PEMSEA

Status, Trends, and Transitions

in Coastal and Ocean Governance and Ecosystems Amidst the Triple Planetary Crisis and Emerging Polycrisis

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About Us

Partnerships in Environmental Management for the Seas of East Asia (PEMSEA) is a regional coordinating mechanism for the sustainable coastal and marine development in the East Asian Seas Region.

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List of Acronyms

ACB	ASEAN Centre for Biodiversity
ACCSAP	ASEAN Climate Change Strategic Action Plan
ADB	Asian Development Bank
ALDFG	Abandoned, Lost, or Otherwise Discarded Fishing Gear
AI	Artificial Intelligence
ASEAN	Association of Southeast Asian Nations
ATSEA	Arafura and Timor Seas Ecosystem Action
BBNJ	Biodiversity Beyond National Jurisdiction
BC	Blue Carbon
BE	Blue Economy
BECCS	Bioenergy with Carbon Capture and Storage
BOD	Biochemical Oxygen Demand
CBD	Convention on Biological Diversity
CCPI	Climate Change Performance Index
CEARAC	Special Monitoring and Coastal Environmental Assessment Regional Activity Centre
CO_2	Carbon Dioxide
COBSEA	Coordinating Body on the Seas of East Asia
CMS	CounterMEASURE II Project
CTI-CFF	Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security
DAC	Direct Air Capture
DIN	Dissolved Inorganic Nitrogen
EAS	East Asian Seas
ENSO	El Niño–Southern Oscillation
EPR	Extended Producer Responsibility
FAO	Food and Agriculture Organization
GEF	Global Environment Facility
GFI	Greenhouse Gas Fuel Intensity
GHG	Greenhouse Gas
GGGI	Global Green Growth Institute
GNC	Global Nutrient Cycling
GRID	Green, Resilient, and Inclusive Development
HABs	Harmful Algal Blooms
IAEA	International Atomic Energy Agency
IAS	Invasive Alien Species

ICM	Integrated Coastal Management
IMO	International Maritime Organization
INCOM	Interconvention Nitrogen Coordination Mechanism
INA	International Nitrogen Assessment
INC	Intergovernmental Negotiating Committee
IOC-UNESCO	Intergovernmental Oceanographic Commission of UNESCO
IoT	Internet of Things
IP	Implementation Plan
IRBM	Integrated River Basin Management
IUU	Illegal, Unreported, and Unregulated
IUCN Asia-Pacific	International Union for Conservation of Nature Asia-Pacific
IWRM	Integrated Water Resources Management
KMGBF	Kunming-Montreal Global Biodiversity Framework
LMEs	Large Marine Ecosystems
MARPOL	International Convention on Prevention of Pollution from Ships
mCDR	Marine Carbon Dioxide Removal
MEP	Marine Environment Protector
MPAs	Marine Protected Areas
MWI	Mismanaged Waste Index
N	Nitrogen
NAPs	National Adaptation Plans
NBSAPs	National Biodiversity Strategies and Action Plans
NDCs	Nationally Determined Contributions
NEAMPAN	North East Asian Marine Protected Area Network
NH_3-N	Ammoniacal Nitrogen
NH_4+	Ammonium
NO_2-N	Nitrite Nitrogen
NO_3-N:	Nitrate Nitrogen
NOWPAP	Northwest Pacific Action Plan
NPAP	National Plastic Action Plan
NUTEC	Nuclear Technology
P	Phosphorus
PACS	Plastics Analysis and Characterization Studies
PEMSEA	Partnerships in Environmental Management for the Seas of East Asia
pH	Potential of Hydrogen
PPM	Parts Per Million
PPE	Personal Protective Equipment
R&D	Research and Development
RA	Republic Act

RAP	Regional Action Plan
RAP MALI	Regional Action Plan on Marine Litter
RCP	Representative Concentration Pathways
SAP	Strategic Action Programme/Plan
SCS-SAP	South China Sea Strategic Action Programme
SDG	Sustainable Development Goals
SDS-SEA	Sustainable Development Strategy for the Seas of East Asia
SEA-MaP	Southeast Asia Regional Program on Combating Marine Plastics
SORB	State of River Basin
SSP	Shared Socio-economic Pathways
TEK	Traditional Ecological Knowledge
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UNCLOS	UN Convention on the Law of the Sea
UNEA	UN Environment Assembly
UNEP	United Nations Environment Programme
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization
WTO	World Trade Organization
WWF	World Wildlife Fund

Executive Summary

The ocean is at a tipping point, facing increasing threats from the *triple planetary crisis* of climate change, biodiversity loss, and pollution, now intensified by a broader *polycrisis* of economic instability, food insecurity, as well as geopolitical tensions. These interconnected challenges are already impacting on ecosystems, human well-being, and economic stability, particularly in the East Asian Seas (EAS) region, where densely populated and ecologically rich coastlines are highly vulnerable. Coastal and marine sectors are under increasing pressure from sea-level rise, ocean warming, acidification, and habitat degradation. Yet, they also offer vital solutions, including blue carbon restoration, offshore renewables, sustainable fisheries, and marine biotechnology, among others. In order to promote resilience and recovery among the most vulnerable, efforts on blue economy must strategically prioritize integration, equity, and science.

This report synthesizes recent developments, trends, and projections in coastal and ocean governance and ecosystems drawing from the latest global, regional, and national data to inform the design of future strategies, especially the updated Sustainable Development Strategy for the Seas of East Asia (SDS-SEA) Implementation Plan for 2023–2030.

The report noted that in spite of the obstacles, global momentum is increasing. This is evident in the Third UN Ocean Conference held in Nice, France, in June 2025, where more than 800 voluntary commitments were gathered, which advanced SDG 14 by establishing new targets on blue finance, deep-sea mining regulation, and marine protected areas. One of the key outcomes was the first-ever coalition of nine key regional organizations in the East Asian Seas region (ATSEA, ACB, COBSEA, CTI-CFF, IOC-WESTPAC, IUCN Asia-Pacific, NEAMPAN, PEMSEA, and the SCS-SAP Project), which agreed on a framework for a Regional Collaborative Network of Marine Protected Areas (MPAs) for the East Asian Seas.

The report also noted a number of recently adopted international environment-related commitments (e.g., KMGBF, BBNJ Agreement, WTO Agreement on Fisheries Subsidies, Revised IMO Biofouling Guidelines, IMO Net-Zero Framework), with others underway (e.g., International Plastics Treaty), highlighting growing global commitment toward sustainable ocean management and development. Notably, several countries from the EAS region have already signed or ratified these instruments. Other recent key outputs from the region include the ASEAN Blue Economy Framework and supporting Implementation Plan (2026–2030) and PEMSEA's Xiamen Ministerial Declaration (2024), which align regional action with global priorities, advancing knowledge sharing, inclusivity, and key integrated management approaches and tools that are aligned with global frameworks like the UN Decade of Ocean Science and Ecosystem Restoration.

In terms of meeting the UN Sustainable Development Goals (SDG) targets, the EAS region shows uneven SDG performance. For SDG 14, in particular, EAS countries perform well on MPAs and aquaculture (14.5, 14.7), but face ongoing challenges with marine pollution, IUU fishing, and access for small-scale fishers (14.1, 14.4, 14.b).

Yet, major challenges persist. Analysis of recent developments in governance and ecosystem status highlights:

- Escalating systemic risks and polycrisis dynamics
- Persistent fragmentation in policy and institutional frameworks
- Gaps in monitoring, data availability, science, innovation, and technology access
- Increased demand for sustainable finance and measurable impact
- Deepening social and ecological vulnerabilities
- The rising urgency for regional cooperation

To address these, a strategic shift is needed, from incremental improvements to transformative, integrated, and inclusive action. PEMSEA and its partners are well-positioned to lead this transformation by serving as a regional integrator, bridging national and local priorities with global commitments, building on the substantial progress made through the PEMSEA partnership over the years.

Based on the synthesis of trends, challenges, and opportunities, the following strategic priorities may serve as reference for identification of strategic action areas in the medium- and long-term, to advance ocean governance and sustainable blue economy transitions in the East Asian Seas region:

- Data, Monitoring, and Research: Strengthen the science-policy interface through improved data systems, ecosystem assessments, and long-term monitoring.
- Policy, Governance, and Regulatory Alignment: Promote coherence across national and regional policies aligned with international commitments.
- Technology, Innovation, and Equitable Adoption: Accelerate access to marine technologies and innovations, ensuring inclusive benefits.
- Capacity Building and Inclusive Governance: Empower local actors, marginalized groups, and youth in decision-making and implementation.
- Innovative and Diversified Financing: Mobilize blended finance and strengthen blue finance pipelines for ecosystem restoration and climate adaptation.
- Collaboration and Integrated Approaches: Deepen multi-level, cross-sectoral cooperation and regional partnerships, and scale up application of integrated ecosystem- or area-based and adaptation approaches.

In conclusion, the East Asian Seas region needs to embrace bold leadership and strengthened partnership as opportunities arise and risks increase. Regional ocean governance can create resilient blue economy pathways and provide real benefits for people, the environment, and the climate by emphasizing integration, innovation, and inclusion.

1 Introduction

"Our world is plagued by a perfect storm on a number of fronts … the lingering effects of the covid-19 pandemic … a growing climate disaster, and worsening violent conflicts … All these challenges are inter-linked … There are no perfect solutions in a perfect storm. But we can work to control the damage and to seize the opportunities available." – UN Secretary-General António Guterres, remarks at the World Economic Forum, January 18, 2023.

The *triple planetary crisis*—climate change, biodiversity loss, and pollution—first emerged in the early 2000s and gradually gained traction through successive UN Environment Assemblies and global reports. By 2022, the United Nations Environment Programme (UNEP) formally adopted the term, emphasizing that these three crises are deeply interconnected and must be addressed collectively as they pose a profound threat to ecosystems, human well-being, and economic stability (UNEA, 2022; UNEP, 2023b).

The call for integrated, whole-of-society approaches—spanning environmental, social, political, and economic dimensions—has long been central to sustainability discourse and recognized in numerous studies and policy frameworks. However, the pace and complexity of global change have accelerated dramatically in recent years. Environmental emergencies are now intersecting with broader global disruptions prompting the resurgence of the *polycrisis* concept in international forums (Tooze, 2022; European Commission, 2023; WEF, 2025, UNEP, 2024).

In this evolving context, the triple planetary crisis remains a core driver, but is increasingly seen as part of a broader and compounding set of systemic threats. While integrated approaches are already being applied in many countries and regions, they must be strategically reinforced, scaled up, and adapted to today's rapidly evolving and dynamic global environment, in order to build resilience and secure a more sustainable and equitable future.

The frameworks of the triple planetary crisis and the broader polycrisis are essential for understanding both the current and emerging dynamics of coastal and ocean governance, particularly in the East Asian Seas region, where densely populated coastlines and rich marine biodiversity face increasing pressures. Climate and disaster-related impacts, marine pollution, and ecosystem degradation threaten not only environmental stability but also livelihoods, food

security, and economic resilience. Yet, these challenges also present strategic entry points for innovation, investment, and strengthened governance as countries in the region reassess and recalibrate their efforts toward 2030.

In 2021, PEMSEA released its Post-2020 Futures Report and Strategy, offering a foresight-driven assessment of trends shaping ocean governance in the region. The report provided a foundation for PEMSEA's broader 2030 Roadmap and SDS-SEA Implementation Plan (IP) 2023–2027, adopted by the East Asian Seas Partnership Council in 2021 and 2022. The Report's findings remain relevant, and this study builds on that foundation by incorporating more recent developments and data mainly from 2021 onward at global, regional, and national levels. The aim is to offer updated insights that can guide the design of the updated SDS-SEA IP 2023–2030 (and even beyond).

Triple Planetary Crisis and Polycrisis in Brief

Triple Planetary Crisis

This concept refers to the three interrelated global environmental emergencies:

- Climate change: driving extreme weather, sea level rise, and ocean warming.
- Biodiversity loss: accelerating species extinction and ecosystem collapse.
- Pollution: including plastic waste, chemicals, and nutrient runoff harming land, air, and water systems.

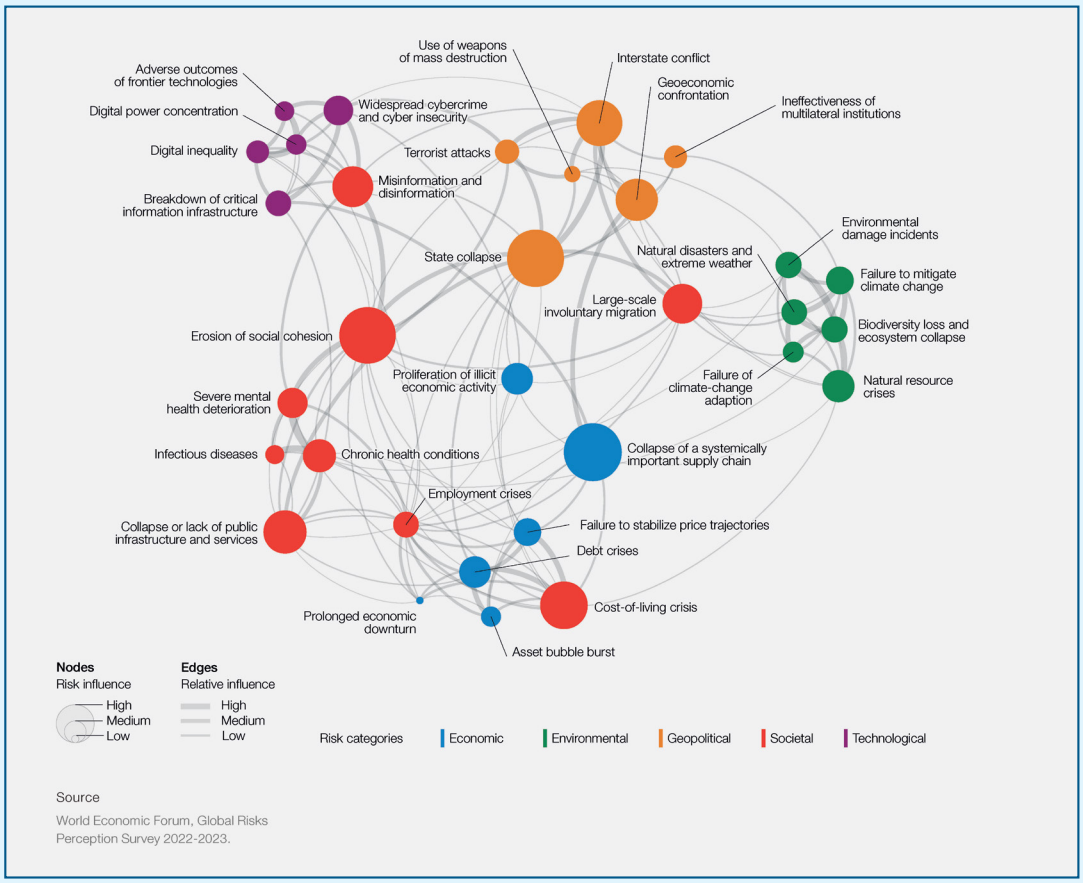
These crises reinforce one another and must be addressed collectively to avoid undermining progress in any one area. (UNEP, 2021a)

Polycrisis

The term polycrisis has seen a modern revival through its prominent use in the World Economic Forum's Global Risks Reports (2023 & 2024), speeches by UN Secretary-General highlighting interconnected global threats, and renewed attention from leading think tanks in analyzing today's complex governance challenges.

- The triple planetary crisis is a central component of this broader framework. It describes a convergence of multiple, interconnected crises-environmental, economic, social, political, and technological, that amplify each other's impacts. (Tooze, 2022; European Commission, 2023)
- Four multi-decade structural forces that are shaping the global risks landscape: Technological acceleration, Geostrategic shifts, Climate Change, Demographic bifurcation (WEF, 2025)

- 18 Emerging signals of change and potential disruptions: thawing of hidden ancient microbes, new emerging zoonotic disease, antimicrobial resistance reaching critical levels, unforeseen impacts of harmful chemical and materials, rapid expansion of space activity, emerging mindset of continuous learning and 'exnovation', deployment of solar radiation modification, autonomous and artificial intelligence weapons systems, amplifying risks of biological agents misuse, uninhabitable spaces, privatized microenvironmentalism, uninsurable future, detachment of decisions from scientific evidence, eco-anxiety, surging fossil fuel subsidies, corruption in carbon offsetting, new tools for rerouting global financial flows, local and network-driven resilience (UNEP, 2024)



Source

World Economic Forum, Global Risks Perception Survey 2022-2023.

Photo by R. Razon/PEMSEA

2 Status and Emerging Trends in Coastal and Ocean Systems and Governance

Coastal and ocean ecosystems are crucial to global sustainability, regulating climate, supporting biodiversity, and sustaining the livelihoods of billions. In the East Asian Seas (EAS) region, these ecosystems play a particularly vital role in underpinning food security, economic activity, disaster resilience, and cultural identity across some of the world's most densely populated and ecologically diverse coastlines. However, these systems are under increasing threat from climate change, biodiversity loss, and pollution, further complicated by socio-economic and geopolitical challenges, as well as rapid technological advancements.

As PEMSEA prepares for 2030, understanding the current status and emerging trends in coastal and ocean systems and governance is important. The subsequent sections highlight changes, developments, challenges and opportunities in line with the triple planetary crisis, as well as both traditional and emerging blue economy sectors, with information spanning global to national levels.

Tracking the Triple Planetary Crisis

A. CLIMATE CHANGE

SELECTED HIGHLIGHTS

Global Climate Status

- CO_2 concentration: 420 ppm in 2023 (+151% vs. pre-industrial)
- 2024: Warmest year recorded (+1.55°C vs. 1850-1900 average)
- Global sea level rise: New high, rate doubled since early satellite data
- Ocean heat content: 8th consecutive record high year
- Ocean acidification: 25% of CO_2 emissions absorbed (2014-2023)
- 40% of surface and 60% of subsurface ocean exceed safe acidity thresholds
- Glacier mass balance: 2023/24 among 3 worst years
- Strong El Niño amplified warming (2023-2024)

Climate Vulnerabilities in East and SE Asia

- Frequent typhoons, flooding, and droughts already observed
- Sea level rise projection (SE Asia): 0.11-0.70 m by 2100
- By 2070: Coastal flooding to impact >50M people annually
- Riverine flooding: US$1.3 trillion damages, 110M people affected

Temperature and Sea Change by 2100 (High Emissions)

- East Asia: +7°C, Southeast Asia: +5°C (high-emissions scenario)
- Extreme heat (>35°C): 50 days/year (East Asia); >180 days/year (SE Asia)
- Sea warming: +1.1°C to +2.9oC average increase

Economic Risks (Asia-Pacific, by 2070)

- GDP losses under SSP5-8.5: -16.9% (up to -26.7%)
- Most affected: Bangladesh (-30.5%), Viet Nam (-30.2%), Indonesia (-26.8%)
- Breakdown of GDP losses:
  - Sea level rise and storm surge: 6.3%
  - Increased cooling demand: 3.3%
  - Riverine flooding: 2.2%
  - Agriculture/ fisheries/ forestry losses: 2.1%

Climate Policy and Energy Trends (CCPI, 2025)*

- Very low performers: China Japan, RO Korea
- Low performers: Indonesia, Malaysia
- High performing: Philippines (esp. energy use)
- China: Top GHG emitter, but strong in renewables
- Japan: Low climate policy rating among G20 countries

** The Climate Change Performance Index (CCPI) 2025, looks at four categories: GHG emissions, renewable energy, energy use, and climate policy*

Recent Status

Climate change is an accelerating present reality. The State of Global Climate described 2024 as a year of record-breaking changes across eight major climate indicators, reflecting an intensifying climate crisis. These indicators include atmospheric greenhouse gas (GHG) concentrations, global mean near-surface temperature, ocean heat content, global mean sea level, ocean surface pH, glacier mass balance, sea-ice extent, and the El Niño–Southern Oscillation (ENSO).

The amount of carbon dioxide (CO_2) in the atmosphere reached an all-time high in 2023 at 420.0 parts per million (ppm), 151% higher than pre-industrial levels, and continued to rise in 2024. The global mean near-surface temperature in 2024 also surpassed the 2023 record and became the warmest year in the 175-year observational record, with 1.55°C above the 1850-1900 average. The global mean sea level reached a new high record, with the rate of rise more than doubling from the early satellite record. Ocean heat content also hit its highest level on record, continuing an eight-year trend of increases. These trends are mainly caused by greenhouse gases released from human activities, with carbon dioxide (CO_2) accounting for about two-thirds of the warming effect since the year 1750 (WMO, 2025).

Due to the absorption of nearly a quarter of human-generated CO_2 emissions from 2014-2023, oceans continue to acidify with a steady decline in surface pH observed over the past four decades (WMO, 2025). Based on a recent ocean acidification planetary boundary assessment, global average ocean conditions had already exceeded safe thresholds by the year 2020, affecting up to 60% of the global subsurface ocean and over 40% of the global surface ocean, causing shrinking habitats for corals, pteropods, and bivalves (Findlay, H., et al., 2025).

According to preliminary data for the hydrological year 2023/2024 there has been another year of severe loss of glacier mass, contributing to the three most negative years on record for glacier mass balance. A strong El Niño event that started in mid-2023 and ended in mid-2024, further amplified global warming during the year. Collectively, these indicators demonstrate a continued and, in many cases, accelerated pace of climate change (WMO, 2025).

The East and Southeast Asian region is home to some of the world's most climate-vulnerable countries and is already experiencing frequent extreme weather events, including typhoons, storm surges, coastal flooding, and prolonged droughts, threatening livelihoods, food security, and economic stability (ADB, 2024).

Based on the Climate Change Performance Index (CCPI) 2025, which looks at four categories [1] including GHG emissions, renewable energy, energy use, and climate policy, East and Southeast Asian countries, specifically China, Japan, and RO Korea were among the 15 countries out of 67 that received very low performance. While the Philippines is among the high performing countries, Viet Nam and Thailand were ranked medium performing, and Indonesia and Malaysia as low performing. The report noted China as the largest emitter of GHG emissions globally, but ranked as one of three best performing G20 countries on renewable energy along with Indonesia and Brazil. Japan received one of the lower ratings among G20 countries in terms of climate policy. In terms of energy use or consumption, the Philippines was the only country receiving very high performance, while RO Korea was listed in the lower range of rankings. (Figure 1)

In a 2024 survey by the ISEAS–Yusof Ishak Institute, 2,931 respondents from 10 ASEAN countries shared views on climate change, policy responses, and regional action. The report reveals that floods (70.3%), heatwaves (51.8%), and landslides triggered by heavy rain (49.8%) are viewed as the most serious climate impacts. Nearly 60% believe their lives will be greatly affected by climate change within the next ten years, with concern rising notably in the Philippines and among higher-income groups. Respondents also reported increasing food insecurity linked to climate-related disasters and policy gaps. National governments are still seen as bearing the most responsibility and cost burden for addressing climate change, though there are varying perceptions in terms of their effectiveness. Businesses are viewed as least active, while support for carbon taxes and cutting fossil fuel subsidies is growing. Solar, hydro, and wind energy were noted as the most favored clean energy options, with increasing interest in hydrogen and nuclear alternatives. Across ASEAN, respondents call for stronger regional cooperation, especially in clean energy infrastructure and financing, to ensure an inclusive and just transition toward a climate-resilient future (Seah et al., 2024).

1 The CCPI 2025 assesses climate action across 63 countries and the EU by weighting GHG Emissions (40%), Renewable Energy (20%), and Energy Use (20%) based on quantitative data, while Climate Policy (20%) is qualitatively evaluated by approximately 450 experts on national and international efforts toward Paris Agreement goals.

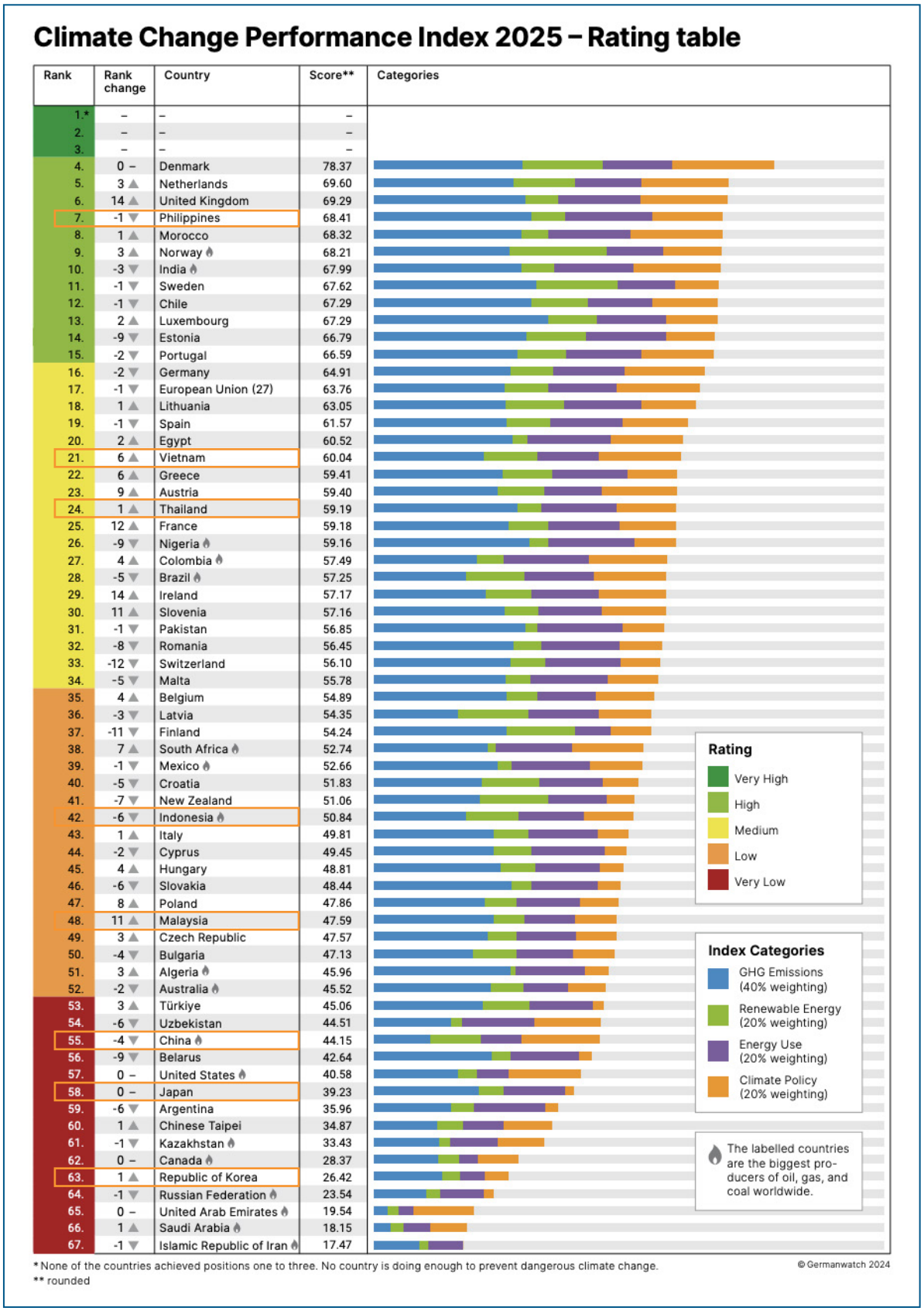


Figure 1. Climate Change Performance Index 2025 Rating Table

Projected Changes, Impacts and Trends

Climate projections suggest that East and Southeast Asia[2] will face increasing biophysical changes throughout the 21st century, even if global greenhouse gas emissions were stopped immediately (ADB, 2024). Severe temperature increases are expected. Under a high-emissions scenario, East Asia may experience average increases of up to 7°C, while Southeast Asia may see increases of nearly 5°C by 2100. East Asia could experience heat extremes of nearly 50 days annually above 35°C, while Southeast Asia may experience extreme heat for over half the year (Climate Tracker Asia, 2024). The surrounding seas are also projected to warm significantly, with average increases between 1.1°C and 2.9°C, further disrupting marine ecosystems and the services they provide (Kay et.al, 2023).

Rising sea levels exacerbate the threat. Under high emissions, sea levels are projected to rise by around 0.8 meters by 2100 worldwide, though local factors and polar ice instability could worsen the impact (ADB, 2024). Parts of Asia and the Pacific are already experiencing relative sea level rise that is twice the global average. In Southeast Asia, especially in coastal areas where the majority of the region's population and infrastructure are concentrated, coastal sea levels could rise by up to 0.70 meters by 2100, intensifying the risk of inundation, saltwater intrusion, and loss of habitable land. Based on satellite altimetry data from 1992–2020, the projection for sea level rise in Southeast Asia's coastal areas ranges from 0.05–0.33 m by 2050 and 0.11–0.70 m by 2100 (Triana and Janottama, 2021).

By 2100, extreme weather events, such as tropical cyclones and typhoons, are projected to become nearly twice as destructive, while rainfall becomes more intense and erratic, raising the likelihood of both severe flooding and prolonged droughts (Dong et al., 2024; ADB, 2024). Coastal erosion, driven by a combination of rising seas, more powerful storm surges, and altered tidal dynamics, is already changing shorelines, damaging critical infrastructure and exacerbating vulnerability especially in Southeast Asia (Kay et al., 2023).

Concerns over declining fisheries in several countries in the region are already being exacerbated by ocean warming and increasing unpredictable weather patterns (Seah et al., 2024). Damages to coral reefs and changes in species distribution are expected under the high-emissions scenario of Representative Concentration Pathways (RCP) 8.5, endangering small-scale fisheries, biodiversity and the food security of coastal populations in Southeast Asia. Though changes in biological systems such as plankton biomass and primary production are less noticeable than those in physical and chemical conditions, they remain significant and potentially disruptive (Kay et al., 2023).

2 The ADB Asia Pacific Climate Report 2024 uses the IPCC standard reference subregions in categorizing regions, with East Asia referring to countries or regions of China, Japan, and Korea, and Southeast Asia referring to Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste, Viet Nam.

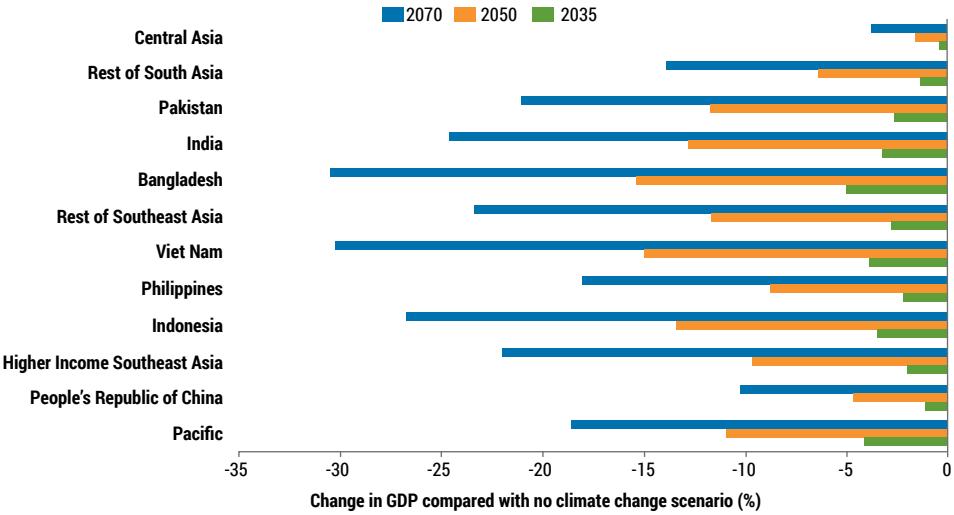
Food security is another growing concern. Southeast Asians viewed prolonged droughts and heat waves, frequently followed by intense flooding, as major threats to availability and affordability of food (Seah et al., 2024). Ocean warming, storm surges, fisheries decline, and saltwater intrusion into farmlands further compound these challenges. Countries such as China, Indonesia, the Philippines, Viet Nam, Malaysia, Singapore, Thailand, Cambodia, Laos, Myanmar, and Timor-Leste are projected to experience reduced crop yields (ADB, 2024).

Human health is also at risk, with rising temperatures expected to reduce labor productivity and increase mortality and health-related risks (ADB, 2024).

Energy demand, particularly for electricity, is projected to rise due to higher cooling needs in East and Southeast Asia (ADB, 2024).

The economic risks posed by climate change are also projected to be severe. By 2070, coastal and riverine flooding could affect over 160 million people annually in Asia and the Pacific, resulting in trillions of dollars in damages under a high-end emissions scenario. Sea-level rise, storm surges, and flooding alone could impact more than 50 million people each year, while riverine flooding could cause up to USD 1.3 trillion in damages and affect over 110 million people. Increased rainfall variability and extreme storms will increase the risk of landslides, especially in mountainous areas (ADB, 2024).

Overall, climate change could lead to a loss of up to 16.9% of regional GDP in Asia and the Pacific by 2070 under the Shared SocioEconomic Pathways (SSP) 5-8.5 scenario. Included in the most vulnerable countries are Bangladesh (-30.5%), Viet Nam (-30.2%), and Indonesia (-26.8%). In more extreme projections, regional GDP losses could reach 26.7%. These estimates probably understate the full impact, as they do not account for broader effects on human health, ecosystem services, or social stability. Sea-level rise and storm surges are projected to be the largest contributors to GDP loss (6.3%), followed by increased energy demand for cooling (3.3%), riverine flooding (2.2%), and reductions in natural resources such as agriculture, forestry, and fisheries (2.1%). Even under more moderate scenarios like RCP4.5 and RCP2.6, the Asia Pacific region is expected to face substantial economic losses, underscoring the urgent need for adaptation alongside mitigation efforts (Figure 2) (ADB, 2024).



GDP = gross domestic product.

Notes: The scenario depicted is SSP5-8.5. Central Asia comprises Armenia Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan Turkmenistan and Uzbekistan. The Higher Income Southeast Asia comprises Brunia Darussalam Malaysia, Singapore, and Thailand. The Pacific comprises the Cook Islands, the Federated States of Micronesia, Fiji, Kiribati, the Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Rest of South Asia comprises Afghanistan Bhutan, Maldives, Nepal, and Sri Lanka. Rest of Southeast Asia comprises Cambodia, the Lao People's Democratic Republic, Myanmar, and Timor-Leste.

Source: Campagnolo, L., G. Mansi, F. Bosello, and D. A. Raitzer. 2024. Quantifying the Economic Costs of Climare Change Inaction for the Asia-Pacific Region. Background paper for the *Asia-Pacific Climate Report 2024: Catalyzing Finance and Policy Solutions.* Asian Development Bank.

Figure 2. Loss of Gross Domestic Product due to Climate Change Under a High-End Emissions Scenario (ADB, 2024)

Recent Initiatives

Several global and regional programs are aligning climate action with sustainable development and resilience goals. By incorporating climate goals into economic development, The World Bank Group's Climate Change Action Plan (2021–2025) advances a Green, Resilient, and Inclusive Development (GRID) approach. It focuses on high-emission sectors for mitigation, scales adaptation, and emphasizes gender-sensitive climate strategies to ensure equitable benefits (World Bank Group, 2021). Similarly, the Global Green Growth Institute's Asia Regional Strategy (2021–2025) supports post-COVID green recovery by promoting renewable energy, circular economy systems, and coastal resilience while leveraging private capital for nature-based solutions and measurable GHG reductions (GGGI, 2021). The International Maritime Organization (IMO) has also taken significant step by approving an IMO Net-Zero Framework, which combines mandatory GHG emissions limits with a global GHG pricing mechanism for the international shipping industry. The framework is expected to be formally adopted in October 2025 and enter into force by 2027 and will be included in a new Chapter 5 of Annex VI of the International Convention on Prevention of Pollution from Ships (MARPOL). The framework establishes a two-tiered system of Greenhouse Gas Fuel Intensity (GFI) reduction targets and introduces the IMO Net-Zero Fund to support the transition. The approved measures will apply to large ocean-going vessels (ships of 5,000 gross tonnage and above) responsible for a substantial portion of international shipping emissions.

At the regional level, the ASEAN Climate Change Strategic Action Plan (ACCSAP) 2025–2030 builds on earlier efforts to implement Nationally Determined Contributions (NDCs), enhance finance and technology support, and foster ASEAN-wide coordination through initiatives such as the ASEAN Climate Change Centre. Complementing these efforts, green finance mechanisms led by ADB and ASEAN, including green bonds, are catalyzing investments in climate-resilient projects. Another initiative is PEMSEA's Blue Carbon Program, supported by a Technical Working Group, which aims to contribute to improving carbon sequestration and coastal resilience by conserving and restoring coastal ecosystems, such as mangroves, seagrasses, and tidal marshes. The program integrates science and policy through the conduct of regional studies (i.e., Assessing the Supply Side of Blue Carbon in ICM and other local sites in the EAS Region and Harmonizing Blue Carbon Accounting Protocols for Coastal Ecosystems in the EAS Region) toward the development of a regional blue carbon accounting protocol, standardized monitoring and certification systems, supports capacity-building via regional trainings, and advances the inclusion of blue carbon in national policies and carbon finance mechanisms.

Most countries in the Asia and Pacific region have prepared National Adaptation Plans (NAPs) and included adaptation priorities in their NDCs as part of their commitments under the Paris Agreement. 36 out of the 44 economies that ratified the Paris Agreement have announced or adopted net zero targets. However, there is a recognized need for concrete roadmaps and to better integrate adaptation into medium-term development plans and expenditure frameworks (ADB, 2024a).

In East Asian countries, the following plans were adopted in support of Climate Change Adaptation (Source: Mid-term Review of PEMSEA's SDS-SEA Implementation Plan 2023-2027):

Country	Key CCA-Related Plans
Cambodia	Climate Change Strategic Plan (CCCSP) 2024-2033
China	National Climate Change Adaptation Strategy to 2035
Indonesia	National Action Plan for Climate Change Adaptation (RAN-API)
Japan	National Plan for Global Warming Prevention (revised in 2025)
Lao PDR	National Strategy on Climate Change of the Lao PDR Vision to the year 2050, Strategy and Programs of Actions to the year 2030
Philippines	National Adaptation Plan (NAP) of the Philippines 2023-2050; Nationally Determined Contribution Implementation Plan 2023-2030

Country	Key CCA-Related Plans
RO Korea	Third National Action Plan (for 2021–2025)
Singapore	National Climate Change Strategy (2012); Climate Action Plan (strategies to achieve 2030 pledge); Long-term Low Emissions Development Strategy (LEDS)
Timor-Leste	First National Adaptation Plan (NAP); National Mitigation Plan (development ongoing)
Viet Nam	National Adaptation Plan (NAP) for the period 2021-2030, with a vision to 2050

To address coastal erosion and protect coastlines, countries in Southeast Asia are using a combination of hard and soft approaches. For instance, Viet Nam has deployed geotube seawalls and reinforced sea dikes with concrete revetments, while Thailand uses stepped rock and concrete revetments that also support tourism and vegetation. Singapore has fortified 70-80% of its coastline with hard walls and embankments. Nature-based soft measures are also becoming popular as low-cost, sustainable solutions. Some examples are Viet Nam's Mekong Delta bamboo fences and geotube breakwaters to reduce wave energy and enhance sedimentation, and Indonesia's permeable dams, among others (Dong et al., 2024).

In terms of technological innovations, one emerging field to monitor and address climate change is Blue Technology (Blue Tech), where startups are creating innovative solutions at the ocean-climate nexus to address issues like climate change, pollution, and biodiversity loss. Underwater robots for data collection and maritime security, marine carbon dioxide removal (mCDR) to extract CO_2 from seawater, energy-efficient industrial technologies for shipping and wastewater are some of the innovations. Ocean sensors aid in scientific research and naval operations, while enhanced aquaculture methods aim to produce seafood more sustainably. The sector is attracting increasing investment, with most funding going to the industrial and aquaculture sectors (J.P. Morgan, 2024 May 8). Artificial Intelligence (AI) and climate technology advancements are also helping to address climate change, particularly through carbon capture and intelligent systems that optimize energy use, forecast climate risks, and streamline sustainability planning across sectors. (e.g., technologies like Direct Air Capture (DAC) and Bioenergy with Carbon Capture and Storage (BECCS), and AI-powered tools such as IBM's emissions monitoring systems and Carbon Trail's AI Copilot) (Carbon Trail, 2024 December 15).

Key Recommendations Identified from Existing Studies

The following compilation synthesizes key recommendations drawn from various climate-related studies:

1) **Policy and Strategic Frameworks**
   - o Enhance integration of National Adaptation Plans (NAPs) and Nationally Determined Contributions (NDCs) into medium-term development plans and budgets
   - o Develop concrete sector-specific roadmaps to support net-zero targets
   - o Mainstream climate adaptation and mitigation, as well as disaster management, in ocean governance and policies
   - o Develop financial incentives (e.g., clean energy fund)
2) **Adaptation Measures and Initiatives**
   - o Expand soft and hard solutions to strengthen coastal resilience and protection
   - o Advance community-level adaptation and planning
   - o Promote market reforms that can help build adaptive capacity (e.g., eliminate harmful resource subsidies)
   - o Conduct assessments or reassessments and communicate results to inform planning and decision-making
   - o Promote interdisciplinary research
3) **Mitigation Efforts and Energy Transition**
   - o Promote decarbonization through renewable energy and energy efficiency
   - o Reallocate and rationalize fossil fuel subsidies toward social and green transition programs
   - o Implement carbon taxes and emissions trading systems
   - o Engage in international carbon markets with robust national strategies
4) **Technological Innovations and Approaches**
   - o Develop data sharing protocols and systems, support R&D, strengthen use of AI or digital tools, and promote blue technology solutions to support data analysis, monitoring, and forecasting
5) **Public Engagement, Capacity Building and Awareness**
   - o Enhance climate education and communication to promote behavior change and make climate data more understandable, accessible and actionable
   - o Ensure inclusive participation by involving indigenous and local knowledge systems in planning and decision-making processes
   - o Invest in skills, infrastructure, funding and access to information

B. MARINE POLLUTION

This section covers marine (1) marine plastic litter, (2) nutrient pollution, (3) oil spills, and (4) biofouling.

Marine Litter

Marine plastic litter is perhaps the most visible and widely recognized form of ocean pollution. Yet despite growing awareness and a surge of initiatives worldwide, it remains one of the most persistent and pressing environmental challenges, with far-reaching impacts on ecosystems, economies, and communities.

SELECTED HIGHLIGHTS

Global Status

- 85% plastics (mainly synthetic polymers and thermosets) (UNEP, 2021b)
- Estimated volume in ocean: 75-199 million metric tons
- Global plastic presence from surface to deep ocean

Regional Sources and Hotspots

- Top 5 Southeast Asian countries for plastic waste generation Indonesia, Thailand,, Viet Nam Philippines, Malaysia
- 1.14 kg/capita/day (Arumdani et al., 2021)
- 80% of marine plastic waste comes from 1,000+ rivers, mostly in Asia (Yu R-S et al., 2023)

Mismanaged Waste Index 2023

- MWI classifications of select countries
- Very High: Cambodia, Indonesia, Myanmar, Philippines, Thailand, Timor-Leste
- High: Malaysia, Lao PDR
- Low: China, RO Korea, Viet Nam
- Very Low: Japan, Singapore

Projected Trends

- 2x increase by 2023
- 3x increase by 2040
- Up to 12 billion metric tons by 2050 in the natural environment (Ng CH, et al., 2023; UNEP, 2021b; Yu R-S, et al., 2023)

Ecological Damage

- Entanglement, ingestion, suffocation
- Coral disease risk increase (due to plastic contact)
- ALDFG (fishing gear) and sea-based pollution > major contributor
- PPE use during COVID-19 > rising land-sea waste

Recent Status

Marine litter and plastic pollution pose a significant threat to marine ecosystems and, potentially, human health (Râpă et al., 2024). At least 85% of the total marine waste is made up of plastics, particularly synthetic polymers and thermosets. The volume of plastics currently in the oceans is estimated to be between 75 and 199 million metric tons. This pollution is widespread and found in all major oceans, from the deepest abyssal environments to remote islands (UNEP, 2021b).

Most marine litter and plastic pollution originate from land-based sources, with 80% of global annual emissions coming from over 1,000 rivers, mainly in Asia. Most of the plastic waste in the ocean is composed of macro-, meso-, and microplastics, with small microplastics making up the highest number of particles on the ocean surface (Yu R-S et al., 2023) (Figure 3). With a generation of 31 million tons of plastic waste annually, Southeast Asian countries are considered significant contributors to the leakage of land-based plastic waste into the seas (Julius and Trajano, 2022 as cited in Ng CH et al., 2023). Indonesia, Thailand, Viet Nam, the Philippines, and Malaysia are the top five countries for the production of large municipal solid waste, at 1.14 kg/capita/day worldwide (Arumdani et al., 2021 as cited in Ng CH et al., 2023).

According to the Mismanaged Waste Index (MWI) for 2023, 97 countries were classified as having a very high MWI level, including Cambodia, Indonesia, Myanmar, Philippines, Thailand and Timor-Leste; 26 countries, such as Malaysia and Lao PDR were rated as high; 17 countries as medium; 31 countries, including China, RO Korea, and Viet Nam, as low; and 41 countries, including Japan and Singapore, as very low (Figure 4) (World Population Review, 2023).

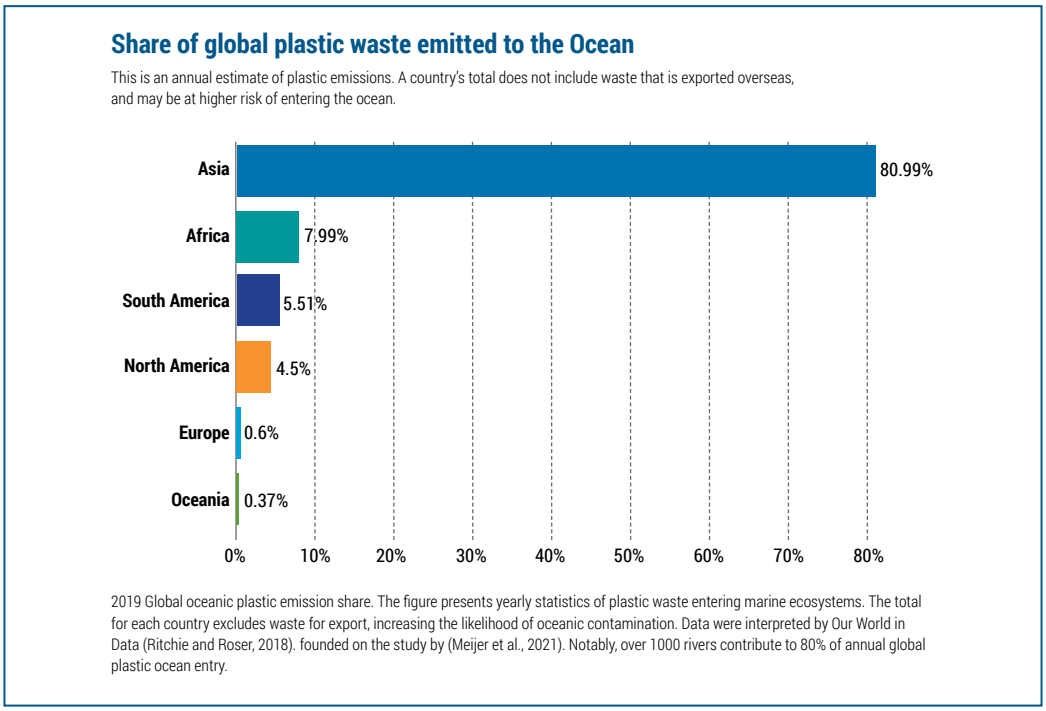


Figure 3. Share of Plastic Waste Emitted to the Ocean, 2019 (Yu R-S, et al., 2023)

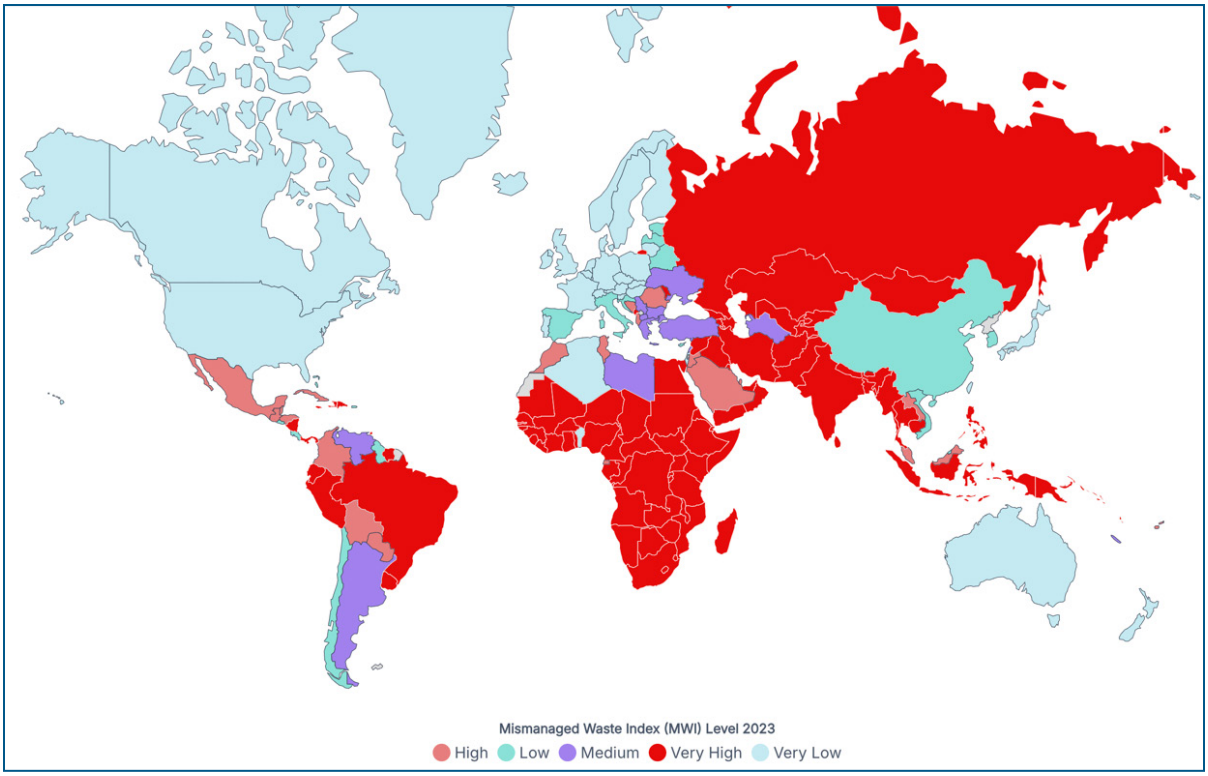


Figure 4. Mismanaged Waste Index Level 2023 (World Population Review)

The first regionally harmonized on-the-ground marine litter survey (covering inland, river, coastal, and sea surface) conducted by CSIRO and COBSEA across Cambodia, Malaysia, the Philippines, Thailand, and Viet Nam, also highlights that majority of the items found originate from mismanaged waste on land. The assessment which covered 1,339 land-based transects and 135 sea surface trawls, revealed that coastlines in the region had the highest debris loads (averaging 5.0 ± 0.5 items per m²). This was followed by river sites (3.0 ± 0.6 items per m²) and inland sites (3.0 ± 0.6 items per m²). The highest average debris density across inland, river, and coastlines combined was found in Thailand, followed by Cambodia, Viet Nam, the Philippines, and Malaysia. In terms of floating debris on sea surface, the highest density of items was found in Phang Nga Bay, off Phuket, Thailand followed by Davao Gulf, off Davao, Philippines. Polystyrene was the most abundant item encountered at sea in the region, followed by soft plastic and plastic lines and fibres. Thailand had much higher densities of floating polystyrene foam and hard plastic, while the Philippines had higher densities of soft plastic, and plastic lines and fibre (CSIRO and COBSEA, 2024).

As for sea-based sources, the largest component of marine litter associated with fisheries and aquaculture is ALDFG (abandoned, lost, or otherwise discarded fishing gear) and wear and tear on aquaculture installations. Regional hotspots for marine debris accumulation include the Mediterranean Sea, the Arctic Ocean, and the East Asia and ASEAN region (UNEP, 2021b). The

Mediterranean Sea is noted as the most polluted sea in Europe, with an estimated accumulated amount of 1.2 million tons of plastic debris and with an additional amount of 229,000 tons of plastic litter flowing into the sea every year (Râpă et al., 2024). While as noted above, Asia contributes the highest estimate of plastic emissions globally.

Accumulation of marine litter and plastic pollution is primarily attributed to waste mismanagement, lack of disposal facilities, increasing demand for disposable products, increased use of single use plastics during COVID, heightened fishing activities, and urban stormwater (Râpă et al., 2024; Jain, 2020 as cited in Ng CH et al., 2023).

Projected Impacts and Trends

The amount of plastics in the oceans is projected to double by 2030 and triple by 2040 if current global plastic production trends continue and no significant action is taken (Ng CH et al., 2023; UNEP, 2021b). By 2050, it is estimated that up to 12,000 million metric tons of plastic waste could be in the natural environment (Yu R-S et al., 2023). The volume of plastic waste from both land-based and sea-based activities continues to grow, with items like personal protective equipment (PPE) used during the COVID-19 pandemic adding to the concern. The sources indicate no evidence that dumping of litter from ships at sea has decreased (UNEP, 2021b).

While scientific understanding of marine plastic pollution has grown, significant knowledge gaps remain. In particular, impacts in marine ecosystems are far better documented than in freshwater systems, where research is still limited despite rivers being a major pathway for plastics to the ocean. In the marine environment, macroplastics cause lethal and non-lethal harm to wildlife through entanglement, suffocation, and ingestion, and gradually degrade into microplastics that release harmful chemical additives. These microplastics are ingested by a wide range of marine species, including seafood consumed by humans, raising concerns about potential impacts on human health, though this remain unclear (UNEP, 2021b). Coral reefs are particularly vulnerable as marine debris can damage coral tissues, create entry points for infection, and significantly increase the risk of disease, with studies showing that rising plastic pollution in reef areas compromises overall reef health (Suman et al., 2023).

Recent Initiatives

In March 2022, the UN Environment Assembly (UNEA-5.2) adopted a landmark resolution to develop a legally binding international instrument on plastic pollution, including in the marine environment, to address the full lifecycle of plastic from source to sea. By April 2025, the Intergovernmental Negotiating Committee (INC) had convened five sessions. Although the initial target was to forge a binding agreement by 2024, negotiations were extended

to 2025 due to key disagreements, particularly over reducing plastic production, banning harmful chemicals, eliminating problematic products, and strengthening design and waste management measures. Despite divisions between oil-producing countries and members of the High Ambition Coalition, a Chair's text was agreed as the basis for continued negotiations in August 2025 in Geneva, Switzerland (UNEP, 2024 December 2). In the lead-up to the Geneva negotiations, "The Nice Call for an Ambitious Treaty on Plastic Pollution" was endorsed by nearly 100 countries during the UN Ocean Conference in Nice, France in June 2025, advocating for a global, science-based agreement addressing the full plastic lifecycle which includes plastic production, phasing out of chemicals of concern and problematic products, improvements to product design, effective means of implementation, and incorporating provisions for an adaptive treaty (Mandard, 2025). At the time of writing, negotiations for the Global Plastics Treaty in Geneva are still underway and are expected to conclude on 14 August 2025.

With the increased attention to marine plastic pollution in recent years, substantial new research has been conducted since earlier reports, providing updated insights into sources, pathways, fate, and impacts of marine litter and plastic pollution. In the ASEAN region, most of the research papers published specifically on marine plastic pollution have appeared from 2017 onwards. (UNEP, 2021b)

There have been significant improvements in monitoring methods and systems for detecting and quantifying litter and microplastics in various environments. Digital technologies, including satellites, drones, and autonomous platforms, are enabling more affordable global monitoring programmes. Machine learning models are being successfully used to predict the distribution and quantities of marine litter, particularly on the seafloor and to identify potential hotspots. For instance, autonomous submarines were used to study the accumulation of debris, largely from fisheries and navigational activities, in the tributary canyons of the Xisha Trough in the northern South China Sea, where accumulation was found to be greater than in any other submarine canyon globally (UNEP, 2021b).

Efforts are also underway to improve monitoring and understanding of plastic pathways, as well as building of capacities on recycling. Some of the key recent initiatives are indicated in Table 1.

Table 1. Examples of Key Recent Initiatives on Land- and Sea-based Plastic Monitoring

Program/Initiative	Brief Description
IAEA's NUTEC Plastics Project (IAEA Nutec Plastics webpage)	Targets pollution at the source by promoting advanced recycling technologies and enhancing marine microplastic monitoring using nuclear science. Currently, 63 countries participate in the monitoring component, with 21 laboratories equipped for basic sampling, five with intermediate capacity (including Japan, the Philippines, and Thailand), and seven with advanced capabilities, such as China. In Asia and the Pacific, NUTEC Plastics also supports polymer waste recycling through radiation technology, with ten countries involved and four pilots—Philippines, Indonesia, Malaysia, and Thailand—leading integrated recycling efforts.
Southeast Asia Regional Program on Combating Marine Plastics (SEA-MaP) (SEA-Map website)	Endorsed by ASEAN Member States in 2022 and will run up to 2027 to prevent land- and sea-based plastic pollution in Southeast Asia. It focuses on reducing plastic consumption, increasing recycling, and minimizing leakage, while strengthening regional policies and institutions for plastics circularity. SEA-MaP also supports innovation, investment, and partnerships through regional platforms, and contributes to monitoring efforts. Its recent output is the *Synthesis Report: Recommendations for a Plastic Pollution Indicator Framework for ASEAN*. The project aligns closely with the ASEAN Regional Action Plan on Combating Marine Debris and highlights progress in areas such as plastic packaging standards and recycled content use.
CounterMEASURE II Project (CMS Counter MEASURE II Project webpage)	The "*Promotion of Action Against Marine Plastic Litter in Asia and the Pacific*," is an initiative funded by Japan and implemented by UNEP Regional Office for Asia and the Pacific. Building on its first phase, which focused on identifying sources of plastic pollution in Asian rivers, the second phase, which started in 2020 expands to assess the impacts of plastic pollution on wildlife, particularly migratory species in the Mekong and Ganges River Basins. The project also focuses on developing monitoring protocols and conducting outreach activities to raise awareness about the impact of plastic pollution on migratory species.

Alongside large-scale monitoring programmes, there are indicator processes and baseline data collection activities at specific locations. The growing number of networks, citizen science projects and participatory processes involved in measuring and tackling marine litter and plastic pollution are yielding results that can support local decision-making. However, in most countries there is no consistent data collection approach suitable for national reporting. (Yu R-S, et.al., 2023).

Various entities are also highlighting *ridge to reef* or *source to sea* as a central framework in marine pollution efforts, guiding integrated management from upland watersheds through river basins to coastal and marine ecosystems to effectively reduce pollution and protect biodiversity. Some key recent initiatives are as follows:

Table 2. Examples of Key Recent Initiatives with Ridge to Reef Emphasis

Organization	Ridge to Reef Emphasis	Recent Programs/Initiatives
ASEAN	ASEAN's Regional Action Plan for Combating Marine Debris (2021–2025) and related frameworks incorporate ridge-to-reef concepts by promoting integrated governance and pollution control across watersheds and coastal zones, and shift to circular plastic economy.	• Established task forces in support of RAP on Marine Debris • Project ASEANO (NIVA and CSEAS Indonesia project in collaboration with PEMSEA and ASEAN) produced the ASEANO Project Toolkit which supports local governments in Indonesia, the Philippines, and Viet Nam with waste management planning, emphasizing circular economy integration • SEA-MaP program as described in the table above
COBSEA	COBSEA's Regional Action Plan on Marine Litter (RAP MALI) and Strategic Directions continue to guide integrated management approaches consistent with ridge-to-reef concepts, with initiatives (monitoring, reduction, enabling policies) covering both land-based and sea-based pollution sources.	• COBSEA Strategic Direction 2023-2027 highlights marine pollution prevention, aligning with SDG 14.1 and relevant UNEA resolutions, through regional guidelines for harmonized marine litter monitoring

Table 2. Examples of Key Recent Initiatives with Ridge to Reef Emphasis (cont.)

Organization	Ridge to Reef Emphasis	Recent Programs/Initiatives
COBSEA		• CSIRO and COBSEA report "Towards a Regional Assessment on Marine Litter in the East Asian Seas," provides harmonized on-the-ground evidence at regional level based on assessments conducted at key sites in Cambodia, Malaysia, the Philippines, Thailand, and Viet Nam. • Other knowledge products developed: (a) Local case studies and pilots on integrated solid waste management good practices to prevent marine litter in Untia, Makassar, Indonesia and Mersing Islands, Malaysia; (b) Proven Practice Guide to Improve Waste Management and Address Plastic Pollution in Southeast Asia; (c) Marine Litter Monitoring Handbook Parts I and II
PEMSEA	PEMSEA's Sustainable Development Strategy for the Seas of East Asia (SDS-SEA) and recent Xiamen Declaration 2024 reaffirm ridge to reef as a key strategy for pollution reduction, ecosystem protection and climate resilience, that is aligned with Integrated Coastal Management (ICM) programs.	• ASEANO Project (as cited under ASEAN) • Marine Plastics ODA Project (2023-2028) funded by the Ministry of Oceans and Fisheries of RO Korea and implemented in 6 sites in the Philippines and 4 sites in Timor-Leste. Key initiatives to date include the Marine Environment Protector (MEP) Program, and application of Plastics Analysis and Characterization Studies (PACS)

Table 2. Examples of Key Recent Initiatives with Ridge to Reef Emphasis (cont.)

Organization	Ridge to Reef Emphasis	Recent Programs/Initiatives
PEMSEA		• GEF/UNDP Integrated River Basin Management (IRBM) Project (2022-2027), in collaboration with ASEAN, supports reduction of pollution, sustaining freshwater environmental flows, and enhancing climate resilience in seven priority river basins draining into the Bay of Bengal, South China Sea, Gulf of Thailand, and Indonesian Sea. The project involving Cambodia, Indonesia, Lao PDR, Philippines, Malaysia, and Viet Nam has initiated development of State of River Basin (SORB) Reports, and assessments for pilot projects with on-the-ground solutions.
ATSEA	The Arafura and Timor Seas (ATS) Strategic Action Programme (SAP) 2024-2033, adopted through a Ministerial Declaration in 2024, identifies four key transboundary issues, including the reduction of marine and coastal pollution including ALDFG.	• With support from the Government of Australia, the ATS region has recently completed an ALDFG Situational Analysis and a Theory of Change to design targeted actions. These efforts are part of the process towards the development of a Regional Action Plan (RAP) to address ALDFG in the ATS region.
World Bank	The World Bank's Waves of Change advisory program, under its Worlds of Change initiative	• This program supports the ASEAN Regional Action Plan for Combating Marine Debris (2021–2025) by generating regional knowledge on plastic packaging standards, waste trade, and pollution assessment methods. Funded by the PROBLUE trust fund, the program also strengthens policy and builds capacity across ASEAN to advance sustainable marine resource management and reduce plastic pollution.

Apart from the above initiatives, various national governments, often with support from international NGOs and development partners, have also launched local marine pollution reduction programs focusing on waste management, plastic reduction, and pollution control in coastal cities and river basins. In East Asian countries, in particular, the following commitments or targets were set to reduce plastic pollution.

Table 3. Country Targets or Initiatives to Reduce Plastic Pollution (East Asian Countries)

Country	Key Target or Initiative to Reduce Plastic Pollution
Cambodia	Cambodia's updated national climate plan includes a pledge to reduce emissions by 41.7% by 2030, with circular economy and plastic reduction as key components.
China	China has implemented a phased ban on single-use plastics, targeting a 30% reduction in single-use plastic bags by 2025 in major cities and a nationwide ban on certain plastic products by 2022–2025. The government promotes circular economy policies, extended producer responsibility (EPR), and plastic recycling targets to reduce marine plastic pollution.
Indonesia	Indonesia has a National Action Plan on Marine Plastic Debris aiming to reduce marine plastic debris by 70% by 2025 through improved waste management, bans on single-use plastics, and community engagement. EPR schemes are being piloted in several provinces.
Japan	Japan targets a 25% reduction in plastic waste generation by 2030, with interim targets for 2025 including significant reductions in single-use plastics and packaging. The country has implemented mandatory recycling laws and promotes EPR schemes for plastic packaging.
Lao PDR	Lao PDR's National Plastic Action Plan (NPAP) 2024–2030 serves as a key national framework that integrates plastic pollution control into the country's broader sustainable development and green growth strategies. Lao PDR has not yet enacted formal Extended Producer Responsibility legislation but is exploring voluntary EPR frameworks as part of the NPAP.
Philippines	The Philippines passed the EPR Act (RA 11898) in 2022, mandating producers to manage plastic packaging waste and reduce plastic pollution. National targets include a 50% reduction in plastic waste leakage by 2025 through bans on single-use plastics, improved collection, and recycling systems.

Table 3. Country Targets or Initiatives to Reduce Plastic Pollution (East Asian Countries)(cont.)

Country	Key Target or Initiative to Reduce Plastic Pollution
RO Korea	RO Korea aims to reduce plastic waste by 40% by 2030, with interim targets for 2025 emphasizing single-use plastic bans, EPR expansion, and circular economy promotion.
Singapore	Singapore aims to reduce plastic pollution through legislative and public engagement initiatives. The Resource Sustainability Act (RSA), introduced in 2019, established the Mandatory Packaging Reporting framework for companies to report on the packaging (including plastic) that they introduce into Singapore annually. Singapore is also developing a beverage container return scheme, which will include plastic bottles. The scheme is scheduled to commence in 2026. The national public campaign "Say YES to Waste Less", launched in 2019, aims to encourage the public to adopt reusable alternatives such as food containers, bottles, and bags for takeaway purchases. Across the hawker centres, the use of reusable cutlery and crockery is encouraged, with some hawker centres banning disposables for dine-in meals.
Timor-Leste	Timor-Leste has declared a zero plastic policy ambition with a commitment to eliminate plastics from the natural environment by 2023. To overcome insufficient infrastructure and regulatory gaps, the government continues to work with local and international partners to build capacity, improve waste management, and reduce plastic pollution in line with this commitment.
Viet Nam	Viet Nam issued a Decree on Packaging, Recycling, and Waste Treatment Obligations in 2022, mandating EPR for manufacturers and importers. The country aims to reduce plastic waste leakage by 50% by 2025 through bans on single-use plastics, improved recycling infrastructure, and public education.

Numerous innovations and solutions are being explored and developed globally. Among these are methods for valuing marine plastic litter through mechanical and chemical recycling, with blockchain technology offering traceability and transparency in the recycling process (Râpă et al., 2024). Innovative technologies like floating booms and nets are being deployed to capture plastic waste in rivers (Yu R-S et al., 2023). In terms of policies, various instruments are being implemented such as virgin plastic taxes, bans on problematic single-use plastics, and Extended Producer Responsibility (EPR) schemes. Sustainable alternatives to plastic are also being developed.

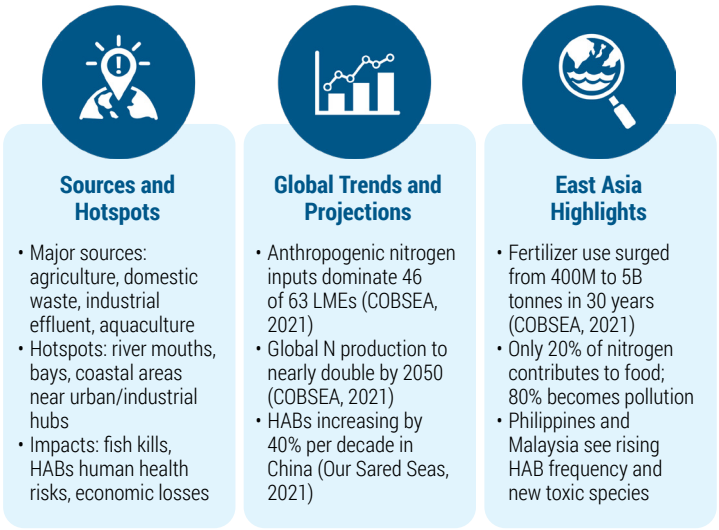
Key Recommendations Identified from Existing Studies

To effectively address plastic pollution, proposed strategies from various studies highlighted the need for a comprehensive and multi-faceted approach, combining innovation, policy, infrastructure, financial mechanisms, and public engagement. Key proposed strategies include:

1) **Regulatory Standards and Definitions and International Agreements:** Harmonize or establish legally binding rules, standards, or laws where coherence is needed globally (e.g., problematic chemicals/products to be prohibited, common approaches to virgin plastic taxes, minimum standards for EPR, standards for reusable design and recyclability, etc.). Leverage existing international agreements and regional programs. In particular, the ongoing negotiations for a binding International Plastics Treaty represent a significant opportunity for coordinated global action (UNEP, 2023a)
2) **Data Sharing and Monitoring Systems:** Address the current fragmentation and lack of comparability in monitoring data. There is an urgent need for standardization, harmonization, and interoperability of datasets and platforms to implement effective global monitoring programmes. This includes streamlining methodologies, data flows, indicator sets, and establishing unified definitions, standards, and formats (UNEP, 2023a).
3) **New Technologies and Innovations:** Tap into artificial intelligence (AI) for plastic detection, sorting, recycling, supply chain optimization, and predictive modeling; deploying unmanned surface vehicles, sensors, and river barriers to intercept waste before it reaches the ocean; and promoting the development and use of biodegradable and sustainable alternatives, such as bioplastics made from cellulose and chitin (Yu R-S, et.al., 2023). Industry 4.0 technologies, like (Internet of Things) IoT devices, machine learning, and 3D printing, offer promising avenues to improve plastic monitoring and transform waste into high-value products (Râpă, M., et.al., 2024).
4) **Financial Investment Mechanisms:** Investments are critical for building effective waste management infrastructure, especially in developing countries, where support for innovation, technology transfer, and capacity building is urgently needed (Râpă, M., et.al., 2024). At the First session of INC, there is a suggestion for establishing a legacy fund to deal with existing pollution, potentially contributed to by industrial leaders, though the matter has not yet gained universal agreement. More broadly, aligning financial flows with the goals of market transformation globally is crucial (UNEP, 2023a).
5) **Education and Awareness:** Robust education and awareness campaigns to promote sustainable behavior and community-based actions like clean-ups and local recycling initiatives remain crucial.

Nutrient Pollution

SELECTED HIGHLIGHTS



Unlike the highly visible marine plastic litter, eutrophication often unfolds out of sight, beneath the surface of coastal and marine waters, making it a silent but equally alarming threat. Though it receives far less public attention, the proliferation of nutrient pollution and its impacts continue to threaten coastal and marine ecosystems.

Eutrophication, driven by excess nitrogen (N) and phosphorus (P) from land-based sources such as agriculture, aquaculture, and wastewater, has rapidly increased in coastal oceans in recent decades. This nutrient overload fuels algal blooms whose decomposition depletes oxygen, leading to hypoxic conditions that disrupt food webs, degrade benthic habitats, and threaten biodiversity. Nutrient enrichment and imbalanced nutrient ratios contribute to the decline of vital coastal ecosystems, while also exacerbating coastal acidification. Combined with ocean warming and deoxygenation, eutrophication is reshaping marine ecosystems and accelerating biodiversity loss (IOC-UNESCO, 2024).

Recent Status

Based on a desk study conducted in East Asian countries, eutrophication is primarily driven by nutrient pollution from agriculture, domestic and industrial waste, and, in some areas, unsustainable aquaculture, with additional sea-based sources such as ship waste, ballast water discharge, and port activities. Hotspots of nitrogen and phosphorus accumulation are commonly found in river mouths, bays, and coastal zones near major cities and industrial hubs. These nutrient loads contribute to harmful algal blooms, pose health risks to marine life and humans, cause fish and shellfish mortality, and result in significant economic and livelihood losses (COBSEA, 2021). Key findings per country are indicated in Table 4.

Table 4. Key Findings on Eutrophication in East Asian Countries

Country	**Highlights of Findings** (culled from COBSEA, 2021)
Cambodia	• Contributing factors: port and offshore development, industry, urban sewerage, and agricultural use of pesticides, fertilizers, and herbicides • Highest total nitrogen (TN) levels found in eastern parts • Highest total phosphorus (TP) levels in Kampot's coastal areas
China	• Most polluted seas: East China Sea, South China Sea, and Yellow Sea. • Hotspots: Liaodong Bay, Bohai Bay, Hangzhou Bay, Pearl River Estuary, and Yangtze River Estuary. • Water quality varies by province, ranging from excellent to very poor. • Lower Pearl River Estuary faces severe eutrophication and annual summer hypoxia for over 25 years. • East China Sea LME is at highest risk for eutrophication; Yangtze River contributes over 90% of nutrient inputs.
Indonesia	• Hotspots: concentrated along northern coasts of densely populated islands like Java and near major coastal cities. • Jakarta Bay experiences organic buildup in sediments, causing near-bottom hypoxia and mass fish kills. • Major sources of nitrogen and phosphorus: domestic wastewater and non-point source pollution.
Malaysia	• Main sources of eutrophication: agriculture, organic waste, untreated sewage, industry, and forestry. • Animal farming and domestic sewage are major contributors of ammoniacal nitrogen (NH_3-N). • River pollution remains a major issue despite ongoing mitigation efforts. • Sewage is the largest source of BOD load.
Philippines	• Main BOD pollution sources are land-based with rivers as key pathway: domestic, agriculture/livestock, industry, non-point sources • HABs frequency and duration are increasing and occur in many tropical food production sites. • New outbreaks are linked to mariculture practices and eutrophication.
RO Korea	• ~66.4% of pollution loads come from non-point sources. • Point sources are strictly regulated, but water quality remains poor in some bays and ports. • In semi-closed waters (e.g., Masan Bay, Shiwha-Lake), excess nitrogen and phosphorus can trigger algal blooms like red tides.

Table 4. Key Findings on Eutrophication in East Asian Countries (cont.)

Country	**Highlights of Findings** (culled from COBSEA, 2021)
Singapore	• Main sources of nitrogen and phosphorus are ranked low due to effective land-based pollution management. • However, eutrophication and HABs have still been reported in Singapore. • Climate change continues to be a challenge.
Thailand	• Key hotspots are in the inner Gulf of Thailand, especially at major river mouths, where water quality standards have been exceeded for the past 20 years.
Viet Nam	• Rapid urbanization and industrialization have severely impacted water quality. • Urban lakes in Hanoi are affected by eutrophication. • Despite issues, coastal water quality in 2018 was generally rated as "quite good", based on low overall pollution risk. • Localized pollution hotspots include: North (aquaculture areas), Central (aquaculture and port areas), and South (high levels of TSS, Fe, NH_4, NO_2-N, NO_3-N, and coliform) • Eutrophication and red tides occur in Southern Central and Southeast Viet Nam; nitrate and COD are key drivers. • 70–80% of marine waste comes from inland sources like factories, industrial zones, and residential areas.

Related to nutrient pollution is a recent groundbreaking study that has revealed widespread ocean darkening, with substantial declines in light penetration across vast areas, posing serious implications for marine ecosystems. The study found that between 2003 and 2022, the global ocean experienced a widespread reduction in light penetration. This phenomenon was observed not only in coastal regions but also across open-ocean areas including polar zones, the North East Atlantic, and the North West Pacific, led to substantial declines in photic zone depth (one of the most productive ocean habitats, supporting 90% of marine life and fundamental for maintaining healthy global biogeochemical processes) of over 50 m in 9% of the ocean and over 100 m in 2.6%. Key causes of this darkening include elevated concentrations of plankton, suspended particulate matter, and colored dissolved organic matter, driven by nutrient and sediment inputs near coasts as well as climate-related shifts in ocean circulation and changes in sea surface temperature. These changes lead to significant loss of habitat for light-dependent marine processes and serious consequences for marine food webs, fisheries and global biogeochemical cycles (Davies and Smyth, 2025)

Projected Changes, Impacts and Trends

According to recent measurements, eutrophication persists and continues to increase (IOC-UNESCO, 2024). In the first half of the 21st century, it is anticipated that global anthropogenic nitrogen production will nearly double (COBSEA, 2021). Despite advancements in treatment technologies, nutrient pollution is expected to increase from 2010 to 2050 based on five Shared Socio-economic Pathways (SSPs) used for global estimates of nutrient discharge from households to surface waters, driven by factors such as income levels, protein consumption, sewerage system coverage, and wastewater treatment efficiency (P.J.T.M. van Puijenbroek, et.al., 2019). The SSP projections estimated that 2-4 billion more people will be connected to sewerage systems, and while nutrient removal efficiency will improve by 10%-40%, nitrogen and phosphorus discharges could still rise by 10%-70%. In developing countries, these discharges are expected to grow substantially, whereas in developed countries they may stabilize or decline slightly. Significant global reductions in nutrient discharge can only be achieved if developing countries adopt at least tertiary treatment and developed countries implement advanced treatment technologies. Moreover, the study indicated that sustainable wastewater treatment targets under SDG 6.3 (Improve Water Quality) are likely to be met by 2030 in developed countries, but only by 2050 in developing countries under more progressive scenarios like SSP1 (major efforts to reduce resource intensity and use of fossil fuels) and SSP5 (traditional development with focus on economic growth and new technology with continued dependence on fossil fuels).

Nutrient pollution affects over 700 coastal areas worldwide, including major hotspots in the Gulf of Mexico, coastal Europe, and increasingly in China, where harmful algal blooms rose by 40% per decade from 1970 to 2015. Due to limited global water quality monitoring, the true scale of the problem is likely underestimated (Our Shared Seas, 2021).

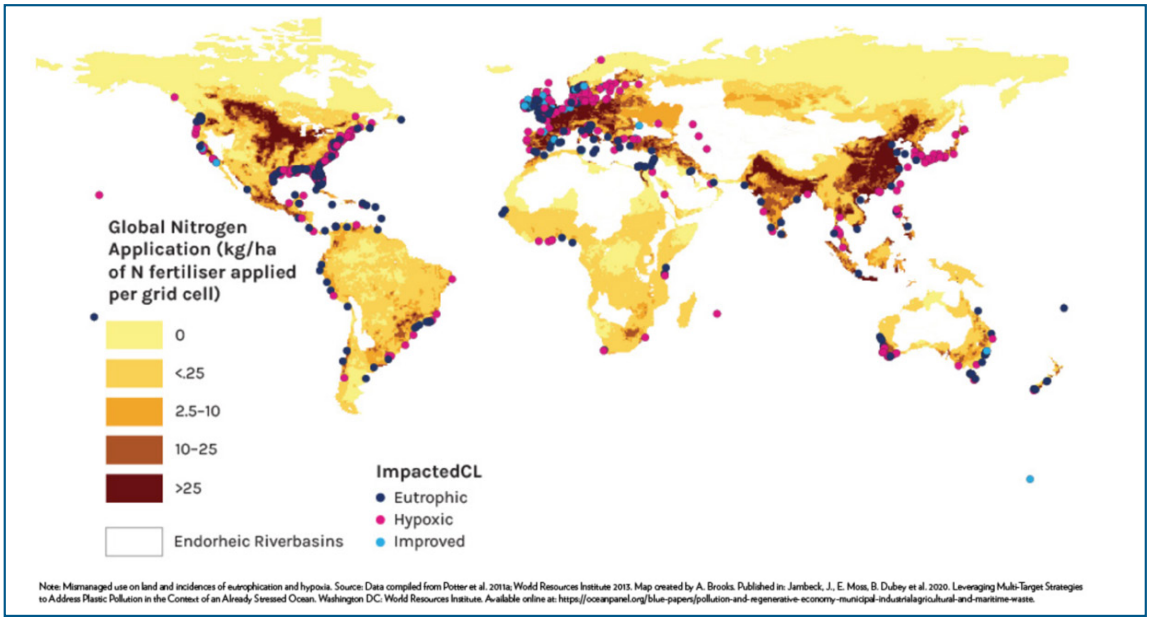


Figure 5. Global Nitrogen Use and Hypoxic Areas in the Ocean (Our Shared Seas, 2021)

Anthropogenic sources account for more than half of the riverine dissolved inorganic nitrogen (DIN) input to the coast in 46 out of 63 Large Marine Ecosystems (LMEs), making many LMES hotspots of nitrogen loading (COBSEA, 2021). Recent global modeling reveals a growing trend toward higher nitrogen-to-phosphorus (N:P) ratios in global freshwater systems and in nutrient exports to coastal seas, which is a key driver of harmful algal blooms (Beusen et al., 2022). Nutrient enrichment of inland and coastal waters is expected to increase across all developing countries, while nutrient delivery to coastal waters is projected to decrease in some scenarios for industrialized and BRIC countries, including improvements in China and the Russian Federation (Beusen et al., 2022).

In East Asia, the use of synthetic fertilizer has increased from around 400 million tonnes (400 x 10^6 tonnes) to over 5 billion tonnes (5,000 × 10^6 tonnes) over the past 30 years; however, only 20% of added nitrogen results in human food, meaning that 80% is wasted and becomes pollution (COBSEA, 2021).

Harmful algal blooms (HABs) are becoming more frequent and lasting longer in countries like the Philippines and Malaysia, with expanding affected areas and growing concern over new toxic species, while in the Philippines, rising precipitation is expected to increase nutrient runoff (Azanza et al., 2024). In contrast, the Republic of Korea has improved sewage treatment capacity and contaminant removal efficiency, helping to mitigate coastal nutrient pollution (COBSEA, 2021).

With regard to the study on ocean darkening, projected trends include potential disruption of marine life and food webs. Light level drops may lead to increased competition and predation risk, and shifts in phytoplankton blooms or fish reproductive timing, among others. The study notes that ocean darkening is an emerging global concern and emphasizes the need for regional analyses and further research to understand its key drivers, causes and long-term impacts, as current data may not fully capture natural variability (Davies and Smyth, 2025).

Recent Initiatives

Global nitrogen management has been greatly aided by the 2019 Colombo Declaration, by setting the goal of halving nitrogen waste by 2030 to address environmental and health issues such as eutrophication, air pollution, and biodiversity loss. This commitment was reinforced in 2022 through a stronger UNEA-5.2 resolution, which recognized the Declaration's ambition and emphasized coordinated intergovernmental action via the Interconvention Nitrogen Coordination Mechanism (INCOM) (UNEP, 2022b).

In support of the UNEA resolution, an International Nitrogen Assessment (INA) has been conducted and is currently undergoing review. The INA is the first global assessment to integrate science, policy, and practice across the entire nitrogen cycle, which aims to guide international action, shape policy, and support sustainable development by providing a comprehensive understanding of nitrogen's role in food security, environmental health, and climate change (INMS website). Several regional initiatives have also been undertaken. One key example is the initial South Asian regional assessment of nitrogen emissions and policy and development of a supporting database (Nissanka, et.al., 2022). The Global Partnership in Nutrient Management, coordinated by UNEP, also provides a multistakeholder platform for addressing excess nutrient pollution, mainly through global advocacy, knowledge sharing, capacity building and collaborative initiatives.

In the East Asian Seas countries, various laws, acts, decrees, and action plans governing environment and water resources protection that specifically address domestic wastewater treatment, industrial and solid waste management, pollution emissions and control, and agricultural practices are already in place. Countries are also signatories to international conventions and parties to different Strategic Action Programmes/Plans developed under LME projects addressing land- and sea-based pollution (COBSEA, 2021). To establish a collaborative approach for the progressive reduction of impacts from excess nutrient emissions on marine and coastal ecosystems in the East Asian Seas region, the COBSEA Collaborative Action Framework on Nutrients Management was adopted in 2024. This Framework highlights the need for holistic marine environmental management by addressing land-based sources of pollution and recognizing their cumulative impacts on ocean health and sustainable economic development (COBSEA, 2024).

Another effort is the UNEP/GEF South China Sea Project's (SCS SAP) plan to update its nutrient carrying capacity model as part of the implementation of its current SAP. The updating may also consider the rapid assessment methodology and impact model from the GEF Global Nutrient Cycling (GNC) Project successfully used in Manila Bay and Laguna Lake in the Philippines.

Through its Special Monitoring and Coastal Environmental Assessment Regional Activity Centre (CEARAC), the Northwest Pacific Action Plan (NOWPAP), recently introduced the use of Global Eutrophication Watch which is a planetary scale tool for assessment of coastal eutrophication developed based on NOWPAP Common Procedure. CEARAC also applies remote sensing technique to detect potentially eutrophicated areas in the NOWPAP region (CEARAC website).

Under ASEAN, the Marine Water Quality Management Guidelines and accompanying Monitoring Manual, adopted in 2008, continues to serve as reference by Member States to guide national-level policies and coordinated regional actions to maintain or improve marine water quality in ASEAN's shared waters (ASEAN Secretariat, 2023).

In collaboration with ASEAN, PEMSEA is currently implementing a GEF/UNDP Project on Integrated River Basin Management which aims to establish functional IRBM mechanisms in priority river basins across six ASEAN countries (Cambodia, Indonesia, Lao PDR, Malaysia, the Philippines, and Viet Nam) to reduce pollution entering rivers and coastal waters, including nutrients and other contaminants, sustain freshwater environmental flows, and enhance resilience to climate change vulnerabilities affecting river basins and connected marine ecosystems. The initiative also promotes the development and use of State of River Basin (SORB) reporting.

Key Recommendations Identified from Existing Studies

Despite some progress, current global actions remain insufficient to meet the 2030 target for reducing nutrient pollution. There is an urgent need for integrated, ecology-based management and restoration strategies, especially in the context of climate-driven disruptions to global nutrient cycles. Achieving meaningful progress will require a combination of technical, institutional, and policy innovations at both national and regional levels. Studies highlight the following recommendations:

1) **Balanced Approach to Nutrient Management:** Adopt innovative technologies and improved nutrient recycling and treatment systems across sectors, particularly in agriculture, aquaculture, and industry.
2) **Monitoring and Assessment:** Establish systems to monitor marine water quality, habitats, and protected areas and track progress, address data and knowledge gaps, and manage nutrient leakage to inform policy and increase stakeholder support.
3) **Research and Knowledge Sharing:** Strengthen mechanisms for improving nutrient use efficiency (NUE), optimizing practices, and estimating the nutrient carrying capacity of water bodies. Disseminate outputs from projects addressing land-based pollution and promoting clean technologies to help scale up best practices.
4) **Regional Integration and Coordination:** Enhance cross-sector, cross-border and cross-conventions to foster more holistic and regionally aligned responses. This includes building connections with other programs, enhancing stakeholder involvement, and drawing from successful models used in other regions.
5) **Strategic Planning:** Develop a regional strategy or action plan for pollution reduction, including integrated river basin management (IRBM) to connect upland and coastal efforts. Establish an Expert Working Group to guide, align and prioritize regional actions.
6) **Capacity Building:** Invest in strengthening monitoring institutions, laboratories, and management teams. Promote awareness and adoption of global toolkits, and focus on improving monitoring and control of non-point sources of pollution, as well as adopting circular economy approaches in waste management.
7) **Enforcement and Governance:** Enhance law enforcement and compliance mechanisms, and support self-regulation as complementary to legal frameworks.

Oil Spill

SELECTED HIGHLIGHTS

Recent Oil Spill Data (2022-2024)

- 2022: 3 major spills (>700 tonnes), 4 minor spills (7-700 tonnes)
- 2024: 6 large, 4 medium spills - higher than 2010s average.
- ~15,000 tonnes of oil spilled globally in 2022
- Notable SE Asia events: MT Princess Empress (Philippines), Pasir Panjang (Singapore)

Long-term Spill Trends

- >90% decrease in tanker spills >7 tonnes since 1970s (ITOPF)
- Spill frequency plateaued in the last decade
- Despite progress, risk remains elevated due to industrial expansion and vessel traffic

Some Regional OSP Initiatives

- ASEAN ROSCP (2018): cooperation framework for emergency response
- GISEA and IPIECA support capacity building in ASEAN
- ATS Strategic Action Programme 2024-2033 prioritizes oil spill management
- GoT Strategic Action Plan (2023-2027), 2024 Transboundary Guidelines on Dispersants
- MERRAC of NOWPAP developing GIS platform for real-time tracking; New guidelines for assessing oil spill response

Oil spills are one of the most visible and destructive forms of marine pollution, as even minor incidents can cause long-term harm on sensitive ecosystems and coastal communities. As the oil industry continues to supply almost half of the world's energy, the threat of spills remains widespread and persistent, making them a routine yet serious source of marine environmental risk (International Enviroguard, July 2023).

Recent Status and Projected Impacts and Trends

According to recent data, oil spills continue to occur globally. In 2022, three major spills (over 700 tonnes) were reported in Asia and Africa, along with four minor spills (between 7 and 700 tonnes) in North America, Asia, and Africa. Approximately 15,000 tonnes of oil were lost to the environment from tanker spills, with the three significant incidents accounting for almost 14,000 tonnes in 2022 (Chandel, A. et.al., 2024). In 2024, six large and four medium oil spills from tanker incidents, primarily involving fuel oil across South America, Asia, Europe, and North America, were recorded, bringing the current decade's average to 7.4 spills per year, slightly above the 2010s average but significantly lower than in previous decades. Recent incidents in Southeast Asia include the sinking of the MT Princess Empress oil tanker in 2023, which contaminated the Verde Island Passage in the Philippines, and a 2024 oil spill in Singapore, affecting Singapore and the southern coast of Johor, Malaysia.

Based on ITOPF's statistics, the frequency of spills greater than 7 tonnes from tankers have decreased over the past half century, and spills in excess of 7 tonnes have reduced by over 90% since the 1970s. However, there has been little change in spill frequency in the last decade (Figure 6).

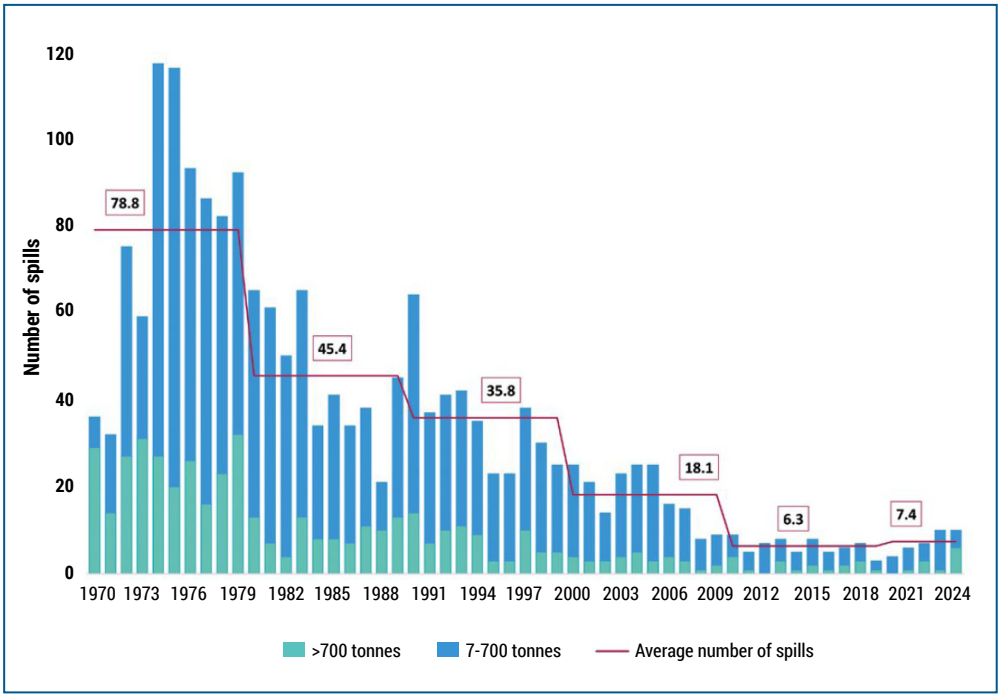


Figure 6. Number of medium (7-700 tonnes) and large (>700 tonnes) tanker spills, 1970-2024 (ITOPF, 2024)

The landscape of oil spill response is described as evolving, with increasing risks and growing repercussions. The industry faces complex challenges, including a potential talent gap and persistent scrutiny regarding the effectiveness and environmental impact of response tools (De Stefani, V., 2023, September 11). Between 2023 and 2030, the worldwide market for oil spill management is projected to increase at a compound annual growth rate (CAGR) of 3.5%, driven by increased safety concerns and the rising number of spill occurrences (Chandel et al., 2024).

Recent Initiatives

Owing mainly to industry efforts, oil spill preparedness and response (OSPR) has evolved from informal guidelines into a more systematic, experience-based framework guided by good practice standards. As legal requirements and environmental awareness grew, national and industry OSPR plans became more comprehensive and advanced, with a stronger focus on

testing through drills and exercises. This maturity has made it possible to better concentrate on areas that were often overlooked like waste handling, which is now recognized as an important element of effective spill response operations (ARPEL, IMO, IPIECA, 2023).

Some of the key recent initiatives include the International Guide for the Assessment of Oil Spill Response Planning and Preparedness (the "2023 International Guide"), which offers a comprehensive, harmonized framework for evaluating and strengthening OSPR programs, integrating over 500 elements drawn from decades of lessons learned, best practices, and innovations. The Guide is complemented by a web-based tool, the ARPEL RETOS™ system, to support continuous improvement through systematic gap analysis and capability enhancement (ARPEL, IMO, IPIECA, 2023). In support of promoting knowledge sharing, the triennial IMO-sponsored conference series continues to serve as major platforms: the International Oil Spill Conference (IOSC) for the Americas, the Interspill event in Europe, and the Spillcon in Asia-Pacific (IMO website).

At the regional level, the ASEAN Regional Oil Spill Contingency Plan (ROSCP), adopted in 2018, provides a mechanism for operational cooperation and resource sharing during oil spill emergencies in the region. The ASEAN has also been working with various collaborators such as the IMO Global Initiative for Southeast Asia (GISEA) and IPIECA in the conduct of trainings and exercises (IMO website and GISEA website). In the Arafura and Timor Seas (ATS) region, a 2022 Regional Assessment on Marine- and Land-based identified the Timor Sea as a marine pollution hotspot due to extensive oil and gas activities and highlighted critical gaps in regional oil spill preparedness and response (Shin, 2021). In line with this, a regional exchange was held through the GEF/UNDP/PEMSEA ATSEA-2 Project and OSRL Singapore, and oil spill management was prioritized as one of four key components in the ATS Strategic Action Programme (2024–2033) (ATSEA, 2023). In the Gulf of Thailand (GoT), a Strategic Action Plan for Oil Spill Readiness and Response (2023-2027) is in place, supporting policy harmonization, capacity building and research and development. The GoT countries (Cambodia, Thailand and Viet Nam) also adopted in 2024 the Transboundary Oil Spill Guidelines for the use of chemical dispersants (IMO, 22 November 2024). In NOWPAP, efforts on oil spill preparedness and response is coordinated through its Marine Environmental Emergency Preparedness and Response Regional Activity Center (MERRAC), and recent efforts are focusing on the development of a web-based geographic information system (GIS) platform for real-time information sharing and management of oil and hazardous and noxious substances (HNS) spill data and Guidelines on the Assessment of Oil Spill Response in the region (UNEP NOWPAP webpage).

Technological and research developments are influencing new developments in oil spill preparedness and response. This includes the integration of autonomous vehicles, AI, and

remote sensing tools, such as unmanned aerial vehicles (UAVs) and satellite-based systems, which enhanced ecological monitoring and spill detection (De Stefani, 2023, September 11; Chandel et al., 2024). Sophisticated modeling tools like NOAA's GNOME and Environmental Response Management Application (ERMA®) are being further developed to improve oil trajectory prediction and environmental impact assessment (NOAA, April 2020).

A parallel track of innovation focuses on environmentally sustainable response techniques. One of the most prominent green solutions is bioremediation, which uses microorganisms to degrade petroleum hydrocarbons, however on-field studies are still limited and potential market is still underexploited (Tedesco et al., 2024); ongoing studies seek to improve its efficacy through enhanced biological and organic processes such as phytoremediation and microbial treatments. Other emerging research priorities include evaluating the effectiveness of clean-up strategies, refining in-situ burning techniques, improving post-spill ecosystem restoration, and investigating the compounded effects of multiple pollutants like heavy metals and oil. Advanced materials, such as nanofibrous polymer membranes, are also being explored for use in oil recovery and purification systems (Chandel et al., 2024).

In addition to technological and scientific advances, collaboration and shared resources are gaining renewed emphasis. Cooperative agreements between governments, industries, and communities are seen as critical to enabling rapid, well-resourced responses. Innovative approaches like citizen science and community-based environmental tracking are emerging as complementary tools that can expand monitoring coverage and enhance public engagement in spill response and recovery (De Stefani, 2023, September 11; Chandel, A., et.al., 2024).

Key Recommendations Identified from Existing Studies

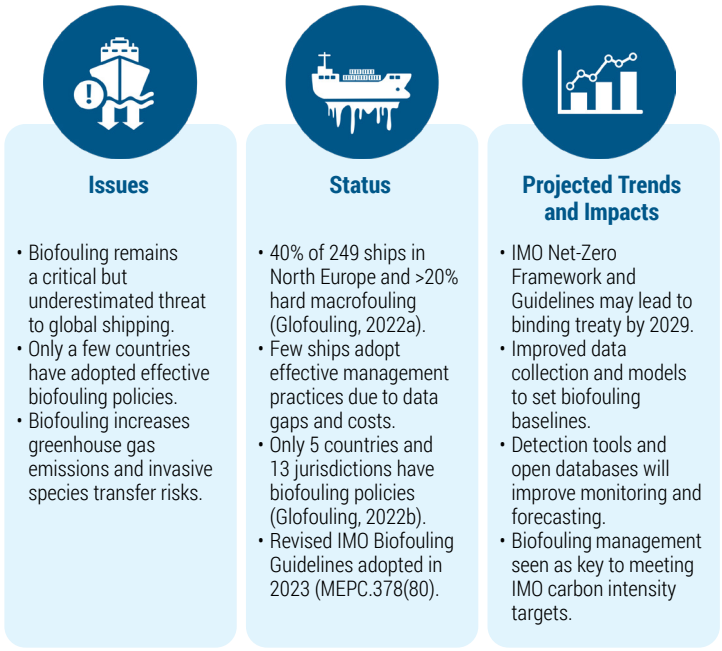
Various assessments and studies on oil spill preparedness and response offered the following recommendations to further enhance efforts (ARPEL, IMO, IPIECA, 2023; De Stefani, 2023 September 11):

1) **Strategic Planning and Risk Assessment:** Establish a robust and adaptable framework that integrates strategic planning, risk assessment, and operational readiness. This includes the development and maintenance of comprehensive OSPR plans, supported by well-defined spill scenarios, clear roles and responsibilities, and thorough risk analyses.
2) **Operational Readiness, Training, and Monitoring:** Conduct regular training and exercises including establishment of proper procedures for monitoring, reporting, communication, and coordination to strengthen preparedness and to guide strategic decision-making throughout the incident.

3) **Waste Management Planning:** Ensure the inclusion of waste handling protocols in OSPR plans, particularly for large spills that generate significant waste.
4) **Data Systems and Information Management:** Develop data management systems to support real-time information sharing, incident tracking, and post incident evaluations, that are aligned with national and regional systems.
5) **Collaboration and External Coordination:** Foster cross-sector and cross-border cooperation, such as mutual aid agreements and links with specialized services, to enhance response capacity, especially during large-scale incidents.

Biofouling

SELECTED HIGHLIGHTS



A type of biological marine pollution known as 'biofouling' occurs when aquatic organisms, such as microorganisms, plants, algae, and animals, accumulate on surfaces and structures immersed in or exposed to the aquatic environment (GEF-UNDP-IMO GloFouling Partnerships Project and GIA for Marine Biosafety, 2022a). It is considered as a global issue affecting various industries, especially the shipping industry (Weber and Esmaeili, 2023). It causes several major environmental impacts:

1) Spread of invasive aquatic species (IAS), as ship hulls serve as a primary pathway for non-indigenous species introduction, often more so than ballast water (Weber and Esmaeili, 2023; GEF-UNDP-IMO GloFouling Partnerships Project, 2022a; IMO, 2023);

2) Increased greenhouse gas (GHG) emissions due to added hull drag that reduces fuel efficiency and can raise fuel consumption by up to 90%, significantly contributing to climate change (GEF-UNDP-IMO GloFouling Partnerships Project and GIA for Marine Biosafety, 2022a); and

3) Chemical pollution from the use of anti-fouling systems (AFS), which often contain harmful biocides such as organotins that pose risks to marine life and human health (GEF-UNDP-IMO GloFouling Partnerships Project and GIA for Marine Biosafety, 2022b).

Recent Status and Initiatives

Biofouling remains a widespread and underestimated issue for global shipping, with anti-fouling coatings often compromised by varying operational and environmental conditions. For instance, a recent survey of 249 ships in Northern Europe found that 40% of ships had more than 20% hard macrofouling (large, distinct multicellular organisms like barnacles and algae) on their flat bottoms (GEF-UNDP-IMO GloFouling Partnerships Project and GIA for Marine Biosafety, 2022a). However, due to limited public data and variation in ship operations, the global extent of biofouling's contribution to GHG emissions is unclear, and effective biofouling management practices are currently adopted by only a small proportion of internationally operating ships (GEF-UNDP-IMO GloFouling Partnerships Project, 2022b).

The IMO Marine Environment Protection Committee (MEPC) has called on countries on the urgent application of the 2011 IMO Biofouling Guidelines, but based on a recent review, only 5 countries (Australia, Chile, New Zealand, South Africa, and the United States) and 13 sub-national jurisdictions had implemented either mandatory or voluntary biofouling management policies. The most comprehensive mandatory policies are in New Zealand and California, which include documentary, reporting, and verification requirements and are consistent with the IMO Guidelines (GEF-UNDP-IMO GloFouling Partnerships Project and GIA for Marine Biosafety, 2022b). In 2023, the MEPC adopted the revised Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species (Resolution MEPC.378(80)). These guidelines aim to minimize biofouling for all types of ships by providing a globally consistent biofouling management approach (IMO, 2023).

The seas of East Asia are critically important as they represent the global hotspot for shipping connectivity. This high shipping traffic increases the potential for biofouling to act as a medium for IAS transfer in the region. Recognizing this, a Regional Strategy on Biofouling Management for East Asia has been developed and adopted in 2023.

The **Regional Strategy on Biofouling Management for East Asia** is part of the UNDP/GEF/IMO GloFouling Partnerships Project initiated in 2019. The project aims to help developing countries minimize the impacts from aquatic biofouling by developing tools and solutions to implement the IMO Guidelines for the control and management of ships' biofouling. PEMSEA serves as a Regional Coordinating Organization (RCO) within the GloFouling Partnerships Project and played a role in the strategy's development and adoption.

The Regional Strategy on Biofouling Management is designed to provide guidance to countries around the seas of East Asia in enhancing their national biofouling strategies. It aims to provide a common framework that allows national strategies to complement each other and to offer specific assistance in implementing anti-biofouling strategic action. The strategy is intended to work in conjunction with the IMO's Biofouling Guidelines, linking it to a global approach. (PEMSEA, KIOST, Glofouling Partnership, 2024)

Another member of the Glofouling Partnerships Project is the Secretariat of the Pacific Regional Environment Programme (SPREP). In 2023, the SPREP Regional Taskforce met and developed a preliminary draft of the regional strategy and action plan for managing biofouling and invasive aquatic species in the Pacific region (SPREP, 31 July 2023).

Projected Changes, Impacts and Trends

There is a trend toward the creation of regional and national biofouling management strategies and policies as a result of the increased awareness of the risks posed by biofouling, especially with regard to IAS transfer and GHG emissions. The revised IMO Biofouling Guidelines (2023), IMO Net-Zero Framework, and development of Regional Strategies on Biofouling Management are intended to serve as building blocks towards the development of a legally binding framework for controlling and managing ships' biofouling to minimize IAS transfer, with international requirements anticipated earliest in 2029 (IMO, 11 April 2025).

Future efforts are expected to prioritize the collection of large-scale industry data to establish baseline biofouling levels, improve prediction models of ship performance under varying conditions, and develop automated image-based detection tools, laying the groundwork for data-driven forecasting and the creation of open global biofouling databases (GEF-UNDP-IMO GloFouling Partnerships Project and GIA for Marine Biosafety, 2022a; Weber and Esmaeili, 2023).

Effective biofouling management is emerging as a key strategy for improving fuel efficiency and reducing GHG emissions, with potential to support short- to medium-term compliance with IMO carbon intensity targets while longer-term fuel and technology solutions are still in development (Weber, F. and Esmaeili, N., 2023; GEF-UNDP-IMO GloFouling Partnerships Project and GIA for Marine Biosafety, 2022a).

Emerging innovations in biofouling management focus on sustainable materials, advanced cleaning, smart monitoring, and collaboration. Research is advancing biodegradable, low-toxicity coatings, while commercial providers continue to refine anti-fouling solutions. In-water hull cleaning using Remotely Operated Vehicles (ROVs) is becoming more efficient and eco-friendly, with growing emphasis on debris capture standards to reduce IAS spread and pollution (PEMSEA, KIOST, Glofouling Partnerships, 2024).

Automated detection tools and integrated data systems are being developed to monitor fouling and support predictive models (Weber and Esmaeili, 2023). Regional collaboration, through initiatives like the GloFouling Partnerships, is also promoting R&D, technology exchange, and joint demonstrations to accelerate adoption of next-generation solutions.

Key Recommendations from Existing Studies

To effectively address the environmental and operational impacts of biofouling, the following recommendations are provided based on various studies:

1) **Policy and Strategy Implementation:** Strengthen implementation of policy frameworks such as the IMO Biofouling Guidelines, including ship-specific Biofouling Management Plans (BFMPs) and Record Books (BFRBs), and promote establishment and implementation of national and regional strategies such as East Asia's Regional Strategy on Biofouling.
2) **Research and Data Systems:** Conduct national and regional baseline assessments (e.g., on IAS), and establish integrated information systems to enhance data collection, analysis, and data accessibility.
3) **Technology and Capacity Development:** Facilitate technology transfer through joint demonstrations, technology exchange fairs, and partnerships with industry. In parallel, invest in capacity building, training and awareness campaigns and develop materials to promote good practices and improve understanding of biofouling impacts and management strategies.
4) **Regional and International Cooperation:** Encourage cross-border cooperation through initiatives like the GloFouling Partnerships.

C. MARINE HABITAT AND BIODIVERSITY DEGRADATION AND LOSS

Marine habitats such as mangroves, coral reefs, seagrasses, salt marshes, and tidal flats provide critical services from carbon sequestration and climate regulation to shoreline stabilization and nursery grounds for marine biodiversity. It is estimated that there are over two million species in the ocean, though many remain undiscovered, with over 200,000 currently known (Wu and Chen, 2023). Despite their importance, the status of marine habitats and biodiversity is alarming.

SELECTED HIGHLIGHTS

Marine Biodiversity

- 30% of marine species are endangered (IUCN)
- Global wildlife populations down 69% since 1970 (WWF, 2022)
- Coral Triangle: hotspot with 75% of mangrove species, but severely threatened
- Endangered marine species peaked at 239 in 2020
- 59% of Southeast Asia's sharks/rays threatened
- Dugongs declining; populations fragmented
- 5 sea turtle species in region; hawksbill and leatherback critically endangered

Mangroves

- 14.7 million ha mangroves globally (2020)
- 46% of mangroves in South/Southeast Asia-Pacific
- Indonesia: 20% of global mangrove area
- 3.4% global loss (1996-2020); SEA lost 245000 ha (4.85%)
- Project loss in SEA: US$2.2B/year by 2050

Seagrass

- 1/3 global seagrass lost since 1879
- Loss rate now 7% per year (since 1990)
- Only 26% of seagrass within MPAs
- SEA: 65% of beds declining at 11%/year (2000-2020)
- A lack of long-term monitoring data hinders a full regional understanding of seagrass trends, especially in Southeast Asia.

Coral Reefs

- US$2.7T/year ecosystem value (US$36B tourism)
- 2009-2018: global coral cover down 13.5%
- 2019: slight recovery (+0.7%)
- 27-30% of global reefs in East Asia (590M people supported, 170M highly dependent)
- 24.5% in MPAs; only 1% highly protected
- SEA reefs hit hard by 2023-2025 global bleaching
- 44% of reef-building coral species now threatened, up from 33% in 2008 (IUCN, 2024).

Salt Marshes

- Key blue carbon and coastal defense ecosystems
- 1.452.84 km^2 lost globally (2000-2019)
- Annual global loss rate: 0.28% (peaked at 0.33% in 2015-2019)
- Found mainly in China, Japan, DPRK, ROK
- Major knowledge gap: insufficient regional data
- Yangtze Estuary: key global salt marsh restoration site

Recent Status and Trends

A. Marine Biodiversity

According to estimates of the International Union for Conservation of Nature (IUCN), more than 30% of marine species are currently endangered or threatened, with fish and benthic organisms showing especially sharp declines. Numerous marine species, such as seals, turtles, and whales, are either critically endangered or in the brink of going extinct (Wu and Chen, 2023). The WWF's Earth Vitality Report 2022 states that since 1970, the global population of

mammals, birds, fish, and amphibians has declined by an average of 69%. The largest decline has been in the populations of freshwater species, which have declined by an average of 83% in just a few decades (Chen and Li, 2024). The Pacific and Indian Oceans have the highest numbers of endangered marine species, with the Pacific-Western Central ranking first. This region overlaps with the Coral Triangle, the world's richest marine biodiversity hotspot, home to 75% of mangrove species, 45% of seagrass species, and 58% of tropical molluscs. Despite its biodiversity, it is also the most impacted by climate change and overfishing. The number of endangered marine species showed a fluctuating upward trend from 2006 to 2023, peaking at 175 in 2008 and rising sharply to 239 and 226 in 2020 and 2021, respectively (Figure 7) (Chen and Li, 2024).

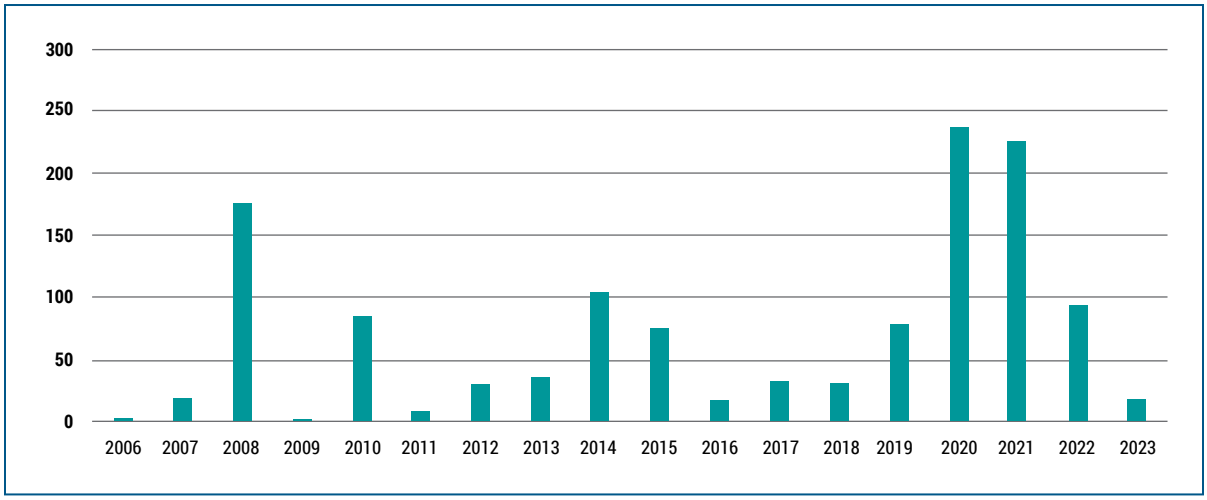


Figure 7. Trend of listed endangered species in major global marine areas (IUCN data, Chen and Li, 2024)

In East and Southeast Asia, recent assessments also indicate a decline. Data show that 59% of assessed marine shark and ray species in Southeast Asia are threatened with extinction, and 72.5% are in decline, with rays being more vulnerable than sharks (Clark-Shen et al., 2023). The IUCN classified dugongs as vulnerable to extinction and are in decline across their range; in Indonesia, populations are fragmented and isolated, with only a few adults remaining in most areas (Dewi et al., 2025). The region is also home to five sea turtle species, green, loggerhead, hawksbill, olive ridley, and leatherback. Hawksbill and leatherback turtle populations are critically endangered or in steep decline, whereas green turtles remain relatively widespread. Among the major threats are habitat loss, bycatch, illegal trade, and climate change impacts on nesting beaches and foraging habitats (Ng et al., 2024; CMS, 2024 March 11).

One of the main causes of irreversible losses in biodiversity is climate change, which is also causing substantial damage to terrestrial, freshwater, and coastal and open-ocean marine ecosystems, resulting in mass mortality or even the extinction of numerous species (cited from

IPCC 2023 in ADB Key Indicators for Asia and Pacific, 2024). In particular, marine biodiversity globally is projected to face substantial habitat loss and species turnover by 2050 and 2100, particularly under high-emission scenarios, with tropical and polar regions being especially vulnerable. Regionally, in Southeast Asia and the East Asian Seas, coastal habitats like mangroves, seagrasses, coral reefs, and salt marshes, as well as marine species continue to face degradation and threats from human activities and climate change impacts like warming, acidification, and sea level rise.

Another key threat is overfishing, which led to drastic declines in fish, shellfish, and other marine organism populations, with some species nearing extinction. As per the Food and Agriculture Organization (FAO) 2025 Review of the State of World Marine Fishery Resources, 35.5% of fishery stocks are overfished, while 64.5% of all fishery stocks are exploited within biologically sustainable levels. Overfishing has been increasing by about one percent per year on average, while nearly two-thirds of marine stocks are fished within biologically sustainable levels globally. Furthermore, there is still a noticeable gap between well-managed and underperforming areas (FAO, 2025 June 11).

As indicated in previous sections, marine pollution which includes plastic waste, oil spills and wastewater discharge also severely impacts marine habitats and biodiversity. Other drivers of degradation include invasive species, as well as coastal development, aquaculture, urbanization and industrial activities that cause loss of breeding grounds and changes in ecosystems.

B. Mangroves

Globally, mangrove forests are found in 123 tropical and sub-tropical nations and territories, and they covered a total area of 14.7 million ha in 2020. Approximately 46% of the world's mangroves are distributed over South Asia, Southeast Asia, and Asia-Pacific, with Indonesia having about 20% of the global mangrove area (Cited from Bunting et al., 2020 in Blanton et al., 2024). Between 1996 and 2020, the global area of mangrove forests has decreased by 524,500 ha (3.4%). Southeast Asia has experienced the greatest net losses of mangroves, which totaled about 245,700 ha (4.85%) from 1996 to 2020 (Cited from Leal and Spalding, 2022 in Blanton et.al, 2024).

A study estimating the impact of mangrove loss in Southeast Asia under a business-as-usual scenario from 2000 to 2050 reveals a significant decline in ecosystem service value, highlighting the cost of inaction in mangrove conservation. By 2050, the region is projected to lose out approximately USD 2.2 billion annually in ecosystem service benefits, such as coastal protection, carbon storage, and fisheries support, with estimates ranging from USD1.6 to 2.8 billion (Table 5) (Brander et al., 2012).

Table 5. Change in mangrove area and value in Southeast Asia by country 2000-2050 (Brander et al., 2012)

Country	Mangrove area in 2000 (ha;000's)	Change in mangrove area 2000-2005 (ha; 000's)	Total value change (US$/ annum; millions)	PI 95% low (US$/ annum; millions)	PI 95% high (US$/ annum; millions)
Brunei	16	-1	-4	-4	-4
Cambodia	54	-4	-2	-1	-2
Indonesia	4329	-1656	-1728	-1239	-2241
Malaysia	699	-220	-279	-228	-330
Myanmar	338	-80	-50	-36	-64
Philippines	102	-6	-11	-10	-12
Thailand	250	-25	-36	-32	-41
Viet Nam	254	-90	-48	-33	-64
TOTAL	6042	-2082	-2158	-1582	-2759

C. Seagrass

Over the past decades, seagrass meadows have experienced significant global decline, driven by coastal development, population pressures, climate change, and ecological degradation. Since 1879, nearly one-third of seagrass coverage has been lost, with the rate of decline accelerating to 7% per year since 1990. Seagrass meadows are among the least protected ecosystems, with only 26% of documented seagrass meadows are located within marine protected areas (Hu et al., 2021). In Southeast Asia, a study on temporal changes in seagrass beds from 2000-2020 found that 65% of observed meadows are declining more than the global average, with an average annual loss rate of 11%. Seagrass loss in Viet Nam and southern China is largely linked to rapid coastal development, while some recovery was noted in Thailand, possibly due to natural regeneration following the 2004 tsunami. Some of the main threats include coastal development, aquaculture, destructive fishing, sedimentation, and poor water quality. Natural events such as typhoons, floods, tsunamis, and El Niño-Southern Oscillation (ENSO) events also contribute to declines, though their impacts may be intensified by climate change. Notably, poorly planned restoration efforts like mangrove planting in seagrass areas have also caused degradation, underscoring the importance of evidence-based coastal management (Kenji et al., 2021). A number of reports have also noted the scarcity of data on temporal change in seagrass beds, making it difficult to assess seagrass bed trends in the whole Southeast Asia.

D. Coral reefs

Although covering less than 0.2% of the seafloor, coral reefs support at least 25-30% of all known marine species. They underpin the safety, coastal protection, well-being, food, and economic security of hundreds of millions of people. Their global value of goods and services is estimated at USD 2.7 trillion per year, including USD 36 billion from tourism (Souter et al., 2021). Since 2009, the trend in global average hard coral cover has been downward. Between 2009 and 2018, global average hard coral cover dropped from 33.3% to 28.8%, marking a 13.5% decline. Limited data for 2019 indicated early signs of recovery, with a slight increase of 0.7% in coral cover (Souter et al., 2021).

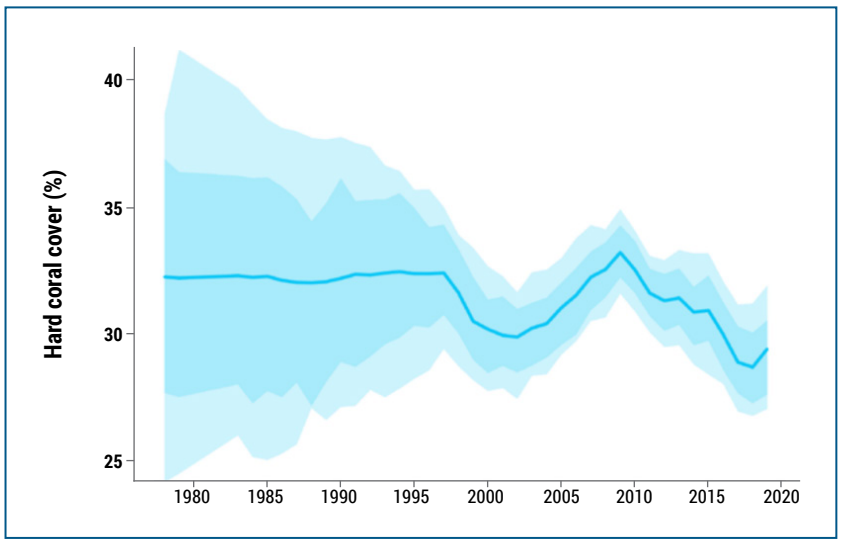


Figure 8. Estimate Global Average Cover of Hard Coral (Souter et al., 2021)

In East Asia, coral reefs support the well-being of 590 million people, including 170 million people who are likely highly dependent on reefs for their food or livelihood. The region holds 27-30% of the world's coral reefs, with estimates from UNEP-WCMC and GCRMN ranging from 40,249 km^2 or 27% global share to 78,272 km^2 or 30% global share. However, only 24.5% of these reefs are located within marine protected areas and just 1% are in "Fully or Highly Protected" areas (Global Forest Watch, n.d.). Long-term data (1983 to 2019) reveals trends distinct from other global reef regions, notably there is no clear regional decline in coral cover or shift toward macroalgal dominance, possibly due to resilience from reef diversity and varied local conditions. Still, coral cover is negatively affected by human pressures and in particular by bleaching (Kimura et.al., 2022). Southeast Asia is especially vulnerable to bleaching events, as its coral reefs are adapted to thrive in relatively lower sea surface temperatures. Heat stress from January 2023 to March 2025 has affected 84% of the world's reefs, the most severe global bleaching event on record, severely affecting East and Southeast Asia (ICRI, 2025 April 23).

The IUCN Red List assessment in 2024 also shows that 44% of reef-building coral species are now threatened, up from one-third in 2008, with climate change and ocean warming identified as the leading causes (IUCN, 2024 November 13). Local solutions, such as reef restoration, pollution reduction, and sustainable fisheries, are essential but must be matched by efforts to limit global warming to below 1.5°C to safeguard coral reef futures (ICRI, 2025 April 23). There is also an urgent need for long-term, data-driven reef monitoring with finer taxonomic and spatial resolution, as well as enhanced regional collaboration and capacity to better understand and manage reef ecosystems in the region beyond national boundaries (Kimura et al., 2022).

E. Salt marshes

Salt marshes coastal habitats are important for carbon storage and coastal protection. A total of 1,452.84 km^2 of salt marshes were lost worldwide. The global loss rate was 0.28% per year from 2000 to 2019, with 2015 to 2019 having the highest global loss rate at 0.33% per year (Campbell et al., 2022).

In East Asia, tidal marshes, which include salt marshes, are found primarily in China, Japan, DPR Korea, and RO Korea, but studies and information on salt marsh distribution, status and trends in the region remains limited, pointing to a critical need for monitoring and analysis of changes over time (PEMSEA, 2021a). A global study on salt marsh restoration, however, highlighted Yangtze estuary in China as one of the concentration points for global salt marsh restoration projects (Wang, Li, Lin, and Ma, 2022).

Recent Initiatives

In recent years, a number of key global frameworks have emerged, marking a significant step forward in the conservation and protection of marine habitats and biodiversity. Central to these efforts are the UN SDG 14 (Life Below Water), the UN Decade on Ocean Science for Sustainable Development (2021–2030), known as the Ocean Decade, and the UN Decade on Ecosystem Restoration (2021–2030). These initiatives helped spur attention and advancement of conservation efforts by mobilizing science, policy, and public engagement to restore and sustainably manage ocean ecosystems. Complementing these frameworks are the Kunming-Montreal Global Biodiversity Framework (KMGBF) and the recent Agreement on Biodiversity Beyond National Jurisdiction (BBNJ) under the UN Convention on the Law of the Sea (UNCLOS), which aim to strengthen global cooperation and action on marine biodiversity conservation.

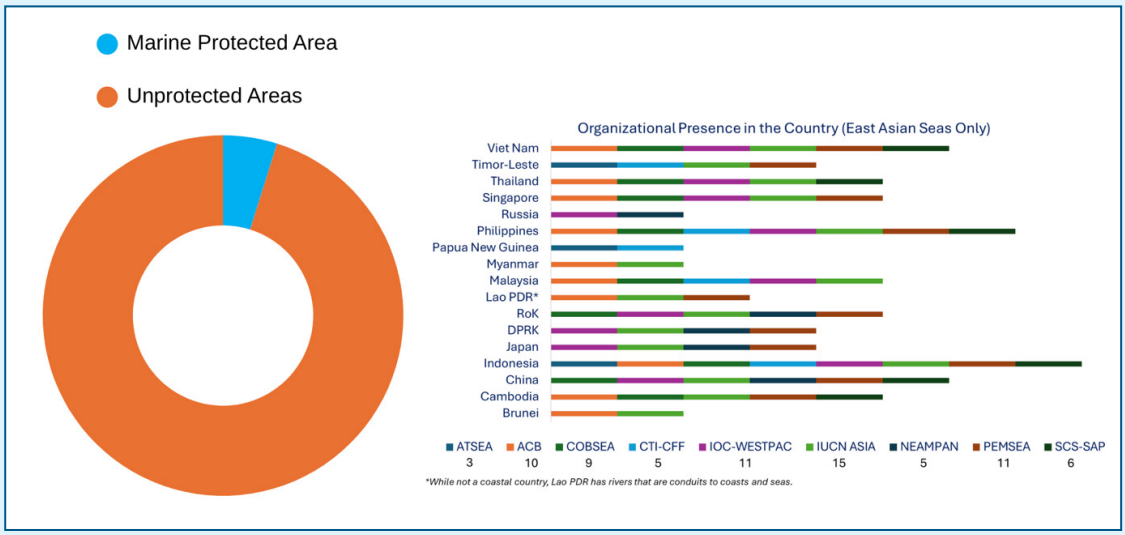
The **KMGBF** was adopted on 19 December 2022 by the Parties to the Convention on Biological Diversity (CBD), replacing the CBD's Strategic Plan for Biodiversity 2011-2020 and its Aichi Targets. The framework is made up of four global 2050 goals and 23 global 2030 targets, which are broken up into four broad topics: (1) biodiversity conservation and restoration, (2) nature's contribution to people, (3) access and benefit sharing, and (4) tools and solutions for mainstreaming and implementation. Key commitments include protecting 30% of land and marine areas, restoring degraded ecosystems, reducing invasive species and pollution, and integrating biodiversity into government and business decision-making. As of November 2024, approximately 119 Parties had submitted national targets, and 44 had updated their National Biodiversity Strategies and Action Plans (NBSAPs) (National Committee on Biosafety and Biotechnology, 2025).

UN member states adopted the **BBNJ Agreement**, also referred to as the High Seas Treaty, in 2023 after nearly two decades of negotiations, marking a major step toward conserving and sustainably using marine biodiversity in areas beyond national jurisdiction. The BBNJ Agreement closes a major legal gap by establishing the first binding framework to conserve marine biodiversity in the high seas (covering over two-thirds of the ocean), enabling the creation of MPAs critical to meeting the 30x30 global target. The Agreement addresses key issues such as marine genetic resources and benefit-sharing, area-based management tools, environmental impact assessments, and capacity building. While it outlines the necessary principles, mechanisms, and institutional structures, many operational details remain unresolved. To prepare for implementation, the UN General Assembly established a Preparatory Commission, which will meet through early 2026. The agreement is open for signature from 20 September 2023 to 20 September 2025 and will enter into force after 60 ratifications. At the recent conclusion of the UN Ocean Conference in Nice, France, a total of 50 countries have already ratified and 136 signed the BBNJ Agreement, with several other countries already indicated their intent to deposit their ratification very soon. The momentum on ratification signifies high level attention to ocean conservation (High Seas Alliance, 2025 June 13).

In line with the KMGBF and BBNJ Agreement, the **30x30 Ocean Action Plan** was launched at the June 2025 UN Ocean Conference in Nice. It aims to protect 30% of the world's oceans by 2030 through well-managed marine protected areas (MPAs), addressing the current gap where only 2.7% of oceans are effectively protected. The plan calls for coordinated global action to expand MPAs, implement the BBNJ Agreement, and empower Indigenous and local communities, while tackling barriers such as data

fragmentation, limited financing, and political inertia (Friends of Ocean Action, 2025; UNEP, 2025). It also highlights the economic benefits of ocean protection, estimating an USD 85 billion annual return by 2050 from restored ecosystem services.

Echoing the global 30x30 commitment, nine leading organizations from the East Asian Seas (EAS) region formed an unprecedented alliance at the 2025 UN Ocean Conference to pursue a shared vision for a **Regional Collaborative Network of MPAs in the EAS region**. Building on momentum from the 2024 EAS Congress in Xiamen, China and 2025 Our Ocean Conference in Busan, RO Korea, the event affirmed collective commitment to achieving SDG 14 and the 30x30 global target through joint action, capacity building, and transboundary MPA governance for a more connected and resilient regional seascape. The organizations included: ATSEA, ACB, COBSEA, CTI-CFF, IOC-WESTPAC, IUCN Asia-Pacific, NEAMPAN, PEMSEA, and the SCS-SAP Project.



In the case of PEMSEA member countries, five PEMSEA Country Partners (CPs) have completed and/or submitted their updated National Biodiversity Strategic Action Plans (NBSAPs) from 2023, while the rest of PEMSEA CPs are still undertaking consultations to revise or develop new NBSAPs to align with the KMGBF goals and targets, to date

Updated NBSAPs	Ongoing Consultations/Review/Updating
• BSAP 2023-2030 (submitted in May 2024) • Indonesia IBSAP 2025-2045 (launched in 2024) • Japan NBSAP 2023-2030 (adopted in March 2023) • RO Korea NBSAP 2024-2028 (approved by the Cabinet in December 2023) • Philippines: PBSAP 2024-2040 (adopted through DENR Department Administrative Order (DAO) 2025-23 which took effect on 27 July 2025)	• Cambodia NBSAP 2016-2025 • DPRK NBSAP 2015-2020 • Singapore NBSAP 2009 (updated in 2019) • Timor-Leste NBSAP 2011-2020 • Viet Nam NBSAP 2021-2030 • Lao PDR NBSAP 2026-2030 (undergoing completion)

As of December 2025, a total of eight PEMSEA Country Partners have ratified the BBNJ agreement, while China has signed the same in Sept 20, 2023 (High Seas Alliance 2025).

Signed	Ratified
• China (20 September 2023)	• Cambodia (9 June 2025) • Indonesia (10 June 2025) • Lao PDR (20 September 2023) • Philippines (20 September 2023) • RO Korea (19 March 2025) • Singapore (24 September 2024) • Timor-Leste (26 September 2024) • Viet Nam (9 June 2025)

The inclusion of Other Effective Area-based Conservation Measures (OECMs) in global conservation targets (i.e., Aichi Targets 2010 and KMGBF 2022) also reflects growing recognition of their importance in achieving biodiversity goals. As of March 2023, 17.08% or 634 terrestrial areas have been recognized as OECMs alongside with 267,089 designated Protected Areas (PAs). For marine areas, 8.26% are protected by 195 OECMs and 18,445 PAs (Mitali et al., 2023).

In line with SDG 14.5.1 (coverage of protected areas in relation to marine areas), an ADB report showed trends over time in the mean percentage of each important site for marine biodiversity (i.e., those that contribute significantly to the global persistence of biodiversity) that is covered by designated protected areas and other effective area-based conservation measures (Figure 9) (ADB, 2024b).

ADB Regional Member	Target 14.5: By 2020, conserve at least 10% of coastal and marine areas, consistent with national and international law and based on the best available scientific information				
	14.5.1: Average Proportion of Marine Key Biodiversity Areas Covered by Protected Areas (%)				
	2010	2015	2021	2022	2023
Developing ADB Member Economies					
Central and West Asia					
Afghanistan	...	...	...	...	...
Armenia	...	...	...	...	...
Azerbaijan	...	...	...	...	...
Georgia	35.6	35.6	35.6	35.6	35.6
Kazakhstan	...	...	...	...	...
Kyrgyz Republic	...	...	...	...	...
Pakistan	14.6	14.6	14.6	14.6	14.6
Tajikistan	...	...	...	...	...
Turkmenistan	...	...	...	...	...
Uzbekistan	...	...	...	...	...
East Asia					
China, People's Republic of	6.8	7.1	7.1	7.1	7.1
Hong Kong, China	32.5	32.5	32.5	32.5	32.5
Korea, Republic of	32.7	36.8	38.7	38.7	38.7
Mongolia	...	...	...	...	...
Taipei,China	...	...	...	...	...
South Asia					
Bangladesh	34.4	34.5	38.8	38.8	38.8
Bhutan	...	...	...	...	...
India	4.2	4.2	4.2	4.2	4.2
Maldives	–	–	–	–	–
Nepal	...	...	...	...	...
Sri Lanka	46.3	50.0	50.0	50.0	50.0
Southeast Asia					
Brunei Darussalam	5.4	5.4	5.4	5.4	5.4
Cambodia	41.2	41.2	51.0	51.0	51.0
Indonesia	16.0	22.9	25.7	25.7	25.7
Lao People's Democratic Republic	...	...	...	...	...
Malaysia	16.1	19.7	19.7	19.7	19.7
Myanmar	9.3	9.3	19.2	19.2	19.2
Philippines	33.6	34.7	46.6	46.6	46.6
Singapore	3.3	3.3	3.3	3.3	3.3
Thailand	36.3	41.6	44.0	44.0	44.0
Timor-Leste	18.7	18.7	19.6	19.6	19.6
Viet Nam	18.7	24.6	24.6	24.6	24.6
The Pacific					
Cook Islands	17.8	17.8	50.1	50.1	50.1
Fiji	16.5	16.5	16.5	16.5	16.5
Kiribati	32.9	32.9	32.9	32.9	32.9
Marshall Islands	6.7	7.8	7.8	7.8	7.8
Micronesia, Federated States of	1.6	1.6	1.6	1.6	1.6
Nauru	–	–	–	–	–
Niue	...	...	...	...	...
Palau	49.4	72.3	72.3	72.3	72.3
Papua New Guinea	1.9	1.9	1.9	1.9	1.9
Samoa	54.2	54.2	54.2	54.2	54.2
Solomon Islands	3.1	3.2	3.2	3.2	3.2
Tonga	19.2	19.2	19.2	19.2	19.2
Tuvalu	...	...	...	...	...
Vanuatu	3.3	3.3	3.3	3.3	3.3
Developed ADB Member Economies					
Australia	53.6	61.6	65.6	65.6	65.6
Japan	45.7	64.6	66.5	66.5	66.5
New Zealand	46.5	47.1	47.1	47.1	47.1

... = data not available, – = magnitude equals zero, ADB = Asian Development Bank.

Source: United Nations. SDG Global Database. https://unstats.un.org/sdgs/dataportal (accessed 16 July 2024).

Figure 9. SDG14.5.1 Average Proportion of Marine Key Biodiversity Areas covered by Protected Areas (ADB, 2024b)

There was also a boost in scientific research and monitoring globally to understand marine organisms' distribution, abundance, body size, and changes, providing scientific foundations for conservation. This includes monitoring DNA of marine organisms to assess population numbers, distribution, and genetic variations, enabling a better understanding of marine biodiversity and evolutionary history (Wu and Chen, 2023). To address a major gap in marine biology and understanding of marine species, a new Marine Organismal Body Size Database (MOBS) was developed, broadening dataset and understanding beyond larger, well-studied organisms by incorporating smaller species, which are crucial to marine food webs and ecosystem functioning. The MOBS database currently represents about 40% of known marine species, with projections aiming for 75% coverage within two years (Joseph, 2025 June 12). Another ongoing initiative is the Marine Biodiversity Survey of Southeast Asia (MBSSEA), which is targeted for release in 2026. The MBSSEA aims to improve biodiversity knowledge and research capacity, focusing on understudied species and cryptic marine biodiversity, which is crucial for conservation and sustainable development (Philanthropy Asia Alliance, n.d.). While key global platforms continue to keep track of status of marine habitats, such as the International Coral Reef Initiative (ICRI) and its operational network, the Global Coral Reef Monitoring Network (GCRMN), the Global Ocean Observing System (GOOS) and Marine Biodiversity Observation Network, Global Mangrove Watch, World Database on Protected Areas, World Database on OECMS, Marine Protection Atlas, and Ocean Biodiversity Information System, among others.

Another evolving field that is gaining popularity is marine biotechnology or blue biotechnology. Apart from application in food and medicine, marine biotechnology is also being tapped for energy and various environmental solutions. These include environmental remediation and bioremediation, where marine microorganisms are harnessed to clean up pollutants like oil spills and microplastics, as indicated under the marine plastics section. It also plays a crucial role in bioenergy and biofuel production, particularly through the cultivation of algae for sustainable energy sources (Bora, 2024). The field also contributes significantly to the cosmetics and cosmeceuticals industry, yielding novel active ingredients with beneficial properties, but while marine cosmetics have great potential, their development requires further cross-disciplinary collaboration, funding, and careful handling of intellectual property, sustainability, safety, and regulatory challenges (Rotter et al., 2024). In the industrial sector, marine organisms are sources of unique enzymes for use in various manufacturing processes (e.g., textiles, detergents) and the development of advanced biomaterials like biodegradable plastics, surgical implants, and bio-adhesives (Ghattavi and Homaei, 2023). Lastly, marine biotechnology is vital for agriculture (e.g., eco-friendly pesticides, salt-tolerant crops) and plays an increasingly important role in ocean conservation by providing tools for ecosystem monitoring, restoration, and the protection of endangered marine species (Rotter et al., 2021).

Blue Carbon programs are also gaining traction as a nature-based solution for climate change adaptation and mitigation, as well as for biodiversity conservation and protection. According to the World Bank, carbon sequestration and storage by mangrove, salt marsh, and seagrass ecosystems has been valued at roughly USD 190 billion per year in terms of global blue carbon wealth, however, there remains a lack of scientific information on blue carbon ecosystems which is limiting their actionability and inclusion for reporting to UNFCCC. To guide governments in catalyzing and scaling up public and private investment in blue carbon as part of their blue economy development, the World Bank developed the Blue Carbon Readiness Framework (World Bank, 2023). PEMSEA has also launched its blue carbon program which aims to enhance blue carbon strategies in the East Asian Seas region through research, capacity building, and regional collaboration. Key initiatives to date include the establishment of a Technical Working Group, publication of a regional "Assessment of Supply Side of Blue Carbon in ICM and Local Sites" and "Harmonizing Blue Carbon Accounting Protocols", as well as conduct of roundtable discussion and a regional training workshop to evaluate blue carbon ecosystem inventories, standardize carbon stock protocols, and identify capacity gaps in integrating blue carbon in ICM.

Application of ICM, marine spatial planning, nature-based solutions are still widely used. In addition, various technological advancements are also revolutionizing marine biodiversity, protection and conservation. Some of these include drones and autonomous underwater vehicles and remotely operated vehicles, remote sensing, smart sensors and acoustic monitoring, AI and machine learning, computer vision technology, among others.

Traditional Ecological Knowledge (TEK) and traditional practices are also gaining recognition in marine conservation because they offer deep, long-term insights into ecosystems based on generations of local and indigenous experience. TEK approaches often include sustainable methods like rotational fishing and territorial use rights, which help prevent overfishing and support ecosystem health. It also strengthens community involvement and ownership, making conservation efforts more effective and lasting. TEK provides valuable ways to adapt to environmental changes, including climate change, by drawing on centuries of observation and experience. Some examples of TEK in marine conservation include:

- Sasi (Indonesia/Misool) - A 400-year-old system that temporarily bans fishing in certain areas or of specific species to prevent overuse.
- Tara Bandu (Timor-Leste) - An ancient customary law that sets rules for using natural resources, with symbols hung in place to show bans on harmful activities.
- Sato-umi (Japan) - A traditional approach to coastal management that helps boost biodiversity and support healthy marine ecosystems.

Future Challenges

A variety of new issues are posing increasing threat to marine biodiversity, requiring new thinking and innovative approaches. Growing demand for critical minerals needed for net-zero transitions is turning attention to deep-sea mining, which raises serious environmental concerns. Meanwhile, the possibility of metal deposition from re-entering space debris creates a new atmospheric risk. Social equity issues are also emerging, such as "privatised micro environmentalism," where access to artificial, exclusive ecosystems may deepen inequality and undermine collective conservation. This requires a mindset shift wherein continuous learning and "exnovation," or phasing out of unsustainable technologies, practices and norms is needed. Financial systems are also adapting, with new taxonomies guiding investments toward genuinely sustainable, climate-aligned activities. Together, these trends highlight the urgency to implement coordinated, adaptive, and transparent strategies to protect marine biodiversity as a pillar of planetary and human health (Navigating New Horizons, 2024).

Key Recommendations from Existing Studies

Addressing marine biodiversity degradation and loss is a complex, long-term endeavor requiring collective efforts from various sectors. Key recommendations include:

1) **Policy and Governance:** While actively participating in international and regional ocean governance, focus on creating and enforcing strong marine biodiversity conservation laws. Expand marine protected areas (MPAs), speed up the creation of marine nature reserves, such as by using bays as planning units, and strengthen protection for key ecosystems, endangered species, and ecological corridors. Align ocean research with policy needs through clear, structured processes. Promote the use and exchange of best practices, common methods, and shared policies for tackling ocean issues, such as standardized marine pollution monitoring. Finally, to lower risks during the transition to sustainability, ensure stable policies and educate businesses about how their operations rely and impact on nature.
2) **Management and Restoration:** Strengthen the repair and restoration of damaged marine ecosystems by implementing targeted measures. Control human activities impacting marine life by reducing overfishing, controlling marine pollution, and limiting marine development. Some actions may include careful design of sites, species selection, and novel planting technologies to enhance survival and establishment of salt marshes, conduct of field surveys to determine true distribution and threats to seagrasses, and future studies should incorporate true absence data into models. Priority is also needed to rare and endangered species.

3) **Science, Knowledge, and Data:** Improve and expand management strategies based on marine and coastal ecosystems, emphasizing a deeper comprehension of and response to various stressors, such as climate change and human impacts. To better understand the population, distribution, and health of marine organisms as well as the effects of human activity on them, scientific research and monitoring efforts should be intensified. Address important knowledge gaps, such as the effects of priority pollutants, sources, sinks, fate, and distribution in deep ocean waters, small island developing states, and less developed nations. Adopt metrics other than GDP and include nexus-related data in public spending evaluations. Create cutting-edge, openly accessible databases to enhance analysis outcomes.
4) **Collaboration and Public Engagement:** In order to conserve marine biodiversity, strengthen international transboundary cooperation by creating cooperatively managed cross-border protected areas, conducting collaborative scientific research, and exchanging data. To encourage public concern and support for marine conservation, raise public awareness and improve marine education using various media platforms. Encourage co-management systems and the fair distribution of benefits from marine resources by utilizing traditional ecological knowledge (TEK). To raise awareness of the value of ocean science, cultivate close ties between the scientific community and professional communicators.
5) **Financial and Economic Reforms:** Financial and economic policies should be reviewed and reformed to shift incentives and direct resources towards supporting and restoring biodiversity and related benefits across nexus elements. Economic assessments should take into account the various benefits of blue economy ecosystems, including those that cannot be measured.

Developments in the Blue Economy Sectors

The blue economy sits at the nexus of the triple planetary crisis and wider global polycrises, as it both depends on and influences the health of ocean and coastal systems. As highlighted in the preceding section, climate change impacts such as sea level rise, ocean warming, and acidification combined with unsustainable practices like overfishing, habitat loss, and pollution are undermining ocean health and the services it provides. At the same time, maritime industries contribute to emissions and other drivers of change.

Blue economy approaches offer pathways to reverse these trends. Some initiatives include offshore renewable energy, blue carbon restoration, climate-smart fisheries, and integrated ocean governance. Key approaches and tools include marine protected areas, ecosystem-based management, marine spatial planning, sustainable tourism, circular economy practices, and marine biotechnology, among others.

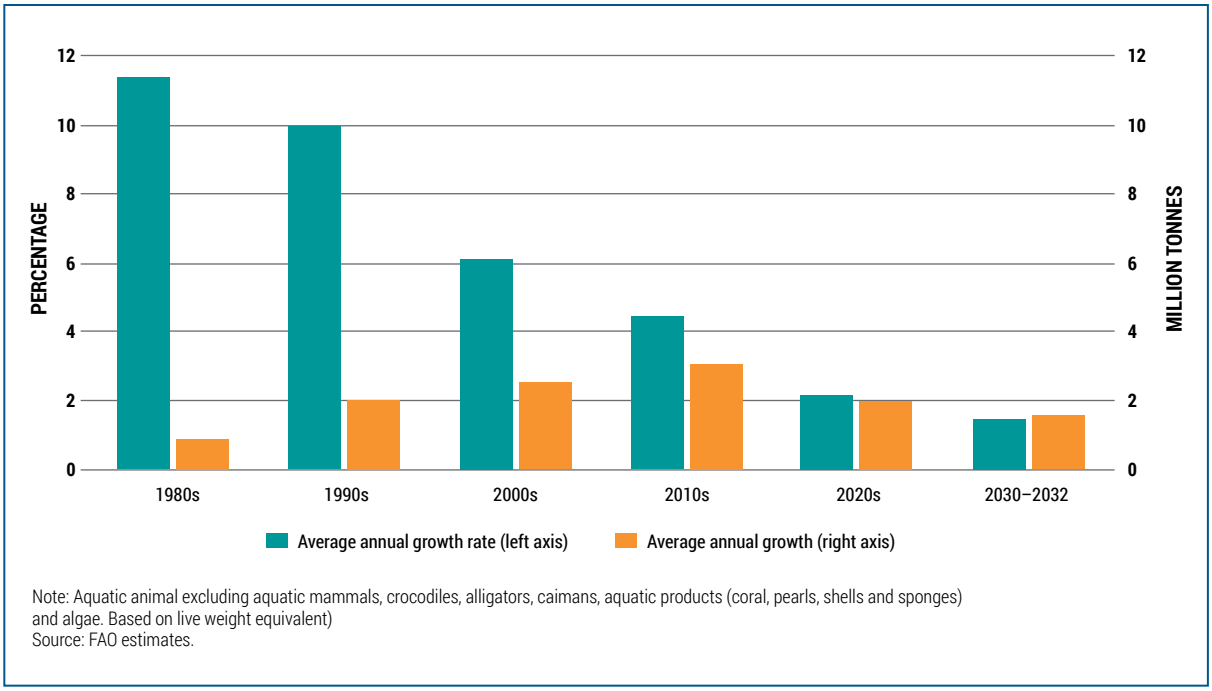
Beyond environmental benefits, a sustainable blue economy can bolster food security, diversify livelihoods, and strengthen resilience, particularly in small island and coastal states. Healthy oceans also support human health through safe seafood and marine-derived medicines, for instance.

Alongside integrated policies, strong political commitment, cross-sector collaboration, inclusive governance, and innovative solutions, a crucial enabler of Blue Economy is sustained financing support to turn vision into action and ensure long-term impact.

This section focuses on key developments in both traditional and emerging blue economy sectors, including recent progress in blue financing.

FISHERIES AND AQUACULTURE WITH LINKS TO BLUE FOOD

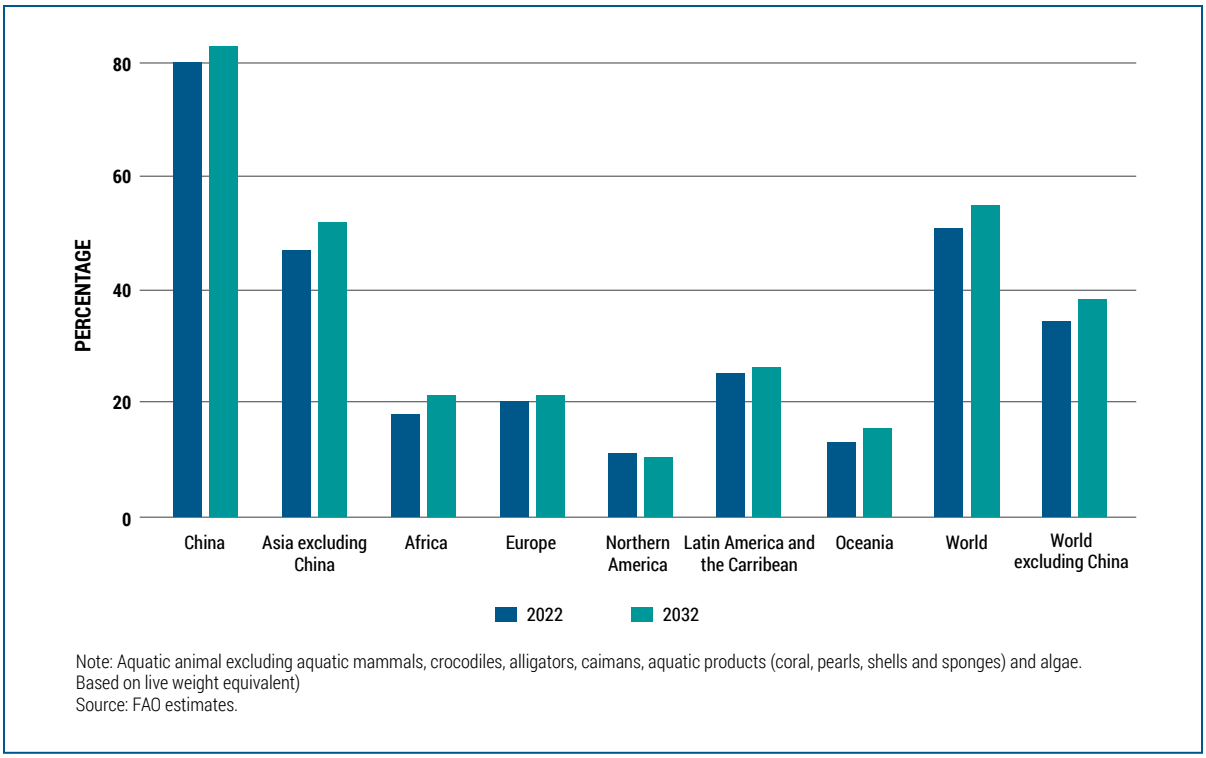
According to FAO's recent report, the global fisheries and aquaculture sector continues to evolve, with aquaculture showing strong and consistent growth. Aquaculture production is projected to grow at an average annual rate of 1.6% from 2022 to 2032, less than half the 4.0% rate of the previous decade, due to factors like stricter environmental regulations, limited water and site availability, rising disease risks, and slower productivity gains. (Figure 10).



Note: Aquatic animal excluding aquatic mammals, crocodiles, alligators, caimans, aquatic products (coral, pearls, shells and sponges) and algae. Based on live weight equivalent)
Source: FAO estimates.

Figure 10. Annual Growth of World Aquaculture Production by Volume, 1980-2032 (FAO, 2024)

Capture fisheries are projected to grow by 3 million tonnes, reaching 94 million tonnes by 2032, a 3% increase from 2022. Temporary declines of around 2% may occur in some years due to El Niño impacts, particularly in South America. Growth will be driven by stock recovery through better management, expanded fishing in underexploited areas, technological advances, and reduced discards. While China will remain the top producer, both for aquaculture and capture fisheries, its output is expected to drop by 4% due to stricter environmental policies and fishing controls. The share of farmed species in global aquatic animal production is projected to rise from 51% in 2022 to 54% by 2032, and from 35% to 38% excluding China. Aquaculture's contribution will grow across all continents except North America, where it will remain at 11%, the lowest globally. By 2032, regional shares will reach 15% in Oceania, 22% in Africa, 21% in Europe, 26% in Latin America and the Caribbean, and 67% in Asia or 52% excluding China (FAO, 2024) (Figure 11).



Note: Aquatic animal excluding aquatic mammals, crocodiles, alligators, caimans, aquatic products (coral, pearls, shells and sponges) and algae. Based on live weight equivalent)
Source: FAO estimates.

Figure 11. Share of Aquaculture in Total Fisheries and Aquaculture Production of Aquatic Animals by Region and Volume, 2022 vs 2032 (FAO, 2024)

Fish stock sustainability is still an issue as only 62.3% of evaluated marine stocks were deemed biologically sustainable in 2021, a decrease from prior years. The "Blue Transformation" strategy, which prioritizes inclusive development, sustainable practices, and better governance, is being promoted by the FAO in response.

Trade in fish and fishery products is expected to grow further, driven largely by the expansion of aquaculture. While this may help stabilize or even reduce fish prices in global markets, climate change presents serious challenges. Marine fish biomass is predicted to decline due to rising ocean temperatures, acidification, and falling oxygen levels, particularly in tropical areas. Aquaculture is also increasingly affected by environmental risks such as disease outbreaks, harmful algal blooms, and extreme weather events, highlighting the need for better risk management (FAO, 2024).

The sector's future is being significantly shaped by technology. From managing feeding and aquaculture infrastructure to monitoring fish behavior, innovations like artificial intelligence, robotics, and smart monitoring systems are being used to enhance fish farming operations. Despite this progress, many of these technologies still face limitations due to data gaps and costs. Continued investment in innovation, better management of marine resources, and

stronger international cooperation will be critical to achieving long-term food security and climate resilience (FAO, 2024).

Meanwhile, policy and governance efforts are focusing on reducing harmful subsidies, restoring degraded ecosystems like mangroves, and improving early warning systems to better prepare for climate-related impacts. (FAO, 2024). In line with the objective to prohibit harmful fisheries subsidies, the World Trade Organization (WTO) Agreement on Fisheries Subsidies was adopted.

The **WTO Agreement on Fisheries Subsidies** was adopted at the 12th Ministerial Conference (MC12) on June 17, 2022. The Agreement prohibits subsidies contributing to illegal, unreported, and unregulated (IUU) fishing, fishing on overfished stocks, and fishing in unregulated high seas. It supports sustainable fisheries management, benefiting marine ecosystems and millions of people dependent on fishing for their livelihoods. It fulfills SDG Target 14.6, the first SDG target to be fully met through a multilateral agreement and is the first WTO agreement focused on environmental sustainability. The Agreement is not yet in force and negotiations are ongoing to enhance the Agreement (WTO, n.d.)

For PEMSEA member countries, 10 out of 11 are WTO members (except DPRK). For this particular agreement, 8 PEMSEA Country Partners have already deposited their instrument of acceptance with the WTO (WTO, 2024):

- Cambodia (6 May 2024)
- China (27 June 2023)
- Japan (3 July 2023)
- Lao PDR (13 May 2024)
- Philippines (27 February 2024)
- RO Korea (23 October 2023)
- Singapore (10 February 2023)
- Timor-Leste (30 August 2024)

Linked to fisheries is blue food production. Blue foods encompass all aquatic animals, plants, and algae harvested or cultivated for human consumption. The East and Southeast Asian region is considered a global powerhouse in blue food production, especially in aquaculture, with China alone contributing about 35.5% of the world's fish and seafood output in 2022 (East Asia Forum, 2025). Blue foods are deeply woven into regional diets, livelihoods, and cultural traditions, providing critical nutrition and underpinning food security as climate change

increasingly threatens terrestrial agriculture. While recent studies suggest Southeast Asia's marine capture fisheries include a higher proportion of underfished stocks than the global average (Mongabay, 2025), persistent challenges remain, including overfishing in certain areas, habitat degradation, and governance fragmentation, especially at land-sea interfaces that complicate the management of transboundary issues like marine pollution and declining fish stocks (East Asia Forum, 2025).

Millions of people depend on the blue food industry for their livelihoods, especially in small-scale aquaculture and fishing. However, these communities are becoming more susceptible to market volatility, resource depletion, and climate change (ADB, 2024). To ensure resilience and sustainability, there is growing recognition of the need to diversify and enhance alternative livelihoods. Initiatives such as integrated multi-trophic aquaculture, seaweed and shellfish farming, and ecotourism are being promoted as sustainable livelihood options that reduce pressure on overexploited stocks while providing new income streams (WorldFish Center, n.d.; ADB, 2021). Similarly, the development of community-based ecotourism and value-added seafood processing offers pathways for economic diversification and empowerment, particularly for women and youth (ADB, 2021).

A shift toward more equitable and sustainable blue food systems is indicated by recent institutional and policy developments. Integrated, cross-sectoral, and participatory approaches to blue economy development are prioritized in the 2021 ASEAN Blue Economy Framework, which focuses on sustainable aquaculture, preventing illegal, unreported, and unregulated (IUU) fishing, and strengthening regional cooperation (ASEAN, n.d.). The use of digital tools, artificial intelligence, and remote sensing to enhance monitoring, traceability, and resource management is also accelerating technological innovation. However, disparities in capacity and equitable access still exist, especially for vulnerable coastal communities and small-scale fishermen (East Asia Forum, 2025).

National initiatives, such as Indonesia's efforts to expand sustainable blue food production, are demonstrating the potential for transformative change in nutrition and rural livelihoods (Stanford Report, 2025). At the global level, the FAO's "Blue Transformation" agenda highlights the historic milestone reached in 2022, when global aquaculture production surpassed capture fisheries for the first time, underscoring a significant trend toward farmed aquatic foods (GEO Blue Planet, n.d.).

To create resilient, inclusive, and sustainable blue food systems, focusing on a few key actions is essential: strengthening policies and their enforcement by aligning national rules with global sustainability goals, and investing in better data and research to understand challenges like microplastics, ALDFG and climate impacts. It is also crucial to support sustainable alternative

livelihoods such as integrated aquaculture and ecotourism. Furthermore, building local capacity fostering inclusive governance, valuing traditional knowledge, and securing diverse or innovative funding for sustainable fisheries and aquaculture, as well as alternative livelihood initiatives are crucial.

MARITIME TRANSPORT AND SHIPPING

The maritime transport sector remains central to global trade, facilitating over 80% of the world's trade (Economist Impact, 2023). Due to lessening global economic pressures and better-than-expected economic performance in large economies, the volume of maritime trade worldwide grew by 2.4% in 2023, exceeding projections following a contraction in 2022 (UNCTAD, 2024). Additionally, the sector accounts for about 3% of greenhouse gas emissions worldwide (Economist Impact, 2023).

In 2023, 95% of global shipbuilding was produced in China, South Korea, and Japan. Notably, China alone supplied more than half of the world's new ship capacity for the first time. However, shipyard capacity is unevenly distributed, Tier 1 yards are overbooked, while Tier 2 yards remain underused, resulting in longer delivery times and newbuild prices that are over 40% higher than in 2020. Although global fleet capacity grew by 3.4%, outpacing the 2.4% growth in maritime trade, concerns over container shipping overcapacity were eased as rerouting around the Cape of Good Hope increased voyage distances and reduced vessel speeds (UNCTAD, 2024).

UNCTAD's review of maritime transport also showed that the global shipping fleet is aging, with an average of 12.5 years by deadweight and 22.4 years by vessel count as of early 2024. Over half the fleet is now older than 15 years. Ship scrapping remains low, as operators keep older vessels active to benefit from high freight rates and ongoing route disruptions. Demand in the second-hand market remains strong, particularly for bulkers, tankers, and LPG carriers, with nearly 60% of ships sold in 2023 being over 15 years old (UNCTAD, 2024).

Global port dynamics are changing, trade routes are changing, and new demand centers are being created by population growth concentrated in Asia and Africa (Economist Impact, 2023). Shorter voyages, higher costs, and changing port competition based on supply chain value as well as cargo volumes are all consequences of trends like deglobalization, regional trade blocs, and changing trade-to-GDP ratios (Notteboom et al., 2022; Economist Impact, 2023). While increased focus on cybersecurity and energy security reflects growing geopolitical tensions, shipping consolidation, the rise of mega-ships, and multi-port governance are changing competitive landscapes (Notteboom et al., 2022).

The sector's transition is heavily reliant on environmental imperatives. Carbon pricing, natural solutions like blue carbon, and the use of green fuels like hydrogen and ammonia are all pushing ports and shipping to decarbonize. By 2050, the effects of climate change, such as sea level rise, will force people to relocate and endanger important ports, particularly in the case of a "Delayed Transition." Meanwhile, it is anticipated that the rise of AI, blockchain, immersive technologies, renewable energy, and port digitization will transform maritime operations. Socially, the future workforce and the socioeconomic function of ports will be altered by automation, shifting labor migration trends, and the need for more equitable port development. In order to remain resilient in the face of these convergent challenges, the sector must embrace innovation, inclusivity, and integrated planning (Economist Impact, 2023).

In support of sustainable maritime transport and shipping operations and initiatives, various studies offered the following recommendations. To reach net-zero emissions by 2050, the maritime sector must accelerate decarbonization through operational changes and investment in cleaner fleets. This includes supporting green fuels like hydrogen and ammonia, redesigning ports for fuel supply and storage, and retrofitting ships with alternative energy and carbon capture systems. Empowering port communities and investing in green infrastructure are also key to driving the transition (Economist Impact, 2023; UNCTAD, 2024).

Effective risk management, strategic planning, and collaboration among stakeholders from the shipping companies, ports, traders, and governments, are essential for resilient maritime supply chains. Using alternative routes, improving port facilities, and working more closely with other countries can help reduce dependence on crowded shipping lanes and ease traffic at key points. Leveraging technology and early warning systems improves readiness, while supporting supply chain workers helps address labor shortages (UNCTAD, 2024). Ports must also boost flexibility, interconnectivity, and resilience through stronger stakeholder engagement, digital upgrades, and climate-adaptive planning (Notteboom et al., 2022).

With the advent of new fuels and technologies, the welfare of seafarers must be given top priority, with fair compensation, suitable work and rest schedules, and strong health and safety protocols. It is also important for industries to recruit, train, and develop fresh, varied talent while giving them the digital know-how and necessary skills, including specialized training courses (i.e., for managing potentially hazardous new fuels like ammonia) (Economist Impact, 2023). Addressing the social effects of automation is also crucial in order to guarantee that it creates better-paying, higher-quality jobs (Notteboom et al., 2022).

To advance low-carbon shipping and fleet renewal, regulatory certainty, shipyard investment, and collaboration between shipping industries and governments are essential. Adapting to market shifts requires ongoing monitoring, while promoting free and regional trade can help

buffer global disruptions (UNCTAD, 2024). Innovation, data sharing, and cybersecurity must be prioritized, alongside exploring new port governance and revenue models that reflect broader performance metrics beyond cargo volume, including sustainability and resilience (Notteboom et al., 2022).

COASTAL AND MARINE TOURISM

In 2019, tourism accounted for 10.3% of all jobs (333 million) and 10.3% of the global GDP (USD 9.6 trillion), making it a significant driver of socioeconomic growth. At least half of the world's tourism industry is made up of coastal and maritime travel, or "blue tourism," which sustains millions of jobs. By 2030, it is expected to account for 26% of the ocean economy, making it the largest value-added segment (Blue Tourism Initiative, 2023). Tourism also accounts for 30% of the GDP of Small Island Developing States (SIDS), which is double the global average. In certain SIDS, it can reach 90%. Over 350 million people visit coral reefs each year, generating an estimated USD 36 billion in revenue and boosting the economies of more than 70 nations (High Level Panel for a Sustainable Ocean Economy, 2020).

Similar to other blue economy sectors, coastal and marine tourism is also highly vulnerable to climate change impacts, including extreme weather, sea level rise, and ocean warming, which threaten coral reefs and coastal infrastructure. Tourism is also a significant contributor to global greenhouse gas (GHG) emissions (8-11% in 2013), particularly from transport and accommodation. Other risk factors are habitat loss, increased pollution, and degradation of vital ecosystems like mangroves and coral reefs caused by coastal urbanization and land-use changes, which are often fueled by tourism (High Level Panel for a Sustainable Ocean Economy, 2020).

The coastal and marine tourism industry was also significantly affected by the COVID pandemic, which led to a drastic drop in international arrivals, a 50.4% fall in tourism receipts in 2020, and the loss of 62 million jobs. It also caused depletion of human capital and increased cost for attracting and retaining staff. While the pandemic exposed the fragility of coastal and marine tourism, it also created opportunities for sustainable transformation (High Level Panel for a Sustainable Ocean Economy, 2020). Noted shifts include growing demand for domestic, nature-based, and eco-friendly travel, increased pressure on low-traffic ecosystems, and rising interest in low-impact options like virtual tourism and long-term stays for digital nomads. Wellness and cultural tourism are also on the rise, with travelers seeking immersive, slower-paced, and community-centered experiences (Khurana & Khurana, 2025).

Recent trends in coastal and marine tourism highlight a global move toward more sustainable, inclusive, and resilient models. Initiatives like the Ocean Panel's 2030 Goal and the Blue Tourism Initiative emphasize integrated ocean governance to restore ecosystems, curb climate and pollution impacts, and support sustainable livelihoods in coastal communities. In Southeast Asia, the ASEAN Ecotourism Standard (AECOS) redefines ecotourism through a certification framework that balances environmental stewardship, economic growth, and community well-being (The ASEAN Admin, 2025 February 11). Smart tourism is also gaining momentum, with countries adopting digital technologies to enhance visitor experiences while minimizing environmental impact. For example, Singapore leads in "intelligent tourism" with AI-driven visitor management, contactless payments, and digital guides (Leong, Leong, Leong, 2024, August 14). Policies supporting digital nomads, such as long-term visas in Indonesia and Thailand, reflect evolving tourist demographics and behaviors (Khurana & Khurana, 2025, April 16).

Nature-based solutions are key to the evolving tourism model, with efforts to restore reefs and coastal ecosystems attracting eco-conscious travelers (Blue Tourism Initiative, 2023). Community-led tourism is also growing, emphasizing local sourcing and culture; integration of traditional knowledge to promote regenerative and culturally rooted travel is also cited in some countries like Japan, Palau, and New Zealand (High Level Panel for a Sustainable Ocean Economy, 2020).

To advance sustainable and resilient coastal and marine tourism, various studies and forums have put forward the following insights and recommendations: Policies must promote integrated governance, aligning national and regional strategies with global commitments such as the 2030 Agenda and the Paris Agreement. Strengthening cross-sector and multi-stakeholder collaboration, including through marine regional partnerships, is essential for informed decision-making and knowledge sharing. Circular economy practices should be encouraged across the tourism value chain, alongside the expansion of sustainability certification programs, particularly for small operators. Diversifying tourism products through eco-friendly innovation, improved business linkages, and technical support can help create inclusive, low-impact economic opportunities. Integrating climate action into tourism planning is equally critical, supported by capacity building, financial incentives, and awareness initiatives. Tools such as carrying capacity assessments, visitor impact monitoring, and place-based marketing can help manage tourism pressures while promoting regenerative tourism and cultural preservation.

Moreover, digital innovation plays a key role, with investment in smart tourism infrastructure and responsible technology use needed to bridge digital divides and enhance visitor management. Improved data systems and indicators are important for tracking tourism's environmental and socio-economic impacts. Building future-ready skills through research partnerships,

climate science integration, and community-based training will further empower local actors. Sustainable financing must be expanded through mechanisms such as user fees, conservation trust funds, blue bonds, and incentives for SMEs. Equally important is institutionalizing collaborative governance, using sustainability indicators beyond GDP and supporting inclusive co-management structures.

OFFSHORE OIL AND GAS

Offshore oil and gas is experiencing a notable resurgence, with most new discoveries, extraction projects, and investment approvals in 2024 occurring offshore, prompting some to label the 2020s as "deepwater's decade". Offshore discoveries accounted for roughly 60% of global discoveries in the 2010s, but that number rose to roughly 73% in the 2020s (Global Energy Monitor, 2025 March 3). At least 8 billion barrels of oil equivalent (bboe) were found offshore in 2024 alone, with 85% of that amount concentrated in significant fields like Mopane (Namibia) and Nokhatha (Kuwait). This momentum continued in 2025 with the discovery of Kuwait's Julaiah field (Global Energy Monitor, 2025 March). In 2024, 71% of new field startups were offshore, and all 12 projects that reached final investment decisions (FIDs) were offshore, including Exxon's Whiptail and TotalEnergies' GranMorgu (Global Energy Monitor, 2025 March 3).

This boom is largely attributed to falling deepwater development costs and technological advancements unlocking previously inaccessible reserves, alongside claims of lower carbon intensity in newer offshore projects. However, critics caution that the industry's environmental impact is still substantial because of "Scope 3" emissions (those from end-use combustion) which represent 80-85% of total oil and gas lifecycle emissions (Global Energy Monitor, 2025 March).

Offshore oil and gas production remains active in East and Southeast Asia, with notable developments in 2024. China launched six offshore projects, the largest being CNOOC's Bozhong 19-6 (13-2) field in the Bohai Sea, which began production in May 2024. CNOOC is targeting a 5.6% production increase in 2025 compared to 2024 (Global Energy Monitor, 2025 March).

In Southeast Asia, Indonesia, Malaysia, and Viet Nam were the top crude oil producers in 2023. The region's leading fields included Indonesia's Banyu Urip and Rokan PSC, Malaysia's Gumusut-Kakap and Malikai, Brunei's Champion Complex, and Viet Nam's Su Tu field. However, overall crude oil and condensate production in the region declined by 5.29% in 2023 and is expected to continue falling at a compound annual growth rate (CAGR) of 8.68% through 2030 (Offshore-Technology, 2024 September).

As the world's oil production declines, Southeast Asia is seeing what analysts refer to as "offshore gas renaissance". New offshore gas projects, especially in Indonesia and Malaysia, have the potential to draw up to USD 100 billion in investments. In addition to recent discoveries in Malaysia by Petronas, PTTEP, and Shell, significant developments include the Inpex-operated Abadi LNG, Eni's deepwater projects, and BP's Tangguh Ubadari CCS in Indonesia. Since the CO_2 content of more than half of these planned gas projects exceeds 5%, carbon capture and storage (CCS) solutions are now considered necessary for funding and regulatory approval. But obstacles like exorbitant prices, inadequate infrastructure, and unstable political environments still impede advancement (Offshore Magazine, 2024 July 10).

Decommissioning is becoming a key concern in Southeast Asia, with over 200 offshore fields, more than 1,500 platforms and 7,000 wells, expected to shut down by 2030, at a projected cost of USD 30-100 billion. Countries like Malaysia, Indonesia, Thailand, and Brunei are leading efforts under regional frameworks such as ASCOPE's guidelines. Completed projects include Premier Oil's Anoa field (Indonesia), Petronas' Dana and D30 (Malaysia), and Chevron's Erawan Block (Thailand). Thailand is progressing with its Decomm 2.0 program, while Malaysia plans to decommission over 150 wells by 2028, allocating USD 2 billion. However, limited recycling infrastructure poses a challenge to sustainable decommissioning (Bureau Veritas South East Asia, 2025, February 28).

Offshore oil and gas operations present significant environmental, climate, and social risks throughout their lifecycle. Exploration activities like seismic surveys disrupt marine life through intense noise pollution, while drilling and toxic discharges degrade ecosystems (Affatati,A. et al, 2023; Sinay, 2024 February 1). These processes also interfere with carbon-sequestering species and contribute to future emissions (Sinay, 2024 February 1). Social risks include threats to livelihoods and food security, particularly when coastal communities lose access to fishing grounds (Center for International Environmental Law, 2023 November 30).

Offshore platforms emit large amounts of methane, spills cause long-term damage, and routine discharges, light, and noise pollution continue to harm ecosystems. Liquefied Natural Gas (LNG) transport adds emissions and spill risks, as seen in Peru, Thailand, and the Philippines. Decommissioning can leave leaking infrastructure behind, shifting cleanup costs to governments. The "rigs-to-reefs" conversion approach raises further concerns by potentially spreading invasive species and allowing companies to bypass full decommissioning (Center for International Environmental Law, 2025).

Innovation and stricter regulations are driving a significant shift to the maritime industry. Cleaner fuels like biofuels, hydrogen, and ammonia are becoming more popular, while digital tools, such as AI, big data, and Digital Twins, help improve fuel efficiency and maintenance.

Emission-reduction measures include onboard carbon capture, shore power at ports, and environmental monitoring via IoT sensors and acoustic systems. Robotics are also enhancing safety and precision in offshore operations (Sinay, 2025, February 13).

Regulatory frameworks are also accelerating this transition. The IMO's strategy targets carbon neutrality by 2050 with intermediate targets for 2030 and 2040, while the EU's "Fit for 55" package brings maritime transport into its Emissions Trading System, aiming to cut 55% emissions by 2030. Despite temporary increases in fossil fuel output due to geopolitical tensions, the long-term trajectory remains focused on phasing out fossil fuels in line with global climate goals (Center for International Environmental Law, 2025; European Commission, 2025).

OFFSHORE RENEWABLE ENERGY

With energy potential that more than doubles the world's electricity demand, offshore renewable energy (ORE) is widely acknowledged as an essential part of climate mitigation efforts. It includes a wide range of clean and natural sources, such as solar, thermal, waves, tides, and offshore wind (Spalding, J., White, C., & Ross, L., 2025). Among these, offshore solar, and ocean and tidal currents have continuously demonstrated greater energy potentials than other resource types. Rapid growth, ongoing technological advancements, and quick market expansion are characteristics of ORE's global development (Su et al., 2024).

The offshore wind energy sector is rapidly expanding as a key pillar of the global clean energy transition, driven by climate goals and energy security efforts (GWEC, 2024). The renewable energy market, valued at USD402.84 billion in 2023, is projected to triple to USD1.2 trillion by 2035 (Market Research Future, 2024), with onshore and offshore wind costs falling by 68% and 60% between 2010 and 2021 in Europe due to technological advances (Ember, 2025). Supportive policies, including tax incentives and national targets, are driving investment. Global offshore wind power capacity increased by 8.4 GW in 2022 alone according to IRENA statistics. Of this, the offshore wind power installed capacity in China increased by 4.1 GW (accounting for 49%), with a cumulative installed capacity of 30.5 GW (Su et al., 2024).

Due to China's significant growth under its 14th Five-Year Plan and significant new installations, the Asia-Pacific region overtook Europe as the largest offshore wind market in 2022, with 34 GW total, though Europe remained a leader in floating wind (Mercom India, 2023 September 6; The Asset, 2025 May 15). Southeast Asia is relying on offshore wind and energy imports to power renewables in response to growing energy demand. The Philippines leads ASEAN in project awards with over 20 GW in offshore wind contracts, while Viet Nam aims for 10 GW by

2030 despite grid and policy obstacles (Source of Asia, 2024). While several challenges remain including regulatory obstacles, discussions about a supergrid for Southeast Asia are gaining momentum (Climatebase, 2025 Feb 28).

Globally, the United States offshore wind industry is contending with significant project delays and financial setbacks due, in part, to policy shifts. In contrast, Japan and South Korea are demonstrating positive advancements in their offshore wind sectors (Ship Universe, 2025).

Offshore wind power remains a major player in the renewable energy sector, due to abundant wind resources, flexible siting, and proximity to coastal markets. Fixed offshore wind, especially with monopile foundations, remains the dominant technology for shallow waters (Su et al., 2024). Meanwhile, floating offshore wind is emerging as a key solution for deep-sea deployment, with the potential to unlock 80% of global offshore wind capacity by 2035. Though still costly, prices are expected to fall significantly by 2050 (Ship Universe, 2024; Su et al., 2024).

Tidal energy is a clean, predictable, and largely untapped renewable resource with strong potential for sustainable development. A 1 MW plant in central Italy showed favorable returns, especially with policy support, and similar promise exists in East and Southeast Asia. South Korea's west and south coasts have a technical tidal energy potential, with key sites identified in Incheon-Gyeonggi and Jeollanam-do (Hwang & Jo, 2019). In the Philippines, Southeast Asia's first tidal power plant is being built on Capul Island, Northern Samar. Set to begin operations in late 2025, the 1 MW plant will replace diesel with clean energy as part of a solar and battery-integrated microgrid, with plans to replicate the model in other off-grid communities (Water Power Magazine, 2024).

Wave energy is a promising but underused renewable source with growing potential. The Marine Energy Council supports deploying at least 300 MW of wave energy by 2035 (Water Power Magazine, 2024 March 28). Offshore Solar and thermal energy, along with tidal and ocean currents, are found to have consistently higher energy potentials than other offshore renewable energy types on a global scale. (Spalding, J., White, C., & Ross, L., 2025)

The European Union is a major force in offshore renewables, aiming for at least 60 GW of offshore wind and 1 GW of ocean energy by 2030, rising to 300 GW and 40 GW by 2050. With 19.38 GW of offshore wind installed by 2023, the EU is boosting infrastructure resilience, cybersecurity, and updating the Trans-European Networks for Energy (TEN-E) Regulation to support growth (European Commission, n.d.).

The growth of offshore renewable energy brings both major challenges and opportunities. Key hurdles include high installation costs, environmental impacts, limited grid capacity, regulatory

uncertainty, and conflicts with maritime activities like fishing and shipping (Su et al., 2024; Ship Universe, 2025). Natural disaster risks and rising operational costs also add complexity (Source of Asia, 2024). Despite this, the sector holds immense potential with advancements in floating wind and storage, declining costs, and integration with other marine industries. Offshore renewables are expected to generate over 3 million jobs by 2030, strengthen energy security, and drive economic growth, while also reshaping maritime logistics and infrastructure (Ship Universe, 2024; Market Research Future, n.d.).

Emerging Blue Economy Sectors

Apart from the above well-established blue economy sectors, the following sectors are gaining traction due to technological advances, climate change response, and the shift toward sustainability:

Blue Carbon

Blue carbon ecosystems are gaining prominence for their exceptional climate mitigation potential, sequestering more carbon per acre than even a tropical rainforest (NOAA Climate.gov, 2022 September 29). Coastal wetlands store carbon 55 times faster than tropical rainforests (cited from McLeod et. al., 2011 in Ramsar Convention on Wetlands, 2021). Global estimates of total carbon storage in blue carbon ecosystems range from 10,450 to 25,070 million tonnes of carbon in the first metre of soil (Ramsar Convention on Wetlands, 2021). Restoration could recapture 0.62-1.06 Gt CO_2 globally per year (cited from Macreadie et.al, 2021 in High Level Panel for a Sustainable Ocean Economy, 2023). Complementary ocean-based solutions like macroalgae cultivation and marine carbon removal (mCDR) are also being explored (Ocean Visions, 2024 November 14). Key initiatives such as the Blue Carbon Initiative, IPBC (with 54+ partners), and PEMSEA's blue carbon program linked to ICM are some examples driving global and regional progress.

Deep Sea Mining

Deep-sea mining (DSM) is advancing rapidly amid growing controversy, especially over polymetallic nodules and hydrothermal vent extraction. The International Seabed Authority (ISA) during its 30th Assembly session in July 2025, advanced significant progress toward finalizing the Mining Code, including the second reading of draft exploitation regulations. Other key results included the approval of the development of a Common Heritage Fund, concurrence to prepare the groundwork to evaluate the potential economic impacts of seabed mining, adoption of standardized procedure for the development, establishment and review of Regional Environmental Management Plans, launching of the Deep-Sea Biobank in partnership with RO Korea, and establishment of 1 November as the International Day of the Deep Seabed as proposed by the sponsoring countries, Fiji, Jamaica, Malta and Singapore (International Seabed Authority, 2025 July 30).

Biotechnology and Biosprospecting

Marine biotechnology and bioprospecting are advancing rapidly, driven by cutting-edge tools such as artificial intelligence and advanced computational programs that enable research on natural substances, such as medicines, enzymes, and nutrients, derived from marine animals, bacteria, fungi, and algae (Cabral et al., 2024). In recent years, marine bioprospecting has surged, identifying thousands of unique natural products with diverse applications. While many of these compounds remain in the research or early development stages, several have already entered the pharmaceutical, cosmetic, food, and industrial enzyme markets (Osathanunkul, 2025). A 2024 market analysis of the global marine biotechnology market indicated its worth at USD 6.2 billion in 2024, with anticipated growth at CAGR of 7.9% from 2025 to 2033 and be worth USD 12.29 billion by 2033 (Market Data Forecast, n.d.).

Nature-based Carbon Credits

Nature-based carbon credits and solutions are experiencing rapid expansion, driven by both market demand and inclusive implementation. According to a Taskforce on Scaling Voluntary Carbon Markets (TSVCM)-informed study by McKinsey, demand for voluntary nature-based carbon credits is projected to grow 15-fold by 2030, potentially reaching a market value of over USD 50 billion annually and trading 1.5–2 Gt CO_2 per year (Blaufelder et al., 2021, January 29). By 2030, nature-based solutions collectively could reduce or remove at least 5 $GtCO_2e$ per year, increasing to at least 10 $GtCO_2e$ per year by 2050. Most of this potential comes from nature-based solutions related to forests (62%), followed by grasslands and croplands (24%), peatlands (10%), and coastal and marine ecosystems (4%) (UNEP & IUCN, 2021)

Desalination and Blue Water Technologies

In recent years, advancements in blue water technologies, particularly in seawater desalination and water reuse, have focused on boosting efficiency, sustainability, and scalability. China's large-scale reverse osmosis plant in Shandong and its national target of 3.5 million m^3/day by 2025 demonstrate a strategic response to coastal water scarcity (Aquatech Amsterdam, 2025). Advances in desalination technology and rising water treatment costs from stricter regulations are expected to make the ocean an increasingly competitive water source by 2030. Projections indicate reduction of freshwater production costs from seawater by 25% by 2022 and up to 60% by 2030 (IDRA Global Connections, 2024). As the desalination market is expected to grow from USD 1.68 trillion in 2025 to USD 2.57 trillion by 2030, emerging technologies emphasize renewable energy use, carbon-efficient filtration, and zero-liquid discharge to address both rising demand and environmental concerns (StartUs Insights, 2025).

Digital Ocean and Marine Data Services

Recent developments in digital ocean and marine data services highlight the growing integration of satellite remote sensing, AI, and cloud technologies to enhance ocean monitoring, marine spatial planning (MSP), and ecosystem management. The EU's Ocean and Waters Mission (2021-2030, with piloting in 2021-2025) exemplifies this shift by creating a digital ocean knowledge system, the European Digital Twin of the Ocean (EU DTO) that combines environmental monitoring, AI analytics, and participatory governance to support sustainable blue economy goals and transboundary MSP (European Commission, Directorate-General for Research and Innovation, 2025). AI-driven tools analyze large datasets to identify habitat hotspots, track environmental changes, and inform data-based decisions. In East Asia, some examples using big data-driven policy simulators, digital twin technology, and AI-powered analytics for evidence-based marine spatial management, which support data-driven analysis for optimal siting of maritime infrastructure, resource management, and maritime safety are also available (EAS Congress 2024 Secretariat, 2025).

Blue Circular Economy

The Blue Circular Economy (BCE) has gained momentum globally, focusing on waste reduction, recycling, and circular practices in marine industries such as fisheries, aquaculture, shipping, and ports. Efforts in Southeast Asia, supported by finance mechanisms, aim to transform marine waste into economic value while protecting ecosystems (Asian Development Bank, 2024). Innovations include recyclable and biodegradable fishing gear, ghost net recovery systems, and digital tracking tools like blockchain to enable transparent, circular supply chains. Regional initiatives such as ASEAN's Blue Economy Implementation Plan (2025) promote integrated approaches to marine spatial planning, fisheries, and waste management (ASEAN, 2025; European Commission, 2021). Globally, cities and coastal regions are scaling circular strategies through collaborative governance, biotechnological valorization of marine waste, and various awareness programs (OECD, 2024; Entnerd, 2025; ScienceDirect, 2025).

Eco-Labeling and Sustainable Certification Systems

Sustainable seafood certification efforts have advanced significantly through the work of the Marine Stewardship Council (MSC) and Aquaculture Stewardship Council (ASC), with expanding application, influence, and scope into emerging blue economy sectors, especially in developing coastal regions and novel marine farming systems. The MSC delivered over 529 global certifications by mid-2023 and launched regional "Pathway Projects" to support fisheries including in India, Indonesia, Mexico, and South Africa (Marine Stewardship Council, 2022; ScienceDirect, 2023). Its revised Fisheries Standard (version 3.0) enhances marine protections and excludes fisheries targeting marine mammals, while maintaining assessments and annual audits (Marine Stewardship Council, n.d.). The ASC introduced a consolidated Farm Standard in 2025 and launched an Improver Programme to support uncertified farms, while enhancing its Chain of Custody (CoC) requirements with digital traceability to combat seafood fraud (Aquaculture Stewardship Council, 2024a, 2024b).

Blue Financing

Blue finance is an essential enabler of marine conservation, coastal resilience, and sustainable ocean economies. It links investment with the protection and restoration of coastal and ocean ecosystems, directly addressing the triple planetary crisis (One Ocean Foundation, 2024). Despite its growing recognition, SDG 14 (Life Below Water) remains the least funded of all SDGs, which highlights a significant gap between global ambitions and investments. It was estimated that about USD 175 billion is needed annually in order to build a sustainable and inclusive blue economy, yet only USD 30 billion has been mobilized since 2010, underscoring the urgent need to close this critical financing gap (IISD, 2025).

Recognizing the need to accelerate blue finance, several international programs like the World Bank's PROBLUE and the International Finance Corporation (IFC) have emerged as some of the drivers in this effort. PROBLUE's portfolio now includes over 247 projects across 100 countries,

focusing on coastal resilience, pollution management, and the integration of blue finance into national budgets and policies (World Bank, 2025a). IFC has disbursed over USD2 billion in blue loans and bonds to support sustainable fisheries, marine pollution reduction, and circular economy infrastructure, including key projects in the Philippines and Thailand, among others (IFC, 2022).

Blue bonds (debt instruments) and blue loans (credit facilities for those that meet clear blue economy criteria) remain to be the main tools of blue financing, earmarked for ocean sustainability projects such as marine protected areas (MPAs), wastewater management, sustainable aquaculture, and coastal zone management. Some examples include Thailand's first blue bond (USD 300 million), Ecuador's private sector blue bond (USD40 million), and Morocco's forest restoration and fisheries reform initiatives (World Bank, 2025b). Debt-for-nature swaps have also gained attention with examples seen in Ecuador's Produbanco blue loan in support of sustainable fishing practices (IFC, 2023 March 29) and in the Philippines with IFC's USD100 million investment in BDO Unibank's inaugural blue bond in 2022 (IFC, 2022).

In recent years, there has also been an increased integration of Environmental, Social, and Governance (ESG) criteria in investments related to ocean health. Despite some recent market volatility, global ESG assets are projected to reach USD34 trillion by 2026, with allocations to blue-aligned strategies (Sustainability Magazine, 2025). Blended finance, combining public or philanthropic funding with private investments, is also gaining popularity. Since 2010, the IFC has used USD5.9 billion in concessional funds to mobilize USD32.6 billion in private capital for ocean conservation, climate resilience, and sustainable fisheries efforts (International Finance Corporation, n.d.). Examples of key blended finance platforms include: The Minderoo Foundation's Blue Bond Incubator, being developed in collaboration with the Ocean Risk and Resilience Action Alliance (ORRAA) and Callund Consulting, aims to unlock up to USD70 billion in blue bond issuance by 2030; the ReOcean Fund, launched by the Prince Albert II of Monaco Foundation in partnership with Monaco Asset Management (MAM), with secured funding of at least €50 million; the Circulate Capital's Ocean Fund which has raised USD76 million, including USD10 million from IFC for tackling marine pollution and supporting aquaculture; and various initiatives of members of the Asian Venture Philanthropy Network (AVPN) (AVPN Asia, 2025 May 30)

To address the ocean finance gap, the Blue Economy and Finance Forum (BEFF) was held as part of the Third UN Ocean Conference (UNOC3) in June 2025. BEFF emphasized the need to: invest in ocean health through innovative financial instruments and nature-based solutions; transform the shipping industry by accelerating decarbonization and circular infrastructure investments; scale up sustainable ocean governance through inclusive, data-driven approaches; and mainstream blue criteria into national economic planning and financial

regulations to attract long-term capital. The event also featured scalable solutions such as the DP World USD100 million MENA Blue Bond for port decarbonization, and the expansion of blended finance models supporting fisheries reform and waste reduction in the Global South (IISD, 2025).

Despite the growing momentum on blue finance, several challenges must be addressed to scale blue finance effectively. During BEFF, the need to bridge the USD2.5 trillion funding gap (sovereign and private) needed by 2030 was emphasized and highlighted blue bonds, debt-for-nature swaps, and blended finance as options. The Forum also underscored the need to integrate blue criteria into national policies and financial regulations to reduce risk investments and mainstream sustainability (Baltic Sea & Space Cluster, 2025 May 6; ICRI, 2025).

Photo courtesy of Preah Sihanouk Province

3 Global and Regional Synergies in Ocean Governance: Advancing Coastal and Ocean Sustainability Amidst the Planetary Crisis

In the lead-up to the 2025 UN Ocean Conference (UNOC3) in Nice, France, a convergence of global and regional efforts has highlighted the urgent need to address the interconnected challenges of the triple planetary crisis alongside broader systemic pressures constituting the polycrisis. One important milestone was the 2024 UN Summit of the Future, where countries adopted the *Pact for the Future*. The Pact reaffirmed commitments to ocean sustainability by advancing SDG 14, promoting climate resilience, strengthening multilateral science-based ocean governance, and emphasizing the importance of intergenerational equity and ecosystem protection (United Nations, 2024a; United Nations, 2024b). As stated in various sections above, there were also a number of instruments and initiatives at the international level that emerged and are shaping the future of ocean governance across a range of critical thematic areas, including, the KMGBF (2022), BBNJ Agreement (2023), WTO Agreement on Fisheries Subsidies (2022), Revised IMO Biofouling Guidelines (2023), the IMO Net-Zero Framework (2025), and the ongoing negotiations on International Plastics Treaty.

Parallel regional initiatives have already been laying the groundwork for integrated coastal and ocean governance. In the East Asian Seas region, several platforms such as ASEAN, ACB, PEMSEA, COBSEA, CTI-CFF, NEASPEC, NOWPAP, SCS-SAP Project, WESTPAC, and recently established ATSEA program have been advancing ecosystem-based or ecosystem-based adaptation management, ICM, MSP, EAFM, IRBM, IWRM and inclusive, climate-resilient approaches. Key recent regional outputs include: the ASEAN Blue Economy Framework (2023) and supporting Implementation Plan for 2026-2030; COBSEA's Marine and Coastal Ecosystems (MCE) Framework (2023) and Collaborative Action Framework on Nutrients Management (2024); CTI-CFF's Regional Plan of Action (RPOA) 2.0 (2021–2030); Arafura and Timor Seas Strategic Action Programme (2024-2033); the outcomes of the 2024 PEMSEA East Asian Seas Congress, and the 2024 Xiamen Ministerial Declaration, which align closely with global priorities while responding to regional contexts. These efforts are also aligned with global science-policy frameworks such as the UN Decade of Ocean Science for Sustainable Development and the UN Decade on Ecosystem Restoration (2021–2030), which promotes scientific foundation, knowledge-sharing mechanisms, and innovative tools necessary for informed decision-making, ocean literacy, and ecosystem recovery (IOC-UNESCO, 2024; UNEP, 2023; PEMSEA, 2024).

The June 2025 UN Ocean Conference further amplified this momentum. Through the *Nice Ocean Action Plan* and its political declaration, the conference mobilized over 800 voluntary commitments targeting accelerated SDG 14 delivery, particularly expanding marine protected areas to 30% of the ocean by 2030, tackling marine pollution, regulating deep-sea mining, and scaling blue finance for vulnerable coastal and island nations. It also marked progress toward the High Seas Treaty's entry into force with increase in ratification, while initiatives like the Blue NDC Challenge signaled growing integration of ocean-based climate solutions into national climate agendas. As noted in earlier sections, organizations from the EAS region also agreed on a framework for a Regional Collaborative Network of MPAs in the East Asian Seas. Importantly, the conference underscored the role of inclusive governance, calling for stronger participation from Indigenous peoples, local communities, and youth, and reiterated the need for science-informed policies and open data. However, the conference also highlighted enduring gaps, particularly around equitable benefit sharing and capacity challenges in the Global South and small island developing states (UN, 2025; WRI, 2025; Geneva Environment Network, 2025).

In this evolving ocean governance landscape, the SDGs, particularly SDG 14, serve as a unifying framework for aligning global and regional ocean sustainability targets. While SDG 14 remains the least funded of all SDGs globally, regional efforts in East and Southeast Asia are making measurable, though uneven, progress across relevant marine and coastal targets. According to the Sustainable Development Report 2024, EAS countries demonstrate strong performance in SDG indicators related to marine protected areas (14.5) and aquaculture productivity (14.7) but continue to face persistent challenges in curbing marine pollution (14.1), addressing IUU fishing (14.4), and ensuring equitable access to marine resources for small-scale fishers (14.b) (Sachs et al., 2024; UNESCAP, 2024). Various regional initiatives, including the ASEAN Blue Economy Implementation Plan and PEMSEA's SDS-SEA Implementation Plan are helping to localize and operationalize SDG 14 and interlinked goals, including SDG 13 (Climate Action), SDG 2 (Food Security), SDG 6 (Clean Water), and SDG 12 (Sustainable Consumption), through cross-sectoral approaches.

In terms of progress across the 17 SDGs, a recent ESCAP report on SDG Progress in the Asia Pacific region[3] reveals both encouraging gains and significant challenges. Overall, positive strides have been made in poverty reduction (Goal 1), health (Goal 3), and innovation (Goal 9). However, there are serious setbacks including in areas with implications to ocean sustainability.

3 The ESCAP 2025 report categorized Asia Pacific into five subregions, including East and Northeast Asia (China, DPR Korea, Japan, Mongolia, and RO Korea) and Southeast Asia (Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste, and Viet Nam).

Though progress have been made in national disaster risk reduction strategies and plans, SDG 13 (Climate Action) has seen regression across the Asia Pacific region, largely due to extreme weather events and continued emissions of greenhouse gases. Progress on SDG 14 (Life Below Water) is hindered by declining sustainable fisheries and rising marine pollution. Meanwhile, SDG 15 (Life on Land) is affected by increase in proportion of land degradation. SDG 12 (Responsible Consumption and Production) shows unsustainable consumption and production trends, including increase in fossil fuel subsidies. Additionally, gaps in data and monitoring limit visibility into progress on SDG 5 (Gender Equality) and SDG 16 (Peace, Justice and Strong Institutions) (ESCAP, 2025).

Figure 12 highlights the following insights specific to East and North-East and South-East Asian regions:

- Low or limited data availability for indicators under Goals 5 (Gender Equality), 14 (Life Below Water), and 16 (Peace, Justice and Strong Institutions).
- Regression in Goals 9 (Industry Innovation and Infrastructure) and 12 (Responsible Consumption and Production), particularly in East and North-East Asia.

Looking more specifically at PEMSEA member countries, based on national SDG progress analysis from the ESCAP SDG Gateway (accessed on May 9, 2025) (Figure 13)[4], the region displays an uneven landscape of SDG performance.

- SDG 7 (Affordable and Clean Energy) shows mixed results across the region. While it ranks among the top-performing goals in China, Japan, Lao PDR, RO Korea, and Singapore, it is regressing in Cambodia, DPR Korea, Timor-Leste, and Viet Nam, highlighting disparities in energy access, efficiency, and the pace of clean energy transitions.
- SDG 1 (No Poverty) and SDG 3 (Good Health and Well-Being) are among the best-performing goals in Indonesia, the Philippines, DPR Korea, and Timor-Leste, reflecting positive progress in basic human development indicators.
- SDG 17 (Partnerships for the Goals) emerges as a regressing goal in both China and the Philippines, underscoring the need to strengthen regional and global cooperation mechanisms.
- Other environmentally-related significant goals, such as SDG 15 (Life on Land) in Indonesia, and SDG 4 (Quality Education) in Viet Nam, also show signs of stagnation or regression.

4 The ESCAP SDG Gateway is updated annually, typically in conjunction with the release of the Asia-Pacific SDG Progress Report. This research report recognizes that countries are/may also be maintaining their own SDG tracking systems, which could include data or updates not yet incorporated into the ESCAP SDG Gateway.

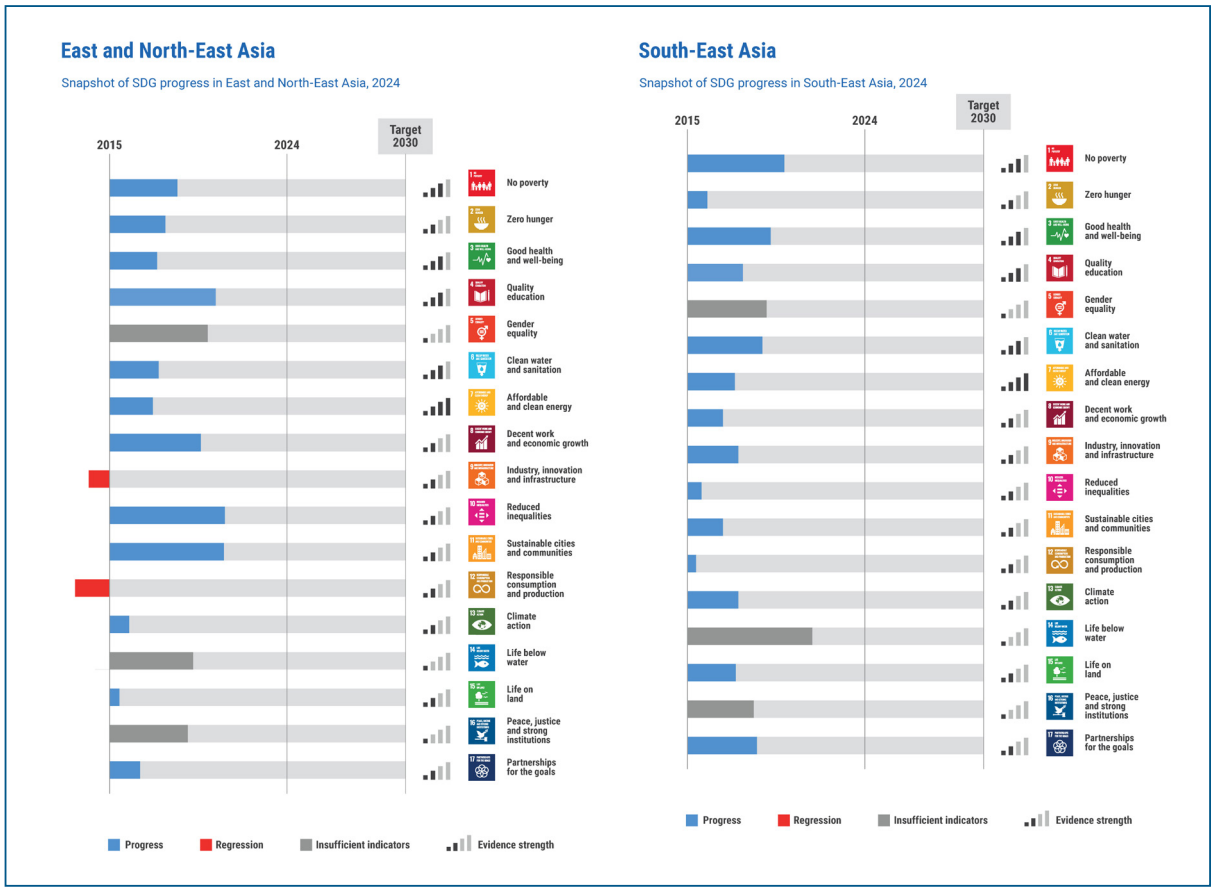


Figure 12. Snapshot of SDG Progress in East and North-East Asia, and South-East Asia. (ESCAP, 2025)

Figure 13. Synthesis of best performing and regressing SDG goals in PEMSEA member countries, lifted and compiled from ESCAP SDG Gateway (as of May 9, 2025).

The uneven progress toward the SDGs across the EAS region not only highlights the urgency of action but may also be a reflection of the diverse socio-economic contexts, governance structures, and institutional capacities of countries in addressing sustainability challenges. While some countries have made commendable progress in areas such as clean energy, health, or poverty reduction, others continue to face challenges in environmental governance, resource management, and cross-sectoral coordination.

4 Common Strategic Priorities Based on Review of Trends in Coastal and Ocean Governance and Ecosystems

Our coasts and oceans face accelerating risks from climate change, biodiversity loss, and pollution. These threats are converging with significant socio-economic and technological shifts, requiring bold, integrated, and forward-thinking solutions. A review of various sectors and issues reveals important insights that can guide strategic planning to improve coastal and ocean governance in the East Asian Seas (EAS) region.

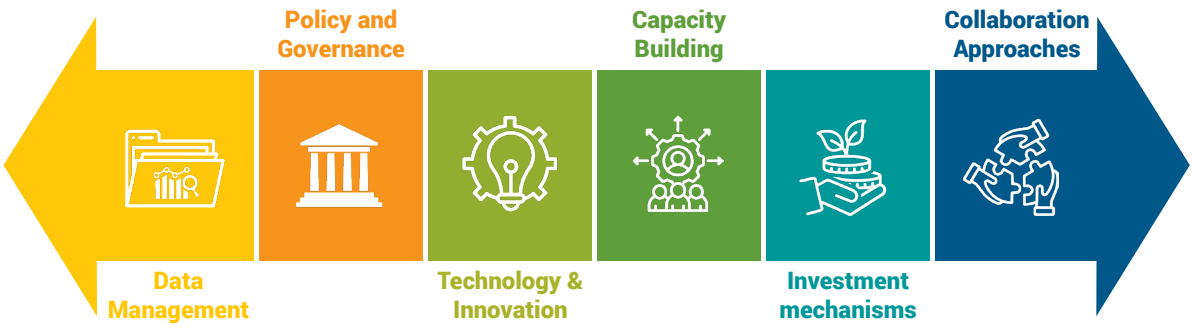
Key Challenges and Dynamics

- **Escalating Systemic Risks and Polycrisis Dynamics:** There is a rise in complex, interconnected crises that impact sustainable coastal and ocean development and governance.
- **Persistent Governance Fragmentation:** Fragmented governance across land-sea interfaces, different jurisdictions, and various institutional levels continues to hinder effective, large-scale action.
- **Innovation and Technology Gaps:** Despite a surge in ocean-climate solutions, "blue" technologies, and digital systems (e.g., AI, remote sensing, autonomous vehicles), significant disparities remain in equitable access, adoption, and the capacity to fully leverage these innovations, especially for vulnerable and resource-limited communities.
- **Growing Demand for Financing, Transparency, and Measurable Outcomes:** There is increasing pressure for more and diverse funding, greater transparency, and clear, measurable results in blue economy and sustainability initiatives. This includes calls for innovative financial tools, fiscal reforms, and stronger accountability.
- **Deepening Vulnerabilities and the Need for Inclusive Engagement:** Coastal communities, particularly those relying on small-scale fisheries, living in low-lying areas, or in biodiversity hotspots, face escalating risks. Addressing these challenges requires stronger, more inclusive engagement that empowers local communities and integrates traditional and indigenous knowledge.
- **Rising Importance of Regional Coordination:** Regional cooperation is increasingly vital for tackling shared transboundary challenges, harmonizing policies, and scaling up effective solutions in the face of common risks and opportunities.

Building on more than three decades of experience, PEMSEA has established strong foundations particularly in Integrated Coastal Management (ICM) and has progressively expanded its application alongside other integrated management approaches. Its work has addressed diverse issues, demonstrated tangible on-the-ground benefits, and cultivated robust partnerships and networks from the local to the international level involving various sectors. Over the years, PEMSEA has proven its effectiveness in delivering bilateral and multilateral donor-funded projects, continually evolving in alignment with the SDS-SEA vision and the East Asian Seas countries' commitments. This provides PEMSEA with a solid base as it updates its strategic programming to 2030 and beyond. In this context, the evolving ocean dynamics present a crucial opportunity for PEMSEA to further strengthen its role as an integrator and innovation catalyst, bridging local priorities with global commitments and driving systemic, transformative change.

Strategic Priorities for Coastal and Ocean Governance

Based on the review of current status, trends, challenges, and opportunities, several foundational action areas are crucial for accelerating sustainable blue economy transitions and addressing the triple planetary crisis. The following priorities generated from the review can serve as reference to guide PEMSEA's medium- to long-term strategic planning:



- **Data, Monitoring, and Research:**
  - Standardize methodologies and harmonize data flows across sectors and borders.
  - Invest in advanced monitoring tools (e.g., AI, remote sensing, autonomous vehicles, smart sensors).
  - Address critical knowledge gaps, by conducting research and assessments in various areas of coastal and marine environment (e.g., the health impacts of microplastics, biofouling's greenhouse gas contributions, salt marsh distribution, and marine species baselines, etc.).
  - Promote interdisciplinary research, robust knowledge-sharing platforms, and monitoring and reporting to support evidence-based policymaking and scale effective practices.

- **Policy, Governance, and Regulatory Alignment:**
  - Strengthen the alignment of national plans (e.g., Nationally Determined Contributions (NDCs), National Biodiversity Strategies and Action Plans (NBSAPs), National Adaptation Plans (NAPs)) with international frameworks and commitments.
  - Enhance the enforcement of environmental laws and regulations.
  - Simplify and clarify regulatory pathways to encourage sustainable investments.
  - Foster adaptive, ecosystem-based management approaches that bridge land-sea and cross-sectoral divides.

- **Technology, Innovation, and Equitable Adoption:**
  - Accelerate the deployment and equitable adoption of "blue tech," sustainable materials, marine biotechnology, and digital tools that support maritime services and ecological restoration.
  - Facilitate technology transfer and targeted research and development (R&D), ensuring innovations are accessible to everyone, particularly marginalized and vulnerable communities, while acknowledging importance and application of Traditional Ecological Knowledge (TEK).

- **Capacity Building, Public Engagement, and Inclusive Governance:**
  - Invest in human capital, climate and ocean literacy, and community infrastructure.
  - Integrate traditional, local, and indigenous knowledge into management and decision-making processes.
  - Strengthen participatory mechanisms to ensure diverse stakeholders, especially women, youth, and marginalized groups, are meaningfully engaged.

- **Innovative and Diversified Financing:**
  - Develop and scale innovative financial mechanisms, such as green/blue bonds, conservation funds, and blended finance models.
  - Implement fiscal reforms, including subsidy reallocation and user fees, to incentivize sustainable practices and identify new investment streams.

- **Collaboration and Integrated Approaches:**
  - Build and sustain strong cross-border and cross-sector partnerships, leveraging source-to-sea strategies and ecosystem-based and adaption management tools like Integrated Coastal Management (ICM) and Marine Spatial Planning (MSP).
  - Advance nature-based, nexus and systemic approaches, and inclusive solutions that address the interconnectedness of environmental, social, and economic systems.

In summary, the convergence of escalating risks and emerging opportunities underscore the need to move beyond incremental change. By strengthening priorities and actions on integration, innovation, and inclusivity, the East Asian Seas region can build resilience, drive sustainable blue economy transitions, and deliver on both local priorities and global commitments.

Photo by J. Singlador/PEMSEA

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