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Somia LAKHDARI

`lakhdari.somia@univ-khenchela.dz`

Abbès Laghrour University of Khenchela

Lynda RAIS

Abbès Laghrour University of Khenchela

Dahbia Derdah

Université Paris-Saclay

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Global research on Branchiopoda: A bibliometric and network analysis

1. Somia LAKHDARI^{1,2 *}

¹Laboratory of Biotechnology, Water, Environment and Health, Abbes Laghrour University, Khenchela, Algeria.

²Departement of ecology and environment, Abbes Laghrour University, Khenchela, Algeria.

lakhdari.somia@univ-khenchela.dz

ORCID: <https://orcid.org/0000-0002-4505-5932>

2. Lynda RAIS^{1,2}

¹Laboratory of Biotechnology, Water, Environment and Health, Abbes Laghrour University, Khenchela, Algeria.

³Department of molecular and cellular biology, Abbes Laghrour University, Khenchela, Algeria.

ORCID: <https://orcid.org/0000-0003-2171-3483>

Rais.lynda@univ-khenchela.dz

3. Dahbia DERDAH⁴

Dahbia.derdah@universite-paris-saclay.fr

derdahdahbia9@gmail.com

⁴ Paris University Institute of Technology, University of Paris Saclay.

ORCID: <https://orcid.org/0009-0004-8102-0771>

Global research on Branchiopoda: A bibliometric and network analysis

Abstract

Branchiopoda, particularly fairy shrimps (Anostraca), tadpole shrimps (Notostraca), and clam shrimps (Spinicaudata and Laevicaudata), collectively termed large branchiopods occupy an important position at the intersection of freshwater ecology, ecotoxicology, palaeontology, aquaculture, and conservation biology. However, this literature has not previously been mapped as an integrated research field. This study characterizes global publication output, scholarly influence, collaboration patterns, and thematic development. Scopus records were retrieved using a combined TITLE-ABS-KEY search for branchiopod*, Anostraca, Notostraca, Spinicaudata, and Laevicaudata. Cladocera was not included as a standalone search term; nevertheless, records mentioning Branchiopoda could still include cladoceran studies. The analysis was restricted to English-language research articles and documented using a PRISMA-style screening workflow. Descriptive and network analyses were conducted with Bibliometrix/Biblioshiny, VOSviewer, and CiteSpace. The initial search returned 3,297 records; after applying the language and document type criteria, 2,862 articles published between 1913 and 2026 were retained. Publication output was sporadic before 1990, increased rapidly during the 1990s and early 2000s, peaked at slightly more than 130 articles per year in the mid-2000s, and subsequently stabilised at a level well above the pre 1990 baseline. The United States led corresponding-author output and international collaboration, followed by China, Germany, Belgium, and Italy, while citation impact was concentrated in the United States, Belgium, and China. Keyword co-occurrence and thematic analyses identified three recurrent domains: taxonomy and palaeontology; freshwater ecology and conservation; and ecotoxicology, largely centred on *Artemia* as a bioassay organism. Across four time periods, the field shifted from early pharmacological, bioassay organism. Thematic evolution across four periods traces a transition from early pharmacological/bioassay and general crustacean literature toward molecular systematics and, more recently, conservation-oriented and climate related research. Bibliographic coupling of journals identified six journal clusters spanning limnology, taxonomy, morphology and phylogenetics, palaeontology, biogeography, and ecotoxicology and aquaculture, with *Hydrobiologia* and acting as central interdisciplinary hubs.

Keywords:

Branchiopoda; *Anostraca*; bibliometric analysis; collaboration networks; ecotoxicology; thematic evolution.

1. Introduction

Branchiopoda, is an evolutionarily ancient and ecologically important class of crustaceans situated, at the intersection of freshwater ecology, biodiversity conservation, and environmental monitoring (Brendonck et al., 2008; Dolmans et al., 2025; Pinceel et al., 2020; Rogers, 2014). Ecologically, branchiopods occupy a foundational role in aquatic food webs, serving as primary consumers of phytoplankton and bacteria while simultaneously constituting a vital prey source for invertebrates, fish, and waterbirds in both permanent and temporary water bodies (Brendonck et al., 2008; Dumont & Negrea, 2002; Waterkeyn et al., 2016). Scientifically, Branchiopoda encompasses a taxonomically diverse assemblage including Cladocera, Anostraca, Notostraca, Spinicaudata, and Laevicaudata, collectively distributed across freshwater ecosystems ranging from arctic ponds to tropical saline lakes (Alonso, 1996; Christopher Rogers, 2014; Dumont & Negrea, 2002; Rais & Amarouayache, 2018). From a conservation standpoint, many large branchiopod species are strictly associated with Mediterranean Temporary Ponds (Alonso, 1996; Samraoui et al., 2006), a habitat listed as a priority under the European Union Habitats Directive, and are increasingly threatened by land use change, agricultural intensification, groundwater extraction, and prolonged drought driven by climate change (Blaustein et al., 2004; El Amerany et al., 2025; Waterkeyn et al., 2010; Zacharias & Zamparas, 2010). The progressive desiccation and degradation of temporary wetlands worldwide has placed numerous branchiopod species under conservation pressure, prompting their inclusion in regional and national red lists and intensifying scientific attention toward their ecology, distribution, and resilience (Christopher Rogers, 2014; Dolmans et al., 2025; Rais et al., 2025).

Beyond their ecological significance, branchiopods hold substantial scientific and applied value across multiple disciplines. *Daphnia magna* (Cladocera) has emerged as one of the most widely used model organisms in ecotoxicology and environmental risk assessment, forming the basis of internationally standardized bioassays for testing water quality is increasingly compromised by the presence of trace concentrations of pharmaceutical contaminants, including anticancer drugs, antidepressants, anti inflammatory drugs, beta blockers, and lipid regulating agents. (Jansen et al., 2011; Tkaczyk et al., 2021). *Artemia* species (Anostraca), commonly known as ‘brineshrimp’,

play a key economic role in the global aquaculture industry, particularly in the rearing of fish and shrimp larvae. The production of cysts by these species constitutes a multi million dollar industry (Gajardo & Beardmore, 2012; Lavens & Sorgeloos, 2000; Madkour et al., 2023; Van Stappen, 2002). At the same time, Triops and related Notostraca have attracted growing interest in agricultural contexts due to their capacity to disturb soil in flooded rice fields, suppressing weed growth through bioturbation (Dumont & Negrea, 2002; Machado et al., 2017; Mura, 1999). The convergence of ecological, ecotoxicological, aquacultural, and agricultural dimensions has progressively broadened and diversified Branchiopoda research, rendering it an interdisciplinary and increasingly applied field of inquiry.

Branchiopoda are small to medium sized crustaceans characterized by flattened, leaf like appendages (phyllopods) that function simultaneously in locomotion, respiration, and filter feeding (Obregón Barboza et al., 2002). Most species produce highly resistant dormant eggs known as resting eggs or cysts, which can remain viable in dried sediments for decades and are readily dispersed by wind, water, and migratory water birds, a strategy that enables colonization of ephemeral and geographically isolated habitats (Brendonck et al., 2008; Vanschoenwinkel et al., 2013). This unique combination of biological traits; ecological plasticity, resting egg production, and sensitivity to environmental stressors positions Branchiopoda as exceptional bioindicators of ecosystem health and climate driven hydrological change (Rogers, 2014; Waterkeyn et al., 2010).

Despite the growing volume of publications on Branchiopoda across ecology, ecotoxicology, systematics, and aquaculture, no comprehensive bibliometric study has yet been conducted to systematically map the global research landscape of this class. From a theoretical perspective, existing reviews of branchiopod research are largely discipline specific, focusing either on large branchiopod biogeography (Brendonck et al., 2008; Rogers, 2014), *Daphnia* based toxicology (Jansen et al., 2011), or *Artemia* aquaculture applications (Gajardo & Beardmore, 2012); without integrating the full scope of scientific output into a unified analytical framework. These siloed assessments, while valuable within their respective disciplines, do not capture the intellectual structure, collaborative dynamics, thematic evolution, or emerging research frontiers of Branchiopoda scholarship as a coherent and interconnected whole. From a practical standpoint, the absence of a cross disciplinary bibliometric mapping leaves researchers, conservation

practitioners, and aquaculture stakeholders without a synthesized view of the field's knowledge base, high impact actors, productive journals, and conceptual trajectories information that is increasingly essential for prioritizing research investments, identifying collaboration gaps, and anticipating future directions.

The present study makes four principal contributions to Branchiopoda scholarship. First, it provides the first comprehensive bibliometric mapping of global Branchiopoda research, integrating multi software visualization and network analysis tools. Second, it identifies the core knowledge clusters and traces their thematic evolution across distinct temporal phases, from early taxonomic and ecological foundations to recent ecotoxicological and molecular frontiers. Third, it reveals global collaboration patterns and geographic concentrations shaping the production and citation impact of Branchiopoda research. Fourth, it proposes a conceptual roadmap for future research that integrates ecology, conservation biology, ecotoxicology, molecular systematics, and aquaculture perspectives within a coherent, sustainability oriented framework.

To address these gaps, the present study conducts a comprehensive, longitudinal, and multi software bibliometric analysis of Branchiopoda scholarship spanning the full available publication record on Scopus, integrating Bibliometrix/Biblioshiny, VOSviewer, and CiteSpace. Notably, this study is the first to systematically combine extended temporal coverage with complementary bibliometric tools, including thematic evolution mapping, bibliographic coupling, Bradford's Law, and burst detection, to reveal both the structural foundations and emerging frontiers of Branchiopoda research within a single, coherent analytical framework.

2. Methods

This bibliometric study was conducted following the BIBLIO checklist for biomedical and ecological bibliometric research (Montazeri et al., 2023), ensuring methodological rigor and transparency. The screening and selection process was illustrated using a PRISMA-style flow diagram (Fig. 1), adapted for bibliometric studies to document the inclusion and exclusion of records systematically.

Scopus was used as the sole data source due to its extensive coverage of biological and environmental sciences and its robust metadata suited for bibliometric analyses (Burnham, 2006). The search covered the full available publication record up to April 2026 and was limited to

publications in English. Eligible document types included original research articles, while reviews, conference papers, and editorials were excluded to ensure analytical consistency and comparability across the dataset.

To capture the full breadth of Branchiopoda related research, a comprehensive search strategy was applied to titles, abstracts, and author keywords (TITLE-ABS-KEY). The search terms were designed to encompass the class level descriptor as well as all major constituent orders, combining the wildcard term *branchiopod** with the order level terms *Anostraca*, *Notostraca*, *Spinicaudata*, and *Laevicaudata*. *Cladocera* was deliberately excluded from the query to maintain a focused scope on large branchiopods and to avoid inflation of the dataset with the extensive literature associated with *Daphnia* and related microcrustaceans, which constitutes a distinct and sufficiently broad research domain to merit independent bibliometric treatment. The full search string applied was as follows:

TITLE-ABS-KEY (branchiopod* OR Anostraca OR Notostraca OR Spinicaudata OR Laevicaudata) AND DOCTYPE (ar) AND LANGUAGE (English)

The initial search without language or document type restrictions retrieved **3,297** documents. After applying the restriction to English language original research articles exclusively, the dataset was reduced to 2,862 documents. Following reduplication using unique Scopus EIDs and additional verification in Bibliometrix (R) to eliminate any redundant records across exports, a final cleaned dataset of **2,862** articles was retained for bibliometric analysis (Fig. 1).

Screening and eligibility criteria were defined to include documents directly relevant to Branchiopoda, encompassing studies addressing their taxonomy, ecology, biogeography, ecotoxicology, physiology, aquaculture, molecular biology, or conservation. Non English publications, grey literature, and studies in which branchiopod taxa appeared only peripherally or as part of broader zooplankton assemblages without specific taxonomic focus were excluded.

Data extraction captured a wide range of bibliographic fields, including title, authors, year of publication, journal, institutional affiliations, countries, funding information, author keywords, indexed keywords, references, and DOIs. Citation metrics included global and local citations, h index, g index, m index, and total citations per year (TC/year), allowing evaluation of scholarly impact at multiple levels of analysis.

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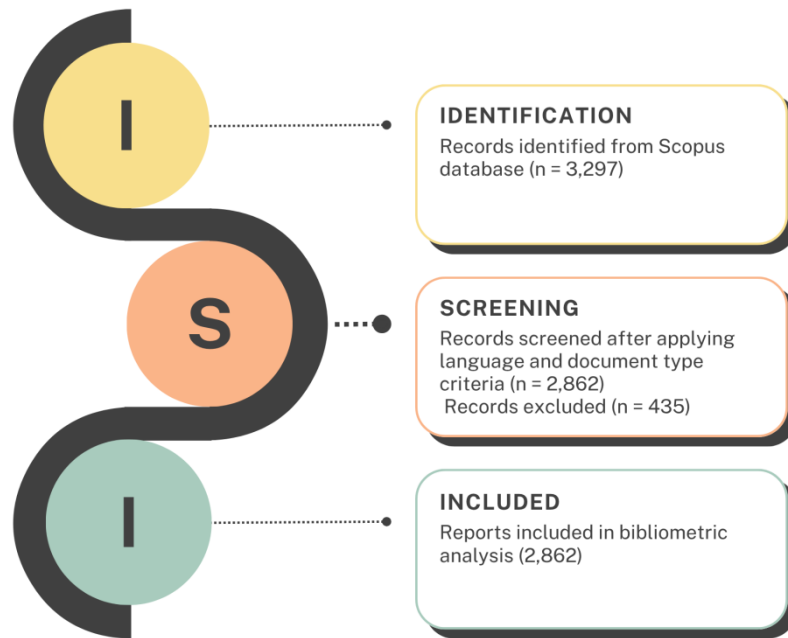


Fig. 1 Flow diagram of the bibliometric identification and screening process.

2.1. Analytical framework and software

complementary software environments were used to examine the structure of Branchiopoda research (Al-Shattarat et al., 2025; Hassanein & Mostafa, 2023; Tahat et al., 2025). Bibliometrix and Biblioshiny (R package, version 5.0) were used for descriptive performance analysis, publication and citation trends, source and author productivity, co-word analysis, thematic mapping and evolution, and three-field plots (Aria & Cuccurullo, 2017, 2026). VOSviewer (version 1.6.20) [report the exact version] was used to construct co-authorship, keyword co-occurrence, citation, and bibliographic-coupling networks, together with density and overlay visualisations (Van Eck & Waltman, 2010). CiteSpace (version 6.3) was used for reference co-citation analysis, timeline visualisation, and cluster labelling of recent research fronts (Chen, 2014).

2.2. Thresholds and parameter settings

To ensure comparability and reproducibility, we predefined thresholds and clustering/normalization options for each analysis. In VOSviewer, co authorship maps were generated using full counting, with a minimum threshold of ≥ 5 documents per author; the final author collaboration network was visualized using association strength normalization, with clustering resolved via the VOSviewer modularity based algorithm. For keyword co occurrence analysis, author keywords were cleaned prior to network construction synonyms were merged (e.g., "branchiopod" and "branchiopoda"; "fairy shrimp" and "anostraca"; "tadpole shrimp" and "notostraca"), and plural/singular forms were harmonized and a minimum occurrence threshold of ≥ 5 was applied; density and overlay maps used the same association strength normalization and default clustering resolution.

In Bibliometrix/Biblioshiny thematic mapping, themes were derived from author keywords using a minimum word frequency of ≥ 5 , and clusters were positioned using Callon's centrality and density metrics; thematic evolution was computed by splitting the full timespan into three periods to capture long , mid , and short term conceptual shifts. Bibliographic coupling of journals applied a minimum source productivity threshold of ≥ 5 documents per journal, retaining only the most productive outlets for network construction.

In CiteSpace (restricted to the most recent decade for burst detection), we used a 1 year time slice, g index ($k = 25$) for node selection, pathfinder pruning combined with merged network pruning to improve network readability, and reported thematic clusters using standard LLR (Log Likelihood Ratio) based labeling; keyword bursts were detected using the default burst detection procedure with the same time slicing (Benameur et al., 2024; Hassanein et al., 2025; Tharwat et al., 2025)

3. Results

3.1. Dataset characteristics and annual output

The final corpus comprised 2,862 English language research articles. Annual output from 1913 to 2026 (Fig. 2) shows several distinct phases. Before 1990, publication was sparse and irregular, generally remaining below 15 articles per year. Output increased rapidly during the 1990s and early 2000s and reached a maximum of approximately 130 articles per year between 2000 and 2005. Thereafter, annual production fluctuated around a substantially higher plateau. The

apparent decline in the most recent period should be interpreted cautiously because 2026 represents a partial publication year and recent Scopus records may not yet be fully indexed.

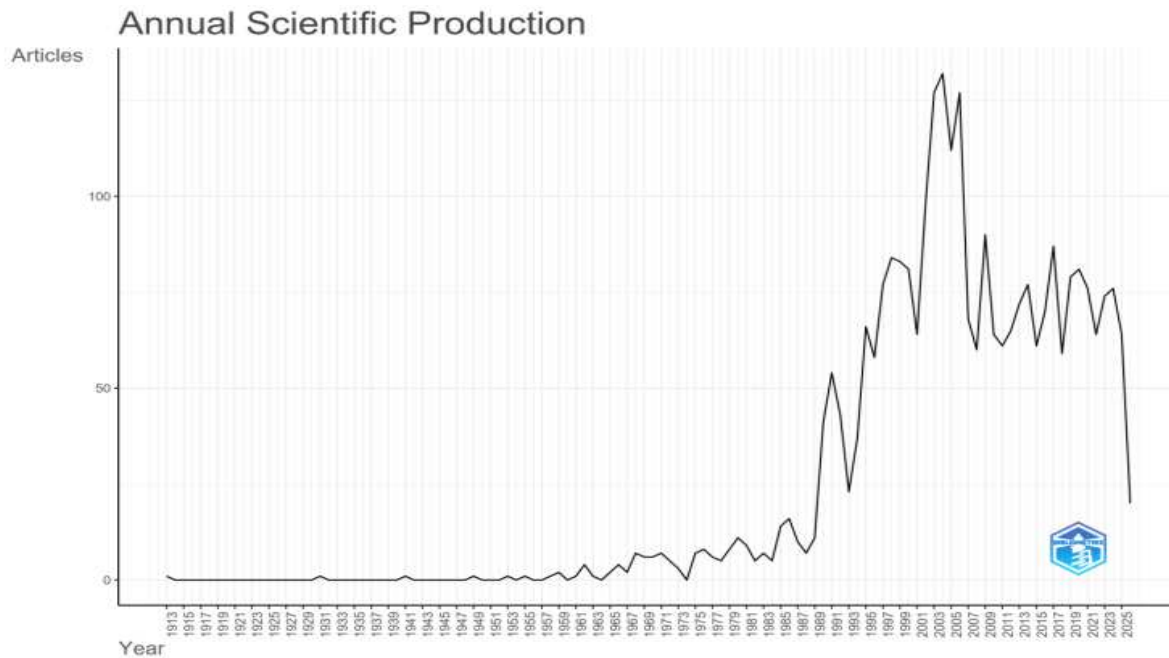


Fig. 2 Annual scientific production in Branchiopoda-related research, 1913-2026.

3.2. Growth and citation patterns

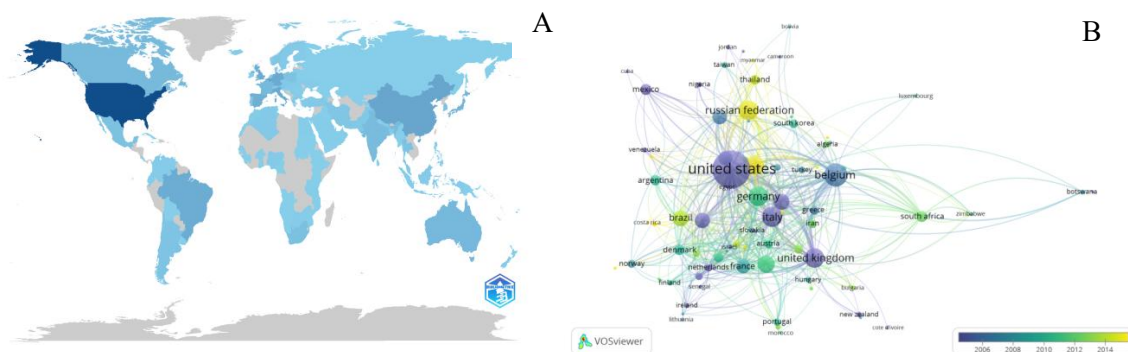
Across the 1913–2026 period, annual publication output increased from a negligible pre-1990 baseline to a peak of slightly more than 130 articles in the mid-2000s. annual growth rate of 17.84%. Since the peak, output has remained well above the pre-1990 baseline. Any downturn in the final years must be interpreted in light of partial year coverage and indexing delays (Fig. 2).

Citation impact has accumulated in parallel with this rising productivity, although it remains concentrated among a limited number of documents and countries. The corpus has attracted a total of **65,357** citations, averaging **24.69** citations per article , with a field h index of 102. The most frequently cited studies are dominated by foundational syntheses of large branchiopod diversity and by methodological papers underpinning the use of *Artemia* in bioassays, The most frequently cited studies are dominated by foundational works on groundwater and AI applications, notably Podgorski J.; Berg M. (2020), Global threat of arsenic in groundwater (1402

citations), Govindaraju R.S. (2000), Artificial neural networks in hydrology. II: Hydrologic applications (1381 citations), and Freeze R.A.; Cherry J.A. (1979), Groundwater (1261 citations). At the country level, total citations concentrate in the United States, Belgium, and China (Fig. 3C, E), with the leading nation accumulating on the order of 1,150 citations; this mirrors the geographic concentration of productivity discussed in Section 3.3 and confirms that a small group of Global North research systems has shaped both the volume and the influence of Branchiopoda scholarship.

3.3. Geographic distribution and international collaboration

Country level analyses of publication output, corresponding-author affiliation, citation impact, and collaboration (Fig. 3) revealed a pronounced geographic concentration. The United States was the leading contributor and occupied a central position in the international collaboration network. Belgium showed a comparatively high proportion of multiple-country publications, indicating a strongly internationalised publication profile. Germany, China, Italy, Brazil, and the United Kingdom also formed well connected collaboration clusters. Overall, the network was dominated by North American, European, and East Asian countries, whereas many countries in Africa, the Middle East, Central Asia, and Latin America were less represented.



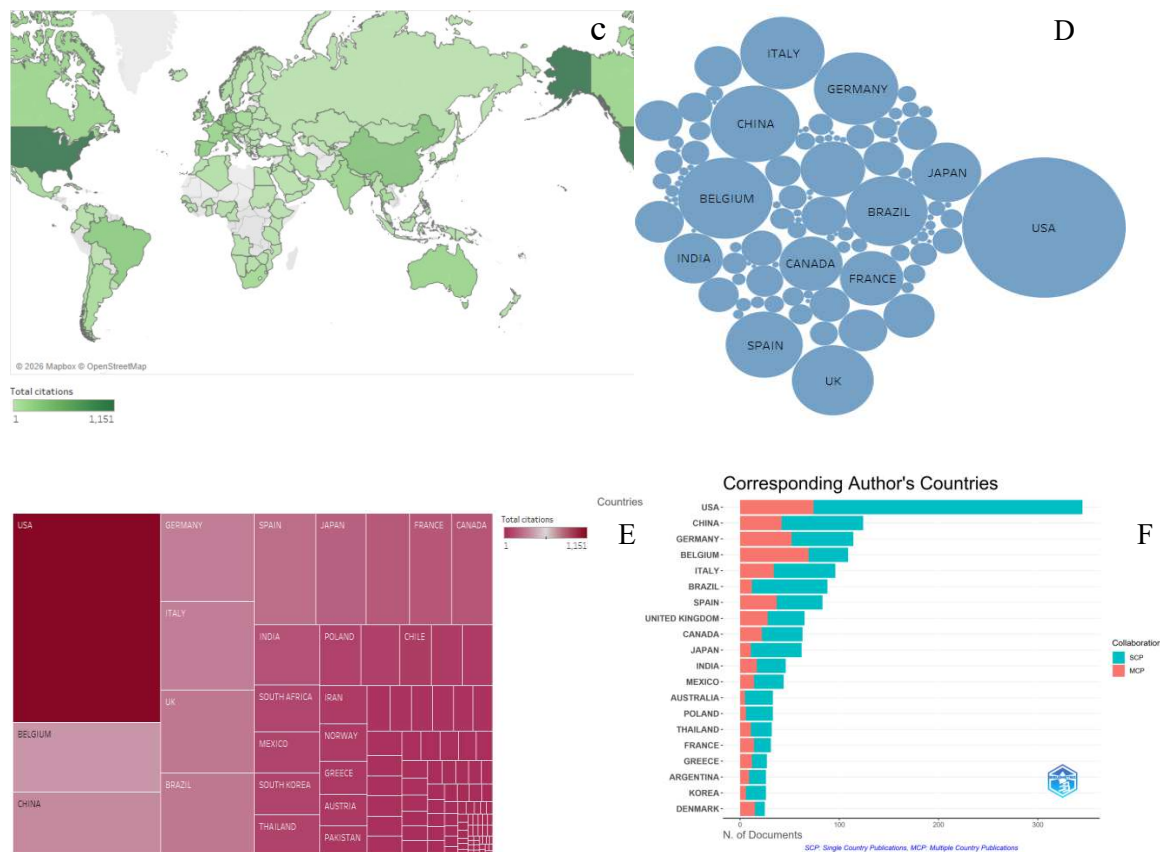


Fig. 3 Global distribution and collaboration in Branchiopoda research. (A) Geographic distribution of publications. (B) Country co-authorship network generated in VOSviewer. (C) Heat map of total citations by country. (D) International collaboration network. (E) Treemap of total citations by country. (F) Corresponding-author countries, distinguishing single-country publications (SCP) from multiple-country publications (MCP).

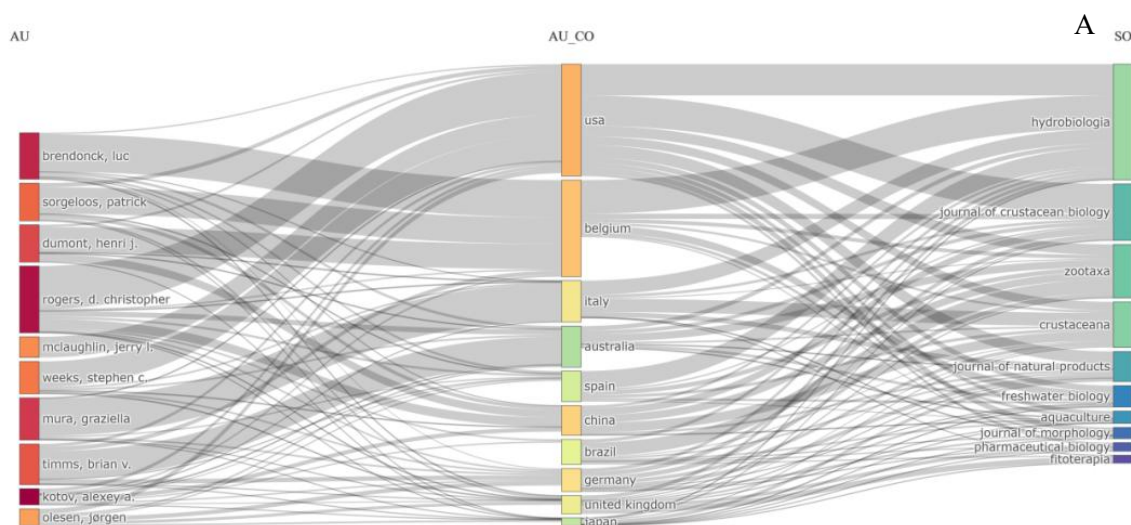
3.4. Author, country, and source linkages

The three-field plot (Fig. 4A) links prolific authors with their countries and preferred publication venues. Leading contributors including Brendonck L., Sorgeloos P., Rogers D.C., Weeks S.C., Mura G., Timms B.V., Kotov A., and Olesen J. were affiliated mainly with institutions in the United States, Belgium, Italy, Australia, and China. Their publications were concentrated in *Hydrobiologia*, *Journal of Crustacean Biology*, *Zootaxa*, *Crustaceana*, and *Freshwater Biology*. A smaller stream connected authors to pharmacology-oriented outlets such as *Journal of Natural Products* and *Phytotherapy Research*, reflecting the use of the anostracan species; *Artemia salina*

brine-shrimp lethality assays rather than a shared taxonomic focus. The co-authorship network (Fig. 4C-D).

comprised approximately eight loosely connected groups organised around regional and thematic specialisations. These included large-branchiopod ecology; systematics and biogeography; cladoceran systematics; *Artemia* aquaculture and genetics; Mediterranean and South American crustacean biology; waterbird-mediated dispersal and conservation; and two smaller morphology and evolutionary groups. The network therefore indicates strong, long-standing research teams but limited integration across regional and disciplinary boundaries.

Resolves into roughly eight loosely interconnected groups organized largely along regional and taxonomic lines: a large branchiopod ecology cluster around Brendonck L., Riddoch B.J., Pinceel T., and Persoone G.; a systematics/biogeography cluster around Dumont H.J., Rogers D.C., Van Damme K., Padhye S., Martin J.W., and Weeks S.C.; a Cladocera systematics cluster around Kotov A.A., Neretina A.N., Smirnov N.N., Sinev A.Y., and Paggi J.C.; an *Artemia* aquaculture/genetics cluster around Sorgeloos P., Asem A., Sun S.C., De Clercq P., and Lukić D.; a Mediterranean/South American crustacean biology cluster around Mura G., Stoch F., Alonso M., Machado M., and Cohen R.G.; a water bird mediated dispersal and conservation cluster around Abatzo poulos T.J., Gajardo G., Green A.J., Amat F., and Vasileva G.P.; and two smaller morphology/evolutionary clusters around Scanabissi F. and Mantovani B., and around Sousa F.D.R., García París M., and Elmoor Loureiro L.M.



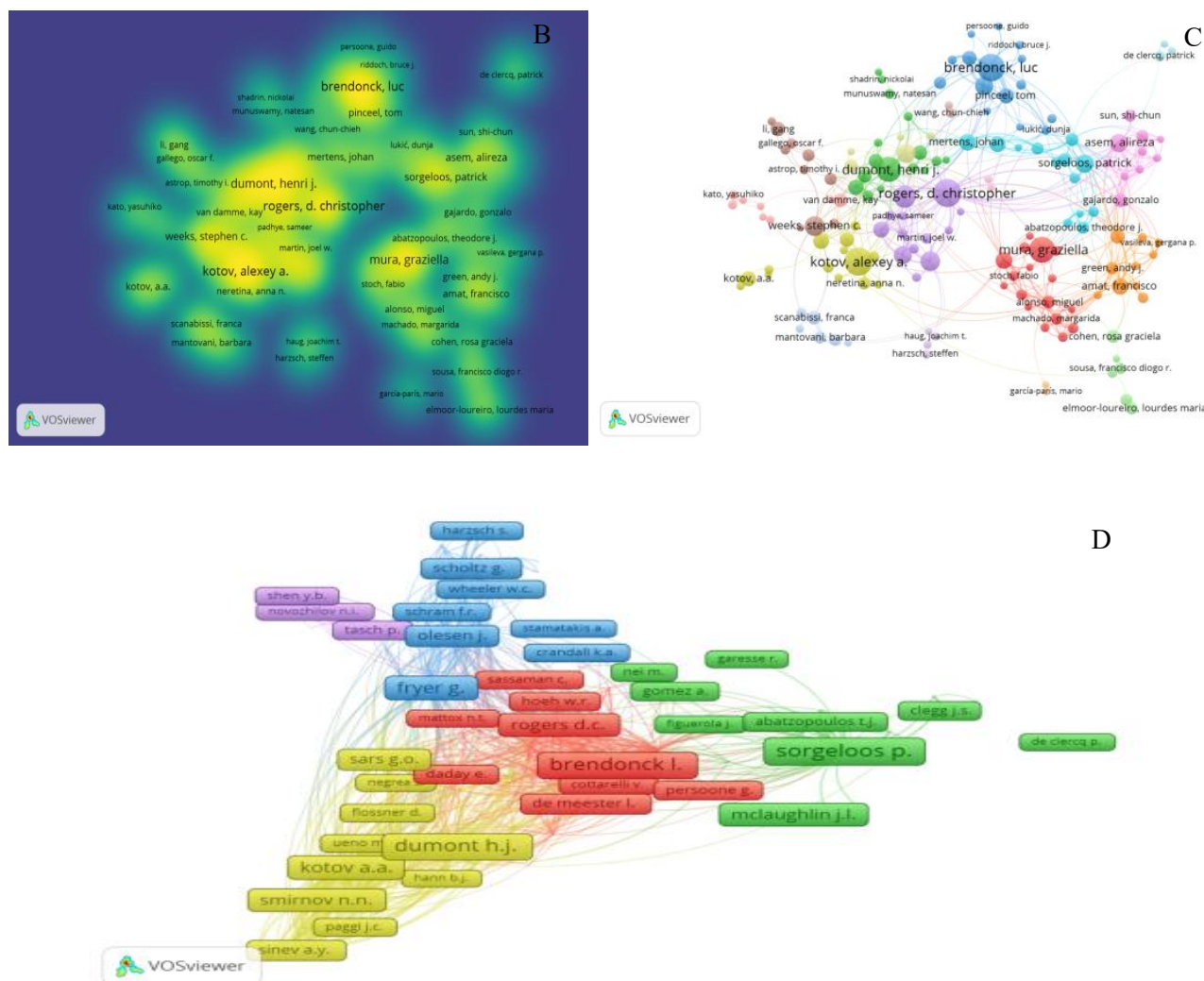


Fig. 4 Author productivity, linkages, and collaboration. (A) Three-field plot linking authors, countries, and source journals. (B) Country collaboration network showing inter-country co-authorship ties. (C–D) Co-authorship networks generated in VOSviewer.

3.5. Mapping of constructing terms

The highest frequency descriptors included crustacean, Branchiopoda, nonhuman, Crustacea, Anostraca, and animals (Fig. 5A). The full co-occurrence network (Fig. 5B–D) contained five visual clusters that could be consolidated into three broad thematic domains. The first domain, taxonomy and palaeontology, linked phylogeny, Arthropoda, Hexapoda, Insecta, Pancrustacea, cladistics, ontogeny, cuticle, Gondwana, evolution, biostratigraphy, and the Yixian Formation. The second domain, freshwater ecology and biodiversity, linked Branchiopoda, Laevicaudata, taxonomy, Cladocera, Chydoridae, Anomopoda, zoogeography, biodiversity, wetlands, species

richness, community structure, Copepoda, zooplankton, and regional descriptors. The third domain, ecotoxicology and bioassays, centred on *Artemia*, *Artemia franciscana*, *Artemia salina*, brine shrimp, salinity, temperature, hatching, cytotoxicity, bioassays, insecticidal and antibacterial activity, cyanobacteria, microalgae, and toxicity. The recurrence of these domains is consistent with the journal-coupling structure described in Section 3.7.

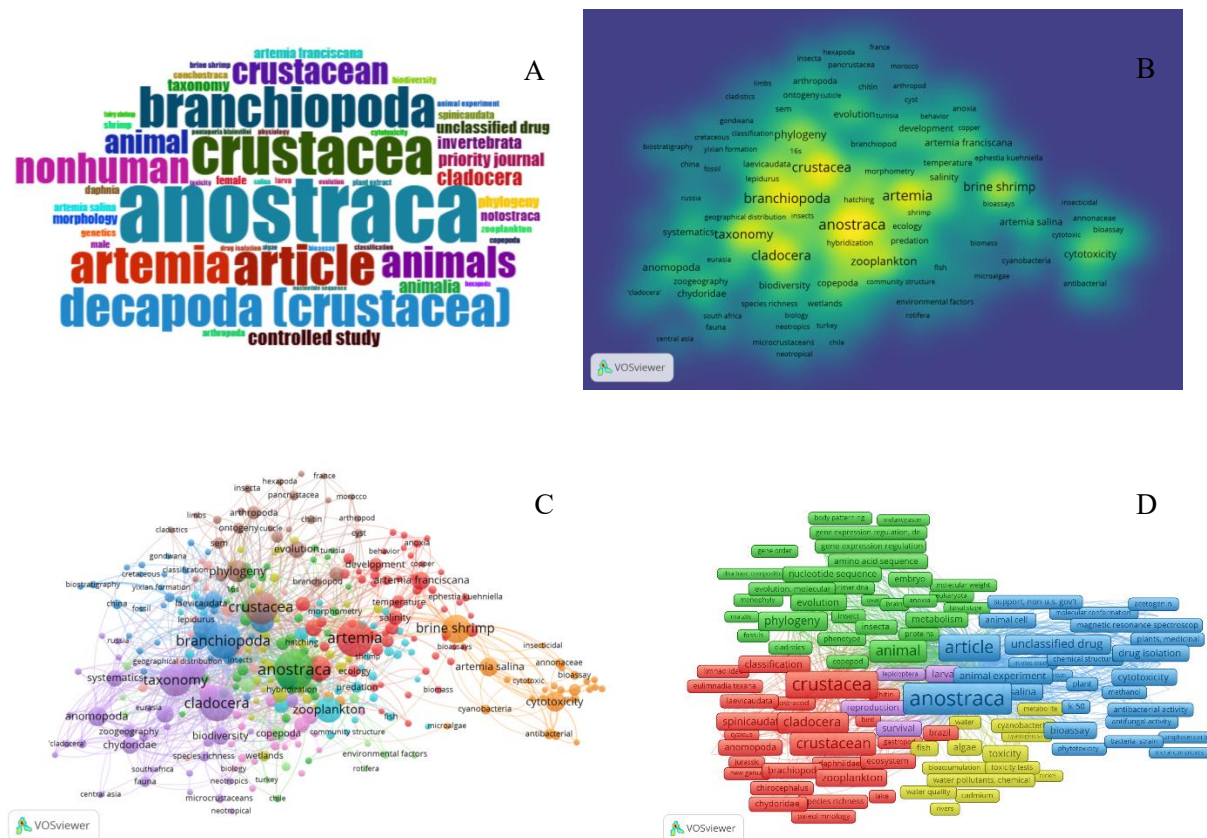
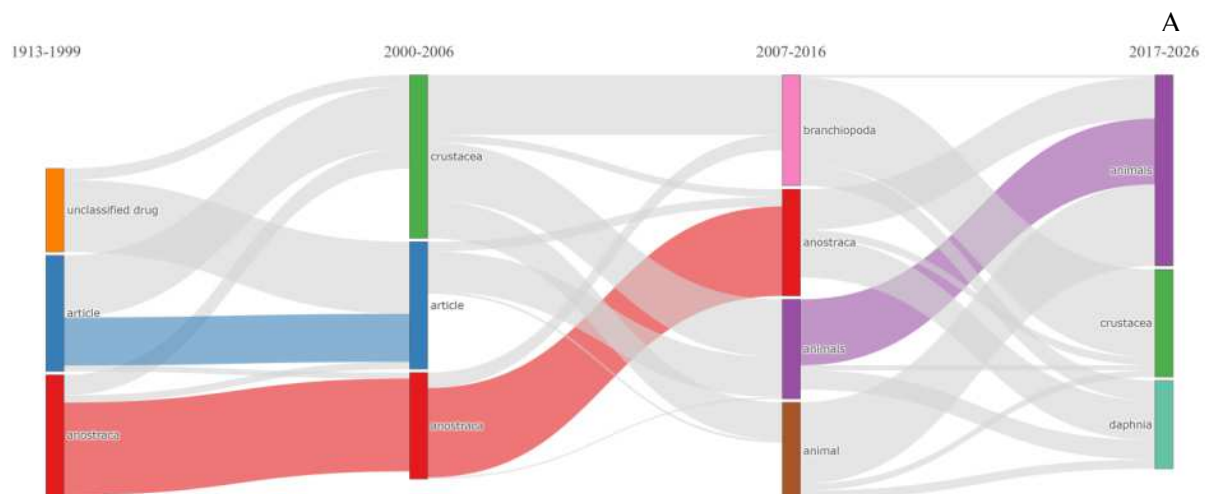


Fig. 5 Keyword analysis of Branchiopoda research. (A) word cloud comprising the 35 most frequently cited keywords by the authors, without normalisation, highlighting dominant terms such as « Animalia », « Branchiopoda », « Crustacea », « Decapoda » and « Artemia ». (B) Density visualization showing keyword intensity, where warmer colors indicate higher frequency and cooccurrence strength. (C) Network visualization of keyword co-occurrence, revealing five main clusters: Artemia / brine shrimp (red), Crustacea / phylogeny (blue), Anostraca / zooplankton (green), Branchiopoda / cladocera (purple) and Development / morphology (green). (D) Overlay visualization showing the temporal trajectory of terms, with orange/yellow nodes indicating emerging research topics.

3.5. Mapping of constructing terms

3.6. Thematic evolution of Branchiopoda research

The thematic evolution analysis divided the corpus into four periods (1913-1999, 2000-2006, 2007-2016, and 2017-2026) and revealed a three-phase conceptual trajectory (Fig. 6). In 1913-1999, “unclassified drug”, “animals”, and “cytotoxicity” appeared as niche themes, whereas “Anostraca”, “Decapoda (Crustacea)”, and “*Artemia*” occupied the basic-theme quadrant. This pattern indicates that early literature combined dispersed pharmacological and bioassay studies with general crustacean taxonomy. In 2000-2006, “article”, “nonhuman”, and “controlled study” remained niche themes, while “Anostraca”, “*Artemia*”, and “Crustacea” persisted as basic themes. During 2007-2016, “Branchiopoda” and “Crustacea” moved into the motor-theme quadrant alongside “Anostraca” and “*Artemia*”, indicating consolidation of the field around an explicit taxonomic identity. In 2017-2026, “*Daphnia*”, “fairy shrimp”, and “toxicity” appeared as niche themes, while “Crustacea”, “crustacean”, and “Branchiopoda” occupied the basic-theme quadrant. Overall, the results trace a shift from early pharmacological, bioassay, and general crustacean studies to a more coherent taxonomic-ecological field in which conservation and molecular themes are increasingly visible. The presence of “*Daphnia*” in the latest period also confirms that the class level wildcard retrieved some cladoceran related records.



B

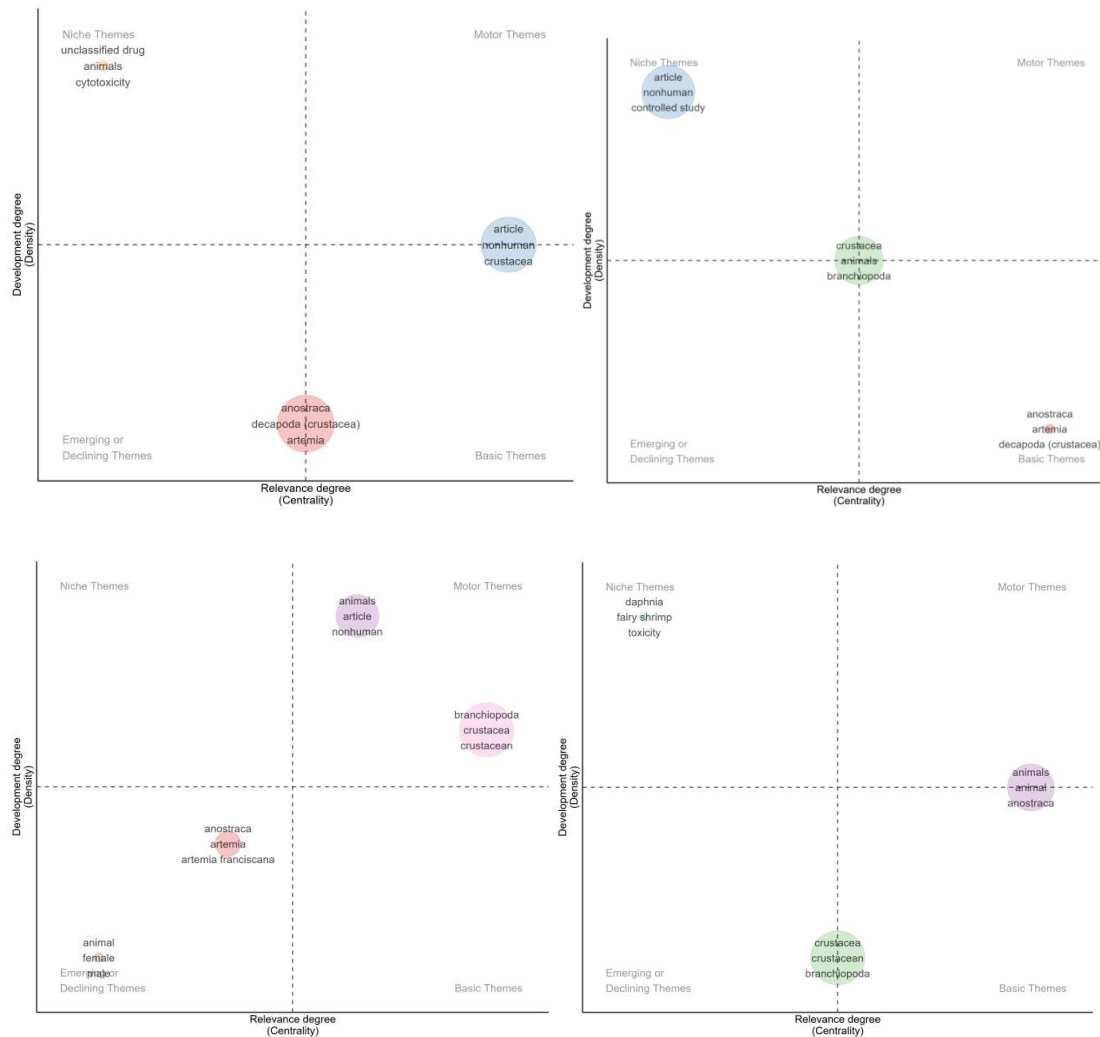


Fig. 6 Thematic evolution and thematic maps. (A) Evolution of keyword themes across four periods. (B) Thematic maps positioning clusters according to Callon's centrality and density.

Complementing this temporal picture, the keyword co occurrence networks in Fig. 7 resolve the conceptual architecture of the field into a small number of stable clusters. Across the different clustering resolutions, three groupings recur: a taxonomic and phylogenetic cluster built around crustacea, phylogeny, arthropoda, and article; a freshwater ecology and biodiversity cluster organised around branchiopoda, cladocera, taxonomy, zooplankton, and biodiversity; and an ecotoxicology and bioassay cluster centred on anostraca, Artemia, Artemia franciscana, and toxicity. The overall thematic map (Fig. 8), which positions author keywords by centrality and density, is consistent with this structure: crustacea, branchiopoda, and crustacean occupy the basic theme quadrant as broad, well established descriptors; anostraca, article, and decapoda (Crustacea) appear as motor themes driving current work; animals,

animal, and phylogeny form a developed but more specialised cluster; and *Artemia franciscana*, together with narrower descriptors such as survival, falls into the emerging or declining quadrant.

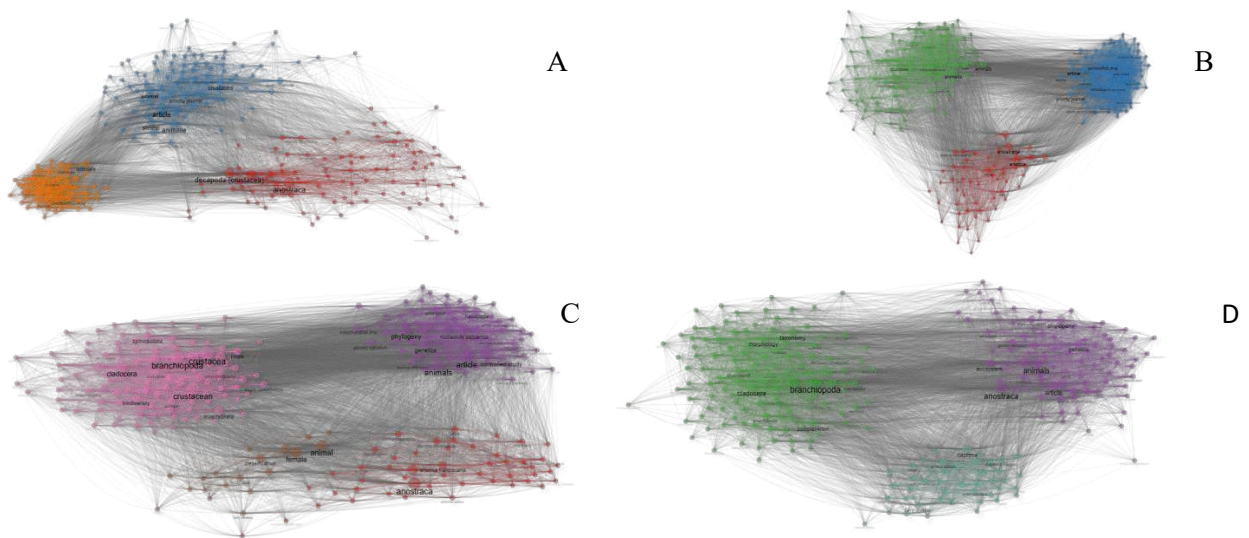


Fig. 7 Keyword co occurrence networks of Branchiopoda research generated in VOSviewer. (A) Overall topological organisation of the author keyword co occurrence network; (B-D) the principal thematic clusters resolved at increasing clustering resolution, recovering a taxonomic/phylogenetic group, a freshwater ecology and biodiversity group, and an *Artemia* centred ecotoxicology group.

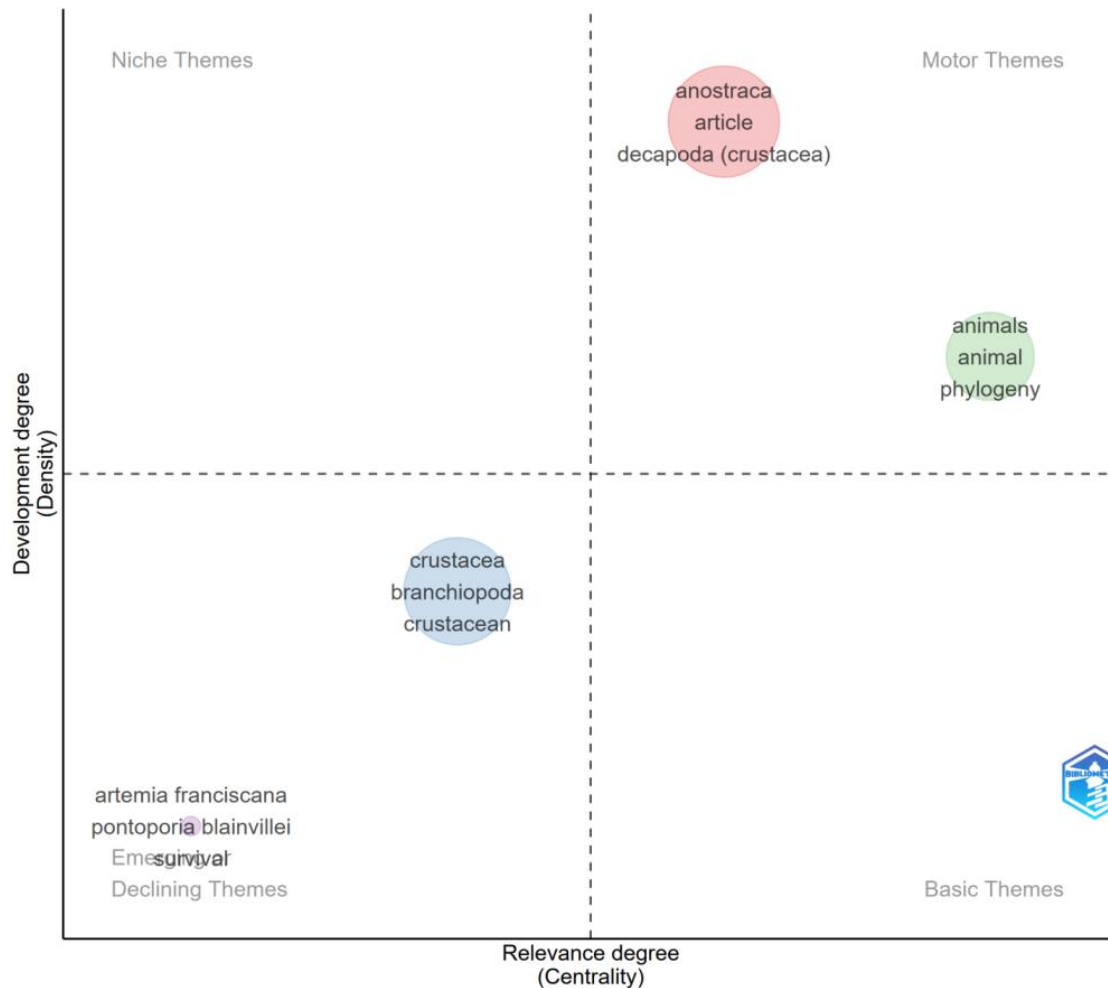


Fig. 8. A thematic map of research on branchiopods, based on the keywords used by the authors. The themes are plotted according to their centrality (relevance, x axis) and their density (development, y axis). The quadrants correspond respectively to driving themes (top right), niche themes (top left), fundamental themes (bottom right) and emerging/declining themes (bottom left), there by illustrating the conceptual structure and the maturity of research on branchiopods.

The temporal distribution of title terms (Fig. 9) reinforces this trajectory. Activity before the mid 1990s is dominated by terms such as intoxication, embryogenesis, and microscopy, reflecting the field's early physiological and pharmacological orientation. The middle period is characterised by high frequency descriptors including anostraca, non human, controlled study, and toxicity, marking the consolidation of standardised *Artemia* bioassays alongside core taxonomic work. The most recent terms-among them conservation, climate change, species richness, phylogenetic analysis, DNA extraction, and recombination-indicate a clear shift toward conservation biology,

biogeography, and molecular and genomic approaches, consistent with the conservation genomics frontier emphasised in the Discussion.

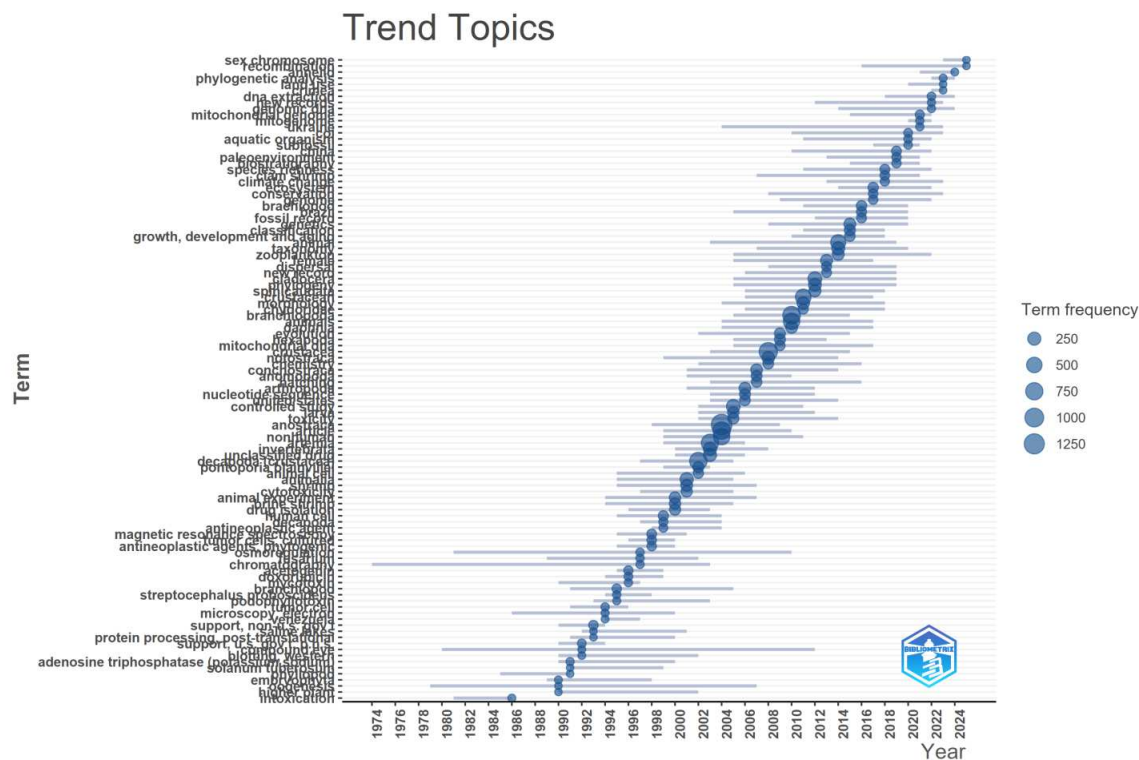


Fig.9 Trending topics in research on branchiopods, identified on the basis of tri grams appearing in titles. The horizontal lines represent the period of activity for each topic, whilst the size of the circles indicates the frequency of the terms, thereby highlighting the evolution over time and the intensity of the research.

3.7. Bibliographic coupling and interdisciplinary linkages (Fig. 10)

The results of bibliometric analysis show that scientific output on Branchiopoda is organised into several relatively compartmentalised ‘worlds’, corresponding to distinct disciplinary traditions (freshwater ecology, taxonomy, morphology and phylogeny, palaeontology, crustacean biology, aquaculture and ecotoxicology). This fragmentation confirms the existence of silos already highlighted by co authorship networks, but it also sheds light on the structuring role of certain journals that act as bridges between these communities. In particular, « *Hydrobiologia* » and « *Zootaxa* » stand out as major bibliographic hubs, where references from ecology, taxonomy and, more broadly, freshwater biology converge.

The peripheral position of the aquaculture and ecotoxicology cluster indicates that applied research (for example, on the optimisation of *Artemia* strains for fattening or on ecotoxicological testing) draws on a body of references largely separate from that of fundamental work in systematics, ecology and evolution. This bibliometric distance suggests that applied approaches rely primarily on literature from engineering and nutrition, whilst failing to sufficiently incorporate the biological and evolutionary constraints specific to the species under study. Such a disconnect can have practical consequences: for example, the failure to recognise cryptic speciation within the *Artemia franciscana* species complex when selecting strains for aquaculture can compromise both production performance and the ecological validity of ecotoxicological assays.

Indeed, it appears that journals covering a broad disciplinary spectrum, foremost among which is « *Hydrobiologia* », it play a central role as an “interface” between basic science and its applications. They serve as forums where insights from ecology, taxonomy and the environmental sciences converge, and where applied findings can be situated within a broader evolutionary and ecological framework. The bibliographic coupling diagram thus highlights a key challenge for research on Branchiopoda: to encourage citation and publication practices that strengthen these bridge journals, in order to narrow the gap between applied and fundamental research communities and to minimise the risk of misinterpreting biological responses.

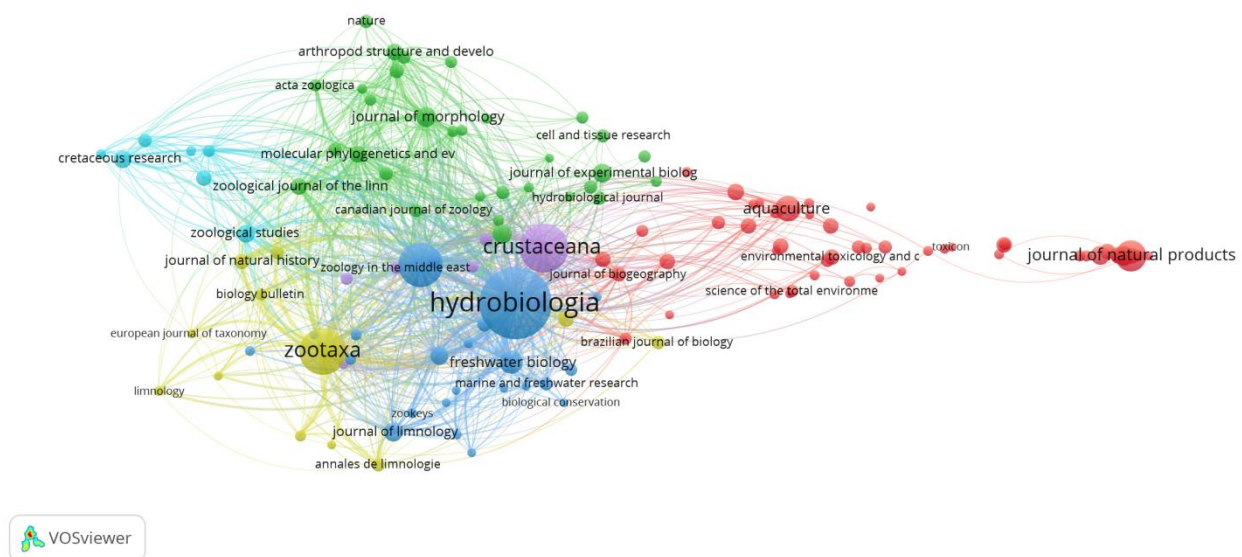


Fig. 10 Bibliographic coupling of journals in Branchiopoda research (N = 92, threshold ≥ 5 documents) revealed six clusters: (1) freshwater ecology and limnology, (2) taxonomy and biodiversity, (3) morphology, molecular phylogenetics, and evolution, (4) palaeontology, (5) crustacean biology and biogeography, and (6) ecotoxicology, aquaculture, and applied environmental sciences. Hydrobiologia and Zootaxa emerged as central sources, highlighting the interdisciplinary nature of the field. An interactive version of the map is available in the Supplementary Information .

3.8. Reference co-citation structure and temporal dynamics

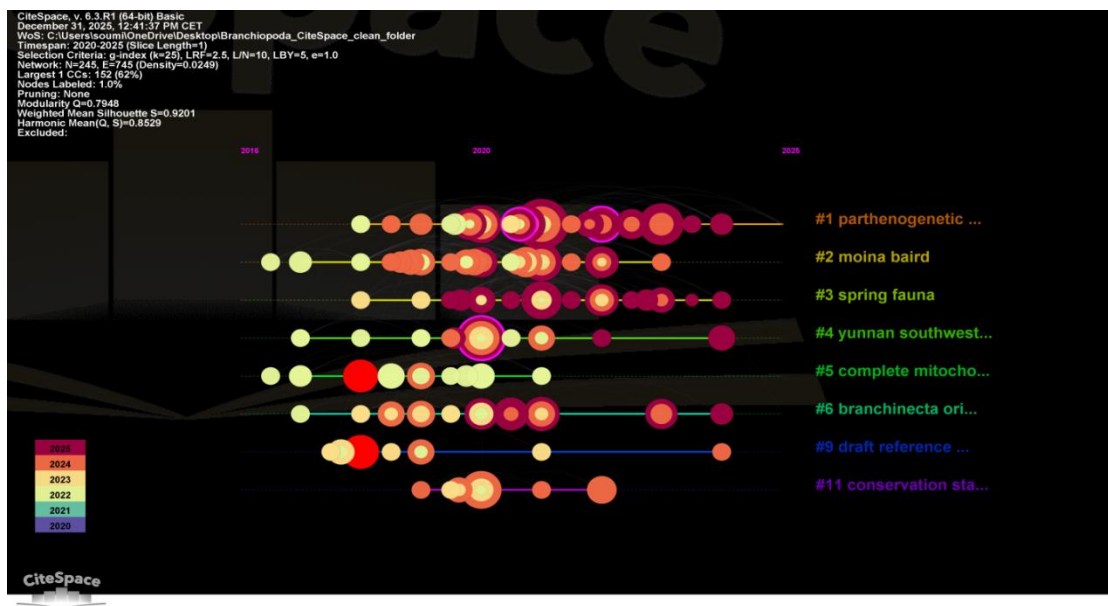
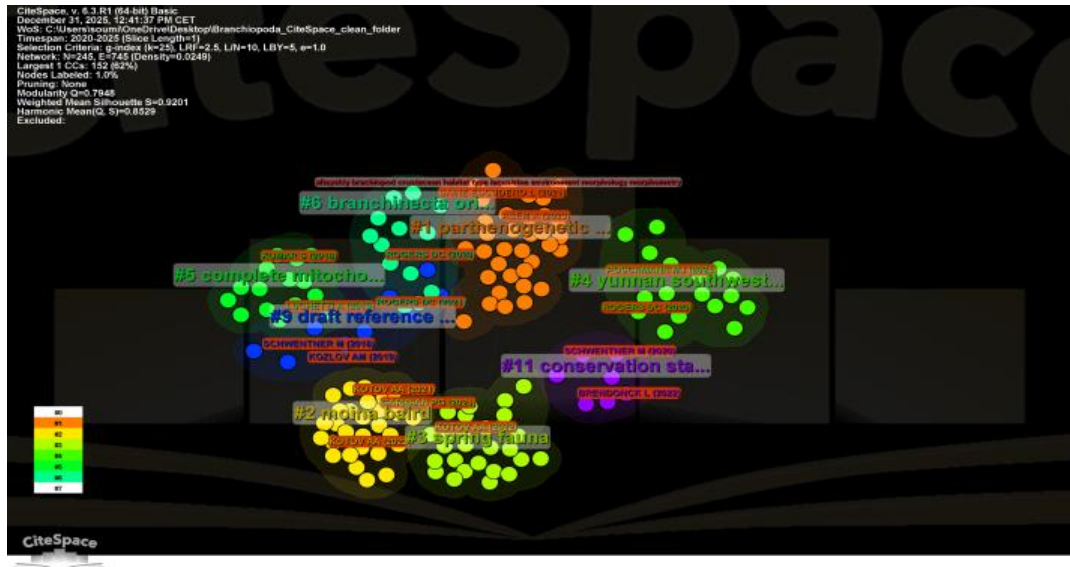


Fig. 11 Intellectual structure and temporal evolution of recent Branchiopoda research. (A) Reference co-citation cluster network generated using CiteSpace. (B) Timeline visualisation showing the temporal distribution and persistence of the principal co-citation clusters.

The reference co-citation network reconstructed in CiteSpace for the most recent decade comprised 246 nodes and 745 co citation links, with an overall network density of 0.0249 (Fig. 11A). CiteSpace identified 29 clusters. The largest connected component contained 152 nodes, representing 62% of the complete network. The clustering solution exhibited high modularity ($Q=0.7948$) and a high weighted mean silhouette value ($S=0.9201$). The harmonic mean of modularity and silhouette was 0.8529. These values indicate a clearly differentiated intellectual structure together and within cluster consistency.

The major visible clusters were associated with parthenogenetic reproduction, the taxonomy and diversity of the genus *Moina*, spring and seasonal freshwater fauna, regional biodiversity in southwestern China, complete mitochondrial genomes, *Branchinecta orientalis*, draft reference genomes, and conservation status. Collectively, these clusters demonstrate that recent Branchiopoda scholarship is structured around several complementary research fronts, including reproductive biology, classical and integrative taxonomy, regional faunistics and biogeography, molecular phylogenetics, mitogenomics, conservation genomics, and habitat conservation.

The network several densely connected groups of references, indicating that recent studies frequently draw upon common bodies of taxonomic, molecular, ecological, and conservation literature. Molecular and genomic clusters were positioned close to taxonomic and biogeographic clusters, suggesting increasing integration of morphological identification, DNA based species delimitation, phylogenetic reconstruction, and geographic distribution research.

4. Discussion

This study presents the first comprehensive bibliometric mapping of Branchiopoda research. Spanning 1913 to 2026, this study reveals a body of literature that is relatively modest compared with that devoted to other invertebrate taxa, yet structurally coherent and constantly expanding (Gauthier, 1928; Seurat, 1930). Since the 1990s, research has focused more on three recurring areas : taxonomy and palaeontology, freshwater ecology, and conservation and ecotoxicology. It relies largely on *Artemia*, which is used as a bioassay organism. In contrast, whilst bibliometric analyses of taxa whose production and consumption markets are concentrated in Asia show that research on branchiopods is primarily carried out in the United States and in Western and Southern Europe, China makes a significant contribution to productivity and citation impact, without, however, exercising the overwhelming dominance observed in other bibliometric fields. The geographical distribution observed is closely linked to the intellectual origins of the discipline; the ecology and systematics of large branchiopods have largely developed around longstanding European research programmes focusing on Mediterranean temporary pools and the conservation of North American spring pools (Alonso, 1985; Christopher Rogers & Hegna, 2020; Padhye et al., 2017; Pérez-Bote, 2004; Timms & Hudson, 2009; Van den Broeck et al., 2015),

whilst research into *Artemia* aquaculture has developed independently around industrial centres for the production of brine shrimp cysts in the Americas, Europe and Asia (Lavens & Sorgeloos, 2000; Rollefson, 1939; Seale, 1933; Sorgeloos et al., 2001).

The collaborative network is organised around a particularly dense Euro American core, to which nodes located in Africa and the Global South are linked (Chergui et al., 2024; De los Ríos-Escalante & Amarouayache, 2016). These relatively peripheral nodes reflect a trend that has been widely confirmed in bibliometric studies on biodiversity and freshwater ecology (authors), expertise in taxonomy and conservation remains concentrated in a small number of well resourced institutions, even though many of the temporary wetlands and endorheic basins harbouring the greatest diversity of branchiopods are found in Africa, the Middle East, Central Asia and South America. This asymmetry constrains both the completeness of global distribution records and the capacity of range country scientists to lead conservation assessments of their own fauna, and it points to a clear opportunity for capacity building partnerships modelled on the

more balanced collaboration already evident between European and select Southern Hemisphere groups (e.g., South Africa, Argentina, and Chile).

The convergence of keyword co-occurrence and bibliographic coupling on the same three broad domains is the clearest structural result of this study. Large branchiopods Anostraca, Notostraca, Spinicaudata, Laevicaudata), are studied mainly as components and indicators of temporary-wetland biodiversity (Belk, 1998) whereas *Artemia salina* is widely used in natural-product and general toxicity screening (Filipe et al., 2022; Ntungwe et al., 2020). Although they share the same taxon, these two research communities differ in their disciplinary roots, their methodological choices and, in most cases, the authors who shape their theoretical frameworks. They are primarily linked by a small number of highly central journals such as « Hydrobiologia » and « Zootaxa » on the taxonomic/ecological side, and « Aquaculture », « Journal of Natural Products » and « Environmental Toxicology and Chemistry ».

Several limitations should be considered. First, reliance on Scopus alone may have excluded records indexed only in Web of Science, regional databases, or local repositories. Second, the English language and article only restrictions omit non-English literature, reviews, and conference proceedings that may contain regionally important evidence. Third, Cladocera was omitted as a standalone search term but was not strictly excluded: records containing branchiopod* could still enter the corpus, as indicated by the presence of *Daphnia*, *Moina*, and other cladoceran terms in the results. The study should therefore be interpreted as a Branchiopoda-related mapping produced by a large-branchiopod-oriented query, not as a perfectly delimited census of either Branchiopoda sensu lato or large branchiopods alone. Fourth, 2026 was a partial publication year at the search date, so recent output is underestimated. Fifth, citation indicators reflect scholarly visibility rather than conservation, industrial, or policy impact. Finally, burst-detection results were not reported in this version and should not be claimed until the corresponding outputs are fully analysed.

Future work should compare Scopus with Web of Science and relevant regional databases, incorporate multilingual searches, and evaluate how alternative query designs affect the balance between large branchiopods and Cladocera. Document-level citation and burst analyses could identify influential studies and emerging fronts more precisely. Given the increasing visibility of molecular and conservation terms, future bibliometric monitoring should also track the adoption

of genomics, environmental DNA, and integrative taxonomy in conservation assessments. Particular attention should be given to whether international collaboration expands equitably in African, Middle Eastern, Central Asian, and Latin American countries that contain substantial but still incompletely documented branchiopod diversity.

5. Conclusion

This bibliometric analysis provides a global overview of Branchiopoda related research retrieved through a large-branchiopod-oriented Scopus query. Publication output expanded rapidly from the 1990s and later stabilised at a level well above the historical baseline. The field is organised around three recurrent domains: taxonomy and palaeontology; freshwater ecology and conservation; and ecotoxicology, largely centred on *Artemia* as a bioassay organism. The United States, Western Europe, and China dominate productivity, citation impact, and international collaboration, while many countries in Africa, the Middle East, Central Asia, and Latin America remain underrepresented. Thematic analyses indicate a transition from early pharmacological, bioassay, and general crustacean studies towards a more integrated taxonomic-ecological field that increasingly incorporates molecular and conservation approaches. *Hydrobiologia* and *Zootaxa* act as central hubs linking basic and applied research. These findings provide a baseline for monitoring future growth, collaboration gaps, and the emergence of molecular and conservation-oriented research in Branchiopoda.

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Data availability All data is available upon requests to the authors.

Declarations

Competing interests The authors declare that the research was conducted in the absence of any commercial relationship that could be interpreted as a potential conflict of interest.

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Consent to publish This is not applicable.

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