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Framing Ocean Literacy as a Policy Tool to Address Marine Litter within Sustainability Transitions

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ABSTRACT

Marine litter persists as a complex global challenge, demanding not only technical solutions but also transformative shifts in public behavior, governance, and education. Ocean Literacy (OL) has emerged as a strategic framework to enhance societal understanding, foster civic engagement, and support sustainable marine policies. This systematic literature review network analysis examines the evolution of OL from an educational initiative into a multidimensional policy tool that advances behavioral change, public participation, and circular economy (CE) principles in combating marine litter. By systematically synthesizing over 60 peer-reviewed articles and policy documents sourced from Scopus-indexed journals and international initiatives such as the UN Decade of Ocean Science for Sustainable Development, this study maps the conceptual development and practical applications of OL across formal education, informal learning, community engagement, and governance contexts. Findings reveal that OL promotes environmental awareness, pro-ocean behavior, intergenerational learning, and local stewardship, contributing to reductions in single-use plastics, improved recycling practices, and enhanced citizen science participation. Furthermore, OL aligns effectively with CE strategies by fostering responsible consumption, reuse, and locally driven marine management. Despite these advancements, significant barriers remain particularly in low-resource settings stemming from structural, institutional, and cultural constraints. Scaling up OL requires inclusive, context-sensitive approaches, investments in teacher training, curriculum development, and community-based initiatives. This review underscores OL's potential not merely as an educational strategy but as a cross-sectoral policy mechanism to catalyze systemic, equitable, and sustainable solutions to marine litter.

1. Introduction

Marine litter represents one of the most pervasive and complex challenges to global marine ecosystems, with an estimated 11 million metric tons of plastic entering the ocean annually [63].

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Addressing this crisis requires integrated approaches that go beyond technical solutions, emphasizing behavioral change, community engagement, and systemic governance aligned with Sustainable Development Goals (SDGs 14, 12, and 4). This systematic literature review network analysis contributes to the growing discourse on the role of Ocean Literacy (OL) in environmental governance, specifically in addressing the pervasive issue of marine litter. Although the concept of OL emerged in the early 2000s, it has since expanded significantly most notably within the context of the UN Decade of Ocean Science for Sustainable Development to encompass dimensions such as knowledge, behavior, communication, emotional connection, and activism [39,60]. Despite this progress, OL has yet to be fully leveraged as a policy instrument for combatting marine pollution. Critics argue that although public awareness about marine debris is growing, it often remains superficial, disconnected from behavioral change, and hindered by curriculum gaps and teacher training deficiencies [3,16,51]. Moreover, empirical studies reveal that low levels of OL correlate with diminished support for marine litter policies and reduced willingness to engage in reduction practices [54,55]. In coastal regions and island communities where the impacts of marine litter are most visible, disconnections persist between ocean connected lifestyles and formal education systems [18,29]. While OL initiatives, such as informal learning programs and citizen science efforts, show promise in shifting perceptions and inspiring local action, their long term effectiveness and integration into policymaking remain under evaluated [41,67]. Therefore, framing OL not only as an educational priority but also as a strategic policy tool could catalyze more inclusive, informed, and sustained responses to marine litter challenges.

A positive outlook on Ocean Literacy (OL) as a policy tool has increasingly been expressed by advocates who recognize its potential to reduce marine pollution through behavioral change and enhanced public participation in ocean governance. OL is perceived as an effective means to foster awareness and individual responsibility for the marine environment while facilitating cross-sectoral collaboration through education, communication, and community empowerment [48,61]. Studies have shown that enhanced ocean literacy is positively associated with ocean-friendly behavior, including the reduction of single-use plastics and increased participation in recycling and coastal cleanup initiatives [43,57]. Moreover, the integration of OL into both formal and informal education can bridge knowledge gaps across generations and social groups, providing a strong foundation for public involvement in decision-making related to marine litter management [44]. Proponents further argue that, when systematically incorporated into environmental policies, OL can support the circular economy agenda in coastal and small island communities by promoting community-based waste management and the sustainable reuse of marine resources [49].

In light of the complex and multifaceted challenges posed by marine litter, the aim of this systematic literature review network analysis is to provide a balanced and evidence-based perspective on the potential and limitations of Ocean Literacy (OL) as a policy tool in addressing this global issue. This is not a technical analysis of marine waste treatment technologies, but it draws on over 60 academic and policy-oriented publications that collectively provide the conceptual and empirical foundation of the ocean literacy discourse, as evidenced by recent works on marine citizen science [12,30], sustainability education [20], ocean governance [26], and public engagement strategies [30,31]. Based on key authors and initiatives in this emerging field, the review is structured to first examine the conceptual development and measurement of OL in both educational and governance contexts, and second, to evaluate its role in enhancing stakeholder engagement and promoting behavioral change toward marine litter prevention. Particular emphasis is placed on OL initiatives that align with the United Nations Decade of Ocean Science for Sustainable Development and the Sustainable Development Goals (especially SDG 14), as these frameworks underscore OL's relevance to policy. While this review centers on OL applications in formal education systems,

community outreach, and citizen science, it does not encompass broader environmental education strategies or technical waste management infrastructures. However, many of the insights generated here are also applicable to related domains such as climate education, plastic governance, and participatory coastal planning.

The value of this article lies in its comprehensive assessment of the potential and limitations of Ocean Literacy (OL) as a policy instrument for addressing marine litter in a sustainable manner. It reinforces existing studies that demonstrate the central role of OL in enhancing public awareness, promoting behavioral change, and strengthening community engagement in ocean governance [40]. Among the growing body of literature, this systematic literature review network analysis is distinctive in framing OL within a broader historical context as a societal response to the need for reconceptualizing human ocean relationships, while also presenting it as a transformative policy approach within the framework of the United Nations Decade of Ocean Science for Sustainable Development. This perspective moves beyond the traditional knowledge-deficit model, incorporating underexplored social, emotional, and cultural dimensions relevant to marine litter prevention [22,35]. Despite the increasing recognition of Ocean Literacy (OL) in marine education and outreach, there remains a critical gap in scholarly reviews that synthesize its role as a formal policy instrument in marine governance, especially concerning marine litter reduction and circular economy alignment. Most existing reviews focus on pedagogical or awareness outcomes without linking OL to systemic change or sustainability transitions. This systematic literature review network analysis addresses that gap by positioning OL as a transdisciplinary mechanism that bridges public engagement with environmental policy. To our knowledge, this is one of the first reviews that explicitly frames OL as a strategic enabler of policy-based marine litter interventions. In doing so, OL is positioned not merely as an educational strategy, but as a foundational pillar for fostering collective awareness and concrete action in support of a circular economy in coastal and marine contexts.

2. Method

PRISMA enhances transparency, minimizes selection bias, and facilitates evidence-based decision-making, making it highly valuable for rapidly evolving and widely impactful fields such as marine education and environmental awareness. In this study, PRISMA was used to systematically review the literature on ocean literacy from 2015 to 2025, using the search query ("ocean literacy"). The selection of keywords was specifically designed to encompass studies relevant to ocean understanding, coastal ecosystem-based education, community engagement, and policies supporting ocean literacy. The term "ocean literacy" is used because it is widely adopted in the international literature as a conceptual umbrella that encompasses knowledge, attitudes, and actions towards the ocean. This strategy aims to balance specificity and inclusivity, preventing the inclusion of irrelevant studies while still ensuring comprehensive coverage of scientific publications that discuss the development, application, or evaluation of ocean literacy. With this approach, the study is able to map current research trends and support the development of evidence-based marine education strategies.

The selection of the appropriate database is crucial to ensure that the obtained literature has high scientific quality and reflects a comprehensive coverage of the existing research. For that reason, document searches were conducted through several major academic databases, including Scopus, ScienceDirect, SpringerLink, Wiley Online Library, SAGE Journals, and MDPI. Inclusion criteria were set to limit the search to English-language documents published between 2015 and 2025, which explicitly address the topic of ocean literacy from a conceptual, educational, or implementational aspect. Additionally, the main focus was given to peer-reviewed journal articles available in open access, in order to ensure data transparency and scientific replication. Of the total 207 documents

obtained, 54 were published in the period 2024–2025. After further screening based on accessibility, only 20 open access journal articles met the criteria and were included in the final analysis. This approach allows for a more accurate mapping of the latest trends, methodological approaches, and contributions of the literature to the development of ocean literacy, particularly in the context of education, public participation, and knowledge-based policies.

Table 1
Inclusion and exclusion criteria

Inclusion Criteria
1. The research work explicitly focuses on the concept or application of ocean literacy.
2. The study is published in a peer-reviewed scientific journal.
3. The publication is written in English.
4. The article was published within the time range of 2015 to 2025.
5. The study is accessible as an open access publication.
Exclusion Criteria
1. The research does not address ocean literacy as a central theme.
2. The study is an editorial, opinion piece, or news article.
3. The publication is not written in English.
4. The study was published outside the 2015–2025 time frame.
5. The article was not published through a peer-review process.
6. The article lacks an abstract or is missing essential bibliographic information.

Table 1 shows the criteria used to determine which studies will be included and excluded in this systematic review. These criteria are applied to ensure that only relevant, methodologically strong, and reliable studies are analyzed in this review. Inclusion criteria require articles to explicitly focus on the topic of ocean literacy, be written in English, published in peer-reviewed scientific journals, and fall within the time frame of 2015 to 2025. Additionally, only journal articles available as open access are considered for further analysis, in order to support openness and scientific replication. Conversely, studies that do not directly discuss ocean literacy, such as editorials or opinions, are not available in English, are not published through the peer review process, or do not fall within the specified time frame, are excluded from the analysis. By applying these strict selection criteria, the review ensures that only publications with significant scientific contributions to the development of ocean literacy are included. Out of a total of 207 documents found, 20 open access journal articles met all the criteria and were selected for further analysis.
To ensure a rigorous and systematic selection process, 15 conference proceedings articles and 15 review articles were excluded from the analysis. Conference proceedings articles were omitted due to limitations in methodological depth, the potential of not undergoing a stringent peer-review process, and the variability in quality that could affect the reliability of the findings. Similarly, review articles were excluded to avoid redundancy, given that the primary objective of this study is to provide an original and comprehensive synthesis of primary empirical research related to ocean literacy. By focusing the selection exclusively on peer-reviewed journal articles available in open access, this systematic review ensures that only studies with high methodological validity are included. This approach not only enhances the quality of the analysis but also strengthens the credibility and relevance of the findings in supporting the development of evidence-based marine literacy education policies and practices.

Table 2
Quality criteria

1. Is the purpose of the study clearly stated and aligned with ocean literacy themes?
2. Are the conceptual or theoretical frameworks related to ocean literacy clearly explained?
3. Are the research methods and educational/intervention strategies described in sufficient detail?
4. Are the results of the study presented clearly and supported by relevant data or evidence?
5. Do the authors identify limitations of the study and provide recommendations for future research?

The feasibility stage is the third step in the SLR process, which involves a thorough evaluation of each journal article in full-text to determine its suitability for inclusion in the final synthesis. Out of the 54 journal articles that passed the initial screening process, 34 articles were excluded because they did not meet the established quality criteria. The articles selected for further analysis are evaluated based on their alignment with the research objectives, clarity of the conceptual or theoretical framework related to ocean literacy, the research methods used, the strength of the data and results, and the acknowledgment of the study's limitations. Table 2 systematically summarizes these quality criteria. Specifically, 22 articles were excluded because they did not adequately explain the approach or framework of ocean literacy used, while 12 articles did not present in-depth analysis or did not directly address the research question. To ensure accuracy and objectivity, the evaluation was conducted independently by three researchers from Indonesia with experience in the fields of education and marine policy. Any differences of opinion are resolved through discussion, and if necessary, a third researcher is involved to reach a consensus. This multi-evaluator review approach strengthens the validity of the selection process, ensuring that only studies with high methodological quality are further analyzed. Articles that lack methodological clarity or have reporting weaknesses are still considered carefully. If the weaknesses are considered substantial and can compromise the integrity of the findings, the article is excluded. However, studies that offer significant insights despite having minor shortcomings are still discussed with reviewers for the final inclusion decision.

In the PRISMA framework, the Inclusion stage is the final stage in the study selection process after the Identification, Screening, and Eligibility stages. At this stage, the final list of articles that fully meet all inclusion criteria is established and prepared for systematic and in-depth analysis. In the context of this study, the Inclusion stage produced 20 open access journal articles that explicitly discuss the topic of ocean literacy within the 2024–2025 timeframe. These articles were selected because they demonstrate a strong relevance to the research question, have a clear methodological foundation, present credible empirical data, and are equipped with abstracts, methodologies, and traceable research results. All articles are worthy of analysis using thematic and narrative approaches to identify trends, challenges, as well as conceptual and practical contributions in the development of ocean literacy. Thus, the Inclusion stage ensures that only high-quality and academically meaningful publications are further analyzed in this study.

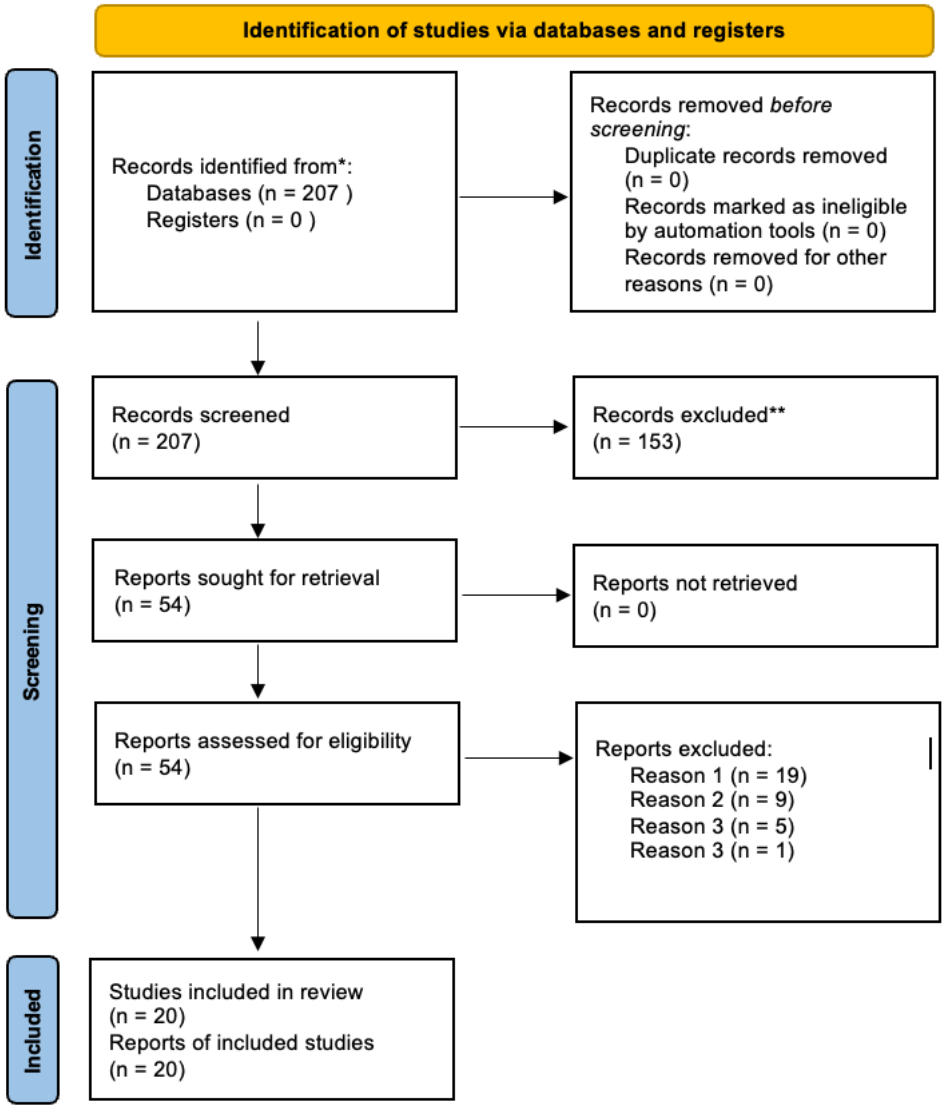

Fig. 1. PRISMA framework

3. Result and Discussion

Trend Publication

Figure Y1 shows the trend of scientific publications related to ocean literacy education during the period from 2010 to mid-2025. From the graph, it can be seen that the number of publications was relatively low and stagnant during the period 2010–2017, with only a few sporadic publications per year. However, the trend changed significantly since 2018, marking the beginning of a surge in research interest in this topic, with the number of publications increasing nearly fivefold compared to previous years. This increase continues, peaking in 2024 with more than 30 publications, making it the most productive year so far. The year 2025, although still mid-year, is already showing promising results with more than 20 publications, potentially matching or even surpassing the previous year's record.

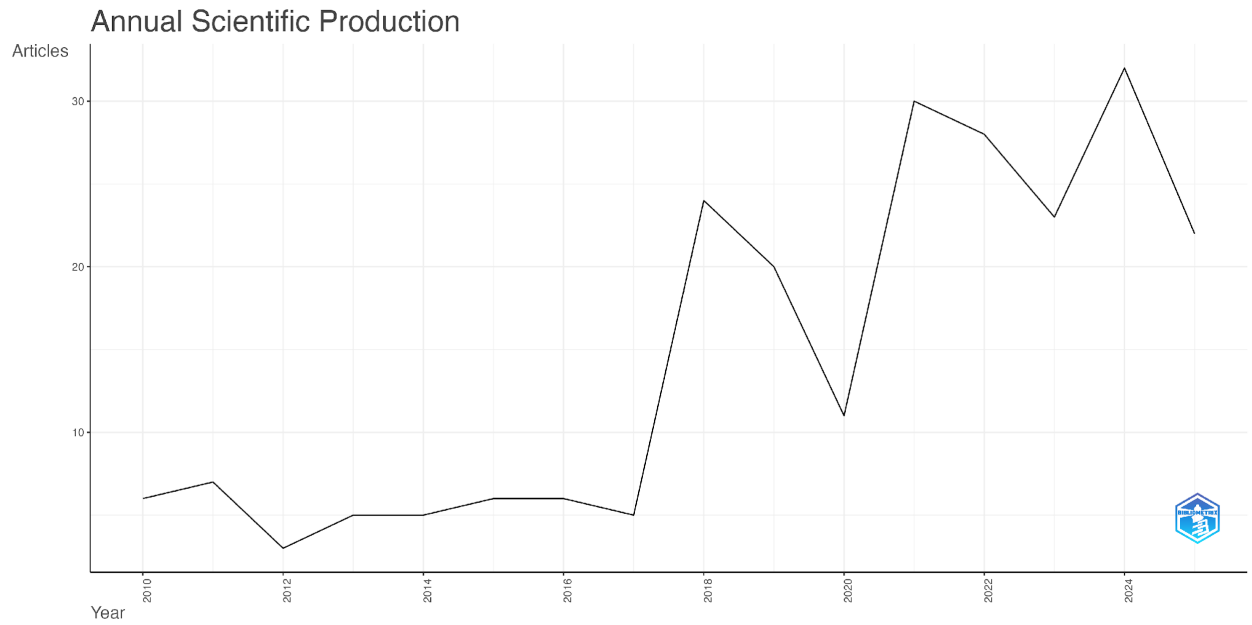

Fig. 2. Annual scientific production

Table 3 shows the distribution of core journal sources based on Bradford's Law, which categorizes 10 journals into two different productivity zones. The Bradford's Law analysis is useful for identifying the most relevant and productive core journal sources in a research field, thereby helping researchers to focus their literature search efficiently and strategically. The data in Table Y1 identifies Zone 1 as the most core source with the highest relative contribution to the research topic, encompassing six journals with the highest publication frequency: Frontiers in Marine Science, Exemplary Practices in Marine Science Education: A Resource for Practitioners and Researchers, Sustainability (Switzerland), Environmental Education Research, Mediterranean Marine Science, and Marine Policy. This zone indicates that the research field is highly focused on interdisciplinary topics of marine science, education, and sustainability.

Meanwhile, Zone 2 consists of journals with relatively narrower or more applied scopes, such as Key Challenges in Geography, Marine Pollution Bulletin, Journal of Geoscience Education, and Marine Technology Society Journal. This dispersed distribution indicates that the related research topics still rely on core journals but are beginning to expand into other relevant field journals. This could be due to the interdisciplinary nature of the topic, involving issues related to the ocean, environment, education, and policy.

For education practitioners and marine researchers, this finding indicates the need for access to various types of cross-disciplinary literature, not just from conventional marine journals. For educators and vocational education institutions, the distribution of journals in Table Y1 encourages awareness of the importance of collaboration with other disciplines such as geography, environmental education, and technology to design effective research and education strategies. This data shows that marine education issues are not only studied in the realm of pedagogy but are also recognized as important in the context of sustainability, public policy, and maritime technology.

Table 3
Core sources by Bradford's Law

SO	Rank	Freq	cumFreq	Zone
FRONTIERS IN MARINE SCIENCE	1	16	16	Zone 1
EXEMPLARY PRACTICES IN MARINE SCIENCE EDUCATION: A RESOURCE FOR PRACTITIONERS AND RESEARCHERS	2	14	30	Zone 1
SUSTAINABILITY (SWITZERLAND)	3	13	43	Zone 1
ENVIRONMENTAL EDUCATION RESEARCH	4	12	55	Zone 1
MEDITERRANEAN MARINE SCIENCE	5	12	67	Zone 1
MARINE POLICY	6	11	78	Zone 1
KEY CHALLENGES IN GEOGRAPHY	7	7	85	Zone 2
MARINE POLLUTION BULLETIN	8	7	92	Zone 2
JOURNAL OF GEOSCIENCE EDUCATION	9	6	98	Zone 2
MARINE TECHNOLOGY SOCIETY JOURNAL	10	5	103	Zone 2

Table 4 illustrates the local impact of various journal sources that publish articles related to the research topic, with indicators such as h-index, g-index, m-index, total citations (TC), number of publications (NP), and year of first publication (PY_start). The journals with the highest impact are seen in Frontiers in Marine Science and Marine Policy, which each have an h-index and g-index of 5 and 11, respectively, indicating consistent contributions to this topic. Frontiers in Marine Science recorded the highest m-index (0.714), followed by Mediterranean Marine Science (0.667) despite only starting to contribute in 2020. The highest total citations (TC) were recorded by Marine Policy (209), followed by Environmental Education Research (196), indicating that both journals are highly influential despite their relatively lower m-indexes (0.455 and 0.444). Meanwhile, other journals such as the Journal of Environmental Education, Marine Pollution Bulletin, and Journal of Geoscience Education have lower h-indexes (2) with m-indexes below 0.2, indicating a slower accumulation of impact.

Table 4
Sources' local impact

Source	h_index	g_index	m_index	TC	NP	PY_start
FRONTIERS IN MARINE SCIENCE	5	11	0,714	134	16	2019
MARINE POLICY	5	11	0,455	209	11	2015
ENVIRONMENTAL EDUCATION RESEARCH	4	12	0,444	196	12	2017
MEDITERRANEAN MARINE SCIENCE	4	7	0,667	49	12	2020
KEY CHALLENGES IN GEOGRAPHY	3	4	0,6	20	7	2021
EXEMPLARY PRACTICES IN MARINE SCIENCE EDUCATION: A RESOURCE FOR PRACTITIONERS AND RESEARCHERS	2	3	0,25	10	14	2018
JOURNAL OF ENVIRONMENTAL EDUCATION	2	3	0,154	112	3	2013
JOURNAL OF GEOSCIENCE EDUCATION	2	3	0,133	15	6	2011
MARINE POLLUTION BULLETIN	2	7	0,2	79	7	2016
MARINE TECHNOLOGY SOCIETY JOURNAL	2	2	0,133	6	5	2011

This data shows that although some journals do not have a very high number of publications, the articles published are able to gain significant attention and become important references. This analysis is important for researchers to choose journals that not only have a high reputation but also have the potential to provide quick visibility, such as Frontiers in Marine Science and Mediterranean

Marine Science. It also emphasizes that this topic is still developing across disciplines and that high-impact opportunities remain open for relevant and high-quality individual articles.

Figure 3 displays a world map illustrating the geographical distribution of research documents related to the topic of ocean literacy in education, based on the authors' country affiliations. From the visualization, the United States ranks at the top with 181 documents, followed by Australia (64), Brazil (60), Italy (57), and China (46), indicating the dominance of North America, Europe, and Asia in this research contribution. Other countries with significant contributions include Malaysia (4), India (4), Indonesia (31), the UK (82), France (32), Spain (39), Poland (20), and Canada (43). Meanwhile, several countries such as Tanzania (3), Ethiopia (1), and South Africa (10) also contributed, albeit in smaller numbers.

These findings indicate that the topic of ocean literacy in education has become a global concern, although its distribution remains uneven. Countries with strong educational and marine research ecosystems, such as the United States, the UK, and Australia, excel, likely due to support for marine education policies, maritime research funding, and the integration of sustainable development goals (SDGs) into national education. On the other hand, Indonesia's position with a significant contribution (31 documents) reflects the increasing awareness of the importance of ocean literacy in developing countries, alongside efforts to strengthen maritime education and locally-based vocational training. We analyze that the approach of ocean literacy in education is no longer limited to developed countries, but is beginning to be adopted and developed in various regions of the world, including the Global South. This opens up opportunities for international collaboration and cross-cultural knowledge exchange to strengthen maritime education that is relevant to regional challenges. For vocational and general education, this geographical context highlights the importance of local adaptation in the implementation of ocean literacy, in accordance with local socio-economic and ecological conditions. Figure Y2 emphasizes that the movement for ocean literacy in education is a global and inclusive phenomenon, and opens up discussions about the imbalance in research distribution, opportunities for international collaboration, and the need for cross-country contextual approaches to support ocean sustainability through education.

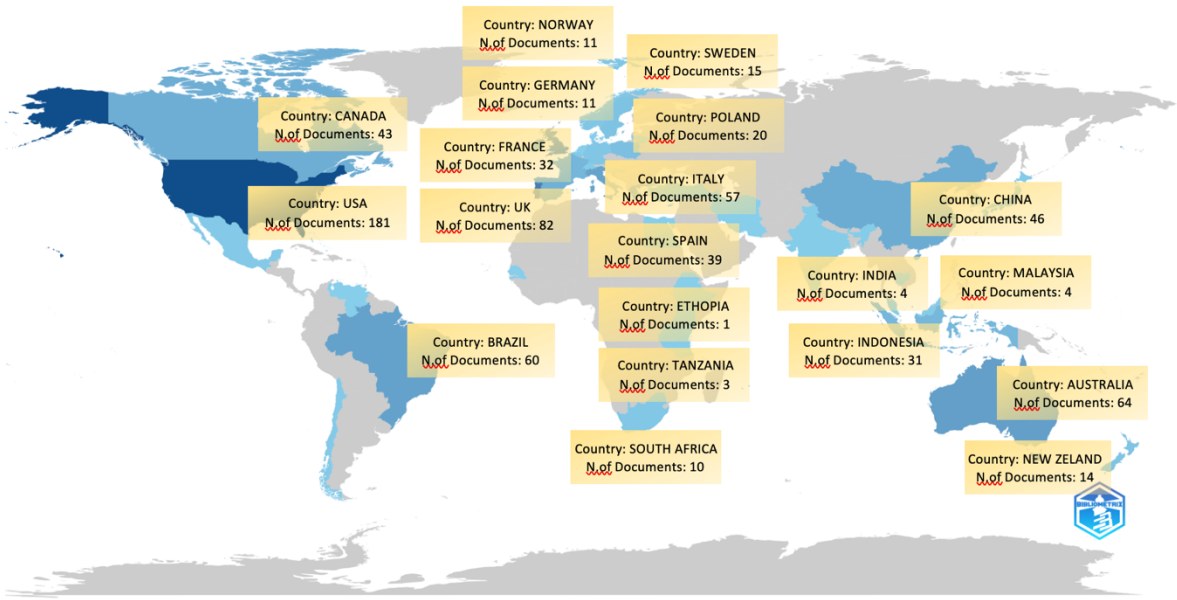

Fig. 3. Countries' scientific production

The sharp increase in publications can be explained by several key factors. First, the increasing global awareness of the marine environmental crisis, especially within the framework of the United Nations Decade of Ocean Science for Sustainable Development (2021–2030), which encourages the integration of ocean literacy into formal and non-formal education policies. Second, the development of experiential-based educational methodologies, such as immersive learning, citizen science, and interdisciplinary approaches, makes this topic increasingly relevant for educators and researchers. Third, pressure from national and international policies related to the sustainable management of marine resources makes ocean literacy a key competency that needs to be instilled early through education.

From the impact perspective, the findings of this trend are important for educators, policymakers, and the academic community. The surge in publications indicates a significant opportunity to strengthen ocean literacy-based education curricula that can build critical awareness, behavioral change, and citizen skills in supporting marine sustainability. For authors and readers of scientific articles, this publication trend indicates that ocean literacy education has developed into a solid, relevant, and potentially further-explored research niche, for example, related to program impact assessment, innovative pedagogy, and the integration of digital technology. Overall, this graph not only reflects the quantitative growth of publications but also indicates a shift in the educational paradigm towards a more inclusive, science-based, and ocean sustainability-oriented approach.

This systematic literature review network analysis addresses three key research questions to guide a comprehensive understanding of Ocean Literacy (OL) as a policy tool for addressing marine litter: (1) How has the concept and implementation of OL evolved about global ocean governance and public engagement over the past two decades? (2) What are the primary objectives of marine litter policy, particularly in terms of fostering behavioral change, public participation, and intergenerational awareness? (3) In what ways can OL serve as an essential mechanism to support these policy objectives, particularly through education, community involvement, and alignment with circular economy principles? These questions are explored through a synthesis of international research and practice, drawing from both formal educational interventions and informal, community-based initiatives; by critically engaging with the emerging dimensions of OL ranging from emotional connection to adaptive capacity, this review positions OL not only as a tool for communication and knowledge dissemination but as a transformative element in the broader effort to prevent marine pollution and promote sustainable ocean stewardship. Figure 2 illustrates the chronological evolution of Ocean Literacy (OL) over the past two decades, aligning with shifting priorities in marine litter policy and ocean governance.

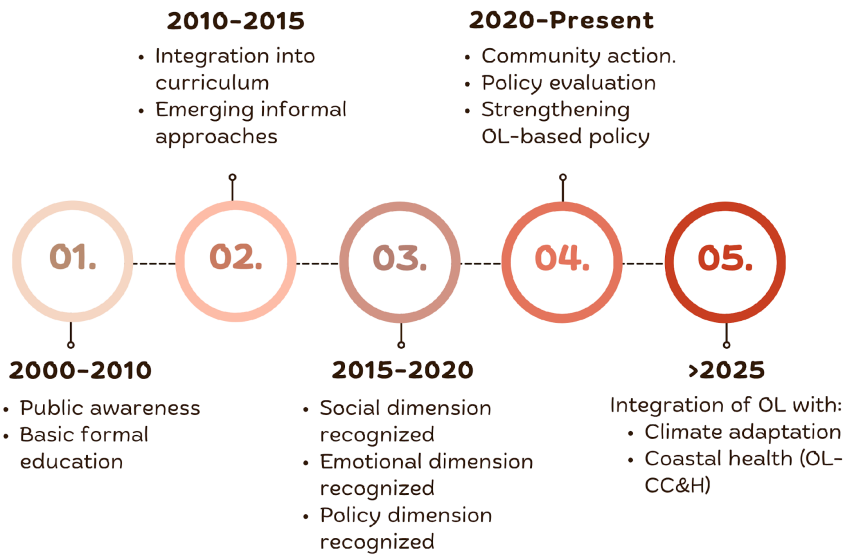

Fig. 4. Timeline of the evolution of Ocean Literacy (OL)

Since its inception in the early 2000s, Ocean Literacy (OL) has evolved from knowledge-based education efforts into a transdisciplinary policy framework that incorporates social, emotional, and public governance dimensions [23,47]. From early awareness and formal education (2000–2010), OL expanded into school curricula and informal programs (2010–2015), followed by integration into global agendas and evaluative frameworks (2015–2020) [9,64]. In recent years (2020–present), OL has been applied as a policy and behavioral change tool through action-based education and community interventions [25,58]. Looking ahead, OL is increasingly aligned with climate adaptation and coastal health (OL-CC&H), emphasizing systemic, collaborative, and intergenerational approaches [17,65]. However, this evolution has been uneven globally, with adoption advancing more rapidly in countries with strong educational and policy infrastructures while developing nations continue to face implementation challenges [14].

The approach used in this systematic literature review network analysis is exclusively focused on reviewing scientific literature indexed in the Scopus database and relevant international policy documents concerning Ocean Literacy (OL). The author conducted a systematic search for peer-reviewed articles that explore the relationship between ocean literacy (OL) and issues such as marine litter, coastal community behavior, and the role of education and public participation in sustainable ocean governance. Keywords were carefully selected to capture various dimensions of OL, including knowledge, awareness, attitudes, and collective action. In addition to academic literature, this review also examined key international policy frameworks, such as the United Nations Decade of Ocean Science for Sustainable Development (2021–2030) and the UNESCO-IOC Ocean Literacy Framework [64], as well as policies from the European Union and other global institutions that explicitly integrate ocean literacy (OL) as part of their marine management and marine litter reduction strategies [17, 63]. This approach enables a comprehensive conceptual and policy synthesis to evaluate the potential of OL as a transformative tool in fostering awareness, responsible behavior, and public engagement in systemic and sustainable marine litter management.

Concept and Implementation of Ocean Literacy (OL) Evolved in Relation to Global Ocean Governance and Public Engagement

The first research question is addressed through a chronological analysis of the development of Ocean Literacy (OL) since its conceptual emergence in the early 2000s, referencing key milestones, evolving goals, and expanding dimensions. As illustrated in Figure 1, the trajectory of OL is examined within the context of shifting priorities in ocean governance, from an initial emphasis on scientific knowledge transfer to more holistic and participatory frameworks that encompass emotional connection, activism, and adaptive capacity [47,52]. This review highlights how early OL efforts were largely centered on formal education systems and focused on raising awareness, though they often relied on a knowledge-deficit model. Over time, however, OL has evolved by incorporating broader socio-cultural and behavioral dimensions, enabling its application in informal education, community-based programs, and policy interventions. For example, earlier models that narrowly framed marine litter as a technical issue have increasingly been replaced by integrated approaches that position OL as a catalyst for behavioral change, policy innovation, and civic engagement [56]. This transformation reflects a growing recognition of OL's relevance not only in education but also in marine conservation, environmental justice, and circular economy strategies.

Building on this evolution, scholars have expanded the definition and scope of OL to better meet the demands of contemporary ocean governance. McKinley *et al*., [39] emphasize that the original knowledge-based definition of OL has become increasingly insufficient. Their study introduces an expanded framework comprising ten dimensions, ranging from knowledge and behavior to emotional connection and adaptive capacity. This broader conceptualization positions OL as a holistic instrument supporting the United Nations Decade of Ocean Science and broader sustainability agendas. Consequently, OL is now understood as both a cognitive and relational construct, integrating scientific, civic, and affective domains to foster greater public engagement in sustainable ocean governance.

In response to gaps in formal curricula, informal marine education programs have emerged as vital platforms for fostering OL. O'Brien *et al*., [46] demonstrate that such programs in Australia's Great Southern Reef region allow students to engage in immersive, context-driven experiences that significantly enhance their connection with marine environments. Their mixed-methods study shows that while 89.4% of participants were familiar with OL principles, only about half of the informal educators had formally integrated them into their programs. Nonetheless, the study emphasizes that experiential learning such as field trips and community projects—can powerfully complement and even compensate for the lack of OL integration in formal systems, particularly in nurturing pro-ocean attitudes and behavior.

The institutionalization of OL in policy and education systems necessitates robust frameworks for evaluation and implementation. Liu *et al*., [37] address this need by proposing an integrated OL assessment model using the Delphi-AHP methodology, which encompasses both scientific and socio-cultural dimensions. Their two-tier framework comprising seven Tier 1 and twenty-nine Tier 2 criteria serves as a guiding reference for policymakers and educators alike. By weighting and prioritizing various OL elements, the model offers a standardized tool to assess public ocean understanding and guide curriculum development, resource allocation, and regulatory decisions. This highlights the maturation of OL as a policy-relevant instrument grounded in empirical rigor.

Despite growing institutional and scholarly attention, significant gaps remain in the practical implementation of OL, especially within formal education systems. Costa *et al*., [14] investigated OL integration in public schools across the Azores archipelago and found that although teachers generally acknowledge the importance of OL, 58% do not incorporate ocean-related themes in their

lessons. The study links this gap to structural barriers, such as the absence of OL in official curricula and the lack of accessible educational materials. These findings underscore the urgency of embedding OL more deeply into school systems and align with calls for policy reform and capacity-building to ensure that OL becomes a normative element of education and public engagement on ocean issues.

Primary Objectives of Marine Litter Policy, Particularly In Terms of Fostering Behavioral Change, Public Participation, And Intergenerational Awareness

Contemporary marine litter policies have evolved beyond technical solutions focused solely on reducing plastic waste and pollution. Increasingly, these policies emphasize the importance of cultivating sustainable behaviors, promoting environmental stewardship, and encouraging active public participation [27,32]. As noted by Bettencourt *et al*., [10], effective marine litter governance frameworks aim to bridge the gap between scientific data and public engagement by incorporating Ocean Literacy (OL) into educational and policy-making processes. These efforts align with a growing body of research emphasizing that addressing the root causes of marine pollution requires a transformation in societal attitudes and behaviors, not merely improved waste infrastructure [21,34,53,59]. Furthermore, Costa *et al*., [15] highlight that embedding OL into national education strategies allows marine policy objectives to become more actionable at the local level.

Education plays a central role in translating policy into community-level action [33,45]. Studies by Freitas *et al*., [20] and Qu *et al*., [54] demonstrate that localized and participatory marine education initiatives are among the most effective strategies for fostering sustainable behavioral change. In Brazil, for example, co-creation methods and community engagement through OL programs have led to measurable reductions in littering and increased environmental advocacy among youth. Similarly, Qu *et al*., [54] found that individuals with a strong perception of marine OL particularly in terms of emotional and personal connection exhibited higher intentions to engage in actions against marine pollution. These findings underscore the importance of tailoring OL programs to local contexts, using culturally relevant tools and experiential learning to ensure that environmental messages resonate with diverse communities.

Beyond formal education, intergenerational learning and citizen science have emerged as powerful components of marine litter policy strategies. Hartley *et al*., [27] demonstrated that children who participate in OL initiatives can act as “change agents,” influencing the attitudes and behaviors of their families, thereby creating a ripple effect within communities. This intergenerational dynamic not only strengthens the sustainability of behavioral change but also reinforces community identity and environmental values. Moreover, as highlighted by Freitas *et al*., [20] and Bettencourt *et al*., [10], the integration of citizen science projects into marine policy fosters trust, increases public awareness, and enables communities to take ownership of marine conservation efforts. These participatory approaches help bridge the policy-implementation gap and ensure that marine litter governance is inclusive, equitable, and effective over the long term.

OL Serve as an Essential Mechanism to Support these Policy Objectives, Particularly through Education, Community Involvement, and Alignment with Circular Economy Principles

Ocean Literacy (OL) has proven to be an effective driver of behavioral change in communities dealing with marine litter, especially when aligned with everyday consumption and waste practices [4,24]. Qu *et al*., [54] found that higher levels of OL were significantly associated with reduced use of single-use plastics and a greater willingness to participate in environmental activities such as beach

clean-ups. Similarly, Liu *et al*., [37] proposed a structured framework for assessing OL through multi-tier indicators, which helps policymakers and educators evaluate the behavioral dimensions of marine engagement. These tools not only guide public education strategies but also enable alignment with circular economy (CE) principles by promoting waste reduction and responsible consumption practices. In this way, OL becomes an actionable mechanism for advancing sustainability goals within marine and coastal policies.

The integration of OL into school curricula and community programs further strengthens its role in supporting marine litter policy [5,13,38]. As shown by Costa *et al*., [14], local schools that embed OL in their daily practices through cross-disciplinary projects, marine-themed lessons, and local beach monitoring are more likely to internalize sustainable behaviors and contribute to local waste governance. McRuer *et al*., [41] extend this finding by emphasizing the value of youth engagement, noting that students equipped with OL competencies often act as environmental ambassadors within their communities. These educational interventions not only enhance ecological knowledge but also empower individuals to become active participants in policy implementation, thus closing the gap between environmental understanding and collective action.

Beyond education and behavior change, OL contributes directly to the advancement of circular economy (CE) strategies, especially in regions burdened by plastic pollution [28,50,66]. Freitas *et al*., [20] demonstrate how OL initiatives in Brazilian coastal communities support the transition from linear waste systems toward circular models by fostering awareness of resource limitations, reuse strategies, and collaborative problem-solving. McKinley *et al*., [39] further assert that OL's ten-dimension framework including emotional connection, trust, and adaptive capacity provides a foundation for systemic transformation, enabling communities to shift from passive recipients of policy to proactive agents of change. Thus, OL is not only a tool for understanding marine environments but also a policy lever that aligns local actions with global sustainability frameworks such as the SDGs and CE principles.

Another critical dimension of Ocean Literacy (OL) in marine litter policy is its potential to enhance social equity and inclusivity in environmental decision making [2,7]. Marginalized and coastal communities are often the most affected by plastic pollution, yet their voices are frequently underrepresented in marine policy processes [6]. OL provides a platform for these communities to participate meaningfully by equipping them with the knowledge, language, and tools necessary to engage with local and national governance structures [42,62]. McRuer *et al*., [41] emphasize that when OL is approached not just as a set of scientific facts but as a culturally responsive and place-based practice, it can bridge social divides and democratize access to marine conservation efforts. In this way, OL aligns with principles of environmental justice, ensuring that marine litter solutions are shaped by diverse perspectives and grounded in local realities.

As Ocean Literacy gains traction as a policy instrument, national and international strategies have begun to formally integrate OL frameworks into marine governance [36]. Initiatives such as the "Blue Schools" network in Europe and the Ocean Decade Implementation Plan by UNESCO-IOC serve as vehicles for mainstreaming OL into national education and marine policy agendas. McKinley *et al*., [39] note that such initiatives mark a strategic pivot positioning OL not only as an educational imperative but as a cross-sectoral policy priority tied to Sustainable Development Goals (particularly SDG 14 and SDG 12). The integration of Ocean Literacy (OL) into long-term strategic domains such as marine spatial planning, waste management, and youth engagement reflects a growing governmental acknowledgment that cultivating a knowledgeable and empowered citizenry is fundamental to advancing circular and sustainable marine economies. In addition to conceptual developments and empirical findings, several practical initiatives have demonstrated how Ocean Literacy (OL) can be operationalized within policy frameworks to advance marine litter reduction and

foster sustainable behavioral change. Table 1 summarizes selected OL-based policy initiatives from different regions, highlighting their core dimensions, target audiences, policy linkages, and key outcomes.

Tabel 5
Summary of key ocean literacy-based policy initiatives

Initiative	Region	OL Dimension	Target Audience	Policy Linkage	Outcome
Blue Schools Network	EU	Curriculum integration, civic engagement	Students and teachers	SDG 14.2, EU Marine Strategy	Improved coastal awareness
COLLECT Citizen Science	Africa & SE Asia	Emotional connection, participation	Youth & women groups	Ocean Decade Action	Waste reduction, intergenerational learning
Ocean Incubator Toolkit	Global (UNESCO)	Adaptive capacity, co-creation	NGOs, educators	Ocean Decade & SDG 12	Curriculum resource & capacity building

The initiatives summarized in Table 1 illustrate the diverse ways in which Ocean Literacy (OL) is being translated into actionable policy frameworks across different regions and governance contexts. The *Blue Schools Network* in Europe exemplifies formal curriculum integration that fosters civic engagement among students and teachers, directly supporting the EU Marine Strategy and SDG 14.2. Similarly, *COLLECT Citizen Science* projects in Africa and Southeast Asia leverage community participation particularly among youth and women to build emotional connections with marine environments and drive behavioral change through locally relevant actions aligned with the UN Ocean Decade goals. On a global scale, the *Ocean Incubator Toolkit* developed by UNESCO promotes adaptive capacity and co-creation among educators and NGOs, reinforcing systemic policy linkages with SDG 12 and broader circular economy principles. Collectively, these initiatives demonstrate that OL-based interventions can serve as effective policy levers by enhancing public engagement, facilitating cross-sector collaboration, and embedding sustainability values within both formal education systems and grassroots community efforts.

4. Conclusion

This systematic literature review network analysis underscores the transformative potential of Ocean Literacy (OL) as a cross-sectoral policy instrument for addressing the pervasive challenge of marine litter. The findings reveal that OL has evolved from a narrow knowledge-based educational approach into a multidimensional framework that integrates cognitive, behavioral, emotional, and participatory dimensions aligned with contemporary sustainability and governance agendas. OL not only enhances public understanding of marine ecosystems but also fosters pro-environmental behaviors, intergenerational learning, and community engagement, which are pivotal for effective marine stewardship. Empirical evidence consistently demonstrates that higher levels of OL are associated with tangible actions such as reduced plastic consumption, increased recycling, and active participation in coastal conservation initiatives. Moreover, OL supports the transition toward Circular Economy (CE) principles by promoting responsible consumption, resource reuse, and locally driven marine management practices. However, the review also highlights persistent structural, institutional, and cultural barriers, particularly in low-resource settings, that limit the integration of OL into formal curricula, policies, and community programs. Overcoming these barriers requires sustained investment in teacher training, culturally relevant curricula, and inclusive community

engagement strategies that respect and leverage local knowledge systems. Initiatives such as the UN Decade of Ocean Science for Sustainable Development and the Blue Schools network exemplify promising pathways for embedding OL into governance frameworks and fostering societal resilience, equity, and sustainability. Overall, this review positions OL as more than an educational priority—it is a strategic, policy-relevant mechanism capable of catalyzing systemic change at individual, community, and institutional levels, and advancing collective efforts to address marine litter within broader sustainability transitions.

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