REPTILES & AMPHIBIANS

Herps at Height: Records of Seven Species Utilizing the Upper Canopy in Northwestern Ecuador

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Abstract.—Canopy research has not developed as rapidly as other fieldwork due to the inherent difficulty of accessing this ecosystem. Using a blend of industrial and arboriculture rope access techniques, we confirmed occurrences in the canopy of five reptile and two amphibian species in the Chocoan forests of northwestern Ecuador. Advanced methods were utilized that allowed us to sample not only the main trunk, but the outer branches, terminal ends of branches and tall mid-canopy shrubs. We add to the handful of studies focusing on herpetofauna in the canopy with our natural history records of these species which can go a long way to aiding future studies and ex-situ conservation measures.

Resumen.—La investigación en el dosel no se ha desarrollado con la misma velocidad que otras áreas debido a la inaccesibilidad de este ecosistema. Utilizando una combinación de técnicas de acceso con cuerdas de arboricultura e industria, confirmamos la ocurrencia de dosel de cinco especies de reptiles y dos especies de anfibios en los bosques del Chocó del noroccidente del Ecuador. Empleamos métodos avanzados que nos permitieron muestrear no solamente el tronco principal, sino ramas exteriores de árboles y arbustos altos. Nuestros registros de historia natural de las especies registradas se suman al número reducido de estudios enfocados en la herpetofauna de dosel, lo que podría ser un aporte para futuros estudios y medidas de conservación ex-situ.

Tropical forests offer a wide diversity of niche, micro-habitat, and resource gradients that vary from ground to canopy across the landscape, and as such they harbor a large proportion of the world's biodiversity (Pillay et al. 2022). Tropical forest canopies are among the most species-rich habitats on Earth, with estimates that they support roughly 40% of extant species, 10% of which are canopy specialists (Ozanne et al. 2003; Davis et al. 2011; Whitworth et al. 2016).

Guayasamin et al. (2006) argued that even limited sampling effort in the canopy can greatly improve species-richness assessments and reduce bias in our understanding of community structure through the sampling of contrasting microhabitats. Despite this, the canopy still remains a comparatively unexplored biotic frontier (Basset et al. 2003; Lowman and Schowalter 2012). Much of this is likely due to the obvious difficulties in accessing the canopy. Canopy science has taken many forms over the last few decades, with an array of different methods pioneered and utilized by various studies in multiple countries (Lowman et al. 2012; Lowman and Schowalter 2012). These methods have ranged from blimps and canopy walkways to rope-access techniques (Lowman et al. 2012; Lowman and Schowalter 2012).

Further, few studies have focused on basic ecological knowledge of arboreality and utilization of high canopy microhabitats, particularly for amphibians and reptiles (Moffett 2000; Kays and Allison 2001; Basham et al. 2022). The complex three-dimensional structure of the canopy itself and the epiphytes that grow within it create a challenging but interesting environment. Some work has identified relationships between bromeliads and herpetofauna such as lizards (Jorge et al. 2021) and frogs (Sabagh et al. 2017). Identifying the vertical space occupied by a particular species in its given habitat allows greater insight to its ecological role in the ecosystem (McCracken and Forstner, 2014).

Herein we present records of five species of reptiles and two amphibians we encountered utilizing the canopy in the Canandé Reserve in the Chocoan forests of Esmeraldas in northwestern Ecuador.

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Methods

Fundación Jocotoco's Canandé Reserve is located in the Chocó region of northwestern Ecuador (0.51889 N, 79.21527 W). The reserve extends over more than 8,000 hectares and has an elevational range of 100–500 m asl. The reserve is defined as evergreen lowland forest with dominant trees in the families Myristicaceae, Arecaceae, Moraceae, Fabaceae, and Meliaceae (Ministerio del Ambiente del Ecuador 2013). The canopy reaches around 30 m on average with emergent trees extending upward of 40 m in crown height. In the mid- and understory, plant species most commonly encountered are in the families Rubiaceae, Melastomataceae, and Arecaceae. Many palms (genera *Geonoma*, *Manicaria*, *Attalea*, and *Phytelephas*) also are encountered in these forests (MAE 2013; Yánez-Muñoz et al. 2023).

We used a variety of rigging methods to survey the canopy. These included traditional canopy-access methods on static fixed lines, moving rope systems like those used by arborists that allow movement throughout the canopy, and the rigging of horizontal tension lines (zip lines) between trees. This final component allowed us not only to reach terminal branches of the trees that would not normally support body weight, but also allowed us to rappel to the ground from anywhere along this tension line, giving us access to the midstory of the forest (Fig. 1). Eight trees were rigged and sampled during the day and at night over 20 days in September 2022. Sampling involved *ad libitum* searching through microhabitats such as epiphytic plants, bromeliads, moss, and inside tree holes or cavities. Heights above ground were measured using a 50 m tape reel. Photographs of the locations were taken for all individuals encountered and, where appropriate, basic measurements of the sites were recorded. No temperature or humidity measurements were recorded due to failure of the device. Identification was by OT and KN-S and was cross-checked via photographs by Mario Yánez-Muñoz at the Instituto Nacional de Biodiversidad (INABIO), Quito. To conform to our level of research permit within the reserve, handling and capture was avoided apart from the survey when KN-S was present, as she held a higher-level permit for the reserve for her own research. As such, we were able to handle and measure the *Pristimantis* sp.

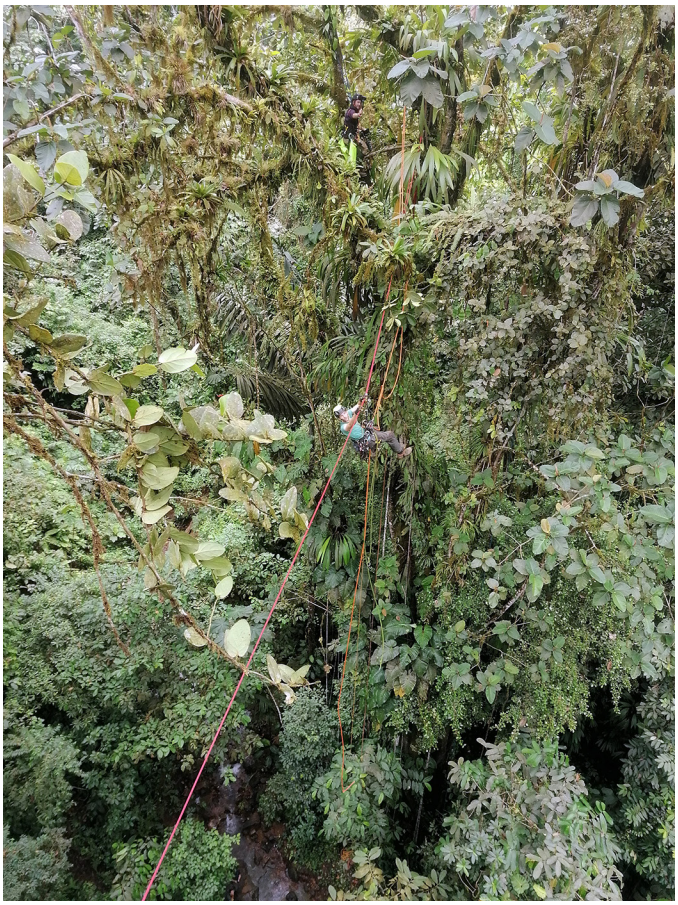

Figure 1. Example of a horizontal tension line between two trees. From this system we were able to rappel down and search in the smaller trees and vegetation over the river. Photograph by Sam Preston.

Results

Anolis chloris.—Multiple individuals of this species were seen moving around the larger branches of a Laguno Tree (*Vochysia macrophylla*) on 29 September 2022, with the initial sightings recorded around 1430 h (Fig. 2B). The lizards were displaying their dewlaps to each other and were remarkably bold, often venturing within one meter of us. The lizards were at various heights in the tree, but the initial encounter was 36.4 m above the forest floor (Fig. 3D). Interestingly, we had climbed this tree previously and not found anything in the canopy despite conditions being similar.

Anolis gracilipes.—The individual was encountered at 2319 h on 17 September 2022 (Table 1) sleeping on the leaf of an epiphytic plant (Fig. 2A) believed to be in the family Bignoniaceae on a Matapalo Tree (*Ficus* sp., Fig. 3A). The plant was 27.3 m above the forest floor, slightly below the tree crown. The individual was sleeping with its head downward in the center of the leaf and had lost most of its tail.

Anolis lyra.—The individual was found asleep on the leaf of a small palm (Cyclanthaceae) 29.1 m above the forest floor at 2242 h on 13 September 2022 (Table 1). The palm was growing epiphytically in a Sande Tree (*Brosimum utile*). The individual was sleeping with its head toward the ground and the leaf measured 22 x 4 cm (Fig. 2D, Fig. 3B).

***Anolis* sp.**—This individual was encountered at 1518 h on 29 September 2022 while observing individuals of *A. chloris*. The lizard was resting with its eyes closed on the branch in an area out of direct sun (Fig. 2C). It was located halfway toward the terminal end of one of the main branches of the crown of a Laguno Tree (*Vochysia macrophylla*) 34.1 m above the forest floor (Fig. 3C). The photographs suggest that this was *A. pentaprion* but that would be a significant range extension and perhaps one of the first records of this species in

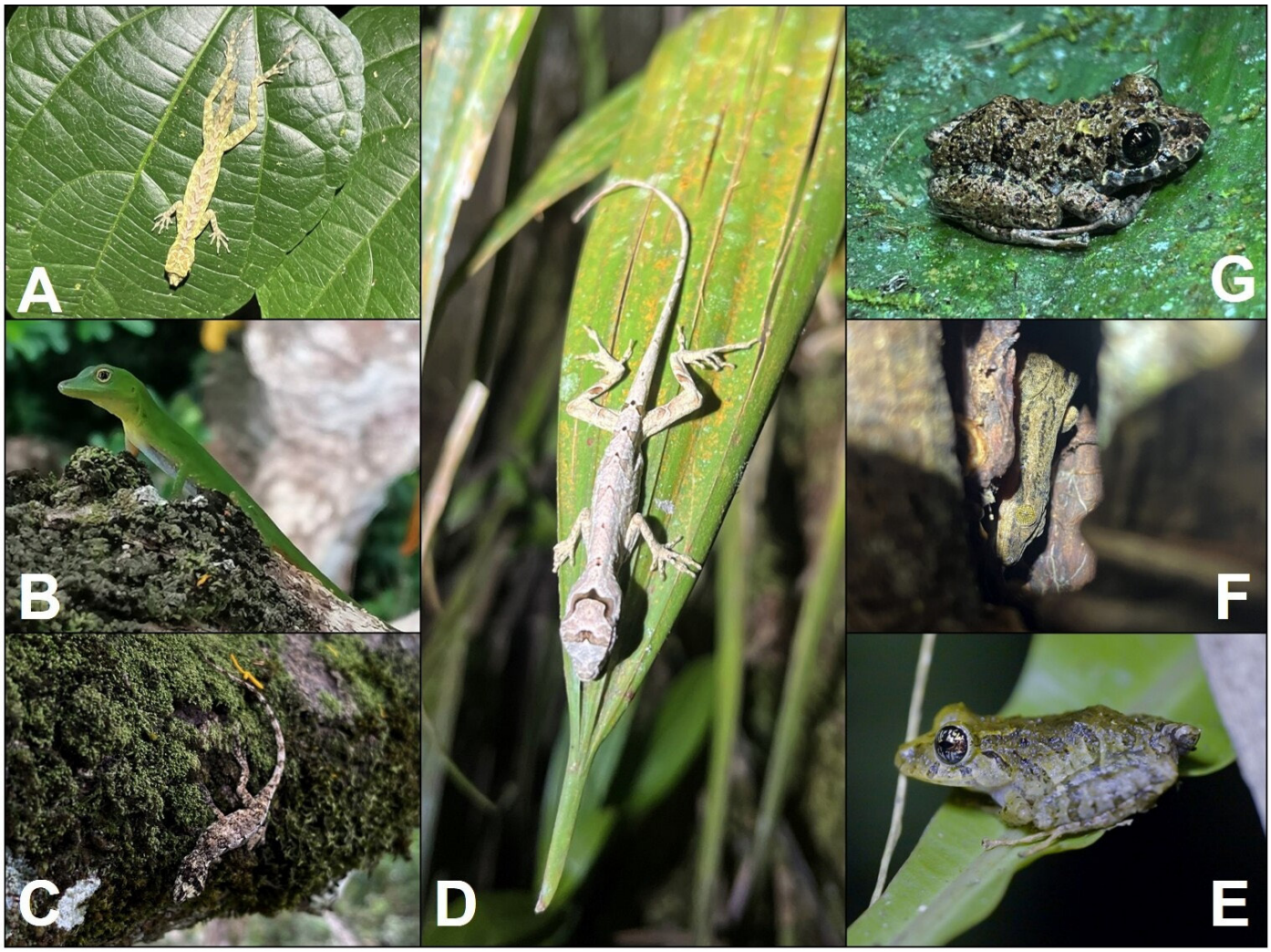

Figure 2. Photographs of reptiles and amphibians encountered in the upper canopy: *Anolis gracilipes* (A), *Anolis chloris* (B), *Anolis* sp. (C), *Anolis lyra* (D), *Pristimantis latidiscus* (E), *Thecadactylus rapicauda* (F), and *Pristimantis* sp. (G). Photographs by Oliver Thomas (A, C-D, F, G), Sam Preston (B), and Ross Vernon McDonald (E).

Ecuador. Such a claim demands stronger evidence than we were able to provide without capturing the lizard.

Pristimantis latidiscus.—The individual was encountered on the flat surface of a leaf of a small epiphytic palm (Cyclanthaceae) in the lowest section of the crown of a Matapalo Tree (*Ficus* sp.), 34.2 m above the forest floor at 2254 h on 21 September 2022 (Fig. 2E, Fig. 3E).

***Pristimantis* sp.**—The individual, which we were unable to identify to species (Fig. 2G), was encountered sitting on the stem of a palm (Cyclanthaceae, Fig. 3G) growing epiphytically in the canopy of a Matapalo Tree (*Ficus* sp.) at 2135 h on 17 September 2022 (Table 1). The initial site of encounter measured 34.2 m above the forest floor. This individual measured 35.4 mm SVL and underwent a change in both color and texture of the skin during the short period of handling. The frog was released where initially encountered. This individual is thought to represent a new species of the genus *Pristimantis* but further evidence would be required to confirm this.

Thecadactylus rapicauda.—This individual (Fig. 2F) was encountered at 2226 h on 27 September 2022 very high in a Sande Tree (*Brosimum utile*) inside a small cavity in a branch (Fig. 3F). The cavity was 41.1 m above the forest floor and the opening measured 85 x 30 mm, but was larger inside.

Discussion

Herein we provide observations of seven species of Neotropical herpetofauna utilizing the high canopy in northwestern Ecuador. The majority of the encounters we made were of individuals on epiphytic plants within the canopy, whereas others used the main branches of the tree or cavities within them. We also made the majority of our observations while climbing at night with just a single daytime survey providing observations of two species of *Anolis* active in the tree.

Fewer encounters were made than we had originally anticipated, although vertical migrations of frogs down from the canopy to avoid the harsher conditions of the dry sea-

Table 1. Reptiles and amphibians encountered in the canopy at the Fundación Jocotoco's Canandé Reserve, Ecuador.

Species	English common name / Spanish common name	Date (2022)	Time	Height (m)	Notes
Anolis chloris	Boulenger's Green Anole / Anolis verdes de Boulenger	29 Sept	1430	36.4	Moving around on the main branches of the tree, displaying
Anolis gracilipes	Charm Anole / Anolis encantadores	17 Sept	2319	27.3	Sleeping on an epiphytic vine (Bignoniaceae) just below the tree crown
Anolis lyra	Lyre-head Anole / Anolis de cabeza lira	13 Sept	2242	29.1	Asleep on an epiphytic palm (Cyclanthaceae) in the canopy
Anolis sp.	NA	29 Sept	1518	34.1	Resting on one of the main tree branches
Pristimantis latidiscus	Disc Robber Frog / Cutín del Chocó	21 Sept	2254	32.4	Resting on an epiphytic palm (Cyclanthaceae)
Pristimantis sp.	NA	17 Sept	2135	34.2	Perching on the stem of an epiphytic palm (Cyclanthaceae) in the canopy
Thecadactylus rapicauda	Turnip-tailed Gecko / Salamanquesas gigantes occidentales	27 Sept	2226	41.1	Inside a tree hole high in the canopy

son (Basham and Scheffers 2020; Basham et al. 2022) might have been responsible. Currently unclear is whether the species of the canopy community are spending short periods of time with daily shifts, extended periods of time with seasonal migrations (Basham and Scheffers 2020), or perhaps all of their lives in the canopy. Further research will be needed but such insights could provide one explanation for the low encounter rates we recorded.

Bromeliads and epiphytic plants are used by herpetofauna as sites of reproduction, shelter, foraging, or thermoregulation (Sabagh et al. 2017; Jorge et al. 2021). McCracken and Forstner (2014) found 14 species of herpetofauna (10 anurans and four reptiles) utilizing the tank-bromeliad *Aechmea zebrina* in the canopy in the Ecuadorian Amazon and among these was the gecko *Thecadactylus solimoensis*, which was recorded 31.5 m above the forest floor. Our results show that the sister species from the west of the Andes, *T. rapicauda,* utilizes tree cavities in the high canopy. Additionally, two species of *Anolis* (*A. ortonii* and *A. transversalis*) were encountered utilizing the same tank-bromeliad species in the canopy.

The body of research surrounding canopy-dwelling anoles is focused mostly on species in the Caribbean, in line with much of the other work on the genus (Dial and Roughgarden 2004 and references therein). In Ecuador, the species *Anolis heterodermus, A. parvauritus*, *A. peraccae*, *A. punctatus*, and *A. purpurescens* are known to be canopy dwellers (Moreno-Arias et al. 2021; Torres-Carvajal et al. 2022). Our results add *A. lyra* and *A. gracilipes* to this list.

Similarly for the amphibians of the genus *Pristimantis* in Ecuador, *P. acuminatus, P. aureolineatus*, *P. orphnolaimus*, and *P. waoranii* have been observed in the canopy by McCracken and Forstner (2014) during their tank-bromeliad study. Additionally, *P. muricatus* and *P. parvillus* have confirmed records in the canopy (Ron et al. 2022). *Pristimantis enigmaticus*, *P. eugeniae*, *P. limoncochensis*, *P. omeviridis*, and *P. subsigillatus* also are suspected to be canopy dwellers (Ortega-Andrade et al. 2015; Ron et al. 2022). Our observations add *Pristimantis latidiscus* to the list of canopy-dwelling *Pristimantis* frogs in Ecuador but further work in the west of the country would undoubtedly reveal more.

Natural history studies are the fundamental building blocks of our understanding of how species interact with their environment and can aid in the efficiency of the more advanced studies by streamlining methodology for sample collection, or improve methods of ex-situ conservation (Smith et al. 2009; Michaels et al. 2014). Nevertheless, the lower publication power of these short notes and natural history information in comparison to modelling or genetic studies is probably the cause of our comparative lack of knowledge about the basic ecology of many taxa, particularly herpetofauna (McCallum and McCallum 2006).

While the scientific discipline of canopy science has continued growing over the past 40 years, the vertical stratification of species distribution has been the main focus given its comparative ease in an already challenging sampling environment as it requires little or no lateral movement. Future work should focus on horizontal distribution within canopy layers as this has received little emphasis except for a handful of studies on invertebrates and bromeliads (Nakamura et al. 2017). This study offers one such method upon which movement throughout trees, including the small, terminal branches and tall shrubs of the midcanopy, can be safely achieved with advanced rigging techniques. An obvious barrier to the advancement of canopy science is the time and

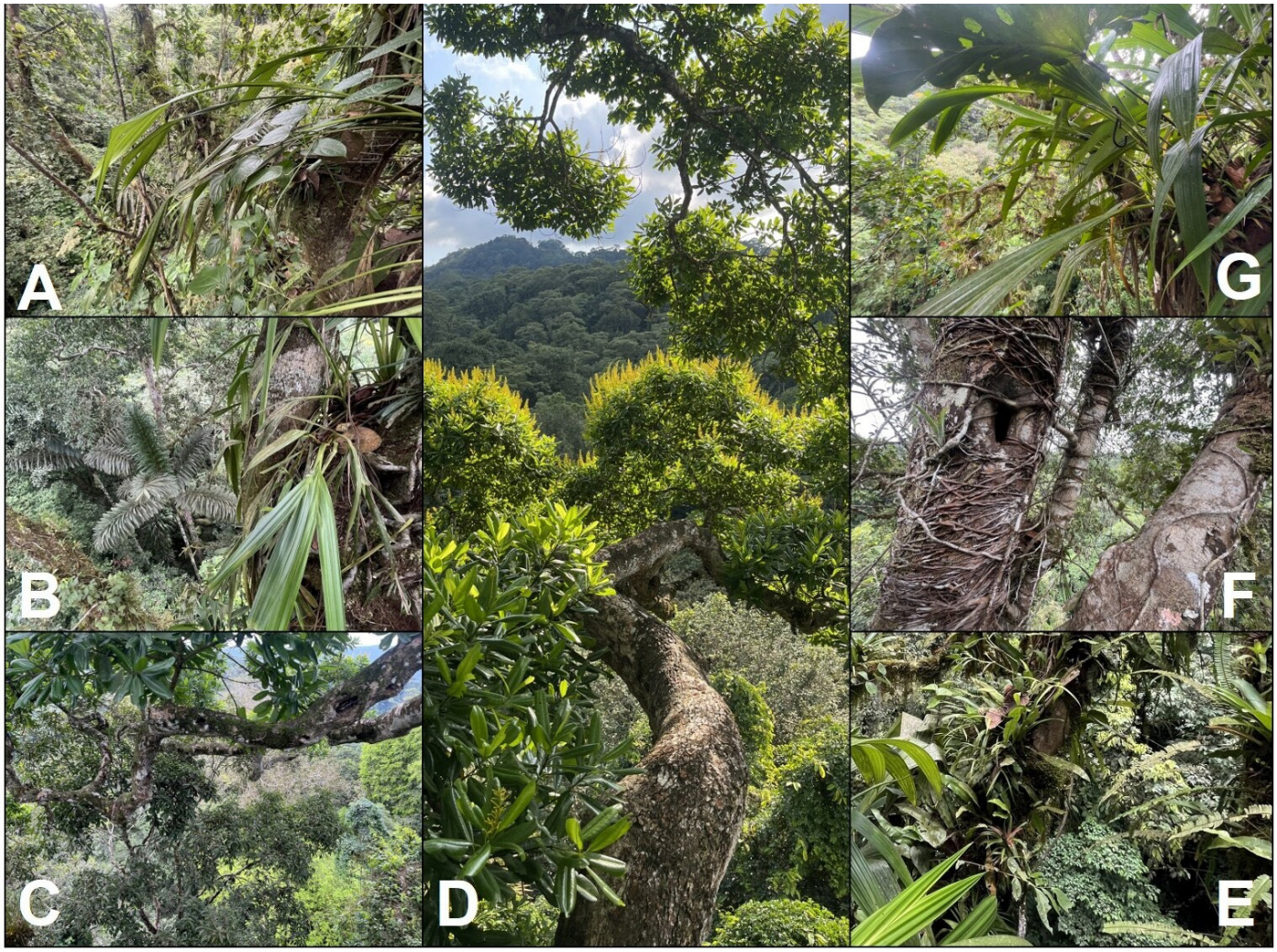

Figure 3. Photographs of habitat where reptiles and amphibians were first encountered in the canopy (see also Results): *Anolis gracilipes* (A), *Anolis lyra* (B), *Anolis* sp. (C), *Anolis chloris* (D), *Pristimantis latidiscus* (E), *Thecadactylus rapicauda* (F), and *Pristimantis* sp. (G). Photographs by Oliver Thomas

training required to become competent and safe in any of the many techniques used to access the canopy. Researcher safety while climbing is a necessary and important constraint in climbing surveys, as some trees, or specific areas within them, simply cannot be accessed while adhering to acceptable margins of safety. Rope-access methods are especially useful as the ongoing costs are minimal (other than equipment maintenance and eventual replenishment) and the operator can collect incredibly valuable information from any tree (within reason) across a range of different environments.

Forests are being lost worldwide at a staggering rate, with frightening reports of biodiversity loss accompanying them, particularly in the tropics — the hotspots of diversity (Barlow et al. 2016; Pillay et al. 2022). Arboreal biodiversity is more greatly affected by forest loss and disruption than terrestrial biodiversity (Tregidgo et al. 2010; Whitworth et al. 2016) and the forest canopy is estimated to hold a significant portion of the world's biodiversity (Ozanne et al. 2003; Lowman and Schowalter 2012). Without a full understanding of what is living in the canopy and the ecology of these species, we could be gravely underestimating the rates of biodiversity loss. As such, more research in the canopy, with a focus on less-well-studied taxa, should be prioritized in tropical forest research.

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