Received: 21 October 2025 | Revised: 2 February 2026 | Accepted: 5 March 2026 | Published online: 18 March 2026

REVIEW

FinTech and Sustainable Innovation
2026, Vol. 00(00) 1–12
DOI: 10.47852/bonviewFSI62027953

Blue Finance: Financial Innovation for Sustainable Oceans

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Abstract: We review the literature on blue finance to develop a conceptual framework. We include peer-reviewed studies and selected policy reports in our analysis. These aid in the mapping of instruments, governance mechanisms, and financial technology (fintech)-enabled monitoring. This nascent topic links capital raising and allocation to the use of ocean resources. It is aligned with United Nations Sustainable Development Goal 14 (conserving and sustainably using oceans, seas, and marine resources). Through the literature, we examine blue bonds, debt-for-nature swaps, and blended finance. We assess how the literature links risk and return to impact credibility. We illustrate how fintech supports monitoring, verification, and disclosure. Our PRISMA analysis identifies substantive research on governance, particularly in the areas of marine protected financing, coastal resilience, and regulatory frameworks. These concepts ensure credible measurement and reduce information asymmetry. In this context, we discuss how digital finance mechanisms, including blockchain verification and blue carbon markets, can enhance transparency and traceability. We argue that blue finance can shift investor preferences and reduce the risk of "blue-washing," the equivalent of greenwashing.

Keywords: blue finance, green finance, blue bonds, ocean conservation, SDG 14

1. Introduction

Blue finance refers to the "*mobilization of capital for the sustainable economic use of ocean resources*." It is an increasingly recognized mechanism for aligning ocean-based economic activity with marine conservation and sustainable development. We review the literature on it to gain insights that allow us to develop a conceptual framework. In markets, the concept is used to adapt established financial instruments to ocean contexts. In this way, it complements measurable environmental goals and targets. Its proponents use financial technology (fintech) for monitoring, verification, and disclosure. These manifest themselves through data richness and sensor-enabled reporting that both improve traceability and auditability of outcomes. Application areas include fisheries, coastal infrastructure, conservation, and marine biodiversity. The concept sits within the policy architecture of the United Nations Sustainable Development Goal 14, Life Below Water (SDG 14). It is often positioned as a complement to green finance, which channels capital toward improved environmental outcomes. The difference between the two related terms is that blue finance prioritizes ocean systems and marine-dependent communities. Green finance is more focused on the land-based ecological footprint. Thompson [1] argues that the link is additive rather than substitutive, since blue instruments follow the logic of green markets while responding to ocean-specific risks and externalities.

Implementing blue finance requires practitioners to use a growing set of fintech digital tools [2]. These include blockchain verification, automated environmental impact tracking, and AI-driven monitoring platforms. There are clear linkages to finance. Instruments such as sovereign and corporate blue bonds combine conventional debt finance with measurable marine outcomes. Similarly, debt-for-nature swaps and blended public–private structures are used to mobilize capital (Tirumala & Tiwari [3] and [4]. These typically incorporate digital verification of fund flows and tokenized impact credits. This in turn can be aided by real-time monitoring of marine projects through satellite or ocean-based surveillance. Such digital enhancements facilitate transparent reporting and automation of compliance to set targets. In this way, blue finance links financing to sustainability criteria. At the same time, it helps improve traceability. Examining these elements is integral to our literature review. Their technical aspects and adoption influence both the effectiveness of blue finance and the evidence base for its effectiveness.

While ecological concerns, economics, and financial intermediation provide the conceptual core, blue finance also depends on standard cash-flow drivers [5]. In this respect, risk–return expectations shape the pricing of blue bonds, financial instruments, and project balance sheet construction. It is also still rooted in the cost of capital and the viability of projects (Bayraktarov et al. [6]). That said, capital structure decisions influence whether funding is raised through sovereign guarantees, concessionary tranches, or private debt and equity. Each has a different implication for leverage and investor risk. The literature suggests that these are in turn impacted by sustainability preferences and the signaling given by the ecosystem at large.

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The adoption of blue finance faces challenges. The issues resemble those encountered by green finance in its early development. Rogge [5] identified these as the definition of sustainable objectives, the identification of key performance indicators, the reliability of reporting, and the difficulty in verification. Broby and Yang [7] explore these issues and argue that fintech can help with the latter. In this respect, fintech provides the tools for its monitoring (Sharma et al. [8]).

Despite its obvious sustainability credentials, the academic understanding of blue finance remains fragmented [9]. The term "blue" in the name stems from the blue economy. One definition of the latter focuses on ocean-based financing activities in "*meeting the twin goals of protecting our oceans and coasts and enhancing its potential contribution to sustainable development*" (Partnerships in Environmental Management for the Seas of East Asia). Another definition incorporates inland water activities. This element is seen as "*an integrated, holistic, cross-sectoral, and cross stakeholder approach that creates value-added and value-chain of resources from oceans, seas, and fresh water in inclusive and sustainable way*" (Association of Southeast Asian Nations & Economic Research, Blue Economy Framework).

Much of the focus of scholars has been on ocean-based activities. This is typically descriptive and is largely comprised of case studies. These include cases on initiatives such as the Seychelles sovereign blue bond and the BDO Unibank Blue Bond in the Philippines [10]. Another is the debt-for-nature swap deal of Belize. This instrument uses both use-of-proceeds bonds and sustainability-linked loans. Fontana-Raina and Grund [11] detail its characteristics. In this respect, the bond incorporates covenants linked to the failure to achieve an agreed conservation milestone by a set timeline. This then triggers repayment changes and an increase of the annual payment of USD1.25 million per year for the first missed milestone, and an additional USD250,000 for each additional missed milestone.

We found that only a few studies adopt robust empirical approaches. These tend to evaluate financial performance and ecological outcomes [12, 13]. We suggest this is largely due to the infancy of the field. We propose that this offers researchers a potential area for future research. Accordingly, this review has three objectives: (i) to define blue finance and distinguish it from adjacent sustainable finance labels; (ii) to synthesize the academic and policy literatures on instruments, governance, and monitoring; and (iii) to identify a future research agenda for ocean finance, with particular attention to fintech applications.

In summary, our review of the blue finance literature covers its foundations, instruments, governance, and empirical findings. We show how scholars have used these to assess the topic and how its application is used to support sustainable ocean initiatives. We evaluate papers from finance, marine policy, and technological innovation journals and use these to identify research gaps and inform future policy design.

2. Methodology

We apply a systematic approach. We designed and reported in accordance with the updated PRISMA 2020 guidance for systematic reviews (Page et al. [14]). Our objective is to capture the conceptual scope of blue finance, the financial instruments used, and the associated policy frameworks. We also follow the protocol recommended by Tranfield et al. [15]. As a result, our search was designed to ensure transparency and comprehensive coverage. As part of this, we defined three categories of terms.

The first of the term categories captured the core concept, especially the search term *blue finance*. Other key terms such as *blue economy finance, ocean economy finance, marine finance*, and *ocean sustainable finance* were used. These anchored our output around the central theme of financing sustainable ocean and coastal activities. These ensured that we incorporated studies, such as Zhu et al. [16], which have a general focus on financial mechanisms.

The second category targeted financial instruments and mechanisms (Tirumala & Tiwari [3]). The terms we included in this batch were *blue bond, debt-for-nature swap, sustainable fisheries investment, marine ecosystem service payment, ocean carbon credit, blue carbon market*, and *blended finance* (used in combination with *marine* or *ocean*). This category was an important addition because much of the blue finance literature is structured around specific tools rather than the broader concept. Including these terms enabled the identification of empirical and theoretical work on the design and effectiveness of these instruments. This is important because without it, there is the risk of blue-washing.

The third area of focus was on policy, governance, and cross-cutting themes. This category was a catch-all. Key phrases included *Sustainable Development Goal 14, UN Ocean Decade AND finance, marine conservation finance, coastal resilience investment, financial regulation AND blue economy, and combinations such as impact investing AND ocean or marine, ESG AND blue economy, and fintech AND blue finance.* This last focus area captured regulatory frameworks, digital financial innovations, and sustainability practices (Virto [17]). These aspects reflect the day-to-day nature of implementation and deployment.

2.1. Search results

Our searches were conducted initially in Google Scholar. However, to mitigate selection bias associated with relevance-ranked paging, Web of Science, Scopus, and EconLit were treated as the primary source. As per [18], this ensured the retrieval of records that addressed the overall concept. Peer-reviewed journal articles were given priority, although key policy reports were included and, where relevant, mentioned in the text.

Records were exported from each database, deduplicated, and screened at the title and abstract level before full-text assessment. Importantly, screening decisions were taken against the eligibility criteria, and reasons for full-text exclusions were recorded. The final corpus comprised 50 studies. Figure 1 summarizes the identification of the relevant papers (n = 910), deduplication (n = 650), screening (n = 650), full-text assessment (n = 120), and included studies (n = 50) in a PRISMA flow diagram.

The initial searches were undertaken through July 2025. The aim of this was to ensure a broad capture of both peer-reviewed journal articles and highly cited working papers. The search strings followed the three-category structure outlined earlier. To maximize recall, as per Moher et al. [19], each keyword was searched both as a standalone term and within the title, abstract, and citations. This was done to ensure that any article mentioning the concept, even indirectly, could be retrieved.

The scale of literature captured is illustrated in Table 1. We emphasize this illustrates unrefined search results and represents a snapshot in time as of September 2025. For example, the

Figure 1
PRISMA flow diagram for study identification, screening, eligibility assessment, and inclusion

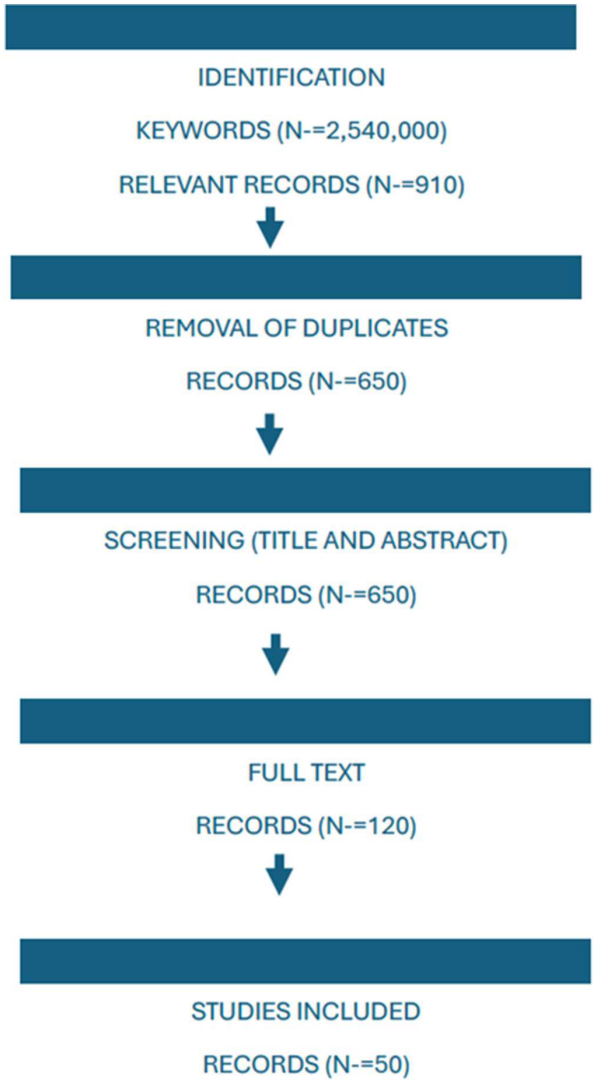


Table 1
Key instruments and mechanisms in blue finance

Keyword	Approx. results
Blue finance	2,540,000
Blue economy finance	1,090,000
Marine finance	1,240,000
Coastal finance	1,430,000
Ocean sustainable finance	395,000
Marine sustainable finance	451,000
Blue bond	5,990,000
Ocean bond	1,450,000
Debt-for-nature swap	7,540
Marine debt conversion	78,900
Sustainable fisheries investment	902,000
Marine ecosystem service payment	89,200
Ocean carbon credit	238,000
Blue carbon market	872,000
Blended finance marine	35,400
Blended finance ocean	42,300
Sustainable Development Goal 14	4,350,000
SDG14 finance	15,200
UN Ocean Decade finance	284,000
Marine conservation finance	363,000
Marine protected area finance	331,000
Coastal resilience investment	372,000
Ocean climate adaptation finance	163,000
Public–private partnership marine	279,000
Public–private partnership ocean	315,000
Financial regulation blue economy	589,000
Financial regulation marine economy	597,000

Note: (unrefined search results, accessed in September 2025).

search for the key term blue finance returned approximately 2,540,000 results. This contrasts with more specific terms, such as debt-for-nature swap, which yielded just 7540 results. These figures reflect the relative maturity and diffusion of different subtopics. Table 1 summarizes the number of papers in which all the key terms used appeared at least once.

In view of the large count, to achieve a manageable review set, the results were sorted by relevance and citations. The results for each "studies included" keyword were screened using cite count to identify the main scholarly papers and to reduce the corpus to a meaningful number. The Google ExCITATION add-in was used to rank the papers by SJR.[1] This combination emphasizes transparency and a balance between breadth, quality, and depth. Full texts of the relevant studies, including those cited in this review, were then examined. In total, this represented about 50 of the total count.

The unrefined search volumes reveal interesting patterns. Terms directly linked to market instruments, such as *blue bond* (5,990,000 results) and *Sustainable Development Goal 14* (4,350,000), dominate the results. This suggests the concept has a strong emphasis on alignment with the SDGs. In that respect, with capital-raising mechanisms and policy frameworks.

The core conceptual phrases, such as *blue finance* itself (2,540,000) and the related term *coastal finance* (1,430,000), attracted substantial research attention. We believe that this reflects a broad scholarly engagement with the topic, or at least acknowledgment of its relevance. By contrast, the more specialized or emerging searches delivered lower counts. Examples include *debt-for-nature swap* (7540), *blended finance marine* (35,400), and *marine ecosystem service payment* (89,200). While these concepts are established in practice, policy research on them remains relatively limited. That said, we would note that mainstream finance research rarely engages at the instrument level.

The less substantial results for the terms *blue carbon market* (872,000) and *sustainable fisheries investment* (902,000) point to growing, but not yet mainstream, research interest. Collectively, these word/phrase counts highlight the maturity of certain financing approaches and, at the same time, the nascent state of others. We suggest these unrefined search results provide a useful guide to

[1] https://excitation.tech/

Table 2
Key journals for blue finance and blue economy research

Journal	SJR (2024)	Quartile	ABS	ABDC
Journal of Financial Economics	16.6	Q1	4*	A*
Marine Policy	1.169	Q1	2	A
Technological Forecasting and Social Change	3.472	Q1	3	A
Environment and Planning	2.047	Q1	3	A*
Journal of Economic Studies	0.519	Q2	2	B
Journal of Risk and Financial Management	0.48	Q2	NA	B
Natural Resources Forum	0.744	Q1	NA	NA
Fishes	0.523	Q2	NA	NA
Sustainability	0.688	Q1	NA	NA
Business Strategy & Development	0.827	Q1	NA	NA

areas where further theoretical and empirical work is warranted. For example, how a linkage can be made to carbon trading.

2.1.1. Research quality

We observe that blue finance research is poorly represented in quality publications. This came as a surprise. We expected lower volume, but not lower-level scholarship. Further, we found that this is more prevalent within journals that combine sustainability and financial innovation perspectives.

We summarize our quality metric evaluation in Table 2. The highest ranked paper we identified is by Hong and Kostovetsky [20] in the ABS 4* *Journal of Financial Economics*. *Marine Policy* stands out as the most established outlet in terms of the number of papers. This journal has consistently published work on blue bonds and innovative marine funding mechanisms. These two areas are the most important from a delivery perspective [1, 4]. Submissions to *Marine Policy* must contribute to the formulation and understanding of the marine economics, so it is totally aligned with blue finance.

High-impact interdisciplinary journals, such as *Technological Forecasting, Social Change*, and *Environment and Planning*, provide additional reporting avenues for research output. They publish articles on technological innovation, financial intermediation, and environmental policy (Shan et al. [21] and Christiansen [12]). The finance-oriented journals, notably the *Journal of Economic Studies* and the *Journal of Risk and Financial Management*, also offer strong platforms for econometric analysis (Thanh Ha, [2]; Sharma et al. [8]). We note the absence of the very top-tier finance journals, such as the *Journal of Finance*. We attribute this to the strong quantitative bias of such publications.

There is also a cluster of sectoral journal titles from other disciplines. These include *Natural Resources Forum, Fishes, Sustainability, and Business Strategy and Development*, which were notable in their coverage. We attribute this to the fact that finance itself is a very quantitative discipline. These capture research on resource governance, fisheries finance, and corporate sustainability. Collectively, these various avenues illustrate that the topic is an evolving interdisciplinary field. In totality, the body of knowledge includes both empirical and conceptual work.

2.2.2. Research insights

Despite its promise, blue finance faces several challenges. Some commentators suggest these limit its effectiveness and scalability. The first is the lack of standardization, as identified by Mathew and Robertson [22]. There are no universally accepted definitions in the literature. As a result, projects are selected and evaluated under heterogeneous criteria. For example, the term is sometimes interpreted to include unsustainable extractive industries such as deep-sea oil, gas, and mineral exploration. This creates inconsistencies in impact measurement and hinders comparability across jurisdictions and instruments [1, 4]. It is our contention that the absence of a shared framework increases the risk of "blue-washing." This is where projects are labeled as sustainable but fail to deliver measurable ecological benefits.

A second constraint concerns the effect of transparency and the validity of impact measurement (Benzaken et al. [23]). Although many of the case studies we reviewed illustrated commitment to environmental targets, few provided a robust analysis of long-term goals. In this respect, independent verification of biodiversity gains, carbon sequestration, or community benefits is often lacking (Christiansen [12]). In addition, the literature highlights a gap in assessing social equity impacts. This means that many papers failed to document how benefits are distributed among communities and vulnerable groups. As the oceans are, by definition, distinct geographies from human settlement, this is not surprising.

We note that regulatory and financial risks were cited as impeding the adoption of blue finance techniques [24]. The regulation of the oceans is poorly defined in international law. In practice, the UN Convention on the Law of the Sea (UNCLOS) provides the core legal framework by defining maritime zones. These include exclusive economic zones and what are termed the "high seas: This convention also specifies rights and duties over resources and navigation. However, day-to-day governance is also shaped by specialized institutions, including the International Maritime Organization. In many jurisdictions, adopting such finance techniques against this backdrop creates uncertainty around property rights, licensing, and compliance requirements. We argue that this weakens investor confidence and raises transaction costs [2]. Exchange-rate volatility, sovereign risk, and limited hedging options also discourage private capital from entering long-term marine projects. This is particularly the case in small island developing states such as Mauritius and lower-middle-income economies such as the Philippines.

We also found that social equity concerns remain significant. As blue finance is a sustainable concept, this is concerning. It can result in funding allocation bias, data gaps, and governance opacity. Without deliberate design, financial activities may reinforce existing inequalities. For example, projects that prioritize

capital-intensive infrastructure over community-led conservation. Also, there is a risk that small-scale fishers and coastal populations are not consulted in decision-making [9]. This misalignment between equity and inclusion undermines the social case on which many blue finance initiatives depend.

We believe that addressing these aforementioned challenges will require coordinated action. This could include developing internationally recognized standards and taxonomies. At the same time, fintech can be used to strengthen disclosure and verification mechanisms. That said, overcoming such obstacles depends on having a stable legal environment and being able to de-risk projects. Together, such action can help ensure that blue finance achieves the dual goals of ocean conservation and sustainable extraction of its resources. Implementation, however, will have to be coordinated at a supernational level, but enacted locally.

3. Conceptual Foundations

From the literature, we extrapolate the insights that give rise to the conceptual foundations we now present. As stated, blue finance is aligned explicitly with SDG 14. This in turn supports international frameworks such as the UN Ocean Decade and the UN Environment Programme Finance Initiative. The concept behind these is to encourage private and public investment in ocean-based solutions (Thompson [1]). Their aim is to direct capital to projects that protect marine ecosystems and enhance ocean-based economic activity. Note that we use the term activity and not exploitation. In this way, the literature suggests that blue finance provides a mechanism for integrating global conservation commitments with consensus goals for sustainability (Christiansen [12]).

There is a whole host of additional global initiatives that reinforce this alignment. We reviewed these as well. The High-Level Panel for a Sustainable Ocean Economy (sometimes referred to as the Ocean Panel), for example, promotes the transformation of national strategies into investable pipelines for blue-related sustainability. Its direction encourages integrated marine spatial planning. The Organisation for Economic Co-operation and Development's Ocean Economy Strategy, similarly, provides a framework for measuring and forecasting the value of ocean industries. This informs policy and investment decisions. Likewise, the *G20 Principles for Quality Infrastructure Investment* incorporate marine and coastal sustainability. This is also designed to promote transparency and resilience in cross-border projects that draw on blue finance funding. Each of these frameworks establishes benchmarks that enhance investor confidence and provide guidance for structuring financial products. Such confidence is essential to attracting capital.

Furthermore, the literature points to the multilateral financial architecture being gradually adapted to accommodate marine priorities. The World Bank's PROBLUE program, for example, offers concessional financing and technical assistance to governments seeking to expand sustainable fisheries and reduce marine pollution. Regional development banks, such as the Asian Development Bank and the African Development Bank, have introduced blue bond guidelines and risk-sharing facilities to catalyze private investment. These mechanisms bridge the gap between global policy aspirations and local implementation. They collectively ensure that blue finance supports both environmental stewardship.

The theoretical base that we identified in the literature combines ecological concerns with financial intermediation (Lessmann & Kalkuhl [25] and Shan et al. [21]). Ecological economics emphasizes the non-substitutable value of marine ecosystems. Long-term capital is required to maintain them. This includes carbon sequestration in blue carbon habitats, coastal protection, and fisheries productivity (Costanza [26]). Financial intermediation theory, a key component of finance theory, is useful in this respect. It explains how banks, markets, and hybrid structures channel funds to activities that exhibit public-good characteristics and such long investment horizons. Instruments, such as blue bonds, and approaches such as blended finance packages, operationalize these principles. They bring with them sovereign guarantees and/or concessional tranches. These help reduce risk for private capital (Tirumala & Tiwari [3]).

We observe that behavioral and institutional perspectives further shape the field. They drive investor demand for sustainability-oriented products. With both private and institutional investors, signaling and reputation affect adoption and pricing. For example, in the salmon farming industry, issues related to stressed fish and disease are pervasive (Zitti & Guttormsen [27]).

It is clear that institutional theory underscores the importance of legitimacy and governance behind blue finance. It delivers credible standards and verification processes. These serve as safeguards against blue-washing [4]. This term is derived from the more common term greenwashing (Berliner and Prakash [28]). All too often, claims are made that are not substantiated. This "spin" is reinforced by digital technologies but can be addressed by blockchain-based traceability and tokenization. Such fintech can enhance transparency and provide auditable evidence of environmental outcomes (Sharma et al. [8]).

Taken together, we argue that blue finance is an emerging subset of sustainable finance. In this respect, it integrates global governance goals, ecological valuation, and financial innovation. These provide a basis for instruments, regulatory structures, and empirical evidence that can advance protection of the oceans.

3.1. Market standards and guidance

The expansion of interest in blue finance is supported by a maturing set of market standards and guidance that define eligibility, reporting, and risk management. We also reviewed these. Such initiatives provide the normative and technical foundation for capital mobilization aligned with SDG 14. They also help reconcile investor requirements for financial return with the ecological imperatives of ocean conservation. Not much has, however, been written about risk management.

The Sustainable Blue Economy Finance Principles, convened by the United Nations Environment Programme Finance Initiative, are widely recognized as the core norms for financial institutions. They emphasize protective, compliant, risk-aware, systemic, inclusive, cooperative, and transparent approaches to financing ocean-related projects. By anchoring directly to SDG 14, these principles offer a baseline for integrating environmental safeguards and social inclusion into lending and investment decisions as per the United Nations Environment Programme Finance Initiative.

Recent non-peer-reviewed reports deepen this guidance. The World Bank's Accelerating Blue Finance report (2025) catalogs financial instruments, structures, and global case studies. They typically illustrate how blended finance, guarantees, and impact-linked instruments can attract private capital on a large scale. The OECD's Promoting Sustainable Ocean Economies report (2025), for example, clarifies the respective roles of private, public, and philanthropic capital and outlines a taxonomy of ocean economy sectors. Similarly, on a regional level, the EU Blue

Economy Report (2024) presents detailed sectoral data, employment figures, and growth forecasts, giving European investors a market lens for assessing emerging opportunities in renewable energy, aquaculture, and marine biotechnology (European Commission [29]).

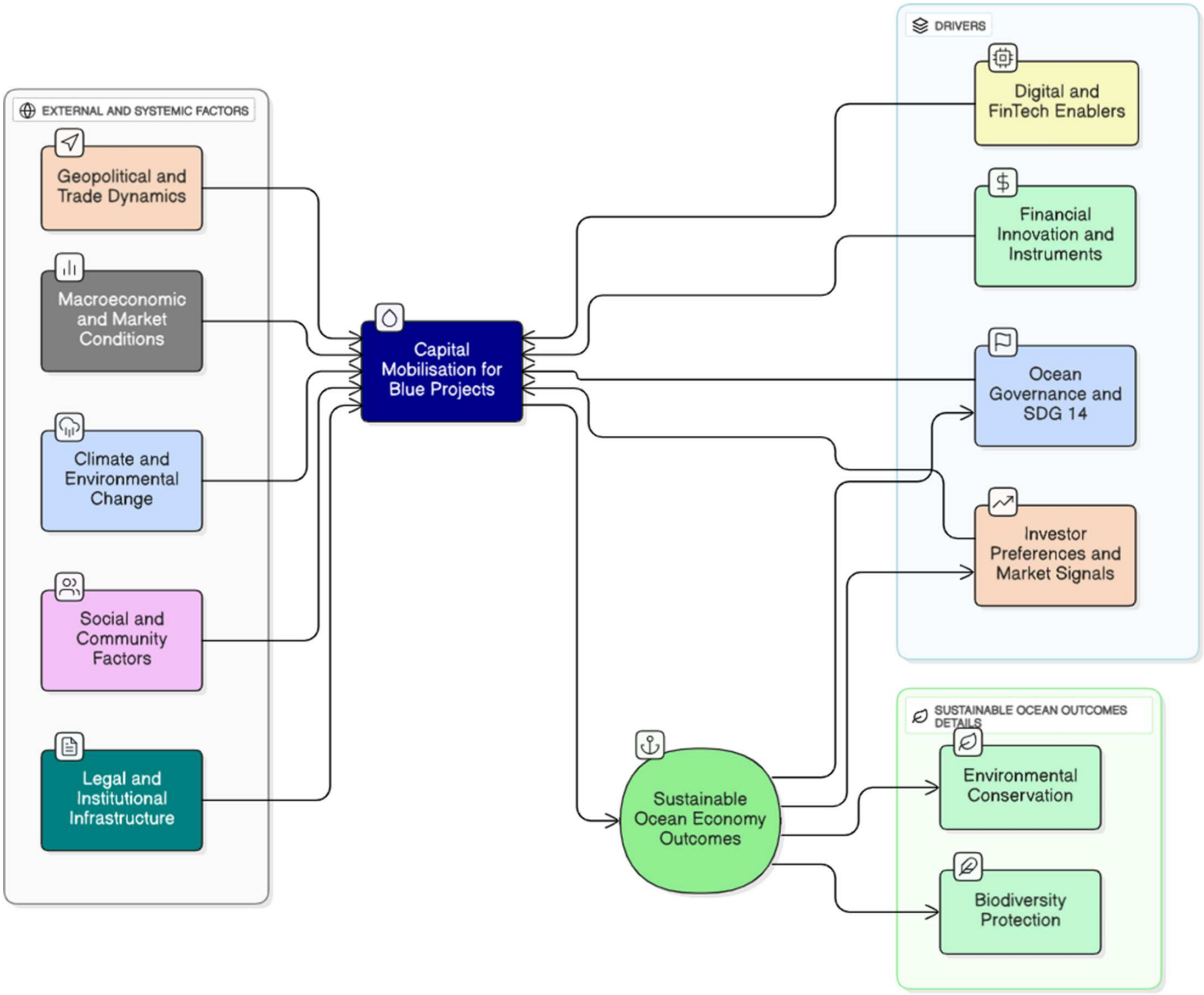
The literature also highlights the multiplicity of different initiatives. As has probably become clear, financing fisheries is very different from sponsoring microplastic cleanup. Both require a specialized focus on instruments and sectors. For blue bonds, the ICMA/IFC/UNEP FI *Bonds to Finance the Sustainable Blue Economy handbook* (2023) and the *IFC Guidelines for Blue Finance* (2022 and the updated version 2.0 in 2025) provide practical criteria on eligible project categories, key performance indicators, and reporting requirements for such classification. Nature-related financial risk is addressed by the Taskforce on Nature-related Financial Disclosures, which issued core recommendations in 2023 and sector-specific guidance for ocean industries such as aquaculture and marine transport in early and mid-2025. In the shipping sector, for example, the Poseidon Principles for lenders and the Sea Cargo Charter for charterers set quantitative targets for emissions alignment and reinforce climate consistency across maritime finance. Corporate issuers and supply-chain participants can also draw on the UN Global Compact Sustainable Ocean Principles, which define responsible business conduct for ocean-exposed sectors.

Collectively, the literature shows that blue finance is moving from concept to market practice. This is largely driven by public concern for the oceans. Publicity about the state of the coral reefs has helped this momentum. The various standards and norms reduce information asymmetry, enhance comparability across issuers, and guide the measurement of ecological outcomes. By standardizing disclosure, risk assessment, and project eligibility, they create the conditions under which private capital can participate confidently and at scale.

3.2. Conceptual framework

Our extrapolated conceptual framework is devised from insights in the literature. It is illustrated in Figure 2. It positions "capital mobilization" at its center. This is the essence of the concept. It is the mechanism through which financial resources are directed to ocean-related investments. We propose that in order to be effective and avoid blue-washing, three sets of determinants interact within this framework: external and systemic factors on the left, financial and technological drivers on the upper right,

Figure 2
Conceptual framework for capital mobilization for blue projects



and sustainable ocean economy outcomes on the bottom left. The figure shows the linkages.

Scholars in our review tend to agree that external and systemic factors define the broader environment for blue finance. Geopolitical and trade dynamics affect cross-border capital flows and supply-chain stability. Macroeconomic and market conditions influence the cost of capital and the risk–return profile of projects. The research suggests that climate and environmental change create both adaptation opportunities and physical risks. Social and community factors shape local acceptance and the distribution of benefits. Legal and institutional infrastructure provides the regulatory certainty and contractual safeguards that underpin investor confidence. Together, these elements condition the availability and direction of capital.

We observe that financial and technological drivers also act directly on the mobilization process. In this respect, digital and fintech enablers enhance transparency, reduce transaction costs, and allow the creation of innovative instruments such as tokenized blue bonds. Financial innovation and instruments widen financing options, including blended structures and sustainability-linked loans. Ocean governance and the implementation of SDG 14 create regulatory incentives and long-term policy support. Investor preferences and market signals align private capital with sustainability objectives through demand for blue-labeled securities and enhanced disclosure standards.

Our framework in Figure 2 aims to capture the various sustainable ocean economy outcomes that we identified. These can be expressed as environmental conservation and biodiversity protection. They represent the ecological and social. Feedback effects are often cited, although we have as yet to see these at a meaningful level. These effects are improvements in ocean health, as a result of successful blue finance intervention. This in turn is supposed to reduce ecological risks and create further investment opportunities, reinforcing the enabling conditions and investor appetite.

What we find is that understanding how capital mobilization occurs is not a simple linear effect. Rather, it is a dynamic process that responds to changing incentives and feedbacks. From the literature, in this respect, it is clear that blue finance depends on the interaction of actors with different time horizons and risk tolerances. Institutional investors, public development banks, and impact funds play complementary roles, with each responding differently to price signals, disclosure requirements, and emerging ocean risks. This multi-actor perspective is important, as it captures how blended finance structures can reduce perceived risks and create investable pipelines for private capital.

Another insight from recent studies is that technological advances reshape the boundary of what can be financed. There is no lack of incentive that something needs to be done, but there has to be a realistic return on investment. In respect of sustainability, this means achieving the goals set. Blockchain-based verification, satellite ocean monitoring, and artificial intelligence (AI) can all enhance the traceability of marine projects can all help. This in turn improves the credibility of environmental impact claims. These technologies, it is claimed, enable the design of new financial products such as smart-contract-based blue bonds and dynamic insurance schemes that adjust premiums according to real-time ocean data.

The literature underlines the role of feedback mechanisms between ecological outcomes and capital flows. Improved ecosystems, such as healthier fisheries or increased carbon sequestration, can generate measurable revenue streams through carbon credits, biodiversity offsets, or ecological footprint (Tekin et al. [2]). Such fintech innovations can also create secondary markets that attract further investment and reinforce conservation. At the same time, scholars warn that failures in ocean governance or sudden environmental shocks can erode investor confidence and stall mobilization. With the threat of rising sea levels, this emphasizes the need for adaptive policy frameworks and robust management.

The presented conceptual framework forms the backdrop for a research agenda. As a nascent field, there is much to address. It points to the importance of measuring capital mobilization not only in terms of volume but also in terms of effectiveness in delivering ecological outcomes. It raises questions about the balance between public and private finance, the optimal use of concessional capital to de-risk projects, and the governance of data that underpins technological drivers. Work is needed on credible identification strategies to test whether labeled instruments improve marine biodiversity, coastal resilience, or blue carbon integrity. Pricing "blue risk" in assets and sovereign credit is also an unexplored subject. Researchers could also test whether exposure to sea-level rise, fisheries depletion, or coral loss forecasts higher expected losses, higher risk premia, or different term structures. By investigating these relationships, the literature will benefit from empirical testing and better policy design.

3.3. Financial instruments and mechanisms

Moving now from conception to implementation, blue finance employs a range of financial instruments. These are designed to mobilize capital for the sustainable use of ocean resources. These instruments adapt established practices from green and sustainable finance to the marine context. They incorporate specific mechanisms related to the ocean economy. The central reference point remains the Green Bond Principles and Green Loan Principles. These were developed by the International Capital Markets Association and the Loan Market Association, respectively. These frameworks' structure capital raising around four components: use of proceeds, project evaluation and selection, management of proceeds, and reporting. Their influence extends directly to blue finance, shaping the issuance of blue-labeled debt and ensuring that funds are allocated to projects with clear marine sustainability objectives.

Among the most prominent instruments, as mentioned, are blue bonds. These are dedicated financing instruments where the proceeds are directed to marine and coastal conservation, sustainable fisheries, and low-carbon maritime infrastructure. They are similar to their green bond cousins. Early examples, such as the Seychelles sovereign blue bond and corporate issues in the Philippines, demonstrate their potential to raise substantial funding while embedding ecological performance targets [10]. These bonds frequently incorporate third-party verification and key performance indicators aligned with SDG 14 to mitigate greenwashing or "blue-washing." Related structures include sustainability-linked bonds and loans, where coupon rates or borrowing costs are adjusted according to the achievement of conservation benchmarks.

Debt-for-nature swaps represent another significant mechanism that is cited. A swap is, as the name implies, something in exchange for something else. These arrangements allow portions of sovereign debt to be forgiven in exchange for commitments to marine protected areas or coastal resilience projects. Such swaps can unlock fiscal space for conservation in small island developing states and lower-middle-income countries while providing investors with measurable biodiversity outcomes (Tirumala and

Tiwari [3]). Another study that addresses this concept is Olsen and de Mariz [30].

Incidentally, in view of our explanation above, we note that the term "swap" is a misnomer. Although the term has become widely used in the global market. In standard markets, a swap is a derivative contract in which two parties exchange cash-flow streams. However, most so-called debt-for-nature "swaps" are better characterized as a negotiated debt restructuring or buyback. Similarly, blended finance structures combine concessional public funds or philanthropic capital with private investment. These are also not exclusively designed from a cash-flow perspective. They do, however, lower risk and improve the commercial viability of projects (such as offshore renewable energy or large-scale mangrove restoration).

Market standards and guidance continue to develop around these instruments and blue finance in general. The *ICMA/IFC/UNEP Blue Economy handbook* and the *IFC Guidelines for Blue Finance* provide detailed eligibility criteria, performance metrics, and reporting templates. Although not peer reviewed, we feel they are clearly part of the body of knowledge on the subject.

Complementary initiatives, such as the Taskforce on Nature-related Financial Disclosures, supply sector-specific risk frameworks for marine industries including aquaculture and shipping. This is also under the umbrella of blue finance. For maritime transport and allied areas, the Poseidon Principles and the Sea Cargo Charter are relevant. These set emissions alignment targets that help lenders and charterers manage climate-related risks while financing vessel retrofits and green ports. Countries have also begun developing their own set of guidelines based on the ICMA, IFC, and other international standards. The Philippines Securities and Exchange Commission, for instance, was recognized as the first regulator to issue blue bond guidelines (that are in alignment with the IFC Guidelines).

New technological capabilities are expanding the possibilities for blue finance and the sort of instruments that can be created. Blockchain-based verification and smart contracts, for example, can be used to automate compliance and payments. Similarly, application programming interfaces (APIs) can be used to integrate environmental data with financial reporting. These innovations reduce transaction costs and improve traceability, enabling instruments such as tokenized blue bonds and dynamic insurance products linked to real-time ocean data [16]. Such fintech-enabled structuring of terms increases market confidence and supports scaling. This in turn makes the environmental impact both auditable and tradeable.

Taken together, we argue that blue finance moves beyond traditional debt or equity to create a tailored suite of solutions for the ocean economy. By combining established sustainable finance principles with emerging digital tools and ocean-specific risk management, they enable the mobilization of private and public capital. It is now possible to do this at a scale consistent with the ecological ambitions of SDG 14 and the UN Ocean Decade.

4. Financial Technology Applications

Moving now to the application, fintech is reported as having a growing role in the mobilization and management of blue finance. This is defined as the movement of financial services to the Internet. Digital innovations, it is claimed, improve the efficiency, transparency, and accountability of capital flows. They also enable new financial products that can be tailored to marine conservation. The literature, including sources from applied science and engineering such as IEEE journals, highlights several mechanisms. Blockchain is frequently proposed due to its ability to provide immutable records of project performance. Automated compliance is another. This can be done through smart contracts [16]. These features reduce enforcement costs, making blue bonds and sustainability-linked loans more attractive to institutional investors. Similar approaches are used in carbon markets and biodiversity credits, where tokenization of ecosystem services requires reliable digital tracking and verification.

One important fintech application is the automation of data collection and compliance (Broby et al. [31]). Automated monitoring systems, a function of what is called regtech, can be used to link oceanographic sensors, satellite imagery, and distributed ledgers. These can record project performance in real time. The aforementioned smart contracts can automatically trigger interest payments or release tranches of capital when predefined ecological indicators, such as coral cover or fish stock levels, are met. This reduces administrative costs, shortens verification cycles, and enhances investor confidence by ensuring that capital is disbursed only when environmental targets are achieved [16].

Also noteworthy fintech tools are APIs. These are simply tools that act as an interface. They expand the reach of traditional finance funding by connecting diverse financial and environmental data sources and linking them to outcomes. They also allow seamless integration between banks, payment processors, and digital monitoring platforms. This means they can be used at the micro level. They enable open banking functions such as instant cross-border settlements and direct linking of investment accounts to blue project performance dashboards. The key advantage of API capability is that it supports blended finance structures, where multiple investors and concessional funders can synchronize disbursements and track outcomes through a single digital interface. It also enhances the granularity of reporting required by international standards such as the IFC Blue Finance Guidelines and the Sustainable Blue Economy Finance Principles.

Internet-based platforms can also be used to strengthen blue finance by broadening participation and lowering entry barriers. Typical fintech mechanisms, such as crowdfunding portals, tokenized securities markets, and decentralized exchanges, can all play a part. These enable small investors to buy fractional interests in blue bonds or biodiversity credits. Obviously, this is in its infancy but could be explored by participants. At the same time, mobile-first banking and e-wallet services could be used to extend financial inclusion to coastal communities and small-scale fishers. This would provide them with savings, micro-insurance, and payment solutions. These services are particularly valuable in small island developing states and lower-middle-income economies. These nations typically lack conventional banking penetration, which remains limited.

Banking sector engagement is another important aspect of blue sectoral development. Commercial and development banks increasingly use digital tools to originate, structure, and monitor blue finance transactions. In this respect, we are talking about dashboards and applications. Digital credit scoring based on alternative data sources, for example, allows lenders to underwrite small marine enterprises and aquaculture ventures with limited conventional collateral. Integration with Economic, Social and Governance (ESG) data feeds ensures that risk assessments can incorporate ocean-specific sustainability metrics. Portfolios can even be constructed with optimal asset allocation to blue issues (Mumtaz [32]). Moreover, in the future, banks adopting open

banking standards can collaborate more efficiently with fintech firms, insurance providers, and impact investors.

These developments indicate that fintech is not simply a back-office efficiency tool for the oceans. It underpins the traceability, scalability, and inclusiveness required to mainstream blue finance. The convergence of automation, APIs, internet-enabled participation, and digitally engaged banking provides the infrastructure for new financial instruments. It also aligns them with rigorous environmental and social safeguards. This integration ensures that capital mobilization can meet the dual imperatives of financial viability and measurable ecological impact.

Distributed ledger technology is also a tool that can be used to support the sector. For example, the creation of decentralized exchanges for blue assets. This is currently theoretical, but research in computer science is advancing it into a practical realm. Also, advances in cryptographic techniques can be used for verifying marine data in near real time. For example, satellite imagery or Internet of Things (IoT)-based sensors placed in marine protected areas can be used for monitoring. This would strengthen the monitoring of marine pollution, fisheries, and carbon sequestration projects. Fintech systems that integrate satellite and oceanographic data with blockchain allow dynamic pricing and risk management. The scientific literature supports this. Edge computing and machine learning can be used to process environmental data streams to trigger automated adjustments in insurance products. For example, the provision of parametric cover for coastal flooding.

AI and data analytics are further enablers of blue finance, as in many sectors [13]. Its use can improve risk assessment by modeling complex ocean and climate interactions. It can also be used for detecting fraudulent reporting of ecological impacts. These applications enhance the robustness of financial projections and lower the perceived risk for investors. Additionally, cloud-based infrastructure facilitates interaction and blended finance structures, allowing small-scale marine enterprises in developing countries to access capital on more competitive terms.

In summary, the literature shows that the technological component of blue finance is not limited to financial innovation alone. Fintech can aid with other areas such as environmental sensing, computer science, and engineering research. It is the integration of these fields that makes the term blue finance a catch-all that enables credible and scalable financial products for the sustainable ocean economy. The combination of secure digital ledgers, real-time environmental monitoring, and AI-based risk analytics supports both investor confidence and measurable ecological outcomes.

5. Future Research Avenues

Our review reveals a striking imbalance between conceptual and empirical work related to blue issues. The most significant gap is the limited availability of quantitative work, as well as a lack of publications in high-quality journals. Also, our analysis identifies a lack of robust, standardized financial data on ocean-related projects. Few manuscripts capture the scale, sectoral distribution, or measurable ecological outcomes of blue finance. Existing records often combine heterogeneous sources, with inconsistent reporting standards and partial coverage of developing regions. This makes it difficult to assess additionality, track long-term impacts, or quantify risk–return profiles. We find this concerning because without reliable empirical evidence, theoretical models of capital mobilization and technological adoption cannot be rigorously tested.

We therefore suggest that future research needs to focus on constructing comprehensive datasets. These need to integrate financial transactions with verifiable environmental indicators. Linking project-level financing data with satellite-based ocean monitoring, blockchain records, and regulatory filings could create a more transparent and comparable evidence base.

We believe that standardized taxonomies of blue finance, analogous to the EU sustainable finance taxonomy, would facilitate such econometric studies. We also suggest that advances in natural language processing and machine learning could be applied to scrape financial data, improving the field and aiding research. All these would make the confidence in financing arrangements and outcomes more aligned.

Beyond data collection, there is scope to develop empirical methodologies that assess causality. For example, between blue finance instruments and marine ecological outcomes. Longitudinal studies could also measure whether blue finance delivers biodiversity gains. We also think that experimental and quasi-experimental approaches, including difference-in-difference methods, could evaluate the effectiveness of digital technologies. These could demonstrate the effectiveness of reducing transaction costs and improving compliance.

Another promising direction is to explore the governance and behavioral aspects of investor participation. While conceptual work highlights the importance of investor preferences and regulatory frameworks, little is known about how investors perceive marine-specific risks. Similarly, little has been written about how these perceptions evolve with new evidence and/or how financial innovation affects their willingness to commit capital. Comparative studies across jurisdictions could identify which institutional arrangements and policy incentives are most conducive to scaling blue finance. We now present a list of suggested topics:

1) To what extent do blue bonds and debt conversions generate measurable ecological benefits relative to comparable non-labeled finance?
2) Which best predicts realized marine ecological improvements, and how sensitive are results to measurement error?
3) How effective are alternative verification approaches at reducing misreporting and bias?
4) Which blended finance instruments most effectively reduce project risk and the cost of capital?
5) How do public–private vehicles compare with project finance structures?
6) Is exposure to ocean-related physical risk priced in sovereign spreads?
7) Do marine protection investments measurably change sovereign term structures over time?
8) Do investors pay a price premium for blue-labeled instruments?
9) Which bond covenants and reporting provisions most reduce post-issuance outcomes?
10) How does institutional capacity affect the credibility of conservation-linked commitments?
11) How are benefits and costs distributed across stakeholders in blue finance transactions?
12) Do satellite observations reduce underwriting uncertainty and lower financing costs for marine and coastal projects?
13) Which data governance arrangements best balance interoperability, accountability, and privacy?
14) Under what conditions do audit trails improve trust and reduce adverse selection in blue finance markets?
15) Are "debt conversion" transactions associated with improved debt sustainability?

16) Do ocean-related insurance products improve recovery speed and welfare for coastal communities?
17) Can resilience bonds tied to ecosystem performance measurably reduce expected losses?
18) How do capacity constraints and climate tail risk shape the feasibility and pricing of financial instruments?
19) Who gains and who bears costs from blue finance interventions, and how do these incidence patterns vary by institutional setting?
20) What are the impacts of blue finance on small-scale fisheries livelihoods?
21) Which taxonomy and disclosure frameworks most improve market discipline and comparability for blue-labeled finance?
22) How should supervisors integrate nature-related financial risk into stress testing and prudential oversight?
23) How does information asymmetry shape liquidity and pricing?

In sum, future research needs to close the empirical gap. To do this, scholars need to build integrated, high-quality datasets, and applying rigorous quantitative methods will allow researchers to move from conceptual models to evidence-based policy and practice. This will strengthen the scientific foundation of blue finance and guide investment decisions that align economic growth with ocean conservation.

6. Conclusion

We examined the literature, conceptual foundations, financial instruments, market standards, and technological enablers of blue finance. The PRISMA analysis shows that blue finance is emerging as a distinct branch of sustainable finance. We identified a body of knowledge that combines ecological economics and financial intermediation. This led us to propose a number of research questions and illustrate the importance of Fintech in driving blue finance forward.

In this way, we have shown that blue finance can be used to mobilize capital for ocean conservation and sustainable marine industries. We showed how it integrates global frameworks such as the Sustainable Blue Economy Finance Principles and draws on advanced financial technologies to enhance transparency and verifiability. By structuring these insights, the paper contributes to a clearer understanding of how capital can be channeled into projects that protect and enhance marine ecosystems.

Our key conclusion is that fintech can be used to enable scale and credibility in sustainable issues related to the oceans. Fintech applications, such as blockchain-based verification, satellite monitoring, and AI-driven analytics, provide measurable ecological outcomes. These tools can be used to reduce information asymmetry and improve compliance with sustainable targets. They allow innovative financial instruments such as tokenized blue bonds and parametric insurance to flourish. We therefore suggest that the application of technology can enhance blue finance outcomes.

The largest research gap identified is the scarcity of robust, standardized empirical data. Current datasets on blue finance, on which papers were based, appeared to be fragmented. As such, they resulted in inconsistent definitions and incomplete coverage of developing regions. This lack of reliable information hampers the ability to quantify financial flows, measure ecological additionality, and evaluate risk–return profiles of the various projects. Addressing this gap will require the construction of integrated datasets linking financial transactions to verifiable environmental indicators, supported by common taxonomies and reporting frameworks similar to those used in green finance. The research areas from which we generated our list of questions include measurement and causal impact.

Future research should focus on methodologies that establish these relationships between financial instruments and marine outcomes. Longitudinal studies can examine whether blue bonds, blended finance structures, or debt-for-nature swaps achieve sustained biodiversity or carbon sequestration benefits. Quasi-experimental designs, such as difference-in-differences analysis, could evaluate how digital technologies reduce transaction costs and enhance monitoring. There is also a need to investigate the behavioral and institutional dynamics that influence investor participation, including risk perceptions and policy incentives across different jurisdictions.

Taken together, the literature draws heavily on environmental sensing, computer science, and engineering research. It is the integration of these fields that enables credible and scalable financial products for the sustainable ocean economy. Blue finance provides a technological foundation that supports both investor confidence and measurable ecological outcomes.

Finally, the integration of marine science and financial innovation remains an open field of inquiry. Linking oceanographic data with financial risk models could improve the pricing of marine ecosystem services and insurance products. Comparative studies across regions can reveal which governance mechanisms most effectively align capital markets with ecological objectives. By deepening the interface between science and fintech, future research will strengthen the evidence base for policy and practice. This will ensure that blue finance delivers both environmental protection and sustainable economic growth at the scale required to meet global conservation goals.

Acknowledgment

The authors would like to thank Allen Jeremiah M. De Leon and the Centre for International and Strategic Studies for the assistance provided and their 2025 report Blue Finance 101: Opportunities and Challenges for the Philippines. The authors are also grateful to Anastasia Broby Hayles for assistance with the concept behind this review.

Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

The data that support this work are available upon reasonable request to the corresponding author.

Author Contribution Statement

Daniel Broby: Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization,

Supervision, Project administration. **Jose Vicente Camus:** Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing.

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How to Cite: Broby, D., & Camus, J. V. (2026). Blue Finance: Financial Innovation for Sustainable Oceans. *FinTech and Sustainable Innovation*. https://doi.org/10.47852/bonviewFSI62027953