Spatial Distribution of coastal ecological provinces of Mangrove, Coral Reef and Seagrass within the exclusive economic zone of the Indian Ocean Rim countries: A review

Abstract

Coastal ecosystems play a crucial role in carbon sequestration, coastal protection, fisheries support, and marine biodiversity conservation in the Indian Ocean Rim (IOR) countries. In this study, globally consistent datasets were used to assess the spatial distribution of mangroves, coral reefs, and seagrass meadows across IOR countries at the basin scale. The Global Mangrove Watch (GMW) was used for Mangrove distribution, UNEP-WCMC: Global Distribution of Seagrasses was used to retrieve seagrass data, and coral reef distribution from UNEP-WCMC's global warm-water coral reef dataset. Quantification of Ecosystem areas was made to enable cross-country comparison within national coastal waters and Exclusive Economic Zones (EEZs).

Mangroves have dominant coverage in Malaysia, Myanmar, Bangladesh, India, and Madagascar, contributing ~15–20% of the mapped coastal ecosystems, driven by monsoon climate, deltaic sediment supply, and sheltered estuarine settings. Mangroves are among the most carbon-dense ecosystems, providing effective shoreline stabilization and land–sea ecological connectivity, although spatially limited.

Mangroves deliver high carbon density and coastal resilience, coral reefs maximize biodiversity per unit area, and seagrasses dominate spatial extent and carbon sequestration. Overall, the analysis shows strong functional complementarity among IOR coastal ecosystems. These results highlight the need for ecosystem-specific, regionally tailored conservation strategies to safeguard blue carbon stocks and marine biodiversity under increasing climate and anthropogenic pressures.

Coral reefs are concentrated in tropical and subtropical environments with favourable thermal and optical conditions and account for ~25–30% of total ecosystem area. Major reef holders appear in Indonesia, Saudi Arabia, Egypt, the Maldives, and Madagascar. Coral reefs support exceptionally high marine biodiversity and function as bedrock for habitats sustaining reef-associated fisheries and ecosystem services despite their smaller spatial extent.

The results revealed that across the Indian Ocean basin, there is a prominent spatial heterogeneity. Most of the coastal ecosystem covered by Seagrass meadows, reflecting vast

coverage in regions with wide shallow shelves and clear waters, primarily in Saudi Arabia, part of Australia, part of China, Madagascar, Kenya, and Yemen. Due to high below-ground biomass and long-term sediment carbon burial, these systems represent the largest blue carbon sink in the region, which also supports critical nursery habitats and coastal water quality.

Keywords: Indian Ocean Rim; Blue carbon; Mangroves; Seagrass meadows; Coral reefs; Marine biodiversity; Coastal ecosystems

Introduction

One of the world's most ecologically diverse and socio-economically important regions are found in the coastal and marine environments of the Indian Ocean Rim (IOR) countries. In the Spanning tropical, subtropical, and arid climatic zones, the Indian Ocean is one. It supports a wide variety of coastal ecologies that provide essential ecosystem services, including shoreline protection, carbon sequestration, biodiversity conservation and fisheries productivity (Alongi, 2012; Barbier et al., 2011). The distinct yet interconnected ecoregions, formed by mangroves, coral reefs, and seagrass meadows, support the structure and functioning of coastal systems. For progressive ecosystem-based management, climate adaptation strategies, and blue carbon accounting in the region, quantifying the spatial extent and distribution of these ecological provinces is crucial.

According to Spalding et al.,(2007) ecological province zones are characterized by similar biological groups, environmental conditions and ecological processes ,and demarcated as spatially coherent regions. The distribution of coastal ecological provinces is shaped by riverine sediment input, shelf morphology, sea surface temperature gradients, tidal regimes, monsoonal circulation, and hydrodynamic processes along the Indian Ocean Rim (Sheppard et al., 2010). sheltered intertidal environments, such as deltas, lagoons, estuaries, are typically occupied by Mangroves; In shallow, warm, and clear waters, coral reefs develop; and in nearshore continental shelf regions with adequate light availability and stable substrates, seagrass meadows are found (Green and Short, 2003; Alongi, 2014). A functional continuum linking terrestrial, coastal, and marine processes formed by these ecosystems.

In the marine spatial planning (MSP) and ecosystem-based management (EBM) the identification and quantification of ecological province zones are increasingly recognized as a cornerstone (UNESCO-IOC, 2017). The assessment of habitat extent, connectivity and fragmentation, which are essential indicators of ecosystem health and flexibility made

possible by spatially explicit information on ecosystem distribution. Coastal populations are growing rapidly, and pressures from urbanization, tourism, aquaculture, and resource extraction are escalating in the Indian Ocean region, where the lack of basin-scale, standardized assessments of coastal ecological provinces restricts effective planning and policy implementation (Halpern et al., 2008; UNEP, 2020).

In the world Mangroves and coral reefs and seagrass meadows are known as carbon ecosystems. This is because they can absorb and store carbon at high rates. (McLeod et al., 2011; Howard et al., 2017). Mangroves and coral reefs and seagrass meadows can do this better than systems on land. Seagrass Meadows are very good at helping to bury carbon in the sediment near the coast over a period of time. Mangroves are also very good at storing a lot of carbon in the sediment and, in the plants that're above the ground (Fourqurean et al., 2012). Coral reefs play a crucial indirect role; although they are not major carbon sinks, they support biodiversity by enhancing fisheries productivity and providing physical coastal protection that safeguards adjacent blue carbon environs (Moberg and Folke, 1999). For accurate estimation of blue carbon stocks, climate mitigation frameworks and for integrating coastal ecosystems into national greenhouse gas inventories Identifying ecological province zones is fundamental (IPCC, 2019) and particularly for climate-vulnerable IOR nations

For biodiversity, coastal ecosystems are really important and contain a lot of species living in them. Coral reefs are an example of this. They support a number of marine species even though they do not take up a lot of space on the ocean floor (Spalding et al., 2001). In fact coral reefs support one-quarter of all marine species, which is a lot considering they only occupy a small part of the ocean. Seagrass meadows function as important nursery, feeding, and shelter habitats for fish and megafauna, while mangroves provide breeding grounds and migratory corridors for a wide range of marine and earthly species (Nagelkerken et al., 2008). Trophic interactions and life-cycle connectivity, increasing overall ecosystem productivity and resilience will be enhanced by spatial overlap and connectivity among these ecological provinces (Mumby et al., 2004). Quantifying their spatial distribution is therefore critical for biodiversity conservation planning, including the identification of priority areas for marine protected areas (MPAs) and ecological corridors.

Despite their demonstrated value, there have been relatively few complete and well-integrated assessments of the three types of ecological provinces — mangrove, coral reef, and seagrass — that exist along the coastlines of the entire Indian Ocean Rim. Most previous

research has either focused solely on individual ecosystems or examined them at local levels (national or sub-regional), and therefore cannot be used to measure the cumulative benefits derived from all of the different types of ecosystems that exist along an area's coastline, nor can they be used to compare the relative contributions made by the various ecosystems located along coastlines in different countries (Short et al., 2007; Friess et al., 2019). A standardized, multi-ecosystem spatial framework would be useful for facilitating transboundary conservation efforts and cooperative regional planning among countries located along the Indian Ocean.

Therefore, the principal goal of the current study was to quantify and describe the spatial distribution of the key coastal ecological province zones — mangroves, coral reefs, and seagrass meadows — along the coastlines of the countries surrounding the Indian Ocean Rim utilizing universally accepted data sets. More specifically, the study sought to (i) identify and characterize the country-specific and regional patterns of the extent of each ecosystem type, (ii) assess the comparative contributions of each of the three types of ecosystems to the overall composition of the coastal environment, and (iii) identify the implications of each type of ecosystem for blue carbon storage, marine biodiversity, and ecosystem-based coastal resource management. The identification and quantification of these ecological province zones will provide a scientifically credible basis for developing long-term, sustainable plans for coastal development, climate resilience, and conservation among the countries surrounding the Indian Ocean Rim.

Study Area

The study focuses on the coastal and marine areas along the coastlines of the countries along the Indian Ocean Rim (IOR) within the boundaries of 15E to 120 E longitude and 45 S to 30 N latitude as depicted in figure-1, and includes the nations bordering the Indian Ocean, such as those found in South and Southeast Asia, East Africa, the Middle East, and the island nations of the Indian Ocean. This region includes a variety of climates ranging from tropical and subtropical to arid, and a variety of coastal ecosystems, such as mangroves, coral reefs, and seagrass meadows.

The IOR coast is dominated by a mosaic of complex geomorphology, broad estuaries and deltas, coral reef complexes, and continental shelfs that collectively deliver essential ecosystem services – from carbon sequestration to fisheries production to storm protection.

Spatial analysis was performed in national coastal waters and Exclusive Economic Zones (EEZs) of all IOR countries for complete basin-wide evaluation.

Data and Methodology

Data Sources

The study used internationally comparable datasets to examine the spatial distribution of three major coastal ecosystems, namely, mangroves, coral reefs and sea grass meadows across IOR countries. Mangrove distribution information was collected from the Global Mangrove Watch (GMW), a source of high-resolution satellite-based maps and change detection for mangroves.

Data on seagrass distribution was taken from UNEP-WCMC Seagrass Database and Short et al. (2020): The Global Distribution of Seagrasses, a set of standardised global seagrass maps where ecosystem boundaries are drawn following a mixture of remote sensing and field observations. Data on coral reef distribution were obtained from the UNEP-WCMC global warm-water coral reef database, which provides geo-referenced information on the location of reefs and their extent and habitat type.

For all the ecosystems, the spatial datasets were worked on within territorial waters and EEZs of IOR countries for consistency among countries. The area under investigation ranges through a diverse range of environmental gradients such as tropical, subtropical and coastal arid zone, covering the diversity of ecological province areas throughout the basin.

Data Preprocessing

All data sets were transformed to the same spatial reference system (WGS 84, EPSG:4326) and raster resolution if applicable, to make them compatible for spatial analysis. Coastal boundaries and EEZ layers were extracted from the Flanders Marine Institute (VLIZ) Maritime Boundaries Database in order to ensure precise demarcation of national jurisdictions. Ecosystem polygons were intersected with each country's coastal waters and EEZ, and overlapping features were dissolved to prevent double counting.

Spatial Analysis

Mangrove, seagrass and coral reef spatial distributions were measured via Geographic Information System (GIS) tools. Area totals were summed at the country and region scale to determine total coverage (km^2) of each ecosystem type. The analysis included:

1. Ecosystem Extent Estimation: Calculation of total area of each ecosystem within national EEZ boundaries.
2. Country-wise Comparison: Compilation of ecosystem extent data across all IOR countries to assess spatial patterns and relative contributions.
3. Visualization: Generation of maps illustrating ecosystem distribution and spatial overlap among mangroves, coral reefs, and seagrass meadows.

Result and Discussions:

The spatial variation of mangrove ecosystems in the Indian Ocean Rim (as can be seen in figure-1) shows a significant regional variability with respect to country-wise mangrove area presented in the graph. Results show that the global coverage of mangroves is very uneven, with a small number of countries containing the bulk of mangrove area and an even greater number having limited and often severely fragmented mangrove systems.

Indonesia is the most prominent contributor compared to all of the other countries. This wide range is mainly due to the fact of Indonesia being rich of long, highly indented shorelines with many islands throughout the country; and some large deltaic and estuarine systems which provides an ideal condition for mangrove establishment and survival. Mangrove productivity in this area is further enhanced by the warm tropical climate, which persists year round and high rainfall. Such mangroves in Indonesia are thus at the heart of mangrove ecosystems within the east Indian Ocean and deliver fundamental services as protection against coastal hazards, to support fisheries, and for blue carbon storage.

The second panel of four countries, consisting of Bangladesh, Malaysia, India and Myanmar possess large area coverage of mangroves. Bangladesh is home to mangroves largely dominated by the Sundarbans, the world's largest contiguous mangrove forest. It is maintained to a great extent by a massive freshwater and sediment supply from the Ganges–Brahmaputra–Meghan river system and by intense tidal forcing in the Bay of Bengal. India has mangroves mostly along the eastern coast (47%) and Andaman & Nicobar Islands, while few are in some of the estuarine areas in West Coast. Myanmar is an estuarine mangrove which demonstrates the role played by deltaic plains and monsoon-related sediment deposition in maintaining these ecosystems. Collectively, these nations suggest that monsoon-dominated, river-impacted coasts are important for having large mangrove areas.

Beyond high mangrove areas lie nations with mid-level stands - take Thailand, Vietnam, Mozambique, or Madagascar. Still, how people once used land, along with growing fish farms, shaped what mangroves now hold. From the western edge of the Indian Ocean, mangrove forests spread across Mozambique, Madagascar. Found hugging expansive shelf zones, alongside rivers meeting the sea, and within quiet bays, these wetlands grow best when nature shapes their space. That mix of coast form and flow tells us why such places thrive so deeply in eastern African landscapes.

Some nations have less mangrove growth than expected due to inclement weather tends to limit growth, while salty waters without much river flow also play a role. In South Asia, Pakistan, much of Tanzania mangrove spread through scattered zones along river mouths and coastal inlets. Mangrove growth happens mostly inside tiny spots that stay protected from open exposure.

Very low mangrove coverage is observed in several countries along the Arabian Peninsula and arid regions of the Indian Ocean Rim. . In the regions, like Saudi Arabia , Iran, the United Arab Emirates , Qatar , Oman , and Yemen exhibit sparse mangrove distribution .Here mangroves are typically restricted to isolated lagoons and coastal embayment, surviving under extreme salinity, high temperatures, and minimal freshwater input. Despite their limited spatial extent, these mangroves are ecologically important and highly sensitive to environmental change.

Countries that are small islands are at the latitudinal boundaries of mangrove distribution also have very few mangrove areas. Sri Lanka has largely surrounded by lagoons and estuaries, while the Maldives has an incredibly small mangrove area due to its coral atoll shape. Djibouti, Somalia, and Egypt display severely scattered and sparse mangrove habitats. The southernmost extent of mangroves in the Indian Ocean is marked by South Africa due to lower temperatures, their development is limited. Within the Indian Ocean Rim sector, Australia, considered in this study of mangroves, with more extensive mangrove systems.

Overall, the results demonstrate that mangrove ecosystems in the Indian Ocean Rim are strongly concentrated in tropical, deltaic, and monsoon-influenced regions, while arid and high-energy coastlines support only limited mangrove development. This uneven distribution has important implications for coastal vulnerability, ecosystem services, and climate change adaptation. In regional carbon sequestration and coastal protection, countries with extensive mangrove coverage play a crucial role. Whereas countries with limited mangrove areas may

be more vulnerable to sea-level rise and coastal erosion, underscoring the need for region-specific conservation and management strategies.

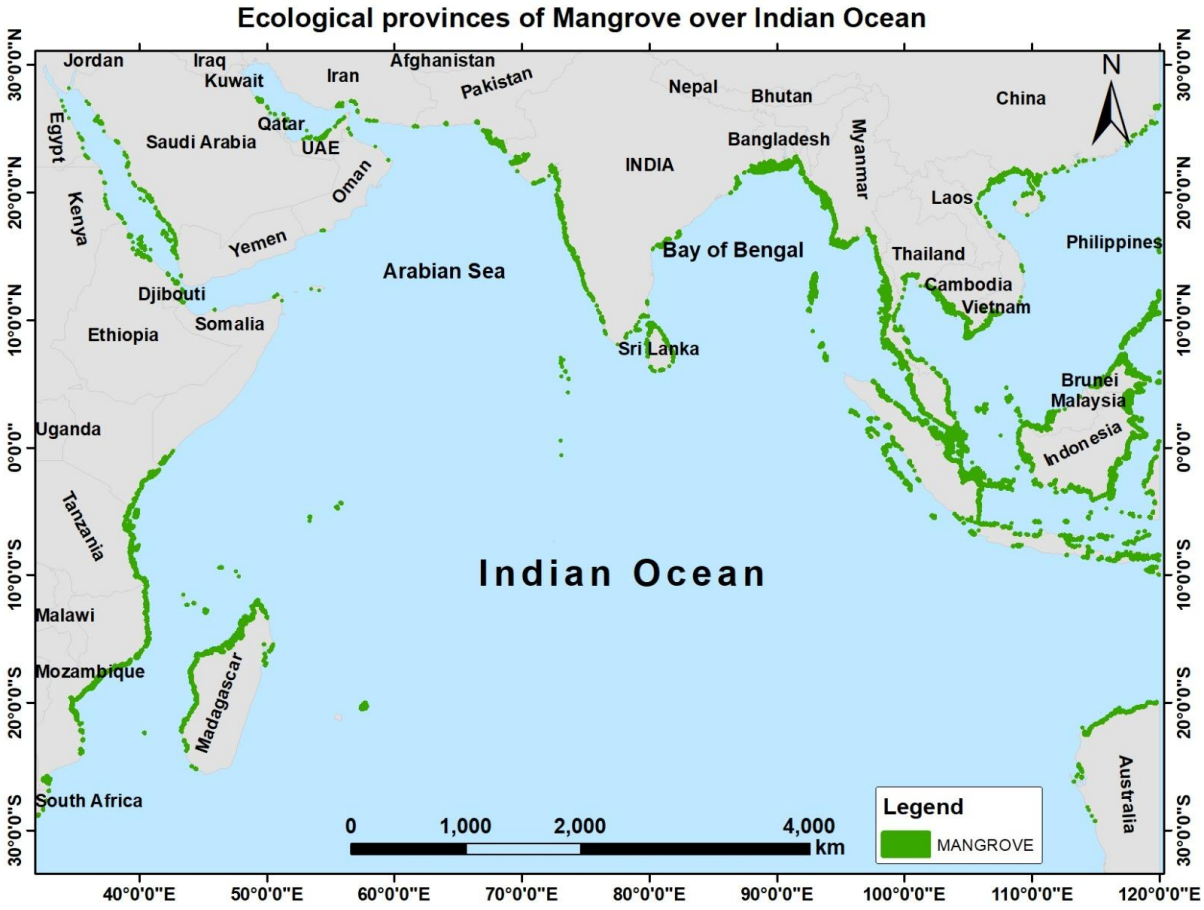

Figure 1: showing the spatial distribution of Mangrove along the coastal zone of Indian Ocean RIM countries

Out in the Indian Ocean Rim, where coral reefs live, patterns shift sharply from one region to another. Driven by a mix of factors like sea surface heat, how clear the water is, depth of the seafloor, breadth of the shelf, movement of ocean currents, even land shape. Look at figure- 2 and you see they tend to hug warm zones, sticking close to shallow stretches where seas barely cover the edge of continents. Islands piled one after another also host them, just as much as scattered island groups tied by reefs. Each nation holds different slices of this world, some nearly empty, others overflowing with reef real estate. A handful grab most of the ocean's coral space, when measured by area across the entire basin.

Indonesia supports the largest coral reef area among all IOR countries clearly dominating the regional reef distribution. Because of this extensive coverage, Indonesia's location is reflected within the Coral Triangle. The presence of extensive shallow-water habitats and its complex archipelagic structure within its EEZ. Indonesia's global significance for coral reef biodiversity, fisheries productivity, and coastal protection is proven by densely distributed reefs along island chains and continental margins. The eastern Indian Ocean region as a whole exhibits high reef density, particularly around Indonesia and neighbouring Southeast Asian countries.

Along the Red Sea, Saudi Arabia holds extensive coral reefs. Though dry and low in river flow, the area supports robust reef life that thrives in a warm, salty sea. In this area Sea floors stretch nearly from edge to shore, helping gentle nutrient-poor currents feed these underwater ecosystems. Continuous reef lines across Saudi shores highlight how wide shore zones plus calm saltwater play key roles in building such habitats. Coral reefs play a major role in shaping the Red Sea's reef network. This shows how linked these coral areas really are across the region.

Across South and Southeast Asia, India hosts a large area of coral reefs - spread largely near the Andaman and Nicobar Islands, along with Lakshadweep's islands, plus scattered parts of the mainland shore. Though broken up in space, these underwater environments still matter deeply, found largely within India's exclusive economic zone in calm, shallow seas. Over in Malaysia, particularly along its far-eastern coastlines and distant island groups, strengthened by warm tropical rhythms. Reef size in Thailand and Vietnam Smaller dimensions tie back to murky sea conditions, heavy river sand flow, along with urban shifts near shorelines - all factors that make it harder for reefs to grow.

When compared to open ocean, island groups show unique patterns of reef spread. Take the Maldives - it hosts about 2,703 km² of coral barriers, even though land space is narrow. This underlines how reefs shape much of what lies inside its exclusive economic zone. Along edges, these barriers link together into ring-like forms, helping hold coasts firm while supporting delicate life forms. Despite its reputation, Sri Lanka hosts only around 107 km² of reef, mostly edge types and scattered clusters near the surface of its continental shelf. Along that coastline, fringing and patch forms dominate rather than large structures. Down in the Indian Ocean, parts of Australia show roughly 1,179 km² covered by coral life. Most of those areas lie beyond what's called the IOR zone, yet still fall within scope.

Along the western Indian Ocean, coral reef distribution is largely controlled by continental shelf width and oceanographic conditions. Mozambique and Madagascar support reef areas that have barely any coral reefs at all. South Africa nearly hits the southern edge of where coral reefs can form across the Indian Ocean. Cooler sea temperatures slow down reef-building there.

Overall, the results demonstrate that coral reef ecosystems in the Indian Ocean Rim are strongly concentrated in tropical, oligotrophic, and shallow-water environments, particularly within island-dominated EEZs and narrow continental shelves. Countries that emerge as major reef holders are Indonesia, Saudi Arabia, Egypt, and the Maldives, while many other countries support smaller yet ecologically cucial reef systems. This uneven spatial distribution significantly implies regional disparities in reef-associated ecosystem services and vulnerability to climate-driven stressors, emphasizing the need for region-specific conservation and management strategies across the Indian Ocean basin.

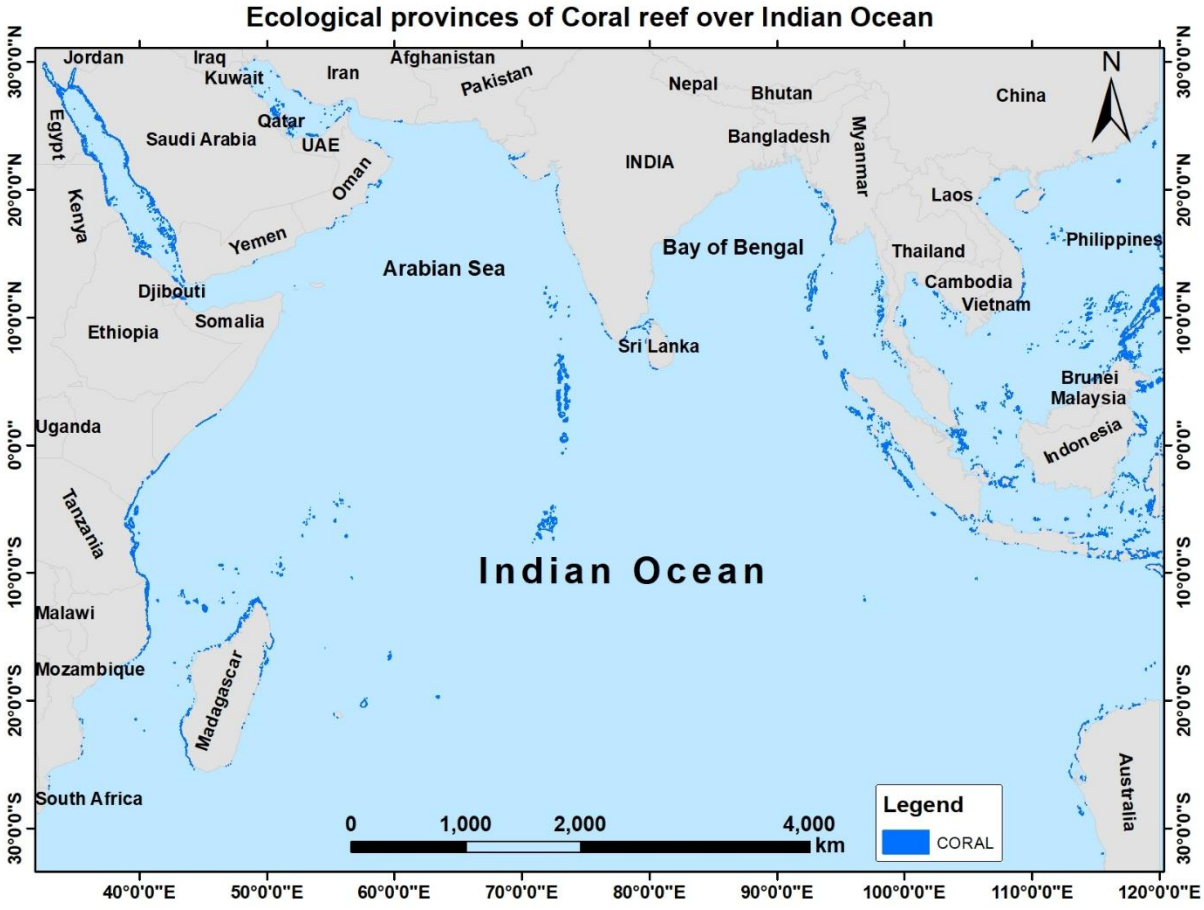

Figure 2: showing the spatial distribution of Coral Reef along the coastal zone of Indian Ocean RIM countries

Across the Indian Ocean Rim, Hydrodynamics - currents and flows - play a role too, alongside climate types and seasons. You can see this spread out clearly in the ecological province map. Meadows mainly live in shallow zones near coastlines, inside lagoons, bays, and on island edges within each nation's EEZ. Unlike coral systems, which often form continuous belts, seagrasses respond sharply to muddy conditions, bed shifts, and human impacts. Their presence is spotty because of it.

Among the IOR countries seagrass ecosystem province of Saudi Arabia supports the largest seagrass making it the dominant seagrass holder in the Indian Ocean basin. Along the Red Sea and Arabian Gulf coastlines, Extensive seagrass meadows occur supported by wide shallow shelves, clear oligotrophic waters, and low riverine sediment input. These huge meadows of sea grass play a critical role in carbon sequestration, habitat provision for fisheries, and nutrient cycling, and particularly within Saudi Arabia's EEZ.

Within the Indian Ocean Rim sector Australia represents another extensive seagrass region. Distribution of these meadows mainly along the western and north-western coasts, where seagrass growth is affected by broad continental shelves and stable substrates. Like the other Madagascar, it supports large seagrass meadows along its west and south edges, wide beds of seagrass grow, found where calm harbours meet rock-like bottoms made of calcium compounds.

Several countries across South Asia, Southeast Asia, and East Africa observed as Moderate seagrass coverage countries. In Yemen, seagrass is largely distributed along sheltered coastal environments and shallow offshore banks. Because of favourable tropical conditions and wide shallow shelves within their EEZs Kenya and Indonesia also support extensive seagrass systems. In India seagrass, mainly concentrated around the Gulf of Mannar, Palk Bay, Andaman and Nicobar Islands, and certain western coast lagoons. Even though these meadows are spatially fragmented due to varying coastal energy conditions and anthropogenic pressures but are ecologically significant.

These findings underscore the need for region-specific conservation strategies, particularly in countries with extensive seagrass meadows that are increasingly vulnerable to coastal development, climate-driven warming, and sea-level rise across the Indian Ocean basin. Looking at everything, data show seagrass covers biggest areas where coastlines have broad shallow beds, open water, and little shaking of ocean mud - often seen in dry land zones like

the Red Sea and Arabian Gulf. On the flip side, shores shaped by heavy rains or flowing rivers tend to host scattered beds instead. What stands out is how much of this habitat clusters in just a handful of designated fishing zones, revealing uneven levels of underwater carbon storage across areas. What we see highlights a gap - solutions must fit each region, especially areas with large seagrass beds now under pressure from rising seas, warmer waters, and growing land use along coastlines throughout the Indian Ocean.

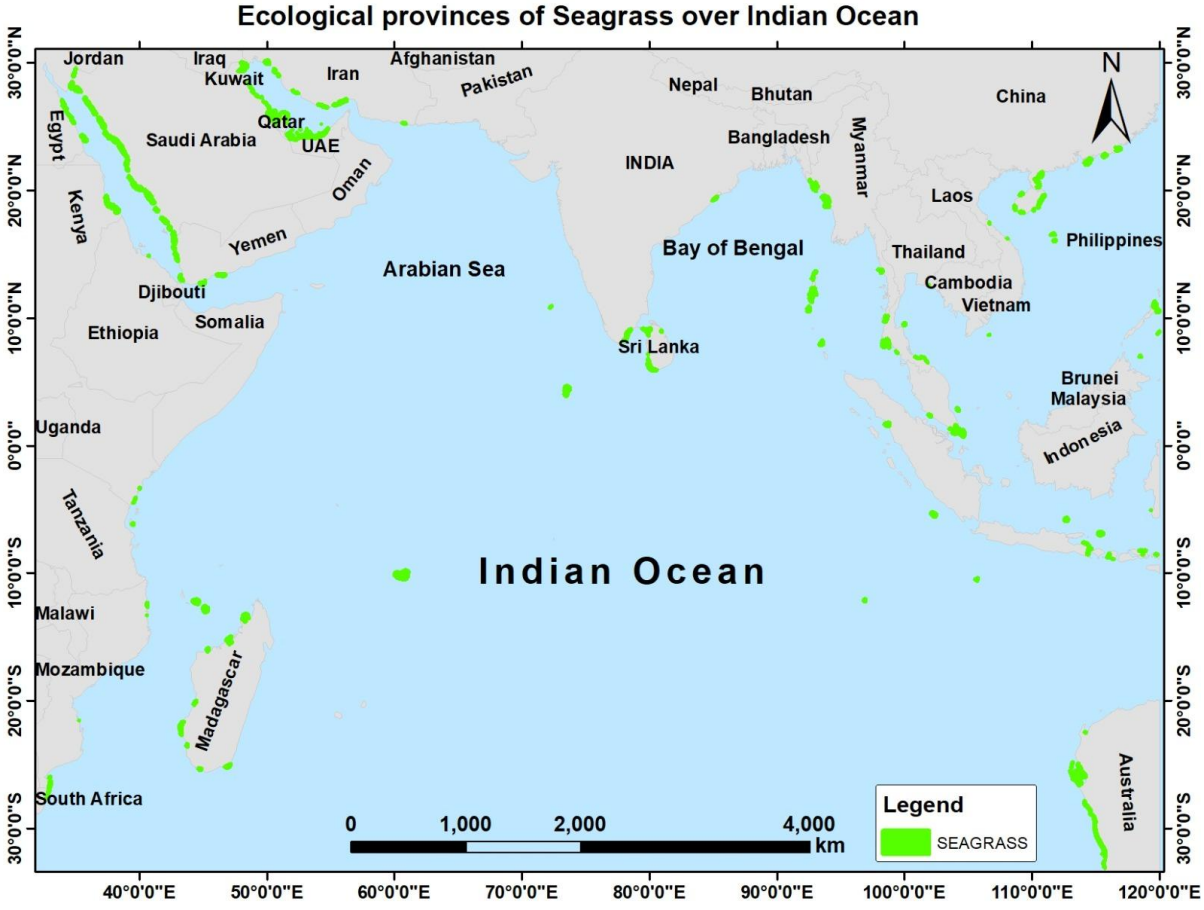

Figure 3: showing the spatial distribution of Seagrass along the coastal zone of Indian Ocean RIM countries

Coastal ecosystem distribution across Indian Ocean Rim (IOR) countries shows seagrass meadows leading the way followed by coral reefs and mangroves because of both natural land shapes and different weather patterns in each area. The total coastal ecosystem area contains seagrass ecosystems which extend across 55-60% of the Indian Ocean according to national statistics that have been combined (Fig-4). The total mapped coastal ecosystems contain coral reefs which cover 25–30% of their area and mangroves which cover 15–20% of their area.

Seagrass meadows are predominated and largely driven by extensive coverage in arid and semi-arid regions of the Arabian Peninsula and parts of the western Indian Ocean. Land like Saudi Arabia alone holds close to a quarter of all such habitats. Neighbouring nations such as Australia, China, Madagascar, Kenya, and Yemen add similar patches too. Together, their share covers over two-thirds of the entire region's covered area. Collectively, these countries contribute more than two-thirds of the basin-wide seagrass extent. Across vast distances, this pattern reveals how seagrass meadows dominate carbon sequestration in the IOR - high underground mass storing large amounts of sediment-derived carbon over decades. In addition, extensive seagrass coverage supports nursery habitats for commercially important fish species, enhances coastal water quality, and stabilizes nearshore sediments.

Approximately one-quarter to one-third of the total coastal area is contributed by Coral reefs form the second-largest ecosystem. Nearly half of the total coral reef area is. Majorly contributed by Saudi Arabia, Maldives, Madagascar and India. Despite occupying a smaller spatial footprint than seagrasses, coral reefs exhibit disproportionately high biodiversity, hosting complex food webs and acting as keystone habitats for reef-associated species. Their distribution reflects favourable thermal regimes, clear waters, and stable substrates, particularly in the Red Sea, central Indian Ocean islands, and parts of the eastern African margin.

In contrast eventhough mangroves contribute the smallest percentage of total area, yet their ecological significance is exceptionally high. in the IOR Countries like as Malaysia, Myanmar, India, and Madagascar together contribute over 60% of the total mangrove area . Although spatially limited, mangroves are among the most efficient blue-carbon ecosystems, storing up to four times more carbon per unit area than terrestrial forests. They also provide critical ecosystem services, including shoreline protection, nutrient cycling, and habitat connectivity between terrestrial and marine systems.

The percentage contribution analysis shows functional ecosystem cooperation because seagrasses store the most carbon and have the largest surface area but coral reefs contain the most diverse species and mangroves store dense carbon while protecting coastlines. The integrated framework needs separate conservation methods for different ecosystems to defend blue-carbon reserves while preserving Indian Ocean Rim marine biodiversity under the fast-paced climate change and human activities which impact the region.

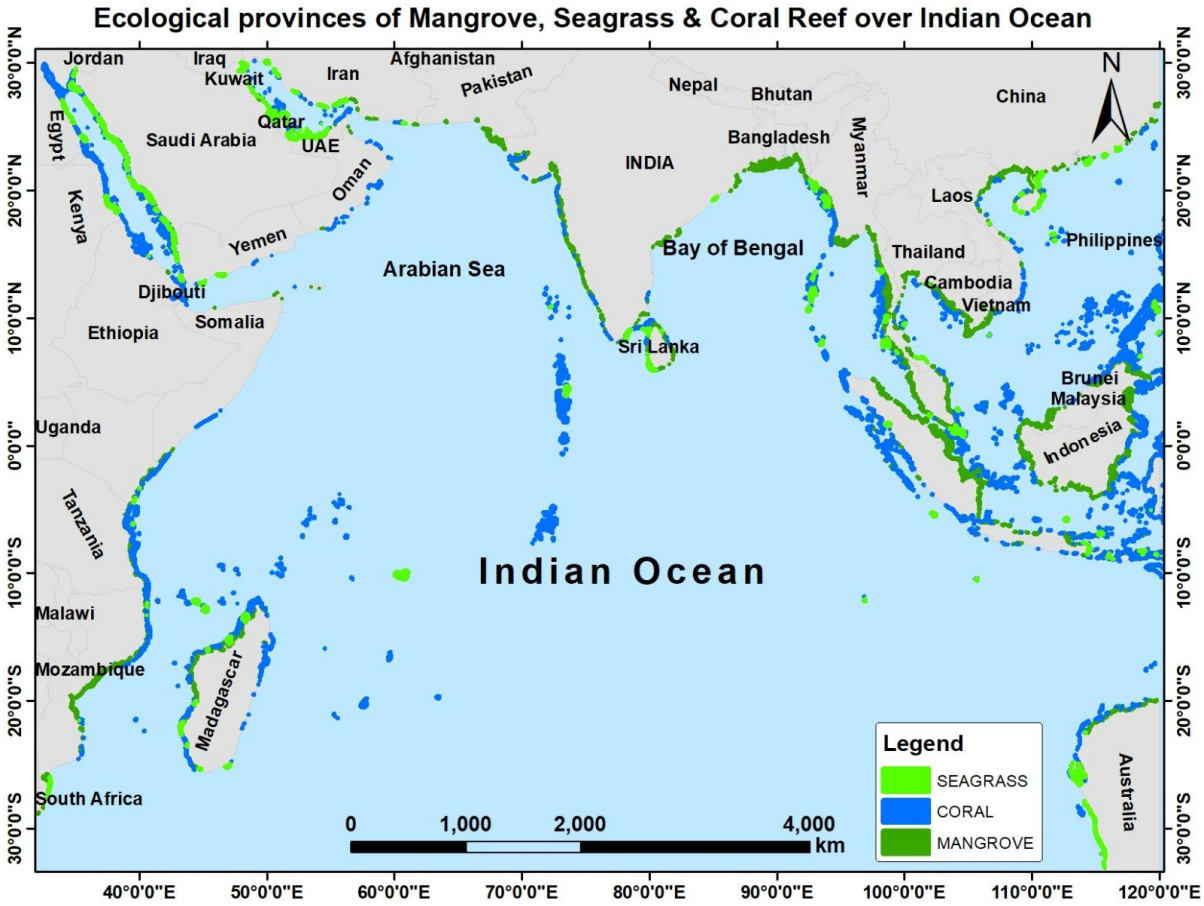

Figure 4: Plot showing the Area (sq.km) distribution of major coastal blue-carbon and marine ecosystems—mangroves, seagrass meadows, and coral reefs—across Indian Ocean Rim (IOR) countries, compiled within national coastal waters and Exclusive Economic Zones (EEZs).

Summary and Conclusion

This study provides a complete, relative contribution and basin-scale assessment of the spatial distribution of three important coastal ecosystems—mangroves, seagrass meadows, and coral reefs- across the Indian Ocean Rim (IOR) countries, using consistent global datasets. The Global Mangrove Watch (GMW) provides Mangrove distribution, while from UNEP-WCMC, seagrass and coral reef extents were obtained, including the Global Distribution of Seagrasses (Short et al., 2020) and the Global Distribution of Warm-Water Coral Reefs. Using these datasets inside national coastal zones and economic shipping areas, the research allows fair comparisons across countries on ocean ecosystems and their importance.

Coastal ecosystems spread unevenly along India's Ocean shore, shaped by varied weather, landforms, seabed size, sand sources, and water patterns. Not surprisingly, seagrass beds take the lead in covering area - over fifty percent of what we've tracked. They thrive where sea beds are broad, shallow, and relatively free of murk, like in areas bordering the Arabian, Red, and western Indian Seas. From coast to coast, seagrass beds spread wide, storing big amounts of blue carbon while holding sediment down for years. Fish begin life here too, feeding fleets far inland without most realizing it.

Being Scattered across warm waters, coral reefs make up only a fraction of coastal space yet play a major role in ocean life. Found largely near equatorial zones, these underwater systems thrive where sea temperatures stay high. Island countries often host vibrant reef communities right offshore. Shelves hugging larger landmasses also host them, though less frequently. Known for sheltering countless sea creatures, one place at a time, they help local fishing remain strong. Waves lose force thanks to reef structure, reducing erosion and stabilizing shorelines nearby. Scattered though they are in the IOR, differences in their spread tie back to uneven access to reef-linked ecosystem benefits, along with sensitivity to shifts like warmer waters and acidic conditions fueled by climate change.

Mangrove ecosystems, although occupying the smallest proportion of total area, play a disproportionate functional role. Their distribution is closely linked to monsoon-influenced, low-energy coastlines, river deltas, and estuarine environments. Mangroves are among the most carbon-dense blue carbon ecosystems, storing substantial amounts of organic carbon in both biomass and sediments while simultaneously offering shoreline stabilization, storm surge protection, and land–sea ecological connectivity.

When looked at together, the spread of coastal habitats along IOR nations shows clear gaps - some areas far less rich than others in both natural resources and ability to face climate shifts. Because of this, saving these spaces means using methods that fit each local context - focusing on where blue carbon is most vital and which spots hold unique life forms under pressure. Working across borders more effectively, tracking changes in ecosystems better, and weaving coastal environments into government plans for climate response could make survival of these systems more likely, even as forces reshaping nature strengthen.

The coastal ecosystems of IOR countries show uneven distribution between different regions which creates substantial differences between areas regarding their ecosystem service delivery and their ability to resist climate change. The implementation of effective

conservation and management strategies requires an integrated ecosystem-based method that should focus on protecting blue carbon reserves and biodiversity areas that exist in specific regions. The Indian Ocean coastal ecosystems need three key elements to maintain their ecological and socio-economic advantages during rising environmental changes: enhanced cross-border collaboration and better ecosystem tracking systems and coastal ecosystems must become part of national climate action plans.

Acknowledgements

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