NETWORK ANALYSIS OF MARINE LITTER IMPACTS ON COASTAL ECOSYSTEMS

Montserrat Compa, Antoni Sureda

Abstract: There is an increase in reporting of marine litter in coastal ecosystems globally, especially in recent years. A literature review was carried out to identify the primary impacts and effects its presence may have on coastal ecosystems worldwide. Various search combinations in the search engine SCOPUS were performed considering 'impacts', 'effects', 'marine litter', 'marine debris', and 'coastal', for a total of 939 studies. Studies considered were published from 1974 to 2024 and an important increase in publications was observed over the last decade, especially for scientific articles. Next, search terms for three categories of predefined impacts and effects were used to identify the main research directions and emerging areas of interest within coastal marine litter research. Overall, this study highlights the focus and trends of current marine litter research globally.

Keywords: coastal health, marine litter, literature review, network analysis

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Introduction

Marine litter is defined as any persistent, manufactured, or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment [1] and is ubiquitously found in global oceans and seas, from the sea surface to the sea floor and especially on coastlines. This has extensively been addressed in several international policies such as the United Nation's sustainable development goal 14 Life Below Water where plastic pollution is one of the top five state of emergency actions that need to be addressed in addition to acidification, ocean warming and overfishing [2] and the Marine Strategy Framework Direction Descriptor 10 which indicates that properties and quantities of marine litter do not cause harm to the coastal and marine environment [3]. Recent estimates indicate the total amount of buoyant marine plastic litter is 3000÷3400 kilotonnes, which is much higher than previous estimates, while the plastic input into the marine environment is 470–540 kilotonnes per year, slightly less than previous estimates [4].

Over the last several decades, there has been an increase in literature reporting the various impacts and effects that marine litter has on the marine environment and its significant threat to coastlines. This includes beaches [5, 6, 7] and estuaries [8, 9, 10], in addition to reports of the presence of litter that can transport hazardous pollutants associated with marine litter, potentially affecting biodiversity and harming ecosystem health. Negative impacts on wildlife, such as ingestion and entanglement, have been reported on a wide range of species, including fish [11, 12], seabirds [13], sea turtles [14], and marine mammals [15], among others. In addition to environmental concerns, there are several economic costs to marine litter that, in turn, can affect tourism [16] and fishing industries through gear loss [17]. Human health risks, from ingestion of contaminated seafood to human exposure and toxic effects, add further urgency to address this widespread issue [18, 19, 20]. Understanding key factors is necessary to develop comprehensive efforts, including improved waste management, public education, and policy interventions, in addition to a more drastic shift toward more sustainable practices.

Using keyword search terms for network analyses in studying marine litter on coastlines is an effective approach as can capture the diverse and complex nature of the problem. Marine litter, which includes various solid objects such as plastic bottles and fishing nets, has numerous sources and impacts that keywords can help identify and categorise. Keywords such as "marine debris," "plastic pollution," and "fishing gear waste" allow for a comprehensive dataset collection, ensuring that all relevant aspects are covered. This approach helps identify the specific impacts on different coastal environments, such as beaches and mangroves, as well as the threats to wildlife from entanglement and ingestion. Economic and social implications, such as the decline in tourism and fishing industry impacts, can be traced using terms like "economic costs" and "tourism decline." Keywords also facilitate the understanding of other impacts, such as the spread of invasive species, public health concerns, and the aesthetic and recreational value of coastal areas. Moreover, they help to explore policy and management strategies by highlighting terms such as "waste management" and "public awareness." A previous study by Liu et al. (2023) [21] identifies how network analyses are useful to understand the

toxicological implications of microplastics and nanoplastics in soil. By mapping relationships and interactions between these aspects, network analyses can reveal key nodes and links between the co-occurrences of keywords, providing insights into priority areas for intervention. This structured exploration helps in formulating targeted and effective solutions, making the use of keyword search terms a robust method to understand and address marine litter on coastlines.

In this study, we review and analyse the major impacts of marine litter on coastal ecosystems around the world that have been observed historically over the previous half century. The main objective of this study is to (i) provide a synthesis of the current impacts of marine litter on coastal ecosystems and (ii) perform a methodological review of previous research highlighting the important insights from studies.

Materials and Methods

The following search terms were used in the search engine SCOPUS on March 17, 2024: ‘impacts AND marine AND litter AND coastal’ OR ‘impacts AND marine AND debris AND coastal’ OR ‘effects AND marine AND debris AND coastal’ OR ‘effects AND marine AND litter AND coastal’. A total of 939 studies were returned. The search was performed in unison to avoid duplicates. From here, important information such as year of publication, types of publications and the top journals were analysed to provide a descriptive analysis.

In this study, we used the litsearchr package R [22], which was created to facilitate reproducibility and transparency, to identify the main direction research in moving towards. To achieve this, two network analyses were performed; the first used keywords and the second network analysis used search terms for three groupings of impacts and effects of marine litter. For the first network analysis, keywords served as nodes or attributes, helping to map connections between different types of litter, their sources, and impacted areas. To complete this, we used the author’s keywords that were reported in each study. For the inclusion of a keyword, the relevant search terms had to be included at least twice. Then all the abstracts were searched for the incidence of the selected keywords. From this, a network analysis was performed to determine linkages between search terms. For the second network analysis, to determine terms of impacts and effects, we follow Agamuthu et al. (2019) [23] for their descriptions of impacts and effects summarised into three categories: injury to or death of marine organisms, harm to the marine environment and effects on human health and economy. Finally, the results from the search term network were graphed to determine the possible links between the search terms.

Results and Discussion

A literature search was carried out to identify the impact of marine plastic pollution that affects coastal ecosystems worldwide. Various search combinations in SCOPUS were performed considering 'impacts', 'effects', 'marine litter', 'marine debris', and 'coastal', for a total of 939 studies. The results from the search data are

presented in Figure 1A and highlight the trend in publications on the impacts and effects of marine litter in coastal environments. The studies considered were published from 1974 to 2024, with an exponential increase over the past decade, an indication an increase in the interest in researching and/or reporting in this field. A slow and steady increase in reporting was observed the first decades, followed by the rapid and exponential growth of the more recent years, which is indicative of the growing understanding of the importance of researching the negative effects of marine litter on coastal ecosystems. The rise in publications highlights a growing focus on addressing marine litter and developing strategies to mitigate plastic contamination and promote marine health worldwide. Regarding the types of publications from the past 50 years, the majority are scientific research articles (78%) followed by reviews (9%), conference papers (7%) and book chapters (5%) (Figure 1B). There were other types of publications (conference review, data paper, erratum, note, book, and short survey) which all represent less than 1% of the publications.

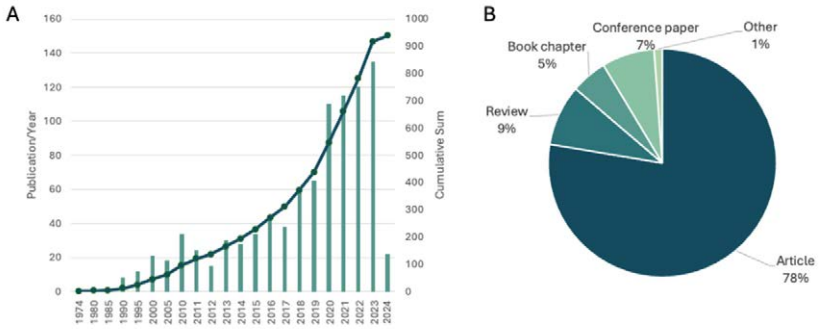

Figure 1 – Summary of the results from the literature by A) Annual scientific production from the Scopus search results containing the keywords for impacts of marine litter on coastal areas barplot (publications year) and a scatterplot on the second axis for the cumulative sum of publications, B) pie chart for the percent of each type of article classified by research article, review, conference paper, book chapter, and other types of articles.

In regarding the top ten journals where publications from our search terms were located, Marine Pollution Bulletin, Science of the Total Environment and Environmental Pollution were the top three journals (23 %, 8.3 % and 4.7 % respectively) (Table 1). Next, we report the h-index according to SCImago Journal Rank (SJR), which is a journal's number of articles (h) that have received at least h citations over the whole period. In general, the h-index ranged from 48 to 353 (Table 1). Regarding the top publishers, the three most predominant journals have the highest h index according to the SJR, Marine Pollution Bulletin (h-index = 229), and Science of the Total Environment (h-index = 353), and Environmental Pollution (h-index = 301). Moreover, the Impact Factor for each of the journals presents the measures for the average number of citations received in a particular

year by papers published in the journal during the two preceding years according to the Journal Citation Reports, and for this study, we opted for the Impact Factor (IF) determined for the year 2022. For the studies published during the time frame, the IF ranged from 0.42 to 9.8 (Table 1). The journals with the highlight IF were Science of the Total Environment (IF = 9.8), Environmental Pollution (IF = 8.9), Marine Pollution Bulletin (IF = 5.8), and Environmental Science and Pollution Research (IF = 5.8). Overall, these results give insight into main journals where scientific results are being presented on the implications of marine litter in coastal environments.

Table 1 – Top 10 journals returned from the search to determine the impacts and effects of marine litter on coastal environments.

Journal	Number of Studies	% Publications	h-Index	IF (2022)
Marine Pollution Bulletin	220	23.4	229	5.8
Science of the Total Environment	78	8.3	353	9.8
Environmental Pollution	44	4.7	301	8.9
Frontiers in Marine Science	23	2.4	101	3.7
Ocean and Coastal Management	19	2.0	107	4.6
Marine Policy	13	1.4	123	3.8
IOP Conference Series: Earth and Environmental Science	11	1.2	48	0.42
Marine Environmental Research	10	1.1	111	3.3
Marine Geology	10	1.1	159	2.9
Environmental Science and Pollution Research	9	1.0	179	5.8

In Figure 2A, we can observe the results from the network analysis of the keywords observed throughout all the abstracts of the publications from the literature search with the top keywords being ‘marine environment’, ‘plastic debris’ and ‘marine debris’ being the top keywords. Here we can observe that the terms that appear near the centre are linked to each other by darker lines, an indication of increased importance regarding marine litter research in coastal areas, such as 'marine plastic', 'coastal areas', and ‘fishing activities’. While search terms that appear in the outside margins of the graph with very faint green lines indicate that they are not as closely related to the other search terms or the co-occurrence

was not very common, such as ‘Gulf of Mexico’, ‘intertidal zone’ and ‘blue carbon’, which are more targeted features. This also highlights areas where future research is needed, such as coastal wetlands and coastal dunes, or specific sentinel species like the loggerhead turtle, as well as other endangered species. These results highlight that despite a growing amount of research in this field, there are still many gaps into the impacts and effects marine litter has on coastal habitats and ecosystems.

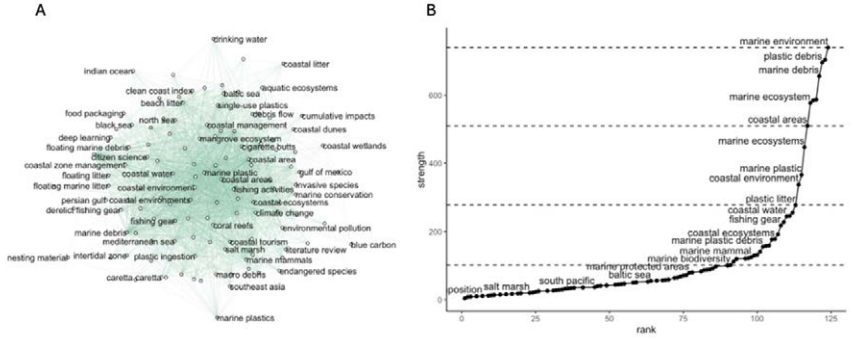

Figure 2 – Network analysis of the indexed keywords (A) and ranking of the most keywords based on strength (B). Horizontal lines are the cutoff points.

The next and final step in the network analysis for keyword search terms, was to rank the terms by importance by determining the strength of each term. This is defined as the number of other terms each of the search terms appears with and ranked in ascending order and establishing cut-off points or changepoints, where the strength of the next strongest term is much greater than that of the previous one (places where the ascending line ‘jumps up’). In Figure 2B we can observe 4 cut-off points just before the strength of the term increases. In terms of sources, we can observe that fishing activities and fishing gear are both potential sources in addition to being affected by marine litter through economic impacts, which are reported in the literature. Moreover, we can observe specific locations globally where an increase in marine litter research is occurring, specifically in the south Pacific and the Baltic Sea.

For the second evaluation, a network analysis was performed to determine the presence of the target search words within the three categories for impacts and effects. Here, the abstracts were searched and for the inclusion of a keyword present at least twice. In terms of the category of injury to or death of marine organisms, a total of 38 search terms were defined, and the results indicated 425 studies included these terms. In Figure 3A, we can observe a high co-occurrence between ingest-entanglement, ingest-organisms, and organism-toxic.

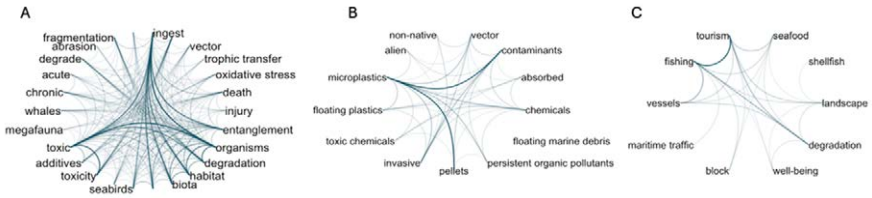

Figure 3 – Results from the network analysis for: A) injury or death to marine organisms, B) harm to the marine environment and C) effects on human health and economy.

Regarding the harm to the marine environment (Figure 3B), a total of 17 search terms were used, which resulted in the selection of 253 studies. From here, microplastics-contaminants and microplastics-pellets links were the most predominant. The results indicated that some of the primary harm caused by plastic litter is the dispersion of invasive species in addition to the leachates of the hazardous contaminants associated with plastic litter, such as persistent organic pollutants and phthalates. Finally, in Figure 3C, a total of 11 search terms were used which resulted in 309 studies and a total of 353 observations. The network graph highlights the link and observed effects on human health and economy, where fishing and tourism are more closely linked. In terms of fishing, marine litter can become entangled in gear and vessels, causing significant economic losses. The accumulation of marine litter and debris contributes to the degradation of pristine environments and landscapes, leading to loss of tourism revenue and an aesthetically unpleasant experience [23].

Conclusions

The results of the network analysis underline the primary lines of research on the impacts and effects of marine litter in coastal areas. Marine litter, primarily plastic pollution, in coastal marine ecosystems is a growing problem that is unlikely to decrease in the future without the application of stricter transboundary policies in addition to other management approaches such as extended producer responsibility schemes. Many of the primary harm discussed within the studies in the literature search include direct impacts which can cause environmental damage, disrupting the functioning and equilibrium of these areas and harmful effects on coastal biodiversity. Furthermore, many studies provide physical evidence, such as entanglement and ingestion of these items, which can have a variety of toxicological consequences, including irreparable harm and even death. Additionally, there are also several economic impacts that range from clean-up costs of marine litter removal to the destruction of fishing gear or endangerment by ships causing navigational harm. This has a variety of social consequences, including a negative public perception by reducing visual attractiveness, which may deter tourists, potentially creating indirect economic costs to local communities. In summary, this study highlights the global focus and predominant trends in current marine litter research.

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References

[1] UNEP (2009) - *Marine litter: a global challenge.* Regional Seas, United Nations Environment Programme.

[2] UN-SDG (2023) - *The-Sustainable-Development-Goals-Report-2023.pdf*.

[3] T. Maes *et al.* (2016) - *Harm caused by Marine Litter. MSFD GES TG Marine Litter-Thematic Report*, JRC Technical report, DOI: 10.2788/690366.

[4] M. L. A. Kaandorp, D. Lobelle, C. Kehl, (2023) - *Global mass of buoyant marine plastics dominated by large long-lived debris*, vol. 16, no. 8, DOI: 10.1038/s41561-023-01216-0.

[5] J. Anastácio, J. M. Candeias, H. Cabral, I. Domingos (2023) - *Relationships between marine litter and type of coastal area, in Northeast Atlantic sandy beaches*, *Mar Environ Res*, vol. 183, 105827, DOI: 10.1016/j.marenvres.2022.105827.

[6] M. Compa, C. Alomar, M. Morató, E. Álvarez, S. Deudero, (2022) - *Spatial distribution of macro- and micro-litter items along rocky and sandy beaches of a Marine Protected Area in the western Mediterranean Sea*, Mar Pollut Bull, vol. 178, 113520, DOI: 10.1016/j.marpolbul.2022.113520.

[7] J. S. Jones *et al.* (2022) - *Microplastic distribution and composition on two Galápagos island beaches, Ecuador: Verifying the use of citizen science derived data in long-term monitoring*, Environmental Pollution, vol. 311, 120011, DOI: 10.1016/j.envpol.2022.120011.

[8] A. Bakir, S. J. Rowland, R. C. Thompson (2014) - *Transport of persistent organic pollutants by microplastics in estuarine conditions*, Estuar Coast Shelf Sci, vol. 140, pp. 14–21, DOI: 10.1016/j.ecss.2014.01.004.

[9] I. Mazarrasa, A. Puente, P. Núñez, A. García, A. J. Abascal, J. A. Juanes (2019) - *Assessing the risk of marine litter accumulation in estuarine habitats*, Mar Pollut Bull, vol. 144, pp. 117–128, DOI: 10.1016/j.marpolbul.2019.04.060.

[10] L. Guilhermino *et al.* (2021) - *Microplastics in fishes from an estuary (Minho River) ending into the NE Atlantic Ocean*, Mar Pollut Bull, vol. 173, 113008, DOI: 10.1016/j.marpolbul.2021.113008.

[11] T. Romeo, B. Pietro, C. Pedà, P. Consoli, F. Andaloro, M. C. Fossi (2015) - *First evidence of presence of plastic debris in stomach of large pelagic fish in the Mediterranean Sea*, Mar Pollut Bull, vol. 95, no. 1, pp. 358-361, DOI: 10.1016/j.marpolbul.2015.04.048.

[12] A. Markic, J. C. Gaertner, N. Gaertner-Mazouni, A. A. Koelmans (2020) - *Plastic ingestion by marine fish in the wild*," *Crit Rev Environ Sci Technol*, vol. 50, no. 7, pp. 657–697, DOI: 10.1080/10643389.2019.1631990.

[13] J. A. Van Franeker, K. L. Law (2015) - *Seabirds, gyres and global trends in plastic pollution*, Environmental Pollution, vol. 203, pp. 89-96, DOI: 10.1016/j.envpol.2015.02.034.

[14] Q. A. Schuyler *et al.* (2016) - *Risk analysis reveals global hotspots for marine debris ingestion by sea turtles*, Glob Chang Biol, vol. 22, no. 2, pp. 567-576, DOI: 10.1111/gcb.13078.

[15] A. Solomando, F. Pujol, A. Sureda, S. Pinya (2022) - *Evaluating the Presence of Marine Litter in Cetaceans Stranded in the Balearic Islands (Western Mediterranean Sea)*, Biology (Basel), vol. 11, no. 10, 1468, DOI: 10.3390/biology11101468.

[16] M. Qiang, M. Shen, H. Xie (2020) - *Loss of tourism revenue induced by coastal environmental pollution: a length-of-stay perspective*, Journal of Sustainable Tourism, vol. 28, no. 4, pp. 550-567, Apr., DOI: 10.1080/09669582.2019.1684931.

[17] C. Wilcox, G. Heathcote, J. Goldberg, R. Gunn, D. Peel, B. D. Hardesty (2015) - *Understanding the sources and effects of abandoned, lost, and discarded fishing gear on marine turtles in northern Australia*, Conservation Biology, vol. 29, no. 1, pp. 198–206, DOI: 10.1111/cobi.12355.

[18] M. Smith, D. C. Love, C. M. Rochman, R. A. Neff (2018) - *Microplastics in Seafood and the Implications for Human Health*, Current environmental health reports, vol. 5, no. 3, pp. 375–386, DOI: 10.1007/s40572-018-0206-z.

[19] M. S. Bhuyan (2022) - *Effects of Microplastics on Fish and in Human Health*, Frontiers in Environmental Science, vol. 10. Mar. 16, 2022. DOI: 10.3389/fenvs.2022.827289.

[20] Y. Li, L. Tao, Q. Wang, F. Wang, G. Li, M. Song (2023) - *Potential Health Impact of Microplastics: A Review of Environmental Distribution, Human Exposure, and Toxic Effects*, Environment & Health, vol. 1, no. 4, pp. 249-257, DOI: 10.1021/envhealth.3c00052.

[21] H. Liu *et al.* (2023) - *Micro- and nanoplastics in soils: Tracing research progression from comprehensive analysis to ecotoxicological effects*, Ecological Indicators, vol. 156. 111109. DOI: 10.1016/j.ecolind.2023.111109.

[22] E. M. Grames, A. N. Stillman, M. W. Tingley, C. S. Elphick (2019) - A*n automated approach to identifying search terms for systematic reviews using keyword co-occurrence networks*, Methods Ecol Evol, vol. 10, no. 10, pp. 1645-1654, DOI: 10.1111/2041-210X.13268.

[23] P. Agamuthu, S. B. Mehran, A. Norkhairah, A. Norkhairiyah (2019) - *Marine debris: A review of impacts and global initiatives*, Waste Management and Research, vol. 37, no. 10. pp. 987–1002, DOI: 10.1177/0734242X19845041.

[24] C. Biamis, K. O. Driscoll, G. Hardiman (2021) - *Case Studies in Chemical and Environmental Engineering Microplastic toxicity: A review of the role of marine sentinel species in assessing the environmental and public health impacts,*" *Case Studies in Chemical and Environmental Engineering*, vol. 3, n. 100073, DOI: 10.1016/j.cscee.2020.100073.