

**RESEARCH ARTICLE****ECOLOGICAL STATUS OF SATHURUKONDAN MANGROVE WETLAND, BATTICALOA, SRI LANKA: COMPOSITION, DIVERSITY AND VEGETATION PATTERN**

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**ABSTRACT**

Sathurukondan wetland in the Batticaloa District contains valuable mangrove resources, yet baseline ecological information remains rather scarce. This study assessed mangrove vegetation from May to October 2023, focusing on species distribution, abundance, and diversity. A total of 59 line transects and 99 quadrats were established to compile a species checklist and evaluate community structure using diversity indices such as the Shannon–Wiener index, Pielou’s evenness, and Margalef richness. Vegetation patterns were further analyzed through relative density, frequency, dominance, and Importance Value Index (IVI). Results identified eight true mangrove species from six families, including five Least Concern (LC) and three Near Threatened (NT) species, along with nine associated species. *Excoecaria agallocha* was the dominant species with the highest ecological importance (IVI = 145.78), while *Aegiceras corniculatum* showed the lowest distribution. Other notable species included *Lumnitzera racemosa*, *Sonneratia caseolaris*, and *Rhizophora apiculata*. Overall diversity was low ( $H' = 1.132$ ), with low evenness ( $J = 0.544$ ) and richness ( $d = 0.794$ ), indicating limited heterogeneity and uneven species distribution. These patterns suggest ecological imbalance, potentially driven by natural conditions and increasing human pressures such as fishing and tourism. This study provides a crucial baseline for future conservation and management efforts.

**Keywords:** *Diversity indices, Importance Value Index, Line transect, Mangrove, Vegetation analysis.*

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## **1. INTRODUCTION**

Mangroves are salt-tolerant, evergreen forest ecosystems that occur mainly in tropical and subtropical intertidal regions. Globally, they occupy about 15.6 million hectares [1] and consist of woody, seed-bearing, flowering plants that function as facultative halophytes. These species are highly specialized both morphologically and physiologically [2], enabling them to survive in waterlogged, saline, and oxygen-poor environments. Adaptations such as salt filtration, aerial roots, vivipary, and efficient freshwater conservation allow mangroves to withstand tidal inundation, strong winds, and fluctuating sediment conditions. Mangroves typically occur along sheltered coastlines [3], estuaries, and lagoons, where their distribution is influenced by tidal amplitude and hydrological gradients [4], [5].

Ecologically, mangrove forests are among the most productive ecosystems on Earth and provide a wide range of provisioning, regulating, cultural, and supporting services [6]. They act as natural barriers during storms and tsunamis, reduce coastal erosion [7], and serve as critical nursery grounds for numerous marine organisms. For coastal communities, mangroves supply timber, fuelwood, traditional medicines, and various livelihood opportunities [8]. At a global scale, they are increasingly recognized for their substantial carbon storage capacity and their importance in climate-change mitigation [9]. Additional ecological functions include storm-surge buffering [10], sediment stabilization, and value as sites for education and research [11]. In Sri Lanka, mangroves occur in a patchy distribution along lagoon margins, estuaries, and river mouths [12]. Recent assessments by the Forest Department estimate approximately 16,017 ha of mangroves nationwide, representing less than 0.03% of the island's land area. Despite their ecological and socio-economic value, scientific knowledge on the structure, diversity, and spatial patterns of many local mangrove systems including Sathurukondan remains limited [13, 14]. This gap highlights the need for baseline data, plot-level ecological assessments to support conservation and management. Hence, the objective of the present study is undertaken to study the mangrove vegetation, their distribution, abundance and diversity of true mangrove species in Sathurukondan.

## 2. MATERIAL AND METHODS

### 2.1 Study site

The present study was carried out within the mangrove stands located across the Thannamunai, Sathurukondan, and Pillayaradi GN Divisions of the Batticaloa District on the eastern coast of Sri Lanka, centered around the approximate coordinates 7°44'12" N and 81°39'47" E. The sampling area extends along both sides of the A-15 Batticaloa–Trincomalee highway, encompassing a total mangrove cover of 22.15 ha. For systematic assessment, the mangrove habitat was subdivided into ten plots (A–J), with plot sizes varying according to local vegetation structure, landscape features, and shoreline configuration. These spatial differences among plots provide important context for understanding patterns in species distribution, diversity, and dominance observed across the study area

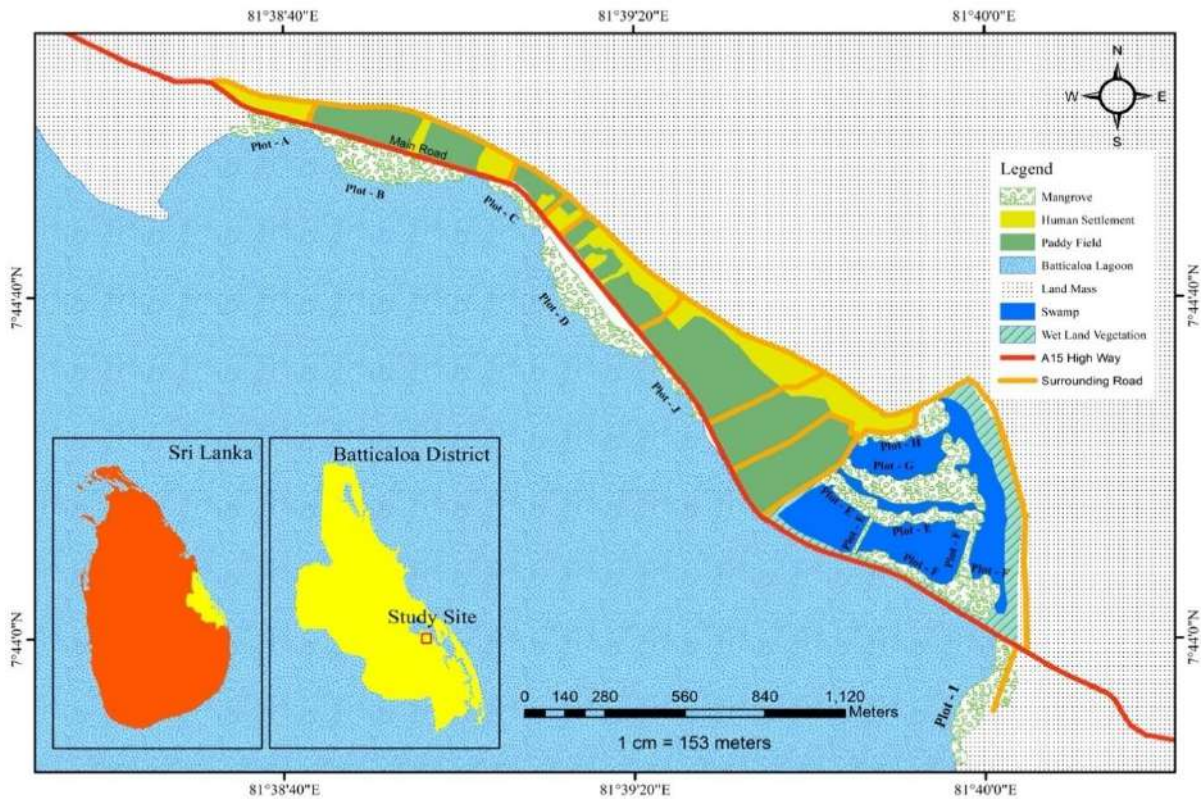


Figure 1: Distribution of mangrove plots (A–J) in the study sites

### 2.2 Sampling and Data collection

Fixed-area plot measurements, using standard quadrat techniques, were employed to assess the vegetation characteristics of the mangrove community following established methodological guidelines during May to October 2023 as fortnightly basis [15, 16]. The

locations of transects were marked using Global Positioning System (GPS) for future reference. A total of fifty-nine 150 m long transect lines were established in entire plot perpendicular to shore. Lengths of transects for mangrove surveys depend on the extent of vegetation cover. Along each transect line, maximum four 10 m x 10 m quadrats (100 m<sup>2</sup>) were laid out in 10 m intervals were also established in order to enhance accuracy [17]. The process yielded a total of 99 quadrats across study sites as shown in Table 1. The species of mangrove located outside the quadrats were included as a part of species inventory. Enumeration of mangrove within the sampled quadrat, species name, number of species, number of individuals, tree diameter at breast height (DBH) were obtained from each sub-plot (100 m<sup>2</sup>).

### **2.3 Species identification**

All study sites were surveyed through repeated field visits conducted at different times during the study period. Mangrove species present in each plot were identified to the lowest possible taxonomic level and classified as either true or associate species using standard field guides and mangrove identification manuals [18, 19]. For further clarification photographs were taken tree shape, leaf apex, leaf margin, leaf shape, leaf types, leaf arrangement, blooming spot, inflorescences, fruit shapes and root types using camera (Nikon, Japan) for further confirmation of species level.

*Table 1: Area and length of studied mangrove plots in study site*

Plot	Area		Length (m)	No. of transects	No. of quadrats
	Ha	m <sup>2</sup>			
A	1.2	11,994	690	5	7
B	4.55	45,331	1260	8	13
C	0.94	9,354	610	5	5
D	3.88	38,781	1220	8	12
E	0.24	2,370	380	3	12
F	1.19	11,878	570	4	12
G	5.3	53,026	1700	10	18
H	1.78	17,785	990	6	9
I	2.67	26,675	1100	7	8
J	0.4	4,815	670	3	3
<b>Total</b>	<b>22.15</b>	<b>222,009</b>	<b>9,190</b>	<b>59</b>	<b>99</b>

## 2.4 Conservation status

Identified mangrove species categorized according to the national IUCN status based on available literature [19].

## 2.5 Diversity analysis

Quadrat data collected during the field surveys were examined to describe the structural features of the mangrove community, such as species frequency, density, and abundance. Standard diversity indices were then applied to evaluate species richness, overall diversity, evenness, and dominance across the different sampling sites [20].

$$\text{Shannon – Weiner diversity index } (H') = - \sum_{i=1}^s p_i \ln p_i$$

Where, H': Shannon-Weiner Diversity Index,  $P_i$ : number proportion of each species in each sample, S: total number of species,  $\sum$  = sum from species 1 to species S

$$\text{Pielou's evenness index } (J) = \frac{H'}{\ln S}$$

Where:  $J$ : Pielous's Evenness,  $H'$ : Shannon's Diversity Index, S: total number of species

$$\text{Margalef richness index } (d) = \frac{(S - 1)}{\ln N}$$

Where:  $d$ : Margalef index, S: total number of species, N: total number of individuals

Calculated diversity indices categorized as follows, For Shannon-Weiner ( $H'$ ) diversity index as very low (<1.999) while low (2.000-2.499), moderate (2.500-2.999), high (3.000-3.499) or very high (> 3.500 [21], [22]. For Pielou's evenness index ( $J$ ) can be interpreted as fair distribution (0.96-1.00), Good distribution (0.76-0.95), Moderate distribution (0.51-0.75), Poor distribution (0.26-0.50), and very poor distribution (0.00-0.25) [23].

## 2.6 Community structure

For community structural features of the mangrove forest, the following formula was computed based on [24]. Basal area of individual trees, stand basal area, and stems per ha

for each species were calculated. The values for basal area were used in computing for relative dominance. These are the essential factors in identifying the relevance and functions of the different species found in the area. DBH (diameter at breast height) was measured using a standard diameter tape (D-tape), which provides direct diameter readings based on girth. This is the recommended tool for mangrove structural assessments due to its accuracy, flexibility, and ability to wrap around irregular stems. Only live mangrove individuals with a diameter at breast height (DBH)  $\geq 2.5$  cm were included in the quantitative structural analysis. This threshold aligns with standard mangrove assessment protocols [25, 26]. Saplings and seedlings with DBH  $< 2.5$  cm were not recorded and excluded from the structural metrics (density, basal area, IVI), as their inclusion could bias comparisons among plots with different age structures. Only living stems were included in all density, dominance, and diversity calculations. For Multi-Stemmed Individuals trees branching below breast height, each stem with DBH  $\geq 2.5$  cm was measured separately and treated as an individual stem for basal area calculations. This approach ensures accurate representation of species dominance and is widely accepted in mangrove structural analysis [27].

$$\text{Basal area per tree (m}^2\text{)} = \frac{\pi \text{DBH}^2}{4}$$

$$\text{Stand basal area} = \frac{\text{sum of basal area per species}}{\text{total area of plot}}$$

$$\text{Stems per ha} = \frac{\text{no. of living stem in plot per species}}{\text{area of the plot}} \times 10000$$

$$\text{Relative dominance} = \frac{\text{total basal area of a species}}{\text{total basal area of all species}} \times 100$$

$$\text{Relative density (RD}_1\text{)} = \frac{\text{density of a species}}{\text{total density of all species}} \times 100$$

$$\text{Relative frequency (RF}_i\text{)} = \frac{\text{frequency of a a species}}{\text{total frequency of all species}} \times 100$$

*Importance vlaue (IVI)*

$$= \text{relative density} + \text{relative frequency} + \text{relative dominance}$$

### 3. RESULTS AND DISCUSSION

#### 3.1 Species composition

A total of 6751 standing live mangrove trees representing Eight true mangrove species belonging to six different families were identified at 10 plots of entire study site. As per the numerical abundance *Excoecaria agallocha* > *Lumnitzera racemosa* > *Rhizophora apiculata* > *Sonneratia caseolaris* > *Avicennia officinalis* > *Avicennia marina* > *Aegiceras corniculatum*. Among this *E.agallocha* was the predominant species and was the only species recorded in all plots studied, while *Aegiceras corniculatum* was rare. Based on the conservation status categories of the IUCN Red List of Threatened Species, three species (*Avicennia officinalis*, *Rhizophora apiculata*, *Lumnitzera racemosa*) is listed as Near Threatened, while the rest are of Least Concern status. Nine mangrove associated plants were identified in sampling area during the study period (Table 2). Among these associates *Acrostichum aureum* was the numerically abundant species which present at all the sampling plots followed by *Derris trifoliata* while *Phoenix pusilla* was rare.

Table 2: Number of true mangrove species recorded in each plot at study site

Species	No. of individuals in each plot										
	A	B	C	D	E	F	G	H	I	J	Total
<i>Avicennia marina</i> (LC)	10	23	7	32	-	3	-	2	19	1	<b>97</b>
<i>Avicennia officinalis</i> (NT)	15	53	21	64	-	21	-	8	68	6	<b>256</b>
<i>Rhizophora apiculata</i> (NT)	15	39	11	150	38	3	68	13	16	2	<b>355</b>
<i>Rhizophora mucronata</i> (LC)	2	22	-	45	17	-	11	4	9	-	<b>110</b>
<i>Sonneratia caseolaris</i> (LC)	30	68	14	82	-	38	3	22	20	1	<b>278</b>
<i>Lumnitzera racemosa</i> (NT)	-	109	-	263	548	146	110	19	10	-	<b>1205</b>
<i>Excoecaria agallocha</i> (LC)	217	299	323	770	641	726	1096	190	95	82	<b>4439</b>
<i>Aegiceras corniculatum</i> (LC)	-	-	-	-	-	-	-	-	8	3	<b>11</b>
<b>Total no. species</b>	<b>06</b>	<b>07</b>	<b>05</b>	<b>07</b>	<b>04</b>	<b>06</b>	<b>05</b>	<b>07</b>	<b>08</b>	<b>06</b>	<b>6751</b>

### 3.2 Mangrove diversity analysis

The diversity analysis employed three standard indices species richness ( $d$ ), species evenness ( $J$ ), and species diversity ( $H'$ ) with values varying across the ten sampling plots as summarized in Table 3. Descriptively, the overall Shannon–Wiener diversity index for the study area was 1.132, indicating low species heterogeneity. Pielou’s evenness index ( $J = 0.544$ ) reflects a moderate but uneven distribution of individuals among species, while Margalef’s species richness index ( $d = 0.794$ ) further confirms low richness, with only eight true mangrove species recorded across all plots. These descriptive results highlight numerical dominance *Excoecaria agallocha*, which occurred abundantly in every plot sampled. In all plots where *Excoecaria agallocha* becomes numerically and ecologically dominant, its high relative abundance disproportionately influences diversity indices, leading to lower Shannon diversity and Pielou’s evenness values because fewer individuals are shared among the remaining species. This pattern with high dominance by one species often reflects competitive exclusion and limited habitat heterogeneity, resulting in reduced opportunities for less abundant species to establish, mature, and persist. Empirical studies across tropical mangrove systems show that when Euphorbiaceae members like *Excoecaria agallocha* attain high relative density and importance values, overall species diversity tends to be lower and distribution is more skewed toward the dominant species, thereby diminishing evenness and richness metrics within plots.

*Table 3: Diversity indices of studied mangrove plots in study sites*

<b>Diversity indices</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	<b>F</b>	<b>G</b>	<b>H</b>	<b>I</b>	<b>J</b>	<b>Overall</b>
No. of species	6	7	5	7	4	6	5	7	8	6	8
Total no. of individuals	289	613	376	1406	1244	937	1288	258	245	95	6751
Shannon Diversity index	0.908	1.531	0.592	1.385	0.868	0.793	0.558	0.988	1.668	0.588	1.132
Pielou’s Index	0.507	0.787	0.368	0.712	0.626	0.413	0.346	0.508	0.802	0.328	0.544
Margalef index	0.882	0.935	0.675	0.828	0.421	0.731	0.559	1.081	1.272	1.098	0.794

The diversity indices calculated for the ten plots show considerable variation in species composition and ecological structure across the Sathurukondan mangrove landscape. Shannon diversity index ( $H'$ ) ranged from 0.558 (Plot G) to 1.668 (Plot I), with an overall mean of 1.132, indicating low species heterogeneity. According to ecological thresholds proposed by [28], Shannon values below 2.0 typically reflect ecosystems where a few species dominate numerically, reducing overall structural complexity. This pattern is clearly evident in the present study, where *Excoecaria agallocha* alone comprises 65.7% of all individuals, significantly suppressing the proportional abundance of co-occurring species. Such dominance reduces evenness, which is reflected in the low overall Pielou's index ( $J = 0.544$ ), indicating that individuals are not evenly distributed among species.

Ecologically, this type of skewed distribution is characteristic of mangrove forests experiencing environmental filtering or disturbance-driven homogenization [29, 30]. *Excoecaria agallocha* is a disturbance-tolerant species with broad salinity tolerance and strong colonization ability, enabling it to expand rapidly in altered or low-salinity habitats [31]. The extremely high densities observed in Plots D, E, F, and G suggest that this species has outcompeted others, particularly rarer taxa such as *Aegiceras corniculatum* and *Avicennia marina*, which show minimal representation.

Margalef's richness index ( $d$ ), which ranged from 0.421 to 1.272, further indicates low species richness across the study area. Richness was highest in Plot I ( $d = 1.272$ ), where eight species were recorded, likely due to lower disturbance pressures and greater habitat heterogeneity. Global studies in Indonesia [30, 32] and the Philippines [33] similarly report that mangrove stands dominated by one or two species most commonly *Rhizophora* sp. or *Avicennia* sp. exhibit significantly lower richness and evenness compared to mixed stands with minimal disturbance.

The spatial analysis of species counts suggests clear disturbance gradients across plots. Plots closer to human access points showed greater prevalence of cut stumps, brush-pile fishing structures, and waste accumulation. These same plots (notably D, E, F, G) also correspond to lower Shannon and evenness indices, supporting the idea that anthropogenic pressure disproportionately affects species distribution. Multiple studies [34, 35] emphasize that direct extraction (firewood, poles, brush-pile material) selectively removes

slower-growing or preferred species, indirectly creating competitive release for more disturbance-tolerant species like *Excoecaria agallocha*. This aligns with the present findings, where *Excoecaria agallocha* dominates in exactly those plots with highest indicators of disturbance.

Additionally, community interactions appear to be shaping species patterns. Local fishers often prefer using *Lumnitzera racemosa* and *Rhizophora apiculata* for brush-pile construction, making them less abundant in high-use zones. Incorporating community perceptions would support this interpretation: similar socio-ecological studies in Kenya [36] and the Philippines [37] have shown that species preferences in local livelihoods strongly correlate with patch-level diversity outcomes.

### 3.3 Vegetation analysis

Mangroves vegetation was also analyzed by using the values of relative density, relative frequency and relative dominance. The summations of these values were added to attain species importance value index (IVI) in the entire studied area shown in Table 4.

*Table 4: Importance Value Index (IVI) of each species at studied site*

Species	No. of individual	Di	RDi (%)	Fi	RFi (%)	RDo (%)	IVI (%)
<i>Avicennia marina</i>	97	0.97	1.44	0.21	5.95	4.71	12.1
<i>Avicennia officinalis</i>	256	2.56	3.80	0.47	13.31	5.3	22.41
<i>Rhizophora apiculata</i>	355	3.55	5.26	0.52	14.45	7.67	27.38
<i>Rhizophora mucronata</i>	110	1.10	1.63	0.27	7.65	4.23	13.51
<i>Sonneratia caseolaris</i>	278	2.78	4.12	0.53	15.01	13.21	32.34
<i>Lumnitzera racemosa</i>	1205	12.05	17.85	0.54	15.30	11.42	44.47
<i>Excoecaria agallocha</i>	4439	44.39	65.74	0.98	27.48	52.56	145.78
<i>Aegiceras corniculatum</i>	11	0.11	0.16	0.03	0.85	0.9	1.91
<b>Total</b>	6751	67.51	100	3.56	100	100	300

The Importance Value Index (IVI) provides a comprehensive measure of the ecological significance of each species within a mangrove stand by integrating its relative density, relative frequency, and relative dominance. In the present study, *Excoecaria agallocha* recorded an exceptionally high IVI of 145.78%, far exceeding all other species and indicating its overwhelming ecological dominance across the landscape. This pattern reflects both its numerical superiority constituting 65.74% of all individuals and its substantial basal area contribution (52.56% relative dominance). Such disproportionate dominance reveals a structurally simplified mangrove community in which a single tolerant species outcompetes others, a well-documented phenomenon in disturbed or environmentally constrained mangrove systems [29, 31]. Further, this plant is dioecious, producing only male or female flowers on different individuals pave the path for higher pollination capacity. Therefore, this species quickly establishes the colony very rapidly are possible explanation of higher IVI of *Excoecaria agallocha*. This might be the reasons for high density of *Excoecaria agallocha* in all the study area

The next most influential species were *Lumnitzera racemosa* (IVI = 44.47%), *Sonneratia caseolaris* (IVI = 32.34%), and *Rhizophora apiculata* (IVI = 27.38%). These species, although present in appreciable numbers, show markedly lower ecological weight compared to *Excoecaria agallocha*. Their moderate IVI values suggest localized importance, particularly in shoreline or low-salinity zones. For instance, *Rhizophora apiculata*, with strong prop-root support systems, often forms wave-resistant fringes [38]. The moderate IVI of *Sonneratia caseolaris* aligns with its preference for estuarine, low-salinity habitats [39]. Meanwhile, *Lumnitzera racemosa* appears abundant in several plots, likely due to its tolerance of fluctuating water regimes and moderate anthropogenic pressure.

The extremely low IVI of 1.91% for *Aegiceras corniculatum* indicates that this species is highly restricted in distribution. Past research confirms that *Aegiceras corniculatum* thrives under narrower salinity ranges (~30–32 ppt) and specific sediment conditions [40]. Its low representation in this study likely reflects environmental mismatch, competitive exclusion by *Excoecaria agallocha*, and possible anthropogenic suppression. Selective harvesting such as removal for brush-pile fishing or firewood often reduces sensitive species first, paving the way for fast-growing, disturbance-tolerant species to dominate [34].

From an ecological perspective, the IVI pattern observed here resembles trends documented in several tropical mangrove regions. In the Sundarbans and parts of Indonesia, for example, stands dominated by a single species (often *Avicennia* or *Rhizophora*) show markedly reduced structural diversity and low resilience to hydrological or climatic disturbances [32, 33]. Similar cases of homogenization driven by selective resource extraction and environmental filtering have been reported from East Africa and Southeast Asia. The dominance of *Excoecaria agallocha* in the present study thus represents a potential warning sign of ecological imbalance, indicating that the system may be undergoing functional simplification and losing its capacity to buffer disturbances.

Overall, the IVI data clearly demonstrate a mangrove assemblage heavily skewed toward a single species, with reduced contribution from others that ordinarily support structural complexity, habitat heterogeneity, and ecosystem multifunctionality. This has important management implications: species with low IVI values require conservation attention, while plots characterized by extreme dominance (high IVI for *Excoecaria agallocha*) should be prioritized for restorative planting and regulated resource use. Restoration strategies may include enrichment planting with underrepresented species, reduction of brush-pile harvesting, and strengthening community-based monitoring programs to prevent further structural imbalance.

#### **4. CONCLUSIONS**

The selected study area, are home to eight true mangrove species belonging to six different families, including 5 Least Concern (LC) and 3 Near Threaten (NT) species. Among them *Excoecaria agallocha* dominated, while, *Aegicerus corniculatum* showed very low number of distributions. Similarly, there were 9 mangrove associates were identified. The combined assessment of diversity indices and Importance Value Index (IVI) clearly demonstrates that the Sathurukondan mangrove ecosystem is structurally imbalanced and ecologically stressed. The overall low Shannon diversity ( $H' = 1.132$ ), low evenness ( $J = 0.544$ ), and low richness ( $d = 0.794$ ) reveal a community dominated by a few species with limited heterogeneity. This pattern is strongly reinforced by the IVI results, which show an extreme dominance of *Excoecaria agallocha* (IVI = 145.78%), indicating that it

overwhelmingly dictates stand structure, density, and basal area. Such disproportionate dominance suppresses the ecological contributions of other mangrove species, resulting in reduced functional diversity, poor evenness, and diminished resilience.

Moderately important species such as *Lumnitzera racemosa*, *Sonneratia caseolaris*, and *Rhizophora apiculata* contribute to stand structure in specific habitat zones but remain far below the ecological influence of *Excoecaria agallocha*. Meanwhile, species such as *Aegiceras corniculatum* persist at very low abundance and restricted spatial distribution, highlighting their vulnerability to both environmental constraints and anthropogenic disturbances. The spatial pattern of diversity also aligns with observed human pressures plots experiencing higher disturbance (cutting, brush-pile fishing, trampling, waste deposition) coincide with lower diversity and stronger dominance, reflecting disturbance-driven homogenization. Ecologically, these findings indicate that the mangrove community is moving toward simplification, reduced species redundancy, and weakening ecosystem services such as shoreline protection, nursery provision, and carbon storage. Ecosystems with low richness and high dominance are also known to be less resilient to environmental shocks, including salinity fluctuations, tidal changes, and anthropogenic stress.

Overall, the study concludes that urgent conservation, Conduct regular village-level awareness sessions on the ecological value of mangroves, Develop simple illustrated guides identifying the locally threatened species (*Aegiceras corniculatum*, *Avicennia marina*) and explain why their protection is important, Train fishers and youth groups on sustainable harvesting techniques, avoiding excessive removal of *Avicennia* and *Lumnitzera* for brush-pile fishing, Restore species with low IVI values (*Aegiceras corniculatum*, *Avicennia marina*) through selective enrichment planting in suitable microhabitats, Prioritize restoration in degraded plots with low richness and high dominance of *Excoecaria agallocha*, to counteract homogenization, Develop co-management committees involving local fishers, women's associations, Divisional Secretariat, and the Forest Department, introduce community-managed no-cut zones in patches with rare species to allow natural regeneration

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