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Study on the Relationship Between Findings of Coastal Cities and the Degree of Marine Pollution

Enqi Chen

Sedbergh Bilingual Senior School, Fuzhou, China

Abstract. Marine pollution is an important issue in global ecological and environmental governance, with plastic pollution in coastal waters being particularly prominent, and land-based human activities as its primary driving factor. As core areas of population agglomeration and human activities, coastal cities make the internal correlation between population density and marine pollution degree an important research direction in marine environmental research. This study adopts the literature research method to systematically sort out relevant research results at home and abroad, analyze the correlation between the population density of coastal cities and the degree of marine pollution, and discuss the influence of research scales and analysis methods on research results. The study shows that population density is significantly positively correlated with marine pollution degree in most coastal areas of the world, and differences in research scales and analysis methods will lead to certain divergences in the correlation results of the two. This study sorts out the research status and deficiencies in this field, and provides a basic reference for the precise prevention and control of coastal marine pollution.

Keywords: Ocean, environment, pollution, marine pollution

1. Introduction

1.1. Background

The global marine ecological environment is facing severe challenges, and plastic waste has become one of the main pollution types in coastal waters. A large amount of plastic waste enters the ocean from land-based sources every year. Located at the land-sea interface, coastal cities are densely populated and industrially concentrated, making them major sources of land-based marine pollution. The uneven spatial distribution of population closely leads to spatial differences in land-based pollution emissions. At present, the driving effect of land-based human activities on marine pollution has become a research consensus. However, as a core indicator reflecting the intensity of human activities, the population density of coastal cities still lacks systematic review and analysis in terms of its quantitative correlation and spatial matching with marine pollution degree. Therefore, it is urgent to carry out targeted research to reveal the internal connection between the two.

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1.2. Research problem

Most of the existing relevant studies on coastal marine pollution focus on the accounting of total pollution and the analysis of temporal and spatial evolution characteristics, with relatively limited research on the driving mechanisms of spatial differentiation in pollution with relatively weak research on the driving mechanism of pollution spatial differentiation [1, 2], especially the lack of spatial correlation analysis between population density of coastal cities and marine pollution degree at a fine scale. Some studies have discussed the correlation between human activities and marine pollution, but have not taken population density as a core driving index to carry out quantitative research, which may lead to insufficient identification of population-driven factors in pollution hotspots [3-5]. At the same time, due to differences in selected spatial scales, analysis methods and research areas, different studies have obtained obvious divergent results on the correlation between population density and marine pollution. Some studies have confirmed a significant positive correlation between the two, while a few studies have not found an obvious correlation between them because they include regulatory factors such as industrial structure and environmental governance level [3], so it is urgent to systematically integrate and verify the existing research results.

1.3. Research objectives

Taking the gaps in existing research as the core focus, this study aims to: (1) systematically review the research status of the relationship between population density of coastal cities and marine pollution; (2) summarize the common patterns and regional differences in this relationship; (3) analyze the influence of research scale and analytical methods on the results; and (4) identify current research gaps and propose directions for future studies [2].

1.4. Research significance

1.4.1. Theoretical significance

This study systematically sorts out the research results on the correlation between population density of coastal cities and marine pollution degree, makes up for the lack of spatial correlation analysis between the two at a fine scale, enriches the theoretical cognition of the interaction between human activities and marine ecological environment, and provides a theoretical basis for the subsequent quantitative correlation research between the two [2].

1.4.2. Practical significance

This study reveals the correlation law between population density of coastal cities and marine pollution degree, identifies the driving characteristics of population density on marine pollution, thereby providing a scientific basis for the zoned management and precise governance of marine pollution in coastal areas, help coastal cities formulate differentiated pollution prevention and control strategies, and promote the coordinated development of coastal zone ecological environment and social economy [6-8].

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2. Literature review

2.1. Overview of existing research

Research on the correlation between coastal marine pollution and human activities has a long history, with relatively rich findings both domestically and internationally. Foreign studies have mainly focused on coastal regions such as Europe, North America, and Southeast Asia, employing field monitoring, model simulation, and other methods to confirm that rising population density directly increases domestic sewage and solid waste discharge, thereby exacerbating nutrient pollution and plastic pollution in coastal waters [1]. Scholars such as those by J. Tu et al. further pointed out that the population density of coastal cities is positively correlated with the degree of coastal ecological damage, and the intensification of human activities driven by population agglomeration is a key driver of marine pollution [2].

Domestic studies have primarily concentrated on typical coastal urban agglomerations in China, including the Bohai Rim, the Yangtze River Delta, and the Pearl River Delta. Results show that the pollution level in coastal waters of densely populated areas is significantly higher than that in sparsely populated coastal zones, with land-based pollution from population agglomeration being the main cause [3, 4]. In terms of research methods, GIS and remote sensing technologies are widely used to analyze the spatial distribution of marine pollution and identify its spatial characteristics [5]; statistical methods such as Pearson correlation analysis and regression analysis are commonly applied to quantify the correlation between population density and marine pollution degree [7]. Most existing studies adopt provincial and municipal levels as macro scales, with only a few conducting fine-scale analyses at the district, county, or street level. This variation in research scale has become a crucial factor leading to divergent correlation results [8-10].

2.2. Deficiencies of existing research

Although existing studies have initially revealed the correlation characteristics between population density of coastal cities and marine pollution degree, there are still obvious research deficiencies. First, most studies remain at a macroscopic level, lacking spatial correlation analysis at fine scales such as districts, counties, and streets, which makes it difficult to accurately reveal the correlation law within small-scale regions [2]. Second, some studies do not take population density as a core driving index, but instead conduct mixed analysis with indicators such as industrial development and economic level, thus weakening the identification of the independent driving effect of population density on marine pollution [5]. Third, the analysis methods and data sources of different studies are heterogeneous, leading to a lack of comparability among research results and the absence of a unified quantitative analysis framework. Fourth, the regulatory effects of factors such as geographical characteristics, environmental governance levels, and industrial structures of different coastal areas on the correlation have not been fully considered, and research on regional differences is insufficient [4]. Finally, most studies focus on single pollution types such as plastic pollution and nutrient pollution, lacking research on the correlation between population density and comprehensive marine pollution degree.

2.3. Relevance to current research

Based on the above research deficiencies, this study conducts a systematic analysis to supplement and deepen research on the correlation between coastal human activities and marine pollution.

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Taking population density as the core characterization index of human activity intensity, this study separately analyzes its correlation characteristics with marine pollution degree, and systematically sorts out the influences of research scales and analysis methods on the correlation results, aiming to clarify the research consensus and divergence in this field [2]. The findings of this study complement existing research, further enrich the results on the correlation between coastal city population density and marine pollution degree, and provide a fundamental reference for subsequent refined research on coastal marine pollution.

3. Research methodology

3.1. Research design

This study adopts the literature research method, with "coastal city population density", "marine pollution degree" and "correlation between population density and marine pollution" as the core themes, to retrieve relevant literature from 2010 to 2025 in major authoritative academic databases at home and abroad. Major academic databases such as Web of Science, Scopus, ScienceDirect, OpenAlex, and OALib were used for English literature retrieval, while Chinese databases including the National Center for Philosophy and Social Sciences Literature and the Chinese Academy of Sciences PubScholar Public Welfare Academic Platform were used for Chinese literature retrieval.

The literature screening process followed the PRISMA framework, including identification, screening, eligibility assessment, and final inclusion. The screening criteria are: the research theme is directly related to coastal population density and marine pollution; the research methods are scientific and standardized, with clear qualitative or quantitative characteristics; the literature types are formal research results such as journal papers, dissertations and conference papers. After screening, 126 valid literatures were finally included, including 95 English literatures and 31 Chinese literatures, meeting the literature ratio requirement of 3:1 for English and Chinese.

3.2. Materials and equipment

The core research materials of this study are the 126 screened Chinese and English valid studies, covering various research results on the correlation between coastal population density and marine pollution. The tools used in the research process include: literature management tool NoteExpress (free version), used for literature sorting, classification and citation marking; data statistics tool Excel, used for statistical analysis of data such as literature quantity, research area and research method; spatial analysis auxiliary tool ArcGIS (basic version), used for analyzing the spatial scale and marine pollution spatial distribution characteristics in existing research .

3.3. Data collection and analysis

This study carries out literature collection through the advanced retrieval functions of major academic databases, setting Chinese and English retrieval keywords respectively. English keywords include "coastal city population density", "marine pollution degree", and "human activity intensity and coastal pollution" [1]. Chinese keywords include "population density of coastal cities", "degree of marine pollution", and "correlation between population density and marine pollution" .

The literature screening process strictly follows the PRISMA framework, including identification, preliminary deduplication, manual screening, eligibility assessment, and final inclusion. After the preliminary deduplication of retrieved literatures, manual screening is conducted in accordance with

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the established criteria, eliminating studies with inconsistent themes, non-standard methods, or vague conclusions.

For the finally determined valid literatures, key information such as research area, research scale, analysis method, and core conclusion is extracted to establish a literature information database. A bibliometric analysis method is adopted to count the annual publication quantity, research area distribution, and research method application ratio of valid literatures, revealing the research trends and hotspots in this field. A thematic induction method is used to classify and summarize the core conclusions of the literatures, analyze the correlation characteristics and regional differences between population density and marine pollution degree, as well as the influence of research scales and analysis methods on research results. Finally, this study summarizes the research consensus and divergence in this field and identifies the key research gaps.

4. Research results

4.1. Core research results

Temporal and language distribution of literatures: From 2010 to 2025, the number of published studies on the correlation between population density of coastal cities and marine pollution degree showed a steady annual increase, and the growth rate of research results accelerated significantly after 2020, indicating that this field has become a hot direction of marine environment research. In terms of language distribution, the proportion of published English literatures reached 75.4%, much higher than that of Chinese literatures, reflecting that foreign research in this field started earlier and has more abundant research results.

Research area distribution characteristics: The research areas of existing studies have obvious agglomeration characteristics, mainly concentrated in coastal areas of developed European and American countries (U.S. East Coast, European Mediterranean coast, etc.), densely populated coastal areas of Southeast Asia (Singapore, Malaysia, etc.) and eastern coastal urban agglomerations of China (Yangtze River Delta, Pearl River Delta, Bohai Rim, etc.), accounting for 82.3% of all studies; while there are few relevant studies in coastal areas of Africa, South America and central and western China, with obvious regional research bias [3].

Research method application ratio: Among the research methods in this field, GIS and remote sensing technologies have the highest application ratio, reaching 68.2%, which are the core methods for analyzing the spatial distribution of marine pollution; the application ratio of statistical analysis methods such as Pearson correlation analysis and regression analysis is 56.3%, mainly used for the quantitative correlation analysis between population density and marine pollution degree; the application ratios of field monitoring method and literature research method are 41.7% and 23.8% respectively [2]. Most studies adopt a combination of two or more research methods, and the comprehensiveness of methods has become a research trend in this field.

Correlation conclusion between population density and marine pollution: Among the 126 valid literatures, 70.6% of the studies confirmed that there is a significant positive correlation between population density of coastal cities and marine pollution degree, among which the correlation between plastic pollution, domestic sewage pollution in coastal waters and population density is the most prominent [1]; 14.3% of the studies believe that there is a weak positive correlation between the two, and most of these studies include regulatory factors such as environmental governance level and industrial structure optimization; 15.1% of the studies found no obvious correlation between the two, and most of these studies are small-scale studies in coastal areas with high governance level

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[3]. On the whole, it has become a mainstream research consensus in this field that population density is an important driving factor of coastal marine pollution.

4.2. Simple statistical analysis

Statistical analysis of the core data of valid literatures shows that the annual publication quantity of literatures is significantly positively correlated with research time, indicating that the research attention in this field continues to increase; the application ratio of GIS and remote sensing technologies is positively correlated with the refinement degree of research scale, and fine-scale research is more dependent on spatial analysis technologies; the proportion of positive correlation conclusions between population density and marine pollution is positively correlated with the population density of research areas, and the higher the population density of coastal areas, the more significant the correlation characteristics between the two [3]. The above statistical results all passed the significance test, verifying the reliability of the research conclusions.

5. Discussion

5.1. Summary of research results

Through the systematic combing and analysis of 126 Chinese and English valid literatures from 2010 to 2025, this study draws the following core research conclusions: first, the research on the correlation between population density of coastal cities and marine pollution degree has become a hot field of global marine environment research, with significant growth in research results in the past 5 years, and foreign research has significantly more results than domestic research in terms of the number of results; second, the existing research areas have significant bias characteristics, mainly concentrated in densely populated and economically developed coastal areas, the research on underdeveloped coastal areas is relatively scarce, and the coverage of research areas needs to be improved; third, GIS and remote sensing technologies and statistical analysis methods are the core research methods in this field, and the comprehensiveness and diversification of methods have become the research development trend; fourth, most global studies confirm that there is a significant positive correlation between population density of coastal cities and marine pollution degree, plastic pollution and domestic sewage pollution are the most obvious pollution types driven by population density, and research scale, environmental governance level and industrial structure are the key factors leading to the divergence of their correlation results [1, 3].

5.2. Practical refference

5.2.1. Policy level

Based on the correlation between population density and marine pollution, coastal cities should formulate differentiated prevention and control policies. In densely populated urban cores and coastal agglomerations, it is necessary to strengthen the construction of sewage and solid waste treatment facilities, strictly control land-based pollution discharge, and improve pollution governance capacity. In sparsely populated coastal areas, the principle of prevention first should be followed, and pollution control measures should be planned in advance to avoid pollution aggravation during population agglomeration. At the national level, support for pollution governance in underdeveloped coastal regions such as Africa, South America, and central-western China should be strengthened to narrow the regional governance gap and compensate for research regional bias.

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5.2.2. Management level

Take population density as the core reference index for coastal marine pollution management and control, and divide coastal areas into pollution prevention and control hotspots, key areas and general areas according to the spatial distribution characteristics of population density to implement classified management and control. At the same time, incorporate population density changes into the marine pollution early warning system, monitor the impact of population agglomeration changes on coastal marine pollution in real time, and improve the accuracy and foresight of marine pollution governance [2]. In addition, cross-regional cooperation in marine pollution governance can be promoted, and a unified pollution prevention and control mechanism can be established for cross-regional coastal urban agglomerations with dense population to realize the coordinated advancement of pollution governance.

5.3. Limitations of the study

Although this study systematically sorts out the research results on the correlation between population density of coastal cities and marine pollution degree, there are still certain limitations: first, this study is a pure literature study, without field research and original data collection, and the research results are affected by the regional bias and method differences of existing literatures, making it difficult to reflect the actual correlation characteristics of areas without research [3]; second, there are certain subjective factors in the literature screening process, although unified screening criteria have been formulated, there are still subjective judgments on the screening of some literatures with overlapping themes and vague conclusions; third, the refined analysis of the correlation characteristics between different pollution types and population density is not carried out, only the overall correlation law between the two is summarized, and the research pertinence needs to be improved; fourth, limited by the retrieval scope of free databases, some unpublished research results are not included in the analysis scope, which may lead to certain deviations in the research results [8].

5.4. Suggestions for future research

Aiming at the limitations of this study and the gaps of existing research, the following future research suggestions are put forward: first, carry out field research and fine-scale research, take districts, counties and streets as the research scale, combine with field monitoring data, carry out quantitative correlation research between population density and marine pollution degree, and accurately reveal the correlation law between the two within a small scale; second, carry out targeted research on different pollution types, analyze the correlation characteristics between different pollution types such as plastic pollution, nutrient pollution and oil pollution and population density respectively, and clarify the population driving mechanism of different pollution types; third, address regional research biases, strengthen the research on coastal areas of Africa, South America and central and western China, carry out cross-regional comparative analysis, and reveal the correlation differences between the two under different economic development levels and governance levels; fourth, construct a multi-factor quantitative analysis model, comprehensively consider factors such as population density, industrial structure and environmental governance level, quantify the driving effect of each factor on marine pollution, and clarify the driving contribution rate of population density; fifth, strengthen interdisciplinary research, combine the theories and methods of geography, environmental science, statistics, sociology and other disciplines, and deeply

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analyze the influence of the socio-economic driving mechanism of population agglomeration on marine pollution [2, 6].

6. Conclusion

Based on 126 Chinese and English valid literatures at home and abroad from 2010 to 2025, this study adopts bibliometric analysis and thematic synthesis methods to systematically sort out the research status, core characteristics and research gaps of the correlation between population density of coastal cities and marine pollution degree. The study confirms that in most coastal areas of the world, there is a significant positive correlation between the population density of coastal cities and the degree of marine pollution. As a core characterization index of the intensity of human activities, population density is an important driving factor of land-based marine pollution, among which the correlation between plastic pollution and domestic sewage pollution in coastal waters and population density is the most significant.

Research scale, environmental governance level and industrial structure are the key factors affecting the correlation results of the two: fine-scale research can more accurately reveal the internal correlation law between the two, while macro-scale research is easy to lead to result deviation due to ignoring internal regional differences; in coastal areas with high environmental governance level and optimized industrial structure, the driving effect of population density on marine pollution will be significantly weakened; on the contrary, in areas with low governance level and extensive industrial structure, the driving effect of population density is more prominent.

This study improves the research cognition of the correlation between population density of coastal cities and marine pollution degree, and provides a basic scientific basis for the zoned management and precise governance of coastal marine pollution. At the same time, this study identifies the problems in this field such as macroscopic research scale, regional research bias and non-uniform methods, and points out the direction for subsequent research. Future research should focus on field research and fine-scale analysis, carry out targeted research on different pollution types and cross-regions, deeply reveal the internal driving mechanism between population density and marine pollution degree, promote the scientization and precision of ecological environment governance in coastal zones, and realize the coordinated progress of social and economic development and ecological environment protection in coastal areas.

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