# Final Evaluation Report

| Your Details | |
|---|---|
| **Full Name** | Francisco Xavier Velasquez-Espin |
| **Project Title** | Unexplored Biodiversity: Canopy Amphibians in the Cloud Forest |
| **Application ID** | 36818-1 |
| **Date of this Report** | August 18th, 2023 |

**1. Indicate the level of achievement of the project's original objectives and include any relevant comments on factors affecting this.**

| Objective | Not achieved | Partially achieved | Fully achieved | Comments |
|---|---|---|---|---|
| Record and sample canopy invertebrate fauna and herpetofauna | | | X | After climbing a total of 19, we ended up finding eight individuals. Despite this finding, the numbers for accurate ecological analysis and conservation attempts. Thus, as was mentioned in the proposal, we focused on the other selected taxa invertebrates. However, we ended up sampling 96 different bromeliads and in this sense the findings are useful. In addition, ants (Formicidae) are one of the 10 different orders of invertebrates we find in the canopy. We focus on this group and based on rarefaction analysis we end up having a sampling coverage of 85%. In other words, based on this statistical analysis we sampled more than 85% of the total species of ants that live inside the canopy. Hopefully, this result is an insight into the whole efficiency of the sampling. Nevertheless, we haven't run any proper statistical analysis to address this with the rest of the invertebrates' orders. |
| Obtain data about climatic conditions, presence or absence of pathogens of interest such as the fungus *Batrachochytrium dendrobatidae* (B.d.), responsible for the worldwide population decline of more than 500 amphibian species | | | X | Across our study area Mashpi-Tayra reserve, we ended up sampling 96 bromeliad water tanks. Every bromeliad was sampled. In this sense, we achieve the objective and in addition, PhD student Maria del Mar Moretta Urdiales is using the sampled water to see the presence of the pathogen and compare it with other areas and canopies of Ecuador. |

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| The study proposed here is also likely to result in surprises, such as the discovery of new species for science. This information could be directly used in the conservation of Andean cloud forests, especially in the face of the threat of mining concessions. | | | | We have certainty about new species and records of ants (Formicidae). From the genus: *Megalomyrmex*, *Apterostigma*, and *Cyphomyrmex*. Based on the rarefaction test the maximum amount of ant species present in the bromeliads of the cloud forest is 53. We ended up sampling 41 species. Thus, the potential 12 other species could present some new species. Once again, this is only for ants, we have sampled at least 10 more orders. In this sense, the total number of new species of invertebrates could increase exponentially. In addition, we are working with the eight individuals of amphibians to see their phylogenetic relationships to see if they are new species. |
| Current efforts in conservation biology in the Neotropics rely heavily on two key elements: (i) the presence of endemic species, and (ii) the presence of endangered taxa. Funding to protect and expand natural reserves is tightly related to the uniqueness of the ecosystems. Our work has the potential to make a substantial contribution to such lines of support. Additionally, Ecuador is a novel situation in terms of avoiding extractive activities within biodiverse areas because its legislation recognizes Nature as a subject for rights; this means that if the evidence is provided that a certain area has | | | | We successfully explored the canopy, and, in this sense, we have certainty that there is the presence of endemic species that could present threats such as mining and deforestation. Nevertheless, these findings are not complete due to the tremendous number of samples obtained for invertebrates. However, this study serves as a foundation study. Thus, the first part, sampling and classifying the species is complete. |

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| unique species, it is likely that legal actions can limit or prohibit activities that will fragment, contaminate, or substantially alter natural conditions. | | | | |

**2. Describe the three most important outcomes of your project.**

**a).** The unexplored environment of the canopy was successfully explored. With a total sample of eight amphibians, one gecko, and 1310 individuals of ants represented across 23 different genera and 41 different morphospecies. In addition, other 10 different orders of invertebrates were sampled.

**b).** For Formicidae (ants), based on rarefaction analysis, we reach a sampling coverage of 85%. In other words, we sampled most of this diversity. As a foundation study, the samples will represent the beginning of understanding not only the diversity presented inside the treated cloud forest but the ecology of these fascinating invertebrates.

**c).** Finally, we implement abiotic variables to understand the role of factors such as height from the ground, temperature inside and outside the bromeliad, and elevation, in the composition and structure of the ant community. Based on the GLMs models run we have found a direct impact of height from the ground (distance of the canopy) and the internal temperature of the bromeliads against the abundance of ants. These findings will serve as a key to understanding how biodiversity and abundance shape the community and ecology of organisms inside the unexplored layer of the canopy.

**3. Explain any unforeseen difficulties that arose during the project and how these were tackled.**

As was mentioned in the description of the project the focus was on anurans. However, after the first month of field research, we found anurans but not as abundant as we expected. Despite the value of our findings, we can't run a proper statistical analysis to understand the community composition. We are still working with these amphibians but instead of focusing on their ecology, we are evaluating taxonomically the species found with high hopes of finding new species for vertebrates. However, for the other component of the project, the invertebrate history was different. The size of the samples and the time for working on them have drastically shaped the trajectory of the study. Not by changing the main reasoning and focus of the project but by changing the target organisms. As was mentioned in the proposal this study was part of my Master's project at USFQ (https://www.usfq.edu.ec/es/posgrados/maestria-en-ecologia-tropical-y-conservacion). Thus, to graduate I need to develop a more complete thesis not only focusing on taxonomy but also on ecology. Among terrestrial insects, ants (family:

Formicidae) are one of the most diverse taxa with a cosmopolitan distribution, reaching almost every microhabitat (e.g., underground, forest floor, understorey, and canopy). Ants have been studied for centuries in comparison to other taxa, making them ideal for biodiversity studies. A manuscript is in preparation it is planned to be submitted to a proper journal this year. In this sense, we tackled the challenging task of understanding unexplored environments and facing science with unexpected changes. Finally, it is important to mention that we need to change the focus group from amphibians to ants. Thus, to achieve our conservation attempts we a taxonomical change to "Our objective is, by exploring the canopy and knowing its ant inhabitants, to make a specialised integrative conservation plan that contributes to the overall conservation of the site using the high-altitude ants.", providing also with unique ecological and biodiversity data that will be available for the scientific community, try to use ants as an umbrella species (increasing the attention in the group due to sci-fi movies).

**4. Describe the involvement of local communities and how they have benefitted from the project.**

The unexpected changes during the research present a direct benefit to the collaborative nature of the study. In this sense, we have not only expanded the scientific community behind the project, adding collaborators to the manuscript but also the local community's involvement. To increase the size of the sampling for continuing searching both amphibians and invertebrates we expand our research to Tyra reserve which also belongs to "Fundacion Futuro" part of the "Mashpi Lodge" both key partners in this process. The expansion also includes expanding the expedition team. Giving opportunities to local rangers and other volunteers to be part of the field component. Here it is important to mention that we allow young undergrad students to learn field sampling techniques: Salome Herrera and Juan Diego Chavez (both from USFQ), and two field research photographers: Amanda Quezada and Jose Vieira. Nevertheless, none of them climb the trees to sample the bromeliads activity that requires specialized training (this was performed by myself).

**5. Are there any plans to continue this work?**

Yes, this first approach to exploring the unexplored gives us an impressive insight into the potential biodiversity that is holed in the canopy layer of the threatened Andean-Choco ecosystem. This is a little drop presented by this study. What is most remarkable about it is that we have sampled a significant amount of diversity. In this sense, the collections that will be deposited in USFQ will be useful for a high number of potential studies especially related to taxonomy presented in the other orders of insects found. The collection will be useful for undergrads and graduate students who are interested in the taxonomy of invertebrates. Continuing the project for many potential years.

Nevertheless, it is still a drop to understand the complex patterns of diversity and ecological processes presented inside this ecosystem and forest layer. I am grateful to continue my graduate studies at the University of Houston for pursuing a PhD. Thus, I want to continue exploring this layer and the founding of a second Rufford

Grant will be appreciated and adequate for doing this not only in the Mashpi-Tayra Forest but in other places inside the Ecuadorian Choco.

We estimate to start the logistical planning of this new challenging project in the summer of 2024. We are working on a proposal for submission to the 2nd Rufford Small Grant.

**6. How do you plan to share the results of your work with others?**

As a former student of the master's ecology programme at USFQ (https://www.usfq.edu.ec/es/posgrados/maestria-en-ecologia-tropical-y-conservacion), the study conducted here was part of the thesis project developed for the programme. Thus, the results were already exposed in the "Universidad San Francisco de Quito ciclo de charlas en ecologia tropical y conservacion, presentacion de tesis de maestria", and we are working on the manuscript for submission to a scientific journal. In addition, as part of the agreement with "Fundacion Futuro" we need to present to the communities the findings which are planned to be presented at the beginning of 2024. We are continuing to work on talks with students. In addition, it is expected once the manuscript is published to continue attracting attention to the project by reaching out to other media (such as journals and digital communication portals).

**7. Looking ahead, what do you feel are the important next steps?**

The next step is to continue improving the first part of the manuscript. Now, we have a fully complete master's thesis available at the USFQ online library and attached to this document. This is the first step to sharing the results with the world. Now, we are working on the manuscript for submission to a scientific journal. To accomplish this, we need to improve the mentioned thesis. Thus, we are adding phylogenetic molecular analysis to the study. Now, we are working with Macrogen and my laboratory at USFQ LBE (https://instituto-biosfera.org/laboratorio-biologia-evolutiva/) in addition to one graduate student Daniela Franco for obtaining a phylogenetic tree with the 41 species of ants found in the canopy. With this analysis, we will see the real number of ant species number found inside the Mashpi-Tayra cloud forest.

**8. Did you use The Rufford Foundation logo in any materials produced in relation to this project? Did the Foundation receive any publicity during the course of your work?**

The logo of The Rufford Foundation was used in presentations of the mentioned thesis and study for people at USFQ and Mashpi Lodge. This is a way to recognize the importance of the support provided by The Rufford Foundation in this study and give credit to all the people involved. As part of the MSc programme, I encourage my classmates to apply to Rufford and similar founding programs to conduct science feasibly.

**9. Provide a full list of all the members of your team and their role in the project.**

**Juan Manuel Guayasamin Ph.D.**
Universidad San Francisco de Quito
Juan Manuel's role was related to the advice and supervision of the project, as co-director of my thesis. In addition, he provides me with a proper space work and all the laboratories' facilities. Juan Manuel was my tutor since my undergrad thesis at USFQ as well. In this sense, he is a keystone component not only for the topics mentioned before but for his intellectual contribution and unconditional help.

**Shawn F. McCracken Ph.D.**
Texas A&M University-Corpus Christi
Shawn's role was related to the external advice and supervision of the project, as part of my graduation committee. In addition, he accomplishes the expert role in the team. Shawn is a remarkable canopy ecologist. His expertise was crucial for the development of the project by providing climbing equipment until the ones provided by the Rufford Foundation for the development of the project.

**David Rodriguez Ph.D.**
Texas State University
David's role was related to the external advice and supervision of the project. He was part of my graduation committee. In addition, David provides his experience as a geneticist and herpetologist for the project. Despite the low number of amphibians found we are working on them with his help.

**Ryan L. Lynch M.S.**
Third-millennium alliance
Ryan's role was related to canopy field research training. Ryan is an expert climber who helps me train. In addition, he helps me training in the research station JCR (https://www.tma.earth) providing me with equipment for learning.

**Maria del Mar Moretta Ph.D. (S)**
Texas State University
Mar´s role was related to the fieldwork. She was part of the "canopy climbers". In addition, Mar is helping with the amphibians-related part of the project. It's important to mention that tree climbing is a complex activity. In the sense regardless of the climber once we reach the canopy, we collect samples for B.d disease a project carries on by Mar.

**Moises Tenorio**
Third millennium alliance
Moises role was related to the field work. He is a professional tree climber who have train in several different ecosystems across south America. His expertise in the field was key to reaching the canopy and performing this project. In addition, he fulfills the role as a consultant to choose the most adequate and safe tree. His years of expertise allow us to reach difficult access parts of the canopy.

In addition, the following collaborators are involved in the publication of the manuscript.

**Daniela Rosero Lopez Ph.D.** (Community Ecology)
**Giovanni Ramon Ph.D.** (C) (Ant ecology)
**Holden s. Jones Ph.D.** (S) (Mapping)
**Daniela Franco MSc** (Phylogenetics)

**10. Any other comments?**

As I mention before the unexpected findings lead the project to focus not only on amphibians but also in invertebrates. In this sense, the remarkable findings are prepared to be publish in a scientific paper in order to show and indicate the biodiversity hidden inside the canopy layer. In addition, we are using phylogenetics tools to assess the ant (Formicidae) biodiversity found inside the canopy bromeliads of the cloud forest. However, I would like to introduce the results presented in my MSc thesis who unfortunate was needed to be finish in a specific time. We plan to add the DNA component to the statistical and ecological results presented in the section of ANNEX results. Finally, I am currently studying a PhD in the University of Houston planning to apply once again to The Rufford foundation for continuing exploring the canopy.

**ANNEX – Results**

**Abstract**

The documentation of biodiversity in tropical ecosystems is a cornerstone of conservation biology. This study describes the ant community composition in the canopy of the Tropical Andes, one of the most significant biodiversity hotspots in the world. Fieldwork was conducted at Mashpi-Tayra Reserve, located in the Andean-Chocó Biosphere at 775-1295 m.a.s.l in Ecuador. Using ants as our target group, we focused on three main goals: (i) to assess the richness and abundance of Formicidae inside the canopy bromeliads of the cloud forest; (ii) to understand which abiotic variables explain the composition of the ants community; and (iii) to link our results to conservation efforts. We sampled 65 canopy bromeliads located at different elevations above ground level (17.3–35.3 m). Within those bromeliads, we found 1310 ant individuals, representing 41 species, with the highest possibility of finding endemic species. Rarefaction analysis estimates that our sampling documented 85% of the ant species richness in the area. The most abundant genus sampled was Megalomyrmex with 557 individuals a remarkable ecological finding. General Linear Models indicate that the variables that better explain ant abundance are the location of the bromeliad's height and the internal water tank temperature of the bromeliad. We found no influence of elevation (m above sea level) and external environmental temperature. Our findings are the first attempt to document the diversity of canopy ants in the canopy of the Ecuadorian cloud forests. We expect that this foundation study with the recorded biodiversity will be used as a tool for conservation attempts and environmental legal frameworks.

**Ant community composition**

The ant bromeliad survey resulted in a total of 1310 individuals from 41 morphospecies, 6 subfamilies (Ectatomminae, Formicinae, Heteroponerinae, Myrmicinae, and Ponerinae, and 23 genera. The Dolichoderinae subfamily is represented by 3 genera: Azteca (2 morphospecies), Dolichoderus (1), and Tapinoma (3). The subfamily Ectatomminae presents only 1 genus, Holcoponera, and 1 morph. Formicinae is represented by 3 genera: Brachymyrmex (1 morphospecies), Camponotus (5 morphospecies), and Nylanderia (3 morphospecies). Heteroponerinae is confirmed by 1 genus and 1 morphospecies, Acanthoponera. The subfamily Myrmicinae is the most represented of all the 7 subfamilies with 8 genera: Acromyrmex (1 morphospecies), Apterostigma (2 morphospecies), Crematogaster (2 morphospecies), Cyphomyrmex (2 morphospecies), Megalomyrmex (1 morphospecies), Pheidole (5 morphospecies), Solenopsis (2 morphospecies), Wasmannia (1 morphospecies). Finally, the subfamily Ponerinae presented 7 genera: Anochetus (1 morphospecies), Hypoponera (1 morphospecies), Mayaponera (1 morphospecies), Neoponera (2 morphospecies), Odontomachus (1 morphospecies), Pachycondyla (1 morphospecies), and Rasopone (1 morphospecies). (See Fig.3, Fig.4, and Table.1).

**Interpolation and extrapolation for species diversity**

The function iNEXT (iNtrapolation and EXTrapolation) from R generates the rarefaction curves and sampling coverage. Based on the obtained results, with an observed richness (sample size) of 41 (Quartile Deviation Lower Control Limit (LCL)

34.09 and Quartile Deviation Upper Control Limit (UCL) 47.90), we have an overall Sampling Coverage (SC) of 0. 85 (LCL 0.79 and UCL 0.91). The double sample size extrapolation reaches an SC of 0.94 (LCL 0.88 and UCL 1) (Fig.3). Formicidae canopy community presents a species richness observed value of 41 and an estimator of 61 (Standard Error (S.E.) 15.13, 91-41). For the Shannon diversity or Shannon entropy, we have an observed value of 28 with an estimator of 37 (S.E. 3.81, 44.13-29.17). The Simpson diversity or inverse Simpson Concentration presents an observed value of 18 with an estimator of 21 (S.E. 3. 479, 28.29-14.66). (See Table 4, Table 5, and Table 6).

**Shannon, Simpson, Evenness and, Density**

Four diversity indices (Shannon, Simpson, Evenness, and Density) were calculated with the R package "Vegan: Ecological diversity" (n = 65) in order to estimate the biodiversity of the cloud forest canopy, see summary Table 7.

**Environmental drivers of ant diversity in canopy bromeliads**

The estimated results obtained by the GLM model are presented in Table 8. The variable Height (Hei) and Internal Temperature (TI) are significantly correlated with the abundance values. The correlations are positive (an increase in Hei and TI produces increases in abundance). The other variables, Elevation (Elev) and, External Temperature (TE), do not significantly affect the abundance. To test the influence of abiotic variables on the community composition, we constructed a General Linear Model (GLM), as follows:

**GLM**

Full model

Ab ~ Elev + Hei + TI + TE

Mathematical notation of the model

$Abi \sim Poisson(\mu_i)$

$E(Abi) = \mu_i$ and $var(Abi) = \mu_i$

$\log(\mu_i) = \eta_i$

$\eta_i = \beta 1 + \beta 2\, xElevi + \beta 3\, xHeii + \beta 4\, xTIi + \beta 5\, xTEi$

Call of the formula: Ab Abundance is the dependent variable, and Elev Elevation, Hei Height, TI Internal temperature, and TE External temperature are the independent variables. *The overdispersion of the model was: z = 2.3964, p-value = 0.008279 and dispersion 60.32102.

**Analysis of Deviance (ANOVA)**

The p-value obtained for the fitted model, by comparing it to a null model with the ANOVA function, was significant statistically 2.2e-16 (<0.05) (See Table. 9).

**Tables**

**Table 1.** Diversity and abundance of Formicidae found in the canopy of the cloud forests of Mashpi-Tayra Reserves, Ecuador.

| **Subfamliy** | | **Genera** | **Morphospecies** | **Abundance** |
|---|---|---|---|---|
| Dolichoderinae | | *Tapinoma* | 3 | 43 |
| Dolichoderinae | | *Azteca* | 2 | 23 |
| Dolichoderinae | | *Dolichoderus* | 1 | 10 |
| Ectatomminae | | *Holcoponera* | 1 | 1 |
| Formicinae | | *Nylanderia* | 3 | 74 |
| Formicinae | | *Camponotus* | 5 | 35 |
| Formicinae | | *Brachymyrmex* | 1 | 32 |
| Heteroponerinae | | *Acanthoponera* | 1 | 1 |
| Myrmicinae | | *Solenopsis* | 2 | 158 |
| Myrmicinae | | *Pheidole* | 5 | 165 |
| Myrmicinae | | *Megalomyrmex* | 1 | 557 |
| Myrmicinae | | *Crematogaster* | 2 | 69 |
| Myrmicinae | | *Apterostigma* | 2 | 32 |
| Myrmicinae | | *Cyphomyrmex* | 2 | 3 |
| Myrmicinae | | *Wasmannia* | 1 | 82 |
| Myrmicinae | | *Acromyrmex* | 1 | 2 |
| Ponerinae | | *Rasopone* | 1 | 2 |
| Ponerinae | | *Mayaponera* | 1 | 6 |
| Ponerinae | | *Odontomachus* | 1 | 2 |
| Ponerinae | | *Anochetus* | 1 | 7 |
| Ponerinae | | *Neoponera* | 2 | 3 |
| Ponerinae | | *Pachycondyla* | 1 | 2 |
| Ponerinae | | *Hypoponera* | 1 | 1 |

**Table 2.** Subfamilies and bromeliad occurrence of Formicidae found in the canopy of the cloud forests of Mashpi-Tayra Reserves, Ecuador.

| **Subfamily** | **Bromeliad occurance** |
|---|---|
| Myrmicinae | 62 |
| Formicinae | 27 |
| Dolichoderinae | 16 |
| Ponerinae | 14 |
| Ectatomminae | 1 |
| Heteroponerinae | 1 |

**Table 3.** Genera and bromeliad occurrence of Formicidae found in the canopy of the cloud forests of Mashpi-Tayra Reserves, Ecuador.

| Genera | Bromeliad occurrence |
|---|---|
| Megalomyrmex | 21 |
| Pheidole | 17 |
| Nylanderia | 16 |
| Camponotus | 9 |
| Solenopsis | 8 |
| Tapinoma | 7 |
| Anochetus | 5 |
| Crematogaster | 5 |
| Dolichoderus | 5 |
| Wasmannia | 5 |
| Azteca | 4 |
| Apterostigma | 3 |
| Neoponera | 3 |
| Brachymyrmex | 2 |
| Cyphomyrmex | 2 |
| Odontomachus | 2 |
| Acanthoponera | 1 |
| Acromyrmex | 1 |
| Holcoponera | 1 |
| Hypoponera | 1 |
| Mayaponera | 1 |
| Pachycondyla | 1 |
| Rasopone | 1 |

**Table 4.** Asymptotic estimates of ant species richness and diversity indexes (ChaoShannon and ChaoSimpson) in the sampled bromeliads.

| | **Assemblage** | **Diversity** | **Observed** | **Estimator** | **Standard Error** | **Lower Control Limit** | **Upper Control Limit** |
|---|---|---|---|---|---|---|---|
| 1 | *Formicidae* | Species richness | 41 | 60.93359 | 15.13197 | 41 | 90.5917 |
| 2 | *Formicidae* | Shannon diversity | 27.82461 | 36.653 | 3.814616 | 29.17649 | 44.12951 |
| 3 | *Formicidae* | Simpson diversity | 18.46154 | 21.47727 | 3.479073 | 14.65842 | 28.29613 |

**Table 5.** Diversity estimates with rarefied and extrapolated samples, size-based (the diversity estimates with respect to sample size).

| **Assemblage** | **t** | **Method** | **Order.q** | **Quartile Deviation** | **Quartile Deviation Lower Control Limit** | **Quartile Deviation Upper Control Limit** | **Sampling Coverage** | **Sampling Coverage Lower Control Limit** | **Sampling Coverage Upper Control Limit** |
|---|---|---|---|---|---|---|---|---|---|
| *1* | 1 | Rarefaction | 0 | 1.875 | 1.529464 | 2.220536 | 0.08730159 | 0.06265662 | 0.1119466 |
| *10* | 32 | Rarefaction | 0 | 29.37335 | 24.796656 | 33.950042 | 0.74273291 | 0.67645297 | 0.8090129 |
| *20* | 65 | Observed | 0 | 41 | 34.09587 | 47.90413 | 0.85208696 | 0.79393016 | 0.9102438 |
| *30* | 96 | Extrapolation | 0 | 47.84051 | 38.88215 | 56.798865 | 0.9028455 | 0.83932428 | 0.9663667 |
| *40* | 130 | Extrapolation | 0 | 52.80231 | 41.112647 | 64.491966 | 0.93966349 | 0.8790658 | 1 |

**Table 6**. Diversity estimates with rarefied and extrapolated samples, coverage based (the diversity estimates with respect to sample coverage).

| Assemblage | Sampling Coverage | t | Method | Order.q | Quartile Deviation | Quartile Deviation Lower Control Limit | Quartile Deviation Upper Control Limit |
|---|---|---|---|---|---|---|---|
| *1* | 0.08730159 | 1 | Rarefaction | 0 | 1.875 | 1.529464 | 2.220536 |
| *10* | 0.74273304 | 32 | Rarefaction | 0 | 29.37335 | 24.796656 | 33.950042 |
| *20* | 0.85208696 | 65 | Observed | 0 | 41 | 34.09587 | 47.90413 |
| *30* | 0.9028455 | 96 | Extrapolation | 0 | 47.84051 | 38.88215 | 56.798865 |
| *40* | 0.93966349 | 130 | Extrapolation | 0 | 52.80231 | 41.112647 | 64.491966 |

**Table 7.** Summary table of all the variables measured in this study, from the abiotic variables (*Elev, Hei, TE, TI, pH,* and *Am*) and biotic variables such as the diversity indices (*Den, Bs, Bsi, Ev, Ab, Riq*).

| Variables | Min | Median | Mean | Max. | Standard Deviation | Standard Error | Code | Unit |
|---|---|---|---|---|---|---|---|---|
| *Elevation* | 775.00 | 882.00 | 920.50 | 1295.00 | 146.90 | 18.22 | *Elev* | meters above the sea level (m.a.s.l) |
| *Bromeliad Height from the ground* | 17.26 | 24.10 | 24.47 | 35.30 | 3.92 | 0.49 | *Hei* | meters (m) |
| *Environmental temperature* | 19.60 | 22.80 | 22.87 | 27.10 | 1.71 | 0.21 | *TE* | celsius (°C) |
| *Bromeliad Internal temperature* | 19.10 | 20.80 | 21.11 | 24.00 | 1.08 | 0.13 | *TI* | celsius (°C) |
| *Potential of hydrogen* | 2.00 | 4.50 | 4.55 | 6.90 | 0.77 | 0.10 | *pH* | pH |
| *Bromeliad Area* | 0.58 | 2.55 | 3.04 | 8.08 | 1.69 | 0.21 | *Am* | Square meters |
| *Species density* | 0.00 | 14.52 | 51.19 | 383.66 | 88.48 | 10.98 | *Den* | Individuals per unit area (ind/m2) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Shannon-Weaver Biodiversity index* | 0.00 | 0.09 | 0.33 | 1.42 | 0.41 | 0.05 | *Bs* | Shannon diversity index |
| *Simpson Biodiversity index* | 0.00 | 0.22 | 0.32 | 1.00 | 0.35 | 0.04 | *Bsi* | Simpson diversity index |
| *Species Evenness* | 0.00 | 0.57 | 0.53 | 1.00 | 0.37 | 0.06 | *Ev* | Pielou's evenness index |
| *Abundance* | 0.00 | 4.00 | 20.15 | 254.00 | 40.47 | 5.02 | *Ab* | Individuals |
| *Species Richness* | 0.00 | 2.00 | 1.86 | 7.00 | 1.45 | 0.18 | *Riq* | Species number |

**Table 8.** GLMs Coefficients Table of the fitted model:
Ab ~ Elev + Hei + TI + TE

| | **Estimate** | **Std. Error** | **z value** | **Pr(>\|z\|)** | |
|---|---|---|---|---|---|
| *Intercept* | -3.9742067 | 0.7061833 | -5.628 | 1.83E-08 | *** |
| *Elev* | -0.0001908 | 0.0002443 | -0.781 | 0.435 | |
| *Hei* | 0.1289656 | 0.0066191 | 19.484 | < 2e-16 | *** |
| *TI* | 0.1732154 | 0.0335423 | 5.164 | 2.42E-07 | *** |
| *TE* | 0.0077775 | 0.0225015 | 0.346 | 0.73 | |

**Table 9.** Analysis of Deviance (ANOVA) Table from the fitted model Ab ~ Elev + Hei + TI + TE against a null model

| *Model 1: Ab ~ Elev + Hei + TI + TE* | | | | | | |
|---|---|---|---|---|---|---|
| *Model 2: Ab ~ 1* | | | | | | |
| | **Resid. Df** | **Resid. Dev** | **Degrees of freedom** | **Deviance** | **Pr(>Chi)** | |
| *1* | 60 | 2408.6 | | | | |
| 2 | 64 | 2848.8 | -4 | -440.29 | < 2.2e-16 | *** |

## Figures


**Figure 1**. Sampling distribution, location of the 13 sampled trees located in Mashpi-Tayra.

**Figure 2.** Tree sampling in Mashpi-Tayra cloud forest. Left, FVE in the crown of a tree sampling a bromeliad. On the right, FVE uses the Single Rope Technique to reach the canopy of the cloud forest.

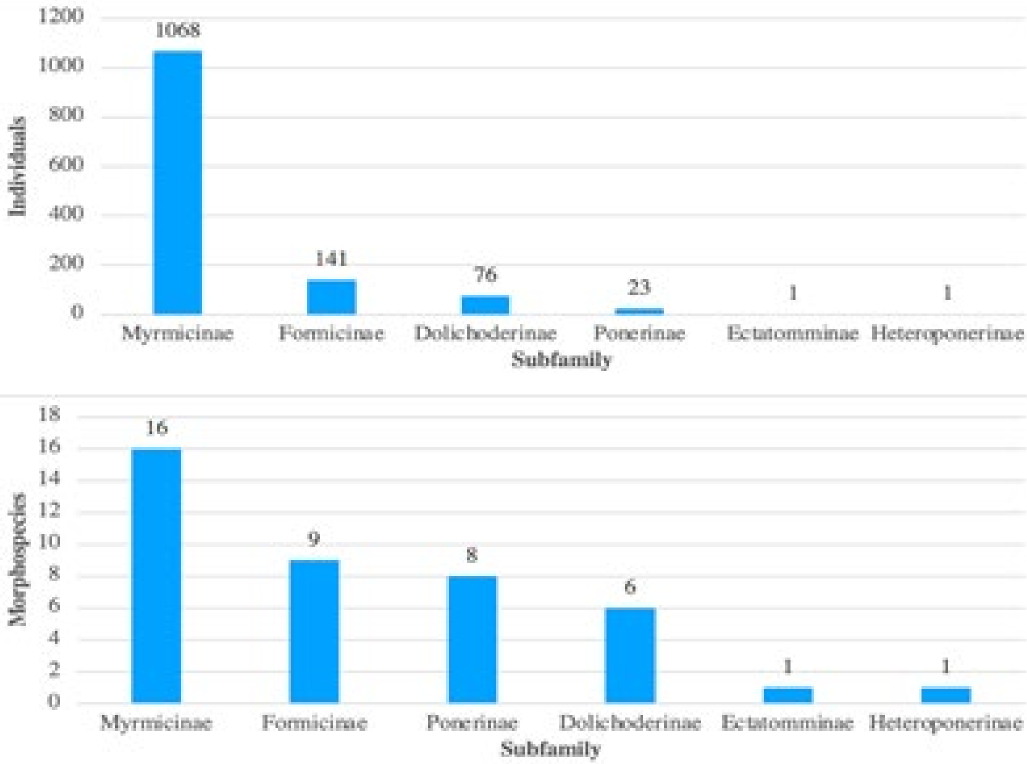


**Figure 3**. Bar chart of ants (Formicidae) abundance by subfamilies found in bromeliads from the canopy of cloud forest in the Andean Chocó bioregion

(Above). Bar chart of ants (Formicidae) richness by subfamilies found in bromeliads from the canopy of cloud forest in the Andean Chocó bioregion (Below).

**Figure 4**. The collage shows some of the incredible diversity of Formicidae found in bromeliads from the canopy of cloud forest in the Andean Chocó bioregion.

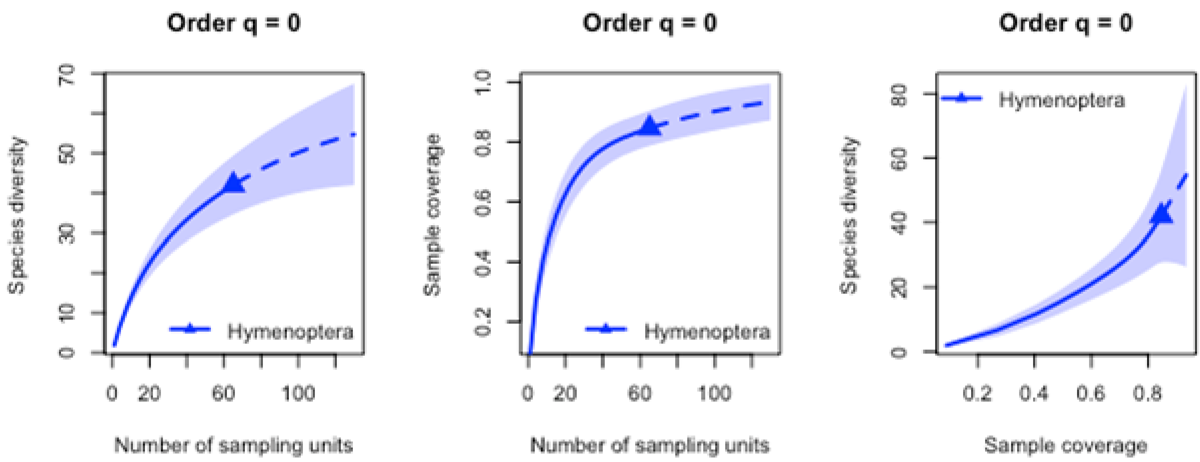


**Figure 5.** Interpolation and extrapolation for species diversity. (a) Sample-size-based and (c) coverage-based rarefaction (solid line segment) and extrapolation (dotted line segments) sampling curves for species richness (q = 0) with 95% confidence intervals for the canopy ant data. The solid dot represents the reference samples. (b) Sample completeness curves linking curves in (a) and (c). Sample-size-based (a)

plots the diversity estimates with respect to sample size and Coverage-based (c) plots the diversity estimates with respect to sample coverage.
statistically 2.2e-16 (<0.05) (See Table. 9).

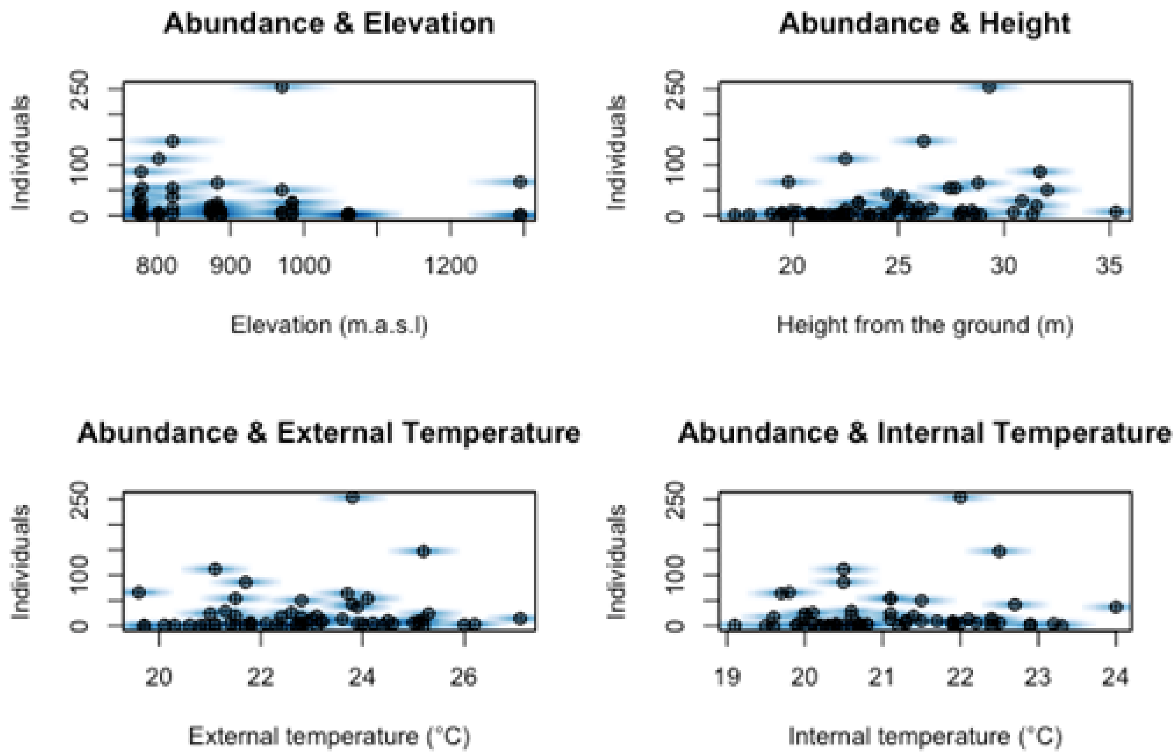


**Figure 6**. Formicidae abundance inside each bromeliad (n = 65) against the four analyzed variables. Height from the ground (Hei); Elevation (Elev); Internal temperature (TI); and External temperature (TE). All graphs by themselves have non-statistically significant coefficients of correlation.

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