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Mangrove composition and structure at the Welu Estuary,Khlung District, Chanthaburi Province, Thailand

Suk-ueng, N.[1], Buranapratheprat, A.[2], Gunbua, V.[2], Leadprathom, N.[3]
[1] *Biological Science Program, Faculty of Science, Burapha University, Chonburi 20131, Thailand*
[2] *Department of Aquatic Science, Faculty of Science, Burapha University, Chonburi 20131, Thailand*
[3] *Faculty of Marine Technology, Burapha University, Chanthaburi 22170, Thailand.*

Abstract:*The largest mangrove areas in the eastern part of Thailand are located in Chanthaburi province, but most of them have deteriorated and are abandoned. A healthy mangrove area in the Weluestuary, Khlung district, Chanthaburi province is selected as the study area. Mangrove composition, structure and distribution were investigated to be used as a baseline for mangrove conservation in the surrounding area. Twenty-six mangrove speciesincluding 15important true mangrove species, namely A. alba, A. officinalis, B. cylindrica, B. gymnorrhiza, B. hainesii, B. parviflora, B. sexangula, C. tagal, E. agallocha, R. apiculata, R. mucronata, S. caseolaris, S. ovata, X. granatum and X. moluccensis, were identifiedfrom the field survey.Based on structure and community, R.apiculata appeared dominant in the area. The composition and structure results, in terms of number of trees, total stem basal area, tree density and IVI, revealed distribution of these true mangroves following different distances.Consequently, E. agallocha, X. granatum and X. moluccensis presented in the same zones as theAvicenniaceae, Rhizophoraceae and Sonneratiaceae families. This result suggested that E. agallocha, X. granatum and X. moluccensis can be used to rehabilitate the lost mangroves in the Welu estuary and other deteriorated and abandoned mangrove areas.*

Keywords: *Mangrove species, Mangrove structure, Mangrove community, Mangrove conservation, Chanthaburi province*

I. Introduction

Mangrove, an estuarine ecosystem, is located in the sheltered coastline and inland areas along the banks of rivers and streams in the tropics and subtropics of the world. The benefits of mangrove structuresincludeproviding a nursery habitat for young aquatic animals, coastal fisheries, sediment trapping and coastal protection from storms and waves.Structural and community characteristics of mangrove forestsare reflected by thedistribution of mangrove species[1]. According to Tomlinson[2], 114 mangrove species were found throughout the world.Among them, 50 species were found in Southeast Asia[3]. Three pioneer families, namely Avicenniaceae, Rhizophoraceae and Sonneratiaceaeare important to mangrove ecosystems due totheir structural characteristics.Natural adaption of individual mangrove species has resulted in mangrove structure and zonation[4, 5].

Over-exploitation of mangrove for such activities as, aquacultures and tourism are considered as major causes to mangrove area decreases [6, 7]. Global mangrove areas have reduced during the past 25 years (1980-2005) from 18.8 to 3.6 million hectares (ha). Mangrove areas in Thailand decreased from 368,000 ha in 1961 [8] to 276,000 ha in 2010 [9].Such a situation requires efficient rehabilitation supported by research and knowledge to maintain complex mangrove ecosystems[10].

The Welu estuarine mangrove is considered as the largest mangrove area in the eastern part of Thailand with high abundance and biodiversity of flora and fauna [11]. Unfortunately, this area decreasedin size from 19,000 ha in 1975 [11]to 7,206 ha in 2009 [12]due to shrimp farming and tourism. Demand forthe mangrove reforestation is therefore needed. This researchaims to investigatemangrove composition and structurein a healthy mangrove area in the Welu estuary, Khlung district, Chanthaburi province. The survey results will provide knowledge and support for mangrove ecosystem studies and conservation.

II. Materials And Methods

The mangrove area in the Welu estuary, under responsibility of Mangrove Resource Development Station 2 (MS2), Khlung district, Chanthaburi province, is chosen as the study site (Fig. 1). The approximate area is 134 ha located from latitude 12°21′42″ N to12°23′20″ N andlongitude 102°19′59″E to102°21′38″E.

Visual surveys on foot and by boat were carried out from December 2009 to February 2010. A healthy mangrove area was selected from the topographic map, with a scale of 1:50000, Series L 7018 Sheet 5334I [13], the satellite image retrieved from the Geo-Informatics and Space Technology Development Agency (GISTDA) andthe survey results of the study site. Line transects [14, 15] were applied on the study site for ground truth observations. Theywere used for collecting the information of mangrove species following Sutherland[14] and

Krebs[16]. The length of transects variedfrom 150 m to 825 m in accordance with size and shape of the study area (Fig. 1).The dimension of each plot was 15×15 m[17], and the numbers of plot were calculated from this [18]. Seventy-six study plotswere fixed along the transect lines,anda stratified random sampling technique with mangrove zonation derived from field survey results was used.

All live mangrove trees with diameter at breast height (DBH) (1.30 m from the ground) greater than4 cm [11]in the study plots were measured from January to March 2011. The number of individual tree and tree species [2]in each plot were recorded. For small trees, DBH was directly measured using a Vernier caliper, but for large trees, tree girth at breast height (GBH) was measured using a measuring tape. GBH was then converted to DBH by divided by π [17, 19].

Structural analysis was determined using the density of each species (number of tree 0.01 ha^{-1}), species basal area ($m^2$0.01 ha^{-1}) and total basal area of all species (m^2ha^{-1})[20]. The importance value index (IVI) was used as an indicator of a given species within a stand of mixed mangrove species [21]. It was calcualted by summation of three terms namely the relative density, relative dominance and relative frequency of each species. Community analysis was defined by using Shanon-Wiener Diversity Index [22]. Overall analytical process is shown in Figure 2.

III. Results

3.1 Mangrove species composition and structure

Ten line transects (298 plots)were established, and the studyarea was separated into 2 zones (zone A and B). Zone A included 4 line transects (A1 A2 A3 and A4), and Zone B had 6 line transects (B1 B2 B3 B4 B5 and B6). Each line transect of Zone A and Zone B was randomly sampled for 4 and 10 plots, respectively. The number of selected plots altogether totalled 76(Fig. 1).Twenty-six species of mangroves were found in this study site.Of these 15 species, namely*Avicennia alba*, *Avicenniaofficinalis*, *Bruguieracylindrica*, *Bruguieragymnorrhiza*, *Bruguierahainesii*, *Bruguieraparviflora*, *Bruguierasexangula*, *Ceriopstagal*, *Excoecariaagallocha*,*Rhizophoraapiculata*,*Rhizophoramucronata*, *Sonneratiacaseolaris*, *Sonneratiaovata*, *Xylocarpusgranatum* and *Xylocarpusmoluccensis*weredefined as important true mangrove species.In total 2,748 trees were sampled, of which 2,143 trees (78% of all number of trees) in 74 plots of occurrence were identified as *R. apiculata*.Species diversity of the MS2 site was 1.06. *R. apiculata* showed the highest species diversity at 0.194,followed by*E.agallocha* (0.144), *Lumnitzeraracemosa*(0.120) and *Lumnitzeralittorea* (0.116) (Table 1).

Mean DBH ofimportant true mangrove species with a large number of trees in medium size classes was compared to number of treesin small and large stem classes (Fig. 3).For instance, *A. alba* and *A. officinalis* appear in mean DBH ranged from 9.6-24.2 cm. *X.granatum*and *X.moluccensis* show mean DBH in the range of 9.1-15 cm.Species basal area and tree density of each mangrove speciesis as shown in Table 1. *X.moluccensis*showed maximum basal area (62.05 $m^2$0.01 ha^{-1}), followed by*X.granatum* (36.81$m^2$0.01 ha^{-1}), *Heritieralittoralis*(36.17 $m^2$0.01 ha^{-1}), *R.apiculata*(28.2 $m^2$0.01 ha^{-1}) and *E.agallocha*(21.09 $m^2$0.01 ha^{-1}).The basal area of all species in the study site was 2.63 m^2ha^{-1}.Tree density for individual species varied from 0.26 to 1,599 trees 0.01 ha^{-1}. *R. apiculata*met with maximum tree density (1,599 trees 0.01 ha^{-1}) or 78% of the total tree density. This is followed by*E.agallocha* (96.3 trees 0.01 ha^{-1}), *L.racemosa* (73.9 trees 0.01 ha^{-1}),*L.littorea* (70.9 trees 0.01 ha^{-1}) and *B.gymnorrhiza* (47.8 trees 0.01 ha^{-1}), respectively (Table 1).As shown in Table 2, the greatest number of IVI was recorded for *R. apiculata*(120.48), followed by *X.moluccensis* (26.08), *E.agallocha* (24.80) and *X.granatum*(22.27).

3.2Mangrove distribution and zonation

The results from structural analysis described in section 3.1 can be categorized by distribution of mangrove species in 9 zones according to landward distances from the Welu river for the 0 to >720 m (Table 3). The results of this relationship are shown in Figures 4-6. Twelve species of important true mangroves, namely *A.alba*, *A.officinalis*, *B.gymnorrhiza*, *B.parviflora*, *B.sexangula*, *C.tagal*, *E.agallocha*, *R.apiculata*, *R.mucronata*, *S.caseolaris*, *X.granatum* and *X.moluccensis* are mostly found in zone 1 (0-90 m).

High total stem basal areaof about 83.1, 48.4, 19.5 and 19.2 (m^2) for *X.moluccensis*, *X.granatum*, *E.agallocha* and *R.apiculata*, respectively (Fig. 4) are dominant in zone 1.The tree density in zone 1 (664.9 trees 0.01 ha^{-1}) is also higher than in other zones.The numbers of speciesand treesdecreasefrom zone 2 to zone 9. Total stem basal area and tendency of tree density (R^2 = 0.8043)also decrease with increasing landward distances from the Welu river (Fig. 5).

The highestIVI of important mangrove species are mostly found from zone 1 to zone 3.IVIof *E.agallocha*, *X.granatum* and *X.moluccensis* are, for example, 124.5, 51.63 and 46.92, respectively. However, 6 important mangrove species, *B. cylindrica, B. parviflora, B. sexangula*, *C. tagal*, *E. agallocha*, *R. apiculata* and *S. ovata*, showed higher IVI in zone 4to zone 9 than that zone. *B. hainesii*, *B.sexangula*and *C.tagal*showed high IVI in zone 5 (22.02), zone 6(33.61) and zone 4 (18.22), respectively. *B. parviflora* and *S. ovata*presented the highest IVI in inland area (zone 8), while *R. apiculata*showed high IVI inzone 4 to zone 9 (except zone 8) (Fig. 6).

IV. Discussion

According to the regional mangrove classification scheme, this mangrove area is described as riverine forest,found in river banks and creeks that receive a high freshwater input from upstream and are flooded daily by the tidal regimes [1,23].The number of mangrove species at the present time is more than thatrecorded byAksornkoae [11].Four species namely *Acrostichumaureum*, *R. candelaria* (*R. apiculata*), *R. mucronata* and *Lumnitzera* spp.were investigated. Eighteen species in 7 families defined as true mangroves, growing in the zone of tidal influence [24] are higher than that in the Coringa mangrove forest, the Godavari Delta, India.They also confirm the high biodiversity of the mangrove forest (following the discussion of Ashton and Macintosh [25]) in MS2 site. Among them, 15 species are considered as important true mangroves because their structural characteristics (e.g. root systems) are beneficial to a mangrove ecosystem [23].Obviously, *R.apiculata*is dominant because of a high number and frequency (number of plots of occurrence) distributed in the area. Other species with low frequencies are restricted to specificareas of the forest [26].The mangrove forest has higher species diversity than tree communities in the mangrove reserve area on Qi'ao Island in the Pearl river estuary, China [27]. On the other hand, species diversity is lower than in Sematan study plots, Malaysia [25] and Sundarban mangrove forest, Bangladesh [28].

Mean DBH of important true mangrove species in Figure 3 is more abundant in the medium size class (5-15 cm) compared to those with small (<5 cm) and large (>15 cm) stems [29]. The results of DBH classification show that structure of mangrove species has been developing. Growth of the tree diameterin the area is expected to increase year by year (e.g. Chen et al. [30]).Species basal area of *R. apiculata* occupies less of the mangrove area than *X. granatum* and *X. moluccensis*because DBH of *R. apiculata* in natural forest was frequently observed as 10 cm in diameter [29]. Consequently, *X. granatum* and *X. moluccensis*were the most important species,based on DBH and species basal area due toa 38% contribution to total species basal area. However, they showed lower tree density than*R. apiculata*, *E. agallocha*and *B. gymnorrhiza*, respectively(Table 1).The MS2 mangrove area also has a wide range of species basal area and tree density following different distance of plots. This indicates that the mangrove ecosystem in this area has a variety of structure and composition [25, 31]. Based on these results, this mangrove area can be determined as a healthy mangrove ecosystem.

Mangrove conservation should considermangrove composition and structure according to their zonation [32, 33]. Nine categories of distances were established to represent species compositions and structures. The quantitative values especially in tree density decrease logarithmically as the distance increasesfrom river to land. The highest number of important true mangroves (12 species),with the greatest structural development are found in zone 1 adjacent to the Welu river.The results suggested that not only the main pioneer families (Avicenniaceae, Rhizophoraceae and Sonneratiaceae) but also Euphorbiaceae (*E.agallocha*) and Meliaceae(*X.granatum*and *X.moluccensis*) are vital to this ecosystem.Although, *E. agallocha* seemed to prefer land area (zone 2, 3 and 6), the species exhibited a high total stem basal area (19.5 m^2) and number of trees (55 trees) in zone 1.

Zonation of *E. agallocha* in the Coringamangrove forest is mostly found in land area [34, 35]. In addition, Ashton and Macintosh [25] observed that *X. granatum*in Sematan mangrove forest in Malaysiawas found in middle and high tide zones.*X. granatum and X. moluccensis*were presented in the same zone in the mangrove area of western peninsular Malaysia [36, 37]. *X. moluccensis*in the SegaraAnakan mangroves in Indonesia showed the zonation in high tide and were occasionally inundated by exceptional tide [38, 39]. Surprisingly, *E.agallocha*, *X.granatum*and *X.moluccensis*in MS2 mangrove forest can naturally adaptto the same environmental factors as pioneer species. They are, therefore, able to be replanted in the lost mangrove forests. In most mangrove areas, such as in China, Colombia, Indonesia and Panama, three main pioneer families were planted for mangrove rehabilitation [41]. In Thailand, reforestation of abandoned shrimp ponds used only Rhizophora family including*B. cylindrica*, *B. parviflora*, *C. tagal*, *R. apiculata* and *R. mucronata* (e.g. Iftekhar [42]).However, suitable species for plantingin a specific mangrove area should be decided by environmental conditions according to mangrove zonation so that reforestation and rehabilitation in a deteriorated mangrove area will be successfully achieved [43, 44, 45].

V. Conclusion

The mangrove area in the Welu estuary, Khlung district, Chanthaburi province, is considered as a healthy mangrove ecosystem. Twenty-six mangrove species were identified in the field survey. Of these 26 species, 15 species, namely *A.alba*, *A.officinalis*, *B.cylindrica*, *B. gymnorrhiza*, *B. hainesii*, *B. parviflora*, *B.sexangula*, *C.tagal*, *E. agallocha*, *R. apiculata*, *R. mucronata*, *S. caseolaris*, *S. ovata*, *X. granatum* and *X. moluccensis* were defined as important true mangrove species. *Rhizophoraapiculata* is dominant in the area because it showed the highest number and frequencyof treesin the study site.The composition and structure resultsalso revealed the distribution of these mangroves by distances from the river.*E. agallocha*, *X. granatum* and *X. moluccensis* presented the same zonation asAvicenniaceae, Rhizophoraceae and Sonneratiaceae families. This result suggests that*E. agallocha*, *X. granatum* and *X. moluccensis*can be used to rehabilitatethe lost mangroves in the Welu estuary and other deteriorated and abandoned mangrove areas.

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Table1 Mangrove species and structure in MS2.

Species	Number of trees	Number of plots of occurrence	Species basal area ($m^2$0.01 ha^{-1})	Tree density (number of trees 0.01 ha^{-1})	Species diversity
*Avicennia alba**	15	8	12.51	11.2	0.028
*Avicenniaofficinalis**	17	7	9.68	12.7	0.031
Casuarinaceae					
*Casuarinaequisetifolia****	1	1	0.71	0.7	0.003
Combretaceae					
*Lumnitzeralittorea**	95	20	13.89	70.9	0.116
*Lumnitzeraracemosa**	99	13	3.22	73.9	0.120
Euphorbiaceae					
*Excoecariaagallocha**	129	28	21.09	96.3	0.144
Leguminosae-Caesalpinioideae					
*Cynometrairipa***	2	2	0.53	1.5	0.005
*Cynometraramiflora***	1	1	0.65	0.7	0.003
*Intsiabijuga***	21	10	16.99	15.7	0.037
Malvaceae					
*Hibiscus tiliaceus***	6	5	1.98	4.5	0.013
*Thespesiapopulneoides***	3	2	0.92	2.2	0.007
Meliaceae					
*Xylocarpusgranatum**	44	15	36.81	32.8	0.066
*Xylocarpusmoluccensis**	8	4	62.05	6.0	0.017
Myrsinaceae					
*Rapaneaporteriana***	4	2	0.47	3.0	0.010
Myrtaceae					
*Melaleucacajuputi****	8	2	0.50	6.0	0.017
Rhizophoraceae					
*Bruguieracylindrica**	2	1	0.18	2.2	0.007
*Bruguieragymnorrhiza**	64	8	3.24	47.8	0.088
*Bruguierahainesii**	2	1	0.16	1.5	0.005
*Bruguieraparviflora**	6	5	2.54	4.5	0.013
*Bruguierasexangula**	10	6	1.40	7.5	0.020
*Ceriopstagal**	2	2	0.42	1.5	0.005
*Rhizophoraapiculata**	2,143	74	28.20	1,599	0.194
*Rhizophoramucronata**	16	3	1.17	11.9	0.030
Sonneratiaceae					
*Sonneratiacaseolaris**	12	4	6.86	9.0	0.024
*Sonneratiaovata**	1	1	0.25	0.7	0.003
Sterculiaceae					
*Heritieralittoralis**	35	11	36.17	0.26	0.057

*true mangrove species, ** mangrove associates, ***neither true mangrove species nor mangrove associates

Table 2 Importance value index of important true mangrove species in the mangrove area.

Species	Relative value (%)			Importance Value Index (IVI)
	Density	Dominance	Frequency	
Avicennia alba	0.55	4.86	3.40	8.81
Avicenniaofficinalis	0.62	3.76	2.98	7.35
Excoecariaagallocha	4.70	8.19	11.91	24.80
Xylocarpusgranatum	1.60	14.29	6.38	22.27
Xylocarpusmoluccensis	0.29	24.08	1.70	26.08
Bruguieracylindrica	0.07	0.07	0.43	0.57
Bruguieragymnorrhiza	2.33	1.26	3.40	6.99
Bruguierahainesii	0.07	0.06	0.43	0.56
Bruguieraparviflora	0.22	0.99	2.13	3.33
Bruguierasexangula	0.36	0.54	2.55	3.46
Ceriopstagal	0.07	0.16	0.85	1.09
Rhizophoraapiculata	78.04	10.95	31.49	120.48
Rhizophoramucronata	0.58	0.45	1.28	2.31
Sonneratiacaseolaris	0.44	2.66	1.70	4.80
Sonneratiaovata	0.04	0.10	0.43	0.56

Table 3 Zonesof mangrove species according to landward distances from the river.

Zones	Landward distances from the river (m.)
Zone 1	0-90
Zone 2	90-180
Zone 3	180-270
Zone 4	270-360
Zone 5	360-450
Zone 6	450-540
Zone 7	540-630
Zone 8	630-720
Zone 9	>720

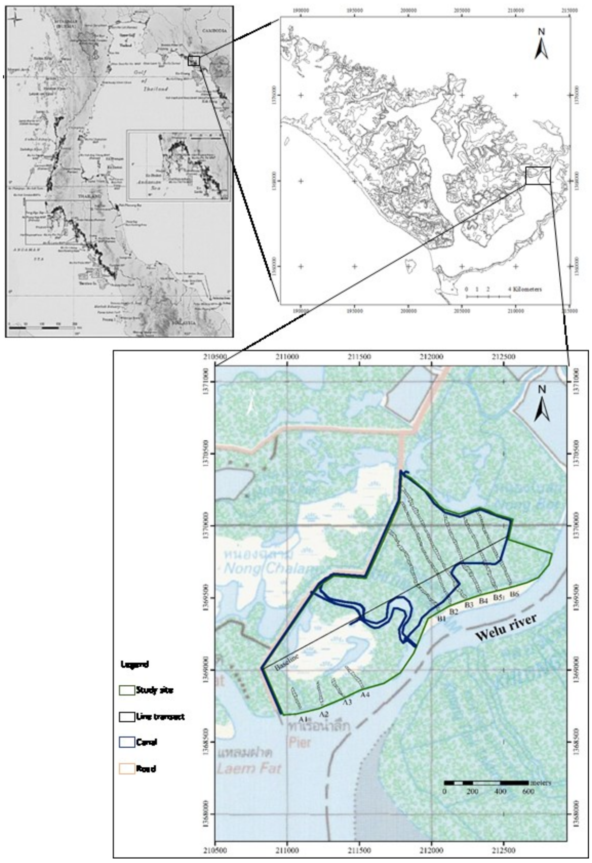

Figure 1 The study site and plots at the Welu estuary. (Modified from Tuck et al., 2012; Office of Mangrove Resources Conservation, n.d.).

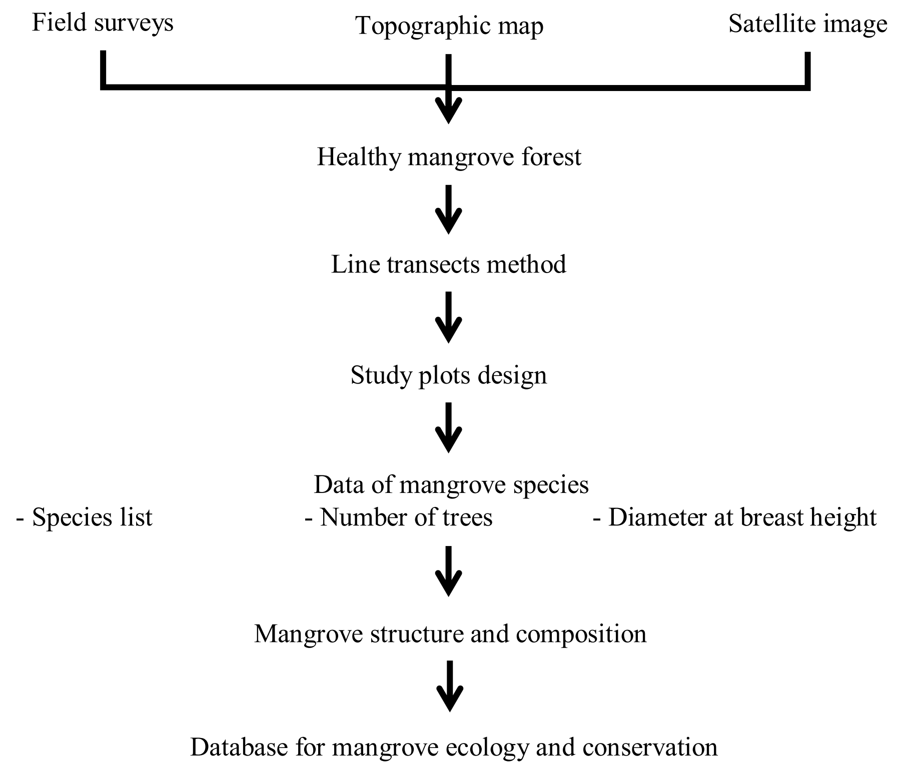

Figure 2 Research plan for mangrove ecology and conservation.

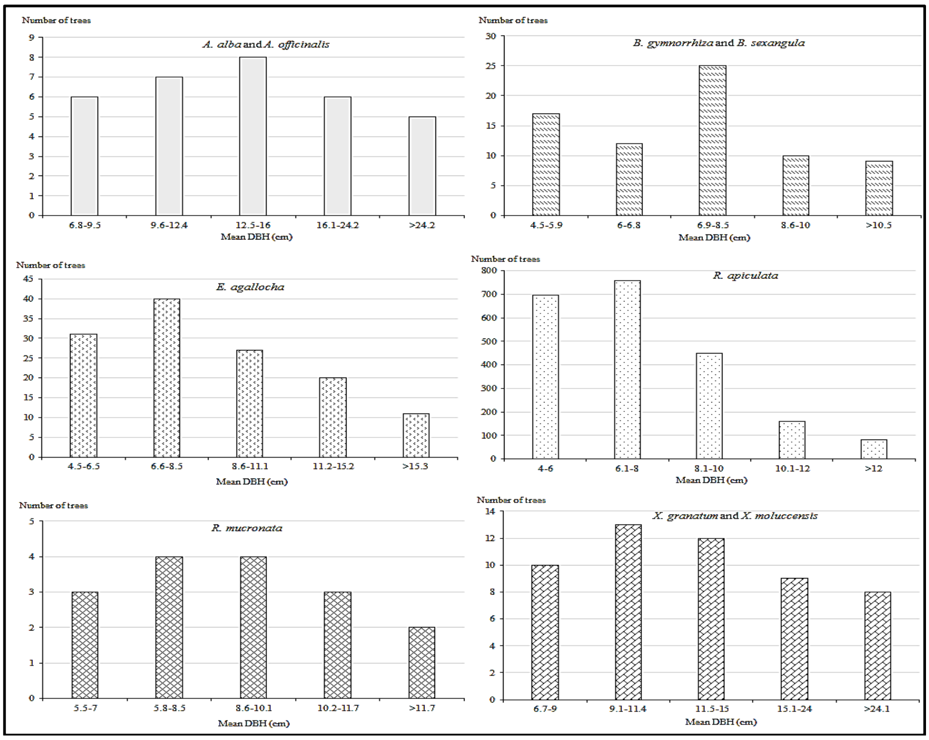

Figure 3 Mean DBH of important true mangrove species (except *B. cylindrica*, *B. hainesii*, *B. parviflora* and*C. tagal*).

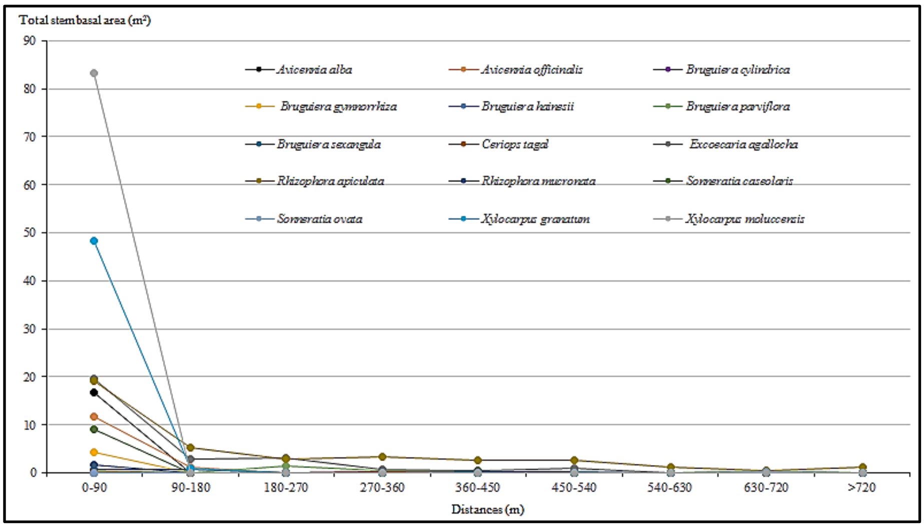

Figure 4 Relationship between distances from the Weluriver to land and totalstem basal area of important true mangrove species.

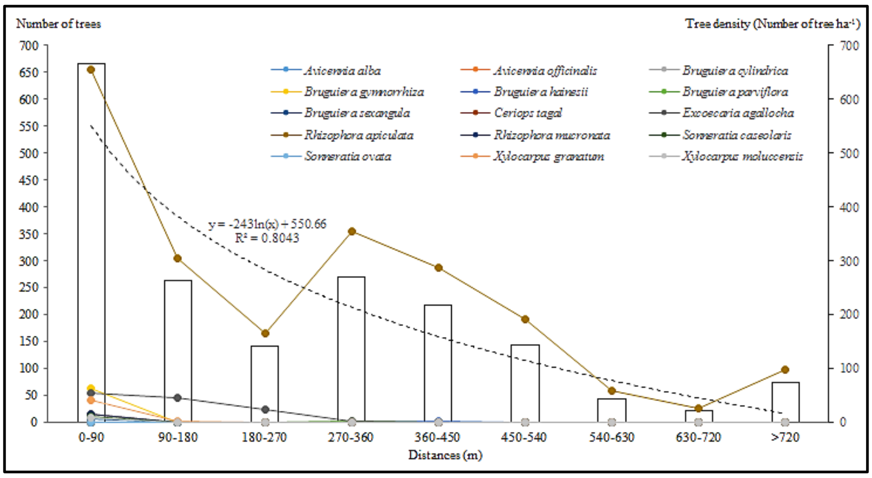

Figure 5 Relationship among distances from the Weluriver to land, number of trees and tree density of important true mangrove species.

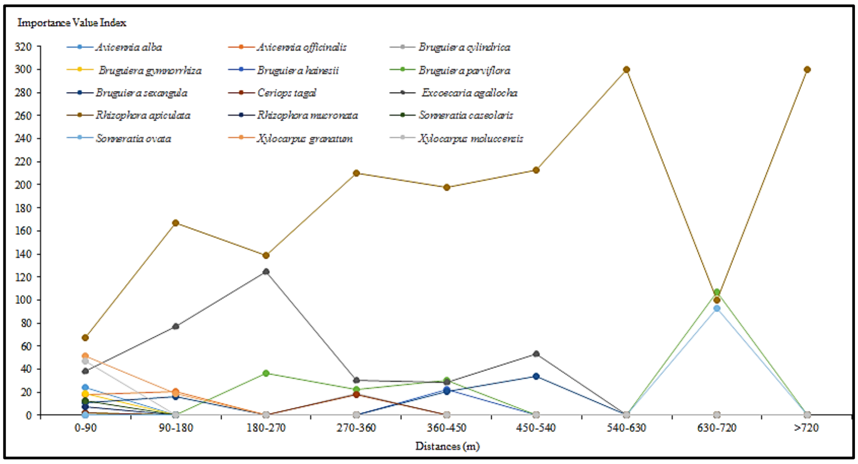

Figure 6 Relationship between distances from the Weluriver to land and IVI of important true mangrove species.