



OPEN ACCESS

EDITED BY

Qi Xu,
Jinan University, China

REVIEWED BY

Bowen Zhu,
The Affiliated Infectious Diseases Hospital of
Soochow University, China
Chao Fu,
Zhejiang Wanli University, China

*CORRESPONDENCE

Yue Wu

✉ yuewuufighting@163.com

RECEIVED 10 August 2025

ACCEPTED 25 August 2025

PUBLISHED 04 September 2025

CITATION

Chai Y and Wu Y (2025) The marine community of shared destiny driving paradigm shift in vessel pollution governance: an integrated governance framework for sustainable ocean development. *Front. Mar. Sci.* 12:1682990. doi: 10.3389/fmars.2025.1682990

COPYRIGHT

© 2025 Chai and Wu. This is an open-access article distributed under the terms of the [Creative Commons Attribution License \(CC BY\)](https://creativecommons.org/licenses/by/4.0/). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

The marine community of shared destiny driving paradigm shift in vessel pollution governance: an integrated governance framework for sustainable ocean development

Yuhong Chai and Yue Wu*

School of Law, Lanzhou University, Lanzhou, China

Within global economic integration, the shipping industry handles over 80% of global trade and is a key driver of economic growth. Consequently, marine vessel pollution control has become an issue of increasing significance. While the International Convention for the Prevention of Pollution from Ships (MARPOL) and related treaties and agreements establish foundational provisions for vessel pollution control, they fall short in addressing the contemporary challenges posed by such pollution. China's concept of the Marine Community of Shared Destiny (MCSD) offers a novel ideological framework for global ocean governance. Under this framework, a new governance structure for marine vessel pollution control is being established—integrating hard and soft law, shared responsibility, and technological empowerment. This structure aims to transition relevant conventions from voluntary guidelines to mandatory constraints, enhance transparency and credibility through blockchain technology, and ultimately achieve multi-stakeholder governance to establish a new order for controlling marine vessel pollution. The MCSD concept, by creating new systems and using technology, can effectively balance countries' own interests with the shared interests of the world. It offers a practical reform plan that is both sound in theory and workable in practice. This provides useful guidance for making the shipping industry more environmentally friendly and improving how the world manages shared ocean resources.

KEYWORDS

marine community of shared destiny (MCSD), vessel-sourced pollution, MARPOL convention, governance framework, marine environmental protection

1 Introduction

Against the backdrop of ocean globalization, maritime transport serves as both an economic linchpin and an environmental liability. In the context of global economic integration, international shipping accounts for over 80% of global trade volume, acting as a pivotal driver of economic globalization while playing critical roles in national security and international prestige. These interest-driven factors have collectively fueled the sector's rapid expansion, while concurrently intensifying environmental challenges—notably vessel-sourced pollution.

Statistical evidence indicates that up to 35% of marine pollutants originate from shipping activities, including the unregulated discharge of ballast water, cargo hold washings, and bilge oil wastewater, all of which introduce oil residues that degrade water quality and endanger both aquaculture and human health. According to ICTT data (in 2023), the use phase carbon dioxide equivalent emissions in the global shipping sector reached 911 million tons, with approximately 86% of emissions coming from international shipping activities (ICTT, 2025).

These escalating impacts underscore systemic governance deficiencies. The interconnected nature of the ocean necessitates transnational cooperation, yet intensifying human activities have led to increasing pollution incidents both within national jurisdictions and on the high seas. Most transboundary pollution now exceeds the capacity of unilateral control, causing expanding ecosystem damage. While existing treaties establish obligations for relevant entities, they remain insufficient to address ongoing marine environmental degradation.

Careful management of this essential global resource is a key feature of a sustainable future (Commission on Sustainable Development, 2025). Consequently, the concept of the Marine Community of Shared Destiny must be introduced to reconcile state sovereignty with global public interests, further clarify responsibilities for transboundary marine environmental governance, and promote the sustainable development of the marine ecological environment.

2 The imperative of integrating the marine community of shared destiny concept into vessel-sourced pollution control

2.1 The dilemma of global marine governance: confronting unilateralism, regulatory lag, and technological fragmentation

The global marine governance system evolves through cyclical interactions between globalization and fragmentation, yet its effectiveness is increasingly undermined by geopolitical dynamics, exacerbating governance deficits. This deterioration is evident in the

unilateral approaches adopted by major powers, which erode the foundations of multilateral cooperation. As a result, governance resources are diminished, international coordination capacity is weakened, and existing regimes are unable to effectively address critical challenges such as vessel-sourced pollution.

ITOPF data (1970-2020) recorded 466 major spills (>700 tons), 1,381 intermediate spills (7–700 tons), and >10,000 minor spills, collectively causing substantial economic damage. The International Convention for the Prevention of Pollution from Ships (MARPOL)—the cornerstone of Vessel pollution governance—is facing a profound adaptive crisis. Its regulatory stringency imposes significant technical and financial burdens, while revisions to its rules lag behind emerging pollution threats. At the implementation level, data fragmentation severely compromises the enforceability of obligations among flag, port, and coastal states. Divergent technical standards further create compliance barriers, as incompatible pollution monitoring systems hinder cross-border data integration, thereby widening the governance gap and exacerbating the environmental deficit in global oceans.

2.2 The MARPOL convention's adaptive crisis: emerging pollutants, data fragmentation, and enforcement deficiencies

The MARPOL Convention displays significant regulatory gaps regarding emerging pollutants, highlighting a structural contradiction between the pace of technological advancement and the slow legal response. Key sources of pollution—such as copper pyrithione from antifouling paints and microplastics in vessel washwater—remain unregulated due to their exclusion from controlled substance lists (Mo, 2024). Over 5,000 distinct plastic polymers have been identified in marine environments, yet their bioaccumulation pathways remain unaddressed in current pollution monitoring frameworks. Revising MARPOL annexes requires approval by two-thirds of the IMO Marine Environment Protection Committee member states, a process that typically takes 5–7 years, whereas new pollutants are emerging approximately every two years.

Furthermore, data fragmentation undermines the convention's effectiveness. Emission monitoring primarily relies on manual sampling and shipowner self-reporting, which creates loopholes for paper compliance. Pollution tracing is hampered by disconnected databases across flag, port, and coastal states, allowing non-compliant vessels to evade detection by switching ports. Additionally, quantifying the ecological damage caused by pollution is obstructed by the absence of pollution impact models and sovereignty-based restrictions on data sharing.

Meanwhile, enforcement mechanisms suffer from systemic imbalances. From 2025, the Red Sea and Gulf of Aden will be designated MARPOL Special Areas under Annexes I (oil) and V (garbage). However, inadequate waste reception facilities in coastal States enable continued non-compliant discharges. Flag state

oversight is weakened by limited capacity in open-registry states (e.g., Panama, Liberia), with only 35% of global vessels receiving comprehensive inspections in 2022. Port State Control standards also vary significantly, as developed economies detain non-compliant vessels at much higher rates than developing countries, creating a pollution sink effect, whereby vessels toward ports with weaker enforcement. Finally, compensation mechanisms remain insufficient: the International Convention on Civil Liability for Oil Pollution Damage only addresses oil spills, leaving vessel-sourced greenhouse gas emissions and biotoxic contamination outside the scope of liability frameworks.

2.3 Operational principles of the marine community of shared destiny: common responsibility, technology sharing, and interest coordination

The imbalance of human interests in the high seas is significant (Blasiak and Claudet, 2024). The traditional principle of freedom of the seas has enabled developed States to prioritize self-interested activities in these areas while neglecting governance obligations. As a critical evolution beyond this paradigm, the MCSD both inherits and advances maritime legal theory—serving as both a concept proposed by China and a global public good. Global marine rule of law constitutes the foundational guarantee and implementation pathway for the MCSD. Anchored within the broader Community with a Shared Future for Mankind, the MCSD pursues shared responsibility, technology sharing, and interest coordination.

Shared responsibility is the foundational principle for addressing the enduring tragedy of the commons in vessel-sourced pollution governance, where uneven allocation of obligations remains a core problem. The MCSD framework calls for reconstructing an equitable duty system (Wang, 2023), urging all states to participate actively in marine pollution control. Addressing this transboundary challenge requires international cooperation through joint rulemaking, institution-building, and coordinated response mechanisms.

Technology sharing is the core operational mechanism for achieving effective governance. While Article 202 of the United Nations Convention on the Law of the Sea provides for technical assistance, its non-mandatory nature allows technological monopolies by developed states and creates cross-border data barriers, thereby reducing governance efficiency and hindering access to clean technologies for developing countries. The MCSD promotes global ocean governance by institutionalizing technology transfer channels, ensuring capacity-building, and mandating the dissemination of critical technologies (Bai and Wang, 2023; Zhang, 2021).

Ultimately, the MCSD seeks to achieve synergistic benefits: expanding common interest through multilevel community structures to realize sustainable marine resource sharing and harmonious human-ocean coexistence (Jin, 2021). This framework advocates civilizational mutual learning, respects

diverse marine traditions and values, transcends cultural divides, replaces hierarchical models with coexistence, and fosters marine civilization innovation (Xiang, 2023).

3 A collaborative governance framework for the marine community of shared destiny: integrating hard and soft law, tripartite responsibility coordination, and technology-driven implementation

The various issues facing the marine environment are closely interrelated and must be considered as a whole. The principle of MCSD guides the global marine governance process, shifting the focus of marine resource utilization from development to protection.

The common heritage of mankind principle, enshrined in UNCLOS, mandates international cooperation in marine resource development. The MCSD concept further emphasizes integrating national interests within the broader community interest, fostering a transition in rule-making: from major power domination to inclusive consultation, and from power-based jurisdiction to responsibility-based co-governance. An integrated governance framework flowchart. As shown in Figure 1 below, It's essential that we adopt a holistic human perspective., guided by the MCSD. This can be achieved by integrating hard and soft law instruments, activating a tripartite responsibility mechanism, using technology to facilitate the implementation of conventions, and working together to promote sustainable marine development.

3.1 Dynamic governance: balancing hard law's rigidity with soft law's flexibility

International maritime law designates the oceans as the common heritage of mankind and imposes on all States the obligation to cooperate in protecting the marine environment. Therefore, all states have the responsibility to strengthen their marine protection and governance efforts.

To improve vessel pollution governance effectiveness, a binding regulatory framework must be established. Embedding the precautionary principle within MARPOL would authorize the IMO's Scientific Group to initiate emergency regulatory procedures for emerging pollutants—such as microplastics and underwater noise—and include them in Annex controls. To address inadequate flag state oversight, a joint liability system should be introduced, requiring cargo owners to assume supplementary compensation for pollution caused by chartered vessels.

Within the limits of sovereign consent, Consideration should be given to requiring member states to report key emissions data to the IMO. The European Union's Emissions Trading System is a case in point. It mandates that ships calling at EU ports submit third-party verified carbon emission data. This data is then cross-checked with

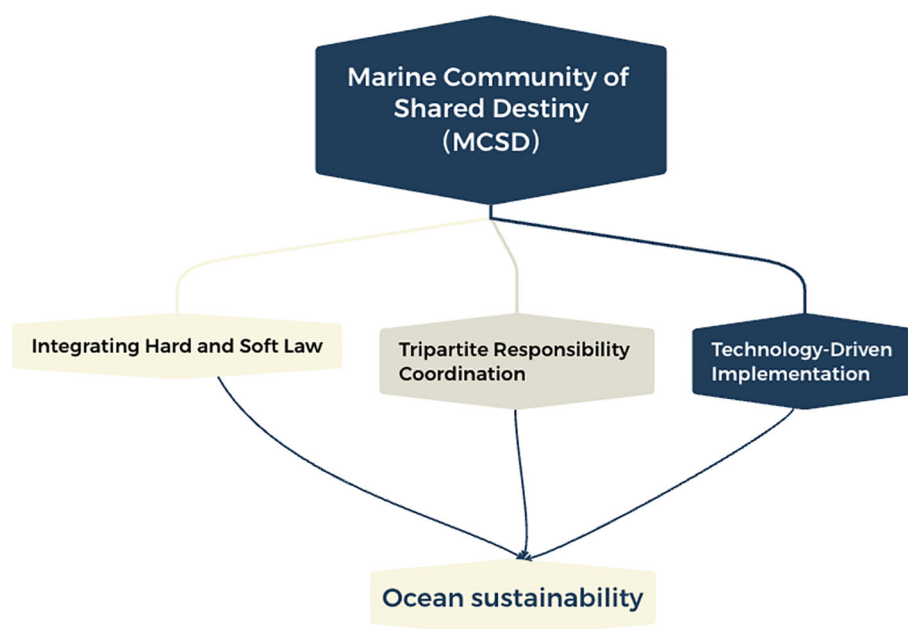


FIGURE 1
An integrated governance framework flowchart.

the IMO database to form a regional-global dual regulatory network. This network is in accordance with Article 110 of the United Nations Convention on the Law of the Sea, an international vessel pollution response team may board and inspect a vessel suspected of discharging toxic substances on the high seas after obtaining authorization from the flag state and providing sufficient evidence.

Hard law enforcement must be based on common interests, while soft law innovation must serve common governance. Industry self-regulation and regional cooperation can play vital roles. For example, incorporating BIMCO's Vessel Lifecycle Ecological Standards into charter party templates would incentivize cargo owners to select CII Class A vessels. Establishing a zero-carbon shipping technology pool with 50% low-carbon patent access for developing countries would also be a crucial step. Regionally, East Asian states could develop a Marine Emission Control Zone Roadmap with phased standards to promote international norm convergence. Simultaneously, an APEC Blue Corridor Fund could subsidize green ammonia-fueled vessels, accelerating technological transitions through economic incentives.

Collectively, hard and soft law instruments establish a comprehensive governance framework for controlling vessel-source pollution.

3.2 Tripartite responsibility linkage: state supervision, regional organization coordination, and corporate accountability

International law scholar observed: A State is accountable to the people it represents and is the trustee of their interests (Henkin,

2005). As primary duty-bearers for marine pollution control, States must implement institutional reforms to enhance oversight mechanisms. To strengthen flag State supervision, a vessel automation classification system aligned with ISO 23791 should be established. This enables intelligent certification alongside blockchain-based lifecycle records, mandating tamper-proof data black boxes that capture real-time fuel consumption and emissions. Flag States bear ultimate responsibility for ensuring data authenticity within this framework.

At the port state level, smart targeted inspections based on global risk data should be deployed. These should include mandatory 24-hour arrival inspections with prepaid detention deposits and mechanisms for port states to claim ecological restoration compensation—creating an integrated enforcement system.

Marine environmental issues affect the common international domain, so international organizations are required to take action to pursue common interests (Jutta, 2003). The IMO continues to play a vital role in promoting pollution control through legal frameworks established in global conferences (e.g., Copenhagen, Cancún, Durban). Regional organizations, as intermediary governance actors, can enhance effectiveness. For example, regional emission control alliances can impose area-specific bans on non-compliant vessels, while joint monitoring networks reduce enforcement costs. Regional technology pools and innovative financing tools (e.g., the EU Blue Bond) can support clean port infrastructure in developing countries, fostering regional communities of shared interest.

Enterprises must also be held accountable. A cargo owner green list system could prioritize low-carbon cargo transportation. Fuel suppliers could be required to pay ecological guarantee deposits that link emergency pollution response with biofuel R&D, thus reinforcing corporate environmental responsibility.

3.3 Technology-driven convention enforcement: blockchain evidence, AI analytics, and transparent maritime data

To improve enforcement, blockchain technology can create tamper-proof traceability systems through distributed ledgers. In the fuel supply chain, IoT-integrated blockchain systems can record real-time data on fueling time, sulfur content, and supplier identity. Smart contracts can automatically freeze deposits and penalize cargo owners upon detecting sulfur violations. Cross-chain interoperability platforms can facilitate data exchange among flag, port, and coastal states. Sometimes, vessels systems from different brands cannot share data well. This can harm navigation safety and efficiency. It may also cause problems during emergencies. Better data sharing between systems is still needed.

AI-driven predictive analytics can enable risk prevention through multi-source data integration. By combining satellite sensing, drone-based SO_x infrared spectroscopy, and AIS trajectory reconstruction, a global dynamic vessel emission map can be created for grid-scale monitoring.

Full transparency across the maritime supply chain is essential. Shipyards should use blockchain to record green design indices and predicted NO_x emissions. Fuel producers must disclose crude oil origins and desulfurization methods. During operations, maritime IoT can track per-mile fuel use and ballast water treatment, enabling cargo owner oversight. At the end of life, shipbreaking yards can document hazardous material handling via blockchain-verified video, linking environmental compliance to financing eligibility. Varying privacy laws across regions create data compliance problems. Unintentional violations could result in significant fines or legal action. International agreements must address these issues.

4 Sustainable safeguards for the marine community of shared destiny governance: pathways and global prospects

4.1 Elevating soft law efficacy: from voluntary guidelines to certification-based mandates

Under the MCSD framework, enhancing soft law effectiveness in vessel-sourced pollution control is a key regulatory evolution—transitioning from voluntary guidelines to certification-based obligations. Instruments such as the IMO Guidelines on Green Shipping Practices lack enforceability due to their reliance on state willingness, resulting in free-rider problems. Regional disparities in implementation and fragmented standards raise compliance costs and worsen regulatory inefficiency.

The MCSD offers the normative foundation for soft law enhancement through shared responsibility, technical equity, and governance legitimacy. A path forward includes consensus-building

through joint declarations (e.g., modeled on the London Declaration on plastic waste) that transform political commitments into quasi-legal obligations. Integrating soft law into certification regimes, with third-party audits by international classification societies in partnership with national authorities, can operationalize green certification. The IMO's Global Fuel Oil Consumption Database provides a real-time verification tool. Judicial reforms should include rebuttable presumptions of negligence for uncertified vessels and empower port states to impose stricter liability regimes.

4.2 Synchronizing technology cycles with convention evolution: ensuring compliance transparency through blockchain

States that lead in maritime technology typically exhibit stronger marine environmental governance and wield greater influence in shaping global frameworks (Quan, 2019). Strengthening vessel pollution governance requires continuous innovation and foundational research, which together act as catalysts for institutional reform.

Under the MCSD framework, technological advancement and international legal evolution must proceed concurrently. Blockchain technology ensures compliance transparency and credibility. First, updated technical provisions—such as the 2024 MARPOL Annex VI amendment mandating three-year retention of bunker delivery notes—exemplify this shift. Second, blockchain enables closed-loop monitoring of fuel sulfur content, emissions, and cross-border enforcement mechanisms. Third, synergistic interaction between technology and convention reform drives systemic upgrades, including shore-to-ship coordination, regional-global standard harmonization, and enhanced judicial enforceability. These developments establish a dynamic regulatory ecosystem spanning the complete bunker-to-exhaust lifecycle. For instance, Mexico's Port of Veracruz applies blockchain to enhance cargo security, while Rotterdam Port partners with Samsung SDS and ABN AMRO Bank to achieve full shipping traceability, improving transparency and operational efficiency.

4.3 Transitioning to multistakeholder ocean governance: from sovereignty competition to shared-benefit paradigms

Collective action under IMO 2020 regulations reduced high-sulfur fuel oil usage by over 80%, as verified by IMO data. The UN 2030 Agenda for Sustainable Development prioritizes ocean sustainability, emphasizing equitable benefit-sharing for all humanity, especially developing nations. This vision of human-ocean harmony drives greater cooperation to unlock marine potential and ensure oceans remain a cornerstone of global sustainability (Wang, 2025).

The MCSD concept accelerates this shift-from sovereignty-based governance to multistakeholder, interest-aligned models. States and other actors must adopt a strategic perspective to reconcile national interests and forge shared benefits. The MCSD

promotes principles of shared risk, mutual gain, and joint action. Common interest now forms both the basis and objective of global marine cooperation.

Ultimately, the MCSD does not merely supplement existing frameworks—it transforms them. By advancing conceptual and institutional evolution, it offers an innovative, forward-looking trajectory for global ocean governance (Chu and Wang, 2024).

5 Conclusion

we should foster a sense of community of shared destiny in the oceans and seas and promote sustainable marine development. The Marine Community of Shared Destiny is not an abstract ideal but a practical roadmap for overcoming the core challenges of vessel-sourced pollution: unilateralism, regulatory lag, and enforcement gaps. Through shared responsibility, it dismantles cooperation barriers; through technology sharing, it eliminates monopolies; and through interest coordination, it redefines maritime ethics.

Deep integration of the MCSD framework into MARPOL reform and implementation—through a governance model based on joint control, shared innovation, and mutual benefit—provides a vital pathway for protecting global ocean commons and achieving sustainable development.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Author contributions

YC: Supervision, Resources, Conceptualization, Investigation, Writing – review & editing, Writing – original draft, Methodology,

Funding acquisition. YW: Project administration, Formal Analysis, Writing – original draft, Validation, Methodology, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

- Bai, J., and Wang, Y. (2023). The application of capacity-building and marine technology transfer standards in the BBNJ agreement: A discussion on China's response under the concept of the community of shared future for mankind, published in the wuhan university. *J. Int. Law* 2023, 33. doi: 10.13871/j.cnki.whuirl.2023.05.00
- Blasiak, R., and Claudet, J. (2024). Governance of the high seas. *Annu. Rev. Of Environ. And Resour.* 49, 549–572. doi: 10.1146/annurev-environ-01023-022521
- Chu, X., and Wang, L. (2024). Marine community of shared destiny: China's contribution to the transformation of the global marine governance system. *J. Dalian Maritime Univ. (Social Sci. Edition)* 2024, 28. Available online at: https://kns.cnki.net/kcms2/article/abstractv=MmR6bzzH81Hfrc_QqGcpP_TiU6mjwXRz3pHFVrKKFBWoVCwwzGeDJ7z_bComS-6zDhmZ-JFgQFh8-2Kb_IMMejV2LiPEeM6V9NIekxzmYMQm-9CeImyzz4LM9SMdCRYIX_gnVhL4ATjavG64TTPtxPbiDtPFY1pA9Y06f3NRthkVXz4WxW0Ew==&uniplatform=NZKPT&language=CHS
- Commission on Sustainable Development (2025). *Oceans-United Nations Sustainable DevelopmentGoal 14: Conserve and sustainably use the oceans, seas and marine resources*. Available online at: <https://www.un.org/sustainabledevelopment/oceans/> (Accessed August 15, 2025).
- Henkin, L. (2005). *International law: politics and values. 2005 edition*. Ed. N. Zhang, Z. Ma, Y. Luo, S. Ye and S. Xu (Beijing: China: University of Political Science and Law Press).
- ICTT (2025). *Global shipping emissions continue to rise: ICCT study reveals global shipping structural changes and emission reduction challenges*. Available online at: <https://mp.weixin.qq.com/s?biz=Mzg4OTI0OTM4Mg==&mid=2247493980&idx=1&sn=15c5d161af76fac95f08a9b799372bf5&chksm=cec0576a45f49e0c31d5aa4d46d97c1c09dd3a4e543b7f5d34fbd59865fb21d659d6fd92604&scene=27> (Accessed August 16, 2025).
- Jin, Y. (2021). *The three core value goals of the 'Marine community of shared destiny* (Shanghai, China: Shangguang News). Available online at: <https://export.shobserver.com/baijiahao/html/369443.html>. (Accessed July 20, 2025)
- Jutta, B. (2003). "Stockholm declaration and the structure and process of international environmental law," in *The stockholm declaration and law of the marine environment*. Ed. M. H. Nordquist (Leiden, Netherlands: Martinus Nijhoff Publishers).
- Mo, J. (2024). Environmental sources, fate, toxicological effects, and health risks of copper pyrrithione: an overview. *Front. Environ. Sci. Engineering*. 18, 132. doi: 10.1007/s11783-024-1892-4
- Quan, Y. (2019). Multi-level governance of the global marine ecological environment: challenges and future directions. *Legal Stud.* 2019, 1002–6274(2019)03-148-13. Available online at: https://kns.cnki.net/kcms2/article/abstract?v=MmR6bzH81EjF7tNd5A3l0GDqrUNyVQA8X1cTfa-VXmJWhK26-03_JoIZfLZAVezeMyB3GP9fqmhdhR5ge1amnuD7kCewF_sHwXTS7H7xDufPmzcage8_mGcho6-6f2rISN

dPttjEB27hd3Zx3aMMXzVUBT107ffvMEZImJO4YAMm-6ZSBUPQ==&uniplatform=NZKPT&language=CHS

Wang, J. (2023). *Adhering to the Concept of a Community of Shared Future for the Ocean to Advance Global Ocean Governance*, published in *Learning Times* on February 15, 2023. Available online at: <http://theory.people.com.cn/GB/n1/2023/0215/c40531-32623974> (Accessed July 3, 2025).

Wang, Y. (2025). *Harmonious Coexistence, Joint Progress: Advancing Global Marine Governance to a Higher Level — Wang Yi's Address at the Opening Ceremony of the*

Fifth 'Marine Cooperation and Governance Forum. Available online at: https://www.mfa.gov.cn/wjzbzhd/202411/t20241126_11533256.shtml (Accessed July 12, 2025).

Xiang, X. (2023). *Deeply understanding the original contributions of the marine community of shared future* (Guangzhou, China: Guangming Online (Theory Channel)). Available online at: <https://baijiahao.baidu.com/s?id=1781781156533154018&wfr=spider&for=pc>.

Zhang, L. (2021). A review of international marine technology transfer rules under the concept of the 'Marine community of shared destiny.