

Diversity and zonation of mangrove flora in Belitung Island, Indonesia

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Abstract. Irawan A, Chikmawati T, Sulistijorini. 2021. Diversity and zonation of mangrove flora in Belitung Island, Indonesia. *Biodiversitas* 22: 2981-2992. Mangrove is an important ecosystem located in the coastal tidal zone in tropical and sub-tropical regions. This ecosystem is characterized by the presence of plant species that can survive in brackish and inundated zone of seawater. There are many mangrove forests in Belitung Island, Indonesia, but the data of mangrove flora diversity and zonation in this island have not been described. This study aims to reveal the diversity and analyze the zonation of mangrove flora in Belitung Island. This research was conducted using a cruising method to explore the diversity of mangrove flora species and a line transect to analyze the zonation of mangrove flora. The exploration locations for diversity of mangrove flora were Kuale Tambak Beach, Asam Beach, Belitung Mangrove Park Area, Manggar River, Sentigi Beach, Sabong Beach and Kembiri Beach. Mangrove flora zonation was observed in Asam Beach (north), Kembiri Beach (south) and Kuale Tambak Beach (east). The result showed that mangrove flora in Belitung Island consisted of 12 families, 16 genera and 24 species. Species found were dominated by 8 species from the Rhizophoraceae family with the largest number of species were from the genera of *Bruguiera* and *Rhizophora*. The species of *Bruguiera* included *Bruguiera gymnorrhiza*, *Bruguiera sexangula*, *Bruguiera cylindrica* and *Bruguiera parviflora*. Meanwhile, the *Rhizophora* species that have been found were *Rhizophora apiculata*, *Rhizophora mucronata* and *Rhizophora stylosa*. The Kembiri beach had the highest number of species of mangrove flora with 18 species. The zonation of mangrove flora at each research location showed a different zonation pattern. The mangrove vegetation on Kuale Tambak Beach was behind the *Casuarina equisetifolia* vegetation, while the mangrove vegetation on the Asam and Kembiri Beaches directly faced the sea. The difference in zonation patterns is likely caused by local topography on Belitung Island, substrate conditions and salinity factors on the mangroves of Belitung Island.

Keywords: Belitung, diversity, flora, mangrove, zonation

INTRODUCTION

Mangroves are important ecosystems in the world that grow in tropical and subtropical regions. The world's mangrove ecosystem was estimated at about 15.2 million hectares in 2005 (FAO 2007). Mangrove forests are only found in a few countries in the world in which Indonesia, Australia, Brazil, Nigeria and Mexico alone contribute to 48% of the world's mangrove area (FAO 2007). Indonesia has 2.5 million hectares of mangroves area or equal to 19% of the global mangroves, making Indonesia as the country with the largest mangrove ecosystems (FAO 2007; Giesen et al. 2007).

Mangrove flora has different characteristics from most terrestrial plants. The root system of mangrove plants is adapted to grow on mangrove ecosystem, which is periodically inundated by brackish water. Some types of roots are anchor roots, pencil roots, knee roots or buttress roots (Krauss et al. 2014; Hendy and Cragg 2017; Martinez and Buot Jr. 2018). In addition, the types of fruit in mangrove plants are vivipary, crypto-vivipary or non-vivipary (Karyamsetty 2017).

The dominant flora found in mangrove forests is the family of Rhizophoraceae. The genera of Rhizophoraceae include *Rhizophora*, *Bruguiera*, *Ceriops* and *Kandelia*. Apart from the Rhizophoraceae, there is also the family of

Acanthaceae, Apocynaceae, Arecaceae, Combretaceae, Euphorbiaceae, Lythraceae, Meliaceae, Myrtaceae, Primulaceae and Rubiaceae (Noor et al. 2012). In addition, there is also a naturally hybridized mangrove species, *Bruguiera x dungarra* which is a hybridization of *Bruguiera exaristata* and *Bruguiera gymnorrhiza*, which is found in Northeast Australia (Duke and Kudo 2018).

The species of mangrove tends to form zonation pattern in which each zone from the seashore to the inland has different mangrove species (Tomlinson 1994). This zonation is formed due to the ability of the mangrove flora to grow on a specific type of substrate. These mangrove species grow specifically on the type of mud, sand, or rocky mud substrate, as well as their sensitivity to salinity and tides (Bunt and Williams 1981). Different water salinity and soil type in each zone will form the distribution pattern of mangrove plants (Islam et al. 2019). For example, *Sonneratia* prefers sandy and inundated substrates (Chen et al. 2013), while *Avicennia* is more tolerant to a wide salinity range (Basyuni et al. 2012; Martinez and Buot Jr 2018), and *Rhizophora* prefers muddy and inundated substrates (Hoppe-Speer et al. 2011).

Besides the differences in species across zones, the floristic composition of mangrove species also varies in different locations. For example, in the Mai Po, Hong Kong mangrove vegetation is dominated by *Kandelia obovata*,

Avicennia marina and *Acanthus ilicifolius* (Liu et al. 2018). The mangrove forest in Cengkong Beach, East Java is dominated by *Sonneratia alba*, *Rhizophora mucronata*, *Bruguiera gymnorhiza* and *Ceriops tagal* (Mughofar et al. 2018). Mangrove vegetation in Metinaro, Timor Leste is dominated by *Rhizophora apiculata* (Costa et al. 2019). The species of mangroves found in Tanjung Panjang Nature Reserve, Gorontalo are *Ceriops tagal*, *Rhizophora mucronata* and *Rhizophora stylosa* (Baderan et al. 2018). Mangrove ecosystem in Tanamon Beach, North Sulawesi is dominated by *Sonneratia alba*, *Avicennia marina* and *Xylocarpus granatum* (Yuningsih et al. 2013). The composition and stands of mangroves in Alas Purwo National Park are dominated by *Bruguiera cylindrica*, *Rhizophora mucronata*, *Avicennia officinalis* and *Xylocarpus moluccensis* (Heriyanto and Subiandono 2012). The mangrove area on the coast of Sebatik Island, East Kalimantan is dominated by *Sonneratia alba*, *Rhizophora apiculata*, *Avicennia alba* and *Rhizophora mucronata* (Ardiansyah et al. 2012).

Several studies of mangrove flora have been carried out in the Province of Bangka-Belitung Islands, Indonesia. Research on the potential and composition of mangroves flora in the Nasik Strait, Belitung District obtained eight species of mangrove flora (Firmansyah et al. 2013). The diversity and distribution of mangroves in the small islands of Manggar Sub-district, East Belitung District are reported to be nine species of mangrove flora (Ridho et al. 2015). A study of mangrove distribution in Pongok Island, South Bangka shows that mangrove vegetation in the area is dominated by *Rhizophora*, *Avicennia*, *Sonneratia* and *Bruguiera* (Umroh et al. 2016). The mangrove vegetation in Sebongkok Island, East Belitung consists of seven species and dominated by *Rhizophora* spp. (Akhrianti 2016). In the northern adjacent islands of Tambelan and Serasan, *Bruguiera gymnorhiza* and *Rhizophora stylosa* are the dominant species (Ulumuddin and Setyawan 2017).

While several studies on mangroves have been conducted in Bangka-Belitung Islands, the mangrove flora in Belitung Island has not been studied taxonomically and ecologically. This study aims to describe the diversity and analyze the zonation of mangrove flora species in Belitung Island by taxonomical and ecological studies. Several locations of mangrove forests in Belitung Island will be proposed as conservation areas. The data of the species of mangrove flora in this study can be used to improve the conservation status of the location. The mangrove data can also be used as a database of mangrove flora diversity for development of flora conservation in Belitung Island, the Province of Bangka-Belitung Islands.

MATERIALS AND METHODS

Study period and area

Field exploration was carried out from October 2019 to November 2019 in several mangrove forest locations in Belitung Island, the Province of Bangka-Belitung Island, Indonesia (Figure 1). The identification of mangrove flora species and data analysis was carried out from November 2019 to March 2020 at the Plant Resources and Ecology Laboratory of the Department of Biology, Mathematics and Natural Science Faculty, IPB University, Bogor, Indonesia.

The exploration locations for mangrove flora in Belitung Island were Kuale Tambak Beach (Sukamandi, Damar Sub-district), Asam Beach (Aik Kelik, Damar Sub-district), Belitung Mangrove Park Area (Juru Seberang, Tanjung Pandan Sub-district), Manggar River (Mekar Jaya, Manggar Sub-district), Sentigi Beach (Dukong, Simpang Pesak Sub-district), Sabong Beach (Tanjung Rusa, Membalong Sub-district) and Kembiri Beach (Kembiri, Membalong Sub-district). The detailed information of each sampling location is presented in Table 1.

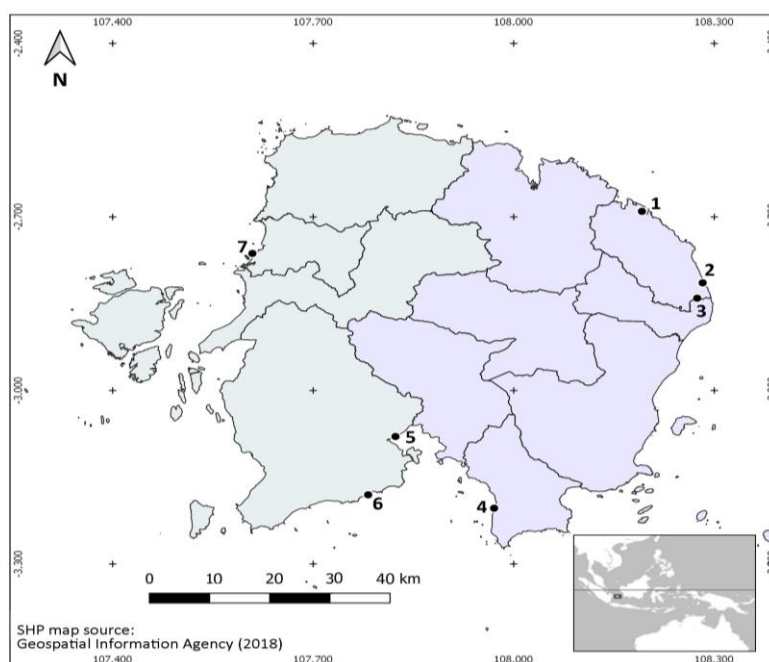


Figure 1. Map of sampling location points in Belitung Island, Indonesia (showed by dot and number 1-7)

Table 1. The coordinate location of research sampling in Belitung Island, Indonesia

Sampling location	Sub-district	Conditions	Coordinate position	
			Latitude (S)	Longitude (E)
Asam beach	Damar	Primary forest, natural tourism and fishing activity	2°41'25.40"	108°11'30.43"
Kuale Tambak beach	Damar	Natural tourism and fishing activity	2°48'49.86"	108°16'57.44"
Manggar river	Manggar	River near mines and settlements	2°50'25.71"	108°16'28.02"
Sentigi beach	Simpang Pesak	Natural tourism	3°12'12.76"	107°58'14.54"
Sabong beach	Membalong	Primary forest	3°10'49.32"	107°46'56.10"
Kembiri beach	Membalong	Primary forest	3° 4'46.45"	107°49'23.27"
<i>Belitung Mangrove Park</i>	Tanjung Pandan	Restoration forest and natural tourism	2°45'47.14"	107°36'32.78"

Data collection procedure

Assessment of mangrove diversity

We conducted the cruising method to collect field data and herbarium samples to determine the diversity of mangrove flora (Rugayah et al. 2004). Exploration paths in each mangrove forest include the edge of the mangrove forest adjacent to the open sea, the middle part of the mangrove forest and part of the border between the mangrove forest and the mainland forest. The cruising line schematic is shown in Figure 2.A. Each individual mangrove plant was taken several twigs consisting of leaves, flowers and fruit to make herbarium specimens. Some characteristics recorded in the field include: root type, flower color and the other part that allow discoloration when it was made into a herbarium.

Assessment of mangrove zones

We used the line transect method to study the zonation of mangrove plants (Phillips 1959). Mangrove species zonation was observed in Asam Beach (north), Kembiri Beach (south) and Kuale Tambak Beach (east). Transect establishment was carried out perpendicularly to the shore strandline (Figure 2.B). The length of the transect corresponds to the area of the mangrove forest. Transects on Asam Beach about 200 meters, Kembiri Beach about 150-300 meters, and Kuale Tambak Beach about 50-65 meters. The distance between the transects is about 150-500 meters. Mangrove flora zonation was observed along these transects. Environmental variable data were measured

at each research station (Figure 2.B). The measurement site consists of 3 stations of each beach, namely: station 1, the station closest to the sea (front mangrove); station 2, the station in the middle of the mangrove; and station 3, the farthest station from the sea (back mangrove). Soil samples were taken from each different substrate condition to analyze the substrate type. The measured abiotic data are salinity, water pH, water temperature, air humidity, air temperature, wind velocity and light intensity.

Species identification

Identification of mangrove flora used Giesen et al. (2007) and Noor et al. (2012). Whereas, the identity of mangrove specimens collected from field were then confirmed with Herbarium Bogoriense (BO) specimens.

Data analysis

Diversity index values were calculated using the Shannon-Wiener diversity index (Magurran 1988). The percentage abundance of species was calculated by comparing the number of individuals of one species to the total number of individuals of all species.

The zonation of mangrove flora was described based on the species finding on each research transect. Analysis of the interaction of mangrove species with abiotic factors was done using Canonical Correspondence Analysis (CCA) with Monte Carlo permutation test in the software program Canoco for Windows 4.5.

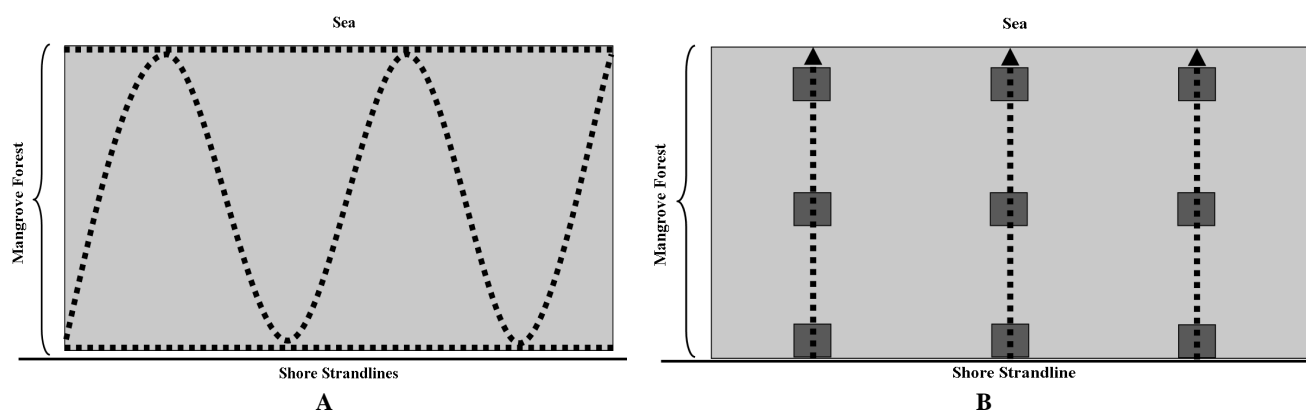


Figure 2. The methods of data collection applied in this study in Belitung Island, Indonesia: A. The cruising line scheme is shown as dotted line for diversity data collection; B. Line transect (dashed line) for zonation data collection and environmental data plot (square symbol)

RESULTS AND DISCUSSION

Diversity of mangrove flora

The mangrove flora found in Belitung Island consisted of 12 families, 16 genera and 24 species. These species of mangrove flora were obtained from several locations in Belitung Island (Table 2). The largest family dominating the mangrove flora was Rhizophoraceae consisted of eight species. The genera with the most species are *Bruguiera* and *Rhizophora*.

The largest number of species of mangrove flora were found in Kembiri Beach consisted of 18 species. The diversity index value at this research station was 2.7 while that in the eastern region of Belitung Island (Kuale Tambak Beach) was 2.61 and on Asam Beach was 2.53. The values of the Shannon Wiener diversity index at all research stations were greater than 1 but less than 3 ($1 < H' < 3$). The index value indicates that all research stations had a moderate category of diversity (Wilhm and Dorris 1968).

The species of mangrove flora with the highest to the lowest percentage of species abundance are presented in Figure 3. The mangrove flora species with the highest abundance percentage were *Rhizophora apiculata*, *Rhizophora mucronata* and *Bruguiera gymnorhiza* (Figure 4). The three species with the highest percentage of abundance are the members of the Rhizophoraceae, the

largest plant family in the mangrove ecosystem. The abundance percentage of *Rhizophora apiculata* was 14.44%, *Rhizophora mucronata* was 11.24% and *Bruguiera gymnorhiza* was 8.59%. *Rhizophora apiculata* was found with the highest number of individuals at each research station. The species of mangrove flora with the lowest percentage of species abundance was *Finlaysonia obovata*. This climbing mangrove species was only found in Kembiri Beach as many as 2 individuals. Its abundance value was 0.18%. Other species of mangrove flora with low abundance that were only found at one research station were *Aegiceras corniculatum* (0.46%) and *Bruguiera parviflora* (0.73%) in Kembiri Beach and *Avicennia marina* (0.91%) in Belitung Mangrove Park.

The associate mangrove species were found in several mangrove ecosystems in rare stands in some areas including Sabong Beach, Kembiri Beach and Belitung Mangrove Park. There were four associate mangrove species found in Sabong Beach, namely *Scaevola taccada*, *Planchonella obovata*, *Hibiscus tiliaceus* and *Cycas rumphii*. Five associate mangrove species found in Kembiri Beach were *Cerbera manghas*, *Intsia bijuga*, *Planchonella obovata*, *Cerbera odollam* and *Hibiscus tiliaceus*. Several species of associate mangroves in the Belitung Mangrove Park consisted of *Scaevola taccada*, *Hibiscus tiliaceus*, *Terminalia catappa* and *Pandanus tectorius*.

Table 2. List of mangrove flora species in Belitung Island, Indonesia

Family	Species	Site						
		PKT	PA	BMP	SM	PSt	PSb	PK
Acanthaceae	<i>Acanthus ilicifolius</i>				+		+	+
Acanthaceae	<i>Avicennia alba</i>	+	+	+	+			
Acanthaceae	<i>Avicennia marina</i>			+				
Apocynaceae	<i>Finlaysonia obovata</i>							+
Arecaceae	<i>Nypa fruticans</i>	+	+	+	+		+	+
Combretaceae	<i>Lumnitzera littorea</i>	+	+	+			+	+
Combretaceae	<i>Lumnitzera racemosa</i>	+			+	+	+	
Euphorbiaceae	<i>Excoecaria agallocha</i>	+	+	+	+	+	+	+
Lythraceae	<i>Pemphis acidula</i>	+	+	+	+	+		
Lythraceae	<i>Sonneratia alba</i>	+	+	+	+			+
Malvaceae	<i>Heritiera littoralis</i>		+		+		+	+
Meliaceae	<i>Xylocarpus granatum</i>	+	+				+	+
Primulaceae	<i>Aegiceras corniculatum</i>							+
Pteridaceae	<i>Acrostichum aureum</i>	+		+	+	+		+
Pteridaceae	<i>Acrostichum speciosum</i>	+	+		+	+	+	+
Rhizophoraceae	<i>Bruguiera cylindrica</i>	+	+	+	+			
Rhizophoraceae	<i>Bruguiera gymnorhiza</i>	+	+	+	+	+	+	+
Rhizophoraceae	<i>Bruguiera parviflora</i>							+
Rhizophoraceae	<i>Bruguiera sexangula</i>					+		+
Rhizophoraceae	<i>Ceriops tagal</i>		+					+
Rhizophoraceae	<i>Rhizophora apiculata</i>	+	+	+	+	+	+	+
Rhizophoraceae	<i>Rhizophora mucronata</i>	+	+	+	+	+	+	+
Rhizophoraceae	<i>Rhizophora stylosa</i>	+	+	+				
Rubiaceae	<i>Scyphiphora hydrophyllacea</i>	+	+	+	+	+	+	+
Total (species)		17	16	14	15	10	11	18
Shannon-Wiener index (H')		2.61	2.53	2.49	2.51	2.19	2.4	2.7

Notes: PKT. Kuale Tambak Beach; PA. Asam Beach; BMP. Belitung Mangrove Park; SM. Manggar River; PSt. Sentigi Beach; PSb. Sabong Beach; PK. Kembiri Beach; (+): present

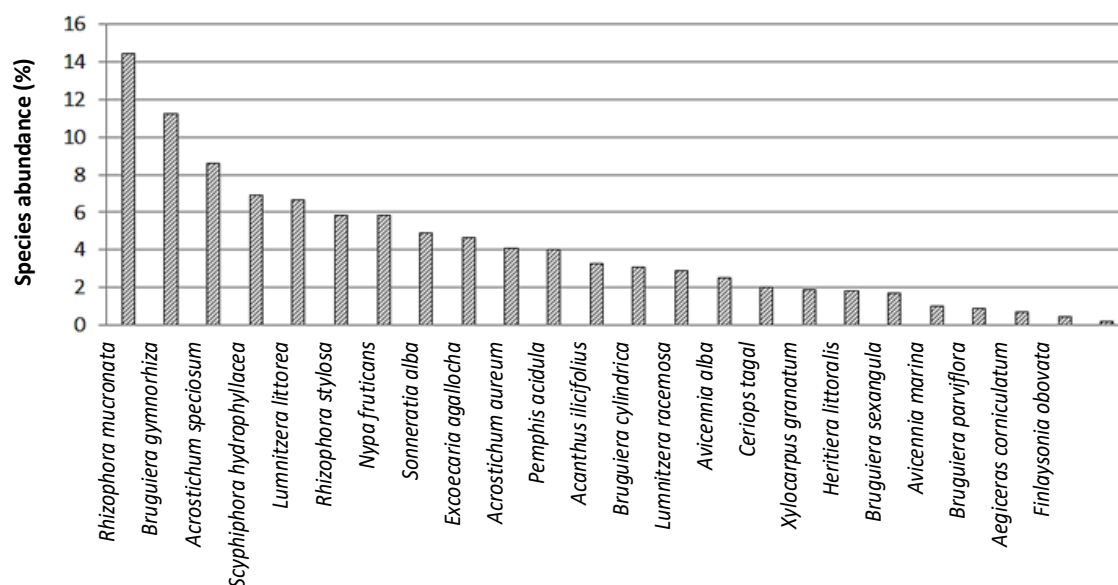


Figure 3. Species abundance percentage of mangrove flora

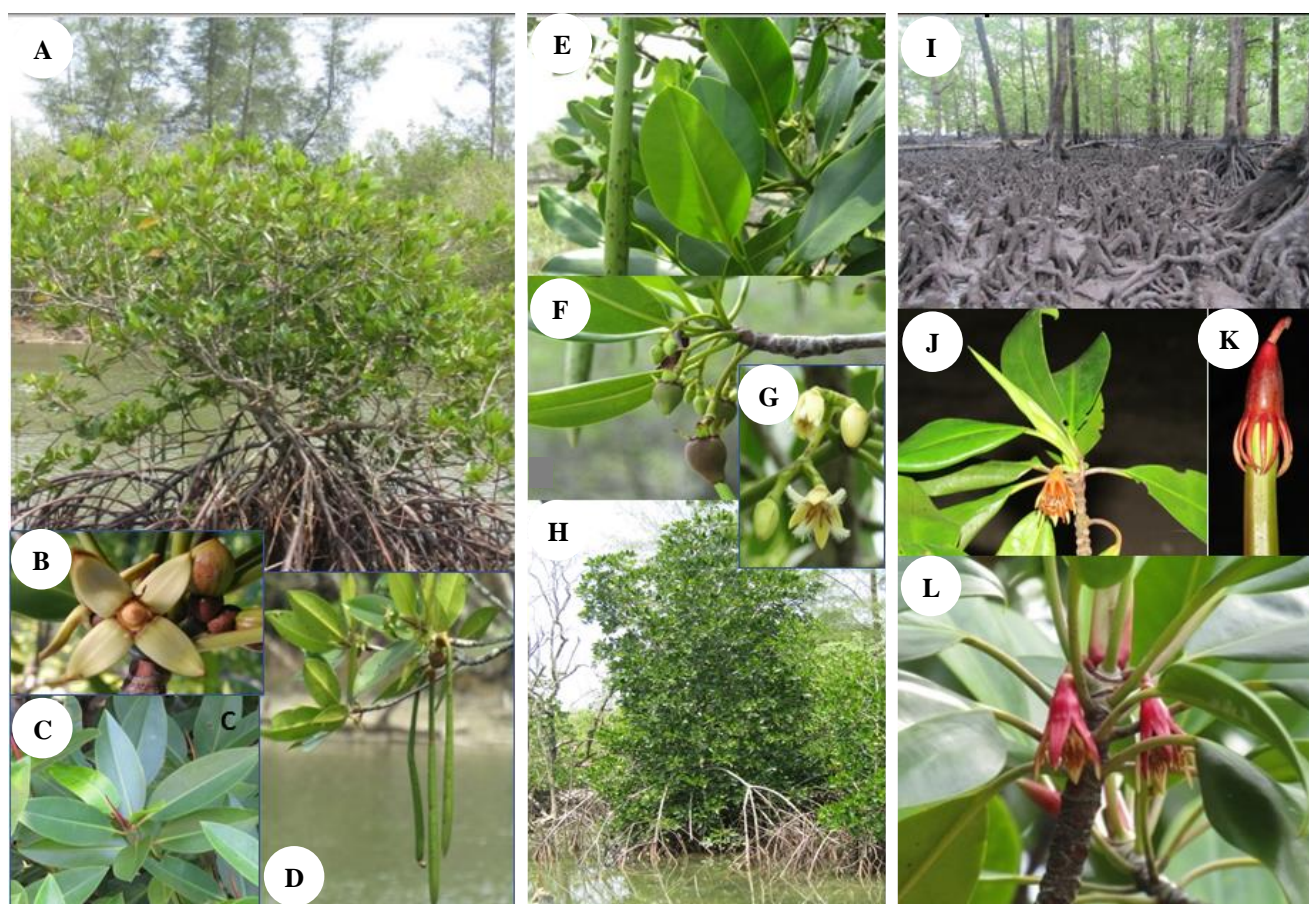


Figure 4. The mangrove species with the highest abundances found in all research sites in Belitung Island, Indonesia. A-D. *Rhizophora apiculata*, E-H. *Rhizophora mucronata*, I-L. *Bruguiera gymnorhiza*

We provide an identification key and diagnostic description of mangrove flora in Belitung Island as described below.

The identification key for mangrove flora in Belitung Island

1. a. Leaves simple 2
b. Leaves compound 21
2. a. White latex present 3
b. White latex absent 4
3. a. Trees; leaves alternate, apex acuminate; flower unisexual *Excoecaria agallocha*
b. Lianas; leaves opposite, apex rounded; flower bisexual *Finlaysonia obovata*
4. a. Stipules present 5
b. Stipules absent 14
5. a. Stipules persistent *Scyphiphora hydrophyllacea*
b. Stipules caducous 6
6. a. Inflorescences paniculate; flowers unisexual
..... *Heritiera littoralis*
b. Inflorescences solitary or cyme; flowers bisexual 7
7. a. Root systems knee root 8
b. Root systems stilt root 12
8. a. Leaf apex obtuse; sepals 5; petals 5 *Ceriops tagal*
b. Leaf apex acuminate; sepals 6-14; petals 6-14 9
9. a. Flower compound; sepals 6-8; petals 6-8 10
b. Flower solitary; sepals 10-14, petals 10-14 11
10. a. Calyx lobes 1-2 cm long, reflexed
..... *Bruguiera cylindrica*
b. Calyx lobes 0.2-0.5 cm long, erect
..... *Bruguiera parviflora*
11. a. Calyx red; petal bristles present
..... *Bruguiera gymnorhiza*
b. Calyx yellowish; petal bristles absent
..... *Bruguiera sexangula*
12. a. Inflorescences 1-2 flowered; petals glabrous
..... *Rhizophora apiculata*
b. Inflorescences 3 or more flowers; petals hairy 13
13. a. Bark brownish, bark fragments square; leaf blade 7-9 cm long; inflorescences 3-4 flowered
..... *Rhizophora mucronata*
b. Bark blackish, bark fragments irregularly; leaf blade 4-6 cm long; inflorescences 6-8 flowered
..... *Rhizophora stylosa*
14. a. Pneumatophore pencil roots present 15
b. Pneumatophore pencil roots absent 17
15. a. Leaf apex acuminate; sepals 4; petals 4, yellow 16
b. Leaf apex rounded; sepals 6-8; petals 6-8, white
..... *Sonneratia alba*
16. a. Inflorescences spike, flowers attached along the inflorescence stalk *Avicennia alba*
b. Inflorescences cyme, flowers clustered at the ends of the inflorescences *Avicennia marina*
17. a. Shrub; leaf margin spinose *Acanthus ilicifolius*
b. Tree; leaf margin entire 18
18. a. Flower solitary; sepals 6; petals 6 ... *Pemphis acidula*
b. Flower compound; sepals 5; petals 5 19
19. a. Leaves alternate; inflorescences umbellate
..... *Aegiceras corniculatum*
b. Leaves spiral; inflorescences racemose or spike 20

20. a. Leaves oblanceolate; inflorescences racemose, terminal; petals red; stamens red; pistil red ... *Lumnitzera littorea*
b. Leaves obovate; inflorescences spike, axillary; petals white; stamens white; pistil white
..... *Lumnitzera racemosa*
21. a. Young leaves curled up; reproduction with spore .. 22
b. Young leaves not curled up; reproduction with flower 23
22. a. Leaflet apex cuspidate *Acrostichum aureum*
b. Leaflet apex acute *Acrostichum speciosum*
23. a. Leaves rosette; leaflets 50-100; apex acute
..... *Nypa fruticans*
b. Leaves spiral; leaflet 2-6; apex obtuse
..... *Xylocarpus granatum*

Species diagnostic description

Acanthus ilicifolius L., Sp. Pl. 639 (1753)

Shrub, up to 2 m tall. Pencil root pneumatophore absent. Stem erect, white latex absent. Stipules absent. Leaves simple, opposite, lanceolate, apex acuminate, margin spinose. Inflorescences racemose, terminal. Flower bisexual; sepals 4, green; petals 4, sympetalous, base white, mid to apex bluish. Fruits simple, capsular

Acrostichum aureum L., Sp. Pl. 2:1069 (1753)

Fern, up to 3 m tall. Leaves compound, pinnate; young leaves curled up; leaflet alternate, lanceolate; apex sterile leaflets cuspidate; apex fertile leaflet cuspidate, sporangium covers the abaxial surface when it matures.

Acrostichum speciosum Willd., Sp. Pl. 5(1-2):117 (1810)

Fern, up to 2 m tall. Stem forming rhizomes. Leaves compound, pinnate; young leaves curled up; leaflet alternate, lanceolate; apex sterile leaflet acute; apex fertile leaflet acute, sporangium covers the abaxial surface when it matures.

Aegiceras corniculatum (L.) Blanco, Fl. Filip. 79 (1837)

Small tree, up to 8 m tall. Pencil root pneumatophores absent. Stem erect, white latex absent; bark brownish; young stem reddish. Stipules absent. Leaves simple, alternate, obovate, apex rounded, margin entire, adaxial green glossy, abaxial pale. Inflorescences compound, umbellate, terminal. Flower bisexual; calyx green, contorted; sepals 5; corolla white; petal 5; stamens 5, white; pistil solitary, white. Fruits simple, crypto-viviparous, hypocotyl grows towards the fruit stalk.

Avicennia alba Blume, Bijdr. 821 (1826)

Tree, up to 25 m tall. Pencil root pneumatophores present. Stem erect, white latex absent; bark grayish, not flaky. Stipules absent. Leaves simple, opposite, lanceolate, apex acuminate, adaxial green glossy, abaxial whitish. Inflorescences spike; flower units attached along the stalk. Flower bisexual; calyx green; sepals 4; corolla yellow-orange; petals 4; stamens 4, yellow; pistil solitary. Fruits simple, green-yellowish, viviparous, cone shapes.

Avicennia marina (Forssk.) Vierh., Wien. Math.-Naturwiss. Kl. 71:435 (1907)

Tree, up to 8 m tall. Pencil root pneumatophores present. Stem erect, white latex absent; bark grayish, not flaky. Stipules absent. Leaves simple, opposite, elliptical, apex acuminate, adaxial green glossy, abaxial whitish. Inflorescences cyme; flowers clustered at the end of the stalk. Flower bisexual; calyx green; sepals 4; corolla yellow-orange; petals 4; stamens 4, yellow; pistil solitary. Fruits simple, green-yellowish, viviparous, cone to round shape.

Bruguiera cylindrica (L.) Blume, Enum. Pl. Javae 1:91 (1827)

Tree, up to 10 m tall. Knee root pneumatophores present. Stem erect, white latex absent; bark smooth and grayish. Stipules present, caducous. Leaves simple, decussate, elliptical, apex acuminate. Inflorescences cyme, axillary 2-3 flowered. Flower bisexual; calyx green, sulcate, calyx lobes 1-2 cm long, reflexed; sepals 6-8, rigid, persistent; corolla white; petals 6-8, hairy, caducous, apex bristly; stamens free; pistil solitary. Fruits simple, viviparous; hypocotyl cylindrical, dangling.

Bruguiera gymnorhiza (L.) Lamk., Encycl. Meth. Bot. 4:696 (1798)

Tree, up to 25 m tall. Knee root pneumatophores present. Stem erect, white latex absent; bark brown-blackish, lenticellate. Stipules present, caducous. Leaves simple, decussate, elliptical, apex acuminate. Flower solitary, axillary bisexual; calyx red; sepals 10-14, rigid, persistent; corolla yellowish; petals 10-14, hairy, caducous, apex bristly; stamen free; pistil solitary. Fruits simple, viviparous; hypocotyl cylindrical, dangling.

Bruguiera parviflora (Roxb.) Wight & Arn. ex Griff., Trans. Med. Soc. Calcutta 8:10 (1836)

Tree, up to 25 m tall. Knee root pneumatophores present. Stem erect, white latex absent; bark smooth, grayish. Stipules present, caducous. Leaves simple, decussate, elliptical, apex acuminate. Inflorescences cyme, axillary, 3-6 flowered. Flowers bisexual; calyx yellow-greenish, calyx lobes 0.2-0.5 cm long, erect; sepals 6-8, persistent; corolla yellow; petals 6-8, caducous, apex bristly; stamens free; pistil solitary. Fruits simple, viviparous; hypocotyl cylindrical, smooth, dangling.

Bruguiera sexangula (Lour.) Poir., Encycl. Suppl. 4:262 (1816)

Tree, up to 20 m tall. Knee root pneumatophores present. Stem erect, white latex absent; bark gray-brownish, lenticellate. Stipules present, caducous. Leaves simple, decussate, elliptical, apex acuminate. Flower solitary, axillary, bisexual; calyx yellow to orange; sepals 10-14, rigid, persistent; corolla yellowish; petal 10-14, hairy, caducous; apex not bristly; stamens free; pistil solitary. Fruits simple, viviparous; hypocotyl cylindrical.

Ceriops tagal (Perr.) C.B. Rob., Philipp. J. Sci. C 3:306 (1908)

Tree, up to 10 m tall. Knee root pneumatophores present. Stem erect, white latex absent; bark light grayish. Stipules present, caducous. Leaves simple, decussate, oblanceolate, apex obtuse. Inflorescences cyme, axillary, 4-

10 flowered. Flowers bisexual; calyx green-yellowish; sepals 5, rigid, persistent; corolla white-brownish; petals 5, caducous; stamens free; pistil solitary. Fruits simple, viviparous; calyx lobes on fruits reflexed; hypocotyl clavate, ridged, sulcate.

Excoecaria agallocha L., Syst. Nat. ed. 10. 2:1288 (1759)

Tree, up to 15 m tall. Stem erect, white latex present; bark smooth, grayish. Leaves simple, alternate, elliptical, apex acuminate. Inflorescences spike, dioecious, unisexual. Male flowers apetalous; sepals 3, very small, about 0.5-1 mm; stamens 3. Female flowers apetalous; sepals 3, very small, about 0.5-1 mm; carpels 3, ovary trilocular. Fruits simple, 3 locules.

Finlaysonia obovata Wall. Pl. Asiat. Rar. 2: 48 (1831)

Lianas. Stem climbing, white latex present. Leaves simple, opposite, obovate, apex rounded. Inflorescences cyme, axillary. Flowers bisexual; sepals 5; petals 5, upper hairy; stamens 5, epipetalous; carpels 2, apocarpous. Fruits aggregate, follicle.

Heritiera littoralis Aiton, Hort. Kew. 3:546 (1789)

Tree, up to 20 m tall. Buttress root present. Stem erect; bark grayish, white latex absent. Stipules present, caducous. Leaves simple, alternate, elliptical, apex acute. Inflorescences paniculate, unisexual. Male flowers pinkish to purplish; perianth 5 lobes; stamens monadelphous; anthers 5. Female flowers pinkish to purplish; perianth 5 lobes; pistil solitary, stigma 5 lobes. Fruits simple, green-brownish; seed solitary.

Lumnitzera littorea (Jack) Voigt, Hort. Suburb. Calcutt. 39 (1845)

Tree, up to 35 m tall. Knee root pneumatophores absent. Stem erect, white latex absent; bark blackish; young stem red. Stipules absent. Leaves simple, spiral, oblanceolate, succulent, apex rounded, margin entire. Inflorescences racemose, terminal. Flowers bisexual, produce nectar; calyx green; sepals 5; corolla red; petals 5; stamens 10, red; pistil solitary, red. Fruits simple, ellipsoidal.

Lumnitzera racemosa Willd., Neue. Schriften. Ges. Naturf. Freunde. Berlin 4:187 (1803)

Small tree, up to 8 m tall. Knee root pneumatophores absent. Stem erect, white latex absent; bark brownish; young stem grayish. Stipules absent. Leaves simple, spiral, obovate, succulent, apex obtuse, margin entire. Inflorescences spike, axillary. Flowers bisexual, produce nectar; calyx green; sepals 5; corolla white; petals 5; stamens 10, white; pistil solitary, white. Fruits simple, ellipsoidal.

Nypa fruticans Wurmb, Verh. Batav. Genootsch. Kunsten 1:349 (1779)

Palms, up to 8 m tall. Stem short close to the substrate. Leaves compound, pinnate, rosette; leaflets 50-100, alternate, linear, apex acute. Inflorescences compound, unisexual. Fruits compound, brown, fibrous, shelled.

Pemphis acidula J.R. Forst. & G. Forst., Char. Gen. Pl. 34 (1775)

Small tree, up to 8 m tall. White latex absent; bark brownish, flaking. Stipules absent. Leaves simple, decussate, lanceolate, apex acuminate, margin entire. Flower solitary, axillary, bisexual; calyx green; sepals 6; corolla white; petals 6, thin; stamens 12; pistil solitary. Fruits simple, capsular.

Rhizophora apiculata Blume, Enum. Pl. Javae 1:91 (1827)

Tree, up to 20 m tall. Stilt roots present. Stem erect, white latex absent; bark white-brownish. Stipules present, caducous. Leaves simple, decussate, elliptical, apex mucronate. Inflorescences solitary to 2 flowered, axillary. Flowers bisexual; calyx green-brownish; sepals 4, rigid, persistent; corolla white; petals 4, thin, glabrous, caducous; stamens 12, caducous; pistil solitary. Fruits simple, viviparous; hypocotyl clavate, elongate, dangling.

Rhizophora mucronata Lamk., Encycl. 6:189 (1804)

Tree, up to 25 m tall. Stilt roots present. Stem erect, white latex absent; bark brownish; bark segments squared. Stipules present, caducous. Leaves simple, decussate, elliptical, 7-9 cm long, apex mucronate. Inflorescences cyme, axillary, 3-4 flowered. Flowers bisexual; calyx green; sepals 4, rigid, persistent; corolla white; petals 4, thin, hairy, caducous; stamens 8, caducous; pistil solitary. Fruits simple, viviparous; hypocotyl clavate, elongate, dangling.

Rhizophora stylosa Griff., Not. Pl. Asiat. 4:665 (1854)

Tree, up to 15 m tall. Stilt roots present. Stem erect, white latex absent; bark blackish; bark segments irregularly. Stipules present, caducous. Leaves simple, decussate, elliptical, 4-6 cm long, apex mucronate. Inflorescences cyme, axillary, 6-8 flowered. Flowers bisexual; calyx yellow-greenish; sepals 4, rigid, persistent; corolla white; petals 4, thin, hairy, caducous; stamens 8, caducous; pistil solitary. Fruits simple, viviparous; hypocotyl clavate, elongate, dangling.

Scyphiphora hydrophyllacea C.F.Gaertn., Suppl. Carp. 91 (1806)

Small tree, up to 5 m tall. Stem erect, white latex absent; bark brownish; young stem reddish. Stipules present, persistent on interpetiolar. Leaves simple, opposite, obovate, apex rounded. Inflorescences cyme, 5-10 flowered. Flowers bisexual; sepals 4, green, synsepalous; petals 4, white, sympetalous; stamens 4, epipetalous; pistil solitary; stigma ramified. Fruits simple, cylindrical, sulcate.

Sonneratia alba Sm., Cycl. 33(I): Sonneratia no. 2 (1816)

Tree, up to 35 m tall. Pencil root pneumatophore present. Stem erect, white latex absent; bark white-grayish, flaking. Leaves simple, opposite, obovate, apex rounded. Inflorescences axillary, 1-3 flowered. Flowers bisexual; calyx green, inner reddish; sepals 6-8; corolla white, caducous; petals 6-8; stamens white, numerous, free; pistil solitary. Fruits simple, apple-like.

Xylocarpus granatum J.Koenig, Naturforscher (Halle) 20:2 (1784)

Tree, up to 30 m tall. Buttress root present. Stem erect; bark yellow-brownish, flaking. Leaves compound, pinnate, spiral; leaflets 2-6, oblong, apex obtuse. Inflorescences cyme, axillary, 8-15 flowered. Flowers bisexual; calyx yellow-greenish; sepals 4; corolla white, tubular; petals 4, sympetalous; stamens white, epipetalous; pistil solitary. Fruits 15-25 cm diameter; carpel brownish, 0.5-1.5 cm thick; seeds 8-16, irregular pyramid-like.

Environmental conditions of mangrove ecosystem in Belitung Island

Substrate is a media for plant to grow. In mangrove ecosystem, there are several substrate conditions that differ from substrate of other ecosystem types. The substrate in the mangrove ecosystem is formed through the accumulation of sediment materials which are retained by the roots of mangrove plants. The type of substrate is a mixture of mud, sand and coral or clay with different ratios in each zone (Table 3).

The mangrove ecosystem is a kind of muddy substrate resulted from sedimentation. The sedimentation mud mixes with other materials, such as sand, clay or coral, then forms a variety of mangrove substrates (Table 3). The substrate of mangrove in Kuale Tambak Beach was sandy mixed with some mud. In Asam Beach, the mangrove substrate consisted of sand, coral and some mud. The substrate of the mangrove ecosystem of all stations in Kembiri Beach was dominated by mud with the depth of the mud at station 1 reached 100 cm. There was a low portion of sand at station 1, but at stations 2 and 3, the mud has formed a dense and solid substrate by mixing with clay soil. The high proportion of mud in the Kembiri Beach is influenced by the flow of the Kembiri River which ends in Kembiri Beach. The width of the estuary of the Kembiri River reaches 365 meters. This substrate condition is different from the mangrove ecosystem in Sebongkok Island, East Belitung which is only dominated by sand (Akhrianti 2016).

Table 3. Type of mangrove substrate at each research station in Belitung Island, Indonesia

Substrate type	Kuale Tambak			Asam			Kembiri		
	st1	st2	st3	st1	st2	st3	st1	st2	st3
Muddy	-	*	**		*	*	*****	*****	*****
Sandy	*****	*****	*****	*****	*****	*****	*	-	-
Coral	-	-	-	**	*	-	-	-	-
Clay	-	-	-	-	-	-	-	*	**

Notes: st. station; (*). Present; (-). absent

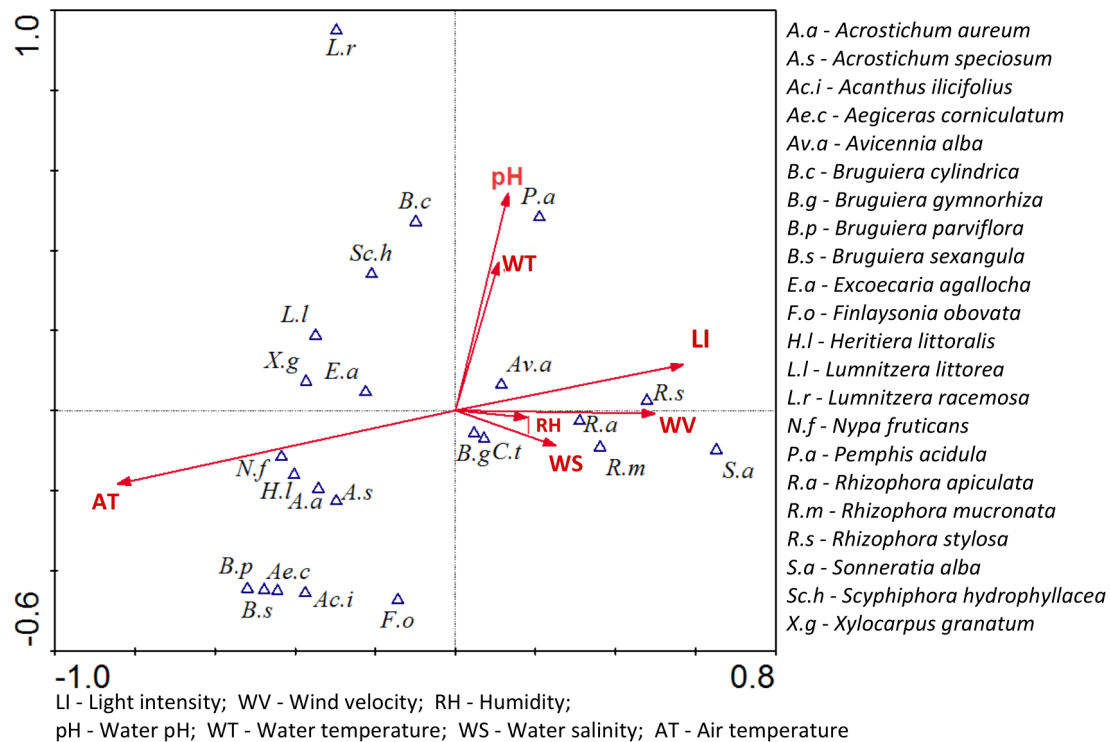


Figure 5. The interaction of environmental factors with the species of mangrove flora analyzed using Canonical Correspondence Analysis (CCA). The graph of CCA shows the ordination of species and environmental factors. Triangle symbols: mangrove species, arrow lines: environmental factors

Analysis of the interaction of environmental factors with the species of mangrove flora was done using Canonical Correspondence Analysis (CCA). The results of the Monte Carlo permutation test showed that all environmental factors measured in this study had significant ($p < 0.05$) interaction with the mangrove flora community except for the water pH ($p > 0.05$), (Figure 5). Salinity, air humidity and wind velocity had influence on *R. apiculata*, *R. mucronata*, *R. stylosa* and *S. alba*. These species are the dominant species that grow closest to the sea and are able to survive in inundated substrate conditions for long time (Cruse et al. 2013). Species *X. granatum*, *E. agallocha*, *B. cylindrica*, *B. parviflora*, *Heritiera*, *Lumnitzera*, *Scyphiphora* and *Nypa* were mostly found in zones adjacent to land zone. These species grow more tolerant to shorter seawater inundation. For other species, the effect of salinity is lower for the mangrove flora on the landward side.

Zonation of mangrove in Belitung Island

The zonation of mangrove flora is the ability of mangrove plant species to grow in specific substrates or zones that are most suitable for their growth (plasticity). Its zonation is also influenced by local topographic contours that form vegetation patterns (Tomlinson 1994)

The result showed that the mangrove forest in Kuale Tambak was located behind the beach casuarina vegetation (Figure 6). The Kuale Tambak coastal area was overgrown by terrestrial plant vegetation, while the mangrove forest

was under the tidal influence of the watershed which boils down to the Manggar River. The zonation in the Kuale Tambak Beach from the coast to the mainland was coastal forest vegetation, such as *Scaevola taccada*, *Pandanus tectorius* and *Casuarina equisetifolia*. Then, closer to the mangrove forest, there was *Acacia mangium*, where *S. taccada* and *Pandanus tectorius* were found again. The mangrove vegetation began with *R. apiculata*, *Lumnitzera racemosa*, *B. cylindrica* and *R. stylosa*. Furthermore, *R. mucronata*, *R. apiculata* grow together with *Sonneratia alba*, *B. gymnorhiza* and *Ceriops tagal*. Near the riverbank, there were *R. apiculata*, *R. stylosa*, *S. alba*, *B. gymnorhiza* and *Avicennia alba*. Across the river was also covered by *R. apiculata*, *R. mucronata* and *S. alba*.

Asam Beach had mangrove vegetation in the intertidal zone. The seaward facing zones were covered by *Sonneratia alba*, *R. mucronata*, *R. apiculata* and *Pemphis acidula* (Figure 7). At the back of that species were *R. stylosa*, *B. gymnorhiza*, *Ceriops tagal* and *R. apiculata*. Furthermore, *R. apiculata*, *R. mucronata*, *Lumnitzera littorea*, *Bruguiera gymnorhiza* and *Ceriops tagal* species still grow well. Approaching to the border with landward, there were *Xylocarpus granatum*, *Heritiera littoralis*, *Scyphiphora hydrophyllacea*, *B. gymnorhiza* and *R. apiculata* also *Ceriops tagal* species. The mangrove forest floor in the backside was covered by mangrove ferns (*Acrostichum speciosum*). At the border of mangrove forests and land vegetation were *Podocarpus neriifolius*, *Hibiscus tiliaceus* and *Pandanus tectorius*.

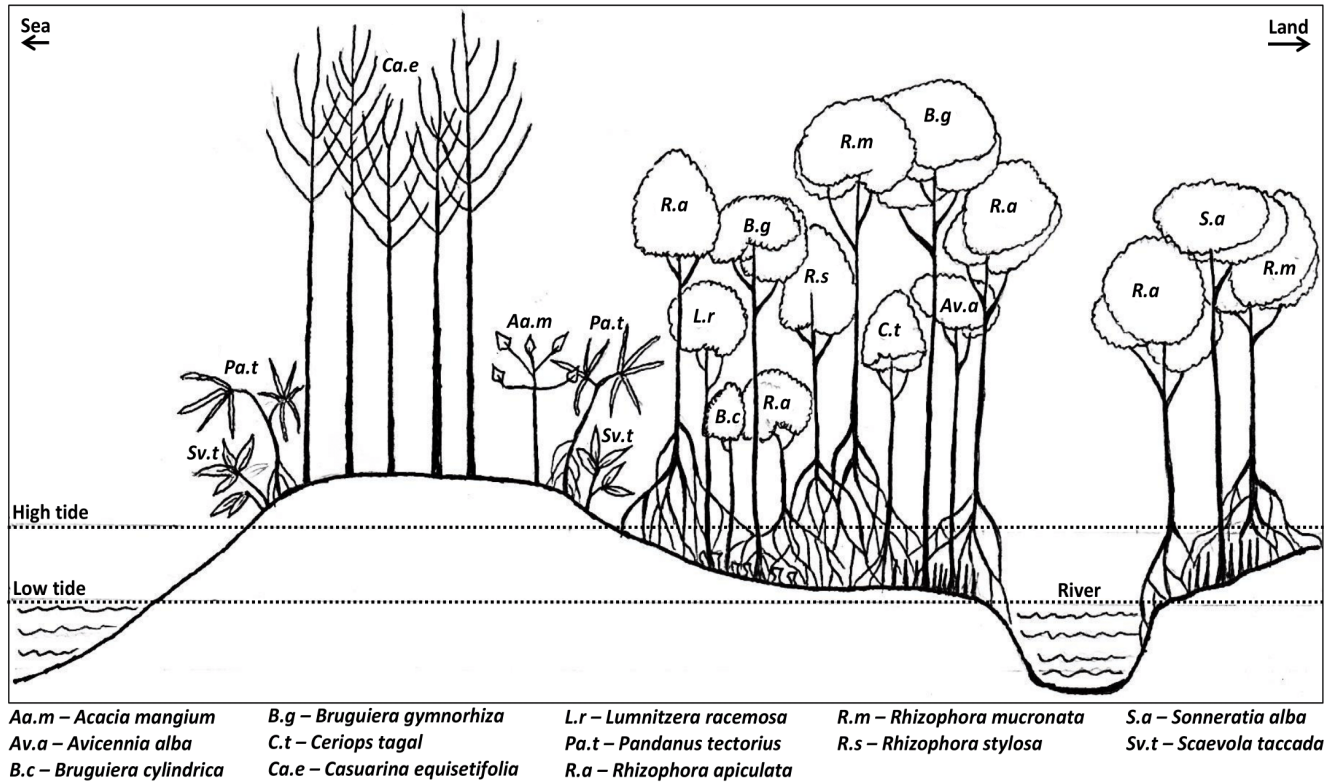


Figure 6. Schematic cross-section of coastal area in Kuale Tambak beach, Belitung Island, Indonesia

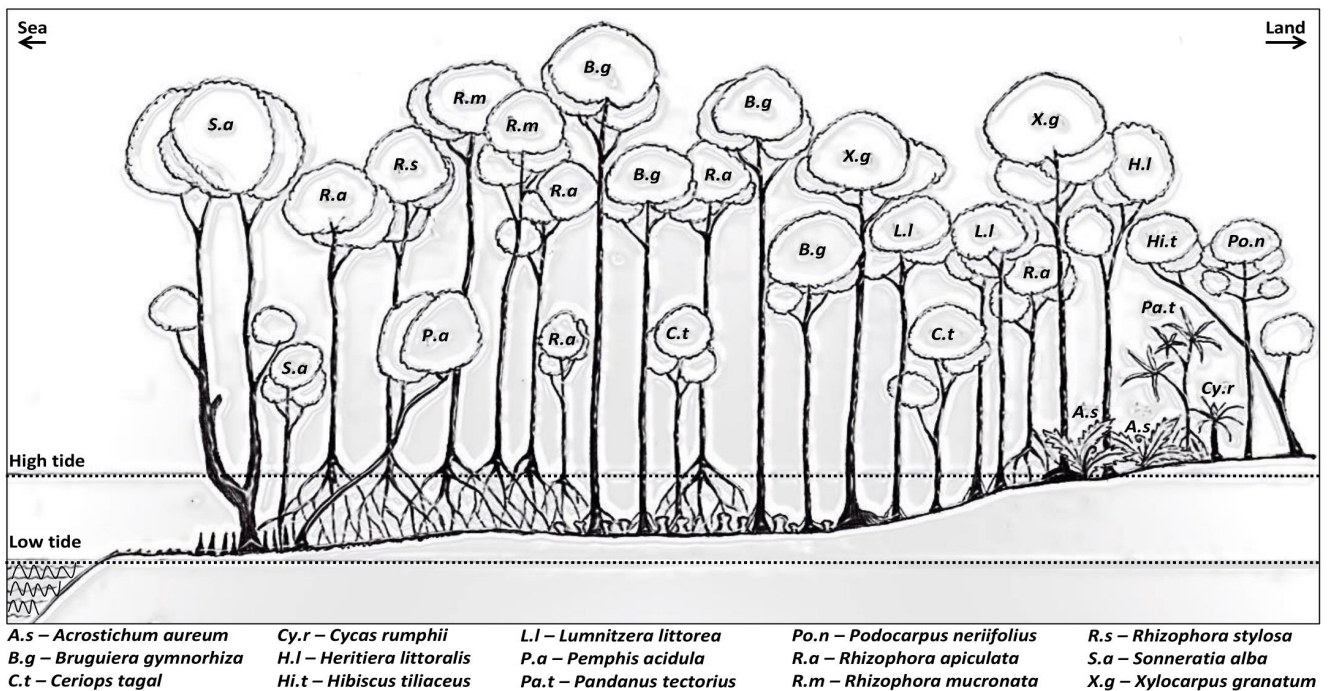


Figure 7. Schematic of mangrove flora zonation in Asam beach, Belitung Island, Indonesia

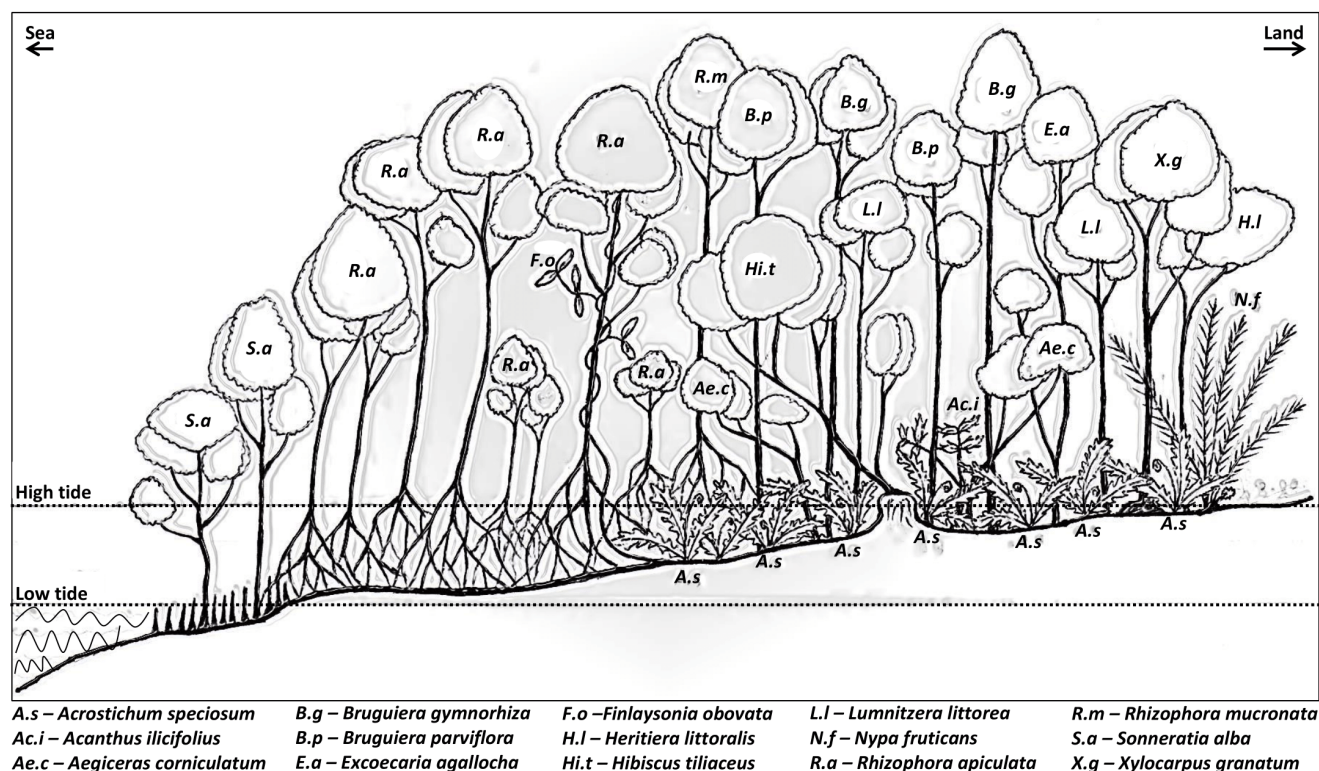


Figure 8. Schematic of mangrove flora zonation in Kembiri beach, Belitung Island, Indonesia

The mangrove forest in Kembiri Beach was in intertidal zone adjacent to the estuarine of the Kembiri River. The mangrove forest in seaward facing zones was covered by *Sonneratia alba* and dominated by *R. apiculata* (Figure 8). Furthermore, there was the *Rhizophora* zone (*R. apiculata* and *R. mucronata*). Then there were a climber mangrove species *Finlaysonia obovata*, that climbed on *R. apiculata*. In their backside was *B. parviflora*, *Aegiceras corniculatum* and *R. apiculata*. Furthermore, to the landward border, there were *Lumnitzera littorea*, *B. gymnorhiza*, *Excoecaria agallocha*, *Nypa fruticans* and *Xylocarpus granatum*. The forest floor was dominated by mangrove ferns (*Acrostichum speciosum*). Also, there was the associate mangrove species (*Hibiscus tiliaceus*) which grows on higher ground mounds in mangrove area.

Mangrove vegetation in Indonesia generally consists of 5 flora groups, namely *Rhizophora*, *Sonneratia*, *Bruguiera*, *Avicennia* and *Nypa* (Kusmana 2014). *Rhizophora apiculata* can grow in the front to the back of the mangrove forest. *Rhizophora apiculata* is tolerant species and able to dominate in mangrove forest areas (Giesen et al. 2007). The species of *Rhizophora stylosa* was not found in the mangrove area of the Kembiri Beach, but grew well in the Kuale Tambak and Asam beaches. *Rhizophora stylosa* prefers sandy substrate (Kusmana 2014), while the substrate at Kembiri was dominated by mud, so these species were not found. It was very rare to find *Avicennia* species in the Kembiri and Asam sites. *Avicennia* was more common in the Belitung Mangrove Park area. The substrate in Belitung Mangrove Park was sandy with some mud on seaward facing side and always inundated which is very

suitable for *Avicennia*. *Avicennia* species are usually found on the seaward side with submerged sandy substrates or in shallow sandy estuaries with low salinity water (Giesen et al. 2007). The Asam Beach substrate, which was dominated by coral rock and deep muddy in the Kembiri, it is not potential for *Avicennia* to grow properly. The difference in zonation patterns of mangrove flora is caused by local topography on Belitung Island, substrate conditions and salinity factors on the mangroves of Belitung Island.

In conclusion, the diversity of mangrove flora in Belitung Island consists of 24 species belonging to 16 genera and 12 families. Rhizophoraceae dominates the mangrove vegetation, consisted of *Bruguiera* (4 species), *Rhizophora* (3 species) and *Ceriops* (1 species). The zonation of mangrove flora in every location shows a different zonation pattern. This pattern is influenced by local topography, substrate conditions and salinity factors that affect the ability to grow in each species of mangrove flora. The species of mangrove flora that are tolerant of salinity are able to grow in areas with seawater inundation for long time, while the intolerant species more able to grow in landward areas.

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