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Topic: Human Right Issues of Artificial Intelligence (AI) Gaps and Challenges, and Affected Future Legal Development in Various Countries

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*

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climate-resilient and just ocean governance in an era of rapid technological and environmental change.

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

1. Introduction

The global ocean is at a tipping point. Climate change is fundamentally altering marine ecosystems, necessitating a transition toward "Climate-Resilient Ocean Governance." This governance model requires real-time, high-resolution data to monitor changing oceanic conditions (Stephens, 2022, p. 58). AI-enabled Marine Autonomous Systems (MAS), including Uncrewed Surface Vessels (USVs) and Autonomous Underwater Vehicles (AUVs), are the vanguard of this transition.

However, the rapid deployment of these systems outpaces the development of international legal norms. The primary instrument of ocean governance, UNCLOS, was drafted in an era when autonomy was science fiction. The central legal question is whether the existing framework can accommodate non-human agency in maritime operations while ensuring environmental protection. This paper explores the regulatory gaps and proposes a roadmap for an integrated legal framework that leverages AI for oceanic climate resilience.

The global maritime domain is currently facing a "double disruption": the existential threat of climate change and the rapid proliferation of Artificial Intelligence (AI). As the oceans absorb over 90% of the heat generated by greenhouse gas emissions, the legal structures governing the seas are being pushed to their limits. Simultaneously, the emergence of Marine Autonomous Systems (MAS) offers both a technological lifeline and a profound legal challenge.

The "Constitution of the Oceans," UNCLOS (1982), was drafted in a pre-digital era. It assumes human presence on vessels—a "master" and "crew" who are physically and legally responsible for the ship's conduct. However, AI-enabled MAS operate through complex algorithms that can adapt to environmental variables without real-time human intervention. This shifts the focus of ocean governance from human behavior to algorithmic reliability.

The digital transformation of the maritime sector has introduced Marine Autonomous Systems (MAS) powered by Artificial Intelligence (AI). These technologies—ranging from uncrewed surface vessels (USVs) to autonomous underwater sensors—offer immense potential for monitoring climate change and managing marine resources efficiently. However, the current

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international legal framework, primarily UNCLOS 1982, does not yet specifically address the operationality of AI at sea within the context of climate resilience. This paper analyzes the regulatory challenges and the opportunities for integrating MAS to strengthen climate-resilient ocean governance.

For climate-vulnerable states like the Maldives and Nigeria, the regulation of AI is not merely a technical concern but a matter of national security and environmental justice. If AI systems are deployed to monitor IUU fishing or map the seabed for carbon sequestration without a clear legal framework, there is a risk of "digital maritime colonialism," where data-rich nations dictate the terms of ocean health at the expense of the Global South.

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.

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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

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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).

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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).

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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

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. Mandatory Technology Transfer of climate-monitoring AI to SIDS. Strict Liability for environmental damage caused by autonomous algorithmic failure.

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