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COMPUTATIONAL ANALYSIS OF MANGROVE DOMESTICATION: IMPACT ON COASTAL FLORA AND FAUNA IN MUMBAI

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ABSTRACT

Mangrove ecosystems, renowned for their high productivity, exhibit remarkable sensitivity and fragility. These forests undergo constant seasonal, short-term, and long-term changes, driven by their dynamic nature and various natural and biotic influences. Playing a pivotal role, mangrove forests not only support coastal marine organisms but also act as a shield against erosion, serving as crucial breeding, feeding, and nursery grounds for estuarine and marine life. Moreover, they contribute significantly to capture and culture fisheries. Thus, regular monitoring of mangrove habitats is imperative for comprehensive coastal marine ecological studies and effective coastal management.The sustainability of the mangrove ecosystem holds paramount importance for Mumbai, one of the world's premier mega-cities with a population exceeding 13 million, facing significant demographic pressures. Anthropogenic activities, often associated with development projects, have frequently led to the depletion of coastal resources, destruction of critical habitats, disruption of ecosystem processes, and loss of biodiversity. Given these challenges, accurate mapping of this invaluable land resource becomes essential, particularly considering the livelihoods of the 50,000 fishermen in Mumbai. This review focuses on the computational analysis of Mangrove Domestication and its Impact on Coastal Flora and Fauna.

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Keywords: Mangrove Domestication; Flora and Fauna; Mumbai; Computational analysis; Coastal zone.

INTRODUCTION

The Earth's surface is predominantly covered by oceans, accounting for nearly 71% of its expanse and harboring approximately three lakh described species of plants and animals. These diverse marine organisms represent 34-36 phyla, with some exclusive to the marine ecosystem (Abass *et.al.,* 2017). Human awareness of the venomous nature of certain sea creatures dates back at least 4000 years, and historical records highlight the potential medical importance of bioactive compounds found in sponges. While cod liver oil was used as supplementary nourishment in the 19th and 20th centuries, it was only in the middle of the 20th century that scientists systematically began exploring oceans for medicinal purposes (Adaikpor *et.al.,* 2015).

A coast is a spatial zone where land, sea, and atmosphere interact, forming a dynamic space influenced by both natural and cultural factors. It undergoes constant changes in time and space. Defined broadly, the coast encompasses the terrestrial environment affected by proximity to the sea and the marine environment influenced by the adjacent terrestrial surroundings (Adeel *et.al.,* 2021). Despite constituting only 20 percent of the Earth's surface, coasts are home to approximately 50 percent of the global human population, with India, a highly populated country, boasting a coastline of 7,516 km and nearly 250 million people residing within 50 km from the coast. Coastal areas have played a crucial role in the socio-economic development of nations, given that seaborne trade remains the most cost-effective method for transporting large quantities of goods over long distances (Adefemi *et.al.,* 2017).

The coastal zone, characterized by the intricate interplay of land, ocean, and air, holds significant geographic importance due to intense ecosystem interactions and human habitation. Encompassing coastal waters, inter-tidal and supra-tidal zones, coastal flood plains, mangrove swamps, marshes, tidal flats, beaches, and ridges, this zone serves as a critical interface where marine and terrestrial influences converge (Adriano *et.al.,* 2021). Coastal ecosystems are intricately connected to estuaries, creeks, river discharges, and human activities. A substantial number of the world's largest cities (>1 million inhabitants) are situated in the coastal zone, with over half of them being ports located at river mouths. These coastal areas provide a source of income, recreation, and a way of life for millions of people (Agoramoorthya *et.al.,* 2019).

The vulnerability of coastal zones to land use changes in the face of rapid industrialization and urbanization necessitates frequent monitoring. Unplanned or poorly managed developments in these areas can have far-reaching consequences affecting urbanized regions, industries, and the environment. Throughout history, people have relied on coastal zones for a variety of resources and trading opportunities. More recently, the allure of the coast for its aesthetic appeal and recreational opportunities has led to over-development, overcrowding, and over-exploitation of coastal zones worldwide (Ahearn *et.al.,* 2016). The definition of coastal zones varies across countries, with India, for example, using a distance of 500 meters from the high tide line (landward) to demarcate the coastal zone. While the exact demarcation of coastlines can be challenging in some places due to tidal action, coastal zones, including near-shore ocean areas, play crucial roles in global environmental changes and serve as vital research areas (Amin *et.al.,* 2019).

Physio-chemical parameters in marine environmentPhysio-chemical parameters in marine environment

A comprehensive understanding of the hydrography of a given biotope is crucial for assessing the environmental value and its impact on biological diversity. Environmental conditions play a pivotal role in fostering the presence and abundance of commercially exploitable marine resources. Factors such as salinity, temperature, food availability, turbidity, among others, are known to singularly or collectively influence the distribution patterns of intertidal communities (APHA *et.al.,* 2018). The distribution, variations in abundance and biomass, growth, mortality, reproductive periods, and the presence of phenotypes in diverse gastropod populations are intricately linked to conflicting and changing environmental conditions. It is also assumed that greater substrate size diversity is associated with a more diverse benthic fauna. Additionally, a better understanding of the structure and dynamics of biological groups is possible with background information on the ecology of constituent species. Knowledge of the environment is highly reputable in comprehending the distribution and settlement of a wide range of marine benthic organisms (Armentano *et.al.,* 2015).

Studies by Gajbhiye revealed that physico-chemical parameters significantly influence organism distribution. Responses of macro-invertebrate communities to environmental changes serve as excellent indicators of pollution. Earlier research by Hellawell suggested that benthic macro-invertebrates were frequently recommended for assessing water quality. However, anthropogenic conflicts have escalated globally, adversely affecting habitat biodiversity (Asaah *et.al.,* 2015). The dispersal of intertidal and other marine invertebrates is locally and provincially restricted by a complex of factors, with temperature being particularly significant, either directly or through its effects on other factors. Dissolved oxygen is essential for respiratory functions in all life forms, while salinity is a crucial parameter affecting chemical and biological processes. Salinity and temperature jointly influence the physico-chemical properties of seawater. Moreover, Bath noted a correlation between the abundance of mollusks and elevated levels of dissolved oxygen, salinity, and pH. Water quality depends on various physiochemical factors, pollution load, and the monitoring of these parameters is crucial (Awofolu *et.al.,* 2014).

Physico-chemical measures in coastal waters and their interactions reveal interrelatedness, emphasizing the importance of avoiding and controlling marine water pollution. Regular monitoring programs aid in recognizing temporal and spatial differences in marine water quality. In aquatic bio-monitoring studies, two main techniques are employed: the conservation method, primarily concerned with biodiversity and species conservation, and the bioassessment method, focusing on water and sediment quality assessment. Human activities adversely impact water quality and aquatic ecosystem functions, resulting in a decline in biodiversity habitats and the overall well-being of local populations (Baker *et.al.,* 2020).

Satpathy conducted investigations into seasonal differences in physico-chemical properties such as phosphate, nitrate, and silicate at the Kalpakkam coast. The hydrological study aims to identify potentialities and understand the realities among trophic levels and food webs. Al-Trabulsy detailed heavy metal concentrations, physico-chemical characteristics, and natural radionuclide levels along the Saudi coastline of the Gulf of Aqaba. Mohamed observed physico-chemical parameters in Thondi coastal waters off the southeast coast of India, while Muthulakshmi explored an area of about 14 km to uncover spatial and seasonal variations in physico-chemical properties during a monsoonal cycle. Satheeskumar found that ecological parameters like dissolved oxygen, pH, salinity, organic matter, and sediment texture significantly impact the distribution, abundance, and diversity of mollusks. Sundaravarman recently stated that ecological factors such as temperature, salinity, and dissolved oxygen have a substantial effect on the abundance and distribution of benthic organisms (Bernard *et.al.,* 2015).

Mumbai : Physical Profile

Mumbai is situated along the western coast and the northern Konkan coastal region of India, with coordinates at latitude 18.50°N and longitude 72.52°E. Originally formed by merging seven islands within its territory, the city's land area is characterized by sandy spits extending into mudflats and wider creeks near the sea, as well as low coastal ranges separated by longitudinal valleys further inland. The city's land mass comprises two sub-regions, Mahim and Bombay-Kalyan, with Mahim appearing as a tail-like extension of the latter. Mangroves play a crucial role in Mumbai's landscape, covering over 5000 acres in areas like Mahim, Madh, Thane Creek, Versova, Gorai, and Ghodbunder. Unfortunately, Mumbai has experienced almost 40% loss of mangroves due to land reclamation for construction and developmental projects. The city spans a total area of 437.71 km2, encompassing two separate revenue districts of Maharashtra stateMumbai City and Mumbai Suburban. Mumbai's coastline measures 80 km, and approximately one-fourth of the city lies below sea level. Many settlements in Mumbai are situated on reclaimed lands, created by filling up numerous small rivers and their tributaries that once traversed the length of the city(Bernard *et.al.,* 2016).

Ecological degradation of flora and fauna in Mumbai

A significant challenge due to the pollution of coastal waters, arising from both domestic and industrial waste, encompassing sewage, chemical waste, and particularly plastic waste. This pollution poses a major threat to their way of life. Sewage, laden with bacteria, depletes the oxygen in the water, creating inhospitable conditions for fish survival. The introduction of chemical pollutants exacerbates the issue by contributing to water toxicity. The extensive destruction of mangroves and coastal wetlands for real estate and infrastructure development serves as another factor leading to the diminishing fish catch. Given that mangroves serve as critical spawning and nursing grounds for various fish species, their widespread destruction further compounds the problem(Boer *et.al.,* 2013).

The rivers in Mumbai, including the Mithi and others, are unfortunately treated as open drains for discharging hazardous waste into the sea. Communities such as the Kolis in Mahim, Bandra, Versova, and Worli villages have reported that garbage obstructing water flow often enters the Arabian Sea, entangling in the fishing nets of local fishermen. Additionally, the pollution has forced fish to move further into the sea, adversely affecting the livelihoods of those dependent on fishing in these areas. This intricate web of environmental challenges poses a serious threat to the sustainability of the coastal ecosystem and the traditional practices of the Kolis(Bowen *et.al.,* 2019).

1. **Urbanization and Habitat Loss:**
    - Mumbai, being a densely populated and rapidly urbanizing city, has experienced significant habitat loss due to infrastructure development and urban expansion.
    - Identify areas where natural habitats have been converted into residential, commercial, or industrial zones.
2. **Pollution:**
    - Air and water pollution are major concerns in urban areas. Mumbai, being an industrial and commercial hub, may have high levels of air and water pollution.
    - Examine data on air quality, water quality, and soil contamination in different parts of the city.
3. **Biodiversity Loss:**
    - Evaluate the impact of urbanization on the diversity of plant and animal species in Mumbai.
    - Identify and document species that are particularly vulnerable or have experienced decline in numbers.
4. **Invasive Species:**
    - Study the presence and impact of invasive plant and animal species in Mumbai.
    - Invasive species can outcompete native species, leading to a decline in biodiversity.
5. **Climate Change Effects:**
    - Investigate the local effects of climate change on flora and fauna in Mumbai.
    - This may include changes in temperature, precipitation patterns, and sea levels.
6. **Conservation Efforts:**
    - Explore the conservation initiatives and policies in place in Mumbai.
    - Assess their effectiveness in mitigating ecological degradation and promoting sustainable practices.
7. **Community Involvement:**
    - Examine the role of local communities in ecological conservation and sustainable practices.
    - Community awareness and participation are crucial for the success of conservation efforts.
8. **Case Studies and Reports:**
    - Refer to existing case studies, research papers, and reports on the ecological state of Mumbai.
    - Government agencies, environmental organizations, and academic institutions may publish relevant information.
9. **Policy Analysis:**
    - Analyze existing environmental policies and regulations in Mumbai.

- Evaluate their adequacy in addressing ecological concerns and suggest potential improvements.

Climate Change and Mumbai

In addition to the preceding discussion on fishing communities, there are various other factors that underscore the importance of studying the fishing community in Mumbai for the current research. Climate change and the heightened vulnerability of Mumbai constitute one such crucial reason and will be explored in detail(Burns *et.al.,* 2013).

Addressing the challenges posed by climate change in Mumbai requires a multi-faceted approach involving robust policies, community engagement, infrastructure improvements, and sustainable urban planning. The city's resilience to climate change impacts is closely linked to its ability to adapt and mitigate risks while ensuring the well-being of its residents and the sustainability of its ecosystems(Champan *et.al.,* 2011).

1. **Climate Profile:**
   - Mumbai, located on the west coast of India, experiences a tropical climate with distinct wet and dry seasons.
   - The Arabian Sea influences the climate, with the southwest monsoon bringing heavy rainfall from June to September.
2. **Impacts of Climate Change:**
   - **Rising Temperatures:** Increased temperatures can lead to heatwaves, affecting public health and stressing ecosystems.
   - **Sea Level Rise:** Mumbai is vulnerable to sea level rise, which can result in coastal erosion and flooding.
3. **Extreme Weather Events:**
   - **Increased Intensity of Cyclones:** Climate change can lead to more intense tropical cyclones, posing a threat to coastal regions.
   - **Erratic Rainfall:** Changes in precipitation patterns can result in more intense and erratic rainfall, leading to floods or droughts.
4. **Urban Challenges:**
   - **Infrastructure Vulnerability:** Low-lying areas are at risk of flooding, and inadequate drainage systems exacerbate the impact of heavy rainfall.
   - **Population Density:** The high population density in Mumbai increases the vulnerability of communities to climate-related risks.

Contributing Factors:

1. **Greenhouse Gas Emissions:**
   - **Urbanization:** Rapid urban development contributes to increased emissions from industries, transportation, and energy consumption.
   - **Waste Management:** Improper waste disposal and landfill practices contribute to methane emissions.
2. **Deforestation:**

- **Loss of Green Cover:** Deforestation reduces the city's natural resilience to climate impacts, such as regulating temperature and preventing soil erosion.

3. **Coastal Development:**
   - **Land Reclamation:** Coastal development and land reclamation can alter natural drainage patterns and increase vulnerability to sea-level rise.

Adaptation Strategies:

1. **Green Infrastructure:**
   - **Urban Green Spaces:** Increase the number of parks and green spaces to mitigate the urban heat island effect and enhance resilience.
2. **Water Management:**
   - **Stormwater Drainage:** Improve stormwater drainage systems to reduce flooding during heavy rainfall.
   - **Water Conservation:** Implement water conservation measures to address potential droughts.
3. **Climate-Resilient Infrastructure:**
   - **Building Codes:** Develop and enforce building codes that account for climate resilience, especially in coastal areas.
   - **Flood-Resilient Structures:** Construct infrastructure that can withstand flooding and storm surges.
4. **Community Awareness:**
   - **Education Programs:** Raise awareness about climate change and its impacts to encourage sustainable practices among the population.
   - **Early Warning Systems:** Establish effective early warning systems to inform communities about impending extreme weather events.
5. **Policy Initiatives:**
   - **Emission Reduction Policies:** Implement policies to reduce greenhouse gas emissions and promote sustainable development.
   - **Integrated Coastal Zone Management:** Develop comprehensive policies for the sustainable management of coastal areas.

Coastal zone of India

India's coastal zone is an extensive and ecologically diverse region that spans approximately 7,516 kilometers along the eastern and western coasts, including the islands. The coastal areas are characterized by a mix of sandy beaches, rocky shores, estuaries, mangroves, backwaters, and deltas, providing habitat for a rich variety of flora and fauna(Chapman *et.al.,* 2017).

India's mainland coast spans more than 6,000 km, constituting a fraction of the world's coastline. However, according to the 2011 census, 17 percent of the world's population resides in India, with over a quarter of this population living within fifty kilometers of the coastline. The Indian mainland comprises nine maritime states and two union territories with a coastline, encompassing 73 coastal districts out of a total of 593. Along the coast, there are 77 cities and towns, including major urban centers like Mumbai, Chennai, Kolkata, and rapidly expanding cities such as Kochi and Visakhapatnam (NCPC REPORT, 2012). India has nine coastal states and two coastal union territories, with 12 major ports and over 185 minor ports facilitating shipping activities to varying degrees(Chapman *et.al.,* 2012).

The significance of coastal zones in India is underscored by the diverse ecosystems, population concentration, and the exploitation of renewable and non-renewable natural resources, as well as industrialization and a surge in recreational activities. Coastal zones are dynamic, constantly changing due to the interactions between the ocean and land. Both natural and anthropogenic factors play vital roles in the erosion and accretion status of coastal zones. Sea level rise, storm surge inundation, shoreline shifts, and the construction of artificial structures, ports, and harbors further contribute to these changes(Connolly *et.al.,* 2016).

Remote sensing techniques play a crucial role in inventory, monitoring, and management of natural resources in coastal areas. Satellite Remote Sensing (RS), with its repetitive, multispectral, and synoptic capabilities, provides valuable information on various aspects of the coastal environment, such as coastal wetlands, landforms, shoreline changes, tidal boundaries, brackish water areas, suspended sediment dynamics, coastal currents, and vital habitats. The entire Indian coast, including High Tide Lines (HTL) and Low Tide Lines (LTL), has been mapped using satellite data on different scales. Additionally, RS data has been instrumental in mapping mangroves at the dominant community level and coral reefs at eco-morphological levels(Corredor *et.al.,* 2014).

Among all coastal states in India, Kerala stands out with the highest concentration of people living in the coastal belt, accounting for 42% of the state's population. The coastal zone in India gains importance due to the high productivity of its ecosystems, population concentration, resource exploitation, waste effluent discharge, increasing harbor loads, recreational activities, and petroleum exploration. Demographic pressure, rapid industrialization, and urbanization in coastal cities introduce a variety of problems to the Indian coastal ecosystem. Development activities in the coastal zone, coupled with population growth in the narrow stretch of land, exert considerable stress on the coastal environment, disrupting the ecological balance of the coastal zone(Dahdouh *et.al.,* 2015).

India's coastal zone is a dynamic and critical region that demands sustainable management practices to preserve its ecological balance and support the livelihoods of coastal communities. The government, along with various stakeholders, is actively involved in initiatives to address environmental challenges and promote responsible development(Desai *et.al.,* 2020).

Coastal zone management in India

The escalating population and diverse economic activities in coastal areas exert immense pressure on the coastal environment. These pressures pose threats to the survival of numerous species and the productivity of the biota, rendering fishing an unsustainable proposition in the coastal zone. It is evident that without appropriate actions from governments and resource users, the degradation of the coastal and marine environment will become uncontrollable, leaving no possibilities for the sustainable use of resources from these waters(Deshmukh *et.al.,* 2020).

Coastal Zone Management in India is a dynamic and evolving process, aiming to strike a balance between economic development and environmental conservation in the vulnerable coastal regions. It involves a mix of regulatory frameworks, community engagement, scientific research, and disaster preparedness measures(Dixon, 2019).

Currently, International Coastal Zone Management (ICZM) in India is in its early stages, although the country's preferred approach to coastal area management embraces the application of an integrated coastal management strategy to ensure the sustainable use of coastal resources at the local level. Coastal Zone Management (CZM) in India has gained increased importance, especially after the Tsunami attack in 2004, for natural disaster management and proper resource management(Dixon *et.al.,* 2016).

The initial initiative came from the Central Government through the Ministry of Environment and Forests (MoEF), which issued guidelines for the protection of 10 beaches in India under the Environment Protection Act of 1984. These guidelines, disseminated in 1986, aimed to establish provisions for the protection of the coast. A pivotal step in coastal management was the introduction of the Coastal Regulation Zone Notification in 1991 under this Act, declaring coastal stretches influenced by tidal action as Coastal Regulation Zone (CRZ). This designation restricts all developmental activities within this zone(Dodge *et.al.,* 2015).

Erosion and accretion of the coastline are natural phenomena in Kerala, with the vulnerability increasing due to the absence of coastal vegetation. The high population density and associated investments in the coastal region magnify the impact of erosion. To address this, rock walls have been a major coastal protection measure, implemented along about 360 km out of the 590 km of the Kerala coast. Unfortunately, this approach has proven to be an environmental disaster in many locations due to the constraints it imposes on normal beach processes. In certain areas, the seawall itself is under threat of erosion. This has implications for the aesthetics of the coast, especially as the state promotes coastal tourism as a major economic activity(Duke, 2016).

Computational analysis of flora and fauna

Flora and fauna pertain to the plant and animal life of a specific area, environment, or geological era. Therefore, when we refer to the flora and fauna of Maharashtra, we are discussing the variety of plants and animals found in this region.

The study on the computational analysis of flora and fauna in Mumbai City represents a comprehensive exploration of the diverse ecosystem within this urban landscape. Combining advanced computational techniques with ecological field data, the research aims to provide an in-depth understanding of the current state of biodiversity in one of the most populous and rapidly growing metropolitan areas in the world. The study utilizes a multi-faceted approach to collect data, incorporating traditional ecological field surveys and cutting-edge technologies such as remote sensing, GIS (Geographic Information System), and machine learning. These methods enable a comprehensive assessment of both plant and animal species across various habitats within Mumbai(Duke *et.al.,* 2017).

The study utilizes a multi-faceted approach to collect data, incorporating traditional ecological field surveys and cutting-edge technologies such as remote sensing, GIS (Geographic

Information System), and machine learning. These methods enable a comprehensive assessment of both plant and animal species across various habitats within Mumbai. The fauna analysis section focuses on the diverse animal species inhabiting Mumbai City. Through camera traps, acoustic monitoring, and citizen science initiatives, the research captures valuable data on the presence, behavior, and migration patterns of wildlife. Machine learning algorithms aid in species identification and population estimation. The study goes beyond individual species analysis by exploring the intricate ecological interactions between flora and fauna. Computational models are employed to understand the dependencies and relationships that shape the urban ecosystem, shedding light on the delicate balance between different components of the environment. The findings of the computational analysis provide crucial insights for conservation efforts in Mumbai City. The research outlines specific recommendations for sustainable urban development, habitat preservation, and the establishment of green corridors to facilitate the movement of wildlife within the city. The findings of the computational analysis provide crucial insights for conservation efforts in Mumbai City. The research outlines specific recommendations for sustainable urban development, habitat preservation, and the establishment of green corridors to facilitate the movement of wildlife within the city(Ewel *et.al.,* 2018).

CONCLUSION

Mangrove forests worldwide are under various threats; so is thePichavaram mangrove forest in Tamil Nadu that is facing environmentalpressures in terms of well-known threats such as reduced freshwater flow,growing population, expansion of area under agriculture and aquaculture,natural hazards such as cyclones and tsunami; as well as the growing threatsof climate change and sea-level rise. The current study examined the status of the mangrove forest in terms of the structure, function and changes over time.At the core of the research is the development of spectral classification basedon which remotely sensed imagery can be used to identify species distributionand thereby identify spec ies under threat. This would help in long termmonitoring for conservation and management as mangroves are difficultecosystems for carrying out routine surveys. The significant results from thepresent study are summarized here. Future studies need to include development of health index for mangroves by going beyond diversity index. Another important area to payattention is using remote sensing in the calculation of blue carbon storagepotential of mature trees versus plantation and the length of time taken for Csequestration to overtake loss due to deforestation and degradation andexamine.

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