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STRUCTURE OF MANGROVE FOREST AT AMPHOE KHLUNG CHANGWAT CHANTABURI, THAILAND

ห้ามนำออกนอกห้องสมุด

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ลักษณะโครงสร้างของป่าชายเลน อำเภอขลุง จังหวัดจันทบุรี

ป่าไม้ชายเลน หรือป่าเลนหรือเป็นที่รู้จักกันโดยทั่ว ๆ ไปในนามของป่าไม้โกงกางนั้น เป็นกลุ่มของสังคมพืช ซึ่งส่วนใหญ่จะเป็นพวกไม้ไม่ผลัดใบที่มีลักษณะทางสรีรวิทยา และการปรับตัวทางโครงสร้างที่คล้ายคลึงกัน ลักษณะที่เด่นชัดคือ พื้นที่ขึ้นอยู่จะต้องมีน้ำทะเลท่วมถึง มีดินเป็นดินเลนหรือเลนปนทราย ซึ่งมีพันธุ์ไม้ที่สำคัญ เช่น โกงกาง, แสม, ตะบูน ลำพูนเป็นต้น จะพบทั่ว ๆ ไปตามชายฝั่งทะเล บริเวณปากน้ำ อ่าว ทะเลสาป และเกาะต่าง ๆ ของประเทศในแถบโซนร้อน โดยเฉพาะในประเทศไทยมีป่าชนิดนี้อยู่ประมาณ ๑,๙๕๔,๔๖๕ ไร่ หรือ ๓,๑๒๗ ตารางกิโลเมตร โดยขึ้นอยู่ในจังหวัดต่าง ๆ ตามชายฝั่งทะเลหรืออ่าวไทย ถึง ๒๒ จังหวัด

ป่าชายเลนนับว่าเป็นสภาพสิ่งแวดล้อมที่ธรรมชาติได้สร้างสรรไว้อย่างยอดเยี่ยม ทั้งนี้เพราะได้เกิดขึ้นด้วยการอยู่ร่วมกันของพันธุ์ไม้และพันธุ์สัตว์ และได้พิสูจน์ตัวมันเองแล้วว่าเป็นพื้นที่ที่มีกำลังผลิตสูงโดยเฉพาะพลังงานอินทรีย์ซึ่งเกิดขึ้นมากกว่าที่ตัวมันใช้ และเป็นประโยชน์ต่อมนุษย์ทั้งในด้านการใช้ไม้และเป็นแหล่งที่สัตว์น้ำนานาชนิดอาศัยอยู่

แม้ว่าป่าชายเลนจะให้เอนกประโยชน์ทางเศรษฐกิจที่เห็นอยู่ทุกวันนี้และยังจะสำคัญยิ่ง ๆ ขึ้นไปในอนาคต แต่ความรู้หรือเรื่องราวที่ว่าด้วยระบบนิเวศน์วิทยาของป่าเลนยังมีน้อยเหลือเกิน การศึกษาถึงลักษณะโครงสร้างของป่าชายเลนนี้ จะเป็นส่วนหนึ่งที่จะได้ทราบถึงรายละเอียดของสังคมพืชเป็นต้นว่าการกระจายของพันธุ์ไม้ และลักษณะอื่น ๆ เพื่อเป็นพื้นฐานในการศึกษาระบบนิเวศน์วิทยาของป่าเลนในด้านอื่นต่อไป สำหรับผลการศึกษาลักษณะโครงสร้างของป่าเลนในท้องที่อำเภอขลุง จังหวัดจันทบุรี พอสรุปได้ดังนี้คือ

การแบ่งโซนของพันธุ์ไม้ซึ่งคือความหนาแน่นของพันธุ์ไม้สำคัญที่ขึ้นอยู่ในพื้นที่ต่าง ๆ จากชายฝั่งน้ำลึกเข้าไปจนถึงป่าบก การแบ่งโซนพอสรุปได้ คือ

๑. ไม้พวกโกงกางทั้งโกงกางใบใหญ่ (*Rhizophora mucronata*) และโกงกางใบเล็ก(*R. apiculata*) จะขึ้นอยู่หนาแน่นบนพื้นที่ใกล้ฝั่งน้ำ โกงกางใบเล็กจะมีอยู่หนาแน่นมากกว่าโกงกางใบใหญ่ และมีจาก (*Nypa fruticans*) ขึ้นอยู่หนาแน่นในบางท้องที่ใกล้ฝั่งน้ำ

๒. ถัดจากโซนของไม้โกงกางจะเป็นพวกไม้แสม (*Avicennia sp*) และประสัก(*Bruguiera spp*) ขึ้นอยู่ สำหรับไม้แสมบางทีจะพบขึ้นอยู่ติดกับชายฝั่งน้ำบางในบางท้องที่

๓. ลึกเข้าไปจากโซนของไม้แสมและประสักจะพบกลุ่มไม้ตะบูน(*Xylocarpus spp*) ขึ้นอยู่หนาแน่น พื้นที่ไม้พวกนี้ขึ้นอยู่หนาแน่นเลนมักจะแข็ง

๔. ในพื้นที่บางแห่งจะพบว่าพวกไม้โปรง(*Ceriops spp*) และฝาด (*Lumnitzera spp*) ขึ้นอยู่ถัดจากโซนของไม้แสมและประสักแต่ดินมักจะเป็นเลนไม่แข็งนักและมีน้ำท่วมถึงเสมอ

๕. โซนสุดท้ายซึ่งขึ้นอยู่บนพื้นที่ซึ่งเป็นเลนแข็ง และมีน้ำทะเลท่วมถึงในบางครั้งบางคราว เมื่อระดับน้ำทะเลขึ้นสูงสุดจะเป็นพวกไม้เสม็ด (*Melaleuca leucadendron*) ขึ้นอยู่อย่างหนาแน่น และโซนนี้ถือว่าเป็นแนวติดต่อระหว่างป่าเลนกับป่าบก

๖. พวกปรง(*Acrostichum aureum*) จะพบทั่ว ๆ ไปในป่าเลน แต่จะมีขึ้นอย่างหนาแน่นในพื้นที่ถูกถาง

จากการศึกษา diversity index โดยใช้ Shannon diversity index พบว่าป่าชายเลนที่อำเภอขลุงมีค่าประมาณ ๐.๘๙๒๐ ซึ่งสูงกว่าค่า diversity ซึ่งหาได้จากป่าชายเลนในรัฐฟลอริด้าทางใต้ ซึ่งมีค่าเพียง ๐.๔๐๗๐ เท่านั้น อันนี้ก็แสดงให้เห็นว่าป่าที่อำเภอขลุงมีพรรณไม้หลายชนิดและเจริญเติบโตได้ดีกว่าป่าที่ฟลอริด้า

ปริมาตรของไม้ซึ่งห่างจากพื้นที่ชายฝั่งทะเลลึกเข้าไปถึงป่าบก พบว่าปริมาตรไม้ค่ำในพื้นที่อยู่ใกล้ฝั่งน้ำ (๓๐ – ๓๕ ลูกบาศก์เมตรต่อแฮกแตร์) ซึ่งเป็นพื้นที่ปกคลุมด้วยไม้

โกงกางเป็นส่วนใหญ่ ทั้งนี้เพราะป่านี้ได้เคยผ่านการทำไม้มาแล้ว ป่าจะมีปริมาตรสูงสุด (๑๒๐ ลูกบาศก์เมตรต่อแอกแตร์) ในพื้นที่ตอนกลางซึ่งมีไม้พวกตะบูนและแสมขึ้นอยู่ ทั้งนี้เพราะว่าไม่ได้นำไม้ดังกล่าวนี้ออกมาใช้ประโยชน์เลย ส่วนพื้นที่ลึกเข้าไปจนถึงป่าบกซึ่งมีไม้เสม็ดขึ้นอยู่หนาแน่นนั้นจะให้ปริมาตรประมาณ ๔๐ – ๔๘ ลูกบาศก์เมตรต่อแอกแตร์

อย่างไรก็ดี เพื่อการปรับปรุงป่าเลนในบริเวณแห่งนี้ให้ดีขึ้น น่าจะได้ใช้ประโยชน์จากไม้อื่นนอกจากโกงกาง เช่น พวกแสม และตะบูนให้เต็มที่ ทั้งนี้นอกจากจะมีประโยชน์จากไม้โดยตรงแล้ว ยังจะช่วยให้การสืบพันธุ์ตามธรรมชาติของไม้โกงกางขยายไปอย่างกว้างขวางอีกด้วย นอกจากนี้การจัดการปลูกสร้างสวนป่าก็ควรจะดำเนินการต่อไป โดยเฉพาะในพื้นที่ซึ่งป่าถูกทำลายและปกคลุมด้วยพวกปรงในอัตราที่มากขึ้นอีกด้วย สำหรับการจัดป่าเพื่อประโยชน์อื่น ๆ เช่น การทำนากุ้ง ก็ควรจะได้จัดทำและแบ่งพื้นที่ให้แน่นอน

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INTRODUCTION

The term "mangrove" generally embodies two different concepts (Du, 1962). It refers to an ecological group of evergreen plant species belonging to several families but possessing marked similarity in their physiological characteristics and structural adaptations to similar habitat preferences. It also implies a complex of plant communities fringing the sheltered tropical shores. Such communities usually have a border of trees which are normally species of Rhizophora associated with other trees and shrubs growing in the zone of tidal influence both on the sheltered coast itself and inland lining the banks of estuaries.

Schimper (1903) defined "mangrove" to include the formation below the high tide mark. Consequently, he and many others have used the term "tidal forest" as a synonym of "mangrove forest." However, the true mangrove may form only a part of the whole intertidal zone. They often occur above and below the intertidal zone as well as on coasts where there are no tides at all (Davis, 1940; Richards, 1952).

Chapman (1970) stated that the global distribution of mangrove vegetation has been represented by two major groupings, the mangrove of the old world or Indo-Pacific region, and those of the New World and West Africa. The distribution of the former extends from East Africa, up the Red Sea, around India, Southeast Asia, the Philippines, and up to Southern Japan, to Australia, New Zealand, and Oceania as far East as Samoa. The New World mangroves occupy the Atlantic coast of Africa and the Americas, along with a small area on the Pacific Coast of Central and South America.

Banijbatana (1957) explained that in Thailand, the mangroves occur on the sheltered muddy shores and low lying boggy ground of river and stream estuaries along both banks of the Gulf of Thailand and on the West Coast of the peninsula. The total area that is occupied by mangroves is approximately 164,539 ha. About four-fifths of this area is located on the West Coast of the peninsula bordering the Indian Ocean. The remaining area is found on the East Coast (22,780 ha) and West Coast (6,580 ha) of the Gulf of Thailand.

In Thailand, the mangrove forest plays a very important economi role. This results primarily because of the:

1. Potential for mangrove exploitation and its ultimate effect on the ecosystem;
2. Apparent close relationship between the presence of mangrove forest areas and the accompanying high productivity of the associated coastal waters;
3. Growing interest in aquaculture programs associated with the mangroves;
4. Increased demand for land and for the reclamation of coastal areas involving mangrove forests.

Such potential uses raise many significant questions about the management of the mangrove ecosystem in Thailand. These include:

1. What is the actual extent of the mangrove area and what are the structural and functional characteristics of the mangrove ecosystem?
2. How can the mangroves be intensively managed for timber, tannins, and charcoal production?
3. What relationships exist between the fisheries within and near the mangroves areas and the actual functioning of the

mangrove ecosystem?

The answers to these questions are not available at the present time. The investigation reported here can provide some answers to these questions.

The objective of this investigation is to provide information on the structure of the mangrove ecosystem especially dealing with species zonation, diversity and stem-volume.

DESCRIPTION OF THE STUDY AREA

Location

The study was located in the mangrove forests at Amphoe Khlung, Changwat Chantaburi on the Northeastern coast of the Gulf of Thailand. The area is between 12° and 13° north latitude; and between 102° and 103° longitude, east of Greenwich. The area is approximately 19,000 ha (or 119, 355 rais) and is representative of a very well developed mangrove forest in Thailand. The study area and extent of mangrove forest at Amphoe Khlung, Changwat Chantaburi is shown in Figure 1.

Vegetation

More than 27 genera of trees and other plants are commonly found in the mangroves at Amphoe Khlung. Among these genera, *Rhizophora* is the most abundant and has the widest geographical distribution. The most dominant and valuable species normally belong to the Rhizophoraceae while the accessory species consist of several unrelated families. They are:

Family	Scientific Name
Rhizophoraceae	*Rhizophora candelaria*, *R. mucronata* *Bruguiera cylindrica*, *B. conjugata* *Ceriops roxburghiana*, *Kandelia rheedii*
Sonneratiaceae	*Sonneratia caseolaris*, *S. alba*

AMPHOE KHLUNG, CHANGWAT CHANTABURI

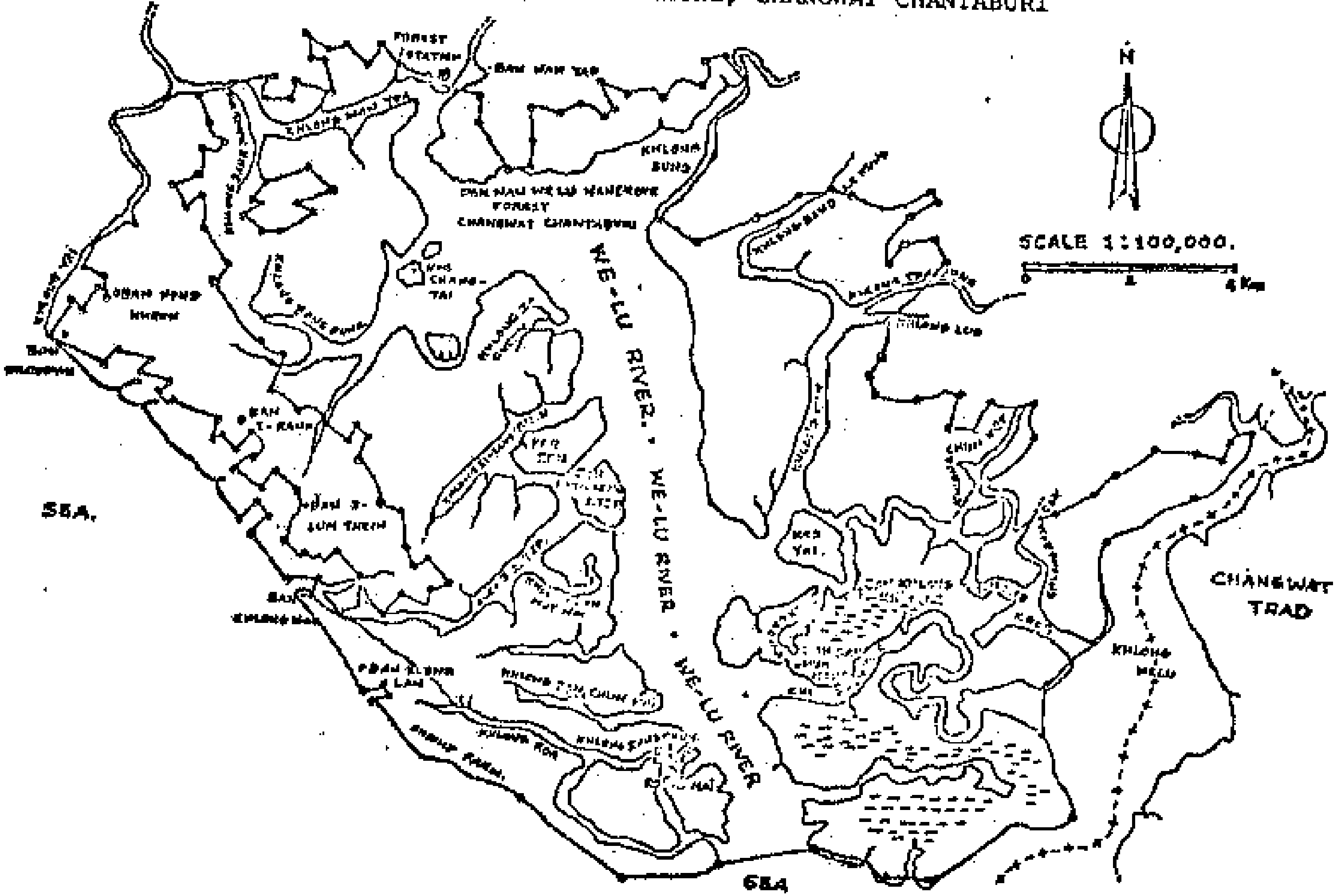

Figure 1 Mangrove forest at Amphoe Khlung, Changwat Chantaburi.

Verbenaceae	*Avicennia alba*, *A. officinalis*, *Clerodendrum inerme*
Meliaceae	*Xylocarpus obovatus*, *X. moluccensis*
Myrsinaceae	*Aegiceras corniculatum*
Caesalpiniaceae	*Caesalpinia didyna*, *Intsia retusa*
Palmae	*Nypa fruticans*, *Phoenix paludosa*
Sterculiaceae	*Heritiera littoralis*
Combretaceae	*Lumnitzera racemosa*
Myrtaceae	*Melaleuca leucadendron*
Apocynaceae	*Cerbera odollam*
Acanthaceae	*Acanthus ebracteatus*, *A. ilicifolus*
Euphorbiaceae	*Excoecaria agallocha*
Polypodiaceae	*Acrostichum aureum*
Rubiaceae	*Litosanthes biflora*, *Scyphiphora hydrophyllacea*
Malvaceae	*Hibiscus tiliaceus*, *Thespesia populnea*
Lauraceae	*Cassytha filiformis*
Ebenaceae	*Diospyros ferrea*
Flagellariaceae	*Flagellaria indica*

Climate

The climate at Amphoe Khlung, Changwat Chantaburi, is profoundly influenced by the monsoon but both regional and micro-climates are undoubtedly important in the mangrove ecosystem. Regional climate dictates which plant species may develop in an area, whereas micro-climate determines soil properties, particularly salinity, which is effected by temperature-rainfall interaction. It also influences competition between species. The regional climate needs to be considered in relation to the original establishment of the present vegetative patterns but the micro-climate provides conditions for seedling development in established communities and therefore influences the maintenance of existing patterns.

Regional climatic data for Changwat Chantaburi were obtained from records kept by the Meteorological Department, Ministry of Prime Minister. Data for 1951 to 1970 are presented in Figure 2. Micro-climate data are fragmentary, and have not been presented in detail.

Temperature -- Mean monthly temperatures vary between 25° C and 29° C. Highest values occur from February to May, when temperature may exceed 33° C. Minimum temperatures of about 20° C occur in December and January.

Rainfall -- The highest rainfall in Changwat Chantaburi generally occurs from May to October, with September being the wettest month (590 mm). The least rainfall occurs from November to April, with December and January being the driest months of the year (11 and 13 mm respectively).

Atmospheric moisture -- Relative humidity is generally lowest from November to April, with an average value of about 77%. This results from the high temperatures and low rainfall during these months. The mean monthly value for the remaining six months is about 87%.

Evaporation -- In Changwat Chantaburi, evaporation is most extreme from November to April when rainfall is at its lowest and temperatures are

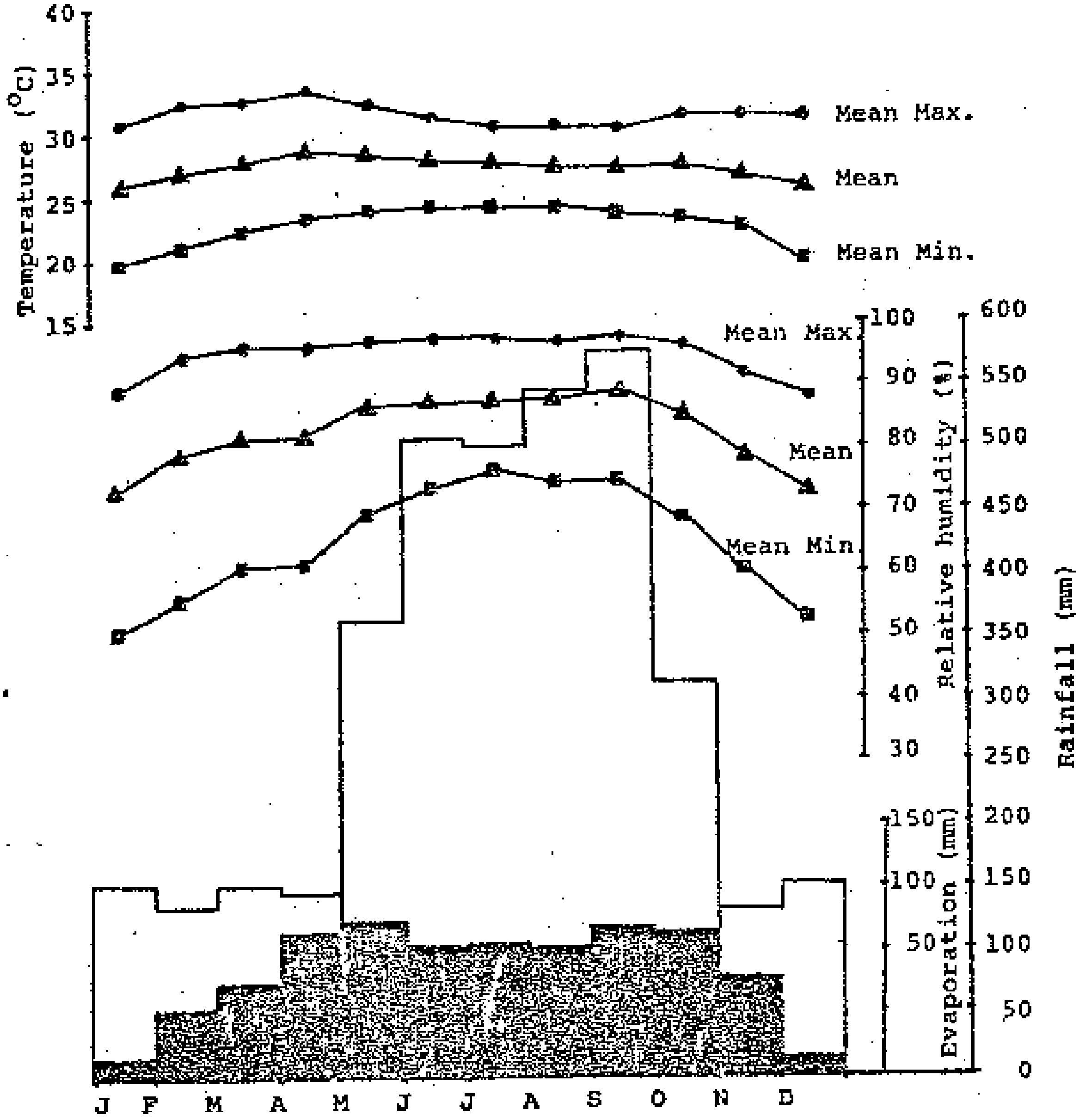

Figure ˆ Climatological data at Changwat Chantaburi, 1951-1970 (from Meteorological Department, Ministry of Prime Minister, Bangkok, Thailand).

rising to their monthly maximums. The highest evaporation values, 151 mm, occur in December and January, and the lowest in August, 102 mm.

Soils

Surface soil properties of samples taken at varying distances from estuary to land in the mangrove community at Amphoe Khlung, Changwat Chantaburi, are presented in Table 1.

The physical characteristics vary with distance from estuary to land. Sand content increases and is silt and clay percentage decrease in the more landward zones. However, soil textures are essentially all sandy loams throughout the study site except in the zone at the edge of the estuary where it is a loam.

pH -- The surface soil in the more landward zones tends to be more acid than those nearest to the estuary. The pH of the inland soils remains relatively constant, 3.6 to 3.9. Soils at the estuary bank have a pH of 4.3.

Cation eschange capacity -- All cation exchange capacities seem to be relatively low, with the highest value being about 11 meg/100 gm soil at the estuary bank. The lowest value is about 4.0 meg/100 gm soil at the landward areas. This reflects the relatively low level of organic mater content in these soils. The organic matter of the surface soil was found to be greater at the estuary edge than inland, where the values range from about 12.5 to 2% respectively.

Soil chlorinity -- Soil chlorinity is primarily of tidal flooding. The chlorinities of the surface soils at different distances from the estuary varied from the highest occurring at the estuary bank, 1.69% to the lowest concentration, 0.42% at 140 m from the bank.

Table 1. Surface soil properties in the mangrove community at Amphoe Khlung, Changwat Chantaburi in 1975.

Distance from estuary to land, m	Sand %	Silt %	Clay %	Texture	pH	C.E.C.* meg/100 gm soil	O.M. %	N %	P ppm	K ppm	Cl⁻ %
0	47.6	37.8	14.6	loam	4.3	10.95	12.49	0.62	10.0	118.0	1.69
20	61.2	21.9	16.9	sandy loam	3.6	6.12	5.38	0.27	5.1	132.5	0.94
60	58.1	21.9	20.0	sandy loam	3.9	11.20	9.01	0.45	6.1	139.8	0.98
100	72.5	20.2	7.3	sandy loam	3.7	6.90	4.32	0.22	5.4	135.8	0.82
140	68.9	20.9	10.2	sandy loam	3.8	4.00	2.14	0.12	2.8	190.0	0.42

Nitrogen, phosphorus and potassium content of the surface soils indicate that where nitrogen and phosphorus decrease in the more landward zones, the potassium content, in contrast, increases.

A comparison of surface soil properties of natural mangrove communities at different locations in Thailand is shown in Table 2. The studies included in Table 2 have found soil textures to vary from sandy loam to clay loam along with various soil chemical properties.

Tides

The daily rise and fall of water regulates many features of the mangrove community, e.g. floristic zonation, soil and water properties, and faunal distribution. Tides at Changwat Chantaburi, as recorded by the Hydrographic Department, Royal Thai Navy, in 1974 - 1975 are diurnal, with an average amplitude of 2.4 m for spring tides and 0.6 m for neap tides. The entire mangrove area is generally under water at high spring tides but the water at neap tides barely reaches the fringes of the trees.

Table 2. A comparison of surface soil properties of **natural** mangrove communities at different areas in Thailand.

Location	Sand %	Silt %	Clay %	Texture	Bulk Density gm/cc.	pH	O.M. %	N %	P ppm	K ppm	C.E.C. meg/100 gm soil	Cl^- %	Reference
Amphoe Kabur, Ranong	62.5	27.7	9.8	Sandy loam	0.86	4.4	5.84	0.29	10	210	-	0.65	Senisrisanti-1975
Amphoe Takoapa, Pang-nga	56.1	29.5	14.4	Sandy loam	0.78	3.3	9.38	0.47	2	157	-	0.95	Senisrisanti-1975
Amphoe Meong, Krabi	14.5	66.3	19.2	Silty clay	0.67	5.2	10.71	0.55	12	900	-	1.70	Senisrisanti-1975
Amphoe Seekoa, Trang	60.3	28.4	11.3	Sandy loam	0.66	3.2	7.25	0.36	3	163	-	1.04	Senisrisanti-1975
Amphoe Kantang, Trang	58.7	30.3	11.0	Sandy loam	0.97	4.5	7.56	0.38	6	448	-	0.60	Senisrisanti-1975
Amphoe Langoo, Satul	21.0	49.6	29.4	Clay loam	0.67	3.7	11.37	0.57	10	474	-	1.99	Senisrisanti-1975
Amphoe Khlung, Chantaburi	-	-	-	-	0.30	5.5	12.80	0.64	2.2	-	-	-	Zinke, 1975
Amphoe Kraburi Pang-nga	65.7	21.3	13.0	Sandy loam	-	4.0	4.80	0.24	4.5	151.5	6.9	0.69	Kongsangchai-1973
Amphoe Khlung, Chantaburi	61.6	24.5	13.9	Sandy loam	-	3.9	6.67	0.34	5.9	143.2	7.8	0.97	Aksornkoae, 1975

Review of Literature

Mangrove Forest Types

Classification procedures for mangrove vegetation have received little attention. Snedaker and Pool (1973) classified the mangrove forests of southern Florida into five main types: basin forest, riverine forest, fringe forest, overwash forest and dwarf forest. Type distinction was based on the apparent differences in species composition and gross structure of the mangrove forests. These appear to be strongly controlled by local patterns of tides and terrestrial surface drainage.

Zonation

In most mangroves, different species dominate certain bands or Zones which are clearly delimited from the others. This characteristic zonation pattern results from differences in the rooting and growth of seedlings resulting from competitive advantages which each species has along a gradient from below the low water to above the high water lines (Kuenzler, 1968).

Macnee (1968) reviewed the three zonation schemes that have been proposed for the mangroves of the Indo-Pacific region. One was based on frequency of inundation (Watson, 1928), another on soil salinity (de Hamn, 1931), and a third on the generic name of the dominant trees (Walter and Steiner, 1936). Similar schemes have been applied to the mangroves of the New World by David (1940) and de la Cruz (1969) who compared the zonation of mangrove stands in the eastern and western hemisphere.

Factors That Effect Zonation

Physical and Chemical Soil Factors

The Physical and chemical aspects of the soil play an important part in mangrove zonations. According to Macnae (1968), the soil of Rhizophora forests is usually soft. Macnae and Kalk (1962) report that in Mocambique, Rhizophora prefers wetter, stickier soils. Steenis(1958) points out that Rhizophora mucronata is a typical species of deep soft mud while Gledhill (1963) found it, along with Avicennia marina and Brugueira gymnorrhiza, growing in sandy areas in Aberdeen Creek. Although Avicennia marina was also found in muddy substuata, Rhizophora was found by Gledhill (1963) to be typical of riverside swamps on deep silt, which is consistent with Jordan's (1964) findings that Rhizophora is specific for fresh, soft silty soils while Avicennia germinanz colonizes the more firm and sandy soils along the coastal areas in Sierra Leone.

Certain species of mangroves grow only in well-drained soils (Macnae, 1968). These include Xylocarpus spp, and such mangrove associations as Osbornia octodonta and Pemphis acidula. Avicennia marina, particularly at its distributional limits, becomes taller in the better drained soils of the creek edge than further inland. It develops on beaches where the substratum is relatively firm due to partial tidal wave action. According to Macnae and Kalk (1962), Avicennia prefers a low slope angle from the beach and can tolerate sandy soils in the landward edge or muddy in the seaward fringe. Carter (1959) states that as the soil profile changes from coastal accretion to firmer mud, conditions become unfavorable for Avicennia and more favorable for Bruguiera. Chapman and Ronaldson (1958) pointed out that Avicennia grows taller on the well-drained banks out that *Avicennia* grows taller on the well-drained banks close to streams in New Zealand.

Further inland, the *Avicennia* stand passes into a forest of *Bruguiera cylindica* which characteristically develops on stiff blue clay soils with a shallow humus layer and a well-marked surface drainage but no creek. *Bruguiera parviflora* is an "opportunist" species which frequently becomes established in a cleared area and then may act as a nurse tree to the colonization of *Rhizophora spp* or other *Bruguiera spp* (Watson, 1928). *Bruguiera cylindrica* and *B. parviflora* from a 15-20 m high understory in the *Rhizo-phora* forests of Southeast Asia (Macnae, 1968). Macnae (1968) also found that *Bruguiera* forests of Southeast Asia frequently support a herb-layer of the fern *Acrostichum spp*.

Generally, species of *Ceriops* develop into dense thickers or as undergrowth on the well-drained soils. In Southeast Asia, *Ceriops tagal* and *Ceriops dacandra* form an understory in the *Rhizophora* forest (Macnae, 1968). The *Nypa* association constitutes one of the most important features of the mangrove throughout the Southeast Asiatic and Indo-Malaysian regions. It occurs in Waterlogged soils (Macnae, 1968). The fern *Acrostichum* is widely distributed in marshy, brackish habitats, usually associated with mangroves (Chapman, 1970).

Drew (1974) stated that the fern *Acrostichum aureum* may reach a height of 3-4 m under favorable conditions in South Vietnam. This fern is associated with the palm *Phoenix paludosa* and the mangrove species of *Excoecaria agallocha*, *Derris trifolia* or *Ceriops spp*. The fern population tended to increase on the upland sites where the soil is drier (Vu-Van-Cuong, 1964).

Navalkar and Bharucha (1948, 1949) describe the chemical and physical factors of the mangrove soil in India. Cause and effect relations of zonation are not explicitly stated. However, Navalkar and Bharucha (1950) concluded that neither calcium carbonate, humusnor pH play an important part in determining plant associations. They felt the main considerations are related to amounts of exchangeable bases in the soil.

The role of organic matter in mangrove soils or with-in specific species zonation has received little study. The most comprehensive study was made by Giglioli and Thornton (1965). Their studies showed that the organic carbon content. (1.724x % organic matter) of mangrove soils is derived from water-borne residues, leaf litter and decomposing root material. The organic carbon content of soils under young <u>Rhizophora</u> was found to be 3.7% while that under old <u>Rhizophora</u> was between 3.3% and 5.7% These values are less than the 11.9% organic carbon found under <u>Rhizophora</u> by Hesse (1961). Hesse also showed the organic carbon under <u>Avicennia</u> to be approximately 5.5%

A great deal of information exists on the pH of mangrove soils, mostly those under <u>Rhizophora</u>. The soil under <u>Rhizophora</u> is generally reported to be slightly more basic than under <u>Avicennia</u> when in a saturated state. The acidity difference is reversed, however, and more marked upon soil drying. Hesse(1961), found the pH of <u>Rhizophora</u> soils in Sierra Leone, West Africa, to be 6.6 as compared to 6.2 in the soil under <u>Avicennia</u>. Upon soil drying under aerobic conditions, the pH of <u>Rhizophora</u> soils fell to 4.6 while that of <u>Avicennia</u> soils decreased to but 5.7. Thornton and Giglioli (1965) in a study of the mangrove swamp of

Keneba, Lower Gambia River basin, found the pH of soils under Rhizophora to be approximately 5.0 while under Avicennia the pH was 6.0 or above. Tomlinson (1957) also reported low pH values for soils under Rhizophora of the mangrove forest in Sierra Leone. Zinke (1974) found that Rhizophora in South Vietnam occurred on soils with a pH of 7.2 Other chemical soil properties that my have an effect on the zonation of mangrove forest are related to levels of nitrogen, phosphorus and sulphur. Hesse (1961) analyzed mangrove soils for total nitrogen, ammonia nitrogen and nitrate nitrogen under Rhizophora, Avicennia and recently deposited tidal alluvium. He found that the total nitrogen, ammonia nitrogen and nitrate nitrogen under Rhizophora was approximately 0.4400% 1 ppm and 1 ppm dry weight and under Avicennia to be 0.3900% 8 ppm and 2 ppm respectively. The total nitrogen, ammonia nitrogen and nitrate nitrogen concentration of the recently deposited tidal alluvium were 0.3500% 13 ppm and 1 ppm respectively.

Sulphur is readily evident in the soils of mangrove areas. The presence of hydrogen sulfide gas is quite noticeable upon removal of mangrove mud. Analysis of alluvium showed total sulphur to be 0.244% oven dry weight, soils under Rhizophora had 2.224% sulphur content and soils under Avicennia had 0.577% sulphur (Hesse, 1961). Thornton and Giglioli (1965) found differences in total free sulphur between the soils under young and old Rhizophora and Avicennia. In the young Rhizophora soils the amount of free sulphur increased sharply below the 6" level with the surface concentration being 2 mg/g soil and the underlying soil containing from 6-8 mg/g. Old Rhizophora soils also increased in free sulphur from a surface value of 4.5 mg/g to 7.8 mg/g at lower levels. The

Avicennia soils decreased in free sulphur from 9 mg/g at the surface to 6-8 mg/g throughout the profile.

Soil Water Salinity

Soil water salinity, a saline quality of soil and water, is another important factor influencing species zonation within the mangrove forest. Mangroves occur in regions of high, low or variable salinity. Salinity appears to be of importance not because the salt is essential for growth but because it reduces competition from other species (Kuenzler, 1968). This has been shown by Borman(1917), who grew species of _Rhizophora_, _Avicennia_ and _Leguncularia_ for two to three years in salt-free water or soils.

According to Davis (1940) the conclusions regarding the importance of salinity in mangroves are as follows: 1)Salinity fluctuates widely with seasonal rainfall; 2) Most of the mangroves are tolerant of a wide range of salinity. A brackish condition is most favorabel for optimum growth. 3) Zonation corresponds to seasonal salinity averages of the soil solution and surface water; 4) The soil solution usually is more saline and fluctuates less than the surface water; 5) The highest salinity is found where the water level is close ot the soil surface, and with a consequent high rate of evaporation; 6) Saline conditions of both surface water and soil water extend farther inland than the normal range of the tide. The low topographic relief of the land prevents rapid salt leaching.

Macnae (1968) gives the salinity tolerances of several of the mangrove species. _Avicennia marina_ appears to have the widest range of tolerance, with growth possible in almost fresh water or in soils with a water salinity exceeding 30% According to Jordan (1964) the Avicennia zone soils of Sierra Leone have a higher salinity because they are more permeable. Sonneratia alba, Sonneratia apetala, and Sonneratia griffithii are all found on the seaward fringe and would seem to prefer waters of near normal salinity. Sonneratia caseolaris only grows where the salinity is less than 10%.

Species of Bruguiera usually grow in those portions of the mangroves with salinities less than 25% Bruguiera porviflora reaches optimal growth with salinity levels of 20% Bruguiera sexangula prefers soils with a salinity of 10% or less. Bruguiera gymnorhiza has a salt tolerance of 10-25%. Species of Ceriops, particularly Ceriops tagal, will survive and grow where salinities exceed 30%

According to Watson's (1928) classification scheme, two types of Rhizophora forest occur in Malaya, Thailand, Southeast Asia, and the wetter parts of the Indonesian archipelago. Rhizophora mucronata lies behind a seaward fringe and passes backward and upstream along side a channel, river, or creek where water salinity of around 20% or more overflows the banks. It gives way to Rhizophora apiculata when water of salinity of less than 15% floods the forests. Chapman (1944) showed that on the Jamaican shoreline, Rhizophora mangle had a high optimum salt tolerance. Savory (1953) said that in West Africa, Rhizophora racemosa has often been reported to grow well in fresh water conditions but Rhizophora mangle has only been found associated with salt-swamp.

The different mangrove species have fairly specific tolerances. Outside these ranges, it appears that salinity acts as a limiting factor for growth (Steenis, 1958).

Drainage and Soil Moisture

The drainage characteristics of the soil influences the establishment and successional development of the mangrove forest. Drainage regulates such ecologically important factors as soil water chlorinity (Giglioli and King, 1966) and pH (Thornton and Giglioli, 1965; Hart, 1959). Chapman and Ronaldson (1958) have suggested that the height of Avicennia marina in New Zealand is controlled by the drainage of the underlying soil. Defferent genera of mangrove trees have been shown to require different soil drainage regimes. Thom (1967) found that Avicennia requires a higher, drier, and more compact soil than either Rhizophora or Laguncularia. On the other hand, he found Bruguiera to prefer only waterlogged soils.

Giglioli and King, 1966), measuring soil moisture, found that the surface soil under old Rhizophora had a moisture content from 43% to 196% (% by wt dry soil). Clarke and Hannon (1967) found their surface soils to have a moisture range of from 28.6% to 143.3% (% by wt dry soil), They also found the subsurface soil moisture to vary from 29.5% to 98.2% (% by wt dry soil) while Giglioli and King (1966) give no value but remarked that the underlying clays of Rhizophora soils have a more constant soil moisture content than the surface soils.

Frequency of Tidal Flooding

Frequency of tidal flooding is one of the most significant factors that help regulate species zonation of mangrove forest. Macnae (1968) states that the zones of trees in mangrove are associated with rising ground level and the resulting decrease in frequency of tidal flooding. This relationship forms the basis for Watson's (1928) inundation classes and for de Hann's (1931) water zone with salinity. Zone width is a function of the slope of the shore and the range of the tide.

The following is a summation of Macnae's (1968) description:

"Although the rate of rise and fall of the tide is highest when it is crossing the flats, the fact that it is crossing these flats causes a slowing down of the current and allows deposition here. When the water has reached the upper flats within the mangrove the flow is further impeded by the obstruction caused by the trees and their pneumatophores. The region whre those are most thickly developed is in the seaward fringes of Avicennia and of Sonneratia and within the Rhizophora forests, and these appear to be the region of greatest decomposition. Beyond the seaward fringes the bank of accretion sometimes slopes quite steeply, down to the mean sea-level. The soft, ill-consolidated soils are always waterlogged, and are reached by all or almost all tides. The soils are firm and well-consolidated at a point where tidal water no longer reaches them. The boundary between these soft and firm soils lies towards the upper margina of the Rhizophora forest."

The actual mechanisms by which the frequency of tidal flooding limits growth are not discussed. They are perhaps associated with species defferences in requirements for successful seedling establishment and with soil changes related to silt deposition.

Species Diversity

There are a few studies of species diversity of mangrove forests reported in the literature. Snedaker and Lugo (1973) determined the diversity index of the mangrove at Rookery Bay forest in South Florida. Diversity indices(H) were calculated by using the Shannon index for general diversity equation where $H = -\sum pi \log pi$ or $-\sum(\frac{Ni}{N}) \log (\frac{Ni}{N})$ (H is Shannon index; Ni is importance value for a specific species; N is total of importance values for all species and pi is importance probability for each species which is equivalent to $\frac{Ni}{N}$) (Odum, 1971). They found that the diversity indices from five plots were 0.4472, 0.4896, 0.2894, 0.3696 and 0.3228. The lowest value was where the black mangrove was dominant and highest value was found in the ecotone between the red and black mangrove. In general, diversity was relatively low in all plots.

Materials and Methods

The natural mangrove community at Amphoe Khlung, Changwat Chantaburi was selected for the study area. In the past, the area has been selectively cut but there has been no disturbance since approximately 1970. Ten transect lines, each approximately 100 to 150 m long, were established from the estuary to the land throughout the mangrove area. Distance between transect lines was variable depending upon species zonation and distribution.

A 5 x 20 m plot was laid out at 10 m intervals along each and at right angles to the transect lines. Trees within each plot larger than 5.5 cm in diameter at 10 cm above the root collar for _Rhizophora_ and at breast height for other species without prop roots were measured as follows:

a. number of individuals by species was determined by actual count.

b. diameter at 10 cm above the root collar and at breast height (dbh) was obtained by using a diameter tape.

c. total height was measured by using a regular meter tape and haga altimeter.

Trees smaller than 5.5 cm at 10 cm above the root collar for _Rhizophora_ and at breast height for other species within the plot were classified as seedlings. The number of seedlings by species for each plot was counted.

The species of undergrowth was also recorded for each plot.

The importance value for each tree species was calculated by the summation of the percentages of relative density, relative frequency and relative dominance, where:

$$\text{relative density} = \frac{\text{No. of individuals of species x}}{\text{Total of individuals of all species}} \times 100$$

$$\text{relative frequency} = \frac{\text{Frequency of species x}}{\text{Sum of frequency values for all species}} \times 100$$

$$\text{relative dominance} = \frac{\text{Basal area of species x}}{\text{Total basal area of all species}} \times 100$$

Frequency is defined as the probability of finding the species in any one plot. Basal area is the cross-sectional area of the tree at 10 cm above the root collar for Rhizophora and at the breast height for other species.

The Shannon index for species diversity was determined with the following equation:

$$H = -\sum\left(\frac{Ni}{N}\right)\log\left(\frac{Ni}{N}\right)$$

$$= -\sum Pi \log Pi$$

Where:

Ni = importance value for a specific species

N = total of importance values for all species

Pi = importance of probability for each species $\left(\frac{Ni}{N}\right)$

Comparison of the actual measured stem-volume of 180 trees of different size-classes with the volume estimated geometrically, assuming mangrove stems approximate either a cylinder or cone, indicated that estimates assuming conical geometry were in error by only - 17% whereas estimates assuming cylindrical geometry were in error by about + 65%. Tree stems were, therefore, assumed to approximate cones in geometry. The total stem-volume of each tree was obtained by multiplying the basal area (cross-sectional area)., measured at 10 cm above the root collar for Rhizophora, and at breast height for other species, by one half the total height. This estimate was then increased by 17% to adjust for the known error in assuming conical geometry.

Results and Discussion

Plant Zonation

The mangroves at Amphoe Khlung, Changwat Chantaburi, extend upwards just above the level of high water of neap tides almost to that of high water of ordinary spring tides. Different species tend to dominate certain bands or zones which are clearly demarked from the others. However, there are occasionally some areas where over-lapping does occur (Figure 3). These different zonation patterns may result from differences in species adaptations to adverse site factors such as: waterlogged soils, salinity, poor soil aeration, and strong prevailing seashore winds. Such adaptations are: the presence of stilt roots, pneumatophores, thick and leathery leaves with thick cuticle, water storage tissue, deep seated chlorenchyma, salt-secreting glands, fruits and seed capable of floating in water for a number of days without deterioration, and vivipary (Venkatesan, 1966).

The distribution of mangrove trees in this area can be described in the following manner. Along the margin of the estuaries and channels running through the mangrove, and where the soil surface is waterlogged and very muddy, pure stands of Rhizophora are found with roots arching into the water. The two common species are Rhizophora candelaria and R. mucronata. The former tends to be the more abundant and has a wider distribution than the latter. Occasional trees of Rhizophoras may also occur in the wetter, muddier areas in the middle of the thickets of other species. Nypa fruticans is also sparsely found in this zone but mostly along the stream margins.

The belts or zones of Bruguiera and Avicennia, variable in width, occur behing the zone of Rhizophora. Avicennia tends to be distributed in a well-defined zone, whereas

Table 3. Species diversity and density of mangrove trees in different areas from the estuary to the land at Amphoe Khlung, Changwat Chantaburi.

Distance from estuary to land, m	Species diversity $H=-\sum pi \log pi$	Number of Individuals per 0.1 ha										
		Rhizophora candelaria	*R. mucronata*	*Brugueira conjugata*	*Avicennia alba*	*Xylocarpus obovatus*	*X. moluccensis*	*Ceriops roxberghiana*	*Lumnitzera spp*	*Melaleuca leucadendron*	*Excoecaria agallocha*	Total
5	0.3073	180	46	2	-	-	-	-	-	-	-	228
20	0.4081	171	38	2	5	-	-	-	-	-	-	216
35	0.5042	82	-	81	28	1	-	-	-	-	-	192
50	0.6762	70	-	86	7	5	8	7	-	-	-	183
65	0.8030	56	-	25	-	49	7	25	3	-	3	168
80	0.7214	9	-	35	-	43	-	31	10	2	10	140
95	0.7139	12	-	30	-	34	-	27	14	5	3	125
110	0.5915	-	-	-	-	45	-	45	23	20	2	135
125	0.5667	-	-	-	-	45	-	47	17	25	-	134
140	0.5804	-	-	-	-	21	-	56	37	29	-	143

Study area total 0.8790

The importance values of the dominant species of mangrove forest at Amphoe Khlung, Changwat Chantaburi, were determined and plotted against the distances from the estuary to the land (Figure 4). The major species were Rhizophora candelaria, R. mucronata, Bruguiera conjugata, Avicennia alba, Xylocarpus obovatus, X. moluccensis, Ceriops roxburghiana, Lumnitzera spp, Melaleuca leucadendron and Excoecaria agallocha. Figure 4 indicates that the importance values of Rhizophora candelaria and R. mucronata were highest at the edge of the estuary (204 and 73 respectively) and tended to decline to zero at approximately 100 and 30 m from the edge of the estuary respectively.

Bruguiera had a very low value (6.7) at the edge of the estuary, and reached a peak where the importance value was 115 at abpit 50 m, and then gradually declined to zero at approximately 100 m. Avicennia had a well - defined zone between about 15 to 55 m and had the highest value (104) at 35 m from the estuary bank. Xylocarpus obovatus had a low importance value (4.6) at 35 m from the edge of the estuary and then increased to a peak (132) at around 95 m, and declined to 65 on the landward side. X. moluccensis was found approximately between 40 to 70 m from the edge of the estuary with the average importance value of 22. The distribution of Ceriops was similar to Lumnitzera since they were found about 50 m from the edge of the estrary with the importance values of 17 and 40 respectively. Both species gradually increased in the importance values (98 and 91 respectively) at 140 m, but the importance value of Ceriops markedly fell off somewhat at about 95 m (50) and then increased up to a value of 98 at 140 m from the estuary bank. Excoecaria had a well-defined zone found approximately between 60 to 115 m from the edge of the estuary with the average importance value of about

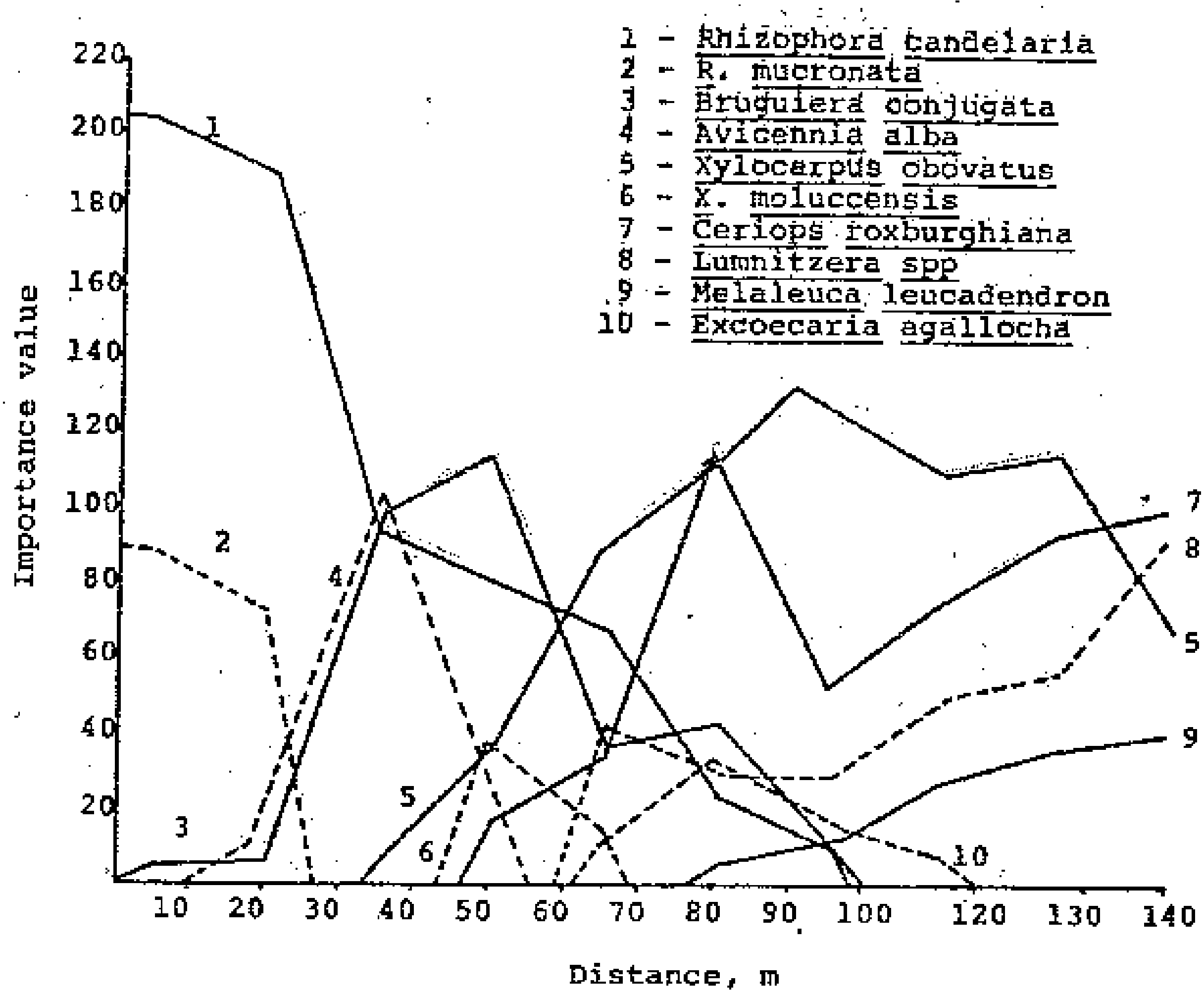

Figure .: Importance values of main species of mangrove forest at Amphoe Khlung, Changwat Chantaburi, as related to distance from the estuary to the land.

Melaleuca leucadendron had low importance value (7) at about 75 m and then the value gradually increased and reached to 40 on the inland side.

Stand Volume

The stand volume of the mangrove forest was determined at the different plot areas from the estuary edge towards the forest (Figure 15). Volumes are variable throughout the area, but data indicate that the values tend to increase from the mangrove margin to the area between the mangrove edge and the landward sites, then the volumes decrease on the areas nearest to the inland side. Stand volume in each area is dependent upon tree size, density and species composition. Volumes at the mangrove-water edge, approximately 30 to 35 m^3/ ha, due to the small tree sizes and relatively comprises few species. The area at the landward side has a higher stand volume, about 50 to 84 m^3/ ha. The highest stand volume, approximately 120 m^3/ha, is found in the middle zone where the area is composed of more species of larger size.

Noakes (1957) reported that the volume for the best stand in Mala the Perak Mangrove, is about 248 m^3/ha. The volume from the average Malayan mangrove forest is much less than this amount. Noakes found that in the Selangor mangrove, volumes were only 110 m^3/ha.

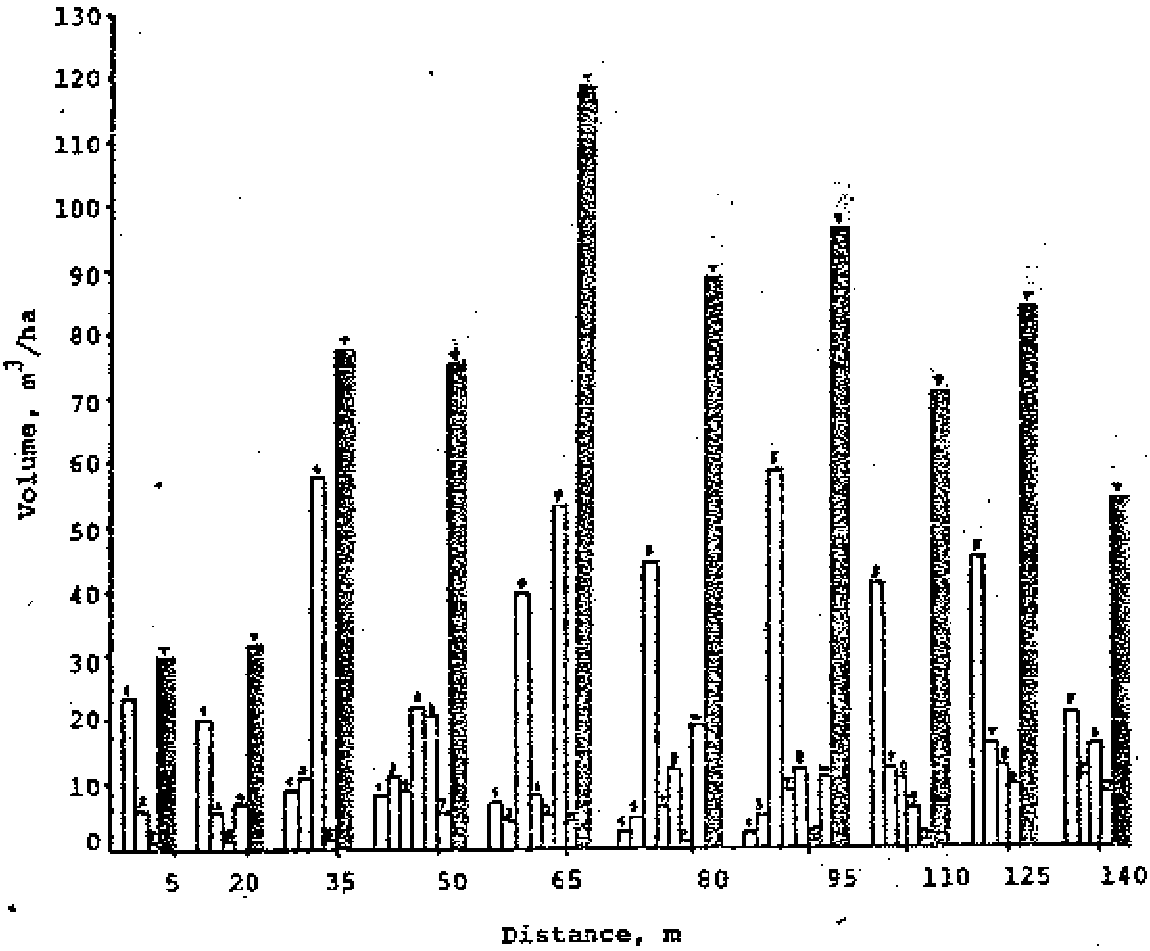

Figure 5. Distribution of stem volumes from estuary to the land of the main species of mangrove forest at Amphoe Khlung, Changwat Chantaburi: 1) Rhizophora candelaria 2) R. mucronata, 3) Bruguiera conjugata, 4) Avicennia alba, 5) Xylocarpus obovatus, 6) X. moluccensis, 7) Ceriops roxburghiana, 8) Lumnitzera spp, 9) Melaleuca leucadendron, 10) Excoecaria agallocha. Black columns represent the total volume.

SUMMARY AND RECOMMENDATIONS

Summary

Mangrove Community Structure

The mangrove community at Amphoe Khlung, Changwat Chantaburi, consists of more than 27 genera of trees and other plants, but only a few are dominant in the structure of the ecosystem. Rhizophora candelaria and R. mucronata are the dominant plants found both on the banks of the brackish estuaries and on the edges of the channels running through the forest. Soils of this site are usually waterlogged, and much wetter, muddier, and less acid than other areas more inland.

The area behind the Rhizophora zone is generally colonized by Avicennia and Bruguiera. These species may occur sparsely in the Rhizophora zone, with Avicennia more abundant in the area of Rhizophora than Bruguiera.

Xylocarpus obovatus, X. moluccensis and Excoecaria agallocha commonly occupy the areas adjacent to the Avicennia and Bruguiera Zone, wherever the soils are drier, and less subject to frequent tidal inundation. In areas that are flat and soils are high in clay content Ceriops and Lunmitzera may occasionally colonize the site. Of these two species, Ceriops commonly occurs in thickets but the latter species is sparsely distributed.

Areas of high elevation that are infrequently inundated by salt water tidal flooding during extreme high tides are dominated by Melaleuca leucadendron. A palm, Nypa fruticans, is a plant characteristically found on the estuary edge where the area is flooded by all tides. Another palm, Phoenix paludosa, and the fern, Acrostichum aureum, are commonly established in the intermediate zone between the inundated mangrove and the non-flooded site. <u>Acrostichum</u> is widely distributed, occurring most commonly wherever mangrove forests have been severely disturbed by cutting. It also appears sparsely throughout the whole range of mangrove forest.

Species diversity varied from the edge of the estuary towards the mangrove forest. The sites along the banks of the estuaries where <u>Rhizophora</u>, <u>Avicennia</u> and <u>Bruguiera</u> are dominant have the highest density with the lowest species diversity. The intermediate zone between inundated mangrove and unflooded sites, where the area is occupied by <u>Xylocarpus</u>, <u>Lunmitzera</u> and <u>Excoecaria</u>, has the greatest species diversity with approximately sixteen tree species, but the number of individuals is low. On the landward side, where the area is flooded only by extreme high tide and occupied by <u>Melaleuca leucadendron</u> eight associated species occurred with low density. The diversity value (H) found in this mangrove forest was 0.8790.

Stand volume varied from the edge of the estuary to the landward side, with the lowest stand volume (approximately 30 to 35 m^3/ha) occurring on the area where <u>Rhizophora</u>, <u>Avicennia</u> and <u>Bruguiera</u> are dominant. The intermediate area between the inundated mangrove and the unflooded forest occuped by <u>Xylocarpus</u>, <u>Ceriops</u>, <u>Lumnitzera</u> and <u>Excoecaria</u> produced the highest stand volume (about 120 m^3/ha). On the landward side, dominated by <u>Melaleuca leucadendron</u>, stem volume (approximately 50 to 84 m^3/ ha) was between those two areas.

Recommendations

The wise management of the mangrove ecosystem depends upon a comprehensive ecological knowledge of this forest type. Thus far, mangrove management in Thailand has been based primarily upon economic returns, with little regards given to any importance of environmental considerations. The objective of the Thailand Royal Forest Department is to manage this resource on a sustained yield basis, with due emphasis being given towards effective environmental quality control.

The recommendations reported are based on preliminary investigations done in the mangrove forest at Amphoe Khlung, Changwat Chantaburi. Although they are only directly applicable to the development of this particular mangrove area, it is felt that they may also be utilized in the management of mangrove forests located elsewhere in Thailand. These recommendations are:

1. In order to increase the yields of naturally occurring Rhizophora, which is currently the major high-value mangrove species, the other less commercially desirable species such as Avicennia, Xylocarpus, and Lomnitzera should be removed. Such removal will encourage the natural regeneration and high growth rate of Rhizophora.
2. An intensive use study of Avicennia, Hylocarpus and Lumnitzera should be undertaken to learn of what use can be made of them. The promotion of

the greatest use of these additional mangrove species would reduce the intensive demand now being made of <u>Rhizophora</u>.

3. It has been the pratice to plant mangrove species particularly <u>Rhizophora candelaria</u> and <u>R. mucronata</u> in areas away from the estuary edge which are often much drier than is optimum for good growth and survival. On such sites, channels or small water-ways should be constructed that would allow sea water to flood these areas. The results would be an increase in growth and a reduction in mortality.

4. To intensify the management of the mangrove forest, and immediate and massive trees planting program must be undertaken to avoid a serious timber supply deficit. Plantations are strongly recommended since they produce a much higher stem-volume in a shorter period of time than occurs in natural forests. Estimates of what the investment costs of such a massive tree planting program would be made. Planting should be made in both disturbed forest area and the area covering by fern, <u>Acwstichum aureum</u>. The fern should be removed and burned before planting operation.

LITERATURE CITED

Banijbatana, D. 1957. Mangrove forest in Thailand. Proc. 9th Pacific Sci. Congr. (Bangkok) 1957 :22-34.

Bowman, H. H. M. 1917. Ecology and physiology of the red mangrove. Proc. Amer. Phil. Soc. 61:589-672.

Carter, J. 1959. Mangrove succession and coastal change in Southwest Malaya. Trans. Inst. Br. Geogr. 26:79-88.

Chapman, V. J. 1944. The 1939 Cambridge University expedition to Jamaica. 1) A study of the botanical processes concerned in the development of the Jamaican shore-line. 2) A study of the environment of *Avicennia nitida* in Jamaica. J. Linn. Soc. Bot. 52:407-86.

Chapman, V. J. and J.W. Ronaldson. 1958. The mangrove and salt marsh flats of the Auckland Isthmus. New Zeal. Dep. Sci. Ind. Res. Bull. 125:1-79.

Chapman, V. J. 1970. Mangrove phytosociology. Trop. Ecol. 11:1-19.

Clarke, L. D. and N. J. Hannon. 1967. The mangrove swamp and salt marsh communities of the Sydney district. I. Vegetation, soils and climate. J. Ecol. 55:753-71.

Davis, J. H., Jr. 1940. The ecology and geologic role of mangroves in Florida. Papers from Tortugas Lab. 32. Carnegie Inst. Wash. Publ. 517:305-412.

de Hann, J. H. 1931. Het een en ander over de Tijlatjap 'sche vloedbosschen. Tectona. 24:39-76 (English summary).

de la Cruz, A. A. 1969. Mangroves-tidal swamps of the tropics. Sci. Rev. 10 (11):9-16.

Drew, W.B. 1974. The effects of herbicides in South Vietnam. B. The ecological role of the fern (*Acrostichum aureum*) in sprayed and unsprayed mangrove forests. National Academy of Sciences. p. 13.

Du, L. V. 1962. Ecology and silviculture of mangrove. Yale Univ. School of Forestry. Unpublished mimeo. p. 26.

Giglioli, M. E. C. and I. Thornton, 1965. The mangrove swamps of Keneba, Lower Cambia River basin. I. Descriptive notes on the climate, the mangrove swamps and the physical composition of their soils. J. Appl. Ecol. 2:81-103.

Giglioli, M. E. C. and D. F. King. 1966. The mangrove swamps of Keneba, the Lower Cambia River basin. III. Seasonal variation in the chloride and water content of swamp soils, with observations on the water levels and chloride concentration of free soil water under a barren mud flat during the dry season. J. Appl. Ecol. 3:1-19.

Gledhill, D. 1963. The ecology of the Aberdeen Creek mangrove swamp. J. Ecol. 51:639-703.

Hart, M.G. R. 1959. Sulphur oxidation in tidal mangrove soils of Sierra Leone. Plant and Soil 11:215-36.

Hesse, P. R. 1961. Some differences between the soils of Rhizophora and Avicennia mangrove swamps in Sierra Leone. Plant and Soil 14:335-46.

Jordan, H. D. 1964. The relation of vegetation and soil to the development of mangrove swamps for rice growing in Sierra Leone. J. Appl. Ecol. 1:209-12.

Kongsangchai, J. 1973. Soil properties and vegetation in various tidal zones of mangrove forest at Pang-Nga. M.S. thesis. Fac. of For., Kasetsart Univ., Bangkok, Thailand. p. 76 (In Thai).

Kuenzler, E. J. 1968. Mangrove swamp systems. Coastal Ecological System of the United States. Eds. H. T. Odum, B. J. Copeland and E. A. McMahon, 353-83. Chapel Hill, N. C.: Int. Mar. Sci., Univ. North Carolina. p. 1878.

Macnae, W. 1968. A general account of the fauna and flora of mangrove swamps and forests in the Indo-West - Pacific region. Advan. Mar. Biol. 6:73-270.

Macnae, W. and M. Kalk. 1962. The ecology of the mangrove swamps of Inhaca Island, Mocambique. J. Ecol. 50:19-34.

Navalkar, B.S. and F. R. Bharucha. 1948. Studies in the ecology of mangrove IV. The hydrogen ion concentration of the sea water, soil solution and the leafcell-sap of the mangroves. J. Univ. Bombay. 16:35-45.

Navalkar, B. S. and F. R. Bharucha. 1949. Studies in the ecology of mangroves. V. Chemical factors of mangrove soils. J. Univ. Bombay. 17:17-35.

Navalkar, B. S. and F. R. Bharucha. 1950. Studies in the ecology of mangroves. VI. Exchangeable bases of mangrove soils. J. Univ. Bombay. 18:7-16.

Noakes, D. S. P. 1951. Notes on the silviculture of the mangrove forests of Matang, Perak. Malayan Forest. 14:183-96.

Noakes, D. S. P. 1957. Mangrove. Trop. Silvicult. 2:309-18.

Odum, E. p. 1971. Fundamentals of Ecology. Philadelphia: Saunders. 3rd ed. p. 574.

Richards, p. W. 1952. The Tropical Rain Forest: An Ecological Study. Cambridge Univ. Press, Cambridge. p. 450.

Savory, H. J. 1953. A note on the ecology of Rhizophora in Nigeria. Kew Bull. 1:127-28.

Schimper, A. F. W. 1903. Plant Geography on a Physiological basis. Oxford Univ. Press, Oxford. p. 839.

Seniarisanti, T. 1976. Changes of Vegetation and Soil Properties of Mangrove Forest After Strip Clearing and Strip Clearing with Seed Tree. Fac. of For. Kasetsart Univ. Inpress.

Snedaker, S. C. and A. E. Lugo. 1973. The role of mangrove ecosystems in the maintenance of environmental quality Atlanta, Ga.: U. S. Bureau of Sports Fisheries and Wildlife. Available Through NTIS, Springfield, Va. In press.

Snedaker, S. C. and D. J. Pool. 1973 Mangrove forest types and biomass. In. The role of mangrove ecosystems in the maintenance of environmental quality and a high productivity of desirable fisheries. Snedaker, S. C. and A. E. Lugo. Eds. The Center for Aquatic Sci., Gainesville, Fla. C. 1-13.

Steenis, C. G. G. J. Van. 1958. Rhizophoraceae. Fl. Males. 5:431-93.

Thom, B. G. 1967. Mangrove ecology and deltaic geomorphology. Tabasco, Mexico. Ecol. 55:301-43.

Thornton, I. and M. E. C. Giglioli. 1965. The mangrove swamps of Keneba, Lower Gambia River basin. II. Sulphur and pH in the profiles of swamp soils. J. Appl. Ecol. 2:257-70.

Tomlinson, T.E. 1957. Relationship between mangrove vegetation, soil texture and reaction of surface soil after empoldering saline swamps in Sierra Leone. Trop. Agric. Trinidad 34 (1):41-50.

Venkatesan, K. R. 1966. The mangroves of Madras State. Indian Forest 92:27-34.

Vu-Van-Cuong-Humbert, F. S. C. 1964. Flore et vegetation de la mangrove de la region de Saigon-Cap Saint-Jacques, Sud Viet-Nam. Ph. D. diss., Univ. Paris. p. 199.

Walter, H. and M. Steiner. 1936. Die "Okologie der Ost-Afrikanischen Mangroven. Z. Bot. 30:65-193.

Watson, J. G. 1928. Mangrove forests of the Malayan Peninsula. Malay. For. Ref. Singapore: Fraser and Neave, Ltd. p. 275.

Zinke, P. J. 1974. The effects of herbicides in South Vietnam. B. Effect of herbicides on soils of South Vietnam. National Academy of Sciences. p. 39.

Zinke, P. J. 1975. Thailand Forest Soils. Agri. Exp. Station, Univ. of Calif., Berkeley. In press.

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* In Thai with English summary