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Role of Mangroves in Coastal and Estuarine Stewardship

A Case of Sea Level Rise in Trivandrum, Kerala

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ABSTRACT: *The discussion is an attempt at proposing coastal and estuarine resilience and stewardship for the case of Trivandrum, Kerala, in the event of climate crisis. Its intent, is sixfold: to identify traces of mangrove patches; to understand its evolution, morphology, distribution, tidal elevation and zonation; to identify the causes and consequences of its exhaustion; to evaluate its contribution towards the performance of the coastal built-unbuilt environment. Thereby, to derive a green platform for ecological restoration and formulate a policy framework that regards the place's socio-cultural-political attributes: CRZ etc. This discussion further suggests the methodology and methods required to restore the mangroves, weave a livable and climate-responsive built-unbuilt fabric, promote public awareness and stewardship.*

KEYWORDS*: Mangrove restoration, Climate-responsive built-unbuilt fabric, Policies, Stewardship "Mangroves are to a coastal area, what rain forests are to the Western Ghats." –Manoj Kumar IB (Menon & S, 2019)*

1. INTRODUCTION

The recent consecutive floods and landslides in Kerala, 2018-2019, reminded Malayali of the Periyar flooding in '99. It has led God's own country and its dormant administration, to hard hitting realizations about ignorance towards the 2011 Western Ghats Ecological Expert Panel report (prepared by the Green Tribunal – appointed - Gadgil Committee). The disregard of the report was primarily due to its misinterpretation that the demarcation of the Ghats into 3 ecologically sensitive zones framed a half cooked action protocol; and consecutively instilled fear in the locals, about loss of their livelihood to government's land acquisition strategies. For a state with a high literacy rate, such negativity that arose, can only be attributed to man's unfamiliarity of his ground.

Today, with the Western Ghats wearing down its resilience, it is imperative to introspect and inform about the stability of other significant ecosystems in the state: the 'Kandalkkaadu'- mangrove ecosystems at the estuarine belts of Arabian Sea. These nature's kidneys whose halophytic vegetation, root structure help adapt to tidal fluctuations, also check floods and erosion. Characterized as spatial and ecological archetypes, its density and distribution across the state, have marginally decreased due to coastal clearance, for siting urban development, architecture etc. Veli in Thiruvananthapuram is an example where such degrading phenomenon can be witnessed of late.

In a recent study conducted by Climate central, the Land Projected to be below the Annual Flood Level in central Kerala by 2050, is a shocking revelation.

The alarming rate and intensity at which climate crisis has been affecting natural systems and their resources, hence calls for urgent stewardship.

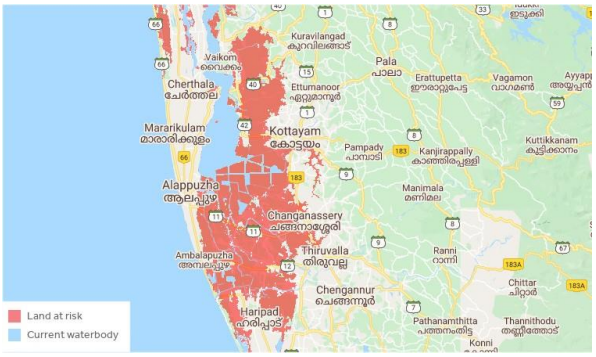

Figure 1: Land projected to be below annual flood level, Kerala. (2019, Retrieved from https://coastal. climatecentral.org)

1.1. Coastal and estuarine ecosystems in Kerala

Kerala is divided into three geographical regions: Highlands, which slope down from the Western Ghats onto the Midlands of undulating hills and valleys into an unbroken 580 km long coastline with many picturesque backwaters, interconnected with canals and rivers.(Source: Wikipedia) A larger concentration of backwaters and rivers lie in Central Kerala, also making it the most vulnerable during flooding. They are constituted within the T.S.Canal, which has been identified as National Waterway III and runs in the North South direction along the state.

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The physiographic elevation of Trivandrum, however keeps the district safe from the annual flooding, but is highly susceptible to encroachment by the sea. The coastal and estuarine profile of the state is as shown in Fig. 2.

Figure 2: Coastal and Estuarine profile of Kerala. (2019, Information sourced from https://www.mapsofindia.com/maps/kerala)

1.1.1. Mangroves - Kandalkkaadu

Distribution

Considering Kerala has 44 rivers, the state has very limited mangrove forests. Kochi had 700 sq.km of mangrove cover in early 1950s as compared to 25 sq.km today, all over the state. (Menon & S, 2019)

Kannur district has the largest concentration of mangroves in the state. Poovar and Veli have recorded presence of mangroves in Trivandrum district. Fig.4 shows the distribution of mangroves within Kerala as recorded in 2019.

Ecological archetype:

- Significance of the ecosystem

Mangrove ecosystem as an ecological archetype, renders unavoidable significance to the larger ecology of a place.

Figure 3: Mangroves in Kerala. (Retrieved from https://th.thgim.com/news/national/kerala/uavkbp/article28726329.ece/alternates/FREE_660/27TVMANGROVEETREE)

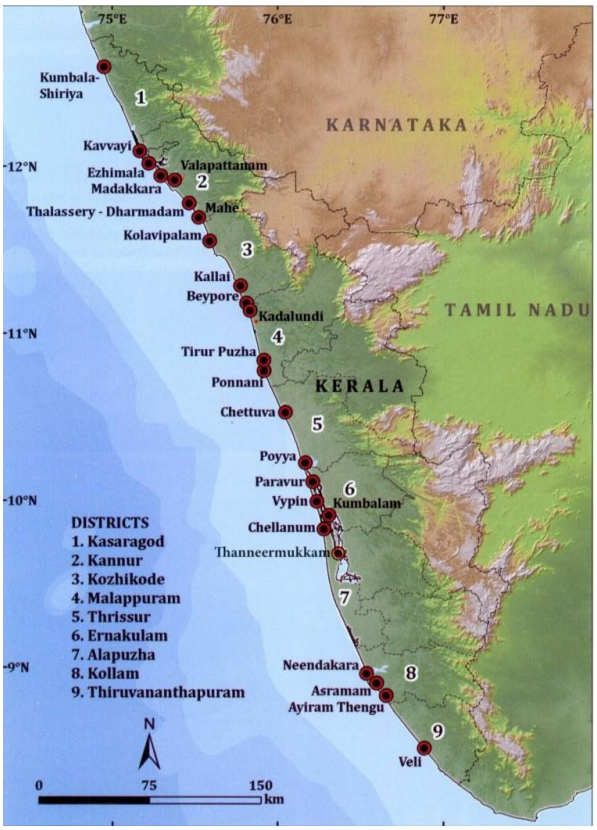

Figure 3: Mangroves in Kerala. (Retrieved from https://th.thgim.com/news/national/kerala/uavkbp/article28726329.ece/alternates/FREE_660/27TVMANGROVEETREE)

Ecosystem Services:

Direct Values

- Environmental benefits
  - Root structure adapts to tidal fluctuation, holds the soil intact, thereby protecting the shore from erosion and provides structural resilience to tides.
  - Reduces the impact, risks and extent of damage caused by floods, tsunami or cyclones.
  - Stores C02 and reduces global warming.
  - Nurtures biodiversity. Indirect Values
- Boosts Tourism
- Sustains Livelihood

Spatial archetype:

- Floristic expressions of mangroves hold deep sense of association for a Malayali. Of the Floristic diversity in Mangroves - Rhizophoraceae, Avicenniaceae and Sonneratiaceae are three families of species seen in the state. (Kerala State Council for Science, 2019)
- Renders textural fractals and characteristics to the ecological fabric of an area.

1.2. Trends and practices in coastal and estuarine stewardship in Kerala

As a part of coastal and estuarine stewardship, the following are the major steps that have been taken within Kerala, in the recent years:

- Kerala State Action Plan on Climate Change.
- The shoreline change assessment for Kerala, prepared by the National Centre for Sustainable Coastal Management (NCSCM). Vulnerability mapping and zonation of land that is projected to be inundated during coastal flooding.
- Coastal regulation zone: All constructions are required to be carried out with strict adherence to CRZ.
- 500m from the sea
- 50m from the backwater

These distances are to be strictly left from the water edges and devoid of permanent constructions.

65 major CRZ violations were found in the state in 2019, by the Kerala Coastal Zone Management Authority (KCZMA), out of which four private sector apartments were adjourned to be demolished, by the supreme court. (Ameerudheen & K, 2019)

- Physical control measures such as groynes, bunds and breakwaters.
- Meteorological early warning systems that can ensure response, recovery, prevention and preparedness for hydro-meteorological hazards.
- Artificial sea walls made from quarried rocks, and rarely the rightful mangroves as the natural eco-buffer for coastal defense.

2. COASTAL AND ESTUARINE ECOSYSTEMS IN TRIVANDRUM

2.1. Profile of the study area

The area chosen for study includes the estuarine points along the part of National Waterway III in Trivandrum district. The scope of the study further investigates the possibility of mangrove restoration strategies and techniques inspired by a mangrove community, to instill resilience to a coastal ecosystem. The major estuarine points along the studied stretch include Poovar, Veli, Poonthura, Edayar, Valiyathura, Panathura, Veli – Shanghumukham. Major sea level rise has been observed at each of these points.

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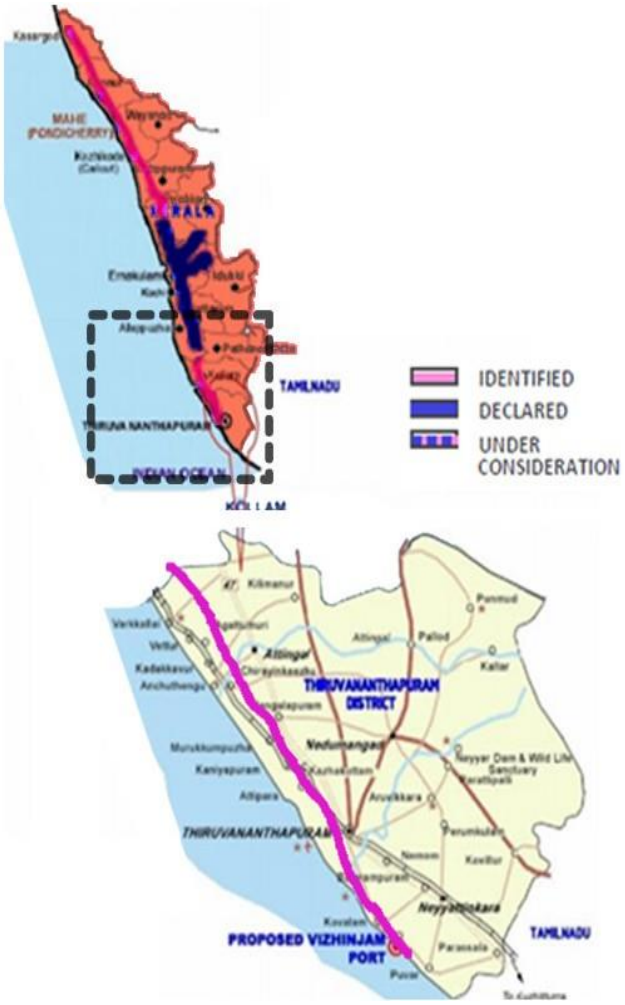


Figure 5: National Waterway 3 in Kerala.

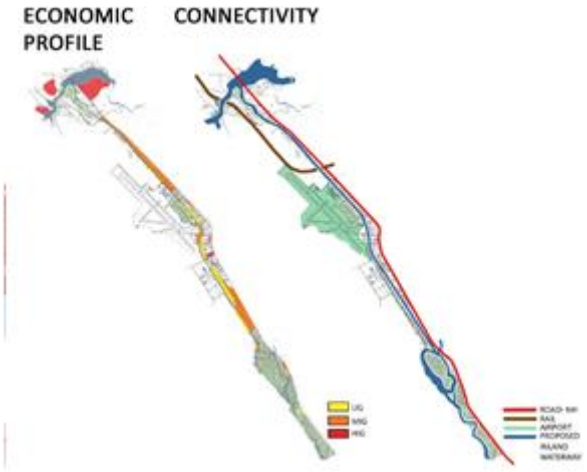
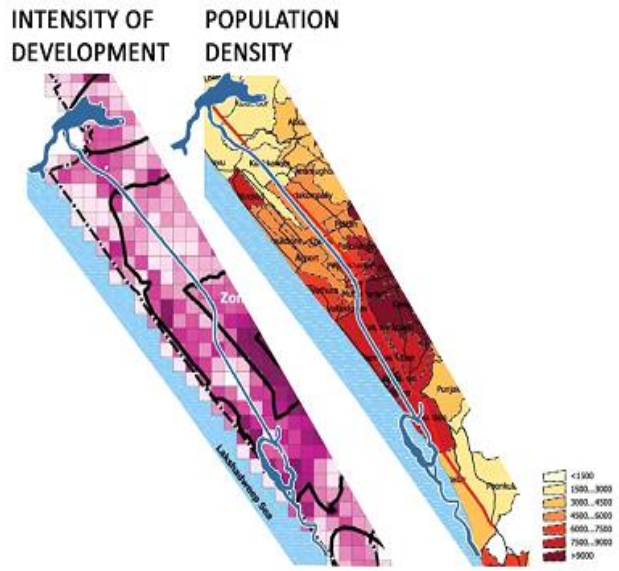


Figure 6: Profile of the study area- Estuarine points along National Waterway 3 (Parvathy Puthanar) in Trivandrum. Source: Author

Figure 7: Sea level rise. (Retrieved from https://cdn.vox-cdn. com)



CAUSES OF SEA LEVEL RISE

Erratic monsoons, extreme temperatures. (Climate Action Network South Asia, 2017)

Figure 8: Valiyathura coastline erosion. (Retrieved from https://india.mongabay.com/2018/06/keralas-climate-refugees-increase-as-the-sea-eats-into-the-coast/)

Figure 9: Valiyathura coastline erosion. (Retrieved from https://india.mongabay.com/2018/06/keralas-climate-refugees-increase-as-the-sea-eats-into-the-coast/)

"The erosion in Valiyathura, Poonthura and Panathura of Thiruvananthapuram seems to be progressive as the beach was not restored. But in Shankhmugham the erosion is cyclic and the beach gets restored after the rough season."(John, 2018)

Veli and Poovar have identified presence of mangroves as shown in Fig.11.

Figure 10: Land devoured by the sea at Shanghumukham. (Comparative analysis of years 2003 & 2019. Retrieved from Google maps.)

The objective of the study is manifested through a site situated at the Veli estuary as shown in Fig 12., originally rich in mangrove population, but has wrongly evolved in its ecological succession.

The chosen site is along the Veli backwater that currently exists as Veli tourist village and falls under the tourism promotion zone in the 2031 Trivandrum Master Plan, as shown in Fig. 13. The lands adjacent to the site have been proposed to be developed into a mobility hub, hypermarket, etc.

Figure 11: Presence of Mangrove patches at Veli, Poovar, along National Waterway III, Trivandrum. (Retrieved from KCZMA)

Figure 12: Veli- Akkulam along Parvathy Puthanar. (Retrieved from Google maps.)

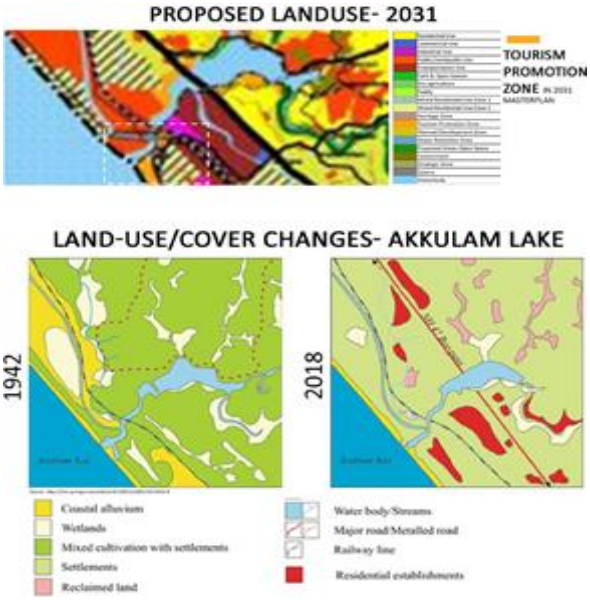


Figure 13: Demarcation of proposed Landuse 2031 and Evolution of Veli-Akkulam estuary.

(Retrieved from https://link.springer.com/article/10.1007)

The mangrove population on the site has been depleted marginally due to urban development and anthropogenic activities, and been limited to the area under private ownership - ISRO headquarters on the opposite side of the site, along the bank of the Veli-Akkulam estuary, as shown in Fig. 14.

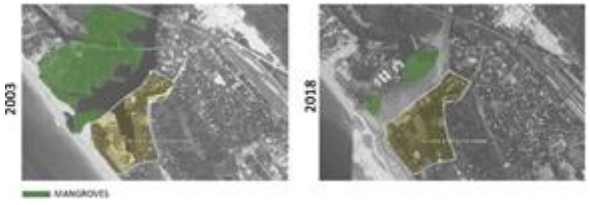


Figure 14: Depletion of Mangroves at Veli-Akkulam estuary. (Source: Google maps)

2.2. Threats faced by the Mangrove ecosystem at Veli

Even though Trivandrum was relatively unaffected by floods in 2018 and 2019, due to its raised topography compared to the other districts, the coastal edge continues to be devoured per passing year.

Figure 15: Land devoured by the sea and receding shoreline at Veli-Akkulam Estuary. (Comparative analysis of years 2003 & 2019. Retrieved from Google maps.)

Causes of Mangrove Depletion

- Irresponsive coastal engineering and accommodation of walkways along the banks of the backwaters.

Figure 16: Hardscaped walkway and Boating at Veli tourist village. (Retrieved from https://img.manoramaonline.com/content/dam/mm/en/travel/travel-news/images/2018/7/30/thiruvananthapuram-tourist-village.jpg)

- Anthropogenic activities like boating, etc.
- Lack of legal framework for governance and conservation of mangroves
- Urban development
- Illegal cutting, logging and clearance in lands acquired by the private sector, due to misconception that mangrove propagation produces very low financial return
- Aquaculture
- Competition and exhaustion for land resources
- Pollution
- Accumulation of debris and non-bio-degradable waste

Consequences

Coastal inundation has been predicted to occur by the year 2050, by many meteorological research based International organizations like Climate Central. org, etc.

Identified Hazards

- Sea Level rise
- Shoreline receding
- Livelihoods and coastal settlements will be affected
- Major destruction during Tsunami, Coastal flooding, unexpected hydro-meteorological changes.
- Disruption of Geo-hydrology of the area

Figure 17: Temporary remedies using seawalls. (Retrieved from https://india.mongabay.com/2018/06/keralas-climate-refugees-increase-as-the-sea-eats-into-the-coast/)

- Temporary problem solving remedies like sea walls only worsen the situation by preventing the coastline from replenishing itself. (John, 2018)

3. STEWARDSHIP MEASURES DERIVED FROM AN ECOLOGICAL ARCHETYPE

The principle employed in mangrove ecosystems, where the vegetation's buoyancy and resilience fight water level rise and erosion, is a prime interpretive trait, that can be adopted into developing multiple technologies.

However, before implementing solutions with mangroves, the vulnerability and risks of the coast need to be assessed, along with a detailed site analysis that familiarizes one with the specificity of the site.

Out of the many ways of managing mangroves for coastal protection, the focus is on the methods of biomimicry and mangrove restoration.

3.1 Appraisal: Biomimicry of mangroves as coastal defense structures

A lot of research generated coastal structures, innovatively emulate the function and form of mangroves. Such biomimicry, studies the root structure of the mangroves in a hydro-dynamic analysis, that investigates and records its response to the mobilizing fluids around. A product developed by Florida Atlantic University (FAU) in a research in ocean and mechanical engineering, involved wave-tank studies, physical prototyping, and producing precast panels inspired from mangrove root structures as an attachment to existing sea walls. The key principle employed for the design, was derived from permeability and filtration showcased by the characteristics of a rich mangrove edge, and marsh of a mangrove forest.

This solution accommodates defense structures within the property limits, thereby avoiding; ownership and legislation conflicts, property extension and installation of freestanding structures. Further to

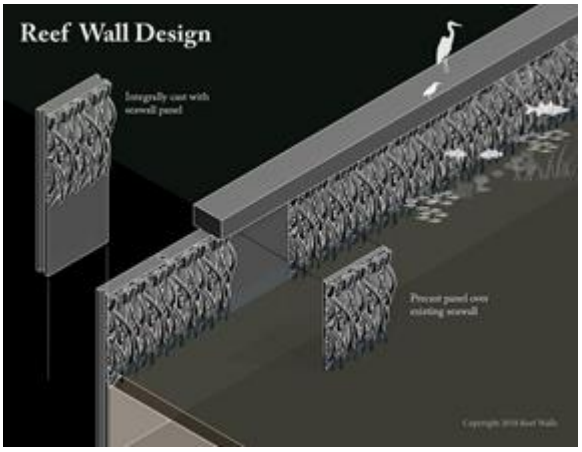


Figure 18: Reef wall panel. (Retrieved from https://www.ansys.com/blog/biomimicry-mangroves-improve-coastal-erosion-coastal-barriers)

generate the coexistence of biodiversity, oyster shells were mixed with the concrete mix. On documenting the panels, colonization was observed along the panels. (Riet, 2019)

Such methods, however may create repercussions, as they still do not restrict encroachments onto the coast, but suggest immediate problem solving through material solutions for coastal erosion.

3.2 Mangrove Restoration

Mangrove restoration can be carried out on a site if necessary ecological conditions pre-exist or can be achieved through hydro-topographic modulation, and if the social scenario of the area is made to understand the benefits and effectiveness of such an ecosystem thereby obtaining their consent and support for propagation and management of the same.

Parameters for Mangrove suitability

Mangrove restoration can be successfully carried out for an area that has been geo-morphologically evolved with the presence of a mangrove community. For the process to be successfully strategized and executed, the land or marsh near an estuary should:-

Fall in a patch inundated by tides Fall under the tidal limits and have a Salinity level greater than 30ppm

Fig.19 and Fig. 20 show the sequence required to check the mangrove suitability of a patch near an estuary. The site chosen to demonstrate the same, is the site at the Veli estuary.

The site's geometry has a mouth like opening, that favourably allows tidal influx twice a day. The tidal inundation is recorded at 0.93m.

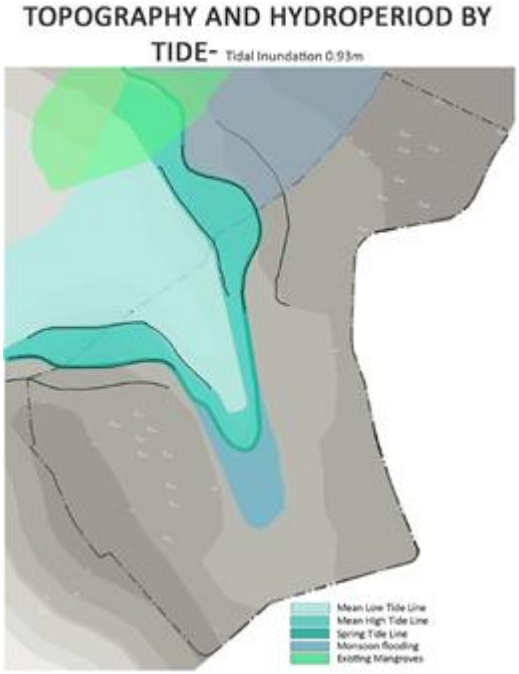


Figure 19: Predicting Mangrove suitability and revegetation possibility. (Source: Author)

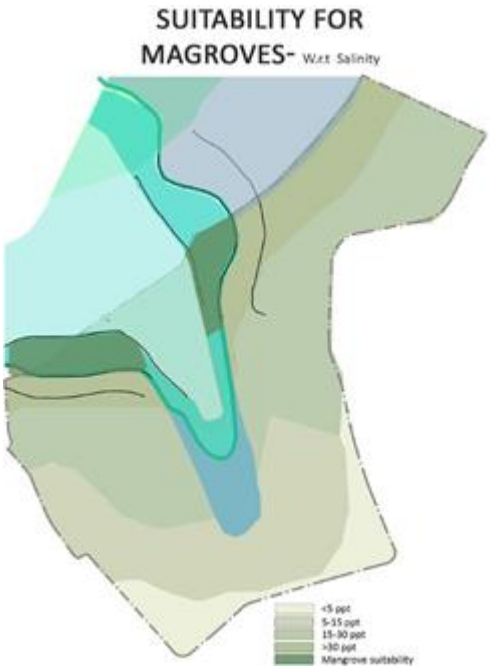


Figure 20: Predicting Mangrove suitability and revegetation possibility. (Source: Author)

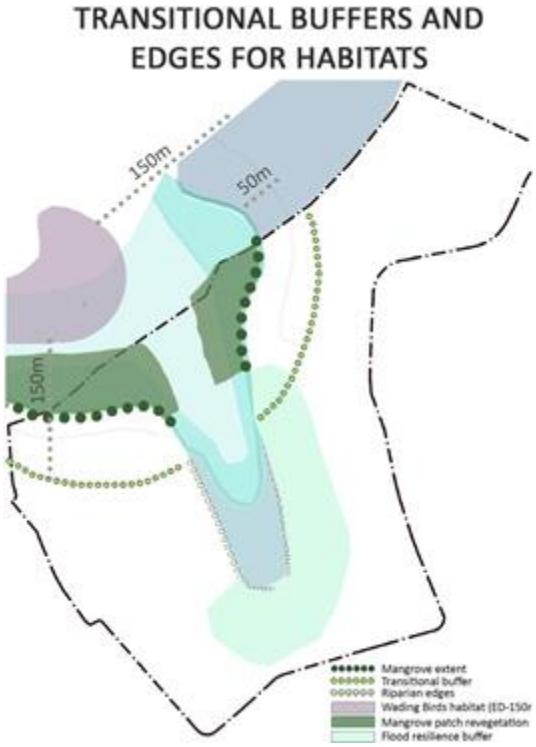


Figure 21: Transitional buffers and Habitat zonation. (Source: Author)

Fig.21 shows the further possible demarcation of habitats based on birds' escape distances, breeding of aquatic life, flood resilience buffer and a slow transitional buffer that extends minimum 50m landward.

The sequence of processes required to achieve ecological conditions for mangrove recovery and mangrove revegetation includes:-

- Reference substrate grading for tidal marsh enhancement (regrading the land for tides to inundate in the same slope as in patch that already has mangroves propagated, in the immediate vicinity of the site).
- Mangrove propagation in a nursery, that is situated within the same site to ensure uniformity in the salinity levels and intensity of the tides.
- Once the mangroves achieve 2 ft height, they are tied to Bamboo sticks and arranged on the marsh land, that is now regraded and ready for propagation.

In Fig.22, the darker blue water denotes the HTL and lighter blue is LTL. The zonation as shown in the images is as per the hierarchy and root structure based on tidal resilience in any ideal mangrove ecosystem.

Any planting strategy adopted and choice of the species that need to be used in the afforestation planting palette, should be informed from the native planting list of the region. Once revegetated

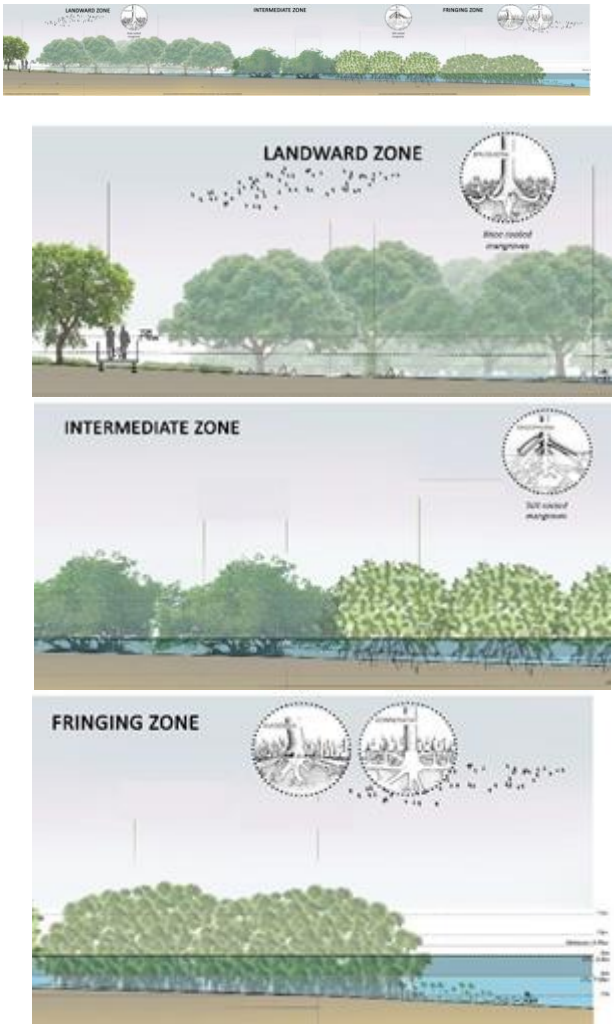


Figure 22: Section demonstrating Mangrove zonation in a restoration attempt with Key species; Knee rooted (Bruguiera), Stilt rooted (Rhizophora) and Peg rooted mangroves (Avicennia and Sonneratia) in Landward, Intermediate and Fringing zones respectively. (Source: Author)

and afforested, the site can effectively buffer itself from coastal erosion and flooding. The principles incorporated in mangrove restoration, if employed and executed sequentially, thus can be used to safeguard any edge of an estuary or coast.

4. CONCLUSION

The explorations attempted on the basis of understanding an ecological archetype provide a Green Platform: to reinterpret and reimagine processes and technologies. The study and the investigations suggest the following mandate for successful coastal and estuarine stewardship:-

Climate Change Frameworks

Strategic plans adopted towards biodiversity conservation in international conventions such as Ramsar Convention, Convention on Biological Diversity, World Heritage Convention, etc. (Slobodian, 2018) should be primary case studies to layout national, regional and local environmental, legal frameworks.

Policies and Guidelines for Environmental planning

An integrated system of reforms, guidelines and policies need to be laid out as the foundation for any resolution that is targeted at risk reduction and stewardship of coasts. Hence Coastal zone management master planning that addresses local, physical and non-physical factors, is essential to be formulated. Such a master plan ideally includes coastal regulation framework based on different zonations that are informed from detailed Environmental impact assessment, site analysis and character study.

Awareness

Promote public awareness and stewardship - develop familiarity among people, especially within students towards mangroves; its ecosystem services and conservation principles.

Local governance and benefits for all tiers of the society

There is a need for decentralized power and sociopolitico environmental agendas for protection of mangroves. Participation in decision making process; provision of incentives for citizens who volunteer to provide assistance, and get rehabilitated from illegally encroached land along the coast; further speed up a stewardship process. The local people or private institutions need to be brought in favor of the adopted measures, to ensure effective pre and post management, be it: community, public, private or in partnership. (Hema & Indira Devi)

Check on Anthropogenic activities

There is a need for anthropogenic activities like aquaculture and tourism to be under strict supervision; legalized and controlled. The concerned authorities should relook into the ownership and status of property rights for lands within the CRZ range.

Environmental Conservation Methods and Methodologies

For a state like Kerala, with all its waterbodies and extensive coastline, coastal and estuarine stewardship will turn effective only through natural and interpretive means coupled with thorough Coastal zone regulation for all scales. The scalability and innovativeness of the solutions will further improve the performance of the coastal builtunbuilt environment and weave a liveable and climate-responsive built-unbuilt fabric. The two explored methods of bio-mimicry and mangrove restoration extend future possibilities of research. However any proposed method or methodology should be appropriated to local and ideal socio- political and ecological conditions, for achieving long term solutions.

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