GLOBAL TRENDS IN ZOOPLANKTON RESEARCH OF FRESHWATER ECOSYSTEMS DURING 1991-2020: A BIBLIOMETRIC ANALYSIS

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Abstract. Zooplanktons play an important role in the whole freshwater ecosystem, which are the main quality food for almost all fish in their juvenile stage and are the main basic component of the high trophic levels in the aquatic food web. In the context of global environmental change, freshwater zooplankton is experiencing rapid loss of biodiversity and ecosystem integrity. However, our understanding of the geographical distribution pattern of freshwater zooplankton and the diversity-affected ecological factors is still very limited. In order to investigate the research status and future development trend of zooplankton in global freshwater, 26176 publications about freshwater zooplankton/zooplankter indexed by Web of Science from 1991 to 2020 were analyzed with a bibliometric approach in our study. The research contents mainly included the output trend of publications related to the freshwater zooplankton/zooplankter filed over time, the journals with greatest number of zooplankton publications, the countries from which the authors came from, the co-authors and cooperation across countries, the associated keywords in the research areas and so on. This study was searched on a scientific website for scientific study that have limited scientific relevance for the future researches on the freshwater zooplankton.
Keywords: *research hotspot, bibliometrics, aquatic food web, citations, scientific research, impact*

Introduction

Zooplanktons are small, microscopic and free-swimming animals, which are the good food sources for many aquatic animals (Rathod and Patil, 2019). The main nutrition sources of zooplankton in water are phytoplankton, bacteria and organic matter (Donk et al., 2011). Despite small individuals, zooplankton has a large number of species, which can adapt to and exist in various types of water such as oceans, lakes, reservoirs, freshwaters and so on (Krylov, 2013; Abe et al., 2020). Because the zooplanktons are in the middle of the aquatic ecosystem food chain, their community structure changes directly or indirectly affect the community structure changes of other aquatic organisms

(Kar et al., 2016). The metabolism and secretion of zooplanktons can promote the decomposition and circulation of organic matter, which are also highly sensitive to the changes of the water environment. In general, the different types of zooplankton are distributed in various types of water bodies, so the dominant species and other information on zooplankton can reflect the pollution degree of water environment (Kang et al., 2020). And some surveys have shown that the amount, type and diversity of freshwater zooplankton have a significant impact on the entire aquatic food web (Pickhardt et al., 2005; Smyntek et al., 2010; Allard et al., 2011). The researches on the freshwater zooplankton have become an important topic worldwide in recent years because of the research significance of zooplankton (Lovern, 1935; Milstein et al., 2006; Zargar et al., 2007; Hannes et al., 2008; Balvay et al., 2009; Warren et al., 2016; Hitchcock et al., 2016; Elias-Gutierrez et al., 2018; Choi et al., 2019; Li et al., 2019; Tremblay et al., 2019; Kalcheva et al., 2020; Qin et al., 2020). However, it is difficult to find the research focus, research background and specific research direction in a large number of publications. Many problems have not been completely solved including the output trend of publications related to the freshwater zooplankton/zooplankter filed over time, the journals with greatest number of zooplankton publications, the countries from which the authors came from, the co-authors and cooperation across countries, the associated keywords in the research areas and so on. So it is rather necessary to find a new method to overcome these problems (Wang et al., 2015).

Currently, bibliometric analysis has been widely applied to quantitative and qualitative analysis of research results and trends in many disciplines (Keiser et al., 2005; Li et al., 2009; Zhang et al., 2013; Chen et al., 2020). In particular, this method can be applied to detect metal ions in freshwater environment (Irfan et al., 2021), detect the environmental health risks (Andrade et al., 2017), detect the carbon cycling (Zhi et al., 2015) and so on. However, with this method, the scientific research and development trend in the field of freshwater zooplankton are not clear. Web of Science is the citation index database in the ISI database, containing more than 8,000 of the world's most influential, peer-reviewed, high-quality journals (Sevinc, 2004; Zhang et al., 2016), which can search for the popular published articles in related fields according to the search keywords, author's name, title, publication year, affiliations (journals, countries, and regions) and other detail information (Mosicheva et al., 2018). In view of the importance of freshwater zooplankton in aquatic ecosystem function and the lack of bibliometric analysis in this field, this study uses the bibliometric analysis method to analyze the development status of freshwater zooplankton during 1991−2020. The research objectives of this study are as follows: (1) Which countries and journals are the dominant publishers in the field of freshwater zooplankton? (2) Which are the research focus in the field of freshwater zooplankton during the period 1991-2020? (3) Which kind of methods can be applied to accurately locate the gradient relationship between freshwater plankton and freshwater environmental parameters in the future?

Materials and methods

Establishment of database

The methods we used in the present study are cited from the previous literature (Rumin et al., 2020) with minor revisions. The establishment of database was built through a literature search. The use of "Web of Science" database was compulsory to obtain a format compatible with the bibliometric analysis using the analysis software. The

keywords "zooplankton or zooplankter" and "freshwater" were used to list all relevant publications in the worldwide for the period 1991 to 2020. The relevant publications were from the European countries, American countries, Asian countries and Oceania countries. Furthermore, both "zooplankton" and "zooplankter" were selected as keywords due to the fact that the publications related to both were very similar.

Data sources

The data sources of this study mainly included the published articles related to the keywords "zooplankton or zooplankter" and "freshwater" from 1991 to 2020, all of which were inquired from all citation indices in the Web of Science. And then XML files can be obtained, which contained the title, keyword, abstract, publication year, published journal, authors' name, authors' affiliation, citation times and other related information. The search query was constructed as below: (TS = (zooplankton* OR zooplankter*) AND TS = (freshwater*)).

Extraction of country names

All the names of the countries were taken from the authors' affiliations. The affiliations from Peoples R China, Hong Kong, Taiwan were treated as from China. The affiliations from England, Scotland and Wales were treated as from the United Kingdom. The names of some former countries were updated, containing "Ussr" (Russia) and so on. The author's relationship with the states/provinces does not take into account the country names. Publications with only one country name are considered to be co-published domestically, while publications with multiple country names are considered to be co-published internationally.

Co-word analysis of keywords and cooperation among countries

Co-word analysis is an analytical means to discover disciplinary structure of the field of science by analyzing the forms of items (words or pairs of noun phrases) that occur together in the same text body (Cheng et al., 2014; Ravikumar et al., 2015). The classical co-word analysis methods for the countries were mainly for the following steps: Firstly, extract the names of countries. Secondly, the preparation of the country name library. Thirdly, the construction of a co-occurrence matrix and the specific processes are as follows:

(1) a term-document-matrix was generated for the selected country names library; (2) the term-document-matrix was converted into a co-occurrence one. Finally, the ideas for cooperation between countries: a graph was generated where the countries were represented as nodes and their associations were represented as lines between each node. The line width and node width were trimmed for readers.

The procedures of the keywords co-word analysis were as follows: Firstly, the keywords of publication in the Web of Science were summarized. And the spellings of keywords were simplified as much as possible and changed to lowercase, such as "freshwater-zooplankton/zooplankter" to "freshwater zooplankton/zooplankter"; Secondly, the constriction of the top 20 popular keywords database. Thirdly, the construction of a co-occurrence matrix and the specific processes were as follows: (1) term-document-matrix was established for the popular topic keywords; (2) the term-document-matrix was converted into a co-occurrence matrix. Finally, the keywords were further visualized by co-word analysis.

Furthermore, the number and percentage of the single or cooperation articles among the countries or institutions were determined according to the *Equations (1-4)* respectively as follows:

$$CA^1 = TA^1 - SA^1 \qquad \text{(Eq.1)}$$

$$PCA = 1 - SA^1/TA^1 \times 100\% \qquad \text{(Eq.2)}$$

$$SA^2 = TA^2 - CA^2 \qquad \text{(Eq.3)}$$

$$S = SA^2/TA^2 \times 100\% \qquad \text{(Eq.4)}$$

where CA^1 is the number of cooperation articles among the countries, TA^1 is the total number of country articles, SA^1 is the number of single country articles, PCA is the percentage of cooperation articles among the countries. SA^2 is the number of single institution articles, TA^2 is the total number of institution articles, CA^2 is the number of cooperation articles among the institutions, S is the percentage of single institution articles.

The trend analysis of keywords

The presence percentage of every keyword per year was calculated by dividing the annual frequency by the total frequency, and then adjusted the total annual frequency to compensate for the overall raise in the total frequency. Each keyword was checked for trends by MK (Mann-Kendal trend test, MK). In the case of p values less than 0.05, the trend was considered to be significant, otherwise neither increase nor decrease.

Statistical analysis

In this study, all the data handing, block generation and statistical analysis were carried out using the self-written R code. In addition, the MK trend test was used to examine the increase or decrease trend of keyword frequency and statistical quantity/percentage of the relevant publications on freshwater zooplankton during the study years. The formation and analysis of partial figures in the study were performed using OriginPro 8.5.1 data analysis and mapping software (OriginLab Co., MA, USA) and Excel data analysis and mapping software.

Results

The total number and rising tendency of total publications

The total number of publications in the area of freshwater zooplankton/zooplankter in the Web of Science from 1991 to 2020 is 26176. As shown in *Figure 1,* the publication output increased slowly before 2000. And then the total number of publication output increased rapidly after 2000 and reached the maximum in 2020. The total number of publications in the field of zooplankton/zooplankter in the Web of Science for each year from 2000 to 2020 was as follows: 2000 (77 publications), 2001 (845 publications), 2002 (848 publications), 2003 (1028 publications), 2004 (993 publications), 2005 (1094 publications), 2006 (1090 publications), 2007 (1104 publications), 2008 (1246 publications), 2009 (1197 publications), 2010 (1304 publications), 2011 (1342

publications), 2012 (1401 publications), 2013 (1443 publications), 2014 (1446 publications), 2015 (1412 publications), 2016 (1434 publications), 2017 (1517 publications), 2018 (1537 publications), 2019 (1722 publications) and 2020 (1798 publications). The main reasons for the rapid increase in the number of publications after 2000 were the rapid development of the related information technologies and the substantial increase in the internet availability.
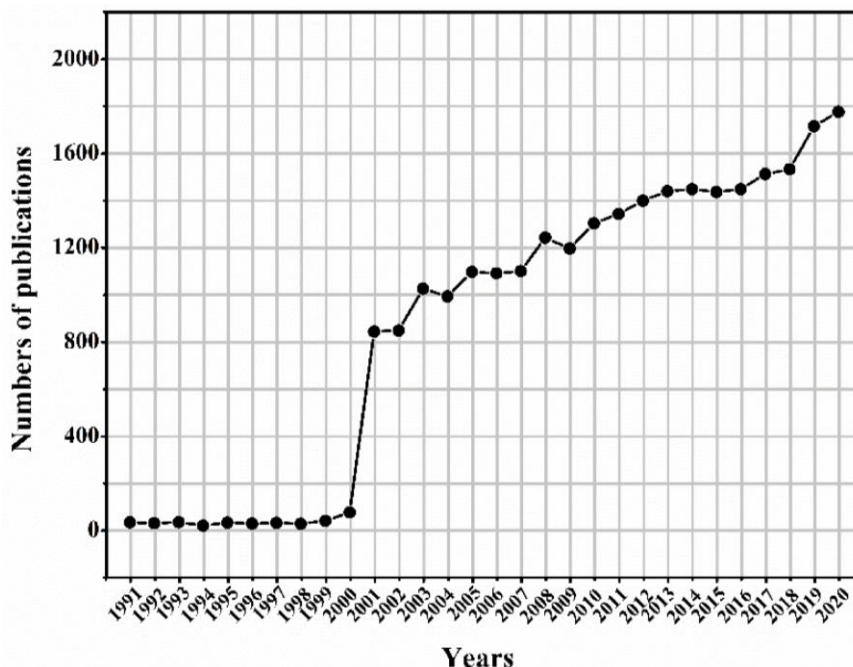
Figure 1. Temporal trends of publications output in the field of freshwater zooplankton between the 1991 and 2020 in the Web of Science

The details of top 10 journals of the total publications

The top 10 journals of the total publications are listed in *Table 1*. As depicted in *Table 1*, the journal "*Hydrobiologia*" topped the list with 1146 publications. However, the total citation of the journal "*Hydrobiologia*" was much lower than the journal "*Limnology and Oceanography*" and journal "*Plos One*" because of the low impact factor. As the second ranked in the number of publications, the journal "*Journal of Plankton Research*" also had a low impact factor and the number of total citations was the lowest in the top 10 journals, the impact factor and total citation number are 2.149 and 6746, respectively. Although the journal "*Progress in Oceanography*" had the highest impact factor (4.06), the number of total citations was much lower than the other journals excepted the journal "*Journal of Plankton Research*". Simultaneously, the journal "*Plos One*" had the highest total citations, but the number of the publications and the impact factor were relatively low.

The details of top 20 countries of the total publications and their cooperation

Figure 2 shows the schematic diagram of the top 20 countries published number in the Web of Science in freshwater zooplankton research area and their cooperative networks. And the detail information of the top 10 countries has also listed in *Table 2*. In terms of

the total of publications, the USA contributed the most publications (26.3%) and played an important role in international cooperation networks. And the number of total publications was much higher than the Canada (Rank two in *Table 2*). Because the total of publications in the United States were much higher than those in other countries, all other metrics such as cooperation article and single country article were also ranked first. Although China ranked fourth for the number of total publications, it showed a higher percentage of single country article than other countries except USA. As for China, the number of single country article was 1211. Among the top 20 countries with the highest numbers of publication on the Web of Science between 1991 and 2020, there are thirteen countries in Europe, four countries in the Americas, two countries in Asia and one country in Oceania. Among the thirteen countries in Europe, six countries (Germany, UK, France, Spain, Norway and Russia) contributed more than 50 % to international cooperation.

Table 1. *The top 10 journals with the number of total publications and the category of journals related to the field of freshwater zooplankton between the 1991 and 2020 in the Web of Science*

Journal	TA (%)	IF	TC
Hydrobiology	1146 (4.4)	2.385	25221
Journal of Plankton Research	961 (3.7)	2.149	6746
Marine Ecology Progress Series	945 (3.6)	2.326	37574
Limnology and Oceanography	660 (2.5)	3.778	29383
Freshwater Biology	574 (2.2)	3.835	15145
Deep Sea Research Part II Topical Studies in Oceanography	514 (2.0)	2.697	11188
Progress in Oceanography	407 (1.6)	4.06	9511
Plos One	385 (1.5)	2.74	688786
Ices Journal of Marine Science	336 (1.3)	3.188	11699
Marine Biology	334 (1.3)	2.05	17198

TA: total article, IF: impact factor (2019), TC: total citations (2019)

Table 2. *Top 10 most productive countries in the publications related to the field of freshwater zooplankton between the 1991 and 2020 in the Web of Science*

Country	TA[1]	TA[1] R(%)	CA[1] (CR)	SA[1] (CR)	PCA (%)
USA	6986	1 (26.7)	2702 (1)	4284 (1)	38.7
CANADA	2400	2 (9.2)	1264 (4)	1136 (3)	52.7
GERMANY	2143	3 (8.2)	1380 (3)	763 (5)	64.4
P. R. CHINA	1819	4 (6.9)	608 (8)	1211 (2)	33.4
UK	1527	5 (5.8)	1502 (2)	25 (10)	98.4
FRANCE	1427	6 (5.5)	1047 (5)	380 (9)	73.4
SPAIN	1331	7 (5.1)	793 (7)	538 (7)	59.6
NORWAY	1271	8 (4.9)	835 (6)	436 (8)	65.7
RUSSIA	1225	9 (4.7)	395 (10)	830 (4)	32.2
JAPAN	1207	10 (4.6)	513 (9)	694 (6)	42.5

TA[1]: the total number of country articles, R: rank, CA[1]: the number of cooperation articles among the countries, SA[1]: the number of single country articles, PCA: the percentage of cooperation articles among the countries
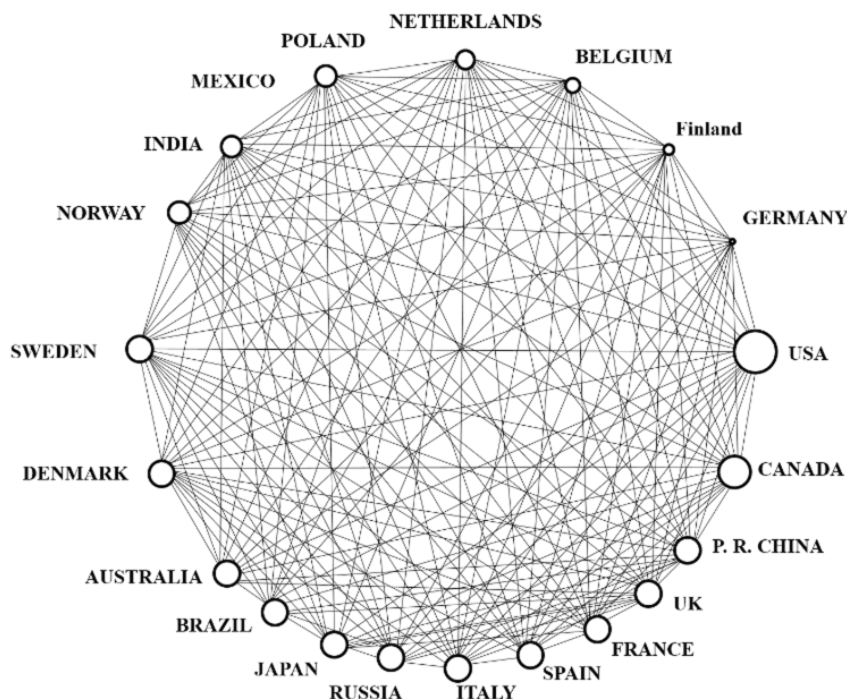
Figure 2. *Sequence and correlations of top 20 countries in the publications related to the field of freshwater zooplankton between the 1991 and 2020 in the Web of Science (The size of the circle in the figure shows a positive correlation with the number of publications)*

The details of top 10 productive institutions and their cooperation

The top 10 most productive organizations are listed in *Table 3*, three of which are from the USA, two from China, three from the European and two from Canada. The Centre national de la recherche scientifique (CNRS, France) topped the list with 961 publications and 960 cooperation articles. And the number of total publications of Chinese Academy of Sciences (China) was 696, ranking sixth in the list. Furthermore, as depicted in *Table 3*, most of the institutions were mainly dependent on the international cooperation, only the Fisheries Oceans Canada, Canada and NOAA, USA on a single publication with about ten percentages.

The sequence and correlations of top 20 keywords from freshwater zooplankton publications

The correlations of top 20 keywords from freshwater zooplankton publications are shown in *Figure 3*. As depicted in the *Figure 3*, the keyword "zooplankton" was strongly correlated with the "responses", "phytoplankton", "food web", "biodiversity" and "distribution". The keyword "biodiversity" was strongly correlated with the "species", "phytoplankton" and "zooplankton". The keyword "food web" was strongly correlated with the "phytoplankton", "species" and "zooplankton".

The uptrend and other trends of top 50 keywords from freshwater zooplankton publications

Figure 4 shows the top 50 keywords for uptrend and other trends, which can be classified into the following four types: (1) Research region, including "freshwater",

"river" and "surface waters". (2) Research contents, including "zooplankton", "rotifera", "water quality", "food web", "organic carbon, "growth", "species", "distribution", "phytoplankton", "trophic structure", "community", "equilibrium", "distribution", "biomass", "stationary distribution" and so on. (3) Environments, including "ecological quality", "nutrients", "water quality", "pollutions", "eutrophication", "heavy metal", "water quality", "pollutions", "climate change", "aquatic environment", "environmental fluctuations", "nutrient limit", "river connectivity" and so on. (4) Research methods, including "sampling", "model", "monitor", "dynamical analysis" and biological evalution".

Table 3. *Top 10 most productive institutions in the publications related to the field of freshwater zooplankton between the 1991 and 2020 in the Web of Science*

Institutions	TA^2	TA^2 R	CA^2 (CR)	SA^2 (CR)	S (%)
CNRS, France	961	1	960 (1)	1 (5)	0.1
National Oceanic Atmospheric Admin, USA	901	2	890 (2)	11 (4)	1.2
Russian Academy of Sciences, Russian	899	3	886 (3)	13 (3)	1.4
Helmholtz Association, Germany	832	4	832 (4)	0 (6)	0
University of California System, USA	795	5	787 (5)	8 (5)	1.0
Chinese Academy of Sciences, China	696	6	695 (6)	1 (5)	0.4
Fisheries Oceans Canada, Canada	582	7	527 (8)	55 (2)	9.5
NOAA, USA	530	8	470 (10)	60 (1)	11.3
Chinese Academy SCI, China	529	9	529 (7)	0 (6)	0
CSIC, Canada	513	10	512 (9)	1 (5)	0.2

TA^2: the total number of institution articles, R: rank, CA^2: the number of cooperation articles among the institutions, SA^2: the number of single institution articles, S: percentage of single institution articles
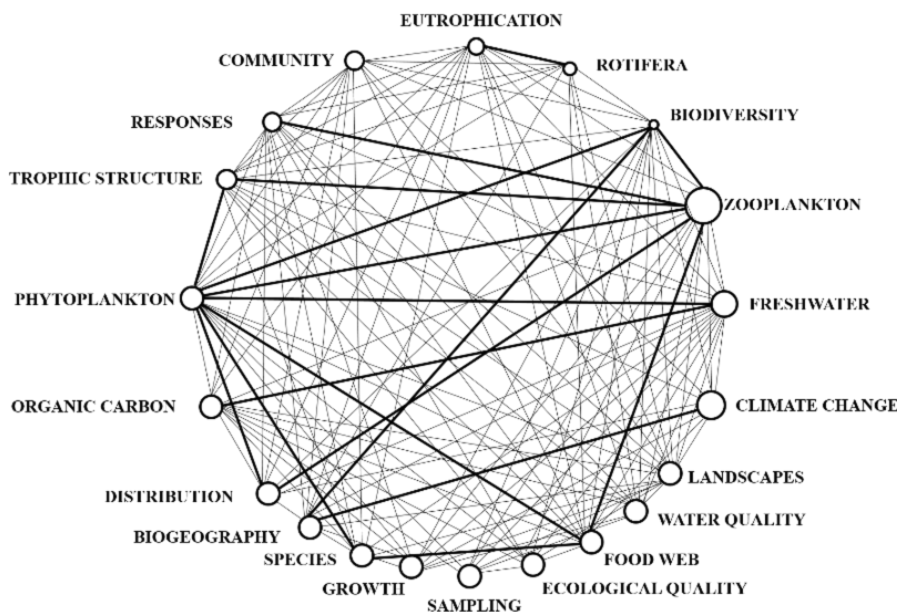
Figure 3. *Sequence and correlations of top 20 keywords in the publications related to the field of freshwater zooplankton between the 1991 and 2020 in the Web of Science (The size of the circle in the figure shows a positive correlation with the frequency of keywords)*
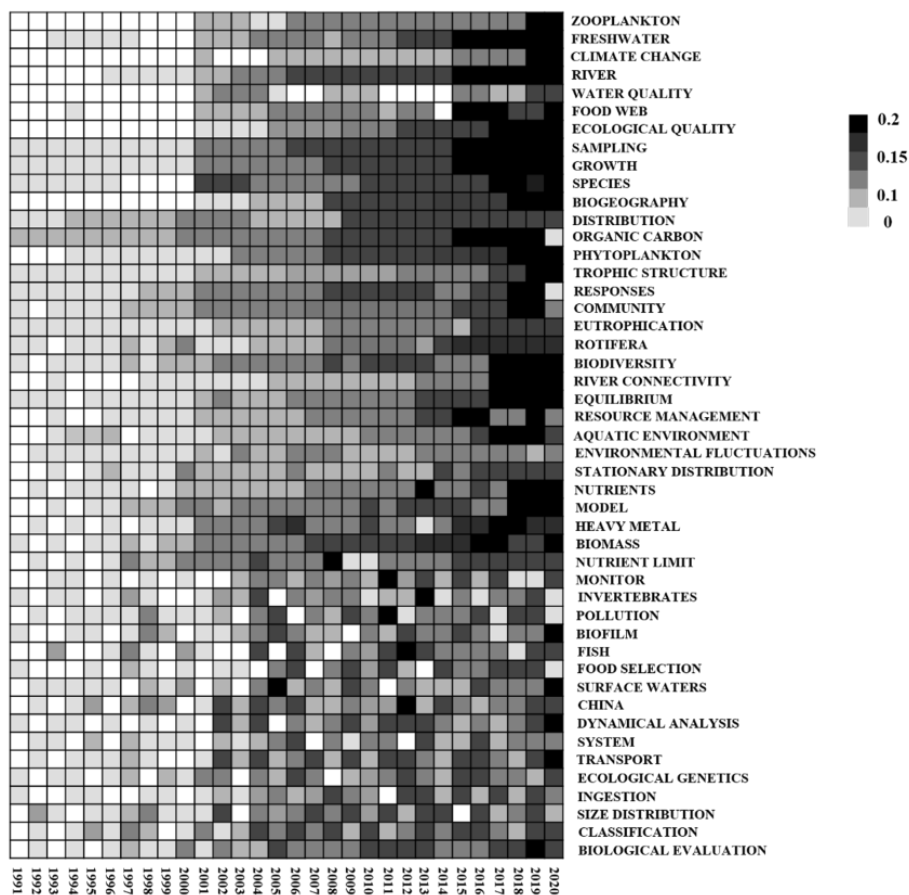
Figure 4. Top 50 keywords with ascending trend in the publications related to the field of freshwater zooplankton between the 1991 and 2020 in the Web of Science. (Full spelling of all keywords): zooplankton, freshwater, climate change, river, water quality, food web, ecological quality, sampling, growth, species, biogeography, distribution, organic carbon, phytoplankton, trophic structure, responses, community, eutrophication, rotifera, biodiversity, river connectivity, equilibrium, resource management, aquatic environment, environmental fluctuations, stationary distribution, nutrients, model, heavy metal, biomass, nutrient limit, monitor, invertebrates, pollutions, biofilm, fish, food selection, surface waters, China, dynamical analysis, system, transport, ecological genetics, ingestion, size distribution, classification, biological evaluation)

Discussion

Output trend of publications

As the above data depicted, the number of publications on the Web of Science showed a gradual upward trend between 1991 and 2020, which was consist with the growth trend in other research areas (Zhang et al., 2010; Yi and Jie, 2011; Liao and Huang, 2014; Beskaravainaya and Kharybina, 2018; Seftel, 2019). Particularly since 2001, the number of publications have been an extremely rapid growth trend, possibly due to the environmental pollution problems and shortages of traditional energy sources, and many countries had invested significant funds and implemented significant supportive policies for the sustainability of the development of natural water resources. For example, the EU Water Framework Directive (2000−2015a) provided a framework for the sustainable

development of natural waters. Although the guidelines came into effect during different periods among the countries, their impact on the natural waters of the future was enormous.

Influencing factors of the total publications of journals

The impact factors (IFs) are put forward by E. Garfield in 1972, and have become the universal evaluation index of journals in the world (Lee et al., 2009), which are not only an index to measure the practicability and demonstration of journals, but also an important index to measure the academic level of journals and the quality of publications. The greater the impact factor, the greater the academic influence and function of the journal (Bence and Oppenheim, 2004). Furthermore, the citation frequency of articles is also an important index to evaluate the quality and influence of publications. The quality and influence of highly cited papers are usually very great (Pasterkamp et al., 2007). However, based on the research results in our study, it can be found that the citation frequency of papers published in top journals with high impact factors is not always high, which proves that there is no necessary correlation between the citation frequency and impact factor of publications (Wang et al., 2018).

The effect of international cooperation on the number of publications

Under the background of economic and technological globalization, international cooperation has played an increasingly important role in promoting various research fields. Many researchers have regarded the international cooperation as one of the most effective ways to publish articles and evaluate scientific and technological cooperations between countries (Leeuwen et al., 2009; Chen et al., 2016; Duan et al., 2018). At the same time, there are many factors that affect international cooperation, which mainly includes geographical location, political relations, cultural differences and many other factors. Based on the statistics of cooperation and publication between countries in different continents, it can be seen that among the top 20 countries with the highest numbers of publication on the Web of Science between 1991 and 2020, there are thirteen countries in Europe, four countries in the Americas, two countries in Asia and one country in Oceania. Among the thirteen European countries, six countries (Germany, UK, France, Spain, Norway and Russia) contributed more than 50% to international cooperation. In comparison with the Asia and America countries, the European countries have a significant advantage in the number of cooperation and jointly published articles, mainly because of the issue of the Water Framework Directive in Europe, which provides an excellent opportunity for cooperative researches and publications among European countries and provides a good case for an international range of collaborative researches (Barth and Fawell, 2001; Borja et al., 2006; Leeuwen et al., 2009; Chen et al., 2016). The application of similar directives to the Americas and Asia, and even the world at large, could further strengthen linkages and cooperation between neighboring countries and lead to the development of a harmonized directive on water resources assessment and management strategies on a global scale in the future.

The importance and development trend of the research topic

Through the publications in the field of freshwater zooplankton on the Web of Science, we can find that the researches on freshwater environment have been a popular research topic in recent years. Freshwater environment usually refers to the inland freshwater

resources, including rivers, lakes, canals and underground water, which is vital to the entire ecosystem (Nnadozie and Odume, 2019; Choi et al., 2019; Cuassolo et al., 2020). Freshwater is the indispensable basis for the survival of human beings and the vast majority of organisms, and it has a function to protect biodiversity. Freshwater is an essential resource for irrigation in agricultural production, which determines the expansion and development of irrigation agriculture (Robin et al., 2006). Furthermore, the abundance of freshwater determines the development prospect of industry and the freshwater ecosystem plays an irreplaceable role and influence on pollution purification and climate regulation (Ruesink, 2005). However, the situation of global freshwater resources is not optimistic because of the impact of human production and living. The problems with serious water shortage and water quality deterioration have caused serious and irreversible impact on the natural hydrological conditions of freshwater and changed the quality of freshwater habitat, biological dynamics and ecological stability (Itahashi et al., 2019). In addition, due to the correlation between different aquatic ecosystems, the change of freshwater environment has also affected other aquatic ecosystems, mainly manifested by eutrophication of water environment, heavy metal ion pollution, high organic carbon content, poor stability of zooplankton community and other problems (Atamna et al., 2008; Raunio et al., 2011; Holland et al., 2011; Liu et al., 2020). In the recent years, many researchers have used many methods to solve the above problems. Firstly, the model method has been used to observe and predict the dynamics of zooplankton, and then feedback relevant information such as water quality, pollution level and eutrophication degree (Usha et al., 2006). Sampling method has been used to measure the stability and organic carbon of zooplankton community in real freshwater environment (Stéphane et al., 2004). The monitoring method has been used to collect real-time data and timely analyze the correlation coefficients of the freshwater environment so as to ensure the accuracy and timeliness of the experimental results (Ofukany et al., 2014). The dynamic method was used to analyze the changes and stability of the zooplankton community in the dynamic freshwater environment (Raquel et al., 2013).

The development trends in the field of freshwater zooplankton were reflected by analyzing the frequency of keywords. The results showed that the keywords with high frequency in recent years were as follows: climate change, water quality, food web, responses and so on. The climate change and the quality of freshwater ecosystem have become major research focuses because the quality of freshwater ecosystem has been in serious decline since the beginning of the 20th century due to frequent human activities. The zooplankton was used as a reliable environmental indicator in freshwater, including the streams and rivers, because of the short life cycle, high sensitivity to environmental change, easy sampling and wide distribution of zooplankton. Based on zooplankton to evaluate the degree of environmental pollution, the methods mainly include biomass, biological density, dominant species, zooplankton and other biological indexes and physical and chemical indexes. Recently, many researches have been conducted on the biological monitoring and biodiversity conservation in freshwater ecosystem according to freshwater indices and traits, in which the qualitative and quantitative way were widely applied to tackle a complex mixture of stressors. For example, the Prokopkin et al. developed a one-dimensional ecological model of the meromictic brackish Lake Shira (Russia, Khakasia). The kinetic fitting of oxygen and hydrogen sulfide and the simulated positions of the chemical incline and thermocline in the model are in good agreement with the data of zooplankton abundance, density and dominant species. This model opens the way for future investigations to examine various assumptions about the functioning

of the Lake Sheila ecosystem and to analyse management options for this economically important lake (Prokopkin et al., 2010). Furthermore, the zooplankton formed the base of the food web in many aquatic ecosystems, the abundance and composition of which determined the quantity and quality of food available to other aquatic life (Choi et al., 2012). The food webs were very complex in common so the stable isotope analyses were applied to trace the origin and transfer of organic matter in aquatic food webs (Careddu et al., 2015), which can provide insight and build the trophic relationships among organisms. In recent years of researches, the eutrophication and humification impacted nutrient cycles and the efficiency of carbon transfer in the planktonic food webs (Karpowicz et al., 2020a). Zooplankton are an important link between trophic levels in aquatic ecosystems, and their response to organic carbon is likely to have broad implications for lake food webs (Bowszys et al., 2020). A fundamental question regarding energy flow in rivers and streams is whether the basal component of the food web is predominantly driven by allochthonous or autochthonous sources (Guo et al., 2016). Although many researches have been conducted and proved the terrestrial sources were mainly fuel stream food webs, the widespread use of biochemical tracers in the recent years has challenged the view of dominant terrestrial sources, and highlighted the importance of zooplankton food sources in freshwater food webs (Pitt et al., 2009). Based on studies using a number of biochemical tracers, the nutrients of zooplankton have been demonstrated to be the main basis of freshwater food webs (Ryan et al., 2013). Zooplankton based food chains are generally considered as an efficient method to transfer energy and carbon to higher trophic levels (Metillo et al., 2019).

The zooplankton can respond to changes in the water environment in a variety of ways. For example, the ecological response of zooplankton to reduced light is a measure of pollution in the aquatic environment (Williamson et al., 2020). The response of zooplankton communities with different population densities to different pesticides and insecticides (Chang et al., 2005). The response of zooplankton to nutrient enrichment and fish in shallow lakes (Vakkilainen et al., 2004). The zooplankton community has fast responses to oxygen stress in the aquatic environment (Karpowicz et al., 2020b). In a word, the response behavior of zooplankton to the aquatic environment can provide insights into the degree of pollution in the aquatic environment and other species diversity.

The present qualitative and quantitative methods in zooplankton

The production and life of human beings are closely related to climate change and the decline of water quality in freshwater ecosystem (Bollens et al., 2014). Since the 1990s, zooplankton research and comprehensive evaluation of freshwater ecosystem have been two important issues in zooplankton research. It is very necessary to study zooplankton systematically. Firstly, zooplankton is an important bait for fish and other economic animals in the upper and middle waters, which is of great significance to the development of fisheries. Secondly, because the distribution of many zooplankton is related to climate, zooplankton can be used as a sign of warm or cold current changes (Keister et al., 2012). Thirdly, due to eutrophication, many dominant populations of zooplankton in freshwater can be used as indicators of water pollution (Wei et al., 2017). Because of the above reasons, many new identification methods of zooplankton in freshwater environment have been developed and applied all over the world (Medellin and Escribano, 2013; Uusitalo et al., 2016; Berges et al., 2020). A part of them are quantitative research methods, which mainly studies the biomass and diversity index of zooplankton in

freshwater environment (Tsuboko and Burton, 2018). The other part of them are the qualitative research methods, which are based on the characteristics, composition, spatial distribution and dominant species of zooplankton community (Ramdani et al., 2009). However, the results obtained by these two methods alone are often not satisfactory because they often ignore the impact of complex pressure factors on freshwater zooplankton. And the combination of qualitative method and quantitative methods can better deal with the complex mixed source pressure (Wang et al., 2017). In addition, compared with the traditional classification analysis method, the combination of qualitative and quantitative analysis can better transform the different classification components of geographical regions into similar complementary features. According to the results of this study, the common qualitative and quantitative research methods used in the field of freshwater zooplankton in the Web of Science from 1991 to 2020 are as follows: (1) Sampling; (2) Model; (3) Monitor (4) Dynamical analysis, which can provide a reference for the development and utilization of freshwater plankton germplasm resources in the future (Ringelberg et al., 2003; Morley et al., 2012; Woods et al., 2015; Li et al., 2017).

Application significance of integrated technology

Zooplankton refers to the small aquatic animals suspended in the water, which can't produce organic matter by themselves in the name of heterotrophic invertebrates and chordate larvae, and together with phytoplankton constitute plankton. Zooplankton which can participate in the decomposition and circulation of organic matter in aquatic ecosystem through their own excretion and secretion, not only feed on phytoplankton, bacteria and debris in water, but also be preyed on by fish and other aquatic animals (Day et al., 1990; Lochmann et al., 2007). Because many zooplankton species are very sensitive to pollutants, they can be used as indicators to monitor and evaluate water quality (Hallanger et al., 2011; Nizzetto et al., 2012; Peng et al., 2018). Zooplankton can bio-accumulate and transfer pollutants, playing an important role in ecotoxicology and water environmental protection (Fisk et al., 2001).

In addition to the traditional fixed-point sampling method, with the advance of science and technology, many new freshwater zooplankton detection technologies have realized the organic combination of micro detection and macro detection and promoted the development of freshwater zooplankton research. Among them, the most common micro-techniques include PFU artificial matrix method, which is easy to operate and suspend under water, not affected by water depth, water quality and water flow velocity (Xu et al., 2005; Jiang et al., 2007). It can avoid the influence of macro-zooplankton and other invertebrates on zooplankton measurement and ensure the authenticity of test results. Furthermore, the freshwater zooplankton can affect all aspects of freshwater, seawater and terrestrial ecosystems to a great extent because of the freshwater zooplankton plays an important part in the food web (Pereira et al., 2007). In order to better trace and analyze the specific situation of aquatic ecological environment, stable isotope analysis of carbon and nitrogen has been successfully applied to trace the source and transfer of organic matter in aquatic food webs, providing a comprehensive view of time and space for the nutritional relationship between organisms (Hoeinghaus et al., 2011). By tracing the transfer and transformation process of isotopes in the food chain, we can accurately analyze and locate the correlation coefficient of freshwater zooplankton, so as to investigate the aquatic environmental indicators such as water quality, eutrophication degree, environmental fluctuation, nutrient structure and nutrient limit (Logan et al.,

2008). And the stable carbon and nitrogen isotope analysis method can not only trace the transfer and transformation process of freshwater zooplankton, but also challenge the view of the main terrestrial sources, and highlight the importance of zooplankton in the stream food web. The stable carbon and nitrogen isotope analysis showed that freshwater zooplankton is an important component of food web in aquatic ecosystem (Robson et al., 2016). In addition, the dominant community species and structure characteristics of freshwater zooplankton are very important to study the ecological structure, stability and pollution degree of freshwater environment. It is very necessary to find out the gradient relationship between freshwater zooplankton and freshwater environmental parameters, providing suggestions for the management and development of freshwater resources and environment in the future.

Conclusion

The number of publications on Web of Science showed a gradually increasing trend from 1991 to 2020, which was closely related to the strong support and mutual cooperation of the government. For example, the EU Water Framework Directive provides excellent opportunities for collaborative researches and publications among European countries, and a good case for collaborative research on an international scale. The adoption of similar directives among neighboring countries throughout the world could further strengthen ties and cooperation among neighboring countries, with the aim of gradually developing a unified directive on water resource assessment and management strategies on a global scale.

The impact factor (IF) of journals is related to a certain extent to the number of publications and their cited frequencies. And the freshwater zooplankton is the main food source of many aquatic animals as indicators to monitor and evaluate water quality, which plays an important role in ecotoxicology and water environmental protection. With the progress of science and technology, there are many new freshwater zooplankton detection technologies. Among them, the most representative technologies are PFU artificial matrix method and stable isotope analysis of carbon and nitrogen, which can not only combine qualitative and quantitative methods to deal with complex pressure source mixture, but also realize the organic combination of micro and macro with highly accurate results. By tracing the transfer and transformation process of isotopes in the food chain, we can accurately analyze and locate the correlation coefficient of freshwater zooplankton, so as to investigate the aquatic environmental indicators. And the stable carbon and nitrogen isotope analysis method also shows the freshwater zooplankton is an important component of food web in aquatic ecosystem. And the dominant community species and structure characteristics of freshwater zooplankton are very important for studying the ecological structure, stability and pollution degree of freshwater environment. It is very necessary to find out the gradient relationship between freshwater plankton and freshwater environmental parameters, providing suggestions about the management and development of freshwater resources and environment in the future.

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