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RESEARCH ARTICLE OPEN ACCESS

A review of the effects of salinity on zooplankton: avisualization based on CiteSpace

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Abstract:
This paper employed the bibliometric method using CiteSpace visualization software to comprehensively and systematically analyze the research hotspots and frontier trends of the effect of salinity on zooplankton based on the publications in the Web of Science Core Collection during 1994-2023. The results showed that research in this field began in 2004 and has shown an overall increasing trend. Researchers from the United States and China are more active in this field, and Europe has a larger proportion. Salinization, egg production, and community structure were the core directions in this field, and the research developed into three stages.
Keywords: salinity; zooplankton; CiteSpace; bibliometrics

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I. Introduction

As primary consumers in the food chain, zooplankton feed on bacteria, debris, and phytoplankton, which can alter phytoplankton community structure and further affect aquatic ecosystem function(Duggan, Green, and Shiel 2002). Thus, zooplankton plays an important role in water ecosystems and are essential in maintaining the biological balance of water environments (Li et al. 2019). The response of zooplankton to environmental factors is critical for ecological understanding and management.Nowadays, with climate change, the intensification of global warming, glacier melting, sea level rise, and the increasingly serious intrusion of seawater, the impact of salinity on zooplankton has been gradually addressed(Di Lorenzo et al. 2008; Araújo et al. 2015; Yuan et al. 2020).However, studies on the effects of salinity on zooplankton can be divided into several aspects, such as different time periods, different types of water bodies, different research objects (communities or individuals), different models and predictions, and so on.The literature review can help researchers quickly grasp the research content and progress in this field, which is of great significance.

The goal of this work is to give a comprehensive and systematic scientometric review of the research on the influence of salinity on zooplankton. More particularly, our research focuses on the network of institutional cooperation, co-authorship, and co-occurring keywords derived from CiteSpace, a visualization tool that analyzes references gathered from the Web of Science Core Collection (WoSCC). As a result, knowledge domains, quantified research patterns, intellectual structure, and emerging trends in this field can be explored, which is beneficial for obtaining more accurate and complete information as well as providing insights into research topics and trend evaluation over time from various perspectives. This article's strategy and results may be useful for future research as an alternate display of research progress.

II. MATERIALS AND METHODS

2.1. Collection of publications

The publication was retrieved from the Web of Science Core Collection (WOSCC): Science Citation Index Expanded (SCI-E),which is regarded as the most important and most frequently used scientific database in most fields(Ouyang et al. 2018).The search strategy could be described as the following: Topics = (“zooplankton” and “salinity”), time span = 1994–2023, and language = English.We gathered 2075 publications on this topic based on the aforementioned criteria and performed a preliminary analysis.Although algal studies have been ongoing sincethe early 20th century(Sha et al. 2021), the effect of salinity on zooplankton has only begun in the last 20 years. Therefore, we concentrated on reviewing the pertinent literature from 2004 through 2023.

2.2. Analysis of publications

Chen et al. (Chen, Ibekwe-SanJuan, and Hou 2010)created CiteSpace, a piece of software for doing scientometric analysis, which is used to detect and visualize emerging patterns and developments in the world of scholarly publishing. It can highlight ground-breaking and well-known scientific articles as well as highlight the dominant themes in the entire area (Wu et al. 2019).In this review, the 1-year time interval was used to analyze individual networks to form an overview of how the scientific field has been evolving over the years.To identify study characteristics and developing trends on the impacts of salinity on zooplankton, an analysis of cooperative and co-occurrence networks as well as co-cited ones with the frequency, centrality, and burst of authors, institutions, and keywords will be undertaken by CiteSpace (version 6.1 R6).

III. RESULTS AND DISCUSSION

3.1. Characteristics of publication outputs

There were 2075 publications about the relationship between salinity and zooplankton on the WOSCC from 2004 to 2023 (Fig. 1). These publications include three main document types: Article, Review, and Proceedings paper, with "Article" accounting for more than 91% of total publications.Although the concept of critical salinity has been proposed and studied for decades, the relationship between salinity and zooplankton had not been studied in detail until 2004, when there was a sudden increase in the number of publications. From 2004 to 2022, the number of publications has generally increased, especially in 2020, when it reaches a maximum of 154. Since only statistics up to 28thJune 2023 were tallied when this article was written, the lower number of publications in 2023 cannot be interpreted as a sign that this field is becoming less popular. The number of publications in 2023, on the other hand, is not expected to show a discernible decrease trend based on the 62 publications in half a year.The increasing publication number not only showed the field's evolving understanding but also was to do with researchers studying the relationship between salinity and zooplankton as a result of climate change.

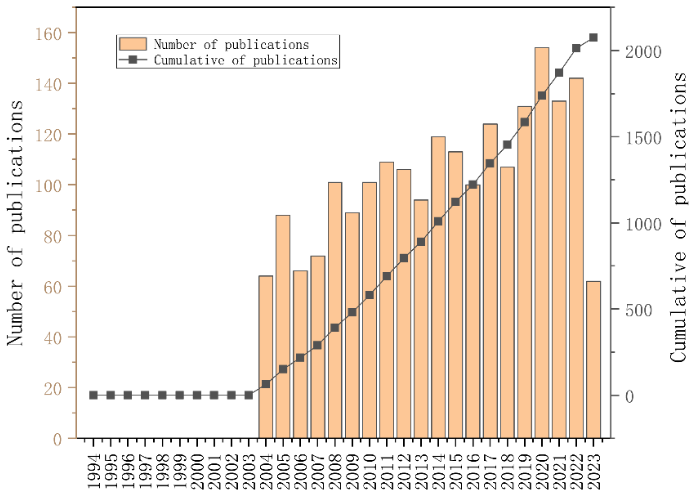

Fig. 1. The number of publications in each year and the cumulative number of publications from 2004 to 2023.

3.2. Cooperation network analysis

3.2.1. Author analysis

The total number of authors related to all 2075 articles was 6919. The average number of authors per article was 3.3. The most productive authors were Hwang Jiang-Shiouwith 14 articles, followed by Relyea Rick A with 12 articles, Hintz William D with 10, and Arnott Shelley E with 10. The top 12 productive authors were listed in Table 1.

Table 1 The top 12 productive authors.

Name	Total publication	Name	Total publication
Hwang Jiang-Shiou	14	Souissi Sami	9
Relyea Rick A	12	Schuler Matthew S	9
Hintz William D	10	Jeppesen Erik	8
Arnott Shelley E	10	Ayadi Habib	7
Dvoretsky Alexander G	9	Perissinotto Renzo	7
Dvoretsky Vladimir G	9	Bollens Stephen M	7

The cooperation network of authors was shown in Fig. 2., the nodes were 692, the edges were 344, and the density was 0.0014. According to Fig.2., Hwang Jiang-Shiou had the maximum number of publications and had higher cooperation with Souissi Sami, who published 9 articles from 2007 to 2013.

Furthermore, the academic community that revolved around Relyea Rick A, which includes Hintz William D, Schuler Matthew S, Mattes Brian M, and others, has published more than 36 publications, demonstrating the team's significant impact in this field. Additionally, Arnott Shelley E completed 10 publications without strong connections with other researchers. From a global perspective, most researchers mainly conduct small-scale independent research, indicating that most researchers in this field are widely distributed and relatively independent.

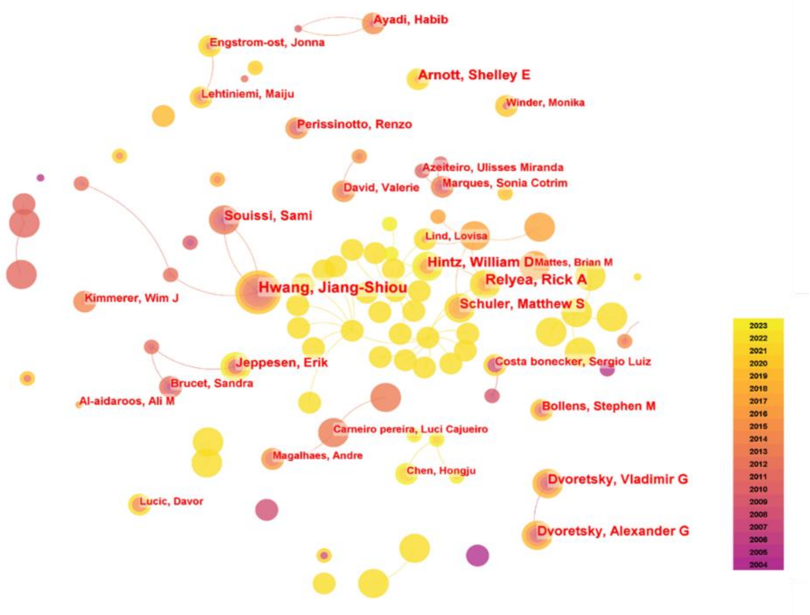

Fig. 2. Network of co-authors

3.2.2. Institutions analysis

According to statistics on the institutions to which the authors belong, the 2075publications came from 1830 institutions.The Chinese Academy of Sciences (Chinese Acad Sci) ranked first in the number of publications, with 63 publications, accounting for 3.04% of the total publications (Table 2). The National Oceanic and Atmospheric Administration (NOAA) and the Russian Academy of Sciences (Russian Acad Sci) had 58 publications and 48 publications respectively, accounting for 2.80% and 22.31% of the totalpublications.The top 14 institutions came from 9 countries, of which 4 research institutions belong to America, with a total of 144 papers, accounting for 6.94% of the total publications, and3 research institutions belong to China, with a total of 111 papers, accounting for 5.35% of the total publications, which showed scholars in the United States and China were more active in this field. In addition, the total number of publicationsin European countries was 163, accounting for 7.86%, which showed that Europe's contribution to this field cannot be ignored.

Table 2 The top 14 institutions.

Rank	Institution	Count	The proportion of Publications /%	Centrality
1	Chinese Acad Sci	63	3.04	0.1
2	NOAA	58	2.80	0.15
3	Russian Acad Sci	48	2.31	0.03
4	Univ Maryland	34	1.64	0.1
5	Univ Washington	32	1.54	0.09
6	CSIC	25	1.20	0.06
7	Fisheries & Oceans Canada	25	1.20	0.04
8	Univ Chinese Acad Sci	25	1.20	0.01
9	Natl Taiwan Ocean Univ	23	1.11	0.09

10	Univ Coimbra	23	1.11	0.04
11	Aarhus Univ	23	1.11	0.12
12	Univ Fed Rio de Janeiro	22	1.06	0
13	CNRS	22	1.06	0.1
14	San Francisco State Univ	20	0.96	0.05

From the cooperative relationship of research institutions and the centrality (Fig. 3.), in the top 14 institutions, NOAA with the greatest centrality0.15, and Aarhus University(Aarhus Univ) with the second greatest centrality 0.12 had frequent cooperation and communication with other research institutions. Chinese Acad Sci, University of Maryland(Univ Maryland),and Centre National de la Recherche Scientifique(CNRS) with a centrality of 0.1 were all the core research institutions and occupied important positions in this field.

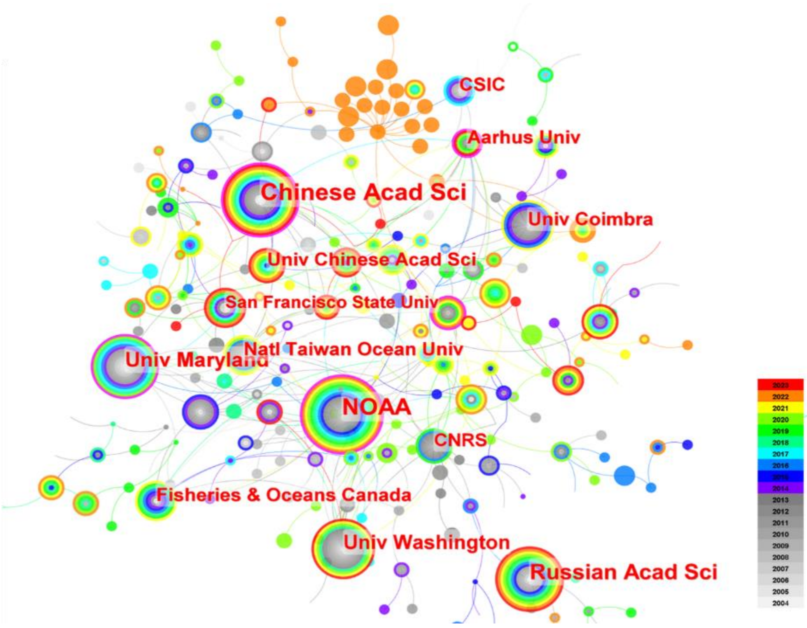

Fig. 3. Network of institutions.

3.3. Hot research topics

Keywords are highly refined and summarize the article's core content, and their frequency can reflect the research direction and content of a specific field. According to the analysis of keywords from 2075 publications, a total of 564 keywords were collected. The analysis showed that in this field, the top 5 keywords with the highest frequency were zooplankton, salinity, abundance, phytoplankton, and dynamics (Table 3), while the top 4 centrality keywords were eutrophication, diversity, copepod, and food web.

Table 3 The top 10 keywords.

Rank	Keyword	Count	Centrality
1	zooplankton	635	0.01
2	salinity	240	0.05
3	abundance	231	0.04
4	phytoplankton	214	0.04
5	dynamics	209	0.02
6	variability	209	0.04
7	temperature	196	0.03
8	community structure	192	0.05
9	water	186	0.05
10	community	185	0.03

Keywords were clustered into 8 clusters including #0 salinization, #1 egg production, #2 community structure, #3 sea, #4 mangrove, #5 diel vertical migration, #6 gelatinous zooplankton, and #7 stable isotopes (Fig. 4.). The keywords from 2004 to 2007 were mainly eutrophication, fresh water, population dynamics, and food web, which about the effect of increased salinity caused by water eutrophication on zooplankton community(Gasol et al. 2004; Marques et al. 2007; Nielsen et al. 2007; Sarma et al. 2006). The keywords from 2008 to 2017 were crustacea,crustacean zooplankton,salinity tolerance, indicator,daphnia magna, and brine shrimp, indicating the effects of salinity on specific species have been extensively studiedand find out indicators in different environments(Gökçe and Özhan Turhan 2014; Brucet et al. 2009; Ghannay et al. 2015; Heine-Fuster et al. 2010; Jernberg, Lehtiniemi, and Uusitalo 2017). The keywords from 2018 to 2023 were connectivity,estuarine system,functional diversity,andearth system model, indicating the study of salinity on zooplankton turned to community function and model prediction(Xiao et al. 2020; Nandy and Mandal 2020; Setubal et al. 2020).

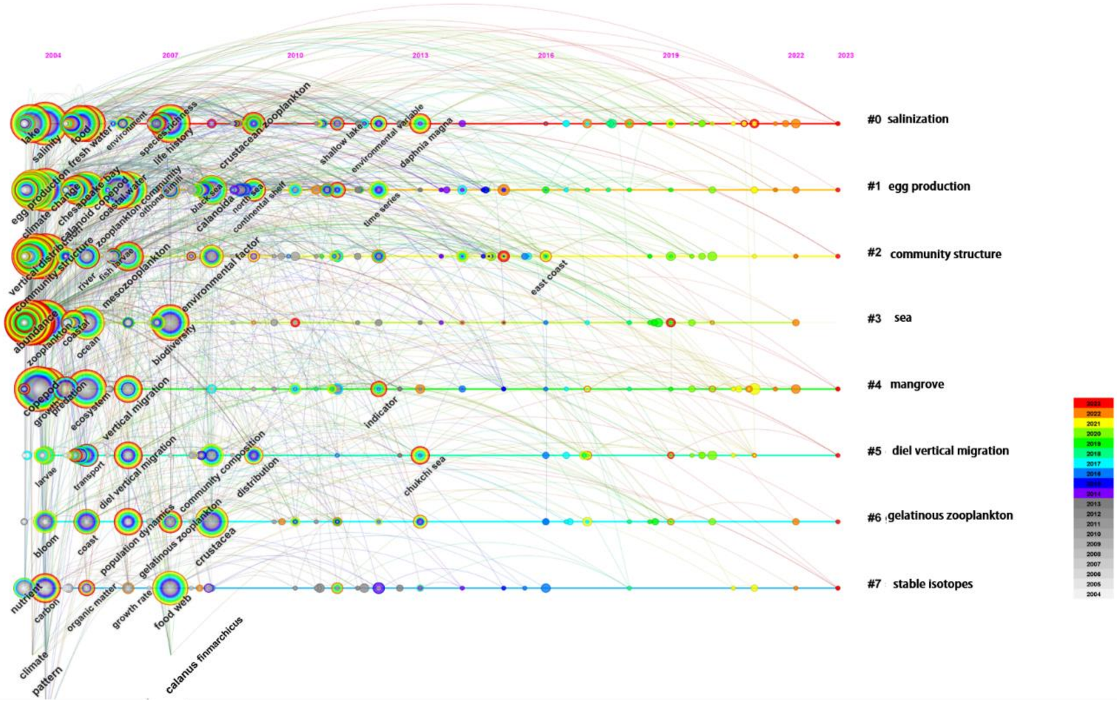

Fig. 4. Timeline of the keyword.

IV. Conclusions

This study provided a thorough review of the relationship between salinity and zooplankton in the past 20 years by the scientometric analysis and elaborates on the research progress of the major hotspots during this period. The research about the effect of salinity on zooplankton has not been paid attention to until 2004, although the critical salinity concept was proposed in the early 20th century. Current research shows that the effect of salinity on zooplankton has been focused on globally in recent decades due to ongoing global warming, sea levels rising, and seawater invasion, and it may become more serious in the coming decades. This analysis provided a comprehensive picture of the relevant literature and research directions. These findings will be useful for future research on the effect of salinity on zooplankton.

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