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A STUDY OF FROND VOLUME AND WAVE ATTENUATION IN THE MANGROVE FOREST OF *Nypa fruticans* AT KELANTAN DELTA, TUMPAT, KELANTAN

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Abstract: Wave reduction in a mangrove forest has been studied in the Kelantan Delta of Peninsular Malaysia on the coast of Tumpat. The frond volume and the wave height reduction are used to estimate the ability of *Nypa fruticans* in wave attenuation. Two water loggers were used to measure the wave reduction at different locations inside the mangrove forest. The reduction rate of the wave amplitudes changed substantially with the frond volume and distance inside the mangrove forest. The wave reduction increases with the increasing distance inside the mangrove forest. Also, it is found that the wave reduction decreases with the increasing water level. The percentage of wave reduction ranged from 32.303% to 57.291% while the average wave reduction over a 5 m distance at the selected site is as much as 48.47%.

KEYWORDS: Wave attenuation, *Nypa fruticans*, Frond volume, Kelantan delta

Introduction

A mangrove forest is a unique ecosystem generally found along sheltered coasts. It is a very dynamic and highly-productive ecosystem. It not only plays multiple ecological functions essential to its surrounding habitats, but is also an important resource for coastal communities. Mangrove forests are found in tropical and subtropical regions between 25° N and 25° S (Lugo & Brown, 1990). Mangrove forests in Malaysia cover 637,164 ha and represent 2.5% of the global mangrove resource. As a whole, Malaysia wetlands directly or indirectly contribute more than RM 5 billion to the economy every year.

Mangroves are quite important from the ecological, physical, biological and economic point of view. They serve many purposes including protecting coastlines from erosion, storm damage and wave action. They also provide habitat to many species, serve as a nursery ground, protect coral reefs and seagrass beds from sedimentation and man–made events. According to Kathiresan and Bingham (2001), mangroves create a unique ecological environment that host a rich assemblage of species.

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The earlier studies of mangroves were limited compared to other coastal vegetations like salt marshes (Knutson, 1988) and seagrass beds (Fonseca & Cahalan, 1992). The wave reduction by mangroves were earlier studied by Magi *et al.* (1996) and Mazda *et al.* (1997) who have shown through observed data the quantitative effects of *Rhizophora stylosa* and *Kandelia kandel*, respectively, on the reduction of sea waves. Massel *et al.* (1999) also studied the effect of *Rhizophora* sp. on the reduction of sea waves based on a mathematical model. Later *et al.* (2006) discussed the characteristics of wave reduction due to the drag force of *Sonneratia* sp. at the Vinh Quang Coast in Northern Vietnam while Quartel, *et al.* (2007) discussed the wave reduction due to the drag force for *Kandelia kandel* in the Red River Delta, Vietnam.

This paper focuses on the ability of *Nypa fruticans* in wave reduction at Tumpat, Kelantan in Peninsular Malaysia. Five species of mangrove forests, such as *Sonneratia caseolaris*, *Nypa fruticans*, *Aviccenia alba*, *Rhizophora mucronata*, and *Bruguiera gymnorrhiza,* were found in the area (Satyanarayana *et al.*, 2010). However, the *Nypa fruticans* was chosen because this species is found in abundance in the region. The main aim is to investigate the effects of nypa species in the reduction of waves generated by the passage of fishing boats in the estuary. The waves reduce as they propagate into the mangrove forest due to the fronds of the vegetation. The objective of this paper is to quantify the percentage of wave reduction by *Nypa fruticans* at Tumpat, Kelantan, and to determine the relationship between wave attenuation and frond volume.

Methods

Study area

The study site at Tumpat, Kelantan which is part of the Kelantan Delta, located between the latitude of 06^{o}11.00’N to 06^{o}13.00’N and the longitude of 102^{o}10.00’E to 102^{o}14.00’E was chosen. This area covers approximately 1300 ha including 17 islands. The main river running through the delta is Sg. Kelantan, which meets the South China Sea in the east of the study area (Figure 1). The changes that occurred in the Kelantan Delta have resulted from fluvial or tidal erosion and depositional processes, while changes along beaches have resulted from the erosion, lateral transport and deposition of beach sediment by wave action (Raj, 1985).

In the region one can find many stands of *Nypa* sp. However, the study site located at 6^{o}12’20.52”N and 102^{o}10’36.72”E where N*ypa fruticans* has very dense vegetation was chosen. Figure 1 shows the topographical map of Tumpat and an idealised transect of *Nypa fruticans* from the vegetation’s edge to the interior of the mangrove forest.

Firstly the area at Kelantan Delta was surveyed to find the best transect for *Nypa fruticans*. After a suitable location was decided, a transect was set up whose length was 5 m inside the mangrove forest from the vegetation’s edge (Figure 1). Along the transect five locations, each 1 m apart were chosen. The first location at the vegetation’s edge has been designated as plot 0, while plot 1 refers to the next location 1 m inside the mangrove, and so on. For this study three sets of readings were recorded. For reading 1, two water loggers were set up at plot 0 and 1; for reading 2, they were set up at plot 0 and 3; and finally, for reading 3, the equipment were fixed at plot 0 and 5. For each reading, the data were collected for one tidal cycle during the spring tide.

Observation of root density data

The trees along the 5 m long transect line are marked for the purpose of measuring the frond volume of the vegetation. For this purpose, a series of 1 m^2 areas are designated along the transect line from the front to the back of the mangroves. Each frond of the vegetation that falls within the plot is measured for their diameter at every 20 cm from the bottom upwards. Measurements are taken up to the height of 60 cm since the high-tide level inside the mangrove forest was found to be approximately 60 cm.

To measure the trunk diameter, calipers were used while the height of the trunk was measured by using a measuring tape. The trunk is assumed to be cylindrical in shape. Thus, using the equation: D = r^2 h where = 3.142, radius and height, the volume of the trunk (frond volume) is obtained within each area.

Wave-data sampling

Wave-height data were collected using Boart Longyear Interfels water logger (Boart Longyear, Germany). The parameters that can be obtained from the water loggers are water depth, pressure and temperature. However, we have used only the water depth in our study. At a given plot along the transect, one water logger is fixed vertically near the bottom of the mangrove tree (Figure 2).

Two water loggers are set up at two locations to sample the water levels and associate parameters at 1-second intervals for each reading (Table 1). The water loggers were left for the collection of data for one tidal cycle, after which the data was analysed for mean wave height, and subsequently wave attenuation as the equipment was moved to other locations inside the mangrove.

During the course of wave-data collection, fishing boats would pass through the study site and thus generate small waves. The wave fluctuations recorded by a water logger due to each passing boat is called a wave burst which contains a set of waves. The dates, readings and number of wave bursts recorded for the sampling variability are presented in Table 1. Three sets of readings were taken on 12-14 May 2008. For readings 1 and 2,

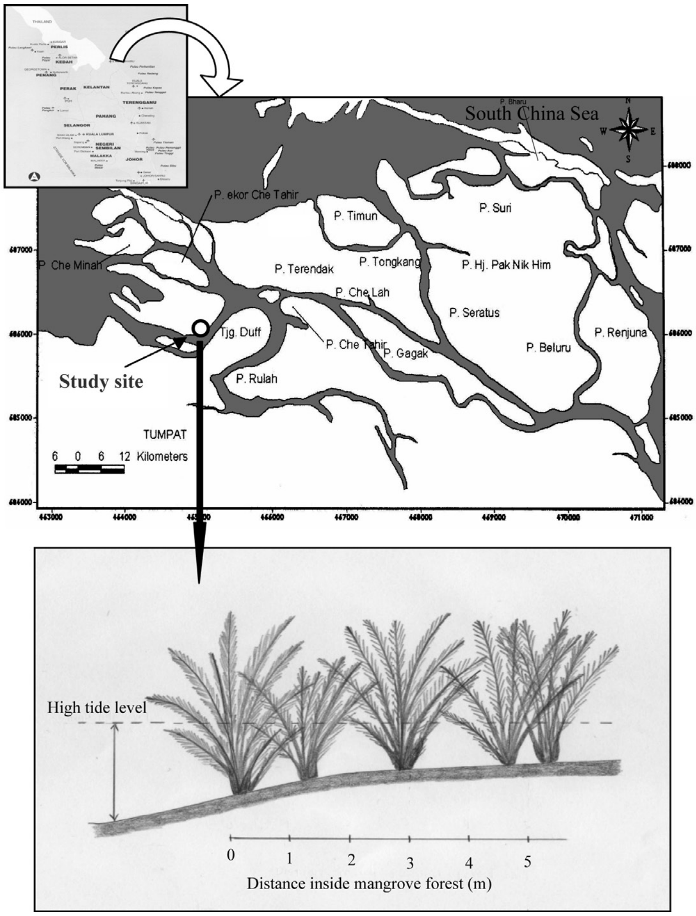

Figure 1: Topographical map of Tumpat, Kelantan and idealised transect of *Nypa fruticans*.t

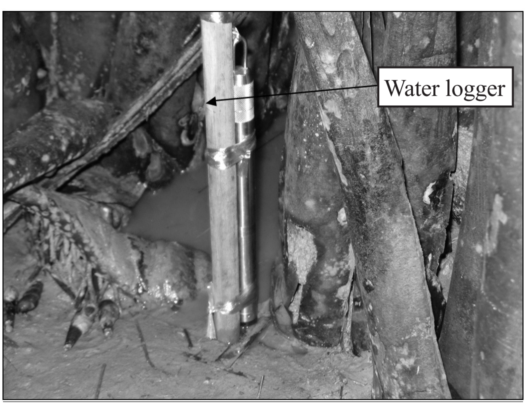

Figure 2: Picture of water logger during the data collection.

the number of wave bursts were 15 each and for reading 3, only 9 wave bursts were identified. In the three readings, the number of waves ranged from 3-14 in all the 39 wave bursts.

Table 1: Sampling variability using two water loggers at Tumpat, Kelantan.

Date	Reading	No of wave bursts	Plot 0	1	2	3	4	5
12/5/2008	1	15	√	√				
13/5/2008	2	15	√			√		
14/5/2008	3	9	√					√

One of the wave bursts is shown in Figure 3. Each wave burst rode over the tidal wave and was captured by the water logger. Wave heights of more than 2 cm are taken into account while waves smaller than 2 cm are ignored as they are considered wind-induced waves (Quartel *et al*., 2007).

After identifying the waves 1 to 9, their mean height was used to compute the wave reduction.

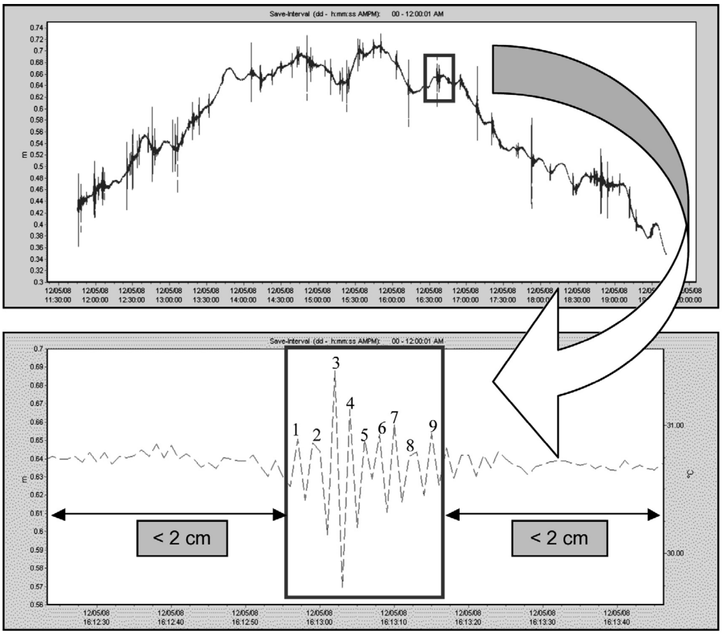

Figure 3: Example of a wave burst and identification of associated waves.

Following Mazda *et al*., (1997), the wave reduction is given by

$$r = \frac{H_S - H_L}{H_S}$$, where

r = reduction, percentage reduction= r x 100
H_s = wave height in front of mangrove (plot 0)
H_L = wave height at a location' L' inside the mangrove forest

Results

Frond-volume analysis

The frond-volume data are computed from the front to the back of the mangrove along the transect. All fronds from within a 1m x 1m base up to a height of 60 cm are measured for length and diameter. Further, they are divided into three vertical layers of 20 cm each, from the bottom to the top as shown in Figure 4. The measured frond data are reported in terms of volume (frond volume). At the study site, the vegetation is found to be fronting the riverbank. The frond-volume measurement for each vertical (20 cm) layer and 1 m horizontal plot are given in Table 2.

The clustering nature of nypa, with leaves growing from the bottom and without stems also caused the frond volume to be highest at the bottom and gradually reduced above it. As the fronds fan out toward the top, the volume becomes less. Compared to the other species, the volume of the frond and leaves for nypa is much larger at the bottom.

Wave reduction

Wave attenuation is the decline in the wave amplitude as the wave passes through a mangrove forest. The percentage of average wave reduction for three sets of readings for *Nypa fruticans* is shown in Table 3. The percentage of wave reduction for reading 1 is 32.303% which increases to 55.83% for reading 2 followed by 57.29% for reading 3. Thus, the average percentage of wave reduction for *Nypa fruticans* over a 5 m distance at the selected site is 48.47%.

For *Nypa fruticans* at Tumpat, the wave reduction is found in 0 – 60 cm level as the tidal amplitude at the time of the experiment was about 60 cm. This means that, in this case, the wave reduction did not exist above 60 cm. The percentage of wave reduction is highest in 0 – 20 cm level (57.963%) because in this level there are many big trunks which tend to attenuate the

Table 2: Frond volume (in cm^3) for each 20 cm level from the ground for each plot from the front to inside the mangrove.

Plot along transect	Layer 0 - 20 cm	Layer 20 -40cm	Layer 40 -60cm	Average (cm^3)
1	22000.69	9598.46	7857.49	13152.21
2	21480.85	6911.42	4989.09	
3	16045.41	5956.16	4494.46	11037.11
4	21461.22	8404.78	6911.83	
5	7292.59	3275.44	2539.28	9947.94
Average	17656.15	6829.25	5358.43	

Table 3: Wave reduction for *Nypa fruticans*.

Reading	Average wave reduction (%)
1	32.303
2	55.828
3	57.291
Average	48.47

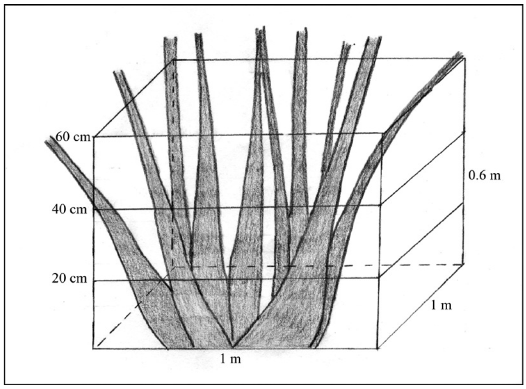

Figure 4: A one square meter plot within an idealised *Nypa fruticans* transect and the 20 cm vertical layers.

Table 4: Wave reduction vs. vertical height (each 20 cm level) for *Nypa fruticans*.

vertical level (cm)	wave reduction (%)
0 - 20	57.963
20 - 40	54.503
40 - 60	24.709

waves more effectively. Table 4 shows average wave reduction vs. vertical height (each 20 cm level) for *Nypa fruticans*.

Discussion

Frond volume ***variability***

The root system of the mangrove is one of the primary components that help in the reduction of waves (Mazda *et al*., 2006). The analyses of frond-volume variations on a horizontal and vertical basis for the *Nypa fruticans* are discussed below.

The Figure 5 shows the relation between frond volume and distance inside the mangrove forest for *Nypa fruticans*. It may be seen that the average frond volume decreases with the increasing distance inside the mangrove forest. The average frond volume at plot 1 (1 m inside the mangrove forest) is found to be the highest.

Relation between average frond volume and vertical layers is shown in Figure 6. The vertical variability in frond volume for this species of mangrove vegetation shows a declining trend with height above the ground. Frond volumes are higher closer to the ground in the first level (0 – 20 cm) because the fronds in this level have larger diameters in comparison to other levels.

Wave reduction

Figure 7 shows the relation between average wave reduction and distance inside *Nypa fruticans*. For three sets of readings, it may be seen that the percentage wave reduction increases with the increasing distance inside the mangrove forest.

Figure 8 shows a graph of average wave reduction vs. vertical levels for *Nypa fruticans*. It is found that the wave reduction decreases with increasing water level. The percentage of wave reduction is highest in the first layer of water depth (0 – 20 cm) and the percentage wave reduction decreases as the water depth increases. This is similar to the results reported by Quartel *et al*. (2007) and Mazda *et al*. (2006).

Relation between average frond volume and average wave reduction vs. distance

In Figure 9, the variation of average frond volume and average wave reduction vs. distance inside the mangrove are presented. It is seen that the frond

Figure 5: Relation between frond volume and distance in mangrove forest.

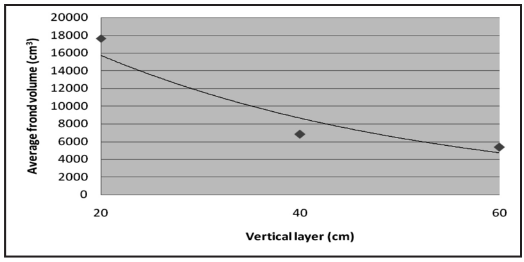

Figure 6: Relation between average frond volume and vertical layer (of 20 cm height).

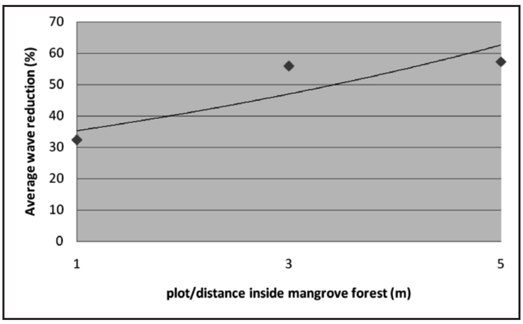

Figure 7: Relation between wave reduction and distance inside mangrove forest.

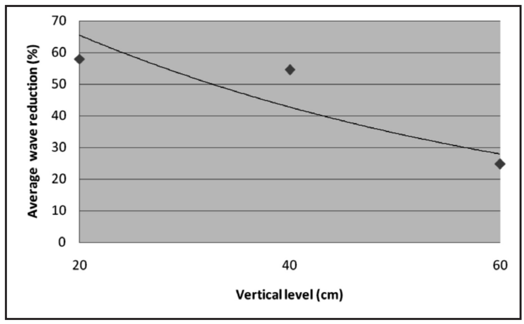

Figure 8: Relation between average wave reduction and vertical level.

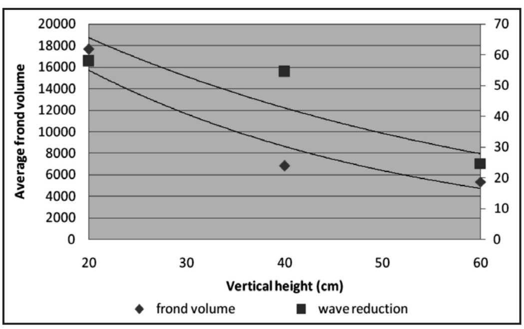

Figure 9: Relation between average root density and average wave reduction vs. distance inside the mangrove.

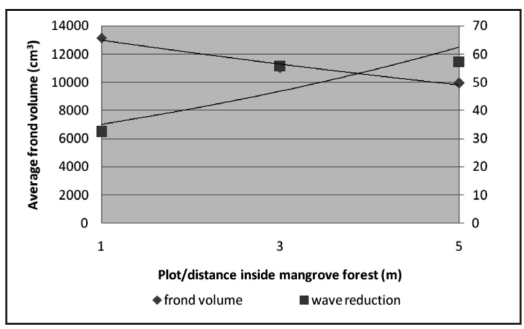

Figure 10: Relation between average frond volume and average wave reduction vs. vertical height.

volume decreases as the wave reduction increases inside the mangrove forest. It suggests that the nypa is a good mangrove species to effectively reduce the wave amplitudes.

Relation between average frond volume and average wave reduction vs. vertical height

Figure 10 gives a relation between average frond volume and average wave reduction vs. vertical height. It may be seen from the figure that both frond volume and wave reduction decrease with increasing vertical height.

Conclusion

Variations in the frond volume and wave reduction are studied as the waves enter the mangrove forest. From frond-volume measurements it is found that the average frond volume decreases with increasing distance inside the mangrove, while for vertical layers it is seen that the average frond volume decreases with increasing level of water. Also, the average wave reduction increases with increasing distance inside the mangrove while average wave reduction decreases with increasing water level. Thus, it may be concluded that *Nypa fruticans* is a good absorber of wave action because this species can attenuate the waves with about 48% reduction in wave height. This is largely because nypa has dense vegetation and the trees have big and strong trunks. It is found that the root density decreases while the wave reduction increases with increasing distance inside the mangrove. Also, the root density and wave reduction decrease with increasing vertical height.

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