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MORPHOLOGICAL VARIATIONS AMONG MANGROVE PLANTS FROM VISAKHAPATNAM COAST OF ANDHRA PRADESH INDIA

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ABSTRACT

The present work investigates a revision of morphological diversity among dominant mangrove species along the Visakhapatnam coast of Andhra Pradesh. A total of 8 species of mangrove plants and 9 species of mangrove associates were recorded and collected for morphological characterization and herbarium preparation. Comparative analysis of root, leaf and reproductive traits revealed adaptive variations linked to salinity tolerance, tidal inundation and substrate type. A detailed morphological description was presented for each reported species and a revised identification key for selected mangrove species was prepared to aid future research and conservation efforts.
Keywords: *Avicennia marina*, *Acanthus ilicifolius*, mangrove associate, viviparous, pneumatophore.

Introduction

Mangroves are specialized group of trees and shrub species that thrive along the intertidal regions of tropical and subtropical coastlines around the world.

Mangrove vegetation is broadly categorized into **"true mangroves"** and **"mangrove associates"** (Tomlinson, 1986). True mangroves are species that are entirely dependent on the mangrove ecosystem, play a dominant role in community structure by forming pure stands, and exhibit distinct morpho-physiological adaptations to their environment (Tomlinson, 2016). These adaptations include the development of specialized aerial roots such as pneumatophores that facilitate respiration in waterlogged, anaerobic soils; structural support mechanisms like buttress and knee roots; maintenance of low water potentials and high intracellular salt concentrations; salt excretion through leaves; and the production of buoyant, viviparous propagules for dispersal and regeneration (Duke *et al*., 1998). Thus, Knowledge about the mangrove forest is very crucial for the ecology, conservation and sustainable management of this diverse and unique plant community (Suwignyo *et al*., 2015).

In India total mangrove cover is 4991.68 square km (ISFR, 2023) that is 0.15% of the total geographical area of the country and around 5% of mangroves of the world (ISFR, 2023)

According to the India State of Forest Report (ISFR) 2023, the total mangrove cover in Andhra Pradesh has been assessed at 421.43 km², comprising 213.90 km² of moderately dense mangroves and 207.53 km² of open mangroves, with no area recorded under the very dense category. Although the state has shown a net increase of 13.01 km² in mangrove cover, indicating positive trends in mangrove regeneration and coastal ecosystem restoration. In Andhra Pradesh, about 421.43 sq.km is covered by mangrove vegetation, out of which about 256.06 sq.km is located in the estuarine complex of Krishna-Godavari rivers, spreading over Krishna, Guntur and East Godavari districts. The remaining mangrove area is present in Prakasam, Guntur, Nellore and West Godavari districts (ISFR, 2021; 2023). Within the state, Visakhapatnam district accounts for 0.31 km² of mangrove cover, all categorized as open mangroves,

Mangroves of Andhra Pradesh are moderately rich in diversity. Although true mangrove diversity in Andhra Pradesh and new mangrove habitats with additions to the flora of the Srikakulam district were accounted yet lesser-known mangrove habitats and floristic features were presented in Visakhapatnam, Guntur, Prakasam and Nellore districts in Andhra Pradesh (Swain *et al*., 2008; Basha *et al*., 2018).

Once Visakhapatnam was rich in Mangrove forests along the coastline, rivers and main land areas close to the sea. Thick mangrove which includes more than 30 species of major and minor mangrove plants and several other mangrove associates were recorded in and around Visakhapatnam District (Venkanna *et al*., 1989).

Visakhapatnam coastline extends over a length of 135 km intersected with a number of rivers joining the Bay of Bengal. Visakhapatnam district occupies an area of approximately 11,161 square kilometers.

From an extensive stretch of mangrove wetlands, the once-vibrant green cover of Visakhapatnam has now become considerably constricted. For decades, these mangroves served as the green lungs of the city, providing crucial habitat for numerous avifaunal and marine species. However, rapid industrialization and urban developmental activities have led to significant degradation of these ecosystems. Ground-truthing surveys have revealed the presence of approximately 220 hectares of mangrove patches within the district, which, notably, were not documented in the Forest Survey of India (FSI) assessments, despite the agency's biennial monitoring and mapping of forest resources across the country. Furthermore, elevated soil salinity in several areas has been observed to negatively affect mangrove growth and regeneration, thereby constraining their spatial expansion and overall ecological vitality (Rao and Dora, 2009; Patel & Srinivas, 2024).

Although morphological characterization of mangroves has been done by various researchers throughout the world (Chaudhary, & Choudhury, 1994; Reddy, 2008; Standish, 2009; Roy *et al.*, 2009; Ragavan *et al.*, 2016: Nabeela *et al.,* 2019; Mariano *et al.*, 2019; Ragavan *et al*., 2021). But the literature pertaining to morphological features of Mangroves occurring in Visakhapatnam with illustrations and geo referenced data of the site of occurrence are documented to a limited extent. Morever the morphological features and flowering and fruiting period also varies in different geographical ranges depending upon the local environmental gradients so area specific field identification material would be useful for identification and conservation of plants.

With this gap, the present research work is mainly based on the revisionary floristic survey, plants collection and herbarium preparation of mangroves from the coastline of Visakhapatnam for identification of mangroves and revision on their morphological characters so that the strategies for their conservation can be formulated.

Materials and Methods

Field survey and Plant Collection

Field surveys were conducted at regular intervals during 2021–2022 across different seasons with the objective of collecting plant species from various coastal localities of the Visakhapatnam district and its adjoining areas. During each field visit, observational notes were recorded in a field notebook, documenting details such as habit, habitat, plant height, flower and fruit colour, and time of anthesis. Plant specimens were carefully collected in polythene bags and transported to the laboratory for further examination.

Fig. 1 : Map of the study area with sites of exploration and collection

Flowering and fruiting twigs were collected for the preparation of herbarium specimens and subsequent morphotaxonomic studies aimed at the identification and classification of species. Collections were made during different seasons and from multiple localities to capture potential seasonal and spatial variations in the vegetation of the study area during the survey period.

A list of surveyed localities, plant species, their site of the collection along with their longitude and latitude were noted (Table 1, 2 & 3) and distribution map is presented (Figure 1.).

Table 1 : Explored localities of Visakhapatnam district

S. No.	Locality	Latitude	Longitude	Altitude(m)
1	Appikonda	17.56856944	83.17080556	0.5
2	Bangaramma Palem	17.41462778	82.85868056	8
3	Chepaluppaada	17.85110278	83.41337222	10
4	China Rushikonda	17.78886667	83.38779444	2
5	Endada Beach	17.76831667	83.37095278	8
6	Gosthani river confluence	17.89678611	83.45113333	4
7	Gosthani River creek	17.90810278	83.44589444	2
8	Megha	17.75905556	83.32482222	28
9	Mutyalamma Palem	17.53578611	83.08980833	5
10	Near HPCL plant port road	17.706808	83.259131	3
11	NTPC Simhadri Super Thermal Power Plant	17.59781111	83.07971944	12
12	Pentakota	17.29915556	82.60883889	3
13	Port Road near Solar Plant	17.717726	83.255451	3
14	Pudimadaka Beach	17.493135	83.000345	2
15	Relli Beach	17.84205556	83.40819444	2
16	Sagar Nagar Beach area	17.76224444	83.35980278	5
17	Thimmapuram	17.81322222	83.41056667	7
18	Visakhapatnam Port Trust near Sardar Vallabhai Patel Bridge	17.71273611	83.26310278	2

Table 2 : Sites of plant collection with georeferences

S. No	Locality	Latitude	Longitude	Altitude(m)
1	Near HPCL plant port road	17.706808	83.259131	3
2	Port Road near Solar Plant	17.717726	83.255451	3
3	Pudimadaka	17.493135	83.000345	2
4	Relli Beach	17.84205556	83.40819444	2
5	Visakhapatnam Port Trust near Sardar Vallabh Patel Bridge	17.424601	83.154455	1

Table 3 : List of true mangrove species collected from Visakhapatnam

S.N.	Plant name	Family	Latitude	Longitude	No. of plant collected	Voucher No.
1.	*Acanthus ilicifolius*	Acanthaceae	17.717726	83.255451	15	FRCCE VSKP7, FRCCE VSKP11
2.	*Avicennia marina*	Acanthaceae	17.486482	82.995344	20	FRCCE VSKP 6, FRCCE VSKP 16
3.	*Bruguiera cylindrica*	Rhizophoraceae	17.493135	83.000345	10	FRCCE VSKP 1
4.	*Bruguiera gymnorhiza*	Rhizophoraceae	17.485889	82.995772	10	FRCCE VSKP 2
5.	*Ceriops decandra*	Rhizophoraceae	17.515433	82.992657	5	FRCCE VSKP 5
6.	*Ceriops tagal*	Rhizophoraceae	17.486482	82.995344	5	FRCCE VSKP 4
7.	*Excoecaria agallocha*	Euphorbiaceae	17.717726	83.255451	15	FRCCE VSKP 8, FRCCE VSKP 15
8.	*Rhizophora apiculata*	Rhizophoraceae	17.485228	82.996169	5	FRCCE VSKP 3

Herbarium specimen preparation

Plant specimens were collected and carefully preserved, dried and mounted on herbarium sheets following the standard practices of herbarium preparation (Smith, 1971; Bridson & Forman *et al.,* 1998) and the accession number was given to each specimen. All the required information related to the species collection site, date and name of the collector was recorded on the labels (Figure2, 3). The finally prepared herbarium sheets were deposited in the Herbarium of Indian Council of Forestry Research and Education-Coastal Ecosystem Centre (ICFRE-CEC), Visakhapatnam (under Institute of Forest Biodiversity, Hyderabad).

Identification and authentication

Identification of all plant speciments was done with the help of different regional flora of Visakhapatnam and a photographic field identification guide of Indian Mangroves (Kumari *et al*., 2002; Reddy, 2008).

Fig. 2: Herbarium specimen of Mangrove plant species

Fi. 3 : Herbarium specimen of Mangrove associates

Results and Discussion

In the present study, A total of 8 true mangrove species belonging to four families and 6 genera have been recorded from the natural mangrove areas of Pudimadaka, port area and HPCL plant road of Visakhapatnam. The recorded plant included seven woody tree species and one shrub. Morphological descriptions of true mangroves species were presented along with photographic images of whole plant, leaf, flower and propagules (Figure 4-11).

(1) *Acanthus ilicifolius* L

- **Family:** Acanthaceae
- **Local name:** Alisi (Tel.)
- **Eng. name:** Sea Holly, Holy Mangrove

Shrub upto 2 m to approximately 15 m tall (Figure. 4A) and erect. Stems stout, scarcely branched, glabrous, often with upward facing stipule like spines at nodes; base with stilt roots. Leaves glabrous, shining, thick , oblong to oblong-lanceolate, blade- 6-14 × 2-5 cm , secondary veins 5-7 on each side of mid vein, base cuneate, margin pinnatifid and with few large spines, serrate, or subentire, apex truncate. Petiole 3-6 mm; Inflorescence terminal spike, up to 16.5 cm; bracts broadly ovate, 7-8 mm, caducous; bracteoles ovate, ca. 5 mm, leathery. Flower zygomorphic, Calyx posterior and anterior, lobes 1-1.3 cm, margin scarious or sometimes crispate, apex emarginate; lateral lobes ovate, ca. 1 cm, margin entire. Corolla white or bluish to pinkish, 3-4 cm; tube ca. 6 mm; lip obovate, 2.2-3 cm, thinly leathery, outside with soft trichomes, apex 3-cleft. Stamens equal; filaments ca. 1.5 cm; anther theca with a line of trichomes on both sides of suture. ovary bilocular, Stigma capitate. Style ca. 2.2 cm. Capsule 2.5-3 cm. Seeds light yellow, reniform (Figure.4)

- **Flowering and fruiting:** Fl. March and April; Fr-Aug-Sep.
- **Field identification:** plant can be identified in field on the basis of its stem with upward facing spine, leaves thick green with spiny margins; inflorescence with purple, whitish or bluish flower in terminal spike. Bracteole persistent.
- **Conservation Status:** Least Concern

(2) *Avicennia marina* (Forssk.) Vierh.

- **Family:** Acanthaceae
- **Local name:** Tellamada (Tel.)
- **Eng. name:** Grey mangrove

Small tree up to 1 to 5 m height, spreading, stem glabrous, thin pencil like pneumatophore leaves 5-6.5 x 1.5-2.0 cm, simple, elliptic to oblong , tip acute cuneate at base, thick whitish green hairy on abaxial surface ; adaxial surface dark green and turns blackupon drying; Petiole short Inflorescence terminal cyme: Flowers small, yellow and sessile; Bract and bracteole ovate, hairy. Calyx green hairy five lobed. Corolla hairy 4 lobed. Stamen 4 alternate with corolla lobes. Ovary globose and pubescent, style short glabrous. Fruit is ovoid capsule with prominent beak (Figure 5).

- **Flowering and fruiting:** Fl.-May- July. Fr.-June - Aug.
- **Field identification:** Leaves elliptic oblong with acute apex, upper surface dark green, blackens upon dry while lower surface pale green and pubescent, axillary cyme small yellow flowered. Pneumatophores pencil shape.
- **Conservation Status:** Least Concern

(3) *Bruguiera cylindrica* (L.) Blume

- **Family:** Rhizophoraceae
- **Local name:** Urudu (Tel.)
- **English name:** White Burma mangrove, Small leaved orange mangrove

Trees up to 3m of height, Stem smooth, buttressed at the base with many knee roots; twig reddish brown with many stipule scars. Leaves 8-10 cm oblanceolate, thick, smooth, shiny, acute apex with cuneate base. Inflorescence axillary mostly three flowers on a common peduncle. Flowers whitish green, small, calyx with reflexed lobes. Mature propagules slightly curved towards the apex**.** (Figure.6)

- **Flowering and fruiting:** November to March
- **Field identification:** Knee roots, Bark fissured three small flowers on common peduncle.
- **Conservation Status:** Least Concern.

(4) *Bruguiera gymnorhiza* (L.) Lam. ex Savigny

- **Family:** Rhizophoraceae
- **Local name:** Kandringa (Tel.)
- **English name:** Large leaved orange mangrove.

Trees up to 5 m height, Bark rough and fissured. Stem base with knee roots. Leaves 9-12 x 3-4cm, simple, shiny, thick, elliptic oblong often red dish on the lower side of midrib; petiole reddish, Flower

solitary, axillary. Calyx bright red tube ribbed, lobes 7-11., Petals turn brown on maturity, Fruit or propagule cigar shape with longitudinal ridges. (Figure 7).

- **Flowering and fruiting:** Throughout the year.
- **Field identification:** Long elliptic leaf with reddish green petiole, Cigar shape propagules, Large and bright red Calyx.
- **Conservation Status:** Least Concern.

(5) *Ceriops decandra* (Griff.) Ding Hou

- **Family :** Rhizophoraceae
- **Local name:** Thogra (Tel.)
- **English name:** Yellow mangrove.

Trees up to 3m height. Stem branches deliquescent, reddish brown; Leaves 5-7x 2-2.5 cm, obovate, rounded at apex, cuneate at base, margins entire. Flowers small, white arranged in condensed axillary cymes. Fruits ovoid propagules always in upright position. (Figure.8).

- **Flowering and fruiting:** Throughout year.
- **Field identification:** Ovoid leaf with rounded tip and cuneate base, short petiole and peduncle. Propagules in upright position.
- **Conservation Status:** Near threatened

(6) *Ceriops tagal* (Perr.) C.B. Rob.

- **Family:** Rhizophoraceae
- **Local name:** Gedara (Tel.);
- **English name:** Yellow mangrove, Spurred Mangrove

Trees up to 4 m height, Stem orange brown: Leaves obovate, thick, green, rounded at apex, cuneate at base with petiole large, Inflorescence multi flowered cyme peduncle long Flowers small, light yellow, Calyx five lobed, Petals small white. Propagule green to brown, long up to 10cm,tapering. (Figure 9).

- **Flowering and fruiting:** May to June
- **Field identification:** Branching pattern pyramidal, Leaves green obovate, petiole long. Peduncle long. Propagules long and ridged tapering below.
- **Conservation Status:** Least Concern

(7) *Rhizophora apiculata* Blume

- **Family:** Rhizophoraceae;
- **Local name:** Uppu Ponna (Tel.)
- **English name:** Tall stilted red mangrove, Twin flowered mangrove

Trees up to 5m in height, Stem with many upward growing branches, prominent leaf scars, base with numerous branched stilt roots. Leaves broadly elliptic ovate, apex acute. Flowers two in axillary cyme, sessile bract short, corky, brown, calyx with four lobes, yellow Corolla white membranous and caducous, Fruits long, cylindrical and smooth propagule, pointed towards the end. (Figure.10).

- **Flowering and fruiting:** January-April; August-November.
- **Field identification:** Oblong leaves with apiculate tip, flower in pairs, corky bract, smooth long and green propagule.
- **Conservation Status:** Least Concern

(8) *Excoecaria agallocha* L.

- **Family :** Euphorbiaceae
- **Local name:** Tilla (Tel.)
- **English name:** Blind your eye mangrove, Milky mangrove.

An evergreen shrub or a small tree up to 10m height, Leaves light green in male plants, longer, female plants,; dark green and smaller, margins wavy, alternate, simple. Inflorescence axillary, unisexual, male inflorescence bracteate, spirally arranged, female inflorescence catkin with glandular bract, ovary trilocular. Fruit capsule (Figure.11).

- **Flowering and fruiting:** June-August; September-November.
- **Field identification:** Dioecious tree, latex secreting leaves, Male plants with spirally arranged flowers and female with trilocular ovary and glandular bracts, arranged in catkin inflorescence.
- **Conservation Status:** Least Concern

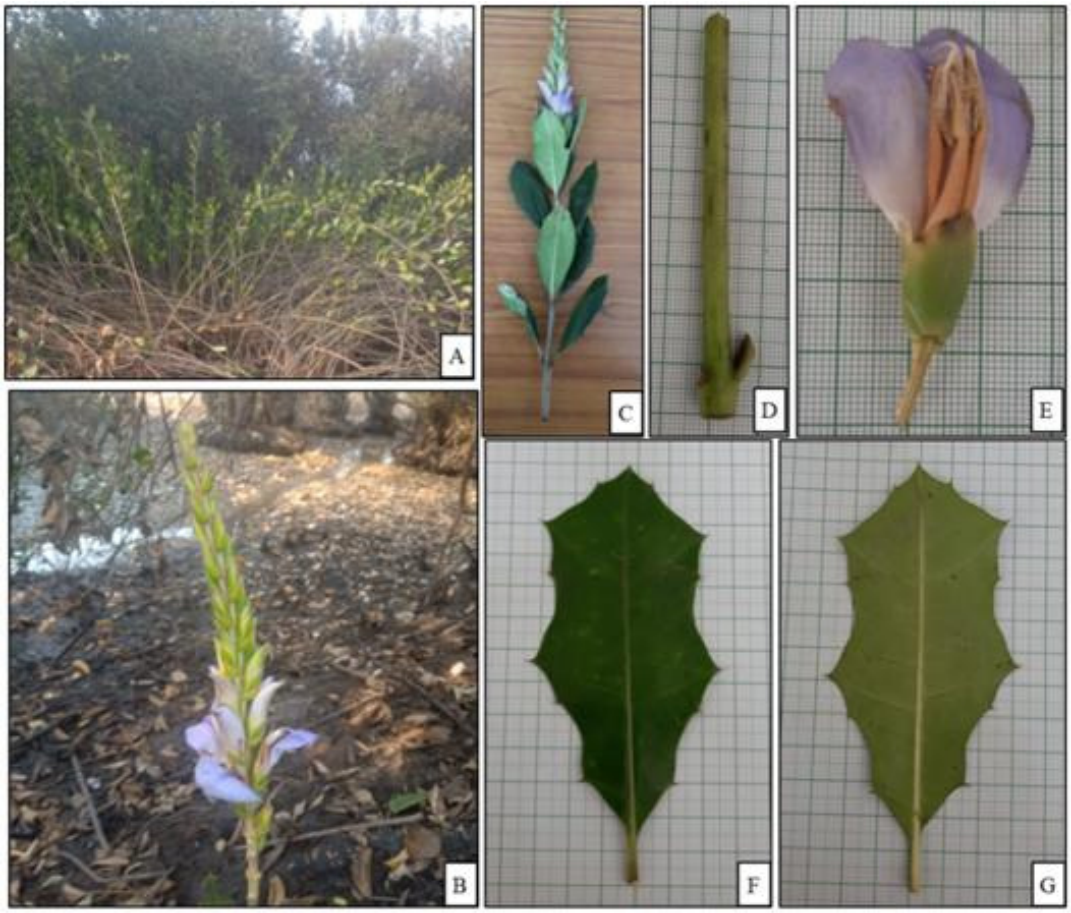

Fig. 4 : *Acanthus ilicifolius*: A. Habit B.C. Flowering twig D. Stem E. Flower F. Leaf adaxial surface G. Leaf abaxial surface

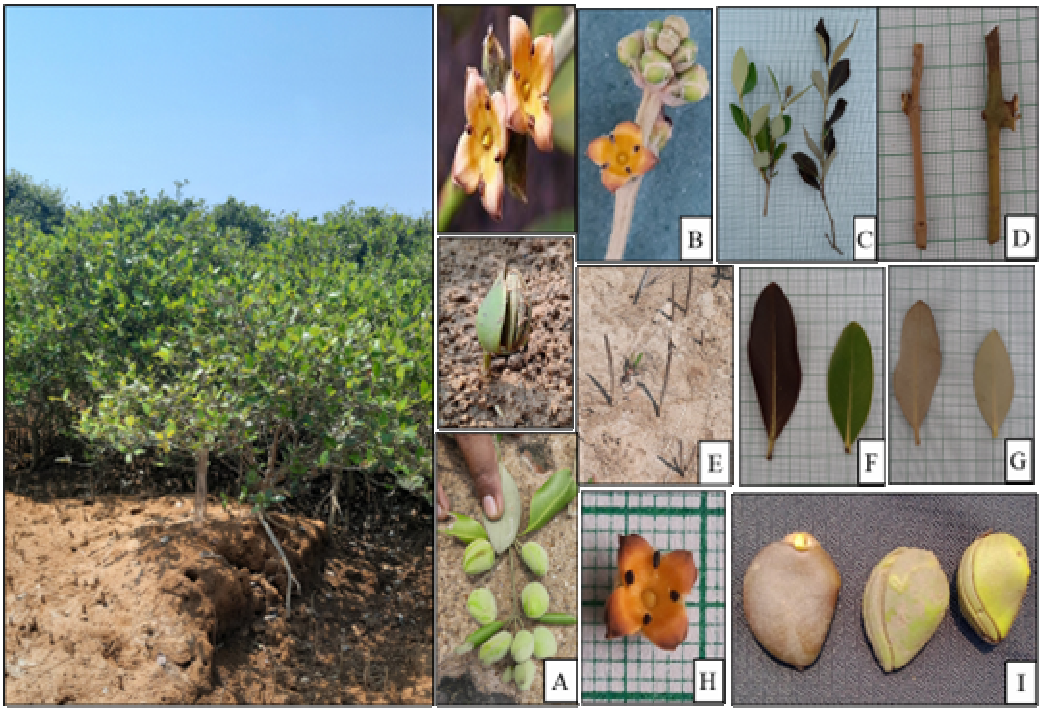

Fig. 5 : *Avicennia marina:* A. Habit B. Inflorescence C. Plant twig D. Stem E. Pneumatophores F. Leaf adaxial surface G. Leaf abaxial surface H. Flower I. Propagule

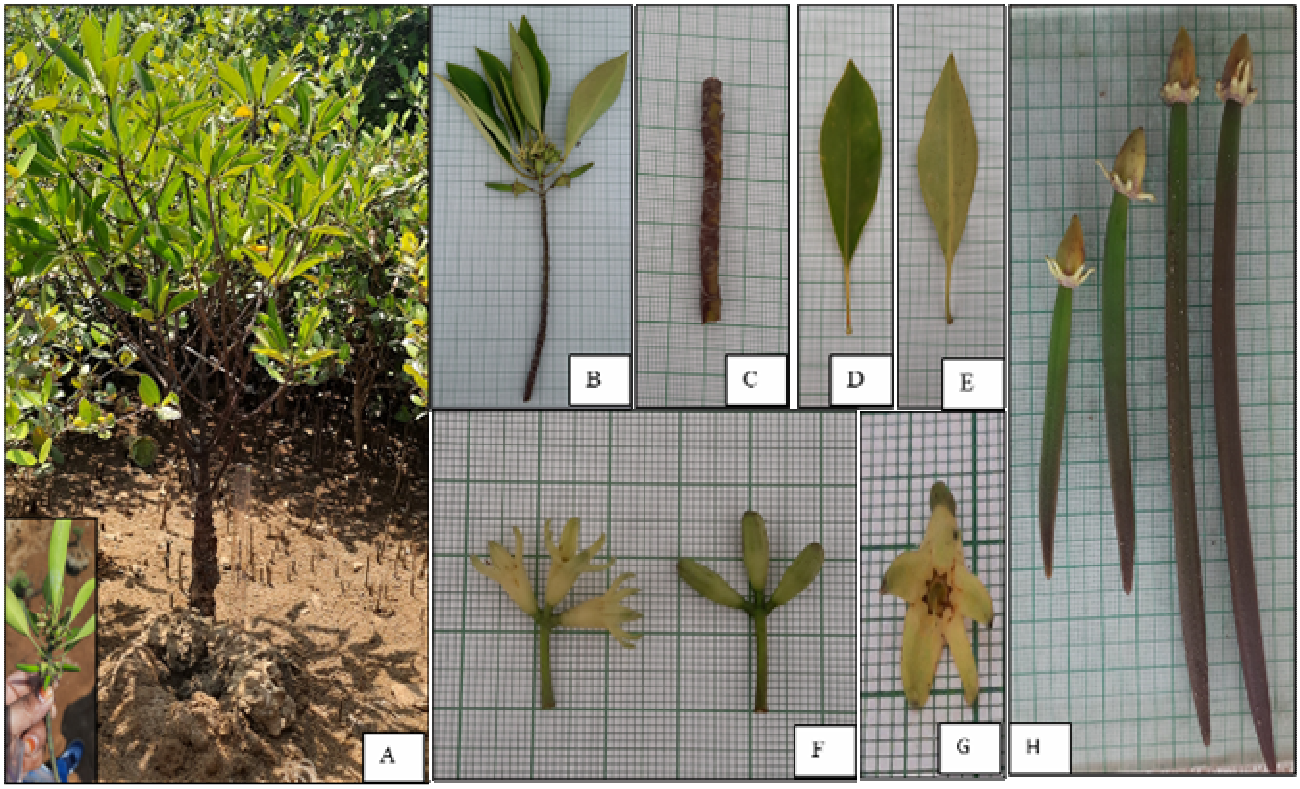

Fig. 6: *Bruguiera cylindrica:* A. Habit B. Plant twig C. Stem D. Leaf adaxial surface E. Leaf abaxial surface F. Inflorescence G. Flower H. Propagule

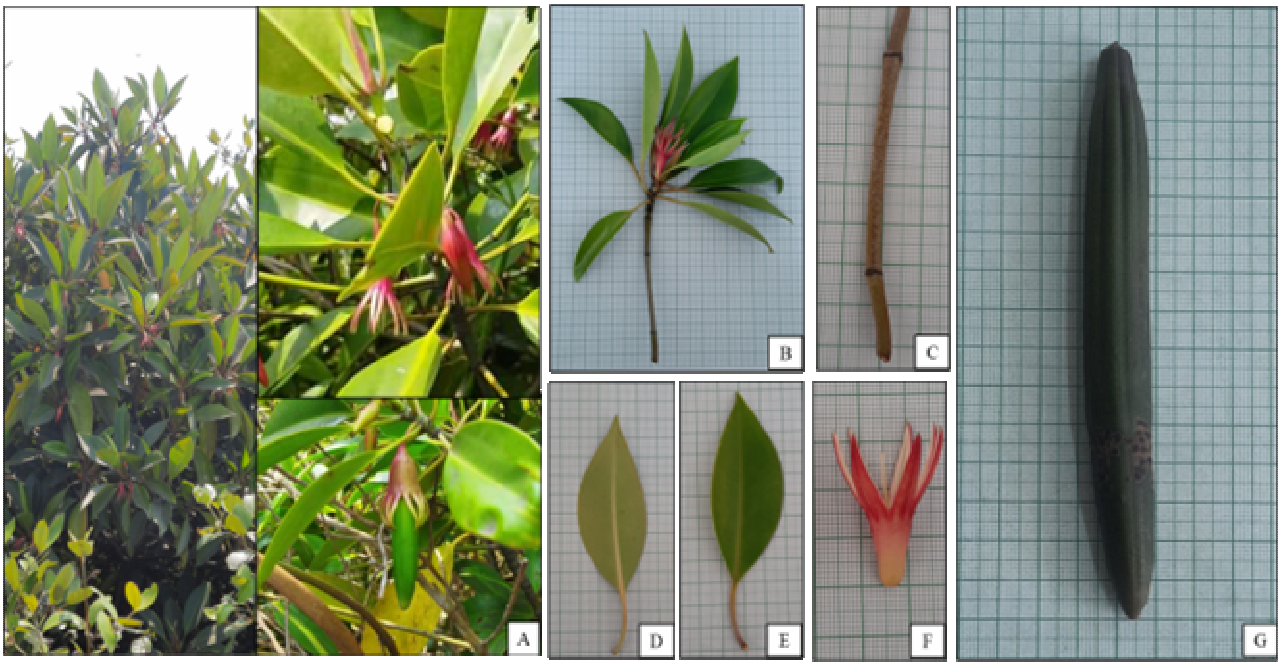

Fig. 7 *: Bruguiera gymnorhiza*: A. Habit B. Plant twig C. Stem D. Leaf adaxial surface E. leaf abaxial surface F. Flower G. Propagule

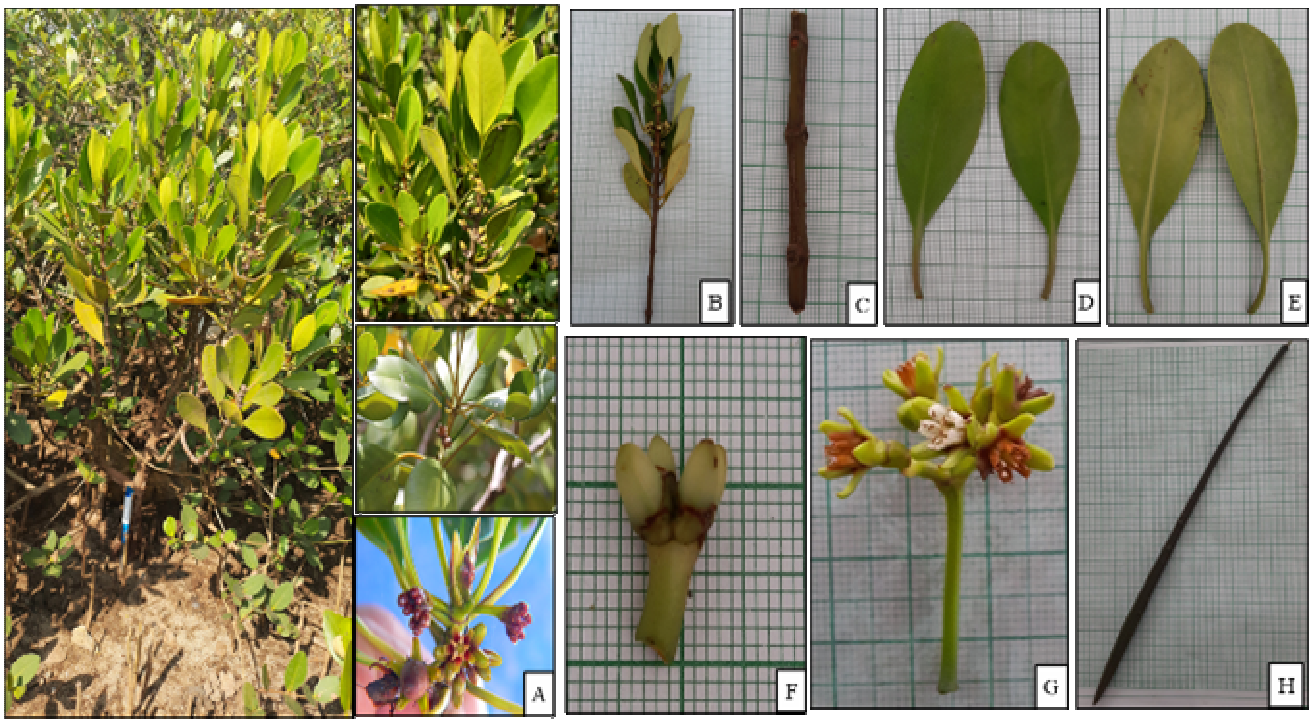

Fig. 8 : ***Ceriops decandra*****:** A. Habit B. Plant twig C. Stem D. Leaf adaxial surface E. Leaf abaxial surface G. Floral Bud G. Flower H. Propagule

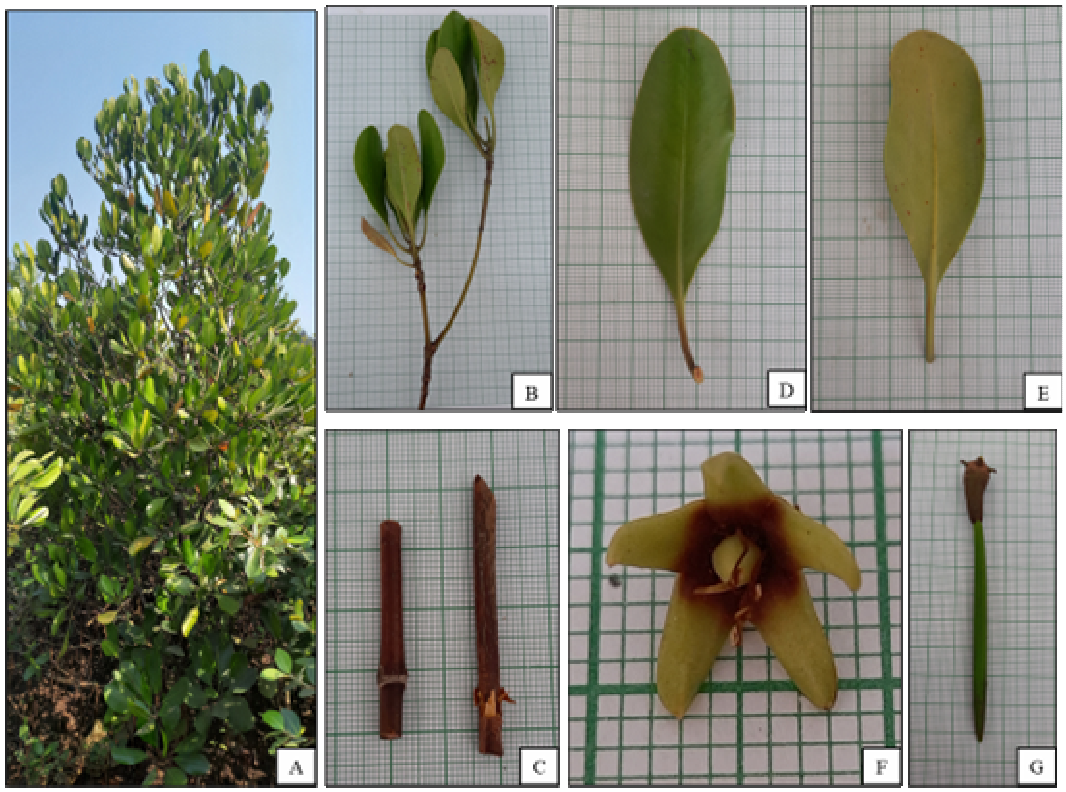

Fig. 9 : ***Ceriops tagal*****:** A. Habit B. Plant twig C. Stem D. Leaf adaxial surface E. Leaf abaxial surface F. Flower G. Propagule

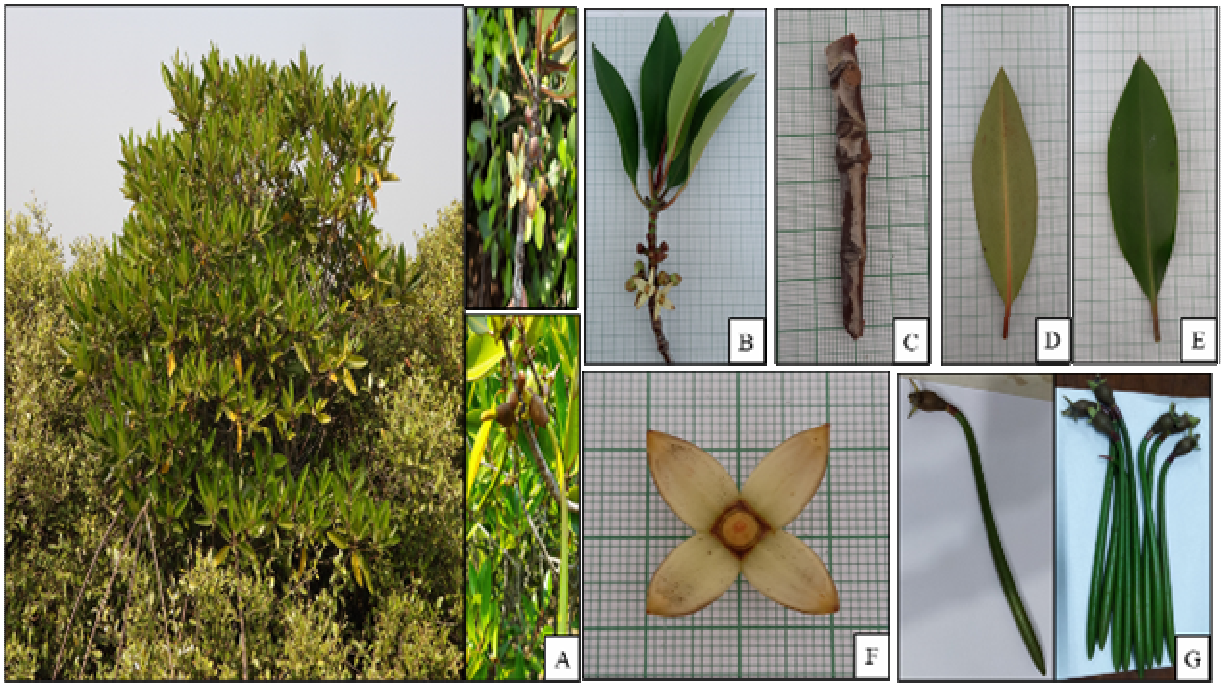

Fig. 10 : *Rhizophora apiculata*: A. Habit B. Plant twig C. Stem D. Leaf adaxial surface E. Leaf abaxial surface F. Flower G. Propagule

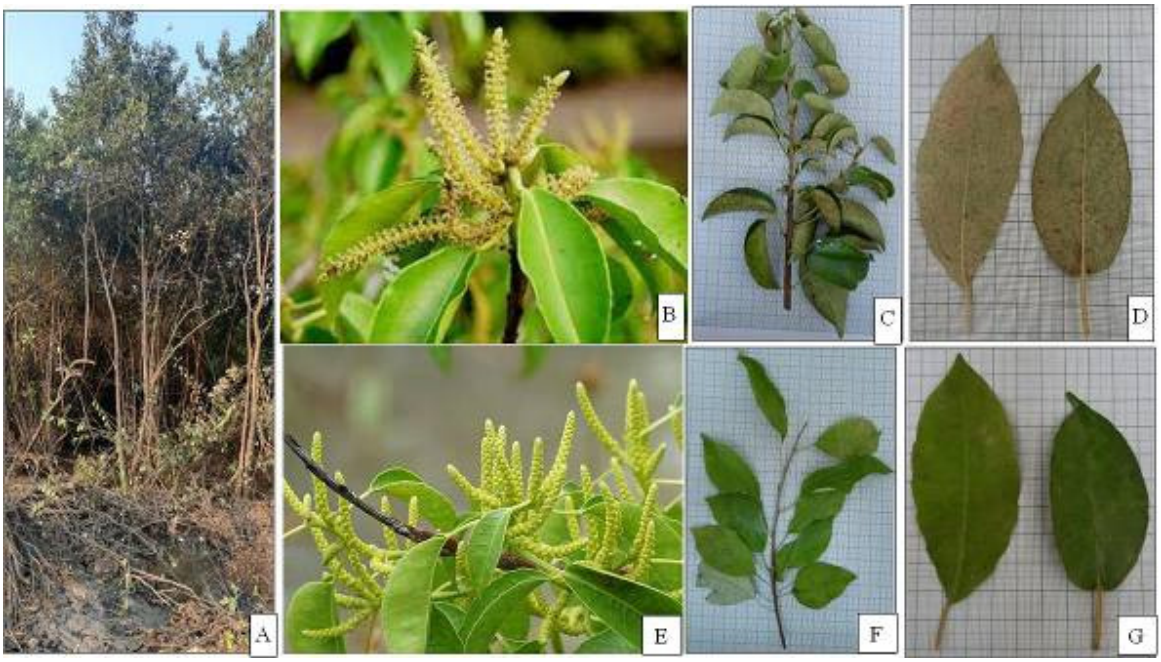

Fig. 11 : ***Excoecaria agallocha*** **A.** Habit. B &C. Male plant D. Male plant leaf E &F twig Female plant twig G. Female plant leaf

Fig. 12 : Mangrove associates from Visakhapatnam

The above-described species represent the true mangroves recorded from the intertidal zones of Visakhapatnam. In addition to these, nine mangrove associate species namely *Desmanthus virgatus*, *Fimbristylis complanata*, *Oryza coarctata*, *Passiflora foetida*, *Pentatropis capensis*, *Sesuvium portulacastrum*, *Solanum nigrum*, *Suaeda fruticosa*, and *Suaeda maritima* were also frequently observed in the study area (Figure 12). These species have been listed along with their respective families and local names, and herbarium specimens were prepared and deposited at ICFRE–Centre for Forest Conservation and Ecological Studies (CEC), Visakhapatnam for future reference and documentation.

The comparative study revealed significant morphological variation among studied species. Root adaptations included pneumatophores (*Avicennia marina*), prop roots (*Rhizophora apiculata*), and knee roots (*Bruguiera cylindrica, B.gymnorhiza*). Leaves varied in size, texture, and salt excretion patterns. Vivipary was observed in *Rhizophora* and *Bruguiera* species. A summary of morphological traits is presented in Table 4.

Table 4 : Comparative morphological features and adaptive traits of Mangrove species

Species/ Family	Leaf Shape/Texture	Root Type	Stem Features	Flower Type	Fruit Type	Adaptive Traits
A. ilicifolius/ Acanthaceae	Opposite, oblong to lanceolate, leathery with pinnatified margins	Stilt roots	Semi-woody, erect or spreading; often forms thickets	Bluish-purple, tubular, bilabiate flowers in spikes	Oblong, 4-seeded capsule	Salt excretion through salt glands of leaves; succulent tissues for water storage; spiny leaves deter herbivory

A. marina /Acanthaceae	Opposite, elliptic to oblong; thick, leathery, glossy green above, silvery beneath blackens upon maturity	Pencil-like pneumatophores (respiratory roots)	Greyish bark with lenticels; soft and corky	Small, yellowish-white, funnel-shaped flowers	Oval, single-seeded, greenish drupe	Salt excretion through leaf glands; pneumatophores for gas exchange; cryptovivipary; high salt tolerance
B. cylindrica /Rhizophoraceae	Opposite, elliptic to oblanceolate; glossy, leathery.	Knee or buttress roots	Cylindrical, grey-brown bark; lenticellate	Small, white to pale green flowers, often three flowers on one peduncle	Cylindrical viviparous propagules slightly curved at base	Viviparous seedlings; pneumatophores for respiration; salt exclusion by roots
B. gymnorhiza //Rhizophoraceae	Opposite, broadly elliptic oblong; glossy, leathery, reddish petiole	Buttress roots and knee roots	Dark brown rough bark; lenticellate; strong, woody stems	Large, red to orange solitary flower with long calyx lobes	Large, cigar-shaped viviparous propagule	Viviparous germination; salt-excluding roots; buttress roots provide anchorage
C. decandra /Rhizophoraceae	Opposite, obovate to elliptic; leathery, shiny	Stilt roots, occasionally knee roots	Grey to reddish-brown bark; thin and fissured	Small, white flowers in axillary clusters	Small, cylindrical, viviparous propagules always in upright position	Salt exclusion by roots; vivipary; stilt roots stabilize in soft mud
C.tagal/ Rhizophoraceae	Opposite, elliptic to obovate; leathery, thick	Stilt roots	Grey bark; smooth or slightly fissured	Small, white, tubular flowers	Long, slender viviparous propagules tapering position	Vivipary; salt exclusion; thick cuticle minimizes water loss
R.apiculata/	Opposite, elliptic with a distinct apical tip; leathery	Stilt roots and aerial prop roots	Brown bark; smooth with lenticels	Small, white flowers in pair of axillary clusters	Long, cylindrical viviparous propagules pointed at end	Stilt roots for support and aeration; vivipary; salt exclusion by roots
E.agallocha/ Euphorbiaceae	Alternate, elliptic to obovate; thin, glossy, exudes milky latex Leaves are longer and light green in male plants while female plants have shorter and dark green leaves	Normal underground roots (no aerial roots)	Smooth, grey bark; branches with latex	Small, greenish-yellow, unisexual flowers	3-lobed capsule, dehiscent	Deciduous in dry season; salt tolerance; latex deters herbivory; grows in less inundated zones

Earlier Swain *et al.,* 2008 recorded 10 species of mangroves viz., *Acanthus ilicifolius, Aegiceras corniculatum, Avicennia marina*, *Avicennia officinalis, Bruguiera cylindrica, Bruguiera gymnorrhiza, Ceriops decandra, Excoecaria agallocha, Rhizophora apiculata* and *Sonneratia apetala*, from Bangarammapalem (Sarada and Varaha estuarine complex), Gangavaram (Dibbapalem), Meghadrigedda, Pentakota and Pudimadaka areas of Visakhapatnam. However during present study only eight true mangrove species were documented suggesting possibly the extinction of the remaining species from the study may be due to continuously destruction of their habitat in the process of urbanization, mining activities, timber use and fishing harbour development etc.(Reddy *et al.*,2007). The findings of the study highlight the existing distribution and potential areas suitable for mangrove growth within the district, thereby emphasizing the need for detailed monitoring and conservation planning for these fragile ecosystems.

In the present study, several important observations were made regarding the mangrove vegetation of the Visakhapatnam coastal region. *Avicennia marina* was identified as the dominant mangrove tree species, exhibiting luxuriant growth and widespread distribution throughout the study area. The second most dominant species recorded was *Excoecaria agallocha*. However, there remains taxonomic ambiguity concerning the classification of *Excoecaria agallocha* and *Acanthus ilicifolius* as true

or strict mangroves, primarily due to the absence of viviparous propagules and their occasional occurrence within mangrove habitats. Furthermore, other true mangrove species such as *Bruguiera cylindrica*, *B. gymnorhiza*, *Ceriops decandra*, *C. tagal*, and *Rhizophora apiculata* were recorded only from the Pudimadaka region, where they occurred in very sparse populations and limited distribution.

Another interesting observation from the study area pertains to the reduced height of *Avicennia marina* individuals. In the present study, the species attained a height of only 3–5 meters, whereas earlier records have documented this species reaching up to 10–15 meters under favorable conditions. Remarkably, in the Pudimadaka region, some individuals were observed to be as short as one meter, yet were found in complete flowering and fruiting stages, indicating successful reproduction despite their stunted growth. This reduction in height may be attributed to adverse environmental conditions, such as high soil salinity, water stress, or anthropogenic disturbances, influencing the overall growth performance of the species.(Naidoo, 2006).

Another noteworthy observation from the present study concerns the exceptional height of *Acanthus ilicifolius*. The species was recorded attaining a height of up to 15 meters, which is a remarkable deviation from its previously reported maximum height of about 5 meters, as *A. ilicifolius* is typically characterized as a shrub or undershrub. This unusually tall growth form may be attributed to the species' adaptation for light acquisition, as the plants were found growing beneath the canopy of *Excoecaria agallocha* trees. Furthermore, the study also reports distinct morphological variations in the leaves of male and female plants of *Excoecaria agallocha*, which may serve as a useful diagnostic feature for field identification of the species.

The mangrove ecosystems of Visakhapatnam are currently under severe pressure from both anthropogenic activities and natural disturbances, including climate change, coastal storms, and developmental encroachments (Swain *et al*., 2009). The progressive decline signifies an alarming trend of habitat degradation and loss of ecological integrity. If the current rate of destruction of this critical coastal vegetation continues unchecked, it may eventually lead to the complete disappearance of mangrove ecosystems not only from Visakhapatnam but also from other vulnerable coastal regions, resulting in severe ecological and socio-environmental consequences.

Conclusion

The present study highlights the current status of mangrove vegetation and its associates in different natural mangrove habitats of Visakhapatnam district, including Pudimadaka, HPCL Colony, and the Port area. A revised identification key for the mangrove species of the region was developed. Among the recorded species, Avicennia marina, Excoecaria agallocha, and Acanthus ilicifolius were found to be dominant, while other true mangroves occurred in sparse populations. The continuous degradation of mangrove habitats is a matter of serious concern, necessitating immediate attention from the State Forest Department. Awareness among local communities regarding the ecological importance of mangroves is equally crucial. Hence, a collaborative effort involving government agencies, NGOs, and local people is imperative to restore degraded areas through effective reforestation and conservation initiatives to ensure the long-term sustainability of Visakhapatnam's mangrove ecosystem.

Identification Key for Mangrove identification

1a. Viviparous seedling present 2

1b. Viviparous seedlings absent 3

2a. Plantwithout pneumatophores 4

2b. Plant with pneumatophores, upper surface of leaves dark green turns black when, lower surface hairy and whitish green……..*Avicennia marina*

3a. Tree with milky latex, unisexual flowers present, leaves alternate .....……..*Excoecaria agallocha*

3b. Shrub without milky latex, unisexual flowers absent, leaves opposite, generally with spinate margins ……*Acanthus ilicifolius*

4a. Leaf oblong elliptic with a cute apex 5

4b. Leaf obovate with rounded apex 6

5a. Leaf apex apiculate, flower bracteate, flower in pair below each node ……*Rhizophora apiculata*

5b Leaf apex not apiculate, flower ebracteate 7

6b. Branching pattern deliquescent, Petiole and peduncle shorter flowers 4-16 ..... *Ceriops decandra*

6b. Branching pattern pyramidal, Petiole and peduncle longer, flowers 2-4. .....……. *Ceriops tagal*

7a. Flower solitary, Calyx large, orange or scarlet red, Calyx 10 14 lobed, leaf mid rib and petiole reddish…….....……*Bruguiera gymnorhiza*

7b. Flowers 3 on common peduncle, Calyx small yellowish green, leaf mid rib green ……*B. cylindrica*

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Declaration

I declare that the manuscript has not been published in any journal/book or proceedings or in any other publication, or offered for publication elsewhere in substantially the same or abbreviated form, either in print or electronically.

References

Basha, S.K.M., Indiraprydarsini A., & Johnpaul M. (2018). *Mangrove Diversity of Southern East Coast of Andhra Pradesh, India. International Journal of Engineering Research & Technology* (IJERT), **07**(07), 333-337.

Bridson, D.M., & Forman, L. (1998). *Herbarium handbook*. Royal Botanic Gardens, Kew, 334 pp.

Chaudhuri, A.B., & Choudhury, A. (1994). *Mangroves of the Sundarbans. Volume 1, India*. International Union for Conservation of Nature and Natural Resources (IUCN), 247 pp.

Duke N., Ball M., & Ellison J. (1998). Factors influencing biodiversity and distributional gradients in mangroves. *Global Ecology & Biogeography Letters*, **7**(1), 27-47.

ISFR (Indian State Forest Report), (2021). Forest Survey of India, MoEF & CC.

ISFR (Indian State Forest Report), (2023). Forest Survey of India, MoEF & CC.

Kathiresan, K. and Bingham, B.L. (2001). Biology of mangrove and mangrove ecosystems. *Advances in Marine Biol*ogy, **40**, 81-251.

Kumari, G.R., Rao P.S.N. & Subbarao, G.V. (2002). *Flora of Visakhapatnam District, Andhra Pradesh*. Vol.2, Botanical Survey of India.

Mariano, H.G. Dagoc, F.L.S. Espra, A.S. Amparado, R.F. (2019) Mangrove Diversity, Taxonomic of Classification, and Morphological Characteristics Natural Reforested Mangrove Forests in Selected Municipalities of Zamboanga Del Sur, Mindanao Island. *Journal of Biodiversity and Environmental Sciences*, **15**, 86–99.

Nabeelah Bibi, S., Fawzi, M. M., Gokhan, Z., Rajesh, J., Nadeem, N., Kannan R.R R. Albuquerque R.D.D.G. and & Pandian, K.S.S.K. (2019). Ethnopharmacology, phytochemistry, and global distribution of mangroves A comprehensive review. *Marine drugs*, **17**(4), 1-82.

Naidoo, G. (2006). Factors contributing to dwarfing in the mangrove *Avicennia marina*. *Annals of botany*, **97**(6), 1095-1101.

Narasimha Rao, G.M. and Dora, S.S.N. (2009). An Experimental Approach to Mangroves of Godavari Estuary. *Indian Journal of Forestry,* **32**(3), 431-432.

Patel, R. & Srinivas, T. (2024). Conservation and Restoration of Mangroves in Visakhapatnam Coastal Lands Using the Encased Methodology. *Journal of the Indian Society of Coastal Agricultural Research*, **41**(2), 134-139.

Ragavan, P., Kathiresan, K., Rana, T.S., Saxena, A., Mohan, P.M., Jayaraj, R.S.C. Ravichandran, K. & Mageswaran, T. (2021). *Indian mangroves- A photographic field identification guide*, New India Publishing Agency, New Delhi.

Ragavan, P., Saxena, A., Jayaraj, R.S.C., Mohan, P.M., Ravichandran, K., Saravanan, S., & Vijayaraghavan, A. (2016). A review of the mangrove floristics of India. *Taiwania*, **61**(3), 224-242.

Rao, G.S. (1977). Flora of Visakhapatnam District, Andhra Pradesh. *Nelumbo-The Bulletin of the Botanical Survey of India*, 122-126.

Reddy, C.S. (2008). *Field identification guide for Indian mangroves* (Vol. 1). Dehradun, Bishen Singh Mahendra Pal Singh.

Reddy, C.S., Pattanaik C., & Murthy M.S.R. (2007). Assessment and monitoring of mangroves of Bhitarkanika Wildlife Sanctuary, Orissa, India using remote sensing and GIS. *Current Science*, 1409-1415.

Roy, S.D., Krishnan, P., George, G., & Kaliyamoorthy, M. (2009). *Mangroves of Andaman Nicobar Islands*. C.A.R.I. (ICAR), Port Blair.

Sarno, S., Suwignyo R.A., Dahlan Z., Munandar M., & Ridho M.R. (2015). Primary mangrove forest structure and biodiversity. *International Journal of Agriculture System*, **3**(2), 135-141.

Smith, C.E. (1971). *Preparing herbarium specimens of vascular plants* (No.348). Agricultural Research Service, US Department of Agriculture.

Standish, H. (2009). Mangrove Morphological Change Across an Environmental gradients. STA, **152**(23.91), 5-52.

Swain, P.K., Rao N.R. & Mohan S. (2008). New mangrove habitats and additions to the flora of Srikakulam district, Andhra Pradesh, India. *Indian Journal of Forestry*, **31**(3), 431-434.

Swain, P., Rama, Rao N., & Pattanaik, C. (2009). Mangrove forest cover of Visakhapatnam coast is under threat. *Current science*, **97**(8), 1112-1113.

Tomlinson P.B. (2016). The Botany of Mangroves. 2. Cambridge University Press, 436 pp.

Tomlinson, P.B. (1986). *The Botany of Mangroves*. Cambridge University Press, Cambridge, 413pp.

Venkanna, P., Raju, B., &Rao, G.N. (1989). Mangrove and associated Flora of Visakhapatnam. *Geobios New Reports*, **8**(2), 157-158.