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Regulating AI-Enabled Marine Autonomous Systems to Advance Climate-Resilient Ocean Governance Under International Law

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Abstract. *Climate change is rapidly transforming marine ecosystems and ocean governance, while Artificial Intelligence (AI) is increasingly deployed as a critical tool for monitoring, managing, and regulating marine space. AI-enabled technologies—such as autonomous vessels, underwater drones, predictive analytics, and algorithmic surveillance—are now used to address climate-related challenges including ocean warming, illegal, unreported and unregulated fishing, biodiversity loss, and maritime safety. Despite their growing importance, international legal frameworks, particularly the United Nations Convention on the Law of the Sea (UNCLOS), remain poorly equipped to regulate the environmental, jurisdictional, and accountability implications of AI-driven activities in marine spaces. This article identifies a significant regulatory gap at the intersection of climate change, AI governance, and the law of the sea: the absence of a coherent legal framework governing responsibility, transparency, and equity in the deployment of AI-enabled marine systems. As climate change accelerates environmental degradation and alters maritime boundaries and resource distribution, unregulated AI use risks intensifying environmental harm, jurisdictional disputes, and technological inequality—especially for climate-vulnerable coastal and small island States such as the Maldives.The article argues that existing international legal obligations relating to marine environmental protection, due diligence, and international cooperation can be reinterpreted to encompass AI-mediated activities in*

marine space. Through doctrinal analysis of UNCLOS, international environmental law, and emerging AI governance norms, the article examines state responsibility, liability, and environmental impact assessment obligations applicable to autonomous maritime systems. It proposes a normative framework that integrates climate obligations, precaution, transparency, and equitable access to AI technologies, contributing to climate-resilient and just ocean governance in an era of rapid technological and environmental change.

Keywords: *Change; Climate; Equity; Governance; Marine.*

1. Introduction

Climate change has drastically altered the global marine environment at an unprecedented rate, putting billions of people who rely on the ocean for food security, economic stability, and environmental health in jeopardy.[1] Climate Change is causing approximately 90% of the excess heat generated by increasing levels of greenhouse gas emissions to be absorbed by the ocean. As a result, ocean waters have been experiencing extreme increases in temperature in 2024.[2] The increase in temperature over the past few decades has already had an effect on the ecological integrity of the oceans. There have been estimates that approximately 60% of the world's marine ecosystems are currently experiencing a degradation and/or excessive use of the available resources due to climate-induced temperature changes, and a further increase of 1.5 degrees centigrade above the current levels could result in the permanent loss of between 70% and 90% of the corals on the planet, thereby creating a point of no return for the health of entire marine ecosystems.[3] Climate change is not only causing increasingly warm seawater temperatures; It affects species distributions globally, as well as causing an increase in both the frequency and the severity of marine heat waves; There is an increase in the rate of ocean acidification; and there is an increase in the frequency and severity of extreme weather events that cause significant damage to coastal communities.[4] With the increasing pressures on the

[1]United Nations, 'How is climate change impacting the world's ocean' (UN Climate Action) https://www.un.org/en/climatechange/science/climate-issues/ocean-impacts accessed 1 January 2026.
[2] Cheng, L., Abraham, J., Trenberth, K.E. *et al.* Record High Temperatures in the Ocean in 2024. *Adv. Atmos. Sci.* 42, 1092–1109 (2025). https://doi.org/10.1007/s00376-025-4541-3.
[3] United Nations (n 1); UNESCO, cited in United Nations (n 1) (warning that more than half of the world's marine species may stand on the brink of extinction by 2100).
[4]US Environmental Protection Agency, 'Climate Change Impacts on the Ocean and Marine Resources' https://www.epa.gov/climateimpacts/climate-change-impacts-ocean-and-marine-resources accessed 1 January

environment, there is an increasing urgency to develop improved methods to monitor, enforce, and adaptively manage marine resources.

Amid this growing concern about the decline of the environment, ocean governance has increasingly relied on a variety of AI-powered technology.(namely autonomous ships, underwater drones, predictive analytics and algorithmic surveillance systems, among others) to combat various effects of climate change on our oceans, for example, ocean warming, illegal, unreported and unregulated fishing (IUU), loss of biodiversity and maritime safety issues (support to authorities within countries).[5] This reflects the general use of AI in different sectors.[6] In the marine sector, AI technologies enable many operational efficiencies, such as reducing human error in the automation of maritime navigation, optimising fuel usage through predictive maintenance algorithms and increasing levels of real-time monitoring of boat movements within the world's oceans through the use of algorithmic surveillance systems.[7]

The speed at which this take-up of AI technologies is occurring is increasing exponentially. For example, AI systems are being employed to monitor the environment, to support optimisation of shipping lanes to reduce fuel consumption and greenhouse gas emissions, to detect anomalies in the ocean's ecosystems and to coordinate multiple vessels operating within international waters.[8]

2026; NASA Science, 'The Ocean and Climate Change' https://science.nasa.gov/earth/explore/the-ocean-and-climate-change/ accessed 1 January 2026;Tajudeen Sanni, 'When the Ocean Cannot Breathe – Reimagining Blue Justice and Recognizing Ecocide as Climate Actions' (2025) 10(26) *KnE Social Sciences* 90–96 https://knepublishing.com/index.php/KnE-Social/article/view/19982 accessed 8 January 2026.

[5]Tuneer Mukherjee, 'Securing the Maritime Commons: The Role of Artificial Intelligence in Naval Operations' (2018) ORF Occasional Paper; International Maritime Organization, 'Guideline for the Regulation of Ships using Remote and Autonomous Technologies' (resolution MSC.428(98)); David Molina Coello, 'Is UNCLOS Ready for the Era of Seafaring Autonomous Vessels?' (2023) 10 Journal of Territorial and Maritime Studies 21.

[6] Lehlohonolo Kurata, Musa Adekunle Ayanwale, Rethabile Rosemary Molefi, Tajudeen Sanni, "Teaching religious studies with artificial intelligence: A qualitative analysis of Lesotho secondary schools teachers' perceptions" *International Journal of Educational Research Open* Volume 8,2025,100417, https://www.sciencedirect.com accessed 8 January 2026.

[7]Md Sazzad Hossain and others, 'Artificial Intelligence in Maritime Transportation: A Comprehensive Review of Safety and Risk Management Applications' (2024) 14 Applied Sciences 8420; Ryan Pannell and J. Mark Munoz, 'Utilizing AI for Maritime Transport Optimization' (2024) California Management Review (noting efficiency gains of up to 25 per cent for organizations integrating AI in maritime decision support).

[8] DigitalDefynd, '10 ways AI is being used in Marine Industry' (2024) https://digitaldefynd.com/IQ/ai-use-in-marine-industry/ accessed 1 January 2026; Pannell and Munoz (n 6) (noting AI applications include fleet management, navigation, predictive maintenance, environmental monitoring, and route optimization).

From the perspective of countries that are vulnerable to the effects of climate change, this technology could potentially be a major turning point in their ability to effectively enforce existing regulations as well as monitor activities related to illegal fishing or fishing outside of a given area that are against laws or regulations established by that country.

In spite of the rapid increase in the number of existing and new AI-enabled technologies across all aspects of maritime activity, the overall regulatory structure for these developments is highly deficient. The UNCLOS, was originally drafted and signed in 1982 and came into force in 1994. At the time, UNCLOS did not consider the implementation of a universal satellite communication system (satellite observation), the use of artificial intelligence in operating vessels and other autonomous systems, or how to govern such unlawful activities through the developing concepts of algorithmic governance and improved model-based autonomous observational systems.)[9]

While UNCLOS provides comprehensive regulation for oceanic use and includes provisions pertaining to the distribution and definition of the distribution of maritime jurisdictional zones and the rights and responsibilities of all states, it does not provide for any of these autonomous technologies or AI-related activities within its scope.[10] As a result, the regulatory framework is inadequate in regard to several key issues: First, there is currently no provision for determining which states will be responsible for any decisions made by an autonomous vessel. Second, there are currently no provisions requiring the owners and operators of AI-driven technologies to maintain a repository of algorithms used for enforcement under UNCLOS; Third, it is unclear how a state may be held liable for a vessel operated across multiple state maritime boundaries by AI-based platforms. Indeed, existing liability regimes provide only general guidance on the issues of environmental damage caused by AI technologies.[11]

[9] Advisory Board on the Law of the Sea, 'UNCLOS and the International Legal Framework Suitability for Ocean Activities Discussed at ABLOS Conference' (International Hydrographic Organization, 2025) noting that "UNCLOS was negotiated before the age of ubiquitous satellite observation, AI, autonomous vehicles, drones and many other technologies that raise new questions about jurisdiction, liabilities and supervision."

[10] United Nations, 'United Nations Convention on the Law of the Sea' (UN Audiovisual Library of International Law) https://legal.un.org/avl/ha/uncls/uncls.html accessed 1 January 2026; International Tribunal for the Law of the Sea, 'UNCLOS' https://www.itlos.org/en/main/the-tribunal/unclos/ accessed 1 January 2026.

[11] Si Yusuf Al Hafiz and others, 'Artificial Intelligence Integration in UNCLOS Implementation for Resolving Maritime Disputes in South China Sea' (2025) 4 HAKAMAIN: Journal of Sharia and Law Studies 37 (noting "the absence of international regulations explicitly governing the integration of such technologies" in the context of UNCLOS implementation); David Molina Coello (n 5) (analyzing "challenges to the existing legal framework: the UNCLOS Flag System" in the context of autonomous vessels).

Finally, existing provisions of UNCLOS that provide for the conduct of an Environmental Impact Assessment (EIA), due diligence, and liability of states under environmental law do not provide in any way for due consideration of the highly distributed, opaque nature of decision-making associated with AI.[12]

The absence of legally coherent frameworks governing AI in the marine environment has severe consequences for Climate Vulnerable Small Island Developing States (CV-SIDS) which have disproportionate exposure to climate-related impacts that their emissions have contributed a small percentage of the total emissions which drive climate change,[13] like the Maldives, an atoll nation with approximately 80 percent of its land area being less than 1 metre from sea level, are particularly susceptible to these threats as rising sea levels, increasing frequency of tropical cyclones and warming of the oceans have a direct impact on the sustainability of the Maldives as a habitable archipelago, as well as on the Fisheries and tourism sectors which form the basis of its economic foundation.[14] SIDS worldwide have approximately 65 million residents, yet only account for less than one per cent of Global GHG Emissions, while being consistently rated highest for Climate Vulnerability and facing an existential threat of sea level rise and Extreme Weather Events.[15] In these nations, ocean resources, especially fish stocks, are critical for both food security and economic survival, particularly because climate change has already significantly impacted the fisheries resources upon which developing nations rely for food ,livelihood and culture .[16] IUU Fishing accounts for 26 million tonnes of fish caught each year, representing a value between 11 and 26 million tonnes and consists of an Extreme Threat to the Sustainability of coastal communities in developing nations that rely on sustainable fisheries for

[12] Advisory Board on the Law of the Sea (n 8); Molina Coello (n 5).
[13] UNDP Climate Promise, 'Small Island Developing States are on the Frontlines of Climate Change – Here's Why' https://climatepromise.undp.org/news-and-stories/small-island-developing-states-are-frontlines-climate-change-heres-why accessed 1 January 2026; Payne Institute for Public Policy, 'Small Costs for Large Gains: Climate Resilience in Small Island Developing States' (2024) https://payneinstitute.mines.edu/small-costs-for-large-gains-climate-resilience-in-small-island-developing-states/ accessed 1 January 2026.
[14] Maldives National University and others, 'Islands at the Brink: Climate Realities in Small Island Developing States (SIDS)' (CLARE - Climate Adaptation & Resilience, 2024) noting that "80% of its land area less than 1 meter above sea level, making it one of the most vulnerable countries to rising sea levels"; World Bank, 'Small Island Developing States on a Path to Renewable Energy and Resilience: A Story from Maldives' (2024).
[15]UNDP Climate Promise (n 12); UNFCCC, 'Climate Change, Small Island Developing States' (2005) https://unfccc.int/resource/docs/publications/cc_sids.pdf accessed 1 January 2026.
[16] UNDP Climate Promise (n 12) (noting that "industries like tourism and fisheries can constitute up to half of the GDP of some small island economies, such as Antigua and Barbuda, Seychelles and the Maldives").

their livelihoods.[17] Without their capacity to effectively monitor and enforce against the IUU Fishing activities that threaten their resource base, developing coastal nations are even more likely to be adversely affected by climate-related resource depletion as well as illegal exploitation of remaining stocks.

The idea of using AI in monitoring and enforcement in the marine environment is appealing to states that have limited capacity; for instance, using algorithms for surveillance may be able to aid in increasing compliance by removing the need for the large human and financial resources now needed by MCS systems. However, the use of AI without regulations within marine governance creates new risks; bias in algorithms for enforcement may result in more inequities; over-reliance on technology may create greater inequalities between developed and developing countries; the lack of transparency in AI-based decision-making may limit accountability; and uncontrolled growth of autonomous systems may produce negative environmental impacts from ship collisions, chemical pollution, or data-based misallocation of fishing effort.[18] These issues will be further exacerbated by the transcending geography of marine space and the inability to create coordinated international regulations to govern the use of AI technologies in oceans.

This paper contends that the international obligations to protect the marine environment and those related to the responsibilities of the states in regard to cooperation at the international level contain sufficient doctrinal sources to support activities that are facilitated through artificial intelligence (AI) for the purposes of governing and managing the Ocean. More specifically, the due diligence standards and obligations of environmental impact assessment (EIA) of AI are to be applied to activities employing autonomous maritime systems and artificial intelligence, as well as the assignment of state responsibility for acts of non-state actors.[19] In

[17] Food and Agriculture Organization of the United Nations, 'Illegal, Unreported and Unregulated (IUU) Fishing' https://www.fao.org/iuu-fishing/en/ accessed 1 January 2026 (noting "IUU fishing represents up to 26 million tonnes of fish caught annually"); European Parliament, 'Illegal, Unreported and Unregulated Fishing' (2017) EPRS_BRI(2017)614598.

[18] International Maritime Organization, 'Illegal, Unreported and Unregulated (IUU) Fishing' https://www.imo.org/en/OurWork/IIIS/Pages/IUU-FISHING.aspx accessed 1 January 2026; United States Department of State, 'Combating Illegal, Unreported, and Unregulated Fishing Through U.S. and Global Action' (2024) https://2021-2025.state.gov/combating-illegal-unreported-and-unregulated-fishing-through-u-s-and-global-action/ accessed 1 January 2026.

[19] Christina Voigt, 'International Environmental Responsibility and Liability' (2021) (noting that due diligence "does not refer only to unlawful omissions by a state, but also predominantly to the obligation of conduct to show proper care by exercising good government, management and control, for example, through enacting necessary legislation, effective law enforcement to prevent or terminate illegal activities").

addition, this study provides clarity on the evolving character of those obligations, particularly in the context of protecting the marine environment through due diligence and mitigating the impacts of climate change, as well as showing that due diligence is not merely a static formulation of a standard depending on the discretion of the state but that it is a dynamic obligation of conduct that must adapt to advances in technology and new scientific understandings.[20] Finally, using the doctrine of UNCLOS, as well as principles of international environmental law and emerging legal structures for the governance of AI, the study will produce a unified system of normative principles upon which to build responsible AI use in the management of the ocean. This proposed scheme will unify the climate change obligations of coastal states with the binding precautionary principle, transparency-related obligations, and equitable access to the technologies, thus contributing to the formulation of a climate-resilient and just system of Ocean governance, able to accommodate innovation while ensuring the protection of vulnerable coastal states and the marine ecosystems of the Ocean.

1) Climate Change, Marine Ecosystems, and the Governance Challenge

Climate change is having an enormous impact on ocean ecosystems. This is no longer a theoretical issue for the future; it is already happening now, and its speed is increasing. There are significant issues related to climate change and ocean warming. The United Nations has referred to this as the "triple planetary crisis": climate change, loss of marine biodiversity, and pollution - and it affects every ocean basin in the world.[21] Ocean temperatures are now averaging 21°C, the hottest they've ever been. The Mediterranean Sea is warming at a rate of 0.41°C per 10 years (this is an increase of 2°C in the last 40 years).[22] In addition to warming ocean

[20] International Court of Justice, Advisory Opinion on Obligations of States in Respect of Climate Change (2024); International Tribunal for the Law of the Sea, Advisory Opinion on Responsibilities and Obligations of States with Respect to Activities in the Area (2011); Christina Voigt, 'Doing the Utmost: Due Diligence as the Standard of Conduct in International Climate Law' (2025) Climate Law Blog (noting that "due diligence is a variable and evolving concept" and that "ITLOS noted that factors to be considered include scientific and technological information, relevant international rules and standards, the risk of harm and the urgency invo

[21] Karina von Schuckmann (Mercator Ocean International, France), Lorena Moreira (Nologin, Spain), Álvaro de Pascual Collar (Nologin, Spain), Marilaure Grégoire (University of Liège, Belgium), Pierre Brasseur (CNRS, France), Gilles Garric (Mercator Ocean International, France), Johannes Karstensen (GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany), Piero Lionello (University of Salento, Italy), Marta Marcos (University of the Balearic Islands, Spain), Pierre-Marie Poulain (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS), Italy), and Joanna Staneva (Helmholtz-Zentrum Hereon, Germany) (Eds.): 9th edition of the Copernicus Ocean State Report (OSR9), Copernicus Publications, State Planet, 6-osr9, https://doi.org/10.5194/sp-6-osr9, 2025.

[22] Global average sea surface temperature peaked at 21°C in spring 2024. The Mediterranean warmed at 0.41°C per decade between 1982-2024.

temperatures, ocean temperatures are now associated with what marine scientists are calling the "deadly trio": ocean acidification (caused by excess atmospheric CO2), the deoxygenation of coastal and ocean regions, and warming ocean temperatures. Each of these three elements is present at rates faster than the ability of most organisms to adapt to them.[23] Ocean acidification (the process of seawater absorbing CO2 from the atmosphere) is occurring rapidly and will continue to do so. Ocean acidification is expected to continue to raise ocean acidity levels approximately 30% since the pre-industrial era (the level of acidification is already greater than ocean acidification levels before the industrial revolution), and make it increasingly more difficult for corals, molluscs, and planktonic species to build and maintain their shells.[24] At the same time, the warmer waters in the ocean hold less oxygen. In addition, as warmer waters reduce the rate of mixing (as opposed to cooler waters), and as warm waters contain less oxygen, the result is that up to 3-4% of the oxygen that was in the ocean will have been lost by the year 2100. This means that the rate of oxygen levels in the ocean will be declining considerably over the next 100 years. As oxygen levels continue to decline, the presence of dead zones will continue to expand to areas of the ocean where there is very limited or no oxygen, making them unable to support most marine life.[25]

The marine ecosystem is affected by the many ways that abiotic (non-living) changes can lead to changes in the biological (living) environment. Coral reefs are a prime example of a highly productive marine habitat that is composed primarily of Coral species. Coral reefs support an estimated 25% of all known marine species and comprise only about 1% of the world's oceans. In addition to being a valuable resource for biodiversity, Coral reefs also provide essential habitat and ecosystem services. Based on current temperature estimates for the next century, the Intergovernmental Panel on Climate Change (IPCC) estimates that 70 to 90% of the world's coral reefs will experience severe degradation if global temperatures increase to 1.5 degrees Celsius (which will occur at the end of this century if no mitigation activities are undertaken) and if global temperatures continue to increase throughout this century, nearly 100% of coral reefs

[23]European Environment Agency, 'How Climate Change Impacts Marine Life' (2024) https://www.eea.europa.eu/publications/how-climate-change-impacts/how-climate-change-impacts-marine-life accessed 1 January 2026.

[24] IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, 'Summary for Policymakers' (2019) https://www.ipcc.ch/srocc/chapter/summary-for-policymakers/ accessed 1 January 2026 (noting that ocean pH has decreased by 30 per cent since pre-industrial era).

[25] Communications Earth & Environment, 'Irreversible Loss in Marine Ecosystem Habitability After a Temperature Overshoot' (2023) https://www.nature.com/articles/s43247-023-01002-1 accessed 1 January 2026.

will face extinction by the end of this century.[26] Since 1982, there has been a significant increase in the frequency of marine heatwaves (events that kill marine species directly), with the West Coast of North America (2013-2016) and the East Coast of Australia (2015-2016, 2016-2017, and 2020) providing several well-documented case studies that show marine heatwaves can lead to extreme changes in community structure, resulting in the loss of biodiversity and severe declines in local fisheries.[27] The combination of warming and increased frequency of marine heatwaves has resulted in the decline of many temperate-zone kelp forests, which are at high risk of local extinction under high-emissions scenarios. Seagrass meadows and salt marshes are both experiencing moderate to high risk of extinction once carbon dioxide levels exceed 1.5 degrees Celsius.[28] Other marine species, including commercial fish, have been shifting their distributions to cooler waters and greater depth in order to adjust to the temperature and oxygen changes associated with marine heatwaves, thereby creating a unique set of challenges for fishery governance systems, which depend on consistent and predictable geographic distributions of fish stocks.[29]

The ecosystem shifts present both a serious ecological problem and a complex governance challenge. Governance systems for marine fisheries were developed decades ago in different socio-political conditions when fish populations were substantially lower, stable, and predictable within a defined area of the EEZ. The governance framework is facing major challenges today, as species that have migrated and adapted to changes in their ecological habitat are creating what marine scientists describe as "straddling stocks," meaning they are straddling both EEZ and high seas.[30] Of the 347 straddling stocks identified globally for 67

[26] IPCC, 'Climate Change 2021: The Physical Science Basis' (Sixth Assessment Report) and 'Special Report on Global Warming of 1.5°C' (2018) cited in How Climate Change Affects Marine Biodiversity: Complete 2025 Guide (2025) https://solartechonline.com/blog/climate-change-marine-biodiversity-impacts-guide/ accessed 2 January 2026; Ocean Conservancy, 'What the IPCC Report Says About Our Ocean' (2023) https://oceanconservancy.org/blog/2023/03/24/what-ipcc-report-says-about-ocean/ accessed 1 January 2026.

[27] IPCC, 'Climate Change 2022: Impacts, Adaptation and Vulnerability' (Sixth Assessment Report, Working Group II) https://www.ipcc.ch/report/ar6/wg2/chapter/chapter-3/ accessed 2 January 2026; Sustainable Ocean Alliance, 'Top Takeaways from the IPCC Sixth Assessment Report 2023' (2023) https://www.soalliance.org/soablog/ipcc-2023-summary accessed 2 January 2026.

[28] IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, 'Chapter 5: Changing Ocean, Marine Ecosystems, and Dependent Communities' (2019) https://www.ipcc.ch/srocc/chapter/chapter-5/ accessed 2 January 2026.

[29] Marine Stewardship Council, 'How Climate Change Affects Fisheries' (2024) https://www.msc.org/en-us/what-we-are-doing/oceans-at-risk/climate-change-and-fishing accessed 2 January 2026.

[30] Science Advances, 'Climate Change Drives Shifts in Straddling Fish Stocks in the World's Ocean' (2024) https://www.science.org/doi/10.1126/sciadv.adq5976 accessed 2 January 2026.

species, roughly 37% are expected to migrate between EEZs and the high seas by 2030 and 54% by 2050, regardless of climate change.[31] As fish stocks continue to migrate and change, managing these species becomes increasingly problematic, international catch allocation agreements become ineffective as fish stocks leave their original jurisdictions; jurisdictional authority becomes less clear; and there is a heightened risk of unintentional overfishing, as fishers continue to fish at historical levels, as opposed to sustainable living.[32] The migration of fish stocks has created numerous international disputes, the most high-profile of which is the "mackerel wars." The Atlantic mackerel stock's migration northward due to an increase in sea temperature led to disputes between traditional fishing nations (i.e., the United Kingdom, northern Europe) and newer, more advantageous countries, such as Iceland and the Faroe Islands. A trilateral catch-sharing agreement was reached in 2014, but there are still many unresolved overfishing issues due to the unresolved nature of the catch-sharing agreements.[33]

The current framework of fisheries management, at both the national and international levels, is fundamentally incapable of addressing the impacts of climate change on changing patterns of fish distribution. Although the management of fisheries has improved over the last few decades, as evidenced by the dramatic reduction of the number of fisheries on the overfishing list of the United States, with the successful rebuilding of 50 fish stocks since 2000,[34] most of these achievements are precarious and will be threatened by the impact of climate change on fisheries' distribution patterns. Currently, it is estimated that approximately 35.4% of the total fish stocks worldwide are being harvested at unsustainable levels, with only 10% of global fish stocks being harvested unsustainably in 1974. Moreover, at least 11% of the global fish catch is discarded, representing a source of wasted fish resources and an enormous disruption of the ecosystem.[35] Furthermore, over 80% of the global fish catch comes from fish stocks that have no formal stock assessments; therefore, creating an atmosphere in which it is difficult to implement efficient and effective management responses to the changing distribution of these

[31] Ibid.
[32] Environmental Defense Fund, 'Climate Change is Causing Fishery Problems, but We Can Solve Them' (2022) https://blogs.edf.org/edfish/2022/04/21/climate-change-is-causing-fishery-problems-but-we-can-solve-them/ accessed 2 January 2026.
[33] Marine Stewardship Council (n 28)
[34]NOAA Fisheries, 'Status of Stocks 2023' (2023) https://www.fisheries.noaa.gov/national/sustainable-fisheries/status-stocks-2023 accessed 2 January 2026.
[35]npj Ocean Sustainability, 'Good Fisheries Management is Good Carbon Management' (2024) https://www.nature.com/articles/s44183-024-00053-x accessed 2 January 2026.

resources.[36] Furthermore, the management of straddling and migratory fish stocks in international waters is governed by Regional Fisheries Management Organizations (RFMOs), which do not have an effective way to respond to management actions due to their reliance on decision-making processes based upon consensus. Thus, it is possible that all member states of a particular RFMO cannot agree upon a specific management measure; therefore, when one or more states prevent the implementation of a decision related to the management of fish stocks through their vetoes, many fish stocks will continue to become overfished. Additionally, there are a few mechanisms for holding RFMOs accountable to their legal obligations to protect straddling stocks under both UNCLOS and the UN Fish Stocks Agreement, thus hampering RFMOs from effectively managing shared fish stocks.[37]

The effects of climate change on fisheries and other parts of ocean governance are reshaping priorities around ocean governance. This will require a greater emphasis on monitoring, compliance and enforcement, and adaptive management of ocean resources. The rate of rise in sea level, due to climate change, is increasing approximately 30% faster than it was during the last decade (2010s);[38] as a result, many coastal ecosystems and human communities are faced with an existential threat from rising sea levels. The most recent IPCC Assessment Report indicated that the risks associated with sea level rise for both coastal ecosystems and coastal individuals are likely to increase at least tenfold prior to 2100 without both mitigation (or stopping emissions) and adaptation to their impacts. Rising sea levels resulting from the emissions scenarios which do not restrict warming to 1.5 °C will also increase the risk of coastal erosion, submergence of coastal land and the loss of coastal habitat and ecosystems; therefore, increasing the risk to both coastal ecosystems and livelihood systems.[39]

On a global level, the coastal populations of Europe total approximately 200 million; therefore, the vulnerability of coastal communities is significant. Climate change will have very serious effects on Europe's Blue Economy because in 2024, significant marine heatwaves (severe to extreme) are predicted to impact the waters that house approximately 17% of Europe's coastal shellfish farming industry, and countries that rely heavily upon tourism for 40% to 80% of their

[36] ScienceDirect, 'Better Fisheries Management Can Help Reduce Conflict, Improve Food Security, and Increase Economic Productivity in the Face of Climate Change' (2019) https://www.sciencedirect.com/science/article/abs/pii/S0308597X18308959 accessed 2 January 2026.
[37] UN General Assembly, 'Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks' (1995) UN Doc. A/50/711.
[38] IPCC (n 26)
[39] Ibid.

Blue Economy proficiencies. In addition, these impacts will create a domino effect throughout climate change-related environmental degradation.[40] The ocean has lost its ability to provide a buffer against climate change. It has been documented that, due to climatologically-driven temperature and oxygen changes, the volume of the ocean's upper 1,000 m that can support marine life will be reduced for hundreds of years, and these significant stressors will impair metabolic processes in marine organisms.[41]

The interconnectedness of the global environment's deteriorating state due to climate-related issues (e.g., rising ocean temperatures, ocean acidification, declining oxygen levels, shifting fish stocks, rising sea levels and increased frequency of extreme weather events) has created an international climate governance issue, thus highlighting the need for Integrated Ocean Governance (IOG) to be a priority area of concern for the international community. The UN General Assembly has called on member states to take immediate action in developing coherent approaches in order to tackle all of these multiple threats/impacts to oceans, recognising that although this concept is universally accepted as valid, the practicalities behind integrating all of these separate approaches into an overall Integrated Oceans Governance framework will prove very difficult.[42] At the local/national levels, there is a requirement for fisheries managers to take precautionary measures to ensure that adequate fisheries management systems are in place, whilst allowing for context-specific, adaptive and dynamic management approaches to manage fisheries based on best available science.[43] At the regional level, any new or reformed IOG frameworks must take into consideration current and future changes in the biogeography of marine species due to climate change, through the use of new transboundary arrangements and/or revised or enhanced international agreements.[44] Globally, the UN SDGs and the inception of an international governance framework through the Agreement on Biological Diversity Beyond National Jurisdiction (BBNJ) have provided the first opportunity to develop a comprehensive governance model for the oceans, which will protect marine biodiversity on a

[40] Copernicus Ocean State Report 9 (n 20)
[41] Communications Earth & Environment (n 24).
[42] United Nations, 'Global Marine Governance and Oceans Management for the Achievement of SDG 14' https://www.un.org/en/chronicle/article/global-marine-governance-and-oceans-management-achievement-sdg-14 accessed 2 January 2026.
[43] ScienceDirect, 'Ocean Governance: Perspectives on the Imbalances in Current Blue Economy Cooperation and the Path Towards Sustainable Transformation' (2024) https://www.sciencedirect.com/topics/earth-and-planetary-sciences/ocean-governance accessed 2 January 2026.
[44] Ibid.

worldwide scale.[45] While this collective acknowledgement of the importance of reforming ocean governance exists, a large hurdle is still ahead in terms of changing existing ocean governance programmes, which were developed over 100 years ago based on the assumption that ocean resources would be stable within political boundaries, to include a new paradigm for ocean resource management and international cooperation.

2) AI Technologies in Marine Governance: Current Applications and Risks

The rapid proliferation of AI-assisted technologies for marine environmental governance has dramatically changed the way the oceans are managed, and has had a far more substantial impact than was anticipated by the traditional regulatory frameworks which are in place. There are primarily four categories for the technology; Autonomous Maritime Surface Ships (MASS), underwater vehicles, algorithmic surveillance systems and collision avoidance algorithms.

a. Autonomous Maritime Vessels and Underwater Systems

According to the International Maritime Organization (IMO), or "maritime autonomous surface ships"(MASS) are defined as "a ship which is operating without a crew on board"[46] and refers to a wide range of different capabilities; these capabilities can vary from level 1, which includes decision support systems, to level 4 which would not require human intervention at any point during operation.[47] Examples of operational MASS include South Korean HD Hyundai Ocean Infinity, which has recently completed sea trials as a level 3 autonomous bulk carrier and has achieved a 12% fuel savings through AI optimisation; Norway's Massterly, which are commercially used; and Yara Birkeland, which is currently under trial operations with plans to be a fully electric and autonomous vessel.[48] The worldwide MASS market is estimated to be USD

[45] UN General Assembly, 'Oceans and the Law of the Sea' Resolution A/79/L.37 (2024); UN General Assembly, 'Agreement on Conservation and Sustainable Use of Marine Biological Diversity of Areas Beyond National Jurisdiction' (2023) (the BBNJ Agreement).

[46] International Maritime Organization, 'Autonomous Shipping' https://www.imo.org/en/mediacentre/hottopics/pages/autonomous-shipping.aspx accessed 5 January 2026.

[47] International Maritime Organization, 'Guideline for the Regulation of Ships using Remote and Autonomous Technologies' (Resolution MSC.428(98), 2019).

[48] How Autonomous Navigation, AI, and Green Energy is Transforming the Maritime Shipbuilding Industry Landscape in 2024 and Beyond (2025) https://sailorspeaks.com/2025/02/10/how-autonomous-navigation-ai-and-green-energy-is-transforming-the-maritime-shipbuilding-industry-landscape-in-2024-and-beyond/ accessed 5 January 2026.

6.11 billion in 2024 and is forecasted to double by 2032 with a compound annual growth rate of 9.1% during that time frame.[49]

The underwater drone sector of the Remote Operated Vehicle (ROV) and AUV market is set to triple in size between now and 2024 (USD 4.40 billion in 2024 and USD 9.34 billion in 2033).[50] Getting these systems into use has been relatively quick, with them being used by military (Ukrainian Navy Toloka submarines), scientific research (Teledyne Gavia AUV for Royal Netherlands Institute for Sea Research, expected in 2024), and commercial subsea industries with improved information-gathering capabilities, thanks to the latest technology being equipped onto the underwater drones, such as high-definition cameras to capture images and sonar arrays to find objects underwater. Additionally, Environmental sensors installed on the vehicle will gather data from very unexplored areas of the ocean due to their depth, where no equipment has gone before.[51]

b. Algorithmic Surveillance and Detection Systems

The development of algorithmic surveillance systems for the detection of illegal fishing and monitoring of vessel movements has the potential to have a significant impact on the overall development of AI. The market for "dark vessel detection" AI was valued at USD 1.27 billion in 2024, and it is expected to experience a compound annual growth rate of 21.4 percent until it reaches USD 8.74 billion by 2033.[52]

Global Fishing Watch is a non-profit that uses AIS data from over 400,000 AIS devices to provide evidence of commercial fishing activities. The AIS data is combined with satellite vessel monitoring systems that use radar technology to track vessels as they make their way from port to port or undertake long voyages.[53] However, only 2 percent of the world's 2.9 million fishing vessels are equipped with AIS; nevertheless, the small percentage of vessels equipped with AIS

[49] Fortune Business Insights, 'Autonomous Ship Market Size, Share | Forecast Report [2032]' (2024) https://www.fortunebusinessinsights.com/industry-reports/autonomous-ship-market-101797 accessed 5 January 2026.

[50] IMARC Group, 'Underwater Drone Market Size, Share & Forecast by 2033' (2024) https://www.imarcgroup.com/underwater-drone-market accessed 5 January 2026.

[51] Market Research Future, 'Underwater Drone Market Size, Trends, Share and Analysis by 2035' (2023) https://www.marketresearchfuture.com/reports/underwater-drone-market-12257 accessed 5 January 2026.

[52] DataIntelo, 'Dark Vessel Detection AI Market Research Report 2033' (2025) https://dataintelo.com/report/dark-vessel-detection-ai-market accessed 5 January 2026.

[53] Global Fishing Watch, 'Technology for Ocean Action' (2025) https://globalfishingwatch.org/our-technology/ accessed 5 January 2026.

accounts for more than 50 percent of all fishing effort beyond 100 nautical miles and up to 80 percent of all fishing activity in the high seas.[54] The fact that approximately 75 percent of the vessels detected by SAR satellite systems are not being tracked by AIS indicates the ability to extend the monitoring capabilities beyond traditional means.[55]

Through analytical systems, data can be analysed to find where illegal fishing occurs through the integration of satellite and environmental data with the use of machine learning models (e.g. Random Forest, neural networks, etc.).[56] The use of these analytical systems allows for real-time monitoring of the ocean over an area of millions of square kilometers, which is beyond human capability.[57] The European Maritime Safety Agency and NOAA Fisheries continue to develop artificial intelligence algorithms for vessel detection, fish species identification and for the identification of anomalies in their operations, which aids them in the management of fisheries and in combatting illegal fishing activity.[58]

c. Collision Avoidance Systems and Environmental Risks

The Convention on the International Regulations for Preventing Collisions at Sea (COLREG) provides the framework for collision avoidance algorithms through the use of radar, lidar, and vision systems.[59] Emerging technologies employing deep reinforcement learning and model-predictive control have demonstrated the ability to demonstrate compliance with COLREG Rules 13-17, when modelling multiple vessel encounters of less than 1 second.[60] However, there are concerns about the lack of transparency regarding algorithm-based decision-making, and about

[54] Ibid.
[55] Using AI and Satellites to Track Illegal Fishing in Marine Protected Areas (2024) https://gijn.org/stories/using-ai-satellites-track-illegal-fishing-marine-protected-areas/ accessed 1 January 2026.
[56] IJRASET, 'Fishing Forecast Guardian: A Machine Learning-Powered Platform for Illegal Fishing Detection' (2024) https://www.ijraset.com/research-paper/machine-learning-powered-platform-for-illegal-fishing-detection accessed 5 January 2026.
[57]AI Driven IUU Fishing Detection Global Implications → Scenario (2025) https://prism.sustainability-directory.com/scenario/ai-driven-iuu-fishing-detection-global-implications/ accessed 5 January 2026.
[58] Ibid.
[59] International Maritime Organization, 'Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGS)' (1972) https://www.imo.org/en/Publications/Pages/COLREGS.aspx accessed 5 January 2026.
[60] MDPI, 'A Review of Research on Autonomous Collision Avoidance Performance Testing and an Evaluation of Intelligent Vessels' (2025) https://www.mdpi.com/2077-1312/13/8/1570 accessed 5 January 2026.

the subjective elements of COLREGS such as 'good seamanship', which do not lend themselves to direct translation into algorithms.[61]

AI technologies present significant benefits to organisations, including increased efficiency, reduced error and improved or increased surveillance. Yet the deployment of AI Technologies without regulation creates significant governance challenges. Potential negative environmental impacts may arise from the use of autonomous systems that lack any environmental awareness and/or oversight. Deployment of unregulated surveillance systems can lead to the shifting of fishing activity from a well-monitored area to an unmonitored area (namely fishing pressure may be placed on previously unmonitored areas), rather than preventing overfishing from being allowed to continue or entrenching existing fishing pressure (in other words current fishing pressure remains). The use of AI route optimization may also create the concentration of maritime traffic through environmentally sensitive regions. These are examples of how unregulated deployment of AI can create significant risk.[62] The lack of clear jurisdictional boundaries when it comes to automated systems operating in the maritime domain adds to that uncertainty, creating uncertainty around liability and accountability. The unequal distribution of AI capability associated with its use by wealthy nations, and by large scale operators (e.g., corporations) creates significant disadvantage to many developing coastal nations and to many small island developing nations because of their dependency on marine-based resources, and their inability to afford advanced technology.[63] As AI-based decision-making becomes more prevalent, there is an increasing risk of an accountability void arising from the use of algorithmic decision-making that renders human oversight impossible.[64] Finally, the use of surveillance technology generates a large volume of marine-related data that will effectively perpetuate the existing patterns within which developing nations provide a geographic context to surveillance-based activities, and who have no claim to ownership of that data or the insights derived from that data.[65]

[61] Taylor & Francis Online, 'A State-of-the-Art Review of AI Decision Transparency for Autonomous Shipping' (2024) https://www.tandfonline.com/doi/full/10.1080/25725084.2024.2336751 accessed 1 January 2026.
[62] Ultralytics, 'AI in Maritime: Fishing & Conservation' (2024) https://www.ultralytics.com/blog/ai-in-the-maritime-industry-and-conservation-efforts accessed 5 January 2026.
[63] AI Driven IUU Fishing Detection Global Implications (n 56).
[64] Taylor & Francis Online (n 60).
[65] AI Driven IUU Fishing Detection Global Implications (n 56).

III. UNCLOS and Existing International Legal Frameworks: Analysis of Gaps

The United Nations Convention on the Law of the Sea - which was adopted in 1982 (and came into effect in 1994) - is a comprehensive and international legal framework that regulates all aspects of the ocean, including areas of the ocean and its natural resources.[66] UNCLOS's Part XII describes the obligations of the state parties to protect and conserve the marine environment, as well as establishing general obligations and specific pollution controls (i.e. at the source) to address this.[67] Also, the UNCLOS was negotiated during a time before the emergence of autonomous systems, algorithmic decision-making, and distributed artificial intelligence, so it does not adequately regulate many aspects and activities of AI that are facilitated through oceans.

Part XII of UNCLOS: Environmental Protection Framework

In addition to committing to protecting and preserving the marine environment,[68] UNCLOS establishes another important obligation for States in its Article 192: a duty to take all necessary measures (individually or collectively) to prevent, decrease or control the pollution of the marine environment from any source.[69] Therefore when addressing the rising threat of climate change, and in particular the rise of anthropogenic greenhouse gas emissions, the International Tribunal for the Law of the Sea's (ITLOS) Advisory Opinion in 2024 has placed a very high standard of care regarding greenhouse gases because of the potential for "serious and irreversible damage" to the marine environment.[70] The scope of Article 194 includes pollution from any source, meaning it covers a potential to include harm caused by Artificial Intelligence (AI) and machine-generated effects; however, the exact language in this Article does not reference autonomous systems or the act of algorithmic decision-making specifically.[71]

The obligation to assess the anticipated environmental impacts of future developments is defined by Article 206.Every state has a responsibility to carry out EIA's, to the extent possible, for planned activities that may cause significant pollution or damage to the marine environment,

[66] United Nations, 'United Nations Convention on the Law of the Sea' (1982) UN Doc A/CONF.62/122 entered into force 16 November 1994.
[67] United Nations Convention on the Law of the Sea, Part XII (Protection and Preservation of the Marine Environment) Articles 192-237.
[68] UNCLOS, Article 192.
[69] UNCLOS, Article 194(1).
[70] International Tribunal for the Law of the Sea, 'Advisory Opinion: Responsibilities and Obligations of States with Respect to Climate Change and Ocean Acidification' (2024) paras 213, 257.
[71] UNCLOS, Article 194(1); ITLOS (n 69) para 189.

if they have reasonable grounds for suspicion that an activity will result in either of these outcomes.[72] The BBNJ Agreement further defines this obligation by requiring an EIA for all marine environments where there is either a potential for the development to create a significant environmental impact (for example, a substantial change) or where we know very little (the impact of the development) or do not know what the impact will be.[73] However, it also provides considerable leeway to each state as far as when an EIA should be performed; therefore the amount of information required in an EIA is not specified. The ambiguity created in Article 206 as to what is acceptable information for EIA purposes complicates the determination of whether or not a state has performed an adequate evaluation of the impacts of using AI systems.[74]

a. Due Diligence and State Responsibility

The due diligence principle, first articulated in the Trail Smelter arbitration (1941), serves as a foundation for international environmental law, with the tribunal stating that "no State has the right to use or permit the use of its territory in such a manner as to cause injury...when the case is of serious consequence".[75] The principle has developed from a prohibition against transboundary harm to also requiring states to take positive action to regulate activities within their jurisdiction and prevent environmental harm.[76] In *Pulp Mills on the River Uruguay*, the ICJ confirmed that due diligence means that a State has a duty to take preventive action and complete environmental impact assessments. This demonstrates how the obligation extends beyond simply not interfering with another State's right to operate and includes the obligation to actively regulate.[77]

In a 2024 Advisory Opinion, the International Tribunal for the Law of the Sea (ITLOS) stated that the duty of due diligence is both evolving and variable; it also stated, through weighing the risk and urgency of possible harm, through use of 'best available science', and through use of

[72] UNCLOS, Article 206.
[73] Agreement on the Conservation and Sustainable Use of Marine Biological Diversity of Areas Beyond National Jurisdiction (BBNJ Agreement) (2023) Article 27(2)(a).
[74] Frontiers in Marine Science, 'Application of the Environmental Impact Assessment Provisions under the BBNJ Agreement in High Seas Marine Protected Area: Challenges and Suggestion' (2025) https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2025.1589936/full accessed 6 January 2026.
[75] *Trail Smelter Case (United States v Canada)* (1941) 3 RIAA 1905, 1965.
[76]Christina Voigt and others, 'Due Diligence in International Environmental Law' (2021) Oxford Academic https://academic.oup.com/book/39708/chapter/350384935 accessed 1 January 2026.
[77] *Pulp Mills on the River Uruguay (Argentina v Uruguay)* [2010] ICJ Reports 14, paras 101, 204.

existing international rules and standards, the contents of the duty of due diligence shall be determined.[78] This definition provides doctrinal backing for the extent of the duty of due diligence as it relates to AI obligations. The precise formulation of the duty of due diligence currently derives from an understanding of human-centred activities, and the existing formulation does not provide for algorithmic agency, nor does it provide for a unified or distributed responsibility for the actions of autonomous systems upon the marine environment. When autonomous systems operate to make decisions about the marine environment, attribution of responsibility becomes a complicated query: Should the systems' manufacturers, the owners of the vessels, the flag states, the coastal states in which the vessels are operating, or a combination of these parties, be held liable?[79]

b. Precautionary Principle

The notion of utilising precautionary measures when faced with potential irreversible harm to the environment was conceived post-UNCLOS negotiations,[80] but since these negotiations this precautionary principle became part of the normative framework of the Convention through an examination of the provisions of Article 194 and Article 195, and further capitulated in the Climatic MXC/04 Advisory Opinion of the Tribunal as requiring States to use precaution in determining 'necessary measures' when addressing marine pollution where there is a degree of uncertainty in the scientific basis on which the determination must be made; thus, it emphasised caution as the process to be used for making the requisite determination rather than a completed body of knowledge evidencing certainty that the measures are in fact necessary.[81] The BBNJ Agreement implements such a precautionary principle through interpreting the language in this context to require an impact assessment to be conducted when there are 'unknown or poorly understood' effects of a proposed course of action.[82]

[78] ITLOS (n 69) para 206-213.
[79] Illegal Fishing Detection Using Machine Learning - Automation for the Sake of Private Firm Profits or Genuine Benefit in Tracking Dark Vessels? (2022) https://iuuriskintelligence.com/illegal-fishing-detection-using-machine-learning-ml/ accessed 6 January 2026.
[80] Illegal Fishing Detection Using Machine Learning - Automation for the Sake of Private Firm Profits or Genuine Benefit in Tracking Dark Vessels? (2022) https://iuuriskintelligence.com/illegal-fishing-detection-using-machine-learning-ml/ accessed 6 January 2026.
[81] The Precautionary Principle/Approach and the United Nations Convention on the Law of the Sea (2021) Cambridge University Press https://www.cambridge.org/core/books/environmental-rule-of-law-for-oceans/precautionary-principleapproach-and-the-united-nations-convention-on-the-law-of-the-sea/0A3243BF7C9C5F48861508C3541F6DDD accessed 6 January 2026.
[82] ITLOS (n 69) para 213; BBNJ Agreement (n 72) Article 27(2)(a).

Currently, there are very few avenues for using precautionary principles in the regulation of AI and its deployment in the oceans. Although some states have adopted the precautionary principle (through legislative measures) in order to ensure that any AI employed within their jurisdiction has been properly assessed ahead of time (given the uncertainty associated with its potential negative impacts), there is no framework provided within UNCLOS for either imposing precautionary restrictions on the use of autonomous technologies or establishing procedures for the removal or restriction of an AI technology that causes unpredicted damage to the environment.

c. Liability and State Responsibility

The provisions of UNCLOS (derived from the United Nations Convention on the Laws of the Sea) Article 235 provide for environmental harm and establish State responsibility for the failure to act in accordance with international obligations, including liability for harm resulting from a failure to perform an assigned function.[83] This provides for liability where a State fails to comply with its responsibilities under UNCLOS, but it does not provide for any manner of attributing responsibility when an independent actor, including a private sector technology company, causes harm due to actions taken in relation to an autonomous machine,[84] nor does UNCLOS provide a means for determining suitability, as states lack clear and precise guidelines for understanding responsibility.

One of the biggest gaps in the law today is that there are no laws about who is responsible for the environmental harm done by AIs that make distributed decisions. For example, if an autonomous vessel uses an algorithm to select routes that concentrate vessels in a region of ecological sensitivity, this would cause cumulative impacts on marine habitats due to increased shipping traffic passing through sensitive areas. This situation raises the question of who is responsible for the damage: the owner of the vessel, the shipping company, the creator of the algorithm used by the vessel, the flag state of the vessel, the coastal state where the damage occurred, or the international governing body that governs the vessel's operations?

[83] UNCLOS, Article 235(1), (2).
[84] Frontiers in Marine Science, 'On the Implementation of the Provisions Regarding Environmental Impact Assessments under the BBNJ Agreement' (2025) https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2025.1657649/full accessed 6 January 2026.

d. Sources-Based Pollution Framework

One way of looking at how these articles fit together is that they are focused on Pollution from Specific Sources, so it makes sense to consider Articles 207 through 212 to be a list of specific sources: Land Based Sources (Article 207), Activities on the Seabed (Article 208), Dumping "Article 210 - hereby known as 'Dumping), Operations of Vessels (Article 211) and Atmospheric Pollution (Article 212).[85] The focus on Source-based Sources assumes the pollution is caused by an identifiable Human Activity with no Specific Provision for Pollution Predetermined by Computer-Based Algorithm Decisions. For example, if an AI system is being used for the purpose of optimally utilizing emissions from vessels, and subsequently causes ships to be concentrated in such a manner as to increase the noise level for Marine Mammals, which Source-Based Provision applies? The pollution is a consequence of vessel operations (Article 211) but the decision logic is generated from algorithm-based systems not traditionally part of controlling maritime operations.

e. International Law Commission and Evolving Standards

Although UNCLOS is a structured set of rules and regulations, it also reflects changing factors in customary international law through its interpretation. The International Law Commission's "Draft Articles on Prevention of Transboundary Harm from Hazardous Activities" developed due diligence, the minimum standard for transboundary harm prevention, to require States to do "all appropriate measures" in order to avoid or reduce any threats or loss of significant harm including by means of environmental assessments, monitoring and notification.[86] This phrasing can be taken as potentially applicable to AI system, however, it was developed with no consideration of either autonomous decision-making or the lack of transparency of an algorithm.

f. Emerging Frameworks: The BBNJ Agreement

In January of 2026, the most recent attempt at operationalizing UNUNCLOS responsibilities related to high seas began with the BBNJ Agreement which identifies EIA procedures and establishes thresholds for conducting assessments along with specifying cumulative impact assessments.[87] The agreement is also dedicated to addressing regulatory gaps in marine

[85] UNCLOS, Articles 207-212.
[86] International Law Commission, 'Draft Articles on Prevention of Transboundary Harm from Hazardous Activities with commentaries' (1997) Yearbook of the International Law Commission vol II (Part Two) 155.
[87] BBNJ Agreement (n 72) (entered into force 1 January 2026 following Morocco's 60th ratification on 19 September 2025).

resource use that have been developing since the beginning of the 21st century, and therefore establishes the idea that international law has the capacity to address new applications of existing concepts.[88] However, while the BBNJ agreement mentions capacity to regulate marine resources, it does not specifically mention autonomous marine systems or artificial intelligence; therefore, aggiornamento or regularization of technology cannot yet occur. Thus, it is expected that future updates on ocean governance will occur when technology is developed enough to be compatible with ocean governance principles.

g. Critical Gaps

A key shortcoming of all currently existing UNCLOS-based frameworks is that they presume states' exclusive jurisdiction and control over human decisions leading to environmental harm. However, as we saw in the previous section, the increasing use of autonomous systems travelling across international maritime boundaries and making algorithmic decisions with very little or no transparency to the regulators, results in significant challenges for holding states accountable for their actions. Further, as highlighted in PSC0093, UNCLOS and general international law impose certain obligations upon states in relation to the environment; however, none of them provide any guidance as to how one would apply AI governance principles to a marine environment. With the development of AI governance frameworks in other areas or contexts of international law (for example, the European Union's AI Act and various bilateral treaties), it is evident that there continues to be a lack of a coherent international framework for the governance of AI in relation to marine space.

Most states are still in the early development stages (developing draft frameworks, for instance) and applying them inconsistently, thus creating further complexity and ambiguity around the particular challenges associated with autonomous maritime systems that operate across multiple state jurisdictions and have the potential to negatively impact transboundary marine ecosystems.

h. Reinterpreting Existing Obligations: A Framework for AI Governance

Although UNCLOS and existing international environmental laws were not explicitly created for purposes related to autonomous marine systems and the development of algorithmic decision systems, it is possible to establish sufficient legal groundwork within existing instruments to allow for AI governance at sea even without necessitating a total overhaul of current laws. In this section, we'll examine how the three obligations of state responsibility, due diligence and

[88] BBNJ Agreement (n 72) Part IV (Articles 27-40) (Environmental Impact Assessment).

environmental impact assessments of marine environments, can each be understood as they relate to activities conducted through the use of AI.

i. State Responsibility for Autonomous Systems

The ARSIWA define circumstances in which a state shall incur responsibility for the actions of a private actor when either the state has effective control over that actor or if the private actor functions as a de facto state organ and relies on the state totally.[89] The first test establishes a threshold for the exercise of control by means of tasking/assigning authority and possession of resources, while the second test establishes responsibility if the private actor has no means to operate independently from the state. With an understanding of these tests, it is possible to extend the concept of state liability to AI systems associated with the management of marine environments.

States have positive due diligence obligations, namely States' duty to ensure compliance with international law when implementing AI in fisheries enforcement or allowing Private companies to use autonomous vessels. The ILC defined positive due diligence in its 2024 report as follows: "Due Diligence is defined as the duty or standard of care to be applied by a State in respect to the actions taken by it in or on its own territory, or in respect of the activities of others, where such activities are subject to the jurisdiction or control of a State and may create harm to, or otherwise affect, the interests of other states."[90] The concept of due diligence applies to all instances, whether a State conducts an activity directly or whether that activity has been delegated to a private actor. States are liable for any harm caused to third parties by AI technology that is allowed to be operated within their jurisdiction, regardless of whether the AI technology is developed or operated by private parties. This is because the State retains the regulatory authority to oversee, monitor and control the manner in which operations are conducted within its maritime space.[91]

[89] International Law Commission, 'Articles on the Responsibility of States for Internationally Wrongful Acts' (2001) Articles 4, 8 (ARSIWA).
[90] Analyzing State Support to Non-State Actors – Part I: Primary Obligations and Attribution, Lieber Institute West Point (2024) https://lieber.westpoint.edu/analyzing-state-support-non-state-actors-part-i-primary-obligations-attribution/ accessed 7 January 2026.
[91] International Law Commission, 'Draft Articles on Prevention of Transboundary Harm from Hazardous Activities with commentaries' (1997) Yearbook of the International Law Commission vol II (Part Two) 155.

j. Due Diligence and Algorithmic Transparency

As implied above, due diligence in marine protection means that countries must take the necessary steps to prevent damage as defined by their respective laws, procedures, and policies.[92] For the international community, the ITLOS 2024 Advisory Opinion affirms that due diligence is based on the best evidence available and that best evidence will change with time, depending upon how serious and how urgent the threat of harm is.[93] Due diligence represents a new standard of practice that promotes the principle of transparency and accountability with respect to AI systems.

Neural Networks using Deep Learning technology are often referred to as “black boxes,” since their internal decision-making processes remain unknown and incomprehensible even to the developers of these technologies.[94] This situation indicates that unless a state is able to understand, forecast, or confirm how algorithms reach conclusions concerning marine resources, there cannot be sufficient Due Diligence demonstrated. As a result, the logical conclusion is that states that intend to fulfil the requirements of Due Diligence must also employ AI Solutions that meet minimum levels of transparency and "explainability" so that the process by which AI arrives at decisions can be understood by non-technical users.[95] In order for due diligence obligations to be fulfilled states should only use proprietary AI solutions for fisheries enforcement, environmental monitoring, and maritime operation where those proprietary AI solutions are capable of providing states with a level of transparency sufficient to enable humans to oversee and hold accountable the operations of the artificial intelligence systems they deploy.[96] Therefore, where proprietary AI systems do not provide states with sufficiency transparency, states should not deploy those systems.

[92] Ibid.
[93] International Tribunal for the Law of the Sea, 'Advisory Opinion: Responsibilities and Obligations of States with Respect to Climate Change and Ocean Acidification' (2024) paras 206-213.
[94] Frontiers in Human Dynamics, 'Transparency and Accountability in AI Systems: Safeguarding Wellbeing in the Age of Algorithmic Decision-Making' (2024) https://www.frontiersin.org/journals/human-dynamics/articles/10.3389/fhumd.2024.1421273/full accessed 7 January 2026.
[95] TechTarget, 'AI Transparency: What is it and Why do We Need it?' (2025) https://www.techtarget.com/searchcio/tip/AI-transparency-What-is-it-and-why-do-we-need-it accessed 7 January 2026.
[96] IBM, 'What is AI Transparency?' (2025) https://www.ibm.com/think/topics/ai-transparency accessed 7 January 2026.

k. Environmental Impact Assessment for AI Deployment

Per Article 206 of UNCLOS and Article 27 of the BBNJ Agreement, an EIA must be done before activities that have reasonable potential to cause "serious pollution" or to cause impacts that are "not understood or incompletely understood."[97] Examples of this uncertainty in using AI/EI in marine governance include: algorithmic surveillance technologies could migrate fishing effort to under-monitored areas; autonomous vessel optimization could lead to an increased concentration of vessels transiting through ecologically sensitive areas; and EI decision-making using distributed methods could create unforeseen environmental consequences from which no single member of the decision-making team will be able to recognize.

Environmental impact evaluations of AI systems must include issues such as: i) potential effects of algorithmic decisions on the environment, including determining how patterns of surveillance or concentration of enforcement will influence fish distribution, ecosystem function and health, marine habitats; ii) the effect of algorithmic decisions on equity between states; and iii) transparency and accountability mechanisms (i.e., whether the system allows for sufficient levels of human oversight and or responsibility assignment). iv) Adaptive management provisions for establishing protocols to withdraw (to modify) an AI system that has produced unexpected impacts.[98] In the BBNJ Agreement, the provisions related to capacity building and technology transfer reinforce that equitable access to AI technology should be included in EIA requirements to assure that technologically disadvantaged marine authorities do not continue to experience disparities.[99]

l. Precautionary Principle and AI Governance

The precautionary principle mandates taking precautionary steps to prevent serious or unstoppable damage, even if it is not scientifically sound.[100] When applied to AI, the precautionary principle indicates that nations need to provide assurance that AI-based systems

[97] UNCLOS, Article 206; BBNJ Agreement (n 72) (2023) Article 27(2)(a).
[98] Frontiers in Marine Science, 'Application of the Environmental Impact Assessment Provisions under the BBNJ Agreement in High Seas Marine Protected Area: Challenges and Suggestion' (2025) https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2025.1589936/full accessed 7 January 2026.
[99] BBNJ Agreement (n 72) Articles 35-40 (Capacity-building and transfer of marine technology).
[100] The Precautionary Principle/Approach and the United Nations Convention on the Law of the Sea (2021) Cambridge University Press https://www.cambridge.org/core/books/environmental-rule-of-law-for-oceans/precautionary-principleapproach-and-the-united-nations-convention-on-the-law-of-the-sea/0A3243BF7C9C5F48861508C3541F6DDD accessed 7 January 2026.

will be safe for use in marine governance before these systems can legally be used; rather, nations would need to experiment on and learn from the setbacks and outcomes of the AI Systems after deployment. If an AI System has significant opaqueness, shows signs of unknown algorithmic bias, or has the probability of harming the ecological systems, it would not be prudent or ethical to deploy until sufficient test and transparency have been provided.[101] If a nation deploying an AI System cannot clearly explain how these algorithms made the decisions impacting the stewardship of that coastal state's marine resources, that coastal state is justified in taking precautionary measures.

m. Marine Technology Transfer and Equitable Access

The BBNJ Agreement and Part XIV of UNCLOS impose obligations on developed nations to provide marine technology to developing nations (as defined in the BBNJ Agreement), which is stated to include "the necessary information, data, software, hardware and knowledge base for the study and sustainable use of the Ocean".[102] This definition includes AI and the algorithm-driven technologies applied in marine governance. The responsibility to deliver this technology is directly opposed to restricting access to proprietary AI surveillance technologies or allowing private companies to establish a monopoly over the algorithms utilized to monitor shared marine resources.[103]

Organizations involved in Technology Transfer to developing states in AI must establish mechanisms that address: (i) The ability for developing nations to gain access to and obtain the information and data derived from surveillance systems currently operating within the boundaries of these waters, (ii) Building capacity within these nations to allow for a greater understanding of, auditing of and the ability to operate AI without assistance of a technologically advanced nation, (iii) Providing for preventing dependence on purchasing surveillance or monitoring technology from private firms in technologically advanced nations on an ongoing basis.[104]

[101]Knight First Amendment Institute, 'Transparency's AI Problem' (2025) https://knightcolumbia.org/content/transparencys-ai-problem accessed 7 January 2026.
[102] BBNJ Agreement (n 72) Article 1(10); UNCLOS Part XIV (International Cooperation and Coordination) Articles 276-277.
[103] ScienceDirect, 'Capacity Building and Technology Transfer for Improving Governance of Marine Areas Both Beyond and Within National Jurisdiction' (2020) https://www.sciencedirect.com/science/article/abs/pii/S0308597X20301469 accessed 7 January 2026.
[104]Ocean Equity Research, 'BBNJ Ratification and Implementation' (2024) https://oceanequityresearch.org/themes/bbnj-ratification-and-implementation/ accessed 7 January 2026.

n. Synthesising the Framework

Reinterpretations combine to create a consistent normative structure for AI governance in marine areas including (1) State Responsibility, that states who use or allow the deployment of AI in an area within their jurisdiction are responsible for ensuring compliance with all applicable international law, such as environmental clauses in UNCLOS, throughout the entire life cycle of an AI regardless of whether it is operated by a government entity or developed by a private industry. (2) Transparency Standards, AI used to govern the seas must provide minimum standards of transparency to establish human supervision and accountability; therefore, governments will not authorise the operation of AI that is incapable of providing adequate explanations or being auditable. (3) Environmental Assessment, All AI operations must conduct environmental assessments to determine potential ecological, equity or governance risks. Special consideration must be given to precautionary constraints specific to those systems where the consequences of their operation are uncertain. (4) Fair Access, All states with advanced technology are required to make their technologies and information regarding AI used to govern the seas available to those states that are developing their economies and industries so as to combat the establishment of ongoing technology-based disadvantages.

IV. Toward a Normative Framework: Climate-Resilient and Just Ocean Governance

The synthetic integration of Section V's foundational principles for marine governance with AI reflects a doctrinal requirement for a normative framework that supports AI governance query in Marine space. The following discussion elaborates on the ways as to how the proposed regional governance methods may be used as examples for implementing AI Governance framework s through examples outlined in Section IV.

1) The Integrated Framework: Four Pillars

The framework rests on four core pillars adapted from existing international law and emerging regional practice:

Pillar 1: Due Diligence in Integrating Climate Change into Governance and Regulatory Frameworks. The ITLOS's Advisory Opinion of 2024 on the issue of climate change clearly articulated that, pursuant to Article 194, paragraph 1 of UNCLOS, all States are required to take all necessary measures to prevent, reduce and control marine pollution caused by anthropogenic greenhouse gas emissions. Therefore, the standard of due diligence established by the ITLOS is one of a stringent standard, since there is a higher likelihood of experiencing very

serious and irreversible damage to the marine environment because of these emissions.[105] The requirement that States apply these stringent due diligence standards to artificial intelligence systems developed and employed in the governance of the marine environment is important because the AI technology used to optimize vessel routing must demonstrate the ability to reduce greenhouse gas emissions, not simply redistribute them throughout the various maritime areas; and that surveillance systems must enhance, rather than undermine, enforcement of fisheries laws and regulations; and autonomous systems must have increased operational transparency, so affected States can verify the logic behind decisions made relating to climate change based on the results of their operations.[106] The clarification provided by ITLOS that a State's obligations under UNCLOS are separate from, and may be greater than, a State's obligations under the Paris Agreement means that, at a minimum, AI systems will need to comply with the Paris Agreement's temperature target of 1.5 degrees Celsius, as well as the precautionary approach toward ecosystem-based management of the marine environment.[107]

Pillar 2: The precautionary principle is supported by the requirement for transparency in relation to how "high-risk" AI systems are developed or used.[108] However, states must ensure that AI systems are safe for marine governance prior to being used (i.e., before the system is used for decision-making) and that all relevant (scientific) information is available to those using AI systems that affect marine governance decisions. The EU Artificial Intelligence Act establishes a process whereby states can ensure safety, transparency, and conformity with regard to "high-risk" AI systems used for autonomous maritime environmental monitoring.[109] AI systems that contribute to marine environmental management must be able to meet minimum transparency levels to allow for human oversight and algorithmic explainability for environmental impact

[105] International Tribunal for the Law of the Sea, 'Advisory Opinion: Responsibilities and Obligations of States with Respect to Climate Change and Ocean Acidification' (2024) paras 213, 257.
[106] Ibid. paras 206-223 (establishing that states must take "all necessary measures" to prevent, reduce and control GHG pollution, with obligations extending beyond Paris Agreement commitments).
[107] Ibid. para 223 (holding that "the Paris Agreement does not require the Parties to reduce GHG emissions to any specific level according to a mandatory timeline" and therefore "the obligation under article 194, paragraph 1, of the Convention would [not] be satisfied simply by complying with the obligations and commitments under the Paris Agreement").
[108] The Precautionary Principle/Approach and the United Nations Convention on the Law of the Sea (2021) Cambridge University Press https://www.cambridge.org/core/books/environmental-rule-of-law-for-oceans/precautionary-principleapproach-and-the-united-nations-convention-on-the-law-of-the-sea/0A3243BF7C9C5F48861508C3541F6DDD accessed 7 January 2026.
[109] European Commission, 'Artificial Intelligence Act' (2024) https://artificialintelligenceact.eu/ accessed 1 January 2026 (establishing risk-based governance framework with high-risk systems subject to conformity assessments, transparency documentation, and post-market monitoring).

assessment, and they must provide an explanation of their decision-making rationale to affected states. AI systems that cannot demonstrate substantial transparency or can only provide vague descriptions of their decision-making rationale should not be used, being consistent with the precautionary principle of precautionary restraint.

Pillar 3: The Technology Transfer and Equitable Access Pillar of the BBNJ Agreement compels developed nations to provide developing nations with access to the means of production (through technology transfers) and includes anything related to marine resources (i.e., data, information, software, hardware, etc.) to assist in improving their ability to manage sustainably the oceans.[110] In terms of AI systems, developed states need to prevent the monopolization of key technologies (i.e., marine governance tools) for surveillance and monitoring purposes by the private sector so that sufficient technological capacity can be provided to developing coastal states, particularly small island developing states whose economies rely significantly on marine resources, enabling them to utilize equivalent technology independently.[111] This Pillar prohibits the current practice of generating surveillance and monitoring data from developing state waters collected by third-party entities and sold back as commercial services to developing coastal states; instead, it requires that developed states provide developing states with reasonable levels of technology transfer and capacity building, as well as data access sufficient for the development of independent governance capability.

Pillar 4: Cumulative Impact Assessment and Adaptive Management. The BBNJ Agreement stipulates that comprehensive environmental assessments must include evaluations of cumulative impacts from multiple anthropogenic activities.[112] In the context of AI governance, this extends to the need for assessing cumulative impacts of decision-making across autonomous systems; while each autonomous system optimises to achieve specific goals, the aggregate effect of many autonomous systems can result in unintended ecological or social effects. States must develop an adaptive management process in which they are continually monitoring and evaluating the performance of artificial intelligence systems and are responsive to any negative side effects created as a result of AI decisions; this feedback loop will facilitate on-going improvements to governance in this area.

[110] BBNJ Agreement (n72) Article 1(10); Articles 35-40 (Capacity-building and transfer of marine technology).
[111] BBNJ Agreement (n72) Articles 35-40.
[112] BBNJ Agreement (n 72) Article 27(2)(a) (requiring EIAs address cumulative impacts); Article 35 (establishing capacity-building and technology transfer obligations).

2) Regional Frameworks as Implementation Models

The governance approaches emerging at a regional level demonstrate how to operationalize the four pillars outlined in the framework. The EU Artificial Intelligence Act establishes a risk-based governance structure for AI systems that classifies these systems by risk level. The Act requires that "high-risk" AI systems undergo mandatory assessments of compliance, provision of documentation related to the provision of transparency, and ongoing post-market monitoring prior to being deployed.[113] Under the EU framework for autonomous maritime systems and environmental monitoring AI, the EU Artificial Intelligence Act demonstrates compliance with Pillar Two's (Transparency Requirement) by specifying that developers of these systems must demonstrate that the systems are safe, provide documentation describing their algorithm's methods of decision-making, and conduct ongoing monitoring to ensure they remain in compliance after their deployment.[114] The EU's Maritime and Ocean Governance Strategies also incorporate the principles of this Act into the context of broader environmental protection laws and policies via creating linkages between the requirements of regulating autonomous systems and the requirement for ecosystem-based management under the Marine Strategy Framework Directive.[115]

The EU's Common Information Sharing Environment (CISE) provides an infrastructure to facilitate the integration of Governance of the Marine Environment, creating a model of Europe in which the individual member states collaborate via shared information protocols on the provision of surveillance and situational awareness across the Member States.[116] Furthermore, this model provides for Pillar 3 (Equitable Access), establishing mechanisms that allow the member states to provide access to members of the surveillance data and collaborate on the decisions regarding Governance, thus eliminating any information asymmetries that may cause disadvantages to smaller or less technologically advanced member states.

[113] European Commission (n 108).

[114] European Commission, 'EU Maritime and Ocean Governance Strategies' (2021) https://ec.europa.eu/growth/tools-databases/maritime/ accessed 7 January 2026; European Maritime Safety Agency, 'Artificial Intelligence and Data Analytics in Maritime Surveillance' (2024) https://www.emsa.europa.eu/ accessed 7 January 2026.

[115] European Commission, 'Directive 2008/56/EC on Marine Strategy Framework Directive' (2008); European Commission, 'Maritime Spatial Planning Directive 2014/89/EU' (2014).

[116] European Commission, 'Common Information Sharing Environment for the EU Maritime Domain (CISE)' https://www.emsa.europa.eu/cise/ accessed 7 January 2026.

The African Union's Continental AI Strategy, which was endorsed in 2024, has explicitly incorporated AI Governance into Climate Adaptation and Climate Resilience agendas, and establishes that the development of "Ethically and Responsibly Developed Artificial Intelligence" should advance the Regional Climate Resilience objectives. [117]The AU has established this Strategy to create a framework for future binding regional agreements on AI Governance in marine areas, even though the current Strategy is not legally binding or enforceable. The AU has also created a framework for embedding climate objectives in continental-level AI Frameworks, through its linkage of AI Governance to Climate Resilience as part of the AU's Agenda 2063 Climate Adaptation Planning initiatives.[118]

ASEAN's Guide on AI Governance and Ethics lays out principles that all members in the region should follow when developing AI. The four main principles include: transparency, fairness, accountability and security.[119] Although these principles are not legally binding, they serve as a guideline for future regional agreements on the deployment of AI within marine governance, particularly in regard to: shared fisheries and transboundary marine zones. The establishment of regional working groups (e.g., the ASEAN Working Group on AI Governance) indicates a strong commitment to developing a coherent and consistent set of regional standards, with the potential to include the establishment of regulations for the autonomous operation of marine resources when technology has advanced.[120]

3) Operationalising the Framework: Institutional Mechanisms

Operationalizing this framework requires institutional mechanisms at multiple governance levels:

On a flag state basis, the state must create laws requiring AI system developers and operators to show that their products and services comply with all relevant international, national, and local laws and to have performed due diligence in relation to the development and deployment of said products. An example is the "European Union Artificial Intelligence Act" (EU AI Act) which would create a pre-market conformity assessment and a post-market monitoring obligation,

[117] African Union, 'Continental AI Strategy' (2024) https://au.int/ accessed 7 January 2026 (integrating AI governance within climate adaptation and resilience agendas).
[118] African Union, 'Agenda 2063: The Africa We Want' (2013) https://au.int/agenda2063 accessed 7 January 2026.
[119] ASEAN, 'ASEAN Guide on AI Governance and Ethics' https://www.asean.org/ accessed 7 January 2026 (establishing principles of transparency, fairness, accountability, security, and privacy for regional AI development).
[120] ASEAN, 'ASEAN Working Group on AI Governance' https://www.asean.org/ accessed 7 January 2026.

thereby ensuring that AI systems continue to perform satisfactorily and meet environmental standards during their life cycle.[121]

At regional level, RFMOs, the Regional Seas Programs, and regional AI governance initiatives, such as ASEAN's Working Group on AI Governance, can formulate regional guidelines (binding / non-binding) for how AI will be used to manage the oceans. This could include, among other things, requiring assessments of cumulative adverse effects produced from AI surveillance and enforcement; creating technology transfer systems to provide fair and equitable access to this information; and establishing systems for sharing information regarding AI management issues and solutions.

At the global level, the provision in Article 237 of UNCLOS indicating that the Convention applies "without prejudice to the environmental obligations imposed under other treaties" allows for the incorporation of principles of international governance of Artificial Intelligence into the legal framework that governs AI in marine spaces. One potential way to address governance of Artificial Intelligence in marine regions is through the creation of an international instrument, either through amendments to UNCLOS or through a new implementing agreement or Non-Binding guidelines developed by the International Maritime Organization, which would bring together the framework presented here as one coherent set of Global Standards.

4) Climate-Resilience and Justice Integration

AI governance integrates climate resilience and equity through both the protection of the environment and the equitable distribution of resources. Countries that are vulnerable to climate change, especially small island developing states at risk of extinction due to climate change-induced rise in ocean and sea levels, should use AI technology rather than be disadvantaged by technological reliance on wealthier countries.[122] Technology transfer and the provision of capacity building must not be viewed as optional components of AI governance. By incorporating these components into AI governance frameworks, developing countries will be able to independently understand, audit and use AI systems that affect the management of their marine resources.

[121] European Commission (n 108).
[122] UNDP Climate Promise, 'Small Island Developing States are on the Frontlines of Climate Change – Here's Why' https://climatepromise.undp.org/news-and-stories/small-island-developing-states-are-frontlines-climate-change-heres-why accessed 7 January 2026.

In addition, the framework needs to be transparent to allow vulnerable nations to ensure that AI systems being used around the world do not jeopardise their interests in ocean resiliency and resource sustainability. Moreover, nations that depend on marine fisheries also need to be able to assess if algorithmic surveillance does indeed enable enforcement concentration at the expense of their fleets of vessels, or does reliance on autonomous vessel optimization systems enable the externality of costs borne by developing coastal communities.

5) Conclusion

This article has identified that there is a significant regulatory gap regarding the intersection of climate change, artificial intelligence, and ocean governance that relates to the lack of any coherent international legal exigencies governing responsibility, transparency and equity for AI-enabled marine systems; the risk of harm from applying AI unregulated on top of Climate Change's degradation of habitat present environmental hazards that will affect society disproportionately (as experienced by coastal states that are particularly vulnerable to the effects of Climate Change).[123]

The article indicates methods to remedy this gap without creating entirely new frameworks related to laws governing due diligence, marine environmental protection, or state responsibilities. Existing international obligations related to marine environmental protection, due diligence requirements, and state responsibilities provide sufficient doctrinal material to cover AI-mediated activities, whereby with appropriate reinterpretation based on current customary international law and the climate advisory opinion from the ITLOS, due diligence, environmental assessment, and transfer obligations can include automated systems and algorithm-led decision-making processes.[124]

State liability stretches to include the actions of private entities within the jurisdiction of the state; therefore, the government has a responsibility to enact rules and regulations for appropriate use of, and compliance with, its AI systems.[125] ITLOS has defined due diligence as an evolving and dynamic process; hence there must be at least a baseline of both transparency

[123] United Nations, 'How is climate change impacting the world's ocean' (UN Climate Action) https://www.un.org/en/climatechange/science/climate-issues/ocean-impacts accessed 7 January 2026; UNDP Climate Promise, 'Small Island Developing States are on the Frontlines of Climate Change – Here's Why' https://climatepromise.undp.org/news-and-stories/small-island-developing-states-are-frontlines-climate-change-heres-why accessed 7 January 2026.
[124] International Tribunal for the Law of the Sea, 'Advisory Opinion: Responsibilities and Obligations of States with Respect to Climate Change and Ocean Acidification' (2024) paras 206-213.
[125] ARSIWA Articles 4, 8.

and a requirement for AI systems used in marine areas to provide, explain and demonstrate their decision making.[126] Environmental impacts from AI must be taken into account, as part of an environmental assessment; however, there should also be consideration for the potential cumulative or compounding effect of all AI.[127] Therefore, developed countries that transfer AI technology must also actively support developing countries in achieving access and using AI technology; failure to do so could result in technological inequity and disadvantage to certain regions in terms of how AI is applied to ocean management and governance.[128]

The development of new regional approaches offers valuable opportunities for the implementation of the aforementioned Principles. The European Union's AI Act establishes a risk-based governance structure through the use of a pre-market Conformity Assessment process for all High-Risk Systems.[129] The African Union's Continental Strategy on AI incorporates a framework for AI Governance into all activities related to climate adaptation,[130] while the ASEAN's Guide to AI Governance sets out key principles for both transparency and accountability as applied to the marine environment.[131]

The proposed Normative Framework is built upon four Pillars: (1) Due Diligence associated with Climate Integration; (2) Requirement for Precautionary Transparency; (3) Provision for Equitable Access and Technology Transfer; and (4) An Adaptive Management Approach for Impact Assessment, both individually and cumulatively. The successful Implementation of this Framework will require coordinated Action on the part of Flag States, Regional Organizations and Global Entities, wherein Flag States will establish Conformity Assessments prior to entering the Market; Regional Organizations will develop Binding Standards, and Global Coordination will be established to avoid Regulatory Fragmentation.[132]

It is unnecessary for international law to remain behind the technology curve. Due diligence, precaution, and environmental assessment are all principles of international law that can adequately apply to future technological advances by broadly interpreting and implementing

[126] ITLOS paras 206-213.
[127] UNCLOS, Article 206; BBNJ Agreement (n72) Article 27(2)(a).
[128] BBNJ Agreement (n 72) Articles 35-40 (Capacity-building and transfer of marine technology).
[129] European Commission, 'Artificial Intelligence Act' (2024) https://artificialintelligenceact.eu/ accessed 7 January 2026.
[130] African Union, 'Continental AI Strategy' (2024) https://au.int/ accessed 7 January 2026.
[131] ASEAN, 'ASEAN Guide on AI Governance and Ethics' https://www.asean.org/ accessed 7 January 2026.
[132] European Maritime Safety Agency, 'Artificial Intelligence and Data Analytics in Maritime Surveillance' (2024) https://www.emsa.europa.eu/ accessed 7 January 2026; United Nations Environment Programme, 'Regional Seas Programmes' https://www.unep.org/regionalseas/ accessed 7 January 2026.

existing principles. As such, countries may use these multiples to create equitable and climate-resilient ocean governance structures, which would protect vulnerable ocean environments and states while also allowing for ongoing innovations in rapidly evolving environmental technologies.

2. Research Methods

This study employs a normative legal research methodology. It utilizes a doctrinal approach to analyze the intersection of: The United Nations Convention on the Law of the Sea (UNCLOS) 1982. International Environmental Law (The Paris Agreement, CBD, and BBNJ). Emerging norms in AI Governance and Ethics (UNESCO and IMO guidelines). The research focuses on identifying "regulatory lacunae" (legal gaps) in the attribution of state responsibility for autonomous acts and the interpretation of *due diligence* in the context of machine learning.

3. Results and Discussion

3.1. Challenging the "Ship" Concept in UNCLOS

MAS is defined as platforms capable of operating without direct human intervention on board, utilizing AI algorithms for navigation and data collection (Ringbom, 2019, p. 145). In the climate context, MAS plays a crucial role in gathering real-time data on ocean acidification, sea surface temperatures, and the migration patterns of marine biota affected by global warming.

The deployment of MAS allows for the monitoring of vast maritime areas with significantly lower carbon emissions compared to conventional research vessels (Petrig, 2021, p. 22). This aligns with the decarbonization efforts of the maritime industry driven by the International Maritime Organization (IMO).

The legal status of MAS remains ambiguous. Under Article 94 of UNCLOS, a Flag State must exercise effective jurisdiction and control. If an AI-enabled vessel operates without a human master, does it satisfy the "social and technical" requirements of the Convention? We argue for an evolutionary interpretation of "Master," where the legal responsibility is transferred to the Remote Operator or the Algorithm Provider.

The primary challenge lies in the interpretation of the terms "ship" or "vessel" under UNCLOS 1982. Traditionally, the law of the sea assumes the presence of a master and crew on board to ensure the safety of navigation (Kraska, 2020, p. 8).

1) Article 94 of UNCLOS: Dictates the duties of the flag State to ensure safety at sea. The use of AI raises questions regarding legal liability: who is held responsible if a collision at sea occurs due to an algorithmic failure? (Veal et al., 2019, p. 310).

2) Legal Status: There is currently no consensus on whether small autonomous sensors should be categorized as "ships" entitled to the right of innocent passage or merely as scientific equipment subject to the regime of Marine Scientific Research (MSR).

3) Advancing Climate-Resilient Ocean Governance

Resilient ocean governance requires proactive regulatory adaptation. Integrating AI-generated data into international legal decision-making can accelerate responses to climate disasters (Stephens, 2022, p. 56).

Future regulations should focus on:

1) Global Technical Standards: Developing ethical and technical codes through the IMO for MAS operationality (The MASS Code).

2) Data Transparency: Ensuring that climate data collected by AI is accessible for the global interest, reflecting the principle of the *common heritage of mankind*.

3) Legal Liability**:** Shifting the paradigm from the "Master's responsibility" to the liability of AI developers and shore-based operators (Carey, 2023, p. 112).

The regulation of AI-enabled MAS is a prerequisite for achieving climate-resilient ocean governance. While UNCLOS provides a solid foundation, evolutionary interpretation or new legal instruments (such as the MASS Code) are necessary to accommodate autonomous technologies. With the right regulatory framework, MAS will serve not only as a navigational tool but as a primary instrument in safeguarding global marine ecosystems against the threats of climate change.

AI can process "Big Ocean Data" to predict sea-level rise and monitor coral bleaching with 99% accuracy. However, the "Black Box" nature of AI—where the reasoning behind a decision is opaque—poses a threat to transparency in ocean governance. If an AI redirects a vessel through a Marine Protected Area (MPA) to save fuel, who is liable for the ecological disturbance?

Under international law, states are responsible for "national activities" in the marine environment. We propose the concept of "Algorithmic Due Diligence." States must be held to a

higher standard of care when deploying AI, including mandatory "Algorithm Impact Assessments" (AIA) before a MAS is authorized to enter international waters.

The digital divide threatens to exclude SIDS from the benefits of AI-driven ocean governance. Equitable access to AI tools is a prerequisite for "Climate-Resilient Governance." Without technology transfer (Part XIV, UNCLOS), AI will only serve to reinforce existing maritime power imbalances.

MAS refers to any platform that can navigate and perform tasks in the maritime environment without human intervention on board (Ringbom, 2019, p. 142). AI enhances these systems through machine learning (ML), allowing them to process environmental variables and optimize routes for fuel efficiency or data accuracy.

Climate resilience in ocean governance depends on the "Science-Policy Interface." MAS contributes to this by:

1) Lowering Carbon Footprints: Unlike traditional research vessels, small MAS units are often battery-powered or use renewable energy (Petrig, 2021, p. 25).

2) Persistent Observation: MAS can remain at sea for months, monitoring carbon sequestration and heat absorption (Carey, 2023, p. 89).

3) Risk Reduction: Operating in extreme weather conditions (e.g., hurricanes) where human presence is unsafe.

Under UNCLOS, the status of a "ship" or "vessel" confers rights (such as innocent passage) and duties (such as environmental compliance). However, UNCLOS does not provide a definitive definition of a ship.

Traditional interpretations suggest that a ship requires a "Master" and "Crew" (Kraska, 2020, p. 12). Article 94(4)(b) requires that every ship must be "in the charge of a master." If an AI is in charge, does the system lose its status as a ship? Most scholars now argue for an Evolutionary Interpretation (Klein, 2021, p. 204), where the function of the vessel (navigation and transport) outweighs the method of control (human vs. algorithmic).

If MAS is used solely for climate monitoring, it may fall under the MSR regime (Part XIII of UNCLOS). This requires the consent of coastal States for operations within the Exclusive Economic Zone (EEZ). The tension arises when MAS is used for both commercial/military

purposes and climate data collection, creating a "dual-use" legal ambiguity (Veal et al., 2019, p. 308).

The International Regulations for Preventing Collisions at Sea (COLREGs) were designed for human perception. Rule 5 requires a "proper look-out by sight and hearing." AI systems use LiDAR, Radar, and Computer Vision. Whether these sensors satisfy the "sight and hearing" requirement remains a point of intense legal debate (Gunnarsson, 2021, p. 45).

In the event of a collision or an oil spill caused by an MAS, determining liability is complex. Traditional maritime law uses the "fault-based" system of the Master's negligence. With AI, the "fault" may lie with:

1) The software developer (Product liability).

2) The shore-based controller (Operational liability).

3) The owner of the MAS (Strict liability).

To advance climate resilience, the law must ensure that liability regimes do not stifle the deployment of green MAS technologies while ensuring that "the polluter pays" (Tsimplis, 2022, p. 115).

The International Maritime Organization (IMO) is currently developing a Marine Autonomous Surface Ships (MASS) Code. This code aims to provide a mandatory instrument for the safe, secure, and environmentally sound operation of MAS. A climate-resilient MASS Code must:

1) Standardize data-sharing protocols for environmental monitoring.

2) Mandate energy-efficient AI algorithms to minimize the "digital carbon footprint."

3) Create a "Remote Operator" certification that mirrors the traditional Master's qualifications (IMO, 2023, p. 12).

The newly adopted Agreement on Biodiversity Beyond National Jurisdiction (BBNJ) emphasizes the use of the best available science. AI-enabled MAS can provide the high-tech monitoring needed for Marine Protected Areas (MPAs) in the high seas (Wright, 2024, p. 22).

Climate data collected by AI should be treated as a global public good. There is a risk that private corporations or wealthy States will monopolize "AI-derived ocean intelligence," leading to a

digital divide in ocean governance (Freestone, 2023, p. 301). International law must mandate "Open Science" for all MAS-collected climate data.

4. Conclusion

This article has identified that there is a significant regulatory gap regarding the intersection of climate change, artificial intelligence, and ocean governance that relates to the lack of any coherent international legal exigencies governing responsibility, transparency and equity for AI-enabled marine systems; the risk of harm from applying AI unregulated on top of Climate Change's degradation of habitat present environmental hazards that will affect society disproportionately (as experienced by coastal states that are particularly vulnerable to the effects of Climate Change). The article indicates methods to remedy this gap without creating entirely new frameworks related to laws governing due diligence, marine environmental protection, or state responsibilities. Existing international obligations related to marine environmental protection, due diligence requirements, and state responsibilities provide sufficient doctrinal material to cover AI-mediated activities, whereby with appropriate reinterpretation based on current customary international law and the climate advisory opinion from the ITLOS, due diligence, environmental assessment, and transfer obligations can include automated systems and algorithm-led decision-making processes. State liability stretches to include the actions of private entities within the jurisdiction of the state; therefore, the government has a responsibility to enact rules and regulations for appropriate use of, and compliance with, its AI systems.[133] ITLOS has defined due diligence as an evolving and dynamic process; hence there must be at least a baseline of both transparency and a requirement for AI systems used in marine areas to provide, explain and demonstrate their decision making.[134] Environmental impacts from AI must be taken into account, as part of an environmental assessment; however, there should also be consideration for the potential cumulative or compounding effect of all AI.[135] Therefore, developed countries that transfer AI technology must also actively support developing countries in achieving access and using AI technology; failure to do so could result in technological inequity and disadvantage to certain regions in terms of how AI is applied to ocean management and governance. The integration of AI into marine systems is inevitable, but its regulation must be intentional. To advance climate-resilient ocean governance, international law must shift from a "human-centric" to a "system-centric" accountability model. We recommend: A New IMO Code for AI Transparency in Navigation.

[133] ARSIWA Articles 4, 8.
[134] ITLOS paras 206-213.
[135] UNCLOS, Article 206; BBNJ Agreement (n72) Article 27(2)(a).

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