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Clustering of Mangrove Dominant Species in Ranong, Thailand

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ABSTRACT: The Ranong mangrove forest ecosystems located on the Andaman sea coast of Thailand was studied using the Point Centered Quarter (PCQ) method to determine the mangrove vegetation and the dominant mangrove species. Mangrove cluster was evaluated using cluster analysis, specifically the standardized relative Euclidean distance method. Seven zones were identified and named after the dominant species: Zone I) *Rhizophora apiculata - Xylocarpus granatum*, Zone II) *Rhizophora apiculata - Ceriops decandra*, Zone III) *Avicennia officinalis*, Zone IV) *Avicennia marina*, Zone V) *Rhizophora apiculata - Rhizophora mucronata*, Zone VI) *Rhizophora apiculata - Avicennia officinalis* and Zone VII) *Rhizophora apiculata*. We recommend that the dominants should be utilized in mangrove reforestation of the ravaged mangrove ecosystem following the recent tragic tsunami in the Andaman Sea.

KEY WORDS: dominant species, mangrove vegetation, cluster analysis, Ranong.

INTRODUCTION

Mangrove forests play a key role in the food chain that support population of fishes, prawns and other seafood (SAREC, 1995). They are dominated by various species of trees, shrubs and herbs capable of growth and reproduction in brackish and salty water (Aksornkoae *et al.*, 1992; Ong, 1995; Smith and Smith 2004; Doydee *et al.*, 2008).

Aside from straddling the land and seascape, mangroves contribute to habitat complexity and the diversity of the associated fauna of the ecosystem. (Hutchings and Saenger, 1987; Othman, 1994; Lee, 1998; Tri *et al.*, 1998; Mackintosh *et al.*, 2002; Ashton *et al.*, 2003; Ellison, 2008).

They provide natural resources and are the breeding grounds and nursery sites of many species of shrimp, crab and marine fish (Sasekuma *et al.*, 1992; Barbier and Strand, 1998). They provide important indirect benefits, such as shoreline stability and water quality. They absorb nutrients and trap the sediment flowing down rivers from the uplands (Buot, 1994; Field, 1996; Janssen and Padilla, 1999; Anongponyoskun and Doydee, 2006; Ellison, 2008).

In the 2004 tsunami, lives and property were lost along the Ranong coastal, their landscape was severely damaged. However, it was observed that the presence of dense mangrove forest somehow mitigated the negative impact of the tsunami ravaging the coast. Thus, the purpose of this study is to examine the mangrove vegetation and zonation patterns in Ranong, Thailand. It is hoped that the study will provide baseline data for the planning of an appropriate mangrove rehabilitation strategy along the Andaman coast in Ranong.

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MATERIALS AND METHODS

Study area

The study was conducted in Ranong, Thailand (9°43'N to 9°57'N and 98°29'E to 98°39'E). Ranong has long expanses of sandy beaches, unspoiled natural forests, waterfalls, parks, and a biosphere reserve area. Three districts were selected, based on accessibility, the size of mangrove patches and associated elements such as channels and distance. These were Mueang, Kapoe and Suk Samran. Two sites were selected from each district namely: Mueang (Ngaw [1] and Rachakrud [2]), Kapoe (Bangben [3] and Banghin [4]), and Suk Samran (Talaynog [5] and Hadsaykaow [6]) (Figure 1). Within each site, samples of mangrove species were taken from 2 orientations: perpendicular to (A) and parallel with (B) the channel.

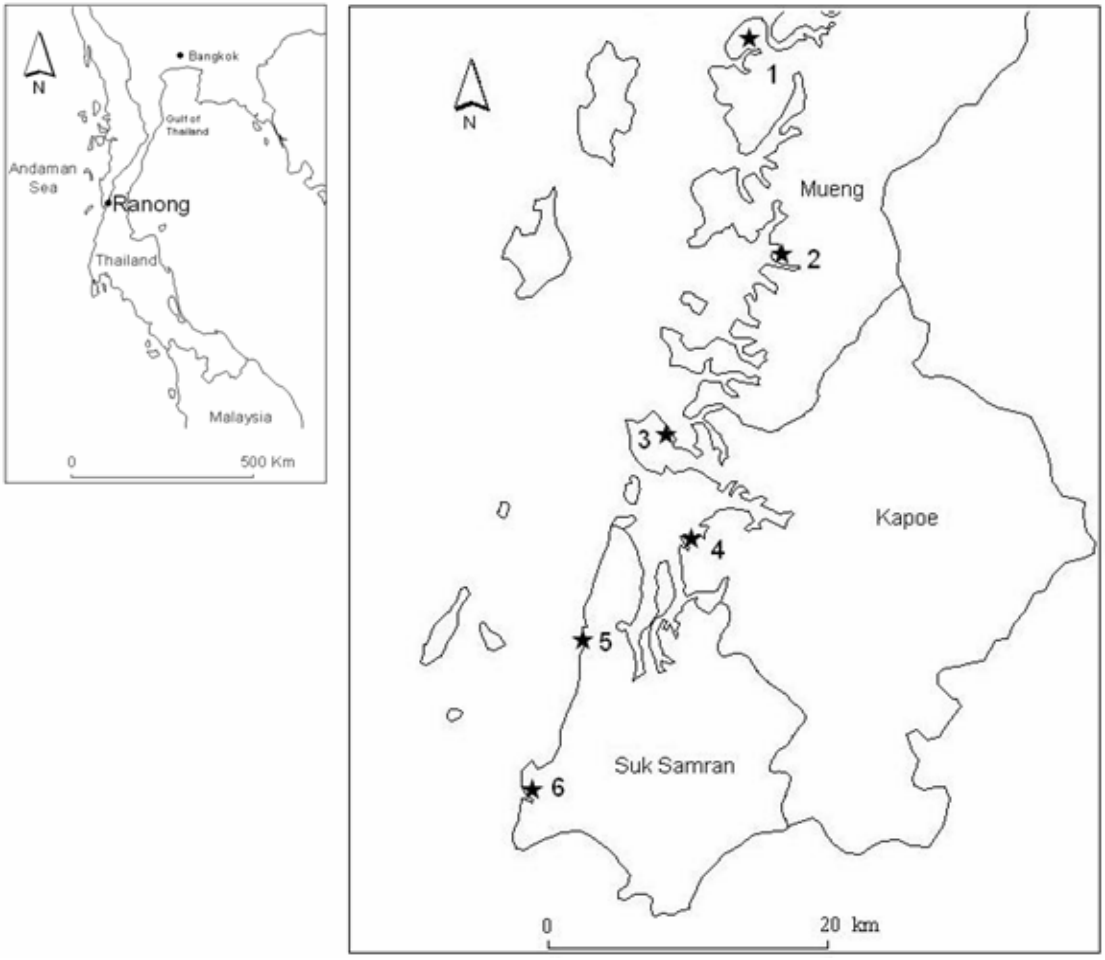

Figure 1. The 6 study sites in the mangrove landscape along the Andaman coast in Ranong, Thailand: Mueang (Ngaw [1] and Rachakrud [2]), Kapoe (Bangben [3] and Banghin [4]) and Suk Samran (Talaynog [5] and Hadsaykaow [6]).

Data collection and measurement

The identification of mangrove species (960 individual trees) was done at 6 study sites, divided into a total of 12 sub-study sites. The coordinates of every sampling site were recorded with the Global Positioning System (GPS). The Point Centered Quarter (PCQ) method of Mueller-Dombois and Ellenberg (1974) was used to study the species composition. Determination of the dominant species was based on the Relative Basal Area (RBA) values following Ohsawa (1984), as follows:

$$d = \frac{1}{N} \left\{ \sum_{ieT} \left(X_i - \overline{X} \right)^2 + \sum_{jeU} X_j{}^2 \right\}$$

Where d is the deviation, X_i is the actual percent share (RBA value) of the top species (T) [i.e., the top dominant in the one-dominant model or the two top dominants in the two-dominant model and so on], $\overline{X}$ is the ideal percent share based on the aforementioned model, X_j is the percent share of the remaining species (U), and N is the total number of species.

Figure 2. An overview of the Ranong mangrove forest communities.

Cluster analysis

The RBA of the dominant species was subjected to cluster analysis using the standardized relative Euclidean distance of PC-ORD software. A dendrogram was then constructed using Ward's method. Each distinct zone was named after the dominant species of the zone.

RESULTS

The dominants of the Ranong mangrove vegetation (Figure 2) at the 6 study sites are presented in Table 1. A and B in the tables refer to the PCQ line orientation where A means perpendicular to and B means parallel with the channel of each sampling site. *Rhizophora apiculata* was the most dominant in Ngaw A with more than 2600 cm of total basal area. Furthermore, this species showed the highest relative frequency (50%), relative density (66.25%), relative basal area (73.93%) and importance value (190.18%) compared with other mangrove species.

The Importance Values (IV) shows that the key dominant species was *Rhizophora apiculata* found in 5 out of 12 sites, while *Ceriops decandra* and *Bruguiera parviflora* were present in 2 sites. The rest of the dominant species namely *Avicennia marina, A. officinalis* and *R. mucronata* were found only in one particular site (Table 1).

The results of the dominance analysis of the mangrove ecosystems using Ohsawa's model (1984) based on RBA are shown in Table 2. *Rhizophora apiculata* was found in 10 sites from the total of 12 sites.

Cluster analysis determined 7 mangrove vegetation zones in Ranong based on RBA (Table 3) namely: Zone I) *Rhizophora apiculata - Xylocarpus granatum* zone, Zone II) *Rhizophora apiculata - Ceriops decandra* zone, Zone III) *Avicennia officinalis* zone, Zone IV) *Avicennia marina* zone, Zone V) *Rhizophora apiculata - Rhizophora mucronata* zone, Zone VI) *Rhizophora apiculata - Avicennia officinalis* zone, and Zone VII) *Rhizophora apiculata* zone (Figure 3).

Zone I. *Rhizophora apiculata - Xylocarpus granatum* Zone. *Rhizophora apiculata* and *Xylocarpus granatum* were the main components of the mangrove forest in Banghin (Figure 3). Its location coordinates are 438415E and 1047968N as defined by the Universal Transverse Mercator (UTM) projection. This site in the Kapoe district was the most inaccessible because of its considerable distance from the sea and the very muddy state of the ground. Under such conditions, *R. apiculata* and *X. granatum* accounted for an RBA value of 27% and 27.84%, respectively. This site can be reached only on foot. This inaccessibility is a factor against the overexploitation of the resources of the zone. The tallest tree was recorded at 16 m while the shortest was at 2 m. The maximum Diameter at Breast Height (DBH) value was 35 cm while the minimum was 1.6 cm. All the extreme values in terms of height and DBH were observed at the Banghin A site of this zone.

Zone II. *Rhizophora apiculata - Ceriops decandra* Zone. This mangrove forest zone (Figure 3) is adjacent to Zone I (446180E and1055825N). It encompasses the Bangben sites in the Kapoe district. *Rhizophora apiculata* was again identified as the dominant species with the RBA value of 36.65% (Table 3). *Ceriops decandra* was observed to be the other dominant mangrove tree with an RBA of 30.03%. The combination of these trees together with rare occurrences of *Avicennia marina, Bruguiera cylindrica* and *Heritiera littoralis* seemed to have created an ideal habitat for small marine animals, making this area a prosperous fishing village. Further, maximum plant height in the zone was 10 m while the minimum was 3 m. In terms of DBH, the highest value was 23 cm and the lowest value was recorded at 0.9 cm.

Zone III. *Avicennia officinalis* Zone. Zone III is composed of a single sampling site, Rachakrud (site B) in the Mueang district of Ranong (Figure 3). Its coordinates are 452553E and 1075827N based on UTM projection. Contrary to most of the zones, Zone III is very near to the beach. This location makes the soil very sandy and the water more saline in nature. These conditions contributed to the dominance of *Avicennia officinalis* as this mangrove tree exhibits a high tolerance to salinity. Although the zone had *A. officinalis* as the dominant species, the RBA of this tree was only 38.59% (Table 3). The presence of *Aegiceras corniculatum, Avicennia alba, A. marina, A. officinalis, Bruguiera cylindrica, B. parviflora, Excoecaria agallocha, Heritiera littoralis, Rhizophora apiculata, Sonneratia alba* and *Xylocarpus granatum* contributed to the diversity of this zone. The highest tree was 15 m while the lowest was 1.5 m, with DBH values in the range 2.1 and 52 cm representing the minimum and maximum values, respectively.

Table 1. Dominance of mangrove vegetation in twelve sampling sites in Ranong, Thailand.

Study Site		Site No.	Species	No. of occurrences	No. of trees	Total basal area	Frequency	ativeRel frequency (RF)	Relative density (RD)	Relative basal area (RBA)	Important value (RF+RD+ RBA)
Ngaw	A*	1	*Rhizophora apiculata*	19	53	2620.22	95	50.00	66.25	73.93	190.18
	B	2	*Rhizophora apiculata*	13	37	2094.60	65	34.21	46.25	31.13	111.59
Rachakrud	A	3	*Avicennia marina*	13	30	3986.43	65	28.89	37.50	35.75	102.14
	B	4	*Avicennia officinalis*	11	24	7712.39	55	18.97	30.30	38.59	87.55
Bangben	A	5	*Ceriops decandra*	15	32	1083.03	75	32.61	40.00	25.92	98.53
	B	6	*Ceriops decandra*	16	32	1001.46	80	34.78	40.00	30.03	104.82
Banghin	A	7	*Bruguiera parviflora*	11	23	775.81	55	26.83	28.75	21.77	77.35
	B	8	*Rhizophora apiculata*	13	38	1294.28	65	31.71	47.50	27.84	107.05
Talaynog	A	9	*Bruguiera parviflora*	16	35	1517.59	80	36.36	43.75	23.02	103.13
	B	10	*ataRhizophora mucron*	17	29	2378.89	85	40.48	36.25	42.91	119.63
Hadsaykaow	A	11	*Rhizophora apiculata*	16	30	4696.72	80	35.56	37.50	46.75	119.81
	B	12	*Rhizophora apiculata*	17	52	4265.52	85	44.74	65.00	66.77	176.51

* A =PCQ perpendicular to the channel
B =PCQ parallel with the channel

Table 2. Dominance analysis of mangrove ecosystem using Ohsawa's model (1984).

Study sites		Sites no.	Dominant species	RBA %
Ngaw	*A	1	*Rhizophora apiculata*	73.93
	B	2	*Avicennia officinalis*	31.43
			Rhizophora apiculata	31.13
			Bruguiera parviflora	17.08
Rachakrud	A	3	*Avicennia marina*	35.75
			Xylocarpus moluccensis	20.09
			Sonneratia alba	17.20
	B	4	*Avicennia officinalis*	38.59
			Sonneratia alba	25.22
			Avicennia marina	16.95
Bangben	A	5	*Rhizophora apiculata*	27.80
			Ceriops decandra	25.92
			mXylocarpus granatu	17.55
			Lumnitzera littorea	10.12
	B	6	*Rhizophora apiculata*	36.65
			Ceriops decandra	30.03
			Xylocarpus granatum	15.15
Banghin	A	7	*Xylocarpus granatum*	37.96
			Bruguiera parviflora	21.77
			Ceriops tagal	19.42
			Rhizophora apiculata	18.40
	B	8	*s granatumXylocarpu*	33.41
			Rhizophora apiculata	27.84
			Sonneratia alba	21.98
Talaynog	A	9	*Rhizophora apiculata*	39.65
			Rhizophora mucronata	25.15
			Bruguiera parviflora	23.02
	B	10	*Rhizophora mucronata*	42.91
			Rhizophora apiculata	38.22
Hadsaykaow	A	11	*lataRhizophora apicu*	46.75
			Rhizophora apiculata	41.32
	B	12	*Rhizophora apiculata*	66.77
			Rhizophora mucronata	23.94

* A = PCQ perpendicular to the channel
B = PCQ parallel with the channel

Table 3. The percentage relative in twelve sampling basal areas of mangrove tree species.

Name of species (family)	Mangrove Forest Site											
	Ngaw		Rachakrud		Bangben		Banghin		Talaynog		Hadsaykaow	
	*A	B	A	B	A	B	A	B	A	B	A	B
Aegiceras corniculatum (Myrsinaceae)	1.24			0.23								
Avicennia alba (Avicenniaceae)		8.03	0.26	9.11								
Avicennia marina (Avicenniaceae)			35.75	16.95	0.40	10.10						
Avicennia officinalis (Avicenniaceae)	6.80	31.34	4.90	38.59					5.58	1.23	6.80	6.55
Bruguiera cylindrical (Rhizophoraceae)	3.36	0.66	0.68	0.38		0.60	0.50					0.45
Bruguiera gymnorrhiza (Rhizophoraceae)			3.85									
Bruguiera parviflora (Rhizophoraceae)	7.81	17.08	8.82	1.46		3.24	21.77	0.39	23.02	15.03	3.77	1.54
Ceriops decandra (Rhizophoraceae)	0.97	1.39			25.92	30.03					0.63	0.66
Ceriops tagal (Rhizophoraceae)	0.76	2.44					19.42	4.68	2.25	2.62	0.09	
Excoecaria agallocha (Euphorbiaceae)				0.47	3.80	0.91						
Heritiera littoralis (Sterculiaceae)					0.50							
Lumnitzera littorea (Combretaceae)				2.32	10.12							
Lumnitzera racemosa (Combretaceae)					7.23							
Rhizophora apiculata (Rhizophoraceae)	73.93	31.33	1.37	2.89	27.80	36.65	18.40	27.84	39.65	38.22	46.75	66.77
Rhizophora mucronata (Rhizophoraceae)		6.71	17.20			3.32	1.18	11.70	25.15	42.91	41.32	23.94
Scyphiphora hydrophyllacea (Rubiaceae)					6.68							
Sonneratia alba (Sonneratiaceae)			6.85	25.22			0.76	21.98				
Xylocarpus granatum (Meliaceae)	5.12		20.09	2.38	17.55	15.15	37.96	33.41	1.09			0.09
Xylocarpus moluccensis (Meliaceae)		1.14	0.22						3.26		0.63	

* A =PCQ perpendicular to the channel
B =PCQ parallel with the channel

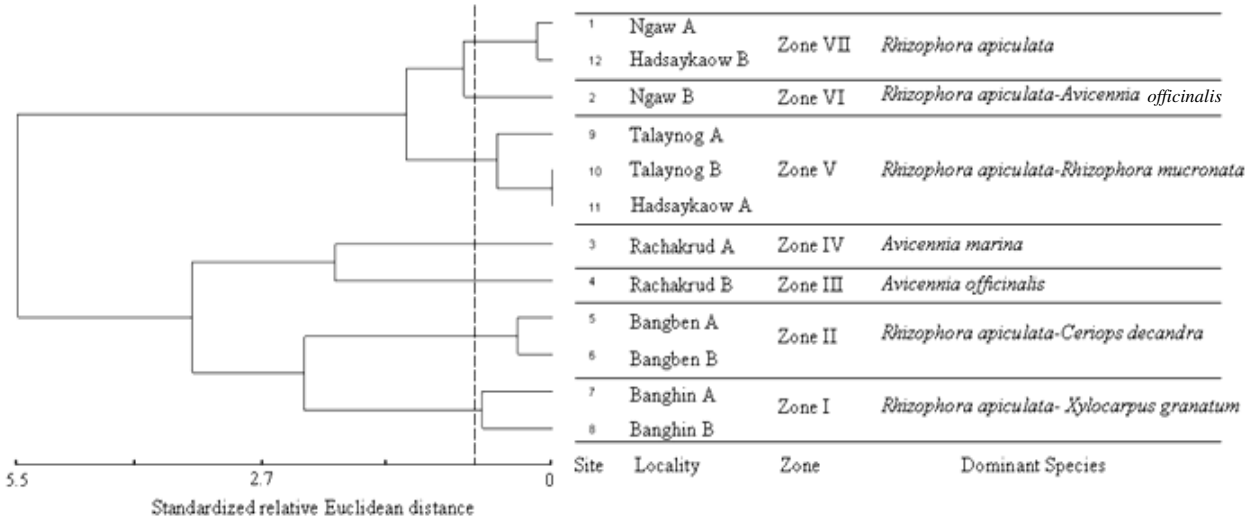

Figure 3. Dendrogram of 12 localities obtained by Ward's method using the standardised relative Euclidean distance. The 7 zones based on relative basal area (RBA) are: Zone I) *Rhizophora apiculata - Xylocarpus granatum*; Zone II) *Rhizophora apiculata - Ceriops decandra*; Zone III) *Avicennia officinalis*; Zone IV) *Avicennia marina*; Zone V) *Rhizophora apiculata - Rhizophora mucronata*; Zone VI) *Rhizophora apiculata - Avicennia officinalis*; and Zone VII) *Rhizophora apiculata*.

Zone IV. *Avicennia marina* Zone. This zone shared the condition and location of Zone III, as it was also at the Rachakrud (site A) in the Mueang district (Figure 3). However, Zone IV represents the PCQ that ran perpendicular to the channel. Although the zone was different in orientation, the soil in this zone was also sandy. Zone IV was named after the dominant species, *A. marina.* This zone exhibited diversity among the mangrove vegetation with the presence of trees such as *Avicennia alba, A. marina, A. officinalis, Bruguiera cylindrica, B. gymnorrhiza, B. parviflora, Rhizophora apiculata, R. mucronata, Sonneratia alba* and *Xylocarpus granatum*. Consequently, aquatic and non-aquatic animals such as fish, crabs and birds were found because of the availability of various trees that suited their needs. *Avicennia marina* had an RBA value of 35.75 % (Table 3). The maximum tree height was 17 m and the minimum was 3 m. The highest DBH value recorded was 44.3 cm while the lowest was 4.6 cm.

Zone V. *Rhizophora apiculata-Rhizophora mucronata* Zone. This zone (Figure. 3) is composed of three 3 study sites. Based on UTM projection, Talaynog A and B shared coordinates at 434784E and 1037286N while Hadsaykaow A had coordinates 444351E and 1062783N. Both study sites are located at the Suk Samran district of Ranong. Talaynog was found to have a sandy soil despite its distance from the beach. The Talaynog sites are located in front of a canal that leads to the bay. The sea current was responsible for the sand mixture in the soil of this zone. *Rhizophora apiculata* and *R. mucronata* adapts very well to the condition of this zone. These dominant species occupied most of the zone having RBA values of 46.75 % and 42.91 %, respectively (Table 3). Trees in the zone had a maximum height of 17 m and a minimum of 1.5 m. The highest DBH value recorded was 30.2 cm while the lowest was 1.4 cm.

Zone VI. *Rhizophora apiculata-Avicennia officinalis* Zone. This zone (Figure 3) is located at Ngaw B, which is a section of the Mueang district in Ranong. The coordinates of this zone are 450261E and 1091349N, defined by UTM projection. *Rhizophora apiculata* and *A. officinalis* inhabit most of the zone with RBA values of 31.33 % and 31.34 %, respectively (Table 3). Ranong Biosphere Reserve is located within the zone; hence, government officials have their conservation and ecotourism activities in this zone. The maximum height of mangrove trees in this zone was 15 m and the minimum was 1.8 m. The highest DBH value was recorded at 33.3 cm while the lowest was 1.1 cm.

Zone VII. *Rhizophora apiculata* Zone. This is the only zone (Figure 3) to include two different sites in Ranong. It comprises of Ngaw A at Mueang district (450261E and 1091349N) and Hadsaykaow B at Suk Samran (444351E and 1062783N). The Hadsaykaow site of this zone is farthest from the sea. The distance however did not prevent beach sand from reaching the site. The tsunami had forced the sand from the beach to mix with the soil of this zone. Under this condition, *Rhizophora apiculata* is the most dominant species having an RBA of 73.93 % (Table 3). The trees in this zone had a maximum height of 17 m and a minimum of 2 m. The highest DBH value in this zone was recorded at 30.4 cm while the lowest was 0.6 cm. This zone is characterized by extreme values in both height and DBH as it shares the highest value with zones IV and V while also being found to have the lowest DBH value among all zones.

DISCUSSION

Rhizophora apiculata was the most dominant mangrove species in Zones I, II, V, VI and VII (Figure 3). This result is consistent with PCQ data (perpendicular to and parallel with the channel). *Rhizophora apiculata* has a strong and solid trunk and is useful in building construction in Ranong. *Rhizophora apiculata* can be used in building complex structures such as houses or simple equipment like rafts or fishing rods. The dominance of this mangrove tree suggests security in shelter and the availability of equipment for the local fishermen. Furthermore, *R. apiculata* provides high quality charcoal. Charcoal is used as an alternative cooking fuel to enhance palatability of fish or crabs.

The notable volume of *R. apiculata* shows that it is the most adapted species in Ranong as similarly reported by Aksornkoae *et al*. (1993) and Primavera (1995). The fruit of *R. apiculata* has good adaptations in terms of dispersal and establishment. It can almost grow and thrive on its own. Therefore, *R. apiculata* can be considered as the best option in the efforts of mangrove reforestation.

The most dominant mangrove species in Zones III and IV (Figure 3) were *Avicennia officinalis* and *A. marina,* respectively. Although fewer in number when compared to the *R. apiculata*, they still provide ecological and practical benefits to the ecosystem and surrounding communities. The dominance of *A. marina* is mainly due to the fact that it has a strong tolerance against salinity. It is not one of the options for locals as a source of construction materials because the trunk of *A. marina* is too rigid to be considered as a source of lumber and, the bark secretes a liquid that causes skin irritation. *Avicennia marina* could be considered in reforesting mangrove forests that are situated near the sea.

The dominance of *A. marina* minimizes the negative effects of natural disasters such as winds and tsunamis. The large circumference of *A. marina* provides a solid shield buffer for the people and

serves as habitat for different types of birds (Aksornkoae *et al*., 1993).

Since *A. marina* can tolerate high salinity, it usually flourishes nearest to the sea and can enhance the growth and survival of crabs and clams as food sources in the fishing trade. Crabs and clams cling to *A. marina* as they are brought in by the tide, while during ebb tide they either continue to cling to the tree or crawl about on the sandy beaches. This leaves them susceptible as prey to other animals or as a food or trade source for man.

Avicennia officinalis exhibits the same traits and contributes the same benefits as the *A. marina*. In addition, *Avicennia officinalis* can thrive better in soil with good drainage located near channels, corresponding to the reports of Aksornkoae *et al*. (1992) and Smith and Smith (2004).

Ceriops decandra was discovered to be one of the most dominant mangrove trees in Zone II (Figure 3). The dominance of *C. decandra* was attributed to the well-developed muddy flats. Although it can be described as a relatively small mangrove tree, the dominance of *C. decandra* has ecological and socioeconomic significance. Its fine prop roots prevent shoreline destruction. Furthermore, the prop roots trap the sediments and result to an increase in land area, therefore creating space for the growth of more *C. decandra*. *Ceriops decandra* forest is also an important habitat of crabs, molluscs, and small fishes. Its existence in Zone II (Figure 2) is a good indicator of the potential abundance in food sources and prosperity in the fishing trade.

In general, the mangrove forest ecosystem of Ranong, Thailand has been established to comprise 7 mangrove zones. Dominant species have been identified and recommendations may be used for future rehabilitation and reforestation initiatives.

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REFERENCES

Aksornkoae, S., G.S. Maxell, S. Havanond and S. Panichsuko 1992. Plants in mangroves. Chalongrat Co., Ltd. Bangkok, Thailand. 119 pp.

Aksornkoae, S., N. Paphavasit and G. Wattayakorn. 1993. Mangroves of Thailand: Present status of conservation, use and management. In: The Economic and Environmental Values of Mangrove Forests and their Present State of Conservation in the South-East Asia/Pacific Region. International Society for Mangrove Ecosystems, Okinawa, Japan, pp. 83–133.

Anongponyoskun, M. and P. Doydee. 2006. The changed coastline in Loi Island, Chonburi Province during 1997 to 2004. *Kasetsart J. (Nat. Sci.)*. 40: 249-253.

Ashton, E.C., D.J. MacIntosh and P.J. Hogarth. 2003. A baseline study of the diversity and community ecology of crab and molluscan macrofauna in the Sematan mangrove forest, Sarawak, Malaysia. *Journal of Tropical Ecology*. 19: 127–142.

Barbier, E.B. and I. Strand. 1998. Valuing mangrove-fishery linkages. *Environmental Resource Economic.* 12: 151-166.

Buot, I.E. Jr. 1994. The true mangroves along San Remigio Bay, Cebu, Philippines. *The Philippine Scientist*. 31: 105-120.

Doydee, P., P. Kamwachirapitakand I.E. Buot Jr. 2008. Species composition of a mangrove ecosystem in Ranong, Thailand, *The Thailand Natural History Museum Journal.* 3(1): 51-58.

Ellison, A.M. 2008. Mangrove ecology-application in forestry and costal zone management, *Aquatic Botany*. 89: 77.

Field, C.D. 1996. Restoration of mangrove ecosystems. International Society for Mangrove Ecosystems, Okinawa, Japan. 250 pp.

Hutchings, P. and P. Saenger. 1987. Ecology of mangroves. University of Queensland Press, St. Lucia, Australia, 388 pp.

Janssen, R. and J.E. Padilla. 1999. Preservation or conservation? Valuation and evaluation of a mangrove forest in the Philippines. *Environmental and Resource Economics.* 14: 297-331.

Lee, S.Y. 1998. Ecological role of grapsid crabs in mangrove ecosystems: implications for conservation. *Marine and Freshwater Research.* 49: 335–343.

Macintosh, D.J., E.C. Ashton and V. Tansakul 2002. Utilisation and knowledge of biodiversity in the Ranong biosphere reserve, Thailand. ITCZM Monograph No. 7. Series 2002. 29 pp.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York, 547 pp.

Ohsawa, M. 1984. Differentiation of vegetation zones and species strategies in the subalpine region of Mt. Fuji. *Vegetation*..57: 15-52.

Ong, J.E. 1995. The ecology of mangrove conservation and management. *Hydrobiologia.* 295:343–341.

Othman, M.A. 1994. Value of mangroves in coastal protection. *Hydrobiologia*. 285: 277-282.

Primavera, J.H. 1995. Mangroves and brackish water pond culture in the Philippines. *Hydrobiologia.* 295: 303-309.

SAREC. 1995. SAREC regional marine science program. The Swedish Agency for Research Cooperation with Developing Countries. Stockholm. Sweden. 39 pp.

Sasekumar, A., V.C. Chong, M.U. Leh and R.D. Cruz. 1992. Mangroves as habitat for fish prawns. *Hydrobiologia.* 247: 195-207.

Smith, R.L. and T.M. Smith. 2004. Elements of ecology, Pearson education, Benjamin Cummings, San Francisco. 682 pp.

Tri, N.H., W.N. Adger and P.M. Kelly. 1998. Natural resource management in mitigation climate impacts: the example of mangrove restoration in Vietnam. *Global Environment Change.* 8: 49-61.