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SPECIES ASSOCIATION AND ECOLOGICAL SIGNIFICANCE OF MANGROVES IN THE ACHARA ESTUARY, SINDHUDURG DISTRICT, MAHARASHTRA

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Abstract:

Mangrove ecosystems exhibit distinct interspecific associations governed by salinity gradients, tidal inundation, and sediment characteristics. The present study investigates species association patterns of mangroves along the longitudinal gradient of the Achara Estuary. Phytosociological surveys were conducted across ten regions representing downstream to upstream zones, each divided into seaward and landward sectors. Quadrat sampling (15 m × 15 m) was used to record species occurrence, and association indices were calculated. The results reveal strong associations among Rhizophora mucronata, Sonneratia alba, and Avicennia officinalis, indicating broad ecological amplitude. Xylocarpus granatum and Cynometra iripa exhibited restricted but ecologically significant distribution, reflecting habitat specialization and conservation importance. Dwarf Avicennia showed limited association and functioned as an ecological indicator of hypersaline and stress-prone microhabitats. The study highlights zonation patterns, habitat sharing, and niche differentiation within the estuarine mangrove ecosystem and provides essential baseline information for conservation and management planning.

Keywords: *Mangroves, Species Association, Estuarine Ecology, Achara Estuary.*

Introduction

Mangrove forests are specialized intertidal ecosystems occurring in tropical and subtropical coastal regions. Their structure and composition are primarily influenced by salinity gradients, tidal inundation frequency, sediment texture, freshwater influx, and geomorphology (1, 2). Within estuarine systems, these environmental factors create distinct zonation patterns and interspecific associations. The Achara Estuary, situated along the Konkan coast, supports diverse mangrove vegetation distributed along a clear downstream-to-upstream gradient. Species association studies help elucidate habitat sharing, ecological compatibility, and niche specialization among mangrove taxa (3,4).

Understanding association patterns is particularly important for identifying rare, endangered, or indicator species within the ecosystem. The present study aims to (i) analyze species associations across the estuarine gradient, (ii) interpret ecological amplitude and zonation patterns, and (iii) highlight the conservation significance of selected mangrove species.

Materials and Methods

Study area

The investigation was carried out along and across the Achara Estuary. The estuary was longitudinally divided into five zones:

1. Downstream
2. Down-midstream
3. Midstream
4. Mid-upstream
5. Upstream

Each zone was further subdivided into seaward and landward sectors, resulting in ten sampling regions representing the complete estuarine gradient.

Phytosociological survey

Multiple quadrat sampling (15 m × 15 m) was employed to record the number of individuals of each mangrove species in all ten regions.

Species recorded

The mangrove flora included, *Rhizophora mucronate, Rhizophora apiculate, Sonneratia alba, Sonneratia apetala, Avicennia officinalis, Avicennia marina,* Dwarf *Avicennia, Ceriops tagal, Aegiceras corniculatum, Excoecaria agallocha, Bruguiera gymnorrhiza, Kandelia candel, Xylocarpus granatum, Cynometra iripa, Acanthus ilicifolius*

Association index

Species association was calculated following Misra (3):

$$\text{Association Index of A} = \frac{\text{Number of regions where both species occur}}{\text{Number of regions where species A occurs}}$$

Values range from 0 (no association) to 1 (complete association).

Results and Discussion

Estuarine zonation and community structure

The mangrove vegetation of Achara estuary exhibited clear zonation along the salinity gradient. Downstream and midstream zones showed greater species overlap due to moderate salinity and regular tidal flushing. Upstream regions displayed reduced overlap and selective distribution.

Strong positive associations (AI ≈ 1.0) were observed among *Rhizophora mucronata*, *Sonneratia alba*, and *Avicennia officinalis*, indicating similar ecological requirements and broad tolerance ranges. These species constitute the structural core of the estuarine mangrove forest.

Avicennia marina also showed positive association with major mangrove taxa, reflecting ecological plasticity and adaptability to fluctuating salinity conditions.

Ecological significance of rare and endangered species

Xylocarpus granatum

Xylocarpus granatum exhibited strong association with *Bruguiera gymnorrhiza* and moderate association with other mangroves. However, its limited regional occurrence indicates restricted ecological amplitude. The species prefers relatively stable, well-drained, mid-estuarine habitats with moderate salinity and reduced physical disturbance.

Due to habitat loss and fragmentation along the Maharashtra coast, *X. granatum* is considered regionally rare and vulnerable. Its presence in Achara estuary signifies the availability of relatively undisturbed microhabitats.

Cynometra iripa

Cynometra iripa demonstrated strong association with *Xylocarpus granatum*, suggesting shared habitat preference in inner estuarine zones. Its restricted occurrence reflects ecological specialization and sensitivity to environmental fluctuations.

The localized distribution of *C. iripa* underscores its conservation importance. Both species act as indicators of habitat stability and ecological integrity within the estuary.

Dwarf Avicennia as an ecological indicator

The dwarf form of *Avicennia* showed weak association with dominant mangrove species and occurred sporadically across the estuary. Its reduced stature is associated with high salinity stress, nutrient-deficient substrata, reduced tidal flushing and micro-elevational differences

Thus, dwarf *Avicennia* functions as a bio-indicator of environmental stress. Its occurrence highlights hypersaline and edaphically constrained microhabitats within the estuarine system. Monitoring its distribution can provide valuable insight into ecological changes and salinity shifts.

Habitat sharing and niche differentiation

The association patterns indicate, broad habitat sharing among dominant mangroves, specialized microhabitat preference among rare species, ecological amplitude differences across taxa and salinity-driven niche differentiation

The coexistence of dominant, rare, and indicator species reflects the ecological heterogeneity of the estuarine environment.

Within the mangrove ecosystem of the Achara Estuary, *Xylocarpus granatum* and *Cynometra iripa* assume special ecological and conservation significance due to their restricted distribution and declining populations along the west coast of India. The association analysis indicates that *X. granatum* shows selective co-occurrence, particularly with *Bruguiera gymnorrhiza*, while occupying comparatively fewer estuarine regions, suggesting a narrow ecological amplitude and preference for relatively stable, moderately saline inner estuarine habitats. Similarly, *C. iripa* demonstrates strong association with *X. granatum* but limited overall occurrence, reflecting habitat specialization and sensitivity to environmental fluctuations such as salinity variations and sediment disturbance. Such restricted distribution patterns have been noted in several mangrove studies and highlight the conservation importance of these taxa (1,2). The presence of these species indicates relatively undisturbed microhabitats within the estuary and enhances its ecological value. In contrast, dwarf *Avicennia* shows weak association with most dominant mangrove species and occurs sporadically in localized patches. This stunted growth form is typically associated with hypersaline soils, nutrient-poor substrata, and reduced tidal flushing, representing a physiological adaptation to environmental stress conditions (2, 5). Hence, dwarf *Avicennia* can be considered an ecological indicator species reflecting stress-prone microhabitats within the estuarine mangrove ecosystem.

Acanthus ilicifolius is an important mangrove associate species observed in several regions of the Achara Estuary. The association data indicate that this species shows positive association with many dominant mangrove taxa, reflecting its wide ecological tolerance within the estuarine environment. Unlike true mangrove tree species, *A. ilicifolius* generally occupies slightly elevated and landward margins of mangrove habitats where tidal inundation is relatively less frequent. Its dense growth in the understorey contributes to sediment stabilization and protection of the soil surface from erosion. The presence of *A. ilicifolius* therefore indicates comparatively stable substrata and transitional zones between core mangrove forests and adjacent terrestrial vegetation. Similar ecological roles of this species in coastal mangrove ecosystems have been reported from different parts of the Indian coastline (2).

Conclusion

The mangrove ecosystem of the Achara Estuary exhibits distinct species association patterns shaped by salinity gradients and tidal dynamics. Dominant species such as *Rhizophora mucronata*, *Sonneratia alba*, and *Avicennia officinalis* demonstrate broad ecological amplitude, whereas *Xylocarpus granatum* and *Cynometra iripa* show restricted distribution and conservation significance.

Dwarf *Avicennia* serves as an ecological indicator of stress-prone microhabitats within the estuary. The study emphasizes the importance of species association analysis in understanding community structure, ecological specialization, and conservation priorities.

Protection of inner and mid-estuarine habitats is essential for maintaining biodiversity and ecological resilience in the Achara estuarine mangrove ecosystem.

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Table 1: Association index values of Achara mangroves

	Rm	Rap	Sal	Sap	Avo	Avm	Avd	Ct	Acg	Exc	Bg	Kc	Xy	Cy	Aca
Rm	--	0.8	1.0	0.1	1.0	0.8	0.2	0.6	0.8	0.9	0.7	0.4	0.4	0.3	0.9
Rap	1.0	---	1.0	0.12	1.0	1.0	0.25	0.75	0.75	0.87	0.75	0.37	0.37	0.25	0.87
Sal	1.0	0.8	---	0.10	1.0	0.8	0.2	0.6	0.8	0.9	0.7	0.4	0.4	0.3	0.9
Sap	1.0	1.0	1.0	---	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0
Avo	1.0	0.8	1.0	0.1	---	0.8	0.2	0.6	0.8	0.9	0.7	0.4	0.4	0.3	0.9
Avm	1.0	1.0	1.0	0.12	1.0	---	0.25	0.75	0.75	0.87	0.75	0.37	0.37	0.25	0.87
Avd	1.0	1.0	1.0	0.0	1.0	1.0	---	0.5	0.5	1.0	0.5	0.0	0.0	0.0	1.0
Ct	1.0	1.0	1.0	0.16	1.0	1.0	0.16	---	0.83	1.0	0.83	0.5	0.5	0.33	1.0
Acg	1.0	0.75	0.75	0.12	1.0	0.75	0.12	0.62	---	1.0	0.87	0.5	0.5	0.37	1.0
Exc	1.0	0.77	1.0	0.11	1.0	0.77	0.11	0.66	0.88	---	0.77	0.44	0.44	0.33	1.0
Bg	1.0	0.85	1.0	0.14	1.0	0.85	0.14	0.71	1.0	1.0	---	0.75	0.57	0.42	1.0
Kc	1.0	0.75	1.0	0.25	1.0	0.75	0.0	0.75	1.0	1.0	0.75	---	0.75	0.50	1.0
Xy	1.0	0.75	1.0	0.0	1.0	0.75	0.0	0.75	1.0	1.0	1.0	0.75	---	0.75	1.0
Cy	1.0	0.66	1.0	0.0	1.0	0.66	0.0	0.66	1.0	1.0	1.0	0.66	1.0	---	1.0
Aca	1.0	0.77	1.0	0.11	1.0	0.77	0.22	0.66	0.88	1.0	0.77	0.44	0.44	0.33	---

Rm – *Rhizophora mucronata*, Rap – *R. apiculata*, Sal – *Sonneratia alba*, Sap – *S. apetala*, Avo- *Avicennia officinalis*, Avm- *A. marina*, Avd- *Avicennia* dwarf, Ct- *Ceriops tagal*, Aeg- *Aegiceras corniculatum*, Exc- *Excoecaria agallocha*, Bg – *Bruguiera gymnorrhiza,* Kc-*Kandelia candel*, Xy – *Xylocarpus granatum*, Cy – *Cynometra iripa*, Aca – *Acanthus ilicifolius*.