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Bibliometric analysis of microplastic pollution in marine and coastal environments: trends and perspectives

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Abstract: The global increase in plastic production and the inefficient management of its waste have turned microplastic pollution into a growing threat to marine and coastal ecosystems, affecting biota, ecological functions, and human health. This study aimed to quantitatively analyse the scientific evolution of research on microplastic pollution in marine and coastal environments, identifying patterns of growth, collaboration, and thematic specialisation. Bibliometric mapping was applied to 6,510 records retrieved from Scopus (1980–2026) using Bibliometrix 5.1.1 and VOSviewer 1.6.20, assessing indicators of productivity, impact, cooperation, Lotka's and Bradford's laws, and RPYS spectrography. Results reveal an annual growth rate of 5.55%, involving 15,398 authors, an average of 11.6 co-authors per article, 29.48% international collaboration, and a mean citation rate of 65.9 per document. Marine Pollution Bulletin leads the field with 1,332 articles, while China ranks first in global output (1,387 documents), followed by the United States (735) and Italy (585). The dominant subject areas are Environmental Sciences (38.6%) and Biological Sciences (17.9%). In conclusion, research on marine–coastal microplastics has reached a stage of structural maturity and international impact, consolidating itself as a key interdisciplinary field for ocean pollution mitigation and the advancement of SDGs 6, 12, and 14.

Keywords: Marine pollution, scientific bibliometrics, international cooperation, ecotoxicology, ocean sustainability.

Resumo: O aumento global da produção de plásticos e a gestão ineficiente de seus resíduos transformaram a poluição por microplásticos em uma ameaça crescente aos ecossistemas marinhos e costeiros, afetando a biota, as funções ecológicas e a saúde humana. Este estudo teve como objetivo analisar quantitativamente a evolução científica sobre a poluição por microplásticos em ambientes marinhos e costeiros, identificando padrões de crescimento, colaboração e especialização temática. Aplicou-se a cartografia bibliométrica a 6.510 registros recuperados da base Scopus (1980–2026), por meio do Bibliometrix 5.1.1 e do VOSviewer 1.6.20, avaliando indicadores de produtividade, impacto, cooperação, leis de Lotka e Bradford, e espectroscopia RPYS. Os resultados evidenciam um crescimento anual de 5,55 %, com 15.398 autores, 11,6 coautores por artigo, 29,48 % de colaboração internacional e média de 65,9 citações por documento. A revista Marine Pollution Bulletin lidera com 1.332 artigos, enquanto a China ocupa a primeira posição em produção global (1.387 documentos), seguida pelos Estados Unidos (735) e pela Itália (585). As áreas dominantes são Ciências Ambientais (38,6 %) e Ciências Biológicas (17,9 %). Em conclusão, a pesquisa sobre microplásticos marinho-costeiros atingiu uma fase de maturidade estrutural e impacto internacional, consolidando-se como um campo interdisciplinar essencial para a mitigação da poluição oceânica e o cumprimento dos ODS 6, 12 e 14.

Keywords: Poluição marinha, bibliometria científica, cooperação internacional, ecotoxicologia, sustentabilidade oceânica.

Introduction

Global plastic production has grown exponentially since the mid-20th century, reaching 400.3 million tonnes in 2022, compared with less than 2 million in 1950 [1]. If current trends persist, global production is expected to triple by 2060, accompanied by a parallel increase in mismanaged plastic waste [2]. Between 19 and 23 million tonnes of plastic waste entered aquatic ecosystems in 2016 [3], and the latest projections suggest that, in the absence of substantive interventions, this Figure could exceed 53 million tonnes annually by 2030 [4]. Global estimates indicate that over 170 trillion plastic particles currently float on the ocean surface, with an accumulated mass exceeding 2.3 million metric tonnes [5]. This persistent waste flow has led the United Nations to classify plastic pollution as one of the three planetary crises, alongside climate change and biodiversity loss [6].

Microplastics (MPs), defined as plastic particles or fibres smaller than 5 mm, represent a particularly concerning fraction due to their high dispersion, persistence, and ability to transport pollutants [7]. Their origin may be primary, when deliberately manufactured at this size (e.g., cosmetic microbeads, industrial pellets), or secondary, when derived from the fragmentation of larger plastics through physical, chemical, or biological processes [8]. Their microscopic size increases the surface-to-volume ratio, enhancing the adsorption of persistent organic pollutants (POPs), heavy metals, and antibiotics [9]. Microplastics have been detected in all marine matrices – water, sediments, benthic organisms, plankton, and seabirds – with concentrations ranging from 0.001 to over 100,000 particles m^{-3} depending on region and sampling method [10].

The ecological consequences are multiple and complex. Experimental studies and meta-analyses have demonstrated physiological and behavioural alterations in invertebrates and fish, including growth inhibition, tissue damage, oxidative stress, and impaired reproductive success [11]. Moreover, trophic transfer of microplastics has been confirmed across marine food webs and in commercially important species such as Mytilus edulis, Sardinops sagax, and Thunnus albacares, suggesting a potential risk to human health [12]. Recently, average concentrations of 240,000 particles L^{-1} (90% nanoplastics) were detected in bottled water using stimulated Raman microscopy, evidencing the infiltration of these particles even in human-consumption matrices [13].

In line with the international commitments of the 2030 Agenda for Sustainable Development, reducing microplastic pollution is directly linked to SDG 14, "Life below water", particularly target 14.1, which urges the prevention and significant reduction of marine pollution of all kinds, especially that originating from land-based activities, including marine debris and nutrient pollution, by 2025 [14]. This challenge also intersects with SDG 12, "Responsible consumption and production", target 12.4, which aims to achieve the environmentally sound management of chemicals and all wastes throughout their life cycle [15], and with SDG 6, "Clean water and sanitation", target 6.3, focused on improving water quality by reducing pollution and minimising the release of hazardous chemicals and materials [16]. Within this framework, understanding the scientific and geographical dynamics of research on microplastics in marine-coastal ecosystems acquires strategic value, as it generates evidence to monitor progress towards these goals and strengthen global policies for the prevention, mitigation, and governance of plastic pollution [17].

Simultaneously, scientific attention towards microplastics has expanded steadily and multidisciplinarily, driven by their detection in extreme and remote environments – from Antarctic ice and abyssal sediments to the marine atmosphere and alpine snow [18]. In coastal ecosystems, where river discharges, industrial, port, and fishing activities converge, concentrations can exceed 100,000 particles kg^{-1} of dry sediment, highlighting their role as sinks and secondary reservoirs of plastic pollution [19]. This global recognition has stimulated new research lines focusing on molecular ecotoxicology, trophic bioaccumulation, the development of biodegradable biopolymers, and the application of advanced monitoring technologies such as Raman spectroscopy, satellite remote sensing, and oceanic dispersion models [20,21].

Nonetheless, substantive gaps persist in understanding transport pathways, in situ degradation processes, and chronic effects on filter-feeding organisms, benthic communities, and key ecosystem functions [22]. These limitations underscore the need for integrative approaches that bridge scientific observation with environmental management and coastal public policy, thereby consolidating a knowledge framework that supports the transition towards a sustainable and circular ocean economy [23].

Understanding the complexity and dynamism of microplastic pollution in marine and coastal environments – with the aim of guiding effective mitigation, monitoring, and management strategies – requires first a comprehensive view of the scientific development achieved over recent decades. This panorama leads to the central research question: What is the level of scientific development, specialisation, and collaboration in the study of microplastic pollution in marine and coastal ecosystems, and how has it evolved over time? From this overarching question arise twelve specific research inquiries guiding the present analysis: i) How has scientific production on marine–coastal microplastics evolved over time?, ii) What types of documents predominate in the field, and what has been their relative weight during the study period?, iii) Which thematic areas within Scopus are most closely related, and how are they interconnected?, iv) Which institutions and countries lead production, and what is their relative contribution to global knowledge?, v) Who are the most influential authors, and how are their trajectories and collaboration networks characterised?, vi) To what extent does author productivity conform to Lotka's law, and what does this reveal about the concentration of scientific leadership?, vii) Which journals account for the largest dissemination of studies on marine and coastal microplastics?, viii) How is the core of dissemination structured according to Bradford's law and the zones of specialisation?, ix) What is the degree of international cooperation among countries, regions, and institutions?, x) What does Reference Publication Year Spectroscopy (RPYS) reveal about the historical roots and years of greatest impact in the field's evolution?, xi) Which seminal publications, analytical methods, or regulatory frameworks explain the citation peaks identified through RPYS? and xii) What emerging trends and research fronts define the future agenda of the field based on keyword dynamics and thematic mapping?

In light of these questions, the general objective of this study is to describe and quantitatively analyse the evolution of research on microplastic pollution in marine and coastal environments, identifying its temporal, geographical, and thematic patterns, as well as collaboration networks, influential sources, and emerging research fronts, with the aim of providing systematic evidence that contributes to the sustainable management of marine – coastal ecosystems and the fulfilment of the global targets linked to Sustainable Development Goals 6, 12, and 14.

1. Materials and methods

To quantitatively analyse the evolution and scientific structure of research on microplastic pollution in marine and coastal environments, bibliometric mapping was applied as a quantitative method grounded in mathematical and statistical models, aimed at examining scientific production, collaboration patterns, and thematic dynamics in the field. This approach enables the synthesis of trends, the identification of influential authors, institutions, and countries, and the recognition of research gaps and emerging fronts, offering an integrative view of theoretical and methodological developments related to microplastic pollution in marine ecosystems.

The methodological application followed the stages proposed by [24]: (i) formulation of the general and specific research questions; (ii) selection of the reference database; (iii) construction of a reproducible search equation; and (iv) statistical analysis and visualisation of the retrieved metadata.

The study adopted a quantitative, exploratory–descriptive approach with a non-experimental, longitudinal, and retrospective design, covering the period from the earliest available records to 2025. The analytical objective was to trace and interpret the evolution of scientific literature on microplastics in marine and coastal environments, identifying its growth patterns, intellectual structure, and areas of specialisation [25,26].

Based on the research question, the following search equation was formulated, integrating the most representative terms of the thematic domain: TITLE-ABS-KEY ((“microplastic*” OR “micro-plastic*” OR “plastic debris” OR “micro polymer*” OR “plastic fragment*”)) AND TITLE-ABS-KEY ((“marine environment” OR “coastal environment” OR “marine ecosystem*” OR “coastal ecosystem*” OR “ocean*” OR “sea*” OR “marine sediment*” OR “marine biota” OR “marine organism*” OR “seawater” OR “estuar*” OR “mangrove*” OR “coral reef*”)) AND TITLE-ABS-KEY ((“pollution” OR “contamination” OR “environmental impact” OR “ecotoxicology” OR “bioaccumulation” OR “biodegradation” OR “toxic effect*” OR “environmental hazard*” OR “ecosystem impact” OR “spatial distribution” OR “source identification”)) AND NOT TITLE-ABS-KEY ((“macroplastic*” OR “nanoplastic*” OR “waste management” OR “recycling” OR “policy” OR “drinking water” OR “freshwater” OR “soil”)).

The search was executed on 26 October 2025, retrieving 6,510 records without restrictions on language or publication period to ensure the broadest possible coverage of the field. Articles in “early access” status for 2026 were also included, as these possess active DOIs and thus reflect emerging research trends for that year. Scopus was selected as the reference database due to its multidisciplinary scope, refined subject filters, and high-quality metadata, which facilitate the analysis of authors, affiliations, journals, countries, and collaboration networks. The search equation was designed to focus the corpus on marine–coastal studies, excluding records related to continental waters, soils, or waste management, thereby preserving thematic coherence.

Records were exported in Comma Separated Values (CSV) format for statistical processing. Subsequently, a manual curation of the metadata was performed to remove duplicates and non-relevant documents, ensuring the specificity of the analysed corpus. Data were organised in spreadsheets (Microsoft Excel) for normalisation and quality control [27].

The bibliometric analysis was conducted using Bibliometrix 5.1.1 (2025) within the R environment, and VOSviewer 1.6.20 (2023) developed by Leiden University. i) Bibliometrix was used to compute indicators of scientific productivity (authors, countries, journals), impact (citations, h-, g- and m-indices), and collaboration (co-authorships and institutional networks), as well as to apply classical bibliometric laws such as Lotka’s Law (author productivity distribution) and Bradford’s Law (journal core identification) [28]; ii) VOSviewer was employed to construct and visualise networks of keyword co-occurrence, co-authorship, and bibliographic coupling through density maps and clustering based on association strength [29,30].

Additionally, the Reference Publication Year Spectroscopy (RPYS) model was applied to identify the historical roots of the field and detect citation peaks representing conceptual milestones in the evolution of marine microplastic research. The integration of these methods enabled the mapping of the intellectual structure, thematic evolution, and international collaboration networks of the field, providing a panoramic understanding of the scientific knowledge on microplastic pollution in marine and coastal environments and its conceptual development over time.

2. Results

The corpus analysed in Figure 1, comprising 6,510 documents published between 1980 and 2026, exhibits a sustained annual growth rate of 5.55%, confirming the consolidation of research on microplastics in marine and coastal environments as an expanding scientific field. The participation of 15,398 authors and the absence of single-authored works reflect a pronounced tendency towards multidisciplinary collaboration, with an average of 11.6 co-authors per article. International cooperation reaches 29.48%, indicating an active and continuously strengthening global research network. Likewise, the 862 publication sources and 22,484 references demonstrate the thematic breadth and intellectual maturity of the domain. The average of 65.9 citations per document and a mean document age of 3.34 years reveal a field characterised by high visibility and recent impact, while the 11,142 author keywords highlight the conceptual diversification achieved by the scientific community.

Figure 1. General bibliometric indicators of the corpus.

Source: Summary of key information produced in Bibliometrix, based on metadata extracted from Scopus.

Figure 2 illustrates the temporal evolution of scientific production on microplastic pollution in marine and coastal environments between 1980 and 2026. For more than three decades, growth remained incipient and almost linear, with fewer than ten annual publications up to 2014. From 2015 onwards, a marked acceleration is observed, corresponding to the global recognition of the issue by the scientific community and international organisations. The peak output occurred in 2024, with 1,156 articles, representing 17.8% of the total corpus, followed by a slight decline in 2025, attributable to the partial completion of the year and ongoing editorial processes.

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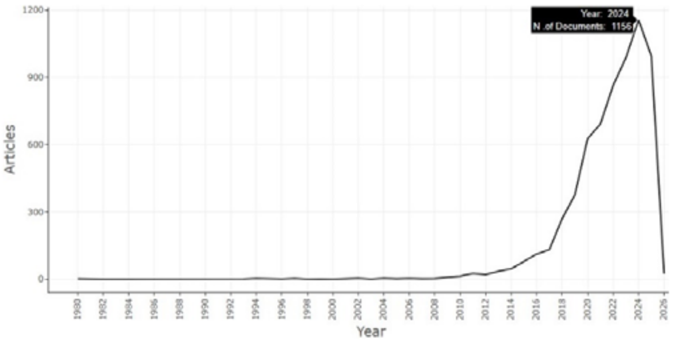
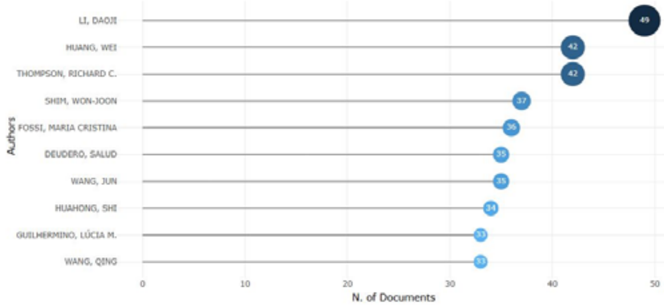
Figure 2. Annual scientific production.



Source: Produced in Bibliometrix using metadata extracted from Scopus.

Figure 3 presents the most productive authors in the study of microplastic pollution in marine and coastal environments. Li Daoji stands out as the leading researcher with 49 publications, consolidating his influence in topics related to transport, distribution, and marine ecotoxicology. He is followed by Huang Wei and Thompson Richard C., both with 42 articles, whose studies have significantly contributed to understanding the global dynamics of microplastics and their effects on marine organisms. Close behind are Shim Won-Joon (37), Fossi Maria Cristina (36), and Deudero Salud (35), recognised for integrating molecular, trophic, and coastal management approaches. The inclusion of researchers such as Wang Jun, Huahong Shi, Guilhermino Lúcia M., and Wang Qing, each with over 30 publications, demonstrates the presence of a cohesive scientific community in which Asia and Europe concentrate global leadership.

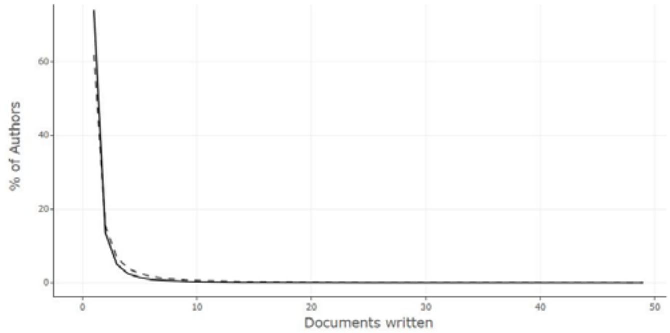
Figure 3. Leading authors.



Source: Extracted from Bibliometrix.

Figure 4 depicts the distribution of author productivity adjusted to Lotka's Law, showing that 69.8% of authors have published only one article, while less than 5% have produced more than five contributions. The theoretical model fits the empirical behaviour with high accuracy ($\beta = 2.43$; $R^2 = 0.91$), confirming the existence of a concentrated productivity structure in which a small group of researchers drives most of the global knowledge on marine microplastics. The near-complete overlap between the observed and theoretical curves validates the field's consistency with bibliometric distribution principles, reflecting a mature core of authors accompanied by a broad emerging base that sustains the growth and thematic diversification of the domain.

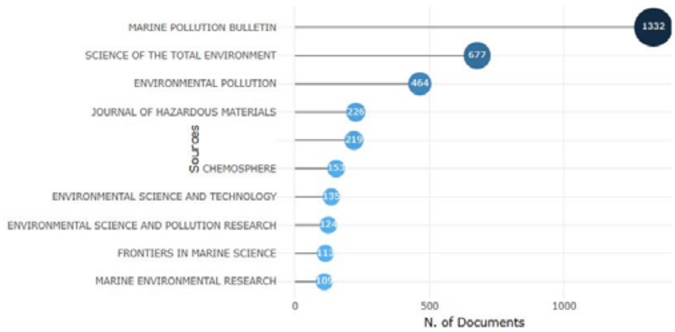
Figure 4. Distribution of authors by productivity – Lotka's Law.



Source: Extracted from Bibliometrix.

Figure 5 identifies the most productive journals in disseminating research on microplastic pollution in marine and coastal environments. Marine Pollution Bulletin leads by a wide margin with 1,332 articles, accounting for 20.5% of the total corpus, consolidating its position as the principal international reference platform for marine–coastal studies. It is followed by Science of the Total Environment with 677 documents and Environmental Pollution with 464, both characterised by their multidisciplinary focus on environmental contamination and toxicology. At intermediate levels, Journal of Hazardous Materials (226) and Chemosphere (219) stand out for concentrating studies on degradation processes, transport mechanisms, and ecotoxicological effects of synthetic polymers. Other influential journals such as Environmental Science and Technology (153) and Environmental Science and Pollution Research (124) further reinforce the prominence of high-impact publishers (Elsevier and Springer).

Figure 5. Leading journals.



Source: Extracted from Bibliometrix.

Figure 6 illustrates the dispersion of publications according to Bradford's Law, which describes the distribution of scientific articles among journals within a specific field. A marked concentration is observed in a small core of sources – primarily Marine Pollution Bulletin, Science of the Total Environment, and Environmental Pollution – which constitute the zone of highest informational density or "Core Sources." This core accounts for

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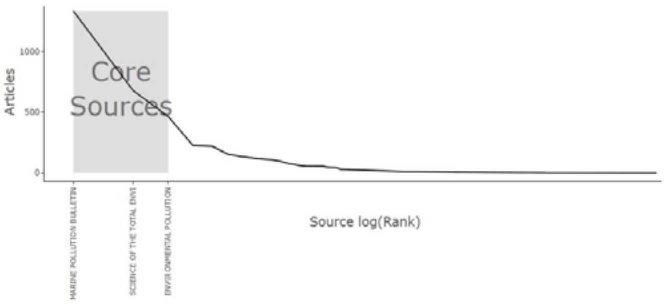
approximately 45% of all articles in the corpus, reflecting its central role in consolidating knowledge on marine microplastic pollution. As one moves towards the outer zones, the number of journals increases while their productivity decreases, revealing a typical bibliographic dispersion pattern.

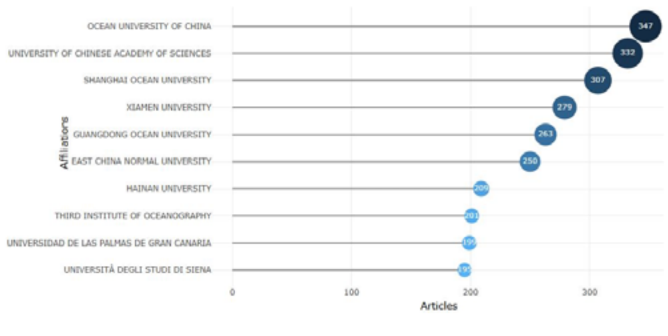
Figure 6. Article dispersion – Bradford's Law.



Source: Extracted from Bibliometrix.

Figure 7 displays the institutions with the highest scientific productivity in the study of microplastic pollution in marine and coastal environments. The Ocean University of China stands out as the leading institution with 347 articles, followed by the University of Chinese Academy of Sciences (332) and Shanghai Ocean University (307), evidencing Asia's dominance in knowledge generation on this topic. Within the same leading cluster, Xiamen University (279) and Guangdong Ocean University (263) contribute substantially through research focused on coastal flux analysis, marine ecotoxicology, and environmental monitoring. Beyond the Chinese axis, the Universidad de Las Palmas de Gran Canaria (195) and the Università degli Studi di Siena (195) represent the European contribution to interdisciplinary research on microplastic pollution.

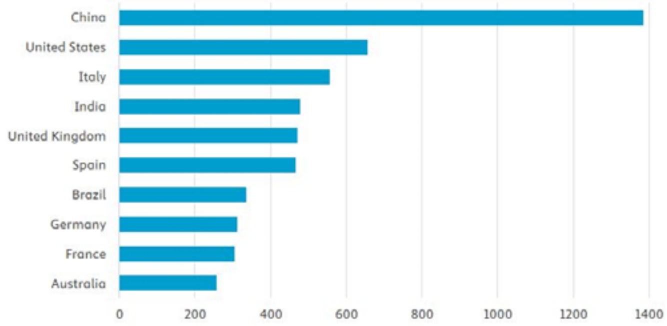
Figure 7. Institutional affiliations.



Source: Extracted from Bibliometrix.

Figure 8 presents the geographical distribution of scientific production on microplastic pollution in marine and coastal environments. China leads by a wide margin with 1,387 documents, representing over 21% of the global total, consolidating its position as the epicentre of research on marine ecotoxicology and plastic pollution. It is followed by the United States with 735 articles, whose contributions focus on ecotoxicological impacts, ocean modelling, and waste management. At intermediate levels, Italy (585), India (541), and the United Kingdom (523) stand out for strengthening international collaboration and advancing studies on microplastic degradation and transport. Spain (501) and Brazil (398) emerge as the main Spanish- and Portuguese-speaking contributors, while Germany, France, and Australia complete the top ten with significant work on physicochemical analysis and marine toxicity.

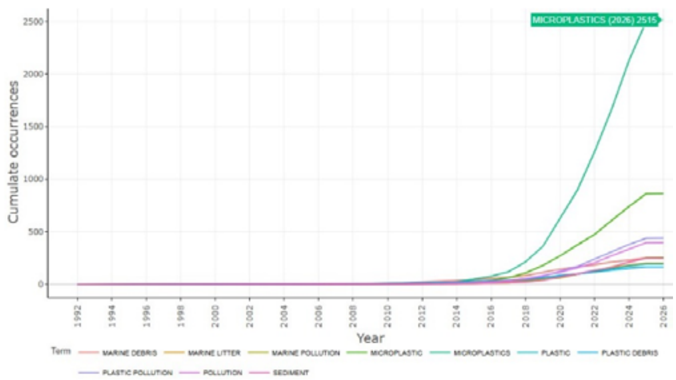
Figure 8. Scientific production by country.



Source: Extracted from Scopus 'Analyze results'.

Figure 9 illustrates the temporal evolution of the most frequently used keywords in the literature on microplastic pollution in marine and coastal environments. An exponential increase is observed for the term "microplastics", which reaches 2,515 cumulative occurrences by 2026, consolidating itself as the central axis of the scientific discourse within the field. From 2015 onwards, the sharp rise in its frequency coincides with the global expansion of studies on plastic pollution and its integration into environmental and oceanic research agendas. Related terms such as "marine pollution", "plastic debris", "marine litter", and "sediment" show more moderate growth, indicating thematic diversification towards ecosystem impact assessment and the characterisation of environmental matrices.

Figure 9. Keyword frequency over time.



Source: Extracted from Bibliometrix.

Figure 10 displays the distribution of scientific production by field of knowledge, highlighting the multidisciplinary nature of research on microplastic pollution in marine and coastal environments. The domain is led by Environmental Sciences,

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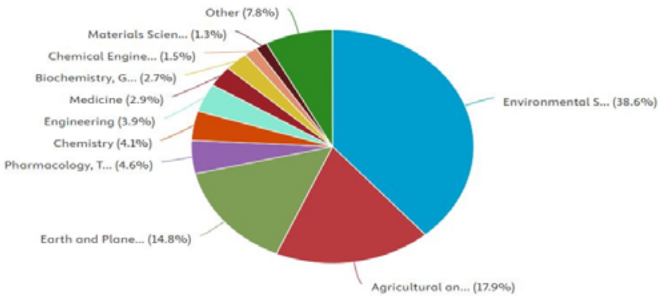
which accounts for 38.6% of publications and constitutes the central axis of the field. It is followed by Agricultural and Biological Sciences with 17.9%, and Earth and Planetary Sciences with 14.8%, reflecting the integration of biogeochemical, ecological, and geological approaches in the characterisation of microplastic pollution. Applied disciplines such as Pharmacology, Toxicology and Pharmaceutics (4.6%), Chemistry (4.1%), and Engineering (3.9%) contribute complementary perspectives focused on toxicological analysis, material synthesis, and the development of remediation technologies.

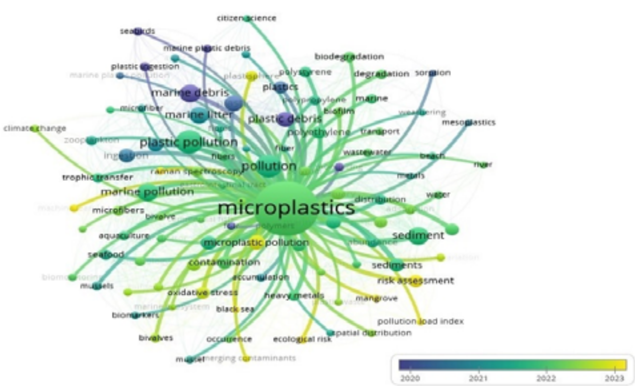
Figure 10. Publications by subject area.



Source: Extracted from Scopus 'Analyze results'.

Figure 11 illustrates the keyword co-occurrence network constructed using VOSviewer, which reveals the conceptual structure and thematic evolution of research on microplastic pollution in marine and coastal environments. The term "microplastics" occupies the central node, showing the strongest co-occurrence links with "pollution", "marine pollution", "plastic debris", "sediment", and "contamination", thereby forming the dominant semantic axis of the field. Three main clusters are identified: the first focuses on processes of degradation, adsorption, and transport; the second on ecotoxicology and bioaccumulation in marine organisms; and the third on environmental risk assessment and coastal management. Yellow tones indicate emerging terms between 2022 and 2023, such as "oxidative stress", "risk assessment", and "mangrove", reflecting the field's expansion towards molecular and ecosystem-based approaches.

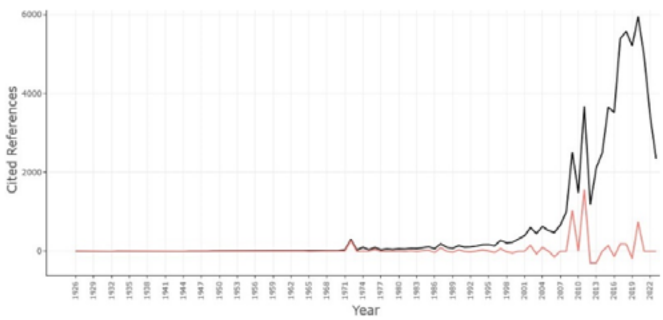
Figure 11. Keyword co-occurrence network.



Source: Extracted from VOSviewer.

Figure 12 presents the Reference Publication Year Spectroscopy (RPYS), which identifies the periods of greatest influence in the development of the field. The profile reveals a sustained rise beginning in the early 2000s and a phase of intensification between 2009 and 2021. Distinct citation peaks are observed in 2009 (2,521), 2011 (3,683), and 2015 (3,659), followed by consecutive maxima in 2017 (5,394), 2018 (5,575), 2019 (5,211), and a record value in 2020 (5,952). The signal declines in 2022 (3,440) and 2023 (2,346), an expected effect given the shorter time window for citation accumulation. Complementary RPYS analyses identify earlier "seed years" (1972, 1987, 1997, 2002, and 2004) as methodological and conceptual turning points.

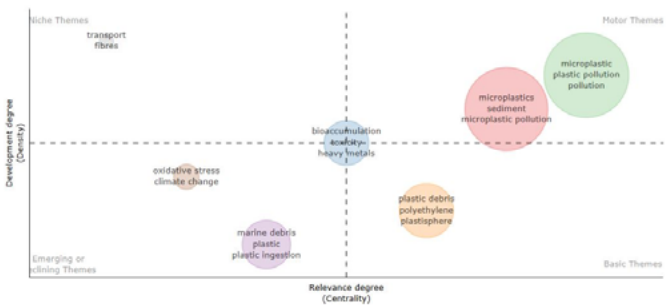
Figure 12. Annual distribution of cited references.



Source: Extracted from Bibliometrix.

Figure 13 presents the thematic map of scientific production on microplastic pollution in marine and coastal environments, constructed from indicators of density (degree of development) and centrality (thematic relevance). In the upper-right quadrant, the driving themes cluster highly relevant and consolidated concepts – most notably microplastic, plastic pollution, and pollution – which structure the core of the field and concentrate the greatest levels of productivity and citation. In the lower-right quadrant lie the basic themes, such as plastic debris, polyethylene, and plastisphere, associated with the physicochemical characterisation and degradation processes of polymers. The upper-left quadrant contains the niche themes, including transport and fibres, which exhibit high specialisation but limited connection with the overall domain. Finally, in the lower-left quadrant emerge developing or declining themes, such as oxidative stress and climate change, reflecting the recent incorporation of physiological and environmental approaches.

Figure 13. Thematic map.



Source: Extracted from Bibliometrix.

3. Discussion

The synthetic indicators of the domain confirm a field in full consolidation, characterised by strong scientific cooperation and recent visibility (Figure 1) [19]. The high mean co-authorship rate and scarcity of single-authored works demonstrate that the study of marine–coastal microplastics requires interdisciplinary teams integrating oceanography, toxicology, geochemistry, and spatial modelling [31,32]. The level of international collaboration suggests that the central research questions transcend regulatory boundaries and that the dynamics of the field are shaped by a global scientific architecture [33]. This collaborative structure, combined with a short mean citation age, indicates a young, dynamic, and methodologically innovative body of evidence [20].

The temporal trajectory reveals a clear transition from an embryonic phase to an exponential growth stage after 2015 (Figure 2) [14]. This surge coincides with the recognition of plastic pollution as a planetary crisis and its inclusion in international regulatory and funding agendas [34,35]. The peak observed in 2024, followed by an apparent decline in 2025 due to editorial windows, suggests a high stabilisation rather than a real decrease. Methodologically, this invites future meta-analyses to incorporate "in-press/early access" strategies to avoid underestimation in the most recent biennium and to enhance temporal tracking of water quality, in alignment with SDG target 6.3 [36,37].

The configuration of authorial leadership evidences an influential epistemic core that shapes the key questions and methods of the field (Figure 3) [34]. The convergence of research lines on transport, distribution, and marine ecotoxicology within a compact group of authors reflects a concentration of expertise that accelerates knowledge accumulation, although it may also introduce geographic or thematic biases if collaboration circuits are not expanded to include currently underrepresented megadiverse regions [38,39].

The conformity of productivity with Lotka's Law confirms a mature concentration pattern in which a highly productive minority supports a broad base of occasional contributors (Figure 4) [6]. This behaviour, typical of consolidated domains, has important operational implications: initiatives for methodological standardisation (mesh sizes, digestion protocols, spectroscopy) and for the adoption of FAIR principles should originate from this "core nucleus" to maximise reproducibility while lowering entry barriers for emerging groups [40–42].

In terms of dissemination, the hegemonic role of Q1 journals with cross-cutting scope in environmental science and toxicology has facilitated the integration of laboratory, field, and regional-to-global modelling evidence (Figure 5) [43]. This editorial concentration accelerates knowledge dissemination and standardises methodologies, yet it may overrepresent classical lines such as invertebrate and fish ecotoxicology at the expense of emerging areas like microplastic–microbiome interactions or synergies with ocean acidification [38,44,45]. Hence, diversifying publication outlets between specialised journals and interdisciplinary coastal management forums is advisable [46].

The dispersion pattern following Bradford's Law shows a compact core of sources concentrating nearly half of the knowledge and a wide periphery providing thematic diversity (Figure 6) [3]. This core–periphery structure is beneficial: the core ensures methodological consistency and traceability, while the periphery introduces niche perspectives (mangroves, reefs, urban estuaries) and emerging methodologies such as hyperspectral optics or metabolomics, expanding the field's scope without fragmenting it [47–49].

At the institutional level, the leadership of Chinese universities and selected European centres reflects sustained investment in ocean science, analytical capacity, and coastal sampling networks (Figure 7) [14]. This predominance has fostered significant advances in understanding transport, sources, and ecotoxicity, though strengthening research nodes in the Global South remains a challenge – regions of high exposure yet limited infrastructure [50,51]. Co-supervision schemes, shared funding, and open access to analytical pipelines represent cost-effective tools to mitigate these asymmetries [52].

The country-level panorama consolidates the Asia–Europe–North America triangle as the backbone of scientific production, with growing contributions from Ibero-American hubs such as Brazil, Spain, and Peru, where research on marine plastic pollution is beginning to consolidate (Figure 8) [53–55]. The distribution reveals a gap between high-productivity regions and ecological impact hotspots (tropical deltas and archipelagos under strong tourism pressure) [56]. Bridging this gap requires comparable monitoring networks and sustained funding for long-term time series in critical sites – an essential condition for assessing policy effectiveness and progress toward SDG 14.1 [57].

The field's semantics have evolved from generic expressions such as "marine litter" towards the articulating concept microplastics, which structures conceptual taxonomy and study protocols (Figure 9) [58]. This shift has enabled the formulation of more specific research questions (size, polymer, morphology, biofilm) and the linking of physiological effects to exposure pathways [59,60]. However, the exclusion of terms such as nanoplastics in certain databases may obscure important subdomains; future search strategies should integrate dual sampling approaches and controlled terminology to minimise bias [61].

The disciplinary distribution confirms a strongly interdisciplinary ecosystem, dominated by environmental sciences with robust linkages to biology and geoscience (Figure 10) [7]. The contributions of engineering and chemistry indicate opportunities to scale technological solutions (advanced filtration, alternative materials, source-point barriers) and strengthen integrated risk assessments (toxicokinetic–toxicodynamic and complex mixture analyses), aligning with SDG 12.4 on sound chemical and waste management [32,62,63].

The keyword co-occurrence network reveals three consolidated thematic axes: (i) physicochemical processes and transport, (ii) ecotoxicology and bioaccumulation, and (iii) risk assessment and coastal management (Figure 11) [64]. Emerging terms such as oxidative stress, risk assessment, and mangrove indicate a progressive integration of molecular and ecosystemic levels – an essential step towards moving from presence-based evidence to causal inference and comparable ecological risk metrics [65,66].

The RPYS profile identifies an extensive genealogy with major influence peaks between 2009 and 2021, during which operational definitions, counting methods, and conceptual milestones on sources and effects were consolidated (Figure 12) [13]. The attenuation observed in 2022–2023 reflects the shorter citation window rather than reduced relevance. For future updates, integrating RPYS with burst detection and local citation analyses would help distinguish methodological innovations from transient trends, thereby strengthening the historical understanding of the field [11,65,67].

The thematic map situates microplastic, plastic pollution, and pollution as driving themes, surrounded by basic clusters (plastic debris, polyethylene, plastisphere) and niche areas (transport, fibres), while oxidative stress and climate change emerge as developing fronts (Figure 13). This configuration reveals an evolving agenda shifting from detection towards causal attribution and adaptive governance [68]. Incorporating gradients of temperature, pH, and hypoxia will enable the quantification of synergies and antagonisms between climatic stress and polymer exposure – key information for designing risk-based coastal policies [7,56,69].

In this context, the thirteen figures converge into four strategic implications: i) a structural maturity sustained by international cooperation and strong authorial–editorial cores that enhance standards and reproducibility (Figures 1, 4, 5, 6) [39]; ii) a geographically asymmetric leadership that drives rapid advances yet requires inclusive strategies for underfunded megadiverse regions (Figures 7, 8) [70]; iii) an interdisciplinary expansion that opens new analytical scales (from biofilm to ecosystem) and creates space for engineering-driven solutions (Figures 9, 10, 11) [20]; and iv) a recent historical density that supports the transition from descriptive evidence to risk-based management and policy evaluation aligned with SDGs 6, 12, and 14 (Figures 2, 12, 13) [16].

Finally, research on microplastic pollution in marine and coastal environments has reached a stage of structural maturity and growing impact, sustained by global collaborative networks and an expanding conceptual framework. The field is evolving from a diagnostic science to a management-oriented science, focused on mitigation and evidence-based policy formulation within the broader paradigm of ocean health and planetary boundaries [22].

4. Conclussions

The bibliometric analysis confirms that research on microplastic pollution in marine and coastal ecosystems has reached a stage of global scientific maturity, characterised by exponential growth after 2015, high levels of international cooperation, and robust interdisciplinary integration. Sustained productivity and strong citation impact reflect a consolidated domain aligned with the objectives of SDGs 6, 12, and 14.

Geographical leadership, concentrated in Asia, Europe, and North America, is complemented by the emergence of Ibero-American hubs, where the field is beginning to institutionalise. At the authorial and editorial levels, the predominance of Q1 journals has promoted methodological standardisation and conceptual coherence, although gaps remain in megadiverse regions of the Global South. The coherence of the domain with Lotka's and Bradford's laws, together with the historical milestones revealed by RPYS, confirms a structured field progressing towards risk-based management and sustainable ocean governance.

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