



OCEAN FUTURES: ADVANCING DECARBONISATION AND INNOVATION IN SHIPPING AND MARINE BIODIVERSITY

POLICY BRIEF
[APCEL-PP-2502]

OCTOBER, 2025



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INTRODUCTION



The ocean is central to global environmental stability, economic prosperity, and human well-being. Yet, as maritime trade expands and climate pressures intensify, the ecological systems that sustain ocean health face mounting risks. The shipping industry—responsible for transporting around 90% of global trade—is both a critical enabler of economic interconnectedness and a source of environmental impacts ranging from greenhouse gas emissions to the degradation of marine biodiversity. Addressing these challenges requires coordinated action that spans legal frameworks, technological innovation, scientific research, and industry practice.

Against this backdrop, the Asia-Pacific Centre for Environmental Law (APCEL)^[1] at the National University of Singapore and Sorbonne University Abu Dhabi (SUAD)^[2] co-hosted the international symposium *“Ocean Futures: Advancing Decarbonisation and Innovation in Shipping and Marine Biodiversity through Law, Policy, and AI”* on 14 October 2025. Held as part of SUAD’s Year of the Ocean initiative, the symposium convened policymakers, legal scholars, scientists, conservation practitioners, and industry leaders to explore how governance and innovation can jointly support a sustainable maritime sector.

Keynote contributions from the UAE Ministry of Climate Change and Environment and the Swiss Federal Office for the Environment highlighted both regional leadership and the global implications of emerging biodiversity frameworks, including the Biodiversity Beyond National Jurisdiction (BBNJ) Agreement.

The symposium prompted three key thematic discussions: decarbonisation in global shipping; regulatory and operational approaches to marine biodiversity protection; and the transformative potential of artificial intelligence and robotics in improving ocean knowledge and conservation outcomes. These discussions are the foundation of this policy brief, which emphasized the need for integrated, cross-sectoral strategies that link climate action, biodiversity protection, and technological advancement in pursuit of a resilient and nature-positive ocean future.

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THEME 1: DECARBONISATION IN THE SHIPPING INDUSTRY

This theme highlighted the interplay between international law, equity principles, and corporate strategies in addressing one of the most pressing issues in global climate governance. The theme highlighted three main discussion issues: international legal framework on governing maritime emissions, implementation of fairness principle under the new International Maritime Organization's (IMO) target, and the industry perspective in decarbonization of shipping.

Theme 1.1: International legal framework on governing maritime emissions.

The International Maritime Organization (IMO) has a crucial role in the shipping industry's decarbonization strategy. This started with its evolving regulatory instruments, such as the Initial IMO GHG Strategy and upcoming revisions aimed at aligning with the Paris Agreement's temperature goals. However, while IMO has made significant strides in setting targets, enforcement remains a critical gap. There is a need for stronger compliance mechanisms and greater harmonization between maritime law and global climate objectives, noting that fragmented regulations risk undermining collective progress.

Theme 1.2: Implementation of Fairness under the new IMO's decarbonization target

Decarbonization under the IMO regime through the lens of the principle of Common But Differentiated Responsibilities and Respective Capabilities (CBDR-RC) is thought provoking. There is a tension between equity and effectiveness in international climate governance, specifically the application of CBDR-RC to shipping—a sector traditionally governed by uniform standards—raises legal complexities, particularly in determining fair burden-sharing among developed and developing nations. Question arises on how fairness can be operationalized without compromising climate ambition, underscoring that a re-interpretation of what fairness means in IMO regulations will play a decisive role in shaping future decarbonization pathways.

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Theme 1.3: the industry perspective in decarbonization of shipping

The example of industry perspective in the shipping industry was outlined CMA-CGM's (one of the biggest shipping companies in the shipping industry) multi-pronged decarbonization strategy, which includes substantial investments in alternative fuels such as bio-LNG and methanol, deployment of digital technologies for route optimization, and collaborative partnerships to accelerate green innovation. It is acknowledged the operational and financial hurdles faced by shipping companies, particularly the challenge of balancing competitiveness with sustainability. While technological solutions are advancing, their scalability and cost implications remain significant barriers, requiring coordinated action across the value chain.

Questions on feasibility of zero-emission vessels and the role of port authorities in enabling green corridors, to the potential for regional cooperation to complement global efforts, remain. There are also concerns about the pace of innovation and whether regulatory frameworks can keep up with technological developments, and the importance of financing mechanisms and public-private partnerships to support the transition.

To achieve decarbonization in the shipping industry, there is a need for interdisciplinary collaboration, bridging law, technology, and economics to accelerate the sector's climate transition. Decarbonization in shipping is not merely a technical challenge but a systemic transformation requiring coordinated efforts across multiple stakeholders.

Decarbonization in the shipping industry illuminated the multifaceted nature of maritime decarbonization. It reinforced that achieving net-zero in shipping demands a holistic approach—strengthening international legal frameworks, embedding equity principles, and fostering industry innovation. This conversation sets the tone for the next theme, signalling that while the road ahead is complex, collective action grounded in fairness and ambition can steer the shipping industry toward a sustainable future.

THEME 2: SHIPPING AND MARINE BIODIVERSITY PROTECTION

Shipping exerts a wide range of pressures on marine biodiversity—from the spread of invasive species and underwater noise to anchoring damage and operational discharges. Addressing these impacts requires coordinated efforts across legal frameworks, regulatory mechanisms, and industry practice. This theme explores these intersections. It discusses how international maritime law, biodiversity governance, and industry-led initiatives can jointly foster a nature-positive maritime future from the legal, policy, and practical perspectives.

Theme 2.1: The negative impacts of shipping on biodiversity and the international regulatory response

There are three important impacts of shipping on marine biodiversity and the international regulatory responses already in place to address these impacts. The three key areas of concern are the spread of alien invasive species, pollution from ship operations, and physical damage caused by anchoring. First, for invasive species, organisms transported through ballast water or accumulating as biofouling on hulls can disrupt local ecosystems when introduced into new environments. This is regulated by the Ballast Water Management Convention (**International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004**), which requires ships to treat or manage their ballast water before discharge. Additionally, there is also the Biofouling Guidelines which promotes consistent practices in hull and equipment maintenance. This guideline is currently ongoing discussions to potentially be transformed into a binding framework. Moreover, there is also the CTU Code, the Code of Practice for Packing of Cargo Transport Units, a joint publication by the International Maritime Organisation (IMO), International Labour Organization (ILO), and United Nations Economic Commission for Europe (UNECE) that provides global guidelines for the safe packing, securing, and unpacking of freight containers and other cargo transport units.

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Second, pollution. Pollution is regulated under the London Convention and London Protocol in restricting the dumping of waste at sea, and the International Convention for the Prevention of Pollution from Ships (MARPOL), the primary international convention addressing six major forms of pollution from ships, ranging from oil and chemicals to garbage and air emissions.

And third, the problem of anchoring in ecologically sensitive areas. This is managed by introducing the concept of Particularly Sensitive Sea Areas (PSSAs) as a legal mechanism through which regions of high ecological or cultural value can receive special protection. The designation of a PSSA may result in routing measures or restrictions designed to prevent damage before it occurs. While these regulatory instruments exist and provide important safeguards, their success depends on consistent implementation, coordinated enforcement, and meaningful commitment by both states and industry actors.

Theme 2.2: The New Biodiversity Beyond National Jurisdiction (BBNJ) Treaty and governance of shipping in the high seas.

The global scale of maritime activity consists over 80% of world trade is carried by sea, with approximately 109,000 merchant vessels operating globally, and shipbuilding, ownership, and registration spanning multiple jurisdictions. This complexity is precisely what makes biodiversity protection in international waters legally challenging. The BBNJ Treaty, builds on the legacy of the 1958 High Seas Convention and the 1982 United Nations Convention on the Law of the Sea (UNCLOS), while reaffirming the principle of the common heritage of mankind. There are two components of the treaty of particular relevance for shipping: Area-Based Management Tools (ABMTs) and Environmental Impact Assessments (EIAs). While the International Maritime Organization (IMO) already administers spatial protection measures under instruments such as Special Areas, Emission Control Areas, and Particularly Sensitive Sea Areas, the BBNJ Treaty introduces new expectations for how such tools might be applied in areas beyond national jurisdiction. The treaty could broaden the range of actors involved in decision-making, including the emerging role of adjacent coastal states in shaping management measures. However, the effectiveness of new protections must be balanced against economic and operational realities: rerouting vessels can incur financial costs and may lead to indirect

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The BBNJ Treaty marks an important normative shift, extending the idea that biodiversity in the high seas is a shared global concern and not simply subject to commercial or jurisdictional convenience. While much will depend on how the treaty interacts with the IMO and industry practice, its reaffirmation of the common heritage of mankind signals an evolving legal landscape in which shipping may increasingly be expected to integrate biodiversity protection into its core operational norms.

Theme 2.3: Regional action and the practical engagement of maritime stakeholders.

The Ocean Health Roadmap is the first framework of its kind, developed specifically for the MENA (Middle East and North Africa) region and co-designed with marine scientists. Initially presented at the UN Ocean Conference, the Roadmap seeks to address not only carbon emissions but also the wider suite of biodiversity-related stressors linked to shipping. These include biofouling-mediated species transfer, underwater radiated noise affecting marine mammals, the growing concern of artificial underwater light, and operational risks such as ship speed and collision impacts in ecologically sensitive areas. The Roadmap is structured around three progressive “journeys” that maritime actors can undertake. The first focuses on decarbonisation, an area where many shipping companies already have established strategies, though with limited direct biodiversity benefits. The second journey centres on sustainability measures beyond carbon, such as improved biofouling management practices and safer hull coatings to reduce the spread of invasive species. The third journey, being the most transformative, deals with operational measures, including noise reduction, route planning, and vessel speed management, which have some of the strongest and most immediate effects on marine life protection. Phase 2 of the Roadmap, involves developing practical stakeholder guidelines to clarify roles and incentives for ports, shipping companies, charterers, and shipbuilders. A key challenge, is the prevailing industry mindset that “no regulation means no action.” The Roadmap therefore aims to demonstrate that voluntary, collaborative measures can deliver both ecological benefits and strategic advantages for the maritime sector.

Questions remain on practical pathways for aligning environmental law, industry practice, and scientific guidance to better protect marine ecosystems. Moreover, there is an

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importance of balancing regulatory clarity with flexible, incentive-based approaches, and the need for stronger regional cooperation in ecologically sensitive waters. There was broad agreement that advancing marine biodiversity protection in the shipping sector will require coordinated action across institutions — from the IMO and national authorities to port operators, shipowners, and financial actors shaping investment decisions. This discussion underscored a shared recognition that sustainability efforts must extend beyond decarbonisation alone to address the full spectrum of biodiversity stressors associated with maritime activity.

THEME 3: THE USE OF ARTIFICIAL INTELLIGENCE(AI) AND ROBOTICS FOR MARINE BIODIVERSITY PRESERVATION.

To better understand and preserve the ocean, it is essential to harness the power of AI and robotics. Despite covering more than 70% of the Earth's surface, less than 5% of the ocean has been explored. Based on the principle that “if we want to save it, we need to know it,” the discussion centres on the challenges of collecting and sharing marine data. The ocean is a global concern that requires a coordinated international response. Yet, ocean data is often gathered by diverse stakeholders who may be unaware of each other’s efforts or reluctant to share their findings. In this context, the importance of F.A.I.R. data—data that is findable, accessible, interoperable, and reusable—has been increasingly emphasized as essential for advancing ocean research and conservation.

Theme 3.1. Robots and AI in underwater research

The use of robotics, particularly underwater research vehicles, has significantly enhanced the capacity to explore and monitor marine environments. Recent developments have introduced artificial swarms of autonomous underwater vehicles that mimic the behaviour of schooling fish. These robotic swarms are capable of inter-communication, allowing them to share information when detecting objects or acoustic signals of interest. This cooperative approach improves the efficiency and coverage of ocean monitoring and mapping, surpassing the capabilities of individual vehicles operating in isolation.

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The application of artificial intelligence (AI) in marine research is expanding rapidly, offering new ways to enhance understanding of ocean systems. Four key uses of AI have emerged as particularly impactful: improving weather prediction; enabling autonomous, real-time detection of marine species and environmental conditions; facilitating underwater visual detection and tracking of moving species; and advancing image processing techniques such as dehazing and visibility enhancement. Additionally, AI is being used for behavioural analysis, helping researchers interpret complex species behaviours in dynamic and uncertain environments. These developments, alongside the integration of robotics, underscore the essential role of advanced technologies in expanding scientific knowledge of the ocean and supporting its conservation.

Theme 3.2: Overcoming data deficiency on cetaceans with innovative data collection methods

The protection of whales, dolphins, and porpoises—particularly in the Gulf region is critical to the health of marine ecosystems. Cetaceans play a vital role in maintaining ecological balance by supporting the marine food web and contributing to nutrient cycling. Moreover, they serve as significant carbon sinks, thereby playing an important role in mitigating climate change and supporting planetary health.

Despite their ecological importance, cetaceans are among the most threatened animal groups, with one in four species at risk of extinction. In many regions, data on cetacean populations remains scarce, suggesting that the actual conservation status of these species may be more severe than currently understood. This data deficiency is largely due to the inherent challenges of studying marine species, which are highly mobile and difficult to monitor. Estimating population sizes, mortality rates, and behavioural patterns is significantly more complex in marine environments than on land, and this lack of data often hampers effective conservation efforts.

The UAE Dolphin Project serves as an example of the practical challenges associated with current data collection methods, such as boat-based surveys and citizen science initiatives. To address these limitations and enhance cetacean protection, collaboration with the shipping industry has been proposed. Partnerships between scientists, governments, and maritime companies can facilitate mitigation strategies—such as

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rerouting shipping lanes to reduce vessel strikes and disturbances—and support the development of new data collection methods, including standardized frameworks for reporting sightings.

Such collaborative approaches underscore the need for greater involvement of private sector actors in cetacean conservation, particularly through improved data gathering and sharing practices.

Theme 3.3. Enhancing data sharing through international regulation

The value of ocean data sharing, particularly data collected by private companies, is increasingly recognized as a key factor in advancing marine science and sustainable ocean management. Sharing such data can build stakeholder confidence, drive innovation, enhance operational efficiency, and support more effective environmental governance. Improved access to ocean data contributes to the development of strategies that promote sustainability within the marine industry.

In response to this need, the Intergovernmental Oceanographic Commission (IOC) has prioritized efforts to increase the availability of privately held ocean data. One initiative under the UN Ocean Decade is the Ocean Decade Corporate Data Group, which brings together major maritime companies—such as TotalEnergies and Ørsted—to develop frameworks for making corporate ocean data publicly accessible.

The role of States in facilitating ocean data sharing was also highlighted, particularly in distinguishing between regulatory approaches in territorial seas versus the high seas. Outcomes from the 33rd session of the IOC Assembly emphasized the importance of public-private cooperation in ocean science. Member States agreed to actively support data-sharing initiatives for activities conducted within their territorial waters and exclusive economic zones. Discussions also included the potential integration of mandatory data-sharing provisions into offshore licensing and permitting processes.

These efforts underscore the leadership role of the UN Ocean Decade in fostering science-policy collaboration and promoting open data as a foundation for effective ocean conservation.

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KEY POLICY RECOMMENDATIONS



STRENGTHEN COMPLIANCE AND ENFORCEMENT IN THE IMO CLIMATE REGIME

While the IMO has established progressively more ambitious decarbonization objectives through the Initial GHG Strategy in 2018 and its revised GHG Strategy in 2023, these commitments remain limited without robust enforcement mechanisms. Strengthening compliance requires aligning maritime regulation more closely with the Paris Agreement's temperature goals, reducing regulatory fragmentation across jurisdictions, and equipping port authorities with clearer authority to monitor and verify emissions-related performance. This may involve enforcing transparent reporting standards, enhancing port state control capacities, and incentivising companies to adopt low-carbon technologies through differentiated port fees or recognition schemes. Only by strengthening compliance and enforcement of the IMO regulatory framework, can the states and industry actors transform ambitious targets into tangible reductions in sector-wide emissions.

OPERATIONALIZE FAIRNESS THROUGH A NUANCED APPLICATION OF CBDR-RC IN SHIPPING

The debate surrounding Common but Differentiated Responsibilities and Respective Capabilities (CBDR-RC) in the maritime sector highlights a core tension in international climate governance: how to reconcile climate justice as fairness with the IMO's uniform regulatory standards. Applying CBDR-RC within a sector traditionally premised on equal treatment requires innovative approaches that attribute the emissions of the vessels to the states that are actually benefits from their operations. Meaningful incorporation of CBDR-RC requires differentiation of state obligations based on their historical contribution and respective capacities to address climate change. Differentiated financial or technical support mechanisms, and capacity-building programs for developing and least-developed countries are helpful but not sufficient.

STRENGTHEN AND HARMONIZE EXISTING IMO BIODIVERSITY TOOLS

Although a robust body of international rules already exists to limit biodiversity impacts from shipping, their effectiveness is constrained by inconsistent implementation and varying levels of enforcement across jurisdictions. Strengthening the application of the Ballast Water Management Convention, enhancing oversight of biofouling through the progression of current voluntary guidelines into a binding global framework, and reinforcing MARPOL's pollution control measures would significantly reduce biodiversity risks associated with routine vessel operations. In addition, expanding the designation of Particularly Sensitive Sea Areas (PSSAs) can help protect ecologically valuable regions from anchor damage and routing pressures. Ensuring that states coordinate enforcement efforts and that port authorities are empowered with adequate inspection resources is essential to translating existing regulatory commitments into meaningful ecological outcomes.

KEY POLICY RECOMMENDATIONS

INTEGRATE THE BBNJ TREATY INTO HIGH SEAS SHIPPING GOVERNANCE

The adoption of the Biodiversity Beyond National Jurisdiction (BBNJ) Treaty represents an important normative evolution in the governance of marine biodiversity in areas beyond national jurisdiction. While the International Maritime Organization (IMO) already administers spatial and operational protection measures, the BBNJ Treaty introduces new expectations for how biodiversity concerns are to be integrated into maritime activity occurring on the high seas. This includes a more systematic use of Area-Based Management Tools (ABMTs) and the application of Environmental Impact Assessments (EIAs) to assess the ecological implications of vessel operations in sensitive ecosystems. Effective implementation will require careful coordination between the BBNJ framework, the IMO, and coastal states to avoid regulatory overlap while ensuring that biodiversity protection is not subordinated to commercial imperatives.

ENCOURAGE REGIONAL AND VOLUNTARY ACTION TO ACCELERATE CHANGE

While multilateral governance plays a central role in shaping maritime environmental standards, regional initiatives and voluntary industry commitments can often move more rapidly and offer practical pathways for implementation. Frameworks such as the MENA Ocean Health Roadmap demonstrate how ports, shipping companies, charterers, and shipbuilders can collaborate to address stressors such as underwater noise, vessel speed, and biofouling, even in the absence of binding international obligations. These initiatives recognize that there are tangible ecological and operational benefits to improving biodiversity performance, including reputational gains, reduced regulatory risk, and smoother port operations. Incentive-based mechanisms—such as green port fees, preferred chartering arrangements, or public sustainability ratings—can encourage maritime actors to adopt biodiversity-positive practices proactively. By fostering a culture of voluntary leadership alongside regulatory compliance, regional and stakeholder-led initiatives can help accelerate the transition toward a more ecologically responsible maritime sector.

KEY POLICY RECOMMENDATIONS

ESTABLISH A COORDINATED AND OPEN OCEAN DATA-SHARING FRAMEWORK FOR INFORMED MARINE CONSERVATION.

Promote the development of a coordinated and open ocean data-sharing framework that enables scientists, governments, and maritime industries to collectively generate, access, and use marine data. Currently, vital information on ocean conditions and species remains fragmented or inaccessible, hindering effective conservation and evidence-based management. Establishing shared data standards, encouraging public-private data collaboration, and integrating data-sharing requirements into marine licensing and operations would significantly strengthen our ability to monitor marine ecosystems, identify emerging risks, and implement targeted biodiversity protection measures. A transparent and interoperable ocean data system is foundational to informed decision-making and sustainable ocean governance.

CONCLUSION

As highlighted throughout this policy brief, the shipping industry sits at the nexus of global trade and environmental impact. Its regulation, with decarbonisation being at the forefront in recent years, is not only a climate imperative but also a catalyst for broader ecological resilience. Legal frameworks, such as the IMO's evolving climate regime and the newly adopted BBNJ Treaty, offer critical pathways for aligning maritime operations with sustainability goals. Marine biodiversity protection must extend beyond regulatory compliance to embrace proactive, regionally tailored strategies, as exemplified by the MENA Ocean Health Roadmap. Voluntary industry leadership, supported by incentive-based mechanisms, can accelerate environmental protection while enhancing operational efficiency and reputational value.



CONCLUSION

However, the success of these regulations and initiatives hinges on robust enforcement, equitable implementation, and increased knowledge. The transformative potential of artificial intelligence and robotics in ocean science highlights the importance of data sharing and collaborative innovation. By fostering open, interoperable data systems and engaging both public and private stakeholders, including the shipping industry, we can unlock new frontiers in marine conservation and ensure that ocean governance is informed, inclusive, and effective.

A resilient ocean future is within reach, but it requires a sustained commitment and collaboration not only amongst scholars of different disciplines but also between researchers, policymakers, industry, and all stakeholders. The international symposium ‘Ocean Futures: Advancing Decarbonisation and Innovation in Shipping and Marine Biodiversity through Law, Policy, and AI’ demonstrated this. We need to strengthen compliance and enforcement in the IMO climate regime, operationalise fairness through a nuanced application of CBDR-RC in shipping, strengthen and harmonise existing IMO biodiversity tools, integrate the BBNJ Treaty into shipping governance, encourage regional and voluntary action to accelerate change, and establish a coordinated and open ocean data-sharing framework for informed marine conservation. The future of ocean governance demands a bold, integrated approach that bridges climate action, biodiversity protection, and technological innovation.

ABOUT US

APCEL

The Asia-Pacific Centre for Environmental Law (APCEL) is a research centre at the Faculty of Law, National University of Singapore. APCEL is committed to promoting research-based capacity building and advancing innovative scholarship in a spirit of partnership. APCEL was established in 1996, in cooperation with the World Conservation Union-Commission on Environmental Law (IUCN-CEL) and UNEP, in response to the call in Agenda 21 to build capacity in environmental law and promote environmental consciousness.

Since its inception, APCEL has pioneered a wide-ranging programme of teaching, research and outreach to galvanise the use of legal mechanisms to address climate change, biodiversity loss, and plastics pollution. Recent projects include research on the Paris Rulebook, sustainability standards, and environmental courts and tribunals. APCEL also brings internationally renowned scholars together, alongside industry and other civil society stakeholders, to share the latest thinking on environmental law and policy at seminars and conferences.

Sorbonne Abu Dhabi

Sorbonne University Abu Dhabi (SUAD), established in 2006 through a visionary partnership between Sorbonne University in Paris and the Government of Abu Dhabi, stands as a bridge between civilizations.

Under its iconic dome on Reem Island, SUAD blends French academic tradition with Emirati ambition, offering world-class programs from bachelor's to doctorate levels across the humanities, sciences, and emerging fields such as sustainability and artificial intelligence.

Today, with a vibrant community of 1,800 students from 81 nationalities, SUAD is both a multidisciplinary research lighthouse for the region and a hub where students are empowered to become critical thinkers and responsible leaders.

Embodying excellence, diversity, and innovation, SUAD shapes future generations and fosters dialogue at the crossroads of cultures.