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Global hotspots and academic trends of vector-borne diseases in the order Diptera (Arthropoda: Insecta): a bibliometric visualisation

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Abstract: Blood-sucking arthropods belonging to the order Diptera, encompassing mosquitoes, sandflies, midges, blackflies, horseflies and tsetseflies serve as vectors for a myriad of pathogens, inflicting substantial harm on both human and animal health globally. The analysis and visualisation of global hotspots and trends pertaining to vector-borne diseases, stemming from these six categories of arthropods, constituted a reliable reference for further delving into the research on Diptera insect vectors. To achieve this, we mined literature information from the Web of Science Core Collection (WoSCC), encompassing all publications related to these six arthropod groups, and leveraged VOSviewer software for bibliometric analysis and visualisation. This resulted in the construction of comprehensive relationship networks encompassing keywords, countries, institutions and authors. A comprehensive analysis encompassed 41,393 research publications, segmented into 34,363 studies on mosquitoes, 1,668 on sandflies, 3,665 on midges, 241 on blackflies, 336 on horseflies and 1,120 on tsetseflies. The bibliometric analysis, coupled with visual characterisation, offered a multifaceted synthesis of the gathered data from diverse angles. The scientometric analysis quantitatively assessed and identified the contributions of keywords, countries, institutions and authors pertaining to the research of each vector. The resulting visualisation knowledge maps elucidate collaborative network relationships within the respective vector research domains. This research endeavour stems from numerous driving forces, and a comprehensive grasp of its future trajectories and research hotspots can empower scientists with historical perspectives and forward-looking insights, fostering the formulation of innovative and impactful research ideas for the years ahead.

Keywords: mosquito, sandfly, midge, blackfly, horsefly, tsetsefly

Vector-borne diseases constitute a significant burden, accounting for over 17% of all infectious diseases globally and claiming more than 700,000 lives annually (Jiménez-Alejo et al. 2022). Arthropods, particularly through their blood-sucking behaviours, disseminate a substantial portion of these diseases worldwide, serving as vectors for a myriad of pathogenic microorganisms, encompassing bacteria, viruses and parasites (Barrozo 2019, Van De Vuurst and Escobar 2023). Notably, dipterans, facilitated by flight, human activities, transportation and animal migration, expand their reach into broader territories and novel regions (Kennedy 2019, Harapan et al. 2020, Aramayo et al. 2022), thereby disseminating pathogens across vast distances (Ortega-Insaurralde and Barrozo 2022), underscoring their paramount global significance. Hematophagous dipterans, particularly mosquitoes, sandflies, midges, blackflies, horseflies and tsetseflies, employ their piercing blood-sucking mechanism to transmit infectious diseases, puncturing the skin of humans and animals, thereby facilitating the spread of diverse pathogens and triggering major public health crises.

Mosquitoes, (Diptera: Culicidae), are hematophagous dipterans that contribute to a disproportionately high share of infectious diseases, claiming the lives of tens of thousands of individuals annually on a global scale (Chandrasegaran et al. 2020). These vectors transmit a range of illnesses, including yellow fever, forest encephalitis, dengue virus, Zika virus, and other viral and parasitic diseases, which frequently necessitate hospitalisation and can be fatal, posing a dire threat to human life (Wu et al. 2019).

Sandflies (Diptera: Psychodidae) are ubiquitous vectors of leishmaniosis, a neglected disease that has emerged as a prominent zoonosis (Pacheco-Fernandez et al. 2023). Delayed treatment can exacerbate the condition, ultimately culminating in mortality (Hamilton 2008). With over 800 species distributed globally, sandflies are commonly encountered near drainage ditches and inhabit primarily the warmer regions of Asia, Africa, Oceania, southern Europe and the Americas, spanning latitudes as far north as 50°N and as far south as 40°S (Maroli et al. 2013).

Midges (Diptera: Ceratopogonidae) exhibit a broad geographical distribution, spanning Asia, Africa, Europe

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(Martínez-de la Puente et al. 2021), Oceania and the Americas (Cotton 2017). These insects serve as vectors for a diverse array of pathogens that can infect both humans and livestock. These pathogens encompass the bluetongue virus (BTV) (Werner et al. 2020), epizootic hemorrhagic disease virus (EHDV), African horse sickness virus (AHSV), Schmallenberg virus (SBV) and Oropouche virus (OROV) (Shults et al. 2021), all of which have significant economic and financial implications for the livestock industry, causing substantial losses in animal health and productivity (Kampen and Werner 2023).

Blackflies (Diptera: Simuliidae) frequently swarm to attack human and animal hosts, resulting in marked skin irritation, changes in texture and intense itching, while also posing a risk for the transmission of onchocercosis and mansonellosis. Their geographical range is expansive, particularly in rural settings, where they thrive along rivers and streams (Nascimento-Carvalho and Maia-Herzog 2017). As a result, the zoonotic diseases that blackflies transmit through biting and the carriage of pathogens hold significant medical, veterinary and economic implications, underscoring their importance across multiple sectors (Ebmer et al. 2023).

Horseflies (Diptera: Tabanidae) efficiently transmit a range of pathogens, including equine infectious anemia virus (EIAV) (Bażanów et al. 2021), lumpy skin disease virus (LSDV) (Sohier et al. 2019), *Trypanosoma theileri* Laveran, 1902, *Trypanosoma evansi* (Steel, 1885) (Dörge et al. 2020), and *Leishmania* spp. (Coelho et al. 2016). The prevalence of these infectious diseases is largely attributed to the ubiquitous presence of horseflies in urban, peri-urban, and pastoral environments.

Tsetse flies (Diptera: Glossinidae), on the other hand, are crucial vectors of African trypanosomiasis (AT), colloquially known as sleeping sickness, which affects both humans and livestock. This devastating protozoal disease is endemic to vast regions of sub-Saharan Africa (Mireji et al. 2022), causing immense financial burdens and severe health consequences (Bouyer et al. 2019).

In light of the mounting hazards and escalating public health significance attributed to hematophagous dipterans, this study endeavoured to provide a meticulous and systematic overview, along with a synthesis of pivotal keywords, diverse countries, esteemed institutions, and influential authors, who had contributed to the extensive body of the literature pertaining to these six distinct arthropod categories.

We employed innovative methods to visualise the intricate knowledge network maps, which served as a powerful tool to coherently narrate the intricate story of the past, present and anticipated future trends within the research landscape. These maps not only illuminated the historical foundations but also revealed emerging patterns and potential avenues for future exploration, thereby facilitating a deeper appreciation of the dynamic nature of this critical research area.

By examining the interconnectedness of various elements within these maps, we gained insights into collaborative efforts, regional specialisations and thematic clusters that emerged over time. This, in turn, fostered a more holistic understanding of the research ecosystem surrounding hematophagous dipterans, empowering researchers, policymakers and public health professionals to make informed decisions and drive forward progress in this vital area of study.

MATERIALS AND METHODS

Data source

The data for this study were gathered from the WoSCC database, a repository renowned for housing the world's most influential journals (AlRyalat et al. 2019). This exhaustive resource was leveraged to compile comprehensive information on keywords, countries, institutions and authors associated with all publications, spanning the earliest available records up until the conclusion of December 2022.

Search strategy

On 7 June 2023, a thorough search was conducted for publications pertaining to the six distinct categories of hematophagous dipterans within the order Diptera. The search employed targeted keywords tailored to each category, including "mosquito" OR "Anophelinae" OR "*Anopheles*" OR "Culicinae" OR "*Aedes*" OR "*Culex*" for mosquito-related publications, "sandfly" OR "Phlebotomidae" OR "*Phlebotomus*" for sandflies, "midge" OR "Ceratopogonidae" OR "Leptoconopinae" OR "*Leptoconops*" OR "Forcipomyiinae" OR "*Lasiohelea*" OR "Ceratopogoninae" OR "*Culicoides*" for midges, "blackfly" OR "Simulidae" for blackflies, "horsefly" OR "gadfly" OR "Tabanidae" OR "Pangoniinae" OR "Chrysopsinae" OR "Tabaninae" for horseflies, and simply "tsetsefly" for tsetseflies.

All retrieved publications underwent a rigorous and independent screening process conducted by three reviewers. This meticulous assessment aimed to exclude any irrelevant materials, such as conference proceedings, revisions, letters, news articles, withdrawn publications, or duplicates that lacked pertinent analyses, ensuring the final selection adhered strictly to the study's objectives and criteria.

Data analysis

The annual count of retrieved publications within the six specialised fields was systematically calculated, and a line graph was used to vividly depict the temporal evolution of publication trends over time. Subsequently, a comprehensive examination of the publication landscape that had hosted these publications was undertaken, leading to the exportation and organised compilation of publication data for further analysis. A systematic evaluation was undertaken of the research objectives encompassed within the publications. After filtering all publications exported from the WoSCC, the text data were integrated into VOSviewer software version 1.6.18 (Van Eck and Waltman 2010), a dedicated platform for constructing visual literature networks.

The files were processed through synonym merging and the establishment of a co-occurrence threshold of five, enabling the visualisation of intricate networks. The subsequent visualisation of relationship maps and network links among keywords, countries, institutions and authors pertinent to the research field underscored historical research trends, the current *status quo*, popular topics and potential future directions. Clusters of items were identified and represented as nodes and links, offering a robust bibliometric

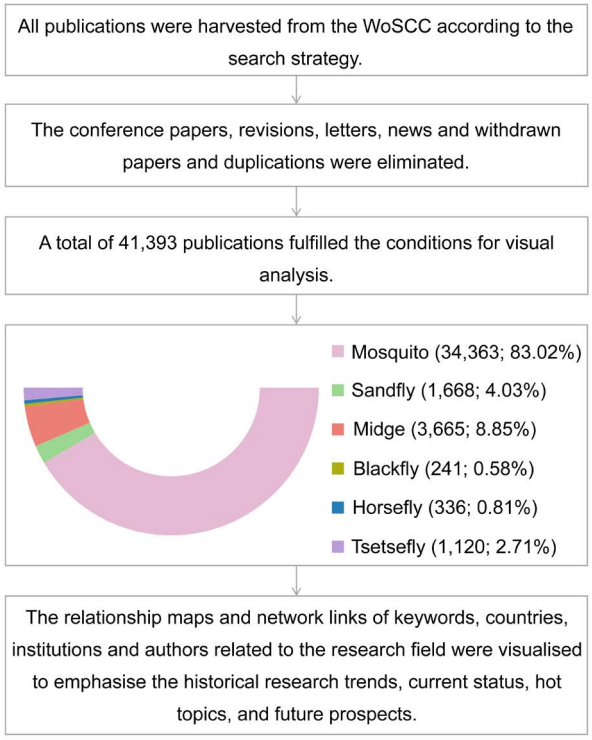

Fig. 1. The flow chart for the screening of publications involved in the study, displaying the process of inclusion of publications, following the exclusion of interfering publications. The relevant publications were selected for the visual analysis and the construction of relationship networks. The methodology of data and general status of publications were also clearly illustrated to elucidate the logic of this holistic analysis.

analysis of the literature. The VOSviewer-generated map featured nodes whose size corresponded proportionally to the frequency of occurrence, while the thickness of the collaborative links directly connecting nodes signified the spatial relationship, also conveyed in a proportional manner (Zhang et al. 2022).

RESULTS

General status

A total of 41,393 publications met the criteria for visual analysis, with 34,363 publications focusing on mosquitoes, accounting for 83.02%; 1,668 on sandflies, accounting for 4.03%; 3.665 on midges, accounting for 8.85%; 241 on blackflies, accounting for 0.58%; 336 on horseflies, accounting for 0.81%; and 1,120 on tsetseflies, accounting for 2.71% (Fig. 1). The annual trend of publication in each of the six fields was summarised in a line chart (Fig. 2).

Notably, the number of mosquito-related publications significantly surpassed that of the other five arthropod categories, steadily increasing over the years, with notable spikes in 2015–2016 and 2019–2020, followed by a stabilisation post-2020. In contrast, the publication counts for the other arthropods did not experience major fluctuations over time.

During our analysis of six arthropod species, the Public Library of Science (PLoS) emerged as the prominent publisher in the USA. Specifically, PLoS ONE ranked foremost

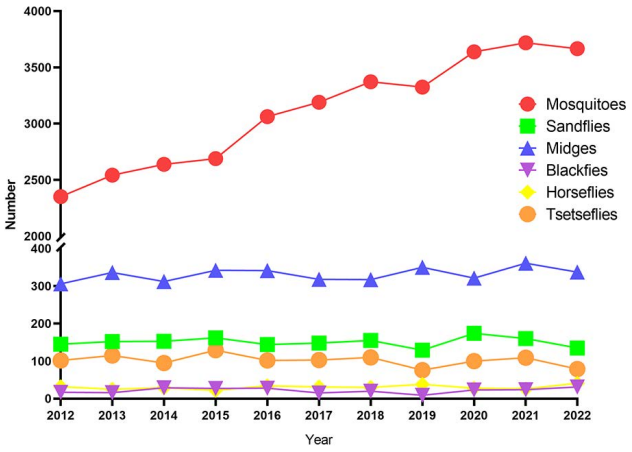

Fig. 2. Line graph of the number of publications in the fields of mosquitoes, sandflies, midges, blackflies, horseflies and tsetseflies from 2012 to 2022.

in the USA for publishing publications on mosquitoes, midges and horseflies. Similarly, PLoS Neglected Tropical Diseases led the pack in publishing research on sandflies, blackflies and tsetseflies, underscoring PLoS's pivotal role in American research on these six vector insects.

Within the realm of mosquito research, American publications demonstrated a broad geographical scope, extending beyond tropical and subtropical regions to encompass temperate countries as well (Schoener et al. 2018, Yang et al. 2020, Chaves et al. 2021). In the fields of sandflies, blackflies and tsetseflies, American publications tended to converge on tropical and subtropical nations, with a distinct focus on developing countries (Meyer et al. 2016, Hirve et al. 2017, Post et al. 2022). Conversely, the study of midges predominantly centred on developed countries where animal husbandry forms a cornerstone of their economies (Carvelli et al. 2019). In contrast, horsefly research received less attention from American publishers, with the bulk of relevant studies being published in journals outside the USA (Fritz et al. 2020).

Mosquito

The bibliometric information disclosed that the five most frequently occurring keywords were mosquito, *Aedes aegypti* (Linnaeus, 1762), Culicidae, transmission and infection. These words appeared five times or more for a total of 8,890 keywords. Among the 165 countries with more than five occurrences, the top five countries were the United States of America (USA), the United Kingdom (UK), China, Brazil and India. Of 185 countries with more than five citation counts, the top five countries sorted by the greatest number of citations were the USA, the UK, France, China and Brazil. A total of 2,937 institutions had more than five occurrences and the top five institutions were the London School of Hygiene & Tropical Medicine, the Institut Pasteur, the University of Florida, the University of Oxford, and the Centers for Disease Control and Prevention.

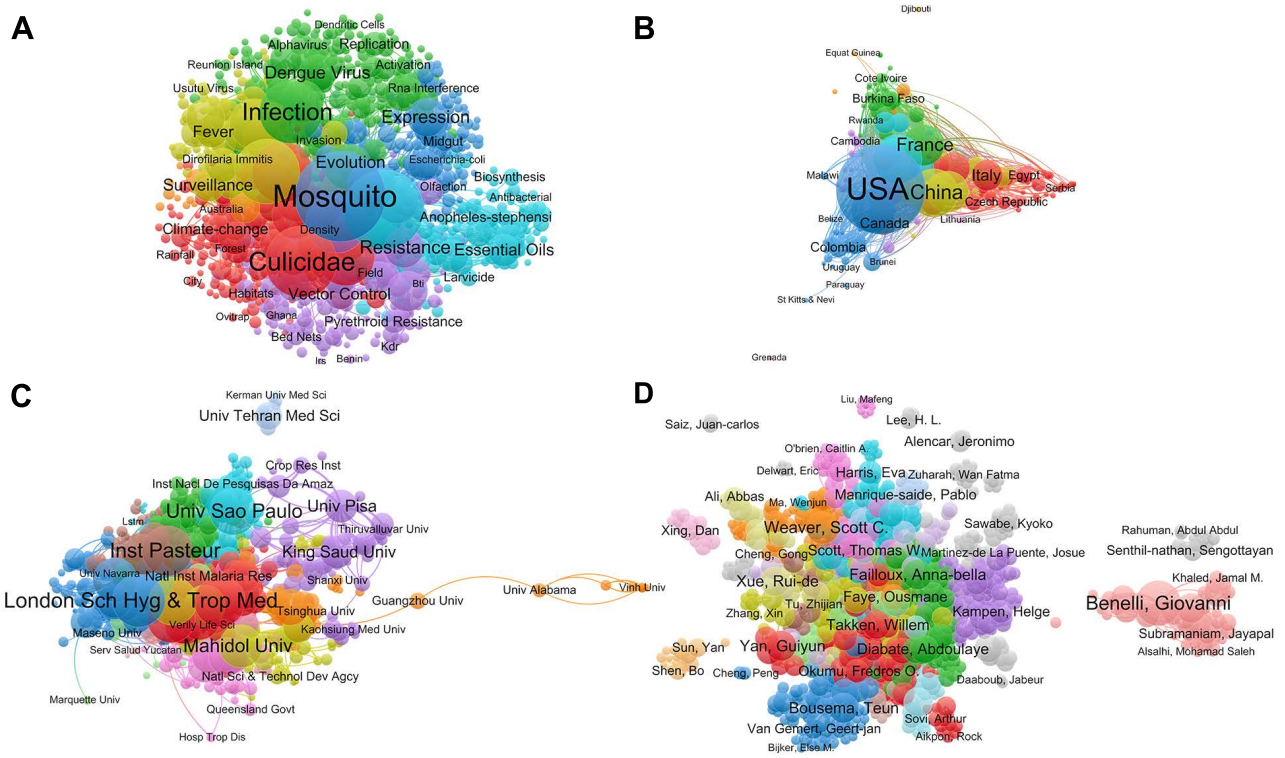

Fig. 3. The relationship network diagrams in terms of mosquitoes. **A** – co-occurrence network of keywords; **B** – co-authorship network of countries; **C** – co-authorship network of institutions; **D** – co-authorship network of authors.

The top five institutions with the most cited publications out of 14,577 institutions with at least five citations were the University of Oxford, the Institut Pasteur, the University of California Davis, the London School of Hygiene & Tropical Medicine, and the National Institutes of Health. A total of 7,671 authors published more than five publications, and the top five authors were Giovanni Benelli, Scott C. Weaver, Teun Bousema, Yan Guiyun and Kadarkarai Murugan. The top five authors of the 77,846 authors with over five citations were Thomas W. Scott, Giovanni Benelli, Simon I. Hay, Oliver J. Brady and Jane P. Messina (Fig. 3).

Sandfly

Quantitative bibliometric data uncovered that 555 keywords appeared at least five times and the five most common keywords were leishmaniasis, sandflies, Psychodidae, infection and identification. The top five countries with a minimum of five publications were the USA, Brazil, Iran, France and Spain. The top five countries ranked by the number of citations out of 106 countries with more than five citations were the USA, France, Brazil, the UK and Spain. There were 199 institutions with at least five publications and the top five institutions were Charles University in Prague, Tehran University of Medical Sciences, the National Institute of Allergy and Infectious Diseases, Hebrew University of Jerusalem, and Aix-Marseille Université.

Of the 1,551 institutions with citation counts greater than five, the top five were Charles University in Prague, the National Institute of Allergy and Infectious Diseases, Tehran University of Medical Sciences, Hebrew University of Jerusalem, and the National Institute of Health Carlos III. Of the 336 authors who published more than five publications, the top five authors were Petr Volf, Yavar Rassi, Amir Ahmad Akhavan, Alon Warburg and Bulent Alten. The top five authors of the 4,959 authors with more than five citations were Petr Volf, Jan Votýpka, Jesus G. Valenzuela, Francine Pratlong and Bulent Alten (Fig. 4).

Midge

The bibliometric data revealed that 1,411 keywords appeared more than five times and the five keywords with the highest number of occurrences were *Culicoides* Latreille, 1809, midges, biting midges, Diptera and bluetongue virus. The top five countries in terms of the number of publications were the USA, the UK, China, Germany and Canada. Considering the number of citations, the top five of the 114 countries with citation counts greater than five were the USA, the UK, Germany, France and Canada. There were 443 institutions with more than five published publications and the top five institutions were Pirbright Institute, Agricultural Research Service, University of Pretoria, University of Gdańsk and University of Florida.

The top five institutions out of the 2,510 institutions with more than five citations were the Pirbright Institute, the French Agricultural Research Centre for International Development, the National Institute for Agricultural Research, the University of Pretoria and Ohio State University. There were 505 authors who published more than five publications and the top five authors were Simon Carpenter, Junichi Yukawa, Gustavo R. Spinelli, Makoto Tokuda and

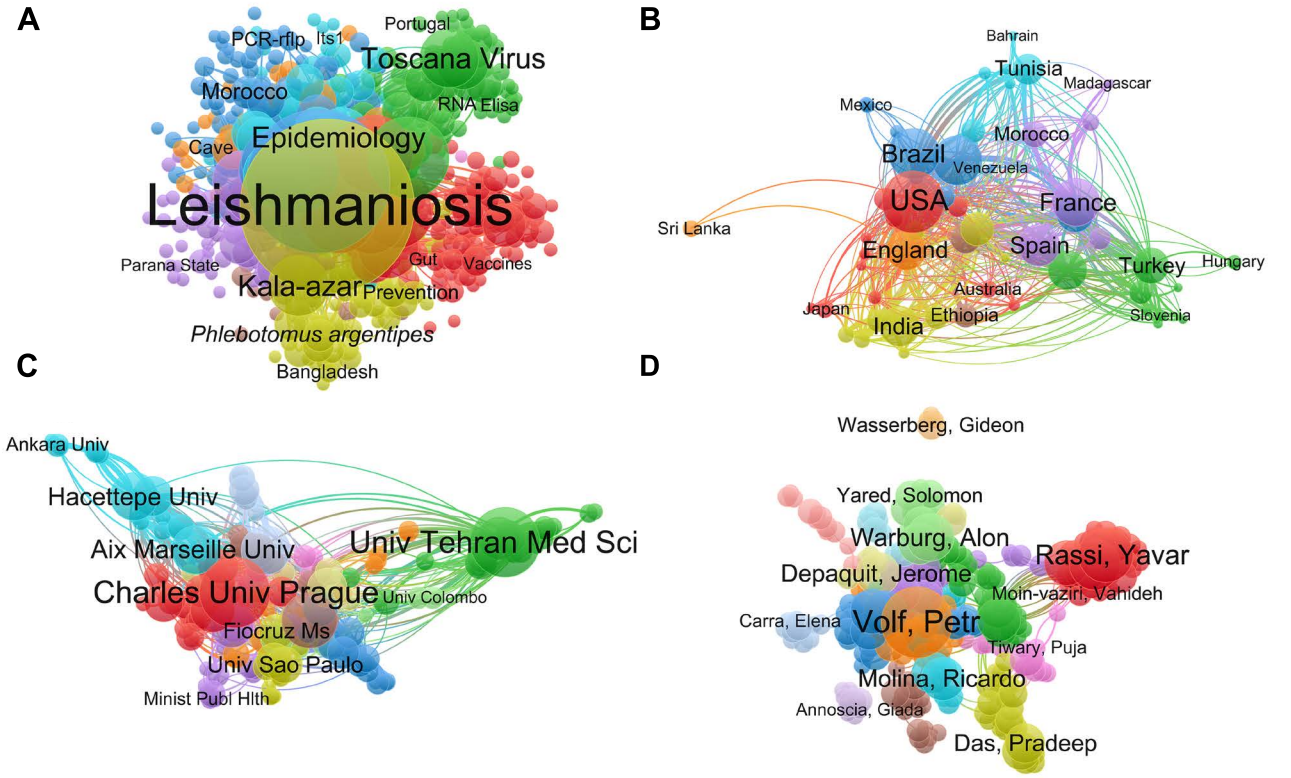

Fig. 4. The relationship network diagrams in terms of sandflies. **A** – co-occurrence network of keywords; **B** – co-authorship network of countries; **C** – co-authorship network of institutions; **D** – co-authorship network of authors.

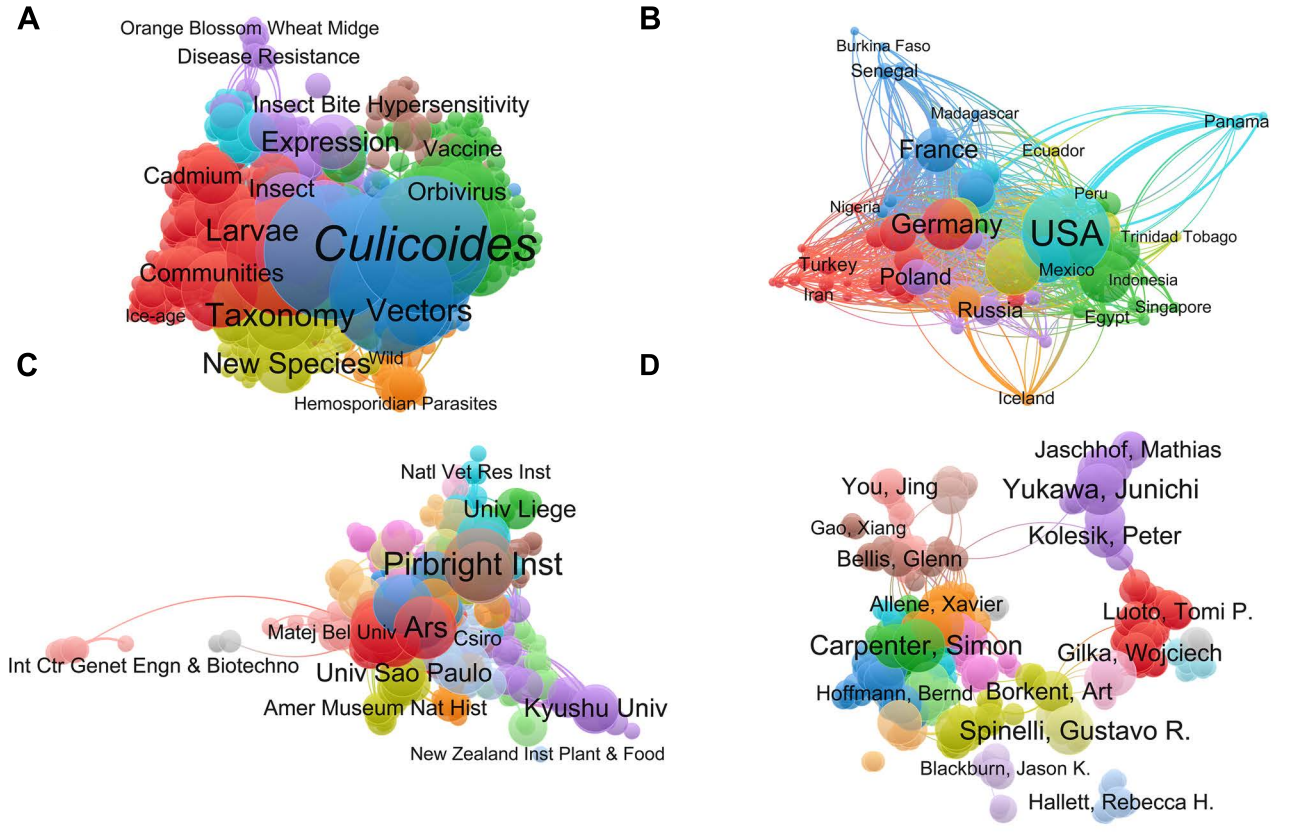

Fig. 5. The relationship network diagrams in terms of midges. **A** – co-occurrence network of keywords; **B** – co-authorship network of countries; **C** – co-authorship network of institutions; **D** – co-authorship network of authors.

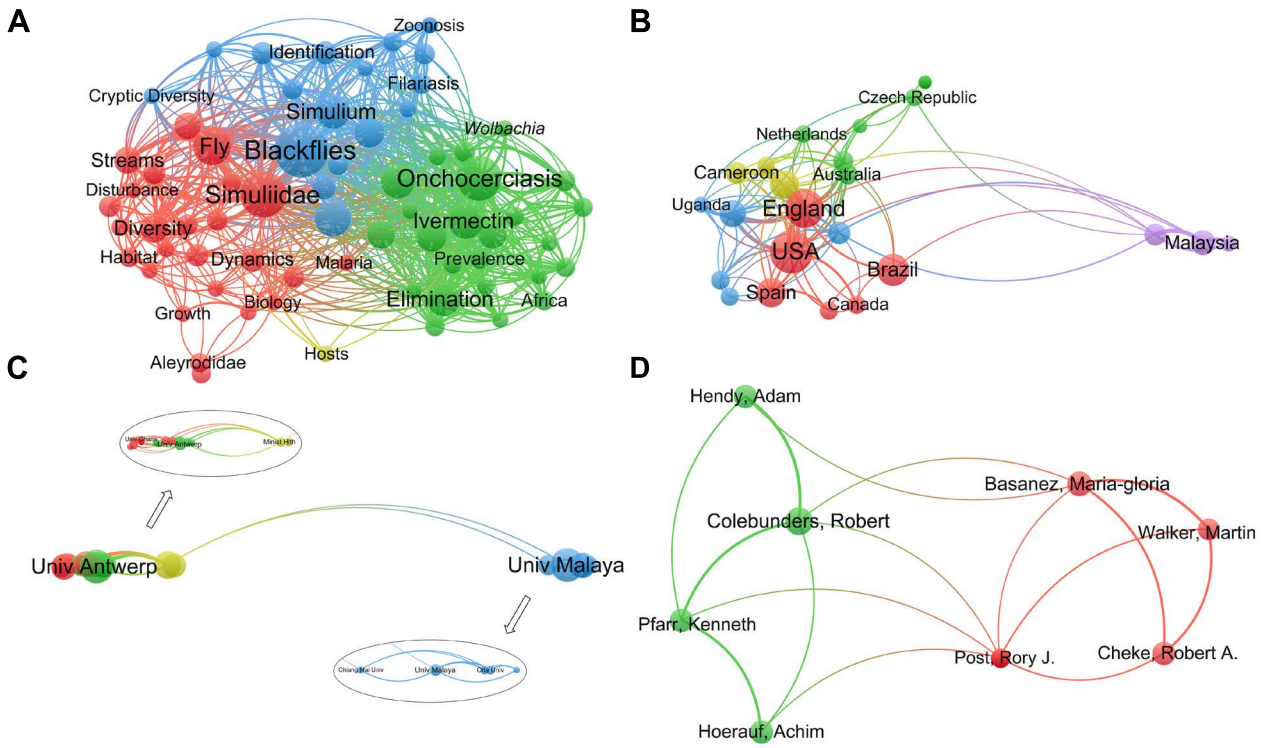

Fig. 6. The relationship network diagrams in terms of blackflies. **A** – co-occurrence network of keywords; **B** – co-authorship network of countries; **C** – co-authorship network of institutions; **D** – co-authorship network of authors.

Claire Garros. The top five authors of the 7,941 authors who had more than five citations were Simon Carpenter, Claire Garros, David L. Denlinger, Nicholas M. Teets and Didier Raoult (Fig. 5).

Blackfly

A total of 67 keywords appeared more than five times in bibliometric analyses and the top five occurrences were blackflies, Simuliidae, onchocerciasis, fly and Diptera. The USA, the UK, Brazil, Germany and Spain were the top five most prolific countries, with a threshold of a minimum of five publications. In terms of citations, the USA, Spain, the UK, Germany and Belgium were the top five citations out of 66 countries with the minimum number of five citations. Twenty-three institutions produced more than five published articles, and the top five institutions were the University of Antwerp, the University of Malaya, the Ministry of Health of the Russian Federation, Imperial College London and Liverpool John Moores University.

The top five institutions of 346 institutions with more than five cited publications were the University of Antwerp, University Hospital Bonn, University of Liverpool, University of Malaya and Ministry of Health of the Russian Federation. Thirteen authors published more than five publications and the top five authors were Hiroyuki Takaoka, Robert Colebunders, Maria-Gloria Basanez, Yasushi Otsuka and Robert A. Cheke. The top five authors of the 739 authors contributing more than five cited publications were Achim Hörauf, Robert Colebunders, Kenneth M. Pfarr, Robert A. Cheke and Martin Walker (Fig. 6).

Horsefly

The bibliometric review indicated that 93 keywords occurred more than five times, with the top five occurrences being Tabanidae, horsefly, fly, Diptera and vectors. A total of 29 countries had more than five publications presented in the network. The top five countries contributing to publications were the USA, Brazil, France, Australia and the UK. The top five countries out of 64 countries with citation thresholds greater than five were the USA, the UK, Australia, Brazil and France. The top five institutions of the 30 institutions with more than five publications were Eötvös Loránd University, Instituto Nacional de Pesquisas da Amazônia, the University of British Columbia, Federal University of Tocantins, and Universidade de São Paulo.

The top five institutions of 366 institutions that were cited more than five times were Eötvös Loránd University, the University of Chinese Academy of Sciences, Lund University, the Natural History Museum and the Hungarian Academy of Sciences. Twenty-five authors published more than five publications and 719 authors contributed more than five citations. The top five authors by number of publications were Gabor Horvath, Augusto Loureiro Henriques, Ádám Egri, Stjepan Krčmar and Thomas P. Sullivan, and the top five by number of citations were Gabor Horvath, Ádám Egri, Miklos Blaho, Susanne Akesson and Vitor H. Paiva (Fig. 7).

Tsetsefly

A total of 444 keywords occurred at least five times and were considered as high-frequency keywords from a bibliometric perspective, and the top five most common key-

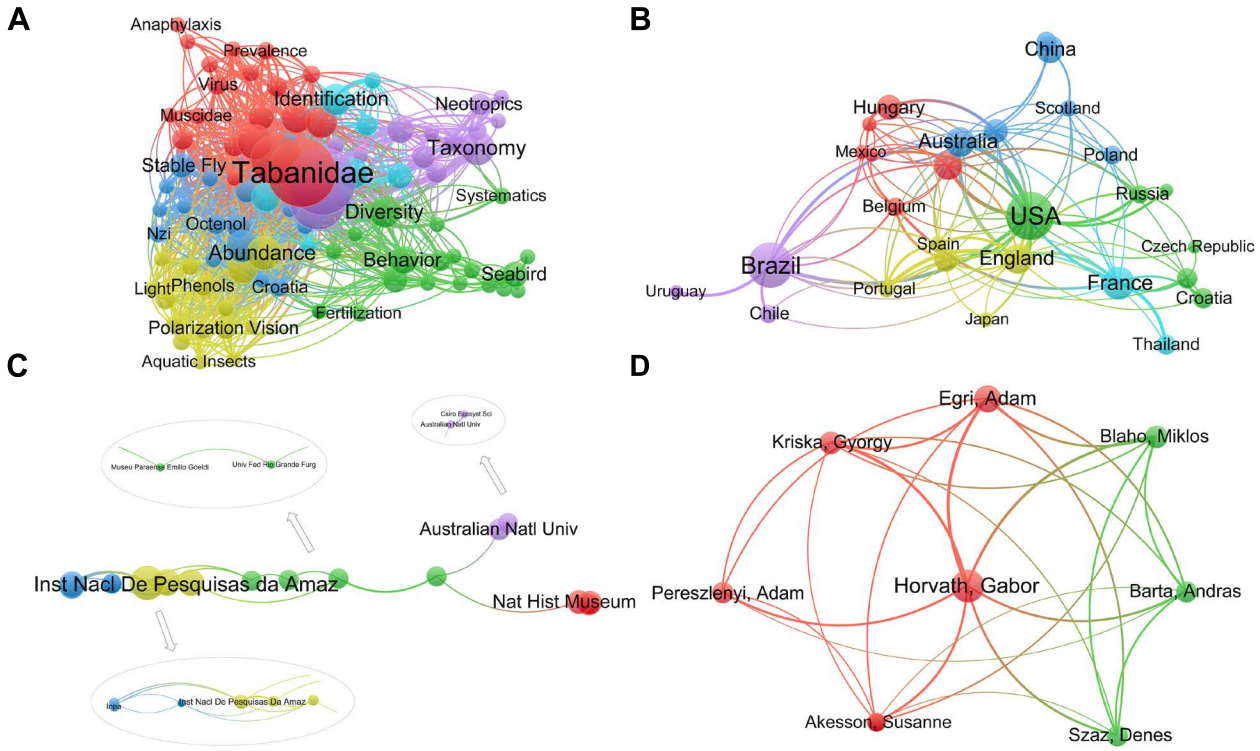

Fig. 7. The relationship network diagrams in terms of horseflies. **A** – co-occurrence network of keywords; **B** – co-authorship network of countries; **C** – co-authorship network of institutions; **D** – co-authorship network of authors.

words were tsetsefly, trypanosomiasis, *Glossina* Wiedemann, 1830, flies and dipteran. The top five countries out of 54 countries with more than five publications were the UK, the USA, France, Kenya and South Africa, and the top five countries out of 91 countries with at least five citations were the UK, the USA, France, Belgium and Switzerland.

The top five institutions of 151 institutions with more than five published publications were the University of Edinburgh, Yale University, the University of Liverpool, Tropical Medicine and Infectious Disease, and the French Agricultural Research Centre for International Development. The top five institutions of the 1,040 institutions with at least five citations were Yale University, the University of Edinburgh, the University of Glasgow, Tropical Medicine and Infectious Disease, and the University of Liverpool. The top five authors of the 206 authors with more than five publications were Serap Aksoy, Jérémy Bouyer, Adly M. M. Abd-Alla, Marc J, B, Vreysen and Brian L. Weiss. The top five authors of the 2,956 authors with more than five citations greater than five citations were Serap Aksoy, Brian L. Weiss, Marc J. B. Vreysen, Jérémy Bouyer, and Jan Van Den Abbeele (Fig. 8).

DISCUSSION

Hazards and hardships imposed by the frequent long-distance movements of six categories of hematophagous dipterans in the order Diptera on the health and lives of humans, livestock and domestic animals worldwide were analysed in this study. The characteristics of publications related to the research field were sorted, enumerated and visualised to demonstrate the historical situation, current research status and prospective views. It is essential to review the relevant opinions and track the hot research spots to improve research efficiency and rapidly develop this field in the future. Various vector-borne diseases transmitted by the six categories of hematophagous dipterans generate substantial public health problems and economic costs. Mosquitoes, sandflies, midges, blackflies, horseflies and tsetseflies transmit a multitude of pathogens to their hosts that lead to significant morbidity and mortality for many humans and animals (Cayla et al. 2019).

The above six categories of arthropods should be adequately analysed by researchers to reduce or eliminate the damage caused by these insects. A quick overview of the research on each arthropod was provided via a comprehensive analysis of previous publications, such as the number, time and source of the publications. The exploration of research trends from an academic perspective can assist scientists in objectively analysing the research process and research focus in this field and can assume an influential role in subsequent research and future challenges. Over the years, there has been a marked increase in publications related to mosquitoes, intimately tied to heightened public concern and the prevalence of mosquito-borne illnesses.

In the global fight against malaria, 2015 emerged as a pivotal year, with numerous countries achieving zero malaria cases. Nevertheless, simultaneously, a considerable number of countries struggled with high prevalence and mortality rates. To address this, the World Health Organisation (WHO) introduced the Global Technical Strategy for Malaria 2016–2030 (GTSM) in the same year, presenting novel approaches for malaria control (Matsumoto-Taka-

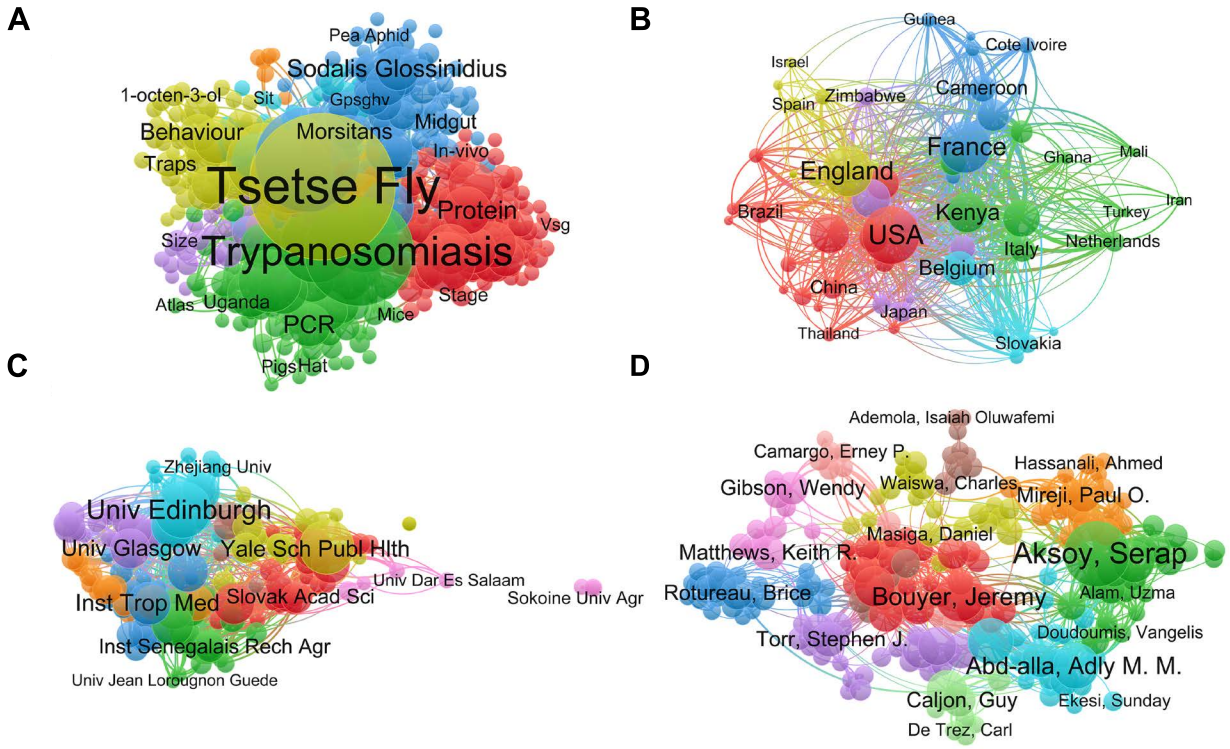

Fig. 8. The relationship network diagrams in terms of tsetseflies. **A** – co-occurrence network of keywords; **B** – co-authorship network of countries; **C** – co-authorship network of institutions; **D** – co-authorship network of authors.

hashi and Kano 2016). This strategy reignited public interest in malaria and its vector, mosquitoes. Concurrently, the Nobel Prize in Physiology or Medicine was awarded to Chinese scientist Tu Youyou for her pioneering work in malaria treatment using artemisinin (Tiwari and Chaudhary 2020). This accolade has inspired numerous international researchers, providing fresh perspectives and fostering a renewed enthusiasm for scientific inquiry.

In 2019, the outbreak of dengue fever in various regions worldwide (Hasan et al. 2021, Mwanyika et al. 2021, Zhang et al. 2021) posed serious threat to public health and safety, once again drawing attention to the role of dengue mosquitoes as vectors of this disease. Since late 2019 through early 2020, the COVID-19 pandemic garnered significant international attention, resulting in a redirection of the world's scientific research efforts from mosquito-borne diseases towards the novel coronavirus (Chen et al. 2022, Lu et al. 2023). Research on mosquitoes and mosquito-borne diseases was impacted. It is anticipated that with the conclusion of the pandemic, research in these areas will resume its rapid growth pace.

In contrast, research output pertaining to sandflies, midges, blackflies, horseflies and tsetseflies has remained stable over time, without a clear trend of increase or decrease. One contributing factor is their comparatively limited environmental adaptability compared to mosquitoes, limiting their global distribution. As a result, the vector-borne diseases associated with these insects are less prevalent, attracting a smaller number of people's and scientists' attention. The distribution of five arthropod groups posed significant challenges in the past, particularly in tropical countries that were plagued by inadequate healthcare environments, contributing to elevated morbidity and mortality rates. The limited scientific and technological capabilities in these regions hindered timely treatment and research initiatives.

The study of midges, which were prevalent in developed countries with sophisticated animal husbandry practices, garnered less attention from scientists. Despite residing in technologically advanced regions, midges primarily affected animal husbandry rather than human health, thus failing to attract the same level of scientific interest. This explains the relatively small number of research publications on midges and the lack of an observable growth trend.

As the leading producer of research publications across these six arthropod-focused disciplines in the past, the focus of American publishers merited a thorough examination. In the realm of mosquito research, their attention closely aligned with the global distribution of mosquitoes and the pervasive threat posed by mosquito-borne diseases. Mosquitoes, renowned for their exceptional adaptability and resilience, posed a formidable challenge to eradication efforts in the past. Diseases transmitted by these insects, including malaria and dengue fever, continued to threaten the lives and well-being of individuals globally.

Consequently, mosquito research attracted keen interest from scientists and researchers worldwide, with American publishers echoing this enthusiasm by focusing on mosquitoes across diverse geographical regions. Analogously, studies involving sandflies, blackflies and tsetseflies also saw American publishers prioritising research that intersected with their distribution patterns and

associated diseases. Developing countries located in tropical and subtropical regions, characterised by their hot and humid climates and relatively underdeveloped public health infrastructures, offer ideal conditions for the proliferation of these arthropods.

The prevalence of these conditions, compounded by limited medical resources, exacerbated disease spread, leading to devastating consequences for affected communities during outbreaks. Midges, however, garnered heightened attention due to their pivotal role in transmitting bluetongue, a devastating disease that had significantly impacted the livestock industry in Europe and the USA, particularly in developed nations where animal husbandry was prevalent. In contrast, the number of publications on horseflies by American publishers was relatively low, with research topics appearing more diversified (Fritz et al. 2020, Horváth et al. 2020). This trend may have been attributed to the greater authority and influence held by other publishers in the horsefly research domain on a global scale.

Utilising the VOSviewer software, networks were visualised based on the keywords, countries, institutions and authors associated with the publications. The inaugural publications on mosquitoes, sandflies, midges, blackflies, horseflies and tsetseflies were released in 1905, 1924, 1916, 1936, 1929 and 1909, respectively. A general trend of annual growth in publication count was observed, primarily fueled by advancements in scientific academia and heightened international communication. This proliferation of publications was correlated with the publication date of the first publication in each respective field. The earlier the research commenced, the stronger the foundational research base, subsequently resulting in a higher volume of publications aligned with the timeline of those initial publications.

The impetus for these early studies stemmed from the ubiquitous presence of these blood-sucking insects and the substantial harm they inflict, likely piquing the interest of scientists. Among the total of 30 keywords, with each insect being assigned five, the scientific community consistently directed their attention towards three pivotal terms: transmission, infection and vectors. These three keywords not only encapsulate the historical breadth of the respective fields but also foreshadow their future trajectories. The six arthropod groups emphasised in the article garnered substantial public interest, primarily due to their status as vectors, playing a critical role in the dissemination of diverse pathogens. Consequently, research endeavours within these six domains naturally inclined towards a deeper exploration of the complexities of the transmission process, investigating the mechanisms of pathogen introduction into host organisms, and elucidating the biology and behaviour of the vector organisms themselves.

This emphasis on transmission, infection and vector organisms is not a recent development but rather a long-standing trend in scientific inquiry. Throughout history, scientists have been captivated by the dynamics of disease spread, leading to numerous discoveries that have enhanced our comprehension of these processes. As we anticipate the future, it is clear that the research path will remain firmly grounded in these three fundamental aspects, as they are pivotal to our endeavours to combat infectious diseases and safeguard public health.

Furthermore, the investigation of these arthropods and their role in disease transmission is gaining paramount importance amidst the emergence and re-emergence of infectious diseases. As pathogens evolve and adapt to changing environments, it is imperative that we maintain a proactive stance by continually expanding our understanding of transmission mechanisms, infection dynamics and vector biology. By doing so, we can devise more efficacious strategies for disease prevention, control and eradication.

Regarding the number of publications pertaining to the six arthropod categories, the USA emerged as the most prolific nation, closely followed by the UK and Brazil. Similarly, in terms of citations, the USA led the way, with the UK and France occupying the subsequent positions. The USA and the UK notably boasted the higher volume of both publications and citations than the other countries over the world, showcasing a significant research advantage. This phenomenon can be attributed to the strong integration of science and technology in both countries. While the large population of the USA contributed to its high research output, the UK—despite its smaller population—has a long tradition of tropical medicine research due to its colonial past. Conversely, in other countries, while scientific and technological capacity is a contributing factor, the distribution and impact of arthropods also play roles, albeit not in direct correlation with the level of research activity.

To systematically organise the intricate data spanning 118 years from 1905 to 2022 and visualise the characteristics of published publications, bibliometric and visual analysis techniques were employed. This approach facilitated the identification of historical developments, current research status, and anticipated future academic trends. By examining the origins of research publications, insights into the factors influencing the field's evolution could be gained. The intricate web of relationships surrounding the six categories revealed a rich tapestry of historical trends and research foci, facilitating a comprehensive analysis of the field. Furthermore, these networks have the potential to expedite research progress, ultimately facilitating the achievement of significant academic breakthroughs.

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