Indian Journal of Ecology (2023) 50(4): 1155-1162
DOI: https://doi.org/10.55362/IJE/2023/4028

Manuscript Number: 4028
NAAS Rating: 5.79

Commensurable Analysis of Scientific Communications Published in Reviews in Aquaculture Applying Scientometric Analysis

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Abstract: This study presents a longitudinal and visualization mapping of scientific communications published in *Reviews in Aquaculture* during the period 2011-2020, applying scientometric approaches to depict the scientific contributions, collaboration trends, and research hotspots in the subject of aquaculture. Metadata of 412 articles published in *Reviews in Aquaculture* was retrieved and downloaded from Scopus database. The network graphs were visualized using '*VOSviewer*' and '*Gephi*' software. The chronological growth of scientific communications published in the journal, most productive authors, institutions, and countries vis-à-vis collaboration trends amongst them were scrutinized. The subject facets engulfed by the journal were identified based on co-occurrence of keywords. The findings would be useful for strengthening collaborative research as well as to pay required attention towards the slenderly explored sub-domains in aquaculture.

Keywords: Scientometrics, Aquaculture, Bibliometrics, Collaboration, Visualization

Despite scalable progress in society, hunger and malnutrition remain the major global issues in contemporary times. As per statistics of the Food and Agriculture Organization (FAO) of the United Nations (UN) for the year 2018, more than 11% of the world population suffers from poverty and lack access to quality food necessary for good human health (Kwasek et al 2020). Fish forms a valuable source of nutrients with special reference to protein in the human diet and it has been recorded that global consumption of aquatic food (excluding algae) has increased at an average annual rate of 3.0% from 1961 to 2019, a rate almost twice that of annual world population growth (1.6%) for the same period, with annual per capita consumption reaching to 20.5 kg in 2019 (FAO 2022). The global fish production was 177.8 million metric tonnes (mmt), including 90.3mmt from capture and 87.5mmt from aquaculture sector, and is expected to cross 200 mmt by 2030 (FAO 2022).

The contribution of aquaculture to the global production of aquatic animals reached a record 49.2% in 2020 along with considerable change in utilization and processing of fisheries and aquaculture production in the past decades. In 2020, 89% (157 mmt) of world production (excluding algae) was used for direct human consumption, compared to 67% in 1960. The reminder (over 20 mmt) was used for non-food purposes, mainly fishmeal and fish oil. Among these two major by-products, fishmeal is considered as highly nutritious for all the major livestock animals including farmed fish and fish oil represents the richest available source of long-chain polyunsaturated fatty acids (PUFAs), with a wide range of critical functions for human health (The Fish Site 2021). In addition to food value of fish and its by-products, fishing and aquaculture provide ample employment and livelihood to a large population viz. in 2020, about 58.5 million people were engaged in capture fisheries (38.03 million) and aquaculture (20.47 million) sector (FAO 2022).

After China, India is the second largest aquaculture producer in the world, with total fish and shell fish production of about 16.248 million metric tons (mmt) during 2021-22 with inland sector share of 12.121 mmt (74.60%) with export earnings of approximately Rs. 57,586.48 crores. Further, within inland fisheries, a major shift from capture fisheries to aquaculture has been witnessed in the last 3 decades and contribution of freshwater aquaculture has increased from 34% in mid 1980s to 78% in recent years. During 2020-21, fisheries contributed 1.10 % to National Gross Value Added (GVA) and 6.72% to the Agricultural GVA (Handbook on Fisheries Statistics 2022). Hence, identification of the prevalent scenario of scientific developments in aquaculture could be pivotal to further strengthen the occupation for uplifting it to a key role player in ensuring food security.

Nowadays, analysis of new trends and topics in various disciplines has attracted considerable attention in the academic and research spheres. Bibliometrics/ scientometrics has emerged as one of the widely used quantitative methods for understanding the changing landscape of concerned disciplines. Since journals are the primary sources of information carrying first-hand accounts of the research in the respective subject(s), scholars have analyzed the articles published therein for presenting the evolution and structure of the concerned subject domains. *Reviews in Aquaculture* is a pioneer journal enlisted amongst the high-impact journals, publishing reviews on developments in aquaculture techniques, policies, and planning. It takes in its ambit peer-reviewed review articles on the diverse aspects of aquaculture encompassing production and market trends, practices and technological developments, aquaculture-environment interactions, species in aquaculture; biology and culture of pivotal and emerging species, artificial propagation of species, feeds and feeding, genetics and aquaculture; health management in aquaculture; policy developments, product quality, and traceability and socio-economics aspects of aquaculture (https://onlinelibrary.wiley.com/journal/17535131). Scientometric analysis of *Reviews in Aquaculture* can help the academicians, researchers, and scholars to understand the strengths and gaps in aquaculture for determining their future course of action for boosting up the profession by paying attention to the research hotspots and for taking measures to fill the gaps, if any.

A few attempts have been made globally to study trends in fisheries and aquaculture applying scientometric analysis. Gasol and Durate (2000) conducted a comparative analysis in aquatic microbial ecology and referred to the analyses of general underlying trends to be useful in formulation of predictions to provide new avenues for research. To examine the impact of humans on fish habitats and the aquatic ecosystem from 1946 to 2014, Tao et al (2016) applied bibliometric analysis on the productive capacity of fish habitats (PCFH) and found that the research on PCFH is becoming a notable area of interest with research emphasis on fish-habitat relationship and fish production, aquaculture techniques and fishery products, habitat conservation and fishery management, and climate change. Qian et al (2018) conducted citation analysis on the *Journal of Fishery Sciences of China* during 2013-2016. Distribution analysis of keywords in the text brought forward that the keyword 'growth', 'gene cloning' and '*Litopenaeus vannamei'* had the most frequent appearances. During the bibliometric analysis of relevant research trends based on academic articles about the aquatic microbial community published during 1991 to 2018, Du et al (2020) found a strong correlation amongst the keywords 'bacteria', 'Denaturing Gradient Gel Electrophoresis', '16S rRNA', 'pyrosequencing' and 'sediment'.

However, none of the studies cited above applied network visualization for better revelations of hidden intricacies amongst the nodes (keywords, institutions, and countries) based on their co-occurrences. The exploration of authorship, institutional and geographical collaborations, identification of sub-domains of aquaculture dealt in by *Reviews in Aquaculture* journal based on co-occurrence of keywords, collaboration trends amongst authors, institutions, and countries using network visualization makes this study a first of its kind in the subject of aquaculture. This study aims to obtain the following objectives:

- To identify predominant authors, institutions, and countries contributing in *Reviews in Aquaculture* and their collaboration status through visualization maps
- To examine predominant subjects of aquaculture research published in *Reviews in Aquaculture* w. r. to author keywords

MATERIAL AND METHODS

Datasets: The bibliographical data about the articles published in Reviews in Aquaculture journal were accessed from *Scopus* for the period 2011-2020. The bibliographical parameters encompassing authors, title, year, source title, volume, issue number, page count, citation data, affiliations and author keywords were included while downloading data. A total of 412 records were downloaded in tab-delimited text (CSV) format and were used for scientometric analysis.

Subject analysis: The subject terms representing theme of records enlisted under the heading 'author keywords' field in the Scopus data were used for subject analysis (n=1490 terms) having one or more occurrences in records retrieved). Further, the singular and plural terms were standardized to avoid duplicity of appearance of terms.

Institutional productivity-cum-collaboration analysis: It was observed that in the original data file retrieved from *Scopus*, the institutional names were not listed uniformly viz. sometimes full name of an institution was given, at other instances only abbreviations were available. Moreover, sometimes name of the department(s)/college(s)/ section(s)/laboratory was also prefixed to the name of the institution. Hence, hurdles were faced in analyzing institutional contributions and collaborations. To overcome this problem, institutional names were examined individually and were standardized manually to bring uniformity for analyzing these through visualization software. The institution(s) with multiple campuses within a country were treated as a single institution(s) for analyzing institutional contributions and collaborations.

Data visualization: The scientometric aspects of records under study viz. prolific authors, institutions and countries, and collaborations amongst them vis-à-vis keywords based subject inferences were mapped using network visualization software '*VOSviewer*' (https://www.vosviewer.com/). Based on the co-occurrence of authors, institutions and countries within same records, respective clusters were developed using cluster schema of *VOSviewer*, each cluster representing inter-related nodes and each node in a network falling under one cluster only. The network visualizations developed have nodes and edges, nodes representing the variable being explored viz. authors, institutions, countries and subject terms and edges representing the links between nodes establishing their inter-connectivity. The thickness of edges indicates the strength of collaboration amongst authors, institutions, countries and co-occurrence of keywords and size of the nodes represents the number of records to which an author, institution and country has contributed and the frequency of occurrence of keywords in articles representing theme of the article(s).

RESULTS AND DISCUSSION

Chronological trends of publications in reviews in aquaculture: The number of records published in *Reviews in Aquaculture* from 2011 to 2020 witnessed significant growth, especially after 2017 (Table 1). The number of records published from 2011 to 2017 witnessed a nominal growth. Thereafter, an exponential growth was observed in publications in the journal, the year 2020 witnessing publishing of maximum number of records. On the other hand, advocating that the scientific communications are supposed to get more citations with the passage of time, the average citations earned by scientific communications were found to be higher in records published during the early years of decade. Year 2013 witnessed maximum number of citations viz. 65.95 citations per article on an average. The up-rise in number of articles and vice-versa for average citations are graphically represented in Figure 1.

Table 1. Number of records and their citation pattern

Year	No. of records	Total citations	Average citations
2011	11	511	46.45
2012	17	609	35.82
2013	22	1451	65.95
2014	18	609	33.83
2015	17	491	28.88
2016	19	615	32.37
2017	23	544	23.65
2018	56	1520	27.14
2019	75	960	12.80
2020	154	718	4.66

Most productive authors: All except 5.09% articles (21 single-author publications of a total of 412) have been the outcome of collaborative authorship. More than two-third of the records (69.42%; 286/412) have been an outcome of collaborative efforts of 2 to 5 authors and 21.60% (89/412) scientific communications were authored by 6 to 10 co-authors, each. A total of 16 articles have been authored in collaboration by more than 10 authors including an article having 28 co-authors in total. A total of 30 authors having contributed to at least four articles were identified and visualized using network visualization software (Fig. 2). As there are little chances that authors may have same surname and first name amongst identified 30 prolific authors, the authorship collaboration map has been developed based on the data processed using *VOSviewer* without any further cross examination of author names. Fourteen clusters, of which seven comprise of two to five authors were developed using cluster schema of *VOSviewer* based on co-occurrences of author names in records. The size of nodes represents the contribution of respective authors in terms of number of articles and edges show the strength of links between authors. Four clusters have 4-5 authors, and 3 have collaborations amongst two authors each. Six scientists from

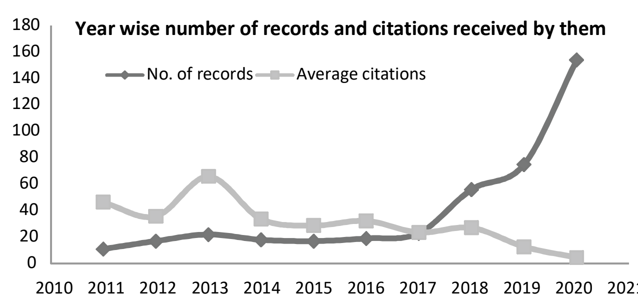
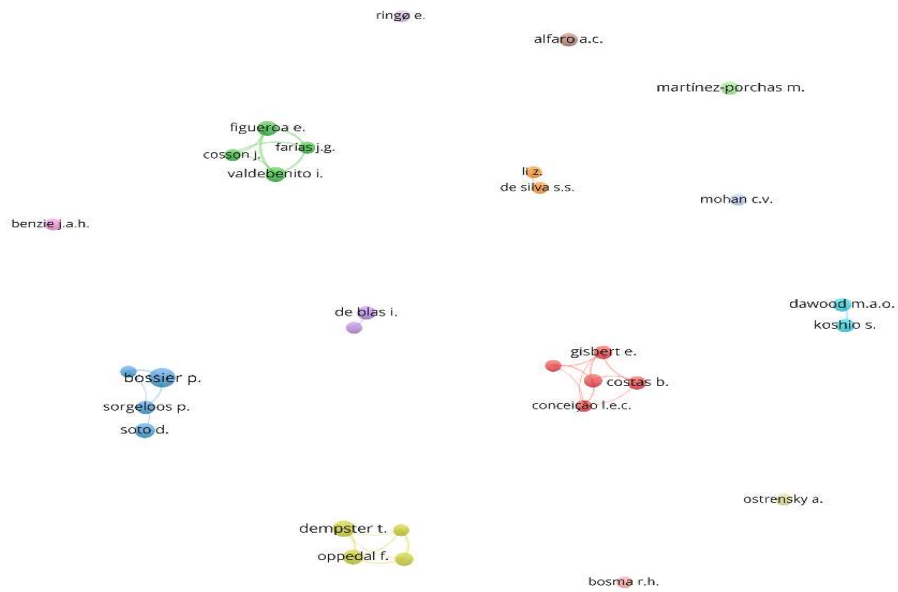


Fig. 1. Chronological growth of publications

Table 2. Top contributor institutions

Name of institution	Links	Total link strength	Documents
Ghent University, Belgium	8	14	18
Wageningen University and Research, Wageningen, Netherlands	9	13	17
Institute of Marine Research, Norway	9	14	15
University of South Bohemia, Czech Republic	1	2	12
University of Stirling, Stirling, United Kingdom	6	8	11



Cluster 1: Boglione C. (D-5; L-0; LS-0; C-869), Conceição L.E.C. (D-4; L-4; LS-5; C-425), Costas B. (D-5; L-3; LS-5; C-1165), Gisbert E. (D-5; L-4; LS-7; C-910) and Yúfera M. (D-5; L-4; LS-8; C-518)

Cluster 2: Cosson J. (D-4; L-3; LS-6; C-681), Farãas J.G. (D-4; L-3; LS-10; C-838), Figueroa E. (D-6; L-3; LS-12; C-1078) and Valdebenito I. (D-6; L-3; LS-12; C-1078)

Cluster 3: Bossier P. (D-9; L-2; LS-5; C-2149), Defoirdt T. (D-4; L-2; LS-4; C-399), Sorgeloos P. (D-5; L-3; LS-4; C-841) and Soto D. (D-6; L-1; LS-1; C-894)

Cluster 4: Dempster T. (D-7; L-3; LS-6; C-3066), Kristiansen T.S. (D-5; L-3; LS-7; C-1640), Oppedal F. (D-6; L-3; LS-8; C-2953) and Stien L.H. (D-4; L-3; LS-7; C-1369)

Cluster 5: Cabanillas-Ramos J. (D-4; L-1; LS-2; C-481) and De Blas I. (D-5; L-1; LS-2; C-1404)

Cluster 6: Dawood M.A.O. (D-5; L-1; LS-4; C-3537) and Koshio S. (D-5; L-1; LS-4; C-1040)

Cluster 7: De Silva S.S. (D-4; L-1; LS-2; C-428) and Li Z. (D-4; L-1; LS-2; C-2303)

Clusters 8-14: Alfaro A.C. (D-5; L-0; LS-0; C-869), Benzie J.A.H. (D-4; L-0; LS-0; C-832), Bosma R.H. (D-4; L-0; LS-0; C-482), Martãnez-Porchas M. (D-5; L-0; LS-0; C-1136), Mohan C.V. (D-4; L-0; LS-0; C-896), Ostrensky A. (D-4; L-0; LS-0; C-884) and Ringã¸ E. (D-4; L-0; LS-0; C-543)

Fig. 2. Most productive authors (D-number of articles, L-number of links, LS-Total Link Strength, C-Citations)

Table 3. Top contributing scientists

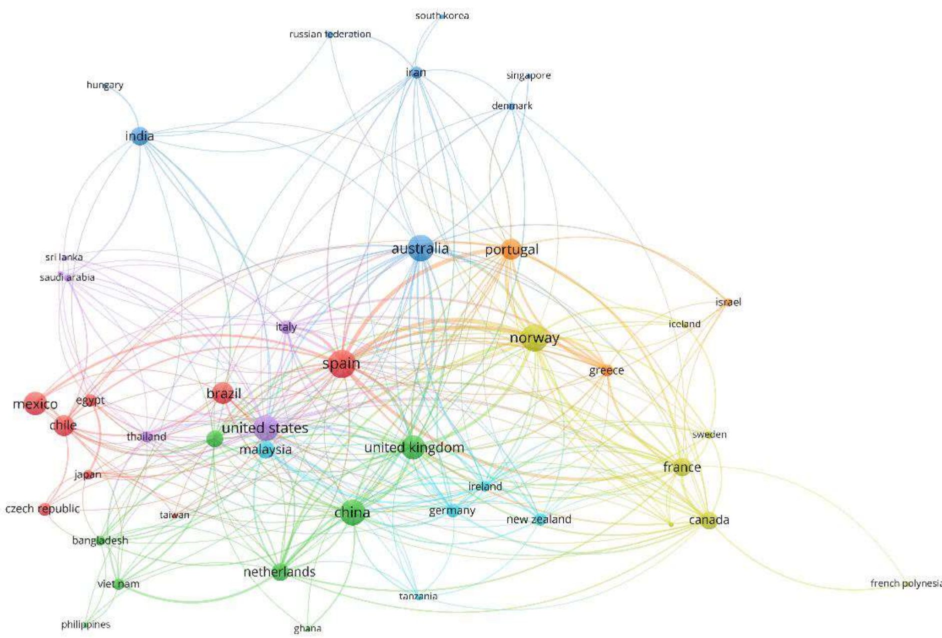
Name of scientist	Institute	Area of expertise/ specialization
Professor (Dr.) Peter Bossier	Director, Laboratory of Aquaculture and Artemia Reference Center, Ghent University, Belgium	Bioscience Engineer - Microbial community management, host-microbial interactions, and genetics
Dr. Tim Dempster	School of Bio-Sciences, University of Melbourne, Parksville, Australia	Ecological Research - Fishing, aquaculture and other anthropogenic practices
Dr. Elias Gustavo Figueroa	School of Aquaculture, Catholic University of Temuco, Temuco, Chile	Biotechnology- Optimization of Reproduction in Chilean Aquaculture
Dr. Oppedal F	Institute of Marine Research, Matre Research Station, Matredal, Norway	Aquaculture Management – Salmon Welfare
Dr. Doris Soto	Interdisciplinary Center for Aquaculture Research (INCAR), Universidad de Concepcion Chile, Concepcion, Chile	Aquaculture, Environmental Impact, and Aquatic Biodiversity
Dr. Valdebenito	School of Aquaculture, Catholic University of Temuco, Temuco, Chile	Reproductive factors in fish of aquaculture interest

Most Influential Authors in terms of Citations– Dawood M.A.O.,Dempster T, Oppedal F., Li Z., Bossier P., Kristiansen T.S., De Blas I., Stien L.H., Costas B. and MartÃnez-porchas M.

4 countries had contributed highest number of articles, whereas ten scientists found to be the most influential authors in terms of citations earned by their articles published in Review in Aquaculture (Table 3).

Major contributing countries: Authors from a total of 62 countries contributed to 412 records. Twenty three nation(s) from the Europe continent collectively contributed to the highest number of records (n=324), followed by contribution of 174 records from 19 Asian nations and 102 records from 4 North America countries. Five South American countries contributed to 66 records. Two Australasia countries added to 57 records and 9 African nations contributed to 26 records (Fig. 3). Two countries (Poland and Nigeria) of the total 62 countries having contributed records to *Reviews in Aquaculture* did not have any international collaboration. Twenty two nation(s) from the Europe, 19 Asian nations, 4 North America countries, 5 South American countries, 2 Australian countries and 8 African nations worked in international collaboration contributing articles for *Reviews in Aquaculture*, depicting the joint efforts at global level to boost aquaculture sector. The network visualization map of the countries having contributed at least three articles published in *Reviews in Aquaculture* was developed. Out of the resulting 46 countries, Poland did not have any article in international collaboration. Hence, it was excluded from network visualization. The top 45 countries with at least three articles published in the journal under study are shown in Figure 3.

Institutional productivity: Authors from 627 institutions/ organizations contributed to the total of 412 records. Thirty nine institutions contributed to 5 or more articles each, of which 6 institutions did not have inter-institutional



Cluster 1	Brazil (D-32; LS-21; C-6732), Chile (D-29; LS-27; C-5477), Czech Republic (D-13; LS-7; C-3166), Egypt (D-12; LS-13; C-6465), Japan (D-8; LS-13; C-2027), Mexico (D-36; LS-13; C-8465), Spain (D-49; LS-100; C-9982) and Taiwan (D-3; LS-5; C-764)
Cluster 2	Bangladesh (D-8; LS-19; C-2480), Belgium (D-21; LS-40; C-4025), China (D-43; LS-57; C-23546), Ghana (D-3; LS-4; C-496), Netherlands (D-23; LS-48; C-3884), Philippines (D-3; LS-4; C-1430), United Kingdom (D-37; LS-75; C-8762) and Viet Nam (D-10; LS-19; C-1390)
Cluster 3	Australia (D-45; LS-62; C-18365), Denmark (D-5; LS-11; C-1085), Hungary (D-3; LS-2; C-344), India (D-25; LS-18; C-7332), Iran (D-12; LS-20; C-2913), Russian Federation (D-5; LS-4; C-3363), Singapore (D-3; LS-3; C-734) and South Korea (D-3; LS-2; C-505)
Cluster 4	Canada (D-22; LS-53; C-5712), France (D-24; LS-67; C-6150), French Polynesia (D-3; LS-3; C-1201), Iceland (D-4; LS-10; C-1094), Monaco (D-3; LS-10; C-752), Norway (D-46; LS-106; C-12400) and Sweden (D-5; LS-17; C-1120)
Cluster 5	Colombia (D-3; LS-8; C-1232), Italy (D-15; LS-52; C-3699), Saudi Arabia (D-5; LS-13; C-1567), Sri Lanka (D-3; LS-8; C-690), Thailand (D-10; LS-30; C-2056) and United States (D-43; LS-70; C-11094)
Cluster 6	Germany (D-14; LS-46; C-3715), Ireland (D-9; LS-33; C-2868), Malaysia (D-23; LS-35; C-6815), New Zealand (D-12; LS-20; C-2923) and Tanzania (D-4; LS-10; C-1142)
Cluster 7	Greece (D-12; LS-46; C-2140); Israel (D-6; LS-10; C-4053) and Portugal (D-30; LS-66; C-5469)

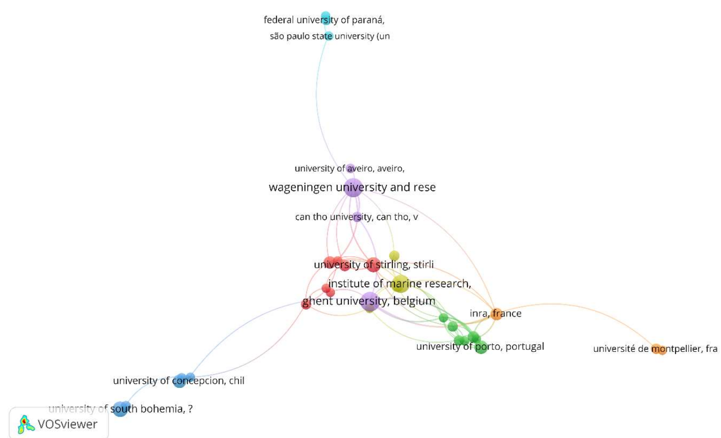
Fig. 3. Most productive countries (D-number of articles, L-number of links, LS-Total Link Strength, C-Citations)

collaboration. Hence, collaboration visualization map of 34 institutions having worked in collaboration with one or more institutions (that contributed to >5 records each) is represented by Figure 4. Scientometric data (number of articles, number of links, link strength) of the top 5 institutions (10 records in collaboration) is also tabulated (Table 2). It has been observed that the academic and research institutions from European countries have contributed predominantly towards the *Reviews in Aquaculture*, having presence in 6 of the total 7 cluster. Cluster 1 represents the collaboration amongst Australia, European and Asian countries. Cluster 2 and 3 depicts the collaborative efforts amongst European nations.

Subject analysis based on keywords: The top 45 keywords (out of the total 1490) having incurred in 5 or more articles were considered for cluster analysis (Fig. 5). A total of eight clusters were identified by clustering schema of *VOSviewer* software. The nodes in figure represent the keywords/ subject terms and edges reveal the relation between different keywords representing subject(s). Subject analysis reveals that the focus of most of the institutes is on sustainable development of fisheries and aquaculture through feed and health management strategies through omics approach. Further, the key word based analysis clearly indicated that intensification of aquaculture practices; environmental impact and resilient measures thereof are also being considered. Cluster analysis indicated that research emphasis is also given on major aquaculture fish (Tilapia and Salmon) and shellfish (Vannamei) species of high economic value at global level.

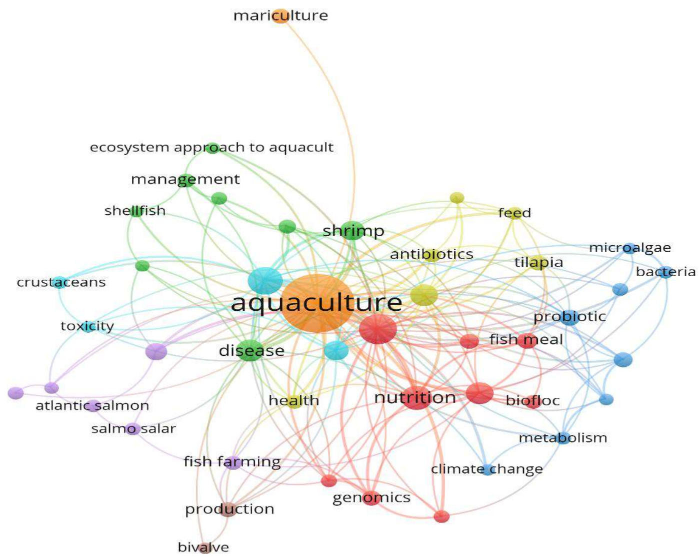
CONCLUSIONS

The study presented trends and hotspots in aquaculture based on scientometric analysis and network visualization of metadata of 412 records published in *Reviews in Aquaculture* retrieved from Scopus database. The distribution of number of records published in *Reviews in Aquaculture* has been found uneven. From the year 2018 onwards, the publication trends of the journal witnessed exponential growth. This could be attributed to the recognition of growing significance of aquaculture globally as correspondingly the scientific outcome on the subject is also growing. *Reviews in Aquaculture* has witnessed contribution of articles from around the globe. A strong international collaboration trend



Cluster 1	CSIRO, Australia; Deakin University, Australia; Shanghai Ocean University, Shanghai, China; Universiti Putra Malaysia, Malaysia; University College Cork, Cork, Ireland; University of Stirling, Stirling, United Kingdom and Worldfish, Penang, Malaysia
Cluster 2	Instituto de Ciencias Marinas de Andalucía, Cadiz, Spain; IRTA, Sant Carles de la Rápita, Spain; University of Algarve, Faro, Portugal; University of Bergen, Bergen, Norway; University of Crete, Greece; University of Porto, Portugal and University of the Algarve, Portugal
Cluster 3	Interdisciplinary Center for Aquaculture Research, Chile; University of Chile, Chile; University of Concepcion, Chile; University of La Frontera, Temuco, Chile and University of South Bohemia, Czech Republic
Cluster 4	Institute of Marine Research, Norway; Norwegian Institute of Food, Fisheries and Aquaculture Research, Norway; University of Melbourne, Australia and University of Tasmania, Australia
Cluster 5	Can Tho University, Can Tho, Viet Nam; Ghent University, Belgium; University of Aveiro, Aveiro, Portugal and Wageningen University and Research, Wageningen, Netherlands
Cluster 6	Federal University of Parana, Brazil; Shantou University, Shantou, China and São Paulo State University (UNESP), Jaboticabal, Brazil
Cluster 7	INRA, France; Université De Montpellier, France and Université Laval, Québec, Canada

Fig. 4. Collaboration map of most productive institutions (n=33) having inter-institutional collaboration and scientometric details of institutions (n=5) that contributed 10 records



Cluster 1	Aquafeed; Biofloc; Fish meal; Genomics; Growth; Metabolomics; Nutrition; Stress and sustainability
Cluster 2	Biodiversity; Disease; Ecosystem approach to aquaculture; *Litopenaeus vannamei*; Management; Meta-analysis; Shellfish and shrimp
Cluster 3	Bacteria; Bioremediation; Climate change; Disease resistance; Immunostimulant; Metabolism; Microalgae and Probiotic
Cluster 4	Antibiotics; Feed; Health; Immunity; Oxidative stress and Tilapia
Cluster 5	Atlantic salmon; Environmental impact; Fish farming; Gene expression; Salmo salar; Spermatozoa
Cluster 6	Crustaceans; Environment; Fish and Toxicity
Cluster 7	Aquaculture and Mariculture
Cluster 8	Bivalve and Production

Fig. 5. Keyword visualization map (O-Occurrences, L-Links, LS-Total Link Strength)

was observed amongst nations as except Poland and Nigeria, all other 60 countries have international collaborations for one or more articles. European nations have contributed maximum number of records and consequently, institutions representing Europe emerged as predominant contributors of articles to *Reviews in Aquaculture*. Moreover, the top five countries having contributed highest number of articles also falls under the European Union with the focus on aquaculture practices with management strategies *vis a vis* environmental impacts. Diverse facets of the subject aquaculture are being explored globally for strengthening of the sector in view of its growing and widening significance towards attainment of sustainable food security.

AUTHOR CONTRIBUTION

Vaneet Inder Kaur - Manuscript writing and critical inputs w.r.to subject matter related discussion; Nirmal Singh - Conceived the idea, manuscript writing and data analysis with software; Harmanjit Singh Banga - Manuscript writing and suggestions for data analysis; Tarvinder Singh Handa - Data retrieval from Scopus and preparation of data for analysis; Gurpreet Singh - Manuscript writing w.r.t. scientometric aspects.

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Received 26 March, 2023; Accepted 20 July, 2023