptiles found during surveys from 2012–2016 in the Premontane Wet Forest (PWF) on Cerro Chucantí. [1] indicates provisional identification; * Species observed in PWF and PMF on Cerrro Chucanti, but outside a transect; ** Species of likely occurrence that have been found in similar habitat and elevations in adjacent peaks of Majé Mountains.

new species of amphibians (Figs. 3–4): *Oedipina* aff. *complex*, *Colostethus* aff. *pratti*, *Silverstoneia* sp., *Pristimantis* aff. *latidiscus,* and *Pristimantis* aff. *ridens*; and reptiles (Fig. 5): *Echinosaura* aff. *palmeri*, *Ptychoglossus* aff. *plicatus*, *Anolis* aff. *fuscoauratus,* and *Geophis* aff. *brachycephalus*. Currently, an integrative taxonomy approach (de Queiroz 2007) is being applied to determine the taxonomic status or relationships of these specimens. The more recent expeditions in 2016 have also provided new material, e.g., *Dermophis* aff. *glandulosus* and *Bolitoglossa* aff. *biseriata*, that was assessed only morphologically, but for which molecular results are not yet available.

Several aspects call for urgent conservation strategies to preserve this high and important diversity hot spot in Eastern Panamá, including the endemism of species and/or isolated populations reported for the Majé Mountains, and in particular for Cerro Chucantí's CPNR (Batista et al. 2014a,b, 2016a,b), the accelerated deforestation rate observed for the region in recent years (G. Berguido pers. comm.), and the latent threat due to climate change (Marchese 2015). The conservation status of the newly described species from Cerro Chucantí and those awaiting description are unknown, whereas others were listed according to IUCN (2016) in Appendix 1.

This survey spent 147 man/hr in the Premontane Wet Forest around the type locality of *Bolitoglossa chucantiensis,* but only two specimens were found. This salamander is rare or occurs at low density, and is probably

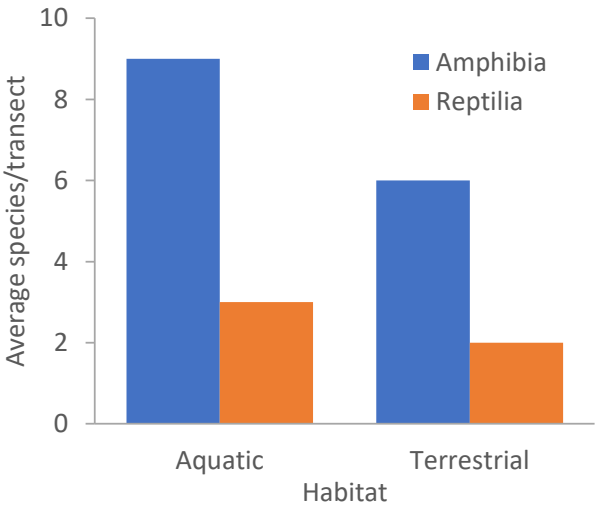

Fig. 11. Species richness across habitats, as average species per transect (#species/transect).

restricted to the peak area of Cerro Chucantí. The Dink Frog (*Diasporus majeensis*) is common, but as with the salamander, it has been reported only from the restricted area above 1,300 m asl. Our decade-long study of these two genera in most of Eastern Panama, combined with intensive surveys elsewhere in the Majé Mountains (e.g., around Ambroya), as well as most other cloud forests of Eastern Panama, lead us conclude that these two species are endemic to Cerro Chucantí (Batista et al. 2014a, 2016a). Since they are each restricted to a small area of less than 5 km² of a high elevation habitat around the peak

of Cerro Chucantí, we can argue for their classification as Critically Endangered, applying the IUCN Red List categories and criteria: B1ab(ii,iii)+2ab(ii,iii) [IUCN 2012]. Anthropogenic pressure around Cerro Chucantí probably will lead to further declines of populations through habitat deterioration and reduction of the area of occupancy. These species will also be allocated to "high" levels of environmental vulnerability score (EVS) by Johnson et al. (2015).

Furthermore, any outbreak of the fungal disease caused by *Batrachochytrium dendrobatidis* (*Bd*) and/or in combination with climate change is an imminent threat to the amphibians of Cerro Chucantí. Although *Bd* has been reported from the lowlands nearby (Küng et al. 2014; Rebollar et al. 2014) and through a cascading mechanism has negatively affected the reptilian fauna in Panama (Zipkin et al. 2020), thus far, no amphibian population decline has been detected on Cerro Chucantí. However, the threat is latent, as *Bd* has already expanded across most of Panama (Lips et al. 2008; Rebollar et al. 2014) and can be expected to affect Cerro Chucantí in the foreseeable future. Hence, bio-security protocols must be applied for visitors to the CPNR reserve (Dood 2010) and *Bd* surveys are urgently required. Since slight temperature fluctuations due to climate change could affect the biology of amphibian and reptile species on Cerro Chucantí, we also recommend that thermoecological experiments be conducted within the habitat of the endemic mountain species.

Despite the sampling effort made in this and previous studies, a caveat about the true species richness remains due to uncertainties regarding species detectability. Despite the combined sampling effort conducted throughout the two studies (Medina et al. 2019 and herein: April, June, July, October, and December), neither study followed a systematic and prolonged sampling method, and they only included visual encounter and opportunistic surveys for a few short duration excursions. For example, this sampling could easily have missed amphibian species with an explosive and temporally limited reproductive mode (e.g., *Hyloscirtus colymba* or *H. palmeri*). Many fossorial snakes (e.g., *Atractus, Micrurus*), lizards (e.g., *Bachia, Diplogossus, Lepidoblepharis*), frogs (e.g., Strabomantidae group), and caecilians (e.g., *Dermophis, Oscaecilia*) are difficult to detect in the leaf litter and require more elaborate techniques, such as pitfall trapping, to record and properly evaluate their population status. Species living in the canopy which rarely come down to the ground (e.g., *Cruziohyla calcarifer, Ecnomiohyla* sp.) are usually missed during short inventories unless they are recorded calling like the Marsupial Frog, *Gastrotheca nicefori* (for which a short calling sequence from this study is accessible at: https://youtu.be/H4QKsMQDWVQ). Therefore, to achieve a broader and more comprehensive insight into the herpetofauna diversity on Cerro Chucantí, additional studies must increase seasonally repetitive surveys, canopy inspections, and pitfall trapping.

Nonetheless, the studies conducted on Cerro Chucantí thus far have increased public awareness through the publication of various articles and online promotion to increase the value and enlarge the protection of the "Cerro" Chucantí Private Nature Reserve and its surroundings. In this context, Rainforest Trust has purchased three legally titled properties in order to establish an important buffer zone that will act as a barrier for preventing squatters from moving into the extensive public wilderness areas, and will discourage poachers from hunting in the vicinity (http://www.rainforesttrust.org/expansion-of-the-cerro-chucanti-nature-reserve/). The land to be purchased is part of the very limited high-elevation cloud forest where many new species have been discovered, in particular amphibians and reptiles described by the authors. As a gateway to over 60,000 acres of public lands, Cerro Chucantí Nature Reserve lays the foundation for the designation of a government national park, an effort that Panamanian NGO ADOPTA (http://adoptabosque.org/) is working hard to achieve.

Acknowledgements.—With this article, we hope to assist important organizations, in particular Guido Berguido with adoptabosque.org, in generating attention for the preservation of this unique and beautifully diverse paradise, the Chucanti Private Nature Reserve. We also would like to thank Jesus Pérez, Benjamín, Luis de Leon, and Sr. Juan Zarzavilla from Rio Pavo for field assistance.

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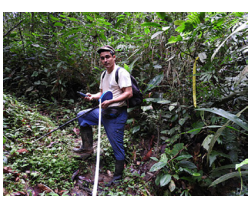
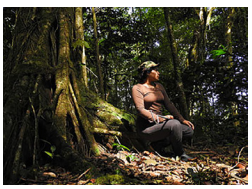
Orlando Ariel Garcés R. is a graduate Biologist with orientation in Animal Biology, and interests in herpetology, conservation, taxonomy, exploration, and photography. Orlando is currently a member of the Mesoamerican and Caribbean Network for the Conservation of Amphibians and Reptiles, as well as the Mesoamerican Society for Biology and Conservation, chapter in Panama. He is experienced in monitoring amphibians and reptiles, as well as the conservation and management of amphibians in captivity.

Rogemif Daniel Fuentes Magallón is a Zoologist who is passionate about nature and neotropical herpetology, and graduated from the University of Panama. With interests in research, rescue, and conservation, he currently collaborates on projects primarily involving amphibians and ophidians, and actively participates in wildlife rescue and relocation projects across the country. Rogemif has previously worked with anurans, snakes, and crocodiles, and collaborated on research with other groups such as scorpions.



Abel Batista is a Biologist by profession and nature lover, who completed a master's degree at the Universidad de los Andes Bogotá, Colombia, and a doctorate at the Senckenberg Institute (in association with Goethe University), Frankfurt, Germany, both focused on the study of amphibians and reptiles in Panama. With 20 years of field experience in Panama, Costa Rica, and Colombia, Abel has carried out various fauna rescue works, monitoring, and research. His main interests are bioacoustics, interactions between anuran communities, and the biogeography, phylogeny, and taxonomy of amphibians in Panama.



Madian Pamela Miranda is a graduate from the Autonomous University of Chiriquí, Panama, where she obtained her Bachelor's Degree in Biology, and she is a biologist by profession and nature lover with seven years of field experience in Panama. She has recently joined the Los Naturalistas (NGO) team. Madian is passionate about amphibians and reptiles, and has collaborated on various amphibian and reptile monitoring and conservation projects. She currently participates in environmental consulting projects, expeditions in search of new species, and conservation.

Marcos Ponce, Lic., is a Zoologist who has been working with amphibians in Panama for 15 years, and has participated in the descriptions of more than 10 new species of amphibians from Panama. Marcos has visited some of the less-explored places in Panamá, and currently is the head of a herpetological group that is evaluating the biodiversity of different national parks in Panama.

Konrad Mebert is an independent researcher and international project coordinator based in Switzerland, who conducts studies globally on amphibians and reptiles in general, but with an emphasis on vipers for the past 15 years. After completing a Master's degree at the University of Zürich, Switzerland, on geographic variation and the effects of inbreeding on the Dice Snake, and a doctoral degree on hybrid zones in North American water snakes at Old Dominion University, Virginia, USA, he currently is associated with the State University of Santa Cruz, Ilhéus, Bahia, Brazil and the IDECC (Institute of Development, Ecology, Conservation and Cooperation) in Italy. He has produced more than 140 professional and popular publications/reports, and two books on water snakes, covering a range of topics on evolution, ecology, biodiversity, and conservation. Many expeditions and a passion of photography have led him to all continents except Australia, and his current (2019) principal study sites are located in Panama, Turkey, Brazil, Slovenia, Ecuador, and China.

Appendix 1. Amphibians and reptiles recorded from the Chucantí Private Nature Reserve (and adjacent peaks of Majé Mountains) and their conservation status. NE indicates Not Evaluated, with other abbreviations for IUCN categories: DD (Data Deficient), LC (Least Concern), NT (Near Threatened), VU (Vulnerable), and EN (Endangered). Abbreviations for EVS (environmental vulnerability score, *sensu* Johnson et al. 2015) are L (Low: scores from 3–9), M (Medium: scores from 10–13), H (High: scores from 14–19), and N (Not scored). Two species received an additional classification in the Panama Conservation Status system: VU for *Dendrobates auratus* and CR for *Sibon lamari*. Red List status designations of potentially new species are listed according to the species of their morphological affinity, and labeled with a respective 'aff.' and epithet. * = Species of likely occurrence that have been found in similar habitat and elevations in the adjacent peaks of Majé Mountains.

Scientific name	IUCN Red List status	EVS category
Class Amphibia (41 species)		
Order Caudata (3 species)		
Family Plethodontidae		
Bolitoglossa chucantiensis	NE	H
Bolitoglossa aff. *biseriata*	NE	NE
Oedipina aff. *complex*	NE	NE
Order Gymnophiona (2 species)		
Family Caeciliidae		
Caecilia isthmica	DD	H
Dermophis aff. *glandulosus*	NE	NE
Order Anura (36 species)		
Family Bufonidae (3 species)		
Rhaebo haematiticus	LC	L
Rhinella horribilis	LC	
Rhinella alata	LC	L
Family Centrolenidae (5 species)		
Cochranella euknemos	LC	L
Cochranella granulosa	LC	L

Appendix 1 (continued). Amphibians and reptiles recorded from the Chucantí Private Nature Reserve (and adjacent peaks of Majé Mountains) and their conservation status. NE indicates Not Evaluated, with other abbreviations for IUCN categories: DD (Data Deficient), LC (Least Concern), NT (Near Threatened), VU (Vulnerable), and EN (Endangered). Abbreviations for EVS (environmental vulnerability score, *sensu* Johnson et al. 2015) are L (Low: scores from 3–9), M (Medium: scores from 10–13), H (High: scores from 14–19), and N (Not scored). Two species received an additional classification in the Panama Conservation Status system: VU for *Dendrobates auratus* and CR for *Sibon lamari*. Red List status designations of potentially new species are listed according to the species of their morphological affinity, and labeled with a respective 'aff.' and epithet. * = Species of likely occurrence that have been found in similar habitat and elevations in the adjacent peaks of Majé Mountains.

Scientific name	IUCN Red List status	EVS category
Espadarana prosoblepon	LC	L
Hyalinobatrachium chirripoi	LC	M
Hyalinobatrachium colymbiphyllum	LC	L
Family Craugastoridae (15 species)		
Craugastor crassidigitus	LC	M
Craugastor fitzingeri	LC	L
Craugastor aff. *longirostris*	LC	M
Craugastor opimus	LC	M
*Craugastor raniformis**	LC	L
Pristimantis caryophyllaceus	LC	L
Pristimantis cerasinus	LC	M
Pristimantis cruentus	LC	L
Pristimantis gaigei	LC	M
Pristimantis moro	LC	L
Pristimantis pardalis	NT	H
Pristimantis taeniatus	LC	L
Pristimantis aff. *latidiscus*	NE	NE
Strabomantis bufoniformis	LC	M
Pristimantis aff. *ridens*	LC	M
Family Dendrobatidae (4 species)		
Allobates talamancae	LC	M
Colostethus aff. *pratti*	LC	M
Dendrobates auratus	LC	L
Silverstoneia sp.	NE	
Family Eleutherodactylidae (2 species)		
*Diasporus diastema**	LC	L
Diasporus majeensis	NE	H
Family Hylidae (5 species)		
Gastrotheca aff. *nicefori*	NE	
Boana rosenbergi	LC	L
Smilisca phaeota	LC	L
Smilisca sila	LC	L
Agalychnis callidryas	LC	L
Family Leptodactylidae (1 species)		
Leptodactylus savagei	LC	L
Family Leiuperidae (1 species)		
Engystomops pustulosus	LC	L

Appendix 1 (continued). Amphibians and reptiles recorded from the Chucantí Private Nature Reserve (and adjacent peaks of Majé Mountains) and their conservation status. NE indicates Not Evaluated, with other abbreviations for IUCN categories: DD (Data Deficient), LC (Least Concern), NT (Near Threatened), VU (Vulnerable), and EN (Endangered). Abbreviations for EVS (environmental vulnerability score, *sensu* Johnson et al. 2015) are L (Low: scores from 3–9), M (Medium: scores from 10–13), H (High: scores from 14–19), and N (Not scored). Two species received an additional classification in the Panama Conservation Status system: VU for *Dendrobates auratus* and CR for *Sibon lamari*. Red List status designations of potentially new species are listed according to the species of their morphological affinity, and labeled with a respective 'aff.' and epithet. * = Species of likely occurrence that have been found in similar habitat and elevations in the adjacent peaks of Majé Mountains.

Scientific name	IUCN Red List status	EVS category
Class Reptilia		
Order Squamata (35 species)		
Family Corytophanidae (2 species)		
Basiliscus basiliscus	LC	M
*Corytophanes cristatus**	LC	M
Family Dactyloidae (5 species)		
Anolis frenata	NE	H
*Anolis apletophallus**	LC	H
Anolis biporcatus	LC	L
Anolis fuscoauratus	NE	M
Anolis vittigerus	LC	H
Family Gymnophthalmidae (4 species)		
Echinosaura aff. *palmeri*	DD	M
*Leposoma southi**	LC	H
Ptychoglossus aff. *plicatus*	NE	H
Ptychoglossus festae	LC	
Family Hoplocercidae (1 species)		
*Enyalioides heterolepis**	LC	M
Family Iguanidae (1 species)		
*Iguana iguana**	LC	M
Family Mabuyidae (1 species)		
*Marisora unimarginata**	LC	H
Family Phyllodactylidae (1 species)		
Thecadactylus rapicauda	LC	L
Family Sphaerodactylidae (2 species)		
Lepidoblepharis sanctaemartae	LC	H
Sphaerodactylus lineolatus	LC	H
Family Teiidae (2 species)		
Holcosus festivus	LC	M
Holcosus leptophrys	LC	H
Family Boidae (1 species)		
Corallus annulatus	DD	M
Family Colubridae (4 species)		
Dendrophidion percarinatum	LC	
Drymobius margaritiferus	LC	L
*Oxybelis brevirostris**	LC	M
Spilotes pullatus	LC	L
Tantilla berguidoi	NE	M

Appendix 1 (continued). Amphibians and reptiles recorded from the Chucantí Private Nature Reserve (and adjacent peaks of Majé Mountains) and their conservation status. NE indicates Not Evaluated, with other abbreviations for IUCN categories: DD (Data Deficient), LC (Least Concern), NT (Near Threatened), VU (Vulnerable), and EN (Endangered). Abbreviations for EVS (environmental vulnerability score, *sensu* Johnson et al. 2015) are L (Low: scores from 3–9), M (Medium: scores from 10–13), H (High: scores from 14–19), and N (Not scored). Two species received an additional classification in the Panama Conservation Status system: VU for *Dendrobates auratus* and CR for *Sibon lamari*. Red List status designations of potentially new species are listed according to the species of their morphological affinity, and labeled with a respective 'aff.' and epithet. * = Species of likely occurrence that have been found in similar habitat and elevations in the adjacent peaks of Majé Mountains.

Scientific name	IUCN Red List status	EVS category
Family Dipsadidae (8 species)		
Imantodes cenchoa	LC	L
Leptodeira ornata	LC	L
Pliocercus euryzonus	LC	M
Oxyrhopus petolarius	LC	M
Rhadinaea decorata	LC	L
Sibon lamari	EN	H
*Sibon nebulatus**	LC	L
Geophis aff. *brachycephalus*		
Family Viperidae (4 species)		
Bothrops asper	LC	M
Lachesis acrochorda	DD	H
Bothriechis schlegelii	LC	M
Porthidium lansbergii	NE	H

IUCN Amphibians	IUCN Reptiles
NE = 8	NE = 5
LC = 31	LC = 27
VU = 1	EN = 1
DD = 1	DD = 3

EVS Amphibians	EVS Reptiles
L = 20	L = 8
M = 3	M = 14
H = 3	H = 12

Appendix 2. Diversity indexes and species richness of amphibians found along transects within the two types of forests at CPNR.

Premontane Wet Forest															
Year	2012				2015			2016							
Transect	T2	T3	T4	Total	T5	T7	Total	T10	T11	T12	T13	T14	T15	T16	Total
Taxa_S	8	10	6	14	9	9	12	6	6	9	5	6	4	7	17
Individuals	85	57	17	159	43	31	74	44	44	43	44	185	9	47	416
Dominance_D	0.28	0.16	0.20	0.16	0.19	0.16	0.15	0.22	0.36	0.21	0.39	0.39	0.48	0.30	0.24
Shannon_H	1.52	1.97	1.70	2.12	1.86	1.98	2.15	1.61	1.22	1.81	1.16	1.14	1.00	1.40	1.73
Equitability_J	0.73	0.86	0.95	0.80	0.85	0.90	0.86	0.90	0.68	0.82	0.72	0.64	0.72	0.72	0.61
Relative richness	0.80	1.67	0.75	0.58	0.75	1.00	0.57	0.75	0.60	2.25	0.25	0.21	0.17	0.88	0.17
Sampling effort	10.00	6.00	8.00	24.00	12.00	9.00	21.00	8.00	10.00	4.00	20.00	28.00	24.00	8.00	102.00

Premontane Moist Forest									
Year	2012	2015	2016						
Transect	T1	T6	T8	T9	T17	T18	T19	T20	Total
Taxa_S	13	16	4	6	6	8	4	5	27
Individuals	59	36	20	12	7	20	6	21	181
Dominance_D	0.098	0.0988	0.3	0.2222	0.184	0.19	0.3333	0.379	0.06328
Shannon_H	2.428	2.553	1.28	1.633	1.748	1.84	1.242	1.245	2.983
Equitability_J	0.9467	0.9209	0.923	0.9112	0.976	0.89	0.8962	0.773	0.905
Relative richness	1.30	1.78	0.67	1.00	1.00	4.00	1.00	0.63	0.53
Sampling effort	10.00	9.00	6.00	6.00	6.00	2.00	4.00	8.00	51.00

Appendix 3. Diversity indexes and species richness of reptiles found along transects within the two types of forests at CPNR.

Premontane Wet Forest

Year	2012				2015			2016							
Transect	T2	T3	T4	Total	T5	T7	Total	T10	T11	T12	T13	T14	T15	T16	Total
Taxa_S	2	2	2	6	2	1	2	1	2	3	2	2	1	4	8
Individuals	3	2	4	9	5	2	7	1	2	5	2	2	1	4	17
Dominance_D	0.56	0.50	0.63	0.21	0.52	1.00	0.59	1.00	0.50	0.44	0.50	0.50	1.00	0.25	0.20
Shannon_H	0.64	0.69	0.56	1.68	0.67	0.00	0.60	0.00	0.69	0.95	0.69	0.69	0.00	1.39	1.81
Equitability_J	0.92	1.00	0.81	0.94	0.97	0.00	0.86	0.00	1.00	0.87	1.00	1.00	0.00	1.00	0.87
Relative richness	0.20	0.33	0.25	0.25	0.17	0.11	0.10	0.13	0.20	0.75	0.10	0.07	0.04	0.50	0.08
Sampling effort	10	6	8	24	12	9	21	8	10	4	20	28	24	8	102

Premontane Moist Forest

Year	2012	2015	2016						
Transect	T1	T6	T8	T9	T17	T18	T19	T20	Total
Taxa_S	10	7	2	1		2	1	1	16
Individuals	10	9	2	1		3	1	1	27
Dominance_D	0.10	0.19	0.50	1.00		0.56	1.00	1.00	0.10
Shannon_H	2.30	1.83	0.69	0.00		0.64	0.00	0.00	2.55
Equitability_J	1.00	0.94	1.00	0.00		0.92	0.00	0.00	0.92
Relative richness	1.00	0.78	0.33	0.17	0.00	1.00	0.25	0.13	0.31
Sampling effort	10	9	6	6	6	2	4	8	51