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DIVERSITY AND ABUNDANCE OF AMPHIBIANS IN THE LONDON 50 HA ENVIRONMENTAL COMPENSATION PROJECT, PANAMA

DIVERSIDAD Y ABUNDANCIA DE ANFIBIOS EN EL PROYECTO DE COMPENSACIÓN AMBIENTAL LONDON 50 HA, PANAMÁ

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Resumen. — Panamá posee 230 especies de anfibios, de las cuales 72 (31.4%) se encuentran amenazadas según la legislación nacional y 19 son endémicas. El área de estudio posee bosques de galería donde se llevaron a cabo los muestreos. Registramos 15 especies de anfibios que representan el 6.5% de las citadas para el país.

Palabras clave. — Anuros, bosque de galería, conservación, especies.

Abstract. — Panama has 230 species of amphibians, of which 72 (31.4%) are threatened according to national legislation and 19 are endemic. The study area has gallery forests where the samplings were carried out. We registered 15 amphibian species that represent 6.5% of those cited for the country.

Keywords. — Anurans, conservation, gallery forest, species.

INTRODUCTION

The fragmentation and alterations of ecosystems are the main cause of the decline in amphibian populations worldwide (López et al., 2015). This is accelerated in the Panamanian tropical forests, with the consequent disappearance of the species that inhabit them (Ibáñez et al., 1994). Sensitivity to habitat modification is unique for each species, but information is lacking on how life history characteristics and habitat use may affect population fluctuations and vulnerability to environmental change for most species. species (McKinney, 2002; Green, 2003; Ficetola & De Bernardi, 2004) including amphibians, which represent a large part of the vertebrate biomass in the world and in turn participate in the food chain of many vertebrates, thus becoming important elements for the stability of the ecosystems they inhabit (Blaustein & Wake, 1990).

In Panama, 232 species of amphibians have been registered, 187 species of Anurans, 34 Salamanders and 11 Cecilians (Frost, D. R., 2023). It represents 3% of the world's herpetofauna, being the second richest in Mesoamerica, after Mexico. At present, knowledge of the richness of amphibians in Panama continues to increase with new studies (Veseley & Batista, 2021).

The situation raised highlights the importance of environmental compensation projects whose priority is to restore or recover the ecosystems and natural resources of our country that have been damaged or deteriorated for various reasons, as well as support the development of activities aimed at conservation " in situ" through reforestation, management, sustainable use and protection of ecosystems and the biodiversity associated with them (Viña-Vizcaino, 2012). The London 50 Ha project was reforested with native trees such as Guayacán (*Handroanthus guayacan*), Roble (*Tabebuia roseau*) and Espavé (*Anacardium excelsum*) to connect the residual and gallery forests of the project, with this study we seek to quantify the richness of amphibian species within the study area.

MATERIALS AND METHODS

Study area

The investigation was carried out within a 50 hectare polygon belonging to the London Environmental Compensation Project, located in the Panama Canal Hydrographic Basin, specifically between kilometers six and seven on the Panama-Colón highway, province of Panama, coordinates of the Central Camp 9.073°, -79.577°, with its highest point to the northeast of the project at about 253 m above sea level and its lowest point northwest of the project at about 98 m above sea level (Fig. 1). In this area there is a tropical climate with a long dry season, annual rainfall between 1,801-2,100 mm and an average annual temperature of 26.6°C to 27°C (Autoridad Nacional del Ambiente, 2010).

The work focuses on remnants of gallery forest associated with the three main water bodies of the project. It is part of the buffer zone of the Soberanía and Camino de Cruces National Parks. It has an irregular topography with steep hills and small streams that flow into the Caimitillo and Mocambo rivers (Fig. 1). We found remnants of Tropical Humid Forest (THF), with notable anthropic intervention. The study area has water throughout its length during the rainy season, however, during the dry season it only maintains a few wells or puddles, supplied by groundwater, in which some species are concentrated for their reproductive process.

Sampling and data collection

Stream 1 was divided into: Section "A" (Q1A) that starts from the central point (9.073°, -79.577°) towards the extreme southeast of the project and section "B" (Q1B) that goes from the same point towards the extreme northwest of the project, each stretch represents a 300m transect, stream 2 (Q2) a 110m transect and stream 3 (Q3) a 150m transect. We carried out sampling for seven months, covering the end of the rainy season (January and February), the dry season (March to May) and the beginning

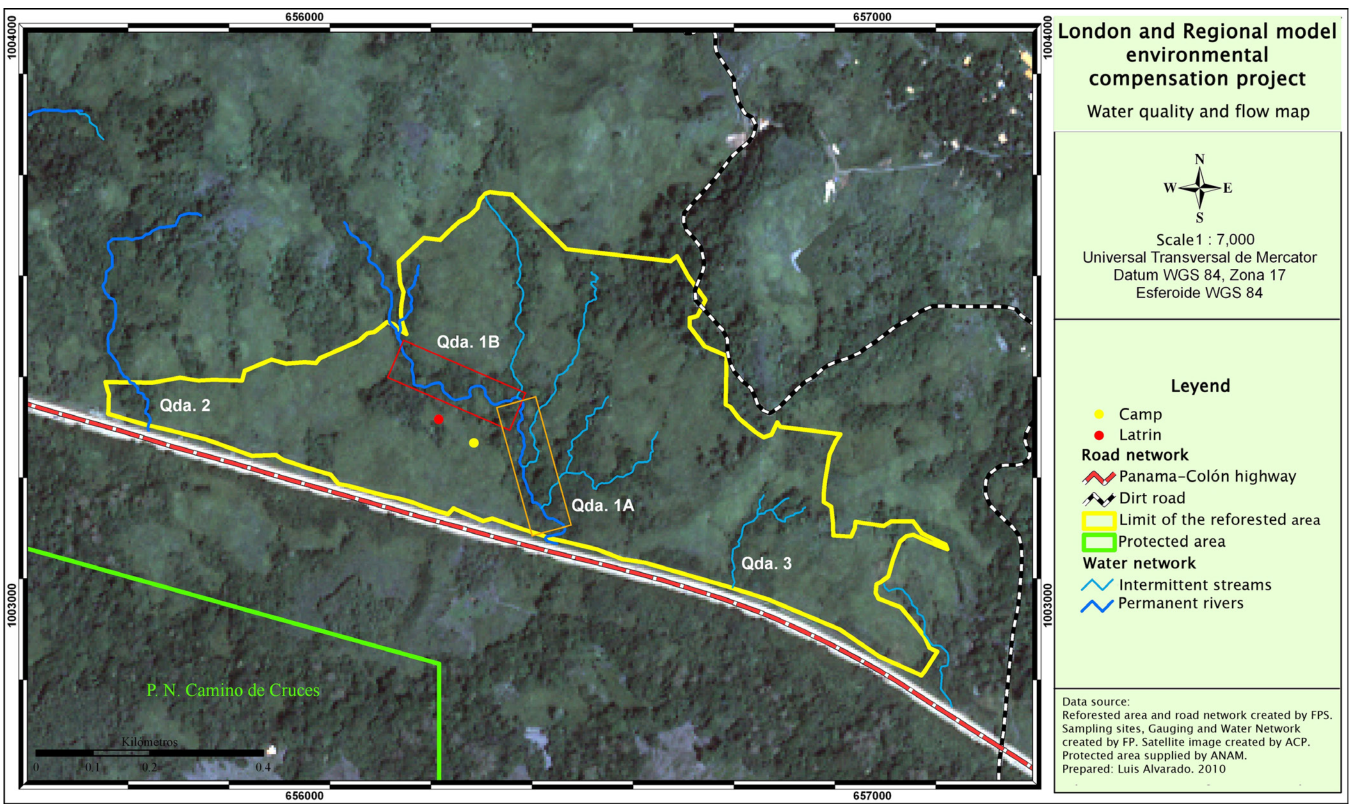

Figura 1. Mapa de las quebradas muestreadas en el proyecto de compensación ambiental LONDON 50 Ha.

Figure 1. Map of streams sampled in the LONDON 50 Ha environmental compensation project.

of the next rainy season (June and July) in 2011, with daytime tours of 7:00 to 11:00 and 16:00 to 18:00 and nightly from 20:00 to 00:00. Applying the generalized search method that consists of evaluating the entire area covered by direct observation, those individuals that were in the forest canopy were recorded with the help of flashlights and sometimes through sporadic vocalizations; This mainly includes bodies of water, vegetation on the banks of streams, with removal of rotten logs to locate those amphibians that inhabit there (Angulo et al., 2006).

Data analysis. We used the Shannon-Wiener index to quantify the diversity of the anuran community from each stream, it was applied using Past 2.17c (Hammer et al., 2001), with which we also generated a species rarefaction curve. The similarity between the transects was qualitatively analyzed using the Jaccard index, which is a statistic that evaluates the similarity between binary data vectors (presence/absence) through the relationship between their intersection and their union; that is, it quantifies the overlap between the data groups to quantify the coexistence of species and with that it shows us which data groups are more similar to each other (Chung et al., 2019). For this, the PRIMER-e v7 program (Clarke & Gorley, 2015) was used, in which the data matrix was transformed into binary data; After the Jaccard index, a dendrogram was generated with the average clustering method and a SIMPROF test with 5% significance, 10 000 permutations and 10 000 simulations. Added a cutoff line to the graph at 50% similarity. For the conservation status of the species observed, we use the IUCN red list (2020) and Mi Ambiente (2016); we determined the ranges of abundance of the species based on the categories established by Rand & Myers (1990): Common: many individuals can be found; Usual: can be found foraging in appropriate habitat and season; Infrequent: unpredictable and Rare: rarely seen.

RESULTS

Observations were higher at the end of the rainy season, between January and early February, reducing significantly during the dry season and gradually increasing at the beginning of the new rainy season from mid-May (Fig. 2). We made a partial effort was 54 and 108 man-hours for day and night tours, respectively, totaling 162 man-hours.

We only observed specimens of the order Anura, a total of 553 specimens grouped into eight families, 13 genera and 15 species (Table 1); Q1A being the richest with 13 species, followed by Q1B

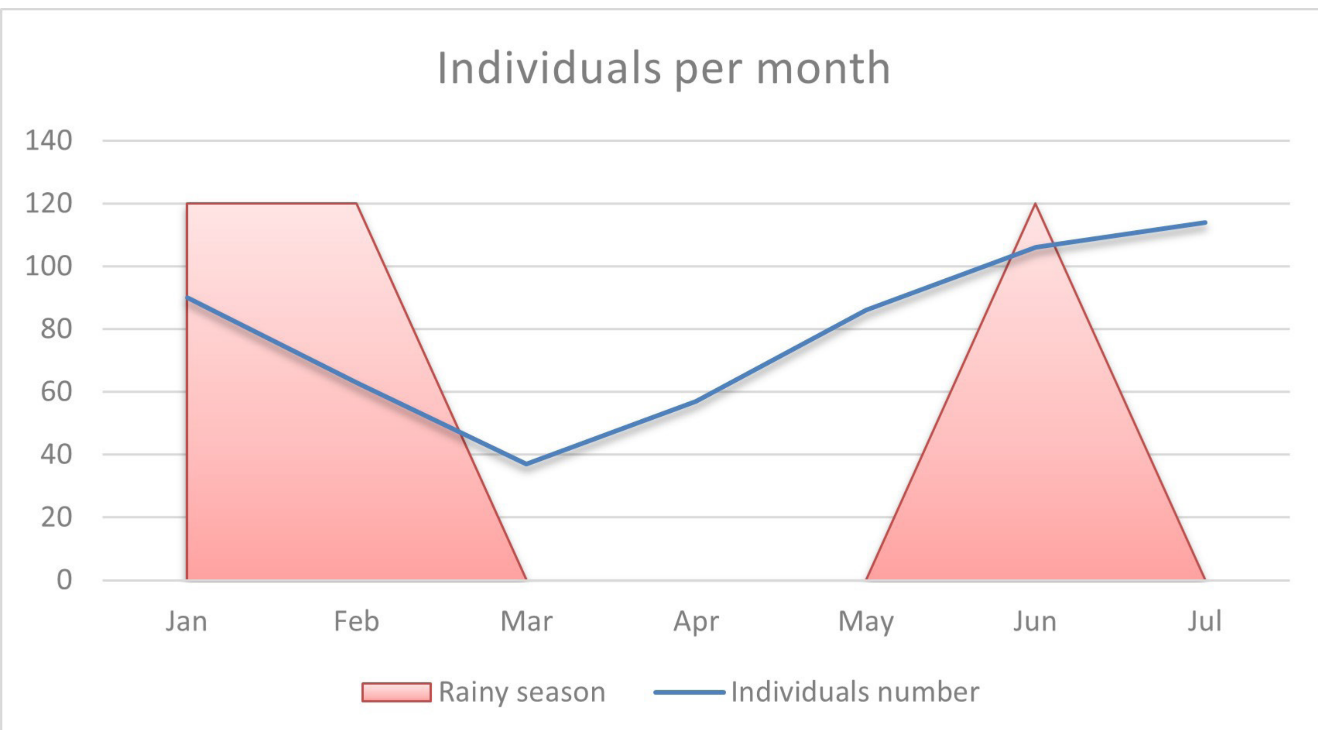

Figura 2. Número de individuos reportados por mes durante el año 2011 en el área de estudio.

Figure 2. Number of individuals reported per month during 2011 in the study area.

with nine, Q3 with three and Q2 with only one species; two of the species found, *Rhinella horribilis* (Fig. 3C) and *Dendropsophus microcephalus*, were also associated with the central camp of the project workers. The most representative families were Craugastoridae and Hylidae with three species, followed by Bufonidae, Eleutherodactylidae and Leptodactylidae with two species each, the rest maintained only one species.

Additionally, species such as *Agalychnis callidryas* (Fig. 3J) of the Phyllomedusidae family, *Hyalinobatrachium tatayoi* (Centrolenidae) (Fig. 3E) and *Engystomops pustulosus* (Leptodactylidae) (Fig. 3L) predominated in the rainy season. All reported species belong to the category of least concern of both the IUCN and Mi Ambiente.

Tabla 1. Especies observadas durante el estudio. Nombre Común (NC), Abundancia relativa (AR). *Área del campamento.

Table 1. Species observed during the study. Common name (CN), Relative abundance (RA). *Camp area

Family	Species	Common Name	N° of individuals	RA (%)	Range of abundance
Bufonidae	**Rhinella horribilis*	Giant Toad	43	7.78	Common
	Rhinella alata	Leaf litter toad	13	2.35	Common
Centrolenidae	*Hylanobatrachium tatayoi*	Tatayo's Glass Frog	80	14.47	Usual
Dendrobatidae	*Silverstoneia flotator*	Rainforest Rocket Frog	5	0.90	Infrequent
Craugastoridae	*Craugastor fitzingeri*	Fitzinger's Robber Frog	58	10.49	Common
	Pristimantis gaigei	Fort Randolph Robber Frog	12	2.17	Usual
	Pristimantis taeniatus	Banded Robber Frog	5	0.90	Usual
Eleutherodactylidae	*Diasporus aff. diastema*	Common Dink Frog	12	2.17	Usual
	Diasporus aff. quidditus	—	2	0.36	Infrequent
Phyllomedusidae	*Agalychnis callidryas*	Red-eyed Multicolored Treefrog	62	11.21	Common
Hylidae	**Dendropsophus microcephalus*	Small-headed Dwarf Treefrog	3	0.54	Infrequent
	Boana rosenbergi	Rosenberg's Treefrog	57	10.31	Common
	Smilisca sila	Panama Cross-banded Treefrog	71	12.84	Common
Leptodactylidae	*Engystomops pustulosus*	Tungara Frog	124	22.42	Common
	Leptodactylus bolivianus	Bolivian White-lipped Frog	6	1.08	Usual

Abundance

The most representative species were *E. pustulosus* with 124 individuals (22.4%), *H. tatayoi* 80 (14.5%), *S. sila* 71 (12.8%), *A. callidryas* 62 (11.2%), *Craugastor fitzingeri* 58 (10.5%) (Fig. 3F), *Boana rosenbergi* 57 (10.3%) (Fig. 3K), and *R. horribilis* 43 (7.8%). These seven species represent 89.5% of the total number of individuals observed. 46.7% of the species (seven) were classified as Common, 33.3% (five species) as Usual and 20.0% (3 species, *Diasporus* aff. *Quidditus* (Fig. 3H), *Silverstoneia flotator* and *Dendropsophus microcephalus*) as Uncommon (Table 1). In transect Q1A we observed 13 species grouped into 12 genera and nine families with a total of 363 specimens (65.6% of the total), the most representative being *E. pustulosus* with 101 individuals. In Q1B 9 species were grouped into nine genera and seven families, which represents a total of 134 copies (24.2%). In Q2 only *S. flotator* one individual (0.2%) and in Q3 we observed three species grouped into three genera and three families with nine individuals (1.6%). In addition, we observed 43 *R. horribilis* and three *D. microcephalus*, both associated with the camp and sites with anthropogenic activity.

The hylids *A. callidryas*, *B. rosenbergi* and the glass frog *H. tatayoi* presented seasonal vertical migration, during the dry season these species were in the highest areas of the trees, near the canopy, and descending to water bodies in the rainy season when its reproductive season begins.

Figura 3. Área de estudio y especies observadas. A) Vista desde el sitio de estudio de la carretera Colon, B) Stream 1 (section Q1A), C) *Rhinella horribilis,* D) *R. alata,* E) *Hyalinobatrachium tatayoi,* F) *Craugastor fitzingeri,* G) *Smilisca sila*, H) *Pristimantis gaigei*, I) *Diasporus aff. quidditus*, J) *Agalychnis callidryas*, K) *Boana rosenbergi*, L) *Engystomops pustulosus*.

Figure 3. Study area and species observed. A) View of the Panama-Colon highway from the study area, B) Stream 1 (section Q1A), C) *Rhinella horribilis,* D) *R. alata,* E) *Hyalinobatrachium tatayoi,* F) *Craugastor fitzingeri,* G) *Smilisca sila*, H) *Pristimantis gaigei*, I) *Diasporus aff. quidditus*, J) *Agalychnis callidryas*, K) *Boana rosenbergi*, L) *Engystomops pustulosus*.

Diversity of anuran communities

According to the Shannon-Wiener diversity index, Q1A (H' = 1.962) is the most diverse stream with a relative abundance and species richness above the rest of the sampled sites, followed by Q1B (H' = 1.866). On the contrary, Q2 and Q3 showed the lowest values with H' = 0 and H' = 0.937, respectively. The study area as a whole has an H' = 2.112, which indicates a normal diversity of species within the study area.

Jaccard Index

The transects are grouped by the number of species that appear or are repeated in each one of them, with Q1A and Q1B being the most related to each other with an IS of 0.69; Q2 and Q3 with IS of 0.33 between them forming two groups that between them have an IS of approximately 0.1 (Fig. 4).

The rarefaction curve (Fig. 5) showed that the asymptote was reached for the site with 15 species and about 350 individuals (seven sampling tours).

DISCUSSION

In Panama we find approximately 230 described amphibian species, of which 188 are anurans (Amphibiaweb, 2023), the total number of anurans found in the London Environmental Compensation Project represents 6.52% of all amphibian species present in Panama, and 7.98% of the anurans. The seven species that represented 89.5% of the anuran community in this region are all species tolerant to human disturbance to varying degrees (Cortés-Gómez et al., 2013; IUCN, 2022), including some of them, such as *Hyalinobatrachium tatayoi* (Fig. 5E), can be highly tolerant of water contamination (Mendoza-Henao et al., 2020).

The existing difference in the species richness of the sampled sites may be related, among other things, to the availability of resources and the type of habitat they maintain, Q1A and B, which present greater species richness due to greater water availability in its channel throughout the sampling and a better-preserved gallery forest (Fig. 5B) unlike Q2 and Q3 that do not have these conditions, however, it has been documented that the

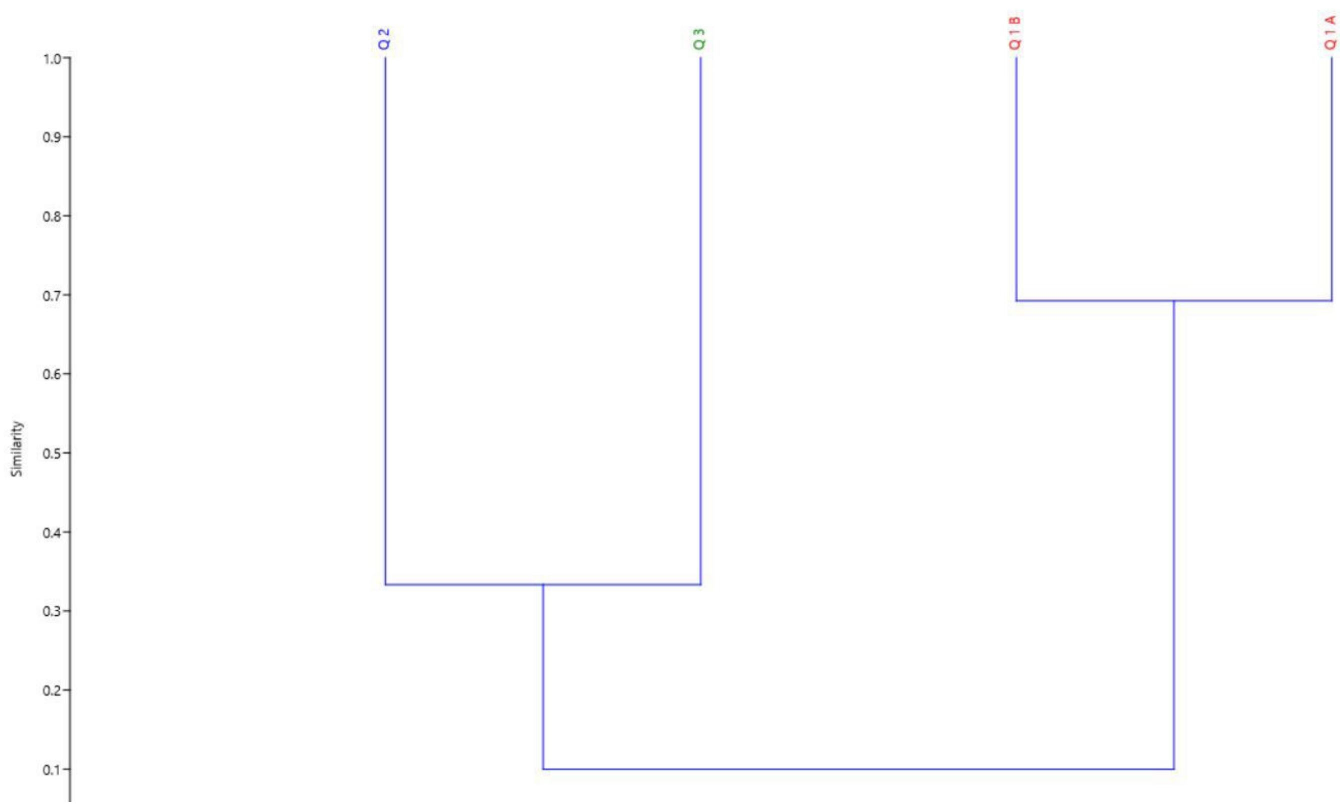

Figure 4. Dendrogram based on the Jaccard similarity index.

Figura 4. Dendrograma basado en el índice de similaridad de Jaccard.

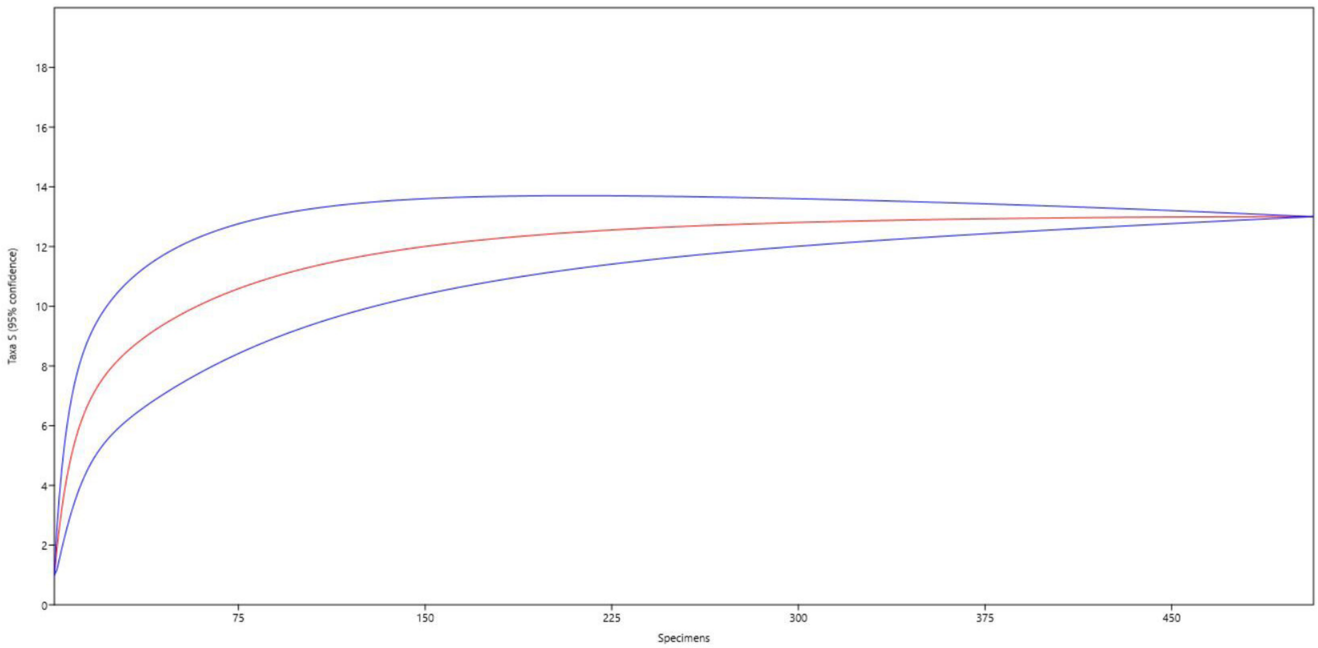

Figura 5. Curva de rarefacción de especies para el proyecto. /**Figure 5.** Species rarefaction curve for the project.

assembly of herpetological communities is not associated to a specific type of variable (Illescas-Aparicio et al., 2016). In open areas, where forest degradation has occurred, there is a greater variability of environmental factors, such as temperature and humidity (Hertz et al., 1993), since different microhabitats are created, which leads both to the displacement of species that do not tolerate these disturbances, as well as the repopulation of tolerant species (Cortes-Ávila & Toledo, 2013; Del Rio et al., 2003; Hanski, 1994), based on this, if the disturbance in this area continues, it is possible that some species disappear, leaving only those that are tolerant.

Based on the interpretation of the Shannon-Wiener index, it is considered that the study area, which as a whole has H' = 2.112, has a medium diversity, since it is between H' = 2.0, which is the minimum before being considered low and H' = 3.0, which is the minimum that a site must have to be considered very diverse (Hernández-Salinas & Ramírez-Bautista 2013, De León-Ortíz, 2014). This normal diversity, very close to low diversity, may be related to forest fragmentation, since only gallery forests remain.

These altered areas tend to present greater fluctuations in temperature and humidity than better-preserved areas, even the forest floor varies, with well-preserved forests having a greater layer of litter that provides protection for amphibians (Illescas-Aparico et al., 2016).

We propose that the vertical migrations of the three tree species are related to reproductive activities, since these were observed in the lower zone of the forest and associated with the sampled streams, during the rainy months, and the use was increased. from the upper part during the dry months. This behavior has been documented in other species of tree frogs, such as adults of *Agallychnis spurrelly* (Ortega-Andrade et al., 2011), and a decrease in reproductive activity and number of individuals found near bodies of water during the dry season have been reported (Muñoz-Guerrero et al., 2007; Touchon & Warkentin, 2009), so it is to be expected that these individuals migrate towards the forest canopy when the rainy season has ended, and like many other frogs, their activity stimulated by rain (Donnelly & Guyer 1994; Vasconcelos, 2010), contrary to the vertical migrations observed in some species of frogs of the Dendrobatidae family, which migrate from the forest floor to the tree canopy during the rainy season (Basham et al., 2020).

It would also be expected that the *Smilisca sila* tree frog would be more common during the dry season, when it descends from trees to water bodies to breed (James, 1944; Malone, 2004). During the study we noticed behavior patterns of some species;

Smilisca sila (Fig. 5I) and *C. fitzingerii* showed a peak in their reproductive activity at the end of the rainy season, however, *Hyalinobatrachium tatayoi*, the only member of the Centrolenidae family recorded during the investigation, showed an inverse pattern, presenting amplexus and egg masses during breeding in the rainy season, demonstrating that environmental seasonality represents an important factor for the reproductive cycles of the species (Wells, 1979; Ibáñez & Smith, 1995; Grifith, 2013).

Similar to what was observed with the results of the Jaccard index, transects Q1A and Q1B were the most similar in terms of their composition of forest and body of water, which were maintained with water throughout the year, so it is of expect that these places with similar characteristics, in addition to presenting continuity between them, maintain similar amphibian communities (Illescas-Aparicio et al., 2016).

The species rarefaction curve for the study area showed a rapid reaching of the asymptote, demonstrating that, with the sampling carried out, almost all of the species found in the site were observed. The continuity of the asymptote line indicates the possibility of counting or resampling previously counted animals and allows inferring about the state of the populations of these species. This information is important for studies of behavior, feeding, and population stability (Batista et al., 2020).

CONCLUSSION

Environmental compensation projects are important to restore areas that have been deforested and thus can function as new habitats or new corridors between habitat fragments for some species (Contieri, 2021). We consider the diversity and abundance of amphibians observed in the study area as normal based on the Shannon-Wiener diversity index and stream 1 in its sections A and B as the most similar habitats according to Jaccard.

After 15 years of this study, it is necessary to repeat it so that, once the site is restored, we can, based on the results obtained and in comparison, with those published in this study, assess and demonstrate the viability of this type of project and how they benefit biodiversity.

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