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Keyword Networks and Research Frontiers in Fisheries and Lake Management: A Comprehensive Bibliometric Approach

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ABSTRACT

Sustainable fisheries and lake management are increasingly important concerns in addressing global ecological challenges. This study presents a comprehensive bibliometric analysis based on 4,241 publications indexed in the Scopus database, using the keywords "fishery" OR "fisheries" AND "management" AND "lake" OR "reservoir" during the period 1937–2025. The analysis includes annual research production, citation trends, and contributions from 936 sources, as well as 125 countries and institutions. The study employs Co-Word Network analysis to identify dominant themes, including ecosystem services, sustainable fisheries, and reservoir ecology, while also highlighting emerging trends such as climate change adaptation and advanced modeling techniques. Keyword network analysis identifies critical nodes such as "fishery management" and "lake ecosystem", which occupy strategic positions within the research landscape. This study not only maps the intellectual structure of research in the field of fisheries and lake management but also identifies potential future research areas. These findings provide valuable insights for academics, practitioners, and policymakers aiming to promote sustainable practices in fisheries and reservoir management.

INTRODUCTION

Fisheries and lake management is a critical component in efforts to maintain ecological balance and ensure the sustainability of water resources. These ecosystems offer a range of essential services, including food supply through fisheries, water quality regulation, carbon cycling, and habitat provision for biodiversity **(Heino *et al.*, 2021; Gacutan *et al.*, 2022; Li *et al.*, 2022)**. However, a variety of anthropogenic pressures—such as overexploitation, pollution, and climate change—have significantly threatened the sustainability of fisheries and lake ecosystems **(Li & Tsigaris, 2024; Tammeorg *et al.*, 2024; Vermaat *et al.*, 2024)**. This situation is further exacerbated by habitat fragmentation

and growing human demands that continue to drive the intensive use of water resources **(Pratiwi *et al*., 2022)**. Without science-based and sustainable management practices, these ecosystems face major threats to food security, environmental health, and biodiversity.

In recent decades, increasing attention to sustainability issues has spurred a rise in research focused on fisheries and lake ecosystems. This is evident in the growing number of studies dedicated to ecosystem-based management strategies, resource conservation, and mitigating the effects of climate change on aquatic systems **(Reid *et al*., 2019; Hussain *et al*., 2020; Capon *et al*., 2021; Duan *et al*., 2023)**. Nevertheless, a fragmented approach remains a major barrier to fully understanding the research landscape. Many studies concentrate on specific regions or issues—such as fish population dynamics, water quality, or pollution impacts—without integrating broader, interdisciplinary themes. As a result, identifying global trends, fostering cross-disciplinary collaboration, and assessing the contributions of specific institutions, countries, and journals becomes challenging.

The absence of a holistic view of the research landscape in fisheries and lake management represents a significant gap that must be addressed. By mapping key research themes, collaboration networks, and patterns in research output and citation, we can derive strategic insights into future research directions. This approach is crucial not only for evaluating current achievements but also for uncovering underexplored areas and maximizing opportunities for international collaboration.

This study aimed to provide a comprehensive overview of the research landscape in fisheries and lake management through bibliometric analysis. The primary goals were to uncover networks of keywords representing central research themes, identify opportunities for new research directions, and evaluate the contributions of institutions, countries, and publication sources to the advancement of sustainable fisheries and lake management. The findings of this study are intended to offer strategic guidance for academics, practitioners, and policymakers in prioritizing evidence-based research and policy development in this field.

MATERIALS AND METHODS

This study uses a bibliometric analysis approach to explore the research landscape related to fisheries and lake management. Bibliographic data were collected from the Scopus database, a comprehensive and reliable source of academic literature. The search was conducted using a combination of keywords: "fishery" OR "fisheries" AND "management" AND "lake" OR "reservoir," ensuring broad coverage of studies relevant to fisheries and lake management at both local and global scales. The time span of publication was not restricted, allowing for the inclusion of research developments from the earliest available records to the most recent data. The metadata collected included titles, abstracts, keywords, author names, institutional affiliations, publication sources, and citation information. All retrieved data were formatted into a CSV file to facilitate further analysis.

Data analysis was conducted using R software and the Bibliometrix package, which is specifically designed for bibliometric analysis and visualization **(Aria & Cuccurullo, 2017)**. R and Bibliometrix were chosen for their high flexibility, analytical transparency, and robust capabilities for science mapping and network analysis. Descriptive analysis was performed to identify publication counts, annual publication trends, and citation patterns, providing an initial overview of research progress in this field.

Network analysis was conducted using Co-Word Network Analysis to map relationships between keywords. This method enabled the identification of thematic clusters, strategic keyword positions (such as betweenness centrality and PageRank), and the structural connections among research themes. Additionally, collaboration patterns among countries, institutions, and authors were examined to better understand the global dynamics of research contributions. Source and citation analysis was used to identify the most influential journals, articles, and authors based on publication volume and citation frequency, offering insights into the leading contributors in the field **(Dervis, 2019; Oyewola & Dada, 2022)**.

The data obtained from Scopus were cleaned to ensure consistency and accuracy. This process included removing duplicate records, correcting indexing errors, and standardizing variations in author or institution names that referred to the same entity. Numerical data, such as publication and citation counts, were formatted appropriately for statistical analysis and visualization.

The results of the analysis were presented through graphs, network maps, and tables. These visualizations were designed to simplify the interpretation of key findings, including publication trends, keyword network structures, and collaboration patterns. All visual outputs were generated using the built-in functions of the Bibliometrix package.

RESULTS

Research in the field of fisheries and lake management has shown significant development over the past few decades. Annual article production has seen a steady increase, reflecting the growing attention to the issue of aquatic ecosystem sustainability. Based on the bibliometric data analyzed, the publication time span covers almost a century, from 1937 to 2025. During this period, there was an average annual growth of 1.26%, with a more significant acceleration in the last two decades. This shows that research in this area is becoming increasingly relevant, especially in the context of climate change and the increasing need for aquatic resources.

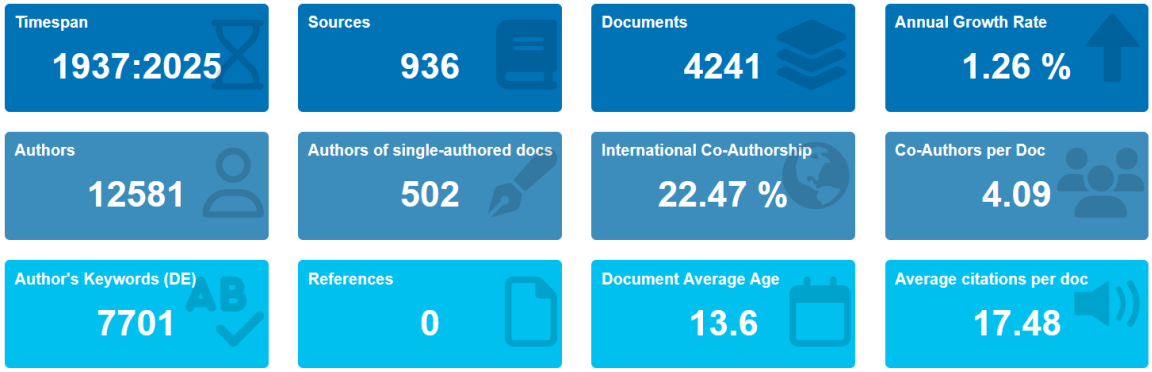

Fig. 1. Overview

The distribution of citations by year also shows an interesting pattern. Articles published in the 2000s tended to receive more citations than previous articles, signaling their greater influence on the scientific community. The article with the highest number of citations is from the last decade, indicating the increasing quality and relevance of the latest research in supporting sustainable fisheries and lake management.

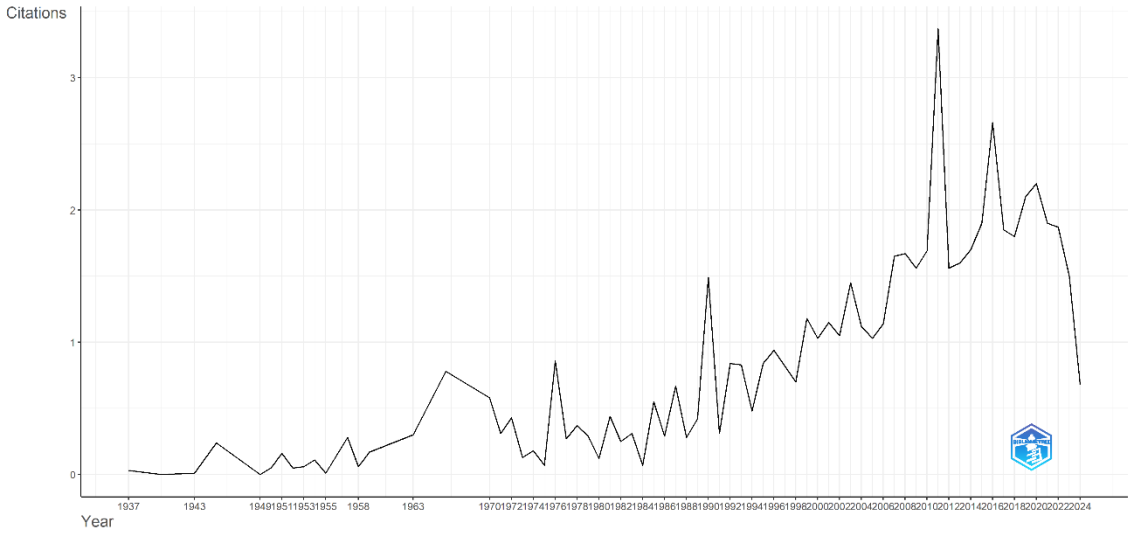

Fig. 2. Average citation per year

Countries such as the United States, Canada, and China are major contributors in the number of publications. The United States occupies the top spot with 4,487 articles, followed by Canada with 1,154 articles, and China with 680 articles. The large contribution of these countries reflects their strong research capacity, both in terms of human resources and infrastructure. In addition, leading institutions such as Michigan State University and the Great Lakes Science Center have also shown significant involvement in producing high-quality research, making them major centers for the development of science in this field.

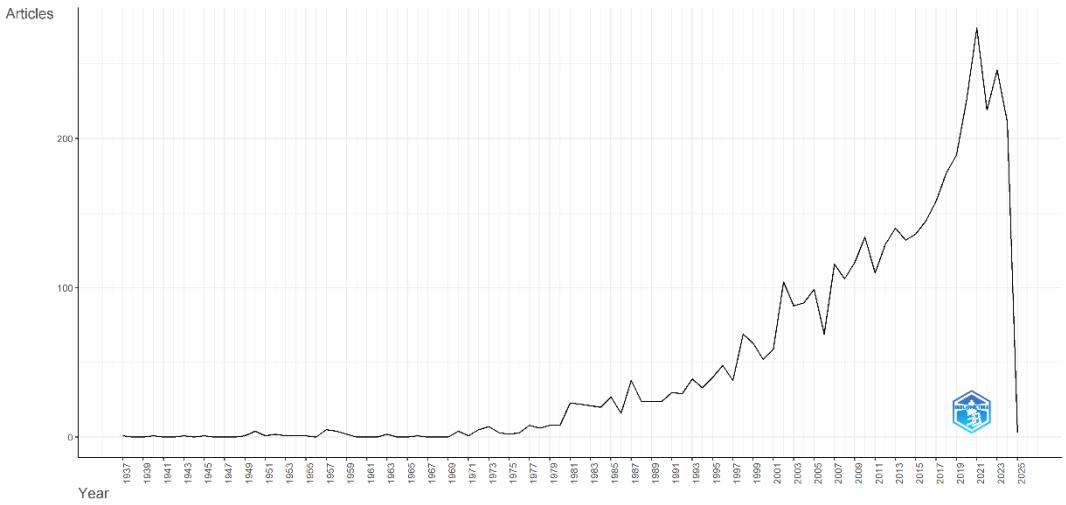

Fig. 3. Annual scientific production

Table 1. Top 5 country production

No	Country	Production
1	USA	4487
2	CANADA	1154
3	CHINA	680
4	BRAZIL	347
5	UK	338

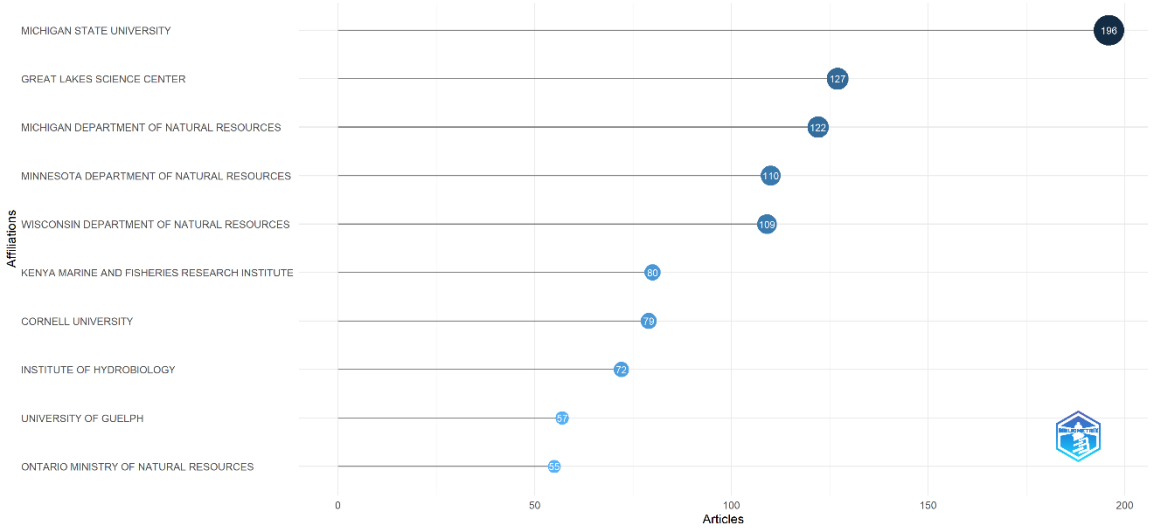

Fig. 4. Top 10 most relevant affiliations

In terms of publication sources, leading journals play an important role in disseminating research results. The North American Journal of Fisheries Management became the journal with the most article contributions, followed by the Journal of Great Lakes Research and Transactions of the American Fisheries Society. The presence of these journals indicates the existence of a strong academic platform for scientific discussion in

the field of fisheries and lake management. These journals are not only a medium to publish research, but also play a role in shaping the direction of development.

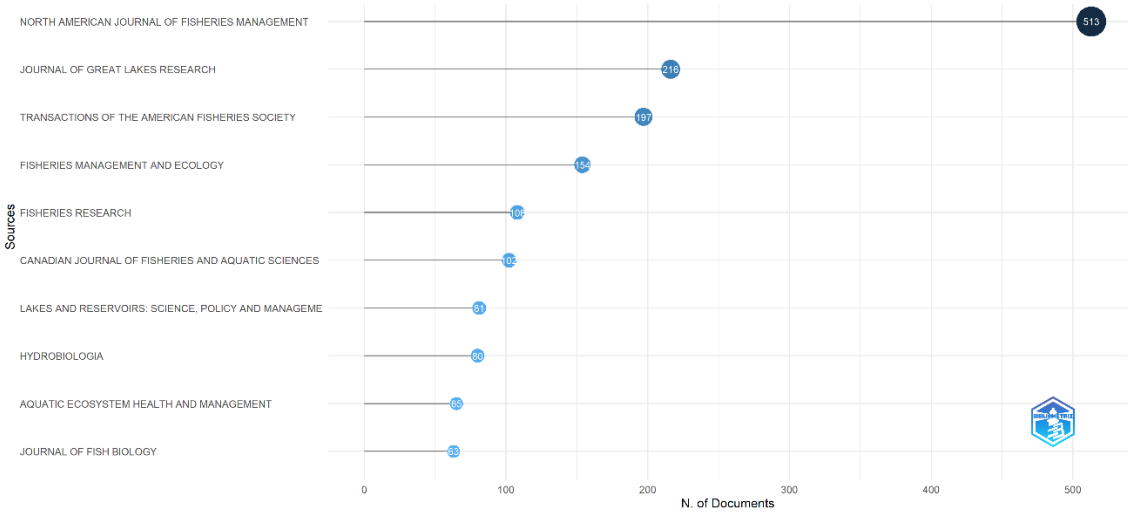

Fig. 5. Top 10 Most relevant sources

Keyword network analysis (CoWord Network) provides in-depth insight into key themes and inter-concept relationships in fisheries and lake management research. Based on the analysis, the dominant themes that emerged included "fishery management," "lake ecosystem," and "sustainable fisheries." These keywords indicate the main focus of research on ecosystem-based management that balances the needs of conservation and sustainable use of aquatic resources.

Fig. 6. CoWord network

The keyword network clusters reveal several groups of interrelated themes. The main clusters include topics such as “reservoir ecology,” which relates to the dynamics of lentic aquatic ecosystems; “fishery sustainability,” which highlights sustainable management practices; and “climate change adaptation,” which addresses the impacts of

climate change on fisheries. The connections among these clusters indicate a multidisciplinary approach in the research, linking ecological, managerial, and policy-related aspects.

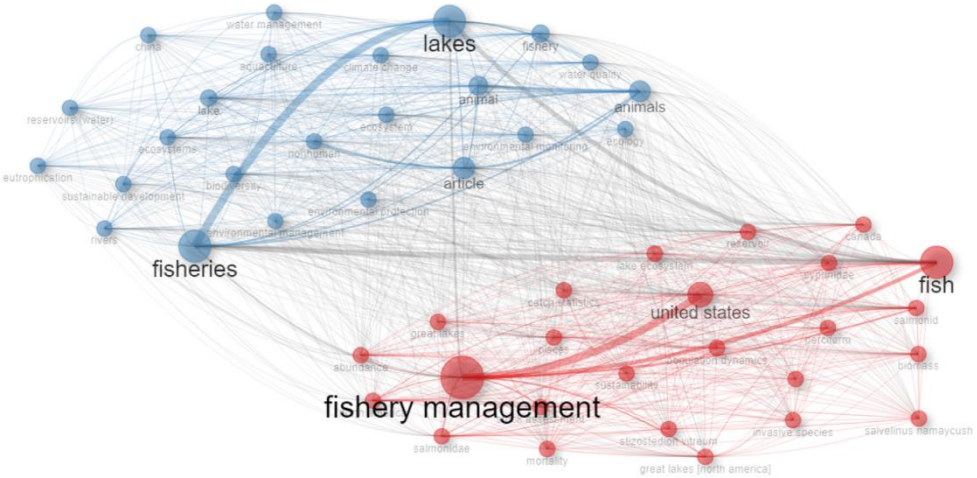

Fig. 7. Network analysis

The discussion of the main themes that emerged showed significant attention to the issue of sustainability and adaptation of aquatic ecosystems to global challenges such as climate change. In addition, an ecosystem-based approach to fisheries and lake management is at the core of most research. These findings show that research has shifted from a traditional approach to resource exploitation to a more holistic and sustainability-oriented paradigm.

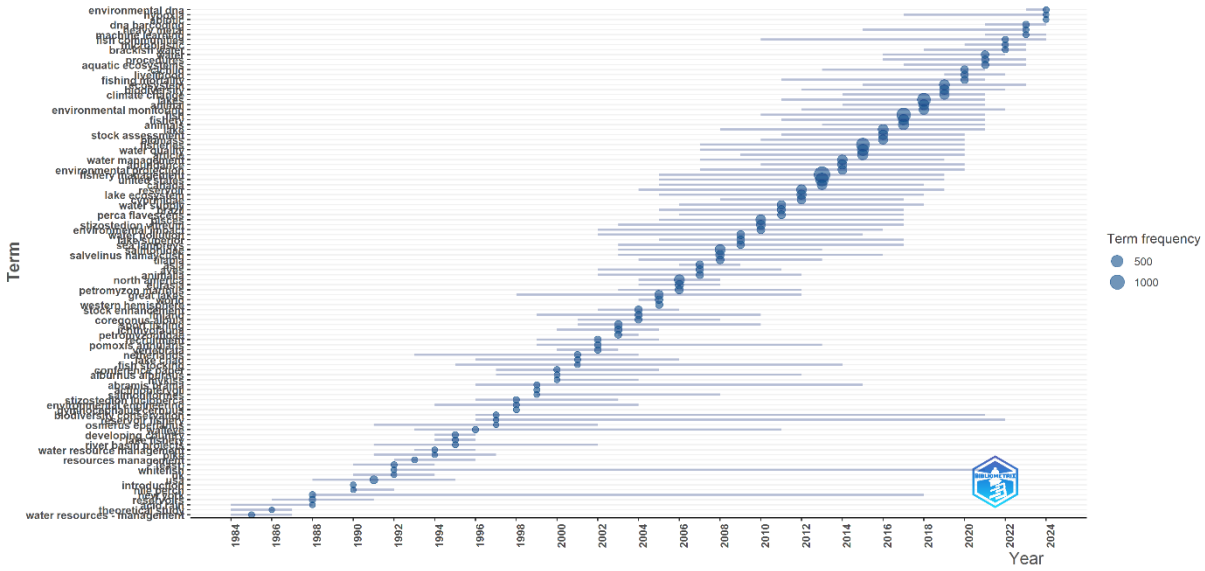

Fig. 8. Trend topics

Research frontiers and emerging trends.

In addition to dominant themes, the bibliometric analysis also reveals potential emerging topics within the field. Keywords such as *"eDNA," "restoration ecology,"* and *"ecosystem-based management"* have gained prominence in recent years, indicating a shift in research direction. These trends reflect methodological innovations, such as the use of environmental DNA (eDNA) to detect species presence, and the adoption of ecosystem-based approaches to restore degraded aquatic systems.

The impact of these emerging keywords on the expansion of the research field is evident from their positions within the keyword co-occurrence network. For instance, the keyword *"eDNA"* shows a high closeness centrality value, highlighting its role in connecting previously unrelated research themes. This suggests that the theme is not only growing in importance but is also contributing to the integration of interdisciplinary knowledge. Furthermore, the rise of such topics offers promising new solutions to long-standing challenges in aquatic and marine resource management.

DISCUSSION

The results of the bibliometric analysis reveal a complex and rapidly evolving research landscape in the field of fisheries and lake management. The consistent increase in article production since the early 21st century underscores the growing relevance of this field, particularly in the face of global challenges such as climate change, ecosystem degradation, and the urgent need for sustainable water resources **(Liu *et al*., 2023; Hlina *et al*., 2024; Jane *et al*., 2024; Ma *et al*., 2024)**. This surge in publications over the past two decades can be attributed to heightened attention toward the Sustainable Development Goals (SDGs), which place aquatic ecosystem sustainability high on the global agenda **(Forio & Goethals, 2020; Elliott *et al*., 2022)**.

The citation distribution indicates that more recent studies are having a greater impact than earlier publications. This trend suggests a growing emphasis within the scientific community on research that offers tangible solutions to environmental and water management issues. Highly cited articles frequently focus on ecosystem-based management, climate change adaptation, and technological advancements such as environmental DNA (eDNA) monitoring **(Stoeckle *et al*., 2017; Du *et al*., 2024; Kim *et al*., 2024; Sieber *et al*., 2024)**.

Developed countries such as the United States and Canada are major contributors in terms of both publication volume and scientific influence. Prominent institutions like Michigan State University and the Great Lakes Science Center play a leading role in producing high-quality research, illustrating how research capacity is often linked to the availability of substantial resources. However, the increasing involvement of developing countries, such as Brazil and China, in the research landscape signals a more inclusive and global engagement with fisheries and lake management issues **(Sorooshian *et al*., 2024;**

Taraniuk *et al.*, 2024). This broader participation fosters diverse perspectives and enhances the global understanding of these challenges.

The keyword co-occurrence network analysis shows that core themes—such as *"fishery management," "lake ecosystem,"* and *"sustainable fisheries"*—dominate the research discourse. These themes reflect a growing paradigm shift from short-term resource extraction to comprehensive, ecosystem-based management. The close association between keyword clusters like *"climate change adaptation"* and *"reservoir ecology"* suggests a strong trend toward multidisciplinary integration. The central positioning of the keyword *"fishery management"* within the network highlights its function as a key thematic bridge linking various areas of research.

Beyond these dominant themes, the analysis also identifies emerging areas with significant potential to shape future research. Keywords such as *"eDNA"* and *"restoration ecology"* represent innovative methodologies that allow for more precise and efficient ecosystem monitoring and restoration. The strategic placement of these terms within the keyword network confirms their growing relevance. These emerging themes not only broaden the research scope but also offer concrete, science-based solutions to increasingly complex water management challenges.

The findings of this study carry important implications for both academic research and practical policy, particularly in the context of sustainable fisheries and lake management. The prominence of themes such as *"fishery management"* and *"lake ecosystem"* within the global research landscape emphasizes the need to prioritize ecosystem-based approaches in policy and management practices. This highlights the critical importance of embedding ecological principles in decision-making frameworks that go beyond short-term economic objectives and instead focus on long-term ecological sustainability.

Moreover, the emergence of new themes like *"eDNA"* and *"restoration ecology"* illustrates the transformative potential of technological innovation in supporting more effective fisheries management. Tools such as eDNA analysis offer real-time biodiversity monitoring capabilities, enabling more responsive and efficient ecosystem management. These technological advancements open the door to the development of new methodologies that can enhance the effectiveness of resource management and accelerate the restoration of degraded aquatic ecosystems.

CONCLUSION

This study successfully uncovered the global research landscape in fisheries and lake management through a comprehensive bibliometric analysis. Dominant themes such as "fishery management," "lake ecosystem," and "sustainable fisheries" indicate a major focus on ecosystem-based approaches to ensure the sustainability of aquatic resources. Keyword network analysis identifies the close relationship between thematic clusters, such as climate

change adaptation and reservoir ecology, reflecting a multidisciplinary approach in this field. In addition, the emergence of new themes such as "eDNA" and "restoration ecology" signifies a shift towards technological innovation and new research methods. The pattern of international collaboration shows the dominance of developed countries, although the contribution of developing countries is starting to increase, providing a more diverse perspective on global challenges. These findings not only provide a holistic mapping of key themes and research networks, but also identify potential for future research development, making these results a strategic guide for academics, practitioners, and policymakers in facing the challenges of sustainable fisheries and lake management.

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Conflict of interest

The authors declare no conflicts of interest related to this work.

Author contributions

Muhammad Fauzi: Conceptualization, Supervision, Writing – Original Draft.
Andri Hendrizal: Data Analysis, Methodology, Writing – Review & Editing.
Budijono: Data Collection, Validation.
Bintal Amin: Resources, Project Administration.

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