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Mangroves as Coastal Defenders: Ecosystem Services and Conservation Imperatives

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Mangroves are unique intertidal ecosystems found in tropical and subtropical areas of the world, that they provide habitat for a wide variety of aquatic and land animals. These ecosystems are extremely productive everywhere in the world while being delicate and rarely distributed. Mangroves have extremely developed morphological and physiological adaptations to adverse conditions to deal with such a hostile habitat. They maintain and protect coastal areas while nourishing the coastal water with nutrients. With rapid industrialization and urbanization, heavy metal pollution has become one of the most prominent problems in the ecological environment of mangrove ecosystems. The relatively high concentration of nutrients and metals suggests that water is in very dreadful condition, which will ultimately affect flora and fauna of this ecosystem.

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Keywords: Mangroves; ecosystems; estuary; biodiversity.

1. INTRODUCTION

Mangroves are unique intertidal ecosystems found in tropical and subtropical areas of the world, that they provide habitat for a wide variety of aquatic and land animals. Mangroves, which are recognized as highly productive ecosystems of tremendous ecological significance, it refer to approximately 60 to 70% of the world's tropical and subtropical coastlines (Twilley et al., 1996). Mangroves play a crucial role as habitats for fish and prawns, offering essential nursery grounds, feeding areas, and protection from predation (Twilley, 1988). This vital function also supports local crab and shellfish farming, which thrives in these regions due to the rich biodiversity (Joseph *et al.,* 2024; Nixon et al., 1984). The mosaic of mangrove habitats offers a range of biodiversity elements that are crucial to the functioning and environmental quality of tropical estuary ecosystems (Salsabilla *et al.,* 2020). "Mangroves protect and maintain a rich marine biodiversity in the tropics and subtropics and are crucial carbon sinks. Recently, ecosystem based solutions to achieve sustainable development has become a hot topic around the world leading to the genesis of several concepts such as nature-based solutions, green infrastructures, ecosystem-based adaptation, working with nature and ecosystem based management amongst others (Alongi et al., 1992). Mangroves protect and maintain a rich marine biodiversity in the tropics and subtropics and are crucial carbon sinks" (Sunkur *et al.,* 2023). Mangroves also play a significant role in maintaining water quality and shoreline stability by regulating the distribution of nutrients and sediment in estuary waters (Thatoi and Biswal 2008; Thatoi et al., 2013). "With rapid industrialization and urbanization, heavy metal pollution has become one of the most prominent problems in the ecological environment of Mangrove ecosystems, which are found along the estuarine shores in tropical and subtropical regions" (Chen, B *et al.,* 2022; Walsh, 1967).

2. HABITAT ADAPTATIONS

Mangrove plants grow in harsh conditions such as high salinity, hypoxic (oxygen-deficient) wet soil strata, tidal pressures, strong winds, and sea waves. Mangroves have extremely developed morphological and physiological adaptations to adverse conditions to deal with such a hostile habitat. The mangrove root system absorbs oxygen from the atmosphere. Mangroves have special roots for this purpose called breathing roots or pneumatophores. Mangroves, like desert plants, store fresh water in their thick succulent leaves. A waxy covering on the leaves seals in water and reduces evaporation. They are found in the intertidal zone, which is where the terrestrial limit for other plant communities ends and the influence of the marine ecosystem begins.

There are types of Mangroves:

Red – Found along the coastlines
Black – Major feature of such mangrove trees is their dark bark. They have access to more oxygen.
White – Compared to Red and Black mangroves; they grow at the highest elevation.

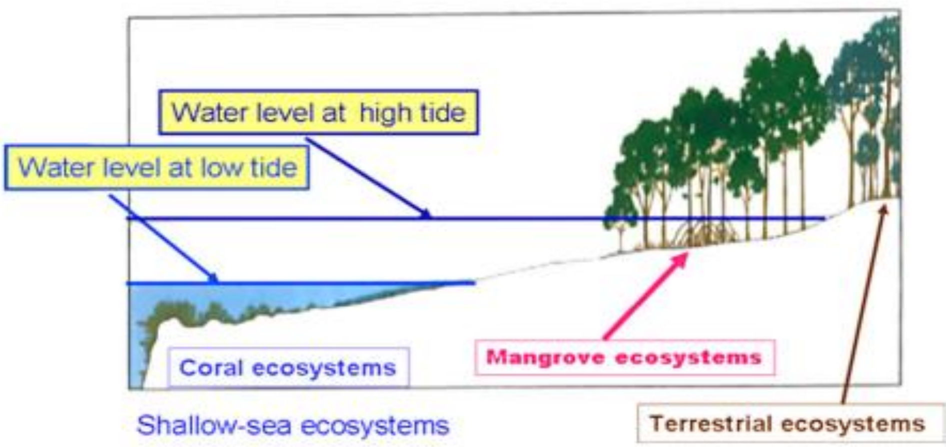

Fig. 1. Occurrence of mangroves in the intertidal zones

Fig. 2. Different mangrove ecosystem

3. SPECIES DIVERSITY

"Mangroves are a diversified group of mostly tropical plants and shrubs that are functionally diverse and complicated. They also provide structure and habitat for a variety of marine and intertidal organisms. Mangrove vegetation takes several forms, including trees, shrubs, palms, and ground ferns. Avicenniaceae and Sonneratiaceae are the only plant families that are entirely composed of mangrove taxa, though this is still contested. True mangrove species have been described as 69 species in 27 genera belonging to 20 families" (Duke, 1992; Kathiresan and Bingham, 2001; Selvam *et al.,* 2004). Asia is the highest diversity of mangrove species, with 44 species recorded. According to FAO (2003), "there are 77 species of mangrove plants worldwide. There are 21 flowering plant genera found in mangroves, indicating a relatively high degree of specialisation for the tidal wetland ecosystem. Twelve angiosperm genera are exclusively mangrove, while ten others comprise non-mangrove species".

"Mangrove ecosystems possess four unique characteristics of high productivity, high return rate, high decomposition rate and high resistance to extreme weather events and anthropogenic activities as one of the unique marine ecosystems in the world" (Wang, 2019; Liu and Wang, 2020; Liu *et al.,* 2020). "Mangrove systems serve as habitat and nursery area for many juvenile fish and crustaceans, which have both direct and indirect socio-economic importance. They also provide erosion mitigation and stabilisation for adjacent coastal landforms" (Harty, 1997). "Mangroves are also one of the world's richest repertoire for biological and genetic diversity of fauna and flora along roughly 60–75% of the world's tropical coastal zones. There is also an amazing richness of microorganisms and microbial diversity in such ecosystems. Furthermore, 90% of the marine organisms spend part of their life cycles in this ecosystem and 80% about the global fish catches are dependent on mangrove wetlands. The net primary productivity of mangrove ecosystem is up to 2000 g $C \cdot m^{-2} \cdot a^{-1}$, with high strength material cycles, energy flow, as well as maintaining biodiversity" (Lin, 1997; Wang, 2019).

4. IMPORTANCE OF MANGROVE FOREST

The mangrove forests are of great environmental significance and socioeconomic value:

- Protect coastlines from wind, waves, and sea currents
- Reducing soil erosion and siltation
- Protecting coral reefs, seagrass beds and shipping lanes
- Providing wood and other forest products, renewable fuel source
- Providing habitat and nutrition for a variety of creatures
- Supporting coastal fisheries and livelihoods
- Essential nursery areas for finfish and shellfish
- Mangrove foliage as feed for domestic animals
- Provide opportunities for tourism, education, and scientific research

Threats:

Large scale clearing: To accommodate the human population, agriculture, and aquaculture. This has resulted in forest fragmentation, loss of biodiversity, and a decline of mangrove dominant shorelines.

Small scale harvesting and grazing: For timber, fuel wood, fodder, and other products of persons and their livestock who venture into the forests?

Industrial threats: Effluent pollution, mining, industrial growth, and oil spills are all causes of pollution.

Conservation of the Mangrove ecosystem:

- ✓ Afforestation
- ✓ Legislation (including laws and policies)
- ✓ Monitoring and Surveys (land and aerial, etc.)
- ✓ Protection (including conservation, parks and reserves development, etc.)

5. CONCLUSION

Mangroves are crucial defenders of coastal ecosystems, serving as natural barrier that protect shorelines from erosion, storm surges, and the impacts of rising sea levels. In addition to their protective functions, these unique forests are critical for supporting biodiversity, offering vital habitats for numerous marine and terrestrial species. Mangroves also contribute significantly to climate change mitigation by serving as efficient carbon sinks, storing large amounts of carbon in their biomass and soil. However, mangroves face increasing threats from deforestation, pollution, and climate change, making their preservation and restoration an urgent priority. Their loss would not only harm wildlife but also disrupt the livelihoods of millions of people who depend on them for resources like fish, wood, and ecotourism. By promoting conservation efforts, enhancing public awareness, and encouraging collaboration among governments, organizations, and local communities, we can ensure that mangroves continue to safeguard coastlines, support economies, and contribute to a healthier environment for future generations.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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