

THE WESTERN FRONTIER OF BRAZILIAN ANT DIVERSITY: CONTRIBUTIONS OF *REDE BIA* TO KNOWLEDGE ON ANT DIVERSITY IN THE SOUTHWESTERN AMAZON

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ABSTRACT

Brazil is the country with the greatest diversity of ants. However, due to its vast size and uneven scientific development, there are still considerable areas with extensive gaps in diversity records. One of these gaps is the state of Acre, located in the southwestern Brazilian Amazon, which represents the western most frontier of Brazilian ant diversity. A total of 394 ant species has been recorded in Acre so far, which is relatively low compared to neighboring regions. In an effort to reduce knowledge deficits in insect biodiversity in the Amazon, the project "*Biodiversidade de Insetos da Amazônia (Rede BIA)*" conducted samplings at 16 sites across the region from 2014 to 2019. As a result, *Rede BIA* added 40 new ant species records for the state and 66 to the collection of the *Laboratório de Ecologia de Insetos*. With these and more recent contributions, the current number of recorded ant species in Acre has reached 479. Given the recent findings of ant occurrence and the lack of stabilization in the sampling efficiency in the *Rede BIA* project, a conservative estimate places the ant species richness in Acre between 750 and 800 species. Considering the high biodiversity value of unsampled areas in Acre, we proposed the implementation of 16 additional sampling sites to increase representativeness and approach the expected ant species richness. However, significant barriers remain, including insufficient funding for field expeditions and a shortage of myrmecologists in the region, both critical obstacles to reaching the expected number.

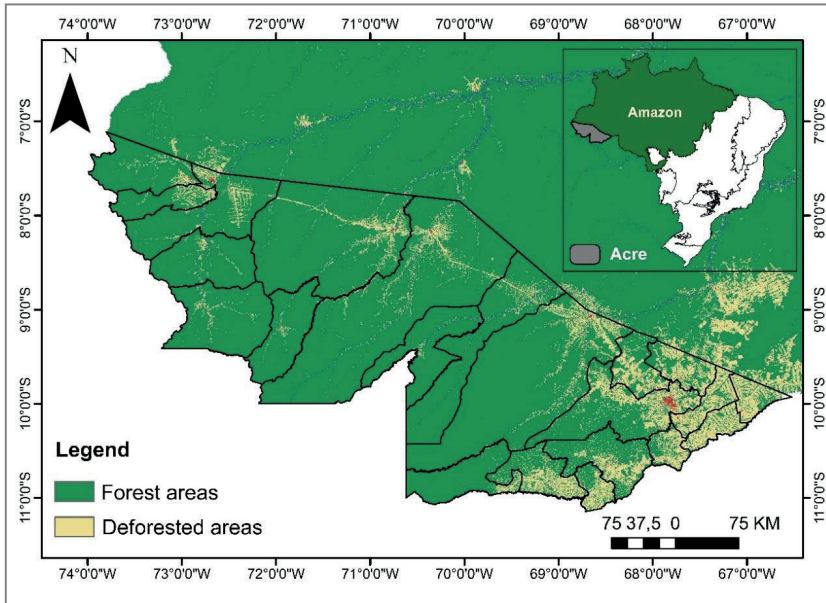
Keywords: Amazon; biodiversity; sampling efficiency; wallacean shortfall.

INTRODUCTION

In Brazil, due to its vast territorial extension and inequalities in scientific development (STEGMANN *et al.*, 2024), knowledge about the geographic distribution of most species remains incomplete. This lack of information is referred to as the Wallacean Shortfall (LOMOLINO, 2004; HORTAL *et al.*, 2015), which hinders efforts to preserve biological diversity. The absence of accurate data can lead to inadequate conservation efforts. The state of Acre, the most portion of southwestern Brazilian Amazon, serves as an example of the Wallacean Shortfall for numerous terrestrial and aquatic organisms (CARVALHO *et al.*, 2023).

Acre is geographically located in a transition area between the eastern Andes Mountain range, the Central Amazonian lowlands and the northern Bolivian Savanna (SOUZA *et al.*, 2003), representing 4% of the Brazilian Amazon (ACRE, 2010). The diversity of soil types, topography, climate, and river basins endows the region with a remarkable heterogeneity of ecosystems and landscapes, which harbor an exuberant biodiversity (ACRE, 2010). Acre has a great variety of vegetation types, with open rainforests, palm trees, bamboo, and lianas covering most of the state (80%), although small patches of dense rainforest and white-sand vegetation are found mainly in the northwestern portion (ACRE, 2010; DALY *et al.*, 2016). Despite approximately 80% of Acre's original vegetation being conserved due to a diversified system of protected areas (ACRE, 2010), an intensive process of land occupation, mainly for pasture establishment has led to around 13% of the state being converted to human-modified landscapes (Figure 1) (INPE, 2024; MAPBIOMAS, 2024).

Figure 1 - Forest cover in Acre state, southwestern Brazilian Amazon in 2023.



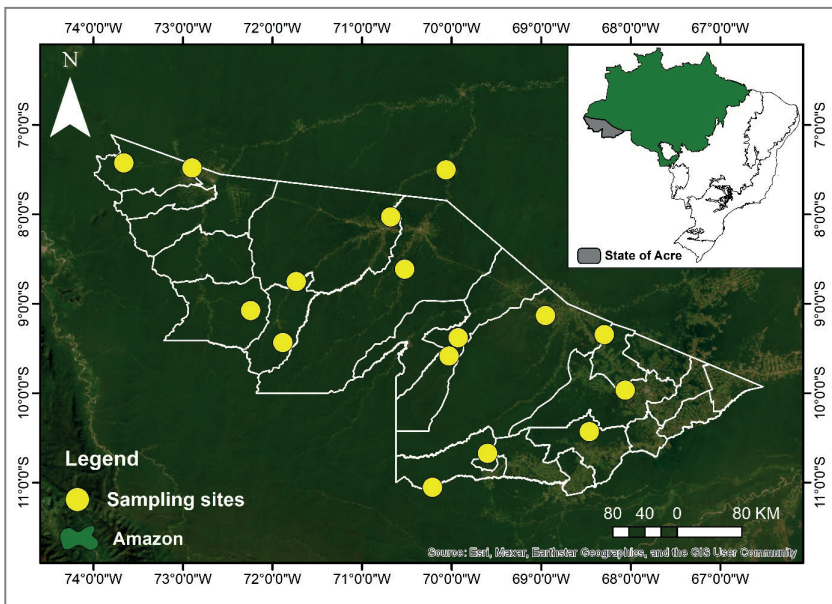
Source: MAPBIOMAS (2025).

Regarding the ant fauna, 394 ant species have been recorded in Acre so far (DUTRA *et al.*, 2024). In comparison to neighboring regions, such as Amazonas (717 species) and Peru (756 species) (JANICKI *et al.*, 2016), this represents a relatively low number of species. Although Acre is much smaller in size than these regions, its limited species record is likely not only related to its area but also to a lack of sampling in southwestern Brazilian Amazon (SCHMIDT *et al.*, 2022). Current sampling efforts are limited to areas surrounding Rio Branco (SCHMIDT *et al.*, 2020), the capital of the state and home to the main *campus* of the *Universidade Federal do Acre (UFAC)*, the primary research institution in the region.

Thus, aiming to reduce knowledge deficits in insect biodiversity in the Amazon, the "*Biodiversidade de Insetos da Amazônia (Rede BIA)*" project conducted ant samplings at 15 sites across Acre and one in southern Amazon from 2014 to 2019 (Figure 2). Specifically, we compared the ant fauna sampled by *Rede BIA* with previous records for Acre from the literature (*i.e.*, DUTRA *et al.*, 2024) and with records from specimens deposited in the ant collection of the *Laboratório de Ecologia de Insetos (UFAC)*. This comparison aimed to assess the increase in knowledge about the ant diversity in Acre and Brazil brought by

Rede BIA. Here, based on the contributions of *Rede BIA* and the recent paper by Dias and Feitosa (2024) on the myrmecofauna of Serra do Divisor National Park – western edge of the state of Acre, we present an updated list of ant species to Acre. Additionally, we evaluate the sampling efficiency of *Rede BIA*, and estimate the expected number of ant species for the state. Finally, we discuss the efforts required to uncover the true diversity of ants in Acre in the coming years.

Figure 2 - Sampling sites of *Rede BIA* project across Acre State an southern Amazonas, southwestern Brazilian Amazon.



Source: Authors collections (2025).

DEVELOPMENT

Rede BIA project

We delineated the 16 sites of *Rede BIA* across the region to achieve a geographically representative range regarding climate, soil types, hydrological basins and forest types (Figure 2). Ant sampling at these sites was carried out from 2014 to 2019, always in forest habitats. In each site, we distributed 10 plots along a transect of 200 m, with plots spaced 20 m apart. Each plot had an area

of 25 m², and in each one, we installed a pitfall trap on the ground surface, one on a tree trunk, and one underground (BESTELMEYER *et al.*, 2000; RIBAS *et al.*, 2003; SCHMIDT; SOLAR, 2010). Additionally, we collected a 1 m² litter sample. The pitfall traps remained in the field for 48 hours, and the ants in the litter sample were extracted using a mini-Winkler extractor for 48 hours. The ants collected from both the pitfall traps and the litter together formed the ant sample for each plot, while the set of ants collected in the ten plots (one transect) formed the ant assemblage for each sampling site, resulting in 16 sample units.

For genus-level identification, we used the key by Baccaro *et al.* (2015), and for the species-level identification, we compared our specimens with those in the ant collection of the *Laboratório de Ecologia de Insetos* (UFAC) and the *Museu de Zoologia da Universidade de São Paulo* (MZSP). We also received assistance from ant taxonomists: Lúvia P. Prado, Mônica A. Ulysséa and Gabriela P. Camacho. All specimens have been deposited in the ant collection at the *Laboratório de Ecologia de Insetos*.

To verify the contribution of *Rede BIA* to the knowledge of Acre's ant fauna, we conducted two comparisons: i) with the ant species list for Acre from Dutra *et al.* (2024), and ii) with the ant collection of the *Laboratório de Ecologia de Insetos*. In both cases, we determined the number of species added and calculated overall dissimilarity (β_{sor}) and its components of turnover (β_{sim}) and nestedness (β_{nes}) (BASELGA, 2010).

To assess the sampling efficiency of *Rede BIA*, we used species accumulation curves. From a species presence-absence matrix, we determined the observed number of species at each sampling site. Additionally, we estimated the species richness for all the sampling sites (n = 16) using Chao2 estimator. Given the high number of rare species (only found in one sampling site, i.e., singletons), we opted for the Chao2 estimator as it accounts for rare species and can be derived from a species presence-absence matrix (MAGURRAN, 2011). The analysis was conducted using the vegan package (OKSANEN *et al.*, 2020) in R program (R Core Team, 2023).

Rede BIA contributions

The *Rede Bia* project reported a total of 405 species, of which 152 were nominally identified and 253 were classified as morphospecies. Among the ants identified at species-level, *Rede BIA* is responsible for three new species records for Brazil: *Pseudomyrmex crudelis* Ward, 1999, *Stegomyrmex connectens* Emery, 1912, and *Strumigenys gundlachi* (Roger, 1862). Notably, *S. connectens* not only represents the first occurrence of the species in Brazil but also includes an undescribed worker of this species, which is only known from its queen and male.

Figure 3 - New ant species records for Brazil provided by *Rede Bia* project. A) *Pseudomyrmex crudelis* Ward, 1999. B) *Stegomyrmex connectens* Emery, 1912. C) *Strumigenys gundlachi* (Roger, 1862).



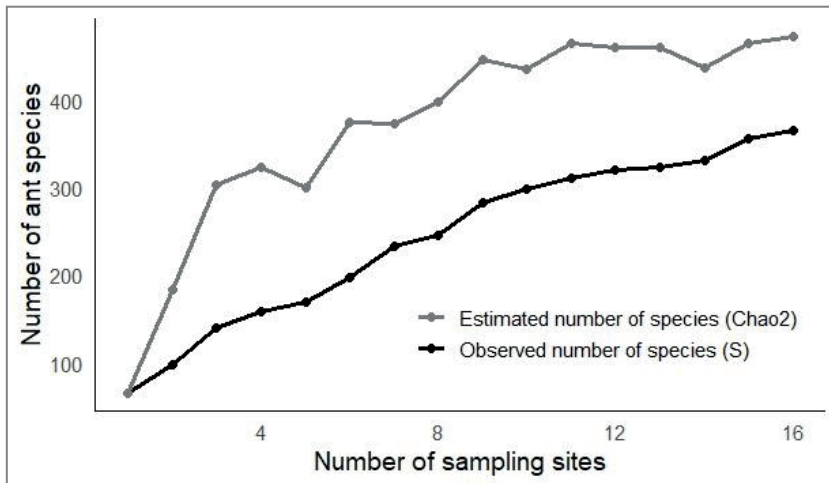
Source: Ant Web (2025). www.antweb.org.

The total dissimilarity between the ant fauna of *Rede Bia* and that reported by Dutra *et al.* (2024) was $\beta_{sor} = 0.59$, with the turnover component (β_{sim}) accounting for 0.27 and the nestedness component (β_{nes}) for 0.32, which was the major factor contributing to this dissimilarity. In absolute terms, *Rede BIA* added 40 new ant species to the list previously registered by Dutra *et al.* (2024), increasing the ant species richness in Acre to 434.

The total dissimilarity between the ant fauna of *Rede Bia* and the ant collection records of the *Laboratório de Ecologia de Insetos (UFAC)* was 0.52, with the turnover component (β_{sim}) accounting for 0.43 and the nestedness component (β_{nes}) for 0.09. This indicates that the *Rede Bia samples* greatly expanded the material available for ant identification in Acre. In total, *Rede Bia* added 66 new species to the ant collection at UFAC.

Regarding the analysis of sampling efficiency, the total number of species observed across the 16 sampling sites was 365, and the estimated richness was 472,40. Both accumulation curves (Figure 3) showed a non-stabilizing trend, indicating that more ant species are likely to be found with increased sampling effort in the region.

Figure 3 - Sampling efficiency of the Rede BIA project in Acre State, southwestern Brazilian Amazon.



Source: Authors' collections (2025).

Updated list of ant species in Acre and its potential richness

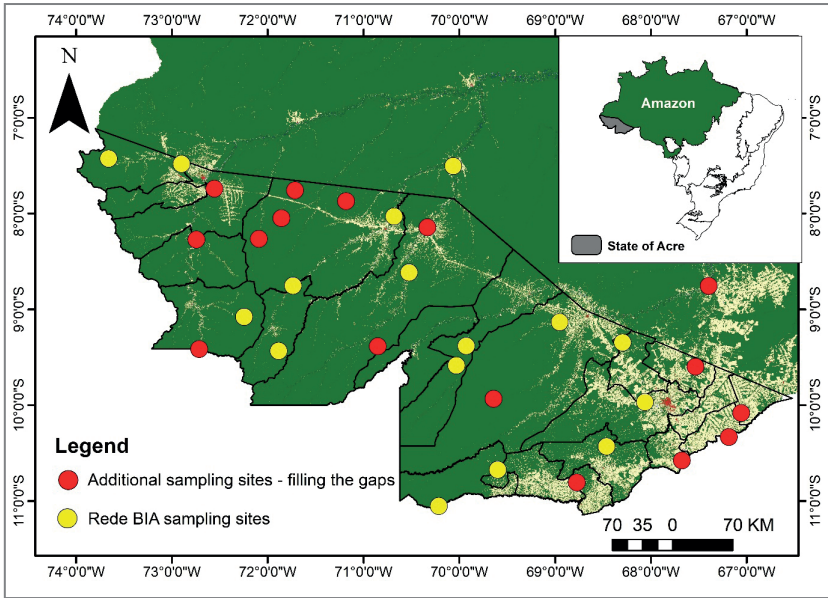
We compiled an updated list of ant species in Acre by incorporating the species occurrence records reported by Dias and Feitosa (2024) and the *Rede BIA* project to the list published by Dutra *et al.* (2024). We considered only once the occurrence of the ant species shared throughout the three species list (e.g. Dias and Feitosa 2024; Dutra *et al.* 2024; *Rede BIA* project). Altogether, these combined records resulted in a total of 479 ant species currently listed for the state of Acre (see Supplemental material: <https://doi.org/10.6084/m9.figshare.29815364.v2>). As an unorthodox attempt to calculate the potential ant species richness in Acre, we added the number of morphospecies sampled by *Rede BIA* ($n = 253$) to this compiled total, resulting in 732 potential species richness to the state. Thus, at a conservative approach, we can postulate that Acre would be the home of 750 – 800 ant species.

FINAL REMARKS

Based on both the estimated species richness from the *Rede BIA* data and the summed potential species richness for Acre, all efforts made thus far have brought us to the midpoint of our journey in documenting the ant diversity in the state. The persistent sampling gaps that still exist in the state continue to reinforce the Wallacean Shortfall (HORTAL *et al.*, 2015). However, our results indicate that southwestern Brazilian Amazon is not only the western frontier of Brazilian ant diversity, but represents one of the highest richness documented for ants with the least sampling effort applied in a single locality worldwide (DIAS; FEITOSA, 2024).

To address the remaining knowledge gaps, we propose the establishment of 16 additional sampling sites (Figure 4, in red), designed to complement the efforts of the *Rede BIA* project (Figure 4, in yellow). According to the sampling relevance analysis provided by Schmidt *et al.* (2020), almost the entire Acre's territory has high sampling relevance due to its environmental heterogeneity and lack of ant surveys.

Figure 4 - Map showing the sampling design of the Rede BIA project (yellow dots) and the 16 additional sampling sites (red dots) in Acre State, southwestern Brazilian Amazon.



Source. Authors' collections (2025).

However, the effectiveness of this complementary sampling design in yielding new ant species records depend on overcoming two key drawbacks: i) securing financial support for biodiversity inventories, and ii) developing human resources specialized in ant diversity.

In terms of financial support, the Amazon region in Brazil receives the lowest level of funding for biodiversity research (STEGMANN *et al.*, 2024). Additionally, nearly all (90-92 %) of the limited funding available in the Amazon region goes to individuals (i.e., CAPES scholarships) and institutions (i.e., CNPq Universal Grants) in Belém and Manaus (STEGMANN *et al.*, 2024). This lack of financial resources lead to sampling efforts being predominantly restricted to easily accessible areas (CARVALHO *et al.*, 2023), thereby limiting the representativeness of biodiversity surveys in regions considered to be frontiers for Amazon biodiversity.

Thus, Brazilian and international funding agencies should create targeted calls to support research projects in regions that represent frontiers for Amazon biodiversity (CARVALHO *et al.*, 2023). However, this support should

be structured carefully to avoid scientific colonialism in the Amazon, such as the dominance of research groups from outside the region or well-established institutions in Amazon in approved projects. Importantly, these calls should allocate a significant percentage of funding for people and institutions based in remote corners of the Amazon, regions that are both biodiversity frontiers and face the greatest limitations in infrastructure and human-resources. One possible requirement could be proof of formal employment at Amazon-based institutions, such as universities and regional research centers, as a criterion for eligibility. This would help ensure that projects are led by professionals who live and work in the region.

Mirroring the trends in financial support, graduate programs focused on biodiversity-related fields, such as botany, ecology, and zoology, are primarily located in Manaus and Belém. In contrast, the *Universidade Federal do Acre*, which maintained a graduate program in Ecology for over 30 years, was ultimately forced close it due to difficulties in meeting the high standards set by CAPES – *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*. This situation perpetuates scientific colonialism in the Amazon, where knowledge of biodiversity in remote areas is often advanced by research groups based outside the Amazon or well-established groups from Manaus and Belém without significant involvement or leadership from local scientists.

Our research group - Ant Ecology Group at the *Universidade Federal do Acre* - has supported the graduation of eight master's students and contributed to four doctoral theses over the past 10 years. Most of the ant records in Acre have come from projects developed by the group. However, sampling the expected or the potential ant species richness suggested by our results remains a significant challenge for this group in terms of ant taxonomy and identification to the species-level. In this context, it is essential to strengthen collaborations with major centers of ant diversity research. In this chapter, such collaboration is evidenced by the co-authorship of taxonomists and by providing the names of consulted specialists and referenced collections (see also Acknowledgments section). Additionally, securing financial support is crucial for conducting sampling expeditions across the countryside of Acre, specifically for establishing the 16 additional sampling sites recommended above.

Acre also lacks centers or institutions for biodiversity research. Most of the existing biodiversity research is conducted by professors at the two *campi* of the *Universidade Federal do Acre*, located in Rio Branco and Cruzeiro do Sul. Since 2008, with the establishment of the *Instituto Federal do Acre*, more researchers have begun exploring the Acre's biodiversity. Regarding ant diversity, to effectively document the expected or the potential ant species richness mentioned above, we suggest the establishment of at least two more research groups led by scientists with permanent positions (*i.e.*, professor or researcher) in existing biodiversity research centers in Acre.

Therefore, the challenge is huge and overcoming it depends not solely on our efforts and actions but also on financial support and the creation of job opportunities in the region. Until then, the pace toward cataloging the full extent of Acre's ant biodiversity will be slow, but we will continue to track the trails of the ants in the southwestern frontier of the Brazilian Amazon.

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