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# Advancing a sustainable blue economy through innovation: a systematic review

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**Abstract**
The blue economy, as a new development model, seeks to balance environmental conservation with economic and social development objectives. This goal remains, however, difficult to achieve due to pressures from human activities on oceans and seas. Addressing this challenge requires the adoption of innovative approaches both in blue economy sectors and in supporting regulatory and policy frameworks. In this article, we conduct a systematic literature review (PRISMA 2020) of papers published from 2012 to 2024 to analyze the significance of innovation in promoting the sustainability of the blue economy. Advanced review tools were used to identify main trends, key contributors, emerging issues, critical gaps, and future research perspectives. Our results indicate a growing integration of environmental considerations within the framework of innovation and blue economy analysis. The research landscape reveals challenges and pressures impacting the marine environment, such as climate change and economic and industrial activities, alongside measures and approaches to mitigate these issues, including high-quality development, conservation management, protection and environmental legislation. Our findings further underscore the necessity for a comprehensive, interdisciplinary approach. Various mediating factors, mechanisms, and leverage actions were identified as essential in enhancing the impact of innovation on the sustainability of the blue economy. Our findings offer significant actionable insights and policy implications, guiding researchers toward underexplored areas of research and providing public policymakers with recommendations for the design of innovation policies and strategic agendas.

**Keywords** Innovation, Blue economy, Sustainable development, Technological development, High quality development, Prisma, Bibliometric technique

## 1 Introduction

The term blue economy was initially introduced by the economist and entrepreneur Pauli Gunter in 1994 to represent a new economic model that draws inspiration from natural ecosystems to solve economic, social and ecological crises. It then gained significant interest since 2012, following the United Nations Rio + 20 conference on promoting the green economy. This conference was an opportunity to adapt the principles and objectives of the green economy to the needs and challenges of the island and coastal

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states, considering the blue economy as an extension of the green economy [1, 2], or more generally of the sustainable development agenda [3].

Since then, this new paradigm has emerged strongly as the subject of numerous international initiatives and actions, notably the SDG 14 aiming to conserve and sustainably use the oceans, seas and marine resources. The blue economy has also been an integral part of regional and national development strategies and action plans.

The blue economy has no universally accepted definition; it is very often defined by several authors through its triple objectives of economic growth, social equity, and environmental sustainability [2, 4]. According to the World Bank [5], "*The blue economy is the sustainable use of ocean resources for economic growth, improved livelihoods and jobs, and healthy marine ecosystems*".

To clarify the ambiguities concerning this term, a number of scientific studies have been carried out, ranging from attempts of conceptualization, to implementation strategies and operationalization tools. The complexity of this concept stems from its transversal nature and the multiplicity of its fields of action. This concept is used differently depending on the context and the various actors (governments, private sector, international organizations, research institutions and non-governmental organizations (NGOs)). Voyer [2] and Midlen [6] have identified several perceptions of the blue economy reflecting the disparities in objectives and priorities pursued by different actors. In this framework, five dominant discourses relating to the ocean emerged, namely the ocean as natural capital, the ocean as a means of subsistence, the ocean as a source of economic opportunities, the ocean as a territory, and the ocean as an engine of innovation. The latter is supported both by research institutions, as well as by governments and companies. It focuses on research networks, public and private investment, innovative financing mechanisms, and competition to develop new industries (such as marine biotechnology) or innovate in existing ones.

The current study aligns with this prevailing perspective by systematically reviewing recent scientific literature on the relationship between innovation and the blue economy. Within this context, innovation plays a key role in enhancing the sustainability of established sectors, fostering the emergence of new ones, and most importantly building a more resilient economic model [7], by promoting the adoption of sustainable alternative solutions, more responsible use of marine resources, and better management of marine ecosystems. The importance of innovation is also apparent in the policy and regulatory frameworks, where transformative measures are required to adapt governance structures and strategic policies to new developments, as emerging blue economy sectors may operate under outdated or non-existent policies. Implementing these measures will effectively support and guide sustainable innovation in ocean-based economic activities.

The aim of our work is therefore to conduct an in-depth analysis of the role of innovation in the sustainability of the blue economy. Our study goes beyond descriptive analysis to critically review the literature and identify mechanisms and fields of action through which this role can be manifested. Thus, our reflections focus on the following questions:

- What is the role of innovation in promoting a sustainable blue economy?
- How is the link between innovation and a sustainable economy addressed in the literature?

- What are the mediating factors by which innovation can contribute to the sustainability of blue economy?

In recent years, a growing number of scientific publications have been devoted to literature reviews and bibliometric analysis of papers related to the blue economy and innovation (Table 1). However, these two concepts have been analyzed independently, focusing on understanding knowledge and intellectual structures [8], identifying research trends and emerging topics [9], or analyzing the links between each of these concepts and sustainability[9, 10]. Consequently, the existing literature lacks a comprehensive analysis of the link between the blue economy and innovation, unlike the green economy, which has been the subject of abundant literature highlighting its synergies with both innovation and sustainability [11–15]. Our study seeks to address this gap by examining how this relationship is manifested and through which channels.

The significance of this study lies in its potential to deepen our understanding of how innovation can foster the sustainability of the blue economy by identifying key mediating and supporting factors that underpin this relationship. These factors are considered as lever actions that provide insights for public policymakers in the formulation of their blue economy and innovation policies and strategic agendas aimed at achieving sustainable development objectives. Furthermore, our research contributes to the academic discourse by highlighting unexplored areas of research, paving the way for future scholarly investigations.

This article is organized as follows: the subsequent section presents a detailed overview of the methodological approach employed. The results section thereafter delineates the primary trends in the literature, along with a content analysis of the articles selected for review. These results are then discussed to contextualize them within the existing

**Table 1** An overview of key previous literature studies on blue economy and innovation

| Authors | Main objectives | Main findings |
|---|---|---|
| Lu, Q., and Li, Z. (2025) | Conduct an in-depth investigation into the development history and hotspots related to the BE research | Growing trend in blue economy research since 2018<br>China leads Blue Economy research, with a significant number of publications, citations and considerable academic impact |
| Başhan, V., and Çetinkaya, A (2025) | Trace the trajectory of global research on blue growth across science, policy, and the blue economy | The intellectual framework of blue growth research encompasses prominent themes such as marine biology, oceanography, sustainability science, and climate change<br>The study highlights significant contributions from various countries, demonstrating extensive global collaboration networks |
| Liang, J., et al. (2022) | Analyzing research trends in blue economy sustainable development to inform future research | The literature in the field is growing annually<br>Most related research is conducted independently, with limited collaboration among institutions<br>Lack of research addressing global and systematic issues |
| Martínez-Vázquez, et al. (2021) | Find links between circular economy and Blue Economy through the Blue Growth | BE is a recent term rooted in sustainable development and requires time for widespread adoption<br>The BG Strategy facilitates the continuation of economic activities in seas and oceans in a more sustainable manner |
| Maier, D., et al. (2020) | Identify common points and future researches between innovation and sustainability | The combination of the concepts of innovation and sustainability in the single concept "sustainable innovation" provides an emerging area of research |
| Dzhunushalieva, G., and Teuber, R. (2024) | Analyze the intellectual structure of academic literature on the SDGs, Innovation, and Science, Technology and Innovation (STI) | Term "sti" is less commonly associated with the SGDs than "innovation<br>References to the term "innovation" is likely to attract a wider readership |

literature by identifying critical gaps and research limitations. Finally, the conclusion summarizes the key findings and highlights promising areas for future research.

## 2 Methods

In this study, we adopt the systematic review as a methodological approach. This type of review is based on pre-defined eligibility criteria to collect articles related to the research question under study. Compared to the other types of review, the systematic review is recognized as methodical, complete, transparent, and replicable, which minimizes subjectivity and bias risks [16].

Our review follows the protocol PRISMA 2020 [17]. The latter allows the definition of search strategy and criteria for article inclusion, and is divided into three main stages. The first called the identification stage consists of operationalizing the research question in terms of research to ensure the most exhaustive possible identification of articles relevant to our subject. The second stage is the selection, aimed at ensuring that the identified articles meet the previously defined inclusion criteria, by screening them first based on titles, keywords, and abstracts, and second by full-text reading. In the third stage, the articles selected will be the subject of relevant information extraction for their analysis.

In doing so, our work provides an in-depth analysis of a new and emerging field of study, namely the link between innovation and the blue economy. Our review provides a better understanding of how this link is addressed in the literature, identifies major trends and gaps, and proposes new research perspectives.

### 2.1 Inclusion criteria

In order to identify articles relevant to our research subject, we used the platform Scopus (accessed on August 03, 2024). The selection of the Scopus database is justified by its comprehensive nature and extensive interdisciplinary coverage, which enhance its depth and breadth. Scopus encompasses a vast corpus of scientific articles from a wide range of fields, representing a significant proportion of academic publications and including numerous top-ranked journals [18]. These features make Scopus a reliable database and distinctly differentiate it from other bibliographic databases, such as ISI and Web of Science, thereby enhancing its appeal to the scientific community for conducting rigorous literature reviews[19].

To perform our research, we mainly used terms often employed interchangeably with the blue economy [2, 4]. Our search terms are: ("blue economy" OR "marine economy" OR "ocean economy" OR "blue growth" OR "sea economy" OR "maritime economy") AND ("innovation" OR "sustainable innovation"). These terms should appear in the title, abstract or keywords. Restrictions were applied to document types, subject areas, language, and years of publication (Table 2). Only original, peer-reviewed scientific articles are included; this excludes book chapters, conference proceedings, review articles, and notes and guarantees the credibility and reliability of the resources used. Furthermore, given the multidisciplinary nature of our research topic, the articles selected are not limited to the social science field, but include environmental science, agriculture, and biological science, which enables a holistic view of our subject. We also considered only the articles published in English to make the analysis logistically possible, and the articles published in 2012 and beyond, which corresponds to the holding of the RIO + 20

**Table 2** Criteria for article identification

| Criteria | Descriptions |
|---|---|
| Article type | Peer-reviewed original research articles |
| Database | Scopus |
| Subject area | Environmental science, social science, agriculture and biological science |
| Years of publication | 2012–2024 |
| Language | English |
| Geographical scope | Without restriction |
| Research objectives | The blue economy and innovation are at the core of the issue and/or subject of the article |

conference, the broadening use of the term blue economy, and its growing emergence among stakeholders [1, 20]. In total, this process has generated 191 scientific articles.

### 2.2 Screening and analysis

An initial review based on titles and abstracts was carried out to retain only articles that met the criteria defined in the previous section. Out of 191 articles retrieved, 108 were excluded, of which 96 articles have research subjects that do not align with our research questions, and 12 are review articles, meta-analysis, or bibliometric analysis. The remaining 83 articles were fully read, in order to examine their contributions related to the innovation within the blue economic context. Thus, 40 articles were excluded as they were not related to our research questions and objectives, leaving 43 eligible articles. The latter were then analyzed (Fig. 1).

This screening exercise involved all authors. The first author reviewed all the articles, and the second independently analyzed a random sample representing 10% of the total number of articles. In the case of non-conformity or disagreement, discussions were held until mutual agreement was reached.

## 3 Results

Based on the previous section, we will first conduct a descriptive analysis of the retrieved articles, by considering the trends, the temporal and the geographical distribution, as well as the methodological approaches used, followed by a content analysis to assess the main research topics examined in the literature.

### 3.1 Overview of selected papers

#### *3.1.1 Trend in volume of publications*

Table 3 provides a descriptive overview of the articles reviewed. The study analyzed 43 articles published in 21 journals, with an annual rate of 20%, and an average citation count of 12 per document. These articles were authored by 214 contributors and involved 23% international co-authorships. This proportion requires further examination by geographical distribution to assess its concentration.

Articles related to our research question started to be published in 2014, with a significant increase occurring between 2020 and 2024 (Fig. 2). During this period, these articles accounted for 88% of total publications, averaging 8 articles per year. This trend indicates that the scientific community's interest in the link between innovation and the blue economy is relatively recent, and is situated more generally in an international context marked by the need to strengthen economic resilience, ensure post-covid-19 recovery, and progress towards the Sustainable Development Goals. Journals such as "Marine

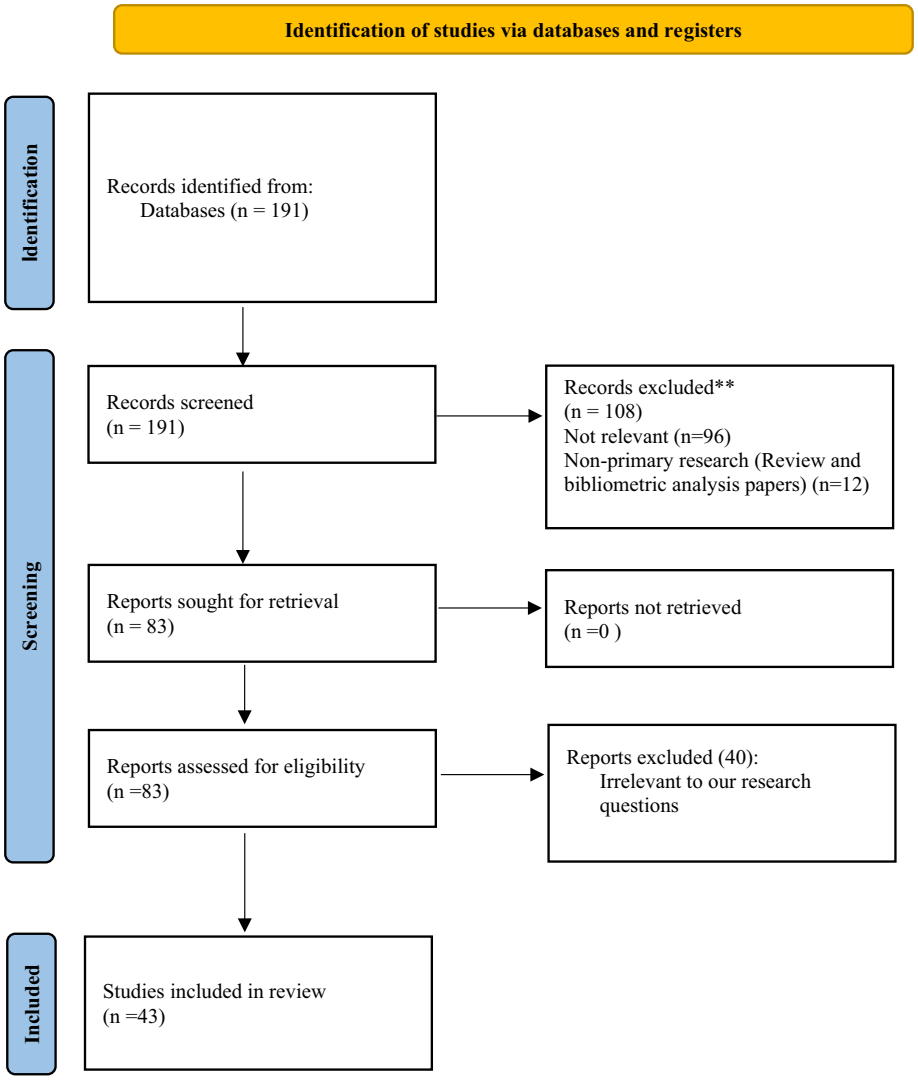



**Fig. 1** The searching and screening process, adapted from PRISMA 2020 flow diagram for new systematic reviews

**Table 3** Descriptive statistics of the analyzed articles

| Descriptions | Results |
|---|---|
| Timespan | 2012–2024 |
| Sources (Journals) | 21 |
| Annual Growth Rate % | 19,62 |
| Average citations per doc | 11,7 |
| Keywords Plus (ID) | 234 |
| Author's Keywords (DE) | 167 |
| Authors | 214 |
| Authors of single-authored docs | 8 |
| International co-authorships % | 23,26 |
| Number of articles | 43 |

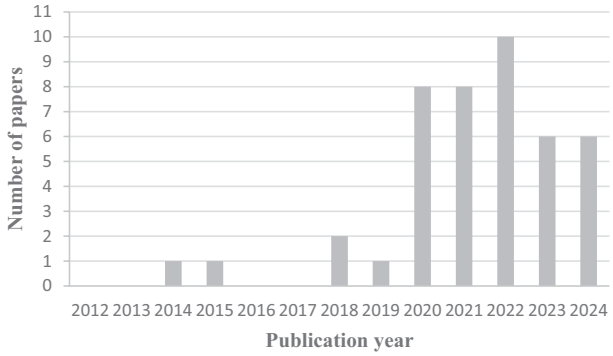



**Fig. 2** Trends in annual publications on innovation and blue economy

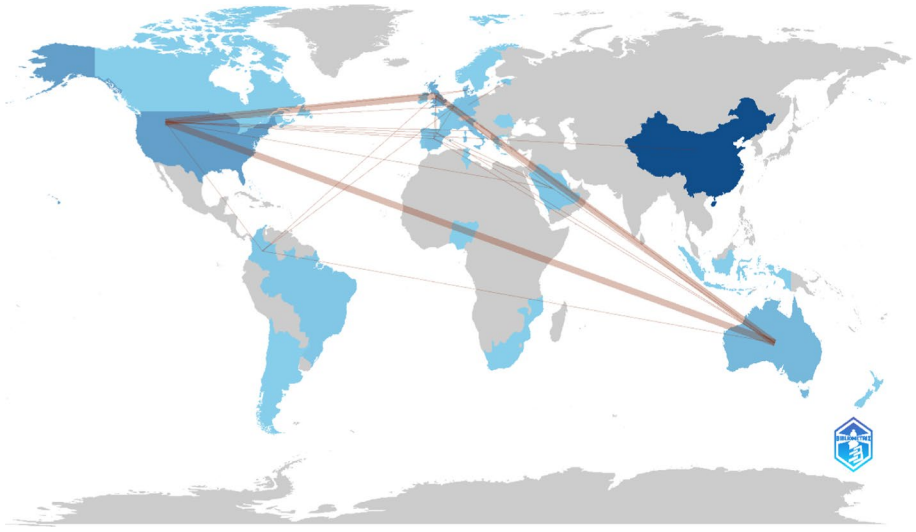


**Fig. 3** Scientific production and collaboration by country

Policy", "Journal of Coastal Research" and "Frontiers in Marine Science" have placed particular emphasis on this link.

#### *3.1.2 Geographic distributions and institutions*

The geographical dimension of the articles, reflected by countries scientific contribution, collaborations between countries, authors' affiliations, funding institutions, and case studies, shows a strong concentration and a predominant position of China, as illustrated in Fig. 3, where the intensity of the blue color corresponds to the volume of contributions, while the gray color signifies a lack of publications in the field. Notably, Western countries—specifically North America, Western Europe, and Oceania—are the primary contributors to the literature. The Middle Eastern country of Saudi Arabia also makes significant contributions, though Latin American and Caribbean nations contribute to a lesser extent. In contrast, there is a notable absence of contributions from African and Eastern European countries. In relation to collaborations between these countries, the Fig. 3 shows that while China has a higher volume of publications, the USA, Australia and the United Kingdom stand out for their leading role in academic cooperation. Through this academic network, these three clusters can enhance the sustainability of the blue economy by facilitating knowledge sharing, promoting technological

innovations, addressing common transboundary challenges, and supporting regional governance.

Studies on the blue economy-innovation nexus are mainly conducted by authors affiliated to the "Ocean University of China", the "University of Galaţi", and the "National Research Council of Italy" (Table 4). They are mainly funded by the National Social Science Foundation of China, a key promoter of innovative research and the advancement of socio-economic knowledge in China. Other funding comes from the EU through programs and institutions such as "INTERREG Atlantic Area", "Horizon 2020 research and innovation program", and the "European Commission". These latter recognize the importance of research and innovation in tackling the common challenges facing the region (such as job creation and sustainable, inclusive growth), and their contribution to current and future policies.

Nearly half of the articles focus on the provinces of China (46%), while 32% are devoted to regions in the North and Mediterranean countries (notably the EU countries), 12% cover the international arena, 5% concern countries in the South (specifically Brazil and Seychelles), and 5% refer to individual countries.

#### *3.1.3 Top influential authors*

A more detailed analysis using Vosviewer software was conducted to identify the most influential authors in our research domain. The analysis revealed three main authors, namely Hugo Pinto, Ana Rita Cruz, and Colin Combe. These authors are distinguished not only by their substantial citation count (62 within our database) but also by their central position in the citation network (Fig. 4), suggesting their structuring role and significant influence in the advancement of scientific work in this field.

Co-citation analysis of authors is further conducted to track pairs of authors who are cited together in a third research document. Specifically, this analysis offers valuable insights into the intellectual structure of a research field. The Fig. 5 illustrates the presence of six clusters of authors that are closely linked in the literature, either through collaboration, thematic similarity, or mutual influence. The leading authors in these clusters are L. Ktari (yellow cluster), C. Faggio (purple cluster), Y. Zhang (red cluster), S.A. Fedoreyev (light blue cluster), A. M. Cisneros Montemayor (green cluster), C. M. Duarte (blue cluster).

#### *3.1.4 Methodological approaches*

Concerning the methodology, the articles reviewed used a wide range of approaches, including quantitative (60.5%), qualitative (30.2%) and mixed methods (9.3%). Quantitative methods include questionnaires as well as econometric and mathematical models (such as the logit, panel data, VAR, PVAR, threshold effects model, gravity models, and grey forecasting models). The qualitative methods used include thematic and content

**Table 4** Top 5 affiliations of authors

| Top authors affiliations | Countries | Number of authors |
|---|---|---|
| Ocean University of China | China | 6 |
| University of Galaţi | Romania | 4 |
| National research council of Italy | Italy | 4 |
| The University of Queensland | Australia | 3 |
| Liverpool John Moores University | United Kingdom | 3 |

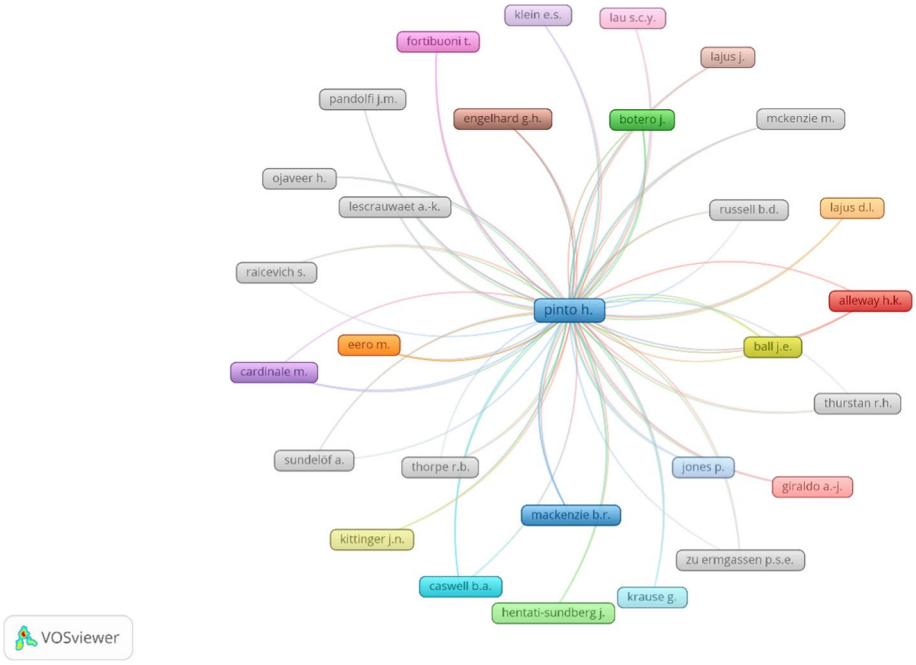



**Fig. 4** Authors' citation analysis

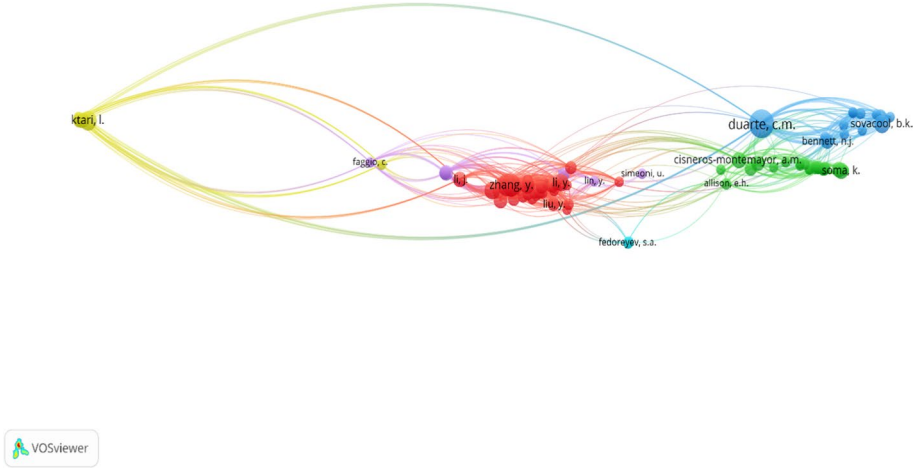



**Fig. 5** Co-citation analysis of authors

analysis, multi-case studies, and interviews. This diversity of methods reflects the complexity of this research subject, requiring the use of a variety of methods and, in some cases, their combination to provide a more comprehensive understanding and ensure the reliability of the results obtained.

#### *3.1.5 Conceptual structure and thematic evolution:*

In our analysis of the research areas explored, we examined the keywords used by the authors. Due to their synthetic nature, these keywords provide a clearer indication of the primary themes and concepts underlying our research focus. This analysis was conducted using Vosviewer software, with the results illustrated in Fig. 6. The size of the nodes represents the frequency of the keywords' occurrences, while the distances

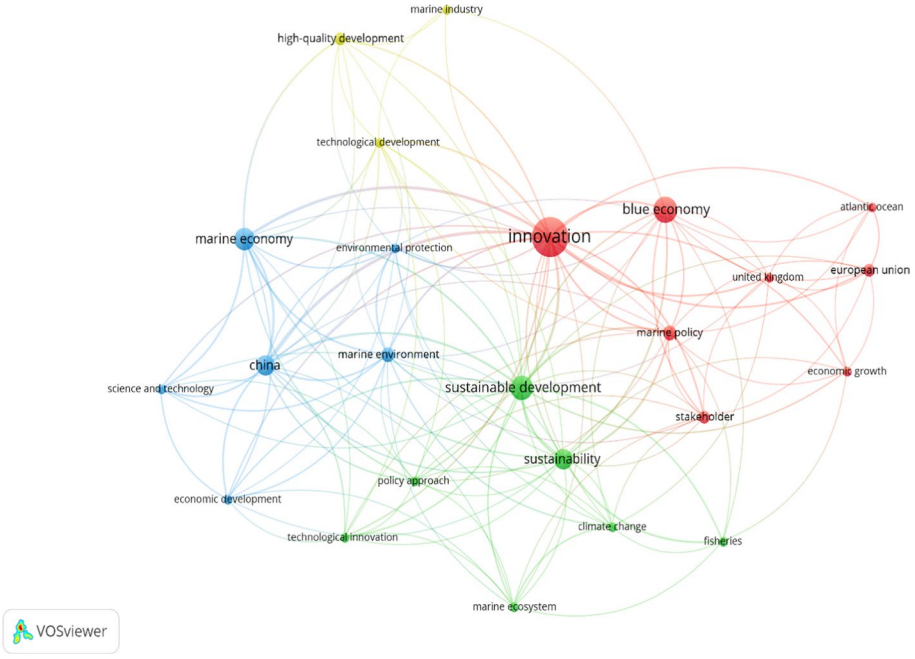



**Fig. 6** Keywords co-occurrence networks

between the nodes reflect the various interconnections among these terms. The figure reveals four distinct clusters: (1) Innovation, which emphasizes the interdependence between innovation and the blue economy, along with the positive outcomes (economic growth) and supportive measures (regulatory frameworks, stakeholders) to this relation; (2) sustainable development, which highlights the necessity for sustainability within marine ecosystems, achievable through well-managed and regulated fisheries, efforts to address climate change, a robust policy approach, and technological innovation; (3) marine economy, which underscores the need to balance economic development with the health of the marine environment, as well as the role of science and technological progress in achieving this equilibrium; and (4) technological development, which stresses the importance of high-quality development and marine technology in alleviating the pressures imposed by resource-intensive marine industries.

The thematic evolution map made by bibliometrix [21] (Fig. 7) illustrates the positioning of various themes based on their developmental status and influence within the research landscape. It underscores that sustainable development, sustainability, and climate change are pivotal themes shaping the literature. The blue economy and environmental legislation emerge as niche themes demonstrating a high degree of internal development. Innovation plays a critical role in advancing this research domain, shifting focus away from traditional fields like marine technology. Furthermore, the marine environment, environmental protection, and conservation management are also recognized as fundamental themes in the field.

### 3.2 Innovation in the blue economy: perspectives from academic literature

This section is dedicated to the thematic analysis of the retrieved articles. This analysis enabled the classification of the articles into six primary themes: maritime clusters, sustainable aquaculture, financing, stakeholder synergies, management systems,

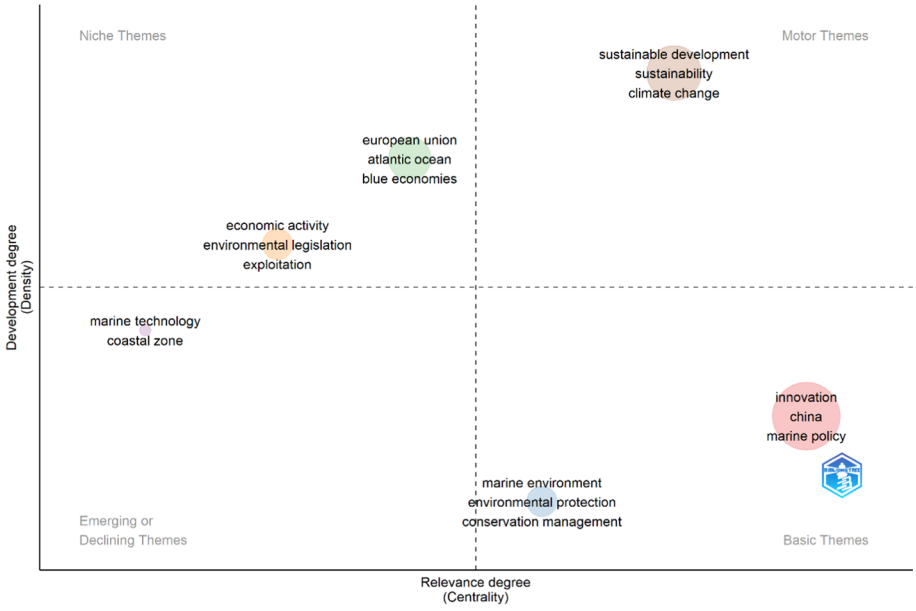



**Fig. 7** Thematic evolution map

high-quality marine economy, and economic policies. These themes primarily pertain to the areas of action through which innovation can enhance the sustainability of the blue economy.

### *3.2.1 Marine clusters*

The articles reviewed indicate that the relationship between innovation and clusters is bidirectional. Innovation not only stimulates the formation of clusters but also creates favorable conditions for further innovation. Pinto [22] argue that innovation can serve as a catalyst for clustering. The authors suppose that innovation capabilities develop through a cumulative learning process that is highly dependent on the surrounding environment. This can result in a concentration of innovation activities facilitated by effective tactical knowledge diffusion, along with a high absorption capacity and a concentration of knowledge-intensive economic activities. Empirical research conducted on several marine organizations operating in the Atlantic region demonstrated that participation in innovation activities enhances cooperation, with organizations possessing skilled human capital being more inclined to collaborate. Conversely, Zhang and Wang (2021) contend that marine industrial agglomeration promotes marine innovation primarily through the establishment of a knowledge resource hub, concentration of capital and talent, and collaboration among various stakeholders. These factors contribute to knowledge diffusion, scale, and learning effects, thereby creating the necessary conditions for marine innovation.

The interaction between innovation and clusters can yield various advantages, including enhanced industry performance, improved access to specialized labor, the promotion of blue growth, efficient innovation [22, 23], and the facilitation of regional development by acting as a smaller-scale innovation system [24]. However, these effects do not occur systematically and may necessitate supporting measures, such as government assistance, better resource allocation in the marine industry, and improved management of marine

services. These measures play a key role in strengthening spatial spillover effects and enhancing the efficiency of marine science and technology innovation [25, 26].

#### *3.2.2 Sustainable aquaculture*

This subsection examines innovative approaches in aquaculture that align economic development with environmental preservation, following blue and circular economy principles. In this context, Corbau [27] highlighted a major issue in shellfish farming, namely: shell waste. They proposed using 3D printing technology to recycle these shells into artificial bio-reefs. This use of shell waste helps enhance coastal ecosystem resilience and reduces the environmental impacts of aquaculture practices.

Rubilar and Cardozo [28] considered open innovation as a critical factor for the success of sustainable aquaculture projects. These authors cited two projects that effectively transformed challenges into opportunities through innovation. The first, URCHINOMICS, turned an environmental challenge into a commercial, ecological, and social opportunity by harvesting sea urchins to mitigate the over-consumption of kelp and produce high-quality eggs in land-based facilities. The preservation of seaweed is of considerable importance due to its effectiveness in carbon sequestration; thus, aquaculture is considered as an innovative solution for managing blue carbon and marine ecosystems, as highlighted by Sovacool et al., [29]. The second project, ARBACIA, has developed biologically active products from sea urchin eggs, contributing to human health while generating sustainable commercial, environmental, and social benefits.

Another form of innovation is illustrated by Ktari et al. [30], namely the Integrated Multi-Trophic Aquaulture (IMTA), which involves the simultaneous cultivation of species from multiple trophic levels, such as algae and mollusks, so that the waste produced by one species becomes nutrients for another. This technique improves water quality by allowing algae to absorb excess nutrients from the mollusks, thereby reducing the environmental impact of traditional aquaculture, while simultaneously increasing productivity. Innovation in aquaculture is thus recognized as a key factor in market competitiveness and the promotion of sustainable development, as emphasized by da Silva et al. [31]. Their research indicates that frugal innovation serves as a significant lever for sustainable development in aquaculture, contributing to the empowerment of small-scale producers while promoting sustainable economic models adapted to local needs.

#### *3.2.3 Financing methods*

The reviewed articles indicate that the current financing mechanisms in the marine sector encompass public funding, bilateral and multilateral development aid, and green bonds, which were originally designed for renewable energy and energy efficiency initiatives. Additional funding sources include philanthropic grants, public–private partnerships, biodiversity offsets and credits, banking credits, and restoration of natural capital credits [32, 33].

Despite their diversity, current investments are insufficient to achieve the goal of the aquatic life-related SDG 14, which aims to conserve and sustainably use the oceans, seas, and marine resources [32]. Although there is a causal relationship and correlation between the total amount of marine financing and the economic growth of related industries, the economic impacts of the loans granted are only perceptible in the long term [34]. Transforming existing investments into a sustainable financing mechanism

requires a framework that accounts for long-term changes to ensure better management of economic transitions [32]. Furthermore, to address the current lack of investment, some authors [32] suggest diversifying funding by mobilizing funds from a variety of sources, encouraging the involvement of private investors and establishing a centralized platform. The involvement of both public and private actors helps increase investment and promote innovation in the maritime sector.

Indeed, public financial support mechanisms, such as subsidies and tax exemptions seem to work more effectively in favor of innovation [35], compared to the private sector [36]. However, the role of the private sector is more apparent in the investment in research and development (R&D), which contributes positively to the innovation process. It would therefore be necessary to develop an optimal structuring of financial products designed for this sector to respond to the particularities of a capital-intensive sector [34], especially as the current impact of private investment remains limited due to its low weight in the overall financing structure [36].

New financing modes like Blue Bonds are being proposed to address these constraints, particularly in vulnerable island economies such as Seychelles. With World Bank support, this financing mode helped restructure the fisheries sector and promote environmental sustainability in this country. However, although encouraging, it has revealed tensions between economic growth priorities and local sustainability and food security objectives. Additionally, the eligibility conditions for these loans seem to favor large companies over artisanal fishermen who need financial resources to modernize their activities.

To address these challenges, integrated financing mechanisms, such as the ocean financing facility, as well as concessional credits and guarantee mechanisms can be considered. Diversifying financing sources, including philanthropic funds and impact investors, is a promising approach to meet the specific needs of vulnerable island economies [32, 37]. While these mechanisms are financially effective, they remain complex and must balance economic imperatives, sustainability, and food security.

#### *3.2.4 Stakeholders*

The selected articles highlight the diverse stakeholders involved in the sustainability of the blue economy through their skills, and practices. The blue economy requires the involvement of a range of stakeholders to address issues along the value chain, such as increasing demand, consumer preferences, and geographical specificities, as well as fostering innovation and maintaining quality and sustainability requirements [38]. These factors are determining in the evolution of the blue economy and highlight emphasize the need for highly qualified human resources [39].

Human resources are essential for creating material wealth, a prerequisite for developing blue economy sectors. This involves not only the quantity but also the quality, structure, spatial distribution, and flow of human resources. A well-structured workforce can generate economic effects, such as economies of scale, structural efficiency, vitality, and overall economic efficiency [40]. The articles in this review emphasize regional and national differences in priorities and challenges related to human resources and innovation within the blue economy framework.

In China, the supply of marine talent is constrained by a declining working-age population, barriers to labor mobility, an unbalanced spatial distribution, and an excess of

unskilled workers [39, 40]. However, China's coastal marine industry is gradually transforming and modernizing, necessitating high-quality talent to balance innovation, economic growth, and environmental protection. While the economy and environment often conflict, innovation is a key strategy for creating shared benefits [41].

In Europe, a skills gap exists in the marine industry of Ireland, Portugal, Scotland, and Spain, particularly in specialized management, finance, marketing, and product innovation skills. This industry struggles to attract talent with advanced degrees such as PhDs or MScs. High costs and unstable economic conditions also limit innovation capacity in these regions [38] In the UK, challenges primarily involve collaboration between universities and industry, hindered by lack of mutual preparation, bureaucratic difficulties, cultural differences, and intellectual property issues, despite the importance of this partnership for training, applied research, and innovation cluster development. Inappropriate policies for SMEs, limited coordination, and low visibility of funding opportunities exacerbate these challenges [7].

In the United States, capitalist markets and technological innovation reinforce racial hierarchies by consolidating economic power among predominantly white owners, diminishing the perceived importance of black workers. These workers encounter poor working conditions, low wages, and institutional racial disparities [42]. Meanwhile, the European Union emphasizes technological innovation for sustainable marine resource management but overlooks social and institutional factors, raising concerns about the approach's long-term viability [43].

The authors recommend several measures to address these challenges, including stakeholder collaboration, regulatory easing, administrative simplification, increased access to financing, and enhanced mobility and international cooperation to meet regional needs [39, 40, 44, 45]. Pinto et al. [38] further suggest developing professional skills through strategic collaborations with training organizations to meet management, finance and marketing needs. In parallel, the integration of advanced technologies is proving important to supporting the industrial transformation of the maritime sector and protecting maritime rights on the international stage [35, 39–41]. Finally, the integration of ecological and social justice principles appears essential to ensure sustainable economic growth in marine environments [42, 43].

#### *3.2.5 Management system*

This subsection is devoted to the case of China and the measures that the government could implement to address the pressures on the marine ecosystem resulting from human activities. Based on the papers retrieved, the marine economy of China faces numerous challenges related to extensive resource use, loss or destruction of the marine ecosystem, inadequate ecological protection, coupled with a management system marked by conflicts and coordination difficulties among the different agencies, the multiplicity of management departments, incipient environmental regulation, and the lack of a systematic and comprehensive marine management mechanism [46–48].

This situation reinforces the need for the government to reform and innovate their management system in order to harmoniously guide the development of the marine economy, improve the country's competitiveness, and sustainably develop the marine industry, perceived as an engine of economic growth [46]. The marine ecosystem is thus perceived as a public good, which once destroyed requires a compensation mechanism,

such as institutional innovation [49]. In this perspective, Ren and Ji [47] used the Pressure-State-Response conceptual model to reflect the cause-and-effect relationship between human activities, resources and the environment. Pressure refers to external disturbances to the ecosystem caused by human activities, state refers to the current situation of the ecosystem, and response refers to compensatory mechanisms and countermeasures to changes in the state of the system, such as the implementation of environmental regulation policies by governments.

To overcome the various challenges faced by China, the authors [46, 49] suggest taking measures to establish a marine management framework relevant to national conditions. Their recommendations include: (i) eliminating ambiguities and clarifying the functions of marine management bodies by well-defined roles, (ii) establishing a comprehensive legal system for marine management to ensure better law enforcement and maritime interests safeguarding, and (iii) developing a monitoring mechanism for decision-making in the field of marine economy. These need to be combined with measures like strengthening financial investment and rational allocation of marine resources to support the gradual introduction of integrated, unified, and coordinated ocean management, at national and regional levels.

#### *3.2.6 High-quality marine economy*

The concept of high-quality development was initiated in China in response to the rapid growth of marine economic activities, generated by traditional resource-intensive industries and a source of major regional disparities. This concept is an adaptation of sustainable development goals to China's current situation, enabling a shift from quantity accumulation to quality accumulation, by considering marine scientific and technological innovation as a driving force [50–52].

The various studies included in our review emphasized the mediating effects, mechanisms and factors affecting the degree of influence of innovation on high-quality development. These mechanisms can be either direct or indirect. Innovation has a straightforward effect on high-quality development, primarily through research. Wu et al., (2020) [53] focus on three categories of research -basic, application, and marine exploitation research- that encompass the complete operational process of creating, developing, diffusing, and applying science and technology in marine technological activities. Their empirical findings reveal that there is a long-term steady and balanced relationship between marine technology innovation and high-quality marine economic development. The primary driving forces behind this relation are mainly research in marine application, followed by research in marine exploitation; basic research has no significant effect. This does not reduce its importance but shows that little investment is being made in marine technological innovation.

Other indirect mediating effects were identified by Feng et al. [54] by assuming that this relation can be established through: (1) green total factor productivity (by means of increased efficiency or intelligent substitution of production factors), or (2) industrial structure optimization (via industrial structure upgrading, or new sectors creation). The results of their empirical analysis applied to 11 coastal provinces confirm that these two factors can independently lead to high-quality development or through the effect of total factor productivity on industrial structure optimization.

Alongside these findings, other authors have focused on potential regional differences in the extent to which innovation influence the development of the marine economy. Many studies [55–57] revealed that these disparities may arise from differences in the level of development or technological progress that act as a strong siphoning effect, absorbing resources and talents, and creating relationships of dependency between regions. Other factors such as the degree of openness to the outside of the world, government investment, and financial development were also identified as disparity generators. The authors state that these disparities need to be considered in the design of policies or strategies aimed at improving the coordination between innovation and the development of the marine economy. More coordinated approach is needed to ensure that all regions benefit equally from technological advances.

#### *3.2.7 Policies and agenda setting*

As the blue economy develops further, innovation is a key driver for ensuring its sustainability and exploring alternative futures for its various sectors. According to Caswell et al. [58], the trajectory that the blue economy can take depends both on the ability to balance economic growth, social equity and ecological sustainability, and on other factors, such as innovation. Accordingly, a number of studies have been conducted to anticipate future innovations, predict trends, or develop scenarios that may shape the future of the blue economy.

In this perspective, Pace et al. [59] performed a prospecting analysis to map the trends influencing the blue economy by 2030. These trends are mainly based on technological and biotechnological advances, leading to the emergence of scenarios, such as the development of eco-communities as vectors of social innovation, the digitization of services and the spread of blue biotechnology 3.0. Spaniol and Hansen [60] further highlighted the trend towards ocean electrification, such as recharging at wind farms, fish farms and offshore container terminals that help foster successful transition to a sustainable blue economy and achieve zero-emissions targets.

In a more thorough analysis, Spaniol and Rowland [61] identified the innovations that are anticipated to have an impact on five sectors of the blue economy (including (1) shipping and maritime operations, (2) shipbuilding, maintenance and repair, (3) ports and cargo handling, (4) offshore wind energy, and (5) ocean infrastructure and harvesting), and their expected time of implementation. The results of their analysis highlight 63 innovations that can be grouped as follows: (1) underwater drones and robots used for inspection, rescuing, maintenance and repair of subsea installations, (2) data and AI-based systems designed to ship performance monitoring, and data sharing between companies, or even pollution management as formerly highlighted by Simionov et al. [62], (3) sustainable and alternative fuels, such as renewable Methanol for deep-sea vessels, and wave energy to power aquaculture farms, (4) innovations in ship and infrastructure design, such as foldable containers for efficient transport, or composite materials for underwater vessel repairs, and finally (5) innovations in ports and logistics, including micro-grids integrated into major ports or offshore container terminals powered by renewable energies. In terms of time horizon, 24% of innovations are expected to be implemented in the short term (before 2025), 54% in the medium term (between 2025 and 2030), and 22% in the long term. In terms of sectors, innovations in shipbuilding,

maintenance and repair are likely to materialize more quickly (in the medium term) than those in the shipping sector (expected by 2050).

The importance of these forecasts and trends lies in the various lessons they provide for public decision makers, industrial companies and researchers in their efforts to establish a sustainable blue economy. For decision makers, these forecasts can serve as a roadmap for defining an innovation policy or industrialization strategy. For companies, these predictions can be used to assess the commercial viability of projects in an innovation portfolio, monitor incoming innovations in their transactional environments or adjust internal strategy. For researchers, the results can be reproduced in other sectors or regions [61].

Although optimistic, these various innovations and scenarios are not devoid of challenges [59, 63], notably: conflicts of interest between nations and between established and emerging sectors, geopolitical and economic tensions (such as cybersecurity threats, trade protectionism), insufficient information exchange between scientists, industries and policymakers, and fragmentation and gaps in interdisciplinary knowledge. These challenges can be balanced by social innovations that can promote the acceptance of new biological technologies by society, and the engagement of various stakeholders to foster communication between disciplines and the mutual exchange of perspectives [64].

## 4 Discussion

This study provides the first comprehensive review of the scientific literature on the relationship between innovation and the blue economy. This review revealed that the role of innovation within the blue economy context lies in its ability to mitigate the impact of human activity on marine resources, to decouple blue growth from the overexploitation of resources, and in the progress of the various blue economy sectors, both established and emerging.

Our findings reveal that this relationship is complex and multifaceted. Consequently, several authors have employed mediating factors to clarify this connection. Specifically, these factors include green technology, green total factor productivity, high-quality talent, research, sustainable financing modes, and optimized industry structure. Complementary support factors are also identified to assist these mechanisms, as illustrated in Fig. 8.

The multidimensional nature of this relationship further underscores the diversity of the levers of action necessary to maximize the positive impacts of innovation on the blue economy. This interdisciplinary approach has also been highlighted by Liang et al. [9], whose bibliometric analysis reveals the diversity of blue economy research themes. Their findings indicate that, in recent years, the blue economy has strengthened its cross-disciplinary integration with other disciplines, benefiting from advances in science and technology.

These connections with other disciplines create fertile ground for innovation, which benefits the blue economy in several ways. On the economic level, innovation contributes to high-quality development, a sustainable marine industry, regional development, disparity reduction, and blue growth. On the environmental level, innovation enhances the sustainability of marine ecosystem and aquaculture. On the social level, it helps ensure social equity, racial integration and inclusive working conditions. These dynamics

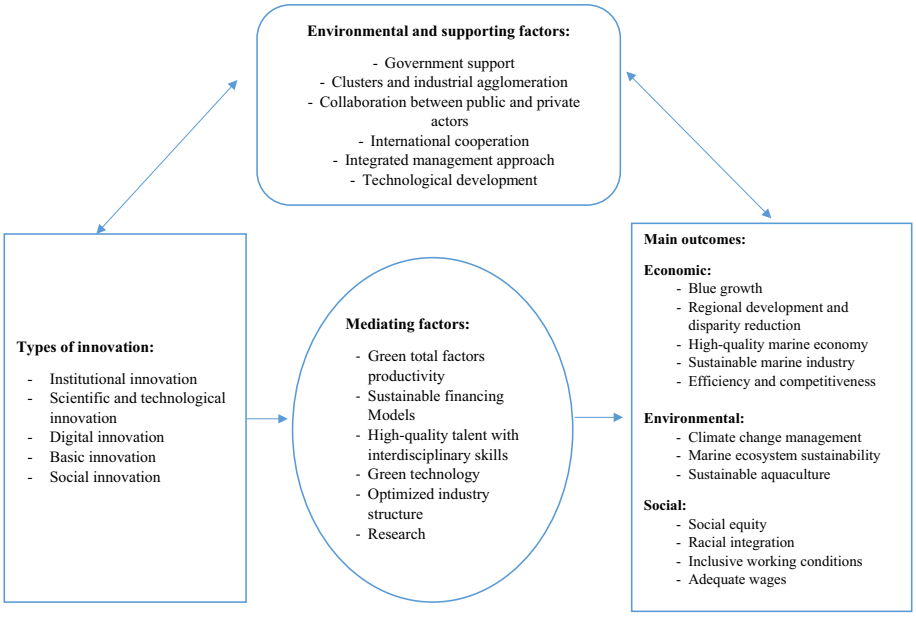



**Fig. 8** Key mechanisms linking innovation to blue economy sustainability

foster a virtuous cycle in which innovation and the blue economy mutually reinforce one another, thereby advancing progress toward sustainable development goals.

Several types of innovation within the blue economy framework have been identified, including disruptive innovation (biotechnology, sustainable aquaculture, marine renewable energy), radical innovation (drones, robots, and artificial intelligence), and frugal innovation in aquaculture. These innovations have demonstrated their effectiveness in reconciling economic development and environmental preservation, transforming environmental challenges into sustainable economic, ecological, and social opportunities. However, comparing to the existing literature, the articles reviewed lacks some emerging technological innovations, such as IoT-based technologies (Internet of Things) that help mitigate negative human impacts on the ocean environment[65], Digital Twin (DT) technology that enhances risk management and promotes sustainable practices [66], and virtual and augmented reality that support training, learning, and skills development [67].

Overall, our review revealed that innovation acts as a driving force for a sustainable blue economy, yet several challenges hinder its full exploitation, notably market dynamics and capacity gaps, such as a shortage of human capital and skills, inadequate information exchange among stakeholders, societal resistance to new technologies, conflicts of interest between nations and between established and emerging sectors, and geopolitical and economic tensions (like cybersecurity threats, trade protectionism). In this sense, a more inclusive and participatory approach, involving governments, businesses, local communities, and scientists, could mitigate these challenges and maximize the impact of innovation on the sustainability of the blue economy.

Thus, our study brings novel insights and shows that the scholarly literature broadly agrees on the critical role of innovation in advancing a sustainable blue economy. However, this relationship is not straightforward, as it depends on various contextual factors. Nonetheless, existing studies exhibit certain limitations, as they rarely address the potential risks associated with these innovations and the emerging sub-sectors of the

blue economy. While these advancements can yield positive outcomes, they may also lead to unforeseen negative consequences. Therefore, it is imperative to gain a deeper understanding of these dynamics to effectively address the challenges and fully capitalize on the opportunities presented by these new developments.

## 5 Limitations and future research

The analysis of these publications has allowed for the identification of several gaps that may lead to new research perspectives. First, the analysis revealed a notable geographical disparity in the level of contribution and influence, with the prevalence of China in the contributions reflected both in the authors' affiliations, and in the funding organizations and case studies. This result corroborates with that of [68], who showed China's active role and influence in the field of blue economy research, outperforming other countries in both publication volume and citation frequency. Our results also show that Western countries, notably the European Union and the United States, come in second position, while African and Eastern European countries are underrepresented and receive little scientific attention. The scarcity of studies calls for increased participation from these countries to incorporate a diverse range of perspectives and to gain a deeper understanding of the specific characteristics that define them. Research findings from Western countries can serve as a starting point for discussion and debate in the underrepresented countries or can be used for comparative purposes.

Second, beyond the USA, Australia, and the United Kingdom, academic collaborations remain weak. Strengthening cooperation between countries is of primary importance to foster the sharing of knowledge, innovative practices, sustainability initiatives, and the development of solutions adapted to local realities, as stated by Vazquez-Brust et al. [69].

Third, our study has enabled the identification of various types of innovation, including institutional, scientific and technological, financial, and digital innovation. However, some innovations remain either unexplored or underexplored. Specifically, circular economy innovation, which offers new ways of generating economic value from ocean resources, has been addressed in only one study within the aquaculture industry. Another area lacking exploration is innovation in spatial planning, particularly data-driven spatial planning, which enables real-time monitoring and adaptive management for improved decision-making and optimized resource allocation, even though data and AI-based systems are featured among the innovations anticipated in the near future. Additionally, one aspect of social innovation that has not received attention is the innovation of behavioral and social norms. This area is essential for transforming industries, governance, and public participation in the blue economy by reshaping attitudes, behaviors, and cultural expectations within communities, thereby promoting more sustainable interactions between humans and marine resources.

Fourth, at the sectoral level, few studies have been devoted to certain sectors. Among the established sectors, small-scale fisheries, logistics, and transport remain insufficiently studied. Likewise, emerging sectors like marine biotechnologies, marine renewable energies, marine waste management, as well as ecotourism, deserve greater attention to fill the gaps in the literature and to better understand the characteristics and specificities of innovations in these sectors. This finding corroborates the conclusions of Martínez-Vázquez et al. [70], who identify several of these sectors as promising areas for future research.

Fifth, the results of our study are highly associated with the restrictions, or inclusion criteria defined at the beginning of the study regarding language, type of publications, or the database. These restrictions may affect the completeness of the results obtained. These limitations are inherent to the method adopted. The keywords used in our research may not be exhaustive, leading to the omission of some relevant works. In addition, the scope of our study is limited by the exclusion of publications published in languages other than English, which may result in the exclusion of research conducted in nations where English is not the primary language. Additionally, the restriction of our investigation to the Scopus database, although rigorous, may reduce the scope of the results obtained. It would be relevant for future work to explore a diversity of sources. These limitations do not undermine the overall significance of our results, which remain relevant for understanding the complexities of the innovation and blue economy nexus and advancing knowledge in this field.

## 6 Conclusion

This study closely examines a growing research topic, namely the relationship between innovation and the blue economy, by conducting a rigorous, in-depth literature review of the scientific papers published during the period 2012–2024. This review shows that attention and interest in this relationship have emerged relatively recently, beginning in 2019, mainly in response to challenges related to climate change, overexploitation of marine resources, as well as the growing commitment to sustainable development goals.

Our results extend our understanding of how innovation can affect sustainable development by identifying key mediating factors and supporting elements that underpin this relationship. These factors primarily include sustainable financing modes, green technology, green total factor productivity, research, and high-quality talent. To optimize their potential effects, these factors can essentially be supported by government support, stakeholder collaboration, and international cooperation. This relational framework provides significant economic, social, and environmental benefits, contributing to the advancement of a sustainable blue economy and progress toward achieving sustainable development goals.

Our results revealed that the blue economy-innovation nexus is addressed in the literature through various lenses encompassing not only economic, social, and environmental dimensions but also institutional, technological, financial and spatial dimensions which reflect both the diversity of the levers of action necessary to maximize the positive impacts of innovation on the blue economy, and the challenges to overcome.

This study provides significant actionable and policy implications. For governments, our research emphasizes the necessity of adopting a comprehensive legal framework for marine management, developing a data-driven monitoring mechanism to support decision-making, and implementing an integrated, unified, and coordinated management approach at both national and regional levels. For industries, industrial agglomeration and clusters, as well as promoting collaboration among various stakeholders, are highly recommended to advance marine innovation and create the necessary conditions for its development. For researchers, in addition to identifying future research directions, our study underscores the importance of enhancing academic collaborations among authors and institutions within Northern countries and between the North and the South. Such

collaborations will facilitate the sharing of experiences, knowledge, and expertise, as well as innovative practices, thereby enhancing efforts to address global challenges.

Future research perspectives should explore emerging technological innovations, such as IoT-based technologies (Internet of Things) and Digital Twin (DT) technology. In addition, it is essential to fill the geographical gaps currently observed in the literature, by devoting more attention to underrepresented regions (Africa and Eastern Europe), whose specific dynamics could enrich the overall understanding of the link between innovation and the sustainable blue economy.

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## Declarations

**Ethics approval and consent to participate**
Not applicable.

**Consent to publish**
All authors agree to publish the article.

**Competing interests**
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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