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Research trends and content analysis of ocean literacy studies between 2017 and 2021

Bulent Cavas[1]*, Sermin Acık[2], Simge Koc[1] and Mısra Kolac[2]

[1]Buca Faculty of Education, Dokuz Eylul University, Izmir, Türkiye, [2]Institute of Marine Sciences and Technology, Dokuz Eylul University, Izmir, Türkiye

Ocean literacy (OL) refers to the ability of citizens to understand and explain the concepts and phenomena related to the oceans, and leads them to positive behavioral change for the protection and sustainability of the oceans. The study presents a bibliometric analysis of ocean literacy-based studies published between 2017 and 2021, in order to provide more meaningful information about (a) the academic journals that mostly publish ocean literacy studies, (b) the content analysis of the articles, (c) country rankings over the years (d) the keywords mostly used and (e) the funding source. The Web of Science (WoS) and Scopus databases were used to find ocean literacy-based articles. Seventy-nine articles from forty ocean literacy academic journals covered by WoS and Scopus were carefully selected using predefined criteria. The results revealed that most of ocean literacy-based articles were published in the Frontiers in Marine Science journal (n=23). The countries that published the most ocean literacy-based articles were UK, Italy, Canada, USA, and Portugal. Most of the studies were supported by governmental budgets (n=44). The most popular concepts in ocean literacy-based studies included "Global OL Perspectives'', "Sustainability", "Citizen Science", "Students' OL Improvement", "Measuring and Evaluating Students and Teachers' OL", "Stakeholders' Effects on OL", "OL Based Books-iBooks-Textbooks" and "Individuals' Affective Domain on OL". By considering the large number of ocean literacy-based articles published in academic journals indexed in WoS and Scopus, this article can contribute significantly to ocean literacy studies and informed and responsible research, as well as to citizen input to policy development on ocean literacy.

KEYWORDS

ocean literacy, research trends, content analysis, journal articles, web of science, scopus

1 Introduction

It is essential to emphasize the significance of the oceans for our planet Earth. Undoubtedly, the oceans have a tremendous impact on all vital interaction. Covering more than 70% of the Earth's surface, our oceans produce over 50% of the oxygen in the atmosphere and provide necessary resources for human life (Costanza, 1999; Visbeck, 2018). Oceans make Earth habitable, influence our weather and climate, support a great diversity of life and ecosystems and play a vital role in energy circulations of the world (Pörtner et al., 2014). Due to the critical role of oceans in the human lives, the connection between the ocean and humans is undeniable (Payne et al., 2022). Unfortunately, many people are unaware of the importance of the ocean's and its intrinsic connection to life on Earth (Santoro et al., 2022).

Human unawareness of this connection increases the pressure on the marine ecosystem by some human-induced factors such as the proliferation of marine industries, environmental pollution, and overfishing which lead to the deterioration. Choosing to remain unresponsive to the destruction of marine environments, which have a significant impact our lives, can lead irreversible consequences in the future (Fauville et al., 2019a). Considering all the threats to the marine ecosystem, it is essential to be an "ocean literate individual" to take remedial steps towards sustainability. To protect the oceans in the face of these threats, attention should be drawn to ocean literacy to raise future generations as ocean-literate individuals (Cava et al., 2005; Fauville, 2017). An ocean-literate individual understands the importance of ocean awareness and is aware of negative situations related to the oceans. As an ocean-literate person, they contribute to the efforts to protect ocean health and strive to eliminate the negative effects. Ocean literacy empowers citizens to use their knowledge of the marine environment and awareness of its issues to communicate about the sea in a meaningful way and make informed and responsible decisions (Mokos et al., 2020a). As the solution to many environmental problems related to the world ecosystem lies in protecting, conserving, and using marine resources sustainably, citizens of all ages need to understand the connection between humanity and the ocean (Santoro et al., 2022).

Ocean literacy emerges as a term that aims to improve the ocean-human relationship and positively affect behaviors by raising awareness of individuals. The most common definition of ocean literacy currently in use was developed by the National Oceanic and Atmospheric Administration (NOAA). It focuses on understanding the influence of the oceans on human beings, as well as the impact of humans on the oceans. New trends also allow for different interpretations of the definition of ocean literacy. Paredes-Coral et al. (2021) explain it as a new term that will be effective in the process of positive change in the relationship of human behaviors on oceans. An ocean-literate person understands the fundamental concepts about the functioning of the ocean, can communicate about the ocean in a meaningful way; and can make informed and responsible decisions regarding the ocean and its resources (Cava et al., 2005; Paredes-Coral et al., 2021). Between 2002 and 2004, a decision was made to start an ocean literacy campaign to draw attention to the lack of ocean-related concepts in the K-12 curriculum

in the United States. Two guiding documents named "Ocean Literacy: The Essential Principles of Ocean Sciences K-12" and "Ocean Literacy Scope and Sequence for Grades K-12" emerged as a result of this campaign and help educators, curriculum and program developers create an effective education process (Schoedinger et al., 2010). The seven essential principles and forty-five fundamental concepts were identified as those needed to support the definition of ocean literacy (Network, 2013). The seven principles of ocean literacy (Table 1) are often used as a guide and a framework due to their decisive impact on studies in the ocean area (Fielding et al., 2019). The first principle, "The Earth has one big ocean with many features.", emphasizes the unique nature of sea water and views all the oceans on Earth as a single entity. It encompasses all the living and nonliving elements that make up the ocean. The interaction between the biotic and abiotic factors that come from the ocean can be explained by the second principle "The ocean and life in the ocean shape the features of the Earth ". The third principle, "The ocean is a major influence on weather and climate", focuses on how the formation of climate and weather events is affected by the heat and temperature differences between the ocean and atmosphere. The fourth principle, "The ocean makes the Earth habitable," explains the cyclic use of oxygen and the importance of photosynthesis reactions. The fifth principle, "The ocean supports a great diversity of life and ecosystems", highlights the biology of the oceans and their role as habitats for all kinds of living things, with an emphasis on deep ocean ecosystems. The sixth principle, "The ocean and humans are inextricably interconnected,", emphasizes the importance of sustainable interaction between humans and the ocean, and all its resources. The last principle, "The ocean is largely unexplored," explains that there are many unexplored parts of the oceans yet to be discovered, and it is recommended that people from different disciplines work together to explore these parts. These principles emphasize the importance and diverse characteristics of the ocean (National Marine Educators Association, 2010).

Being an ocean-literate citizen enables a deeper comprehension of the origins and effects of marine environmental challenges, facilitates informed decision-making in daily activities and leads to more informed participation in the discussion on the future of the oceans. (Fauville et al., 2018). Identifying this set of concepts was recognized as a major step toward empowering educators, scientists, and policy-makers to turn an ocean literacy vision into reality (Cava et al., 2005). In recent years, in addition, to the developments in the

TABLE 1 Seven Principles of Ocean Literacy (Cava et al., 2005).

No	Dimension
1	The Earth has one big ocean with many features.
2	The ocean and life in the ocean shape the features of the Earth.
3	The ocean is a major influence on weather and climate.
4	The ocean makes the Earth habitable.
5	The ocean supports a great diversity of life and ecosystems.
6	The ocean and humans are inextricably interconnected.
7	The ocean is largely unexplored.

USA, many efforts to integrate Ocean Literacy into important environmental issues have been executed worldwide. The European marine science community attempted international cooperation to advance ocean literacy in Europe. The first conference on ocean literacy in Europe was organized in 2012 by the European Marine Science Education Association (EMSEA), The Marine Board (MB) and its Communication Panel (MBCP) (Copejans et al., 2012). In 2015, the United Nations established 17 Sustainable Development Goals, among which SDG14 (Sustainable Development Goal-14) is about the ocean and its protection and sustainability. As a result of these developments, interest in ocean literacy has increased and this movement, which started with the aim of achieving an ocean-literate society in the USA (McKinley et al., 2023), has created an international impact by spreading around the world (McPherson et al., 2018; Paredes-Coral et al., 2021). With this impact, various types of research have emerged as a result of the concern about the future of the marine ecosystem and the increased interest in this field. According to Evans et al. (2021), the lack of access to the required knowledge, appropriate tools, and skilled human resources needed for ocean management remains a significant constraint for the protection and conservation of the marine environment in many regions. Similarly, Chambers et al. (2019), emphasize the growing complex and systemic challenges facing the ocean and call for an urgent need to increase the scale and effectiveness of approaches to marine conservation, including protecting and recognizing the value of all of its services. Additionally, government authorities have initiated the process of including the ocean in their national educational strategies, which is a major step towards advancing widespread knowledge of the marine environment and encouraging young people to pursue blue careers (Santoro et al., 2022). Regardless of countries, the awareness of the negative consequences of the global impact on the marine ecosystem has increased throughout the world. It is now understood by the public that all societies need to develop an understanding to eliminate the devastating effects experienced by the oceans, which are of great importance to the world's ecosystem. Although an ocean literacy program has already been identified as essential to increase awareness and knowledge, lead to informed decision-making, and trigger behavior changes, assessment of effectiveness will be essential to ensure objectives are met (Ashley et al., 2019).

It is very important to make a general assessment to determine what dimensions ocean literacy has reached in the global sense, to see the missing points, and to reveal the current situation. The purpose of this study is to give a 5 years overview of progress on the completion and documentation of studies on ocean literacy from 2017 to 2021 using bibliometric analysis. Five-year bibliometric studies are essential for several reasons. Firstly, they provide valuable insights into the evolving landscape of research and scholarly communication. By analyzing trends in citations, publication patterns, and authorship over this time frame, researchers and institutions can identify emerging areas of interest and measure the impact of their work. Secondly, these studies offer a means to assess the productivity and influence of researchers and institutions, aiding in decision-making processes for funding allocation, promotions, and collaborations. Lastly, 5-year bibliometric studies contribute to transparency and accountability in academia. They enable the evaluation of research

output against established goals and benchmarks, promoting a culture of continuous improvement and innovation within the scholarly community. In a rapidly evolving academic landscape, these studies serve as valuable tools for informed decision-making and progress assessment. The current study used 5 year bibliometric study, however, more than 5 year data will also provide more meaningful conclusions for the further studies.

There are some papers in which the authors used bibliometric analysis. Paredes-Coral et al. (2021) used bibliometric analysis in their research to describe the field's main features, including indicators of growth and research collaboration. In another study, Costa and Caldeira (2018) aimed to provide an overview of the research works' features. It also attempts to identify trends and gaps that could orient future studies. The study examined the articles published between 2017 and 2021, revealing the progress and popularity of the term ocean literacy in recent years and conducted a bibliometric analysis of the literature review using the Scopus and Web of Science (WoS) multidisciplinary databases. Furthermore, of the two publications mentioned, Costa and Caldeira (2018) cover publications from 2004 to 2017, while Paredes-Coral et al. (2021) cover the years 2005-2019. This study supports the other two articles and provides a general comparison of the global development of ocean literacy, the contributions of countries, content analysis, and which journals publish ocean literacy content. Additionally, more accurate comparisons can be made for the future since the process that is close to the present is examined within the scope of the study. From the point of view of originality, it was investigated in detail whether the publications related to ocean literacy received financial support and what the funding source was. Also, when previous studies are examined, it is seen that Turkey's score for publishing on ocean literacy is quite low. Working on this issue in our country will increase both awareness and cooperation.

1.1 Research questions:

1. Which journals have published ocean literacy-based articles in the last 5 years?
2. How was the content analysis of the articles published in journals between 2017 and 2021?
3. How did authors from different countries contribute to the publications of ocean literacy articles between 2017 and 2021?
4. How did the keywords of the published articles in journals vary between 2017 and 2021?
5. What was the funding source of ocean literacy publications between 2017-2021?

2 Methodology

In this study, systematic, bibliometric, and content analysis of published articles on ocean literacy were done in the last five years.

The following sections describe the analysis of the articles obtained from Web of Science and Scopus Databases.

2.1 The systematic analysis

Web of Science (WoS - webofscience.com) and Scopus (scopus.com) databases were used to access the published articles for the systematic analysis. Due to the reasonable availability of search filters, both databases were preferred to access ocean literacy-based articles. The keyword 'ocean literacy' was used to find ocean literacy-based articles on the search page of the database. After searching for ocean literacy, the years 2017-2021 were refined to obtain articles published in the last five years.

In the next step, Social Science Citation Index (SSCI), Science Citation Index (SCI), and Science Citation Index Expanded (SCIE) were refined in WoS. Although Emerging Sources Citation Index (ESCI)-type articles are included in the web of science database, they are excluded from this study. Additionally, articles such as editorials, mini-reviews, conference papers etc. were also excluded. Only Research Reports, Reviews, and Policy and Practice type articles were selected. The criteria for including "ocean literacy" in the title, abstract, or keywords of the studies were applied. Similar articles were found among the articles obtained from the Web of Science and Scopus databases. These publications were carefully sorted, and duplications were avoided.

For this analysis, we followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses [PRISMA] guidelines were followed (Page et al., 2021), and the details of screening and eligibility are presented in Figure 1.

2.2 The bibliometric analysis

Bibliometric analysis is used in many types of reviews (Barboza and Gimenez, 2015; Costa and Caldeira, 2018; Sun et al., 2012). It involves quantitative evaluation of scientific literature, including articles, books, conference proceedings, and patents. By employing bibliometric analysis, researchers can gain insights into various aspects of scholarly communication, such as productivity, impact, collaboration patterns, and research trends. The process of bibliometric analysis typically begins with the selection of a specific research topic or area of interest. Relevant bibliographic databases, such as Web of Science, Scopus, or PubMed, are then queried to gather relevant publications based on specific search criteria, such as keywords, authors, or journal titles. The resulting dataset is usually refined by applying inclusion and exclusion criteria, ensuring the inclusion of only pertinent publications. Additionally, bibliometric studies are effectively used to reveal trends and future perspectives between certain years. The details (titles, author names, countries, abstracts, keywords, aims, methods, findings, and results) of the articles identified through systematic analysis were entered into the Microsoft Excel program. The journals and the number of articles in the last five years were analyzed using MS Excel software. The methodology developed and used by Tsai and Wen (2005) and Lee et al. (2009) was selected to conduct the country analysis (Cavas, 2015).

Each paper is allocated one point. If a paper is published by more than one author, each comes from a different country, one point is divided into certain proportions for authorship from each participating country. For instance, if a paper is written by two authors, one from the UK and the other from US author, then the UK authorship gains a score of 0.6 while the USA authorship acquires a score of 0.4 for this particular paper. Using this method, the accumulated score for successful authorship from each country is calculated and compared by year, as well as by journal issue. Tsai and Wen (2005) (Table 2).

Detailed information for the accumulated score of each country is presented in Table 3.

In addition to the analysis described above, the keywords were also used to see the impact of ocean literacy studies over the years. WordClouds web application (wordclouds.com) was used to show results (de Oliveira et al., 2019).
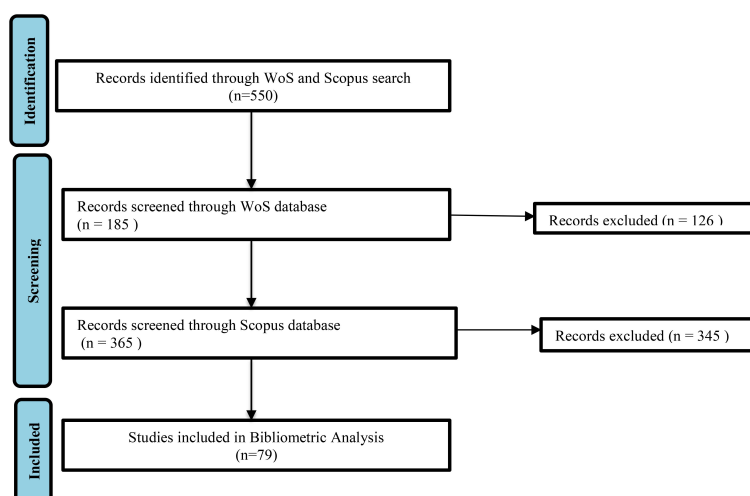

FIGURE 1
PRISMA Flow Chart (based on Page et al., 2021).

TABLE 2 Author's score allocation for multi-author research papers.

Number of Authors	Order of Specific authors					
	1	2	3	4	5	6
1	1					
2	0.60	0.40				
3	0.47	0.32	0.21			
4	0.42	0.28	0.18	0.12		
5	0.38	0.26	0.17	0.11	0.08	
6	0.37	0.24	0.16	0.10	0.07	0.06

2.3 The content analysis

A qualitative content analysis approach (Titscher et al., 2000) was used to provide explanations about the content of the 79 articles based on ocean literacy (Table 4). Determining categories in content analysis is a crucial step in the research process that involves systematically organizing and classifying qualitative data into meaningful and distinct categories. Content analysis is a research methodology used to analyze textual, visual, or audiovisual data to uncover patterns, themes, or relationships within the data. First, the research team carefully read these 79 articles. During this reading process, publication categories were determined by researchers at the first meeting (Downe-Wamboldt, 1992). Then, each researcher independently tried to place the articles in these determined categories. It was anticipated that each publication could belong to more than one category, and this criterion was taken into consideration in the categorical separation process. After three different meetings, the research team reached a consensus on which category or categories each publication should be placed in. Then, the number of publications in each category and their ratios were taken into account, and explanations were given in the results section. The process developed by Tranfield et al. (2003) was followed for data extraction, synthesis, report production, and recommendations.

3 Results

This study was conducted to reveal the systematic, bibliometric, and content analysis of the studies on ocean literacy between 2017 and 2021. The results of the study will be explained by considering the research questions.

3.1 Results for research question 1 (which journals have published ocean literacy-based articles in the last 5 years?)

A systematic and bibliometric analysis was conducted to analyze journals that have published ocean literacy-based articles between 2017 and 2021. The details of the analysis performed are presented in Table 5. As a result of the analysis, it was determined that a total of 79 articles were published in the journals between 2017 and 2021. It was

found that the journal with the highest number of ocean literacy articles (n=23) was Frontiers in Marine Science. The other journals that publish the most ocean literacy-based publications are Environmental Education Research (5), Sustainability (5), and Marine Policy (4). Table 5 provides detailed information such as the name of the journal, Indexing, and the number of articles based on ocean literacy between 2017 and 2021.

3.2 Results for research question 2 (how was the content analysis of the articles published in journals between 2017 and 2021?)

Ocean literacy studies were examined in 20 categories. Categories and reference articles are detailed in Table 4. Among these categories, "Global OL Perspectives" was determined as the most widely used content with 16 references and followed by "Sustainability Issues for OL" and "Citizen Science and OL" corresponding respectively 13 and 6 articles. The categories "Students' OL Improvement" and "Measuring and Evaluating Students and Teachers' OL" also have 6 articles each. The least used categories are: "Ocean Management for OL" (1 article) and "OL for Tourism" (2 articles) (Table 4).

3.3 Results for research question 3 (how did authors from different countries contribute to the publications of ocean literacy articles between 2017 and 2021?)

This part of study provides an overview of the contributions made by different countries to ocean literacy content between 2017 and 2021. It highlights the number of contributing countries each year, their respective scores, and identifies the countries with the highest and lowest contributions. Table 3 displays the contributions of countries in each year. In 2017, Sweden had the largest contribution with a score of 2,000, while Finland had the smallest contribution with a score of 0.015. The number of contributing countries increased from 10 in 2017 to 27 in 2020, showing a significant rise in diversity. Notable contributors varied each year, with countries like the USA, Taiwan, and Italy having the highest

TABLE 3 Country score for publishing OL based articles between 2017 and 2021.

2017		2018		2019		2020		2021	
Country	Score	Country	Score	Country	Score	Country	Score	Country	Score
Sweden	2,000	USA	1,210	Taiwan	4,000	Italy	2,428	Portugal	4,87
Greece	1,000	Portugal	1,010	UK	3,530	UK	2,032	UK	3,461
France	0,920	Canada	1,000	Ireland	3,000	USA	1,429	Australia	3,028
Canada	0,405	Australia	0,790	Italy	2,560	Canada	1,247	Greece	3,02
Netherlands	0,375	Italy	0,580	Canada	2,000	Croatia	1,124	Brazil	2,62
Spain	0,365	Sweden	0,445	Germany	1,570	Germany	1,019	Canada	2,39
Italy	0,150	S.Africa	0,420	Spain	1,510	Ireland	1,000	USA	2,07
Germany	0,070	Ireland	0,370	USA	1,370	Japan	1,000	Poland	1,75
Portugal	0,040	Denmark	0,070	Greece	1,120	Poland	1,000	Italy	1,41
Finland	0,015	Greece	0,040	Turkey	0,790	Slovenia	1,000	Taiwan	1
		Spain	0,030	Australia	0,770	Taiwan	1,000	Belgium	0,722
		UK	0,025	S.Africa	0,700	France	0,691	Switzerland	0,46
		Belgium	0,010	Sweden	0,420	Greece	0,428	Germany	0,432
				Japan	0,230	Mexico	0,067	Japan	0,32
				Portugal	0,150	Norway	0,044	Croatia	0,28
				Croatia	0,070	Belgium	0,029	Spain	0,22
				Estonia	0,070	Spain	0,021	Norway	0,22
				France	0,060	Australia	0,009	France	0,203
				S.Korea	0,050	Venezuela	0,009	N. Zealand	0,181
				Kenya	0,030	Brazil	0,002	B. Isles	0,1
				Vietnam	0,020	S. Africa	0,001	C. Verde	0,08
				Poland	0,010	New Caledonia	0,001	Estonia	0,07
						Senegal	0,001	Sweden	0,07
						Monaco	0,001	S.Korea	0,04
						Cape Verde	0,001	Cambodia	0,03
						Portugal	0,001	Kenya	0,03
						Kenya	0,001	Denmark	0,02
								Mexico	0,02
								Israel	0,019
								Morocco	0,014
								Egypt	0,01
								S. Africa	0,01
								Tunisia	0,006
								Vietnam	0,005
								Cyprus	0,001
								Malta	0,001

TABLE 4 The categories, category definition and reference information about the OL studies in the last five years (2017-2021).

No	Category	Category Definition	N	References
1	Global OL Prespectives	Articles with global OL perspectives, policies and benchmarks	16	Drakou et al. (2017); Evans et al. (2019); Chambers et al. (2019); McCauley et al. (2019); Barracosa et al. (2019); Fernández Otero et al. (2019); Marrero et al. (2019); Stewart (2019); Amaratunga (2019), Mokos et al. (2020a), Claudet et al. (2020); Evans et al. (2021); Cappelletto et al. (2021); Laffoley et al. (2021); Worm et al. (2021); Rölfer et al. (2021)
2	Sustainability issues for OL	Articles where sustainability is associated with OL	13	Fernández Otero et al. (2019), Mokos et al. (2020b), Ashley et al. (2019); Claudet et al. (2020); Koenigstein et al. (2020); Rossano and Calvano (2020); Penca (2020); Lin et al. (2020); Apostoloumi et al. (2021); Kenterelidou and Galatsopoulou (2021); Chang et al. (2021), Ferreira et al. (2021b); Rölfer et al. (2021)
3	Citizen Science and OL	Articles containing the Citizen Science approach	6	Matabos et al. (2017); Kelly et al. (2019), Kelly et al. (2022), Dalby et al. (2021); Kasten et al. (2021); Boaventura et al. (2021)
4	Students' OL Improvement	Articles containing studies on the development of students' OL levels	6	Fauville (2017); Dupont (2017); Ashley et al. (2019), Mokos et al. (2020b), Boaventura et al. (2021); Devenport et al. (2021)
5	Measuring and Evaluating students and teachers' OL	Articles about determining and evaluating students' OL levels	6	Mogias et al. (2019); Tsai and Chang (2019); Ashley et al. (2019); Realdon et al. (2019); Lin et al. (2020); Carvalho et al. (2021)
6	Stakeholders' Effects on OL	Articles examining stakeholders' views and contributions on OL	5	Heck et al. (2018); Lucrezi et al. (2019); Zunino et al. (2020); Fox et al. (2021), Ferreira et al. (2021a)
7	OL Based Books-iBooks-TextBooks	Articles containing the use and evaluation of books in terms of OL	5	McHugh et al. (2020); Aurélio et al. (2021); Mogias et al. (2021); Francis et al. (2021), Pantaleo (2021a)
8	Individuals' Affective Domain on OL	Articles examining the affective characteristics of students towards OL, such as motivation, interest, and career goals.	5	Lucrezi et al. (2018); Tsai et al. (2019); Ashley et al. (2019); Devenport et al. (2021); Schuman et al. (2021)
9	Teaching Environments for OL	Articles for organizing and improving teaching environments for OL	4	Fauville et al. (2018); Tsai (2019); Zielinski et al. (2021), Pantaleo (2021b)
10	Curriculum for OL	Articles with OL-based curriculum development and reviews	4	McPherson et al. (2018); McPherson et al. (2020), Pazoto et al. (2022), Chang et al. (2021)
11	The use of art for OL	Articles where art is used for OL and its effect	4	Dupont (2017); Michałowska (2020); Pantaleo (2021a); Pantaleo (2021b)
12	OL Based Survey Development	Articles including scale development studies to determine students' OL levels	3	Markos et al. (2017); Fauville et al. (2019b); Chang (2019)
13	Reviewing OL Studies	Articles that include studies analyzing and reviewing OL studies	3	Costa and Caldeira (2018); Stoll-Kleemann (2019); Paredes-Coral et al. (2021)
14	Social Media Usage for OL	Articles on the use of Social media for OL studies	3	Kopke et al. (2019); Kenterelidou and Galatsopoulou (2021); Carvalho et al. (2021)
15	Digital technologies for teaching OL	Articles on the use of digital technologies for OL Teaching	3	Andrews et al. (2018); Brennan et al. (2019); Fielding et al. (2019)
16	Deep Sea related issues for OL	Articles using the concept of Deep Sea as the main theme	3	Matabos et al. (2017); Salazar et al. (2019); Darr et al. (2020)
17	Game based education for OL	Articles exploring the use of games for teaching OL	3	Pantò (2019); Koenigstein et al. (2020); Rossano and Calvano (2020)
18	OL Based Educational Programmes	Articles on educational programs designed for teaching OL	3	Uehara et al. (2020); Winks et al. (2020); Sims et al. (2021)
19	OL for Tourism	Articles on the tourism dimension of OL	2	Albayrak et al. (2021), Garcia and Cater (2020)

(Continued)

TABLE 4 Continued

No	Category	Category Definition	N	References
20	Ocean Management for OL	Articles on ocean management	1	Dumała et al. (2021)

TABLE 5 Details of academic journals and the number of OL Based articles in the last five years (2017-2021).

No	The name of the journal	Indexing	The number of articles based on ocean literacy for last 5 years
1	Frontiers in Marine Science	WoS/ SCOPUS	23
2	Environmental Education Research	WoS/ SCOPUS	5
3	Sustainability	WoS/ SCOPUS	5
4	Marine Policy	WoS/ SCOPUS	4
5	International Journal of Environmental Research and Public Health	WoS/ SCOPUS	2
6	Ocean and Coastal Research	WoS/ SCOPUS	2
7	International Journal of Science Education	WoS/ SCOPUS	2
8	Australian Journal of Environmental Education	SCOPUS	2
9	The Journal of Ocean Technology	SCOPUS	2
10	Education Sciences	SCOPUS	2
11	Ecology And Society	WoS/ SCOPUS	1
12	Environment, Development and Sustainability	WoS/ SCOPUS	1
13	Frontiers in Environmental Science	WoS/ SCOPUS	1
14	ICES Journal of Marine Science	WoS/ SCOPUS	1
15	IEEE Access	WoS/ SCOPUS	1
16	Integrative and Comparative Biology	WoS/ SCOPUS	1
17	Journal of Biological Education	WoS/ SCOPUS	1
18	Journal of Marine Science and Engineering	WoS/ SCOPUS	1
19	Journal of Sustainable Tourism	WoS/ SCOPUS	1
20	Journal of the Marine Biological Association of the United Kingdom	WoS/ SCOPUS	1
21	Marine Pollution Bulletin	WoS/ SCOPUS	1
22	Mediterranean Marine Science	WoS/ SCOPUS	1

(Continued)

TABLE 5   Continued

No	The name of the journal	Indexing	The number of articles based on ocean literacy for last 5 years
23	One Earth	WoS/ SCOPUS	1
24	Reviews in Fish Biology and Fisheries	WoS/ SCOPUS	1
25	Sage Open	WoS/ SCOPUS	1
26	Science of the total Environment	WoS/ SCOPUS	1
27	Technology, Pedagogy and Education	WoS/ SCOPUS	1
28	Tourism Geographies	WoS/ SCOPUS	1
29	International Journal of Biodiversity Science, Ecosystem Services and Management	SCOPUS	1
30	Methods in Ecology and Evolution	WoS/ SCOPUS	1
31	International Journal of Learning, Teaching and Educational Research	SCOPUS	1
32	Rendiconti Online Societa Geologica Italiana	SCOPUS	1
33	International Information and Library Review	SCOPUS	1
34	Oceanologia	WoS/ SCOPUS	1
35	Applied Environmental Education and Communication	SCOPUS	1
36	Aquatic Conservation: Marine and Freshwater Ecosystems	WoS/ SCOPUS	1
37	International Research In Geographical And Environmental Education	SCOPUS	1
38	Ethics In Science And Environmental Politics	SCOPUS	1
39	Literacy Research and Instruction	SCOPUS	1
40	Multimodal Communication	SCOPUS	1

contributions in different years. In 2021, Portugal had the highest contribution with a score of 4.87, and the total number of contributing countries reached 36. The paragraph concludes by mentioning that the overall scores for all five years are presented in Table 6, which includes a total of 46 contributing countries. The United Kingdom had the highest total score of 9,048, followed by Italy and Canada. On the other hand, Monaco, New Caledonia, Senegal, Cyprus, and Malta had the lowest contributions, each with a total score of 0.001. This information provides a snapshot of the countries' involvement and engagement in producing ocean literacy content over the specified five-year period, highlighting the varying levels of contributions from different nations.

3.4 Results for research question 4 (how did the keywords of the published articles in journals vary between 2017 and 2021?)

Keywords are important indicators used in the publication process of scientific research. The keywords used in the analyzed studies are important guiding indicators that provide clues about the content and bibliography of the study. By analyzing the keywords, the sub-dimensions of the studies in the determined period were revealed. The themes that researchers associate with ocean literacy and the level of association of these themes are reported.

TABLE 6   Country performance for publishing OL based articles and comparisons between 2017 and 2021.

No	Countries	2017	2018	2019	2020	2021	Total Score
1	UK	–	0,025	3,53	2,032	3,461	9,048
2	Italy	0,15	0,58	2,56	2,428	1,41	7,128
3	Canada	0,405	1	2	1,247	2,39	7,042
4	USA	–	1,21	1,37	1,429	2,07	6,079
5	Portugal	0,04	1,01	0,15	0,001	4,87	6,071
6	Taiwan	–	–	4	1	1	6
7	Greece	1	0,04	1,12	0,428	3,02	5,608
8	Australia	–	0,79	0,77	0,009	3,028	4,597
9	Ireland	–	0,37	3	1	–	4,37
10	Germany	0,07	–	1,57	1,019	0,432	3,091
11	Sweden	2	0,445	0,42	–	0,07	2,935
12	Poland	–	–	0,01	1	1,75	2,76
13	Brazil	–	–	–	0,002	2,62	2,622
14	Spain	0,365	0,03	1,51	0,021	0,22	2,146
15	France	0,92	–	0,06	0,691	0,203	1,874
16	Japan	–	–	0,23	1	0,32	1,55
17	Croatia	–	–	0,07	1,124	0,28	1,474
18	S.Africa	–	0,42	0,7	0,001	0,01	1,131
19	Slovenia	–	–	–	1	–	1
20	Turkey	–	–	0,79	–	–	0,79
21	Belgium	–	0,01	–	0,029	0,722	0,761
22	Switzerland	–	–	–	–	0,46	0,46
23	Netherlands	0,375	–	–	–	–	0,375
24	Norway	–	–	–	0,044	0,22	0,264
25	New Zealand	–	–	–	–	0,181	0,181
26	Estonia	–	–	0,07	–	0,07	0,14
27	British Isles	–	–	–	–	0,1	0,1
28	Denmark	–	0,07	–	–	0,02	0,09
29	S.Korea	–	–	0,05	–	0,04	0,09
30	Mexico	–	–	–	0,067	0,02	0,087
31	Cape Verde	–	–	–	0,001	0,08	0,081
32	Kenya	–	–	0,03	0,001	0,03	0,061
33	Cambodia	–	–	–	–	0,03	0,03
34	Vietnam	–	–	0,02	–	–	0,02
35	Israel	–	–	–	–	0,019	0,019
36	Finland	0,015	–	–	–	–	0,015
37	Morocco	–	–	–	–	0,014	0,014
38	Egypt	–	–	–	–	0,01	0,01
39	Venezuela	–	–	–	0,009	–	0,009

(Continued)

TABLE 6 Continued

No	Countries	2017	2018	2019	2020	2021	Total Score
40	Tunisia	–	–	–	–	0,006	0,006
41	Vietnam	–	–	–	–	0,005	0,005
42	Monaco	–	–	–	0,001	–	0,001
43	New Caledonia	–	–	–	0,001	–	0,001
44	Senegal	–	–	–	0,001	–	0,001
45	Cyprus	–	–	–	–	0,001	0,001
46	Malta	–	–	–	–	0,001	0,001

Many studies can be easily accessed by using keywords. Key words used in this study were analyzed. Word Clouds web application (wordclouds.com) was used to show results (de Oliveira et al., 2019). Figure 2 shows the word cloud created using keywords. The most frequently used keywords were Ocean Literacy (56), environmental education (11), marine education (9), education (5), citizen science (5), Sustainable Development Goals (4), climate change (3), elementary students (3); marine science education (3); public engagement (3); science communication (3), stakeholders (3)public engagement (3), science-policy interface (3), stakeholder engagement (3), and scuba diving (3).

The data obtained show that "environmental education" and "marine education" concepts related to ocean literacy are the most discussed topics respectively. This situation reveals that in recent years, the concept of ocean literacy has been studied more intensively in the field of education which has highlighted the need for further examination of the identified terminology.

3.5 Results for research question 5 (What was the funding source of ocean literacy publications between 2017-2021?)

Forty-four out of the seventy-nine publications examined within the scope of the criteria determined between 2017-2021 received financial support. These publications are detailed in Table 7 (The table is given as Supplementary Material). Most publications were funded by one or more national or

FIGURE 2
Word cloud of keywords used in ocean literacy based publications between 2017-2021.

international institutions, organizations, projects, or programs. Eleven of them were funded by European Union (EU) Horizon 2020 Project. Additionally, 2 publications were funded by the Erasmus+ Programme.

4 Conclusions

This study aimed to make an in-depth analysis by examining studies in the field of ocean literacy between 2017 and 2021. It is anticipated that the results obtained from the study will provide important insights for the development and implementation of policies in the field of ocean literacy. The results of the study are presented under the following headings:

Between 2017 and 2021, articles about ocean literacy were subjected to a thorough bibliometric, content, and methodology analysis. Information about the journals that published ocean literacy-based articles, contributions from various countries, keywords, and content analysis were presented along with an evaluation. A total of 79 articles were found in the Web of Science and Scopus databases that included the concept of "ocean literacy" in their abstracts or keywords sections (excluding conference papers). This restriction was used to ensure a focus on the subject matter, with particular attention given the concept of "ocean literacy."

4.1 Conclusion for research question 1. (which journals have published ocean literacy-based articles in the last 5 years?)

It would be feasible to identify the journals that have published research based on ocean literacy by looking at the recognized publications. Researchers, teachers, and policymakers who are interested in learning more about the most recent developments, trends, and viewpoints in ocean literacy may find this material to be helpful. It is important to keep in mind that various academic fields and journals may have variable availability of papers dependent on ocean literacy. In order to achieve a thorough study, a broad search technique and a large variety of pertinent journals would need to be taken into account. Overall, examining the journals that have published articles on ocean literacy in the previous five years can offer insightful information about the academic environment and assist scholars and practitioners in keeping up with the most recent advancements in this subject.

In the study conducted by Costa and Caldeira (2018), only 52 articles were found up until 2016, including conference papers. In a similar study covering the years 2005-2019, Paredes-Coral et al. (2021) identified 57 publishing outlets for the article and reviews, but it is noteworthy that the identified keywords include a larger field addition to ocean literacy in this study, which offers similar results. It is observed that the number of studies has increased over the years.

According to the research results, Frontiers in Marine Science has been the dominant journal, publishing 23 articles on ocean literacy in the last 5 years. When the number of publishing outlets on ocean literacy was compared in terms of certain periods, the

study by Paredes-Coral et al. (2021) also determined that Frontiers in Marine Science was the most popular journal publishing ocean literacy content until 2019 with 15 articles.

The studies on the concept of ocean literacy merged after 2004 and gradually increased. Considering after 2004, the Frontiers in Marine Science journal is at the forefront of the journals that have increased the number of publications on ocean literacy since 2005. It is the third most-cited marine and freshwater biology journal, advancing the understanding of marine systems and addressing global challenges including overfishing, pollution, and climate change.

The second most published journals on ocean literacy were "Environmental Education Research" and "Sustainability" with 5 articles each Environmental Education Research which aims to advance research-based and scholarly understandings of environmental and sustainability education, ranks fourth among the total journals with the number of articles published on ocean literacy basis of studies covering the period between 2005 and 2019 (Costa and Caldeira, 2018; Paredes-Coral et al., 2021).

Sustainability is an international, cross-disciplinary, scholarly, peer-reviewed, and open-access journal on environmental, cultural, economic, and social sustainability of human beings. It ranked fifth on the basis of studies carried between 2005 and 2019.

It can be inferred from this that both journals Environmental Education Research and Sustainability have risen to the top by increasing their number of publishing outlets in the field of ocean literacy between 2017-2021.

Marine policy ranks third (Costa and Caldeira, 2018) and second (Paredes-Coral et al., 2021) among the journals with the most publications on ocean literacy. A small difference between the results can be attributed to the difference in the evaluation criteria and restrictions for the studies.

4.2 Conclusion for research question 2 (how was the content analysis of the articles published in journals between 2017 and 2021?)

Based on the provided results, it can be concluded that the majority of the studies in the field of ocean literacy were concentrated in several key categories. These categories include:

Global OL Perspectives: With 16 research examining and comprehending ocean literacy from a global perspecive, this category seems to be of considerable interest. This implies an understanding of the significance of taking into account the larger context and global ramifications of ocean literacy activities. The highest number of publications in the "Global Ocean Literacy Perspectives" category was found in 2019, which can be attributed to the emergence of the first World Ocean Assessment (WOA), approved by the United Nations, in which the destruction of the marine environment and the coast is reported globally in 2016, followed by the second one in 2017-2018 and an additional capacity building event in 2019 (Evans et al., 2019).

Sustainability Issues for OL: With 13 publications, this category emphasizes the importance of looking at how sustainability and

ocean literacy are related. The necessity of building a healthy relationship with the ocean is being emphasized by researchers and practitioners who appear to be looking at the role of ocean literacy in tackling environmental and conservation challenges.

Citizen Science and OL: 6 publications have a particular interest in citizen science, which involves involving the public in scientific research. This shows an appreciation for the importance of including the general population in ocean literacy initiatives and harnessing their contributions to increase ocean scientific knowledge.

Measurement and Evaluation of OL in Students and Instructors: 6 studies highlight the significance of monitoring and assessing the impact of ocean literacy initiatives on both students and instructors. This emphasizes the necessity of evaluation procedures and tools to evaluate the results of educational initiatives and guide future development.

Students' OL Improvement: Another category with 6 publications focus on strategies and approaches to enhance students' ocean literacy. This suggests a growing interest in developing effective educational methods and interventions to foster a deeper understanding and connection with the ocean among students.

OL Based Books-iBooks-Textbooks: 5 publications highlight the significance of incorporating ocean literacy content in educational resources, such as books, iBooks, and textbooks. This indicates an acknowledgment of the role of educational materials in promoting ocean literacy and providing accessible information to learners.

Stakeholders' Effects on OL: With 5 publications, this category suggests an exploration of the impacts of stakeholders, such as policymakers, educators, and communities, on ocean literacy initiatives. Understanding the role and influence of stakeholders can help shape effective strategies for promoting ocean literacy at different levels.

4.3 Conclusion for research question 3 (how did authors from different countries contribute to the publications of ocean literacy articles between 2017 and 2021?)

Previous studies conducted in previous years indicated the number of contributing countries as 16 (Costa and Caldeira, 2018) and 33 (Paredes-Coral et al., 2021) until 2019. However, results show that participations has gradually increased, with 46 countries contributing to this research. The highest contributions between 2017 and 2021 were from the UK, Italy, Canada, USA, Portugal, and Taiwan (in that order). Most of the articles have a collaborative approach, with authors from different countries working together and publishing jointly. It is also evident that authors from more diverse countries have contributed to this content in recent years.

Considering the studies carried out by various countries over the years, Sweden, Greece, and France were found to be the countries producing the most publications in 2017. However, the ranking changed in 2018 and the top three countries were the USA, Portugal, and Canada. In 2019, Taiwan, the UK, and Ireland were the top three countries in terms of contribution, but this changed to

Italy, the UK, and the USA in 2020. Furthermore, in 2021, Portugal, the UK, and Australia were the countries found to be producing the most publications.

In terms of total contribution performance over five years on a country basis, the UK has the highest total score.

When examining relevant literature, the results show that the United States was identified as the most active country publishing on ocean literacy, leading with the highest proportion of publications, followed distantly by the UK and Canada, according to studies obtained from 2005 to 2019 (Costa and Caldeira, 2018; Paredes-Coral et al., 2021). Since the first studies on ocean literacy were conducted in the USA, it has had a dominant effect in this field in the past years. Additionally, the USA presented the largest number of publications during the entire period, except in 2014 when it was slightly overtaken by the UK (Costa and Caldeira, 2018). The data obtained from the study also shows that the UK's contribution in this field has increased gradually, especially since 2019.

4.4 Conclusion for research question 4. (how were the keywords of the published articles in journals vary between 2017 and 2021?)

In many studies, keywords are used to indicate the relevant topics of the study. It is possible to obtain general information about the content of research through keywords. The keywords used in the examined studies were carefully reviewed. After this review, it was determined that the most frequently used word was "Ocean Literacy" with 56 uses. Furthermore, it was found that the most commonly used keywords with descending order were as follows ocean literacy, environmental education, marine education, education, citizen science and Sustainable Development Goals. The most commonly used keywords with equal rates continue as climate change, elementary students, marine science education, public engagement, science communication, stakeholders, public engagement, science-policy interface, stakeholder engagement and scuba diving.

When the keywords are analyzed, the idea is that more studies are conducted on ocean literacy with education-oriented variables in terms of frequency of use. The ranking continues with sustainability issues, which are among the popular and frequently studied topics in the recent period. Another noteworthy keyword usage is on citizen science, where awareness-raising activities have recently been carried out for society.

Some researches stressed ocean literacy in terms of education. According to UNESCO-IOC (2022), the idea of Ocean Literacy initially grew from school curricula, and the concept was shaped around integrating scientific information about the ocean into forms suitable for teaching and learning. This required structuring scientific content into principles and concepts. It is understood that the keywords presented with frequency values are considered as sub-dimensions of studies on ocean literacy. Some researches define ocean literacy according to marine science (Tsai, 2019), while others use public engagement (Kelly et al., 2019; Dalby

et al., 2021) as the main subject, and some focus on marine resources and ocean sustainability (Fernández Otero et al., 2019; Santoro et al., 2022). Moreover, recent studies (Heck et al., 2018; Lucrezi et al., 2019) have highlighted the impact of stakeholders.

Ocean literacy is a relatively new term that connects the human dimension to the ocean and that intends to be an incentive for positive change in people's behavior (Paredes-Coral et al., 2021). The findings underline the research topics of publishing outlets, not only as an academic analyses but also as representing global directions of the research on ocean literacy.

4.5 Conclusion for research question 5. (What was the funding source of ocean literacy publications between 2017-2021?)

There are several reasons why studies on ocean literacy need to receive financial support. Financial support is required as a major reason to conduct the research, collect and apply the data. The data collection phase is important in identifying the current state of the oceans and the main challenges. Also, the support of such studies will increase the use of technological equipment and will enable us to approach the problems with a more effective perspective. Another part that requires financial support is the education and awareness part such as creating new educational programs and developing educational tools. In addition, the ocean is a global issue and requires a global study. Financial support enables the expansion of international collaboration, allowing for enhanced cooperation.

When examining the studies in the field of ocean literacy, it was determined that many of them were funded. Out of 59 publications in the Web of Science database, a total of 36 received funding. Additionally, out of 20 publications in the Scopus database, 8 of them received funding. This means that more than half of all publications analysed in Web of Science and Scopus received financial support, while the rest did not receive any support or no information on funding was available. The majority receiving financial support indicates the significance of ocean literacy as a field of study and is important in terms of enabling an effective study to be carried out.

Four publications were funded by the Ministry of Science Technology and two publications were financed by the Erasmus+ Program. The remaining studies were funded by universities, institutions, and projects in various countries.

Furthermore, ocean literacy studies are supported within the framework program, which is the most important and prestigious research program in the European Union. In order to develop and promote ocean literacy, the EU Commission launched the Horizon 2020 call. Within the scope of this call, two projects, SeaChange and ResponSEAble were financially supported. These projects focused on raising awareness of human-ocean relations and various applications for research and development of ocean literacy levels (Pantò, 2019).

In the studies by Drakou et al., 2017; Lucrezi et al., 2018; Ashley et al., 2019; Brennan et al., 2019; Kelly et al., 2019; Lucrezi et al., 2019; McCauley et al., 2019; Pantò, 2019; McHugh et al., 2020; Kenterelidou and Galatsopoulou, 2021 and Boaventura et al., 2021,

it is seen that ocean literacy studies are funded by framework programs such as Horizon 2020.

Financial supports for ocean literacy studies helps to indicate the urgency and criticality of marine ecosystem problems and can increase the visibility of this subject, enabling the discovery of more effective solutions, clearly identifying issues within marine ecosystems, and promoting the disseminations of conservation and capacity-building practices. Exploring the aspect of financial supports within the scope of ocean literacy-related studies will highlight the significance of receiving funding, enabling further research and helping to reach out to these studies globally.

5 Discussion

It is evident that improved public understanding of the ocean and the importance of sustainable ocean use, often referred to as ocean literacy, stands as a pivotal component in collective pursuit of global commitments to sustainable development by 2030 and beyond. Oceans are not just vast bodies of water; they are the lifeblood of our planet, influencing climate, supporting diverse ecosystems, and providing crucial resources for humanity (Kelly et al., 2022). To address these issues and ensure a sustainable future for our oceans, concerted efforts are needed. Initiatives aimed at fostering ocean literacy, promoting responsible ocean stewardship, and advocating for equitable access to ocean resources must be prioritized. Only through a comprehensive approach that combines education, conservation, and inclusive policies can we hope to bridge the gap between humanity and our oceans (Catalano et al., 2019; Stoll-Kleemann, 2019).

The current study shows the progress of ocean literacy content in the scientific literature between 2017-2021. Based on the analyses, "ocean literacy" emerges as a concept whose importance is increasing day by day. Additionally, the increase in the number of studies, collaborations and the support of the European Union on this subject is promising. In the years to come, as a result of these researches, the groundwork for a sustainable future can be laid by focusing on becoming ocean literate and making our world more sustainable.

Academic journals play a pivotal role in advancing ocean literacy on a global scale. Through rigorous research, dissemination of knowledge, and the exchange of ideas, these journals provide a platform for scientists, educators, policymakers, and the public to access up-to-date information on ocean-related topics. They contribute to the development of a comprehensive understanding of marine ecosystems, climate impacts, conservation strategies, and sustainable ocean use. Furthermore, academic journals foster a sense of community and collaboration among ocean researchers worldwide, encouraging interdisciplinary approaches to addressing the complex challenges facing our oceans (Baskerville and Myers, 2002; Jennex and Croasdell, 2005; Katerattanakul et al., 2006). The fact that studies on ocean literacy have been published in more and more different academic journals over the years indicates that future studies in this field will increase.

The imperative for establishing a global baseline for Ocean Literacy across diverse social groups and regions cannot be

overstated. As it is also proved in this study that historically, Ocean Literacy initiatives have been disproportionately centered in the United States, leaving significant gaps in understanding and engagement with the world's oceans. As we stand at the cusp of global environmental challenges, it is paramount that we transcend geographical boundaries and ensure that Ocean Literacy campaigns are inclusive, accessible, and relevant to communities worldwide. By broadening our focus and assessing the state of OL across the globe, we pave the way for a more comprehensive and equitable approach to ocean education and conservation (Schoedinger et al., 2005; Schoedinger et al., 2010; Costa and Caldeira, 2018).

In the modern world, ocean literacy is an important subject of research and discourse. For educated decision-making and effective management of this priceless resource, it is imperative to comprehend the relevance of the ocean in our lives, from its function in regulating the climate to its biodiversity and economic significance (Paredes-Coral et al., 2021).

The results of this study can deliver crucial conclusions that direct and enlighten future investigations by identifying relevant trends, gaps, and influential research. It assists researchers in identifying aspects of ocean literacy that need further study, points out potential interdisciplinary linkages, and provides information on efficient communication tactics for advancing ocean literacy. This well-conducted bibliometric study can ultimately act as a road map, guiding the direction of future research initiatives and enabling a more thorough knowledge of ocean literacy and its implications for sustainable ocean management and conservation.

Following suggestions should be taken into consideration for the further research on Ocean Literacy:

As global environmental concerns intensify, there is an increasing demand for a platform that focuses exclusively on ocean literacy research, education, and advocacy. An academic journal dedicated to this topic would fill a critical gap in the academic publishing landscape. Such a journal would contribute significantly to our understanding of the oceans, empower educators, policymakers, and the public with knowledge, and support collective efforts to safeguard and sustainably manage these vital ecosystems.

Longitudinal data spanning over a decade or more provides the opportunity to identify and analyze enduring trends, shifts, and patterns in scholarly communication. This extended time frame enables researchers to distinguish between short-lived fads and lasting developments, offering a more accurate depiction of research dynamics. Extended data analysis on Ocean Literacy allows for a better understanding of the effectiveness of research policies and funding initiatives over time.

A fair and equitable authorship attribution methodology is essential for accurately acknowledging the diverse contributions of researchers in collaborative academic endeavors in different countries. By refining existing methodologies and promoting transparent contribution statements, academic publishing can better represent the collective effort of research teams and foster a more inclusive and collaborative research environment. It is recommended further exploration and implementation of these changes to address the current bias towards first authors and promote a more accurate reflection of individual contributions in academic publications.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2023.1200181/full#supplementary-material

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