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Marine Biodiversity Conservation: A Bibliometric Study on Ocean Research and Policy

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ABSTRACT

Marine biodiversity is essential for sustaining ocean health, ecological balance, and human livelihoods, yet it faces escalating threats from climate change, overexploitation, and habitat degradation. This study conducts a comprehensive bibliometric analysis to map the evolution and thematic structure of scholarly research on marine biodiversity conservation from 2000 to 2024. Using Scopus-indexed data and VOSviewer software, the study analyzes keyword co-occurrence, collaboration networks, and temporal trends in the literature. Results indicate that "biodiversity," "marine environment," and "conservation" are central research themes, while emerging topics such as "physiology," "nonhuman," and "controlled study" reflect recent shifts toward micro-level and experimental research. The study also reveals the increasing integration of policy-oriented topics, such as marine protected areas and environmental governance, with core ecological concepts. Despite this progress, the analysis highlights geographical imbalances and underexplored areas, including traditional knowledge systems and economic valuation of marine ecosystems. This bibliometric mapping provides valuable insights for guiding future research agendas, enhancing global collaboration, and strengthening the science-policy interface in marine biodiversity conservation.

Keywords: *Marine Biodiversity, Conservation, Bibliometric Analysis, Ocean Policy, VOSviewer*.

1. INTRODUCTION

Marine biodiversity is a fundamental component of Earth's biosphere, contributing not only to ecological stability but also to human well-being and economic sustainability. Oceans cover more than 70% of the Earth's surface and harbor nearly 80% of all life on the planet [1]. This biodiversity supports a range of ecosystem services, from climate regulation and nutrient cycling to fisheries and tourism. However, the very survival of many marine species is increasingly jeopardized by human activities, including overfishing, habitat destruction, pollution, and the overarching threat of climate change [2]. As such, conservation of marine biodiversity has become an urgent global priority, underpinning the efforts of various international frameworks such as the Convention on Biological Diversity (CBD) and the Sustainable Development Goals (SDG 14).

In recent decades, ocean research has grown in both scale and complexity, reflecting an evolving understanding of the interconnectedness between marine biodiversity and planetary health. Scientific exploration has extended into deep-sea ecosystems, coastal habitats, and polar regions, highlighting previously unknown species and intricate ecological interactions. With technological advancements in oceanographic sensors, remote sensing, and genomic tools, marine science has significantly expanded the knowledge frontier [3]. Simultaneously, interdisciplinary research has emerged, integrating oceanography, ecology, environmental economics, and governance to address multifaceted challenges in conservation. The growing body of literature on marine biodiversity reflects the dynamic development of the field, but also signals a need to evaluate how research aligns with global policy agendas and conservation outcomes [4].

Despite the increasing research output, gaps remain in translating scientific knowledge into effective policy and practice. Marine biodiversity policy often suffers from fragmented governance, lack of enforcement mechanisms, and limited stakeholder engagement [5]. The complexity of ocean

ecosystems, combined with jurisdictional challenges in areas beyond national jurisdiction (ABNJ), makes marine conservation particularly difficult. Moreover, the disparity in research focus between economically developed and developing countries further complicates the implementation of equitable and inclusive marine biodiversity strategies. As a result, there is growing interest in assessing the state of knowledge production, its geographical distribution, institutional contributors, and thematic focus areas [6], [7].

Bibliometric methods provide a robust quantitative approach to analyzing the evolution of scholarly knowledge over time. Through the use of citation analysis, co-authorship networks, keyword co-occurrence, and publication trends, bibliometrics helps identify influential publications, emerging themes, and research gaps [8]. Applied to marine biodiversity conservation, this approach enables researchers to map the scientific landscape, assess collaboration patterns, and evaluate how research output supports or diverges from policy initiatives. Notably, bibliometric studies have been successfully conducted in adjacent fields such as climate policy, fisheries management, and environmental governance, reinforcing their value for strategic planning and academic evaluation.

Given the escalating threats to marine ecosystems and the proliferation of conservation research, a bibliometric study focusing on marine biodiversity is both timely and necessary. It serves to synthesize the growing corpus of literature, highlight evolving research priorities, and assess the alignment between academic inquiry and international conservation frameworks. Such a study can inform policymakers, guide funding allocations, and support the development of integrated research agendas that address both ecological and socio-political dimensions of marine conservation. As nations strive to meet commitments under the CBD Post-2020 Global Biodiversity Framework and SDG 14 ("Life Below Water"), understanding the trajectory and impact of marine biodiversity research becomes an essential component of effective policy design and implementation.

Although marine biodiversity conservation has become a major area of scientific and policy interest, the existing literature is highly fragmented, with uneven geographical representation, varying thematic emphases, and limited integration between research and policy. There is a lack of comprehensive bibliometric studies that systematically evaluate the evolution, distribution, and influence of marine biodiversity research in relation to global conservation goals. Consequently, stakeholders face challenges in identifying knowledge gaps, tracking research trends, and aligning scientific output with urgent conservation needs. This study aims to conduct a bibliometric analysis of scholarly literature on marine biodiversity conservation, focusing on the volume, thematic focus, institutional affiliations, geographical distribution, and citation impact of publications.

2. METHODS

This study adopts a bibliometric analysis approach to systematically evaluate scholarly publications related to marine biodiversity conservation. Bibliometric analysis is a quantitative method that enables the assessment of academic literature through indicators such as publication volume, citation count, keyword trends, and collaboration networks [8]. This method is particularly valuable in identifying emerging research themes, influential authors or institutions, and the intellectual structure of a given field. In the context of marine biodiversity, bibliometric analysis facilitates an understanding of how scientific inquiry has evolved, the level of interdisciplinary engagement, and the extent to which research aligns with conservation policies and priorities.

The dataset for this analysis was retrieved from the Scopus database, one of the most comprehensive repositories of peer-reviewed literature in environmental and ocean sciences. The search query was designed using a combination of relevant keywords such as *"marine biodiversity,"*

"ocean conservation," "marine protected areas," and *"sustainable ocean policy,"* limited to titles, abstracts, and keywords. The time frame for the analysis spans from 2000 to 2024, reflecting the most recent developments in ocean research and international policy discourses such as the SDG 14 and the Post-2020 Global Biodiversity Framework. Only journal articles and reviews published in English were included to ensure data consistency. After cleaning the dataset and removing duplicates or unrelated articles, a final sample of 896 documents was analyzed. The data were processed and visualized using VOSviewer, a specialized tool for constructing and analyzing bibliometric networks.

3. RESULTS AND DISCUSSION

3.1 Network Visualization

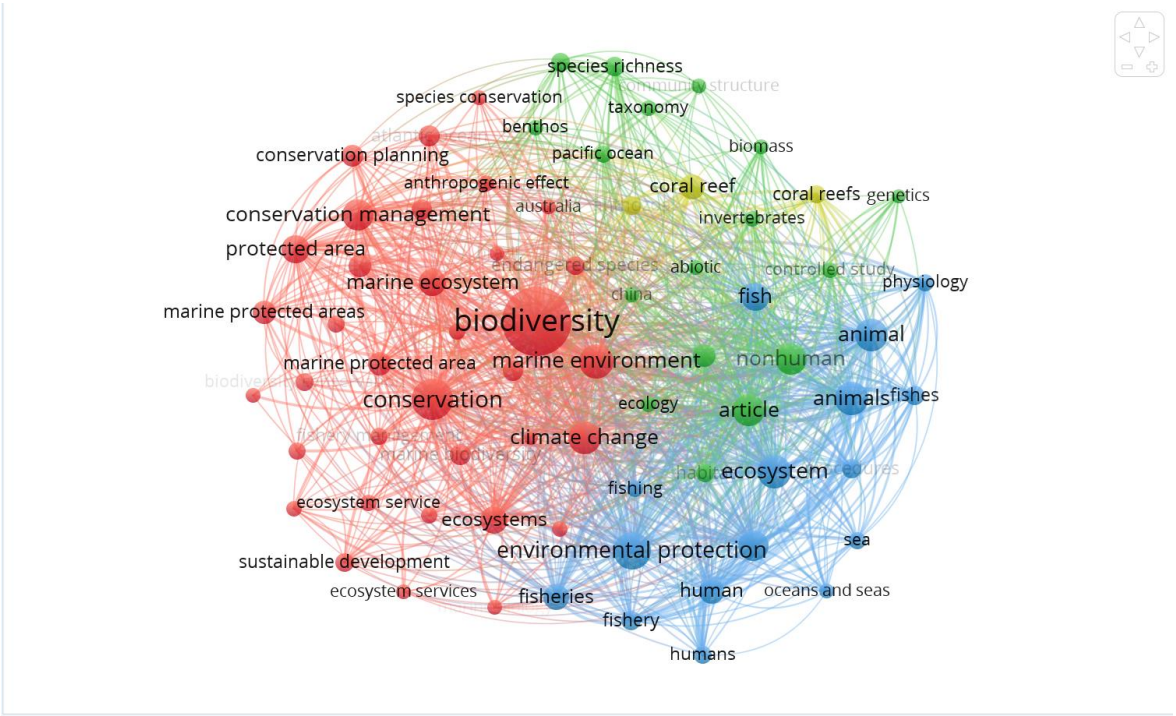

Figure 1. Network Visualization
Source: Data Analysis

At the center of the map, the term "biodiversity" emerges as the most prominent and densely connected keyword, indicating its foundational role in the marine conservation literature. Closely tied to it are terms such as *marine environment*, *conservation*, and *climate change*, which suggests that biodiversity is often discussed in the context of broader ecological and environmental protection issues. The network's dense core reflects the high degree of interconnectedness between fundamental concepts in marine science, especially those linked to ecosystem resilience, species preservation, and climate-driven threats. The red cluster on the left side of the visualization represents keywords associated with marine conservation planning and management. Terms such as *marine protected areas*, *conservation management*, *protected area*, and *conservation planning* dominate this group. This indicates a strong research focus on the institutional, spatial, and strategic aspects of marine biodiversity conservation, such as designing and evaluating the effectiveness of protected zones. The presence of *ecosystem services* and *sustainable development* in this cluster suggests that many studies frame conservation within broader sustainability frameworks, linking ecological outcomes to socioeconomic benefits.

The blue cluster, located in the lower right quadrant, is composed of terms like *ecosystem*, *fisheries*, *environmental protection*, *humans*, and *oceans and seas*. This cluster captures research addressing the interface between human activities and marine ecosystems, including overfishing, resource use, and the role of environmental policy. Keywords like *human* and *fishing* underscore the

anthropogenic dimensions of biodiversity loss and management, highlighting research on human-induced pressures and governance responses aimed at safeguarding ocean health. This cluster often reflects policy-oriented or applied research themes. The green cluster, visible at the top of the map, centers around biological and ecological research themes, particularly coral reef ecosystems and marine species. Keywords such as *coral reef*, *genetics*, *species richness*, and *taxonomy* indicate a focus on species-level and habitat-specific studies. This group reflects contributions from marine biology and ecological taxonomy, dealing with species identification, population structure, and biodiversity assessment techniques. The presence of *biomass*, *benthos*, and *community structure* suggests more fine-grained ecological studies concerned with ecosystem composition and species interactions.

3.2 Overlay Visualization

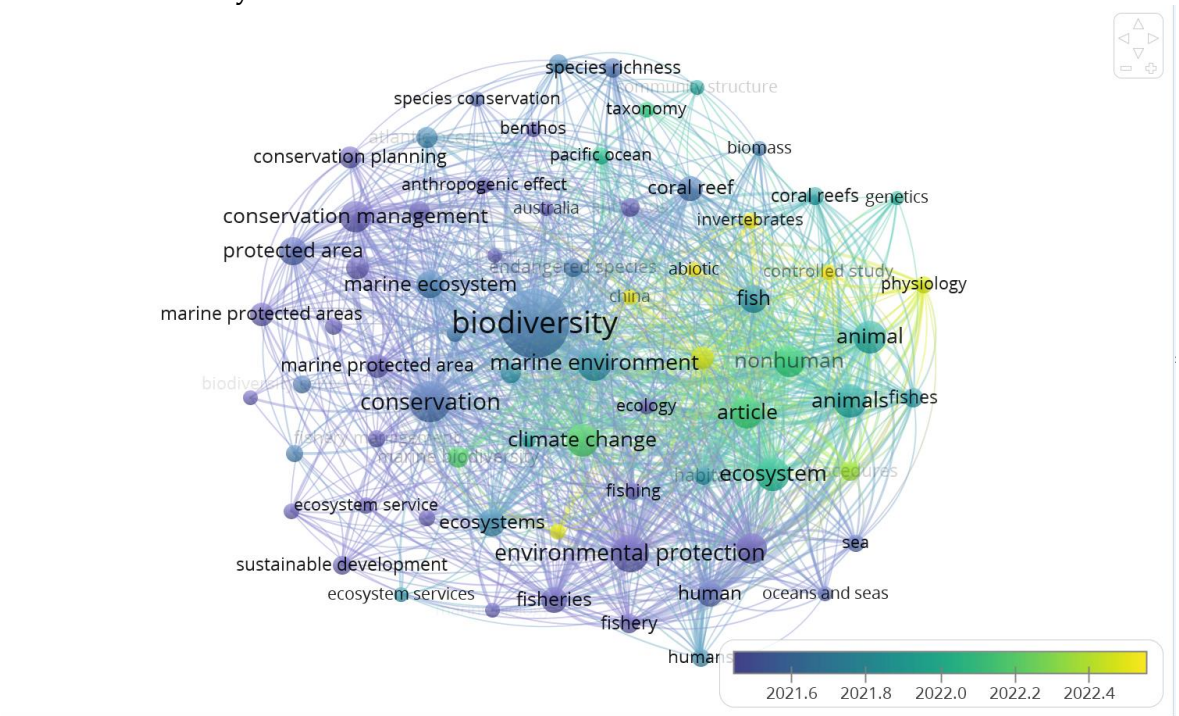

Figure 2. Overlay Visualization
Source: Data Analysis

In this map, colors reflect the average publication year in which keywords appeared, with the color gradient ranging from dark blue (earlier publications around 2021.6) to bright yellow (most recent publications around 2022.4). This visualization provides valuable insights into temporal trends in research topics. Firstly, the core keywords such as *biodiversity*, *marine environment*, *conservation*, *marine ecosystem*, and *climate change* are located at the center of the map and appear in greenish tones, indicating consistent usage throughout the 2021–2022 period. These foundational terms suggest ongoing relevance and reflect the stable, long-term interest in overarching ecological themes. Keywords such as *marine protected areas*, *conservation management*, and *ecosystem services* appear more in blue and turquoise shades, showing that these topics have been more prominent in earlier studies and may have reached a mature research stage.

In contrast, the emerging or recent topics are highlighted in yellow tones, located more on the right and upper-right portions of the map. These include keywords such as *physiology*, *nonhuman*, *fish*, *invertebrates*, and *controlled study*. Their recent emergence indicates a growing focus on experimental, species-specific, and physiological research dimensions of marine biodiversity, possibly driven by advances in marine biology, genetics, and climate impact studies. The yellow hue of *physiology* especially suggests an uptick in research exploring how marine organisms respond to environmental stressors, aligning with broader climate adaptation inquiries.

3.3 Density Visualization

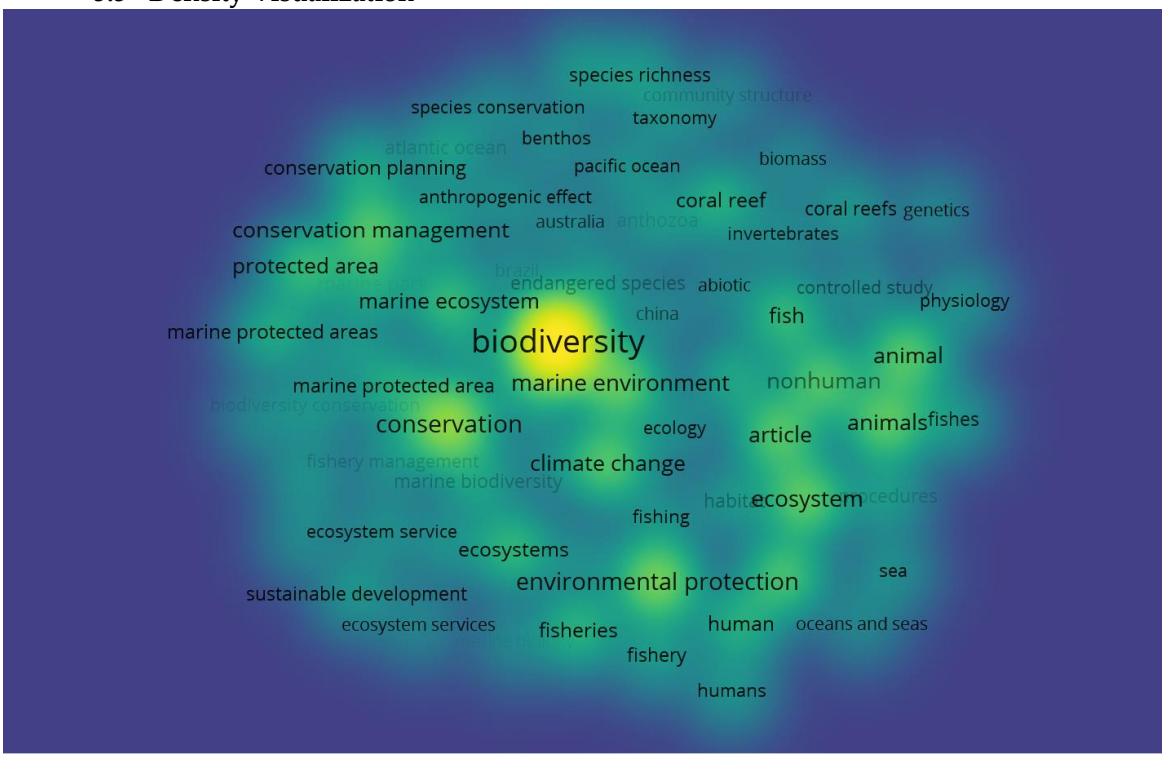

Figure 3. Density Visualization

Source: Data Analysis

Figure 3 above showcasing the concentration and frequency of keyword usage in marine biodiversity conservation literature. Brighter yellow areas indicate high-density zones, where keywords frequently co-occur, suggesting central research foci. At the heart of the map, the terms "biodiversity," "marine environment," "conservation," and "marine ecosystem" are the most concentrated, representing the conceptual core of marine conservation scholarship. Their central location and intensity reflect their consistent appearance across a wide range of studies, underlining their importance in framing ecological, management, and policy discussions. In contrast, keywords in darker green to blue areas (such as *taxonomy*, *anthropogenic effect*, *fishing*, *humans*, and *procedures*) appear less frequently and represent emerging or niche topics. The moderate density of terms like *climate change*, *ecosystem services*, *fisheries*, and *environmental protection* suggests strong but slightly more specialized research activity. These areas reflect the multidisciplinary expansion of the field, as studies increasingly link biodiversity with environmental governance, sustainability goals, and socioeconomic concerns.

3.4 Top Cited Literature

Table 1. The Most Impactful Literatures

Citations	Authors and year	Title
8989	[4]	A safe operating space for humanity
6137	[5]	Effects of biodiversity on ecosystem functioning: A consensus of current knowledge
3617	[9]	Impacts of biodiversity loss on ocean ecosystem services
2738	[6]	Depletion degradation, and recovery potential of estuaries and coastal seas
2625	[7]	Confronting the coral reef crisis
2561	[10]	A global crisis for seagrass ecosystems

Citations	Authors and year	Title
2442	[11]	Emerging threats and persistent conservation challenges for freshwater biodiversity
2353	[12]	Towards sustainability in world fisheries
2313	[13]	The impact of climate change on the world's marine ecosystems
2110	[14]	Declining oxygen in the global ocean and coastal waters

Source: Scopus, 2025

Discussion

This bibliometric study reveals significant insights into the intellectual structure, thematic evolution, and research dynamics of marine biodiversity conservation from 2000 to 2024. The findings not only highlight dominant themes and prolific research areas but also underscore critical shifts in scientific focus over time. Through a series of visual analyses this study offers a comprehensive view of how marine biodiversity scholarship has developed in relation to environmental policy, scientific innovation, and global conservation goals.

The co-occurrence network visualization illustrates a tightly interconnected web of research themes, with *biodiversity* as the most central and highly co-occurring term. This suggests that most studies anchor their focus around biodiversity, either conceptually or empirically. Closely connected terms such as *marine environment*, *conservation*, *climate change*, and *marine protected areas* indicate that researchers consistently frame biodiversity within larger ecological and governance contexts. The red cluster in the network emphasizes the management side of conservation, highlighting terms like *conservation management*, *protected area*, and *ecosystem service*. This cluster shows that marine biodiversity studies are not limited to biology but are deeply concerned with strategic and policy-relevant interventions, aligning with initiatives like the Convention on Biological Diversity (CBD) and Sustainable Development Goal 14.

The blue cluster, consisting of keywords like *fisheries*, *ecosystem*, *humans*, and *environmental protection*, reflects research that bridges ecological health with human impacts and socio-political dimensions. These studies often explore how anthropogenic activities, such as overfishing and habitat degradation, influence marine ecosystems, and how policy tools and governance mechanisms can mediate such impacts. It is noteworthy that this cluster is tightly connected to central nodes like *climate change*, signaling that marine biodiversity cannot be divorced from the larger discourse on environmental sustainability and global change. In this context, marine conservation is not just about species protection, but also about building resilient ecosystems and sustainable livelihoods.

The green cluster, centered on terms like *coral reef*, *species richness*, *genetics*, and *invertebrates*, represents the biological and ecological dimension of marine biodiversity research. These keywords suggest a growing focus on species-specific and habitat-specific studies, often supported by advanced tools such as genetic sequencing and remote sensing. Such studies are essential in providing fine-grained data for understanding the complex dynamics of marine life, particularly in sensitive ecosystems like coral reefs, which are increasingly threatened by warming seas and acidification. The presence of technical terms such as *biomass*, *taxonomy*, and *community structure* also indicates that detailed ecological monitoring is foundational to evidence-based conservation.

The overlay visualization, which maps keyword appearance over time, shows temporal evolution in research interests. Foundational terms like *biodiversity*, *marine ecosystem*, and *conservation* appear in cooler shades (blue to green), reflecting their consistent and long-standing role in the literature. Conversely, newer topics such as *physiology*, *nonhuman*, and *controlled study* appear in warmer shades (yellow), indicating emerging scientific interests. The rise of *physiology* in particular points to a deepening of marine research into organismal responses to stressors such as ocean acidification, pollution, and temperature anomalies. This trend suggests a micro-level turn in marine biodiversity science, where molecular and physiological data complement ecosystem-level analyses.

Interestingly, the overlay also reveals a recent uptick in studies focused on nonhuman animals and controlled studies, suggesting that researchers are increasingly conducting lab-based or mesocosm experiments to simulate environmental conditions. These methodologies provide valuable data for predicting how marine species will respond under future climate scenarios, supporting proactive conservation design. The presence of *abiotic* and *anthropogenic effect* as newer keywords further underscores this transition toward mechanistic and predictive modeling in marine ecology.

The density visualization reinforces the centrality of biodiversity-related terms while revealing research saturation and novelty across different topics. Bright yellow regions such as *biodiversity*, *marine environment*, and *conservation* indicate high research density, meaning that these topics have been extensively studied and form the foundation of the field. Meanwhile, terms with moderate to low density, such as *sustainable development*, *fishing*, *procedures*, and *community structure*, point to underexplored areas or more recent academic interest. This map is useful for identifying potential research gaps. For example, while *sustainable development* appears frequently, its lower density suggests limited integration with core biodiversity discussions, an area ripe for further interdisciplinary inquiry.

These visualizations confirm that marine biodiversity conservation is a multidimensional research field, integrating ecological, policy, technological, and socio-economic perspectives. The evolution of keyword trends shows that while core themes remain steady, the field is dynamically expanding toward greater specialization and integration. Moreover, the increasing appearance of policy-relevant and technical terms reflects a science-policy nexus that is essential for achieving real-world impact. Scholars are not only advancing theoretical understanding but also addressing practical issues related to conservation governance, stakeholder engagement, and adaptive management.

Despite this growth, the study also highlights some persistent challenges and imbalances. For instance, earlier keyword analyses reveal a dominance of literature originating from high-income countries with well-developed marine research infrastructures. Keywords such as *Australia*, *Pacific Ocean*, and *Atlantic Ocean* appear frequently, while regions like Africa and Southeast Asia are underrepresented. This geographical bias may hinder the development of globally inclusive marine policies and may overlook biodiversity hotspots in developing regions. Future research should prioritize equitable collaborations and knowledge production in underrepresented marine regions. Another gap is the limited visibility of indigenous knowledge systems and community-based conservation practices, which are vital in many coastal regions. Their absence from dominant keyword networks suggests a need for better integration of traditional ecological knowledge into scientific and policy frameworks. Similarly, terms related to economic instruments (*blue economy*, *ecotourism*, *marine finance*) are largely absent or peripheral in the maps, indicating that the economic valuation of biodiversity and its role in sustainable development are areas requiring further investigation.

This bibliometric analysis also has methodological implications. The use of VOSviewer and Scopus indexing proves to be an effective combination for mapping academic landscapes, yet it also carries limitations such as language bias (favoring English publications) and database coverage constraints. Supplementing future analyses with sources like Web of Science, Dimensions, or even grey literature repositories could provide a more holistic view of the marine biodiversity knowledge system. Additionally, longitudinal bibliometric tracking, thematic clustering using machine learning, and policy-document co-citation analyses could deepen future research.

CONCLUSION

This study underscores the vibrancy and complexity of marine biodiversity conservation research. It is a field anchored in well-established ecological concepts, yet responsive to emerging global challenges and scientific advancements. The strong presence of conservation, ecosystem services, and climate-related terms reflects the urgency of sustaining marine life under

anthropogenic pressures. Simultaneously, the rise of newer topics like physiology, nonhuman studies, and genetic tools points to an evolving toolkit for marine scientists. Moving forward, a more integrated, equitable, and interdisciplinary research agenda is essential to address both the scientific and policy dimensions of marine biodiversity conservation in the Anthropocene era.

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