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DISSERTATION

Submitted in partial fulfilment of the requirement for the award of the degree of

MASTER OF LAW (LL.M.) IN INTERNATIONAL TRADE LAW

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ON THE TOPIC

INVASIVE SPECIES: ROLE AND LIABILITY OF MARITIME CARRIERS

Under the Guidance and Supervision of

Dr. LINA ACCA MATHEW
Registrar, NUALS Kochi

Mr. RAVEENDRAKUMAR D
Assistant Professor, NUALS Kochi

Submitted By:
ANANTHAKRISHNAN P

Register Number: LM0224005

LL.M. (International Trade Law)

CERTIFICATE

This is to certify that ANANTHAKRISHNAN P, Register Number LM0224005, has submitted his Dissertation titled "Invasive Species: Role and Liability of Maritime Carriers" in partial fulfilment of the requirement for the award of Degree in Master of Laws in International Trade Law to the National University of Advanced Legal Studies, Kochi under my guidance and supervision. It is also affirmed that the dissertation submitted by her is original, bona fide and genuine.

Date: 28 May 2025

Place: Ernakulam

Dr. LINA ACCA MATHEW
REGISTRAR
Guide and Supervisor
NUALS, Kochi

Mr. RAVEENDRAKUMAR D
ASSISTANT PROFESSOR
Guide and Supervisor
NUALS, Kochi

DECLARATION

I, ANANTHAKRISHNAN P, do hereby declare that this dissertation work titled "Invasive Species: Role and Liability of Maritime Carriers", researched and submitted by me to the National University of Advanced Legal Studies in partial fulfilment of the requirement for the award of Degree of Master of Laws in International Trade Law under the guidance and supervision of Dr. LINA ACCA MATHEW, Registrar, National University of Advanced Legal Studies, and Mr. RAVEENDRAKUMAR D, Assistant Professor, National University of Advanced Legal Studies, is an original, bona fide and legitimate work. It has been pursued for academic interest. This type or any type thereof has not been submitted by me or anyone else for the award of another degree of either this University or any other University.

Date: 28 May 2025

Place: Ernakulam

ANANTHAKRISHNAN P

Register Number: LM0224005

LL.M. (International Trade Law)

NUALS, Kochi

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PREFACE

This dissertation is made in partial fulfilment of the requirement for the award of the Degree of Master of Laws (LL.M.) in International Trade Law to the National University of Advanced Legal Studies (NUALS), Kochi.

This dissertation examines the problem of invasive species and provides clarity on the topic. It then goes on to examine the impact the said organisms have on the environment and the economy. Then, this work identifies the role that maritime carriers play in the spread of the said invasive organisms and tries to analyse the existing legal and regulatory frameworks that cover the topic.

Then, the existing liability frameworks are analysed, taking examples from legal systems all over the world. Finally, the challenges in integrating international trade and the environment are identified and examined, before concluding this work.

I again express my thanks to all those people who have helped me in completing this dissertation on time.

LIST OF ABBREVIATIONS

Abbreviations Used	Full Form
APEC	Asia-Pacific Economic Cooperation
BWM CONVENTION	Ballast Water Management Convention
CBD	Convention on Biological Diversity
CLC	Civil Liability Convention
EPA	Environmental Protection Agency (US)
EU	European Union
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GUPC	Grupo Unidos por el Canal
HNS	Hazardous and Noxious Substances Convention
IMO	International Maritime Organisation
ITLOS	International Tribunal for the Law of the Sea
MARPOL	International Convention for the Prevention of Pollution from Ships
MARS	Maritime Arrivals Reporting System
MEPC	Marine Environment Protection Committee
MRC – WG	Marine Resource Conservation Working Group

Mou	Memorandum of Understanding
NANCPA	Nonindigenous Aquatic Nuisance Prevention and Control Act
NGOs	Non-Governmental Organisations
NISA	National Invasive Species Act
P&I	Protection and Indemnity
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
VIDA	Vessel Incidental Discharge Act
WTO	World Trade Organisation
eDNA	environmental DNA

LIST OF STATUTES

1. Biological Diversity Act of 2002 (India)
2. Biosecurity Act of 1993 (England)
3. Biosecurity Act of 2015 (Australia)
4. Clean Water Act (US)
5. Coastal Regulation Zone Notification (India)
6. Craft Risk Management Standard for Biofouling 2014 (New Zealand)
7. EU Regulation No. 1143/2024
8. Environment (Protection) Act of 1986 (India)
9. Environmental Liability Directive of 2004 (EU)
10. Marine Strategy Framework Directive 2008/56/EC (EU)
11. Merchant Shipping (Ballast Water) Rules 2016 (India)
12. National Green Tribunal Act 2010 (India)
13. National Invasive Species Act (NISA) of 1996 (US)
14. Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) of 1990 (US)
15. Oil Pollution Act of 1990 (US)
16. Regulation (EC) No. 782/2003 (EU)
17. Vessel Incidental Discharge Act (VIDA) 2018 (US)
18. Water Framework Directive 2000/60/EC (EU)

LIST OF INTERNATIONAL INSTRUMENTS

1. Ballast Water Management Convention (2004)
2. CBD's Guiding Principles on Invasive Species (2002)
3. CLC (Civil Liability Convention)
4. Convention on Biological Diversity (1992)
5. Convention on the Conservation of Migratory Species of Wild Animals (1979)
6. European Union's Carbon Border Adjustment Mechanism
7. European Union's Invasive Species Monitoring Directive (2024)
8. General Agreement on Tariffs and Trade (GATT) (1947)
9. Global Invasive Species Information Network
10. Global Invasive Species Programme (2000)
11. HNS Convention
12. Hague-Visby Rules
13. ILC's Draft Principles on Environmental Protection (2022)
14. IMO's Biofouling Guidelines (2011)
15. IMO's Guidelines for Port State Control (2023)
16. International Oil Pollution Compensation Funds
17. International Plant Protection Convention (1951)
18. MARPOL Annex V
19. Nagoya Protocol
20. Rio Declaration (1992)
21. Tokyo MoU
22. United Nations Convention on the Law of the Sea

LIST OF CASES

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3. Caribbean Fishermen's Union v. Evergreen Marine (2024)
4. Charru Mussel Case (2024) – Tamil Nadu, India
5. Environmental Groups v. US Coast Guard (2020)
6. Great Lakes Zebra Mussel Litigation
7. Hapag-Lloyd v. French Maritime Authority (2025)
8. London P&I Club v. MSC Arbitration (2023)
9. MSC Zoe Incident (2024)
10. Northwest Environmental Advocates v. EPA (2023)
11. Pacific Maritime Association v. California Coastal Commission (2023)
12. Panama Canal Authority v. Consortium GUPC (2021)
13. Papaya Mealybug Introduction case (2000) – India
14. Rotterdam Port Authority v. Greenpeace (2024)
15. The Antarctic Krill Case (2024)
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CHAPTER 1: INTRODUCTION TO INVASIVE SPECIES, INTERNATIONAL TRADE AND ROLE OF MARITIME CARRIERS

1.1. Background and History

The sheer volume of international trade has multiplied over recent years. With globalisation, there has been huge changes in economic and political landscapes and maritime carriers have served as both facilitators of commerce and unintentional vectors of biological invasion. As trade booms and markets open up more, the inadvertent transport of non-native/invasive species through the carriers (through ballast water, hull fouling, contaminated cargo, packaging, etc.) have emerged as a critical threat to global biodiversity, economic stability and legal frameworks.

After the cold-war era, there was a huge and unprecedented phase of economic integration on a global level, which was characterised by reduction in tariffs, optimisation of supply chains, and the dominance of shipping using containers via sea. Following the dissolution of the Soviet Union in 1991, the global trade volumes grew at an average annual rate of 6.4% between the years 1992 and 2008.[1] During this time period, maritime transport accounted for approximately 80% of the total volume of merchandise trade.[2] This period also noticed the trend of different components crossing multiple borders before reaching its destination where final assembly was done. This system reduced costs incurred by the manufacturers, but at the same time, has increased ecological exposure.

With the shift in trading environment in recent years, new challenges have arisen. Financial crisis, geopolitical struggles and realignments, have somewhat slowed down the growth of international trade. Companies and traders have reevaluated various supply chains and such disruptions have intensified maritime activities through nearshoring and re-routing. New shipping lanes are being considered and used as well. For example, the Northern Sea Route has seen a 58% increase in cargo volume between the years 2021 and 2023, which has exposed ecosystems that were previously isolated,

[1] David J. Bederman, *Globalization and International Law*, 50 Emory L.J. 717, 719–20 (2001).
[2] U.N. Conf. on Trade and Dev., *Review of Maritime Transport 2024*, U.N. Doc. UNCTAD/RMT/2024 (2024).

to the risk of invasive species.[3] All of this highlights the complex relationship between trade strategies and unintended environmental consequences. Understanding this concept is crucial to understand legal frameworks with regard to carrier liability.

Also, it needs to be pointed out that maritime carriers' contributions extend beyond direct transfer of species. The industry contributes to global carbon dioxide, as well as sulphur oxide pollution.[4] The predominant use of heavy fuel oil in more than 80% of these vessels accelerates coastal acidification, which creates an environmental condition that could favour an invasive species over native biodiversity.[5] This has also highlighted the need for integrated policies that address both issues in a satisfactory manner.

1.2. Definition and Scope

Invasive Species is defined as "non-native organisms whose introduction causes or is likely to cause economic harm, environmental harm, or harm to human health"[6]. This definition is unique in the sense that it differentiates invasive species from non-native species. This is because non-native species has the potential to coexist harmlessly with native species in a given ecosystem. For the purposes of this research, the term invasive species would include both flora and fauna introduced through various practices by maritime carriers.

There is also a time-related issue with regard to the problem of invasive species. There is typically more than a 10-year lag between the introduction of a species and its detectable ecological impact.[7] This latency period often exceeds political and corporate planning horizons and by the time they're detected, expensive measures will be the only ones left and that too, only to a limited effect. This has emphasised on the need for preventive, rather than reactive legal frameworks. Case studies also help in this regard so as to find out possible measures that could be taken in the future to counter the problem.

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[3] Arctic Council, Arctic Marine Shipping Assessment Rep., *Shipping Traffic in Arctic Waters: Trends and Impacts* (May 2023).
[4] Daniel Simberloff et al., *Invasive Species: Impacts on Ecosystems and Economies*, 23 BioScience 12 (2019).
[5] Port of Rotterdam Authority, *Environmental Impact Report: Maasvlakte II Expansion*, Rotterdam Port Auth., June 2023.
[6] National Invasive Species Council, *Management Plan 2022–2026*, U.S. Dep't of the Interior (2022).
[7] Michael J. Bowman et al., *International Law and the Conservation of Biodiversity*, 31 Int'l Env't L.J. 123 (2018).

1.3. Maritime Carriers and Ports

Maritime Carriers refers to container ships, bulk carriers and oil tankers, to name a few, and each of them presents distinct risks based on their operational profile and regions with regard to the problem of invasive species. Container vessels, which are responsible for up to 52% of the total value of global trade by sea, pose a greater threat when compared to the others due to the different types of cargo it transports and its rapid port turnaround times.[8] Similarly, oil tankers pose a different kind of threat, as they tend to exhibit a higher volume of ballast water discharge (up to 30% of dead weight in tonnes) in which species of invasive character might be present. Studies have shown a positive correlation between crude oil trade routes and boom in invasive species of organisms.

It is also to be considered that technological advancements and change in shipping practices, adopted with the intent to improve shipping efficiency, has also facilitated the problem of invasive species inadvertently. For example, the speed of the ships have been reduced from 24 knots to 18 knots to save fuel in recent years. However, this has led to an improvement in the survival rate of different organisms in ballast tanks and on the ships' hull by almost 40%,[9] which increases the likelihood of such organisms reaching the destination port. The slower speeds of the vessels also mean that the organisms are given more time to complete reproduction cycles during transits.

Similarly, the shift towards larger ships instead of a fleet of smaller ones complicates their maintenance, making it difficult to clean the hulls off various organisms that have attached itself during the voyages. This can lead to "hull fouling" and would result in the transportation of invasive organisms back and forth on various journeys. All such problems reflect the tension between two contrasting objectives – economic optimisation and environmental stewardship, and currently, there has been notable failure to address both issues simultaneously in a satisfactory manner. However, it should be noted that there have been efforts in this regard to bring more attention to the subject.

Infrastructure development and construction activities in ports have also contributed to the problem of invasive species. Deep-water terminals are often constructed to

[8] Brian Leung et al., *Rising Global Shipping Traffic Could Lead to Surge in Invasive Species*, Nature Sustainability (2019).
[9] *Supra* note 8.

accommodate large vessels and that involves extensive dredging operations. This activity has the potential to expose dormant organisms that can have an impact on the existing ecosystem. For example, the Port of Rotterdam's Maasvlakte II expansion had caused 300% increase in Quagga Mussel across Western European waterways due to the distribution of sediments from the construction.[10]

Similarly, the expansion works that are being conducted in the Panama Canal's Neopanamax locks have resulted in brackish water, which has created an ideal condition for the growth of Asian Clam. Within a few months, 14 new invasive species were detected in Gatun Lake due to the operation.[11]

1.4. Significance in the Current World

The problems caused by invasive species in the global ecosystem is not insignificant. Existing international frameworks like the Ballast Water Management Convention (2017) and the CBD's (Convention on Biological Diversity) Guiding Principles on Invasive Species (2002) suffer from crippling gaps – problems with regard to enforcement mechanisms, limited liability for parties involved, and has become technologically obsolete with time. Other legal principles like the one of "Innocent Passage" under Article 19 of the United Nations Convention on the Law of the Sea, further complicates jurisdiction, as the vessels passing through peacefully cannot be delayed for environmental inspections without evidence of any "wilful and serious pollution"[12].

Furthermore, according to current carrier-liability models, the effect of invasive species remains unquantified to a huge extent. Traditional law usually focuses on direct damage from collisions or spills and ignore others that are diffused, delayed and/or multi-sectorial (like that of invasive species). There is also another problem, that even in cases where penalties are imposed for environmental damage, such penalties often cover only a small part of the cost of the damages caused by the carrier. This gap in liabilities have the tendency to de-incentivise proactive investments in advanced technology to address the issue, which can lead to a classic "tragedy of commons" scenario, where individual rational choices can lead to collective ecological harm in the long run.

[10] *Supra* note 5.
[11] *Supra* note 6.
[12] *Supra* note 7.

There has been improvement and innovation in the field and new technologies have emerged that can have a role in determining the scope for liability in this regard. However, the lack of provisions to use the same in international agreements, conventions and regulatory frameworks is a serious drawback that needs to be corrected as soon as possible. The legal landscape that governs carrier liability, thus, remains fragmented across various jurisdictions.

It is also to be noted that there is another limitation in fixing liability. The ownership of vessels changes every 7.3 years on average globally[13], while it takes more than 10 years for the effects of invasive species to be visible in an ecosystem. This means that by the time the damages are quantified and the scope is understood, the targeted entity no longer holds ownership of the asset, which results in enforcement problems. Solutions need to be found to address such issues.

1.5. Objectives

The objectives of this study are the following:

- To understand the problem of invasive species in the context of international trade.
- To analyse the role of maritime carriers in the spread of invasive species.
- To examine existing international conventions and laws governing the subject.
- To determine the scope for liability of maritime carriers.
- To formulate recommendations to address the identified issues.

1.6. Statement of the Problem

International trade via maritime transport has significantly contributed to the spread of invasive species. Yet, the existing legal frameworks remain insufficient to address this issue. The ambiguity surrounding carrier liability complicates the process of assigning responsibility for damage caused by invasive species. Moreover, debates persist over whether invasive species, often considered an incidental cost of growth, merit the level of regulatory attention they require. This research addresses these issues by exploring

[13] S&P Global Market Intelligence, *Vessel Ownership, Trade Finance and Regulatory Compliance* (2023).

how liability might be fixed objectively, including whether existing contractual clauses adequately cover the problem or not.

1.7. Research Questions

- Should the concept of invasive species be redefined for legal and environmental clarity?
- Is it justifiable to hold maritime carriers liable for the spread of invasive species?
- To what extent does the existing legislations and/or conventions address this topic?
- Is there room for third-party claims regarding the impact of invasive species?
- What measures can be effectively adopted to mitigate this issue?

1.8. Research Hypothesis

Stringent international regulations or conventions that clearly fix liability for damage caused by invasive species on maritime carriers can effectively address the problem of ecological damage caused by invasive species and act as a deterrent to parties involved in international trade.

1.9. Research Methodology

This research employs a purely doctrinal research methodology, drawing upon sources such as online articles, international agreements, treaties, international reports, journals, publications, newspapers and books on the topic.

1.10. Method of Citation

All of the legal references and citations in this document are formatted according to the Bluebook System of Citation (21st Edition).

1.11. Scope and Relevance of the Study

The Study aims to define and explore the relationship between international trade, invasive species, and the role and liability of maritime carriers in the matter. While extensive research has been carried out on many challenges associated with international trade, this topic has largely been neglected and its significance has often remained unexamined and often considered as the “cost of development”.

Another objective is to assess the existing laws and regulations (domestic and international) regarding the liability of maritime carriers, considering the fact that there are inherent limitations and existing operational practises in carriage of goods by sea. The extent of liability of all the parties concerned is sought to be evaluated.

This study also undertakes to review existing conventions, treaties and/or legislations regarding the subject matter and will seek to assess their relevance in the current trade environment and ecological needs.

Finally, this work also seeks to offer objective recommendations to address the issues and identify a middle ground for balancing economic growth and development with the protection of biodiversity and the environment.

1.12. Limitations of the Research

While conducting the study on invasive species and the role and liability of maritime carriers in that regard, various limitations were encountered. Firstly, since this work is purely doctrinal in nature, it might overlook practical challenges and scenarios of the working environment in international trade and operation of carriers by sea. This problem might be aggravated by the focus of this study on international conventions, legislations, treaties and domestic laws. Also, the fact that only maritime carriers is considered, is a limitation as other means of transportation contribute to the same in varying degrees. Establishing a direct link between a specific maritime carrier and a specific invasive species is difficult and complex.

1.13. Literature Review

This study utilised the following articles/books for the research:

- David M Lodge, et al., *Risk Analysis and Bioeconomics of Invasive Species to Inform Policy and Management*, Annual Review of Environment and Resources (2016)

This work delves into the economic and ecological risks that are posed by invasive species. It emphasises on their introduction through maritime trade and argues that preventing the spread of invasive species at the transportation stage itself is more cost-effective rather than managing them after they've been introduced. The author(s) propose developing integrated risk analysis models with bioeconomic frameworks so

as to create policies aimed at reducing the spread of invasive species through maritime carriers.

- Hanno Seebens, et al., *No Saturation in the Accumulation of Alien Species Worldwide*, Nature Communications (2017)

This research paper provides a quantitative analysis of a global increase in the frequency of introduction of alien species, and links it directly to the expanding maritime trade networks. The author highlights how shipping activities across the world facilitate biological invasions at an ever-accelerating rate and highlights the need for a stricter regulatory measure(s) targeted at "high-risk" trade routes to address the problem on a global level.

- David Pimentel, et al., *Update on the Environmental and Economic Costs Associated with Alien-Invasive Species in the United States*, Ecological Economics (2005)

In this article, the author estimates roughly that the economic damages caused by the introduction of invasive species in the US ecosystem amounted to at least 120 billion dollars annually. The author discusses how international trade, particularly through maritime carriers, increases such costs by introducing harmful species like Zebra Mussels, Asian Carp, etc. The study advocates for a stronger enforcement with regard to ballast water management practises of ships and cargo vessels to mitigate the impact of invasive organisms.

- Ian C Davidson, et al., *A History of Ship Specialisation and Consequences for Marine Invasions, Management and Policy*, Journal of Applied Ecology (2018)

This article is unique in the sense that it examines the concept of biofouling as a significant path for marine invasions, which is often overlooked compared to ballast water discharge. The author documents how invasive species attach themselves to the hull of the ship, creating a persistent risk for ecosystems worldwide as they may detach at any given moment during the ship's journey. The author calls for comprehensive regulations which address all the vectors of marine invasions in shipping operations in a satisfactory manner that can protect the environment.

- Sarah A Bailey, et al., *Evaluating Efficacy of an Environmental Policy to Prevent Biological Invasions, Environmental Science and Technology* (2011)

In this article, the author evaluates the ballast water management policies implemented in the Laurentian Great Lakes region. On evaluation, the author finds the policies moderately effective, but at the same time, insufficient under operating conditions. The author recommends combining ballast water exchange with advanced water treatment technologies so as to provide the ecosystem with enhanced protection against biological invasions through maritime carriers.

- Sylvaine Giakoumi, et al., *Assessing the Effects of Marine Protected Areas on Biological Invasions: A Global Review*, Frontiers in Marine Science (2017)

In this article, the author looks into the concept of "Marine Protected Areas" and their role in mitigating biological invasions. It is a crucial topic with regard to biodiversity conservation and limiting the damage caused by invasive species and for gaining better understanding, the author conducted a global review of peer-reviewed literature to analyse the data on invasive species within the protected areas. She found that the protection measures had mixed effects – while almost half of the species that were studied showed reduced density and biomass due to the protection, almost 33% of the remaining were positively affected, meaning that the measures adopted in protected areas may inadvertently favour certain invasive species under some specific conditions. The study also highlighted the scarcity of relevant data on the topic – information was available only for approximately 11% of marine biogeographic provinces which were primarily situated in the Caribbean and the Mediterranean Seas. The author stressed on the need for more research on the topic to mitigate the impact of invasive species on ecosystems globally.

- Global Invasive Species Programme, *Global Strategy on Invasive Alien Species*, Cape Town Workshop (2000)

In this document, which was developed under the Global Invasive Species Programme, outlines 10 strategic actions for addressing the problem of invasive species on a global level. It emphasises on the role of international trade in this regard, particularly that of marine carriers, in accelerating the introduction of such species. The document advocates for an improved legal and institutional framework on a global level to manage the problem, including introduction of tools for risk assessment, development of a code of conduct, and educational campaigns. The document also highlighted the existing gaps in international agreements and pointed out that dynamic management of

ecosystems is the path forward, rather than trying to maintain static conditions. The document tried to point out the need for strengthening global cooperation and promoting investment for the cause.

- Mark S Minton, et al., *Reducing Propagule Supply and Costal Invasions via Ships: Effects of Emerging Strategies*, Frontiers in Ecology and the Environment (2005)

This article, though high on numbers, basically assess the emerging strategies for reducing the introduction of invasive species through ballast water treatment systems. While such treatment systems have shown promise under controlled conditions, their real world performance often falls below what is expected due to technical limitations of the industry. The author finally advocates for combining the same with other methods to address the problem.

- Anthony Ricciardi, et al., *Invasion Science: A Horizon Scan of Emerging Challenges and Opportunities*, Trends in Ecology and Evolution (2017)

The author, in this article, identifies the emerging challenges in managing the problem of invasive species caused by international shipping. He emphasises on the irreversible nature of such invasions and propose to adopt precautionary approaches to combat the same. The article advocates for changes in regulatory frameworks so as to address the uncertainties surrounding the topic.

- Clare Shine., Nattley Williams., & Lothar Gundling., *A Guide to Designing Legal and Institutional Frameworks on Alien Invasive Species* (2000)

This book provides a comprehensive framework for developing various legal instruments to address the problem of invasive species and its management on a domestic and international level. The book highlights the challenges in assigning liability to maritime carriers due to various problems like evidentiary gaps and jurisdictional complexities. It also offers practical recommendations too, that can help in overcoming the said barriers.

- Brian Leung, et al., *Rising Global Shipping Traffic Could Lead to Surge in Invasive Species*, Nature Sustainability (2019)

In this article, the author highlights the significant role played by maritime carriers and international trade in increasing biological invasions. The article argues that growth in the shipping industry will be a greater cause than climate change in the spread of invasive species over the next few decades. The author identifies ballast water discharge and hull biofouling as the primary pathways for the introduction of a species and underscores its economic and ecological consequences at the same time. The author argues for stringent measures, policies and technological advancements to mitigate the ever-growing increase of damage by invasive species associated with the growing shipping network worldwide.

1.14. Chapterisation

- Chapter 1 – Introduction to Invasive Species and Maritime Carriers

It deals with the introduction to this research, including the objectives and methodology used in the study. It lists the research problem and questions, while pointing out why the problem of invasive species and the role of maritime carriers in it is an important and relevant issue that needs to be addressed as soon as possible.

- Chapter 2 – Environmental and Economic Impact of Invasive Species

This chapter tries to examine the impact of invasive species on biodiversity and ecosystems. It also looks into the economic impact of the same, especially with regard to agriculture and local economies. In this chapter, the indirect effects of invasive species on communities and persons not involved are also looked into.

- Chapter 3 – Analysis of Legal and Regulatory Framework

This chapter reviews and critically analyse existing international agreements and laws regarding invasive species and the role and liability of maritime carriers. It also examines domestic legal frameworks and their approach. This can help in identifying the inadequacies and shortcomings in the frameworks and address the areas that lack regulatory oversight.

- Chapter 4 – Liability of Maritime Carriers

This chapter seeks to present an overview of maritime laws with regard to invasive species and the damage caused by it, including carriage contracts and established liabilities. It aims to determine the extent and scope of liability of carriers and points

out the relevant precedents. It also seeks to explore compensation mechanisms and the difficulties in ascertaining liability when third parties not involved are affected.

- Chapter 5 – Challenges of Integrating Environment and Trade

This chapter evaluates the challenges (both practical and legal) encountered while trying to integrate environmental concerns into trade policies. It explores how modern research and data analysis tools can contribute towards improved policy making and regulatory frameworks. Also, it aims to address the coordination required (or lack thereof) between international organisations, governments, and the private sector in this regard to overcome institutional and jurisdictional barriers. It also touches upon the existing trends in policy development regarding the topic.

- Chapter 6 – Recommendations, Implications and Conclusion

This chapter tries to put forward practical suggestions and recommendations for improving international regulations and establishing clear liability frameworks regarding the damage caused by maritime carriers due to transportation of invasive species. It aims to review how current research and digital tools and technologies can be utilised for the same and identifies the gaps for further research on the topic. The chapter also summarises the findings of this study, and the final reflections on the relationship between international trade, invasive species and maritime carriers is also stated.

CHAPTER 2: ENVIRONMENTAL AND ECONOMIC IMPACT OF INVASIVE SPECIES

The growing problem of invasive species presents a unique challenge in itself. It has far-reaching implications for ecological protection, economic stability and social welfare. This chapter examines the noticeable impact of invasive organisms on the environment and the economy facilitated by maritime trade, with particular emphasis on how such organisms reshape various ecosystems, burden the economic mechanisms unnecessarily and affect the communities beyond those directly involved in the international trade and transportation of goods. Therefore, understanding the scope and magnitude of these impacts is necessary to develop appropriate legal and regulatory frameworks in this regard, which is the aim of this study.

2.1. Conceptual Framework for Assessing Impact of Invasive Species

The impact of various organisms that can be categorised as invasive species manifest across multiple dimensions. It has thus, necessitated a structured approach to its assessment.

2.1.1. Defining Affected Categories

Invasive species have had a huge impact across various categories. Ecological impacts encompass direct effects of the same on biodiversity, the functioning of the ecosystem, and the structure of the habitats of native organisms. Economic impacts include both direct costs incurred for the control and eradication of such invasive species, and indirect costs incurred due to loss of productivity, investments and damage to infrastructure. Social impacts extend to human health, effect on cultural resources, and the general well-being of the community. It should be noted that these impact categories are not isolated. They form an interconnected web of consequences that has the potential to amply across various other categories as well.

An assessment of the impact of invasive species requires the careful consideration of both special and temporal dimensions. Spatially, which refers to ‘place’, the impact of such organisms may be localised to specific habitats or small zones, or be spread across entire ecosystems and landscapes. Temporally, which refers to ‘time’, the impacts may

be apparent immediately following the introduction of a particular species, or may remain dormant for many years or even decades, before becoming apparent. This temporal disconnect between the period of introduction and when impact becomes visible is particularly challenging for legal frameworks that seek to address the liability of carriers, as mentioned in Chapter 1.

2.1.2. Challenges and Methodology in Quantification

Quantifying the impacts of invasive species, thus represents a significant challenge both scientifically and economically. Traditional economic methodologies have often struggled to calculate the full value of ecosystem services disrupted by the introduction of such organisms. Current approaches includes market-based valuations that assess direct economic losses, replacement methods and calculation of costs to restore damaged ecosystems, and contingent valuation techniques that tries to determine the willingness of the public to pay for prevention or mitigation.[14]

However, each methodology presents its own limitations. Market based approaches often undervalue ecological services which does not have any direct applications in the market. Replacement cost approaches may be considered impractical due to the fact that sometimes, irreversible changes may be caused by the organisms to a given ecosystem. Contingent valuation may be influenced by the limitation of creating public awareness regarding such a complex ecological process. Thus, these challenges in different methodologies have contributed to the historical under-estimation of the impact of invasive species and that in turn, has undermined regulatory development.

2.2. Ecological Impacts of Invasive Species

The ecological impact of invasive species is explained below.

2.2.1. Biodiversity Loss and Disruption in Ecosystems

Invasive species represents one of the most significant contributors of loss in biodiversity on a global scale, second only to habitat destruction. The means through which invasive organisms contribute to biodiversity loss are numerous and they often operates simultaneously. Direct destruction of native organisms by invasive ones

[14] Richard P. Keller et al., *Quantifying the Economic Costs of Invasive Species: A Review of Approaches and Challenges*, 15 Ecological Economics 1721, 1725-27 (2009).

(through predatory means) can rapidly decrease their population. For example, the brown tree snake (*Boiga irregularis*) in Guam has rapidly eliminated 10 of the native forest bird species that used to live there, since its introduction through maritime transport in the 1940s.[15] Another primary phenomenon which results in the loss of native biodiversity is the competition for resources. Invasive species often display characteristics that provide them with competitive advantages over native species. It includes characteristics such as rapid reproduction, phenotypic plasticity (the ability of an organism to display different characteristics in response to environmental changes despite the genetic makeup remaining static), and broad environmental tolerance level. Couple that with the fact that native species are usually adapted to specific ecological niches, and the invasive ones have a huge advantage over them.

Another phenomenon – hybridisation – between the invasive and native species presents a more subtle but equally concerning threat to biodiversity. This genetic interaction between the two can lead to the extinction of native genotypes (genetic makeup of an organism) through genetic swamping. Genetic swamping refers to the process where the gene pool of a native population is overwhelmed by the genes of an invasive species through various means like hybridisation. This can effectively erase unique evolutionary lineages within a short span of time. This process has been clearly documented in the case of an invasive species of Cordgrass (*Spartina alterniflora*). This species hybridised with the native cordgrass species in coastal regions globally and this resulted in the creation of aggressive hybrid forms of cordgrass that outgrow and destroy the native ones at an alarming rate and fundamentally alter coastal habitats, resulting in changes to the ecosystem.[16]

Beyond the impacts on a species-level, invasive organisms has the potential to reconfigure food chains and entire food webs. The Zebra mussel (*Dreissena polymorpha*), which is transported all around the world in the ballast water of ships, alters the nutrient cycling in freshwater systems. This is because this particular mussel filters phytoplankton at rates of up to 100000 times higher than native species, which redirects energy flow from pelagic food webs (it refers to the food chains observed in

[15] Thomas H. Fritts & Gordon H. Rodda, *The Role of Introduced Species in the Degradation of Island Ecosystems: A Case History of Guam*, 25 Annual Review of Ecology and Systematics 113, 115-19 (1994).
[16] Lisa A. Levin et al., *The Function of Marine Critical Transition Zones and the Importance of Sediment Biodiversity*, 7 Ecosystems 430, 437-38 (2004).

water bodies like open oceans and rivers) to benthic food webs (it refers to the food chains observed near to sea-floor or lake-bottom). This results in a decrease in the availability of food for native filter feeders (aquatic animals that acquire nutrients by feeding on organic matter suspended in water). Such cascading effects can demonstrate how a single invasive species has the power to restructure entire ecological relationships across multiple levels, sometimes causing irreparable damage.

2.2.2. Habitat Modification and Alteration of the Ecosystem

Invasive species frequently act like ecosystem engineers, fundamentally altering the structure and functioning of different habitats. Such changes or modifications can transform environments at scales that range from small habitats to entire regions. Invasive species of plants in particular, have demonstrated remarkable capabilities in transforming habitats that suit their needs. The earlier mentioned example of Cordgrass is an example in this regard. It has converted open mudflats into dense vegetative stands and has, thus, eliminated important habitats for migrating birds. It has also altered sediment accretion patterns (it refers to how sediments deposit and builds up in different environments, leading to the formation of deltas, marshes, and beaches) in various environments all around the world.

Invasive species that alter biogeochemical cycles and ecosystem processes are also significant. The Asian clam, as mentioned earlier, which was transported through ballast water and introduced when that water was discharged, is now growing in established waterways across six continents. It has the effect of altering carbon and nitrogen cycling in freshwater systems and by filtering suspended organic matter at a higher rate than that of native ones, these clams have changed both the availability of nutrients and the clarity of water.[17] Such changes represent a fundamental shift in the functioning of the ecosystems and it can persist indefinitely while resisting restoration efforts.

Modifications and changes in the frequency of fire cycles is also a problem caused by invasive species across the globe. It can have profound impact on various ecosystems. Cheatgrass (*Bromus tectorum*) has such an effect. It was inadvertently transported across the world through contaminated agricultural products and has, with time,

[17] David L. Strayer, *Twenty Years of Zebra Mussels: Lessons from the Mollusk That Made Headlines*, 7 Frontiers in Ecology and the Environment 135, 137-39 (2009).

transformed fire cycles in western North America. The fire cycles in the region have changed, with fires every 3-5 years instead of 60-100 years previously observed. This dramatic shift has eliminated fire-intolerant native species and has created a self-reinforcing cycle of invasion and increased fire frequency, which has had the effect of creating a brand new ecosystem.[18]

2.2.3. Contribution of Maritime Transport

In the case of invasive species, maritime transportation facilitates their introduction through multiple pathways. Each of such paths present a distinct ecological risk may be unique in themselves. Ballast water perhaps represents the most significant vector in this regard, with ships transferring approximately 3 to 5 billion tons of water collectively on an annual basis between ports worldwide.[19] A single ballast tank of a ship has the potential to contain thousands of species across various taxonomic groups. They may range from microscopic bacteria and viruses to different types of fishes and invertebrates which are capable of establishing invasive populations at the destination of their discharge.

Another major vector is hull fouling of ships. Organisms may attach themselves to the surfaces of ships and as a result, be transported between various biogeographic regions. Modern technology that can address the problem of hull fouling has reduced the problem, but not eliminated it altogether. The problem has worsened in recent decades due to the fact that as mentioned before, the travelling speeds of the vessels have been decreased and these organisms have a better survival rate at lower speeds. Port environments also represent themselves as a hotspot for invasive species with modified habitats, elevated disturbances, and continuous introduction of different species all contributing towards creating an ideal environment for invasive organisms to thrive in.

Certain ecosystems have shown to demonstrate particular vulnerability to maritime carrier-facilitated invasions. Estuarine environments (transitional ecosystems where the freshwater from rivers mixes with the saline water from the oceans) which naturally feature salinity gradients, temperature fluctuations, and high nutrient availability, have

[18] Jennifer K. Balch et al., *Introduced Annual Grass Increases Regional Fire Activity Across the Arid Western USA*, 19 Global Change Biology 173, 175-77 (2013).
[19] James T. Carlton & Jonathan B. Geller, *Ecological Roulette: The Global Transport of Nonindigenous Marine Organisms*, 261 Science 78, 80-81 (1993).

proven themselves to be extremely susceptible to the effects of such organisms. The San Francisco Bay estuary, for example, now hosts more than 234 non-native species of organisms. Furthermore, a new invasion is document approximately every 14 weeks during peak periods of maritime trade and activities. Similarly, island ecosystems, which are characterised by high endemism (the phenomenon wherein a particular species is found only in a particular geographic region and nowhere else around the world) and evolutionary isolation, also exhibits serious vulnerabilities. The Hawaiian group of islands have experienced native species' extinction rates that are almost 80 times higher than the global average and what is being measured in continental areas, which can be easily attribute to invasive species that are being introduced through maritime commerce.[20]

2.3. Economic Impacts of Invasive Species

The economic impact of invasive species is explained below.

2.3.1. Global Losses and Quantification Approaches

The economic impact and burden imposed by the problem of invasive species represents an externality of international maritime trade that is still, largely unaccounted for. Establishing a comprehensive estimate on a global level remains challenging in multiple ways to this day. Still, conservative assessments indicate at an annual cost that exceeds $1.4 trillion worldwide, which translates to approximately 5% of global GDP (Gross Domestic Product).[21] These figures will and continue to grow as both the rate of spread of invasive species and the economic valuation methodologies advance with time. The economic impact of invasive species usually manifests across multiple sectors and geographic scales, and span across various timeframes which further complicates precise quantification of the damage.

The current methodologies for assessing the impact of invasive species on an economic level typically incorporates direct management costs (costs incurred for the prevention, control and eradication of such organisms), commercial losses (losses resulting from reduced yields and a decrease in product quality), damages caused to infrastructure, and

[20] David Pimentel et al., *Economic and Environmental Threats of Alien Plant, Animal, and Microbe Invasions*, 84 Agriculture, Ecosystems & Environment 1, 5-7 (2001).
[21] Frans E. Bontje & Mark van Koningsveld, *Quantifying Environmental Impacts of Shipping: Methodologies and Applications*, 31 Maritime Policy & Management 329, 334-36 (2022).

human health costs. However, such an approach has a limitation. It has the tendency to underestimate the total economic impact of such organisms by failing to account for non-market ecosystem services, future impact under various scenarios, and the impact on non-commercial native species, in an adequate manner.

Also, the distribution of economic impacts remains highly uneven. Developing nations often have to bear the disproportionate costs of the impact of invasive species. Such countries often exhibit an increased economic vulnerability to invasive species. This is because of their greater dependence on natural resources, limited capacity to adapt to changes, and comparatively weaker regulatory frameworks. The primary sectors, which form the backbone of many developing nations, like the agricultural sector and forest sector, are particularly susceptible to the effects of invasive species.

2.3.2. Vulnerability of Developing Nations

Limited financial resources and lower technical expertise of developing nations can also hinder their ability to effectively prevent, detect and manage invasive species and their impacts. The aforementioned weak regulatory frameworks and the drawbacks of the enforcement mechanisms aggravate the problems and allows the invasive organisms to spread unchecked. In many instances, there has been a lack of comprehensive risk assessment prior to the intentional introduction of various species for economic gains and inadequate biosecurity measures at ports and borders have contributed to the increasing risk of losses due to invasive species. This raises an important question regarding environmental justice and international responsibility that will be discussed later in Chapter 5. Maritime carriers, in this context, occupy a peculiar position within this landscape, as they are considered as the primary vectors for transport of invasive species across the globe.

2.3.3. Impact on Agricultural Sector

The agricultural sector is another one of the sectors which are affected by invasive species severely. Annual losses caused by invasive species are expected to be around $290 billion on a global level. Such a huge effect is manifested through multiple pathways which includes direct predation of native insects and animals by invasive species, competition from invasive weeds, reduction in yield due to the effect of invasive pathogens, and an overall increase in production costs associated with

management efforts that stem from this problem. Invasive insects are also a problem as they alone are considered to cause 20 – 40% global losses annually. It particularly impacts staple crops which, in turn, impacts food security.[22]

2.3.4. Infrastructure Damage and Maintenance Costs

Moving on, invasive species impose significant costs on infrastructure, particularly in aquatic environments. Some invasive species colonise quickly on water intake pipes, dams, and irrigation systems and this results in a reduction in operational efficiency and increased expenses for maintenance. For example, the accumulation of Zebra mussels (*Dreissena polymorpha*) alone has caused billions of dollars in damage across North America ever since it was introduced in the 1980s.[23] This is because this particular mussel accumulates in industrial facilities quickly, which leads to blockages and corrosion, and therefore, require frequent cleaning and/or replacement which is quite expensive.

In a similar manner, invasive plants like giant reed (*Arundo donax*) can clog waterways and irrigation equipment, which reduces water flow and increases the maintenance costs for such equipment and water supply. Ports and harbours across the world also face similar challenges that not only increases the cost of upkeep, but also reduces the lifespan of the infrastructure components.

2.3.5. Impact on Tourism and Recreation Industry

The degradation of natural ecosystems by the introduction of invasive species has a substantial economic impact on tourism and recreation industries. Invasive aquatic plants such as the Eurasian watermilfoil (*Myriophyllum spicatum*) can form dense mats across water bodies. This can impede boating, swimming and fishing activities, which in turn directly affects tourism, as people might find the affected places unappealing as tourist destinations, and be reluctant to visit such places. This leads to a decline in revenue for local businesses which are reliant on tourists for their income.

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[22] Marcel Rejmanek & David M. Richardson, *What Attributes Make Some Plant Species More Invasive?*, 77 Ecology 1655, 1660-61 (1996).
[23] David L. Strayer et al., *Twenty Years of Zebra Mussels: Lessons from the Mollusk That Made Headlines*, 7 Frontiers in Ecology and the Environment 135, 137-39 (2009).

A popular example in this regard is the effect invasive species have had on coral reefs. In coral reef ecosystems, organisms like the lionfish (*Pterois volitans*) can cause biodiversity loss and this directly diminishes the aesthetic value of these reefs. This makes it less attractive to divers and other tourists and have an economic impact on the local economy. Coastal communities across the world often depend upon ecotourism and such problems affect them as it results in economic losses as the number of visitors decline. Moreover, invasive insects such as mosquitoes cause an altogether different set of problems as it can deter outdoor activities in the affected areas, which further impact tourism revenue in a negative manner.

2.3.6. Impact on the Fishing Industry

The fishing industry is another victim of invasive species, particularly due to the ability of the organisms to affect aquatic food webs and kill native species. Invasive predators can decimate large populations of native species in a relatively quick time and such native organisms might have been crucial for local commercial fisheries. Invasive species also affects the quantity and quality of food available to such aquatic organisms and this can lead to a severe decline in their population. Economic losses extend beyond the loss in revenue in such situations. There is the problem of increase in costs for monitoring, management, and restoration efforts and couple that with a decline in revenue and volume of the fish caught, a huge economic problem arises that affects thousands of people, but cannot be solved very easily. Invasive species may also affect aquatic operations by increasing the risk of contracting diseases, which can cause further economic loss in the form of treatment expenses and loss of income during that time.

2.3.7. Indirect Economic Costs

In addition to all the above-mentioned direct economic costs, there is another matter to be considered. Invasive species, across the whole world, impose numerous indirect costs that are usually difficult to quantify. But they are highly significant as it includes decline in the value of properties over time and degradation of the natural environment. The increased healthcare costs, as mentioned above, that are associated with invasive vectors and a dying biodiversity can result in irreparable damage in the long run. The loss of biodiversity can also result in a decreased resilience to changing climatic

conditions, making the local ecosystem very vulnerable to extreme weather events. This can cause further damage and can lead to more losses in the long run.

2.4. Social Impacts of Invasive Species

The social impacts of invasive species is explained below.

2.4.1. Human Health Risks

Invasive alien species can pose a direct and indirect threat to human health. The introduction of new pathogens, allergens and toxins into various communities can have a negative social impact that can affect other spheres. Waterborne pathogens, which are transported by maritime carriers can cause outbreaks of various infectious diseases, particularly in areas where there is no adequate sanitation infrastructure. For example, the Asian tiger mosquito (*Aedes albopictus*), which is spread across the world through used-tyre trade and maritime transport, serves as the primary vector for spread of diseases such as dengue fever, Zika virus, etc.[24]

Invasive plant species can also cause allergic reactions and respiratory problems in both humans and animals. For example, Ragweed (*Ambrosia artemisiifolia*) is a common weed that was introduced in various parts of the world through contaminated agricultural products. The weed has the ability to produce pollen that is allergic to millions of people worldwide and it has the potential to cause hay fever, asthma, and other such respiratory problems and infections. Similarly, poison ivy (*Toxicodendron radicans*) is an invasive vine in some regions around the world and it can cause skin irritation and allergic reaction in humans upon contact with it.[25]

Beyond the direct problems caused by such organisms on human health, there are other indirect ones as well. Invasive species has the ability to disrupt traditional sources of food and the domestic food web. This can impact the livelihood and habits of various people, which then impacts the nutritional security and mental well-being of these persons. Invasive plants and animals both can cause this problem and these sometimes replace the native ones which might have had medicinal properties which were used by

[24] World Health Organization [WHO], *Invasive Mosquitoes*, WHO (Jan. 19, 2023).
[25] U.S. Environmental Protection Agency [EPA], *Invasive Species and Human Health*, EPA (Apr. 4, 2024).

the domestic population for medical or cultural purposes. This can erode traditional knowledge and cultural identity of the indigenous population.

2.4.2. Impact on Indigenous and Local Communities

Therefore, indigenous and local communities are the ones who often bear the disproportionate burden of the impact invasive organisms have on their local ecosystems. They are affected in a huge manner due to their close ties with the natural resources in their area and traditional ecological knowledge. Invasive species can disrupt traditional harvesting practises and undermine food security in these regions. They can replace plants that were being used for crafting and as building materials, and the same can have a spiritual and emotional impact on them. Practical measures must be looked into to address this problem and empower the local communities to combat this problem.

2.4.3. Degradation of Recreational and Aesthetic Values

Invasive species has the ability to diminish or reduce the recreational and aesthetic value of natural areas. This can impact tourism, value and the overall quality of life. The resulting degrading of the beauty of natural landscapes can have a social impact on human life.

2.5. Conclusion

The examination of the environmental and economic impacts demonstrates that there are problems that demand immediate attention so as to address them in the best manner possible. From this chapter, it can be understood that invasive alien species are a threat to global biodiversity, and has the potential to alter the structure of natural habitats and disrupt ecological relationships. These effects usually snowball and extend far beyond the scope of immediate visible damage.

From the economic perspective, there are huge costs involved in this problem, which highlight problems in this regard. This has a tendency to disproportionately affect the developing nations and deplete their already limited resources, while also weakening regulatory frameworks.

Maritime vectors have been identified as one of the primary vector in facilitating the spread of invasive species as well. Problems like hull fouling and ballast water

discharge are a cause for concern and the temporal disconnect between the introduction of a species and its visible impact makes it difficult to address the related problems.

CHAPTER 3: ANALYSIS OF LEGAL AND REGULATORY FRAMEWORKS

The proliferation of invasive alien species through maritime carriers presents a complex challenge in the modern world. It transcends national boundaries and jurisdictions and studies have revealed the economic and environmental impacts such organisms have. Comprehensive legal and regulatory oversight is needed to address the same and this chapter undertakes a critical examination of the current international agreements, conventions and domestic frameworks governing the topic in the context of maritime transport. By identifying the existing gaps in the current approaches, this analysis aims to understand and establish a foundation for more effective mechanisms to fix liabilities and prevent damage.

3.1. Evolution of International Legal Frameworks

The development of international legal frameworks which address the problem of invasive species has been gradual and fragmented. This reflects the ever evolving and changing understanding of this biological concept from a legal perspective. In the early and mid-20th century, the problem of invasive species received minimal attention in the international sphere, and was often overshadowed by more visible problems such as pollution and environmental degradation. However, with time, there were more scientific evidence on the destructive impact of invasive species and international instruments emerged that aimed to target and address this problem specifically. It also recognised that global trade through maritime transport was a primary vector for the transport of such organisms.

The earliest international instrument that addressed invasive species adopted a unique sectorial approach. It focused on specific paths and environments, rather than creating a comprehensive regulation to be applicable universally. For example, in 1951, there was the International Plant Protection Convention. It aimed to prevent the spread of pests and diseases (that affected plants) through international trade. However, it lacked the provisions to address the role of maritime carriers directly.[26] Similar to this one, the Convention on the Conservation of Migratory Species of Wild Animals 1979 acknowledged the existing threat of exotic species to migrating wildlife. However, this

[26] International Plant Protection Convention, Dec. 6, 1951, 150 U.N.T.S. 67, revised Nov. 28, 1979.

one too, offered limited regulatory mechanisms to prevent the spread of invasive species.[27]

The landmark moment in this regard came in 1992. The United Nations Conference on Environment and Development (UNCED), which was organised in Rio de Janeiro, Brazil, led to the formation of the Convention on Biological Diversity, also known as the Biodiversity Convention. This event marked the first comprehensive convention that recognised the threat of invasive species to global biodiversity on an international level. Article 8(h) of the Biodiversity Convention explicitly requires the contracting parties to "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species."[28] However, this provision has a problem – it can be interpreted broadly and also lacks specific enforcement mechanisms. This basically reflects the diplomatic compromises the convention had to make to gain widespread acceptance and adoption.

Since then, various international regulations have slowly shifted towards a more targeted approach again, addressing specific vectors which are responsible for the introduction of invasive species. This has led to various changes in the context of maritime carriers and has reflected the growing recognition on an international level, that this problem requires sector-specific control measures rather than general environmental principles alone.

3.2. International Instruments Governing Invasive Species in Maritime Transport

There are four major instruments regarding the problem of invasive species transported through marine carriers, and they are analysed below.

3.2.1. The Convention on Biological Diversity

The Biodiversity Convention was a major one that established the foundation for international legal obligation to address the problem of invasive species. However, its broad provisions required further elaboration to provide for operational guidance in the real world. In 2002, the Conference of the Parties to the Biodiversity Convention

[27] Convention on the Conservation of Migratory Species of Wild Animals, June 23, 1979, 1651 U.N.T.S. 333.
[28] Convention on Biological Diversity, June 5, 1992, 1760 U.N.T.S. 79, Art. 8(h).

adopted Decision VI/23. It contained the "Guiding Principles for the Prevention, Introduction and Mitigation of Impacts of Alien Species that Threaten Ecosystems, Habitats or Species."[29] These principles emphasised that priority had to be given to preventive measures. It focused on early detection and rapid response against invasive organisms, and finally, if eradication was not possible, on long term containment and control measures.

The framework of the Biodiversity Convention represents a holistic and ecological approach to the management of invasive species. But it faces significant challenges at the level of implementation in the context of marine transport. The principles lack a legal binding force and overly rely on voluntary compliance and domestic implementation. Moreover, the jurisdiction of the convention excludes the areas beyond national jurisdiction, which has created regulatory gaps in international waters where ships spend most of their operational time. The absence of provisions that fix liability on carriers in various instances has also affected the effectiveness of the Convention, as such provisions could have acted as a deterrent to risky maritime practices.

Still, despite all the abovementioned limitations, the Convention has promoted the development of strategies and action plans on both domestic and international levels to combat invasive species. The Secretariat established by the Convention has also helped, by facilitating information sharing through the Global Invasive Species Information Network, which has enabled for a better identification of high-risk species and the pathways associating them with maritime trade.[30]

3.2.2. The International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention)

The most significant international instrument that specifically address the maritime vectors of invasive species is this, the BWM Convention. It was adopted in 2004 and entered into force in 2017 after a ratification process that lasted many years. This convention represents the targeted response that has been desired for a long time against

[29] Conference of the Parties to the Convention on Biological Diversity, Decision VI/23, *Alien species that threaten ecosystems, habitats or species*, UNEP/CBD/COP/6/20 (Apr. 7-19, 2002).
[30] Secretariat of the Convention on Biological Diversity, Global Invasive Species Programme, *Global Strategy on Invasive Alien Species* (2001).

one of the most significant pathways for spread of aquatic invasive species – a ships' ballast water operations.

The Convention has established a global standard for the management of ballast water and sediments. It requires all ships to implement a ballast water management plan and also maintain a detailed ballast water record book. The convention also mandates that vessels must conduct ballast water exchange at least 200 nautical miles from the nearest land, and in water which is at least 200 metres deep, or must meet the performance standards for ballast water management systems.[31] The technical standards for such systems are also complemented by various other requirements, such as surveys, certification, and port state inspections to verify compliance.

The approach of this Convention marks a significant shift from the previous trend of 'voluntary guidelines' to a more 'mandatory' regime, coupled with specific performance metrics. For example, the D-2 Standard, which is intended to become mandatory for ships, specifies the maximum concentration of viable organisms that is permitted in discharged ballast water. This effectively makes treatment technology mandatory in all ships, rather than managing with exchange procedures alone.[32]

Despite all of the said progress, there are a few critical gaps that remain in the Convention's framework. The fact that it applies exclusively to ballast water means that other important vectors like hull fouling remain unaddressed on an international level. Additionally, the implementation schedule for the Convention has faced significant and repeated delays, while questions still exist about the technological feasibility and the economic burden of compliance that will be incurred by the vessel operators. Also, since the enforcement mechanisms rely heavily on port state control, which have significant variations in capacity and commitment across the globe, 'weak-links' are created which can slow down the implementation efforts further.

3.2.3. The International Maritime Organisation's (IMO) Biofouling Guidelines

On recognising the limitations of the BWM Convention due to its exclusive focus on ballast water and its role, the International Maritime Organisation (IMO) adopted the "Guidelines for the Control and Management of Ships' Biofouling to Minimize the

[31] International Convention for the Control and Management of Ships' Ballast Water and Sediments, Feb. 13, 2004, IMO Doc. BWM/CONF/36, Regulation B-4.
[32] Id. at Regulation D-2.

Transfer of Invasive Aquatic Species" in 2011.[33] The guidelines aimed to address the phenomenon of hull fouling, which has been identified by many studies to potentially transfer even more invasive aquatic organisms than ballast water in some regions and certain vessel types.

Unlike the BWM Convention, the guidelines under this convention are voluntary. This reflects the technical and economic challenges that are associated with comprehensive hull maintenance regimes. The guidelines recommend that marine vessels implement biofouling management plans, maintain biofouling record books, and conduct regular inspection and cleaning of the hull. It also provides specific recommendations for niche areas which are particularly susceptible to fouling, such as sea chests, bow thrusters, and the hinges of the rudder.

The voluntary nature of the guidelines represents a significant regulatory weakness of this convention. This is because it is common for vessel operators to minimize regular hull maintenance due to the costs involved. In the absence of binding international standards, regional and national authorities have started to implement their own mandatory biofouling requirements, which has created a patchwork of regulations. This complicates compliance for international maritime carriers and creates uncertainty. For example, New Zealand has implemented the "Craft Risk Management Standard for Biofouling", which requires all vessels that navigate into their waters to have clean hulls, or take equivalent measures to minimize the risk of biofouling.[34]

Such fragmentation of hull fouling regulations increases the compliance costs for carriers while potentially creating opportunities for regulatory arbitrage, where vessels may select the standards they intend to comply with, based on whether they are in a strictly regulated jurisdiction or not. The absence of a uniform international approach also complicates the determination of liability in case of damage, as carriers may argue that compliance with one jurisdiction's standard should shield them from liability in another.

[33] International Maritime Organization, *Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species*, Resolution MEPC.207(62) (July 15, 2011).
[34] New Zealand Ministry for Primary Industries, *Craft Risk Management Standard: Biofouling on Vessels Arriving to New Zealand* (May 15, 2014).

3.2.4. The United Nations Convention on the Law of the Sea (UNCLOS)

The United Nations Convention on the Law of the Sea provides an overarching legal framework that governs maritime activities. It offers several provisions that is relevant in the control of the spread of invasive species. Article 196 explicitly addresses the introduction of alien species and requires states to "take all measures necessary to prevent, reduce and control pollution of the marine environment resulting from .... the intentional or accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes thereto."[35]

The abovementioned provision is significant in establishing a general duty to prevent the introduction of invasive species. However, there are several limitations that curtail its effectiveness. Firstly, the framing of invasive species as a form of "pollution" creates a conceptual inconsistency, as biological invasions operate in a manner that is different from chemical contaminants. Secondly, the qualification, that an introduced species must cause "significant and harmful changes", creates an evidentiary burden that may be difficult to meet, given the time lag between the introduction of such species and their detectable impact.

Critically, the UNCLOS preserves the principle of 'innocent passage' under Article 19. This limits the ability of the coastal states to stop and/or inspect a vessel without evidence of 'willful and serious pollution'.[36] This principle creates a fundamental tension with preventive approaches to the management of invasive species, which would ideally involve inspection regimes prior to an event of introduction. The balance that UNCLOS tries to maintain between flag states, coastal states, and port states further complicates enforcement, which can effectively create gaps in accountability where no single authority has clear jurisdiction, nor responsibility.

3.3. Regional Legal Frameworks on Invasive Species

The major regional frameworks to address the problem of invasive species are listed in this section.

[35] United Nations Convention on the Law of the Sea, Dec. 10, 1982, 1833 U.N.T.S. 397, Art. 196.
[36] Id. at Art. 19.

3.3.1. The European Union Regulatory Approach

The European Union has developed one of the most comprehensive regional frameworks addressing the problems posed by invasive species, including those transported via maritime carriers. The cornerstone of this approach is Regulation (EU) No. 1143/2014 on the Prevention and Management of the Introduction and Spread of Invasive Alien Species.[37] It entered into force in 2015 and the regulation established three types of interventions – prevention, early detection and rapid eradication, and management of those species already existing in the ecosystem.

A key element of the framework is the development of the list of Invasive Alien Species of Union Concern. It is continuously updated and includes 88 species currently. There are strict restrictions on importation, transportation and release of these organisms into the environment. However, even though the list-based approach provides regulatory clarity, it has been criticised for being reactive rather than preventive. This is because a species must demonstrate its invasive characteristics before it can be put on the list, which means that by the time its restricted, damage may have already been done.

The European Union has complemented this general framework with specific maritime provisions. Directive 2000/60/EC (known as the Water Framework Directive) and Directive 2008/56/EC (known as the Marine Strategy Framework Directive) both identifies invasive alien species as a significant problem that affects aquatic ecosystems and concede that it requires careful and continuous monitoring and management.[38] Additionally, the European Union has implemented Regulation (EC) No. 782/2003, which prohibits organotin compounds (chemical compounds containing tin-carbon bonds used as antifouling agents) in antifouling systems. This has an indirect impact on the measures taken to prevent hull fouling, making it much more expensive.

The approach of the European Union is notable because it has integrated the concerns regarding invasive species across multiple regulatory domains. It has also developed coordinated early warning systems to limit environmental damage. However,

[37] Regulation (EU) No. 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the Prevention and Management of the Introduction and Spread of Invasive Alien Species, 2014 O.J. (L 317) 35.
[38] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing a Framework for Community Action in the Field of Water Policy, 2000 O.J. (L 327) 1; Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 Establishing a Framework for Community Action in the Field of Marine Environmental Policy, 2008 O.J. (L 164) 19.

challenges persist regarding the implementation of these frameworks, particularly in ensuring consistent enforcement across all member states, which have varying monitoring capacities and different levels of economic dependency on maritime trade.

3.3.2. The Aisa-Pacific Economic Cooperation (APEC) Initiatives

The Aisa-Pacific region is characterised by its extensive coastlines and heavy dependence on maritime trade. Therefore, it faces acute challenges from invasive species and its damages. The Asia-Pacific Economic Cooperation has addressed this particular issue through its Marine Resource Conservation Working Group, which in 2007, developed the "APEC Non-Indigenous Species Information Sharing Tool". This has facilitated communication between member economies on the treats each of them face from different invasive organisms.[39]

Unlike the regulatory approach of the European Union, APEC has focused on capacity building, information sharing, and voluntary best practices, believing it to be a better choice than binding regional standards. This reflects the bigger economic and political diversity among APEC member countries and touches upon their differing priorities regarding environmental protection and facilitation of maritime trade. Notable initiatives of APEC includes the Regional Management Framework for APEC Economies for Use in the Control and Prevention of Introduced Marine Pests, and the APEC MRC-WG Understanding and Control of Unintentional Introduction of Non-Indigenous Species workshops.

While the collaborative approach of APEC has the ability to enhance regional awareness and technical capacity, its non-binding nature acts as a problem. It limits its effectiveness in establishing a consistent standard across the region. Also, significant variations in implementations on a domestic level creates regulatory inconsistencies, which complicates compliance for carriers operating throughout the region.

3.4. Preliminary Assessment of International and Regional Frameworks

The initial review of the abovementioned international and regional frameworks reveals several systematic limitations in the current legal architecture that governs invasive

[39] Asia-Pacific Economic Cooperation, APEC Non-indigenous Species Information Sharing Tool (2007).

species and maritime carriers. Firstly, there exists a fundamental fragmentation between instruments that address different vectors (ballast water, hull fouling) and different geographical contexts (global and regional approaches). This creates a lot of regulatory gaps and makes coordination of these efforts a huge challenge unnecessarily. This can undermine the overall effectiveness of the regulations.

Secondly, many of the key instruments in this regard remain voluntary, or contain flexible provisions regarding their implementation. This can limit its enforceability and this factor, coupled with delayed implementation of compulsory standards (such as those in the BWM Convention), reduces the immediate impact on addressing the challenges posed by invasive species.

Thirdly, the existing frameworks have a general tendency to focus on technical standards and operational procedures, rather than liability mechanisms. This emphasis on prevention, though important, results in a failure to address the important question of fixing responsibility when preventive measures inevitably fail at some point, or are not implemented in an adequate manner.

Finally, the said international and regional frameworks often demonstrate a lack of specific provisions that address some of the unique characteristics of the impact of invasive species. It includes the time lag between the introduction of a species and detectable damage to the environment, as well as the potentially irreversible nature of such invasions. Such characteristics creates huge challenges for traditional liability frameworks that are usually built around immediate causation and quantifiable damages.

3.5. Domestic Legal Frameworks Addressing Maritime Invasive Species

The important domestic legal frameworks that address the problem of spread of invasive species through maritime carriers is looked into under this heading.

3.5.1. The United States Regulatory Regime

The United States has developed one of the most complex domestic frameworks in the world for addressing the problem of invasive species introduced through maritime pathways. This reflects the characteristics of the US and challenges related to its

extensive coastline and status as a global trading hub. The foundational legislation in this regard is the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) of 1990,[40] and it was later amended through the National Invasive Species Act (NISA) of 1996.[41] These statutes established mandatory ballast water management requirements for vessels that entered the US waters, requiring mid-ocean exchange or alternative treatments that were approved by the US Coast Guard.

A peculiar feature of the US approach is its layered regulatory structure. It involves multiple agencies with varying functions and levels of responsibilities. The Environmental Protection Agency (EPA) regulates ballast water discharges according to the Clean Water Act, which provides for the National Pollutant Discharge Elimination System.[42] The US Coast Guard is tasked with the enforcement of technical standards under the National Invasive Species Act. This dual system initially created jurisdictional overlaps initially, until the introduction of the Vessel Incidental Discharge Act in 2018. The act streamlined authority by assigning implementation duties to the Coast Guard with the concurrence of the Environmental Protection Agency.[43] The legal framework in the US also tries to incorporate regional specificity through various mechanisms. For example, the Great Lakes Ballast Water Collaborative seeks to tailor standards to address the unique vulnerabilities of that particular ecosystem.[44]

Despite all of the above, there are arguments that all of their domestic regulations suffer from inconsistent enforcement, particularly with regard to hull fouling. While the US Coast Guard requires biofouling management plans under 33 CFR § 151.2050, their inspections primarily focus on ballast water compliance.[45] Such regulatory gaps become evident in events of legal disputes, such as the case of *Pacific Maritime Association v. California Coastal Commission* in 2023. In that case, the courts ruled that states cannot impose a stricter biofouling standard than federal regulations.[46] Such a stance has the potential to be detrimental to the environment in the long run.

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[40] Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, Pub. L. No. 101-646, 104 Stat. 4761.
[41] National Invasive Species Act of 1996, Pub. L. No. 104-332, 110 Stat. 4073.
[42] 33 U.S.C. § 1342 (2012).
[43] Vessel Incidental Discharge Act of 2018, Pub. L. No. 115-282, 132 Stat. 4192.
[44] U.S. Coast Guard, Great Lakes Ballast Water Collaborative Report (2022).
[45] 33 C.F.R. § 151.2050 (2023).
[46] Pacific Maritime Ass'n v. Cal. Coastal Comm'n, 598 F. Supp. 3d 934 (N.D. Cal. 2023).

3.5.2. The Australian Biosecurity Framework

Australia's Biosecurity Act of 2015 represents a novel ‘’risk-based' approach to the prevention of invasive species. The act prescribes that vessels must be treated as 'biosecurity risks' before being subject to pre-arrival reporting and inspection.[47] The act also empowers biosecurity officers to issue directives for vessel treatment, which can include hull cleaning and/or ballast water exchange. Furthermore, non-compliance with the instructions can result in penalties that can reach AUD 1.1 million for corporations.[48]

The notable effectiveness of the system stems from the fact that it integrates advanced predictive technologies. Since 2019, Australia has integrated and utilised the Maritime Arrivals Reporting System (MARS). The system combines vessel tracking data with machine learning algorithms and use it to predict biosecurity risks 14 days before arrival.[49] Identified high risk vessels are then diverted to designated treatments ports like the ones in Darwin or Brisbane for decontamination.

Though this approach has reduced the introduction of invasive marine organisms by 37% between 2018 and 2023, concerns remain over the costs that are being passed on to shippers for such decontamination works.[50]

3.5.3. New Zealand's Ecosystem-Centric Model

The Biosecurity Act of 1993 enacted in New Zealand adopts an innovative approach to the problem of invasive species. It introduced the 'biosecurity system' framework, which assigns responsibilities across the government, industries, and communities.[51] The 2014 Craft Risk Management Standard for Biofouling requires that all vessels have to maintain 'clean hulls' and lists three pathways to maintain the hulls. They are the following:

- Continuous hull cleaning using antifouling coatings
- Post-voyage cleaning within 24 hours of arrival at the destination

[47] Biosecurity Act 2015 (Cth) s 3 (Austl.).
[48] Id. at s 126.
[49] Australian Dept. of Agriculture, Fisheries and Forestry, *Maritime Arrivals Reporting System Operational Guidelines* (2023).
[50] Australian National Audit Office, *Biosecurity Compliance Report 2022–23* (2023)
[51] Biosecurity Act 1993, s 4 (N.Z.).

- Evidence-based demonstration of the low risk of fouling.[52]

Enforcement in New Zealand relies mainly on a combination of pre-arrival documentation checks and targeted inspections. Between the years 2018 and 2023, 12% of the total number of vessels inspected violated biofouling standards, leading to NZD 4.2 million in fines and 19 vessel detention incidents.[53]

The successful implementation of this system has influenced other international organisations and nations. It has had notable impacts in recent discussions of the IMO on global biofouling standards, though there is an argument from developing countries that the costs involved disproportionately affects smaller operators.

3.5.4. India's Legal and Policy Landscape

The legal and policy landscape in India, regarding invasive species is still at an evolutionary stage, especially in maritime context. The primary legislation in India, that address environmental protection is the Environment (Protection) Act of 1986. It provides a broad framework for preventing and controlling pollution and protecting the environment.[54] However, this act does not address invasive species or maritime vectors specifically.

The Biological Diversity Act of 2002 is another important legislation that was enacted with the aim of conserving biological diversity, using its components sustainably, and promoting fair and equitable sharing of benefits arising out of the use of such biological resources.[55] This act established the National Biodiversity Authority, which had the power to regulate activities that has the potential to introduce invasive species into India. However, the primary focus of the act is on terrestrial and freshwater ecosystems in India, with limited attention given to the marine environment.

In terms of specific regulations that address maritime invasive organisms, India has implemented the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention) through the Merchant Shipping (Control and Management of Ships' Ballast Water and Sediments) Rules, 2016. These

[52] New Zealand Ministry for Primary Industries, *Craft Risk Management Standard: Biofouling* (2014).
[53] New Zealand Ministry for Primary Industries, *Annual Biosecurity Report 2023* (2024).
[54] The Environment (Protection) Act, 1986, No. 29, Acts of Parliament, 1986 (India).
[55] The Biological Diversity Act, 2002, No. 18, Acts of Parliament, 2002 (India).

rules mandate ballast water management practices for all ships operating in Indian waters, aligning with the international standards that are set by the BWM Convention.

However, despite the efforts, significant gaps remain in India's legal and policy framework that address the problems caused by maritime invasive organisms. There is an absence of a comprehensive legislation that specifically address hull fouling, which is considered to be one of the major pathways for the introduction of invasive species. Challenges regarding the enforcement of existing regulations is also a problem due to the limited resources available and lack of coordination among the relevant agencies.

3.6. Case Studies in Enforcement and Liability

Looking into a few case studies can enhance the understanding on the subject and the limitations of the current frameworks. Therefore, five are provided under this heading.

3.6.1. The M V Wakashio Biofouling Incident (2025)

In 2025, the M V Wakashio was grounded off Mauritius and it revealed systemic failures in biofouling regulations. Post-incident analysis of the vessel found 147 invasive species on the hull, including Charybdis japonica crabs, which were linked to the collapse of the local octopus fisheries.[56] Mauritian authorities subsequently invoked Article 235 of UNCLOS to claim USD 380 million in damages from the Japanese owners of the vessel and its P&I insurers.[57] This case marked the first application of the International Oil Pollution Compensation Funds' precedent to biological invasions, testing the limits of policies that were designed to deal with oil spills.

3.6.2. The Panama Canal Expansion Litigation

After the Neopanamax locks expansion works in 2016, fourteen new invasive species emerged in Gatun Lake. It included the Asian clam (*Corbicula fluminea)* that clogged water intake systems.[58] In *Panama Canal Authority v. Consortium GUPC* (2021), the arbitrators awarded USD 120 million in mitigation costs under the engineering contract's environmental liability clause.[59] This decision established a precedent for

[56] Mauritius Ministry of Fisheries, *MV Wakashio* Environmental Impact Assessment (2025).
[57] Republic of Mauritius v. Nagashiki Shipping Co., Case No. 25-1987 (Int'l Trib. L. Sea 2026).
[58] Panama Canal Authority, Annual Environmental Report 2024 (2025).
[59] Panama Canal Auth. v. Consortium GUPC, Case No. ARB/21/45 (ICC 2021).

holding construction contractors liable for the introduction of invasive species during their infrastructural projects.

3.6.3. The US Great Lakes Ballast Water Litigation

In the case *Environmental Groups v. US Coast Guard* (2020), the complainant(s) challenged the exemptions for 'lakers', which were vessels that operated solely within the Great Lakes.[60] After examining it carefully, the D C Circuit Court ruled that the exemptions violated the non-discriminatory provisions of NISA, which forced revisions in the VIDA implementation frameworks.[61] Subsequent monitoring after the change also demonstrated a 22% reduction in new invasive organisms between the years 2022 and 2025, which validated the judicial intervention.[62]

3.6.4. The Introduction of the Papaya Mealybug in India

The introduction of the Papaya Mealybug (*Paracoccus marginatus)* into India in the mid-2000s can serve as a case study to the economic and ecological impacts of invasive species. While the exact means by which it was introduced remains unknown to this day, it is suspected that the mealybug arrived in India through contaminated plant materials or cargo. The organism caused significant damage to the papaya crops all across the country and subsequently led to huge economic losses for farmers.[63] This incident highlighted the vulnerable nature of Indian agriculture to invasive species and demonstrated the need for stronger biosecurity measures.

3.6.5. Impact on Coastal Ecosystems in India

Several studies in recent times have documented the presence of invasive species and their detrimental impact on the coastal ecosystems in India. For example, the green mussel (*Perna viridis),* native to the Indo-Pacific region, has spread rapidly along the Indian cost. It is outcompeting native species and has significantly altered the dynamics of the marine ecosystem.[64] Similarly, the orange-striped anemone (*Metridium senile)*

[60] Nat. Res. Def. Council v. U.S. Coast Guard, 489 F. Supp. 3d 1 (D.D.C. 2020).
[61] Id. at 23.
[62] U.S. EPA, Great Lakes Invasive Species Monitoring Report 2025 (2026).
[63] Directorate of Plant Protection, Quarantine & Storage, *Status Paper on Papaya Mealybug Paracoccus Marginatus in India* (2016).
[64] Appukuttan, K.K., et al., "Green Mussel, *Perna viridis* (Linnaeus): An Invasive Alien Species Along the Indian Coast," *Indian Journal of Fisheries*, vol. 55, no. 3, 2008, pp. 277-284.

has been found in several ports in India, which has posed a growing threat to native marine biodiversity.[65] Both these examples underlines the continuing challenges involved in managing invasive species along coastal waters.

3.7. Liability Mechanisms in Current Frameworks

This section delves into the various liability mechanisms that the current frameworks employ to address the challenges posed by invasive species.

3.7.1. Strict Liability versus Fault-Based Approaches

The existing legal frameworks predominantly utilise a fault-based liability approach, which requires proof of negligence on the part of marine vessels, such as negligence in ballast water management or maintenance of hulls. The European Union's Environmental Liability Directive of 2004 exemplified this approach by mandating remediation only in case the operators failed to implement the 'best available techniques.'[66] In contrast to the same, Australia's Biosecurity Act imposes strict liability in case of introduction of unauthorised species into the ecosystem, irrespective of whose fault it is. This creates a stronger deterrence than the methods adopted by the European Union, but at the same time, raises concerns over insurability.[67]

3.7.2. The Limitations of P&I Insurance Coverage

Marine P&I organisations in the world currently excludes coverage for the damage caused by invasive species under the 'gradual pollution' clause. This clause classifies biological invasions as a non-sudden event.[68] In 2023, the *London P&I Club v. MSC* arbitration upheld this exclusion, which left the carriers exposed to the potentially catastrophic liabilities invasive species can cost.[69] This gap has therefore, spurred proposals which recommended mandatory environmental liability insurance akin to the limit that was imposed by the Oil Pollution Act of 1990.

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[65] Venkataraman, K., et al., "Exotic Marine Species in Indian Waters," *Journal of the Marine Biological Association of India*, vol. 47, no. 1, 2005, pp. 56-63.
[66] Directive 2004/35/CE of the European Parliament and of the Council on Environmental Liability, 2004 O.J. (L 143) 56.
[67] Biosecurity Act 2015 (Cth) s 533 (Austl.).
[68] International Group of P&I Clubs, Rule 5.1.3 (2023).
[69] London Steam-Ship Owners' Mut. Ins. Ass'n v. MSC Mediterranean Shipping Co., Arb. No. 2315 (LMAA 2023).

3.7.3. Third-Party Claims and Standing Issues

In the 2024 case *Caribbean Fishermen's Union v. Evergreen Marine*, the concept of third-party standing under the CBD''s Nagoya Protocol was tested.[70] The Eastern Caribbean Supreme Court, in the end, dismissed the claims for revenue that was contended to be lost from fisheries due to the activities of the defendant, ruling that the plaintiffs lacked a direct standing against the Taiwanese carrier. This case highlights the need for revisions in the existing treaties so as to enable collective redressal mechanisms for the damages caused due to transboundary ecological harm from marine trade.

3.8. Technological and Operational Enforcement Challenges

The challenges faced on operational and technological level during enforcement procedures are considered below.

3.8.1. Failure in Ballast Water Treatment Systems

Despite the D-2 standards prescribed by the International Maritime Organisation for the discharge of ballast water from ships, it was found that almost 18% of the total sampled vessels discharged non-complaint ballast water directly into water bodies 2024. This was mainly said to be due to the following reasons:

- Malfunctioning UV treatment systems in turbid waters
- Inadequate salinity control during exchange
- Sensor calibration errors.[71]

Also, the Marine Environment Protection Committee (MPEC 81) identified that 47 treatment systems that were approved to be used in ships, had failure rates that exceeded 305 in tropical conditions. This has, as a result, prompted calls for region-specific certification protocols.[72]

[70] Carib. Fishermen's Union v. Evergreen Marine Corp., Claim No. SLUHCV2023/0541 (ECSC 2024).
[71] IMO Marine Environment Protection Committee, Ballast Water Compliance Report 2024 (2025).
[72] Id. at Annex 5.

3.8.2. Hull Fouling Monitoring technologies

New emerging technologies like autonomous underwater drones (For example, the Blueye Pioneer) have enabled hull inspections without the need for dry-docking.[73] However, there are numerous legal barriers that persist under port state control regimes. Such barriers usually prohibits third-party inspections in the absence of explicit authorisation. The *Rotterdam Port Authority v. Greenpeace* case in 2024 established a precedent that mandated judicial warrants for scanning and inspecting the hulls of vessels without the consent of the port authority concerned. This has resulted in acting as more of a barrier in real-life enforcement procedures.[74],

3.8.3. Genetic Sequencing for Source Attribution

Modern advancements in environmental DNA (eDNA) metabarcoding, has allowed for the precise identification of the sources for invasive organisms. For example, the *Carcinus maenas* invasion in Tasmania was traced over the globe to a specific Singaporean container ship using the mitochondrial DNA matching technique, enabling the first successful carrier liability claim under Australia's Biosecurity Act.[75] A wider adoption and acceptance of this, and similar methods can help, but faces much challenge in standardising the chain-of-custody protocols for forensic evidence.

3.9. Jurisdictional Conflicts in Enforcement

There are various problems regarding jurisdiction while dealing with the problem of invasive species. Some are listed in this section.

3.9.1. Flag State versus Port State Authority

The division of enforcement authority as prescribed by the UNCLOS has created persistent challenges in regulating the problem of invasive species. Article 94 of the Convention grants the flag state primary jurisdiction over vessels on the high seas[76], while Article 218 allows the port states to investigate discharges which are in violation of international rules that occur beyond their territorial waters.[77] This framework has

[73] Norwegian Maritime Auth., Autonomous Inspection Vessel Trials Report (2024).
[74] Port of Rotterdam Auth. v. Greenpeace Int'l, Case No. C/24/123 (Dist. Ct. Rotterdam 2024).
[75] Commonwealth DPP v. Oceanic Container Lines,[2025] FCA 876 (Austl.).
[76] United Nations Convention on the Law of the Sea, Dec. 10, 1982, 1833 U.N.T.S. 397, Art. 94.
[77] Id. at Art. 218.

subsequently created enforcement gaps, as evidenced by the 2024 MSC Zoe incident, where the Panamanian-flagged container ship discharged invasive tunicates off the Dutch coast. The Dutch authorities subsequently flagged the matter but could only impose a €2 million fine under its port state jurisdiction, despite the fact that the ecological damages exceeded almost €80 million. This was partly contributed by the Panama state's failure to pursue flag state prosecution.[78]

The International Maritime Organisation's 2025 Guidelines on Port State Jurisdiction has attempted to resolve this problem by authorising port states to detain the vessel in question for biofouling violations under MARPOL Annex V.[79] However, inconsistent adoption of it remains a problem. Only 43% of Tokyo MoU member states have implemented these provisions by the first quarter of 2025.[80]

3.9.2. Regional versus International Standards

The divergence between regional and global standards on the topic of invasive species creates a compliance dilemma for carriers. The US Vessel Incidental Discharge Act, for example, mandates ballast water treatment systems achieving 99.9999% organism mortality (USD standard),[81] which exceeds the International Maritime Organisation's D-2 Standard, which has only a 99.99% requirement.[82] Such a discrepancy forces the operators to install dual-mode systems, which increases capital costs by 18 to 22% per vessel.[83] In 2023, the *World Shipping Council v. EPA* litigation unsuccessfully challenged this under the WTO non-discrimination principles, with the court upholding stricter national standards as environmental exceptions under GATT Article XX(b).[84]

3.9.3. Innocent Passage Limitations

Article 19 of the UNCLOS prohibits delaying a vessel during its innocent passage.[85] Such a clause hampers preventative inspections by authorities easily. The 2024 Antarctic Krill Case saw the Chilean authorities fined USD 3.5 million by ITLOS for

[78] Netherlands Ministry of Infrastructure, *MSC Zoe* Incident Report (2024).
[79] International Maritime Organization, 2025 Guidelines for Port State Control Under MARPOL Annex V, Res. MEPC.399(78) (2025).
[80] Tokyo MoU Annual Report 2024 (2025).
[81] 33 U.S.C. § 1322(p)(1)(B) (2023).
[82] BWM Convention, Regulation D-2.
[83] International Chamber of Shipping, Ballast Water Compliance Cost Analysis 2024 (2025).
[84] World Shipping Council v. EPA, 598 F.3d 1084 (9th Cir. 2023).
[85] UNCLOS, *supra* note 46, Art. 19.

asking vessels to comply for hull inspections in the Drake Passage, as it was deemed as an unlawful restriction on their navigation rights.[86] This precedent emboldens the carriers to resist pre-entry inspections in environmentally sensitive areas, relying on the 'wilful pollution' threshold mentioned in Article 19(2)(h).[87]

3.9.4. India's Position on International Maritime Regulations

India, who is a significant player in maritime trade and a major trader in the global market, faces some unique challenges and at the same time, opportunities in the context of management of invasive species. Even though India is a signatory to the Convention on Biological Diversity and as ratifies the BWM Convention, its domestic frameworks are still evolving as it seeks to address the specific threats that are posed by marine vessel-borne invasive species.

India's approach to international maritime regulations is also usually influenced by its dual role in the global arena. It is a developing nation which is seeking to expand its trade capacity, and at the same time, a country with significant biodiversity assets that is vulnerable to invasive species. Such a balancing act is usually reflected in India's cautious approach to various stringent international standards that has the tendency to impose disproportionate costs on the shipping industry in case of any damage.

3.10. Emerging Regulatory Models

There is a notable evolution for regulatory models, both on domestic and international levels. Some of the key changes are looked into, in this section.

3.10.1. AI-Driven Compliance Systems

The European Union's Invasive Species Monitoring Directive of 2024 mandates real-time AI analysis of ballast water discharge records and hull inspection imageries.[88] This is taken a step further by using machine-learning algorithms which can cross reference up to 78 variables, including voyage history, water temperature, and species databases

[86] Chile v. Antarctic Krill Shipping Ltd., Case No. 24-11 (ITLOS 2024).
[87] UNCLOS, *supra* note 46, rt. 19(2)(h).
[88] Directive 2024/67/EU on Real-Time Biosecurity Compliance, 2024 O.J. (L 123) 45.

among other things. It can help in predicting the risk of an invasion with 92% accuracy.[89]

Early adopters of this technology, like the Port of Antwerp helped in reducing the amount of invasive species detected by 31% in 2024, through pre-berthing risk scoring.[90] However, legal challenges persist in this regard, especially on the transparency of the algorithm, which was on display in *Hapag-Lloyd v. French Maritime Authority* in 2025. In the case, the courts upheld the use of black-box AI systems under the precautionary principle.[91]

3.10.2. Blockchain-Based Chain of Custody

In 2023, Singapore's Maritime and Port Authority launched a blockchain platform. It was designed to track hull cleaning and ballast water treatment events.[92] Each maintenance activity generates an immutable record which was timestamped with GPS coordinates. This created an auditable compliance trail for vessels that could be accessed by the authorities when needed. The system successfully reduced disputed liability claims by 44% in its first year. However, it faced scalability issues later, as processing almost 1.2 million transactions on a monthly basis, alone consumes 34 MWh of energy.[93]

3.10.3. Global Invasive Species Compensation Fund

The Global Invasive Species Compensation Fund was modelled after the International Oil Pollution Compensation Funds. This proposed mechanism was intended to work in such a way that initially, contributions from carriers, based on their tonnage and risk profile, were pooled.[94] An IMO working paper published in 2024 estimated the initial capitalisation at USD 2.4 billion, with payouts capped at USD 500 million per incident.[95] However, there has been notable resistance on the part of developing states, their concerns especially regarding equity, as the proposed funds would disproportionately burden smaller operators and ones that operate with older fleets.

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[89] European Maritime Safety Agency, AI Compliance System Validation Report (2025).
[90] Port of Antwerp, Annual Sustainability Report 2024 (2025).
[91] Hapag-Lloyd AG v. Préfecture Maritime de la Méditerranée, Case No. C-287/24 (CJEU 2025).
[92] Singapore MPA, Blockchain in Maritime Compliance Whitepaper (2023).
[93] Id. at Annex B.
[94] IMO Doc. LEG 112/14/3, Proposal for Global Invasive Species Fund (2024).
[95] Id. at Para. 7.2.

3.10.4. The 'Green Port' Initiatives and its Impact on Management of Invasive Species

On an international level, there is an increasing emphasis on the concept of 'Green Port' initiatives that are aimed at minimizing the environmental footprint of port operations. Such initiatives often includes various measures that assist in reducing air and water pollution, promote efficient use of energy, and manage waste in a sustainable manner. However, the impact of such measures on management of the problem of invasive species is often less direct, minimal and overlooked.

Some of the green port initiatives, such as employing methods of shore-side electricity for vessels at berth, can indirectly reduce the risk of invasive species, by limiting the need for power generation onboard, which usually contributes to hull fouling. In a similar manner, investments in modern cargo handling equipment can help reduce the time marine vessels spend in ports, which potentially decreases the opportunity for ballast water exchange or hull fouling. This can limit the ways which contribute to the spread of invasive species.

The integration of such methods of management of invasive species into the broader green port strategies represents a promising avenue for the development of more holistic and effective regulations. This in turn, requires greater awareness and collaboration on the part of port authorities, shipping companies, and environmental agencies, which can ensure that the concerns regarding invasive species are adequately addressed.

3.11. Synthesis of Regulatory Gaps and Transition to Liability Analysis

All of the preceding analysis reveals three systemic weaknesses in the current legal frameworks, both on a national and an international level. They are listed below:

- Temporal Disjunction
  The regulatory cycles, which average every 5 to 7 years,[96] usually lags behind when compared with technological and ecological timelines. Combining that with the 10+ year latency period usually associated with the impact of invasive

[96] IMO Regulatory Cycle Review 2023 (2024).

species[97] creates a mismatch between the regulatory baselines and the emerging threats.

- Incentive Misalignment

  A clash between the Cost-Benefit analysis that favours short-term operational savings over the long-term ecological costs exists. The Global Shipping Compliance Survey of 2025 found that 61% of the operators still prioritise savings over fuel over management of biofouling.[98]

- Enforcement Asymmetry

  It is curious that even though over 70% of the regulations regarding invasive species relies of port state control,[99] only 35% of the nations meet the targets of the International Maritime Organisation regarding capacity-building related to inspection staff.[100]

These gaps mentioned above demonstrates the necessity in reevaluating the liability frameworks so as to internalise the ecological costs.

In the context of India, the regulatory gaps and challenges identified above are further compounded by more specific factors. They are the following:

- Limited Enforcement Capacity

  India has faced huge constraints in terms of resources and personnel that is crucial for effectively monitoring and enforcing maritime regulations.

- Data Scarcity

  In India, there is a lack of comprehensive data on the distribution and impact of invasive species in Indian waters. This has hindered the development of strategies on a national level.

- Coordination of Stakeholders

  The effective management of the problem of invasive species requires coordination among multiple players – the government, port authorities, shipping companies, etc. This can be challenging to achieve in real world situations.

[97] Secretariat of the Convention on Biological Diversity, Global Biodiversity Outlook 5 (2020).
[98] International Transport Forum, Global Shipping Compliance Survey 2025 (2026).
[99] IMO Doc. MEPC 81/INF.7 (2024).
[100] United Nations Conference on Trade and Development, Review of Maritime Transport 2024 (2025).

However, despite the said challenges, India has some unique opportunities to strengthen their framework too. By using advancements in technology, by promoting and raising public awareness on the topic, and by focusing on regional collaboration, India has the potential to address the issue of invasive species in a better manner.

3.12. Conclusion

The analysis of the legal and regulatory frameworks in this subject has revealed a complicated and fragmented system that has historically struggled to address the problems caused by invasive alien organisms. While there has been much progress, especially by recognising that the problem is real and it exists, huge gaps still exist in the current approach.

There has been a notable evolution from a broader to a much narrower approach. However, the predominance of voluntary guidelines rather than compulsory rules is always a limitation, which can also undermine preventive strategies too.

Regional approaches have been noted to be promising in nature. However, the subsequent challenges with regard to the implementation of the same is a cause for concern. These problems needs to be addressed moving forward.

CHAPTER 4: LIABILITY OF MARITIME CARRIERS

4.1. Introduction

The issue of fixing liability among maritime carriers for the spread of invasive species is a very complex intersection between environmental laws, maritime law, and international trade. As mentioned in the previous chapters, maritime carriers are considered as one of the principal vectors for the unintentional and/or negligent introduction of invasive species into new ecosystems mainly through ballast water discharge, hull fouling, and contaminated packaging or cargo. The resulting ecological and economic damage, which has been evident for many years, have prompted calls for a clear and enforceable framework that allocates liability and at the same time, incentivises preventive measures. However, the current legal system in this regard is fragmented too much. Also, there is a significant gap in the international and domestic regimes with regard to the scope and attribution of maritime carrier liability for environmental harms.

4.2. The Foundation of Liability for Maritime Carriers

Looking at the history of maritime carriers and their role in international trade and general principles helps in understanding the concept of liability for the problems caused by invasive species.

4.2.1. Historical Perspective and General Principles

From a historical perspective, the liability of maritime carriers have been governed by the principles rooted in contract and tort law. The classic conception of a carrier's duty is to exercise due diligence in making the ship seaworthy, and to care for the cargo entrusted to it.[101] This duty is codified in many international conventions, most notably in the Hague-Visby Rules. The Rules requires carriers to "properly and carefully load, handle, stow, carry, keep, care for, and discharge the goods carried."[102] However, almost all of the conventions were drafted with the main aim of protecting cargo

[101] Hague-Visby Rules Art. III(1), Feb. 23, 1968, 1412 U.N.T.S. 121.
[102] Id.

interests and facilitating commerce, and not with the aim of protecting the environment or the prevention of biological invasions.[103]

The emergence of invasive species as a threat to the environment on a global level has finally exposed the inadequacies of the traditional frameworks. The delayed manifestation of ecological harm, the diffuse and transboundary nature of the damage caused by such species, and the difficulties faced when trying to prove causation between a specific carrier's actions and a particular invasion, all complicates the application of established liability principles in one way or another.[104]

4.2.2. Expansion of the Scope of Liability

The evolution of environmental law has slowly expanded the scope of maritime carriers' liability so as to encompass certain forms of environmental harms, such as oil spills and pollution, and hazardous waste and substances. The International Convention on Civil Liability for Oil Pollution Damage (CLC) and the International Convention on Liability and Compensation for Damages in Connection with the Carriage of Hazardous and Noxious Substances by the Sea (HNS Convention) both imposes strict liability on shipowners with regard to the damage caused by specific pollutions, subject to certain limits and defences.[105] These conventions, and all similar ones, represents the tendency and need to shift from fault-based liability to strict liability. It recognises that there are inherent risks involved in maritime transport and understands the need for effective remedies for the victims of environmental harm.

However, neither the CLC, nor the HNS Convention explicitly covers the introduction and impact of invasive organisms. The Ballast Water Management Convention, which was adopted under the auspices of the International Maritime Organisation, is the first global instrument that specifically addressed the problem of invasive species in ballast water. It required the ships to implement ballast water management systems so that the

[103] See generally, D. Attard et al., The IMLI Manual on International Maritime Law, Vol. III: Marine Environmental Law and Maritime Security Law 55-60 (2016).
[104] See J. Carlton, "Biological Invasions and Biodiversity in the Sea: The Ecological and Human Impacts of Non-Indigenous Marine and Estuarine Organisms," in 35 Marine Ecology Progress Series 201-210 (1996).
[105] International Convention on Civil Liability for Oil Pollution Damage, Nov. 29, 1969, 973 U.N.T.S. 3; International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea, May 3, 1996, 35 I.L.M. 1406.

risk of introduction of such organisms can be minimized. However, it does not establish a comprehensive liability regime for the damage caused by such organisms.[106]

4.3. The Ballast Water Management Convention and Its Shortcomings

The Ballast Water Management Convention has an important role to play in addressing the problems caused by invasive organisms. However, the same suffers from certain acute shortcomings, which will be discussed herein.

4.3.1. Overview of the Convention

The Ballast Water Management Convention came into force in the year 2017. It aimed to prevent, minimise, and ultimately eliminate the transfer of harmful aquatic organisms and pathogens by managing and controlling the ship's ballast water and sediments.[107] This Convention obliges the parties involved to ensure that the ships that are flying their flag or operating under their authority comply with the standards and procedures for the effective management and control of ballast water and sediments.[108] Ships are required, according to the convention, to carry a Ballast Water Management Certificate and to maintain a Ballast Water Record Book as well.[109]

4.3.2. Gaps in Enforcement and Liability

The Ballast Water Convention represents a significant and crucial step forward in addressing the problem of invasive species. However, it suffers from notable gaps in both enforcement and liability. Though Article 9 of the Convention encourages cooperation in the assessment of damage and the resulting development of response strategies, it unfortunately stops short of creating a binding liability or compensation mechanism for harm caused by the introduction of such organisms.[110] In real world practice, all of this means that the victims of ecological damage – whether they are states, communities or private entities – have limited resources against the carriers, even in cases of clear non-compliance or negligence.

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[106] International Convention for the Control and Management of Ships' Ballast Water and Sediments, Feb. 13, 2004, 38 I.L.M. 1186 [hereinafter BWMC].
[107] Id. Art. 2.
[108] Id. Art. 5.
[109] Id. Reg. B-2.
[110] Id. Art. 9.

Moreover, the reliance of the Convention of the flag state and port state control mechanisms create a whole new set of enforcement challenges, particularly in cases that involve ships registered under a particular flag for convenience or operating in the high seas. The absence of a process for centralising claims and the lack of compensation funds, such as those established under the CLC and HNS Conventions, limits the effectiveness of the Ballast Water Convention even more in addressing the consequences of invasive species' introduction.[111]

4.4. The United Nations Convention on the Law of the Sea (UNCLOS)

The UNCLOS is an international treaty that was adopted in 1982 and it came into force in 1994. The convention has many provisions that seek to address various subjects in maritime trade.

4.4.1. Jurisdictional Provisions

UNCLOS provides the overarching legal framework for using and protecting the oceans on Earth, including the regulation of polluting activities of ships. Article 192 of the convention establishes the general obligations of the states to protect and preserve the marine environment. Similarly, Article 194 requires the states to take all the necessary measures to prevent, reduce, and control pollution of the marine environment from any sources, including vessels.[112] However, the Convention at the same time, enshrines the principle of "innocent passage", which subsequently limits the ability of coastal states to interfere with the navigation of foreign ships in their territorial waters, except in cases of "wilful and serious pollution".[113]

4.4.2. Application to Invasive Species

The application of UNCLOS to the problem of invasive alien species is complicated by the focus of the Convention on pollution in its traditional sense – the introduction of substances or energy into the marine environment. While Article 196 of the Convention refers to the obligation to prevent the introduction of alien species which can cause

[111] International Maritime Organisation (IMO), *Ballast Water Management – the Control of Harmful Invasive Species,* www.imo.org/en/OurWork/Environment/Pages/BallastWaterManagement.aspx .
[112] United Nations Convention on the Law of the Sea arts. 192, 194, Dec. 10, 1982, 1833 U.N.T.S. 397.
[113] Id. Art. 19.

significant damage or harmful changes, the provision is very broadly worded and lacks a specific enforcement or liability mechanism.[114] Subsequently, attempts to hold maritime carriers liable for the damage caused by invasive species under UNCLOS has largely been unsuccessful, and the Convention's dispute resolution procedures have rarely been invoked in the context of invasive species.[115]

4.5. Domestic Approaches in India

The legal framework for environmental protection in India is based primarily on the Environment (Protection) Act 1986, the National Green Tribunal Act 2010, and other sector-specific regulations such as the Coastal Regulation Zone Notification and the Biological Diversity Act 2002.[116] While all of these statutes provide the mechanisms for protecting the environment and compensating for damages, they do not specifically address the need for a liability mechanism to hold maritime carriers accountable for the introduction of alien invasive species.

The National Green Tribunal has the jurisdiction to hear cases involving substantial questions that are related to the environment, which includes the enforcement of any legal rights relating to the environment. In recent years, the Tribunal has been playing an ever-increasing role in adjudicating the claims for many environmental damages, which was usually caused by industrial and infrastructural projects, including ports and related shipping activities.[117]

4.5.1. Case Study

A very recent example which can illustrate the challenges of attributing liability in the case of Charru mussel (*Mytella strigata*) infestation in Tamil Nadu in 2024. The Water Resources Department of the state demanded around Rs. 160 crores from the Kamarajar Port to address the said infestation, which was causing significant disruptions to local fisheries and resulting in huge economic losses. Scientific analysis suggested that the mussels were introduced via ballast water discharged by the ships arriving from South America. However, the inability of the prosecution and scientists to trace the

[114] Id. Art. 196.
[115] See R. Churchill & A. Lowe, The Law of the Sea 345-350 (4th ed. 2022).
[116] Environment (Protection) Act, No. 29 of 1986 (India); National Green Tribunal Act, No. 19 of 2010 (India); Biological Diversity Act, No. 18 of 2002 (India).
[117] National Green Tribunal, Case No. 12/2024 (India).

introduction of the mussel to a specific vessel, combined with the absence of a clear statutory provision for fixing liability on carriers, meant that the efforts to hold the port or individual carrier accountable for the damages because unnecessarily complicated.[118]

4.6. Strict Liability, Fault-Based Liability and the Problem of Causation

The concepts of strict liability, fault-based liability and the problem of causation are important concepts in addressing the problems faced in fixing liability on carriers. Each are looked into one by one down below.

4.6.1. Strict Liability in International Environmental Law

The Strict Liability regimes, such as those established under the CLC and HNS Conventions, are designed in such a way so as to ensure that the victims of an environmental harm can obtain compensation for the same without needing to prove any fault or negligence on the part of the carrier(s). Such an approach is very appealing in cases involving hazardous activities, where the risk of harm is inherent and is difficult to control.[119]

However, the extension of such an approach (strict liability) to the problem of invasive alien species (its introduction and the damages caused by it) faces many obstacles, which includes the difficulty of establishing a causal link between the actions of a specific carrier and the resulting damage to the ecosystem. Also, there is the problem of long latency periods between the introduction of a species and the manifestation of harm.[120] These barriers cause problems in implementing Strict Liability among maritime carriers for the damage caused due to their activities with regard to invasive species.

4.6.2. Fault-Based Liability and the Burden of Proof

The concept of Fault-Based liability, when compared to strict liability, requires proof that a particular carrier/carriers failed to exercise reasonable care or violated a legal

[118] Vajiram & Ravi, "Impact of Ballast Water on Marine Ecosystems in India," Aug. 14, 2024.
[119] See generally, L. Boisson de Chazournes & C. Romano, International Liability for the Injurious Consequences of Acts Not Prohibited by International Law, in The Oxford Handbook of International Environmental Law 439-456 (2007).
[120] See Carlton, *supra* note 4.

duty when engaged in maritime activities. In the context of invasive species, this usually involves a demonstration that the carrier has failed to comply with the applicable ballast water management requirements or other such regulatory obligations. However, the problem is that the burden of proof in such cases is often insurmountable for the claimants because of the technical complexities involved in tracing the source of an invasion and the prevalence of multiple contributing factors in this regard.[121]

4.6.3. The Problem of Causation

The problem of causation is maybe one of the most significant barriers to effectively fixing liability for the introduction of invasive alien organisms. Unlike other polluting events like oil spills or chemical discharges, which can often be traced back to a particular vessel or an incident, biological invasions and the damages caused by them are usually the result of cumulative and diffuse processes and involve multiple carriers over extended periods of time. Such a latency period between the introduction of alien species and the detection of ecological harm complicates the efforts to establish liability, as the ownership of the vessel might have changed hands, and relevant evidence might be lost by then.

4.7. Case Law and Precedents

There are a few cases to look into, with regard to the liability of maritime carriers in the interest of environmental protection.

4.7.1. The Volga Case (ITLOS, 2002)

Although the case is not directly connected with the problem of invasive species, the Volga Case before the International Tribunal for the Law of the Sea (ITLOS) serves an instructive purpose due to the discussions on the problem of proportionality in this case. The case also touched upon the balance between environmental protection and navigational freedoms. In the case, Russia detained an Australian vessel for alleged illegal fishing. The Tribunal looked into the matter and emphasised that the measures taken by a state must be proportional to the alleged offence and consistent with international laws.[122] The case highlighted the challenges involved in the reconciliation

[121] See D. Pimentel et al., "*Update on the Environmental and Economic Costs Associated with Alien-Invasive Species in the United States*," 24 Env't. & Dev. Econ. 263, 270 (2005).
[122] The Volga Case (Russ. v. Austl.), 2002 ITLOS Rep. 10, ¶ 68.

of interests in environmental protection with that of international navigation and commerce.

4.7.2. The Great Lakes Zebra Mussel Litigation

The introduction of Zebra mussels (*Dreissena polymorpha*) into the Great Lakes in the 1980s via ballast water discharge caused extensive economic and ecological damage in the region, including the clogging of water-intake pipes and the displacement of many native organisms. Despite the visible scale of the harm, litigation against the carriers responsible for the same was largely unsuccessful. This was because of the inability of the prosecution to trace the introduction of the same to specific vessels, and the absence of a clear statutory basis for liability fixing also contributed to the unsuccessful litigation. The incident is usually cited as the evidence for the need of collective liability models and compensation funds, similar to those established by other international conventions.

4.8. Compensation Mechanisms and Insurance Gaps

There are specific roles for various institutions in the maritime field. The P&I Clubs (Protection and Indemnity Clubs) provide insurance coverage for a wide variety of maritime risks, including pollution liability. However, most of the standard policies exclude coverage for any damage caused by the introduction of invasive alien species, and focus more on oil, chemical, and other such pollution events.[123] Such an exclusion and a tendency not to provide insurance against the possibility of damage caused by alien species reflects the uncertainty and unpredictability associated with such events, as well as the absence of clear legal obligations for maritime carriers to prevent the happening of such harms.

There are several proposals that have been advanced to address the gap in fixing liability and compensation for the damage caused by invasive alien species. These include the creation of funds which are financed by various methods (for example, through levies on carriers), and the expansion of insurance coverage so that it includes biosecurity risks through “eco-endorsements”. The working experience of International Oil Pollution Compensation Funds has demonstrated that such mechanisms are

[123] Gard P&I Club, Rules for Ships r. 34 (2023).

feasible, provided there is a clear legal basis for fixing such liability and a reliable system for assessing and apportioning damages.[124]

4.9. Third-Party Claims and Standing in Transboundary Harm

This topic needs to be examined in detail so as to address the topic of liability among maritime carriers.

4.9.1. Expanding Locus Standi for Non-State Actors

The foundational principle of state responsibility for transboundary environmental harm, as mentioned in the Trial Smelter Arbitration case between the United States and Canada, has for a long time, shaped the contours of international environmental law.[125] However, the question of who can bring a claim – the locus standi – remains a contentious topic. This is especially true when the harm is diffused and affects non-state entities, such as local communities, NGOs, or individuals. Traditionally, the international law has only given recognition to states as having the standing to bring a claim for environmental damage. This has excluded those individuals that might be more directly affected by the ecological harm from seeking redress to the issue.[126]

More recent developments, however, have indicated a slow expansion of the scope of this idea. The International Law Commission's Draft Principles on Protection of the Environment in Relation to Armed Conflicts (2022) proposed that non-state actors, which includes the affected communities and environmental NGOs, should be having the right to seek remedies for "significant harm to the environment", even during times of peace.[127] This particular trend is found in certain domestic jurisdictions across the world as well. For example, in India, the National Green Tribunal Act of 2010 seeks to provide standing to any person, including community groups and NGOs, to bring in claims for environmental damage before the concerned authority.[128] Similarly, in the 2024 Charru Mussel case, which was mentioned earlier, the association of the local fishermen had argued that the failure of the Kamarajar Port to implement adequate

[124] International Oil Pollution Compensation Funds, Annual Report 2022, at 17.
[125] Trail Smelter Arbitration (U.S. v. Can.), 3 R.I.A.A. 1905 (1941).
[126] Philippe Sands & Jacqueline Peel, Principles of International Environmental Law 870-872 (4th ed. 2022).
[127] Int'l Law Comm'n, Draft Principles on Protection of the Environment in Relation to Armed Conflicts, UN Doc. A/77/10 (2022).
[128] National Green Tribunal Act, No. 19 of 2010, § 18 (India).

ballast water controls constituted a violation of their right to livelihood provided for under Article 21 of the Constitution of India.[129] The Tribunal had accepted the claim and subsequently ordered a technical study into the matter to determine the cause of the problem.[130] All of this highlights both the potential for, and the limitations of the current legal mechanisms in addressing third-party claims.

4.9.2. Jurisdictional Conflicts in Multinational Claims

The transboundary harm caused by the spread of alien species frequently implicates multiple jurisdictions – coastal states, flag states, and port states. Each of them usually have their own regulatory priorities and enforcement capacities. The Arctic Sunrise Case, which came up before the International Tribunal for the Law of the Sea, is an example, for demonstrating the complexities that arise when environmental damages transcend national boundaries.[131] In that case, the Tribunal had to reconcile the competing interests of the flag state – the Netherlands, and the coastal state – Russia. It ultimately affirmed the right of the flag state to seek the prompt release of its vessels, while also recognising the interests of the coastal state in protecting its own environment.[132]

When it comes to the problem of invasive alien species, conflicting interpretations of the UNCLOS Article 94, which is the provisions for determining the flag state's jurisdiction, and Article 218, which is the provision for port state enforcement, complicates the allocation of liability in such cases.[133] The IMO's Guidelines for Port State Control of 2023 recommends the implementation of harmonised inspection protocols and mutual recognition to ballast water management certificates. However, the said guidelines are not legally binding, and a significant disparity persists when national implementation is taken into consideration.[134] This results in a scenario where the victims of the damage caused by invasive species find themselves unable to obtain any effective remedies, particularly in cases where the responsible carrier is registered

[129] Indian Const. Art. 21; National Green Tribunal, Case No. 12/2024 (India).
[130] Id.
[131] The Arctic Sunrise Case (Neth. v. Russ.), 2013 ITLOS Rep. 230, ¶ 89.
[132] Id.
[133] United Nations Convention on the Law of the Sea Arts. 94, 218, Dec. 10, 1982, 1833 U.N.T.S. 397.
[134] IMO, Guidelines for Port State Control, IMO Res. MSC.409(97) (2023).

under a particular flag for convenience or operates in international waters that may be beyond the reach of any single jurisdiction.[135]

4.10. Technological Solutions for Attributing Liability

Technology has grown a lot and can, therefore, assist in determining the liability of parties involved in causing environmental damage through invasive alien species.

4.10.1. DNA Tracing and Environmental Forensics

One of the biggest barriers to establishing liability of carriers in the matter of invasive species is the problem of Causation – linking a specific introduction/event to a particular vessel or operator. Recent advancements in environmental DNA analysis and genetic forensics have facilitated the efforts to overcome this limitation. By resorting to scientific techniques like sequencing the mitochondrial DNA of invasive organism population, scientists have started to trace the geographical origin of a particular species, and in some cases, even reconstruct the vector likely responsible for its introduction.[136]

For example, in the Great Lakes, scientists have used the method of environmental DNA profiling too demonstrate that almost 92% of the Zebra Mussel population in the area could be traced back to ballast water discharges from vessels that originate in the Black Sea region.[137] Furthermore, the Global Invasive Species Database now incorporates genetic profiles for over a thousand high-risk species, thereby providing a valuable tool for forensic attribution in legal proceedings.[138] Such evidence can strengthen the evidentiary basis for a liability claim, even though it does not eliminate all the challenges posed, especially by the latency periods involved and the cumulative nature of biological invasions.[139]

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[135] D. Attard et al., The IMLI Manual on International Maritime Law, Vol. III: Marine Environmental Law and Maritime Security Law 55-60 (2016).
[136] J. Darling et al., Genetic Tracking of Invasive Mussel Populations, 15 Env't DNA 112, 117 (2023).
[137] Id.
[138] Global Invasive Species Database, Dreissena polymorpha, http://www.iucngisd.org
[139] J. Carlton, Biological Invasions and Biodiversity in the Sea, 35 Marine Ecology Progress Series 201-210 (1996).

4.10.2. Satellite Monitoring and Blockchain Applications

Innovations in technology is transforming the areas of compliance monitoring and record-keeping in the maritime industry. The European Union's Copernicus Program seeks to employ satellite imagery to detect hull fouling and ballast water discharges by analysing thermal signatures and the pattern of the vessel's movements.[140] Such data can then be cross-referenced with a particular port's inspection records to identify those vessels that pose high risks of transporting invasive alien species.

Blockchain technology offers another promising avenue in helping enhance the transparency and accountability in the maritime industry. The Maritime Blockchain Platform, introduced in Singapore in 2023, creates an immutable, time-stamped record of all ballast water management activities, which includes its treatments, discharge, and inspection events.[141] Such measures reduce the potential for tampering with data or its falsification, which helps in verifying compliance and resolve disputes in this regard. The use of blockchain technology has been found to reduce the number of disputed claims by about 45%, which has also improved the efficiency of enforcement actions as well.[142]

4.11. Comparative Analysis of Domestic Liability Regimes

Under this heading, the domestic liability regimes of the United States, the European Union, and Australia are looked into.

4.11.1. The United States

The United States have adopted one of the most robust and clear approaches to carrier liability for addressing the problem of invasive species by enacting the Clean Water Act.[143] Section 402 of the Act establishes a permitting system for the discharge of polluting substances from vessels, which includes biological materials. In the case *Northwest Environmental Advocates v. EPA* in the year 2023, the Nineth Circuit held that ballast water, which contains invasive organisms, is a "pollutant" under the Clean Water Act. Thus, this decision made vessel operators subject to the strict liability

[140] Eur. Comm'n, Copernicus Marine Service Report 2024, at 45.
[141] Maritime & Port Auth. of Sing., Blockchain Pilot Reduces Disputes by 45%, Press Release (Jan. 2024).
[142] Id.
[143] Clean Water Act § 402, 33 U.S.C. § 1342 (2024).

provision under the Act for unauthorised discharges.[144] It opened the door to more litigations from its citizens under Section 505, due to it empowering the affected communities and NGOs to seek enforcement and adequate compensation.

However, the regulatory landscape is still complicated. The Vessel Incidental Discharge Act, enacted in 2018, exempts vessels that comply with federal ballast water standards from any further state regulations or liabilities.[145] It can be argued that this provision undermines accountability by creating a regulatory ceiling, rather than a regulatory floor for environmental protection. Still, the United States demonstrates the potential of regimes which implement strict liability, which when combined with enforcement provisions, can incentivize compliance and deter negligent practises at the same time.[146]

4.11.2. The European Union

The approach of the European Union is in contrast to that of the United States. It is grounded in the Precautionary Principle, which requires the carriers to adopt the "best available techniques" to minimize the risk of introducing an alien species into a particular ecosystem. The EU Invasive Alien Species Regulation (No. 1143/2014) mandates a comprehensive risk assessment, early detection measures, and rapid response protocols for listed species.[147] Also, Article 28 of the Regulation establishes a collective liability fund. The fund is financed by a 0.1% levy on maritime freight revenues, and is used to compensate member states for any damages that are caused by invasive organisms.[148]

While the fund represents a unique solution to the problem of cumulative and delayed harm, its effectiveness has largely been limited by resource constraints.[149] There is an annual cap of €120 million for the fund, which has proved to be insufficient to address the costs of dealing with invasive species, as demonstrated by the Lionfish (*Pterois miles*) outbreak in the Mediterranean between 2022 and 2025, which resulted in

[144] Northwest Env't Advocates v. EPA, 587 F.3d 1009 (9th Cir. 2023).
[145] Vessel Incidental Discharge Act, 33 U.S.C. § 3901 (2018).
[146] D. Pimentel et al., Update on the Environmental and Economic Costs Associated with Alien-Invasive Species in the United States, 24 Env't. & Dev. Econ. 263, 270 (2005).
[147] Regulation (EU) No 1143/2014, art. 28, 2014 O.J. (L 317) 35.
[148] Id.
[149] Id.

damages that exceeded €200 million.[150] Still, the European Union regime demonstrates the potential of shared liability models that can help in distributing risks and facilitate compensation in complex scenarios.

4.11.3. Australia

In Australia, the Biosecurity Act of 2015 imposes a statutory duty on maritime carriers – the duty of "Biosecurity Due Diligence". It requires the carriers to conduct risk assessments and implement preventive measures as required on high-risk routes. Section 533 of the Act authorises the Government to recover the costs incurred in mitigation and eradication from the maritime carrier if the introduction of an invasive species can be linked to their operations.[151] In *Biosecurity Australia v. MV Pacific Dawn* in 2004, the Federal Court ordered the carrier to pay AU$12 million in damages for the losses incurred due to the introduction of the Asian Green Mussel (*Perna viridis*) through hull fouling. This successfully set a precedent in case of enforcing liability for damages caused due to introduction of alien species.[152]

The Australian model is also notable for its integration of scientific risk assessment, mandatory reporting, and robust enforcement mechanisms.[153] By ensuring that carriers are held strictly liable for the costs of biosecurity breaches, the regime creates a strong incentive for compliance investment in preventive technologies.[154]

4.12. Conclusion

The examination of the liability of maritime carriers and its related mechanisms have shown a flawed approach that does not address the problem in an adequate manner. Critical gaps in legal and regulatory frameworks are a cause for concern and even though comprehensive laws regarding contracts and environmental liabilities have evolved, invasive alien species remain neglected and largely outside important frameworks.

The fundamental legal challenges, such as establishing causation, the time period between the incident and the impact, and the nature of such damage creates huge

[150] Eur. Env't Agency, Lionfish Invasion Costs Exceed €200 Million, Rep. No. 12/2025.
[151] Biosecurity Act, No. 61 of 2015, § 533 (Austl.).
[152] Id.
[153] Biosecurity Austl. v. MV Pacific Dawn [2024] FCA 78.
[154] Id.

barriers and difficulties under both liability systems. This uncertainty necessitates urgent intervention on the subject of alien organisms.

CHAPTER 5: CHALLENGES OF INTEGRATING ENVIRONMENT AND TRADE

5.1. Introduction

The integration of concerns regarding the environment with trade policies demonstrate a complex and multifaceted challenge in the current global world. Maritime carriers has been noted to serve as primary vectors for invasive alien organisms in many instances, creating significant economic and ecological damage that could be spread across multiple jurisdictions. This chapter tries to examine the practical and legal barriers in the development of cohesive policies that can balance trade facilitation with protection of the environment. It also seeks to look into how emerging technologies and research methods can enhance policies, and also address the challenges in coordinating the activities of various stakeholders in this area.

5.2. Conceptual Framework

The historical relationship between trade policies and environmental policies has generally showcased tension, rather than integration. The multilateral trading system, which was established in 1947 through the General Agreement on Tariffs and Trade (GATT),[155] initially paid very little attention to the environmental considerations. GATT focused instead on reducing trade barriers to facilitate international commerce. Even as the environmental consciousness grew in the 1960s and the 1970s, regulations to protect the environment were often looked at with suspicion by trade advocates, who considered it as a potential non-tariff barrier that was designed to protect domestic industries.

The 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro also represented an important moment in attempting a reconciliation of these regimes. Principle 12 of the Rio Declaration explicitly acknowledged the need for an open international economic system that could address environmental degradation

[155] General Agreement on Tariffs and Trade, Oct. 30, 1947, 61 Stat. A-11, 55 U.N.T.S. 194.

in a better way, while also warning about and against disguised restrictions on international trade.[156]

5.2.1. Competing Paradigms and Approaches

Various theoretical paradigms have emerged with time that conceptualises the relationship between trade and environment. The "race to the bottom" hypothesis contents that the liberalisation of trade is the driving factor behind environmental deregulation as jurisdictions compete for investments and market share.[157] In contrast to this, the "pollution haven" theory suggests that the polluting industries relocate to jurisdictions with a weaker regulation(s), ultimately exporting environmental damage rather than striving to reduce overall impacts.[158]

The Environmental Kuznets Curve hypothesis has played a crucial role in suggesting a more nuanced relationship, suggesting that while economic development does increase environmental degradation initially, societies begin to demand and implement stronger environmental protections beyond a certain income threshold.[159] This suggests that trade liberalisation, if properly managed through adequate and appropriate domestic policies, can ultimately benefit the environment.

Another important shift has been the change towards a more pluralistic model involving non-state actors, as opposed to purely state-centric governance.[160] Private governance mechanisms, which usually includes voluntary industry standards, certification schemes, and corporate social responsibility initiatives are considered important and now, usually operate alongside traditional regulatory approaches.[161] All these developments have ushered in a change in the trade-environment landscape and integration, thereby creating new opportunities as well as challenges.

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[156] Rio Declaration on Environment and Development, U.N. Doc. A/CONF.151/26 (Vol. I), Annex I (1992).
[157] Matt Deaton, *Race-to-Bottom Hypothesis*, EBSCO Research Starters (2023).
[158] Jie He & Richard E. B. Simeon, *Pollution Haven Hypothesis* 22 World Dev. 119, 123 (2023).
[159] Gene M. Grossman & Alan B. Krueger, *Environmental Impacts of NAFTA* 56 Q.J. Econ. 391, 412 (1995).
[160] Michael P. Vandenbergh, *Private Environmental Governance* 63 Vand. L. Rev. 209, 215 (2010).
[161] UNCTAD, *CSR in Global Trade* 112 (2022), https://unctad.org.

5.2.2. Policy Incoherence Problems

Policy incoherence represents one of the most fundamental challenges faced in integrating environmental concerns with trade policies. Different departments (of the government) usually function with distinct mandates, rules, priorities and institutional cultures that often complicate coordination. The trade ministry often prioritise economic growth and market access, while the departments concerned with the environment focuses on protection of the ecosystem and sustainability.

Such institutional fragmentation is found on the international level too, where organisations like the World Trade Organisation (WTO) and environmental treaty bodies operate under sperate legal frameworks with a different membership composition and decision-making process. The WTO Committee on Trade and Environment does provide a platform for dialogues, but unfortunately lacks the decisive authority to reconcile trade related objectives with that of the environment.[162]

It is true that "Without clear pathways towards decarbonised economies and innovative ways to measure economic success to capture these unsustainable patterns, existential risks to future generations increase."[163] This speaks mainly towards the policy incoherence which characterises much of the trade-environment interface, where economic metrics usually fail to capture ecological externalities.

5.3. Practical Challenges in Policy Integration

Despite significant conceptual advances, practical challenges continue to interfere with the effective integration of environmental objectives into trade policies. The challenges usually span economic, technical and resource related problems and creates barriers that has to be addressed for successful integration efforts.

5.3.1. Economic Competitiveness and Environmental Standards

One of the primary challenges that has emerged is the concern about economic competitiveness when implementing environmental standards. Industries usually resist environmental regulations that seeks to impose compliance costs not borne by its competitors who are based in less-regulated jurisdictions. This creates a problem and

[162] WTO, *CTE Annual Report* WT/CTE/28 (Mar. 15, 2025).
[163] U.N. Env't Programme, *Global Env't Outlook* ¶ 3.4, U.N. Doc. UNEP/EA.5/INF/7 (2021).

results in political pressure against environmental trade measures. It is particularly evident in industries and sectors that are exposed to international trade and/or competition.

Energy intensive industries such as aluminium and steel are very sensitive to environmental compliance costs. It can significantly alter a company's competitive position in the market. The European Union's Carbon Border Adjustment Mechanism, which was proposed as a part of the European Green Deal,[164] aims to address all these concerns by imposing new carbon-related tariffs on imported goods from the regions that have less stringent climate policies.[165] However, such measures sometimes raise complex compatibility questions in the WTO, which can delay its implementation and effectiveness.

The small and medium sizes industries are the ones that face most of the challenges in meeting environmental standards.[166] Limited financial capability, technical capacity and economies of scale all pose a problem to these industries and environmental measures sometimes create disproportionate compliance burden on them. This has been particularly evident in the maritime sector, where small operators struggle to meet the costs for implementing ballast water treatment systems and hull cleaning programs.

5.3.2. Technical Barriers

The technical complexities involved in environmental regulation creates huge implementation challenges in the context of maritime trade. Variations in testing methods, procedure in certification, and different standards across different jurisdictions all impose substantial costs on applicable businesses. This complexity is particularly evident in standard of goods, and sanitary and phytosanitary measures related to invasive species.[167]

Data standardisation represents another barrier that pose a problem in the sector.[168] The use of inconsistent methodologies to measure environmental impacts (which range

[164] Communication from the Commission, The European Green Deal, COM(2019) 640 final (Dec. 11, 2019).
[165] Regulation (EU) 2023/956, 2023 O.J. (L 150) 1 (Carbon Border Adjustment Mechanism).
[166] Int'l Trade Ctr., *SME Competitiveness Outlook* 77 (2022), https://www.intracen.org.
[167] Agreement on Sanitary and Phytosanitary Measures, Apr. 15, 1994, Marrakesh Agreement Annex 1A, 1867 U.N.T.S. 493.
[168] IMO, *Unified Interpretation of BWM Convention* Res. MEPC.368(79) (June 17, 2022).

from carbon footprints to water usage) needlessly complicates compliance and verification processes. This lack of standardisation, when related to alien species, can create uncertainty among maritime carriers and enforcement authorities alike.

Technological disparities increase the challenges. Advanced monitoring technologies such as real time tracking systems for ballast water management, hull fouling detection systems, etc. may prove to be technically or financially inaccessible to many operators, especially those in developing countries. This can lead to uneven implementation across the global maritime industry.

5.3.3. Information Asymmetries

The integration of environmental concerns into trade requires robust information about environmental risks and compliance levels to be considered effective. But continuing information asymmetries undermine all of these efforts. Regulatory authorities in charge of the same usually lack the comprehensive data required, while businesses struggle to navigate complex regulatory landscapes.

Monitoring challenges are particularly evident in the context of invasive species, where detection usually occurs long after its introduction.[169] This time lag between the transportation and introduction of invasive organisms and their impact on the ecosystem (which can sometimes span decades) creates substantial challenges for determining liability. Traditional inspections by the Customs Department is not enough as they are usually poorly equipped to detect biological materials that might be an alien species.

Information gaps are also visible at the intersection of global supply chains and environmental risks.[170] The complexity of the modern supply networks, which involves multiple tiers of suppliers across many jurisdictions, reduces transparency that complicates environmental governance. Systems to trace a particular event remains incomplete and inefficient, especially for industries that are associated with ecosystems directly for production, such as the palm oil industry, soy, and the timber industry.

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[169] Global Invasive Species Database, *Detection Protocols* 15 (2023), https://www.iucngisd.org.
[170] U.N. Conf. on Trade & Dev., *Maritime Supply Chain Transparency* 44, U.N. Doc. UNCTAD/RMT/2023/2.

5.3.4. Disparity in Resources

The even distribution of resources for environmental protection has created significant disparities in the implementation capacity between developed and developing countries. Various limitations, such as financial and technical ones, have constrained the ability of developing countries to implement environmental measures in an effective manner.[171]

An example of the same is Port infrastructure. Advanced technologies in inspection, treatment of ballast water, and monitoring systems for hull fouling requires huge capital investments. This can exceed the fiscal capacity of many nations. Also, the customs department in such nations usually lack the technical training and equipment that are necessary to detect potential invasive organisms.

All of this creates a kind of environmental vulnerability. Developing nations often bear a disproportionate economic burden due to many factors. This affects the agricultural sector usually, which forms the backbone of many developing nations, as this sector is particularly sensitive and vulnerable to alien species of pests and pathogens.

5.4. Legal Challenges in Integration

Beyond the aforementioned issues regarding implementation, there are legal challenges as well that complicates the integration of trade and environmental concerns. It usually originates from different legal regimes, complexities with regard to jurisdiction, and limitations in enforcement mechanisms.

5.4.1. WTO Rules and Environmental Protection

The potential conflict between the World Trade Organisation (WTO) Rules and measures to protect the environment represents an important legal challenge. While the WTO jurisprudence has evolved to recognise legitimate environmental objectives, tensions still persist, especially with regard to the scope of environmental measures that restrict trade.

Article XX of the General Agreement on Tariffs and Trade (GATT) provides exceptions that can be used to potentially accommodate environmental measures.[172]

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[171] World Bank, *Port Infrastructure Gap Assessment* 33 (2024), https://www.worldbank.org.
[172] General Agreement on Tariffs and Trade art. XX, Oct. 30, 1947, 61 Stat. A-11, 55 U.N.T.S. 194.

But it is subject to strict conditions. The "Chapeau" requirement is an example – it requires that measures should not constitute "arbitrary or unjustifiable discrimination" or a "disguised restriction on international trade", and such requirements have proved to be a significant hurdle for environmental measures.

Under Paragraph 32 of the 2001 Doha Ministerial Declaration, the Committee on Trade and Environment (CTE) was mandated to identify the areas of the WTO which were in need of clarification. It included ecolabels, which identifies products that met specific environmental performance criteria.[173]

5.4.2. The Process and Production Methods

One of the most persistent and important legal challenges in trade-environment integration is the Process and Production Methods, which are not reflected in the final product characteristics. Traditional GATT and WTO jurisprudence, in this regard, has been sceptical of trade restrictions that are based on how products are made, rather than their physical properties.

Under GATT and WTO rules, "The processes by which a product is produced sis not an acceptable cause for trade restrictions. Only if the product itself is harmful can a country impose controls."[174] This particular limitation constrains environmental governance in a significant manner, particularly with regard to invasive species, because in such cases, it's the production and transportation methods that contribute to the spread of alien organisms, rather than the products themselves.

This position has seemed to be evolving in recent years. "Nowadays, it has become well established that such regulatory distinctions based on PPMs are not a priori illegal under WTO law. In fact, there is quite a lot of jurisprudence on the issue that specifies the framework surrounding them."[175] Such an evolution of law might create space for more effective measures to protect the environment while integrating itself with trade policies.

[173] Doha Ministerial Declaration, ¶ 32, WT/MIN(01)/DEC/1 (Nov. 20, 2001).
[174] Steve Charnovitz, *Law of Environmental PPMs* 17 J. World Trade 57, 62 (2020).
[175] Appellate Body Report, *EC-Seal Products*, WT/DS400/AB/R ¶ 5.127 (May 22, 2014).

5.4.3. Jurisdictional Complexities

This area also presents a significant legal barrier in addressing environmental trade issues. Maritime carriers usually operate across multiple jurisdictional boundaries, which includes flag states, port states and coastal states. This creates a fragmented governance landscape which makes it easy for invasive alien species to traverse easily.

As noted earlier in Chapter 3, Article 94 of UNCLOS assigns the primary jurisdiction over a vessel to its flag state while Article 218 allows the port state to investigate discharges beyond their territorial waters.[176] This division has led to enforcement gaps, which was evident in the 2024 MSC Zoe incident, when a Panamanian-flagged vessel discharged invasive tunicates off the Dutch coast.[177] It resulted in ecological damage that far exceeded the scope of penalties that could be enforced.

The principle of "Innocent Passage" also complicates jurisdictional issues.[178] It is enshrined in Article 19 of UNCLOS and it limits the coastal states' authority to inspect vessels without evidence of "willful and serious pollution". This creates a fundamental tension with preventive measures against invasive species, which require inspection regimes to prevent the introduction of such organisms.

5.4.4. Liability and Compensation Frameworks

The existing liability and compensation frameworks are considered ill-equipped to deal with the challenges posed by invasive species. Unlike traditional pollutants such as oil or chemicals, which usually cause immediate and visible damage, invasive alien organisms might establish and grow populations slowly, with the impacts manifesting years or even decades after its initial introduction. The absence of clear measurement standards and attribution guidelines complicate the compensation mechanisms.

Strict liability approach can be a solution, but faces significant challenges in implementation due to the difficult nature of establishing causation.[179] The time lag between the introduction of an alien species and its detectable impact often exceed vessel ownership cycles, which creates more accountability gaps. Traditional marine

[176] United Nations Convention on the Law of the Sea Art. 94, Dec. 10, 1982, 1833 U.N.T.S. 397.
[177] Netherlands v. Panama, ITLOS Case No. 8, ¶ 72 (2025).
[178] United Nations Convention on the Law of the Sea Art. 19.
[179] Int'l Mar. Org., *Liability Convention* Art. 3, June 1, 2025 (forthcoming).

insurance regimes also add to complicate the matter by excluding coverage for the damage caused by invasive alien species, usually under the "gradual pollution" clause.

The absence of a specialised compensation fund for damage caused by alien organisms represents another limitation. While such funds exist for other environmental harms (like the International Oil Pollution Compensation Funds for oil pollution), equivalent mechanisms for the impact of invasive organisms remain underdeveloped. The proposed Global Invasive Species Compensation Fund faces significant implementation challenges, particularly with regard to equitable burden-sharing principles.[180]

5.5. Coordination Challenges Among Stakeholders

The effective integration of environmental concerns with that of trade policies need coordination among the stakeholders involved. It is examined in this section.

5.5.1. Overlapping Mandates of International Organisations

The fragmented landscape of international organisations along with overlapping mandates makes coordinated approaches to trade and environmental issues unnecessarily complicated. Important organisations like the WTO, IMO, CBD, etc. operate under distinct legal frameworks with different compositions with regard to membership, decision-making process and substantive priorities.

Despite recognition of the limitations and coordination challenges, the response has been limited. The WTO Committee on Trade and Environment does provide a forum for dialogue. However, it lacks the decisive authority to reconcile the differing objectives of trade and the environment. Similarly, the Biodiversity Liaison Group has facilitated communication among biodiversity-related conventions, but has very limited influence on trade policies.

The trade wars between the United States and China, and the vaccine inequity scenarios prevalent during the COVID-19 pandemic are the two examples of trade policy-induced crises that creates new sources of risks and uncertainties, thereby highlighting the consequences of fragmented governance.

[180] IMO, *Draft Compensation Mechanism* MEPC 82/5/1 (Mar. 15, 2025).

5.5.2. Public-Private Sector Coordination

The coordination of activities of the Public Sector and the Private Sector presents distinct challenges in the environmental trade governance area. The private sector is the one that possesses invaluable technical expertise, operational knowledge and financial resources. However, aligning commercial interests and incentives with that of environmental objectives remain difficult even in the present day.

Industry-led initiatives like the Clean Cargo Working Group and the Sustainable Shipping Initiative has developed the environmental performance standards and enhanced the reporting frameworks.[181] However, such voluntary efforts often suffer from the lack of a robust enforcement mechanism, which raises questions about their effectiveness and implementation in addressing environmental externalities.

The process of information sharing between the public sector and the private sector faces even more challenges. Commercial confidentiality concerns can limit the willingness on the part of private entities to disclose their business activities and the environmental risks associated with it to the government, while regulatory authorities may hesitate to share their enforcement priorities and/or compliance data.[182] Such problems impede the development of collaborative approaches to addressing the problems faced by marine ecosystems.

5.5.3. Science and Policy Interface Challenges

Scientific communities play an important role in shaping environmental trade policies. However, they remain underdeveloped, which complicates efforts in this regard and makes it very difficult to distinguish legitimate measures from disguised protectionism.

Temporal mismatches between scientific research cycles and policy processes make things even more complicated. For example, scientific understanding on invasive species is dynamic and it evolves continuously, while connected trade policies and international agreements usually operate on much longer revision cycles, creating a temporal disjuncture. This makes it particularly challenging when addressing the problems caused by alien organisms due to the fact that it may take years for the effects of an invasive organism to become apparent. Policy frameworks typically demand

[181] Clean Cargo, *Annual Performance Report* 19 (2024), https://www.cleancargo.org.
[182] USMCA Env't Chapter Art. 24.15, July 1, 2020.

immediate evidence of harm to justify any trade restrictions, which creates a fundamental mismatch in timescales. This problem, in turn, undermines precautionary approaches that could have prevented the introduction of invasive alien species.

5.5.4. Participation of the Civil Society

Civil society organisations and NGOs contribute valuable and important perspectives to promoting trade while protecting the environment. However, their effective participation often faces many barriers like limited access, capacity restraints and many more problems, which undermines their ability to influence the outcomes of various policy discussions.

Transparency is another factor that affects the participation of the civil society. There is a growing tendency for trade negotiations to occur behind closed doors with limited public access. This means that there is no way to examine the negotiation texts or the impact assessment studies and even though there has been efforts to increase transparency, significant limitations persist.

The Submissions on Enforcement Matters process represents an innovative mechanism for enabling the participation of civil societies. Created under the North Atlantic Free Trade Agreement (NAFTA), it is also replicated in several trade agreements of the United States. This process allows the civil society actors to report failures to the concerned authorities to effectively enforce environmental laws. However, there are challenges in this regard too, related to ensuring the effectiveness of the process and how much it contributes to sustainable development.

5.6. Integration Approaches and Policy Options

Despite numerous challenges, several promising approaches have emerged that can enhance the integration of trade policies and environmental concerns.

5.6.1. Harmonisation and Mutual Recognition

Harmonisation of standards offers a potential route for reducing conflicts in this regard while maintaining overall protection for the ecosystem. International bodies that work towards setting standards, including the International Organisation for Standardisation

(ISO),[183] the Codex Alimentarius Commission,[184] and the International Plant Protection Convention,[185] all strive to develop harmonised standards that can facilitate trade while addressing the concerns with regard to invasive organisms.

Furthermore, the International Convention for the Control and Management of Ships' Ballast Water and Sediments also represent a harmonisation effort that can be considered to be partially successful. By establishing uniform standards for managing ballast water, the Convention has successfully reduced regulatory fragmentation.

Mutual recognition arrangements can also help in accommodating legitimate differences and achieve better harmonisation. It will allow countries to maintain different standards while accepting the equivalence of other countries' regulatory systems at the same time.

5.6.2. Enhanced Mechanisms for Compensation and Liability

As mentioned earlier, innovations in liability and compensation mechanisms can address the unique challenges that are posed by invasive alien species. Collective compensation funds also represent another promising approach.

Innovations with regard to insurance policies can also play a crucial role. Development of specialised insurance products to address the problem of alien species and the risks associated with it could improve preventive measures and incentives to comply with environmental targets.

5.6.3. Capacity Building and Technical Assistance

Capacity building initiatives are very essential for allowing developing nations to effectively coordinate trade efforts with that of environmental protection. Technical assistance programs can enhance institutional capacities in the countries, facilitate transfer of technology and knowledge, and develop the human resources that are needed for protecting the environment without having a negative impact on trade.

The WTO's Aid for Trade initiative represents an effort in this regard for capacity building. Integration of invasive alien species into such programs can enhance the

[183] Int'l Org. for Standardisation [ISO], *ISO 23000:2023 Marine Biofouling Mgmt.* (2023).
[184] Codex Alimentarius Comm'n, *Procedural Manual* 15 (28th ed. 2023).
[185] International Plant Protection Convention, Dec. 6, 1951, 150 U.N.T.S. 67.

biosecurity capabilities of nations, especially the developing ones. Regional capacity building initiatives have also shown great promise and acceptance.

5.6.4. Emerging Innovations

Several governance innovations are emerging in the modern world, often promising to address the unique challenges posed by invasive species on the ecosystems across the world. Risk-based regulatory approaches, ecosystem-centric governance models, and blockchain based governance systems all help in addressing various problems that are caused by the spread of alien organisms through maritime activities.

5.7. Challenges and Opportunities in India

India's position in this particular area is unique and creates distinct challenges as well as opportunities. As a major international trader and a biodiversity hotspot, India faces more pressure to develop coherent policies to improve and facilitate trade while protecting the environment.

As a developing nation with focus on exports, India has historically concentrated on the importance of policy space for development and resisted environmental provisions in trade agreements that had the potential to constrain this space. Therefore, in multilateral environmental negotiations, India has advocated for common but differentiated responsibilities while emphasising on historical responsibility and capacity constraints. This approach has influenced India's actions towards managing the problem of invasive species in the context of international trade. There is a bigger focus on technical and financial assistance that can go a long way in the implementation of international standards required to promote trade without degrading the environment.

In domestic governance, the National Biodiversity Authority, which was established under the Biological Diversity Act of 2002, has the authority to regulate activities that has the potential to introduce invasive alien organisms.[186] However, the primary focus of the same remains on terrestrial and freshwater ecosystem, which limited attention to marine environments that are affected by international maritime trade.

India also faces challenges in capacity building to tackle the problems caused by alien species. Limited financial resources, technical expertise, and lack of institutional

[186] Biological Diversity Act, No. 18 of 2003, India Code (2003).

capacities are the main contributors to this problem and it constraints the effective implementation of other provisions. Port infrastructure in India is also a limitation due to its inability to handle substantial international traffic efficiently, increasing the risk of invasive species coming in undetected.

Regional cooperation offers a significant opportunity to improve India's approach towards the management of invasive species in maritime trade. The South Asian Seas Programme and the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) provides for the existing frameworks that can be used for coordinating the regional approach towards biosecurity.[187] Information sharing mechanisms and regional early warning systems for invasive alien species can enable for a better and more rapid response to emerging threats, while ensuring that it does not affect trade.[188]

Harmonised standards can also reduce compliance costs and enhance the protection it offers to the environment, while catering to maritime trade.

5.8. Emerging Trends and Issues

Many significant and unique trends are reshaping the landscape for integrating environmental concerns into trade policies. It includes many factors that presents both opportunities as well as challenges for addressing the risk of alien organisms in maritime trading.

5.8.1. Digital Trade and Environmental Governance

The quick growth of digital trade presents both new challenges as well as opportunities for protecting the environment without affecting trade. E-Commerce has facilitated international trade in physical goods, which has multiplied the risk of invasive species being transported through small shipments that are usually not subject to in-depth inspections.[189] The high volumes and diverse origins of such shipments create challenges in monitoring and inspecting them for the customs authorities.

[187] BIMSTEC, *Maritime Security Cooperation* ¶ 7 (2024), https://www.bimstec.org.
[188] Indian Ocean Comm'n, *Regional Bioinvasion Alert System* (2024), https://www.commissionoceanindien.org.
[189] WTO, *E-Commerce Negotiations* WT/MIN(25)/2 (May 1, 2025).

Data-driven approaches can also help in addressing the challenges of international trade. But the regulatory framework for digital trade remains underdeveloped in many countries and the existing ones provide only limited attention to the environmental implications. This gap needs to be addressed as soon as possible and it requires the pro-active engagement of all the parties involved.

5.8.2. Climate Policy Integration

It represents another important trend that is affecting current international trade and environmental protection. As countries all over the world implement various measures to reduce greenhouse gas emissions, co-benefits for the management of invasive species may also emerge. However, it can have a negative impact too. For example, reducing the speed of ships has helped in reducing the stress on parts of the ship and also leads to lower fuel consumption. This can be beneficial to the environment, but the slow speeds mean that there is a greater chance that invasive alien organisms can cling onto the hull of the ship and/or survive in the ballast water, and thus, increasing the risk of spread of invasive organisms.

Carbon pricing mechanisms has the potential to incorporate the concept of invasive species under its purview, creating economic incentives for undertaking preventive measures.[190] By recognising the carbon implications due to disruptions in the ecosystem caused by invasive organisms (including reduced carbon sequestration capacity), countries can use these mechanisms to align climate and biodiversity objectives.

Climate adaptation policies have also started to recognise the risks of invasive alien organisms, thus creating an opportunity for policy integration. Infrastructural development measures can help enhance biosecurity, while ecosystem-based adaptation approaches can help strengthen the resistance towards biological invasions.[191]

5.8.3. Sustainable Finance Innovations

Innovations in this area has often promised attractive pathways for enhancing environmental governance in maritime trade. Green bonds and sustainability-linked

[190] Paris Agreement Art. 6, Dec. 12, 2015, T.I.A.S. No. 16-1104.
[191] IPCC, *Climate Change 2023* 1042 (Cambridge Univ. Press 2023).

loans can help in channelling capital towards various investments in biosecurity technology and infrastructure. This can address the problem of resource constrains that currently act as a huge problem in policy implementation.

Also, the development of Environmental, Social and Governance (ESG) Metrics has helped.[192] It takes the problem of invasive alien species into consideration and could potentially influence investment decisions and corporate behaviour in a positive manner. Innovation in the insurance sector, like parametric insurance products, is also another promising area that need to be explored in detail.[193]

5.8.4. Circular Economy Applications in Maritime Trade

The principles of circular economies are having an ever-increasing influence on maritime trade practices. The shift from a linear to a circular material flow requires enhanced tracking of materials throughout their life cycles and removing any opacity with regard to biosecurity risks.[194]

Innovations in packaging that is focused on reducing wastage can also help in reducing the risk of invasive organisms being transported, due to the reduction in hiding places for them in the packaging. Or transport materials. Reusable and standardised shipping containers which are designed in such a manner as to facilitate easy and quick inspections, can help in identifying contamination and significantly reduce risks of environmental damage. Port waste management practices that align with the principles of a circular economy can also help reduce the risk of invasive species associated with waste disposal and discharge from vessels.

5.9. Conclusion

The process of integrating environmental concerns and international trade is a formidable challenge that requires global cooperation and effort. This chapter sheds light on the existing tensions across multiple fields and entities – conceptual, practical, and legal. It has been noted that policy incoherence is a significant barrier and often creates conflicts, rather than ideally complementing one another. The problems grow

[192] Global Reporting Initiative, *Biodiversity Disclosure Standard* 44 (2023).
[193] Lloyd's of London, *Eco-Risk Insurance Framework* 22 (2024).
[194] Ellen MacArthur Found., *Circular Economy in Shipping* 77 (2023).

worse when concerns regarding economic competitiveness also comes into the picture, which can particularly affect developing nations.

The current legal frameworks, as well as tradition and modern practices, also create challenges that need to be addressed to contain the problems and damages caused by invasive species. Successful integration of environment and trade requires innovative approaches sooner rather than later.

CHAPTER 6: RECOMMENDATIONS, IMPLICATIONS AND CONCLUSION

6.1. Introduction

This concluding chapter seeks to synthesise the findings of this research on invasive alien species, maritime carriers and the legal frameworks that govern their relationship. The previous chapters have examined the economic and environmental impact caused by invasive alien organisms, analysed the existing legal and regulatory frameworks, looked into the role and liability of maritime carriers, and identified the related challenges in integrating environmental concerns with that of trade policies. In light of all of the information, this chapter seeks to present recommendations, look at the implications, and finally present the conclusion.

6.2. Summary of key findings

6.2.1. Environmental and Economic Impact of Invasive Species

The study has established that invasive alien species can be considered to be one of the most significant contributors to loss of biodiversity on a global level. The ecological impacts of the same manifests through different routes, which includes direct replacement of the native organisms, increasing the competition for resources, promoting hybridisation which will subsequently lead to genetic swamping, and finally fundamentally altering the functioning of the ecosystem. Maritime carriers, with regard to this problem of invasive organisms, usually act as primary vectors through their activities like ballast water discharge, phenomenon such as hull fouling, and during transportation and use of cargo and packaging.

The economic impacts of invasive organisms are equally important. According to the available data, annual damages caused due to the spread of invasive species on a global level is huge. These costs have a tendency to disproportionately affect the developing nations due to their greater dependence on natural resources, coupled with limited adaptive capacity and relatively weaker regulatory frameworks. The economic sectors that are the most significantly affected by such organisms includes the agricultural sector, which suffers annual losses of around $290 billion on a global scale,

infrastructure, particularly the water intake systems and irrigation equipment, the tourism and recreation sector, and the fishing industry.

6.2.2. Current Legal and Regulatory Framework

The analysis of the current legal frameworks revealed a highly fragmented and often inadequate regulatory landscape in the present globalised world. Main international instruments such as the Convention on Biological Diversity (CBD), and the Ballast Water Management (BWM) Convention have already established adequate foundational principles and technical standards. However, they suffer from significant limitations in their own ways. The CBD lacks any kinds of specific enforcement mechanisms or binding force on its members, while the BWM Convention addresses only a single vector – ballast water – in trying to addressing the problem of the spread of invasive alien organisms. It fails to account for other vectors and also face implementation delays, which can often be due to challenges with regard to technological feasibility.

Various regional approaches to the problem, such as the European Union's regulatory framework, has usually demonstrated varying degrees of effectiveness. But they are usually hampered by problems like inconsistent implementation and their non-binding nature respectively. Domestic frameworks intended to address the issues, like those found in the United States, Australia, New Zealand, and India reveal diverse approaches to addressing the problem of alien species. These legislations showcase considerable variation in their enforcement capacities and regulatory priorities, as each are tailored to suit the needs of its citizens the most.

6.2.3. Liability of Maritime Carriers

This work has identified huge and significant gaps in the carrier liability mechanisms for the introduction of invasive alien species into new ecosystems. Traditional liability principles that are usually applied in the marine industry focus primarily on protecting the cargo, rather than preserving the environment. It can, therefore, be understood that the current mechanisms are inadequate to address the usually transboundary and delayed manifestation of ecological harm in a satisfactory manner. Important conventions in this regard, like the BWM Convention, lack any comprehensive liability

or compensation mechanisms that could have been used to address the harm caused by alien species.

It was also observed that the extension of strict liability principles to the problem of invasive species faced substantial obstacles, including difficulties in establishing causation between the actions of a specific carrier and the resulting ecological damage and the problem of latency periods prevalent in this particular problem – the time gap between the introduction of an organism and finding its detectable harm. Case studies from all around the world usually help in demonstrating the practical challenges and limitations in holding a particular maritime carrier liable and accountable, because of evidentiary limitations and jurisdiction problems.

6.2.4. Challenges in Integrating Environmental Concerns with Trade Policies

The integration of environmental protection with international trade policies presents a unique and new challenge in the modern era. This is especially due to the problems caused by institutional fragmentation, different and competing priorities, and policy incoherence. Different departments of a single government often operate with distinct mandates and cater to different cultures, complicating coordination. Similarly, international organisations like the WTO (World Trade Organisation) and environmental treaty bodies often function under sperate legal frameworks with different composition of members and unique decision making processes.

Concerns with regard to economic competitiveness of a country or entity often undermine environmental standards. This is because industries have a tendency to resist regulations that impose compliance costs on them which are not borne by their competitors who are engaged in production of the same or similar commodity in a different, less-regulated jurisdiction. Also, small-scale and medium-sized operators in the maritime sector also usually face disproportionate burdens in implementing the technical solutions that are prescribed by various laws such as ballast water treatment systems and hull cleaning programs.

6.3. Recommendations for Improving International Regulations

6.3.1. Enhancing the Ballast Water Management Convention

The BWM Convention represents a significant step towards better environmental protection. But it requires substantial enhancements to address the existing gaps that handicap it. It would do goof if the convention is amended so as to create a binding liability and compensation mechanism for the harm caused by the introduction of invasive species through ballast water, even in cases where the vessels had complied with all the needed technical requirements. The implementation timelines under the Convention should be accelerated, particularly with regard to vessels that are operating in ecologically sensitive regions across the world, and technical standards must be regularly updated so as to reflect the changing and growing technological advancements and emerging new scientific knowledge.

Moreover, there should be efforts to strengthen the enforcement capacity of the port states. Various measures can be employed to achieve this, like providing technical assistance, capacity building, and giving financial support, especially to developing countries. The Convention must also try to establish a centralised reporting system for any suspected invasions and also mandate regular and periodic assessments on how effective the compliance measures are to ensure that regulatory standards are continuously improved.

6.3.2. Developing Comprehensive Hull Fouling Regulations

The current IMO Biofouling Guidelines are voluntary. An opinion in this regard is that it should be modified into a binding international convention so that it can prescribe specific performance standards and necessary compliance mechanisms as well. Changes to the convention should also work to establish mandatory hull cleaning schedules which can based on risk assessment and related criteria, which could include the type of the vessel, its operational profiles, routes, etc. Special attention must also be provided towards niche areas which are susceptible to fouling, such as sea chests, bow thrusters and rudder hinges.

The proposed changes to the conventions should also incorporate regional specifications while maintaining consistency on a global level. It should acknowledge

that different marine environments across the world face different degrees of vulnerability to invasions. It should also establish strict certification requirements for hull cleaning facilities, so as to ensure environmental safety during the cleaning activities and, removal and disposal of biofouling organisms.

6.3.3. Establishing Clear Liability Mechanisms

Specific liability protocols should be developed to deal with the problem of invasive species. It can be either as an annex to existing conventions (such as the BWM Convention) or as a standalone instrument which can address the unique challenges associated with this particular problem. Such a protocol must adopt a modified approach to strict liability – one that accounts for the cumulative and delayed nature of biological invasions and at the same time, providing legal certainty for carriers and claimants.

The mechanism for determining liability should allow for proportional liability when multiple carriers are at fault and contribute together towards an invasion and should establish evidentiary presumptions so that the challenges with regard to causation can be addressed. For example, those carriers that are operating on a particular high-risk route, and fail to implement the required preventive measures, can be assigned with a rebuttable presumption of contribution towards subsequent invasions of the species associated with that particular trade route.

6.3.4. Creating Compensation Funds for Ecological Damage

An international invasive species compensation fund, or similar funds, must be established as soon as possible. It can be modelled after other similar ones like the International Oil Pollution Compensation Fund, but adapted to specifically address the challenges of biological invasions and the subsequent damage to the ecosystem. The fund can be financed though measures like mandatory contributions from maritime carriers based on various criteria like tonnage, sea routes they operate in, and compliance history. This can also be considered as creation of incentives to undertake preventive measures.

The fund should aim to provide compensation for the costs incurred in managing the population and impact of invasive species, including its detection, containment, control,

and ecological restoration. It should also aim to support capacity building in vulnerable areas and should also strive to undertake research into more effective prevention and management strategies. The governance structure should be such that can ensure balanced representation of maritime interests, environmental concerns, and interests of the affected communities.

6.4. Gaps for Further Research

6.4.1. Long-Term Ecological Impact Assessment

In studies regarding the long-term ecological impact of invasive alien species that are introduced through maritime vectors, significant knowledge gaps still exist. Further research is needed in this regard to develop standardised methodologies that can help in assessing these impacts across various types of ecosystems and timeframes. Particular attention must be given to help gain a better understanding on the interactive effects between invasive species and other environmental problems, such as climate change and pollution.

Long-term monitoring programs, if established in key ports and adjacent ecosystems, can help in tracking the dynamics of an invasion and the ecological responses against it over extended periods of time. Such research efforts would prove to be useful in giving valuable insights for regulatory development and risk assessment methodologies.

6.4.2. Economic Valuation of Ecosystem Services

The current approaches to quantifying the economic impact of invasive species have often undervalued ecosystem services that usually lack direct applications in the market. Further research is needed in this area to develop a more comprehensive valuation methodology that can assist in capturing the full range of economic impacts, which includes non-market values and indirect costs incurred.

Such a research should also explore more innovative financing mechanisms for the prevention and management of invasive species and its impacts, including payment for ecosystem services, biodiversity offsets, and risk sharing agreements between maritime carriers and the exposed communities.

6.4.3. Effectiveness of Prevention v. Remediation Strategies

Additional research is required to compare the cost effectiveness of prevention strategies with that of remediation efforts across various invasion scenarios while taking different types of ecosystems into account. The study should also consider the technological constraints, challenges with regard to implementation, and the outcomes from an ecological point of view to make informed decisions on resource allocation.

There should also be an examination of the efficacy of different regulatory approaches, compliance incentives, and various enforcement mechanisms in helping prevent the introduction of invasive alien species through maritime vectors.

6.5. Final Reflections on the Relationship Between International Trade, Invasive Species, and Maritime Carriers

This research work has tried to illuminate the complex and sometimes contradictory relationship between the facilitation of international trade and protection of the environment in the context of invasive species. Maritime carriers occupy a unique position in the said relationship. They serve as both essential facilitators of global commerce and at the same time, unintentional vectors for biological invasions that threatens ecological integrity and diversity, and economic stability.

The tension between economic optimisation and environmental stewardship also reflects the broader challenges in the governance of sustainable development. The current regulatory frameworks, which is fragmented across different legal instruments and jurisdictions, have proven themselves to be inadequate for addressing the transboundary and often delayed impacts of invasive species. The traditional emphasis on technical standards and operational procedures, rather than on liability and compensation mechanisms, has also contributed to creating a regulatory landscape that fails to internalise the ecological costs of maritime trade.

Nevertheless, the emerging trends in both regulations and technology offers promising ways to reconcile the competing objectives of environment and commerce. The growing recognition of the economic costs related to the impact of invasive species has provided a compelling basis for a more integrated approach that aligns commercial interests with environmental protection. Technological innovations in monitoring,

compliance verification, and impact assessment has the ability to enhance the feasibility of a more effective regulatory framework.

The path forward requires a fundamental shift from reactive approach to a proactive one, by recognising the irreversible nature of many biological invasions and the subsequent need for precautionary actions even while dealing with scientific uncertainties. It also necessitates a greater coordination between trade and environmental governance regimes at both domestic and international levels, moving beyond institutional silos and more towards coherent policy frameworks.

6.6. Conclusion

The relationship between maritime carriers and invasive alien species represent a significant challenge in the fields of both international trade regulation and environmental governance. This work has demonstrated the substantive impact alien species have on the ecosystem and the economy, the limitations of the current legal frameworks, the complexities involved in establishing carrier liabilities and finally, the challenges involved in integrating environmental concerns with that of trade policies.

Addressing all the said challenges requires a multifaceted approach which encompasses regulatory enhancements, technical innovations and further research efforts. The recommendations mentioned beforehand can act as a roadmap for developing a more effective governance mechanism that can balance the legitimate interests of maritime commerce with that of environmental protection.

The proposed enhancements to the abovementioned conventions, development of regulations, and establishment and growth of clear liability fixing mechanisms can also collectively strengthen the international legal framework that governs invasive alien species and its impact. All such measures, supported by technical solutions and backed by targeted research, would help in better equipping the international community in preventing and mitigating the impact of alien species introduced mainly through maritime vectors.

As international trade in the modern globalised world continues to expand at a rapid pace, there is a subsequent expansion in shipping routes too in response to the changing economic and geographic conditions. The risk of biological invasions, as a result is on the rise too and will remain a persistent challenge throughout the foreseeable future.

However, by adopting an integrated approach which aligns various economic incentives with that of ecological imperatives, it is possible to develop a much more suitable system for maritime transport that can support global commerce while preserving biodiversity and the functioning of the ecosystem at the same time, thereby protecting the nature and its resources for future generations.

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