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Research paper

Natural history, population changes, and conservation needs of the Guacharaquita frog *Tachiramantis lentiginosus* (Anura, Strabomantidae) in the Colombian Andes

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Abstract

Natural history, population changes, and conservation needs of the Guacharaquita frog Tachiramantis lentiginosus *(Anura, Strabomantidae) in the Colombian Andes.* *Tachiramantis* is a recently proposed genus that includes seven species, four considered threatened with a declining trend, while three lack sufficient data for conservation assessment. The Guacharaquita frog *Tachiramantis lentiginosus* is one of these species, with substantial information gaps regarding its natural history, threats, and population density changes, particularly in isolated populations such as that studied here. In San Antonio, the only location in Colombia where *T. lentiginosus* is found, we evaluated changes in population density and vegetation cover over 10 years (2014-2024). Additionally, we mapped current threats and describe key aspects of microhabitat use and activity patterns. Analyses were conducted using the Kruskal-Wallis test, and Global Forest Change Analysis. Our findings reveal a significant decline in population density and vegetation cover, with agriculture, cattle ranching, and mining identified as major threats. We also observed variable microhabitat use and a distinct activity period, suggesting the species lacks specific microhabitat preferences and is primarily nocturnal. We conclude that this only known population in Colombia is in decline, facing severe threats that fragment its forest habitat and contribute to cover loss.

Key words: Terrarana, Decline, Conservation, Amphibians, Andean Cordillera, Andean anurans

Resumen

Historia natural, cambios demográficos y necesidades de conservación de la rana Guacharaquita Tachiramantis lentiginosus *(Anura, Strabomantidae) en los Andes colombianos.* *Tachiramantis* es un género propuesto recientemente que incluye siete especies de las cuales cuatro están consideradas amenazadas y presentan una tendencia decreciente, mientras que de las otras tres no se dispone de datos suficientes para evaluar su estado de conservación. La rana Guacharaquita *Tachiramantis lentiginosus* es una de estas especies y se tiene muy poca información sobre su historia natural, las amenazas a las que se enfrenta y los cambios en la densidad demográfica, especialmente en poblaciones aisladas como la que se estudia aquí. En San Antonio, la única localidad de Colombia donde se encuentra *T. lentiginosus*, evaluamos los cambios en la densidad demográfica y la cobertura de la vegetación a lo largo de 10 años (2014-2024). Además, hicimos una relación de las amenazas actuales y describimos los aspectos clave del uso del microhábitat y de los patrones de actividad. Los análisis se llevaron a cabo utilizando la prueba de Kruskal-Wallis y Global Forest Change Analysis. Nuestros resultados revelan una disminución significativa de la densidad demográfica y la cobertura de la vegetación y apuntan a la agricultura, la ganadería y la minería como las principales amenazas. También observamos un uso variable del microhábitat y un período de actividad bien diferenciado, lo que sugiere que la especie no tiene preferencias específicas respecto del microhábitat y es principalmente nocturna. Concluimos que esta única población conocida de Colombia está en descenso y enfrenta graves amenazas que fragmentan su hábitat forestal y contribuyen a la pérdida de cobertura.

Palabras clave: Terrarana, Declive, Conservación, Anfibios, Cordillera de los Andes, Anuros de los Andes

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Introduction

Tachiramantis is one of the genera in the family Strabomantidae with the fewest representative species, there being only seven. It is also among the least studied. It is found in the northern region of the Eastern Cordillera of Colombia and in parts of the Andes Mountains in Venezuela (Arroyo et al 2022, Heinicke et al 2015). Initially, based on skeletal characteristics, external morphology, and anatomy, species within this genus were classified under *Pristimantis*, where most neotropical direct-developing terraran frogs are grouped (Heinicke et al 2007, Hedges et al 2008, Heinicke et al 2015). However, phylogenetic analyses supported by osteological evidence revealed a low affinity between three species and *Pristimantis*, leading to the establishment of a new genus, *Tachiramantis*, which includes *T. lentiginosus* (Heinicke et al 2015).

Tachiramantis lentiginosus (Anura, Strabomantidae) was described by Rivero in 1984 from a female specimen (UPRM-6060) collected at 1,768 m a.s.l. in Guacharaquita, located between La Grita and Páramo de La Negra, Táchira State, Venezuela (Barrio-Amorós et al 2019, Rivero 1984). This is a medium-sized species, with females reaching a snout-vent length (SVL) of 26-30 mm, while males reach 20.8 mm, as described from limited samples of only three specimens (Rivero 1984). *T. lentiginosus* can be distinguished from other species in the genus by 26 unique characteristics, the most diagnostic of which are: (1) presence of post-scapular and supra-inguinal spots, (2) a cantal and supra-tympanic stripe extending past the shoulder from a posterior view, (3) nearly terminal nostrils, and (4) a large tympanum with considerably smaller discs at the surface level (Rivero 1984).

The distribution of *T. lentiginosus* is fragmented, with populations in the northeastern Andes in Táchira State, Venezuela, occupying Andean cloud forests between 1,700 and 1,800 m a.s.l. (Barrio-Amorós et al 2019, Frost 2023). In Colombia, it inhabits Andean cloud forests from 1,390 to 2,300 m a.s.l. on the eastern slopes of the Serranía del Perijá and within the Pamplonita River basin in Norte de Santander department (Bernal and Lynch 2008, Frost 2023, Martínez et al 2014).

Despite being listed as Endangered (EN) on the IUCN Red List (IUCN SSC Amphibian Specialist Group 2021), aspects of its natural history are poorly understood, thus preventing its inclusion in Colombia's national red list of amphibians (Rueda-Almonacid et al 2004). Available information on its natural history is limited to reports of nocturnal behavior near streams, with activity beginning after 18:00 h, and a primary association with areas of primary forest cover, although it may also be found in regions with sparse cover (Martínez et al 2014, Rivero 1984). Regarding microhabitat, only arboreal vegetation is mentioned (Arroyo et al 2022). Although specific threats to this species remain poorly documented, agricultural expansion, mining activities, and the presence of the fungus *Batrachochytrium dendrobatidis* (Bd) in some populations in northeastern Colombia are concerning (Acevedo et al 2016b). These issues not only hinder precise identification of factors affecting the species but also highlight the need to expand knowledge of its natural history and microhabitat and to monitor its population density over time.

This study aims to provide critical insight into potential population changes and the natural history of *T. lentiginosus* by addressing the following specific objectives: (1) to assess population dynamics and vegetation cover changes over 10 years (2014-2024), (2) to map the threats restricting the species' life zone, and (3) to characterize its microhabitat and activity patterns based on the only known population in Colombia.

Material and methods

Study area

The study was carried out over a sampling area of approximately 4.1 km^2 in the only known population of *T. lentiginosus*, located within an Andean forest fragment in the village of San Antonio (7.463333 °N, 72.624985 °W), bordering the municipalities of Chinácota and Pamplonita, Norte de Santander, Colombia (fig. 1). This forest is traversed by La Tigra stream and has a canopy cover of 80% or higher, with dominant vegetation including *Miconia*, *Ficus*, *Eucalyptus*, and *Acacia* (POMCA 2014). The area is also characterized by significant anthropogenic land use activities, these being predominantly coffee cultivation (12 farms), dairy cattle ranching (25 farms), and coal mining (Santa Helena mine), all of which contribute to intense timber extraction (CORPONOR 2010).

Sampling

We monitored populations of the *T. lentiginosus* frog (fig. 2) over 16 nights in two periods (8 nights per period) separated by a 10-year interval. The first sampling was conducted from April to October 2014, and the second from August 2023 to March 2024, both periods comprising dry and rainy seasons. During each sampling period, surveys were conducted from 17:00 to 24:00 h using a visual and auditory search method, employing free and unrestricted searches in different areas every two nights (Angulo et al 2006). The field sampling effort across both periods amounted to 112 person-hours per individual, with three people contributing, resulting in a combined total of 336 person-hours. Each individual captured was handled with gloves and stored separately in a plastic bag until sampling in the area was completed (Angulo et al 2006). During the sampling events, the identification of individual frogs was facilitated by the yellow spots characteristic of the species in the inguinal region. These spots varied in size and arrangement among individuals from 2024 (fig. 2D, 3). Geographic coordinates were recorded using a Garmin eTrex 22x GPS.

Environmental and microhabitat data were collected (fig. 4) only during the 2024 period. The environmental data recorded included ambient temperature (TA) and humidity (HA). We also recorded microhabitat, body temperature (Tc) and substrate temperature (TS), substrate one-centimeter temperature (T1S), and humidity one centimeter of the substrate (H1S), all measured using two Elitech GSP-6 data loggers. However, these last two (T1S and H1S) were taken by bringing the probe to within about one centimeter of the substrate. Ground distance (Ds) and canopy height (Ad) were measured with a CP-120S laser meter, substrate inclination (Is) was measured using a digital inclinometer (Piramide-13965), and litter

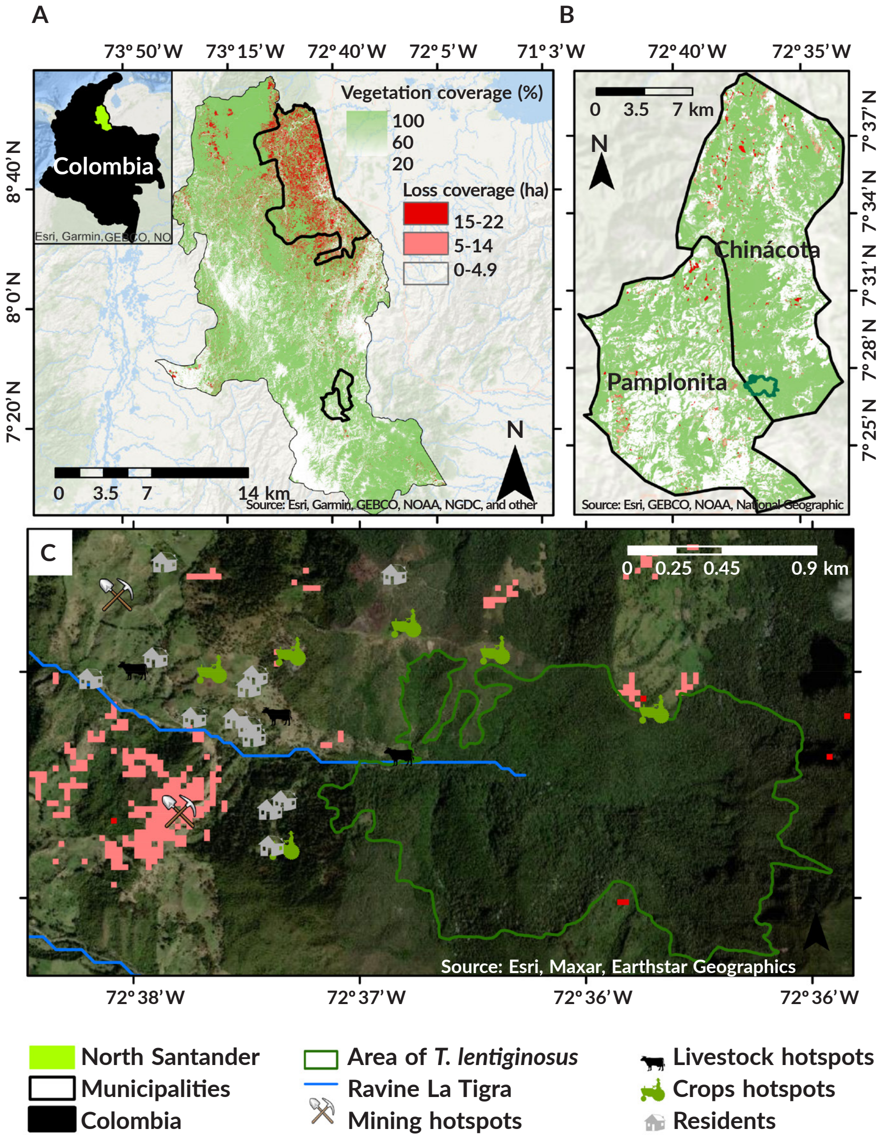

Fig. 1. The study area represents the only known locality for *Tachiramantis lentiginosus* in Colombia. This area includes documented anthropogenic activities impacting the species' life zone, with its size quantified based on local descriptions. The main coordinates used to establish the area of *T. lentiginosus* are available in table 1s in supplementary material.

Fig. 1. *El área de estudio representa la única localidad conocida de* Tachiramantis lentiginosus *en Colombia. En esta área se realizan actividades antropogénicas documentadas que afectan a la zona de vida de la especie, cuya superficie se cuantificó atendiendo a las descripciones locales. Las coordenadas principales utilizadas para establecer el área de* T. lentiginosus *están disponibles en la tabla 1s de material suplementario.*

depth (Ld) was measured using a steel ruler (Redline). Substrate type (S) and vegetation type (V) were recorded following Searcy et al (2013).

To estimate activity patterns, we recorded the time individuals were observed and their advertisement calls. Recordings were conducted actively during multiple surveys, with each session lasting at least two minutes. When an individual was heard vocalizing, we waited for it to call again before recording. After the call was recorded, we searched for the individual. If found, it was included in the abundance data; otherwise, it was only recorded for activity patterns. Vocalizations were captured using a TASCAM-07X recorder and a BOYA unidirectional microphone at 44 kHz and 24-bit resolution (Koehler et al 2027).

Vegetation cover estimates

Vegetation cover, including loss and gain, was estimated for the entire department of Norte de Santander, Colombia, using R Core Team (2024) version 4.3.2 and the Global Forest Change Analysis (gfcanalysis) package (Zvoleff and Cooper 2023). The area corresponding to the department was extracted from Colombia's open cartography and geographic data at a 1:25,000 scale (MAGNA-SIRGAS,

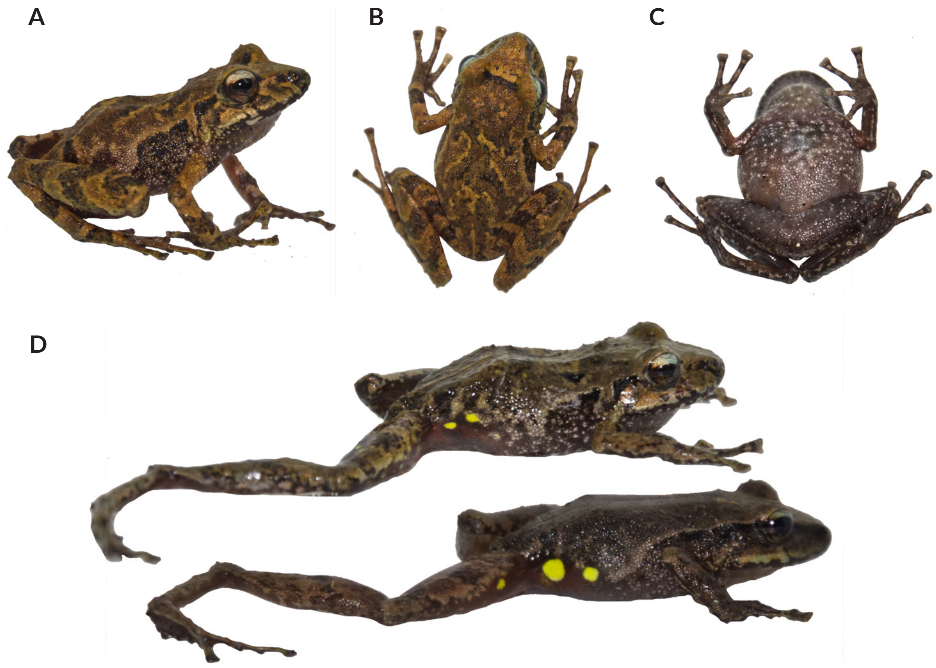

Fig. 2. Photographic record of *Tachiramantis lentiginosus* from the locality of San Antonio, Colombia: A, dorsolateral view; B, dorsal view; C, ventral view; and D, dorsolateral view showing the exposed inguinal area, and highlighting the yellow freckles characteristic of the species. (Photos by Giovany Diaz).

Fig. 2. *Registro fotográfico de* Tachiramantis lentiginosus *en la localidad de San Antonio, Colombia: A, vista dorsolateral; B, vista dorsal; C, vista ventral, y D, vista dorsolateral con el área inguinal expuesta, donde se observan claramente las pecas amarillas características de la especie. (Fotos de Giovany Diaz).*

converted to WGS84), with coverage layers at a maximum resolution of 10 meters (WGS84) (IGAC 2024, Zvoleff and Cooper 2023). While estimates were originally available since 2001, this study focused on data from 2014 to 2023. The missing year (2024) was supplemented with satellite images obtained from USGS EarthExplorer, using the 'purrr' function within the 'gfcanalysis' package. The same resolution, coordinate system, and interference-free area were maintained throughout (Hansen et al 2013, Zvoleff and Cooper 2023).

Statistical analyses

Population density estimates for the 2014 and 2024 periods were derived from abundance data by calculating the relative abundance index for each year (Inger 1980, MacArthur 1960). Statistical comparisons of population density between years were performed using the Kruskal-Wallis H-test under the assumption of non-normal data distribution (Shapiro-Wilk = 0.03 p-value) (McGill et al 1978, Seefeld and Linder 2007). Mapping and quantification of the area impacted by anthropogenic activities limiting *T. lentiginosus*'s habitat were conducted with input from local residents engaged in these activities (Evans and Guariguata 2008, Evans et al 2016). The polygons representing threats and the points marking the farms were identified based on input from local residents, whose assistance was required during the survey. These residents delineated the perimeters of their plots, farms, or work areas and described their activities. The species' habitat area was delineated by spatially joining the most distant recorded locations (table 1s in supplementary material) using a Garmin eTrex 22x GPS and BaseCamp software (Brown et al 2013).

For microhabitat data, the recorded maximum and minimum values were considered, generating a range description for the variables associated with the species (de Oliveira and Eterovick 2010). A principal component analysis (PCA) was performed with the variables: substrate temperature (TS), ambient temperature (TA), temperature at one centimeter below substrate (T1S), ambient humidity (HA), substrate humidity (HS), humidity at one centimeter below substrate (H1S), distance to ground (DS), and substrate inclination (IS), in the R Core Team (2024) software version 4.4.1 using the FactoMineR package (Husson et al 2016) to observe the contribution of each variable (de Oliveira and Eterovick 2010). Taking into account the PCA, the most relevant variables were selected, and density plots were created using the Python packages Pandas (for data manipulation), Matplotlib, and Seaborn (for plot visualization) (Nelli 2018). Finally, substrate use was analyzed by categorizing the perch heights of individuals (height I = 0-0.4 m, height II = 0.41-0.8 m, height III = 0.81-1.1 m, and height IV = 1.11-2.2 m) and visualized through a bipartite network analysis using the Bipartite package in R Core Team (2024) version 4.4.1 (Dormann et al 2008).

The activity pattern was estimated and visualized based on 58 visual and vocal observations of *T. lentiginosus*, using the Circular package in RStudio version 4.4.1

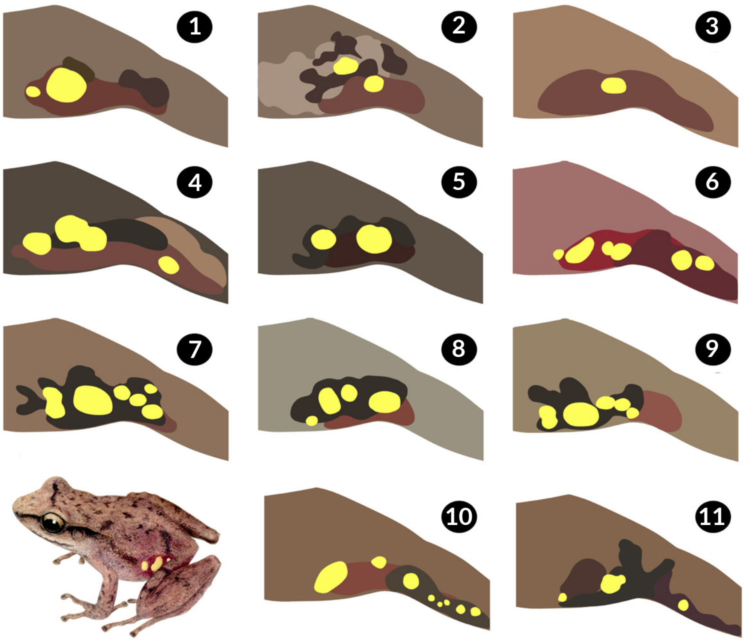

Fig. 3. Digital illustrations showing the inguinal morphological variation in 11 individuals of *Tachiramantis lentiginosus*. These illustrations are based on photographs of independent specimens and were used for their differentiation. (Illustrations by Orlando Armesto).

Fig. 3. *Ilustraciones digitales que muestran la variación morfológica inguinal en 11 individuos de* Tachiramantis lentiginosus. *Estas ilustraciones están basadas en fotografías de varios ejemplares y se utilizaron para su diferenciación. (Ilustraciones de Orlando Armesto).*

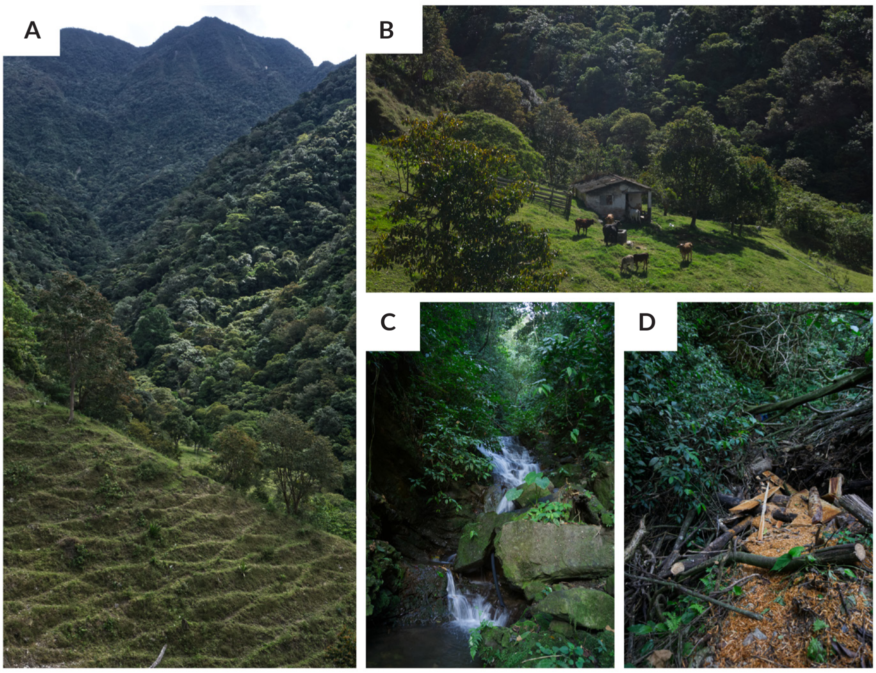

Fig. 4. Photographic record of *Tachiramantis lentiginosus* habitat and associated threats: A, landscape of the forest patch where the species is found; B, forest edge with evidence of cattle presence; C, La Tigra creek within the forest; and D, evidence of logging inside the forest. (Photos by Giovany Diaz).

Fig. 4. *Registro fotográfico del hábitat de* Tachiramantis lentiginosus *y de las amenazas asociadas: A, paisaje del fragmento de bosque donde se encuentra la especie; B, borde del bosque con presencia de ganado; C, arroyo La Tigra en el interior del bosque, y D, rastros de actividad de tala en el interior del bosque. (Fotos de Giovany Diaz).*

Table 1. Microhabitat variables and environmental variables (*) for *Tachiramantis lentiginosus*: M, mean; Min, minimum; Max, maximum; SD, standard deviation.

Tabla 1. Variables de microhábitat y variables ambientales (*) para Tachiramantis lentiginosus*: M, media; Min, mínimo, Max, máximo; SD, desviación estándar.*

Variable	M (n = 18)	Min	Max	SD
T. body (°C)	16.7	13.7	18.5	1.0
T. substrate (°C)	16.6	13.6	18.5	1.0
T. 1 cm substrate (°C)	18.4	16.9	20.1	0.84
H. 1 cm substrate (%)	70.1	62	81	5.62
H. substrate (%)	71.7	63	85	5.64
T. ambient (°C)*	18.5	16.7	20.1	1.05
H. ambient (%)*	71.5	62	83	6.10
Perch height (m)	0.75	0.1	2.16	0.45
Substrate inclination (%)	10.0	0.68	25.2	7.78
Leaf litter depth (m)	0.20	0	0.45	1.15
Canopy height (m)	4.2	1.26	5.52	1.18

(Agostinelli and Lund 2017). Analyses were adjusted to a 24-hour period as described in the package manual, extracting values such as mean hour, median hour, and mean resultant length (r), indicating dispersion (0) and concentration (1). A concentration value of 1 indicates a strong hour preference, with statistical significance evaluated using the p-value (Agostinelli and Lund 2017).

Results

Colombia's only known locality for *Tachiramantis lentiginosus* experiences significant anthropogenic pressure, with 12 properties in the area affected by farming, cattle ranching, and mining activities. In the fragment of the Andean forest studied, which serves as the species' habitat, we recorded 102 individuals: 78 in 2014 and 24 in 2024.

Changes in vegetation cover

It was estimated that between 2014 and 2024, the Department of Norte de Santander had approximately 541,000 hectares of non-forested land, accounting for about 25% of its territory (fig. 1). During this period, 164,542 hectares of forest cover were lost. Within this context, the study area includes the municipalities of Chinácota and Pamplonita, which rank 26th and 31st, respectively, among the 40 municipalities with the highest cover loss in the department: approximately 258 and

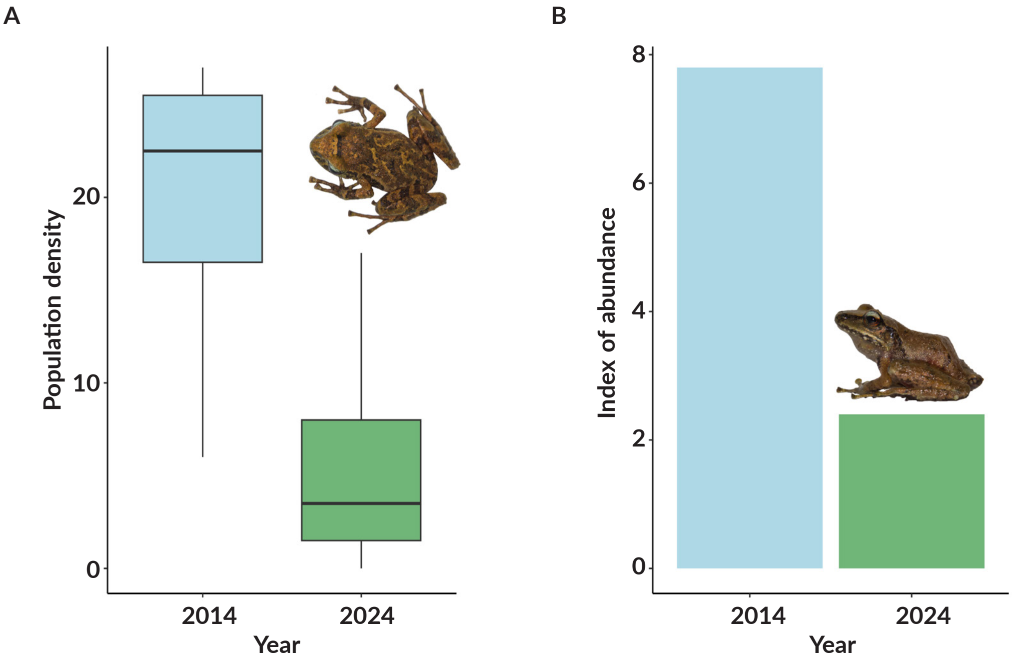

Fig. 5. Variation and significant changes in *Tachiramantis lentiginosus* abundances between the two time periods. The blue bar corresponds to the year 2014 and the green bar to the year 2024. Labels indicate differences between populations of the species over the two time periods represented in a box-plot (A) and a bar graph (B). (Photos by Giovany Diaz).

***Fig. 5.** Variación y cambios significativos de la abundancia de* Tachiramantis lentiginosus *entre dos períodos de tiempo. La barra azul corresponde al año 2014 y la verde al año 2024. Las etiquetas indican las diferencias entre las poblaciones de la especie en los dos períodos de tiempo representados en un diagrama de cajas (A) y un gráfico de barras (B). (Fotos de Giovany Diaz).*

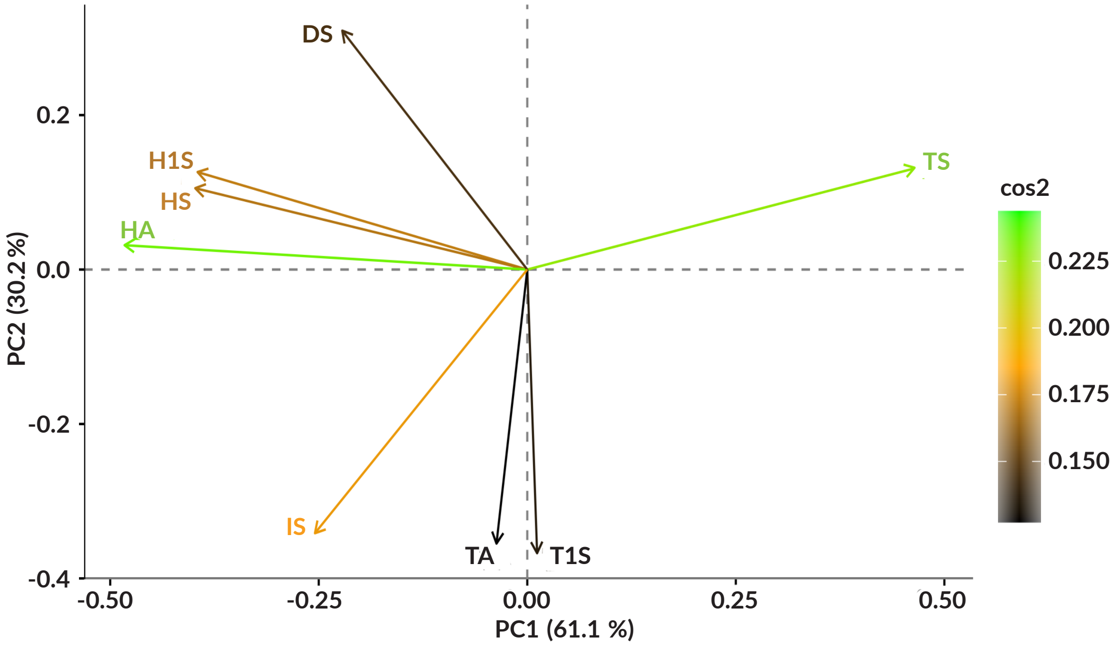

Fig. 6. Principal Component Analysis (PCA) of environmental and microhabitat variables for *Tachiramantis lentiginosus*. The analyzed variables are: TS, substrate temperature; TA, ambient temperature; T1S, temperature at one centimeter below the substrate; HA, ambient humidity; HS, substrate humidity; H1S, humidity at one centimeter below the substrate; DS, distance to the ground; and IS, substrate inclination. (The color bar on the side represents the contribution and explanatory power of the variables in components 1 and 2, with higher values indicating greater representativeness).

Fig. 6. *Análisis de componentes principales (PCA) de las variables ambientales y de microhábitat de* Tachiramantis lentiginosus*. Las variables analizadas son: TS, temperatura del sustrato; TA, temperatura ambiental; T1S, temperatura a un centímetro debajo del sustrato; HA, humedad ambiental; HS, humedad del sustrato; H1S, humedad a un centímetro debajo del sustrato; DS, distancia al suelo; IS, inclinación del sustrato. (La barra de color al costado representa la contribución y el poder explicativo de las variables en los componentes 1 y 2, donde los valores más altos indican una mayor representatividad).*

220 hectares, respectively affected. Additionally, up to 10 areas with more than five hectares of cover loss were identified in San Antonio, with the most impacted zones overlapping with mining activities (fig. 1).

Threat mapping

The most representative activities identified were planting (four sites, 0.55 km^2), cattle ranching (three sites, 0.50 km^2), and mining (two sites, 0.30 km^2). These activities account for approximately 50 % of the estimated habitat for *T. lentiginosus* (2.20 km^2). They are located adjacent to or within one kilometer of the forest fragment where this population is found (fig. 1, 3B, 3D).

Variation in population density of *T. lentiginosus*

Analysis revealed a significant difference in individual density between the two years (p = 0.0433) (fig. 5). However, no significant differences were detected when comparing the sampled area within each year (p = 0.475). This suggests that the observed variation in population density was between 2014 and 2024 (standard deviation [SD] = 9.54) rather than within a single year (SD 2014 = 1.46; SD 2024 = 1.61). These findings indicate that population changes are more pronounced over the long term than as immediate shifts (fig. 5).

Microhabitat characterization of *T. lentiginosus*

Environment and microenvironment

Micro-environmental values were lower than environmental values (table 1). The average body temperature of the animals was 16.7 °C, and the substrate temperature was 16.6 °C, showing minimal variation between the two, unlike the environmental temperature, which averaged 18.5 °C. Humidity measurements showed slight variation between their averages, making this variable more constant (table 1).

Principal Component Analysis (PCA) revealed the correlation and degree of representation for each variable within the first two dimensions (PC1 and PC2), which explain 61.1 % and 30.2 % of the total variability, respectively (fig. 6). Ambient temperature (TA) and temperature one centimeter above the substrate (T1S) showed a moderate positive correlation (-0.39). However, they were less well represented in the first two dimensions, suggesting that their variability is not fully captured by these principal components. Substrate moisture (HS) and moisture one centimeter above the substrate (H1S) exhibited a high positive correlation (0.18), implying that these variables tend to vary together, and potentially reflecting similar micro-environmental conditions at the substrate surface (fig. 6).

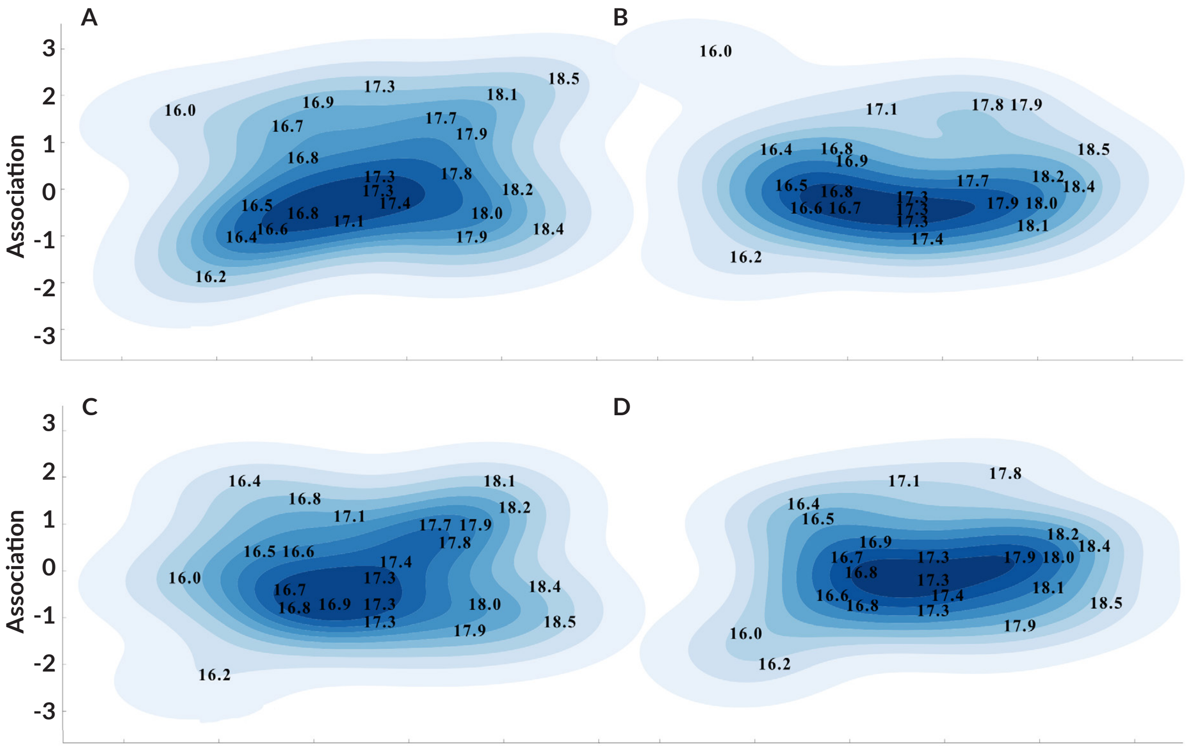

Fig. 7. Association of body temperature with temperature and humidity variables taken from the environment and in the substrate (actual scored values): A, substrate temperature (ST); B, ambient temperature (TA); C, substrate humidity (SH); D, ambient humidity (AH).

Fig. 7. Asociación de la temperatura corporal con las variables de temperatura y humedad tomadas del ambiente y en el sustrato (valores reales anotados): A, temperatura del sustrato (ST); B, temperatura ambiental (TA); C, humedad del sustrato (SH); D, humedad ambiental (AH).

Body temperature (TC) was most influenced by substrate temperature (TS), ambient temperature (TA), substrate humidity (HS), and ambient humidity (HA) (fig. 7). The predominant negative association with humidity variables suggests that body temperature may slightly increase in areas with lower humidity, indicating a possible thermal response to drier conditions (fig. 7).

Substrate use

Tachiramantis lentiginosus was observed on various substrates, including stems, roots, leaves, and trunks. Perch was recorded at different heights, primarily in wooded and sheltered areas, demonstrating a broad range of substrate use (fig. 8).

The network analysis shows a medium connectance value (0.68), indicating that most nodes are connected, though not all possible interactions are present. Robustness values, both high-level (0.51) and low-level (0.56), suggest that the network would remain functional if the highest or lowest interacting nodes were removed. The negative nesting value (-0.28) implies that interactions occur randomly; however, this may result from the limited number of substrate usage records. Finally, the network displays low specialization (0.36), suggesting that *T. lentiginosus* does not exhibit a specific preference for substrate types (fig. 8).

Activity pattern

The activity pattern of *T. lentiginosus* was recorded between 8:00 and 24:00 h. However, the species tended to increase its activity between 16:42 and 21:18 h, suggesting this is its preferred activity window (r = 0.86). Observations show peak activity at 19:30 h, close to the average values (mean = 19:00, median = 19:12) (fig. 9). From the onset of its activity at 16:00 h, it shows slight increases between 17:00 and 18:00 h until reaching its peak at 19:30 h. After that point, it gradually decreases around 20:00 h, eventually dropping to nearly no activity during the day, and then restarts the cycle at 16:00 h the following day. This pattern was observed under conditions of heavy rainfall (12 mm), high humidity (91%), and low temperature (10 °C).

Discussion

Data on population changes for the *T. lentiginosus* frog across the two study periods suggests a decline in the only recorded population in Colombia (Acevedo et al 2016b, IUCN SSC Amphibian Specialist Group 2021). Our results (fig. 5) show a reduction both in population size and density over time, a trend affecting multiple species in the Strabomantidae family (Acevedo et al 2022, Harrison and Henderson 2011, Martínez-Baños et

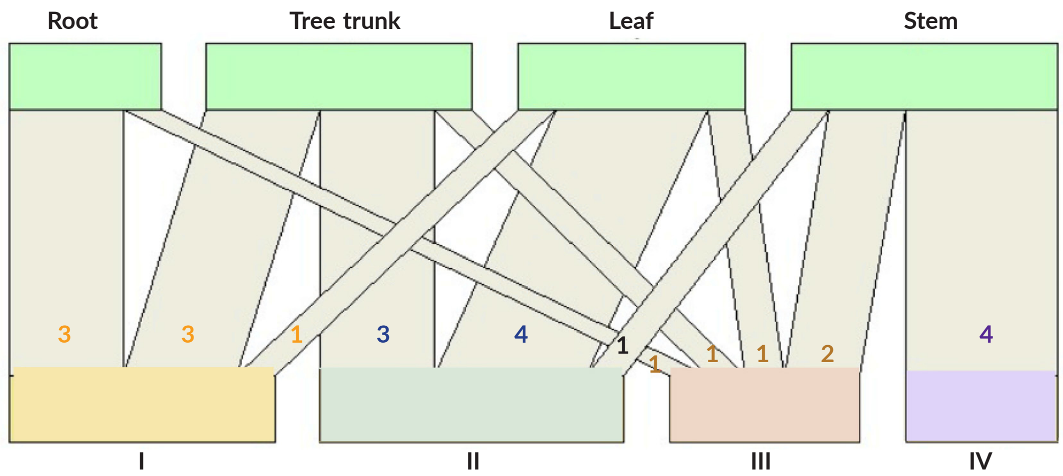

Fig. 8. Substrate use and perch height of *Tachiramantis lentiginosus*. Heights are categorized as follows: height I (0-0.4 m), height II (0.41-0.8 m), height III (0.81-1.1 m), and height IV (1.11-2.2 m). (The numbers (1, 2, 3, 4) within the bars indicate the frequency of individuals observed at each height and substrate type combination.)

***Fig. 8.** Uso del sustrato y altura de percha de* Tachiramantis lentiginosus. *Las alturas se categorizaron de la siguiente manera: altura I (0-0,4 m), altura II (0,41-0,8 m), altura III (0,81-1,1 m) y altura IV (1,11-2,2 m). (Los números (1, 2, 3, 4) dentro de las barras indican la frecuencia de individuos observados en cada combinación de altura y tipo de sustrato.)*

al 2011). Furthermore, the ongoing loss of forest cover due to anthropogenic activities such as agriculture, cattle ranching, and mining, poses a substantial threat by limiting available habitat for anuran species in the region, including the forest fragment where *T. lentiginosus* resides (Acevedo et al 2014, 2016a, 2016b, 2020).

The decline of amphibian populations due to anthropogenic activities is a widely studied issue, particularly in areas where such activities are stable and intense (Stuart et al 2004, Catenazzi 2015, Scheele et al 2019, Wren et al 2024). However, monitoring multiple species over time remains a significant challenge, emphasizing the need for studies documenting and comparing population changes in understudied species (Urbina-Cardona et al 2023). This need applies to *Tachiramantis lentiginosus*, a species belonging to one of the least studied genera in terms of population dynamics, local threats, precise distribution, and natural history (IUCN SSC Amphibian Specialist Group 2021). Within this context, the findings of this study can support effective conservation objectives and strategies (Wren et al 2024).

As evidenced in this study (fig. 6), research focusing on anuran microhabitats suggests that key factors include both substrate and environmental temperature and humidity (Carvajalino-Fernández et al 2021, Pintanel et al 2019). Similar to other species in the Strabomantidae family, *T. lentiginosus* shows high tolerance to variables such as temperature, humidity, slope, leaf litter depth, and canopy height, without a clear preference (Blair and Doan 2009, Vergara-Herrera et al 2023). Observations of *T. lentiginosus* (fig. 8) and other species within the genus *Tachiramantis* indicate no specific preference for perching substrates. Individuals have been observed at various heights, exhibiting predominantly arboreal behavior above 0.4 m, as previously documented for *T. douglasi*, *T. cuentasi*, and *T. tayrona* (Arroyo et al 2008, 2022, Blair and Doan 2009).

The activity patterns of *T. lentiginosus* (fig. 9) indicate primarily nocturnal behavior, with occasional diurnal activity under favorable conditions of rainfall, humidity, and temperature (Arroyo et al 2022). Among species in the genus, this is the first for which formal analyses suggest a defined activity period (Arroyo et al 2008). The observed activity of *T. lentiginosus* aligns with reports for *T. douglasi*, *T. padrecarlosi*, *T. prolixodiscus*, *T. tayrona*, and *T. cuentasi*, which also display nocturnal activity (Arroyo et al 2022, Fernandes-Primon and Rada 2019). However, in this study we noted atypical activity events for *T. lentiginosus*, underscoring the need for further research to determine whether these are sporadic occurrences or whether they indicate an expanded activity period (Arroyo et al 2008, 2022).

Our results strongly support the current threatened status for the species as outlined by the IUCN SSC Amphibian Specialist Group (2021). While this study highlights only some of the threats, the IUCN SSC Amphibian Specialist Group (2021) has broadly identified the following pressures on *T. lentiginosus*: (1) residential and commercial development, driven by recurrent infrastructure projects; (2) agriculture and aquaculture, due to the expansion of non-timber crops, pulpwood plantations, and extensive cattle ranching; (3) energy production and mining, including coal extraction and quarrying; (4) exploitation of biological resources through logging and timber harvesting; (5) alterations to natural systems caused by fires and the use of water tributaries; and (6) the presence of non-native or invasive species, including the *Batrachochytrium dendrobatidis* (Bd) fungus. Furthermore, this study highlights significant changes in individual density, threats, microhabitat, and activity patterns for *T. lentiginosus* in Colombia, emphasizing the need for further data (Urbina-Cardona et al 2023). Given the potential decline of the species in Colombia, future studies should prioritize conservation efforts involving community engagement and initiatives

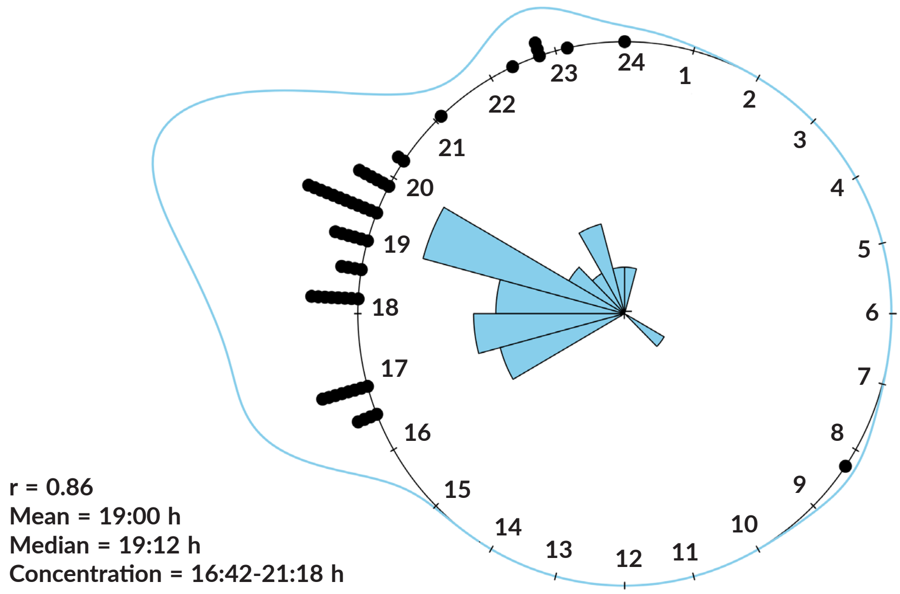

Fig. 9. Activity pattern of the Guacharaquita frog *Tachiramantis lentiginosus* between 8:00 and 00:00 h. The pie chart displays the results, combining the rose diagram (blue bars), data stacking (black dots), and frequency density (blue line). The longer the length of each parameter (blue bars, black dots, and blue line), the higher the frequency of activity during that period.

***Fig. 9**. Patrón de actividad de la rana Guacharaquita* Tachiramantis lentiginosus *entre las 8:00 y las 00:00 h. El gráfico circular muestra los resultados combinando el diagrama de rosa (barras azules), el apilamiento de datos (puntos negros) y la densidad de frecuencia (línea azul). A mayor longitud de cada parámetro (barras azules, puntos negros y línea azul), mayor es la frecuencia de actividad en ese período.*

of regional organizations, focusing on protecting the only forest fragment in the country where this species exists (IUCN SSC Amphibian Specialist Group 2021). Additionally, detailed studies on the natural history, population trends, and activity of Venezuelan populations are essential to determine whether similar conditions occur in populations across both countries

Proposed conservation actions

To support the conservation of *T. lentiginosus* and following IUCN recommendations, three key lines of action have been proposed:

In situ research and monitoring

It is essential to conduct research aimed at understanding the species' ecology and population size, and to implement passive acoustic monitoring to detect changes in population trends. Given the potential threat of emerging diseases such as Bd, studies should assess its prevalence and the species' vulnerability to this infection (Acevedo et al 2016a, 2016b). Collaborations with local communities are strongly recommended to establish participatory and ongoing monitoring programs. Additionally, mark-recapture studies tailored to the size of the species' occurrence areas are needed to improve estimates of population size.

Habitat protection in situ

Is vital to ensure and strengthen habitat protection in areas where the species is present. Although the presence of the species in protected areas in Venezuela is uncertain, habitat protection in Colombia, where the species does occur, should be reinforced. Biosecurity protocols should be continually improved during project implementation to minimize and/or mitigate the spread of Bd fungus and other diseases. Additionally, a regional action plan would be beneficial to preserve forest and water sources and control and prevent invasive species. The Sustainable Development Goals (SDGs) provide a guiding framework for an Action Plan, and the Watershed Management Plans (POMCAS) serve as a foundational tool for annual sustainability reporting. These proposals should be integrated together within rigorous microhabitat studies that examine substrate characteristics, vegetation stratification (e.g., perches), and associated abiotic variables in order to address key questions such as: (1) which aspects of forest cover should be prioritized for conservation; (2) considering the species' generalist tendencies, are there specific substrates that could be excluded?; and (3) how might modifications in vegetation structure influence the species' life history? These, and other questions are critical to the development of effective conservation strategies.

Conservation education

Education and awareness programs should be strengthened through outreach activities and distribution of educational materials focused on the area's social, economic, and environmental context. The educational process should incorporate ethno-education and community involvement, engaging children, youth, and elders, who can contribute and share traditional knowledge (Fonseca Lindao et al 2022). Regional environmental organizations should be involved in coordinating specific actions in areas heavily affected by anthropogenic pressures (Acevedo et al 2011).

Conclusions

This study provides valuable insight into the ecology, population trends, and conservation needs of *Tachiramantis lentiginosus*. Over a 10-year period, we observed that population density and abundance decreased, likely linked to habitat loss driven by agriculture, cattle ranching, and mining. Microhabitat analyses showed that the species tolerates a wide range of environmental conditions, with arboreal tendencies and no strong substrate preference, reflecting the typical generalist behavior of Strabomantidae. Atypical activity events, however, highlight the need for further research into how environmental variables influence its behavior.

To ensure conservation of the species, we recommend mark-recapture studies to obtain accurate population estimates, protection and restoration of the species in its remaining forest habitat. Furthermore, there is the need to identify potential threats such as *Batrachochytrium dendrobatidis* (Bd). Conservation strategies should also integrate community engagement, education, and participatory monitoring alongside regional initiatives aligned with frameworks such as the Sustainable Development Goals and Watershed Management Plans. Expanding studies to Venezuelan populations will provide a broader understanding of the species' status and inform conservation efforts across its range.

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Authors contributions
G Díaz, **AA Acevedo** conceived the study, developed the sampling design, performed the data analysis, and wrote the initial draft. Data collection was performed by **G Díaz**, **D Arrieta-García**, **LJ Ortiz**, **M Martínez**, **O Armesto**, and **AA Acevedo**. Audiovisual resources such as photographs were provided by **G Díaz** and illustrations by **O Armesto**. All authors contributed to the writing of the manuscript and participated in its revision and editing.

Conflicts of interest
No conflicts declared.

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Supplementary material

Table 1s. Main geographic ranges of the individuals of *Tachiramantis lentiginosus* reported in this study in 2024 for northeastern Colombia. All geographic records correspond to the locality of San Antonio, Norte de Santander, Colombia: * coordinates used in mapping the most distant points of the area of *T. lentiginosus*.

***Tabla 1s**. Principales rangos geográficos de los individuos de* Tachiramantis lentiginosus *reportados en este estudio en 2024 para el noreste de Colombia. Todos los registros geográficos corresponden a la localidad de San Antonio, Norte de Santander, Colombia: * coordenadas utilizadas en el mapeo de los puntos más distantes del área de* T. lentiginosus.

ID	Latitude (Y)	Longitude (X)
1	7.460159 °N	72.603669 °W
2*	7.461128 °N	72.617472 °W
3	7.460727 °N	72.609743 °W
4	7.457933 °N	72.611688 °W
5	7.458126 °N	72.607677 °W
6*	7.454371 °N	72.609209 °W
7*	7.456672 °N	72.606667 °W
8	7.455298 °N	72.600242 °W
9	7.457051 °N	72.598138 °W
10*	7.461069 °N	72.600499 °W
11	7.462821 °N	72.603554 °W
12	7.460998 °N	72.607331 °W
13	7.460042 °N	72.609279 °W
14	7.460686 °N	72.611253 °W
15	7.461402 °N	72.612835 °W
16*	7.465477 °N	72.614701 °W
17*	7.465142 °N	72.611941 °W
18*	7.463575 °N	72.613574 °W
19	7.459349 °N	72.608308 °W
20*	7.452523 °N	72.611835 °W
21	7.457160 °N	72.604161 °W
22*	7.455521 °N	72.606926 °W
23*	7.452164 °N	72.604789 °W
24*	7.454274 °N	72.599985 °W
25	7.458106 °N	72.601165 °W
26	7.457171 °N	72.602443 °W
27	7.459755 °N	72.606259 °W