

Enabling new sustainability opportunities from integrated blue sustainable development

Zounachuan Sun,¹ Ningkang Chen,¹ Jinwei Dong,² Mingming Jia,³ and Zhenci Xu^{1,*}

¹Department of Geography, The University of Hong Kong, Hong Kong SAR 999077, China

²Key Laboratory of Land Surface Pattern and Simulation, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China

³Key Laboratory of Wetland Ecology and Environment, Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Changchun 130102, China

*Correspondence: xuzhenci@hku.hk

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Oceans are foundational to global sustainability and human development, regulating climate, sustaining biodiversity, nourishing populations, and driving economies. Ocean-based “blue economy” industries, such as blue food, maritime logistics, marine tourism, and marine biotechnology, create jobs and stimulate value-added. However, the “blue economy” concept has limita-

tions in governing the economic benefits provided by the ocean. It focuses on direct economic outputs, while overlooking the account of the indirect benefits of marine and coastal ecosystem services. Also, it fails to account for the potential devaluation of marine resources due to climate change risks.

We thus provide a paradigm shift to the “Blue Sustainable Development”

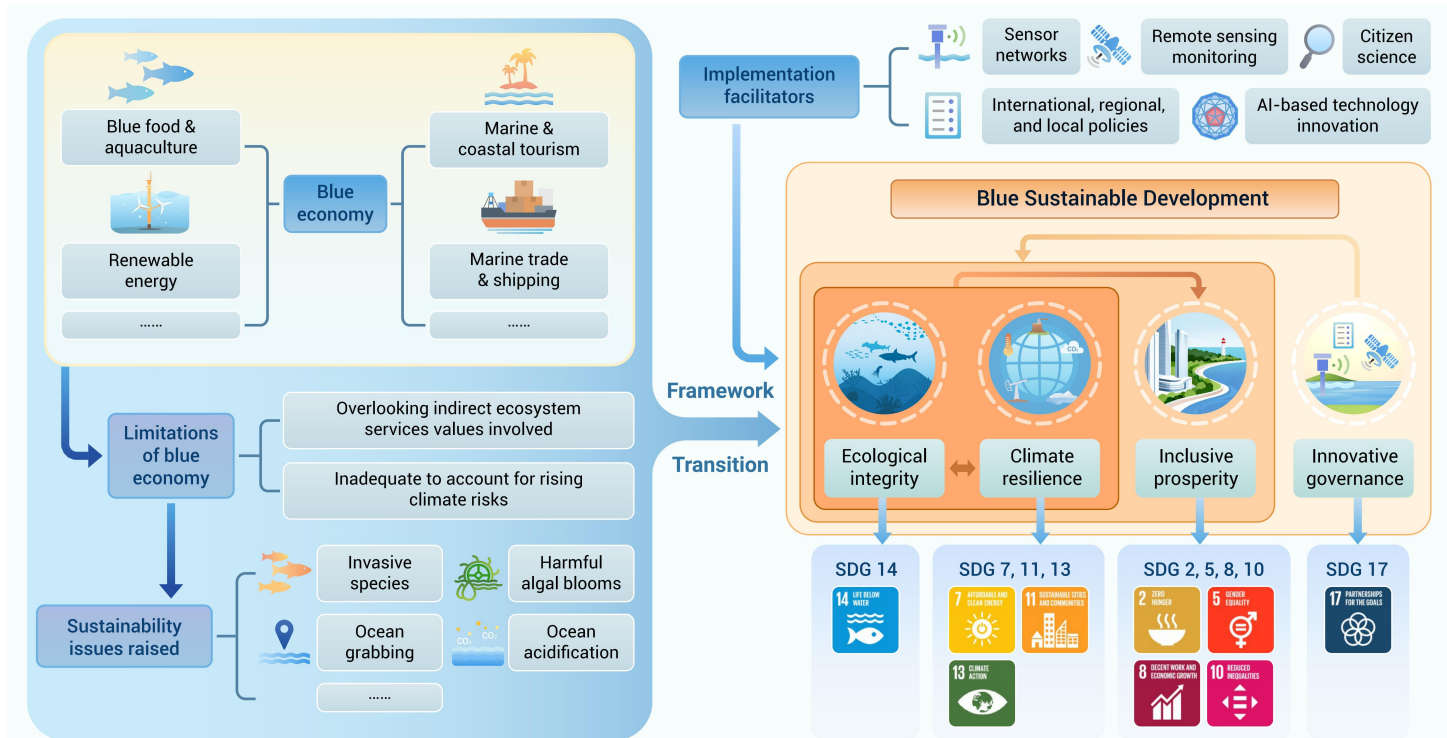


Figure 1. Illustration of Blue Sustainable Development for integrated marine management and global sustainability.

framework, supporting nations that rely on marine-based goods and services in accelerating their pace towards the global 2030 Sustainable Development Agenda and beyond.

BLUE SUSTAINABLE DEVELOPMENT AS A FORWARD STEP FOR GLOBAL SUSTAINABILITY

The Blue Sustainable Development framework comprises four pillars: ecological integrity, inclusive prosperity, climate resilience, and innovative governance. These pillars are based on three traditional sustainability dimensions: environment, society, and economy. The interconnections between the pillars are also crucial for amplifying synergies when determining governance strategies, promoting the achievement of multiple Sustainable Development Goals (SDGs) (Figure 1).

Ecological integrity addresses the conservation of biodiversity, functionality, and regenerative potential in marine and coastal ecosystems. It targets prevention and recovery from present ecological problems, such as harmful algal blooms, invasive species, and coral bleaching. It complements SDG 14 (Life Below Water) and promotes climate resilience. Climate resilience refers to the capacity building of marine ecosystems and coastal communities for climate adaptation (SDG 11), also leveraging the oceans for climate mitiga-

tion through blue carbon (SDG 13) and offshore renewable energy (SDG 7). Ecological integrity and climate resilience support each other, as demonstrated by the Indonesian mangrove conservation, which could benefit 74 million coastal residents, alleviate poverty in 199 regencies, and contribute to reducing national land-sector emissions by up to 16%.¹ Ecological integrity and climate resilience also form the basis for inclusive prosperity. For example, the Mesoamerican Barrier Reef System, the largest barrier reef in the Northern Hemisphere, supports \$4,092 million from tourism and \$615 million from fisheries (Retrieved from https://oceanfdn.org/wp-content/uploads/2021/08/Economic-Valuation-of-Reef-Ecosystems_Infographic.pdf).

Inclusive prosperity also ensures that marginalized groups, such as small-scale fisheries, indigenous communities, and women, benefit equally from marine-based industries. It improves food security (SDG 2), creates jobs (SDG 8), and reduces inequalities (SDG 5 and SDG 10). Innovative governance supports the other three pillars. In the case of public-private collaboration, the Global Fund for Coral Reefs, which covers more than 20 coral-reef nations, employs a win-win strategy of ecological restoration and community economic development through innovative governance. It channels grants and private capital for investing reef-positive businesses and creating jobs. In the context of global transboundary marine governance, the 2023 UN

High Seas Treaty marks a breakthrough. The treaty establishes a legal framework mandating environmental impact assessments for activities in international waters to avoid pressing threats, such as overfishing and deep-sea mining. The innovative governance pillar relates to SDG 17 (Partnerships), implying the development of flexible, collaborative, and transparent governance structures that transcend jurisdictional boundaries.

Integrating the four pillars, the Blue Sustainable Development paradigm can offer new perspectives on addressing global issues arising from the growth of the ocean-based industry. Through cross-sectoral governance and the active involvement of communities, businesses, and nations, this paradigm of ocean sustainability serves to drive global action, contributing to achieving related SDGs.

BLUE SUSTAINABLE DEVELOPMENT FOR GLOBAL MARITIME NATIONS

In the context of countries and regions with different geographical conditions and economic structures, the framework can offer a new perspective to achieve ocean sustainability.

Coastal nations with diverse maritime industries usually face competition for multiple uses of their ocean space. For example, Norway faces tensions due to areas of overlap between offshore wind energy and offshore aquaculture.² Similarly, the multipurpose conflicts also occur in China. Sea use conflicts in the marine spatial planning zone were observed in the cross-boundary area at the provincial level, taking Fujian Province as an example.³ The Blue Sustainable Development Framework can be integrated into Marine Spatial Planning (MSP), a widely used decision-making guidance proposed by UNESCO, to better solve the conflict. The climate resilience and ecological integrity pillars of the framework entail incorporating modelling and projections of ecologically sensitive areas, including spawning areas and coral distribution, and climate risks, such as seasonal and range shifts of fish, and areas sensitive to sea rise, heatwaves, and acidification. The inclusive prosperity pillar can engage marginalized stakeholders and public participation in marine governance decisions.

Moreover, for global fishery-dependent countries, one particular challenge is upgrading the primary fishery industry. For instance, in Peru, one of the world's most productive fisheries, the anchovy fishery has long served industrial fishmeal production, despite its much higher economic value for human consumption than for industrial use.⁴ Incorporating the Blue Sustainable Development Framework helps those countries identify the cross-sectoral linkages that the upgrading industry could relate to, thereby amplifying the socioeconomic and environmental synergies, such as food security, reduced poverty, job creation, and improved production efficiency. Innovative governance can combine mandatory, market-based, and voluntary management strategies, such as price incentives to shift consumer behaviors and ban policies.

Small Island Developing States are special cases with global attention. Those small island nations, spread across 1,000 islands globally, control an area 28 times the country's average land mass and are vulnerable to the disproportionate impacts of natural hazards and fragile ecosystems due to geographical isolation. Achieving Blue Sustainable Development in small island nations can prioritize ecological integrity and climate resilience. For instance, the conservation of rehabilitation of coral reefs can reduce wave energy by up to 97% during storms and alleviate disaster costs.⁵ Palau's Protected Areas Network is an example that established 35 protected areas to safeguard more than 30% of its near-shore marine environment by 2020 (Retrieved from <https://panorama.solutions/en/solution/palaus-protected-areas-network-act>). Hybrid infrastructure solutions, such as seawalls and artificial reefs, increase resilience while maintaining natural functions. Regional alliances and authorities, such as the Pacific Islands Forum Fisheries Agency, can help promote inclusive prosperity through ongoing community-led activities.

Innovative governance will facilitate practical barriers, like financial gaps and insufficient digital governance, for small island nations. Firstly, existing data-sharing platforms like Global Fishing Watch could further enhance their monitoring and surveillance coverage and resolution over small island nations. Secondly, international and regional development banks can promote debt for nature swaps that do not add to the borrower's existing debt. Moreover, Regional partnerships can facilitate cross-institutional dialogue to develop minimum standards agreements. Leveraging global partnerships, the Blue Sustainable Development framework will enhance the capacity of small island nations towards ocean sustainability.

IMPLEMENTING BLUE SUSTAINABLE DEVELOPMENT UNDER THE GLOBALLY INTERCONNECTED CONTEXT

The key enablers for implementing Blue Sustainable Development rely on technological innovation, advanced monitoring systems, and nested policies that span from local to global scales.

Innovative technology is a key facilitator of Blue Sustainable Development. AI-driven aquaculture systems, such as those for water toxicity detection, water quality prediction, and automated detection of biological life cycles for species like soft crab molting, can improve feed efficiency, decrease waste, and monitor fish health, resulting in higher yields with lower environmental impacts. International technology transfer agreements and open-source sharing platforms should be promoted to ensure that small island nations and developing countries have access to affordable innovations.

Enforcing regulations and tracking progress also leverages solid monitoring systems. Satellite and remote sensing techniques provide a top-down approach to monitoring the physical and biogeochemical features of the marine environment, such as products retrieved from the Copernicus Marine Service and NASA's PACE satellite. The bottom-up measures, such as the Internet of Things (IoT), encompass a web of connected sensors, buoys, and underwater probes, and can help collect real-time and location-specific data on water quality, marine biodiversity, and carbon fluxes. Citizen science initiatives that engage local communities will also be significant contributors to data collection.

Policies should be nested from the global level to the local level. The implementations of relevant international agreements, such as the UN High Seas Treaty, the Convention on Biological Diversity, and the Sendai Framework for Disaster Risk Reduction, should be strengthened at the local level by enhancing training for community stakeholders. Regional partnerships should enforce transboundary governance initiatives, such as the Coral Triangle Initiative, to facilitate the management of shared resources and pollution among neighboring states. National and local policies can be refined based on the principle of marine spatial planning. Community-level non-government organizations (NGOs) can help promote citizen science.

With the enablers, Blue Sustainable Development will establish a new sustainability paradigm for managing ocean-based goods and services as a collaborative common. The framework magnifies the interconnected nature of ocean systems and ocean-based economies. Thus, it guides nations relying on marine-based goods and services in refining their development strategies by amplifying synergies between ecological conservation, climate resilience, and socioeconomic equality, thereby accelerating the pace of achieving sustainable development goals based on the oceans.

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AUTHOR CONTRIBUTIONS

All authors contributed to the manuscript and approved the final version.

DECLARATION OF INTERESTS

The authors declare no competing interests.