Policy Interventions for Sediment Classification in the Indian Ocean Region

~Romit Kaware

Abstract

Oceans cover around 70% of our planet and are bustling with biodiversity and mineral resources. Still, the oceans remain one of the least documented areas of the earth. With humanity's growing ambitions and needs, there have been coherent demands for exploring and exploiting seabed resources. Subsequently, the sediment classification systems play a significant role in the exploratory missions, especially in the Indian Ocean Region, which sits on one of the world's vital trade and economic points of convergence. With India's rise as a global power, it must take advantage of the endless opportunities the seabed provides in the economic, ecological, academic and defence sectors. This study will revolve around three broad aspects: sediment-bearing pressure, benthic ecosystem and abiotic element detection. It examines the current regulatory frameworks on a regional, national and local scale concerning the Indian Ocean region. It highlights the current policy and implementation gaps at the different governance levels. The study also sheds light on some vital policy interventions needed for the holistic socio-economic development of the Indian Ocean region.

1. Introduction

The Indian Ocean (IO) has historically served as a crucial maritime corridor, facilitating the exchange of goods, ideas, cultures, and fostering a distinctive sense of unity among its surrounding populations, given its role in connecting three continents[1]. Presently, it is one of the world's most bustling trade routes, accommodating essential energy resources. Approximately 12 per cent of global trade traverses the Suez Canal, with 40 per cent navigating the Malacca[2] Strait, and the Strait of Hormuz witnesses the passage of nearly 21 million barrels of oil[3]. This heightened interest in the Indian Ocean, coupled with maritime vulnerabilities, has aggravated strategic competition among states both within

[1] Michael Pearson, The Indian Ocean, New York: Routledge, 2003, p55

[2] Janet Anderson, Chokepoints and vulnerabilities in global markets, *Roland Gerger*, accessed on 30 July 2023, https://www.rolandberger.com/en/Insights/Publications/Chokepoints-and-vulnerabilities-in-global-markets.html

[3] Carmen Ang, Mapping the World's Key Maritime Choke Points, *Visual Capitalist,* 30 March 2021. Https://www.visualcapitalist.com/mapping-the-worlds-key-maritime-choke-points/

and beyond its borders[4]. This rivalry is further complicated by the challenges of climate change, which pose severe threats to humanity, compelling a race to secure vital resources found in limited geographic areas but abundantly scattered on the ocean floor.[5]

The advancement of maritime technology has significantly enhanced the acquisition of information, data discovery, and monitoring of developments. An exhaustive examination of the topography and composition of surface sediment seabed is essential for comprehending seabed structure revolving around the concept of sediment classification. Effective sediment classification methodologies are pivotal in estimating the sediment-bearing pressure, strength, and stability of sediment layers crucial for offshore construction and exploration endeavours. Among these, the calculation of sediment-bearing pressure[6] represents one of the most crucial applications of Acoustic Seafloor Classification. The benthic ecosystems[7] consist of organisms, such as corals, sponges, and bivalves, residing at the bottom of ocean, lake, or river[8] serve as indicators of environmental health[9], deciphering changes in the structure and diversity of benthic communities caused by pollution or other disturbances. The deep oceans hold substantial reserves of some of the most valuable rare minerals, including 17 rare earth elements, precious metals, lithium, and uranium. The Indian Ocean Region (IOR) boasts abundant reserves of petroleum, natural gas, and essential minerals such as iron, manganese, nickel, and gold[10]. The major focus is on the polymetallic nodules potato-sized concretions of metals like cobalt, manganese and nickel. But as of 2022, there are no commercial mining activities targeting seabed minerals.[11] The discovery of abiotic elements[12] in the Indian Ocean is vital to understanding sediments'

[4] Darshana Barua, Maritime Competition in the Indian Ocean, *Carneige Endowment of International Peace,* 12 May 2022, https://carnegieendowment.org/2022/05/12/maritime-competition-in-indian-ocean-pub-87093

[5] Balaram Vysetti, Deep-sea mineral deposits as a future source of critical metals, and environmental issues – a brief review, *Miner Miner Mater 2023;2:5. Https://www.oaepublish.com/minerals/articles/mmm.2022.12/*

[6] Sediment Bearing Pressure - Technological Interventions In The Indian Littoral Waters. Romit Kaware, MRC

[7] Benthic Ecosystem Assessment - Technological Interventions in The Indian Littoral Waters. Romit Kaware

[8] Sala, Antonello, et al. "Adriaan D. Rijnsdorp1, Ole R. Eigaard2, Andrew Kenny3, Jan Geert Hiddink4, Katell Hamon5, Gerjan Piet1, Antonello Sala6, J. Rasmus Nielsen2, Hans Polet7, Pascal Laffargue8, Mustafa Zengin9, Olavur Gregerson10."

[9] Benthic Indicators. Retrieved from: https://www.epa.gov/national-aquatic-resource-surveys/indicators-benthic-macroinvertebrates

[10] Pabasara Kannangara, Adam Collins, and Barana Waidyatilake, Lakshman Kadirgamar Institute. The Importance of the Indian Ocean: Trade, Security and Norms. Retrieved from: Https://lki.lk/publication/the-importance-of-the-indian-ocean-trade-security-and-norms/

[11] "Exploration Contracts | International Seabed Authority". *Isa.org.jm*.

[12] Abiotic Element Detection - Technological Interventions in The Indian Littoral Waters . Romit Kaware

makeup, movement, and geological processes in this vast marine area. This valuable information serves the dual purpose of aiding in seabed engineering assessments and furnishing input for acoustic propagation models[13].

The significance of seabed resources for national economies and various business entities motivates them to dispatch research teams in pursuit of these valuable assets. While technological progress, which encompasses the integration of Machine Learning (ML), Artificial Intelligence (AI), and the Internet of Things (IoT), has yielded innovative approaches to enhance our comprehension of aquatic environments, it remains insufficient for a comprehensive understanding of the seabed. These advancements must not merely exist on paper but must be recognised, actively deployed in routine practices, and be rendered economically viable. Given this domain's expanding scope and applications, it has become vital to determine the key stakeholders and incorporate them into a comprehensive developmental strategy. This strategy should evaluate gaps within the existing regulatory frameworks, spanning global, regional, and national levels. Moreover, it should entail the creation of frameworks for nurturing expertise and skills that seamlessly integrate value addition, addressing both economic imperatives and the attainment of the United Nations Sustainable Development Goals (SDGs).

The ocean has vast application domains, but for this study, we'll limit ourselves to three significant applications - sediment-bearing pressure analysis, benthic ecosystem assessment and abiotic element detection. This study will examine the policy perspectives for three aforementioned crucial seafloor applications. We'll talk about the current sediment classification in the Indian Ocean Region from a policy point of view from the regional to the local level of governance. Further, we'll examine how policy changes can help deal with these existing policy gaps. We would also present a series of policy interventions that may be developed in the future, thus forming a vital component of the end-to-end model for the region's socio-economic development.

2. Uniqueness of IOR

[13] Lambert, Douglas N, Walter, Donald J, and Griffin, Sean R, Benjamin, Kim C, "Acoustic sediment classification developments," Sea Technology, Sep 1999

The IOR is characterised by robust island nations, some of which possess substantial populations, significant economic activities, global economic significance, and modern institutional frameworks exerting influence on the international stage. The Indian Ocean, in its distinctiveness, assumes a pivotal role in serving both economic and military interests, not only for the coastal states but also for nearly all major global powers positioned beyond its borders[14].

In contrast to the Atlantic and North Pacific Oceans, the Indian Ocean has garnered relatively limited research attention thus far. The IOR constitutes a significant area where both commercial and defence activities have notably expanded, particularly in the 21st century. However, the IOR boasts distinctive political, social, acoustic, and environmental characteristics[15], rendering it susceptible to climatic fluctuations, such as monsoons, tsunamis, hurricanes, and high winds due to its warm nature. Within the Indian Ocean, robust border currents exist, akin to their counterparts in the Atlantic and Pacific Oceans, albeit with notable distinctions[16]. Notably, sonar technology employed for underwater surveillance in the balmy coastal waters of the Indian Ocean encounters limitations in terms of effectiveness. This is attributed to the elevated level of the SOFAR (Sound Fixing and Ranging) channel in the warm coastal seas of the IOR, rendering it acoustically shallow and thereby impeding sonar functionality. Additionally, the surface's sharpness and seabed composition variations influence signal pulses' interaction with the water and substratum, resulting in substantial performance degradation, estimated at around 60% to 70%[17]. Furthermore, the coastal waters of the IOR boast a rich biodiversity, contributing to signal attenuation and complicating data transmission models. Consequently, it becomes crucial to incorporate appropriate adjustments facilitating the acquisition of valuable data under these intricate conditions.[18]

3. Existing Norms on Seabed

[14] **Blue Economy in the Indian Ocean: Governance Perspectives for Sustainable Development in the Region APARNA ROY**
[15] The Sediment Classification Framework for Indian Ocean Region, Romit Kaware MRC
[16] Hood, Raleigh & Wiggert, Jerry & Naqvi, S.W.A.. (2009). Indian Ocean research: Opportunities and challenges. Geophysical Monograph Series. 185. 10.1029/2008GM000714.
[17]Rishabh Patra, Shridhar Prabhuraman, Arnab Das AI & ML based Implementation of the Underwater Channel Model in the Tropical Littoral Waters of the Indian Ocean Region (IOR)
[18]Arnab Das, Acoustic Habitat Degradation Due to Shipping in the Indian Ocean Region, Changing Ecosystems and Their Services, DOI:10.5772/intechopen.90108DOI:10.5772/intechopen.90108, March 2020

Given that a significant portion of marine resources resides in international waters and represents shared assets, a fundamental challenge arises from the fact that these common-pool or open-access resources lack singular ownership. Consequently, when private entities do not possess an exclusive stake in these resources, they may lack sufficient incentives to safeguard or sustainably manage them for future generations, a concept underscored by (Hardin 1969). Therefore, the implementation of effective governmental systems becomes imperative to ensure the responsible stewardship of our environment while harnessing the vast potential of our oceans to enhance the social and economic well-being of our communities. Subsequent sections of this study delve into the global governance policies pertaining to the three domains under examination, spanning from regional to local levels of jurisdiction.

Contemporary ocean governance arrangements, both at the national and multinational levels, are the outcome of the framework established by the UN in the aftermath of World War II, which led to the formation of the United Nations Convention on the Law of the Sea (UNCLOS). UNCLOS dictates the exercise of authority within the EEZ[19] of signatory nations. Such provisions are enlisted in Articles 56 and 60 of Part V [20] [21]. Simultaneously, UNCLOS dedicates Part XII to the legal safeguarding of the marine environment. This comprehensive framework underscores the imperative for nation-states to collaborate in a concerted effort to conserve the high seas and their precious biodiversity as defined in the articles 77, 117, and 118.[22] **[23] [24]** Articles 145 and 194 within UNCLOS highlight the measures aimed at preventing, mitigating, and controlling pollution in the marine environment.[25] In 1973, the International Maritime Organization (IMO) adopted the International Convention for Preventing Marine Pollution from Ships, commonly known as MARPOL[26]. This convention serves as an international instrument designed to combat marine

[19] Global Oceans Governance: New and Emerging Issues, Lisa M. Campbell,1 Noella J. Gray,2 Luke Fairbanks,1 Jennifer J. Silver,2 Rebecca L. Gruby,3 Bradford A. Dubik,1 and Xavier Basurto
[20] 52_Churchill-lowechpt.9-Exclusive-Economic-Zone
[21] https://unctad.org/system/files/official-document/ditctedinf2019d11_en.pdf
[22] https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf
[23] United Nations Convention on the Law of the Sea
[24] Deep Seas Imperilled_ A Case of Lawlessness in the Benthic – The Law Review Anthology
[25] https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf
[26] The Law of the Sea and the Indian Ocean

pollution originating from maritime sources, offering a comprehensive framework for reducing such pollution.

In tandem with UNCLOS, the International Seabed Authority (ISA)[27] assumes control over activities conducted on the global seabed. The ISA has established comprehensive guidelines governing operations, encompassing aspects such as resource discovery and exploitation in international seabed areas[28]. According to ISA guidelines, contractors must conduct comprehensive Environmental Impact Assessments (EIAs) for any activities conducted in international waters. The ISA actively encourages the adoption of state-of-the-art technologies and industry best practices to minimise and identify instances of marine pollution. Additionally, it fosters collaboration among its members, promoting the sharing of information and the development of effective strategies for detecting and addressing oceanic pollution.[29]

The International Union for the Conservation of Nature[30] (IUCN), in the context of marine life preservation, places its focus on the realm of Ocean Governance, which entails the development of protocols and agreements aimed at the preservation of Areas Beyond National Jurisdiction (ABNJ)[31]. Aside from the international forums, many countries and regions implement their own environmental monitoring guidelines. The Environmental Protection Agency (EPA) in the United States offers information on how to measure, monitor, and control benthic ecosystems[32]. Likewise, the European Union (EU) passed the Marine Strategy Framework Directive[33] (MSFD), requiring EU Member States to study and observe their marine environment to achieve good environmental status (GES) for their marine waterways, including their wildlife and the stability of the bottom. This allows for socioeconomic development and reduces conflicts between parties ensuring sustainable growth and blooming marine

[27] https://www.isa.org.jm/national-legislation-database/
[28] https://www.isa.org.jm/about-isa/
[29] https://www.isa.org.jm/protection-of-the-marine-environment/
[30] https://www.iucn.org/sites/default/files/import/downloads/intl_ocean_governance_english.pdf
[31] Deep Seas Imperilled_ A Case of Lawlessness in the Benthic – The Law Review Anthology
[32]https://www.epa.gov/oceans-and-coasts#:~:text=The%20EPA%20protects%20and%20restores,%2Dled%20science%2Dbased%20efforts.
[33] MARINE STRATEGY FRAMEWORK DIRECTIVE, Task Group 10 Report Marine litter APRIL 2010 F. Galgani, D. Fleet, J. Van Franeker, S. Katsanevakis, T.Maes, J. Mouat, L. Oosterbaan, I. Poitou, G. Hanke, R. Thompson, E. Amato, A. Birkun & C. Janssen

ecosystems[34]. The Convention of Barcelona, 1976, aims to keep the Mediterranean Sea from contamination by preventing and removing pollution caused by ships and planes dumping trash. In 2019, the EU passed the long-awaited European Strategy for Plastics to limit the environmental damage by single-use plastic items and abandoned fishing gear[35]. The Kuwait Convention in the Persian Gulf, the Jeddah Convention in the Red Sea and the Gulf of Aden, the Black Sea Convention in the Black Sea, and the Abidjan Convention in West Africa are similar regional directives[36]

In India, a multitude of legislations and regulations oversee the monitoring activities within the EEZ. The management and regulation of India's marine zones, encompassing the EEZ, are delineated within the Territorial Waters, Continental Shelf, Exclusive Economic Zone, and Maritime Zones Act 1976[37]. This comprehensive legislation delineates India's rights and authority concerning its EEZ and establishes procedures for obtaining licenses and permissions for diverse activities, including construction within the EEZ. Furthermore, the Environmental Protection Act of 1986 along with the Coastal Regulation Zone (CRZ) Notification of 2011, prescribes guidelines for securing environmental clearances and dictating construction methodologies. It becomes essential for the establishment, modernisation, or expansion of foreshore facilities, such as ports, harbours, jetties, bridges, sea links, and other infrastructure designed for defence and security purposes[38]. The Environmental Impact Assessment Notification of 2006 mandates that any construction project, with the potential to impact the environment, must undergo a thorough EIA before receiving approval. This requirement extends to construction ventures within the EEZ[39].

The Indian constitution places a significant emphasis on environmental protection and enhancement, a substantial commitment for a nation that

[34] Bevilacqua S, Katsanevakis S, Micheli F, Sala E, Rilov G, Sarà G, Malak DA, Abdulla A, Gerovasileiou V, Gissi E, Mazaris AD, Pipitone C, Sini M, Stelzenmüller V, Terlizzi A, Todorova V and Fraschetti S (2020) The Status of Coastal Benthic Ecosystems in the Mediterranean Sea: Evidence From Ecological Indicators. Front. Mar. Sci. 7:475. Doi: 10.3389/fmars.2020.00475

[35] Madricardo F, Ghezzo M, Nesto N, Mc Kiver WJ, Faussone GC, Fiorin R, Riccato F, Mackelworth PC, Basta J, De Pascalis F, Kruss A, Petrizzo A and Moschino V (2020) How to Deal With Seafloor Marine Litter: An Overview of the State-of-the-Art and Future Perspectives. Front. Mar. Sci. 7:505134. Doi: 10.3389/fmars.2020.505134

[36] Plastics in the Indian Ocean – sources, transport, distribution, and impacts Charitha Pattiaratchi, Mirjam van der Mheen, Cathleen Schlundt, Bhavani E. Narayanaswamy, Appalanaidu Sura, Sara Hajbane, Rachel Whit, Nimit Kuma, Michelle Fernandes, and Sarath Wijeratne

[37] THE TERRITORIAL WATERS, CONTINENTAL SHELF, EXCLUSIVE ECONOMIC ZONE
AND OTHER MARITIME ZONES ACT, 1976

[38] https://parivesh.nic.in/writereaddata/ENV/crz23.PDF

[39] EIA Notification, 2006

upholds the principles of a welfare state. Article 48-A of the Indian Constitution mandates the government to safeguard the nation's forests and wildlife, while Article 51A (g) underscores the fundamental duty of every Indian citizen to contribute to this endeavour. Stringent regulations under the Coast Guard Act (1978), the Merchant Shipping Act (1958) and the Water Act of 1974 prohibit corporate entities from engaging in activities that may lead to pollution of marine ecosystems.[40] The Indian Ministry of Environment, Forest, and Climate Change (MoEF&CC) has announced the Plastic Waste Management Regulations, 2016, to provide the legal framework for plastic waste management in the nation. In addition, the Indian government has launched several initiatives, such as "Swachh Bharat Abhiyan," "National Mission for Clean Ganga," and "Smart Cities Mission," to create a clean and sustainable environment that contributes to the Marine Litter Policy[41]**.** As of July 1 2022, India has decided to cease producing, importing, stocking, distributing, selling, and using identified single-use plastic items with low utility and high littering potential.[42] Subsequently, the National Green Tribunal[43] **[44]** (NGT) holds jurisdiction over all environmental matters and the enforcement of laws relating to environmental protection and conservation, encompassing those that pertain to offshore construction operations.

[40] https://cpcb.nic.in/displaypdf.php?Id=ag9tzs9lcgevzxbyb3rly3rfywn0xze5odyucgrm
[41] GOVERNMENT OF INDIA MINISTRY OF EARTH SCIENCES RAJYA SABHA UNSTARRED QUESTION NO. - 981 ANSWERED ON – 10/02/2022 STATUS OF MARINE LITTER IN THE COUNTRY
[42] https://www.orfonline.org/expert-speak/single-use-plastic-ban-in-india/
[43] https://greentribunal.gov.in/sites/default/files/act_rules/National_Green_Tribunal_Act,_2010.pdf
[44] National_Green_Tribunal_Act,_2010

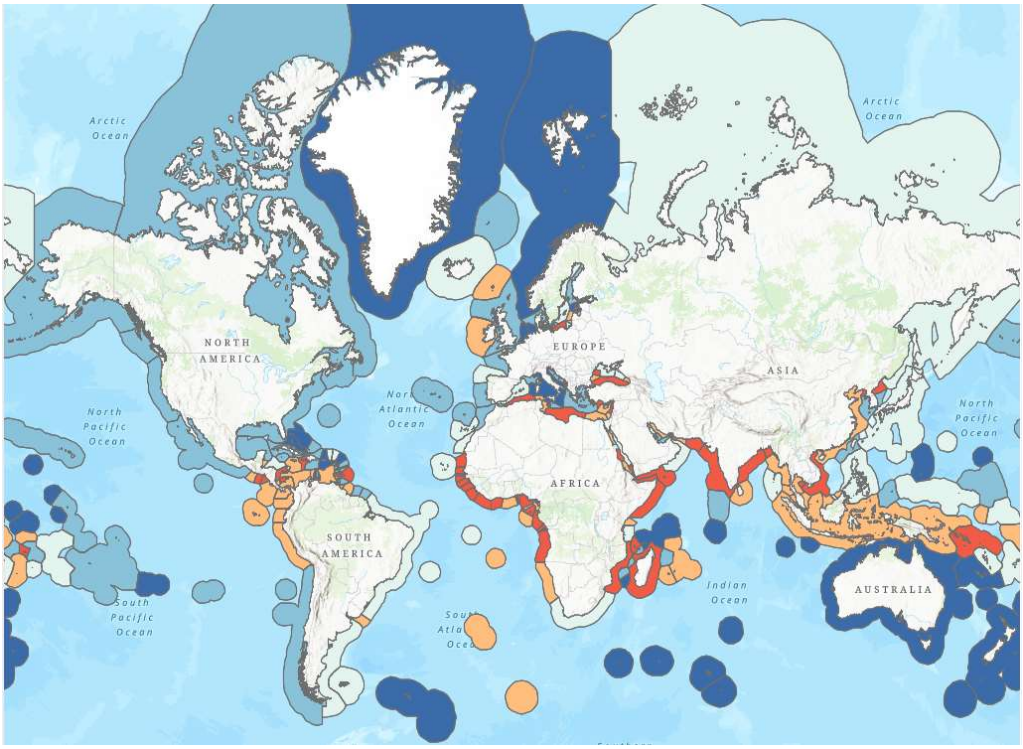


Figure: Limits of the Exclusive Economic Zones of all nations. [45]

4. Policy Challenges

The Indian Ocean occupies a pivotal position on the global stage, serving as a critical conduit for trade, commerce, and travel among various nation-states. This vast expanse of water has long been a significant trade artery, fostering connections between Africa, the Middle East, India, Southeast Asia, and East Asia. In today's dynamic geopolitical landscape, the Indian Ocean is of utmost significance in regional and global politics. Despite its immense potential, the Indian Ocean has not received the same level of attention as the North Pacific or the Atlantic Ocean. Therefore, to formulate comprehensive strategies for monitoring, safeguarding, and harnessing the economic potential of the Indian Ocean[46], it is imperative to begin by identifying the existing gaps within the current systems. Subsequently, we can develop models by drawing insights from how other oceanic systems are managed worldwide.

I. Lack of Regional Co-operation

45 https://www.greenbiz.com/article/mapping-deep-new-age-exploration

46 Hood, Raleigh & Wiggert, Jerry & Naqvi, S.W.A.. (2009). Indian Ocean research: Opportunities and challenges. Geophysical Monograph Series. 185. 10.1029/2008GM000714.

Being located at the major axis of confluence, the nations of the Indian Ocean lag behind the rest of the globe, particularly in comparison to the United States and Europe, which have established a greater number of regional agreements. In the Indian Ocean region, international laws, projects, and programs are still in place, they rarely involve all IOR nations or deal with regional problems. [47] The current state of affairs is characterised by an insufficiency of organisations, capital, and technical capabilities to address the prevailing challenges effectively. In fact, no single organisation includes all of the Indian Ocean Region Countries (IORC) as members. For example, the Southern Indian Ocean Fisheries Agreement (SIOFA) comprises only eight countries, and it is hard for other countries to join because it only covers the high seas of the southern Indian Ocean. The Bay of Bengal Large Marine Ecosystem (BoBLME) is constituted by countries of India, Bangladesh, Myanmar, Thailand, Malaysia, Indonesia, and Sri Lanka collectively[48]. The Indian Ocean Rim Association for Regional Cooperation (IORA) is the most comprehensive of the several structures; however, due to its main focus being economic development in the region, it hasn't gained traction[49]. There is a pressing need to develop a regional deal that will allow for effective regulation of activities related to seabed exploration in the area. Without such a regional framework, research, monitoring and enforcement measures continue to be dispersed and lack a concrete integrated knowledge of the Indian Ocean ecosystem that could foster effective governance mechanisms[50].

In recent times, the nations within the South Asian Association for Regional Cooperation (SAARC) have shown an increasing inclination to collaborate, primarily due to a heightened awareness of the economic consequences of not doing so[51]. Many countries are still grappling with the complexities surrounding seabed exploration and are endeavouring to prioritise it within their agendas[52]. A conference addressing Maritime Challenges And Priorities In Asia[53] shed light on a key issue in regional organisations' effectiveness – the intricate nature of

[47] Blue Economy in the Indian Ocean: Governance Perspectives for Sustainable Development in the Region APARNA ROY
[48] https://oceandecade.org/actions/bay-of-bengal-large-marine-ecosystem-project-ii-boblme-ii/
[49] Blue Economy in the Indian Ocean: Governance Perspectives for Sustainable Development in the Region APARNA ROY
[50] Blue Economy in the Indian Ocean: Governance Perspectives for Sustainable Development in the Region APARNA ROY
[51] https://www.adb.org/sites/default/files/publication/28528/wp54-political-economy-south-asia.pdf
[52] https://carnegieendowment.org/2022/05/12/maritime-competition-in-indian-ocean-pub-87093
[53] MARITIME CHALLENGES AND PRIORITIES IN ASIA, REPORT OF A CONFERENCE ORGANISED BY S.RAJARATNAM SCHOOL OF INTERNATIONAL STUDIES (RSIS) NANYANG TECHNOLOGICAL UNIVERSITY, SINGAPORE

maritime challenges demanding diverse expertise.[54] In contrast to the Association of Southeast Asian Nations (ASEAN), which has established its own rules, such as non-interference and consensus-based decision-making, the IOR lacks stringent regional regulations and a clear sense of collective identity.[55] Since 1960, the number of dead zones in coastal seas, which are caused by eutrophication and kill local animals and plants, has been growing exponentially. Of the 400 such zones that have recently been catalogued [52], about 10 are in the IO region. Due to sheer carelessness, no effort is made to understand and fix these zones, even when they could have big environmental effects, like in Mexico[56] [57]. Geopolitical factors, such as alignment with major powers or regional alliances, can significantly influence mutual trust among states. From the perspective of the IOR, China's growing influence has brought about shifts in the region's political dynamics, further complicating cooperation efforts.[58]

II. Capacity and Capability Limitations

Our knowledge of the Indian Ocean's potential is seeing varied growth across the nations because some countries don't have the right human, institutional, or technological resources. Many of the countries in the region lack the skills and resources they need to handle and protect their marine zones and to contribute to the security of the whole area[59]. Insufficiencies in capital, resources and technical expertise highlight the shortcomings of a governance framework required to address the prevailing issues. The absence of a cohesive strategy among international contributors in the realm of maritime capacity building aggravates the dire situation. Nevertheless, due to financial constraints, tight schedules, and ineffective project planning, numerous initiatives are ephemeral and primarily centre on brief training sessions rather than actual procurement and maintenance. As a result, according to a study, the establishment of a

[54] Capacity Building for Maritime Security: The Western Indian Ocean Experience

[55] A network maritime security approach to intelligence sharingin the iorjamal Barnes and Daniel Baldino

[56]https://www.nature.org/en-us/about-us/where-we-work/priority-landscapes/gulf-of-mexico/stories-in-the-gulf-of-mexico/gulf-of-mexico-dead-zone/

[57] State of Knowledge of Coastal and Marine Biodiversity of Indian Ocean Countries Mohideen Wafar1 *, Krishnamurthy Venkataraman2 , Baban Ingole1 , Syed Ajmal Khan3 , Ponnapakkam lokabharathi

[58] https://carnegieendowment.org/2022/05/12/maritime-competition-in-indian-ocean-pub-87093

[59] Krishnappa Venkatshamy (2013) The Indian Ocean Region in India's
Strategic futures: looking out to 2030, Journal of the Indian Ocean Region, 9:1, 17-41, DOI: 10.1080/19480881.2013.793911

genuinely robust maritime security capability would necessitate a decade-long effort[60].

The maritime sector holds substantial untapped potential and can contribute significantly to the region's socio-economic development. Yet, for developing countries like India, securing the necessary funding to develop such extensive capabilities poses a significant challenge[61]. India has missed a chance by not focusing more on building up its marine capabilities. On one hand, numerous opportunities abound, yet our youthful demographic faces a formidable challenge in securing employment due to an inadequacy of essential skills and knowledge. To illustrate, a substantial scarcity of experts specialising in zooplankton classification has become apparent at institutions like the Central Marine Fisheries Research Institute. Regrettably, no successor has been designated to fill these roles. This predicament is likely mirrored by IORC, which often contends with limited financial resources for establishing scientific positions or funding comprehensive educational pursuits. The vital academic and skill-enhancement courses requisite for translating the Underwater Domain Awareness (UDA) framework into reality encompass robust acoustic survey methodologies, underwater biotechnology, underwater artificial intelligence and robotics. Notably, not a single academic institution within the country presently offers these courses at any level. The establishment of such educational capacity could have yielded manifold benefits, including bolstering heavy industries and their ancillary support sectors, facilitating the training of our youth, and generating thousands of employment opportunities.[62] Even among the younger generation of students, the prospect of pursuing a career in research lacks a considerable degree of allure.[63.] This collective set of circumstances imposes a significant strain on the developmental potential of India.

III. Availability and Accessibility of Scientific Data

[60] Bauman, Peter, and Sarah Hanssen. 2016. Strategic Review of the Trust Fund to Support Initiatives of States Countering Piracy off the Coast of Somalia. Http://www.lessonsfrompiracy.net/files/2017/04/Trust-fundstrategic-Review.pdf

[61] Gurpreet S. Khurana (2017) India's Maritime Strategy: Context and Subtext, Maritime Affairs: Journal of the National Maritime Foundation of India, 13:1, 14-26, DOI: 10.1080/09733159.2017.1309747

[62]

[63] State of Knowledge of Coastal and Marine Biodiversity of Indian Ocean Countries Mohideen Wafar, Krishnamurthy Venkataraman, Baban Ingole, Syed Ajmal Khan, Ponnapakkam lokabharathi

The Indian Ocean stand as the least explored among all the world's oceans[64]. The disappearance of Malaysia Airlines Flight MH370[65] underscored a glaring deficiency in bathymetric data[66] for vast expanses of the world's seas. Despite the public disclosure of information acquired during the search for MH370, it merely encompasses a minuscule fraction, approximately 1%, of the Indian Ocean's seabed[67]. The economic and geopolitical ramifications of seabed mining, coupled with its adverse environmental impacts, present significant challenges for the region.[68] Our comprehension of the geological and chemical dynamics of the seafloor remains far from complete, representing a substantial gap in our knowledge.[69]

India, is recognised as one of the megadiverse nations, containing around 7-8% of the documented global species, but the existing databases are insufficiently exhaustive[70]. Due to a lack of data on benthic communities, for instance, it is challenging to assess the effects of climate change on these habitats and to develop effective adaptation strategies to safeguard them[71]. Accurate sediment classification systems require training data for modelling and prediction. Obtaining high-quality training data in India can be difficult due to limited resources, logistical challenges, and the immensity of the littoral and marine regions. To fully comprehend the marine environment, acoustic data collected from multiple sources, such as sonar systems, underwater gliders, and autonomous underwater vehicles, must be integrated and fused. The accumulation of data from various sources into a common national/regional database is hampered by the absence of standardised guidelines outlining the

[64] Integrated ocean management for a sustainable ocean economy Jan-Gunnar Winther

[65]] Picard, K., Brooke, B. P., Harris, P. T., Siwabessy, P. J. W., Coffin, M. F., Tran, M., et al. (2018). Malaysia Airlines flight MH370 search data reveal geomorphology and seafloor processes in the remote southeast Indian Ocean. Mar. Geol. 395, 301–319. Doi: 10.1016/j.margeo.2017.10.014.

[66] Smith, W. H. F., and Sandwell, D. T. (1997). Global seafloor topography from satellite altimetry and ship depth soundings. Science 277, 1957–1962.

[67] Wölfl A-C, Snaith H, Amirebrahimi S, Devey CW, Dorschel B, Ferrini V, Huvenne VAI, Jakobsson M, Jencks J, Johnston G, Lamarche G, Mayer L, Millar D, Pedersen TH, Picard K, Reitz A, Schmitt T, Visbeck M, Weatherall P and Wigley R (2019) Seafloor Mapping – The Challenge of a Truly Global Ocean Bathymetry. Front. Mar. Sci. 6:283. Doi: 10.3389/fmars.2019.00283.

[68] Integrated ocean management for a sustainable ocean economy Jan-Gunnar Winther

[69] IIOE-2 & Northern Indian Ocean Geosciences: some scientific questions, gap areas and challenges.IIOE-2 & Northern Indian Ocean Geosciences: some scientific questions, gap areas and challenges. (aquadocs.org)

[70] https://www.cbd.int/countries/profile/?Country=in

[71] **Agardy, M. Tundi. "Advances in marine conservation: the role of marine protected areas." Trends in ecology & evolution 9.7 (1994): 267-270.**

tolerance of equipment to be used, data storage and processing techniques conforming to international standards.

Even in situations of favourable circumstances, the establishment of marine governance and the implementation of channels for information sharing might present challenges. Much of the data gathered holds strategic significance, rendering direct sharing impractical. Historically, the security establishments of individual nations have predominantly operated discreetly and maintained a shroud of secrecy. Despite an awareness of the need for change, intelligence agencies have typically adhered to a policy of divulging minimal information or providing only rudimentary insights.[72] Furthermore, private entities have sometimes asserted Intellectual Property Rights (IPR) over the data they collect, obstructing to comprehensive data aggregation. Without robust legal frameworks delineating data rights, the prospect of a shared regional database remains elusive, hampering exploration and development initiatives.

With increasing political ambitions and a deficit of trust among nations, the approaches to data sharing must be meticulously designed to address how data is shared, accessed, and stored. With the new Indo-Pacific Partnership for Maritime Domain Awareness (IPMDA) program, announced at the Quad leaders' summit in Tokyo in May 2023, the QUAD countries agreed to share commercially available satellite data to warn states about illegal fishing in waters within their maritime boundaries. It seeks to share the information in four information fusion centres[73] [74] However the implementation hasn't been properly laid out, as the data is mostly collected by private entities and subjected to strategic importance.

IV. Standardisation

One of the major problems plaguing the Indian Ocean and the Southern Asian region is the lack of channelised efforts towards addressing maritime challenges and disasters. The duration of environmental consequences can be quite diverse, with some enduring effects, while others are relatively short-lived. There is a growing consensus about the need to establish early warning systems,

[72] A network maritime security approach to intelligence sharingin the IOR Jamal Barnes and Daniel Baldino
[73]https://www.cnbc.com/2022/06/09/quads-maritime-initiative-could-spur-militarization-of-indo-pacific.html
[74]https://www.outlookindia.com/international/quad-leaders-rollout-indo-pacific-maritime-monitoring-amid-china-s-aggressive-overtures-news-198285

crisis management protocols, and reaction plans to facilitate societal adaptation to the diverse array of consequences stemming from climate change, ultimately enhancing resilience among affected populations. [75]

The underwater geological processes have a significant role in the well-being of people. Monitoring these processes may provide valuable insights into mitigating the adverse impacts of natural calamities. This can be understood by the 2004 Indian Ocean tsunami, termed as the greatest natural disaster in recorded history, killing over 2.3 million people in 14 countries. The event did wake up the governments of Asia's growing countries and even some foreign groups, which worked to improve tracking systems and set up early warning systems for tsunamis in the area.[76] Humans can't stop nature from being angry, but being better prepared could make the damage from natural disasters less severe, as shown by the 2004 events.[77]

Early warning systems often rely on maritime data to make predictions. In addition to the limited availability of scientific marine data, a significant challenge is that universally accepted data formats may not be suitable for all parties involved. Despite the evident advantages of adhering to widely recognised standards and formats, several research groups may encounter practical constraints in their implementation. Some progress has been achieved by utilising tools such as the Network Common Data Form (NetCDF) templates[78], provided by the National Oceanic and Atmospheric Administration (NOAA). Nevertheless, the ultimate objective of complete and widespread adoption remains unrealised. Given that Information Technology (IT) processes are often pivotal for planning and forecasting, the haphazard collection of data could compromise the interoperability of various systems.[79]

V. National Marine Regulation

Maritime regulations serve as a global framework to facilitate the management of a wide array of marine issues, spanning the realms of private, international, and local concerns. Most of the time, their applicability is limited to small

[75] Indian Ocean Rising: Maritime Security and Policy Challenges Edited by David Michel and Russell Sticklor
[76] https://www.strategicstudyindia.com/2016/09/acoustic-capacity-building-in-indian.html
[77] https://www.strategicstudyindia.com/2016/09/acoustic-capacity-building-in-indian.html
[78] https://www.frontiersin.org/articles/10.3389/fmars.2019.00440/full#footnote2
[79] https://www.frontiersin.org/articles/10.3389/fmars.2019.00440/full

geographical locations. So, a national marine law needs to be a full system of public and private, substantive and process laws that rule all parts of the maritime regime, including maritime security, study, environmental protection, rescue, and recovery[80].

Discussions surrounding India's National Maritime Policy (NMP) draft persist, with the NMP addressing maritime issues, albeit with notable shortcomings. While the NMP outlines its objectives and aspirations, it requires comprehensive execution methodologies and monitoring mechanisms to ensure the policy's enforcement across all levels. Moreover, there is a lack of unified coordination. The NMP aspires to engage government agencies, departments, and the private sector, but achieving seamless collaboration among these entities poses a formidable challenge. For the policy to be executed in a coherent manner, there must be improved integration and collaboration among these stakeholders. To enable the NMP's success, coastal communities, fishermen, and indigenous populations must be active participants. Bridging the gap between policy formulation and real-world impact involves their inclusion in decision-making processes, attentiveness to their perspectives, and addressing their concerns. Furthermore, the absence of a centralised monitoring body complicates the implementation of policy changes necessary for sustained growth.

India boasts several marine research and monitoring organisations dedicated to marine ecosystems, climate and evolution of coastal regions like the National Institute of Oceanography (NIO), the National Centre for Coastal Research (NCCR), the Indian National Centre for Ocean Information Services (INCOIS), and the National Institute of Hydrology. However, India's marine research landscape lacks a centralised authority exclusively dedicated to overseeing marine studies, resulting in a fragmented approach. Moreover, the absence of adequate standardisation and harmonisation of research methodologies poses challenges when comparing and synthesising disparate studies.[81] [82] This deficiency in a centralised governing body for maritime policy has given rise to the concept of

[80]https://www.legalserviceindia.com/legal/article-10806-legal-guide-to-maritime-law.html#:~:text=The%20purpose%20of%20maritime%20law,claim%20damages%20and%20certain%20benefits.
[81]https://government.economictimes.indiatimes.com/blog/water-governance-reforms-are-key-to-sustainable-water-management-in-india/95736850
[82] Haegerbaeumer A, Mueller M-T, Fueser H and Traunspurger W (2019) Impacts of Micro- and Nano-Sized Plastic Particles on Benthic Invertebrates: A Literature Review and Gap Analysis. Front. Environ. Sci. 7:17.

sea blindness[83], representing an inadequate comprehension of ocean-related issues, often supplanted by terrestrial solutions. In the IOR, numerous expeditions are conducted for diverse purposes. The absence of a regulatory authority hampers the monitoring of data quality, environmental impact assessment, data collection processes, and proper documentation, posing substantial impediments to effectively managing these expeditions. There is a widespread lack of awareness by policymakers of potential interactions among activities in the marine environment. An overall policy is needed to guide procedures for resolving this type of difficulty. [84]

VI. Implementation Inefficiencies in the Current System

India's ocean governance strategy is hampered by its geopolitical situation. India possesses the 18th-largest EEZ with a total size of 2,305,143 km^2.[85] Regrettably, India's Ministry of Earth Sciences has only superficially engaged in seabed research. Meanwhile, China has surged ahead in seabed exploration technology, achieving a significant lead with the creation of the world's deepest diving vehicle capable of descending to depths of 7000 meters[86].

India's marine policies suffer from a lack of a central authority. Currently, there are sixteen different ministries, departments, and organisations, including the Indian Navy and the Coast Guard, involved in ocean-related matters. However, there is often a lack of coordination among these entities, resulting in a lack of guidance and sometimes confusion in areas like coastal pollution control and fisheries regulation.[87] The lack of clear roles and responsibilities among these various groups compounds the challenges for countries like India in addressing marine issues. Meeting both legal and practical requirements for monitoring the high seas becomes difficult.[88].

[83] https://www.orfonline.org/wp-content/uploads/2012/12/Maritime_Capacity_of_India.pdf
[84] Towards an integrated marine policy in developing countries Jean-Pierre Levy
[85] http://www.seaaroundus.org/data/#/eez.aspx
[86] https://www.idsa.in/keyspeeches/maritimesecurityofindiafuturechallenges
[87] https://www.idsa.in/keyspeeches/maritimesecurityofindiafuturechallenges

[88] Prakash Gopal (2022) India's maritime security legal framework and its influence on international maritime security cooperation, Maritime Affairs: Journal of the National Maritime Foundation of India, 18:1, 91-103, DOI: 10.1080/09733159.2022.2074583

Local governments often lack expertise in monitoring water bodies, which is a common challenge in many regions. Monitoring these bodies of water, including lakes, rivers, and marine areas, is crucial for assessing pollution, understanding the current state of marine environments, and planning rejuvenation strategies. Local government workers may not have the necessary information and skills for effective water body monitoring. This involves overseeing various aspects, collecting data, and interpreting its significance. Due to limited resources, they often resort to traditional, time-consuming, and costly methods. Even when valuable data is collected, local governments may struggle with analysing and interpreting it to extract practical insights. Furthermore, establishing collaborative partnerships with key entities like educational institutions, environmental agencies, and community organizations can be challenging for local governments. These partnerships are vital for accessing expertise, sharing information, and gaining support for initiatives aimed at monitoring water bodies.

Political interference can disrupt local decision-making and implementation processes, leading to issues such as biased project prioritization, unequal resource allocation, corruption, and disruptions caused by changes in political leadership. Cases like Lake Kolleru[89] [90] in Andhra Pradesh, Vembanad Lake[91] in Kerala, and the rejuvenation of the Ganges[92] illustrate the challenges faced in community involvement and securing funding. Mapping lakes and rivers requires technical expertise in remote sensing, GIS, and hydrology, skills that many local governments in India lack. As debates about responsibility continue, the local environment suffers, and without government intervention, the area and its residents are likely to endure unfavourable conditions for an extended period.[93]

[89] Sreenivasa Rao, Amaraneni, and Ramamohana R. Pillala. "The concentration of pesticides in sediments from Kolleru Lake in India." Pest Management Science: formerly Pesticide Science 57.7 (2001): 620-624.
[90] Kolli, Meena Kumari, et al. "Mapping of major land-use changes in the Kolleru Lake freshwater ecosystem by using landsat satellite images in google earth engine." Water 12.9 (2020): 2493.
[91] Sruthy, Shini, and E. V. Ramasamy. "Microplastic pollution in Vembanad Lake, Kerala, India: the first report of microplastics in lake and estuarine sediments in India." Environmental pollution 222 (2017): 315-322.
[92] Poocharoen, Ora-orn, Robert James Wasson, and Xun Wu. Ganga Rejuvenation: Governance Challenges and Policy Options. 2017.
[93]https://apnews.com/article/india-pollution-river-biodiversity-chemicals-768dd4da40f30d8c83462b312f009b2c

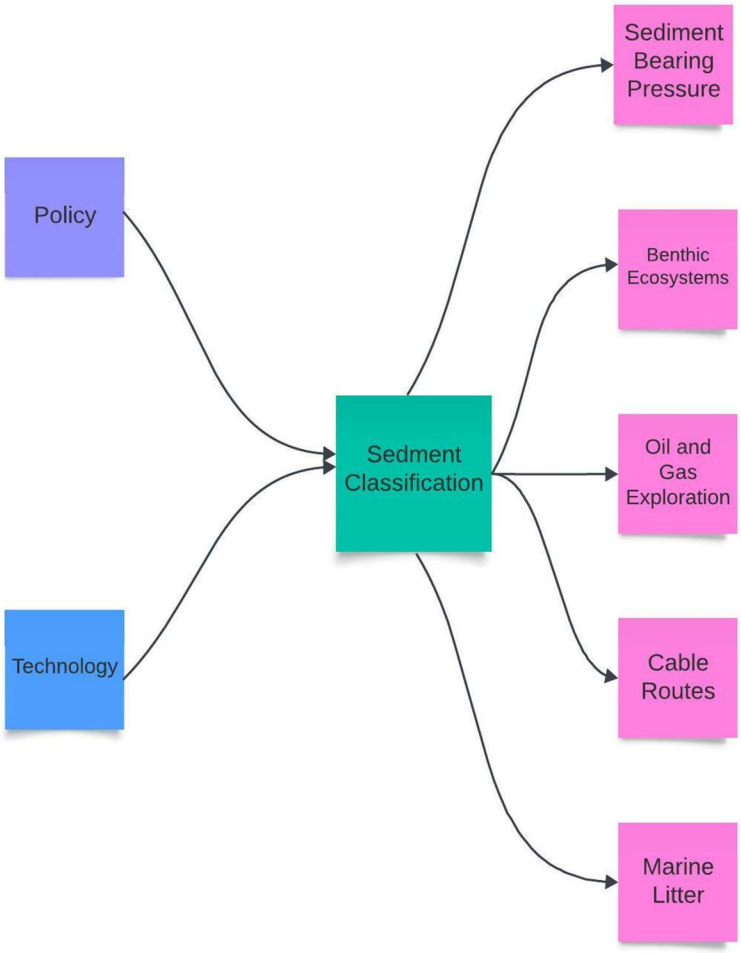


Figure: Sediment Classification Applications

VII. Shallow Planning Viewpoints

Geopolitical factors undermine the effectiveness of substantive maritime governance in the IOR through India's opposition to China's involvement, bureaucratic impediments faced by India in its maritime governance endeavours,[94] and the diversion of Delhi's focus from its maritime governance initiatives. India's engagement in maritime governance is primarily shaped by its geostrategic alliances with key IOR nations, driven by concerns over Beijing's rise in the Indo-Pacific. This dynamic imbues these regional organisations with a heightened political character at the expense of their operational efficiency. For instance, India's reluctance to admit the Maldives into the IORA was rooted in

[94] David Scott (2013) India's Aspirations and Strategy for the Indian Ocean – Securing the Waves?, Journal of Strategic Studies, 36:4, 484-511, DOI: 10.1080/01402390.2012.728134

the Maldives' close ties with Beijing. This situation only changed in 2018 when a pro-India government assumed power in Male, as noted by Mitra in 2018.

Effective policy planning and implementation should involve local groups, utilise local knowledge, and consider the unique characteristics of the areas where policies will be applied. However, lawmakers often lack detailed knowledge of local regions, hindering the development of tailored policies. They may also face challenges related to funding, institutional capacity, and methods for monitoring, reviewing, and updating national policies. In February 2021, a glacier broke off in Uttarakhand's Nanda Devi region[95], leading to a sudden deluge that severely damaged two hydroelectric power plants, numerous bridges, and highways. Experts criticised the government agencies responsible for these structures and the river for their lack of preparedness and oversight. Similarly, Tamil Nadu's coastline has experienced significant erosion, resulting in property loss and infrastructure damage[96]. Due to constantly changing social, economic, political, and environmental conditions, many projects must adapt their original plans. The key to effective planning is ensuring that policy decisions align with the needs of the people[97].

In Goa, India, the sand dunes and their associated vegetation have nearly disappeared due to ill-conceived efforts to enhance beach aesthetics and convert grassy beach areas for tourism-related activities[98]. Similarly, the Dhamra Port project in Bhadrak[99], Orissa, has sparked considerable controversy, mainly because of its proximity to the Gahirmatha beaches, a crucial nesting and mating ground for the rare Olive Ridley turtles. Critics, including scientists, lawmakers, non-governmental organisations, and individual supporters, have voiced concerns about the project's lack of stakeholder consultation and its disregard for future consequences. Local authorities have frequently been sluggish in regulating and enforcing environmental laws, significantly damaging the marine environment and local economies despite the hazards associated with industrial activities. In 2015, for instance, a chemical plant in the cities of Chennai

[95] Mehta, Manish, et al. "Causes and consequences of rishiganga flash flood, nanda devi biosphere reserve, Central Himalaya, India." Current Science 121.11 (2021): 1883-1487.
[96] Natesan, Usha, et al. "Monitoring longterm shoreline changes along Tamil Nadu, India using geospatial techniques." Aquatic Procedia 4 (2015): 325-332.
[97] https://www.newsclick.in/india-no--lan-planning-hurt-weakest-sections-most
[98] State of Knowledge of Coastal and Marine Biodiversity of Indian Ocean Countries Mohideen Wafar1 *, Krishnamurthy Venkataraman2 , Baban Ingole1 , Syed Ajmal Khan3 , Ponnapakkam lokabharathi
[99] Maritime Commerce and Security: The Indian Ocean Amit A. Pandya and Rupert Herbert-Burns with Junko Kobayashi

discharged toxic effluent into Ennore Creek[100], causing the mortality of thousands of fish and negatively affecting the livelihoods of local fishermen.

5. Policy Interventions

The Indian Ocean plays a central role in India's strategic considerations, serving as the primary channel for trade networks and addressing its increasing energy needs. Furthermore, the Central Indian Ocean Basin is a key area for deep-sea exploration and the acquisition of valuable mineral resources. Therefore, maintaining a secure and stable Indian Ocean is essential for fostering the growth of India's industries and businesses, and ensuring governmental stability, given its extensive coastline[101]. Achieving this goal requires comprehensive and adaptable policy interventions due to the complexity of the maritime domain. Identifying and engaging with a central policy authority to lead these efforts is crucial, especially with multiple ministries having distinct roles in Maritime Domain Awareness, each with its own financial and political authority. It is essential to thoroughly assess the existing policies' shortcomings to facilitate effective improvements.

I. Enhanced Participation in Regional Forums

Therefore, enhanced communication among these nations is crucial. Shortly, the dynamics in the Indian Ocean may transition from state-centric dominance to increased competition for limited resources. Although the countries in the Indian Ocean face common challenges, their approaches to solving them differ. As a result, there is an urgent requirement for a swift, clear, comprehensive, multi-tiered, and well-organized regional response to ensure the sustainable management of marine resources in the area.[102]

Addressing coastal challenges would require enhancing existing systems like the Indian Ocean Rim Association (IORA) and the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC). Multilateral frameworks should now incorporate concepts such as UDA, Marine Spatial

[100] Shanthi, V., and N. Gajendran. "The impact of water pollution on the socio-economic status of the stakeholders of Ennore Creek, Bay of Bengal (India): Part I." Indian Journal of Science and Technology 2.3 (2009): 66-79.

[101] ISA -Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area. Https://www.isa.org.jm/files/documents/EN/Regs/PN-en.pdf

[102] Blue Economy in the Indian Ocean: Governance Perspectives for Sustainable Development in the Region APARNA ROY

Planning (MSP), Blue Economy, and collaborations between institutions to address specific gaps in the IOR. Simultaneously, member states and dialogue partners should focus on advancing a government-led blue economy that promotes growth[103] [104]. India must foster positive relations with neighbouring countries[105]. New Delhi should request that the IORA involve its dialogue partners, particularly China and the United States, in substantial coastal governance projects. While the IORA would seek assistance from dialogue partners in addressing specific marine issues as needed, it would not grant them permanent status[106]. Developing a comprehensive regional marine governance plan is essential, and India must take a leadership role in line with the SAGAR Vision. Indian Prime Minister Modi emphasises the need for collaborative efforts in areas such as trade, tourism, investments, infrastructure development, marine science and technology, marine environmental protection, and the overall development of the Ocean or Blue Economy.

As Arnab Das[107] has emphasised, the region's demographic advantage can be harnessed to achieve the objective of "Towards a Resilient Region, Prosperous Economies, and Healthy People. “Collaborative systems should focus on three key aspects: outreach, engagement, and sustainability. Outreach involves informing lawmakers, partners, and practitioners in the region about the significance of the UDA structure from a strategic perspective. Engagement involves lawmakers and other stakeholders to garner support for this critical initiative. Sustainability involves initiating projects that aim to develop policy and technology solutions while building valuable skills and capabilities. We can learn from the projects funded by organizations like Swedish International Development Cooperation Agency (SIDA) that have enabled institutions such as the Western Indian Ocean Marine Science Association (WIOMSA) to enhance

[103] International Maritime Disputes Of India By Tanvi Mathur

[104] Reiss, H., Birchenough, S., Borja, A., Buhl-Mortensen, L., Craeymeersch, J., Dannheim, J., Darr, A., Galparsoro, I., Gogina, M., Neumann, H., Populus, J., Rengstorf, A. M., Valle, M., van Hoey, G., Zettler, M. L., and Degraer, S. Benthos distribution modelling and its relevance for marine ecosystem management. – ICES Journal of Marine Science, 72: 297–315.

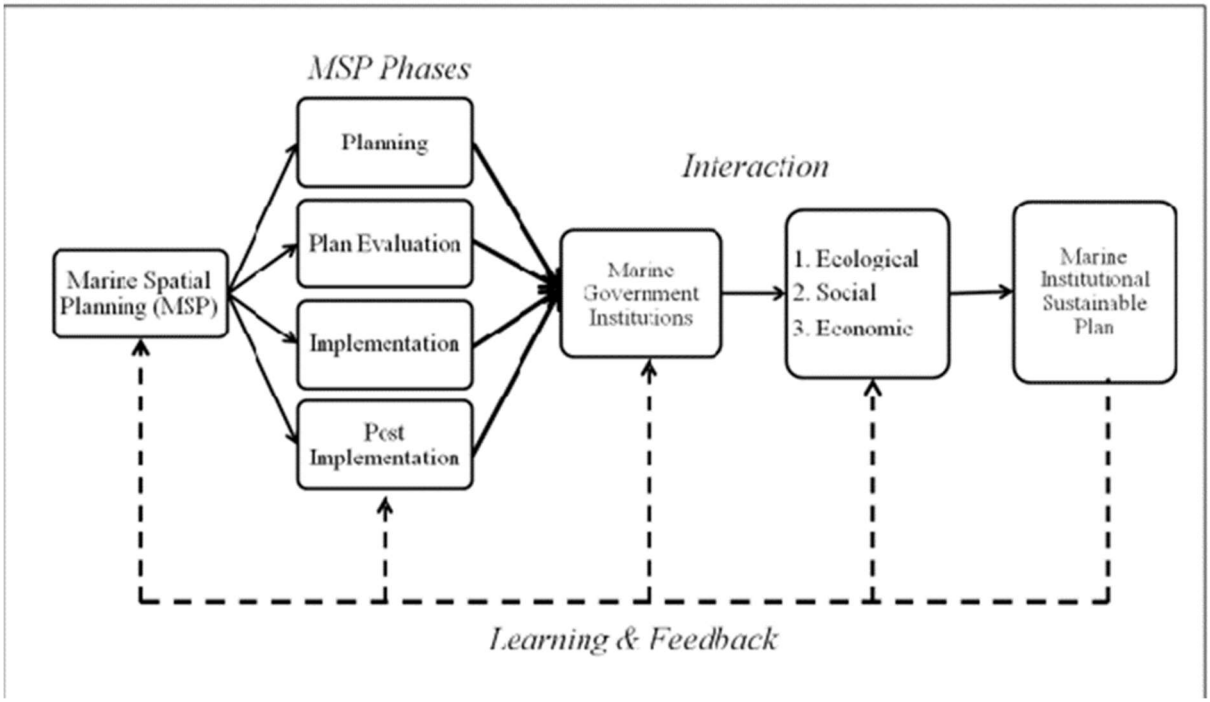
[105] David Scott (2013) India's Aspirations and Strategy for the Indian Ocean – Securing the Waves?, Journal of Strategic Studies, 36:4, 484-511, DOI: 10.1080/01402390.2012.728134

[106] David Scott (2013) India's Aspirations and Strategy for the Indian Ocean – Securing the Waves?, Journal of Strategic Studies, 36:4, 484-511, DOI: 10.1080/01402390.2012.728134

[107] https://thedailyguardian.com/uda-framework-for-bimstec-and-the-way-forward-2/

their capacity in coordinating regional and international initiatives, grant writing, and fundraising.[108]

Creation of specific offices for seabed exploration should be done with acoustics and MSP on priority. Integrating MSP with acoustic sensors in the Indian Ocean can help develop an end-to-end model for maritime domain applications fusing acoustic sensors in the Indian Ocean by providing a framework for analysing and allocating the spatial and temporal uses of marine resources to meet ecological, economic, and social goals.[109] For instance, South Africa was the first country in Africa to implement MSP[110]. In accordance with Liu et al. (2011), the success of MSP hinges on the enhancement of managerial authority, ability, and financial resources, as well as the unwavering commitment and intergovernmental collaboration.[111] **[112]**



[108] Support to marine research for sustainable management of marine and coastal resources in the Western Indian Ocian. Francis, J.; Berg, H.; Souter, P.

[109] Support to Marine Research for Sustainable Management of Marine and Coastal Resources in the Western Indian Ocean Håkan Berg, Julius Francis and Petra Souter

[110] Africa Integrated Maritime Policy, blue growth and a new ocean governance: case studies from the Atlantic and the Indian Ocean José Guerreiro1

[111] Musili Wambua (2022) A critical review of the global legal framework on piracy: 40 years after UNCLOS, Maritime Affairs: Journal of the National Maritime Foundation of India, 18:1, 134-148, DOI: 10.1080/09733159.2022.2091020

[112] Africa Integrated Maritime Policy, blue growth and a new ocean governance: case studies from the Atlantic and the Indian Ocean José Guerreiro

Figure: Marine Strategic Planning Framework[113]

Collaboration among esteemed academic institutions, government bodies, and private enterprises can play a vital role in educating individuals about global operations and the necessary actions to address them. Bringing together the private sector, educational institutions and training centres in research and development is crucial for disseminating knowledge and nurturing talent, especially in fields like information technology and skill development within the Blue Economy sector. Governments can benefit significantly from financial support allocated to their maritime initiatives, often called "blue funding." This funding encompasses various elements, such as early warning systems, vessel monitoring, specialised equipment, laboratories, and training facilities for underwater projects. Given the diverse challenges in the Indian Ocean Region (IOR), promoting innovative ideas is essential. Our institutions can collaborate with international counterparts to create region-specific solutions, fostering advanced research and technological development. Projects like the Indian program on deep-sea benthos, which is part of a search for polymetallic nodules in the Central Indian Ocean Basin, and parallel programs on the geology and geochemistry of mid-ocean ridges are also good ways to instil collaborations.[114]

II. Information Sharing

The Indian Ocean region lags behind in scientific understanding compared to other parts of the world [115] [116].This knowledge gap, spanning science, the environment, trade, and security, has impeded the region's development. Scientific studies are essential for evaluating ongoing projects and crafting strategies to secure government and international funding. Yet, experts frequently face challenges due to fluctuating funding constraints stemming from

[113] Yatim, M. H. M. Et al. "INSTITUTIONAL MAPPING TOWARDS DEVELOPING A FRAMEWORK FOR SUSTAINABLE MARINE SPATIAL PLANNING." ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences 42 (2016): 159-166.

[114] IIOE-2 & Northern Indian Ocean Geosciences: some scientific questions, gap areas and challenges. (aquadocs.org)

[115] Diva J. Amon, Sabine Gollner, Telmo Morato, Craig R. Smith, Chong Chen, Sabine Christiansen, Bronwen Currie, Jeffrey C. Drazen, Tomohiko Fukushima, Matthew Gianni, Kristina M. Gjerde, Andrew J. Gooday, Georgina Guillen Grillo, Matthias Haeckel, Thembile Joyini, Se-Jong Ju, Lisa A. Levin, Anna Metaxas, Kamila Mianowicz, Tina N. Molodtsova, Ingo Narberhaus, Beth N. Orcutt, Alison Swaddling, Joshua Tuhumwire, Patricio Urueña Palacio, Michelle Walker, Phil Weaver, Xue-Wei Xu, Clement Yow Mulalap, Peter E.T. Edwards, Chris Pickens. Assessment of scientific gaps related to the effective environmental management of deep-seabed mining, Marine Policy, Volume 138, 2022, 105006, ISSN 0308-597X, https://doi.org/10.1016/j.marpol.2022.105006.

[116] https://www.bgs.ac.uk/news/deepest-points-of-the-indian-ocean-and-southern-ocean-revealed/

political, economic, or environmental changes.[117] Presently, information sharing primarily occurs through virtual means, including phone calls, texts, emails, and video conferencing. Berg et al.[118] emphasise the significance of sharing information and ideas across maritime boundaries. This necessitates easily accessible, scientifically substantiated, up-to-date, and well-documented information. [119] Numerous organisations, such as the IOC (Intergovernmental Oceanographic Commission), IODE (International Oceanographic Data and Information Exchange), the European Commission, and various funding bodies, advocate for open and free data policies. Prioritising interoperability between data services aligns with the FAIR[120](Findable, Accessible, Interoperable, and Reusable) principles. The success of initiatives like the Coral Triangle Initiative underscores the importance of both official and unofficial data-sharing platforms in facilitating policy support and harmonising diverse national action plans.[121] Additionally, the Pacific Ocean Accounting Portal [122]serves as a noteworthy resource, offering real-time insights into the Pacific Ocean's status by amalgamating public data on its defence, recovery, rehabilitation, and governance.

The expanding volume and diversity of data necessitate a concurrent increase in the demand for proficient data centres and managers. Regional groups should establish Global Data Assembly Centres to consolidate and synthesize data effectively. This cannot be done without providing adequate and sustainable funding for technical data management and for the necessary coordination needed to define and agree on the best processes to be used. [123]Achieving interoperability requires a concerted focus on developing Big Data Infrastructures, Enhancing Data Quality, and establishing standardised protocols. The regional forums should advance the creation of international networks and monitoring systems, leveraging signal processing, computer vision, and machine learning to convert time-series data into actionable metrics.

[117]https://india.mongabay.com/2022/03/india-needs-more-conservation-relevant-research-on-sharks-and-rays/
[118] Support to Marine Research for Sustainable Management of Marine and Coastal Resources in the Western Indian Ocean Håkan Berg, Julius Francis and Petra Souter
[119] Integrated ocean management for a sustainable ocean economy Jan-Gunnar Winther
[120] Support to Marine Research for Sustainable Management of Marine and Coastal Resources in the Western Indian Ocean Håkan Berg, Julius Francis and Petra Souter
[121] Support to Marine Research for Sustainable Management of Marine and Coastal Resources in the Western Indian Ocean Håkan Berg, Julius Francis and Petra Souter
[122] https://www.unescap.org/sites/default/files/Pacific_Ocean_Account_Portal_GOAP_12-15Nov2019.pdf
[123] https://www.frontiersin.org/articles/10.3389/fmars.2019.00440/full#F4

The responsibility lies with our community to either develop or employ tools to bridge the gap between data creators and future users. [124]To maximise the potential of advancements in machine learning, it is imperative to complement them with appropriate training in IT, Big Data, Data Analytics, Cloud computing, IoT, ML, AI and related fields.[125]

We can explore MASE, a similar network. One of its pillars establishes a centre for information sharing in Madagascar and another centre for operation coordination in the Seychelles[126]. The Regional Maritime Information Fusion Center in Madagascar collects, organises, and analyses data about regional waters and shares it with participating nations or the public. The Regional Operation Coordination Center in the Seychelles develops models for optimising the allocation of the region's limited resources, enhancing patrol efficiency, and reducing response times[127]. Regional trips like the International Indian Ocean Expedition[128] (IIOE) would help build study capacity in the countries around the Indian Ocean and encourage attempts to make oceanic data from the area more widely available to scientists.

III. Capacity Building

Similar to other developing nations, the region confronts distinctive challenges that necessitate the involvement of indigenous experts, along with the implementation of tailored strategies and resources. Local scientists possess an intimate understanding of the prevailing circumstances, enabling them to concentrate their research on region-specific issues, thereby paving the way for enduring solutions. Presently, the paramount priority lies in supporting countries, institutions, and their initiatives in enhancing their capabilities for forthcoming progress and advancements.[129]

[124] https://www.frontiersin.org/articles/10.3389/fmars.2019.00440/full

[125] https://www.frontiersin.org/articles/10.3389/fmars.2020.00180/full?&utm_source=Email_to_authors_&utm_medium=Email&utm_content=T1_11.5e1_author&utm_campaign=Email_publication&field=&journalname=Frontiers_in_Marine_Science&id=434328

[126] INFORMATION FUSION CENTRE – INDIAN OCEAN REGION

[127] Effective maritime domain awareness in the Western Indian Ocean Christian Bueger

[128] IIOE-2 & Northern Indian Ocean Geosciences: some scientific questions, gap areas and challenges.IIOE-2 & Northern Indian Ocean Geosciences: some scientific questions, gap areas and challenges. (aquadocs.org)

[129] Support to Marine Research for Sustainable Management of Marine and Coastal Resources in the Western Indian Ocean Author(s): Håkan Berg, Julius Francis and Petra Souter

To make this project successful, it's essential to establish policies integrating various sectors such as acoustics[130], oceanography[131], underwater communication, IT, and domain-specific knowledge, especially in underwater environments. The initial step involves developing a country's human resources and institutions, which can be achieved through foreign, regional, and local training programs and collaborations. Collaboration and Memorandums of Understanding (MoUs) among regional institutions will play a vital role in enhancing regional capacity building. For example, Bangladesh has demonstrated a strong commitment to addressing marine issues by prioritising the marine sector to harness the sea's potential.[132] This significant contrast in capabilities underscores the substantial disparities within the region, even when considering countries beyond India

The primary objective should be to bridge the significant capability gaps among nations[133]. The region can learn from the five-step process the EU uses to plan and carry out civilian capacity-building missions like EUCAP Nestor[134]: (i) monitoring and early warning, (ii) drawing up the Crisis Management Concept, (iii) operation planning, (iv) deployment and implementation, and (v) strategic review[135]**.** Moreover, the Mediterranean Commission on Sustainable Development example could be followed, adapted, multiplied, and generalised.**[136]**

India, with its extensive warm coastal waters, should prioritise the Digital Ocean project[137]. Strengthening acoustic capabilities and expertise is crucial. Collaborative efforts involving esteemed institutions like IITs, IISC, government educational establishments, and the private sector would greatly advance research and technology. Additionally, fostering collaboration for skill development across businesses, academic institutions, and training centres is of utmost importance. India's demographic projection anticipates a population

[130] Kuperman, William, and Philippe Roux. "Underwater acoustics." *Springer Handbook of Acoustics* (2007): 149-204.
[131] Jerlov, Nils Gunnar. "Optical oceanography." (2014).
[132] **BANGLADESH-INDIA AND BANGLADESH-MYANMAR MARITIME VERDICT: IMPACT ON FUTURE MARITIME OPERATIONS IN THE REGION Captain Atiqur Rahman, (G), afwc, psc, BN**
[133] IIOE-2 & Northern Indian Ocean Geosciences: some scientific questions, gap areas and challenges. (aquadocs.org)
[134] https://www.europarl.europa.eu/meetdocs/2009_2014/documents/sede/dv/sede010414factsheeteucapnestor_/sede010414factsheeteucapnestor_en.pdf
[135] Capacity Building for Maritime Security The Western Indian Ocean Experience
[136] Global civil society: lessons from ocean governance Elisabeth Mann Borgese
[137] https://indiafoundation.in/articles-and-commentaries/the-underwater-domain-awareness-framework-infinite-possibilities-in-the-new-global-era/

surge to 1.42 billion individuals by 2023.[138]The Indian government should prioritize enhancing the skills of its personnel to effectively and professionally utilize modern acoustic technology and leverage data features for developing innovative, IOR-compatible solutions. Collaboration between private maritime companies and educational institutions is common for delivering industry-driven training programs. Regarding the lack of subject experts in areas like taxonomy, the student should use current methods like computer-aided models, machine learning, artificial intelligence, etc. In contrast to the boring and time-consuming courses, flexible courses should be introduced, offering job security and future opportunities, making research a more appealing career choice. [139]Additionally, the private sector's involvement in developing Autonomous Underwater Vehicles (AUVs) can be valuable. The private sector can also contribute to the Indian government's Skill India program, which focuses on enhancing skills in sensor technology, data analysis, remote sensing, underwater communication, cloud computing, data security, cybersecurity, marine engineering, and installation. This program aims to improve employability by providing industry-relevant training incorporating cutting-edge techniques like computer-aided modelling, machine learning, artificial intelligence, and more. To establish long-term leadership, India must significantly increase its investment in research, innovation, and technology[140].

The establishment of maritime colleges and training centres holds the potential to meet the burgeoning demands of the industry while nurturing a skilled workforce for the maritime sector through comprehensive educational programs and the establishment of centres of excellence. Substantial financial allocations should be directed toward the fields of geology, marine biology, and marine technology concerning research and development in the maritime domain. This encompasses flood and risk assessment, Maritime Spatial Planning (MSP), benthic ecosystem monitoring, preservation of maritime cultural assets,

[138]https://www.spglobal.com/en/research-insights/featured/special-editorial/look-forward/india-s-demographic-dividend-the-key-to-unlocking-its-global-ambitions

[139] State of Knowledge of Coastal and Marine Biodiversity of Indian Ocean Countries Mohideen Wafar1 *, Krishnamurthy Venkataraman2 , Baban Ingole1 , Syed Ajmal Khan3 , Ponnapakkam lokabharathi1

[140]https://timesofindia.indiatimes.com/blogs/voices/how-funding-for-rd-research-and-development-will-promote-innovation-in-the-online-gaming-industry/

Environmental Impact Assessment (EIA), seabed management, and guidelines for environmental quality related to sediment.

The New Education Policy outlines initiatives, but further efforts are required to establish a seamless collaboration among users, academics, and businesses across various dimensions and modes. Massive Open Online Courses (MOOCs) represent a notable example, as they can cater to a wide audience and be accessible to anyone with internet access [141] [142]. The Ocean Governance Capacity Building Training Programme serves as an exemplary case, initiating multiple training programs aimed at empowering decision-makers, policymakers, and professionals engaged in the blue economy.[143] It encompasses diverse learning modules encompassing marine science research, advanced marine pollution management, protection of endangered species, blue finance, and the attainment of sustainable development goals. Such practical exchanges foster a comprehensive and holistic approach by the international community to address multifaceted challenges.[144]

IV. Standardisation of Procedures

Given the vast and unregulated expanse of the Indian Ocean, it is essential to establish comprehensive disaster management systems with meticulous attention to detail. Ensuring the success of projects requires the development of Standard Operating Procedures. These protocols should outline how information is managed during emergencies, define roles and responsibilities, restructure tasks, establish a crisis management team, and standardise terminology to prevent confusion during alerts.[145] The use of predictive modelling tools is crucial for examining potential future scenarios. These modelling suites should incorporate data on factors such as sea levels, seabed composition, ocean floor topography, and the projected movement of marine life and inorganic materials over time. Global and regionally downscaled sea-level projections (e.g., Kopp et al., 2017) need further refinement to account for localised trends specific to the IOR[146]. Early warning systems should develop new tools, data-sharing methods, and communication protocols to ensure rapid and effective information dissemination. Learning from the Pacific's regional

[141] https://brill.com/view/journals/apoc/8/1/article-p5_002.xml?Language=en
[142] https://brill.com/view/journals/apoc/8/1/article-p5_002.xml?Language=en#fn0075
[143] https://brill.com/view/journals/apoc/8/1/article-p5_002.xml?Language=en#fn0081
[144] https://brill.com/view/journals/apoc/8/1/article-p5_002.xml?Language=en#fn0089
[145] https://www.dgshipping.gov.in/writereaddata/userfiles/file/SOP%20-%20Casualty.pdf
[146] https://www.frontiersin.org/articles/10.3389/fmars.2020.00199/full

tsunami warning system and the International Tsunami Information Centre (ITIC) can enhance tsunami preparedness in countries bordering the Pacific Ocean. These organisations are pivotal in helping Member States assess tsunami risks, implement early warning systems, and educate at-risk communities.[147]

These protocols should encompass a comprehensive response plan outlining the roles and responsibilities of government agencies, environmental protection organisations, the Coast Guard, the Navy, local communities, and foreign enterprises. They should also address resource-sharing and coordination for personnel, boats, vehicles, equipment, and other assets. Challenges in disaster management often stem from financial and staff shortages at lower levels of government, which hinder community-based disaster risk management efforts. This leads to community disaster risk management being frequently overlooked. Therefore, disaster risk management (DRM) should be integrated into plans to generate revenue and enhance community-based natural resource management skills. Training is essential for specialised teams to operate safely and effectively and can be provided by private companies or government agencies specialising in rescue operations training. Developing comprehensive training programs is crucial for teams, and the choice of the right training course depends on various factors: a) The operating environment: Training should align with the geographical requirements of the IOR. b) Certification and ongoing education: Technical rescue professionals must undergo recertification to maintain their skills and expertise. c) Documentation: Individuals, teams, and equipment should maintain records of training and incidents, including details such as training hours, acquired skills, practice sessions, evaluations, and real-world deployments. This documentation serves as a benchmark for a team's preparedness, capacity, and competence, allowing them to assess their performance and identify areas for improvement through regular reviews.[148]

A prevailing challenge lies in addressing issues at the last mile [149], where expert advice alone may not suffice. Establishing experiential learning methods with robust feedback systems is crucial. Effective engagement of experts and

147 https://www.unesco.org/en/disaster-risk-reduction/ews#:~:text=Early%20Warning%20Systems%20are%20%22an,reduce%20disaster%20risks%20in%20advance

148 https://www.insarag.org/wp-content/uploads/2021/06/INSARAG20Guidelines20Vol20II2C20Man20A.pdf

149 **https://www.sei.org/projects/indian-ocean-early-warning-system/**

targeting grassroots populations can be achieved through collaborative discussions between ministerial/government agencies and funders. Environmental awareness and situational consciousness are vital for safeguarding lives, property, and coastal communities. To achieve this goal, concise and comprehensible awareness videos may prove effective.[150]

The regional governments should adhere to internationally recognised data system standards and best practices established by reputable organisations such as the International Oceanographic Data and Information Exchange (IODE) and the Global Ocean Observing System. These standards aim to optimise research data and methodologies, ensuring that information is accessible and usable for all stakeholders. To meet these requirements, datasets should adhere to the FAIR[151] standards: a) Findable: Each dataset should have a unique and persistent identifier and standardised metadata. b) Accessible: Access to the dataset and its contents should be facilitated through a recognised communication protocol and a persistent identifier. c) Interoperable: Data and information should be self-descriptive, using formal, open, and widely recognised languages and ontologies for machine processing. d) Reusable: Data should be accessible and compatible with other datasets, and both data and metadata should provide sufficient context for integration with other data sources.[152] However, as pointed out by de La Beaujardière et al. (2010) and Hankin et al. (2010), the establishment and implementation of shared data and metadata standards and methodologies require a meticulous, time-intensive, well-planned approach, along with rigorous testing and validation.[153]

V. Refocussing by Institutions

Despite global adherence to international regulations, there remains a significant oversight in accommodating local necessities, particularly within the IOR. In fact, a substantial 82% of respondents in a poll asserted that each nation should ratify and enact UNCLOS[154]. Consequently, there is a pressing need for

[150] https://public.wmo.int/en/resources/bulletin/implementing-coastal-inundation-early-warning-systems-blueprint-ew4all

[151] https://www.force11.org/group/fairgroup/fairprinciples

[152] https://www.frontiersin.org/articles/10.3389/fmars.2019.00440/full

[153] https://www.frontiersin.org/articles/10.3389/fmars.2019.00440/full

[154] MARITIME CHALLENGES AND PRIORITIES IN ASIA REPORT OF A CONFERENCE ORGANISED BY S.RAJARATNAM SCHOOL OF INTERNATIONAL STUDIES (RSIS) NANYANG TECHNOLOGICAL UNIVERSITY, SINGAPORE

additional agreements to establish legally binding regulations for seabed exploration.[155] Existing regulations need to be revised to accommodate the diverse geographical, climatic, and environmental conditions in the region. The International Seabed Authority should take on the responsibility of addressing the following issues: 1) Ensuring that environmental and safety data submitted by contractors are made publicly accessible in a transparent electronic format, preserving the original spatial scale and geospatial attributes. 2) Continuously improving data standards to simplify the process of data compilation and standardisation. 3) Developing clear guidelines for personnel regarding data standards, including acceptable electronic data formats, the required level of detail and clarity, and the adoption of widely recognised metadata standards.[156]

Presently, a limited number of industrialised nations possess access to marine genetic resources (MGRs) and the capacity to harness them. Given that MGRs from the deep seabed are regarded as a shared global heritage, there is a call for fair and equitable distribution of benefits to all members worldwide. UNCLOS should examine its potential impact on various regulatory systems to achieve mutual objectives such as the conservation of marine species and the sustainable utilisation of resources. In the pursuit of these shared goals, UNCLOS should also assess potential changes to the maritime order[157].

Acoustic seabed classification plays a crucial role in seabed exploration, and there may be a need for global standards to ensure consistency in data collection. However, the International Hydrographic Organization (IHO) is currently not involved in establishing criteria or standardisation processes for acoustic seabed classification[158]. Many Hydrographic Offices use acoustic methods to classify the seafloor, and this approach offers advantages beyond just maritime safety. Implementing a new system involves significant changes in manufacturing processes, retraining workers to handle a complex new product, shifting priorities, conducting new surveys, and, most importantly, securing new funding. This is a challenging and complex process that can slow down and complicate the initial stages. The IHO has mechanisms to expedite Electronic

[155] International Law and Order: The Indian Ocean and South China Sea Caitlyn Antrim

[156] Transparency in the operations of the International Seabed Authority: An initial assessment Jeff A. Ardron

[157] https://www.jiia-jic.jp/en/japanreview/pdf/ab419c55b1de7bd1c44d2cd192d525d017c62b15.pdf

[158] https://www.hydro-international.com/content/article/use-and-exchange-of-data

Nautical Charts (ENCs) production, assist Member States, and monitor progress to expand global coverage[159].

VI. Central Monitoring Agency

At the national level, it is crucial to develop comprehensive strategies for enforcing laws within territories under national jurisdiction and for coordinating the activities of various agencies. The collapse of the Newfoundland cod fishery in Canada is a clear example of the detrimental consequences of an unregulated and unmonitored marine environment, which can negatively impact livelihoods and public health. Excessive fishing, enabled by modern automated fishing equipment and advanced vessels, declined the fishery. In response, the Canadian federal government imposed a fishing moratorium in 1992, causing significant changes in Canada's natural landscape, economy, and society. This decision resulted in the loss of jobs for over 35,000 fishermen and factory workers across more than 400 coastal communities.[160]

In its 2014 election manifesto, the BJP promised to set up the National Marine Authority (NMA) to ensure that the different bodies in the country deal with marine problems[161]. However, there has been no sign of the NMA for years. It was only in February 2022 that the Indian government appointed its first National Maritime Security Coordinator (NMSC)[162]. India should establish a unified policy body to oversee maritime policy across the government agencies responsible for formulating and implementing its South Asian maritime governance plan[163]. The newly created NMSC[164] office could play a role in this regard. Besides managing relationships with stakeholders, the NMSC would focus on coastal surveillance, including the need for additional coastal radars and Automatic Identification Systems (AIS) on small boats to enhance environmental damage forecasting. Attention to human intelligence is also crucial for greater domain awareness. To avoid information sharing issues

[159] https://iho.int/uploads/user/Services%20and%20Standards/ENC_ECDIS/PSC%20Advice%20IHO_Ed%202.1_Final.pdf
[160] http://www.indiandefencereview.com/spotlights/acoustic-capacity-building-in-the-indian-ocean-region/
[161] Chapter 8 The Indian Ocean Policy of the Modi Government Rajeev Ranjan Chaturvedy
[162]https://maritimeindia.org/strengthening-maritime-security-governance-in-india-a-case-for-state-maritime-security-coordinators/
[163] David Scott (2013) India's Aspirations and Strategy for the Indian Ocean – Securing the Waves?, Journal of Strategic Studies, 36:4, 484-511, DOI: 10.1080/01402390.2012.728134
[164] Prakash Gopal (2022) India's maritime security legal framework and its influence on international maritime security cooperation, Maritime Affairs: Journal of the National Maritime Foundation of India, 18:1, 91-103, DOI: 10.1080/09733159.2022.2074583

caused by overlapping authorities among maritime agencies, the NMSC will need to take proactive measures.[165]

India can look at how other countries handle their marine services. For example, the European Marine Board (EMB) is a place where marine study centres from all over Europe can work together. Diverse technical, cultural and managerial approaches are taken in its planning and regulation under the same EU legislative framework. [166] But stark differences can be observed between the marine governance of EU and India. The European Union member states collaborate as a common entity, with regulatory bodies like the European Commission and European Parliament responsible for shaping and implementing maritime policies. In the EU, maritime research organisations and agencies from member states may be utilised for seabed exploration. In contrast, India has to engage in international agreements autonomously, advocating its interests at UNCLOS. The Indian government and its pertinent ministries or agencies will need to establish and manage its national monitoring authority using its own resources, expertise, and existing institutions. Parallely, India can draw from Australia's Integrated Marine Observing System (IMOS). Through a network of viewing towers, it helps with studying and tracking in the ocean. India should try to set up a national monitoring body to encourage cooperation, data sharing, scientific study, and tracking in the marine realm.

Creating a regulatory body is essential for overseeing all underwater operations in marine and freshwater environments. This body should collaborate with other sectors to establish an effective and successful system[167]. Furthermore, research institutions, government agencies, and academic organisations should work together to support the monitoring agency. It's vital to acknowledge the wealth of existing knowledge about the ocean and leverage both historical wisdom and contemporary scientific advancements. Clear mechanisms should data in place for incorporating scientific findings into decision-making processes. Even as the marine ecosystem changes, historical knowledge should continue to inform ocean management efforts. A single organisation with political and financial

[165] https://www.orfonline.org/expert-speak/indias-maritime-security-coordinator-has-his-mission-cut-out/
[166] The derivation of scienti®c guidelines for best environmental practice for the monitoring and regulation of marine aquaculture in Europe By P. A. Read, T. F. Fernandes and K. L. Miller
[167] https://mrc.foundationforuda.in/wp-content/uploads/2023/01/Report-Final-V6.pdf

authority should oversee the entire project[168]. An overarching objective is to ensure that previous knowledge informs ongoing ocean management efforts, even as the marine environment undergoes dynamic changes. A Group of Ministers (GoM) should be constituted to handle major organisational matters, and a special parliamentary committee can be convened to assess the initiative's economic, sociological, and sociopolitical aspects.[169]

An elaborate strategy vision document must be crafted to elucidate the roles and responsibilities of GoM, the standing parliamentary committee, and the regulatory authority. As a subsequent step following the initial report, the responsibility of developing this strategic vision paper may be entrusted to various planning entities like the Maritime Research Centre (MRC) in collaboration with representatives from governmental bodies and various organisations. The central team tasked with formulating the strategic vision paper will comprise members from the GoM's administrative backend and the parliamentary standing committee. This collaborative team, in conjunction with the GoM and the government standing committee, will meticulously construct a comprehensive plan for government review and consideration. [170]

VII. National Maritime Law/ Integrated Coastal Zone Management

Numerous global and regional maritime regulations apply to India's maritime zones, but their limitations and failure to accommodate local variations create implementation challenges.[171] While India has made strides in its marine strategy over the past two decades, its legal framework falls short of national maritime objectives.[172] Bridging this gap requires a comprehensive national maritime plan that aligns marine policy with future needs. This era demands a holistic national marine plan outlining India's maritime goals encompassing trade, defence, environmental conservation, and infrastructure development[173]. Key marine governance functions include policy formulation, regulatory

[168] Integrated Ocean Management LEAD AUTHORS Jan-Gunnar Winther and Minhan Dai
[169] https://mrc.foundationforuda.in/wp-content/uploads/2023/01/Report-Final-V6.pdf
[170] https://mrc.foundationforuda.in/wp-content/uploads/2023/01/Report-Final-V6.pdf
[171] Deep Seas Imperilled_ A Case of Lawlessness in the Benthic – The Law Review Anthology
[172] David Scott (2013) India's Aspirations and Strategy for the Indian Ocean – Securing the Waves?, Journal of Strategic Studies, 36:4, 484-511, DOI: 10.1080/01402390.2012.728134
[173] https://maritimeindia.org/indias-proposed-maritime-strategy/

frameworks, project execution, coordination, monitoring, and evaluation.[174] A marine policy framework should prioritise seabed exploration for India's economic well-being. According to research[175], the legislative framework should establish a national structure for seabed exploration and governance, coastal marine spatial planning, benthic ecosystem oversight, technology and workforce development, coastal and deep-sea mining regulation, and offshore energy promotion. Current marine resource planning and management lack collaboration and long-term vision, often reacting to developmental pressures without benefiting all stakeholders. Hence, an integrated planning approach[176] is essential to comprehend how increased seabed utilisation impacts industries, marine ecosystems, and the economy.

To ensure effective collaboration among the various governmental departments overseeing maritime affairs, alternative mechanisms for cooperation must be devised. These strategies should be developed at the highest echelons of governance, such as through the establishment of an interministerial committee, having a comprehensive understanding of both current and future maritime operations and the intricate connections between them. To achieve this, an intersectoral committee should be established, which can synthesise information from diverse sources into a comprehensive national marine policy profile. Subsequently, the interministerial committee may establish policy directives and objectives, which shall serve as the bedrock upon which a central planning board shall formulate an amalgamated strategy for maritime affairs.[177]

A systematic approach is necessary to assess the diverse utilisation of maritime regions and make well-informed decisions. In the city of Xiamen, China,[178]the mayor and representatives from various government ministries joined forces to establish a collaborative initiative for coastal management. In a similar way, the marine policy initiative should involve the NITI Aayog. The MRC's interim project report[179] submitted to the NITI Aayog includes proposals for workforce development policies and action plans for the UDA policy framework. Given the

174 Towards an integrated marine policy in developing countries Jean-Pierre Levy

175 Towards an integrated marine policy in developing countries Jean-Pierre Levy

176 Towards an integrated marine policy in developing countries Jean-Pierre Levy

177 Towards an integrated marine policy in developing countries Jean-Pierre Levy

178 Integrated ocean management for a sustainable ocean economy Jan-Gunnar Winther

179 Underwater Domain Awareness (UDA) Framework A National Policy Initiative for Acoustic Capacity & Capability Building - Whole of Nation Approach. Interim Project Report

distinctive nature of the Indian Ocean, collaborative research in marine acoustics should be conducted in partnership with the MoES, INCOIS or other research institutions. The NITI Aayog can integrate a framework that spans across key industries to ensure its broader application. Active engagement from organisations like the MRC can infuse government maritime endeavours with flexibility and novel perspectives.

The policy framework should also encapsulate the ideas of MSP as it serves as a formidable instrument for achieving Sustainable Ocean Management. This would facilitate smoother international collaboration in this regard. A notable illustration of international cooperation is the Memorandum of Understanding (MoU) inked between India and Norway in January 2019. With considerable technical expertise in this field, Norway stands as an ideal partner for India to collaborate with, particularly in the realm of maritime spatial governance.[180] Institutions like the NCCR can formulate strategies spearheading the Marine Spatial Planning initiative. The MoES had previously crafted Coastal Zone Management (CZM) blueprints for regions like Chennai, Goa, and the Gulf of Kutch. Once the framework for marine spatial planning is established, it can be adapted with minor modifications to suit various coastal states and settings.[181]

The policy framework should establish Marine Research Infrastructures (RIs) as formalised entities to encourage technological innovation. Fresh initiatives should emphasise the development of compatible solutions and cutting-edge technology within this domain. Robust training programs can facilitate collaboration between RIs and businesses, creating new employment opportunities. Collaboration between Research Infrastructures and the industry can assist sensor manufacturers in expanding their market presence while gaining access to testing facilities and relevant programs. The initiative should also promote the growth of renewable energy and deep-sea mining, fostering collaboration among government bodies, the corporate sector, and individuals, as the European Marine Board advocates.[182]

[180] https://www.indiascienceandtechnology.gov.in/listingpage/ocean-initiatives
[181] https://www.indiascienceandtechnology.gov.in/listingpage/ocean-initiatives
[182] https://www.frontiersin.org/articles/10.3389/fmars.2020.00180/full?&utm_source=Email_to_authors_&utm_medium=Email&utm_content=T1_11.5e1_author&utm_campaign=Email_publication&field=&journalname=Frontiers_in_Marine_Science&id=434328

The Blue Economy holds significant promise for India's prosperity, particularly under the leadership of Prime Minister Narendra Modi, who is committed to achieving "Security and Growth for All in the Region" (SAGAR) while safeguarding shared marine territories. A comprehensive study conducted by the Federation of Indian Chambers of Commerce and Industry (FICCI) titled "Blue Economy Vision 2025, Harnessing Business Potential for India Inc. and International Partners" sheds light on this vision. However, there are notable gaps in the alignment of regional policies within the SAGAR framework, [183]indicating a need for improvements in the operational structure. Furthermore, limited participation from the business sector has led to redundant efforts by multiple entities[184]. India can draw valuable lessons from the Inter Oceanic Commission's "Bottom-up Regionalism" approach[185]. In the context of SAGAR, the pursuit of "Growth" should prioritise sustainability for India and the littoral nations of the IOR. India should strive to devise innovative regional solutions to preserve marine life, protect coastal populations from climate change impacts, and curb marine pollution[186]. For instance, the "Swachh Sagar" initiative, akin to the successful "Swachh Bharat" campaign, may be used to mitigate the issue of marine trash. [187]

6. Conclusion

The oceans cover about 70% of the earth's important for everything from the air we breathe and the food we eat to the weather and climate. The Indian Ocean remains at one of the most strategic axes of the world, bustling with trade, commerce, exchange of cultures, ideas and biodiversity. The seabed thus provides a variety of crucial applications ranging from construction to security, recreational to ecological. But despite their vital functions, our understanding of such water bodies remains limited. With increasing technological expertise and an ever-growing burden on the current resources, the need for exploration deep into our water bodies is pressing.

We've focussed on the three broad domains - Sediment Bearing Pressure, Benthic Ecosystem Assessment, and Abiotic Element Detection all linked to the

[183] https://www.claws.in/sagar-policy-analyzing-indias-vision-for-maritime-diplomacy/#_edn4
[184] https://www.claws.in/sagar-policy-analyzing-indias-vision-for-maritime-diplomacy/#_edn3
[185] https://www.claws.in/sagar-policy-analyzing-indias-vision-for-maritime-diplomacy/#_edn6
[186] https://www.claws.in/sagar-policy-analyzing-indias-vision-for-maritime-diplomacy/
[187] https://www.indiascienceandtechnology.gov.in/listingpage/ocean-initiatives

sediment classification techniques. The vast applicability of these domains necessitates the establishment of international, regional and national level policies and guidelines to monitor marine assets' use and avoid over-exploitation. The United Nations Convention on the Law of the Sea (UNCLOS) is the supreme authority of the marine domains. It encompasses various guidelines and a legal framework to manage shared resources. The description of various articles it provides the concerned nation-states with standardised guidelines and duties to perform regarding marine biodiversity, security, safety and construction. Apart from UNCLOS, various institutions like the International Seabed Authority (ISA), the International Union for the Conservation of Nature (IUCN), and the International Maritime Organization (IMO) complement the ocean governance in the areas beyond national jurisdiction (ABNJ). In addition, the national laws of India aid in bridging the gaps left by the international guidelines. the Environmental Protection Act of 1986 and the Coastal Regulation Zone (CRZ) Notification of 2011 control many activities along the coast, including those in the EEZ. Likewise, the Merchant Shipping Act of 1958, the Water Act of 1974, the Marine Zones of India Act of 1976, the Coast Guard Act of 1978, and the Environmental Protection Act of 1986 also protect the marine areas of India.

Then, we discussed the primary issues about the current functioning of regional, national, and local governments. The states within the IOR have a somewhat lower level of harmonious relations in comparison to other regions throughout the globe. Indeed, it is noteworthy that there are only a limited number of collectives whereby all members of the International Organisation of Researchers collaborate on matters about certain domains. The complexity of governance increases when a government incorporates legislation from many nations, regional agreements, and regulations from other jurisdictions. Numerous individuals and collectives exhibit divergent and even contradictory objectives. For instance, the conflict arises between approval programmes that establish worldwide benchmarks for manufacturers in impoverished nations, which may inadvertently undermine states' authority and non-governmental organisations (NGOs) in developed countries that strive to safeguard the marine environment on the high seas. These divergent objectives can result in conflicting interests.

In light of India's aspirations to play a significant role in the IOR, it is imperative for these institutions to enhance their capabilities and effectiveness. The limited collection and dissemination of scientific and environmental data pose obstacles to socioeconomic advancement and the development of the blue economy. Despite India's extensive network of waterways, there is a dearth of research on microplastic contamination in the country's rivers. A major challenge lies in the need for regional states to adopt standardised procedures. Implementing uniform protocols and reporting mechanisms would enhance the usability of data across the region. The absence of comprehensive maritime regulations and a centralised authority for marine affairs further complicates the monitoring, management, and surveillance of Indian coastal waters. There is a pressing need for a standardised framework governing sensors' use, specifications, and data storage and processing to address these challenges. This framework should adhere to international standards and facilitate data consolidation from various sources into a national or regional database. The complex legal structure that hinders data sharing also restricts organisational collaboration, while a shortage of technical expertise in various domains further complicates matters. The inability to develop a modern system and enhance workforce skills for innovative problem-solving in the Indian Ocean has hindered India's dominance in the IOR. Additionally, regional disparities have emerged due to inconsistencies in the strategies of key regional players and deficiencies in technical competence.

It is essential to address these gaps to facilitate comprehensive regional development. Due to the distinctive climatic conditions in the IOR, the performance of different acoustic sensors is compromised. However, given the significant population in the region, it is feasible to deploy existing systems from other geographical areas directly in this context. The IOR faces various issues stemming from increasing pressures on resources and divergent interests among nations. To address the issues of regional stability and the impacts of climate change, it is imperative to establish a comprehensive and well-coordinated regional response that operates at several levels. This response should prioritise the sustainable management of maritime resources and effectively mitigate climate change and environmental degradation pressures. The successful implementation of this endeavour necessitates incorporating

Underwater Domain awareness (UDA), Marine Spatial Planning, Blue Economy, and contemporary systems to enhance the workforce's skillset. Additional deliberation is required to formulate strategies for establishing a structure that facilitates data sharing across several areas, including environmental, biological, commerce, and security sectors. Enhanced trust among regional stakeholders, increased collaboration among global institutions, and the involvement of international actors in capacity-building efforts within IOR nations would catalyse a deeper comprehension of the Indian Ocean. Consequently, these developments would facilitate the generation of innovative solutions for effective monitoring and sustainable economic utilisation of the region.

India should prioritise the establishment of a comprehensive national maritime authority and formulate maritime legislation to regulate and govern maritime activities effectively. New Delhi should prioritise the realignment of its emphasis by streamlining internal collaboration and developing clear future objectives. The organisation should prioritise its capacity-building projects to use its substantial personnel as a valuable resource for efficiently implementing its UDA and Blue Economy concepts, therefore contributing to a more promising, wealthy, and secure Indian Ocean region. As we contemplate the post-COVID-19 era and the restoration of normalcy, we must reevaluate our role as custodians of the planet. As humanity embarks upon the United Nations Decade of Ocean Science for Sustainable Development, it is imperative to acknowledge our capacity to effect meaningful change and reverse the current trajectory.