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Visualization analysis of seabream and seabass aquaculture research using CiteSpace

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Abstract

In terms of production, seabream and seabass are the two most important species of marine Mediterranean aquaculture, which is why they have been extensively studied in the literature. This study uses visualization analysis with the CiteSpace software to determine the research status quo and the most important trends of seabream and seabass aquaculture research. The Web of Science (WoS) database was used to select the papers associated with seabream and seabass literature from the period between 1986 and 2020. The results were separated using two indices (Science Citation Index Expand and Social Science Citation Index). The visualization analysis identified the networks for (1) author, institution, country and category co-authorship, in order to find the most prolific authors, institutions, countries and categories respectively; and (2) journal, document and author co-citation, which identifies the most relevant journals, the most important studies and the most cited and influential authors. Finally, a keywords co-occurrence network was built to identify the most important topics and the research frontiers—body of knowledge—of the seabream and seabass aquaculture research—SSAR.

KEYWORDS
co-authorship analysis, co-citation analysis, keywords co-occurrence analysis, seabream and seabass aquaculture research, visualization

1 | INTRODUCTION

On a global scale, fish consumption accounts for nearly 20% of the average intake per capita of animal protein for approximately 3.2 billion people and around 10% for 5.1 billion people (FAO, 2018a). Aquaculture accounts for 47% of the total global fish production (including fish, crustaceans, molluscs and other aquatic animals, but excluding aquatic mammals, reptiles, seaweeds and other aquatic plants) or 53% if non-food uses are excluded (FAO, 2018b). In terms of contribution to aquaculture's production, Europe ranks third after Asia and the Americas, with a production of 2.9 million tonnes including fish, crustaceans and molluscs (FAO, 2018a), and 2.3 million tonnes associated with fish only (FEAP, 2017).

In Mediterranean aquaculture (Spain, France, Italy, Croatia, Cyprus, Greece and Turkey), seabream and seabass represent the second and third most important species, accounting for 30.3% and 28.2% of total farmed fish production in these countries, respectively, while trout ranks first with 36.6% (FEAP, 2017). Given that trout are reared in freshwater, seabream and seabass are the most important species of marine Mediterranean aquaculture.

Given the importance of these two species on marine Mediterranean aquaculture, many scientists have focused their research on various aspects associated with the rearing of these species. However, despite more than three decades of research, according to our best knowledge, there is no evidence of any type of study that allows us to determine the most relevant trends, characteristics and sources of knowledge of this research area: seabream and seabass aquaculture—SSAR.

According to Chen et al. (2014a), the intellectual landscape of a research area can be represented by a network analysis of different entities such as collaborating authors, cited references and most used keywords. These networks shape the knowledge structure, intellectual collaborations, recent developments, important topics and relevant trends, which is important for academia (Chen & Liu, 2020).

Moreover, according to Chen and Liu (2020), the visualization of scientific knowledge using social network analysis or graph theory is an emerging area of bibliometric science. Different software packages have been developed for visualization analysis. CiteSpace, a program developed on Java language by PhD. Chaomei Chen at Drexel University (USA) (Liu et al., 2015), will be used in this study.

Visualization analysis software has been used in a variety of fields, including computing (Niazi & Hussain, 2011; Zhao & Wang, 2011), environmental research and emissions (Li et al., 2018; Ouyang et al., 2018; Yu & Xu, 2017), information science (Hou et al., 2018; Yu et al., 2017), medical research (Chen et al., 2012, 2014b; Liao et al., 2018; Liu et al., 2015; Xie, 2015), natural disaster (Shen et al., 2018), pharmaceuticals (Chen & Guan, 2011), social commerce (Cui et al., 2018) and sustainable development (Zhu & Hua, 2017), amongst others.

Visualization analysis has also been applied for bibliometric studies assessing aquaculture in general (Natale et al., 2012), aquaculture in Malta (McMillan et al., 2016), fisheries and aquaculture in India (Singh et al., 2019) and market access in fisheries and aquaculture international business research (Cordeiro, 2019). To the best of our knowledge, however, this type of analysis has not been applied to the two most important species of marine Mediterranean aquaculture (seabream and seabass). A more general added value of this study is that it analyses for the first time the network analysis on co-authorship, co-citation and co-occurrence in the context of fishery and aquaculture products.

The present study has four main objectives. First, identify the most important authors, institutions, countries and categories associated with SSAR. Second, identify the most relevant journals of SSAR. Third, identify the most influential authors and papers, and fourth, identify the most relevant topics and research frontiers of SSAR. The remainder of the paper is organized as follows: Section 2 presents the data collection and research method, section 3 explains the results, and section 4 offers some concluding remarks.

2 | MATERIAL AND METHODS

2.1 | Data collection

Considering that the Web of Science (WoS) database is one of the most important indexing tools for scientific research, we conducted a search on 25 November of 2019 using the following search strategy:

- Topic = "aquaculture" and ("seabream" or "seabass" or ("sea" and "bream") or ("sea" and "bass")).

This search included published papers that had these words in their titles, abstracts or keywords. The timespan considered included all years available. The two species (seabream and seabass) were included together in the search strategy as they have frequently been studied together (Vanhonacker et al., 2013).

We extracted the information by distinguishing between the Social Science Citation Index (SSCI) and the Science Citation Index Expand (SCIE) in order to make comparisons between these two indices, especially considering the diverse discipline aspects of papers included in each one of them. The search strategy showed 39 publications for the SSCI database and 2199 publications from the SCIE database—two different unbalanced datasets.

2.2 | Research method

The present study relies on the version of CiteSpace 5.6.R1, which generated the networks. Two different projects linked to the SSCI and SCIE indices were created. The SSCI and SCIE projects were characterized by the following time spans: 2004–2020 and 1986–2020 respectively. It can be seen that relatively the SSAR is not only scarcer in SSCI but also more modern. Other parameters set in the projects included a 1 year per slice for co-authorship, co-citation and co-occurrence analysis, as well as the consideration of different node types depending on the types of analysis such as author, institution, country, category, cited reference, cited author, cited journal, keyword and grant.

The analysis included the networks of the most prolific authors, institutions, countries and WoS categories, as well as those attached to the most important journals, cited authors and cited documents. Also, we obtained the map of the most cited keywords of the literature of SSAR. The data of grants were obtained to explain the results found at the country level.

3 | RESULTS AND DISCUSSION

The results of the visualization analysis were extracted depending on the two mentioned indices: Social Sciences Citation Index (SSCI) and Science Citation Index Expanded (SCIE). The SSCI is multidisciplinary and includes more than 3500 social science journals. The SCIE is also multidisciplinary and includes more than 8300 science journals covering disciplines such as agriculture, biology, chemistry, mathematics, medicine, physics, veterinary and others.

The findings of this paper include co-authorship analyses for author, institution, country and category; co-citation analyses linked to the levels of journal, document and author; and keywords co-occurrence analysis, which identifies hot research topics and frontiers.

3.1 | Co-authorship analysis on SSAR

According to Glänzel and Schubert (2005), co-authorship is a visible and well-documented form of scientific collaboration at three different levels of cooperation (individual, institutional and national). In fact, the analysis of co-authorship networks using bibliometric methods tracks every aspect of the scientific collaboration network. Thus, it is possible to determine the most productive researchers in the field from different perspectives: authors, institutions and countries.

3.1.1 | Author Co-authorship analysis

The collaborations between authors for SSCI and SCIE databases are presented, respectively, in Figure 1a,b. The network includes node labels for authors who have a minimum number of papers of 2 and 10 for the SSCI and SCIE databases respectively. In addition, the size of the nodes is in accordance with the number of papers that each author have published, while the distance between the nodes and the thickness of the links indicate the level of collaboration between the authors who have published joint work. The full names of some of the authors shown in Figure 1a,b are provided in the Appendix.

The network shown in Figure 1a presents several small and isolated subnetworks, which denotes that the authors' collaboration is established in small groups with an evident lack of communication between the groups. Three small subnetworks are formed by authors who have published at least two papers. The largest network is the one by L M VERA, J A MADRID and F J SANCHEZVAZQUEZ, all of whom are affiliated with the University of Murcia; the other 2 subnetworks are formed by JOSE FERNANDEZPOLANCO and IGNACIO LLORENTE, and JORDI GUILLEN and TROND BJORNDAL respectively.

On the other hand, the network of the SCIE database presented in Figure 1b shows a much more integrated network than the previous case and includes two large subnetworks judging by the distance between nodes, with some small groups in them standing out above the others. The largest subnetwork shows that the group led by M ANGELES ESTEBAN, along with the team members of ALBERTO CUESTA, JOSE MESEGUER and FRANCISCO A GUARDIOLA, have a strong collaboration between them, as the four researchers are amongst the TOP 9 authors with the most publications. Also, in the same subnetwork, the group formed by GENCIANA TEROVA, G. BERARDINI, SIMONA RIMOLDI and MARCO SAROGLIA presents a strong collaboration amongst them. From the smallest subnetwork, the group formed by MARC VANDEPUTTE, BEATRICE CHATTAIN and PIERRICK HAFFRAY also stands out. In general, the results evidence that the authors in this field usually work in small groups and that there are only a few collaborative interactions between them. Furthermore, the findings suggest that communication between the various groups can be easily promoted and strengthened.

The top 10 authors with the most publications in the field are presented in Table 1a,b for the SSCI and SCIE databases respectively. Table 1a presents only the top seven authors because the rest of the authors have only one publication in the field. Meanwhile, Table 1b includes an 11th author because there is a tie[1] for 10th place.

Results from the SSCI database (Table 1a) indicate that the most prolific authors are TROND BJORNDAL, JORDI GUILLEN and L M VERA, with three publications each one, with the first two contributing to the fields of Economics, Food Science and Marketing, and LM VERA to Biology, Biochemistry, Genetics and Nutrition. Two intermediate groups of the most significant authors have 2 publications each one and are formed by J A MADRID and F J SANCHEZVAZQUEZ from the University of Murcia and contributing to the fields of Biology, Biochemistry, Genetics and Nutrition, and JOSE FERNANDEZPOLANCO and IGNACIO LLORENTE from the University of Cantabria and working on Economics, Food Science and Marketing.

Moreover, regarding the SCIE database (Table 1b[2]), all the authors contribute to the field of Biology, Biochemistry, Genetics and Nutrition, and the most productive author is M ANGELES ESTEBAN with 56 papers, followed by ALBERTO CUESTA AND GENCIANA TEROVA with 33 and 31 papers respectively. Other important authors are MARC VANDEPUTTE with 30 papers, JOSE MESEGUER and P SANCHEZJEREZ with 29 papers each one, BEATRICE CHATAIN with 28 papers, ARIADNA SITJABOBADILLA and FRANCISCO A GUARDIOLA with 27 papers each one, and MARISOL IZQUIERDO and MARCO SAROGLIA with 26 papers each one. Also, it is important to highlight that 4 of the authors are from the University of Murcia, including the two most relevant.

It is important to notice that, amongst both databases, the majority of the authors are from Spain (6 out of 7 in the SSCI database and 7 out of 11 in the SCIE database).

3.1.2 | Institution co-authorship analysis

The collaborations between institutions are presented in Figure 2a,b. The networks are generated following similar instructions as the case of the author co-authorship networks. The size of the nodes indicates the number of papers of a particular institution, while the distance between the nodes and the thickness of the links represent the level of cooperation between the different institutions. The networks present the node labels of institutions that participated in at least 15 papers for the SCIE database and two papers for the SSCI database.

Figure 2a shows 12 labelled nodes (nine universities, one administrative institution, one research institute and one enterprise). The network is formed by small subnetworks with a maximum of four labelled institutions, revealing insufficient interactions between

[1]This fact is going to be recurrent throughout the rest of the paper, and for the sake of exposition, it will be omitted from now on.

[2]Since now, we omit the information that all the Figures and Tables have the denomination a for SSCI and b for SCIE, unless a further clarification is needed.

FIGURE 1 (a) Map of the author co-authorship network of SSAR—SSCI database. (b) Map of the author co-authorship network of SSAR—SCIE database

TABLE 1 Top 10 prolific authors of SSAR papers

Ranking	Counts	Centrality	Authors	Year	Main field	From
a. SSCI database						
1–3	3	0.00	TROND BJORNDAL	2017	EF&M	Norwegian School of Economics (NHH), Norwegian University of Science and Technology (NTNU)
	3	0.00	JORDI GUILLEN	2017	EF&M	Joint Research Centre (JRC), Spanish National Research Council (CSIC)
	3	0.00	L M VERA	2004	BBG&N	University of Murcia, University of Stirling
4–7	2	0.00	J A MADRID	2004	BBG&N	University of Murcia
	2	0.00	F J SANCHEZVAZQUEZ	2006	BBG&N	University of Murcia
	2	0.00	JOSE FERNANDEZPOLANCO	2013	EF&M	University of Cantabria
	2	0.00	IGNACIO LLORENTE	2019	EF&M	University of Cantabria
b. SCIE database						
1	56	0.10	M ANGELES ESTEBAN	2002	BBG&N	University of Murcia
2	33	0.02	ALBERTO CUESTA	2003	BBG&N	University of Murcia
3	31	0.01	GENCIANA TEROVA	2004	BBG&N	University of Insubria
4	30	0.05	MARC VANDEPUTTE	2001	BBG&N	French National Institute for Agricultural Research (INRA), French Research Institute for Exploitation of the Sea (IFREMER)
5–6	29	0.00	JOSE MESEGUER	2002	BBG&N	University of Murcia
	29	0.05	P SANCHEZJEREZ	2007	BBG&N	University of Alicante
7	28	0.01	BEATRICE CHATAIN	2001	BBG&N	University of Montpellier, French Research Institute for Exploitation of the Sea (IFREMER)
8–9	27	0.08	ARIADNA SITJABOBADILLA	1993	BBG&N	Spanish National Research Council (CSIC)
	27	0.00	FRANCISCO A GUARDIOLA	2011	BBG&N	University of Murcia, University of Porto
10–11	26	0.08	MARISOL IZQUIERDO	1999	BBG&N	University of las Palmas de Gran Canaria
	26	0.01	MARCO SAROGLIA	2001	BBG&N	University of Insubria

Notes: Source: Own elaboration based on WoS data and output of author co-authorship analysis in CiteSpace.
Abbreviations: BBG&N: Biology, Biochemistry, Genetics & Nutrition, EF&M: Economics, Food Science & Marketing.

productive institutions and leaving enough room for improvement. One of the most important subnetworks is led by the Norwegian Univ Sci & Technol, which cooperated with NHH (Norwegian School of Economics), CSIC (Spanish National Research Council) and European Commission; while another relevant subnetwork is formed by the Univ Algarve, Sparos Lda, Univ Stirling and Tech Univ Denmark.

Figure 2b includes a total of 32 labelled nodes (22 universities and 10 research institutes) that are highly connected, with some exceptions such as the research institutes of China, the Fisheries Research Agency, Univ Messina and Univ Insubria. From this highly connected network, the most important institutions are the CSIC, Univ Murcia, IFREMER, Univ Algarve, Hellen Ctr Marine Res and Univ Porto.

The top 10 prolific institutions are shown in Table 2a,b respectively; Table 2a shows that the most prolific institution in function of the number of publications is the Spanish National Research Council (CSIC) with four publications, followed by Univ Cantabria, Univ Murcia, Norwegian School of Economics (NHH), Norwegian Univ Sci & Technol and the European Commission with three publications each one. Then, with two publications, there are five institutions: Univ Algarve, Tech Univ Denmark, Sparos Lda, Univ Stirling, Univ Haifa and Univ Cadiz.

On the other hand, Table 2b shows that the most productive institution is again the Spanish National Research Council (CSIC) with 110 publications, followed by Univ Murcia (107), Hellen Ctr Marine Res (94), IFREMER (93), Univ Algarve (86), Univ Porto (74), Univ Las Palmas Gran Canaria (63), INRA (57), Univ Crete (55) and Univ Stirling (48). According to the findings, there is a clear predominance of Spanish institutions (CSIC, Univ Cantabria, Univ Murcia, Univ Las Palmas Gran Canaria) in both databases.

3.1.3 | Country Co-authorship analysis

The country co-authorship networks for SSAR are presented in Figure 3a,b. The nodes represent each one of the countries that originated publications in the field of research, while their size is

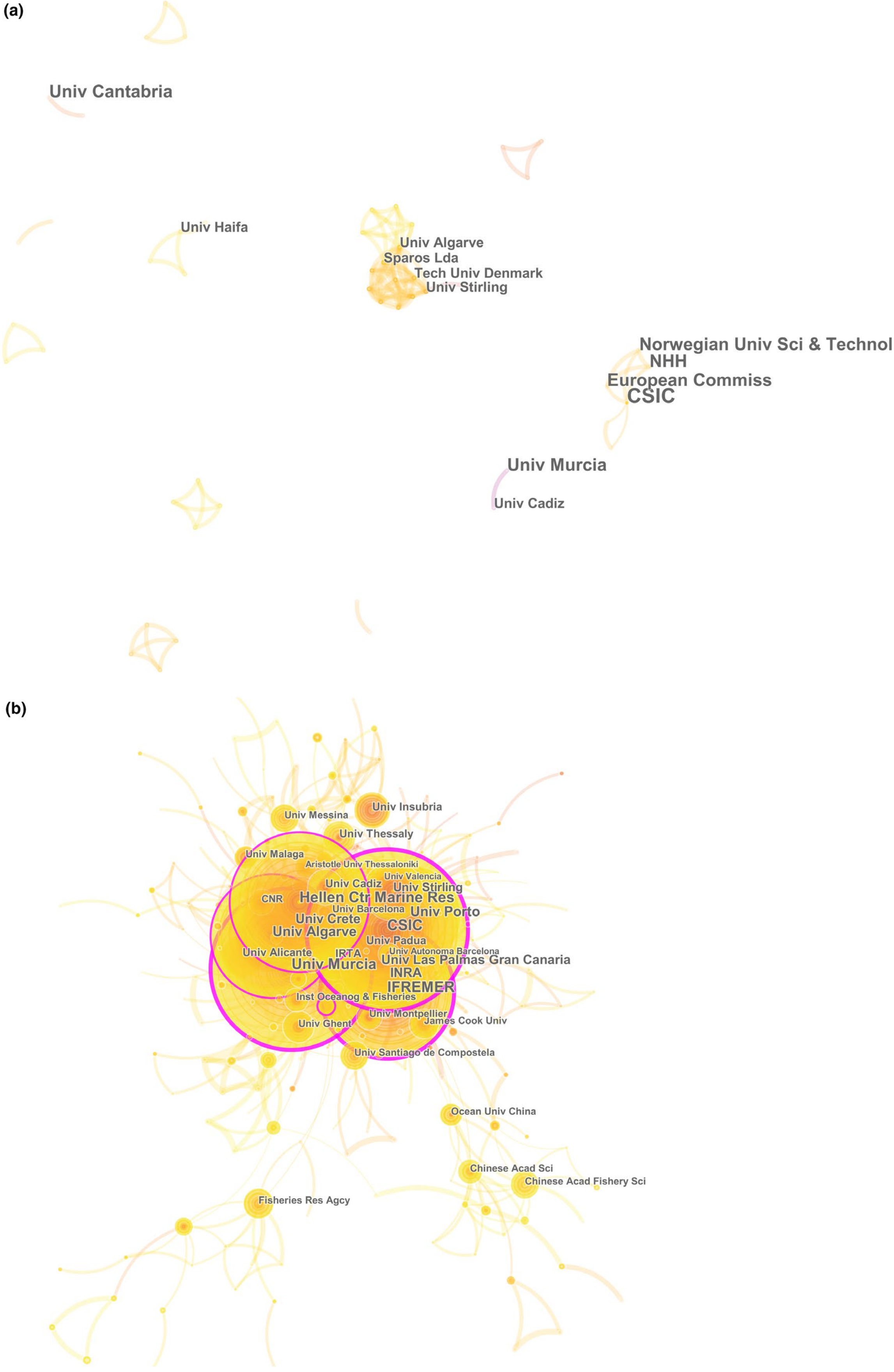

FIGURE 2 (a) Map of the institute co-authorship network of SSAR—SSCI database. (b).. Map of the institute co-authorship network of SSAR—SCIE database

TABLE 2 Top 10 productive institutions of SSAR papers

Ranking	Counts	Centrality	Institutions	Year
a. SSCI database				
1	4	0.01	CSIC (Spanish National Research Council)	2017
2–6	3	0.00	Univ Cantabria	2013
	3	0.00	Univ Murcia	2004
	3	0.00	NHH (Norwegian School of Economics)	2017
	3	0.01	Norwegian Univ Sci & Technol	2017
	3	0.00	European Commission	2017
7–12	2	0.02	Univ Algarve	2017
	2	0.00	Tech Univ Denmark	2017
	2	0.00	Sparos Lda	2017
	2	0.01	Univ Stirling	2009
	2	0.01	Univ Haifa	2018
	2	0.00	Univ Cadiz	2004
b. SCIE database				
1	110	0.21	CSIC (Spanish National Research Council)	1995
2	107	0.23	Univ Murcia	2001
3	94	0.14	Hellen Ctr Marine Res (Hellenic Centre for Marine Research)	2004
4	93	0.24	IFREMER (French Research Institute for Exploitation of the Sea)	1988
5	86	0.16	Univ Algarve	2002
6	74	0.10	Univ Porto	2002
7	63	0.05	Univ Las Palmas Gran Canaria	1999
8	57	0.08	INRA (French National Institute for Agricultural Research)	1999
9	55	0.02	Univ Crete	1994
10	48	0.07	Univ Stirling	1992

Notes: Source: Own elaboration based on WoS data and output of institution co-authorship analysis in CiteSpace.

a measurement of the total number of papers made by each country. Also, the links represent the collaboration amongst countries, while the distance between the nodes and the thickness of these links evidence the strength of the collaborations. Meanwhile, the purple rings around some of the nodes evidence that these are pivotal points that connect diverse sections of the networks (high betweenness centrality), while the thickness of the rings indicates the strength of such high betweenness centrality.

The network includes the labels of the countries that at least originated 30 papers for the SCIE database and all countries without exception for the SSCI database. Figure 3a includes a total of 26 nodes, from which, 21 are integrated into one subnetwork and the remaining nodes represent isolated countries. From the subnetwork, it can be observed that most of the countries are only connected by a maximum of 2 and 3 links, which evidence a lack of collaboration amongst them. Only five countries from Europe (Spain, Italy, Norway, Denmark and Portugal) and one from North America (USA) evidence such relevant collaboration with other countries. Spain and Italy have purple rings, indicating that these two countries play important key roles in the cooperation between countries.

On the other hand, Figure 3b includes 29 labelled nodes, which are highly connected. Amongst these 29 countries, 14 belong to Europe, 8 to Asia, 3 to North America, 2 to South America, 1 to Africa and 1 to Oceania. Judging by the distance between the nodes, six of the nodes of Asia, the two nodes of South America, one of the nodes of North America and the node associated with Africa evidence the lowest collaboration amongst all countries, which indicate that European countries usually have more cooperation between them. In addition, the nodes of Spain, the USA, Italy, France, Portugal, Australia and China have purple rings indicating their pivotal roles in the collaboration network of the SSAR. A remarkable position is again observed in Spain, whose thickness of the purple ring evidence higher importance in its pivotal role.

The top 10 most important countries are shown in Table 3a,b. Table 3a shows that the highest productive country is Spain with 14 papers, followed by Italy (10), Norway (7), Israel (3), Portugal (3), the USA (3), Denmark (3), Turkey (2), France (2), Germany (2), England (2) and Scotland (2). Similarly, Table 3b shows that the most relevant country is again Spain with 535 papers, followed by Italy (270),

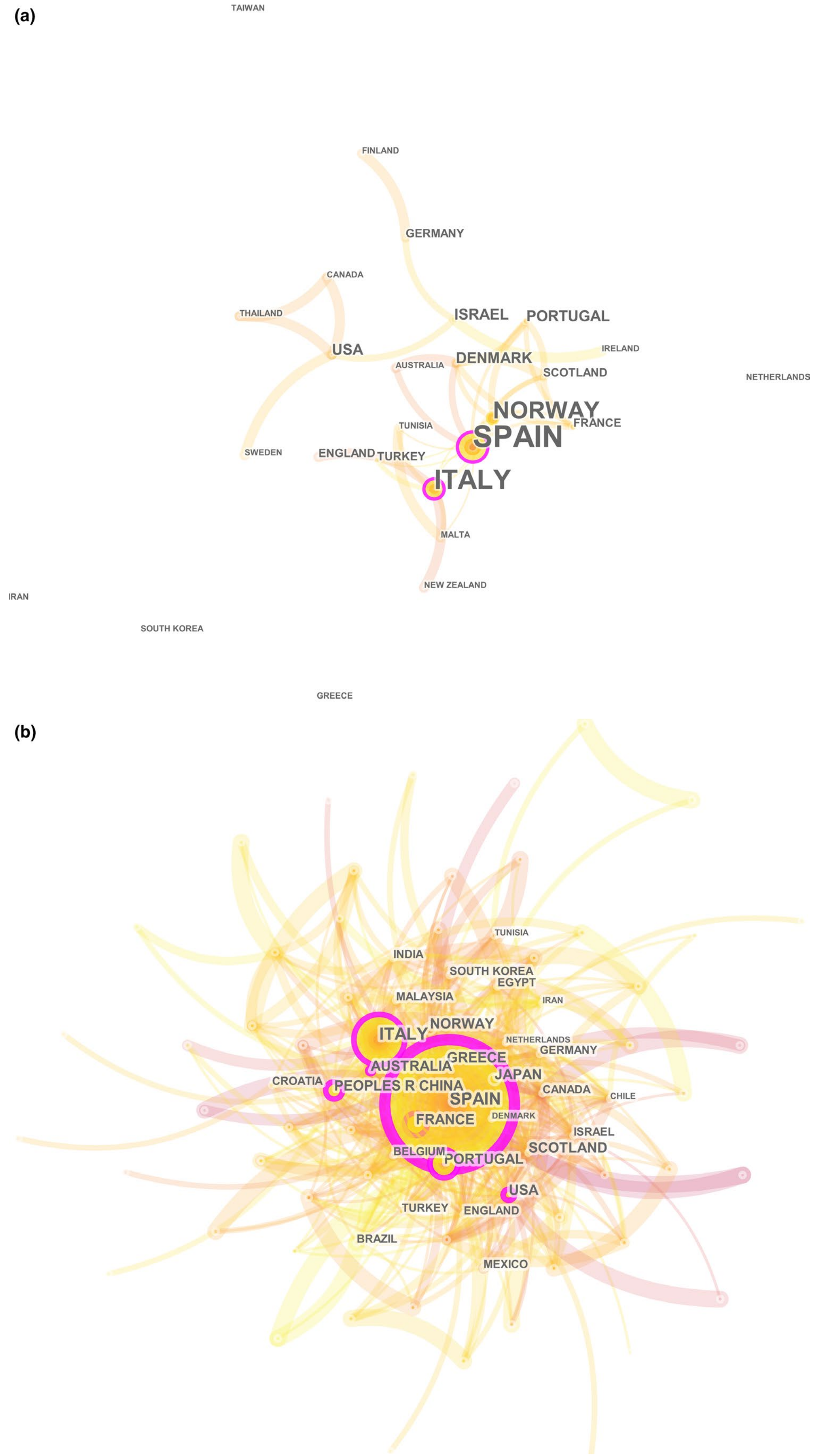

FIGURE 3 (a) Map of the country co-authorship network of SSAR—SSCI database. (b) Map of the country co-authorship network of SSAR—SCIE database

TABLE 3 Top 10 productive countries of SSAR papers

Ranking	Counts	Centrality	Countries	Year
a. SSCI database				
1	14	0.27	Spain	2004
2	10	0.14	Italy	2012
3	7	0.05	Norway	2017
4–7	3	0.09	Israel	2018
	3	0.02	Portugal	2017
	3	0.10	USA	2015
	3	0.16	Denmark	2013
8–12	2	0.02	Turkey	2019
	2	0.00	France	2017
	2	0.04	Germany	2016
	2	0.00	England	2007
	2	0.09	Scotland	2009
b. SCIE database				
1	535	0.22	Spain	1992
2	270	0.04	Italy	1997
3	202	0.09	France	1988
4	198	0.13	Portugal	2000
5	186	0.00	Greece	1994
6	153	0.65	USA	1997
7	131	0.00	Norway	1999
8	129	0.09	Peoples R China	2001
9	126	0.00	Japan	1995
10	114	0.59	Australia	1998

Notes: Source: Own elaboration based on WoS data and output of country co-authorship analysis in CiteSpace.

France (202), Portugal (198), Greece (186), the USA (153), Norway (131), China (129), Japan (126) and Australia (114).

A good strategy to explain at least partially the results according to the country of origin of the publications is to compare the production level with the grants that these countries have received. Table 4a,b show the top 3 and the top 11 productive grants' organizations. It can be seen that the most productive grant organization for the SSCI database is the H2020 European Union with 4 publications, followed by the other two grants given also by the European Union. On the other hand, for the case of the SCIE database, the most productive grant is associated with Portugal with 65 papers; however, Spanish grants dominated the top 11 considering that they have five different grants on the table.

For both databases, the greatest quantity of papers originated from Europe in comparison with other continents, which can be explained by the large number of grants that the institutions have obtained from the European Union and the national governments. Moreover, for the case of the SCIE database, the great productivity of Spain, in terms of the number of papers, which even doubles the country in second place (Italy), is highly supported by having five out of the top 11 grants given for publications of SSAR. In this case, Spain sums about 136 papers funded by national Spanish grants without counting the support they might also have received from supranational organisms such as the European Union. Following this, we can conclude that the efforts that the Spanish national and local institutions have put into the research of this area have paid off significantly. Similarly, Portugal, Norway and China are other valid examples of the national research policies that increased the number of publications.

3.1.4 | Category Co-authorship analysis

The WoS core collection assigns every journal and book included in the database to at least one subject area category, based on the cognitive content of the publication. The interactions amongst categories are shown in Figure 4a,b. To better understand the interactions between the different categories, the network of the SCIE database only includes the labels of those categories that were assigned to at least 30 papers. Similarly, as with the other networks, the links indicate the interaction between different categories, while the thickness and the distance between the nodes represent the level of strength of the interaction. In addition, those nodes that have purple rings around them are considered pivotal points that connect different sections of the network, and the thickness represents the importance of the respective pivotal point.

Figure 4a shows three major subnetworks that can be grouped in categories related to Business and economics, behavioural sciences and psychology and environmental science respectively. The largest subnetwork is related to environmental sciences, grouped by important categories such as ENVIRONMENTAL SCIENCES, ENVIRONMENTAL SCIENCES & ECOLOGY, ENVIRONMENTAL STUDIES, GREEN & SUSTAINABLE SCIENCE & TECHNOLOGY, SCIENCES & TECHNOLOGY—OTHER TOPICS, with the category of ENVIRONMENTAL SCIENCES & ECOLOGY having a key role, which is evidenced by its purple ring. Also, the interactions between the business and economics subnetwork stand out for the categories of FISHERIES, ECONOMICS and BUSINESS & ECONOMICS.

Figure 4b is composed of one large subnetwork that includes 6 nodes with purple rings, evidencing the key pivotal roles of the categories of FISHERIES, MARINE & FRESHWATER BIOLOGY, BIOTECHNOLOGY & APPLIED MICROBIOLOGY, BIOCHEMISTRY & MOLECULAR BIOLOGY, ZOOLOGY and AGRICULTURE. The bigger thickness of the links between the categories of BIOCHEMISTRY & MOLECULAR BIOLOGY, FISHERIES and AGRICULTURE indicates a higher level of strength of the interactions related to these nodes.

Table 5a,b presents the top 10 categories according to the number of papers. Table 5a indicates that the most important category for the SSCI database is FISHERIES with 13 publications, followed by ENVIRONMENTAL SCIENCES & ECOLOGY (12), BUSINESS & ECONOMICS (9), SCIENCE & TECHNOLOGY—OTHER TOPICS (8), ENVIRONMENTAL SCIENCES (8), ECONOMICS (8), ENVIRONMENTAL STUDIES (8), BEHAVIORAL SCIENCES

TABLE 4 Top 10 productive grants of SSAR papers

Ranking	Counts	Centrality	Grants	Region/Country	Year
a. SSCI database					
1	4	0.02	H2020 EU—European Union (EU)	Europe	2018
2–3	2	0.02	EU—European Union (EU)	Europe	2017
	2	0.00	European Commission under the 7th Framework Programme FP7	Europe	2017
b. SCIE database					
1	65	0.10	Portuguese Foundation for Science and Technology	Portugal	2008
2	45	0.10	Spanish Ministry of Economy and Competitiveness	Spain	2012
3	41	0.03	EU—European Union (EU)	Europe	2008
4–5	34	0.04	Seneca Foundation (Murcia, Spain)	Spain	2012
	34	0.02	Spanish Ministry of Science and Innovation (MICINN)	Spain	2008
6	24	0.06	National Natural Science Foundation of China	China	2012
7	23	0.01	Commission of the European Communities—European Union (EU)	Europe	2008
8	13	0.02	Valencia Regional Government	Spain	2009
9	12	0.02	Research Council of Norway	Norway	2010
10–11	10	0.02	European Regional Development Fund (EU)	Europe	2009
	10	0.02	Spanish Ministry of Education and Science	Spain	2008

Notes: Source: Own elaboration based on WoS data and output of grant analysis in CiteSpace. The WoS data are limited because only the funds from 2008 and subsequent years are counted.

(7), GREEN & SUSTAINABLE SCIENCE & TECHNOLOGY (7), PSYCHOLOGY (4), MARINE & FRESHWATER BIOLOGY (4) and PSYCHOLOGY and BIOLOGICAL (4).

Similarly, Table 5b indicates that FISHERIES is also the most important category for the SCIE database with 1279 papers, while other important categories are MARINE & FRESHWATER BIOLOGY (858), VETERINARY SCIENCES (287), IMMUNOLOGY (157), BIOCHEMISTRY & MOLECULAR BIOLOGY (156), ENVIRONMENTAL SCIENCES & ECOLOGY (131), AGRICULTURE (128), BIOTECHNOLOGY & APPLIED MICROBIOLOGY (112), PHYSIOLOGY (108) and ENVIRONMENTAL SCIENCES (98).

3.2 | Co-citation analysis on SSAR

According to McCain (1991), a co-citation occurs when two works are jointly cited in later publications. Co-citation analysis can be applied according to the levels of author, journal and country (Osareh, 2009). Small (1973) concluded that two applications in information retrieval can be associated with co-citation analysis: first, the list of new documents of highly co-cited papers based on the citation indices, and second, co-citation analysis offers a list of the most important documents of the earlier literature for a particular field, which could be seen as a core set for that particular field, and as a result, be the basis of a selective dissemination of information (SDI) system.

3.2.1 | Journal co-citation analysis

A journal co-citation analysis can be used to study the organization of a subject literature (McCain, 1991). The journal co-citation analysis network for SSAR is presented in Figure 5a,b. In this case, the journals are represented by the nodes, while the links determine a co-citation relationship between two journals. The size of the nodes is in function of their importance, while the distance between the nodes denotes how high (smaller distance) or low (bigger distance) the journal co-citation frequency is.

Figure 5a presents a total of 21 labelled journal nodes which include only those journals that have been co-cited at least eight times. The network evidences a high collaboration amongst journals related to economics and food preferences. In this regard, it is important to remark that the most relevant journal (AQUACULTURE) is considerably isolated from the rest of the journals, which indicates a low journal co-citation frequency between this journal and the rest. This may be due to the fact that there are only 39 publications on this database for the area, while there are 2199 papers in the SCIE database, making it more likely that this journal usually cites papers from the SCIE database, especially considering that it is also the most relevant journal for the SCIE database.

Figure 5b shows 23 labelled journals that were co-cited at least 290 times. The nodes are in general highly linked and close to each other, indicating that relevant journals in this database usually co-cite other important journals that are included in the same database.

FIGURE 4 (a) Map of the category co-authorship network of SSAR—SSCI database. (b) Map of the category co-authorship network of SSAR—SCIE database

The top 10 journals in terms of the counts of co-citations are listed in Table 6a,b. Table 6a shows that the top three co-cited journals are AQUACULTURE with 27 citations, AQUACULT ECON MANAG with 19 citations and AQUACULT INT with 17 citations. Similarly, Table 6b shows that the top three co-cited journals are AQUACULTURE with 1892 citations, AQUACULTURE RESEARCH with 1082 citations and J FISH BIOL with 859 citations. These findings indicate that AQUACULTURE, a journal that addresses research on the areas of fisheries and Marine & Freshwater Biology, is the most relevant journal for SSAR in terms of the co-citation counts, also registering one of the highest impact factors in both databases.

The journals of AQUACULTURE, AQUACULT INT and J FISH BIOL appear in both tables, suggesting that these journals are indistinctly cited by either the papers of the SSCI or the ones of the SCIE. Furthermore, Table 6a,b also indicates that the highest impact factor in 2018 for the top journals of SSCI was related to FOOD QUAL

TABLE 5 Top 10 productive categories of SSAR papers

Ranking	Counts	Centrality	Category	Year
a. SSCI database				
1	13	0.03	FISHERIES	2012
2	12	0.31	ENVIRONMENTAL SCIENCES & ECOLOGY	2016
3	9	0.03	BUSINESS & ECONOMICS	2006
4–7	8	0.16	SCIENCE & TECHNOLOGY—OTHER TOPICS	2018
	8	0	ENVIRONMENTAL SCIENCES	2016
	8	0	ECONOMICS	2006
	8	0.06	ENVIRONMENTAL STUDIES	2017
8–9	7	0.1	BEHAVIORAL SCIENCES	2004
	7	0.02	GREEN & SUSTAINABLE SCIENCE & TECHNOLOGY	2018
10–12	4	0	PSYCHOLOGY	2004
	4	0.02	MARINE & FRESHWATER BIOLOGY	2014
	4	0.03	PSYCHOLOGY, BIOLOGICAL	2004
b. SCIE database				
1	1276	0.20	FISHERIES	1988
2	858	0.31	MARINE & FRESHWATER BIOLOGY	1988
3	287	0.19	VETERINARY SCIENCES	1993
4	157	0.05	IMMUNOLOGY	2002
5	156	0.33	BIOCHEMISTRY & MOLECULAR BIOLOGY	1992
6	131	0.02	ENVIRONMENTAL SCIENCES & ECOLOGY	2000
7	128	0.05	AGRICULTURE	1996
8	112	0.22	BIOTECHNOLOGY & APPLIED MICROBIOLOGY	1997
9	108	0.06	PHYSIOLOGY	1999
10	98	0.28	ENVIRONMENTAL SCIENCES	2000

Notes: Source: Own elaboration based on WoS data and output of categories analysis in CiteSpace.

PREFER with 3.684, while it corresponded to the FISH SHELLFISH IMMUN journal with an IF of 3.298 for the SCIE database.

3.2.2 | Document co-citation analysis

Figure 6a,b presents the networks for the document co-citation analysis of SSAR. For these networks, each cited document is represented by a node (including as label the first author and year of publication), in which its size depends on the importance of the document and the distance between nodes indicating the frequency of documents co-citations. In addition, a link joining a pair of nodes indicates a co-citation relationship between them.

Figure 6a shows, in general terms, a low co-citation relationship between most of the studies, especially between those that were co-cited at least by three authors, which are the ones labelled in the figure. Similarly, Figure 6b shows the documents that have at least 15 citations. The figure shows some interactions between some small groups of documents, which indicate that amongst the most co-cited publications, there is a low relationship of co-citations between them, except for the mentioned small groups of documents.

Table 7a,b present the top 10 highest co-cited publications. The columns included in the tables are the number of citations, centrality, first author, year of publication and journal information. Table 7a includes only six publications because the remaining papers of this database have only two or fewer co-citations.

The highest cited publications of the SSCI database are the studies by Claret et al. (2012) and Rodríguez et al. (2013), with five citations each. The study of Claret et al. (2012) analysed consumers' preferences for sea fish, while Rodríguez et al. (2013) determined whether the cultured and wild seabream were integrated into the Spanish market. Other important publications that are co-cited at least four times are related to market integration analysis (Asche et al., 2012; Regnier & Bayramoglu, 2017), consumers' preferences (Carlucci et al., 2015) and the global state of world fisheries and aquaculture (FAO, 2014).

Regarding the top co-cited publications of the SCIE database, the most co-cited publication with 35 citations is a study that described the nutrient requirements of fish and shrimp by the American National Research Council (2011). From the other 11 papers that are included in the top, seven are linked to fish nutrition (Hardy, 2010; Merrifield et al., 2010; Nayak, 2010; Oliva-Teles, 2012; Ringø et al., 2010; Tocher, 2010; Turchini et al., 2009) and

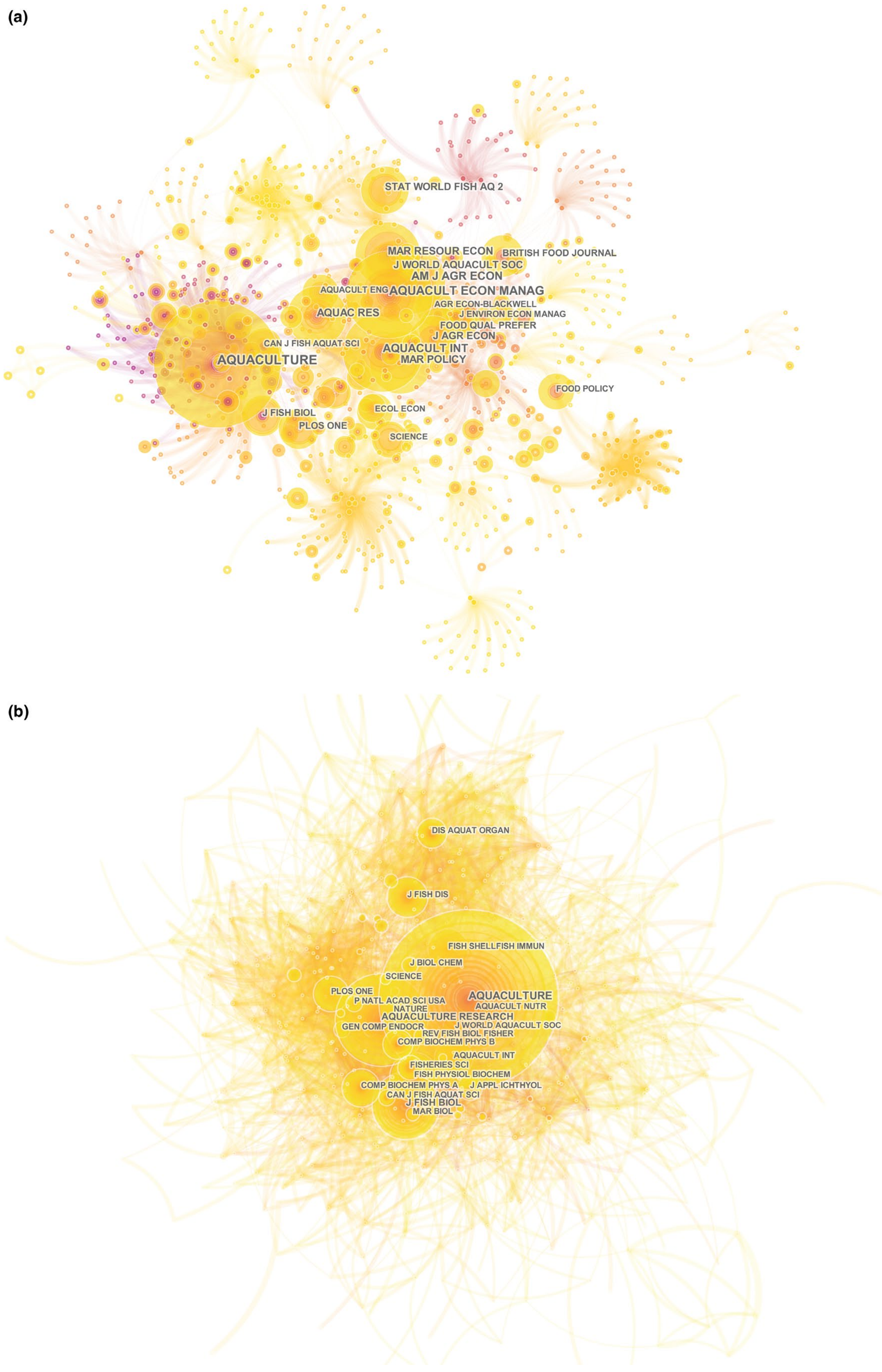

FIGURE 5 (a) Map of the journal co-citation network of SSAR—SSCI database. (b) Map of the journal co-citation network of SSAR—SCIE database

TABLE 6 The distribution of ten 'core journals' on SSAR

Ranking	Counts	Centrality	Cited Journals	IF in 2018	Subject coverage	Year
a. SSCI database						
1	27	0.14	AQUACULTURE	3.022	F, M&FB	2004
2	19	0.08	AQUACULT ECON MANAG (AQUACULTURE ECONOMICS & MANAGEMENT)	3.25	B&E, F	2006
3	17	0.05	AQUACULT INT (AQUACULTURE INTERNATIONAL)	1.455	F	2007
4	15	0.30	AM J AGR ECON (AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS)	2.532	A, B&E	2006
5	14	0.02	MAR RESOUR ECON (MARINE RESOURCE ECONOMICS)	2.8	B&E, ES&E, F	2006
6–7	13	0.00	MAR POLICY (MARINE POLICY)	2.865	ES&E, IR	2014
	13	0.06	AQUAC RES (AQUACULTURE RESEARCH)	1.502	F	2007
8	12	0.03	J WORLD AQUACULT SOC (JOURNAL OF THE WORLD AQUACULTURE SOCIETY)	1.386	F	2006
9	10	0.00	J AGR ECON (JOURNAL OF AGRICULTURAL ECONOMICS)	2.506	A, B&E	2013
10–14	9	0.00	APPETITE	3.501	BSN&D	2017
	9	0.00	FOOD QUAL PREFER (FOOD QUALITY AND PREFERENCE)	3.684	FS&T	2012
	9	0.02	BRITISH FOOD JOURNAL	1.717	FS&T	2009
	9	0.03	J FISH BIOL (JOURNAL OF FISH BIOLOGY)	2.038	F, M&FB	2006
	9	0.00	PLOS ONE	2.776	S&T—Other Topics	2015
b. SCIE database						
1	1892	0.08	AQUACULTURE	3.022	F, M&FB	1988
2	1082	0.01	AQUACULTURE RESEARCH	1.502	F	1998
3	859	0.02	J FISH BIOL (JOURNAL OF FISH BIOLOGY)	2.038	F, M&FB	1992
4	670	0.02	FISH PHYSIOL BIOCHEM (FISH PHYSIOLOGY AND BIOCHEMISTRY)	1.729	B&MB, F, P	1988
5	593	0.01	J FISH DIS (JOURNAL OF FISH DISEASES)	1.988	F, M&FB, VS	1997
6	571	0.03	FISH SHELLFISH IMMUN (FISH & SHELLFISH IMMUNOLOGY)	3.298	F, I, M&FB, VS	1999
7	549	0.00	AQUACULT INT (AQUACULTURE INTERNATIONAL)	1.455	F	1997
8	530	0.04	COMP BIOCHEM PHYS A (COMPARATIVE BIOCHEMISTRY AND PHYSIOLOGY PART A)	2.142	B&MB, P, Z	1997
9	504	0.04	AQUACULT NUTR (AQUACULTURE NUTRITION)	2.098	F	1999
10	480	0.01	J APPL ICHTHYOL (JOURNAL OF APPLIED ICHTHYOLOGY)	0.877	F, M&FB	1998

Notes: Source: Own elaboration based on WoS and Journal citation report 2018 data, and output of co-cited journal analysis in CiteSpace.

Abbreviations: A: Agriculture; B&E: Business & Economics; BSN&D: Behavioral Sciences, Nutrition & Dietetics; B&MB: Biochemistry & Molecular Biology; ES&E: Environmental Sciences & Ecology; F: Fisheries, FS&T: Food Science & Technology; I: Immunology; IR: International Relations; M&FB: Marine & Freshwater Biology; P: Physiology; S&T: Science & Technology; VS: Veterinary Sciences; Z: Zoology.

the rest are related to trends and future prospects of fish feeds (Tacon & Metian, 2008), fish welfare (Ashley, 2007), factors affecting fish organoleptic characteristics (Grigorakis, 2007) and genetics (Dupont-Nivet et al., 2008).

In general, we can conclude that the top co-cited documents of SSAR are related mostly to market integration and consumers' preferences for the SSCI database, while for the case of the SCIE database, fish nutrition is highlighted as the most usual topic.

FIGURE 6 (a) Map of the document co-citation network of SSAR—SSCI database. (b) Map of the document co-citation network of SSAR—SCIE database

TABLE 7 Top 10 co-cited documents related to SSAR

Ranking	Counts	Centrality	Documents
a. SSCI database			
1–2	5	0.13	Rodriguez GR, 2013, AQUACULT ECON MANAG, V17, P380
	5	0.08	Claret A, 2012, FOOD QUAL PREFER, V26, P259
3–6	4	0.00	Carlucci D, 2015, APPETITE, V84, P212
	4	0.00	FAO, 2014, STAT WORLD FISH AQ 2
	4	0.04	Asche F, 2012, MAR RESOUR ECON, V27, P181
	4	0.00	Regnier E, 2017, AQUACULT ECON MANAG, V21, P355
b. SCIE database			
1	35	0.03	NRC(National Research Council), 2011, NUTR REQ FISH SHRIMP
2	34	0.13	Tacon AGJ, 2008, AQUACULTURE, V285, P146
3	31	0.05	Turchini GM, 2009, REV AQUACULT, V1, P10
4	30	0.12	Nayak SK, 2010, FISH SHELLFISH IMMUN, V29, P2
5–6	25	0.12	Ashley PJ, 2007, APPL ANIM BEHAV SCI, V104, P199
	25	0.02	Grigorakis K, 2007, AQUACULTURE, V272, P55
7–9	24	0.03	Merrifield DL, 2010, AQUACULTURE, V302, P1
	24	0.01	Oliva-Teles A, 2012, J FISH DIS, V35, P83
	24	0.03	Ringo E, 2010, AQUACULT NUTR, V16, P117
10–12	23	0.02	Dupont-Nivet M, 2008, AQUACULTURE, V275, P81
	23	0.01	Hardy RW, 2010, AQUAC RES, V41, P770
	23	0.02	Tocher DR, 2010, AQUAC RES, V41, P717

Notes: Source: Own elaboration based on WoS data and output of co-cited document analysis in CiteSpace.

3.2.3 | Author co-citation analysis

According to Chen and Liu (2020), the author co-citation analysis finds the distribution of the highest co-cited and prominent authors for a particular field, and to understand the research topics of relevant authors and the distribution of their subject areas.

The author co-citation networks are presented in Figure 7a,b. Each one of the nodes represents an author, while the links evidence a relationship of co-citations between a pair of authors. Similarly, as with the other networks, the size of the node indicates the importance of the author in terms of the number of citations, while the distance between nodes indicates the frequency of co-citation between authors. Figure 7a shows the labelled authors with 4 citations or more, while Figure 7b depicts the labelled authors with 70 or more citations. The full names of some of the authors shown in these figures are provided in the Appendix.

Figure 7a shows that the network is mostly formed by two main subnetworks, from which the largest one evidences high co-citation frequencies between the different authors based on the short distance between the nodes. On the other hand, Figure 7b shows that the network has only one large subnetwork with a considerable connection amongst most of the nodes.

The top 10 authors by co-citation are presented in Table 8a,b. Table 8a shows that the most co-cited author is an organization: The Food and Agriculture Organization (FAO), with 15 publications. Following that, other important authors are as follows: ASCHE F (12), JAFFRY S (10), BJORNDAL T (9), JOHANSEN S (7), CLARET A (7), NORMAN-LOPEZ A (6), ANDERSON JL (6), RODRIGUEZ GR (6), ENGLE RF (6), NIELSEN M (6) and VERBEKE W (6). Regarding the different institutions that each author represents, two of the authors from the top are from the University of Florida and two others from the University of Copenhagen.

Similarly, Table 8b shows that the most cited author by far is the Food and Agriculture Organization (FAO) with 333 publications; followed by other significant authors such as FOLCH J (142), MONTERO D (126), IZQUIERDO

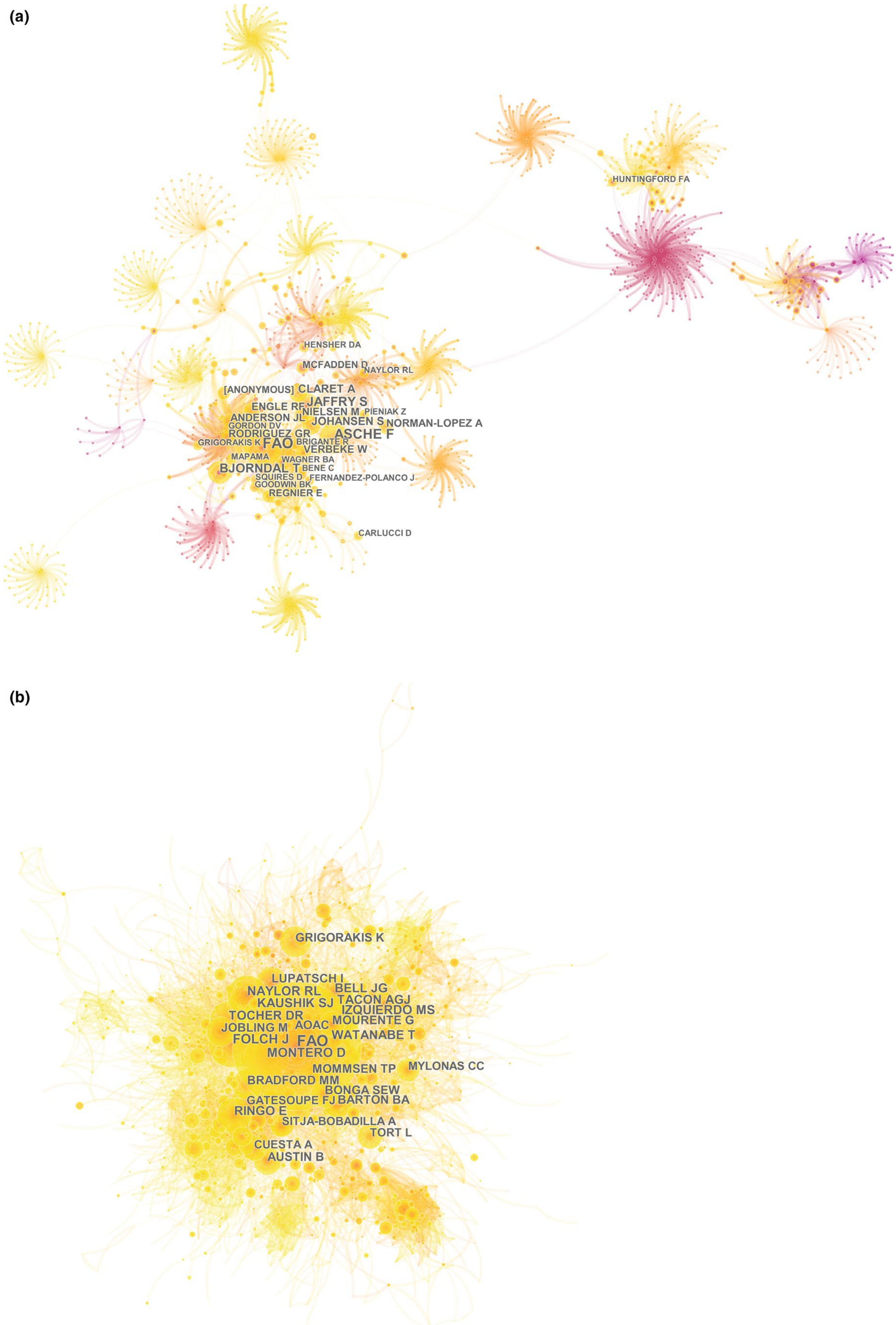

FIGURE 7 (a) Map of the author co-citation network of SSAR—SSCI database. (b) Map of the author co-citation network of SSAR—SCIE database

TABLE 8 Top 10 cited authors of SSAR papers

Ranking	Counts	Centrality	Authors	Year	From	Main field
a. SSCI database						
1	15	0.07	FAO	2009		
2	12	0.11	ASCHE F	2015	University of Florida, University de Stavanger, Norwegian Institute for Research in Economics and Business Administration	EF&M
3	10	0.01	JAFFRY S	2012	University of Portsmouth	EF&M
4	9	0.02	BJORNDAL T	2006	NHH Norwegian School of Economics, Norwegian University of Science and Technology	EF&M
5–6	7	0.00	JOHANSEN S	2015	Aarhus University, University of Copenhagen	EF&M
	7	0.04	CLARET A	2013	IRTA Institute of Agrifood Research and Technology	EF&M
7–12	6	0.00	NORMAN-LOPEZ A	2015	European Commission Joint Research Centre, CSIRO (Commonwealth Scientific and Industrial Research Organization)	EF&M
	6	0.53	ANDERSON JL	2013	University of Florida	EF&M
	6	0.01	RODRIGUEZ GR	2017	University of Santiago de Compostela	EF&M
	6	0.00	ENGLE RF	2015	Leonard N. Stern School of Business, New York University, University of California	EF&M
	6	0.00	NIELSEN M	2015	University of Copenhagen	EF&M
	6	0.07	VERBEKE W	2012	Ghent University	EF&M
b. SCIE database						
1	333	0.03	FAO	2001		
2	142	0.03	FOLCH J	1992	Harvard Medical School, Geisel School of Medicine at Dartmouth	BBG&N
3	126	0.03	MONTERO D	1999	University of Las Palmas de Gran Canaria	BBG&N
4	123	0.04	IZQUIERDO MS	1992	University of Las Palmas de Gran Canaria	BBG&N
5	117	0.03	KAUSHIK SJ	2000	University of Las Palmas de Gran Canaria, INRA (French National Institute of Agricultural Research)	BBG&N
6	116	0.04	NAYLOR RL	2002	Stanford University	EF&M
7	115	0.06	WATANABE T	1992	The University of North Carolina Wilmington	EF&M
8	113	0.03	TACON AGJ	1994	University of Sao Paulo—USP, Aquatic Farms Ltd	BBG&N
9	111	0.02	TOCHER DR	1992	University of Stirling	BBG&N
10	107	0.03	BELL JG	1999	University of Stirling	BBG&N

Notes: Source: Own elaboration based on WoS data and output of author co-cited analysis in CiteSpace.
Abbreviations: BBG&N: Biology, Biochemistry, Genetics and Nutrition, EF&M: Economics, Food Science & Marketing.

MS (123), KAUSHIK SJ (117), NAYLOR RL (116), WATANABE T (115), TACON AGJ (113), TOCHER DR (111) and BELL JG (107). It is important to notice that 3 out of the top 5 authors are from the Universidad of las Palmas de Gran Canaria, while 2 out of the top 10 are from the University of Stirling.

3.3 | Keywords co-occurrence analysis on SSAR

Keywords usually offer information about the most important aspects of the articles (Chen & Liu, 2020). For the present study, Figure 8a,b presents the different keyword maps. In these figures, each node is represented by one keyword. The node size represents the frequency of co-occurrence in the field of SSAR. In addition, Table 9a,b shows the 10 most important keywords according to the number of counts and the centrality, while Table 10a,b exhibits the keywords with the strongest citation bursts for both databases.

Hot research topics

According to the information of Figure 8a and Table 9a, there are five main hot research topics in the SSCI database:

1. *Aquaculture and fishery*: The studies usually make a distinction between farmed and wild species, either for focusing on one of the two types or to make comparisons between them. Aquaculture research is more relevant than fisheries research in this case, as expected.
2. *Fish species*: Even though the research topic is only related to seabream and seabass, several studies of other species such as salmon, tilapia and trout are addressed to make comparisons between the different species and to correlate findings of the studied species into SSAR.
3. *Willingness to pay*: Several of the studies make willingness to pay estimations to measure the impact of different changes in attributes on consumers' preferences. Usually, methodologies like discrete choice models allow this purpose.
4. *Market integration*: Some studies determine whether or not the cultured and wild products are integrated into different markets.
5. *Sustainability*: Amongst the different attributes studied to understand consumers' preferences for seabream and seabass, sustainability is one of the most relevant. Usually, eco-labelled seafood is compared with not eco-labelled seafood in order to determine how consumers value the importance of the labels.

According to the information of Figure 8b and Table 9b, there are three main hot research topics in the SCIE database:

1. *Aquaculture*: The studies analyse aspects linked to fish harvested by aquaculture techniques.
2. *Fish species*: Many studies compare the results of seabream and seabass with similar studies of other species such as trout and salmon. Also, in some other cases, topics already explored in these other species are evaluated for the cases of seabream and seabass.
3. *Fish growth*: The studies aim to determine how to improve the growth of the species by controlling elements such as fish nutrition, genetics and other variables.

3.4 | Research frontiers

Table 10a,b shows the top 19 burst keywords with their respective burst strengths and begin and end years of the bursts. Based on the results, the six frontiers of SSAR for SSCI are as follows:

1. *Sea*: seabream and seabass.
2. *Bass dicentrarchus labrax*: seabass.
3. *Culture*: the culture of fish species (aquaculture).
4. *Aquaponics*: simultaneous production of fish and aquatic plants.
5. *Fish meal*: different types of fish meals that can be given to feed seabream and seabass.
6. *Breamsparus aurata*: seabream.

Similarly, the five frontiers of SSAR for SCIE are as follows:

1. *Growth performance*: Growth performance is one of the most important response variables when assessing the productivity of innovative methods associated with the nutrition of the fish, genetic research and other areas.
2. *Disease resistance*: This is related to the research on selective breeding programmes, which improve disease resistance in the long-term using genetics.
3. *Intestinal microbiota*: The intestinal microbiota affects the feeding, digestive process, growth and energy homeostasis in fish.
4. *Body composition*: The body composition of fish is influenced by their nutritional intake.
5. *Fish meal replacement*: There are alternatives to the conventional fish meal that can improve certain characteristics of the fish like the growth or that offer more sustainable or cheaper options.

4 | CONCLUSIONS

Regarding seabream and seabass aquaculture research, it is important to highlight the existence of a large disparity between the number of papers found in the SSCI database (39), in comparison with those found in the SCIE database (2199). This difference indicates that SSAR is still in its infancy in social sciences such as economics, food science, business and marketing, which are the types of papers assessed in the SSCI database. Considering the existing gap observed, we suggest that researchers in the field should include more topics from the perspective of social sciences for SSAR, as there are still a lot of issues that need to be addressed in the area.

Also, based on the publications, it can be concluded that the most important authors for the SSCI database are T BJORNDAL, J GUILLEN and LM VERA, and for the SCIE are MA ESTEBAN, A CUESTA and G TEROVA, while the most cited authors for the SSCI database are the FAO (Food and Agriculture Organization of the United Nations), F ASCHE and S JAFFRY, and for the SCIE database are the FAO, J FOLCH and D MONTERO. The studies of the current prolific authors on SSAR could be a good start for new researchers in the field, as they help to identify new lines of research that could make a significant contribution in the area.

At the institutional level, the institutions that produced the greatest number of publications for the SSCI database are the CSIC (Spanish National Research Council), Univ Cantabria, Univ Murcia, NHH (Norwegian School of Economics), Norwegian Univ Sci & Technol and European Commission; while for the SCIE are the CSIC (Spanish National Research Council), Univ Murcia and the Hellenic Centre for Marine Research. The institutional interaction on SSAR could be important for institutions in identifying and strengthening current relationships with other important institutions, as well as identifying potential strategic partners for future research projects. Also, it is important to notice that the most prolific authors and institutions are mostly from Spain. Thus, Spanish researchers and institutions in the field can be considered significant partners in future research projects because of their experience in the area.

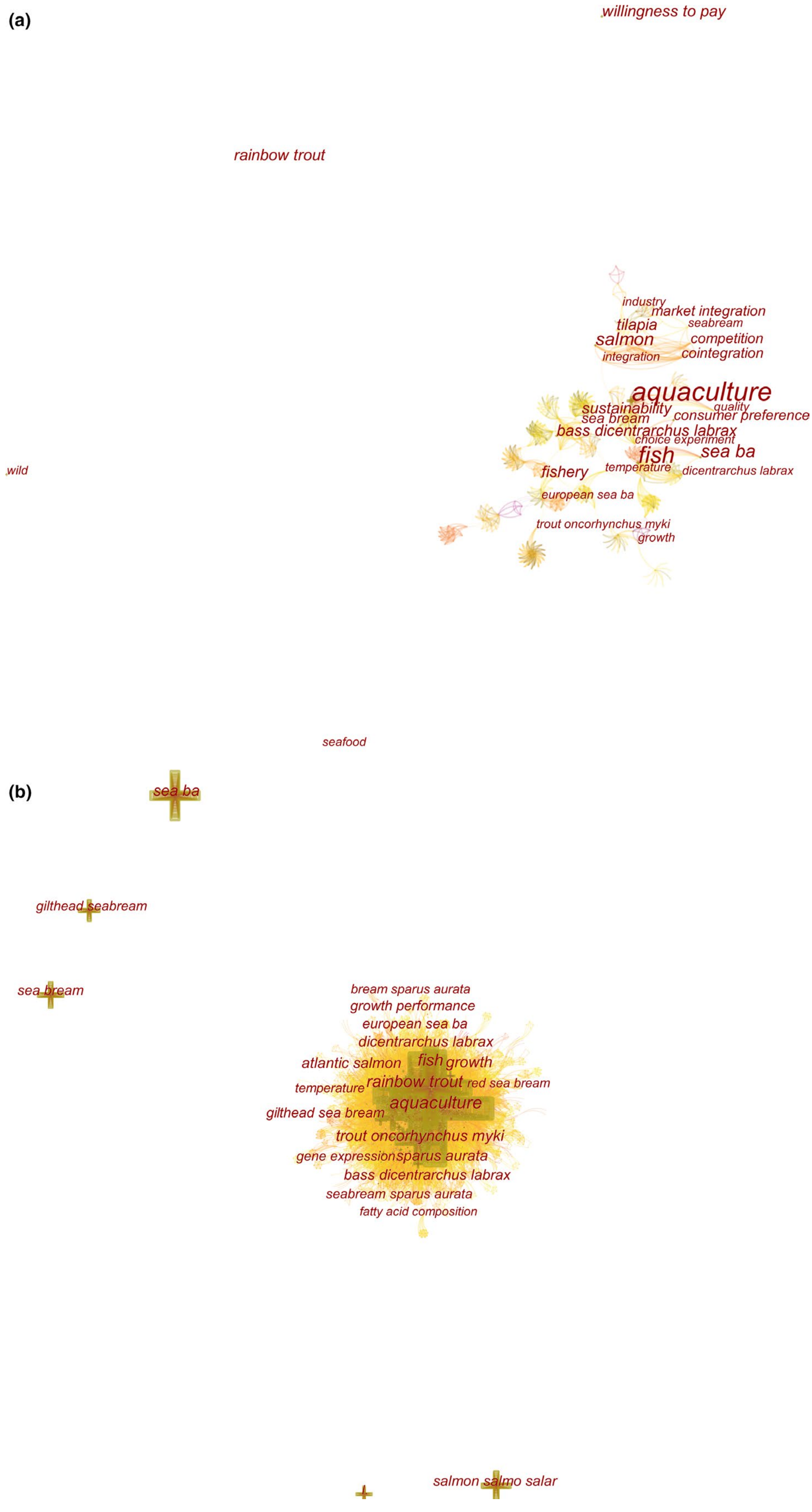

FIGURE 8 (a) Map of the keywords co-occurrence network of SSAR—SSCI database. (b) Map of the keywords co-occurrence network of SSAR—SCIE database

TABLE 9 Top 10 keywords in terms of counts and centrality

By counts					By centrality				
Ranking	Counts	Keywords	Year	Centrality	Ranking	Centrality	Keywords	Year	Counts
a. SSCI database									
1	22	Aquaculture	2013	0	1	0.36	wtp	2019	1
2	14	Fish	2012	0.2	2	0.34	Ecolabeled seafood	2013	2
3–4	7	Sea ba	2013	0.1	3	0.3	Impact	2017	2
	7	Salmon	2009	0	4	0.29	Marine aquaculture	2017	2
5–10	5	Tilapia	2015	0.04	5	0.24	Farmed fish	2017	1
	5	Willingness to pay	2013	0	6	0.22	Attribute	2017	2
	5	Fishery	2016	0.07	7–8	0.21	Choice experiment	2012	3
	5	Bass dicentrarchus labrax	2018	0		0.21	Wild fish	2017	1
	5	Rainbow trout	2006	0	9–10	0.2	Fish	2012	14
	5	Sustainability	2013	0.09		0.2	Random utility model	2013	1
b. SCIE database									
1	680	Aquaculture	1988	0.01	1	0.09	Wild fish	2004	26
2	510	Rainbow trout	1992	0.02	2	0.08	Welfare	2006	30
3	486	Fish	1991	0.02	3–5	0.07	Troutoncorhynchus myki	2001	47
4–5	299	Growth	1992	0.02		0.07	Zebrafish	2005	40
	299	Sea ba	1988	0.03		0.07	Vibrio anguillarum	2002	37
6	289	Trout oncorhynchus myki	1999	0.01	6–9	0.06	Teleost	2004	61
7	244	Dicentrarchus labrax	1988	0.02		0.06	Turbot scophthalmus maximus	2003	53
8	241	Sparus aurata	1996	0.05		0.06	System	2003	37
9	233	Atlantic salmon	1992	0.02		0.06	Selection	2004	30
10	209	Bass dicentrarchus labrax	1997	0.05					

Notes: Source: Own elaboration based on WoS data and output of keyword analysis in CiteSpace.

The countries that generated the greatest of publications for both databases are Spain and Italy. For the SSCI database, Norway is also important, while for the SCIE database, other relevant countries are France, Portugal and France. In general, European countries are the main contributors of papers in the field, which can be explained by the larger amount of grants given by the European Union and national governments, especially for the case of Spain, which dominates both databases by a wide margin. This result showed empirical evidence of the importance of grants in the development of SSAR.

The most relevant journal in terms of the number of citations for both databases is AQUACULTURE by a large margin, which is a multidisciplinary journal addressing all topics of aquaculture research. Also, for the case of the SSCI database, other relevant journals are mostly related to economics, business, management and food preferences, while they are mostly linked to research in biology, physiology, biochemistry, nutrition and related fields for the SCIE database. We suggest that researchers pay close attention to new publications in the most relevant journals in order to stay updated on SSAR trends.

The most cited documents for the SSCI database are the studies of Rodríguez et al. (2013) and Claret et al. (2012), while for the case of the SCIE database are the investigation developed by the NRC in 2011, as well as the studies of Tacon and Metian (2008) and Turchini et al. (2009). These studies might represent the intellectual bases for the development of future SSAR. For the case of the SSCI database, the study of Rodríguez et al. (2013) aimed to understand whether in Spain, cultured and wild gilthead sea bream markets are integrated, while the study of Claret et al. (2012) assessed the preferences for sea fish in Spanish consumers. These results show an important trend in studies that analyse the Spanish market, which could be further explored in future research. Moreover, for the SCIE database, the study of Tacon and Metian (2008) surveyed

TABLE 10 Top 19 Keywords with the strongest citation burst

a. SSCI database

Keywords	Strength	Begin	End	2004–2020
Locomotor activity rhythm	0.9545	2004	2013	
Melatonin	1.2689	2004	2006	
Plasma melatonin	1.2689	2004	2006	
Goldfish carassius auratus	1.0795	2007	2013	
Performance	1.0946	2009	2014	
Quality	1.1071	2012	2013	
Choice experiment	1.1071	2012	2013	
Seafood	1.2133	2016	2017	
Fishery	1.3304	2016	2017	
Cod	0.8067	2016	2017	
Sustainability	0.6277	2016	2017	
Impact	0.7348	2017	2018	
Economics	0.7348	2017	2018	
Sea	0.5795	2018	2020	
Bass dicentrarchus labrax	1.46	2018	2020	
Culture	0.5795	2018	2020	
Aquaponics	0.5795	2018	2020	
Fish meal	0.5795	2018	2020	
Breamsparus aurata	0.5795	2018	2020	

b. SCIE database

Keywords	Strength	Begin	End	1986–2020
Red sea bream	5.0289	1992	2001	
Sparidae	7.0294	1994	2006	
Nitrogen	8.5802	1996	2008	
Culture	6.3712	1996	2006	
Disease	5.096	1997	2006	
Environmental impact	4.4735	2000	2009	
Sediment	4.2694	2001	2009	
Larvae	4.235	2002	2005	
Biomarker	4.5089	2004	2010	
Atlantic halibut	4.8099	2007	2012	
Halibut hippoglossus	4.2066	2008	2011	
Bassdicentrarchus labrax	4.2077	2010	2012	
Growth performance	16.9562	2015	2020	
Bream sparus aurata	4.7692	2015	2016	
Disease resistance	4.9252	2016	2020	
Oxidative stress	5.0695	2016	2017	
Intestinal microbiota	4.3403	2017	2020	
Body composition	4.5416	2018	2020	
Fish meal replacement	4.2584	2018	2020	

Notes: Source: Own elaboration based on WoS data and output of burst keywords analysis in CiteSpace.

different stakeholders concerning the use of fish meal and fish oil within industrially compound aquafeeds, while the investigation of Turchini et al. (2009) compiled information regarding the effects of fish oil replacement for the diets of farmed finfish. Thus, it can be inferred that there is an important interest in SSAR for the area of nutrition, especially for issues related to fish oil, which could represent a good research area for future contributions of emerging authors.

Concerning the categories of the WoS core collection, the most important category for SSAR in both databases is FISHERIES. Other important categories for the SSCI database are the ENVIRONMENTAL SCIENCES & ECOLOGY and BUSINESS & ECONOMICS, and for the SCIE database, the MARINE & FRESHWATER BIOLOGY and VETERINARY SCIENCES. For the case of the SSCI database, the analysis allowed to determine 3 groups of categories associated with business and economics, behavioural sciences and psychology, and environmental science. These results provide direction to researchers in identifying possible future lines of investigation for SSAR.

According to the keyword analysis for the SSCI database, the most important research topics are “Aquaculture and fishery”, “Fish species”, “Willingness to pay”, “Market integration” and “Sustainability”; while for the SCIE database, the most relevant topics are related to “Aquaculture”, “Fish species” and “Fish growth”. In addition, as expected, “Aquaculture” is the most common keyword for both databases. For the social sciences, these results evidence that research on consumers' preferences and willingness to pay for seabream and seabass products, market integration and the effect of sustainability, have received a lot of attention in SSAR.

Also, we found that the research frontiers for the SSCI database are Seabream, Seabass, Culture, Aquaponics and Fish meal, while for the SCIE database are growth performance, disease resistance, intestinal microbiota, body composition and fish meal replacement. Based on the results of the SCIE database, the investigation of fish diseases and nutrition emerges as a promising trend for future research.

The findings of this study provide interesting insights for researchers and stakeholders interested in understanding the main tendencies, trends and research development of SSAR. This could serve as a source of inspiration for researchers to propose new research issues and develop new perspectives. Moreover, the author, institution and country co-authorship analyses, as well as the author co-citation analysis, help researchers identify potential research collaborations. Furthermore, the category co-authorship analysis and keywords co-occurrence analysis may be useful tools for researchers in defining future potential areas of research. In addition, the journal co-citation analysis and document co-citation analysis serve researchers as a tool to identify the main sources that need to be consulted in order to stay updated on SSAR trends. Finally, this paper contributes to the field of aquaculture, by providing a visualization analysis of SSAR using CiteSpace, which could improve the current directions on the existing literature with additional ideas that may help researchers to better study the aquaculture industry.

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CONFLICT OF INTEREST

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

AUTHORS' CONTRIBUTIONS

All of the authors contributed significantly to the research. The contributions according to the CRediT taxonomy are: J.C., J.C.M. and C.R. involved in conceptualization, methodology, investigation and formal analysis; J.C. involved in software, data curation and writing—original draft preparation; J.C.M. and C.R. involved in validation, writing—review and editing, and supervision. All authors have read and agreed to the published version of the manuscript.

ETHICAL APPROVAL

Ethical approval is not required since this study has not generated new data.

DATA AVAILABILITY STATEMENT

Data sharing does not apply to this paper as no new data were generated or analysed in this study.

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APPENDIX

Considering that the networks generated for co-authorship analysis (Table 1a,b) and author co-citation analysis (Table 7a,b) did not include the full names of the authors because of the presentation provided by the CiteSpace software, which cannot be modified, we added a table that includes the full names of the authors for some of the cases (Table A1).

TABLE A1 The authors' full names in Figures 1a,b and 7a,b and their corresponding abbreviations involved

Full names in Figure 1a	Abbreviations	Full names in Figure 1b	Abbreviations
Luisa María Vera	L M VERA	María Ángeles Esteban Abad	M ANGELES ESTEBAN
Juan Antonio Madrid	J A MADRID	Pablo Sánchez-Jerez	P SANCHEZJEREZ
Francisco Javier Sanchez-Vazquez	F J SANCHEZVAZQUEZ		
Full names in Figure 7a	**Abbreviations**	**Full names in Figure 7b**	**Abbreviations**
Food and Agriculture Organization of the United Nations	FAO	Food and Agriculture Organization of the United Nations	FAO
Frank Asche	ASCHE F	Jordi Folch	FOLCH J
Shabbar A. Jaffry	JAFFRY S	Daniel Montero	MONTERO D
Trond Bjorndal	BJORNDAL T	Maria Soledad Izquierdo	IZQUIERDO MS
Søren Johansen	JOHANSEN S	Sadashivam J. Kaushik	KAUSHIK SJ
Anna Claret	CLARET A	Rosamond Lee Naylor	NAYLOR RL
Ana Norman-López	NORMAN-LOPEZ A	Wade O. Watanabe	WATANABE T
James L. Anderson	ANDERSON JL	Albert G.J. Tacon	TACON AGJ
Gonzalo Rodríguez Rodríguez	RODRIGUEZ GR	Douglas R. Tocher	TOCHER DR
Robert F. Engle	ENGLE RF	John Gordon Bell	BELL JG
Max Nielsen	NIELSEN M		
Wim Verbeke	VERBEKE W		