Mangrove Vegetation Zones in Ranong Coastal Wetland Ecosystem, Thailand

Puvadol Doydee[1] and Inocencio E. Buot Jr[2]

ABSTRACT

Mangrove zonation in Ranong coastal wetland ecosystem was conducted from December 2007 to February 2008 using the Point Centered Quarter (PCQ) method to determine vegetation zones and dominant mangrove species. Mangrove vegetation zones were evaluated using cluster analysis particularly the standardized relative Euclidean distance. 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*. The dominant mangrove species in Zones I, II, V, VI and VII was *Rhizophora apiculata*, while *Avicennia officinalis* and *A. marina* were the dominant species in Zones III and IV, respectively. We recommended that dominant native species be utilized for mangrove habitat restoration and mangrove biodiversity corridor establishment in a linear pattern in Ranong coastal landscape, Thailand.

Key words: mangrove vegetation zones, dominant species, coastal wetlands, biodiversity conservation and management

INTRODUCTION

Coastal wetland ecosystems are rich with biodiversity of fauna and flora, particularly mangrove forests. They are dominated by various species of trees, shrubs and herbs capable of growth and reproduction in brackish and seawater (Aksornkoae *et al*., 1992; Smith and Smith, 2004; Doydee *et al*., 2008). Straddling the land and sea, mangrove contributes 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; Macintosh *et al*., 2002; Ashton *et al*., 2003; Ellison, 2008). Mangroves provide natural resources in terms of timber as well as fisheries. Furthermore, they are important breeding and nursery grounds for shrimp, crab and marine fish (Sasekumar *et al*., 1992; Barbier and Strand, 1998).

[1] Research and Development Institute, Kasetsart University Chalermphrakiat Sakonnakhon Province Campus, Muang District, 47000, Thailand
[2] Institute of Biological Sciences, College of Arts and Sciences and School of Environmental Science and Management, University of the Philippines Los Banos, College, Laguna, 4031 Philippines

Mangroves offer important indirect services such as shoreline stability and water quality. They trap nutrients and sediments from river runoffs from the uplands and transport them to coastal waters (Buot Jr., 1994; Field, 1996; Janssen and Padilla, 1999; Anongponyoskun and Doydee, 2006; Ellison, 2008; Doydee, 2009).

During the 2004 tsunami, Ranong coastlines were severely damaged in terms of loss of human lives and properties. However, it was observed that the presence of the dense mangrove forest could somehow mitigate the negative impact of tsunami commonly ravaging the coast. Thus, the purpose of this study was to examine mangrove vegetation and zonation pattern in Ranong coastal zone. It is hoped that the study can provide a baseline data in planning for appropriate mangrove rehabilitation strategy along the Andaman coast in Ranong, Thailand. Mangrove rehabilitation is for coastal barriers; therefore, each zone of mangrove patches should be linked together as biodiversity corridor in the form of linear pattern.

MATERIALS AND METHOD

Study area

The study was conducted in Ranong, Thailand from December 2007 to February 2008 and the location coordinates are 434784-452553E and 1037286-1091349N as defined by the Universal Transverse Mercator (UTM) coordinate system. Ranong has long expanses of sandy beaches, unspoiled natural forests, waterfalls, parks, and a biosphere reserve area. Three districts were selected based on accessibility, size of mangrove patches and associated elements such as channels and distance. These were Mueng, Kapoe and Suk Samran. Two sites were selected from each district namely: Mueng (Ngaw [1] and Rachakrud [2]), Kapoe (Bangben [3] and Banghin [4]), and Suk Samran (Talaynog [5] and Hadsaykaow [6]) (Figure 1).

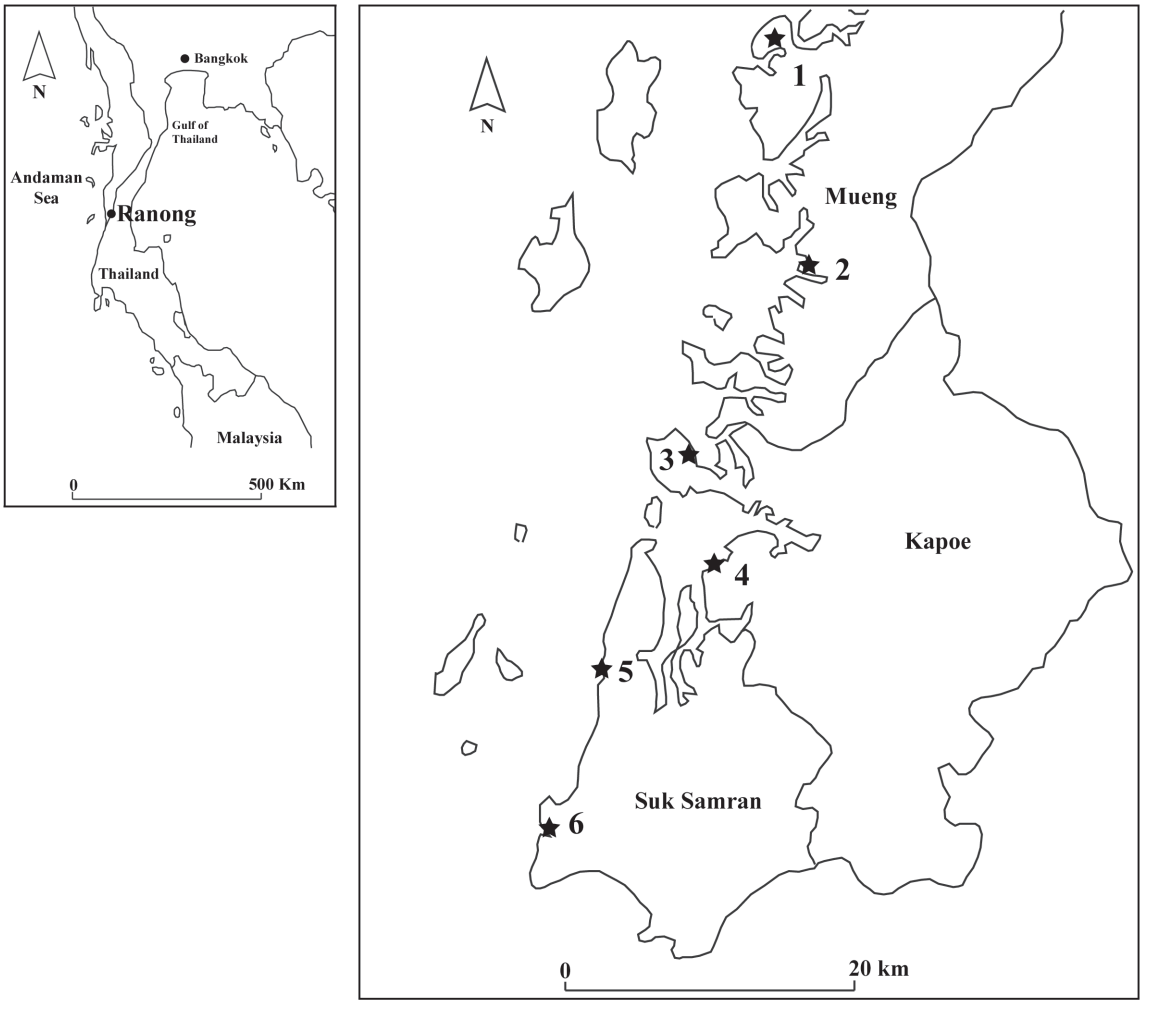

Figure 1. The study area in Ranong mangrove landscape, Thailand, namely Mueng (Ngaw [1] and Rachakrud [2]), Kapoe (Bangben [3] and Banghin [4]) and Suk Samran (Talaynog [5] and Hadsaykaow [6]).

Within each site, samples of mangrove flora species were investigated from two directions, i.e. the line transects running perpendicular to (first direction) and with (second direction) the channel. The diameter at breast height (DBH) and the height of mangrove trees were recorded. Mean annual temperature recorded from 1998 to 2007 in Mueng, Ranong was 27.46^{o}C with a mean annual rainfall of 4,127 mm (Figure 2). The highest rainfall in Ranong was in August, while the lowest rainfall was in January (Doydee and Jaitrong, 2008).

Data collection and measurement

Identification of mangrove vegetation species (960 individuals) were done at six study sites (a total of 12 sub study sites). The

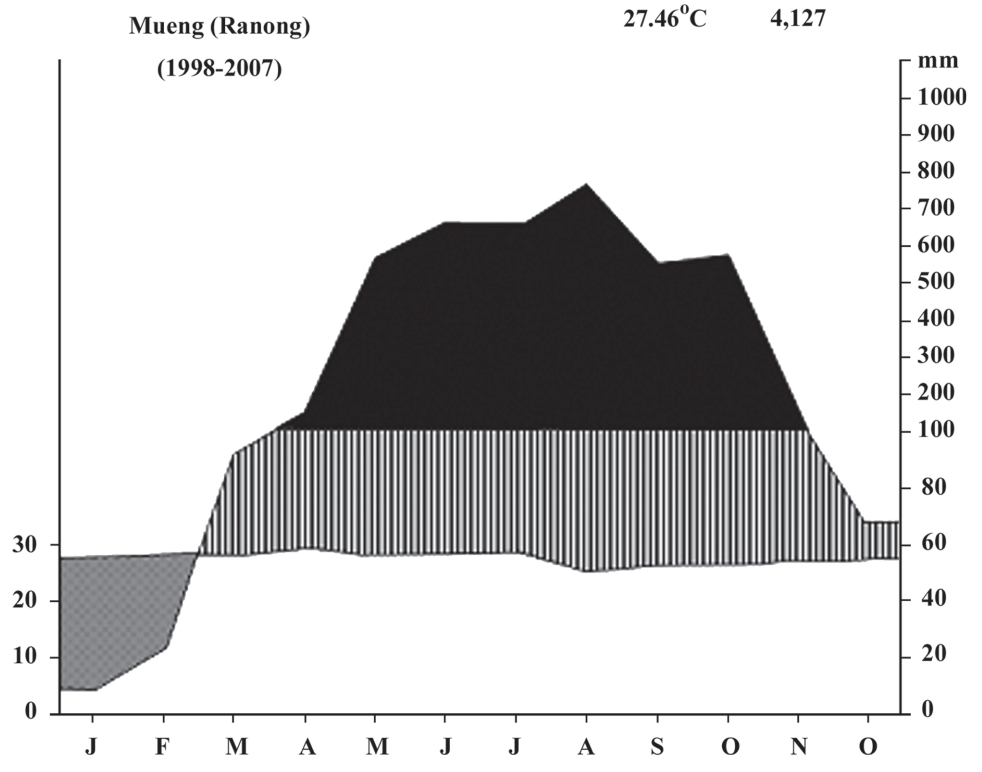

Figure 2. Climograph for Mueng, Ranong Province, the nearest weather station to Ranong mangrove wetland ecosystem

localities of every sampling site were recorded and measured using Global Positioning System (GPS). The Point Centered Quarter (PCQ) method of Mueller-Dombois and Ellenberg (1974) was used to study species composition.

Determining 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 = the deviation, X_i = the actual percent share (RBA values) 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, $\overline{X}$ = the ideal percent share based on the aforementioned model, X_j = the percent share of the remaining species (U), and N = the total number of species.

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

Overview of mangrove stands of all study sites and zonation of mangroves in Ranong, Thailand are presented in Figure 3. The dominant species among mangrove vegetation in sampling sites are presented in Table 1. Tables that were noted with A and B refer to the PCQ line orientation where A means perpendicular to and B means parallel with the channel of each sampling site.

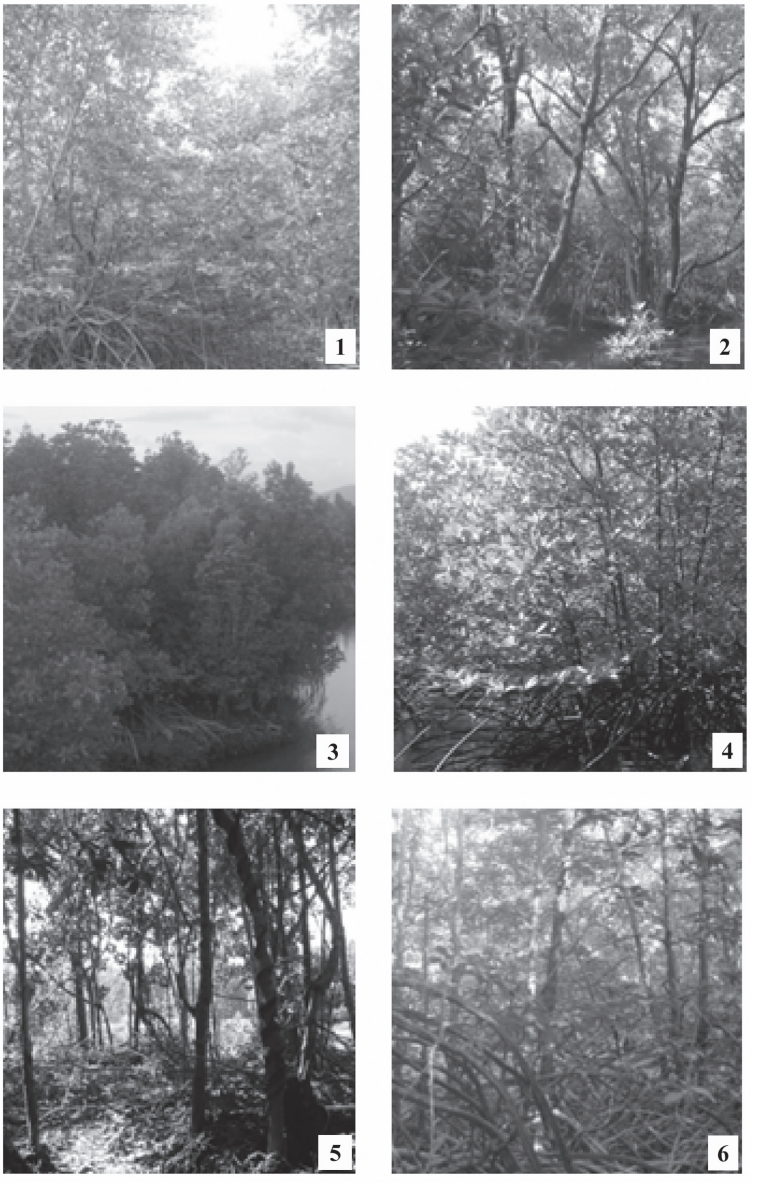

Figure 3. Overview of mangrove stands of all study sites and zonation of mangroves in Ranong, Thailand: Ngaw [1]; Rachakrud [2]; Bangben [3]; Banghin [4]; Talaynog [5] and Hadsaykaow [6]

Table 1. Dominance of mangrove vegetation in the twelve sampling sites in Ranong, Thailand from December 2007 to February 2008

Study Site		Sub Site no.	Species	No. of occurrences	No. of trees	Total basal area (cm)	Frequency	Relative frequency (RF)	Relative density (RD)	Relative basal area (RBA)	Importance 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	*Rhizophora mucronata*	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 transect ran perpendicular to the channel for 20 points and investigated with 25 m distance for each point
B =PCQ transect ran parallel with the channel for 20 points and investigated with 25 m distance for each point

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%) (Table 1).

The importance values (IV) show 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 a particular site (Table 1). Data of dominance analysis of mangrove ecosystem using Ohsawa's model (1984) based on RBA are shown in Table 2. *Rhizophora apiculata* was found in 10 sites out of the 12 sites.

Cluster analysis determined seven 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 4).

Zone I. *Rhizophora apiculata - Xylocarpus granatum* Zone. *Rhizophora apiculata* and *Xylocarpus granatum* were the main species in the mangrove forest in Banghin (Figure 4). Its location coordinates are 438415E and 1047968N (UTM). Found in the Kapoe district, this site was found to be the most inaccessible because of the considerable distance from the sea and muddy substrate. 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 therefore was 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 DBH value was at 35 cm while the minimum was at 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 4) 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 the rare occurrences of *Avicennia marina*, *Bruguiera cylindrica* and *Heritiera littoralis* seemed to have created an ideal habitat for benthos and fishes. However, the abundance of fishery resources depends upon several factors such as salinity and food sources. 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 0.9 cm.

Zone III. *Avicennia officinalis* Zone. Zone III is composed of a single sampling site, Rachakrud (site B) in Mueng district, Ranong (Figure 4). Its coordinates are 452553E and 1075827N. Contrary to most of the zones, Zone III is very near to the

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

Study Site		Sub Site 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
			Xylocarpus granatum	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	*Xylocarpus granatum*	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	*Rhizophora apiculata*	46.75
			Rhizophora mucronata	41.32
	B	12	*Rhizophora apiculata*	66.77
			Rhizophora mucronata	23.94

* A = PCQ transect ran perpendicular to the channel for 20 points and investigated with 25 m distance for each point
B = PCQ transect ran parallel with the channel for 20 points and investigated with 25 m distance for each point

Table 3. The percentage relative basal area (RBA) of mangrove tree species in the twelve sampling sites, Ranong, Thailand

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 cylindrica (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 transect ran perpendicular to the channel for 20 points and investigated with 25 m distance for each point
B = PCQ transect ran parallel with the channel for 20 points and investigated with 25 m distance for each point

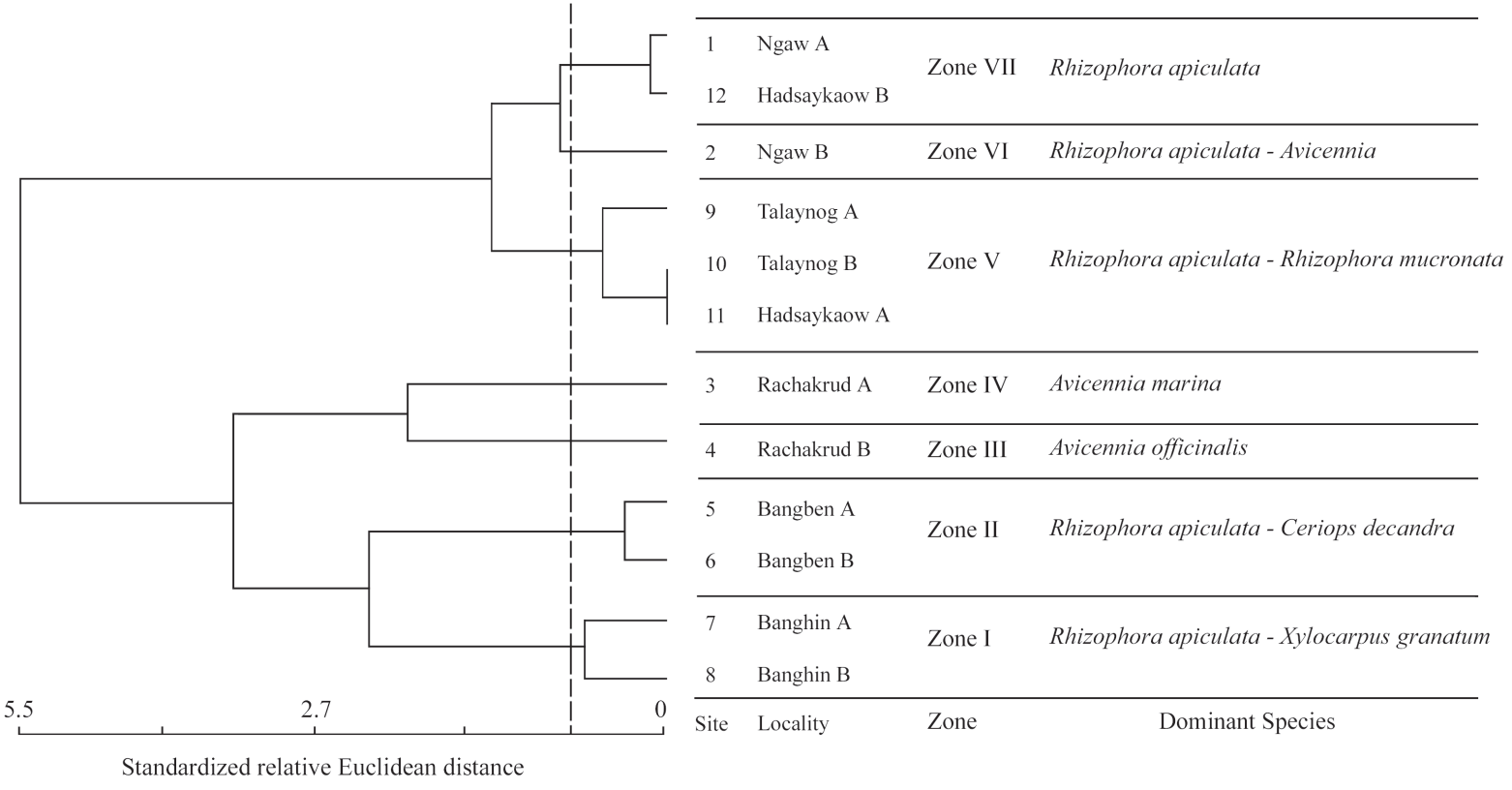

Figure 4. Dendrogram of 12 localities obtained by the Ward's method using standardized relative Euclidean distance. The seven zones based on relative basal area (RBA) are:
Zone I) *Rhizophora apiculata - Xylocarpus granatum*;
Zone II) *Rhizophora apiculata - Ceriops decandra*;
Zone III) *Avicennia officinalis*;
Zone IV) *Avicennia marina*;
Zone V) *Rhizophora apiculata - Rhizophora mucronata*;
Zone VI) *Rhizophora apiculata - Avicennia officinalis*; and
Zone VII) *Rhizophora apiculata*

sandy beach. Thus, the substrate is sandy and more saline. These conditions contributed to the dominance of *A. officinalis* as this mangrove tree exhibits a high tolerance to salinity. Although *A. officinalis* is the dominant species in this zone, its RBA 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.

Zone IV. *Avicennia marina* Zone. This zone shared the condition and location of Zone III, as it was also identified at Rachakrud (site A) in the Mueng district (Figure 4). However, Zone IV represents the PCQ that ran perpendicular to the channel. Though 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 benthos, fish and birds were found because of the condition of the forest i.e. being pristine or dense or productive may bring about a high diversity of mangrove dependent fauna. *Avicennia marina* had 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 4) is composed of three study sites. Based on UTM coordinates, Talaynog A and B shared coordinates at 434784E and 1037286N while Hadsaykaow A had coordinates at 444351E and 1062783N. Both study sites are located at the Suk Samran district of Ranong. Talaynog was found to have a sandy substrate despite its distance from the beach. The Talaynog sites are located along the canal leading to the bay. The currents were responsible for mixing sand in the substrate in this zone. *Rhizophora apiculata* and *R. mucronata* adapt 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). The maximum tree height of 17 m and the minimum of 1.5 m were recorded in this zone. 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 4) is located at Ngaw B, which is a section of the Mueng district in Ranong. The coordinates for this zone is 450261E and 1091349N (UTM). *Rhizophora apiculata* and *A. officinalis* inhabit most of the zone with RBA values of 31.33 and 31.34 %, respectively (Table 3). Since the Ranong Biosphere Reserve is located within the area, conservation and ecotourism activities have been carried out by governmental officials

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 4) to include two different sites in Ranong. It comprises of Ngaw A at Mueng district (450261E and 1091349N) and Hadsaykaow B at Suk Samran (444351E and 1062783N). The Hadsaykaow site of this zone is farthest from the sea. *Rhizophora apiculata* is the most dominant species having an RBA of 73.93 % (Table 3). The mangrove trees in this zone had a maximum height of 17 m and a minimum of 2 m. The highest DBH value of 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

All study sites are in RAMSAR site, with two sub-types of mangroves identified in Ranong Province. They include the *Avicennia-Sonneratia* communities and the *Rhizophora-Bruguera-Xylocarpus* communities (OEPP, 2001). Such species were also found in this research and majoring was simply classified into two sub-types namely, the *Avicennia* communities (Zones III and IV) and the *Rhizophora-Xylocarpus-Ceriops-Avicennia* communities (Zones I, II, V, VI and VII) (Figure 4).

Rhizophora apiculata was the most dominant mangrove species in Zones I, II, V, VI and VII (Figure 4). This result is consistent with PCQ data (perpendicular to and parallel with the channel). *R. apiculata* has a strong and solid trunk and is useful in building construction in Ranong. It 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 availability of equipment for the local fishermen (Primavera, 1995; Doydee and Buot Jr., 2010). Furthermore, *R. apiculata* provides high quality charcoal. Charcoal is used as an alternative fuel for cooking to enhance palatability of fish, shrimps, squids and crabs, among others.

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 Doydee and Buot Jr. (2010). The fruit of *R. apiculata* has good adaptation 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 (Doydee, 2009).

The most dominant mangrove species in Zone III and IV (Figure 4) were *Avicennia officinalis* and *A. marina*, respectively. Although fewer in number as compared to *R. apiculata*, they still provide ecological and practical benefits to the coastal wetland ecosystem and surrounding communities. The dominance of A. marina is mainly due to the fact that it has a strong tolerance with salinity; though it is not one of the options of the locals as a source of construction materials. This is because the trunk of

A. marina is too rigid to be a source of lumber. Also, the bark secretes a liquid that causes skin irritation. *A. marina* could be considered in reforesting mangrove forests located near the sea.

However, the dominance of *A. marina* minimizes the negative effect of natural disasters such as winds and tsunamis, among others. 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 growth and survival of crabs or 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 the sandy beaches. This leaves them susceptible as prey to other animals or as a food or trade source for man.

A. officinalis exhibits the same traits and contributes the same benefits as *A. marina*. In addition, *A. officinalis* can thrive better in soil with good drainage located nearby 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 4). 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 sediments which results in an increased inland area, therefore creating space for its growth. *C. decandra* forest is also an important habitat of crabs, shells, and other small fish. Its existence in Zone II (Figure 4) is a good indicator of potential abundance in food source and prosperity in the fishing trade. However, not only the species of mangrove but also the diversity and condition of the forest including other environmental factors have direct correlation to the abundance of fishery resources.

The mangrove vegetation in the Ranong coastal wetland ecosystem where this study was conducted has been established to comprise of seven mangrove zones. Mangrove dominant native species such as *Rhizophora apiculata*, *Avicennia officinalis* and *A. marina* have been identified and were recommended to be taken into account for mangrove habitat restoration and biodiversity corridor establishment. Each zone should be connected to each other (Doydee, 2009) in a linear pattern with the participation of local governmental units (LGUs) and local communities (Doydee and Buot Jr., 2010). Thus, the mangrove zonation research in this study can be used to improve mangrove rehabilitation and restoration in the Ranong coastal wetland ecosystem

ACKNOWLEDGEMENT

The authors thank the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), College, Laguna, Philippines for funding research and the Kasetsart University, Thailand, for the laboratory and field

facilities. We had fruitful discussions with Dr. Nestor T. Baguinon, Dr. Nathaniel C. Bantayan and Dr. Carmelita M. Rebancos from the University of the Philippines, Los Baños (UPLB), Philippines.

LITERATURE CITED

Aksornkoae, S., Maxell, G.S., Havanond, S. and Panichsuko, S. 1992. **Plants in mangroves.** Chalongrat co., ltd. Bangkok, Thailand, 119 pp.

Aksornkoae, S., Paphavasit, N. and Wattayakorn, G. 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, 83–133 pp.

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

Ashton, E.C., Macintosh, D.J. and Hogarth, P.J. 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 Strand, I. 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. 2009. Mangrove Patch Restoration option in the Ranong Coastal Zone. ***Naresuan Agriculture Journal 12 (Suppl.)***: 362-367.

Doydee, P. and I.E. Buot Jr. 2010. Mangrove Habitat Restoration and Management in Ranong Province, Thailand. ***Proceeding of Coastal Zone Asia-Pacific Conference and World Small-Scale Fisheries Congress,*** Bangkok, Thailand. 9 pp.

Doydee, P. and W. Jaitrong. 2008. The Status of economical aquatic fauna in Ranong mangrove ecosystem after tsunami encroachment. ***Journal of Forestry Management*** 2 (4): 98-106.

Doydee, P., Kamwachirapitak, P.and Buot, I.E. Jr. 2008. Species composition of a mangrove ecosystem in Ranong, Thailand, ***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 Saenger, P. 1987. **Ecology of mangroves.** University of Queensland Press, St. Lucia, Australia, 388 pp.

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

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

OEPP. 2001. **Report on the Nation Environmental Status.** Office of Environmental Policy and Planning (OEPP), Thailand. 340 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.

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

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

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