



## ECOSYSTEMS

# Knowledge Trends and Emerging Challenges in Neotropical Aquatic Insect Research: An Analysis of the VII Symposium on Neotropical Aquatic Insects

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**Abstract:** The Neotropical region harbors rich biodiversity, with aquatic insects playing key ecological roles. Despite research advances, challenges like taxonomic gaps and logistics persist. The seventh Neotropical Aquatic Insects Symposium (VII SIAN; Belém, 2025) gathered 410 participants and 364 abstracts on ecology, taxonomy, biomonitoring, and outreach. Using bibliometric techniques, the presented abstracts were analyzed. Although the SIAN aims to reflect Neotropical research as a whole, the data analyzed in this study primarily represent the Brazilian scientific community (92% of the abstracts), and interpretations should be viewed in that context. Most studies were conducted in Brazil (92%), particularly in the states of Pará, Minas Gerais, and Maranhão. Streams were the most frequently studied environments (69.4%). The most addressed insect orders were Odonata (27.7%), Trichoptera (17.5%), and Ephemeroptera (14.6%). Regarding life stages, 48.9% of the studies focused on immature forms, and 41% on adults. The most prominent research areas were ecology (31.7%) and biomonitoring (26.4%), while taxonomy, conservation, and ecological interactions were less frequently explored. The study highlights the importance of institutional partnerships and the adoption of innovative methods, such as environmental DNA and integrative taxonomy. Additionally, citizen science initiatives have contributed to raising awareness and strengthening research on aquatic insects in the Neotropical region.

**Key words:** Aquatic insects, deficits, Biodiversity, Latin America, SIAN, Brazilian Amazon.

## INTRODUCTION

The Neotropical region covers a vast area stretching from Mexico and the Caribbean to southern South America (Morrone 2017, Morrone et al. 2022). It encompasses a great diversity of terrestrial and aquatic ecosystems, including tropical forests, savannas, open fields, rivers, lakes, high-altitude environments, and coastal regions (Antonelli et al. 2018). This ecological heterogeneity, combined with a complex evolutionary and biogeographical history, has favored the emergence and conservation of unique biodiversity, making the region one of the richest in the world, hosting almost a third of global biodiversity (Raven et al. 2020). This region harbors the greatest diversity of aquatic ecosystems and unique hydrographic regions, with a varied history of colonization, species diversification, and pressure from human activities (Graça et al. 2025).

Much of the Neotropical biodiversity occurs in continental aquatic ecosystems, with insects playing a key ecological role by acting in green and detritus-based food chains and contributing to essential ecological processes such as energy flow and organic matter cycling (Cummins 1973, Wallace & Webster 1996, Jacobus et al. 2019). In addition, aquatic insects are widely used as bioindicators of environmental quality due to some characteristics, such as high abundance and diversity, ease of collection in different environments, and the presence of taxa with different tolerances to anthropogenic impacts (Rosenberg & Resh 1993, Barbour et al. 1999, Chang et al. 2013, Buss et al. 2015, Brasil et al. 2020). This group is represented by a remarkable diversity of orders, including Coleoptera, Diptera, Ephemeroptera, Hemiptera, Hymenoptera, Lepidoptera, Mecoptera, Megaloptera, Neuroptera, Odonata, Orthoptera, Plecoptera and Trichoptera, totaling more than

100,000 species described to date, representing 60% of the known species of aquatic animals (Dijkstra et al. 2014, Vatandoost et al. 2021).

The Neotropical region harbors the highest proportion of global aquatic insect diversity (Balian et al. 2008). In recent years, knowledge on Neotropical aquatic insects has increased considerably. Several reasons can explain this uprise, such as the growing number of taxonomic, ecological, biomonitoring and scientometric studies (Shimano et al. 2013, Miguel et al. 2017, Brasil et al. 2022, Mendoza-Penagos et al. 2022, Alves-Martins et al. 2024, Calor et al. 2024); the activity of societies and research groups, such as the Latin American Society of Odonata (SOL) and the Macrolatinos network; and the organization of events such as Macrolatinos meeting and the Symposium on Neotropical Aquatic Insects (SIAN), which has been held since 2012. These advances have made possible a deeper insight into the diversity, geographical distribution, and ecology of Neotropical species, and have supported strategies for conservation and environmental management (Zizka 2019). However, some challenges persist, such as gaps in taxonomic and ecological knowledge (e.g., Carvalho et al. 2023, Alves-Martins et al. 2024, Salomão et al. 2024, Sonoda 2025), highlighting the need for integrative approaches to monitor and conserve biodiversity and to conduct studies in more remote regions and ecosystems (Morales et al. 2025).

Furthermore, researchers face significant challenges when conducting studies in the Neotropics (Antonelli et al. 2018, Sánchez-Herrera et al. 2024). The vast territorial extent and complex travel logistics make data collection costly and time-consuming, especially in remote areas with no road access (e.g., Carvalho et al. 2023, Alves-Martins et al. 2024). Budget cuts and the resulting lack of long-term public policies to support scientific development are also

significant obstacles that hinder the continuity of research and biomonitoring projects in the long term (Kowaltowski 2021), including time-consuming application often for short term field work and collecting permits. The lack of investment also affects the maintenance of infrastructure in public biological collections that house collections that are fundamental bases for taxonomic studies (which indirectly affects all other types of studies) (Paknia et al. 2015). In addition, there is a large and often historically determined disparity between the different countries of the Neotropical region, leading to inequalities in the training and retention of scientists, as well as in opportunities for funding and scientific infrastructure (Turba et al. 2025). The low number of opportunities for early career scientists and the frequent dependence on external resources or international collaborations are factors that affect the expansion and consolidation of scientific knowledge in the region (De Souza et al. 2020, Nuñez et al. 2021). These problems were analyzed in detail by Sonoda et al. (2025a, b), focusing on the Brazilian context, and by Sanchez-Herrera et al. (2024), who provided a broader analysis covering the global south.

Although the Neotropical region includes many countries, most of the data and experience discussed in this study relate to the Brazilian context, where the majority of the research efforts presented at SIAN have been focused. The study of aquatic insects in Brazil has a long history, with relevant records dating back to the beginning of the 20<sup>th</sup> century. However, the formation of organized research groups only became more evident from the 1970s onwards. This nucleation process intensified in the 1990s, driven by the expansion of public higher education and the consolidation of national programs to promote postgraduate studies (Mariano et al. 2023, Marinoni & Marinoni 2024) and, in 2007, by the

REUNI program (Restructuring and Expansion of Federal Universities), promoted by the federal government.

The growing number of researchers distributed across Brazil favored the emergence of a broad network of researchers working in different regions of the country, which led to the need to create a specific space for scientific exchange: the Symposium on Neotropical Aquatic Insects (SIAN), whose first edition was held in 2012 during the XXIX Brazilian Congress of Zoology in Salvador, Bahia. Since then, the SIAN has grown and established itself as the most important event in the studies of aquatic insects, being held in different regions of Brazil: the II SIAN was in Porto Alegre (RS) in 2013 during the XXX Brazilian Congress of Zoology; the III SIAN was in Ribeirão Preto (SP) in 2015, at the University of São Paulo; the IV SIAN was in Santa Teresa (ES) in 2017, at the National Institute of the Atlantic Forest/Professor Mello Leitão Biology Museum; the V SIAN was in Paraty (RJ) in 2019, at the Casa da Cultura de Paraty (RJ); and the VI SIAN was in Ilhéus (BA) in 2022. In 2025, the event (VII SIAN) was held for the first time in the Amazon region, in the city of Belém (PA), representing an important moment of decentralization and expansion of regional representation in the field of aquatic entomology.

In this context, SIAN has established itself as one of the most important academic meetings in the field of aquatic entomology in the Neotropical region, providing space for the exchange of knowledge and discussion on the main trends and challenges in research with aquatic insects. The VII SIAN, which took place in Belém from February 17 to 21, 2025, 13 years after its first edition, was attended by 410 researchers from six countries. The program included 364 abstracts on ecology, taxonomy, ecotoxicology, citizen science and environmental education, evolution, genetics, epidemiology, ethnobiology,

biomonitoring, and scientific dissemination. The studies presented at the symposium were conducted by well-established researchers in the field as well as graduate and undergraduate students, which speaks of a growing interest among the student community, mostly working in Brazil and from different states and regions.

Given the significance of the VII SIAN for the scientific community and its recent expansion, this study analyzes the main challenges and opportunities highlighted throughout the presentations. This analysis was conducted based on seven guiding questions: (i) What is the geographic distribution of the studied areas? (ii) What types of freshwater ecosystems (e.g., streams, rivers, lakes, groundwater) were most commonly studied? (iii) Which were the most-studied orders of aquatic insects? (iv) Which taxonomic level was most commonly used in the studies (species, genus, family, order)? (v) Which life stages were most commonly studied (adults, nymphs, pupae, larvae, eggs, fossils)? (vi) Which types of studies were most commonly conducted (ecological, taxonomic, genetic, behavioral, scientific distribution and biomonitoring)? (vii) What knowledge gaps and challenges do the studies point to?

## MATERIAL AND METHODS

### Bibliometric approach

To understand the main trends and knowledge gaps in research on Neotropical aquatic insects, we conducted an analysis of the 364 abstracts presented as lectures, oral presentations, and posters during the VII SIAN. We used bibliometric techniques to evaluate the studies presented at the event. Each abstract was reviewed to extract relevant information. Based on the compiled data, we identified patterns in (i) the geographic distribution of the areas that were studied, (ii) the types of ecosystems investigated, (iii) the

insect orders most frequently addressed, (iv) the levels of taxonomic identification used, (v) the life stages of insects studied, and (vi) the types of studies conducted. Additionally, we identified the knowledge gaps and the main challenges reported by researchers (vii). Although the event aimed to represent research from across the Neotropical region, most of the abstracts (92%) were based on studies conducted in Brazil. As such, the patterns and trends identified here primarily reflect the Brazilian scientific landscape.

### Thematic Categorization

The information collected in the studies presented at the VII SIAN was classified into the following thematic categories:

*a) Taxonomic and phylogenetic knowledge.* Studies in this category highlight the shortage of taxonomists relative to the high, yet largely unknown, diversity of aquatic insects and the challenges in identifying many species. They emphasize the need for taxonomic revisions, the description of new species, the association of different life stages, and the integrative use of DNA sequences. Fossil descriptions that support the reconstruction of evolutionary history are also cited. Furthermore, these studies point to the lack of standardized techniques in aquatic insect research, which makes it difficult to integrate and compare databases, impacting the advancement of biodiversity knowledge and conservation efforts.

*b) Ecosystem conservation and management.* These studies address challenges in protecting natural ecosystems, the lack of data on endangered species, and the urgent need for more effective environmental policies. They also discuss environmental degradation, human impacts, and difficulties in establishing protected areas. The lack of government

initiatives and resources for biomonitoring is a recurring concern.

c) *Ecological and functional interactions.* This category includes studies focused on the limited understanding of species interactions and their ecological roles within ecosystems. Authors highlight the need for research on taxa occupying different trophic levels in both green and detritus-based food chains, as well as how anthropogenic pressures affect these interactions. Additional challenges include quantifying ecosystem services and predicting the ecological responses of different taxa to both natural and human-induced disturbances at regional scales.

d) *Methods and new technologies.* These studies emphasize difficulties in adopting and developing modern techniques for species identification and ecological analysis. Researchers emphasize the need to improve methods, such as molecular tools, bioacoustics, stable isotopes, and artificial intelligence for species identification and ecological pattern recognition. Challenges also included acquiring and storing genetic and morphological data, as well as the standardization of sampling protocols.

e) *Citizen science and environmental education.* Studies in this category address barriers to integrating traditional and local knowledge with scientific research, along with the limited participation of non-academic communities in research and conservation initiatives. Authors highlight the need for greater engagement of society through environmental education and citizen science activities, and advocate for inclusive policies that incorporate traditional knowledge into conservation strategies.

## Data analysis

The data extracted from the abstracts were systematized in electronic spreadsheets and organized according to the predefined thematic categories. Quantitative information on geographic distribution, ecosystem types, taxonomic orders, identification levels, life stages analyzed, and type of study was analyzed using descriptive statistics (absolute and relative frequencies). This allowed us to identify patterns and trends in the scientific production presented at the event. To visualize the geographical distribution of the studies (question i), we created a pie chart showing the countries of origin and a choropleth map showing the frequency of studies by Brazilian state. Other variables were presented graphically through infographics and descriptive diagrams, facilitating data interpretation. This mapping revealed that most contributions originated from Brazil, reinforcing the national emphasis in the dataset.

Identification of knowledge gaps and key challenges (question vii) was carried out through qualitative content analysis. We interpretatively reviewed each abstract, categorizing mentions of methodological difficulties, taxonomic limitations, data deficiencies, or specific needs according to the thematic axes defined earlier: taxonomic and phylogenetic knowledge; ecosystem conservation and management; ecological and functional interactions; methods and ecotechnologies; and citizen science and environmental education. The frequency of mentions within each category was then quantified to show the most common research gaps. All analyses were conducted using Microsoft Excel®, while graphical and geographic visualizations were produced using BioRender® and QGIS®.

**RESULTS AND DISCUSSION**

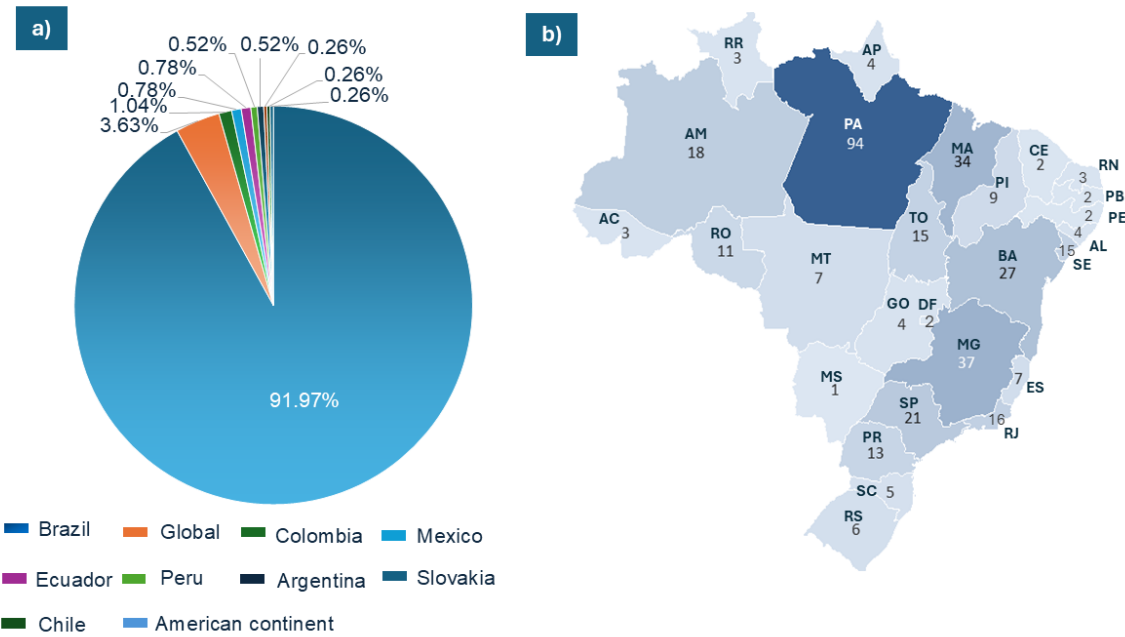
**Geographical distribution of the surveyed areas**

Although the Neotropical region encompasses several countries, the data analyzed in this study primarily reflect the Brazilian scientific community, which represented over 90% of the contributions to the VII SIAN. Therefore, many of the trends and challenges discussed here are presented from a Brazilian perspective, with broader regional implications where appropriate. Most of the aquatic insect studies presented at the VII SIAN were conducted in Brazil (n= 355; 91.97%), followed by studies with global coverage (n=14; 3.63%). Other countries represented included Colombia (n=4; 1.04%), Mexico (n=3; 0.78%), Ecuador (n=3; 0.78%), Peru (n=2; 0.52%), Argentina (n=2; 0.52%), Slovakia

(n=1; 0.26%) and Chile (n=1; 0.26%). Additionally, one study (n=1; 0.26%) specifically focused on the American continent as a whole (Figure 1).

Within Brazil, studies on aquatic insects spanned all states and the Federal District. The state of Pará concentrated most studies (n=94; 25.75 %), followed by Minas Gerais (n=37; 10.14%), Maranhão (n=34; 9.32%), Bahia (n=27; 7.40%), São Paulo (n=21; 5.75%), Amazonas (n=18; 4.93%) and Rio de Janeiro (n=16; 4.38%). States with the lowest representation were Ceará (n=2; 0.55%), Paraíba (n=2; 0.55%), Pernambuco (n=2; 0.55%), Federal District (n=2; 0.55%), and Mato Grosso do Sul (n=1; 0.27 %) (Figure 1).

Within Brazilian territory, the state of Pará stood out, with 94 studies presented, a figure partly explained by the fact that the VII SIAN was held in Belém. The location of scientific events



**Figure 1. a)** Geographic distribution of studies presented at the VII SIAN in 2025. Several studies covered more than one region or country **b)** Number of studies conducted in each Brazilian state. Several studies encompassed more than one state. State abbreviations: AC, Acre; AL, Alagoas; AM, Amazonas; BA, Bahia; CE, Ceará; DF, Federal District; ES, Espírito Santo; GO, Goiás; MA, Maranhão; MT, Mato Grosso; MS, Mato Grosso do Sul; MG, Minas Gerais; PA, Pará; PB, Paraíba; PR, Paraná; PE, Pernambuco; PI, Piauí; RJ, Rio de Janeiro; RN, Rio Grande do Norte; RS, Rio Grande do Sul; RO, Rondônia; RR, Roraima; SC, Santa Catarina; SP, São Paulo; SE, Sergipe; TO, Tocantins. On the map, states with the highest number of studies are shown in dark blue, while those with fewer records appear in progressively lighter shades.

often favors the participation of local researchers due to lower logistical costs for submitting and presenting studies (Mair et al. 2018, Johnson & Chin 2020). This pattern, also observed at other scientific events, reflects structural inequalities in the promotion of research and in the communication and dissemination of scientific knowledge (Mair et al. 2018). The so-called “proximity effect” may also account for the significant number of studies originating from the neighboring states such as Maranhão and Amazonas, which share institutional ties with the event’s host location (Terzi et al. 2013). Conversely, the underrepresentation of states in the Central-West, South, and part of the Northeast highlight’s persistent disparities in infrastructure, funding, and training for biodiversity research in Brazil (Stegmann et al. 2024). This information reinforces the importance of holding future editions of SIAN in these underrepresented regions to foster broader and more equitable participation.

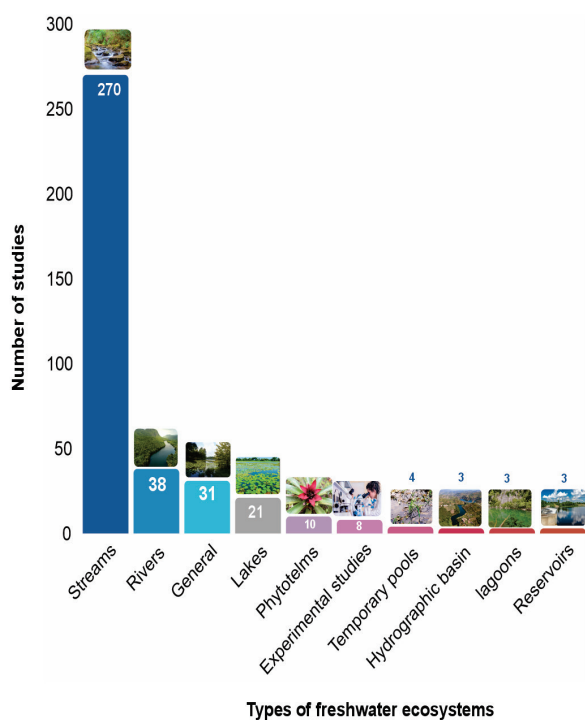
The limited participation of researchers from neighboring Neotropical countries, such as Colombia, Ecuador and Peru, also illustrates ongoing challenges to inclusion in scientific conferences (Kabo et al. 2014). In many low- and middle-income countries, the cost of attending such events can exceed the national gross domestic product (GDP) per capita, making participation financially inaccessible (Doğan et al. 2023). So, this might explain the overwhelming number of Brazilian research in SIAN events. Linguistic barriers within Latin America, particularly between Portuguese and Spanish speakers, also limit participation and knowledge exchange. This scenario underscores the urgent need for policies that promote international integration and South-South academic mobility to enable more equitable collaboration in Neotropical science. Additionally, it emphasizes the importance of

transforming SIAN into a hybrid event (both in-person and virtual). This format would broaden access to participants from diverse backgrounds and institutions, facilitating the emergence of new perspectives, fostering unconventional solutions, and ultimately advancing scientific knowledge (Blackman et al. 2020).

### **Types of freshwater ecosystems**

Most studies on aquatic insects focused on streams (n=270; 69.41%), while a smaller proportion examined rivers (n=36; 9.25%) and freshwater ecosystems in general (n=31; 7.97%), where the type specific ecosystem type was not defined. Other freshwater ecosystems were less frequently represented, including lakes (n=21; 5.40%), phytotelmata (n=10; 2.57%), laboratorial studies (n=8; 2.06%), temporary pools (n=4; 1.03%), hydrographic basins (n=3; 0.77%), ponds (n=3 0.77%), and reservoirs (n=3; 0.77%) (Figure 2). As with other analyses in this study, these patterns primarily reflect research conducted in Brazil and may not capture the full diversity of freshwater research across the Neotropical region.

The predominance of studies conducted in streams is a significant indicator of the current state of knowledge regarding tropical river basins, as these ecosystems are among the most abundant and most threatened (Callisto et al. 2019, Ferreira et al. 2023, Campos et al. 2024). On the other hand, it may also reflect a strong research preference for shallow, lotic environments (Dijkstra et al. 2014, Mazzucco et al. 2015). This pattern can be attributed to a combination of ecological, methodological, and logistical factors (Callisto et al. 2021). Streams, or igarapés as they are called in the Amazon, harbor high aquatic insect diversity, especially in tropical regions, and are highly sensitive to anthropogenic disturbances such as deforestation, diffuse pollution, and



**Figure 2. Types of freshwater ecosystems covered in the studies presented at the VII SIAN in 2025. Some studies were conducted in more than one type of ecosystem.**

land-use change (Juen et al. 2016, Castro et al. 2018, Faria et al. 2021, 2024). Globally, streams represent approximately 75% of the total length of freshwater systems (Downing et al. 2012), and they disproportionately contribute to key ecosystem services, including nutrient cycling, organic matter retention, and habitat provision for both aquatic and terrestrial organisms (Ferreira et al. 2023). At the same time, their connectivity with surrounding landscapes makes them particularly vulnerable to local human impacts.

These characteristics, together with high environmental heterogeneity and the relative ease of applying standardized sampling protocols, make streams excellent systems for biodiversity research and for assessing environmental quality through macroinvertebrates, especially aquatic insects (Maués-Silva et al. 2024). While these ecological and operational advantages

justify the widespread use of streams as model systems, the disproportionate focus on them may lead to a biased and fragmented understanding of aquatic biodiversity (Tornwall et al. 2015). Lentic ecosystems such as lakes, ponds, or less accessible systems like high-altitude phytotelmata (near canopy) and groundwater habitats, often host distinct biological communities, frequently composed of endemic or poorly known species, whose ecological role remain underestimated (Frank & Fish 2008, Dunthorn et al. 2012, Falniowski et al. 2021). The scarcity of studies in these environments limits our ability to detect broader biogeographic patterns and to understand ecological responses to environmental pressures and climate change (Jocque et al. 2013, Gebreselassie et al. 2022). It is also worth noting that lentic ecosystems tend to receive more attention in other scientific forums, such as limnological meetings, including the Argentinian Limnological Meeting and similar regional events, suggesting a disciplinary segmentation in how aquatic ecosystems are studied and discussed. Furthermore, the lack of standardized protocols for sampling in underexplored ecosystems, along with logistical challenges in accessing them, further contributes to their underrepresentation in the scientific literature (Simaika et al. 2024). With this in mind, it is essential to promote research initiatives that more comprehensively encompass a wider variety of aquatic ecosystems. This broader approach would contribute to a more complete and representative understanding of biodiversity (Chang et al. 2025).

### Investigated orders of aquatic insects

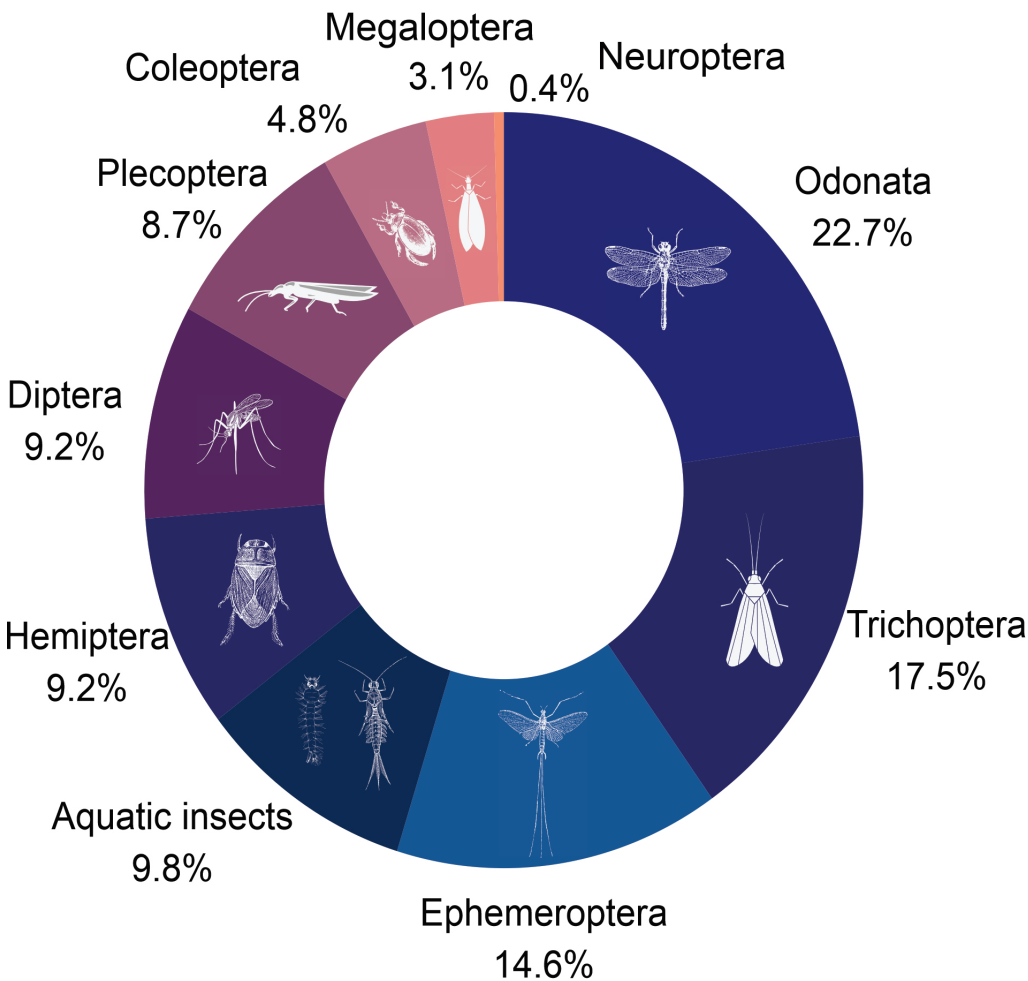
Odonata was the most studied order of aquatic insects and accounted for 27.71% ( $n=104$ ) of the studies submitted, followed by Trichoptera ( $n=80$ ; 17.47%), Ephemeroptera ( $n=67$ ; 14.63%), and studies with more than one order ( $n=45$ ;

9.83%). Other orders studied were Hemiptera (n=42; 9.17%), Diptera (n=42; 9.17%), Plecoptera (n=40; 8.73%), Coleoptera (n=22; 4.80%) and Megaloptera (n=14; 3.06%). The Neuroptera were the least represented order with only 0.44% (n=2) of the studies (Figure 3).

The majority of studies presented at the VII SIAN in 2025 focused on aquatic insects from the orders Odonata, Trichoptera, and Ephemeroptera, which together account for over half of the studies (54.8%). This predominance can be attributed to several factors. Firstly, these orders are widely recognized as bioindicators of water quality due to their greater sensitivity to environmental changes, making them good models for ecological and biomonitoring research (Kietzka et al. 2019, Munyai et al. 2025, Sayer et

al. 2025). Additionally, these orders exhibit high species richness, broad geographic distribution, and relative ease of sampling, characteristics that make them attractive study subjects for researchers (Oliveira-Junior & Juen 2019, Da Silva et al. 2024a). The prominence of these particular groups may reflect a complex combination of ecological, methodological, historical, logistical and social factors, emphasizing the need for a more critical and integrative perspective on the development of aquatic entomology in the Neotropical region (Salomão et al. 2024).

One contributing factor is the historical inertia in the training of professionals (Lagomarsino & Frost 2020). Research groups dedicated to these taxa have strengthened in recent decades, ensuring the continuity and



**Figure 3.** Orders of aquatic insects most frequently addressed in the studies presented at the VII SIAN in 2025. Several studies included more than one insect order. The category “aquatic insects” refers to studies that did not specify a particular taxonomic group.

expansion of studies in these areas (Salomão et al. 2024). Established collaborative networks, reference collections, and accumulated literature further reinforce this focus, creating a self-reinforcing cycle of specialization (García-Roselló et al. 2023). However, interpreting these patterns is not straightforward. Despite their high diversity, groups such as Coleoptera and Chironomidae remain underrepresented, which can be partly explained by factors such as taxonomic difficulties, lack of specialists and even less 'charisma' or visual appeal, especially among undergraduate students, which may affect scientific knowledge of these groups (Leather 2009, Da Silva & Ferrington 2018). In addition, the focus of studies on better-known orders reveals a taxonomic bias that has already been identified by several authors as an obstacle to a broader understanding of aquatic biodiversity (Troutet et al. 2017, Rocha-Ortega et al. 2021).

The large number of studies on Odonata can be attributed in part to the historical accumulation of available taxonomic knowledge, as well as the relative ease with which adults can be collected and identified (Cordoba-Aguilar et al. 2022), including identification keys and taxonomic compilations in Portuguese (Lencioni 2005, 2006), features that favor their use in ecological research (Oliveira-Junior & Juen 2019). In addition, the visual and behavioral attractiveness of these insects contributes to their frequent use in scientific outreach strategies and citizen science programs (Da Silva et al. 2024a, Guerrero-Moreno et al. 2024). It is no coincidence that Odonata is widely used in participatory biodiversity monitoring programs (Bried et al. 2020), such as the National Biodiversity Monitoring Program (Programa Monitora) implemented by the Chico Mendes Institute for Biodiversity Conservation (ICMBio) in federal protected areas (or Conservation

Units) (Brasil et al. 2020, Dantas et al. 2022). In addition, Odonata species are widely studied to assess and monitor anthropogenic disturbances in aquatic and terrestrial ecosystems. They have relatively well-known distribution patterns for both adults (Oliveira-Junior & Juen 2019) and larvae (Silva et al. 2021a, b, 2022) including identification keys and taxonomic compilations.

In contrast, groups such as Coleoptera, Diptera, Neuroptera, and Megaloptera were rarely addressed in the presented studies, revealing important gaps in the knowledge of aquatic insects. In the case of Coleoptera and Diptera, their low representation is not related to their diversity, which is particularly high in the Neotropical region, but rather to the relative lack of specialists working in teaching and research institutions. Although there are researchers working on aquatic Coleoptera and Diptera, the great diversity of this group requires a broader base of taxonomists, which is still limited, especially concerning groups of Diptera without medical importance. This affects the training of new specialists and contributes to the fact that there are few studies on these groups.

On the other hand, the orders Neuroptera and Megaloptera have inherently low diversity, which partly justifies the small number of studies. Although they have few species, these orders play an important ecological role but contain few known taxa, especially in remote or poorly studied areas (Jiang et al. 2022, Ascenzi et al. 2025). Another factor contributing to the underrepresentation of certain groups is related to the difficulties in collecting and identifying these animals, especially in immature stages. The lack of updated and accessible taxonomic keys for many groups and life stages continues to be an obstacle to their inclusion in more comprehensive studies (Orlofske & Baird 2013, Yeo et al. 2018, Zenker et al. 2020). However, it is important to emphasize that the number of

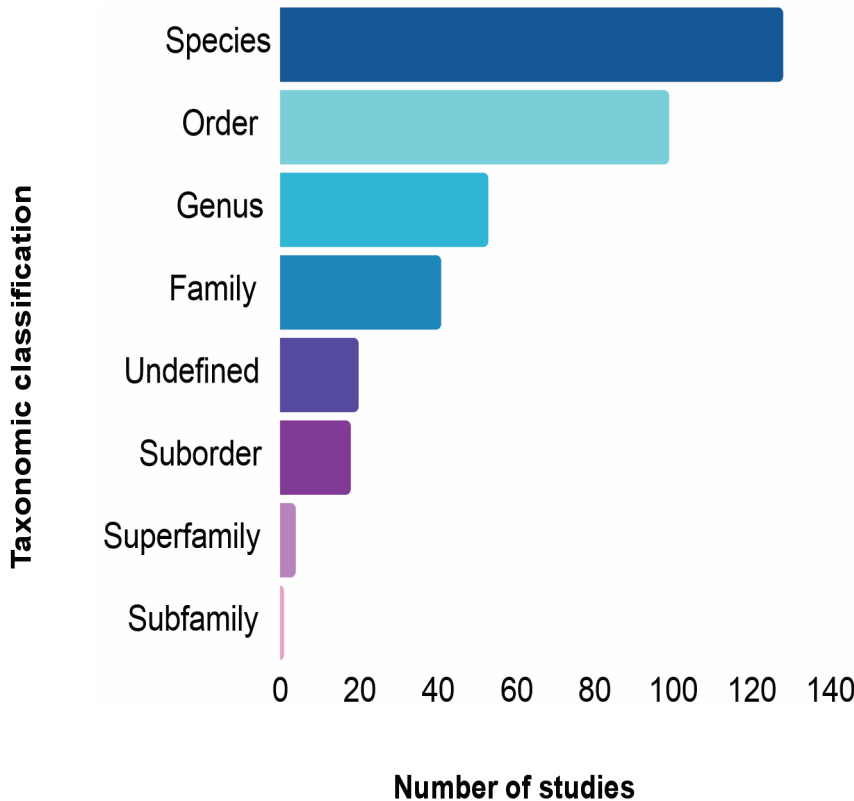
studies presented with a taxonomic focus has contributed to the development and updating of these tools. This reflects the continuous efforts of experts to expand the knowledge base and enable the accurate identification of taxa. This progress is particularly important for conducting phylogenetic analyses and for using refined taxonomic levels that enrich ecological and evolutionary interpretations.

**Taxonomic identification levels used**

Most of the studies analyzed were conducted at the species level (n=128; 35.07%), followed by order (n=99; 27.12%), genus (n=53; 14.52%) and family (n=41; 11.23% levels (Figure 4). In some cases, the taxonomic level used was not specified (n=20; 5.48%). Studies at the suborder (n=18; 4.93%), superfamily (n=4; 1.10%), and subfamily (n=1; 0.27% levels were the least frequent. The predominance of species-level studies reflects the emphasis taxonomists place

on identifications, which are essential for the development of taxonomic keys, the description of new species, and the recognition of immature stages. This focus is crucial for advancing systematics and supporting robust phylogenetic analyses, which rely on a well-resolved taxonomic framework. Moreover, the emphasis on species-level identification highlights the maturity of certain research groups and underscore the importance of taxonomic precision for conducting more detailed ecological, evolutionary, and biogeographical studies.

Accurate species-level identification is essential for analyses of diversity, endemism, and conservation, as well as for a deeper understanding of ecological relationships (Khan 2006, Gugerli et al. 2008). Many of the studies presented at the VII SIAN dealt directly with the description of new species, which necessarily requires work at this taxonomic level. These



**Figure 4. Taxonomic levels used in the studies presented at the VII SIAN in 2025.**

studies also contribute to the recognition of threatened taxa and provide the foundational data required for robust phylogenetic and biogeographic analyses (Vences et al. 2024). The focus on species-level identification thus reflects not only the advancement of taxonomy in the region but also underscores its central role in building knowledge of aquatic biodiversity in the Neotropics.

The considerable number of studies conducted at the order, genus and family levels may reflect both structural and technical limitations, as well as deliberate methodological choices made by researchers. In many cases, the selection of higher taxonomic levels is aligned with specific research questions that can be effectively addressed without species-level data (Giehl et al. 2014). However, this trend also highlights ongoing challenges in the taxonomy of Neotropical aquatic insects. These include a shortage of professionals in academic and research institutions, limiting the training of new taxonomists; underinvestment in biological collections, which restricts the availability of accurately identified material, and limited overall knowledge of tropical biodiversity, which hampers the development of reliable identification tools, especially for immature stages. Even when identification keys are available, their effective use can be hindered by the lack of specialized training, particularly at finer taxonomic levels (Rafael et al. 2009, Godoy et al. 2019).

In addition, logistical constraints in the Neotropics, such as limited access to remote areas and insufficient resources for detailed morphological analyses, often compel researchers to work at coarser taxonomic resolutions (Herrera-R et al. 2023, Sánchez Herrera et al. 2024). To address these imbalances in taxonomic knowledge, it is important to promote expert exchanges and organize training

courses across different regions and countries. This would provide to young researchers access to the needed tools and knowledge for accurate taxonomic identification of aquatic insects, enabling them to contribute to the development of new research lines and methodological approaches (e.g., z-stack microscopy, scanning electron microscopy, and micro-computer tomography), particularly for understudied groups.

The chosen level of taxonomic identification has direct implications for the ecological interpretation and practical application of study results (Carreira-Flores et al. 2024). Studies with low taxonomic resolution may underestimate ecosystem diversity and reduce the effectiveness of biomonitoring programs based on bioindicators (Guerold 2000; Jones 2008). On the other hand, in rapid assessment scenarios or regions where taxonomic knowledge remains limited, such studies can still yield valuable preliminary data to guide future research (Biaggini et al. 2007). In ecological integrity assessment using multimetric indices, family-level identifications have been shown to be sufficient, allowing for faster results and more timely societal responses (Martins et al. 2020, Albuquerque et al. 2021).

### **Life stages studied**

Most of the studies presented focused on organisms in the larval or nymph stage (n=199; 49.38%), followed by the adult stage (n=167; 41.03%), while 8.35% (n=34) of the studies did not specify the life stage examined (Figure 5). The least studied stage was the egg stage (n=1; 0.25%). Exuviae (n=1; 0.74%), and fossil material (n=1; 0.25%) do not represent life stages but they were included here as they refer to the type of material analyzed, aligning with the objective of reflecting the biological focus of the studies.

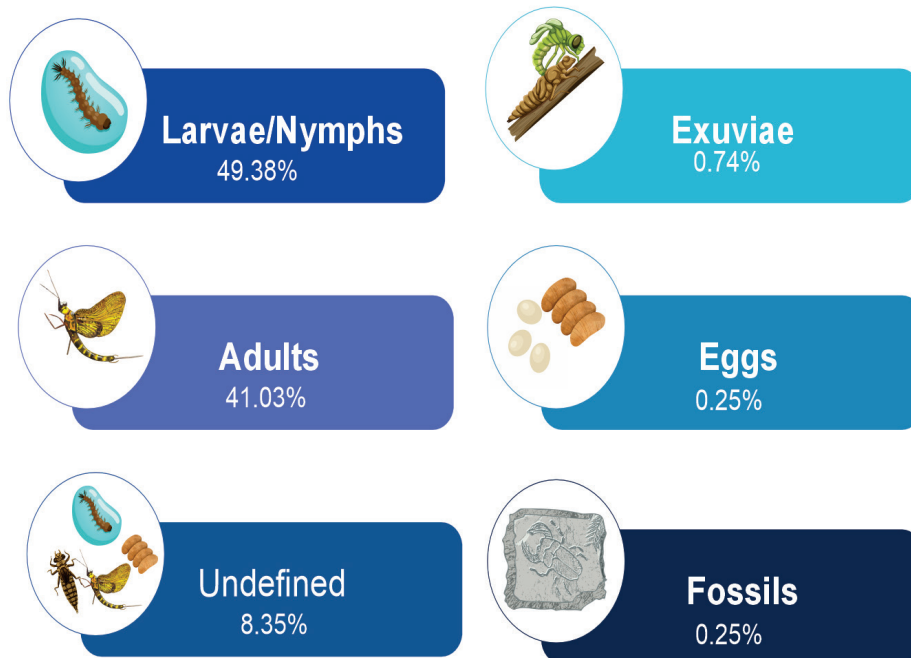
Although grouping these categories with true life stages facilitates data visualization and graphical representation, it is scientifically important to clearly define such classifications in order to avoid misinterpretation related to life cycles and population dynamics (Kendall et al. 2019).

The clear preference for larval and adult stages can be attributed to ecological, methodological, and taxonomic factors. Bioindicator species are effective regardless of life stage, as they are sensitive to environmental changes and capable of rapidly responding to fluctuations in water quality and habitat conditions (Buss et al. 2015). However, the larval stage presents specific advantages for research, such as higher abundance, ease of sampling in shallow aquatic environments, particularly streams and creeks, and the availability of standardized protocols that favor studies focusing on this life stage (Callisto et al. 2021).

Adult stages are also well represented in the studies, largely due to their importance in taxonomy and systematics. In many orders, such

as Odonata, Trichoptera, and Ephemeroptera, accurate species-level identification depends on adult morphological traits, including wing structure, genitalia, and distinctive color patterns. These diagnostic characteristics are typically absent in immature forms. Additionally, well-established identification keys are available for adults of Anisoptera (Garrison & Von Ellenrieder 2015, Garrison et al. 2006) and Zygoptera (Lencioni 2005, 2006, 2017), facilitating refined taxonomic resolution. Such precise identification is crucial for robust analyses on geographic distribution and biogeographic patterns, as accurate species recognition is fundamental to mapping their occurrences. Furthermore, adults are the main dispersal agents and are responsible for colonizing new habitats, making them central to studies investigating spatial occupation processes (Monteiro et al. 2016, Harabiš 2017, Garcia Junior et al. 2019, Oliveira-Junior & Juen 2019).

In contrast, other stages or categories analyzed, such as eggs, exuviae and fossils, were notably underrepresented. Exuviae are



**Figure 5.** Distribution of life stages and other categories investigated in studies presented during the VII SIAN in 2025. Some studies encompassed multiple life stages or developmental stages of the taxa analyzed.

remnants of immature stages and they provide valuable indirect information, including population abundance, structure and even genetic diversity, without the need to collect live organisms (Sittenthaler et al. 2023). They are also used to associate immature stages with adults. Fossils, on the other hand, provide critical historical insights for evolutionary and biogeographic reconstruction, contributing to a deeper understanding of present-day aquatic biodiversity from a historical and evolutionary perspective (Faurby et al. 2024).

The number of studies that did not specify the life stage, categorized as “undefined”, also deserves attention. This highlights a significant methodological limitation, as the absence of this information hinders comparative and integrative analyses that are essential for the advancing knowledge on aquatic insects in the Neotropical region.

In summary, the predominance of studies focusing on larval and adult stages reflects both practical and methodological considerations, as well as long-standing scientific priorities. However, the less-represented categories also offer valuable opportunities for conceptual advancement and for conducting deeper ecological, evolutionary and paleoenvironmental investigations.

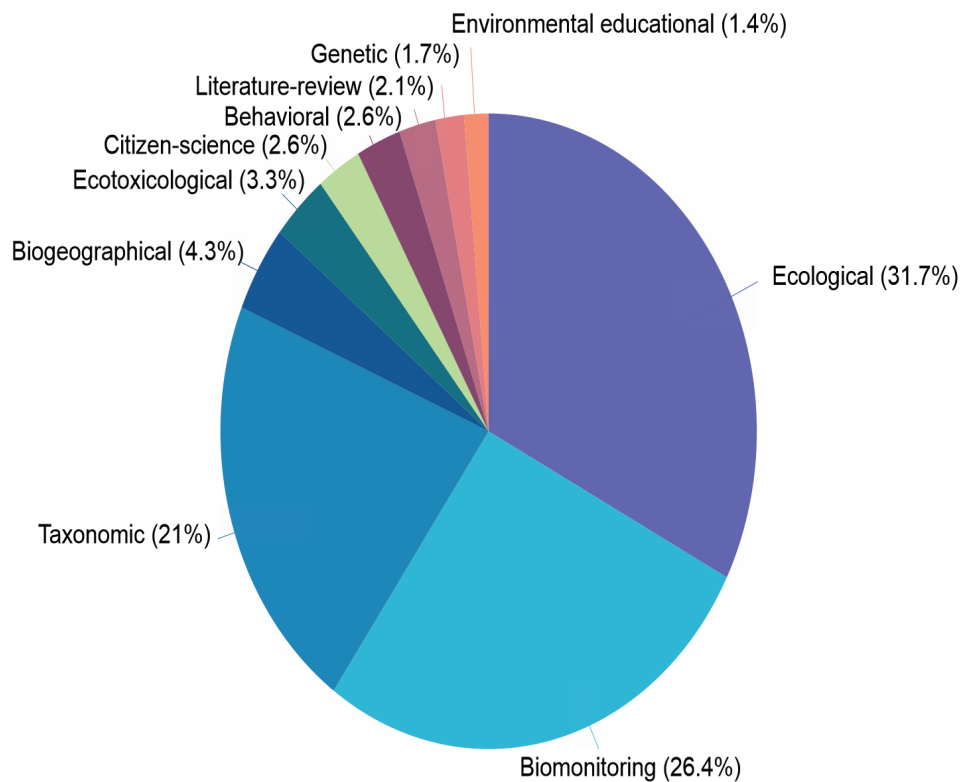
### **Types of studies performed**

The ten most frequent types of studies on aquatic insects were centered on ecology (n=133; 31.67%) and biomonitoring (n=111; 26.43%), followed by taxonomic (n=88; 20.95%), biogeographic (n=18; 4.29%) and ecotoxicological (n=14; 3.33%) studies (Figure 6). Other types of studies, such as citizen science (n=11; 2.62%), behavioral studies (n=11; 2.62%), Literature-review (n=9; 2.14%), genetic studies (n=7; 1.67%), and environmental education (n=6; 1.43%) were also recorded, although less frequently.

It is important to note that this distribution may partially reflect a bias associated with the nature of the event, which traditionally attracts researchers primarily from the fields ecology, biomonitoring, and systematics. Areas such as ecotoxicology or genetics may be more prominently represented at events specifically dedicated to those disciplines. Therefore, the results presented here reflect research trends within the scope and target audience of the VII SIAN and not necessarily represent the broader scientific output on aquatic insects in the Neotropical region.

Although the event aimed to represent Neotropical research, most contributions were from Brazil, which may influence the relative representation of each study type. There is a well-established trend toward prioritizing ecological and biomonitoring approaches within Neotropical aquatic entomology. This pattern reflects a strongly applied research orientation, emphasizing the assessment of anthropogenic impacts and the use aquatic insects as bioindicators of environmental quality, particularly in tropical lotic ecosystems such as Amazonian streams (Chakravarty & Gupta 2024, Salomão et al. 2024, Santos-Silva et al. 2025). The predominance of these two approaches suggests both methodological maturity and practical relevance, supporting water resource conservation and management policies. Recent studies have demonstrated that aquatic insects, due to their high sensitivity to environmental changes, serve as effective tools for diagnosing and monitoring water quality, and are essential for informing conservation and management strategies in freshwater ecosystems (Sánchez Herrera et al. 2024, Sayer et al. 2025). This pattern reflects a research orientation that may be applied or theory-driven.

On the other hand, the significant proportion of taxonomic studies indicates that, despite the



**Figure 6. Categories of studies presented at the VII SIAN in 2025. Note that some studies fell into multiple categories.**

growing emphasis on ecological applications, research progress continues to depend heavily on foundational knowledge (Castro et al. 2020). Persistent taxonomic gaps in the Neotropical region demand ongoing efforts to describe, identify, and systematize its biodiversity (Dijkstra et al. 2014, Duffus et al. 2023). The strong representation of taxonomic studies also reinforces the essential role of taxonomy as a foundational pillar for other research domains, including biomonitoring, genetics, and conservation (Jijón et al. 2025).

The low frequency of studies in areas such as genetics, citizen science, environmental education, and systematic reviews reveals a limited incorporation of innovative methodologies, synthesis-based research, and socially engaged approaches. This scenario suggests that current research on Neotropical aquatic insects still lacks a truly transdisciplinary perspective that integrates molecular, social, and educational dimensions into the study of

aquatic biodiversity (Yates et al. 2015, Krueger et al. 2016). In addition, the underrepresentation of citizen science and environmental education initiatives underscores the need to strengthen the connection between academia and society, enhancing participatory monitoring, local knowledge recognition, and inclusive data generations (Sonoda et al. 2021, Da Silva et al. 2024b, López-López et al. 2024). Therefore, while the results indicate the maturation of ecological and biomonitoring approaches in aquatic insect research, they also highlight the importance of fostering complementary, interdisciplinary strategies (França et al. 2019). Promoting studies that incorporate genetics, behavior, education, and public engagement can expand the scope of the knowledge produced, enhance its societal relevance, and contribute to a more integrated and comprehensive understanding of aquatic insects and the ecosystems they inhabit (Mansourian et al. 2019, Marske et al. 2023, Sitar & Rusu 2023).

### Knowledge gaps and main challenges identified

According to the researchers, the most critical issues requiring further attention in the study of Neotropical aquatic insects include “taxonomic and systematic gaps” (n=244; 50.31%), challenges related to “ecosystem conservation and management” (n=82; 16.91%), and the need for a deeper understanding of “ecological and functional interactions” (n=69; 14.23%). In addition, the importance of “citizen science and community participation” (n=64; 13.20%) and the advancement of “methods and technology in research” (n=26; 5.36%) were also highlighted (Figure 7).

The results reveal that the most recurrent knowledge gap in the research presented at the VII SIAN relates to taxonomy and systematics, highlighting one of the most persistent structural

issues in Neotropical aquatic entomology. This gap stems from a shortage of specialized taxonomists, the lack of updated identification keys and the limited availability of digitized data from biological collections, all of which hinder accurate species identification, life stage association, and the description of new taxa (Cardoso et al. 2011, Hortal et al. 2015, Faria et al. 2020, Engel et al. 2021).

The second major challenge identified is the limited understanding of the life histories and ecological traits of most South America aquatic insect species, which constrains our ability to interpret their ecological roles and responses to environmental changes. This knowledge deficit directly hampers the advancement of other research lines, such as biomonitoring, which depends on the accuracy of organism identification, and conservation, which requires



**Figure 7.** Main knowledge gaps and research challenges identified by contributors to the VII SIAN in 2025. Multiple gaps or challenges were reported in some studies.

detailed diagnoses of local biodiversity (Robinson 2023, Sánchez Herrera et al. 2024, Simaika et al. 2024).

The third major challenge identified pertains to ecosystem conservation and management, which is often rooted in the lack of foundational knowledge about community composition and ecosystem functioning. The limited translation of scientific knowledge into practical management tools, combined with weak collaboration between researchers and policymakers, hinders the implementation of evidence-based environmental policies (Collins et al. 2019, Khomsi et al. 2024). Closely related is the challenge of understanding ecological and functional interactions among Neotropical taxa. Aquatic insects are still predominantly studied as environmental indicators, while their ecological functions, such as organic matter decomposition, herbivory, and nutrient cycling, remain largely underexplored, especially in complex tropical ecosystems (Ramírez & Gutiérrez-Fonseca 2014, Yang & Gratton 2014, Crespo-Pérez et al. 2020).

The four are related to citizen science and community participation, as well as the use of advanced research technologies, highlighting two complementary gaps. The first reflects the limited involvement of civil society in knowledge production, whether through participatory monitoring, environmental education, or the integration of traditional and local knowledge (Da Silva et al. 2024b, Guerrero-Moreno et al. 2024, Cancio et al. 2025). The second concerns the underutilization of emerging technologies, such as metabarcoding, environmental DNA (eDNA), field apps, and automated image analysis, which could enhance the scale, accuracy, and frequency of biodiversity surveys. Together, these challenges reveal a methodological and epistemological stagnation in aquatic entomology, which remains largely centered on

conventional approaches (Hansen et al. 2020, Moolna et al. 2020, Roy et al. 2024). Overcoming these obstacles requires coordinated strategies that support the training of new specialists, strengthen funding of biological collections, develop genetic databases of poorly represented Neotropical species, expand collaborative networks, and promote interdisciplinary research. Strengthening taxonomy, alongside the adoption of innovative technologies and deeper engagement with local communities and decision-makers, can foster a more inclusive and responsive science that addresses the socio-environmental challenges of the Neotropical region.

In line with broader analyses (e.g., Tekwa et al. 2023), the five challenges identified in the studies presented at the VII SIAN emphasize the urgency of policies that support long-term research initiatives, citizen science programs and science communication projects that actively engage local communities in research and monitoring. Such efforts can foster more critical citizenship by promoting the participatory construction and appropriation of scientific knowledge (Giardullo et al. 2023). In addition, the irregular availability of research funding, scholarships and local employment opportunities, as well as inadequate infrastructure in parts of the Neotropics, continue to impede the continuity of growth of research efforts. The integration of modern approaches, such as the use of environmental DNA and metabarcoding, offers promising solutions to some of these barriers by enabling faster and more accurate biodiversity assessment. However, their application in hyper diverse ecosystems like the Neotropics is not without challenges, including high financial costs that remain a barrier for many researchers. Complex community compositions, high species richness, and limited reference databases can constrain the resolution and reliability of

these techniques (Jijón et al. 2025). Therefore, while these tools are valuable, their use must be critically assessed and complemented with traditional approaches to ensure accuracy and robustness in biodiversity studies.

In summary, the VII SIAN demonstrated that promoting the integration and expansion of knowledge on aquatic insects in Neotropics requires fostering international and inter-institutional collaborations, improving access to funding, and supporting initiatives that train new researchers. Furthermore, encouraging the publication of systematic reviews and meta-analyses can help synthesize existing knowledge and clarify future directions for gaps and research on Neotropical aquatic insects.

## REFLECTIONS AND FUTURE PERSPECTIVES

It is important to note that while SIAN aims to represent research from across the Neotropical region, the majority of data analyzed here are derived from Brazil. Future editions should strive to expand international participation and foster broader regional comparisons. This article highlights the growing importance of research on aquatic insects in the Neotropical region, pointing to significant progress while acknowledging persistent challenges. The predominance of studies focusing on specific regions and lotic ecosystems underscores the need for greater geographic and thematic diversification to achieve a more comprehensive understanding of the spatial and temporal distribution of aquatic insects at multiple scales. Furthermore, the underrepresentation of certain taxonomic groups reinforces the importance of expanding research efforts to include a broader range of aquatic insects, as well as deepening knowledge about the life histories and distributions of already studied taxa.

As this study is based solely on abstracts presented during the VII SIAN, the scope of the results may be limited, since other relevant studies may have been published in different scientific forums. Additionally, variations in writing style and level of detail across abstracts may have influenced the categorization of some data. Despite these aspects, we implemented standardization and internal validation strategies to ensure consistency. We believe that results presented here offer a representative and valuable synthesis. However comparative analyses across different SIAN editions will be essential to identify long-term trends and emerging research priorities. Addressing the logistical and financial barriers faced by researchers in the Neotropics requires long term, innovative funding mechanisms and collaborative strategies. In this context, partnerships with private institutions, environmental agencies and government organizations have proven to be fundamental to enabling research and expanding knowledge of aquatic entomology. Collaborations with the private sector, for example, have made scientific projects feasible and supported students' scholarships, contributing to the training of new researchers and advancing the fields of biodiversity and sustainability. By integrating science, industry, and various societal sectors, this collaborative model has the potential to enhance environmental monitoring capacities through the application of new technologies, including environmental DNA, citizen science, bioacoustics, remote sensing, and artificial intelligence to identify, model, and predict ecological patterns. These approaches would not only optimize data collection and analysis in remote areas, but also support the development of more accurate and accessible solutions for conserving Neotropical aquatic ecosystems. This model should be strengthened and expanded

across other regions and sectors. Such collaborations should be further encouraged and diversified to ensure broader geographic inclusion and equitable resource distribution across Neotropical countries.

To further systematize and amplify these efforts, scientific events such as SIAN should incorporate structured workshops that foster collaboration and lead to the co-authorship of joint publications. These workshops can provide targeted mentorship for early-career researchers, enhance scientific writing skills, and focus on addressing key knowledge gaps identified during the event. Expanding and replicating this model to other regions and sectors will be critical to ensure a more inclusive, integrative, and impactful scientific agenda for Neotropical aquatic biodiversity.

Furthermore, partnerships with governmental institutions such as the Brazilian Forest Service (SFB), the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA), and the Chico Mendes Institute for Biodiversity Conservation (ICMBio) have facilitated researcher access to remote and protected areas of the Amazon (Brasil et al. 2020). For example, under the Monitora Program, the ICMBio may offer logistical and operational support for long-term environmental monitoring in floodplains and streams (Brasil et al. 2020), enabling the generation of strategic data that also support decision-making by protected area managers (Roque et al. 2018) for the conservation of aquatic ecosystems (Dantas et al. 2022). It is also important to emphasize that environmental monitoring data collected by public and private entities, especially those tied to environmental licensing, can be integrated into broader networks, thereby enriching the available information and expanding opportunities for analysis and integrated biodiversity management. Partnerships with

governmental institutions such as the Brazilian Forest Service, as well as regional and bi-national agreements involving other Neotropical countries, are also crucial for ensuring access to remote areas, harmonizing monitoring protocols, and promoting transboundary conservation initiatives.

The consolidation and expansion of institutional and intersectoral partnerships, combined with the strengthening of collaborative networks and the implementation of sustainable financing policies, are essential to ensure the continuity and improvement of research in the Neotropical region. In this scenario, SIAN stands out as a strategic space for scientific and human articulation, working as a venue for the dissemination of results, but also as an observatory of trends in aquatic entomology, where emerging collaboration networks, methodological innovations and promising paths for science applied to conservation are revealed. In the coming years, SIAN is expected to further consolidate itself as an instrument for continuous monitoring of scientific production and integration between academia, the productive sector, environmental agencies, local communities and civil society. Beyond its technical and scientific role, SIAN fulfills an irreplaceable function as an in-person event, as it enables the reinforcing interpersonal and emotional connections within the community, creating a space for mutual support, mentorship, and shared purpose. Moreover, the exchange of cultural and practical field experiences is essential for building a diverse and cohesive scientific community. In this sense, SIAN constitutes a representative meeting point, a catalyst for human and scientific connections that are fundamental for the advancement of Neotropical aquatic entomology.

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## Statements declarations

We declare that the manuscript reports unpublished work that it is not under active consideration for publication elsewhere, nor has it been accepted for publication, nor been published in full or in part. We assume the compromise of sending it for English correction at a professional service upon acceptance.

All authors and relevant institutions have read the submitted version and approve of its submission and all persons entitled to authorship have been included. The work conforms to the legal requirements of the country in which it was carried out.

## Data availability

All data related to the bibliometric variables measured from the abstracts submitted to the Symposium are available in the official Book of Abstracts. Additional information or access to specific data can be requested by contacting the corresponding author via email.

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