Knowledge gaps in research on Trichoptera (Insecta) in Brazil

Laura Almeida de Oliveira[1], Daniel Silas Veras[2], Lucas Ramos Costa Lima[3]

Abstract

This study aimed to evaluate scientific production in the different sub-areas of biological sciences of the order Trichoptera in the last 10 years, with an emphasis on research in Brazil. The study data were obtained from the Web of Science platform, which was searched by publications that included the term "Trichoptera" worldwide and in Brazil, with the category of country being generated by the system. All data were verified by refining the search parameters. An overall (worldwide) total of 1,811 publications were identified between 2007 and 2017, of which, 196 referred to research conducted in Brazil, up to the date of the survey. The production of articles on trichopterans, both worldwide and in Brazil, and their scientific repercussions, grew over the 10-year period surveyed, during which, the taxon was referred to in 14,739 citations. Data on the trichopterans were produced mainly in the United States and Brazil. In Brazil, this growth was driven primarily by research in the Southeastern and Northern regions. Biodiversity was the field of research covered by most studies. Waringer and Wolfram Graf were the authors who contributed most papers, worldwide, and Jorge Nessimian was the principal Brazilian author. Despite the growing interest in the trichopterans, there are still many knowledge gaps to be overcome, and it will be necessary, in particular, to increase survey efforts in less well-known regions, stimulate interest in neglected subareas of biological research, and train more personnel, in order to guarantee the long-term conservation of the biological diversity of this group.

Keywords: Biodiversity; Knowledge deficits; Aquatic insects.

Lacunas de conhecimento nas pesquisas sobre Trichoptera (Insecta) no Brasil.
Este estudo objetivou avaliar a produção científica nas diferentes subáreas das ciências biológicas da ordem Trichoptera nos últimos 10 anos, com ênfase em pesquisas no Brasil. Os dados do estudo foram obtidos na plataforma Web of Science, que foi pesquisado por publicações que incluíam o termo "Trichoptera" mundialmente e no Brasil, com a categoria de país sendo gerada pelo sistema. Todos

[1] Mestranda em Biodiversidade UFOPA, Santarém, PA, Brasil, lauraalmeidaoliver@gmail.com

[2] Laboratório de Ecologia de Comunidades, IFMA Campus Caxias, MA – 340, KM 02, gleba Buriti do Paraíso, Povoado Lamengo – Zona Rural, CEP 65600-000, daniel.veras@ifma.edu.br

[3] Prof UESPI Campus Heróis do Jenipapo, Avenida Santo Antônio s/n São Luís, Campo Maior - PI, 64280-000, lucaslima_86@hotmail.com

os dados foram verificados pelo refinamento dos parâmetros de pesquisa. No total (mundial), 1.811 publicações foram identificadas entre 2007 e 2017, das quais 196 referiram-se a pesquisas realizadas no Brasil, até a data da pesquisa. A produção de artigos sobre tricópteros, no mundo todo e no Brasil, e suas repercussões científicas, cresceu ao longo dos 10 anos pesquisados, durante os quais o táxon foi referido em 14.739 citações. Os dados sobre os tricópteros foram produzidos principalmente nos Estados Unidos e no Brasil. No Brasil, esse crescimento foi impulsionado principalmente por pesquisas nas regiões Sudeste e Norte. A biodiversidade foi o campo de pesquisa coberto pela maioria dos estudos. Waringer e Wolfram Graf foram os autores que mais contribuíram com artigos, em todo o mundo, e Jorge Nessimian foi o principal autor brasileiro. Apesar do crescente interesse nos tricópteros, ainda existem muitas lacunas de conhecimento a serem superadas, como aumentar o número de estudos em regiões menos exploradas, o interesse em campo de pesquisa em diversas subáreas biológicas e a intensificação de recursos humanos, a fim de garantir ao longo conservação a longo prazo da diversidade biológica desse grupo.

Palavras-chave: Biodiversidade; Déficit de conhecimento, Insetos aquáticos.

1. Introduction

The insect order Trichoptera Kirby, 1813, known as the caddisflies, comprises a large group, which are distributed throughout all zoogeographic regions, with 3,262 species in the Neotropical region (HOLZENTHAL & CALOR, 2017). In Brazil, a total of 817 trichopteran species have been recorded up to now, of which, 488 are endemic, distributed in 16 families and 70 genera (SANTOS, 2020). The species of this group are referred to as "ecosystem engineers", because their larvae build portable cases or shelters, using modified salivary glands to produce silk used to bind materials such as leaves, fragments of twigs, and sand, activities that modify the habitat, by altering the flow dynamics of the body of water, for example, or decreasing the availability of resources for other organisms (MACKAY & WINGGINS, 1979; MOORE, 2006).

Caddisflies play an important role in lotic ecosystems, where they are fundamental in the transfer of energy between different trophic levels, and present the greatest functional diversity of any group of aquatic insects (CALOR, 2007). Caddisfly eggs and larvae also serve as food for many species of fish, making them an important link in the food webs of freshwater environments (DOMINGUEZ & FERNANDEZ, 2009). The composition and distribution of trichopterans in aquatic environments are of fundamental importance for ecological processes,

and the species richness, abundance and trophic levels of this group are associated with the conditions and resources available in the habitat, and are influenced by the changes that occur in the ecosystem (NOGUEIRA & CABETTE, 2011).

Overall, the number of studies on caddisfly taxonomy (KELLY et al., 2018) and ecology (GODOY et al., 2018) has remained stable over the past 10 years. In Brazil, by contrast, publications on trichopteran taxonomy and checklists (e.g., NETO et al., 2017; NETO & PASSOS, 2018; DESIDERIO et al., 2018) and ecology (e.g., JUEN et al., 2013; BRASIL et al., 2018) have increased over the past five years. In general, then, while the production of scientific knowledge on trichopteran biodiversity has remained constant, worldwide, research has grown in Brazil.

The most effective way to quantify this production is through a scientometric approach. This scientific approach analyses quantitative aspects of activities related to education, technology, science, and innovation. Indicators of this type have become indispensable for the evaluation of scientific productivity and the generation of knowledge, providing important insights into the distribution of research efforts, and in particular, the gaps that exist in specific fields of knowledge (SANTOS et al., 2012; SHIMANO et al., 2013).

The present study investigates the recent production of papers (2007–2017) in different sub-areas of the scientific research on order Trichoptera with emphasis on the research in Brazil. The data were obtained from the Web of Science platform. The principal aim was to identify the main knowledge gaps in the current literature on Brazilian caddisflies.

2. Material and Methods

We conducted a literature search of the Thomson "Institute for Scientific Information – ISI" database (http://portal.isiknowledge.com), based on the abstracts, titles, and keywords of papers published between 2007 and 2017. Papers presenting the combination of words "Trichoptera" and "Brazil*" were selected using the "country" category in the database. The data were analyzed based on categories, including the year of publication of the paper, the authors, country, the language in which the study was published, the area of research, and citations.

The papers that referred to research in Brazil were classified manually according to the region in which the study was conducted. When the title of the paper did not refer to the Brazilian region or state in which the research was conducted, the abstract or other parts of the text

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were read to determine the geographic area of the study. Where this area coincided with two or more different Brazilian states or regions, both were inserted into the database.

Four main scientometric parameters were defined in the present study: (i) the number of papers published on trichopteran biology in Brazil and worldwide, between 2007 and 2017, (ii) the variation in the number of citations that referred to the order Trichoptera over the past 10 years, (iii) the contribution (number of papers) of each author, and (iv) the research areas with the most papers.

A simple linear regression was applied to the data to verify whether the number of citations was related to the number of papers published. The assumptions of normality and homoscedasticity were tested prior to this analysis (ZAR, 2010), which was run in the R statistical environment (R DEVELOPMENT CORE TEAM, 2016).

3. Results and Discussion

A total of 1,811 publications on the Trichoptera were identified in the Web of Science data platform, of which, 196 referred to research conducted in Brazil. During the period covered by the present study, publications peaked worldwide in 2016, when 235 papers were published, representing 12.97% of the total. In Brazil, the peak year was 2017, when 35 papers were published, corresponding to 17.85% of the total (Figure 1).

During the study period, the trichopterans were referred to in 14,739 citations, a mean of 1,400 per year (Figure 2). There was a systematic relationship between the number of publications on trichopterans in a given year and the number of citations that referred to the taxon (r^2 = 0.528, p = 0.011). The papers cited most frequently referred to research on ecological and taxonomic phenomena (Table 1).

The four countries with more publications (Figure 3) were the United States with 26.67% of the total (n = 483), Brazil with 10.82% (n = 196), Germany with 7.67% (n = 139), and Canada, with 5.52% of the total (n = 100). Six other countries produced between 72 and 93 papers during the study period – Sweden (n = 72), Australia (n = 74), Austria (n = 80), Spain (n = 81), China (n = 82) and Japan (n = 93) – and together accounted for 26.58% of the total production of papers.
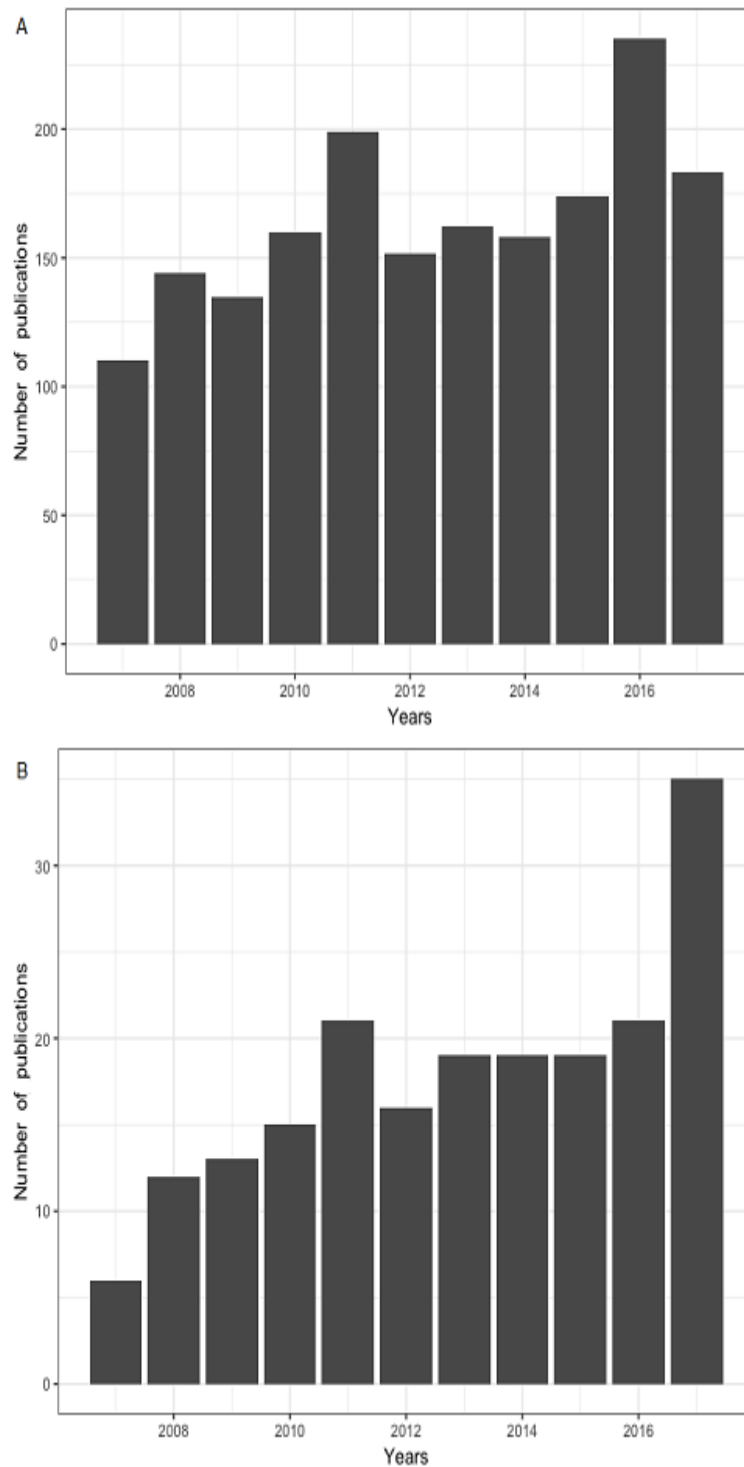
Figure 1 Variation in the number of scientific papers published on the order Trichoptera berween 2007 and 2017: A) Worldwide total; B) Brazil only.
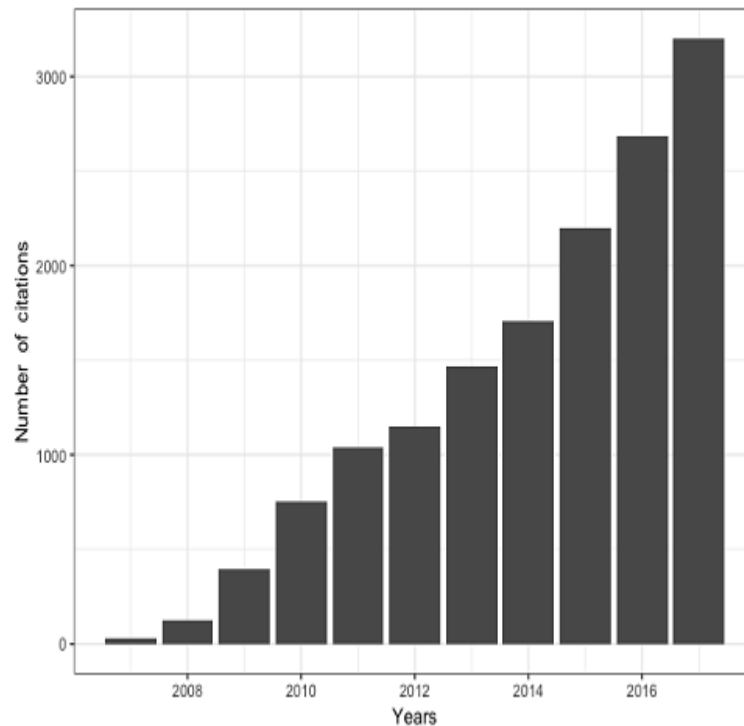
Figure 2. Number of citations identified between 2007 and 2017 that referred to the order Trichoptera.

In Brazil, most of the studies identified in the literature search referred to research conducted in the Southeast region (n = 43%), which accounted to more than twofifths of the total, followed by the North (n = 20%), Northeast (n = 16%), Midwest (n = 11%), and South (10%) regions. The southeastern states of São Paulo and Rio de Janeiro provided the most studies overall. The principal authors that contributed the most papers on trichopterans are identified in Table 2.

A third of the papers identified in the present study (33%) reported research in biodiversity (Figure 3). The next most popular fields were ecology (27%), taxonomy (19%), biology (16%) and morphology (5%).

Our literature search found an increase in the number of papers published on trichopterans worldwide, between 2007 and 2017, with Brazil following the same trend. This growth in the scientific interest in trichopterans is likely related to the importance of this order in the energy flow and matter cycling of aquatic ecosystems (FUJINO et al., 2018; UENO et al., 2018), as well as its potential as a bioindicator of water quality (HOLZENTHAL & CALOR, 2017; SIDERS et al., 2018), as well as increasing anthropogenic pressures on natural ecosystems. An additional factor in Brazil may have

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been the growth in the number of graduate programs during the study period (CIRANI et al., 2015), which is reflected in the training of specialists in trichopteran taxonomy by these programs, supported by leading experts in the biology of aquatic insects, such as Dr. Nessimian, Dr. Hamada, and Dr. Froehlich. As a consequence, these research groups have begun to branch out increasingly, establishing a network of independent researchers (e.g. ALBINO, 2011; CALOR, 2016; CAVALCANTE et al., 2017; ROCHA et al., 2017; NETO et al., 2017).

Table 1. The scientific papers on trichopterans with the largest number of citations (NC) between 2007 and 2017.

Authors	Area	Journal	NC
Bonada, Rieradevall & Prat, (2007).	Ecology	*Hydrobiologia*	182
Morrissey et al., (2015).	Ecology	*Environment international*	162
Brown et al., (2007).	Ecology	*Global Change Biology*	162
Holzenthal, et al., (2007).	Taxonomic	*Zootaxa*	159
Gabriels, et al., (2010)	Ecologogy	*Limnologica-Ecology and Management of Inland Waters*	122

Table 2. Authors with the largest numbers of scientific publications on trichopterans between 2007 and 2017 (worldwide and Brazil only).

World		Brazil	
Author	NPP	Author	NPP
ARINGER, J.	54	NESSIMIAN, J.L.	36
GRAF, W.	54	CALOR, A.R.	22
JOHANSON, K.A.	50	SANTOS, A.P.M.	22
PAULS, S.U.	41	DUMAS, L. L.	21
KUCINIC, M.	41	CALLISTO, M.	13
HOLZENTHAL, R.W.	38	HAMADA, N.	13

NPP = Number of papers published
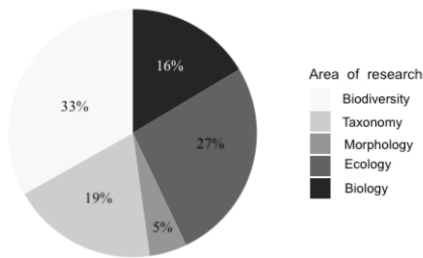
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Figure 3. Number of publications on trichopterans by research area identified between 2007 and 2017.

The observed increase in the number of publications was accompanied by a systematic increase in the number of citations on the trichopterans, with four of the five most cited papers reporting on ecological and taxonomic research. Studies focusing on biodiversity, in particular those with an ecological approach, tend to be cited more frequently than those referring to other scientific fields (SHIMANO et al., 2013). This may be related to the ongoing anthropogenic pressures on biodiversity that is leading to the progressive loss of environmental services, which is reducing the quality of life of many human populations (BLANCO-BECERRA et al., 2015).

The prominence of the United States in the trichopteran literature may be related to the tradition of this country in research on biological indices of water quality that use the abundance of aquatic insects as metrics (DEL TANAGO & JALÓN., 1984). One of the most productive researcher in the United States, Ralph Holzenthal, has made fundamental contributions to the knowledge of trichopteran biology in the Neotropical region. During the study period, the most productive researchers worldwide were Johann Waringer and Wolfram Graf, collaborators from the University of Vienna in Austria.

The productivity of Brazil may be derived from the fact that it is one of the world's most species-rich countries (BRANDON et al., 2005). A majority of the Brazilian papers were produced in the southeast of the country, a region that has that nation's oldest graduate programs, and researchers from the Federal University of Rio de Janeiro, such as Jorge Nessimian and Leandro Dumas. The National Institute of Amazonian Research (INPA) plays a prominent role in northern Brazil, with more than a century of biological research. Neusa Hamada, who studies the biodiversity of aquatic insects, is one of the most important researchers from this institution. In the Northeast, Adolfo Calor has developed a number of important studies in recent years.

By contrast, relatively few publications originated from the Brazilian South and Midwest regions, which implies the existence of Linnean and Wallacean gaps, with potentially

deleterious implications for the understanding of ecological processes in these regions. The lack of publications from these regions may at least partly reflect the general lack of data (SIDONE et al., 2016), with few trichopteran species having been recorded in Fthe Midwest, in particular (PAPROCKI et al., 2004).

Biodiversity, followed by Ecology, are the research fields that generated the largest numbers of trichopteran publications, and these areas of knowledge obviously provide essential data the development of management and conservation strategies (DE ANDRADE FRANCO, 2013).

This is especially important in the context of ongoing shifts in land use, which impact the conditions and resources available in both terrestrial and aquatic habitats, with a direct influence on the diversity of ecosystems (GIMENEZ et al., 2015; MENDOZA et al., 2011). The progressive loss of habitat integrity and the growing risks to the survival of trichopteran populations reinforce the need for research in regions that suffer the greatest environmental pressures, or those that have the largest knowledge gaps on their biodiversity.

4. Conclusion

In the present study, we have shown considerable deficits in the research on the trichopterans, in particular in Brazil, where many regions have yet to be sampled adequately, and few records being obtained from the majority of states in recent years.

One other preoccupying scenario is the combination of a lacks of manpower with the lack of research in many subareas, which limits advances in some key areas, such as the biology of these organisms, which is still incipient, and impedes the development of more systematic studies in ecology and, in particular, biomonitoring.

We confirmed the need for investments in research programs and, in particular, support for research in key areas, such as taxonomy, morphology, biology, and physiology, in order to guarantee the understanding of the evolutionary processes that determine the response capacity of these organisms to environmental changes.

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