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# Analysis and Visualization of Global Research Trends in Sustainable Shrimp Farming Through Bibliometrics

**Mochamad Ibnu Syina Noor*, Yayat Ruhiat, Widya Ernayati K.**

Environmental Studies, Postgraduate, Sultan Ageng Tirtayasa University, Serang, Indonesia

*Correspondence: 7789230008@untirta.ac.id

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**ABSTRACT :** This study aimed to comprehensively examine global research trends in sustainable shrimp farming and identify research gaps that require further investigation. The analysis was based on 294 research articles published between 2014 and 2023 and indexed in the Scopus database. Using bibliometric methods and VOSviewer software, the study evaluated publication output, subject areas, journals, authors, keywords, countries, and other bibliometric indicators to assess the global development of research in this field over the study period. The field of sustainable shrimp farming expanded rapidly, with a continuous increase in the number of publications through 2023. India recorded the highest number of publications, with 47 articles. The most frequently occurring keywords included "Bacterium," "Carbon," "Crustacean," "Food Supplementation," "Immunity," "Microbiology," "Nonhuman," "*Penaeus vannamei*," "Probiotic," and "Vibrio." The bibliometric analysis provided valuable insights into the current status, research progress, and future potential of this field. Based on the findings, several promising directions for future research were identified: (1) the relationship between dietary supplementation and immune responses, including the interactions between probiotics and Vibrio; (2) the immune responses of shrimp species to Vibrio, carbon-related factors, and food supplementation; and (3) the influence of probiotics on the cultivation and health performance of *Penaeus vannamei*.

**Keywords**: Bibliometrics; cultivation; shrimp; sustainable; probiotics

## 1. Introduction

The shrimp farming sector experienced rapid growth and proved to be highly profitable [1]. Intensive shrimp farming underwent significant technological and production advancements in recent decades. This production system had substantial socio-economic impacts on local communities that depended on shrimp farming as a primary source of income and employment. However, despite its economic benefits, intensive shrimp farming also posed considerable environmental and production challenges. Although production initially increased, disease outbreaks and deteriorating water quality eventually reduced productivity. Furthermore, shrimp farming contributed significantly to the pollution and degradation of coastal ecosystems [2]. To maintain the long-term sustainability and global competitiveness of the shrimp farming sector, continuous research on sustainable aquaculture practices and effective solutions to major challenges, particularly disease management and environmental degradation, remained essential [3].

Bibliometrics represented a specialized field within information science that focused on the quantitative analysis and evaluation of scientific publications and their associated metadata. In academic research, bibliometric analysis played an important role in understanding, evaluating, and mapping scientific development, although its potential was often underutilized. Bibliometric analysis served several important functions. First, it assessed research productivity and scientific impact by providing objective quantitative indicators that supported transparent evaluation of scholarly performance, thereby influencing research funding and academic recognition. Second, it facilitated the understanding of the evolution of scientific fields by identifying emerging, established, and declining research topics, thereby assisting researchers, educators, and policymakers in determining future research priorities. Third, bibliometric analysis revealed research collaborations and scientific networks through co-authorship, co-citation, and bibliographic coupling analyses, highlighting opportunities for interdisciplinary and international collaborations. Fourth, it supported the evaluation of research policies, programs, and funding initiatives and was widely used by universities, research institutions, and funding agencies at both national and international levels. Finally, bibliometric analysis mapped the intellectual structure and knowledge dynamics of scientific disciplines through citation network analysis and related techniques, providing deeper insights into knowledge creation, dissemination, and evolution [4].

Achieving sustainable shrimp farming required a comprehensive assessment of recent scientific developments and emerging global issues affecting the sector. Accordingly, bibliometric analysis provided an effective approach for synthesizing current knowledge, identifying dominant research themes, and revealing underexplored areas that warranted further investigation (research gaps) [5].This bibliometric study served as a valuable reference for researchers, practitioners, and policymakers involved in shrimp farming by identifying existing research patterns, clarifying major research directions, and supporting evidence-based policy development [6]. The study aimed to comprehensively examine global research trends in sustainable shrimp farming and identify research gaps that should be addressed to support the achievement of the Sustainable Development Goals (SDGs), particularly SDG 12 on responsible consumption and production and SDG 14 on the conservation and sustainable use of marine ecosystems and life below water.

## 2. Materials and Methods

### *2.1. Theoretical Framework of Bibliometric Analysis.*

Bibliometric analysis provided a rigorous quantitative framework for evaluating scientific communication and assessing the intellectual and societal impacts of academic research [4]. Over the past five decades, this methodology had been increasingly adopted to systematically evaluate academic journals, research institutions, and individual researchers. Its primary objective was to develop a comprehensive understanding of research trends within specific disciplines, map the intellectual structure of scientific fields, and examine patterns of interdisciplinary collaboration [7].

*2.2. Data Source and Search Strategy Formulation.*

To systematically map the scientific development of sustainable shrimp farming, this study followed a structured bibliometric workflow. Data were retrieved from the Scopus database on December 21, 2023. Scopus was selected as the sole data source because of its extensive coverage of high-quality peer-reviewed literature and its comprehensive bibliographic metadata, which are well suited for bibliometric analysis. The search strategy employed a targeted query using the exact phrase "sustainable shrimp farming." To improve the relevance and precision of the retrieved records, the search was limited to appropriate subject areas, thereby excluding publications from unrelated disciplines.

*2.3. Inclusion and Exclusion Criteria.*

To ensure the quality and relevance of the dataset, predefined inclusion and exclusion criteria were applied. The analysis was restricted to publications published between 2014 and 2023, providing a ten-year overview of recent developments and emerging trends in sustainable shrimp farming. Only original research articles and conference papers were included in the analysis. In addition, only finalized publications published in peer-reviewed journals or official conference proceedings were considered. After applying these selection criteria, a final dataset consisting of 294 publications related to sustainable shrimp farming was obtained for bibliometric analysis (BUB).

*2.4. Data Export and Network Visualization.*

After the dataset had been finalized, the complete bibliographic records were exported directly from the Scopus database. To ensure compatibility with bibliometric software, the records were downloaded in both CSV and RIS formats [8]. The exported data were subsequently analyzed using VOSviewer software. VOSviewer was employed to construct and visualize bibliometric networks, enabling the identification of relationships among authors, keywords, institutions, countries, and research topics [8]. The visualization maps facilitated the identification of research clusters, emerging themes, collaboration patterns, and the overall intellectual structure of global research on sustainable shrimp farming.

## 3. Results and Discussion

*3.1. Publication Trends in Sustainable Shrimp Farming.*

Figure 1 illustrates the global publication trend in sustainable shrimp farming over the past decade. As shown in Figure 1, the number of publications indexed in the Scopus database increased steadily between 2014 and 2023, indicating growing scientific interest in this research area. This increase reflected not only a rise in scholarly output but also the increasing scientific and societal importance of sustainable aquaculture.

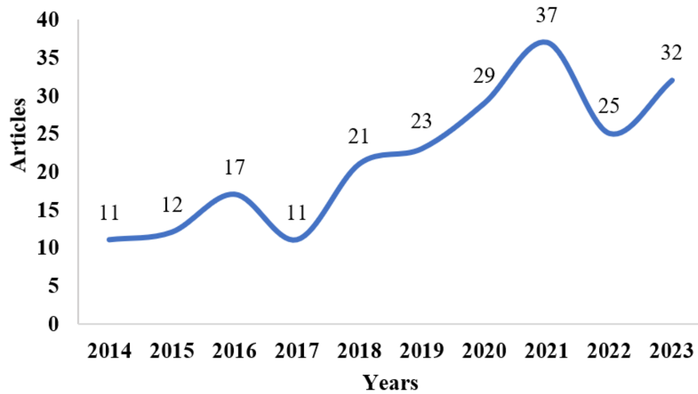


**Figure 1.** Number of Studies on Environmentally Friendly Shrimp Farming in the Past Ten Years.

The expansion of research on sustainable shrimp farming paralleled the rapid growth of the global aquaculture industry, which was driven by increasing demand for fish, shrimp, mollusks, and other aquatic products. This growth was closely associated with the rising global demand for food security, nutritional resources, employment opportunities, and international trade [9]. Despite these developments, the shrimp farming industry continued to face major challenges, including disease outbreaks, poor seed quality, environmental degradation, and marketing constraints, all of which threatened its long-term sustainability [10]. From a scientific perspective, the continuous increase in publications suggested that sustainable shrimp farming had evolved beyond a narrow technical discipline into a multidisciplinary research field. The research focuses gradually shifted from maximizing production toward a more holistic framework that integrated ecological resilience, disease prevention, environmental sustainability, and long-term economic viability. Therefore, the publication trend presented in Figure 1 demonstrated the growing maturity of sustainable shrimp farming research, highlighting its increasing role in addressing both industrial demands and environmental challenges associated with intensive aquaculture systems.

*3.2. Geographical Distribution of Publications.*

Figure 2 presents the ten countries with the highest publication output on sustainable shrimp farming. As shown in Figure 2, India ranked first with 47 publications, followed by Viet Nam with 45 publications. The United States ranked third with 40 publications, while Indonesia occupied the fourth position with 30 publications. Other leading contributors included Bangladesh, Brazil, China, Australia, the Netherlands, and Thailand. This distribution indicated that research productivity was strongly associated with countries where shrimp farming played a significant economic role and where sustainability-related challenges were particularly important.

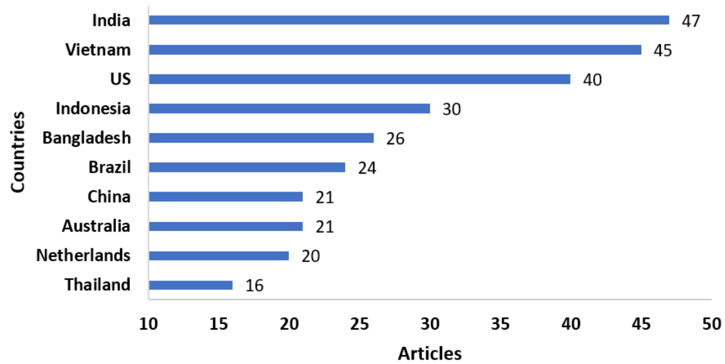


**Figure 2.** Top 10 Countries by Number of Articles on Sustainable Shrimp Farming.

The dominance of Asian countries in publication output reflected the global distribution of aquaculture production. According to the FAO report published in 2022 [11], total global fisheries and aquaculture production reached 214 million tons in 2020, of which aquaculture contributed a record 122.6 million tons with an estimated value of USD 281.5 billion. Between 2018 and 2020, India became the world's second-largest fisheries and aquaculture producer, with a total production of 13.7 million tons [12]; [13]. Consequently, India's leading position in scientific publications reflected not only its strong research capacity but also the strategic importance of shrimp farming for national food security, employment, economic development, and environmental management. The concentration of publications in Asian countries also demonstrated that regions facing the greatest ecological, economic, and operational challenges associated with intensive shrimp farming were simultaneously generating the largest volume of scientific research. Meanwhile, the inclusion of countries such as the United States, Australia, and the Netherlands indicated that sustainable shrimp farming had also attracted considerable attention from countries with advanced technological capabilities, strong regulatory frameworks, and active sustainability research programs. Overall, the geographical distribution shown in Figure 2 suggested that global research on sustainable shrimp farming was shaped by the interaction between production intensity, environmental concerns, technological innovation, and international scientific collaboration.

### *3.3. Distribution of Research by Academic Discipline.*

Table 1 summarizes the distribution of publications on sustainable shrimp farming across different academic disciplines. As shown in Table 1, Agricultural and Biological Sciences accounted for the largest proportion of publications (30.7%), followed by Environmental Science (26.7%). Other contributing disciplines included Earth and Planetary Sciences (9.3%), Social Sciences (8.7%), Engineering (3.6%), Energy (3.5%), Biochemistry, Genetics and Molecular Biology (3.1%), Economics (2.4%), Business, Management and Accounting (2.2%), Computer Science (2.2%), and other disciplines (7.6%). These findings demonstrated that sustainable shrimp farming had developed into a multidisciplinary research field rather than remaining confined to a single scientific discipline.

**Table 1**. Distribution of Publications by Subject Area.

| Subject Area | Number of Documents (n) | Percentage (%) |
|---|---|---|
| Agricultural and Biological Sciences | 90 | 30.7 |
| Environmental Science | 79 | 26.7 |
| Earth and Planetary Sciences | 27 | 9.3 |
| Social Sciences | 26 | 8.7 |
| Engineering | 11 | 3.6 |
| Energy | 10 | 3.5 |
| Biochemistry, Genetics and Molecular Biology | 9 | 3.1 |
| Economics, Econometrics and Finance | 7 | 2.4 |
| Business, Management and Accounting | 6 | 2.2 |
| Computer Science | 6 | 2.2 |
| Other Subject Areas | 23 | 7.6 |
| **Total** | **294** | **100.0** |

The predominance of Agricultural and Biological Sciences reflected the close relationship between shrimp farming and cultivation practices, aquatic animal health, nutrition, feed development, pond management, and biological productivity. Sustainable shrimp farming naturally belonged to this discipline because it integrated agricultural production with the biological processes governing aquatic organisms and their surrounding environments. Likewise, the substantial contribution of Environmental Science highlighted the increasing emphasis on ecosystem conservation, pollution prevention, coastal management, bioremediation, and sustainable resource utilization. Consequently, sustainable shrimp farming was recognized as an approach that aimed not only to maximize production but also to maintain environmental quality, protect aquatic ecosystems, reduce ecological degradation, and improve the long-term economic sustainability of shrimp farming.

The contribution of other disciplines further illustrated the expanding scientific scope of sustainable shrimp farming research. The involvement of Engineering, Energy, Economics, Business, and Computer Science indicated that recent studies increasingly incorporated engineering innovations, energy-efficient production systems, economic sustainability assessments, management strategies, and data-driven decision-support technologies. This multidisciplinary trend reflected the ongoing transition from conventional production-oriented aquaculture toward an integrated sustainability framework that simultaneously considered biological, environmental, technological, economic, and social dimensions. Therefore, as summarized in Table 1, sustainable shrimp farming had evolved into a comprehensive research field requiring interdisciplinary collaboration to address increasingly complex scientific and practical challenges. This broad disciplinary coverage further supported its classification within Agricultural and Biological Sciences while acknowledging its strong connections with environmental sustainability and socioeconomic development.

### *3.4. Author Productivity and Scholarly Influence.*

Figure 3 presents the ten most productive authors in sustainable shrimp farming research based on the number of publications indexed in the Scopus database. As shown in Figure 3, Vijayan, K.K. and Muralidhar, M. were the most productive authors, each contributing six publications. Their academic influence was further evaluated using the Scopus H-index, which measures both research productivity and citation impact [14]. Among these authors, Vijayan, Koyadan Kizhakedath recorded the highest publication output within the dataset and had a Scopus H-index of 25, whereas Muralidhar, Moturi had an H-index of 17. Other leading contributors included Joffre, Olivier M. (H-index = 12), Bush, Simon R. (H-index = 40), Bosma, Roel H. (H-index = 24), Ghoshal, Tapas Kumar (H-index = 13), Dahdouh-Guebas, Farid (H-index = 58), Bui, Thuyet D. (H-index = 6), Bitencourt, Marisa Dantas (H-index = 10), and Austin, Christopher M. (H-index = 32). Among these researchers, Dahdouh-Guebas, Farid possessed the highest Scopus H-index (58), indicating the greatest overall scholarly influence.

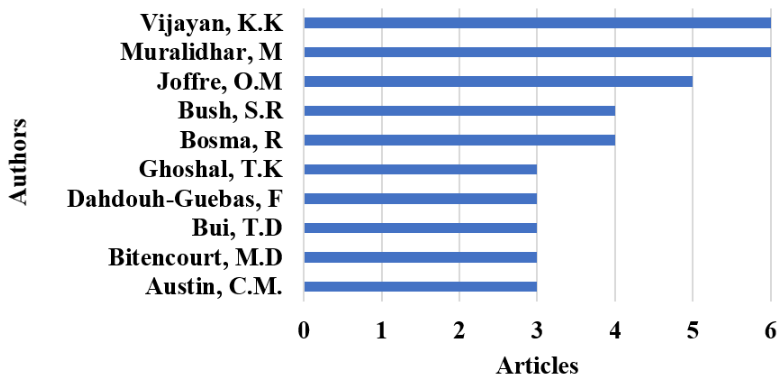


**Figure 3.** Top 10 Articles on Sustainable Shrimp Farming by Number of Authors.

The author productivity analysis demonstrated that research on sustainable shrimp farming was supported by both highly productive researchers and highly influential scholars. This pattern suggested that the field had developed through contributions from specialists in shrimp aquaculture as well as internationally recognized researchers whose expertise extended across aquaculture, environmental science, and sustainability studies. Consequently, sustainable shrimp farming research had evolved through the integration of practical aquaculture knowledge with broader ecological and environmental perspectives. The collaboration patterns reflected by these leading authors also highlighted the interdisciplinary nature of the field. The complex challenges associated with shrimp farming, including disease outbreaks, environmental degradation, and the need for sustainable production intensification, could not be adequately addressed through a single scientific discipline. Instead, collaboration among researchers from diverse backgrounds facilitated knowledge exchange, methodological advancement, and interdisciplinary innovation. Such collaborative networks strengthened the translation of scientific knowledge into practical farming applications and evidence-based policy development, thereby contributing to the long-term sustainability of the shrimp farming industry.

*3.5. Keyword Network Analysis and Research Trends.*

Figure 4 illustrates the bibliometric network generated using VOSviewer, including the Network Visualization (Figure 4A), Overlay Visualization (Figure 4B), and Density Visualization (Figure 4C). Based on the analysis of 294 publications retrieved from the Scopus database, five major keyword clusters were identified. A more detailed analysis of the principal cluster revealed 54 interconnected keywords, as presented in Figure 4. These visualizations provided valuable insights into the conceptual structure of sustainable shrimp farming research by illustrating the relationships among research topics and their evolution over time.

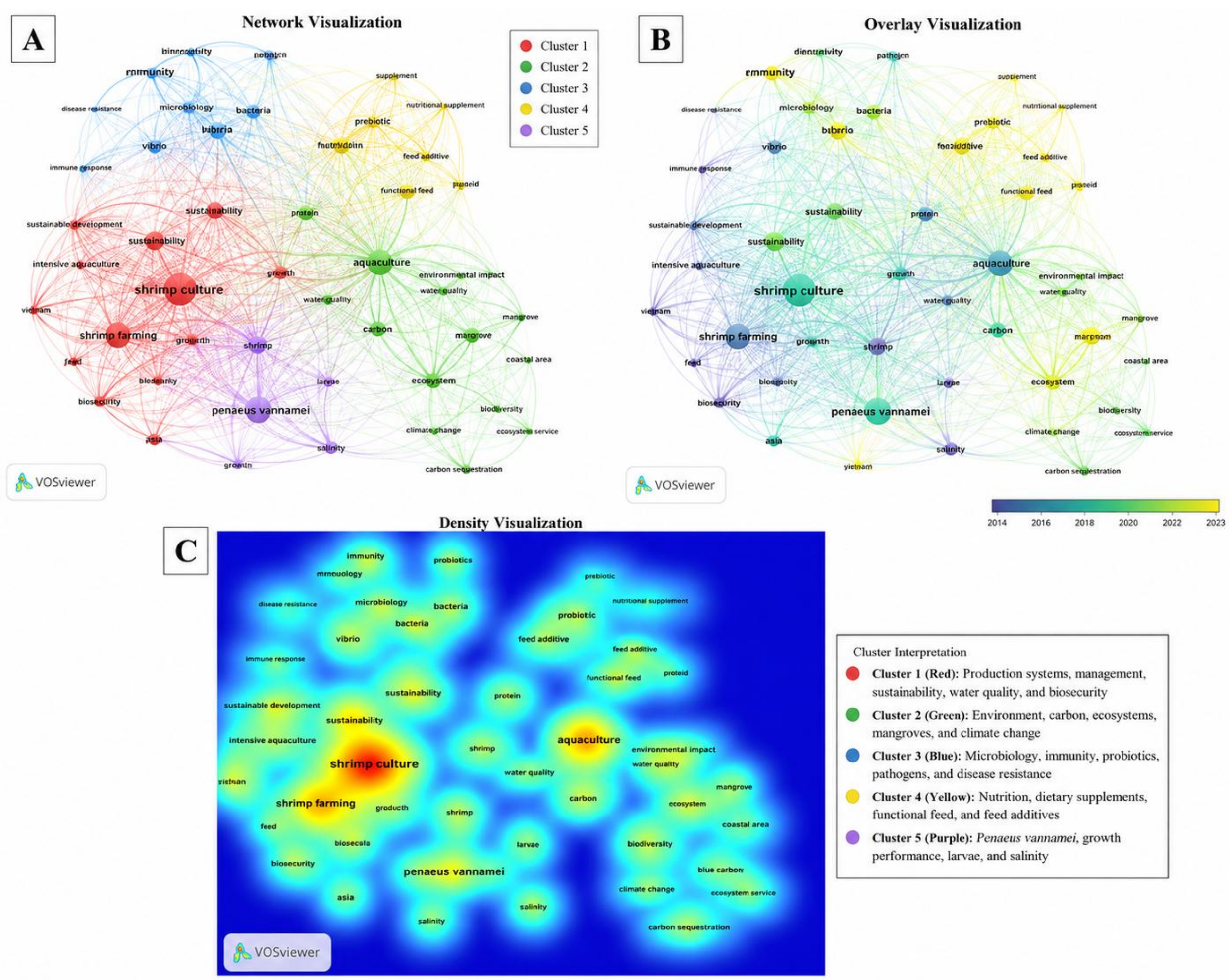


**Figure 4.** Visualization of Network (A). Visualization Overlay (B). Visualization of Density (C) VOSviewer.

The Overlay Visualization (Figure 4B) indicated that several keywords became increasingly prominent after 2020, as represented by the yellow color. These emerging keywords included *immunity*, *probiotics*, *bacteria*, *microbiology*, *non-human*, *Vibrio*, *Penaeus vannamei*, *carbon*, and *dietary supplements*. Their increasing prominence suggested a substantial shift in research priorities. Earlier studies primarily focused on improving production efficiency, whereas more recent research increasingly emphasized biological control, disease prevention, host immunity, ecological resilience, and environmental sustainability. This transition reflected the evolution of sustainable shrimp farming from a production-oriented discipline into an integrated system that balanced productivity, animal health, and environmental stewardship.

One of the most significant developments shown in Figure 4B was the increasing emphasis on disease management and shrimp immunity. Disease outbreaks under intensive farming conditions and the continued application of antibiotics and chemical treatments remained major constraints to sustainable shrimp production [14]. These challenges encouraged researchers to investigate immune enhancement as an essential component of sustainable aquaculture. Furthermore, growing concerns regarding antimicrobial resistance increased scientific interest in environmentally friendly disease-control strategies. Consequently, probiotics emerged as an important research topic because of their ability to improve shrimp immune responses, suppress pathogenic bacteria, and reduce disease incidence. The increasing prominence of *probiotics*, *bacteria*, *microbiology*, and *Vibrio* in the keyword network therefore reflected the transition toward biologically based and environmentally sustainable aquaculture practices [15].

Another emerging keyword identified in Figure 4B was *non-human*, which reflected an expansion in the conceptual scope of sustainable shrimp farming research. Studies associated with this keyword examined the impacts of shrimp farming on non-human components of socio-ecological systems and evaluated ecosystem resilience under aquaculture-related disturbances [16]. This development indicated that sustainability was increasingly assessed beyond economic performance and production efficiency to include ecological integrity, biodiversity conservation, mangrove ecosystems, and wild aquatic populations. The growing importance of this research theme highlighted the recognition that sustainable aquaculture depended on maintaining the health and resilience of surrounding ecosystems.

The increasing occurrence of *dietary supplements* represented another notable research trend. As shown in Figure 4B, dietary supplementation attracted growing scientific attention because of its potential to improve shrimp growth, strengthen immune responses, enhance disease resistance, and promote sustainable feed management [17]. Rather than being considered merely as nutritional inputs, dietary supplements were increasingly recognized as strategic tools for improving farming efficiency, animal health, and environmental sustainability. Their growing prominence demonstrated that nutritional management had become an integral component of sustainable shrimp farming systems.

Among all biological terms, *Penaeus vannamei* remained one of the most prominent keywords in the bibliometric network. Since 2020, this species had attracted considerable research attention because of its favorable biological characteristics, including rapid growth, high survival rates, tolerance to high stocking densities, efficient feed conversion, and high production performance [18]. Moreover, its ability to tolerate a broad salinity range (0.5–40 ppt) enabled cultivation under diverse environmental conditions, thereby increasing its suitability for sustainable aquaculture systems [19]. The central position of *Penaeus vannamei* within the keyword network reflected not only its commercial importance but also its widespread use as the principal model species for evaluating sustainable shrimp farming practices.

Another emerging research theme involved *carbon*, which introduced an important environmental dimension into sustainable shrimp farming research. As illustrated in Figure 4B, increasing attention to carbon-related issues corresponded with global efforts to achieve the Sustainable Development Goals (SDGs), particularly SDG 12 on Responsible Consumption and Production [20] and SDG 14 on Life Below Water [21]. Shrimp farming landscapes have increasingly been investigated for their roles in carbon emissions, carbon sequestration, and carbon storage, thereby linking aquaculture production with climate change mitigation. This research direction was particularly relevant in addressing global challenges such as climate change, ocean acidification, hypoxia, and coastal ecosystem degradation caused by increasing atmospheric carbon dioxide concentrations. Consequently, studies on low-carbon shrimp farming systems and mangrove restoration represented important advances that integrated aquaculture management with climate adaptation and ecosystem conservation strategies [22]. The emergence of carbon-related keywords therefore demonstrated that sustainable shrimp farming had expanded beyond biological production systems to encompass environmental engineering, ecosystem management, and climate governance.

Overall, the Network Visualization (Figure 4A), Overlay Visualization (Figure 4B), and Density Visualization (Figure 4C) collectively demonstrated that sustainable shrimp farming research had undergone a substantial transformation during the past decade. The field had progressed from emphasizing production efficiency toward a comprehensive sustainability framework incorporating disease management, immunity enhancement, microbiology, nutritional interventions, species-specific production, ecosystem resilience, and carbon-related environmental sustainability. This evolution reflected the increasing maturity of the research field and suggested that future advances would rely on stronger interdisciplinary collaboration and systems-based approaches that integrated biological, environmental, technological, and socioeconomic perspectives.

### *3.6. Research Gaps and Future Research Directions.*

Figure 5 illustrates the research gap analysis derived from the bibliometric network. Based on the co-occurrence relationships among the identified keywords, three major research gaps were recognized that may serve as promising directions for future studies. These gaps represent research areas in which conceptual relationships remain weak or insufficiently explored despite the increasing maturity of sustainable shrimp farming research. The first research gap identified in Figure 5 concerns the limited direct relationship between dietary supplements and the keywords *immunity*, *probiotics*, and *Vibrio*. Although these topics appeared within the same bibliometric network, their direct interactions remained weak, indicating that the relationships among nutritional interventions, immune enhancement, beneficial microorganisms, and pathogen control had not been comprehensively investigated. This finding suggested that future studies should examine how dietary supplementation influences shrimp immune responses, microbial community composition, and resistance to *Vibrio* infections under different farming conditions.

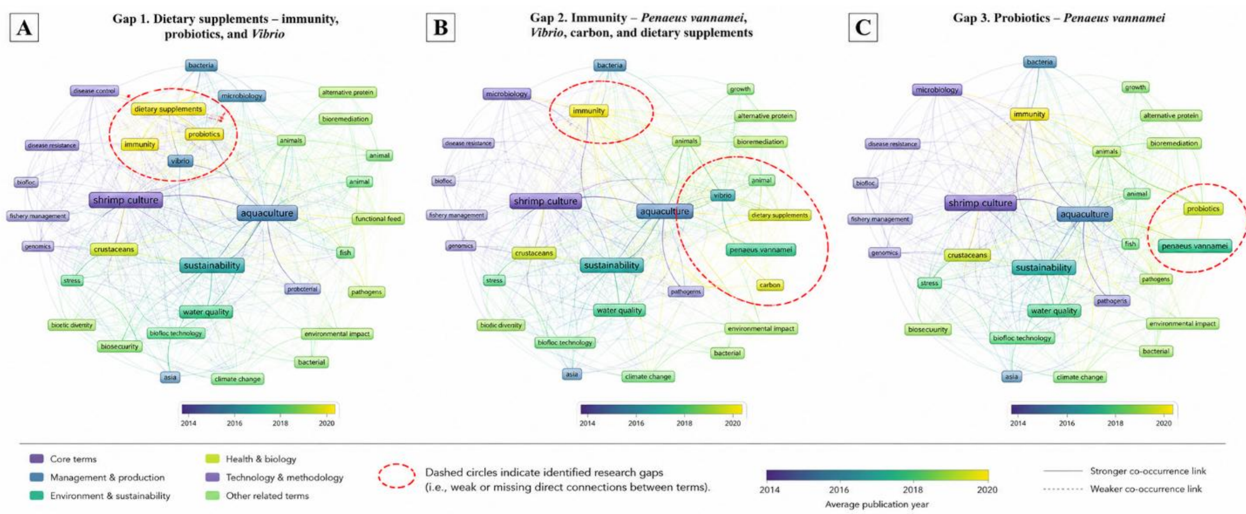


**Figure 5.** Identifying Research Gaps in the Development of Sustainable Shrimp Farming.

The second research gap involved the limited association between *immunity* and several important keywords, including *Penaeus vannamei*, *Vibrio*, *carbon*, and dietary supplements. As illustrated in Figure 5, immunity occupied an important position within the research network but remained weakly connected with these emerging research themes. This finding was particularly significant because immune responses play a central role in protecting shrimp against diseases, environmental stressors, and intensive farming conditions. The absence of stronger conceptual linkages suggested that future research should integrate immunological studies with species-specific cultivation practices, environmental factors, nutritional strategies, and carbon-related sustainability assessments to develop more comprehensive approaches to sustainable shrimp production.

The third research gap identified in Figure 5 was the relatively weak relationship between *probiotics* and *Penaeus vannamei*. Considering that *Penaeus vannamei* is the most widely cultivated shrimp species worldwide and that probiotics have increasingly been promoted as sustainable alternatives to antibiotics, this limited association represented an important opportunity for future investigation. Additional studies are therefore needed to evaluate probiotic formulations specifically designed for *Penaeus vannamei*, particularly under intensive farming conditions, to improve disease resistance, growth performance, and production sustainability.

Overall, the research gap analysis presented in Figure 5 demonstrated that, although sustainable shrimp farming had developed a well-established thematic foundation, several important conceptual relationships remained insufficiently explored. Strengthening the integration among dietary supplements, immunity, probiotics, *Vibrio*, *Penaeus vannamei*, and carbon-related sustainability would substantially advance the scientific understanding of sustainable shrimp farming. Such interdisciplinary investigations would facilitate the transition from descriptive bibliometric mapping toward mechanism-based research capable of generating practical solutions for disease management, sustainable production, environmental conservation, and climate-resilient aquaculture systems.

## 4. Conclusions

This study analyzed 294 publications on Sustainable Shrimp Farming (BUB) indexed in the Scopus database. The dataset was obtained by applying predefined inclusion criteria, including publications from 2014 to 2023, document types limited to research articles and conference papers, and only finalized publications from peer-reviewed journals and conference proceedings. The bibliometric analysis provided a comprehensive overview of global research trends, identified major research themes, and revealed several research gaps that may guide future investigations in sustainable shrimp farming. The results demonstrated a continuous increase in publications related to sustainable shrimp farming over the study period, indicating growing scientific interest and increasing recognition of the importance of sustainable aquaculture. The analysis also revealed that research in this field had become increasingly multidisciplinary, encompassing agricultural and biological sciences, environmental science, engineering, economics, and other related disciplines. Furthermore, keyword network analysis showed that recent research had increasingly focused on themes such as immunity, probiotics, bacteria, microbiology, non-human, Vibrio, *Penaeus vannamei*, carbon, and dietary supplements, reflecting a transition from production-oriented studies toward integrated approaches that considered animal health, environmental sustainability, and climate-related issues. The research gap analysis identified three priority areas for future investigation. First, additional studies are needed to clarify the relationships among dietary supplements, immune responses, probiotics, and Vibrio to better understand their combined effects on shrimp health and disease resistance. Second, future research should integrate immunological responses with *Penaeus vannamei*, Vibrio, carbon-related sustainability, and dietary supplementation to develop more comprehensive and sustainable shrimp farming systems. Third, further investigations are required to evaluate probiotic applications specifically designed for *Penaeus vannamei* under intensive farming conditions, with the aim of improving productivity, disease resistance, and environmental sustainability.

## Author Contributions

Conceptualization, methodology, formal analysis, investigation, data curation, visualization, writing—original draft preparation, writing—review and editing, and supervision were contributed equally by all authors. All authors have read and agreed to the published version of the manuscript.

## Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The bibliographic dataset used in this study was retrieved from the Scopus database and is subject to the database's terms and conditions.

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