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RESEARCH ARTICLE

Parasitic and non-parasitic weed flora in selected areas of the Indian Sundarbans

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ABSTRACT

A study was conducted to investigate the biodiversity and ecological roles of angiosperm plant parasites and weeds, focusing on parasitic and non-parasitic species in selected regions of the Indian Sundarbans. A total of four angiosperm parasites and eight weed species belonging to eight taxonomic families (Loranthaceae, Asclepiadaceae, Poaceae, Cyperaceae, Aizoaceae, Chenopodiaceae, Convolvulaceae and Amaranthaceae) were recorded from the study area. Plants of Loranthaceae and Asclepiadaceae have diverse host preferences. The infestation of parasitic angiosperms, *viz. Hoya parasitica, Viscum orientale, Viscum monoicum* and *Dendrophthoe falcata,* were primarily recorded in the canopies of specific host plants with a preference for *Xylocarpus granatum, Xylocarpus mekongensis, Heritiera fomes* and *Bruguiera* spp. in the intermediate and upper canopy zones; whereas, *Sonneratia apetala, Excoecaria agallocha,* and *Avicennia officinalis* were recorded as rarely infested mangrove species. *Porteresia coarctata* and *Cyperus malaccensis* were two important weeds in the mangrove ecosystem. Besides, *Sesuvium portulacastrum, Suaeda nudiflora, Salicornia brachiata, Sarcolobus carinatus, Heliotropium curassavicum,* and *Ipomoea pes-caprae* were also distributed widely in this region. The frequency, density, and abundance of parasitic and non-plastic weed flora in the study area were recorded to understand their habitat and impact on ecological equilibrium in the mangrove ecosystem.

Keywords: Biodiversity, Host-parasite interactions, Indian Sundarbans, Mangrove plants, Parasitic weeds, Weeds

INTRODUCTION

The Indian Sundarbans, a UNESCO (United Nations Educational, Scientific and Cultural Organization) World Heritage Site, is globally acknowledged for its significance and distinguished for its abundant biodiversity and distinctive mangrove ecology (Sarker *et al.* 2016). There exist the most extensive continuous mangrove forests, spanning over 10,000 square kilometers, and the Ganges, Brahmaputra, and Meghna rivers delta across India and Bangladesh (Mondal *et al.* 2012, Ghosh *et al.* 2015). The Sundarbans hosts 105 mangrove species, including true mangrove, mangrove associate, and angiospermic parasitic plants. Some of the important true mangrove plants in Sundarbans are Sundari (*Heritiera fomes*), Genwa (*Excoecaria agallocha*), Goran (*Ceriops decandra*) and Keora (*Sonneratia apetala*) (Rodriguez *et al.* 2012, Basak *et al.* 2015). Weeds are plants that grow where and when they are not desired, often competing with cultivated plants for light, water, and nutrients (Rathore 2014). Mangrove weeds denote undesirable plant species that infiltrate and proliferate in disrupted mangrove ecosystems, particularly in regions modified by human activities such as sand filling, dredging, or deforestation (Numbere 2020). These weeds may flourish in the distinctive circumstances of mangrove ecosystems, often characterized by salty and marshy soils (Chen 2019).

Angiospermic parasites and weeds directly affect the mangrove ecosystem. Both may affect native mangrove species, possibly decrease biodiversity and change the ecological equilibrium of the mangrove environment. Weeds may also alter the different physical and chemical properties of soil (Mongia *et al.* 2001). Several research findings indicate that some weed species may absorb pollutants from the soil, including heavy metals and hydrocarbons, functioning as bioremediation agents. This may mitigate soil pollution but also result in the buildup of deleterious compounds inside the weeds (Bashir *et al.* 2023). Weeds and parasites may serve as a home for several insect pests and diseases, potentially affecting the mangrove environment and adjacent human populations differently.

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Parasitic plants fulfill a portion of their nutritional needs by extracting resources from their host plants (Parker and Riches 1993). Various categories of parasites demonstrate unique adaptations and strategies for their parasitic lifestyle. They frequently trigger chlorophyll breakdown, rendering photosynthesis unfeasible (Shrestha 2012). They rely on their host plants for moisture, nourishment, and structural integrity. A unique structure, 'haustoria', infiltrates the tissue system of the host to get nutrients (Mallaburn 1992, Ghosh *et al.* 2004, Mathiasen *et al*. 2008). Certain angiospermic parasites depend on a single host plant, while others may infect several plants. Host specificity is dictated by physiological reliability, host availability, and environmental conditions (Bell and Adams 2011). Angiospermic plant parasites are fascinating and ecologically essential, demonstrating unique survival and reproduction strategies (Nickrent 2020). The genus *Loranthus* includes mistletoes, categorized as hemiparasitic plants that adhere to the branches of host trees and shrubs. Parasitic plants from the Scrophulariaceae family infiltrate the roots of adjacent plants to extract water and nutrients. Epiphytic bromeliads are often found in mangroves; nevertheless, their existence is frequently unrecorded in studies of mangrove vegetation (Sousa and Colpo 2017).

Certain angiosperm parasites and weeds may acclimate to the mangrove ecosystem while competing with indigenous plants for resources, exacerbating conservation challenges. An understanding of the parasites and weeds is essential for preserving the ecological integrity of the Sundarbans and sustaining local livelihoods. The present study was carried out to assess the biodiversity and ecological role of angiosperm plant parasites and non-parasitic weeds, to understand their habitat and impact on maintaining ecological equilibrium in the mangrove ecosystem of Indian Sundarbans.

MATERIALS AND METHODS

The Sundarbans is the most significant delta area globally, created by the confluence of three main rivers: the Ganges, Brahmaputra, and Meghna. The Indian Sundarbans, located next to the southern border of West Bengal, include a substantial area of the North 24 Parganas and South 24 Parganas districts. The current research was conducted in designated locations within the Indian Sundarbans area of the South 24-Parganas district in West Bengal (21°31'03"N – 22°30'03"N, 88°10'03"E – 89°51'03"E) from 2019 to 2022. The sample area included the administrative divisions of Basanti, Gosaba, and Kultali. The chosen locations display an abundance of halophytic plant species. The terrain dynamics of these locations lead to significant variations in their surface attributes.

A random region sample was collected by positioning 120 quadrats, each measuring 10 m x 10 m, from September 2019 to March 2022. Utilizing a slide caliper, we documented all trees inside each quadrat exhibiting a circumference/diameter at breast height (dbh) of ≥1cm, along with their quantities and dbh measurements. In instances when dbh measurement proved unfeasible, the girth at breast height (gbh) was ascertained using a measuring tape. Four quadrats measuring 2.5 m x 2.5 m were used to gather samples of shrubs, climbers, and tree seedlings of over 30 cm height. Four quadrats (1 m x 1 m), each situated inside a 10 m × 10 m quadrat, were used to gather samples of herbs, including tree seedlings measuring less than 30 cm in height. Frequency (F), density (DN), abundance (A), relative frequency (RF), relative density (RD) and relative abundance (RA) were obtained (Sreelekshmi *et al.* 2020) as follows:

$$\text{Frequency (F)} = \frac{\text{Number of quadrats of occurrence of a species} \times 100}{\text{Total number of quadrats studied}}$$

$$\text{Density (DN)} = \frac{\text{Total number of individuals of a species} \times 100}{\text{Total number of quadrats studied}}$$

$$\text{Abundance (A)} = \frac{\text{Number of individuals of a species} \times 100}{\text{Number of quadrats of occurrence of the species}}$$

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of species} \times 100}{\text{The sum of the frequency of all the species}}$$

$$\text{Relative density (RD)} = \frac{\text{Density of a species} \times 100}{\text{The sum of the density of all the species}}$$

$$\text{Relative abundance (RA)} = \frac{\text{Total number of individuals of a species in all quadrats} \times 100}{\text{Total abundance of all the species}}$$

The biodiversity indices were calculated to unveil the species richness, dominance, abundance, evenness and others important parameters (Sreelekshmi *et al*. 2020) by using the statistical analytical software PAST 4.03 and IBM SPSS 20. For each quadrat sample biodiversity data were quantified using several ecological indices. The Dominant Index (d) =" $(\frac{ni}{N})^2$, where ni is the number of individuals of species *i* and N is the total number of individuals, measures the dominance of a few species in a community (Simpson 1949). The Shannon-Wiener index [H' = $-\sum_{i=1}^{s} Pi \ln Pi$], Simpson's index [D= $\frac{1}{\sum_{i=1}^{s}(Pi)^2}$)], Pielou's Index for species evenness [J =$\frac{H'}{Log\ S}$] and Margalef's index of species richness [R = $\frac{(S-1)}{\log N}$] were calculated

(Shannon and Weaver 1949, Simpson 1949, Pielou 1966, Margalef 1968). Where s=total no of species, pi= ni/N, ni= total no of individuals of "i" species, N= total no of individuals of all species, ln= natural log. Where s=total no of species, pi= ni/N, ni= total no of individual of "i th" species, N= total no of individual of all species, ln= natural log.

Brillouin Index [$H_B = \frac{\ln(N!) - \sum \ln(ni!)}{N}$], is particularly suitable when the population is completely censused (Brillouin 2013). For richness, the Menhinick Index [$D_{Mn} = \frac{S}{\sqrt{N}}$], relates the number of species S to sample size (Menhinick 1964). The Fisher's Alpha Index [$S_{á} = \alpha \ln\left(1+\frac{N}{\alpha}\right)$ assumes a log-series distribution and is sensitive to rare species (Fisher *et al*. 1943). The Berger–Parker Index [$d_{BP} = \frac{Nmax}{N}$], where Nmax is the abundance of the most common species, measures dominance by the single most abundant species (Berger and Parker 1970). Finally, the Chao-1 Index [$S_{est} = (Sobs + \frac{(F1)2}{2F2})$], where Sobs is observed species richness, F_1 is the number of singletons, and F_2 is the number of doubletons, estimates true species richness by accounting for rare, undetected taxa (Chao 1984).

RESULTS AND DISCUSSION

Host selection and parasitism

In the Sundarbans, parasitic plants might select mangrove species based on their physiological compatibility, chemical signaling, and ecological interactions. Mistletoes (Loranthaceae) might have the potential to parasitize mangrove species that possess dense foliage and adequate nutrients, while they tend to overlook environments characterized by lower nutritional levels. Another species, *Viscum orientale* had the potential to parasitize specific mangrove species, such as *Heritiera fomes*, *Excoecaria agallocha* and *Bruguiera* spp. while *Viscum monoicum* was often found on *Bruguiera* spp. and *Xylocarpus* spp. The important member of Loranthaceae was *Dendrophthoe falcata*, has a broader variety of hosts than the previous ones, including *Xylocarpus* spp., *Excoecaria agallocha*, *Heritiera fomes*, and *Sonneratia apetala*. *Hoya parasitica* (Asclepiadaceae) associated with *Bruguiera* spp. and *Xylocarpus* spp. were found to contribute towards mangrove canopy structural and biological richness (**Table 1**).

Species composition

In the present study, twelve plant species identified were of the families *viz.* Loranthaceae, Asclepiadaceae, Poaceae, Cyperaceae, Aizoaceae, Amaranthaceae, Chenopodiaceae, and Convolvulaceae. Madur kathi, *Cyperus malaccensis* was the most common weed in density (93.33%), followed by another weed, Dhani Ghas, *Porteresia coarctata* (89.17%) and Giria Shak, *Suaeda nudiflora* (87.50%). *Cyperus malaccensis* had the higher abundance (2.74%), underscoring its status as a dominating species although *Porteresia coarctata* (2.25%) and *Heliotropium curassavicum* (2.33%) also had a significant presence. In contrast, species such as Mandala, *Viscum orientate* and Shamu lata, *Viscum monoicum* had lower abundance values, indicating that the angiospermic plant parasites invaded the Indian part of Sundarbans less rapidly than the two types of grasses. High relative frequencies of *Cyperus malaccensis* (21.37%) and *Porteresia coarctata* (20.42%) indicates that the mangrove area changed its habitat due to natural and anthropological effects. The lower relative density values *Viscum orientale* (6.19%) indicates that the lower density of this species might be due to specific

Table 1. Ecological analysis of parasitic and non-parasitic weed species in the Indian Sundarbans

Species	Family	F (%)	D (%)	A (%)	RF (%)	RD (%)	RA (%)	Host plants
Viscum orientate	Loranthaceae	60.83	0.43	0.70	13.93	6.19	8.10	*Bruguiera* spp., *Excoecaria agalloclia. Heritiera fomes*
Viscum monoicum	Loranthaceae	68.33	0.53	0.77	15.65	7.64	8.91	*Bruguiera* spp., *Xylocarpus* spp.
Dendrophthoe falcata	Loranthaceae	55.83	0.60	1.07	12.79	8.73	12.47	*Xylocarpus* spp., *Excoecaria agalloclia, Heritiera fomes, Sonneratia apetala*
Hoya parasitica	Asclepiadaceae	69.17	0.75	1.08	15.84	10.92	12.58	*Bruguiera* spp., *Xylocarpus* spp.
Porteresia coarctata	Poaceae	89.17	2.01	2.25	20.42	29.23	26.13	-
Cyperus malaccensis	Cyperaceae	93.33	2.56	2.74	21.37	37.24	31.80	-
Sesuvium portulacastrum	Aizoaceae	54.17	0.88	1.62	6.37	5.96	7.99	-
Suaeda nudiflora	Amaranthaceae	87.50	1.83	2.10	10.28	12.49	10.37	-
Salicornia brachiate	Amaranthaceae	80.83	1.06	1.31	9.50	7.21	6.48	-
Sarcolobus carinatus	Asclepiadaceae	73.33	1.12	1.52	8.62	7.61	7.53	-
Heliotropium curassavieum	Chenopodiaceae	73.33	1.71	2.33	8.62	11.64	11.53	-
Ipomoea pes-caprae	Convolvulaceae	45.00	1.23	2.72	5.29	8.34	13.47	-

A: abundance, D: density, F: frequency, RA: relative abundance, RD: relative density, RF: relative frequency ecological circumstances or host availability **(Table 1)**. The prevalence of *Cyperus malaccensis* and *Porteresia coarctata* indicated their adaptation to the local environment, possibly owing to their tolerance of soil composition, moisture levels, and sunshine exposure. Semi-parasitic species from the Loranthaceae family, including *Viscum orientale*, *Viscum monoicum*, and Himelata, *Dendrophthoe falcata*, exhibited intermediate frequency and density, indicating a specialized niche reliant on host trees rather than direct competition for terrestrial space (**Figure 1**). These plants could enhance ecological diversity and provide resources for wildlife in their environment. Positive effects of plants belonging to Loranthaceae on forest environment were studied by Burgess *et al.* (2006). Salt-tolerant plants such as *Suaeda nudiflora* and Baro Lonia, *Salicornia brachiata* are crucial to mangroves ecosystem due to their facilitating soil stability and enhancing nutrient cycling. Chagalkuri, *Ipomoea pes-caprae* and *Heliotropium curassavicum* exhibited limited abundance. *Ipomoea pes-carpae* is well-improved in sandy soils, where it helps in erosion prevention and stabilizes banks (Kaufman *et al.* 2015). The trend line (or regression line) fitted to the data points indicated a positive correlation between abundance and relative density. The equation of the trend line is y=5.406x”0.76789 suggesting that as abundance increases, relative density also tends to increase (**Figure 2)** as observed by Kaufman *et al.* (2015). The positive slope of the trend line implies that species with higher abundance also have higher relative density values, indicating a strong relationship between these two variables in this ecosystem. The study emphasized the need to conserve true and mangrove-associated species within the region.

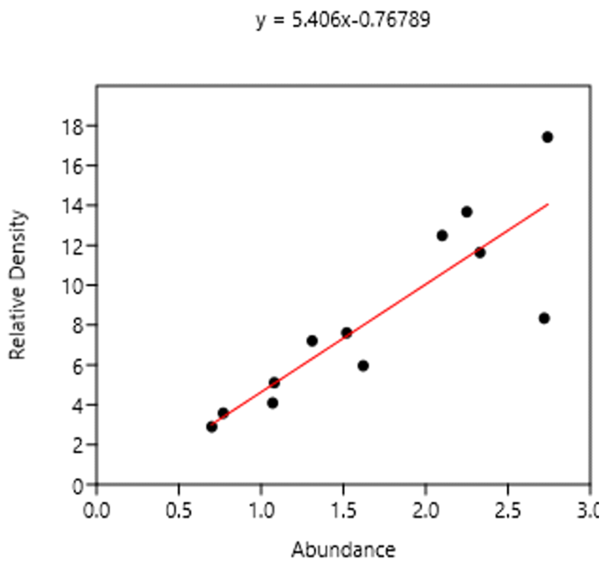

Figure 2. Correlation between relative density and abundance of plant species in the Sundarbans mangrove ecosystem

Species diversity and community structure

The Indian Sundarbans exhibited a comprehensive species richness, distribution, and ecosystem structure within this crucial mangrove area. A total of twelve species were identified, comprising 1,615 individuals, indicative of a diverse ecosystem with a well-balanced species composition. The Dominance Index (d) of 0.12 indicates low dominance within the community structure, implying that no single species significantly overshadows the area (**Table 2**).

The Simpson Index (1-D) of 0.88 reflects a significant level of biodiversity coupled with minimal dominance (Chakraborty *et al.* 2009). The Simpson Index of 1, as noted in this study, indicates significant diversity (Sreelekshmi *el al.* 2020). The Shannon Index (H) of 2.25 reinforces the moderate to high diversity, as higher Shannon Index is generally associated with species richness and evenness. As the Shannon Index considers the abundance and distribution of each species the Shannon Index (H) of 2.25 indicates that the sampled species are diverse and represented in balanced quantities, fostering a robust ecological background (**Table 2**).

The Evenness Index (e^H/S) of 0.86 and the Equitability_J Index of 0.94 indicate a balanced distribution among the species. The Brillouin Index (2.23) considers species abundance and arrangement, closely matching Shannon's diversity outcome and confirming that the community exhibits diversity and even distribution. The Menhinick Index (0.27) and Margalef Index (1.35) are metrics for assessing species richness and sample size. The Fisher's Alpha Index (1.59) introduces an additional layer to this diversity evaluation, indicating

Table 2. Biodiversity indices of the vegetation sampled in the Indian Sundarbans

Number/Indices	Values
Number of the species identified	12.00
Total number of individuals	1615.00
Dominance Index (d)	0.12
Simpson index (1-D)	0.88
Shannon Index (H)	2.25
Evenness Index (e^H/S)	0.86
Brillouin index	2.23
Menhinick index	0.27
Margalef index	1.35
Equitability_J index	0.94
Fisher_alpha index	1.59
Berger-Parker index	0.19
Chao-1 index	12.00

a moderate degree of richness and the existence of less common species within the sample (Satheeshkumar and Khan 2012). The Berger-Parker Index (0.19) reinforces the notion of low dominance among the vegetation species, indicating a well-balanced biodiversity where no single species prevails over the others. This equilibrium illustrates the collaborative framework within mangrove ecosystems, where species frequently utilize resources collectively to enhance the ecosystem's enduring health (**Table 2**).

Species richness

The Chao-1 Index (12) estimates species richness while considering the possibility of undetected species and closely corresponds with the observed species count. This indicates that the sample effectively represents the species present in the area. The indices together illustrate a multifaceted and harmonious ecosystem, showcasing significant species diversity, minimal dominance, and fair distribution among species in the Indian Sundarbans (Das *et al.* 2022).

Furthermore, the significance of high diversity and evenness is especially pronounced in the Sundarbans, where distinctive species interactions - like those involving salt-tolerant plants, sediment-binding roots, and specialized fauna - constitute the basis of a cohesive ecosystem. The low dominance level coupled with high evenness indicates that a diverse array of plants contributes to ecological services, thereby bolstering the stability of the ecosystem. The rich biodiversity is vital in enhancing local ecological health while bolstering global conservation initiatives. The Sundarbans are essential as a significant carbon sink, a sanctuary for rare and endangered species, and a protective shield for coastal communities.

A proliferation of the parasite on branches, especially in clusters, is the most definitive sign of infestation in mangrove trees. Impacted mangroves may show poorer growth and health, indicated by markedly smaller leaves and a general decline in condition. Physiological stress associated with nutritional deficiencies caused by the parasite's resource depletion is most frequently demonstrated as chlorosis or curling leaf symptoms. If the branches have a significant amount of infection, the whole branches can die back, and if not taken care of, the tree can die back, too. Also, Loranthus' spread would hamper sunlight from reaching the leaves of the mangrove and such would reduce photosynthesis and further endanger the decline of the plant. Due to their importance in the sustainable management and preservation of mangrove ecosystems, timely identification of indicators is of primary importance. The strategies for effective management of parasites are necessary to mitigate their impacts and preserve the health of mangrove ecosystems.

Conclusion

The Indian Sundarbans is a unique and critical mangrove environment for coastal stability as well as rare and endangered species. The observed parasitic and non-parasitic weed flora influence the biodiversity of Sundarbans mangroves significantly. They help to maintain the diversity of ecology and adaptability but uncontrolled spread can cause the extinction of native mangrove species. Thus, in order to maintain the ecological balance and the long-term stability of Sundarbans mangrove ecosystem, ecological-checks on the major weeds and the parasitic angiosperms and the control thereof need to be monitored in an opportune manner. Protecting this World Heritage Site is essential, thus protecting regional biodiversity and environmental stability.

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