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Feed production for sustainable aquaculture: A Bibliometric Network Analysis

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Abstract. In recent years, aquaculture has played a fundamental role in human nutrition and livestock for the ability to produce different animal and vegetable protein and lipid sources essential for human and animal health. However, the growing increase in aquaculture has led to a greater demand for ingredients composing feed for aquatic organisms, many of which are derived from wild fish making the aquatic feed production an unsustainable process. For this reason, the aquaculture sector has expanded experimentation to search for alternative ingredients to reduce environmental impact.

This study explored the global scientific literature on sustainable aquaculture with particular reference to feeding using VOSviewer software, which allows for generating, visualizing, and exploring maps based on bibliometric network data. The results allowed a comprehensive overview of the scientific literature on sustainable aquaculture through network maps displaying the relationships among keywords, authors, countries, and journals. In detail, this paper highlighted that in the last years, particularly in recent decades, the research widely focused attention on different aspects of the sustainable aquaculture field. The first journal that researched sustainable aquaculture was the Aquaculture Journal, and the leading countries that pursued this type of research were the USA, UK, and China. Concerning the co-occurrence, the top keywords were aquaculture, sustainability, animals, nonhuman, and sustainable development, highlighting a growing interest in research on microalgae, diet, fishmeal, and climate change. The description of the current state of the art in sustainable aquaculture reported in this article highlighted that the combined use of social network analysis and bibliometrics allows exploring the development of research in specific fields of science and lays the foundations for delving into questions that have not yet been sufficiently investigated.

Keywords: Aquaculture, Sustainability, Aquafood, Aquafeed, Feed, Food, Bibliometric analysis

1. Introduction

Aquaculture is the fastest-growing food sector globally (FAO, 2022). The expected growth of the world population will increase the demand for food, and aquaculture is expected to meet the growing demand. It is estimated that aquaculture production will reach 140 million tons by 2050 to meet future demand for fish and shellfish (Alexander et al., 2015). Aquatic food provides about 17% of animal protein globally. This figure rises to over 50% in several countries, mainly Asian and African (Geremia et al., 2023). However, the production practices make intensive aquaculture unsustainable because of the necessity to preserve the welfare of farmed fish (Napolitano et al., 2022; Palstra et al., 2020), containing the local environmental impacts (Chopin et al., 2001; Klinger and Naylor, 2012; Napolitano et al., 2022). Most of the environmental impacts of the overall intensive aquaculture chain are associated with the production of fish aquafeed, particularly for carnivorous fish (Papatryphon et al., 2004). A key issue is a dependence on marine resources, mainly small pelagic fish, to supply fishmeal (FM) and fish oil (FO), which represent the main components of the fish diet (Natale et al., 2013). The aquaculture industry has made great efforts to find alternative feed ingredients that reduce FM and FO (Hodar et al., 2019). Using vegetable derivates, such as crop-derived ingredients, represents an effective solution to obtain a partial reduction of FM and FO in aquafeed for both carnivorous and omnivorous species (Tacon, 2011). However, using derivates of crops is responsible for high environmental impacts such as climate change, acidification, eutrophication, and soil degradation (Brentrup et al., 2004; Lal, 2009). Land use, water consumption, fuel consumed during agricultural operations, and excessive use of fertilizers and pesticides for farming practices have various consequences on the environment due to greenhouse gas emissions, water and soil pollution, and water eutrophication resulting from agricultural runoff, with effects on human and animal health and loss of aquatic and terrestrial biodiversity, also due to the affections of a wide range of ecosystem services (Dale and Polasky, 2007; Dijkman et al., 2018; Foley et al., 2011; Fry et al., 2016; Malik et al., 2020). Furthermore, using agricultural derivatives for aquaculture removes terrestrial animals' feed resources. In addition, vegetable proteins derived from legumes, grains, or vegetable oils have anti-nutritional factors and low palatability that limit their use (Naylor et al., 2009). Other alternative ingredients available for the fish diet are microalgae because of the fast growth rate compared to the terrestrial crops, high protein content, the ability to use non-arable resources for growth (Catone et al., 2021), and their high nutritional value that can protect the organisms from stress conditions (Carfagna et al., 2015; Napolitano et al., 2022, 2020) and pathogens in aquaculture systems (Ravi et al., 2010). However, the standard medium used for optimal biomass production of microalgae is expensive and environmentally impacting (Geremia et al., 2021), thus reducing the possibility of using them for aquafeed.

In recent years, several attempts have been made to improve sustainability in aquaculture. The Blue Economy directives represent a strategy to mitigate the impacts on aquatic ecosystems of marine economic activities, such as aquaculture, tourism, and fisheries, which have a direct impact on the fauna and flora that they sustain (Ababouch et al., 2015).

The concept of the "Blue Economy" emerged during the United Nations Conference on Sustainable Development (UNCSD) held in the city of Rio de Janeiro in 2012 (Campbell et al., 2021), which aimed at "sustainable use of ocean resources for economic growth, improved livelihoods and employment, and ocean ecosystem health" (World Bank Group, 2017). Following the guidelines of the Blue Economy report, the use of sustainable feeding methods that ensure respect for the environment and, at the same time, the health and welfare of animals represents one of the means to progress the environmental performance of the Aquaculture sector in Europe. The European project EASY FEED reflects these marks, aiming at producing an aquaculture feed formula in which FM and FO are substituted to reduce environmental impacts, making it profitable, as production costs are up to 40 % cheaper than the classical feed (European Commission, 2022).

Growing scientific interest in recent years and increasing attention on political agendas make the blue economy and aquaculture promising fields for scientific investigation. On this basis, the present work aims to provide a specific analysis of the global scientific literature using the bibliometric network analysis (BNA) method (Buonocore et al., 2018). The BNA has been an advantageous tool for quantitatively evaluating trends and patterns in academic literature and highlighting the most relevant scientific contributions in the field of sustainable aquaculture feed production. The literature was explored through a quantitative investigation of network structures based on the relationships between researchers, organizations, countries, and keywords dealing with the investigated topic. Moreover, the exploration was carried out by analyzing the global scientific landscape of the last three decades to trace its evolution and trends.

2. Methodology

2.1 Bibliometric Network Analysis (BNA)

BNA was performed using VOSviewer software (version 1.6.18). VOSviewer allows for creating, viewing, and exploring maps based on bibliometric network data. The output results are displayed in clusters to visualize connections among the bibliometric data. Co-authorship, co-occurrence, and citation analyses were performed to create network maps showing (1) the co-occurrence of keywords, (2) the co-authorship among researchers and countries, and (3) cited scientific journals. In the analyses, the size of items is determined by their "total link strength", number of documents, and the number of citations. The thickness of each connection is based on the “link strength”. Table 1 (Tab. 1) lists the main terms used in the analysis. The resolution parameter determines the number of clusters. The higher its value, the higher the level of detail and, consequently, the number of clusters. Its value can be set arbitrarily by the user to display an appropriate number of clusters in the maps (Van Eck and Waltman, 2018). In our case, we applied a resolution equal to 1 for all the analyses. Table 2 (Tab. 2) lists the different types of analysis.

Tab. 1: Terminology used by VOSviewer software.

Term	**Description**
Items	Objects of interest (e.g., publications, researchers, keywords, authors).
Link	Connection or relation between two items (e.g., co-occurrence of keywords).
Link Strenght	Attribute of each link, expressed by a positive numerical value. In the case of co-authorship links, the higher the value, the higher the number of publications the two researchers have co-authored.
Network	Set of items connected by their links.
Cluster	Sets of items included in a map. One item can belong only to one cluster.
Weight attribute: number of links	The number of links of an item with other items.
Weight attribute: total link strength	The cumulative strength of the links of an item with other items.

Tab. 2: Different VOSviewer types of analyses used in this study.

Types of analysis	**Description**
Co-authorship	In co-authorship networks, researchers, research institutions, or countries are linked to each other based on the number of publications they have authored jointly.

Co-occurrence	The number of co-occurrences of two keywords is the number of publications in which both keywords occur together in the title, abstract, or keyword list.
Citation	In citation networks, two items are linked if at least one cites the other.

2.2 Bibliographic Data Collection

Research study documents from the past three decades used in this study were collected on February 1, 2023, by search on the Scopus web search engine. The research consisted of the terms "Aquaculture" AND "Sustainability" AND ("Aquafood*" OR "Aquafeed*" OR "Feed*" OR "Food*"). Results were exported as .csv files after selecting “Citation information”, “Bibliographical information”, “Abstract & keywords”, and “Include references”. In addition to the analysis of the bibliometric network, the temporal trend of the number of articles published per year was also investigated. Since it is still ongoing, the year 2023 has been omitted from this analysis.

3. Results and Discussion

3.1 Temporal trend analysis

The research on the Scopus database provided 1,636 scientific documents published from 1989 to 2022. The temporal trend of publication showed a growth of the topic since 1989 expressed by an exponential function ($y = 3E\text{-}154e^{0,1775x}$; $R^2 = 0.96$) (Fig. 1). Particularly, the analysis highlighted a great increase since 2010 according to the challenge of sustainability (Borowy, 2013), which is nowadays one of the factors that most influence development policies at the local, national, and international levels, as demonstrated by the 17 Sustainable Development Goals (SDGs) established by United Nations (UN) in the 2015–2030 agenda (Alharthi and Hanif, 2020; UN, 2015) The “Blue Economy” paradigm is strictly connected with the UN-SDGs (Lee et al., 2020) since it focuses attention on responsible and sustainable water management because water is not a resource unlimited (Liu et al., 2017). Water represents the main element of oceans and, in general, the marine environment, with a fundamental role in human life and different economic activities. In this view, the blue economy and the sustainability in aquaculture are instruments to enhance the development of a circular economy (Barroso et al., 2022; Iustin-Emanuel et al., 2014).

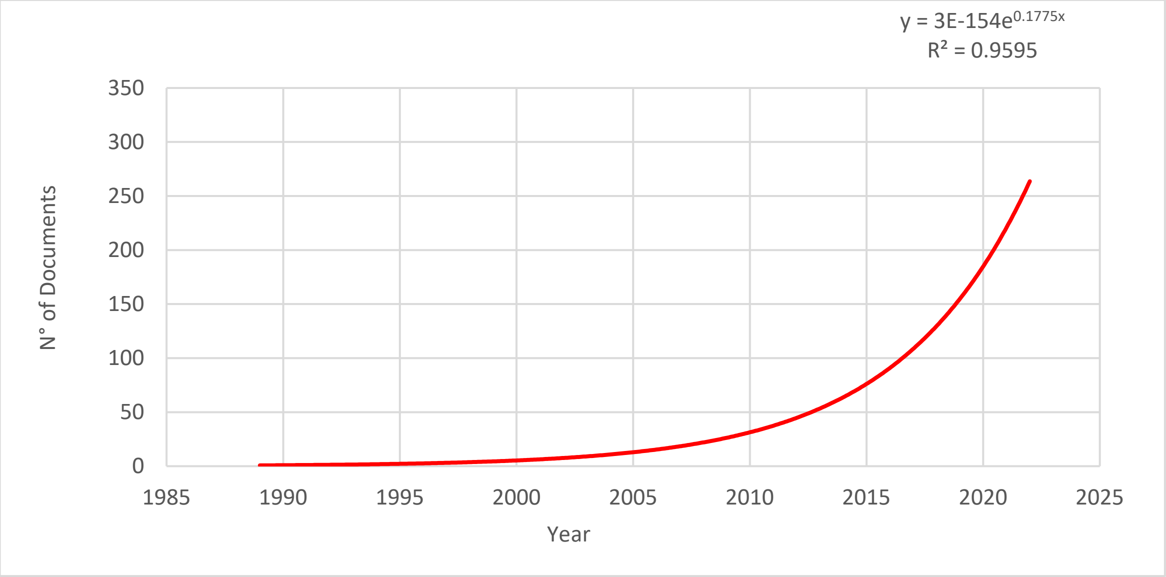

Fig. 1: Temporal trend of scientific articles published on the topic.

3.2 Bibliometric Network Analysis (BNA)

The BNA generated five maps and four tables. Figures 2-5 show items classified according to "total link strength" weight attributes. Figure 6 reports weight attributes based on "Documents". Tables 3, 5, and 6 show the five main countries, authors, and journals. Instead, Table 4 shows the first 10 keywords.

3.2.1 Co-authorship Countries Analysis

Country co-authorship analysis provides 115 countries. Documents with more than 5 countries per item were considered. Furthermore, with a minimum threshold of 5 articles published per country, 63 countries were selected. The network map shows that the selected authors have been divided into 8 clusters reported in Figure 2 (Fig. 2) with different colors. The size of each cluster depends on the number of authors belonging to the same country. As shown, Chinese authors have a strong collaboration with Eastern authors according to the fact that China, South, and Southeast Asia are expected to remain the largest suppliers of farmed fish globally for the foreseeable future (Tezzo et al., 2021). Furthermore, there is strong co-authorship among Western authors.

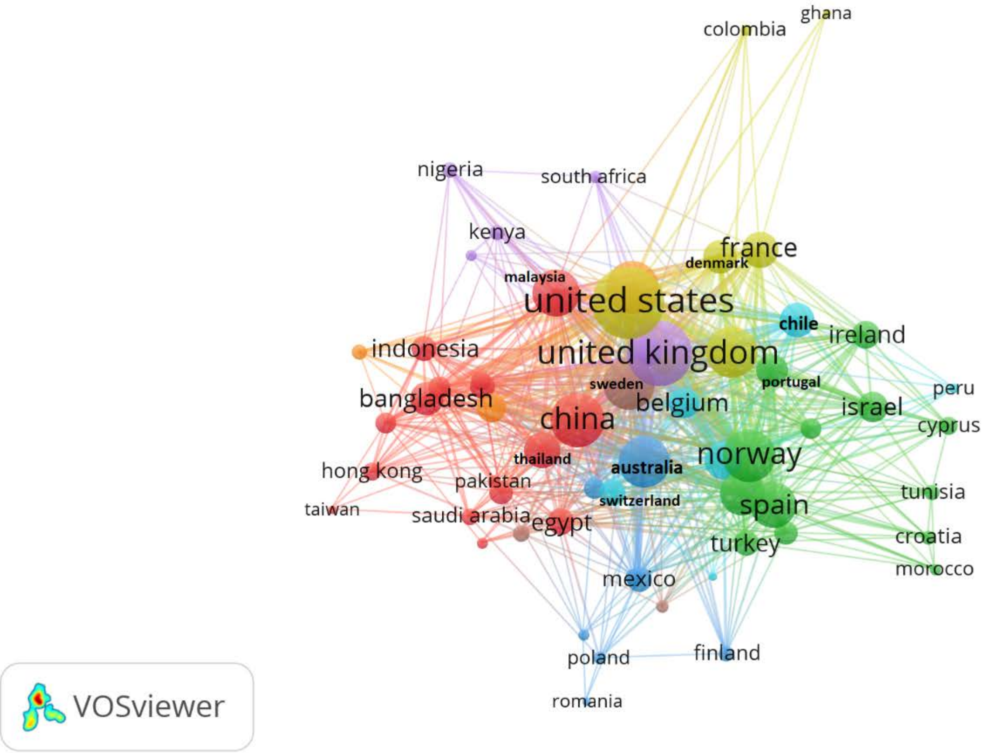

Fig. 2: Co-authorship network map of countries (rank based on total link strength).

Table. 3 (Tab. 3) shows the leading role of the United States in all parameters: documents, citations, and total link strength according to the Co-authorship Countries Analysis.

Tab. 3: Top 5 countries ranked by total link strength.

Countries	Documents	Citations	Total link Strenght
U.S.A.	316	13888	**358**
U.K.	177	7425	**302**
CHINA	124	4442	**203**
NORWAY	120	6793	**199**
NETHERLANDS	81	3273	**195**

3.2.2 Co-occurrence of keywords

The analysis of the co-occurrence of keywords generated 10,396 results. There are 87 keywords selected and grouped into 3 clusters reported with different colors by applying a threshold of 32 occurrences (Fig. 3).

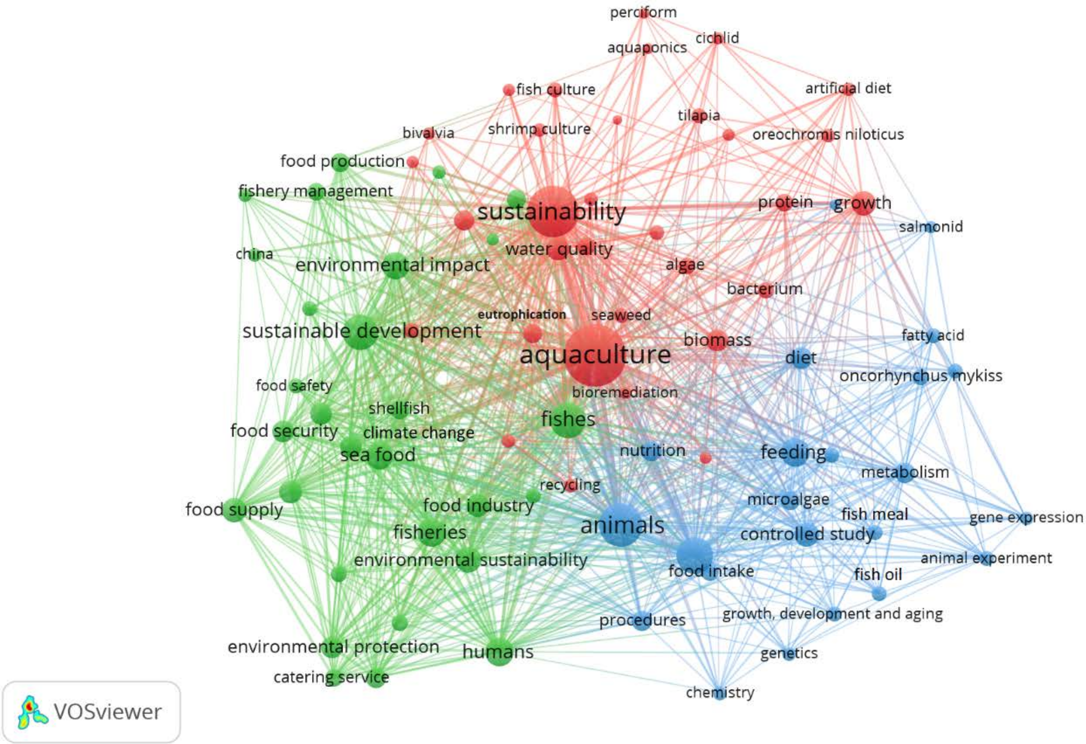

Fig. 3: Co-occurrence network map of Keyword (rank based on total link strength).

The first 10 keywords by "total link strength" are listed in Table 4 (Tab. 4). The term "Aquaculture" was the keyword with the largest total link strength as expected, while "sustainability" showed the second one. Despite the 3 clusters being well-defined, some keywords move among the clusters without clear demarcation. Nevertheless, the network map indicates a strong interest in the investigated topic of sustainable development.

Tab. 4: Top 10 Keyword ranked by total link strength.

Keyword	Occurrences	Total Link strength
AQUACULTURE	989	**5364**
SUSTAINABILITY	741	**3653**
ANIMALS	312	**2631**
NONHUMAN	206	**2009**
SUSTAINABLE DEVELOPMENT	276	**1775**
FISHES	245	**1679**
HUMANS	122	**1232**

FEEDING	135	**1227**
FISHERIES	162	**1178**
ENVIRONMENTAL IMPACT	130	**1069**

Figure 4 (Fig. 4) shows the trend of keywords over time. In recent years (from 2015 to 2019), a growing interest in research fields such as “climate change” and “eutrophication” can be observed, highlighting the interest in the global academic literature on aquaculture environmental impacts. Furthermore, the outcomes highlight recent studies on "diet" (from 2017) and "fishmeal" (from 2019), showing the interest of the global scientific literature in discovering alternative and more sustainable foods such as microalgae. The use of microalgae in aquafeed has been extensively documented, as reported by Napolitano and co-authors (Napolitano et al., 2022), who used the microalgae spirulina (*Arthrospira platensis*) as high-quality proteins to partially replace the fishmeal in the diet of a model fish species (juveniles of Koi Carp, *Cyprinus carpio L.*). The authors also hypothesized a circular economy context based on aquaculture wastewater as a medium for spirulina cultivation subsequently used in aquafeed. Also, a recent role of microalgae in mitigating climate change has highlighted (Catone et al., 2021; Geremia et al., 2021).

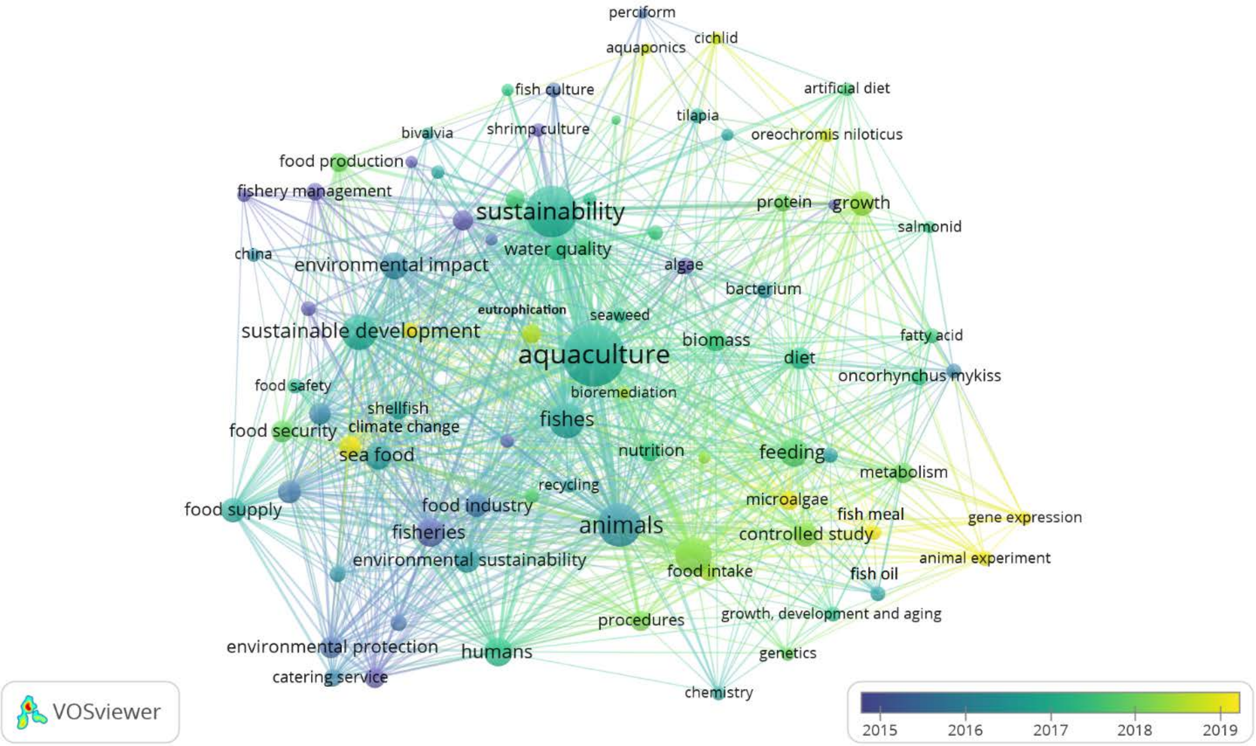

Fig. 4: Co-occurrence network map of Keyword (rank based on total link strength).

3.2.3 Co-authorship authors analysis

The analysis of authors into co-authors yielded 6,245 results. It was restricted to articles with a maximum of 25 authors per document and a minimum of 5 articles published per author and characterized by a minimum of 100 citations per author. The analysis yielded 16 clusters, each composed of 64 authors, as shown in the network map (Fig. 5).

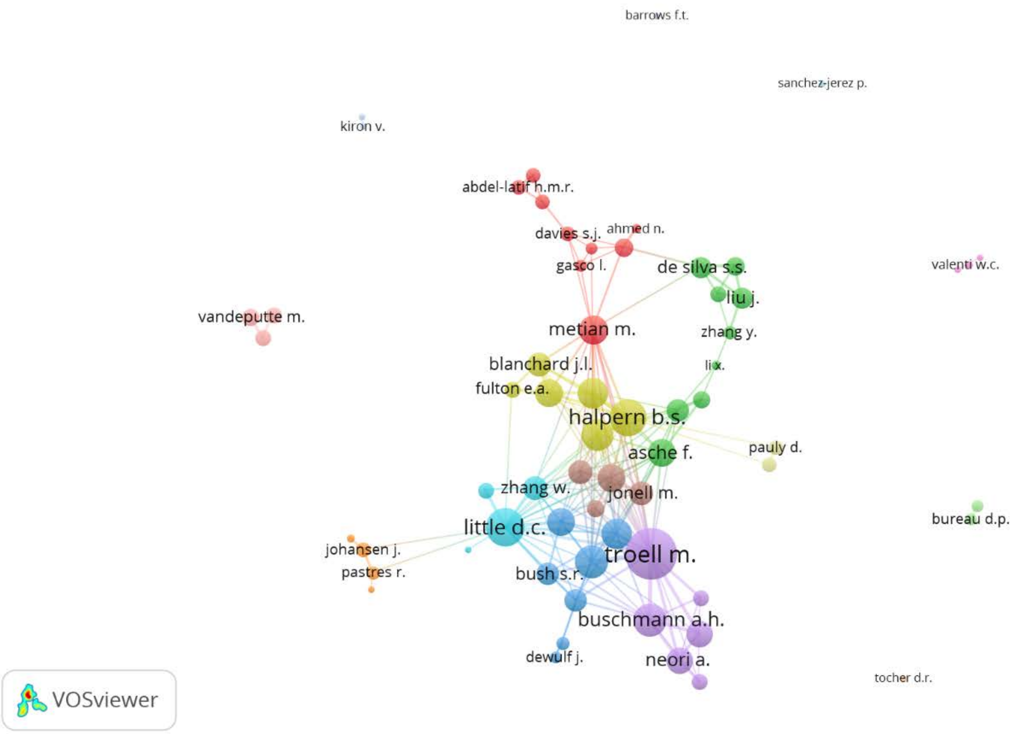

Fig. 5: Co-authorship network map of authors (rank based on total link strength).

Furthermore, Table 5 (Tab. 5) reports the top 5 authors selected on the total link strength. The results show clusters with some authors not connected to the primary network. Despite the United States having an important role in publishing on the subject under investigation, the most cited author is Troell M., a system ecologist from Stockholm University who mainly works with environmental problems associated with aquaculture, other than the development of integrated cultivation techniques (Naylor et al., 2000; Troell et al., 2009). Troell also tries to develop biofilters using seaweeds with the final goal of increasing environmental and economic performance (Troell et al., 1999, 1997). The second author is Little D.C., a specialist in aquatic resource development and aquatic food security at the University of Stirling (Little et al., 2018, 2016, 2012).

Tab. 5: Top 5 authors ranked by Total Link Strength.

Authors	**Documents**	**Citations**	**Total link Strenght**
Troell M.	25	2854	**76**
Little D.C.	20	1104	**42**

Halpern B.S.	13	1066	**40**
Buschmann A.H.	12	2317	**32**
Henriksson P.J.G.	9	286	**30**

3.2.4 Citation analysis of journals

The citation analysis of journals resulted in a total of 619 documents. Applying 10 as the minimum number of documents of a source and 100 as the minimum number of citations, the citation analysis of journals generated 22 meets. The outcomes showed 6 different clusters (Fig. 6).

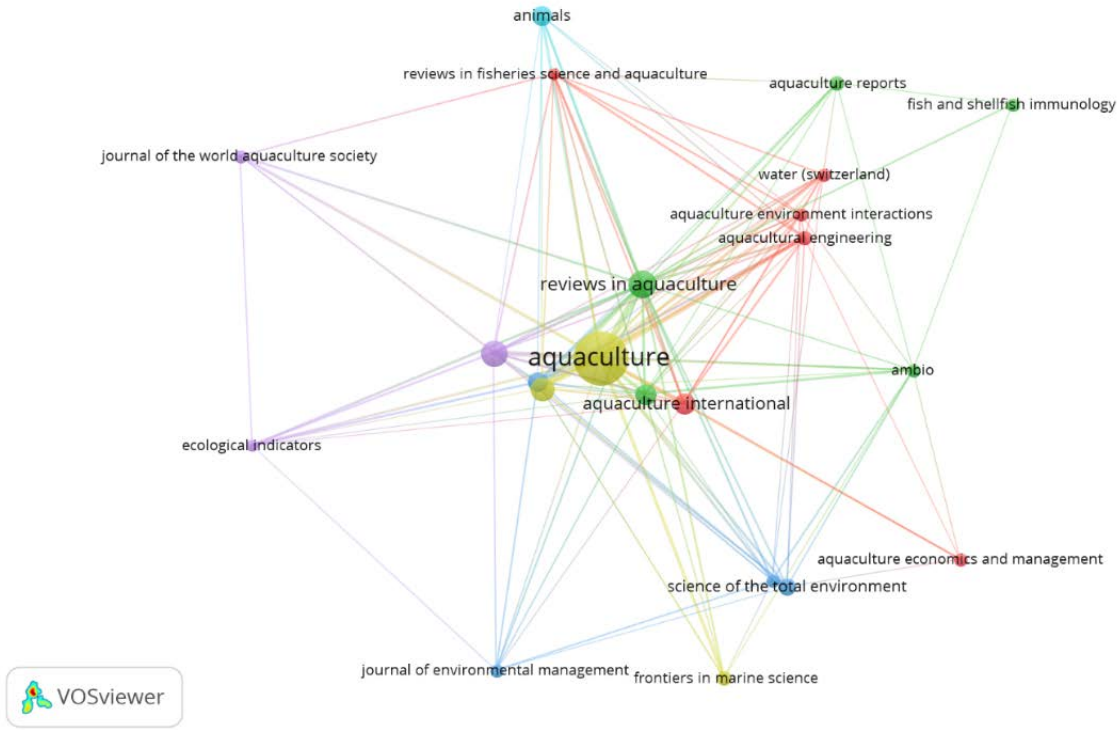

Fig. 6: Citation analysis of a journal (rank based on documents).

Table 6 (Table 6) shows the top 5 relevant journals publishing on the investigated topic, based on “document weight”. The Aquaculture Journal ranks first among all other journals probably thanks to the publication not only of traditional scientific research based on interdisciplinary and transdisciplinary approaches but also of documents coming from non-traditional scientific areas such as sustainability science, social ecological systems, as well as the aquaculture of various species for ornamental, conservation and restoration purposes.

Tab. 6: Top 5 journals ranked by documents.

Countries	**Documents**	**Citations**
AQUACULTURE	**189**	7930
REVIEWS IN AQUACULTURE	**49**	1904
SUSTAINABILITY (SWITZERLAND)	**46**	555
AQUACULTURE RESEARCH	**38**	2411
MARINE POLICY	**29**	748

4. Conclusions

This study explored the global scientific literature on sustainable aquaculture with specific references to feeding from 1988 to 2022. BNA performed using VOSviewer software revealed the trend and evolution of the topic investigated. Network analyses were carried out among countries, keywords, authors, and journals.

The results highlighted an exponential growth in scientific publications focusing on aquaculture, sustainability, and nutrition topics in recent years. The results also showed a strong link between aquaculture and environmental impacts, highlighting the importance of research in that field. These findings are not surprising considering that aquaculture plays a crucial role in achieving the 17 United Nations Sustainable Development Goals, as it has the potential to address many of the challenges the world faces today, from hunger and poverty to environmental sustainability and climate change. BNA application by combining social network analysis and bibliometrics has proven to be a promising approach to exploring global scientific literature through systematic thinking.

References

Ababouch, L., & Fipi, F., 2015, Fisheries and aquaculture in the context of blue economy. Feeding Africa, 2(21–23), 13.

Alexander K.A., Potts T.P., Freeman S., Israel D., Johansen J., Kletou D., Meland M., Pecorino D., Rebours C., Shorten M., Angel D.L., 2015, The Implications of Aquaculture Policy and Regulation for the Development of Integrated Multi-Trophic Aquaculture in Europe. Aquaculture, 443, 16–23, doi: 10.1016/J.AQUACULTURE.2015.03.005.

Alharthi M., Hanif I., 2020, Impact of Blue Economy Factors on Economic Growth in the SAARC Countries. Maritime Business Review, 5, 253–269, doi: 10.1108/MABR-01-2020-0006/FULL/PDF.

Barroso S., Pinto F.R., Silva A., Silva F.G., Duarte A.M., Gil M.M., 2022, The Circular Economy Solution to Ocean Sustainability: Innovative Approaches for the Blue Economy. https://services.igi-global.com/resolvedoi/resolve.aspx?doi=10.4018/978-1-6684-5678-1.ch044, 875–901. doi: 10.4018/978-1-6684-5678-1.CH044.

Borowy I., 2013, Defining Sustainable Development for Our Common Future: A History of the World Commission on Environment and Development (Brundtland Commission). Defining Sustainable Development for Our Common Future: A History of the World Commission on Environment and Development (Brundtland Commission), 1–261, doi: 10.4324/9780203383797.

Brentrup F., Küsters J., Kuhlmann, H., Lammel J., 2004, Environmental Impact Assessment of Agricultural Production Systems Using the Life Cycle Assessment Methodology: I. Theoretical Concept of a LCA Method Tailored to Crop Production. European Journal of Agronomy, 20, 247–264, doi: 10.1016/S1161-0301(03)00024-8.

Buonocore E., Picone F., Russo G.F., Franzese P.P., 2018, The Scientific Research on Natural Capital: A Bibliometric Network Analysis. Journal of Environmental Accounting and Management, 6, 381–391, doi: 10.5890/JEAM.2018.12.010.

Dale, V. H., & Polasky, S. (2007). Measures of the effects of agricultural practices on ecosystem services. Ecological economics, *64*(2), 286-296, doi: 10.1016/j.ecolecon.2007.05.009.

Dijkman T.J., Basset-Mens C., Antón A., Núñez M. (2018). LCA of Food and Agriculture. In: Hauschild M., Rosenbaum R., Olsen S. (eds) Life Cycle Assessment. Springer, Cham, Switzerland, 2018; pp. 723–754, doi.org/10.1007/978-3-319-56475-3_29

Campbell L.M., Fairbanks L., Murray G., Stoll J.S., D'Anna L., Bingham J., 2021, From Blue Economy to Blue Communities: Reorienting Aquaculture Expansion for Community Wellbeing. Mar Policy, 124, 104361, doi: 10.1016/J.MARPOL.2020.104361.

Carfagna S., Napolitano G., Barone D., Pinto G., Pollio A., Venditti P., 2015, Dietary Supplementation with the Microalga Galdieria Sulphuraria (Rhodophyta) Reduces Prolonged Exercise-Induced Oxidative Stress in Rat Tissues. Oxid Med Cell Longev, doi: 10.1155/2015/732090.

Catone C.M., Ripa M., Geremia E., Ulgiati S., 2021, Bio-Products from Algae-Based Biorefinery on Wastewater: A Review. J Environ Manage, 293, 112792, doi:10.1016/j.jenvman.2021.112792.

Chopin T., Buschmann A.H., Halling C., Troell M., Kautsky N., Neori A., Kraemer G.P., Zertuche-González J.A., Yarish C., Neefus C., 2001, Integrating Seaweeds into Marine Aquaculture Systems: a Key Toward Sustainability 1. J. Phycol, 37, 975–986, doi: 10.1046/j.1529-8817.2001.01137. x.

European Commission The EU Blue Economy Report 2022 - Publications Office of the EU Available online: https://op.europa.eu/en/publication-detail/-/publication/156eecbd-d7eb-11ec-a95f-01aa75ed71a1 (accessed on 6 February 2023).

FAO, 2022. The State of World Fisheries and Aquaculture. The State of World Fisheries and Aquaculture. doi: 10.4060/CC0461EN.

Foley J.A., Ramankutty N., Brauman K.A., Cassidy E.S., Gerber J.S., Johnston M., Mueller N.D., O'Connell C., Ray D.K., West P.C., Balzer C., Bennett E.M., Carpenter S.R., Hill J., Monfreda C., Polasky S., Rockström J., Sheehan J., Siebert, S., Tilman D., Zaks D.P.M., 2011. Solutions for a cultivated planet. Nature 2011 478:7369 478, 337–342. doi.org/10.1038/nature10452.

Fry J.P., Love D.C., MacDonald G.K., West P.C., Engstrom P.M., Nachman K.E., Lawrence R.S., 2016, Environmental Health Impacts of Feeding Crops to Farmed Fish. Environ Int, 91, 201–214, doi: 10.1016/J.ENVINT.2016.02.022.

Geremia E., Muscari Tomajoli M.T., Murano C., Petito A., Fasciolo G., 2023. The Impact of Micro- and Nanoplastics on Aquatic Organisms: Mechanisms of Oxidative Stress and Implications for Human Health—A Review. Environments 2023, Vol. 10, Page 161 10, 161. doi.org/10.3390/ENVIRONMENTS10090161.

Geremia E., Ripa M., Catone C.M., Ulgiati S., 2021. A Review about Microalgae Wastewater Treatment for Bioremediation and Biomass Production—a New Challenge for Europe. Environments, 8, 136, doi: 10.3390/ENVIRONMENTS8120136/S1.

Hodar A.R., Vasava R., Joshi N.H., 2019, Fish Meal and Fish Oil Replacement for Aqua Feed Formulation by Using Alternative Sources: a Review. Journal of Experimental Zoology India, 23(1).

Iustin-Emanuel, ALEXANDRU & Alexandru, TASNADI, 2014. From Circular Economy To Blue Economy, Management Strategies Journal, Constantin Brancoveanu University, vol. 26(4), pages 197-203.32.

Klinger D., Naylor R., 2012, Searching for Solutions in Aquaculture: Charting a Sustainable Course Aquaculture: The Cultivation of Algae and Aquatic Plants and Animals. doi: 10.1146/annurev-environ-021111-161531.

Lee K.H., Noh J., Khim J.S., 2020, The Blue Economy and the United Nations' Sustainable Development Goals: Challenges and Opportunities. Environ Int, 137, 105528, doi: 10.1016/J.ENVINT.2020.105528.

Little D.C., Barman B.K., Belton, B., Beveridge, M.C., Bush S.J., Dabaddie L., Demaine H., Edwards P., Mahfujul Haque M., Kibria G., Morales E., Murray F.J., Leschen W.A., Nandeesha M., Sukadi F., 2012. Alleviating poverty through aquaculture: progress, opportunities and improvements 719–783.

Little D.C., Newton R.W., Beveridge M.C.M., 2016. Aquaculture: a rapidly growing and significant source of sustainable food? Status, transitions and potential. Proceedings of the Nutrition Society 75, 274–286,doi.org/10.1017/S0029665116000665.

Little D.C., Young J.A., Zhang W., Newton R.W., Al Mamun A., Murray F.J., 2018. Sustainable intensification of aquaculture value chains between Asia and Europe: A framework for understanding impacts and challenges. Aquaculture 493, 338–354, /doi.org/10.1016/J.AQUACULTURE.2017.12.033

Liu J., Yang H., Gosling S.N., Kummu M., Flörke M., Pfister S., Hanasaki N., Wada Y., Zhang X., Zheng C., Alcamo J., 2017, Water Scarcity Assessments in the Past, Present, and Future. Earths Future, 5, 545–559, doi: 10.1002/2016EF000518.

Malik D. S., Sharma A. K., Sharma, A. K., Thakur R., & Sharma M. (2020). A review on impact of water pollution on freshwater fish species and their aquatic environment. Advances in environmental pollution management: wastewater impacts and treatment technologies, 1st ed.; Kumar, V., Kamboj, N., Payum, T., Eds.; Agro Environ Media—Agriculture and Ennvironmental Science Academy: Haridwar, India, 2020; pp. 10–28, doi:10.26832/aesa-2020-aepm-02

Napolitano G., Fasciolo G., Salbitani G., Venditti P., 2020, Chlorella Sorokiniana Dietary Supplementation Increases Antioxidant Capacities and Reduces ROS Release in Mitochondria of Hyperthyroid Rat Liver. Antioxidants 2020, Vol. 9, Page 883, 9, 883, doi: 10.3390/ANTIOX9090883.

Napolitano G., Venditti P., Agnisola C., Quartucci S., Fasciolo G., Muscari Tomajoli M.T., Geremia E., Catone C.M., Ulgiati S., 2022, Towards Sustainable Aquaculture Systems: Biological and Environmental Impact of Replacing Fishmeal with *Arthrospira Platensis* (Nordstedt) (Spirulina). J Clean Prod, 374, 133978, doi: 10.1016/J.JCLEPRO.2022.133978.

Natale F., Hofherr J., Fiore G., Virtanen J., 2013, Interactions between Aquaculture and Fisheries. Mar Policy, 38, 205–213, doi: 10.1016/J.MARPOL.2012.05.037.

Naylor R. L., Goldburg R. J., Primavera J. H., Kautsky N., Beveridge M. C. M., Clay J., Folke C., Lubchenco J., Mooney H., & Troell M., 2000. Effect of aquaculture on world fish supplies. *Nature 2000 405:6790*, *405*(6790), 1017–1024,doi.org/10.1038/35016500

Naylor R.L., Hardy R.W., Bureau D.P., Chiu A., Elliott M., Farrell A.P., Forster I., Gatlin D.M., Goldburg R.J., Hua K., Nichols P.D., 2009, Feeding Aquaculture in an Era of Finite Resources. Proc Natl Acad Sci U S A, 106, 15103–15110, doi: 10.1073/PNAS.0905235106/SUPPL_FILE/0905235106SI.PDF.

Palstra A.P., Magnoni L.J., Martos-Sitcha J.A., Mancera J.M., Prunet P., 2020 Editorial: Welfare and Stressors in Fish: Challenges Facing Aquaculture. Frontiers in Physiology | www.frontiersin.org, 11, 162, doi: 10.3389/fphys.2020.00162.

Papatryphon E., Petit J., Kaushik S.J., Van Der Werf H.M.G., 2004, Environmental Impact Assessment of Salmonid Feeds Using Life Cycle Assessment (LCA). https://doi.org/10.1579/0044-7447-33.6.316, 33, 316–323, doi: 10.1579/0044-7447-33.6.316.

Ravi M., Lata De S., Azharuddin S., D Paul S.F., 2010. The Beneficial Effects of Spirulina Focusing on Its Immunomodulatory and Antioxidant Properties. Nutr Diet Suppl, 73, doi: 10.2147/NDS.S9838.

Tacon A.G.J.; Hasan M.R.; Metian M. Demand and supply of feed ingredients for farmed fish and crustaceans: trends and prospects. FAO Fisheries and Aquaculture Technical Paper No. 564. FAO, 2011. 87 pp.

Tezzo X., Bush S.R., Oosterveer P., Belton B., 2021, Food System Perspective on Fisheries and Aquaculture Development in Asia. Agric Human Values, 38, 73–90, doi: 10.1007/S10460-020-10037-5/FIGURES/6.

Troell M., Halling C., Nilsson A., Buschmann A. H., Kautsky N., & Kautsky L., 1997. Integrated marine cultivation of Gracilaria chilensis (Gracilariales, Rhodophyta) and salmon cages for reduced environmental impact and increased economic output. Aquaculture, 156(1–2), 45–61, doi.org/10.1016/S0044-8486(97)00080-X.

Troell M., Joyce A., Chopin T., Neori A., Buschmann A. H., & Fang J. G., 2009. Ecological engineering in aquaculture — Potential for integrated multi-trophic aquaculture (IMTA) in marine offshore systems. Aquaculture, 297(1–4), 1–9. doi.org/10.1016/J.AQUACULTURE.2009.09.010.

Troell M., Rönnbäck P., Halling C., Kautsky N., & Buschmann A., 1999. Ecological engineering in aquaculture: use of seaweeds for removing nutrients from intensive mariculture. Sixteenth International Seaweed Symposium, 603–611. https://doi.org/10.1007/978-94-011-4449-0_74.

UN 70/1, 2015 Transforming Our World: The 2030 Agenda for Sustainable Development Transforming Our World: The 2030 Agenda for Sustainable Development Preamble. https://documents-dds- ny.un.org/doc/UNDOC/GEN/N15/291/89/PDF/N1529189.pdf?OpenElement.

Van Eck and Waltman, 2018. VOSviewer - Visualizing scientific landscapes [WWW Document]. URL https://www.vosviewer.com/.

World Bank; United Nations Department of Economic and Social Affairs. 2017. The Potential of the Blue Economy: Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries. © World Bank, Washington, DC. http://hdl.handle.net/10986/26843.