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Bibliometric analysis of ocean literacy: An underrated term in the scientific literature

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ABSTRACT

Since the term “ocean literacy” (OL) was proposed in 2004 by a group of professionals dedicated to ocean sciences, marine education, and general education policies, its principles have spread worldwide. In order to better understand OL-related research a bibliometric analysis was performed with data from databases obtained from Scopus and Web of Science (WoS). Fifty-two publications matched the search criteria (articles and conference papers with OL as part of title, keywords and/or abstract). Analysed parameters included the document types, publishing outlets, authors, countries, institutes, author keywords and title words. The term OL in scientific publications has been quantitatively dominated by the United States of America (USA), followed by the United Kingdom (UK) and Canada. The UK and Italy were the countries with the most international collaborative publications on this theme. In addition, the UK was the country that established the most international collaborations. National Oceanic and Atmospheric Administration (NOAA) was the most productive institution and the Proceedings of the MTS/IEEE OCEANS 2005 was the publishing outlet containing the most publications. The analysis has also revealed the intrinsic link between science and OL, the use of questionnaires to evaluate the level of citizens’ knowledge, values and awareness about marine issues, and the emphasis placed on educational approaches to improve OL.

1. Introduction

The term ocean literacy (OL) is defined as the understanding of the ocean's influence on humans and of our influence on the ocean [1]. The initial discussions around this idea began in the United States of America (USA) in 2004, with the engagement of representatives from several ocean-related areas (educators, researchers and policymakers) [2,3]. The participants were concerned with the lack of public awareness about the importance of oceans and with the absence of ocean topics in the American school curriculum. A series of workshops were organised to discuss what should be understood by Americans about the ocean by the end of high school [3]. The result was the development of a framework comprising a guide entitled “Ocean Literacy – The Essential Principles and Fundamental Concepts of Ocean Sciences for Learners of All Ages” (1st version published in 2005 and 2nd version in 2013) [4] and the start of a national campaign in the USA aimed at achieving an ocean-literate society. The guide identifies seven essential principles (Table 1) and 44 fundamental concepts that students should know by the end of Grade 12. A more detailed document, named “Ocean Literacy Scope and Sequence for Grades K-12″, was also produced in order to detail how educators could help learners build their understanding of the seven Ocean Literacy Principles [5]. Those guidelines, developed to help implement an ocean-dedicated curriculum in the USA, are now largely accepted and have been an inspiration for several initiatives worldwide. Some countries adopted the OL principles and developed new approaches adapted to their reality. Portugal was one of the first countries to adopt the USA OL guides through the initiative “Conhecer o Oceano” (“Knowing the Ocean”), engaging scientists and educators alike (http://www.cienciaviva.pt/oceano/home/). Also, museums, aquariums, and science centres have been restructuring their programs, exhibitions, and activities to incorporate the OL guidelines [6–8].

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Table 1
The essential principles of ocean literacy.

1. The Earth has one big ocean with many features
2. The ocean and life in the ocean shape the features of Earth
3. The ocean is a major influence on weather and climate
4. The ocean makes 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

To achieve an ocean-literate society, the OL principles and concepts should be integrated not only into educational practice, curricula, and textbooks but also in regulations and scientific research [2,9–11]. Some regulations which are essential to implementing responsible ocean policies and management strategies, are currently embedding OL and are aligned with its core principles, although not always explicitly using the term (e.g. Marine Framework Strategy Directive; Blue Growth Strategy; Marine Spatial Planning Directive; Common Fisheries Policy; Birds Directive; and Habitats Directive), as discussed in [10]. Furthermore, at European policy level, the European Union (EU), USA, and Canada signed a transatlantic ocean research alliance that explicitly identified OL as one of the key areas for cooperation among marine scientists [12]. EU awareness of OL is also evident in the recent calls for OL-dedicated projects. For instance, in 2013 it was included in the "Research and Innovation Funding Program – Horizon 2020". In fact, a specific call was dedicated to the topic "Ocean literacy – Engaging with Society" [13]. One of the funded initiatives was the Sea Change project, which targeted its intervention at three main societal groups: the general public, formal educators, and policy makers [14] (http://www.seachangeproject.eu/).

Individual behaviour changes are also essential to ensuring the sustainable use of the ocean and its resources [15]. Anthropogenic pressures demand an urgent change of human behaviours that is only possible if each citizen understands the ocean's vital role, i.e., if each citizen becomes ocean-literate [13,16]. Additionally, enhancing public knowledge and awareness will lead to increased public support for ocean restoration and/or conservation efforts [7,10].

Twelve years after the original OL proposal, it is important to review what has been published as well as to determine what progress has been made. To this end, the present study aims to perform a bibliometric analysis on the term OL, thus providing an overview of the research works' features. It also attempts to identify trends and gaps that could orient future studies. The main objectives were: a) to analyse the OL literature growth over time; b) to identify the countries, institutions, publishing outlets, and authors publishing on OL; c) to identify the collaborations established among countries and among institutions to implement OL initiatives and/or to publish OL studies; d) to identify research trends and gaps on this topic.

2. Materials and methods

2.1. Data collection

The study was conducted during February 2017 through a bibliographic survey using the Scopus and Web of Science (WoS) multidisciplinary databases. Publications were searched from the databases' custom data (from 1900 to 2016 in WoS and from 1960 to 2016 in Scopus) using OL as search criteria. The documents where OL appeared in the title, keywords, and/or abstract were included in the study.

The search resulted in 93 records, all written in English. After removing duplicates in our in-house database, 62 records belonging to different document types remained: 32 articles (61.5%), 20 conference papers (38.5%); 3 notes (5.8%); 3 editorial materials (5.8%); 1 book (1.9%); 1 book chapter (1.9%); 1 conference review (1.9%); and 1 meeting abstract (1.9%). Taking into consideration the representativeness of different publication types, 52 records belonging to the article and conference paper categories were selected for further analysis.

2.2. Data management and analysis

Bibliometric approaches have been widely accepted for evaluating several research topics (e.g. methods, trends, preeminent authors) in most areas of expertise, from natural (e.g. [17,18,19]) to social sciences (e.g. [20–22]. In the present bibliometric study, performance analysis and science mapping [23] were used as procedures to evaluate the publications' characteristics and to display some content features. The focus was placed in the document types, publishing outlets, authors, countries, institutions, author keywords, and title words.

The contributions of institutions and countries were estimated using author affiliations and addresses. Each journal's Impact Factor (IF) was obtained from InCites™ Journal Citation Reports® (Thomson Reuters, Philadelphia, PA) and refers to the year 2015. The term "single country publication" was assigned to outputs of authors from the same country and "single institutional publication" was assigned when the researchers' addresses were from the same institution, even though they belonged to different departments. "National inter-institutional collaborative publication" was used to designate works co-authored by researchers from multiple institutions, but all from the same country, and "international collaborative publication" was assigned for publications with authors from multiple countries. Pairs of collaborative countries and pairs of collaborative institutions were identified through maps based in co-occurrences and drawn in Pajek software.

Pajek is an open source program used for analysis and visualisation of large networks [24]. The data inserted into Pajek was previously obtained with Bibexcel, a free software frequently used to perform bibliometric analysis and to prepare data for mapping in other appropriate software [25]. Further visual improvements were made in Pajek maps.

Title word and author keyword analysis is a relatively simple method to perform content studies to reveal the main topics and trends emerging from the research data. In the present study, the list of words used in the publications' titles and the frequency of their presence (prepositions and other stop words removed) was obtained using the Bibexcel software. First Bibexcel separates the titles into single words and then ranks them according to their frequency. The list obtained was further examined in order to identify and group similar words (ex. engage/engagement, impact/impacts). Author keywords (available only in 24 of the 52 publications) were also obtained with Bibexcel. The same software was used to extract author, institution, and country frequencies from our database.

3. Results and discussion

3.1. Publication characteristics through time

Searching by OL on Scopus and WoS returned 52 publications meeting our criteria (32 articles and 20 conference papers, duplicates excluded). The first records were found in the year 2005 (2 articles and 6 conference papers) (Fig. 1). This finding was expected because the concept was initially proposed in late 2004 with a subsequent OL campaign initiated thereafter.

Assuming that journals and conferences are the main tools in disseminating scientific research results, it may be posited that the pattern of publication in those diffusion media could give us an indication of the themes' importance within the academic research community. Additionally, it could be an indicator of the funding allocated to the research theme, since the number of publications, and their impact, are widely regarded as a useful method of demonstrating the investment return of research and institutional funding [26]. In this case, the number of publications was considerably low and widely variable

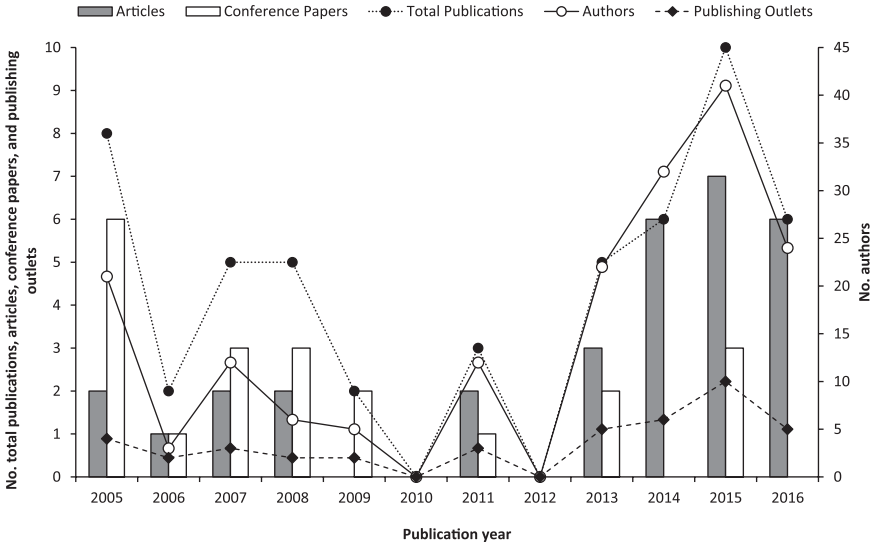

Fig. 1. Number of total publications, articles, conference papers, authors, and publishing outlets (journals + conference proceedings) on "ocean literacy", from 2005 to 2016.

through time (ex: 8 publications in 2005, 1 in 2006, and 3 in 2007 and 2008) (Fig. 1). Those results suggest that research on OL was not successful in terms of number of published scientific studies, at least when compared with "environmental literacy" [16]. Nevertheless, the term has been used extensively in numerous other contexts. A quick search for OL in Google and Google Scholar returned, respectively, around 89 800 and 920 results, confirming that at present OL is a concept broadly accepted and adopted and used as a guide for several activities. In fact, sometimes the term OL is not explicitly mentioned; but its principles can be easily identified in ocean-related literature including, for instance, its evidence in marine policy documents, some written even before the start of the regular use of the term and the launch of the USA OL guides [10].

In this context, French et al. [10] suggest that the OL term should be used in political communications and documents and in follow-up activities and initiatives. This suggestion should be extended to scientific research.

The most productive year was 2015 with 10 publications, of which 7 were articles (Fig. 1). In contrast, in 2010 and 2012 no articles or conference papers were found. Moreover, in 2014 and 2016 no records of conference papers were detected, while in 2009 the pattern was reversed: no articles were published. Between 2005 and 2012, the number of articles was equal to or lower than conference papers, while after 2013 this tendency was inverted. The increasing number of articles in recent years might reflect an increased interest of the scientific community and publishers in the topic and suggests a future positive growth trend. It is possible that at the time of our data collection (February 2017), some publications from 2016 were not yet included in the searched databases and their actual number could be higher. In addition, besides the cumulative low number of publications found, it is plausible that the several projects and initiatives that have been undertaken, not only in the USA but also more recently in Europe with funds allocated to OL projects and initiatives, may result in future scientific research outputs that could increase the actual number of publications.

The number of authors and publication outlets followed the same temporal trend of total articles and conference papers. Their peaks were registered in 2015 corresponding to 41 authors and 10 publishing outlets (Fig. 1).

3.2. Publication activity of journals and conference proceedings

Fig. 2 lists the publishing outlets with the matching number of publications and the IF 2015 (some of the publishing outlets do not

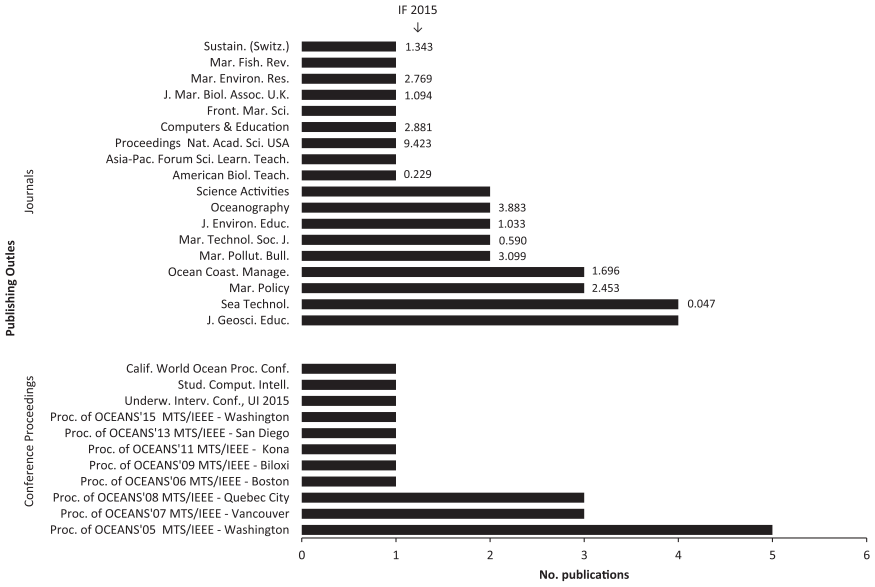

Fig. 2. Publishing outlets used to disseminate studies on "ocean literacy", from 2005 to 2016, with the number of publications and respective Impact Factor 2015. The journal marked with an asterisk includes one publication classified as conference paper, since it was published in a special issue of a conference.

have IF). A considerable amount of journals (n = 18) and conference proceedings (n = 11) published scientific studies on OL. The mean IF was 2.35 ± 2.43 (SD), ranging from 0.047 (*Sea Technology*) to 9.423 (*Proceedings of the National Academy of Sciences of the United States of America – PNAS*). For most publishing outlets only 1 work was found. Some were more productive but none published more than 5 works. The *Proceedings of the MTS/IEEE OCEANS 2005* ranked 1st, corresponding to 9.6% of all published studies, followed by the *Journal of Geoscience Education* and *Sea Technology* journals, which both ranked in 2nd position with 4 articles. *Marine Policy* and *Ocean & Coastal Management*, both with 3 articles, ranked 3rd in the most productive journals group. Together, those 4 journals accounted for 26.9% of all publications and 43.8% of all articles.

When considering only the conference proceedings (Fig. 2), the Proceedings of MTS/IEEE OCEANS 2005, the most productive, were followed by the Oceans Conference Record (IEEE) - OCEANS 2007 and by the Proceedings of the OCEANS'08 MTS/IEEE- Quebec City, both with 3 records and accounting for 21.2% of total publications and 55.3% of all conference papers. The proceedings of the OCEANS conference was the main publishing outlet of conference papers. OCEANS, sponsored by IEEE Oceanic Engineering Society and The Marine Technology Society, is an international forum for scientists, engineers and ocean users to disseminate and exchange their knowledge, ideas and scientific-technical advances in Oceanic Engineering and Marine Technology. Its aim is to raise awareness regarding the vital role of the sea and the use of technology to preserve it. The conference is biannual, one held at various locations in the USA or Canada and one in an international location [27]. OCEANS's scope is aligned with OL principles which explains its predominance as a source of publications, contributing 28.8% of them. From all OCEANS conferences, the most productive was the one held in Washington D.C., in 2005, the year after the official OL was born, probably reflecting the campaign efforts. Afterwards, the yield was inconsistent and in recent years the interest in presenting OL-related works in this conference seemed to decrease; only one conference paper was presented in OCEANS 2009, 2013, and 2015, and none in 2010 or 2012 (Fig. 2).

3.3. Publication activity of countries

Sixteen countries from 4 continents were identified as publishing articles or conference papers on OL (Table 2). Half of the publications (n = 26) were single country outputs of 6 countries; the other half comprised collaborative publications covering 14 countries. Clearly, the USA was the main contributor with 38 records (73.1%) (Table 2), followed by the UK but with a large gap (5 publications, 9.6%), and by Canada (4 publications, 7.7%). The USA's dominance is unsurprising given that it was American specialists and organizations that proposed the term and initiated the OL national campaign [3] as well as the fact that 7 of the 8 OCEANS conferences that contributed to the available scientific literature on OL were held in American cities.

Until 2012 only articles and/or conference papers assigned to the USA were found (Fig. 3), confirming its prominent interest in the topic. It was only in 2013 that other countries started publishing scientific works on OL, but sporadically and with low representation. In addition, the USA presented the largest number of publications during the whole period, except in 2014, when it was slightly overtaken by the UK (Fig. 3).

Globally, 70.8% works (n = 46) were single country and 29.2% (n = 19) international collaborative publications (Table 2). The 3 most productive countries mentioned (USA, UK and Canada) published both single country and collaborative studies. In Fig. 4 the pairs of collaborative countries are shown. The UK was the country that established cooperation with the highest number of countries (n = 7), followed by Italy and Spain (n = 6). The main OL contributor country, i.e. USA, only established 1 international collaboration (with Sweden) (Fig. 4). The USA's other collaborations, corresponding to 19 works, were among institutions within its territory.

Table 2
Performance of countries publishing on "ocean literacy", from 2005 to 2016.

Country	TP (%)	SCP (%)	ICP (%)	AU (%)	AU/TP
United States of America	38 (73.1)	37 (71.2)	1 (1.9)	95 (59.0)	2.5
United Kingdom	5 (9.6)	2 (3.8)	3 (5.8)	28 (17.3)	5.6
Canada	4 (7.7)	3 (5.8)	1 (1.9)	11 (6.8)	2.8
Italy	3 (5.8)	0 (0.0)	3 (5.8)	3 (1.9)	3.0
Greece	2 (3.8)	2 (3.8)	0 (0.0)	4 (2.5)	2.0
Spain	2 (3.8)	0 (0.0)	2 (3.8)	4 (2.5)	2.0
Sweden	2 (3.8)	0 (0.0)	2 (3.8)	3 (1.9)	3.0
Australia	1 (1.9)	0 (0.0)	1 (1.9)	1 (0.6)	1.0
Belgium	1 (1.9)	1 (1.9)	0 (0.0)	1 (0.6)	1.0
Chile	1 (1.9)	0 (0.0)	1 (1.9)	4 (2.5)	1.3
China	1 (1.9)	1 (1.9)	0 (0.0)	2 (1.2)	2.0
Ireland	1 (1.9)	1 (1.9)	0 (0.0)	3 (1.9)	1.5
France	1 (1.9)	0 (0.0)	1 (1.9)	1 (0.6)	1.0
Netherlands	1 (1.9)	0 (0.0)	1 (1.9)	1 (0.6)	1.0
Norway	1 (1.9)	0 (0.0)	1 (1.9)	1 (0.6)	1.0
Portugal	1 (1.9)	0 (0.0)	1 (1.9)	1 (0.6)	1.0

TP – Total publications; SCP – Single country publications; ICP – International collaborative publications; AU – authors; AU/TP – Mean number of authors per total number for publication for each country.
Note: Some authors presented affiliations assigned to multiple countries.

3.4. Publication activity of institutions

Through the authors' affiliations 82 institutions devoted to OL were identified. The more active (with 2 or more outputs) are displayed in Table 3 and the ones with more authors (5 or more) are present in Table 4. In the list of the 10 most productive institutions 8 are from the USA, 1 from Sweden, and 1 from Greece. Regarding the number of authors, only institutions from the USA and the UK were present in the list (Table 4). The National Oceanic and Atmospheric Administration (NOAA) was the most productive institution with 10 publications (26.3%), followed distantly by Oregon State University with 3 records. NOAA was one of the institutions, along with COSEE, National Marine Educators Association, College of Exploration, National Geographic Society, University of California, Berkeley, and Lawrence Hall of Science, which supported the OL campaign [6], thus explaining its productivity.

There is no doubt that collaborative work plays an important role in science. In the present case, half of the outputs (n = 26) were independent publications, i.e., published by a single institution, while the other half were inter-institutional works, comprising both national and international collaborations (respectively, 20 and 6 publications). International collaborations only started in 2014 (Fig. 5). NOAA, besides its high productivity (compared with the other institutions) only has 3 collaborative works, all national (Table 4), i.e., written by co-authors from other American institutions.

The configuration of partnerships among institutions is drawn in Fig. 6. NOAA was the organization that established collaborations with more institutions; it cooperated with 7 institutions. The Beacon Institute for Rivers and Estuaries, University of Rhode Island, University of Gothenburg and Oregon State University, were ranked 2nd, all with 2 inter-institutional collaborations. No institution established a strong relation with any other since they all had a cooperation frequency of one.

3.5. Publication activity of authors

In total, the 52 publications analysed were written by 161 authors (3.1 authors per publication). Ten publications were single author works (19.2%), 10 were written by 2 authors (19.2%), and 13 by 3 authors (25%). The number of authors was variable through the years and two peaks were found: one in 2005 and the other in 2015,

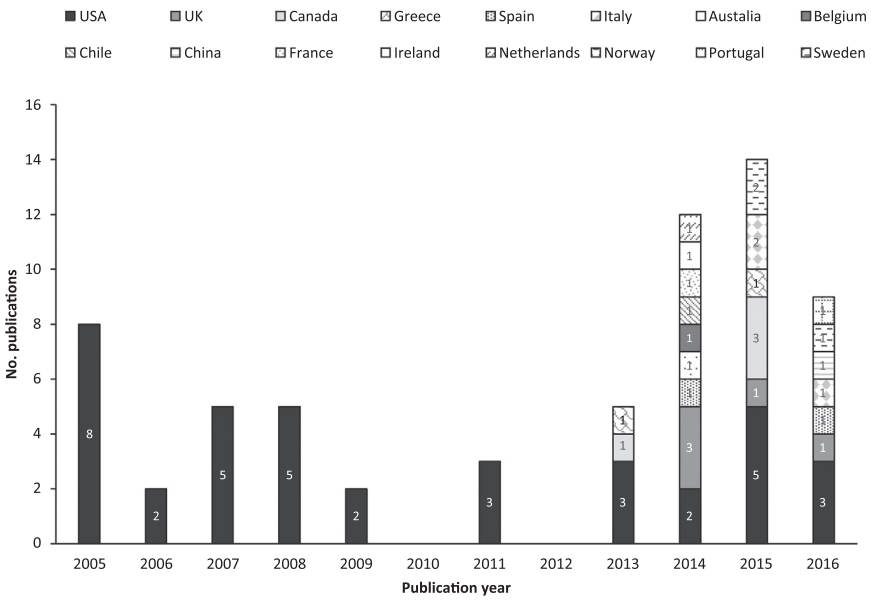

Fig. 3. Number of publications of each country by year, from 2005 to 2016. All institutional addresses of all contributing authors were considered. Some overlap exist, since the same author often has affiliations from different countries, thus contributing to the productivity of 2 or more countries simultaneously. The numbers inside columns indicates the number of publications of the corresponding country.

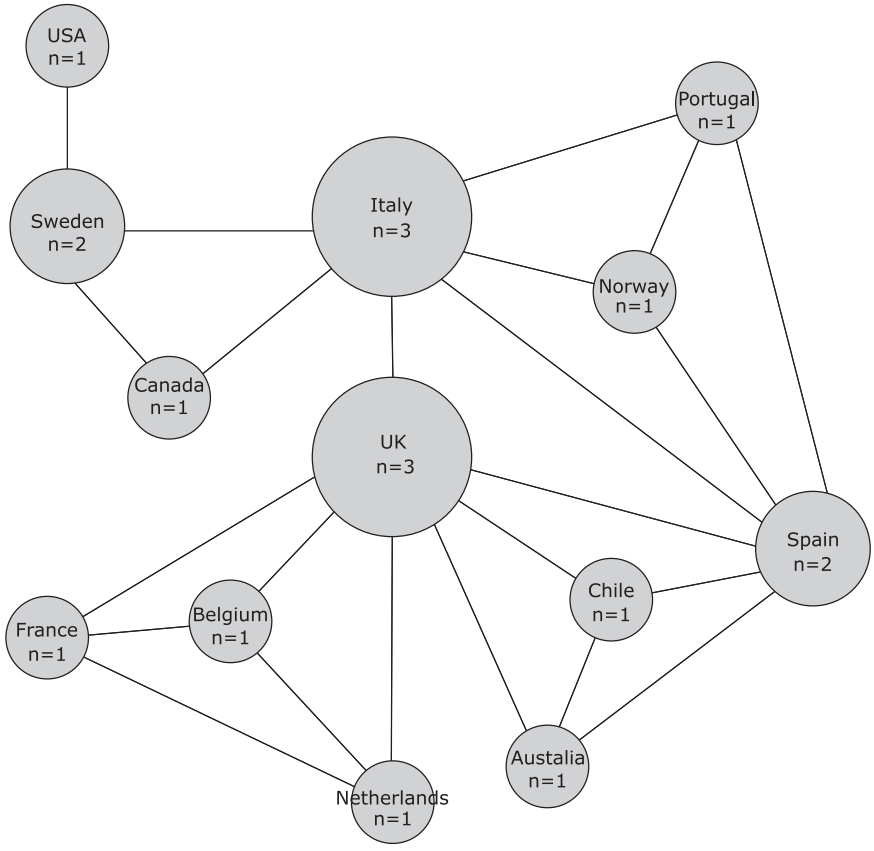

Fig. 4. Collaborative network among countries. The lines represent cooperation between two countries and its width refers to the frequency it happened. In this case, all collaborations had a frequency of 1, meaning that only one collaborative output between the pairs was found. The size of each circle stands for the total number of international collaboration publications. The name of the countries are written inside the circles as well as the number of collaborative publications of each one (n = x).

corresponding respectively to 8 and 12 authors (Fig. 1). The lowest value was recorded in 2006 when only 2 authors were found. Globally, the USA contributed the highest number of authors followed by the UK and Canada, corresponding respectively to 95, 28 and 11 authors (Table 2). The 1st position regarding the mean number of authors per output was occupied by the UK with 5.6 authors per work, while USA dropped to 4th position with 2.5 authors per output (Table 2).

Most authors (n = 148, 91.9%) published only 1 work. Only 13 authors wrote 2 or more publications (Table 5). The main contributor was Keener-Chavis, P. with 5 records (9.6%), followed by Martinez, C. with 3 works (5.8%). Both authors have American affiliations.

3.6. Characteristics of title words and keywords: a brief content review

Title words (TW) and author keywords (AUKW) are often used to reveal research field hotspots and discover the emerging trends in scientific research. Titles are the most visible and probably the most read part of publications. They help readers find the information they are looking for and, if well-chosen, it will synthesize the information of the whole paper and will show the subject focus and emphasis of the study. Consequently, its analysis allows inferences about the tendency of research priorities. Similarly, author keywords can help readers recognise key publication research content because they are chosen to reflect the

Table 3
Active institutions (with 2 or more outputs) publishing about "ocean literacy", from 2005 to 2016.

Institute	Country	P (%)	SIP	NICP	IICP
National Oceanic and Atmospheric Administration (NOAA)	USA	10 (26.3)	7	3	0
Oregon State University	USA	3 (5.8)	1	1	1
Aquarium of the Pacific	USA	2 (3.8)	1	1	0
Beacon Institute for Rivers and Estuaries	USA	2 (3.8)	0	2	0
National Geographic Society	USA	2 (3.8)	1	1	0
Democritus University of Thrace	Greece	2 (3.8)	2	0	0
Savannah State University	USA	2 (3.8)	2	0	0
University of California	USA	2 (3.8)	1	1	0
University of Gothenburg	Sweden	2 (3.8)	0	1	1
University of Rhode Island	USA	2 (3.8)	0	2	0

P: Number of publications.
(%): Percentage relative to all publications.
SIP: Single institute publications.
NICP: National inter-institutional collaborative publications.
IICP: International inter-institutional collaborative publications (at least one of the collaborator institution from another country).

Table 4
Institutions with 5 or more authors writing about "ocean literacy", from 2005 to 2016.

Institution	Country	Publications (%)	Authors (%)
National Oceanic and Atmospheric Administration (NOAA)	USA	10 (19.2)	10 (6.2)
University of California-Davis	USA	3 (5.8)	8 (5.0)
Oregon State University	USA	2 (3.8)	7 (4.3)
University of Hawaii	USA	2 (3.8)	7 (4.3)
University of York	UK	2 (3.8)	7 (4.3)
The University of Exeter Medical School	UK	2 (3.8)	6 (3.7)
Savannah State University	USA	2 (3.8)	5 (3.1)
University of California	USA	2 (3.8)	5 (3.1)
Woods Hole Oceanographic Institution	USA	2 (3.8)	5 (3.1)

authors' reasoning and to represent the main research emphasis of the work. Those two indicators of content were analysed in the present study. Table 6 shows the frequency of the most repeated title words (mentioned 5 or more times) while Table 7 shows the keywords that were present in 2 or more outputs.

Apart from the terms included in the search criteria, i.e., ocean and literacy, the terms science/scientific/scientists, marine and public, were the three most frequent title words (Table 6). With regards to the author keywords, only 7.0% of the 117 keywords identified (n = 8) were present in 2 or more publications (Table 7). Most of them (n = 109, 93.0%) were selected by the authors only once, suggesting diversified studies. The keyword *attitudes* ranked 1st (n = 3, 12.2%), but with a large gap (Table 7), while *questionnaires*, *information sources*, *middle school*, *oceanology*, *knowledge*, *climate* and *Okeanos Explorer* all occupied the 2nd position.

The analysis of the most cited TW and AUKW revealed some researching hot topics and trends. A frequent word in the titles was *science/scientific/scientists* (1st position) revealing a connection between science and oceans. Indeed, OL and *scientific literacy* are intrinsically linked as marine educators have always claimed; they are aware that science concepts can be taught through ocean examples [6].

NOAA, besides being the most productive institution on OL, as mentioned above, also features prominently on the most used title words list (5th position, mentioned in 6 titles, Table 6). This is no doubt the consequence of strong investment and efforts made by this agency in education and outreach programs, which have been designed to improve public OL, both in formal and informal ways [28–30]. Also, NOAA's ship, named *Okeanos Explorer,* was present in 4 titles and 2 times as AUKW (Tables 6 and 7). This ship uses real-time communication with live audiences ashore and is frequently used for OL education and outreach purposes.

Knowledge is one of the OL components and this word was present in 3 titles and chosen as keyword for 2 publications. Those studies highlight the importance of assessing the general public and/or specific societal groups' level of knowledge about the ocean and to identify where they tend to acquire it [11,31–34]. However, the research on the level of knowledge of the general population revealed that, despite the high percentage of human population living in coastal areas, public knowledge about ocean and coastal issues is typically low to moderate, resulting in an ocean illiterate society [2,11,31,32,34–36]. In contrast, they usually show a high valuation of the marine environment and concern.

Diverse approaches have been applied until now not only to assess the level of public OL but also to promote its improvement. The analyses carried out in this study gave some indications about the methods used to achieve this aim. For instance, the keyword *questionnaires* (AUKW, 2nd position, Table 7) was used in 2 publications indicating its convenience as a research tool. As an example, Hynes et al. [37] implemented a nationwide survey by questionnaire to explore the public values, concerns, and preferences towards the Irish *marine* (WT, 2nd position, Table 6) *environment* (WT, 4th position, Table 7), while Hawkins et al. [38] applied a similar tool to assess public *awareness* (WT, 4th position, Table 6) about UK marine protection. In another study, Heck et al. [36] used the same type of research instrument to explore the level of Chinese students' ocean environmental awareness. Although only those 2 works included the keyword *questionnaire*, other works were identified using this as a tool. It was the case, for instance, in Boubonari et al. (2013) and Mogias et al. (2015), who applied

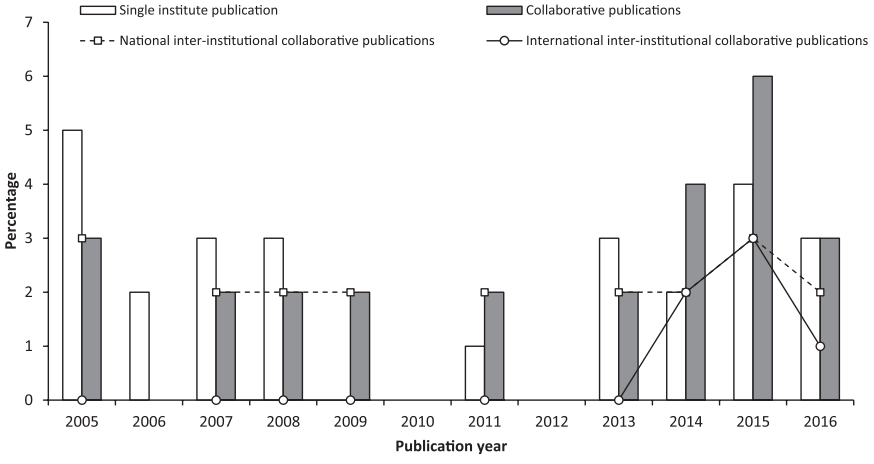

Fig. 5. Single institute publications (independent) and collaborative publications (national and international) on "ocean literacy" by year, from 2005 to 2016.

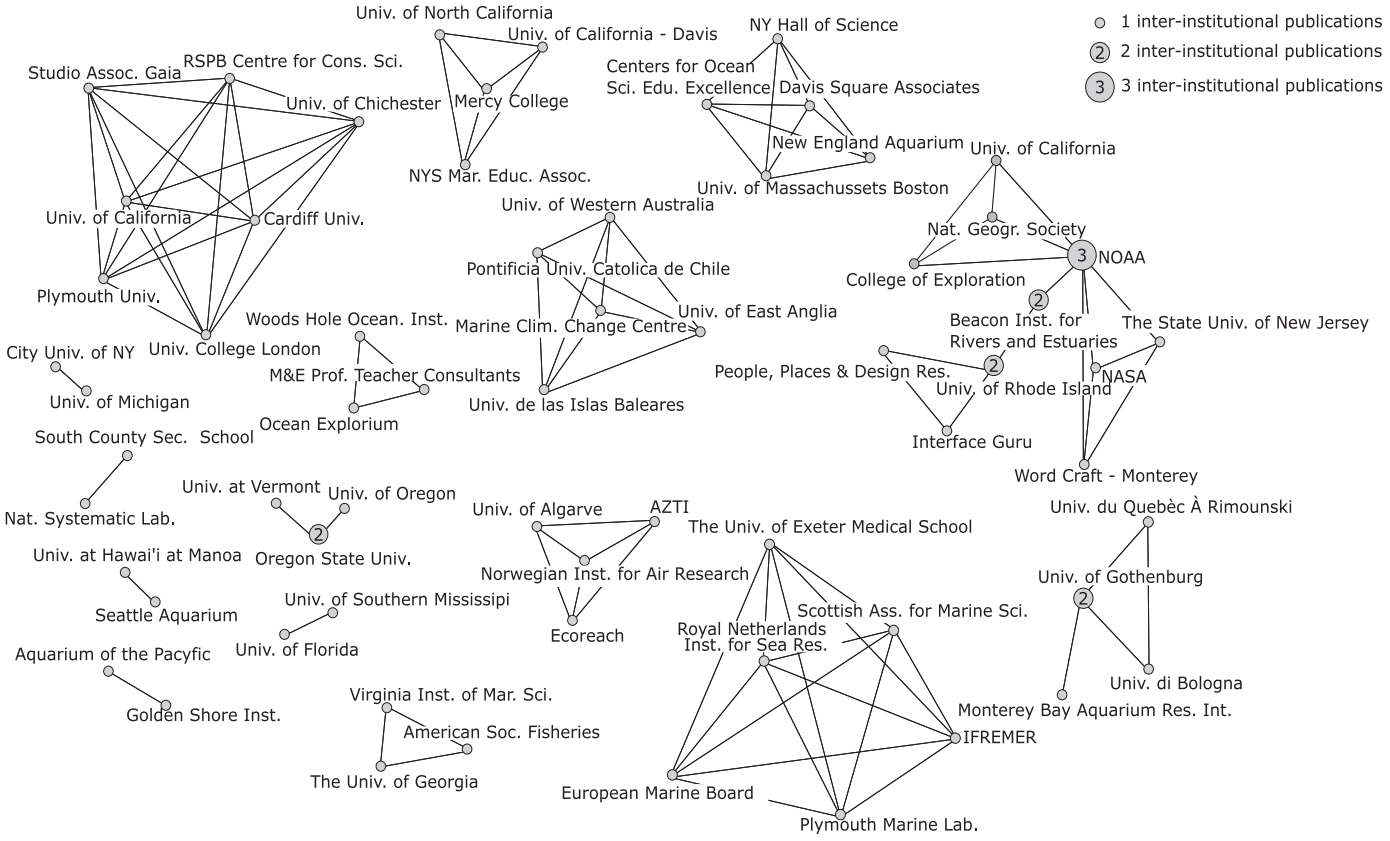

Fig. 6. Collaborative network among institutes. The lines denote collaborations between two institutes and its width refers to the frequency of collaboration. In this case, all collaborations had a frequency of 1, meaning that only one collaborative output between the pairs was found. The size of each circle stands for collaborative publication number.

Table 5
Active authors (with 2 or more published works) writing on "ocean literacy", from 2005 to 2016.

Author	Country	Number of publications (%)
Keener-Chavis P.	USA	5 (9.6)
Martinez C.	USA	3 (5.8)
Boubonari T.	Greece	2 (3.8)
Cava F.	USA	2 (3.8)
Curran M. C.	USA	2 (3.8)
Dupont S.	Sweden	2 (3.8)
Gorell F.	USA	2 (3.8)
Hotaling L.	USA	2 (3.8)
Kevrekidis T.	Greece	2 (3.8)
Markos A.	Greece	2 (3.8)
Schubel J. R.	USA	2 (3.8)
Scowcroft G. A.	USA	2 (3.8)
Steel B. S.	USA	2 (3.8)

(%): Percentage relative to all authors.

Table 6
Frequency of the title words mentioned 5 or more times in publications, from 2005 to 2016.

Title words	Frequency (%)
Science/Scientific/Scientists	20 (38.5)
Marine	12 (23.1)
Public	8 (15.4)
Education	6 (11.5)
NOAA	6 (11.5)
Students	5 (9.6)
Enhancing/Improve/Increase	5 (9.6)
Attitudes	4 (7.7)
Awareness	4 (7.7)
Coastal	4 (7.7)
Environment/Environments/Environmental	4 (7.7)
Exploration	4 (7.7)
Okeanos explorer	4 (7.7)
Ship	4 (7.7)
Teacher/teachers	3 (5.8)
Classroom/Classrooms	3 (5.8)
Curriculum	3 (5.8)
Engage/Engagement/Engaging	3 (5.8)
Impact/Impacts	3 (5.8)
Knowledge	3 (5.8)
Learning/Learnt	3 (5.8)
National	3 (5.8)
Research	3 (5.8)
Role	3 (5.8)
Understanding/Understand	3 (5.8)

The keywords related to filters, i. e., "ocean" and "literacy", are not included in this table. Stopwords (prepositions and empty words) were not included. Combination of plural forms, abbreviations, and other transformations were made.

questionnaires to assess the Greek pre-service teachers' knowledge, attitudes, and self-reported behaviours towards marine issues, but these authors did not include this word in the keyword list nor in the title.

Because all citizens directly or indirectly *impact* (TW, 7th position, Table 6) the *marine* (TW, 2nd position, Table 6) and *coastal environment* (TW, both in 6th position, Table 6), *public* (TW, 3rd position) OL could play a pivotal role in developing individual perceptions and shaping individual behaviours, which could contribute to decreasing or increasing the pressures on the ocean. OL is also essential to implement effective and efficient environmental policies because citizens can play a significant role in decision-making processes, required by both national and international regulations, and in efforts and support for ocean restoration and reforms [7,31,39–41]. In this sense, as stated in several contexts, citizens should be ocean literate in order to be

Table 7
Most frequent author keywords (mentioned 2 or more times) in "ocean literacy" publications, from 2005 to 2016.

Author Keywords	Frequency (%)
Attitudes	3 (12.2)
Questionnaire	2 (8.3)
Information sources	2 (8.3)
Middle school	2 (8.3)
Oceanology	2 (8.3)
Knowledge	2 (8.3)
Climate	2 (8.3)
Okeanos explorer	2 (8.3)

The keywords related to filter, i.e. "ocean literacy" are not included in this table.

engaged in policy discussions in an informed way.

The most used TW (Table 6) and AUKW (Table 7) also suggests that great importance has been attached to the OL educational perspective, since many of the words included in both lists refer to that (e.g. *education* (TW, 4th position, Table 6), *students* (TW, 5th position, Table 6), *teachers* (TW, 7th position, Table 6), *learning* (TW, 7th position, Table 6), *classroom* (TW, 7th position, Table 6), *middle school* (AUKW, 2nd position, Table 7)). In the educational framework, the main focus of the studies was: to understand if ocean science educators are prepared involves knowledge, training, skills and competencies needed to educate and inform students about ocean issues (e.g. [33,42]); to examine the knowledge, valuation, interaction and/or interest of students in ocean subjects (e.g. [11,43]) to describe ocean-related initiatives/activities and materials/tools developed and implemented to provide meaningful educational experiences to boost OL levels, both in formal and informal scenarios [8,28,44–47]. In line with the above, several authors advocate that integration of OL statements into standard school curricula would be an effective solution to create a generation of ocean-literate young people [9,11,42,48]. But, as Schubel & Schubel stated [7], enhancing public ocean literacy is a major challenge and efforts should be undertaken with adults as well as with children.

Despite the approaches already implemented over the studied period, more advanced and in-depth studies are required to understand several other OL issues. The OL baseline across social groups and all over the world are required to identify gaps that should be filled, since until now they were mainly focused in the USA and only recently have other countries started their own OL campaigns. The curricula reformulations should include more ocean-related subjects and issues along with the evaluation of their efficacy. The design of new materials and activities is necessary but also with appropriate monitoring and evaluation ensuring its efficiency and continuous refining. To strengthen international research cooperation on OL, there is a gap that should be filled. As far as these issues are concerned, strategic investments will be needed, not only to undertake OL activities but also to support scientific research related to it.

4. Conclusions

A bibliometric analysis was carried out to study, both quantitatively and qualitatively, global research patterns on OL up to 2016. An overview of the research was presented with information related to document type, publishing outlets (journals and conference proceedings), authors, countries, institutions, title words, and author keywords. Some issues and research trends were also considered.

In recent years, OL has become an interesting topic of research but not as successful in terms of scientific literature as might be expected, since published studies have been sparse. From 2005 (the year when the first publication presenting our criteria was found) to 2016, only 52 articles including conference papers were present in Scopus and WoS databases. The Proceedings of the MTS/IEEE OCEANS 2005 was the publishing outlet with most publications. The USA was the most influential country with the highest number of published works and authors. The most productive institution and the most active author were also from the USA (NOAA and Keener-Chavis, P., respectively). The UK and Italy presented the leading position regarding the number of international collaborative publications. Additionally, the UK established collaborations with the most countries. Finally, the keyword and title word analysis revealed the link between science and OL, the usage of questionnaires as a research tool to evaluate the levels of citizen OL (including general public, students and teachers), and the design of materials/activities to improve the OL levels of a range of groups across society.

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