

# RESISTANCE OF FIVE TIMBER SPECIES TO MARINE BORER ATTACK

K Roszaini & U Salmiah

Forest Research Institute Malaysia, 52109 Kepong, Selangor Darul Ehsan, Malaysia

Received July 2014

**ROSZAINI K & SALMIAH U. 2015. Resistance of five timber species to marine borer attack.** The nature and extent of wood destruction by marine borers at Lumut Naval Base and Endau-Rompin jetties, Malaysia, were studied by exposing test blocks (200 mm × 100 mm × 30 mm) of five wood species (*Koompassia malaccensis*, *Cynometra malaccensis*, *Shorea maxwelliana*, *Dialium platysepalum* and *Eugenia* sp.) for 24 months. A total of 1600 blocks of wood samples representing five species, 40 replicates and four times assessment were tested at two sites. *Koompassia malaccensis* and *Eugenia* sp. were susceptible to marine borers (89.3 and 93.5% respectively at Lumut and 94.1 and 92.4% respectively at Endau-Rompin). The destructions were caused by marine borers from the families Teredinidae and Pholadidae. The attack of marine borers varied depending on timber species with *K. malaccensis* showing maximum destruction.

Keywords: Tropics, molluscans, crustaceans, untreated

## INTRODUCTION

Deterioration of wood when exposed to sea water is faster and more severe compared with when exposed to atmospheric conditions. Marine borers cause substantial damage to wood submerged in salt or brackish waters in temperate and tropical zones. Marine borers are invertebrates that burrow into and damage wood exposed to marine environments (Zabel & Morrell 1992). No wood is immune to marine borer attack (Terry 1999) and no commercially-important Malaysian wood (except for *Neobalanocarpus heimii*) has sufficient marine borer resistance to justify its use in untreated form in any important structure in areas where borers are active (Chong 1979).

Two main groups, namely, the molluscan/bivalvia wood borers (teredinid, e.g. *Teredo* and *Bankia* and pholadid, e.g. *Martesia*) and crustacean borers (limnoriids, e.g. *Limnoria* or gribble and sphaeromatids, e.g. *Sphaeroma* sp.) are responsible for the damage of timber under marine conditions (Edmondson 1953, Menon 1957, Chong 1979, Harinder & Sasekumar 1995). Even though 14 species are identified as teredinid, only two (*Teredo* and *Bankia*) are common in Malaysian marine and brackish waters (Tan 1970, Chong 1979).

The service life of wood in the sea is dependent on marine borer species, water temperature, pollution and depth of immersion of specimens (Barnacle & Cookson 1995, Santhakumaran 1996, Cragg et al. 2001, Brown et al. 2003). The degree of resistance of timber varies from region to region (Cherian & Cherian 1980, Krishnan et al. 1983), with each region having its own dominant species (Radhakrishnan & Natarajan 1987). In general, tropical waters which are warmer are more conducive to marine borers than temperate waters (Santhakumaran et al. 1984). Mangroves are rich in marine borers due to its high temperature (always above 25 °C) and high salinity (1 to 34 PSU) (Untawale et al. 1973).

The distribution and activity of marine wood borers of Peninsular Malaysia have been reported (Walker 1941, Menon 1957, Ong & Lee 1972, Jones et al. 1972, Chong 1979, Eaton 1982, Jubir 1985). Marine wood borers at Lumut, Perak have been studied by Singh and Sasekumar (1994). However, information on the same marine organisms from Endau-Rompin, Pahang (southern Malaysia) and surrounding areas is lacking. Even though marine borers have big impact on economic losses (Brown & Eaton

\*roszaini@frim.gov.my

2001), only a few studies have been carried out in the Malaysian tropics.

In view of this, five species of timbers, i.e. *Koompassia malaccensis*, *Cynometra malaccensis*, *Shorea maxwelliana*, *Dialium platysepalum* and *Eugenia* sp. were tested at two sites, i.e. Lumut Naval Base, Perak and Endau-Rompin, Pahang for 24 months. These wood species were chosen due to their availability particularly in permanent forest reserves, protection forest and government land areas (JPSM 2007). These timbers have been assessed for resistance to termites as well as white- and brown-rot fungi (Ani et al. 2005). *Shorea maxwelliana* is one of the durable timber species in Malaysia while the other four wood species are classified as moderately durable. Other studies reported that *S. maxwelliana* was naturally durable (Lim et al. 1998) and had a lifespan of 15.8 years based on graveyard test (Jackson 1965). *Koompassia malaccensis* and *E. griffithii* have been reported to exhibit higher resistance to two subterranean termites, *Coptotermes curvignathus* and *C. gestroi* (Roszaini et al. 2006, 2009). *Koompassia malaccensis* and *Eugenia* sp. were reported to be highly resistant to white rot fungi, *Coriolus versicolor*, *Pycnoporus coccineus* and *Ganoderma lucidum* and brown-rot fungus *Tyromyces palustris* (Wong et al. 2005). *Eugenia* sp. was tested against marine condition at Port Klang, Malaysia and the untreated stick remained serviceable for less than 2 years (Desch 1954).

## MATERIALS AND METHODS

Samples from five species, namely, *K. malaccensis* (density: 880 kg m<sup>-3</sup>), *C. malaccensis* (975 kg m<sup>-3</sup>), *S. maxwelliana* (975 kg m<sup>-3</sup>), *D. platysepalum* (960 kg m<sup>-3</sup>) and *Eugenia* sp. (800 kg m<sup>-3</sup>) were selected. Experimental blocks of dimensions 200 mm × 100 mm × 30 mm were cut from the heartwood of these species. The samples were randomly mixed and positioned horizontally in test racks (Figure 1). A total of 1600 replicates were prepared. The test racks with wood blocks were firmly immersed in sea water and suspended at the two test sites—the naval base jetty in Lumut, Perak (north of Peninsular Malaysia) and a jetty at Endau-Rompin, Pahang (south of Peninsular Malaysia)—at 1 m below tide to avoid exposure of wood to air during low tide.



**Figure 1** Test blocks specimens after 6 months exposure at Lumut, Perak

Inspections were made every 6 months, i.e. twice a year at each site. Blocks were thoroughly cleaned to have a clear view of borer holes. Incidence of borers was recorded by counting the number of bore holes. Entry holes caused by borers feeding on the blocks were counted. Forty blocks from each species were randomly removed after each exposure period and inspected in the laboratory. Observations on the condition of each specimen and the progress of attack were recorded every 6 months for 24 months. If the visual inspection indicated that a block was heavily infested, it was removed from the test rack. When there was uncertainty, one panel or just one wood sample was removed and sectioned longitudinally to determine the extent of damage. On the other hand, if none of the replicates of a given species appeared to be damaged, all blocks were allowed to remain in the same rack for further observation in the next inspection. All marine borers were identified according to Turner (1971).

## Hydrographic studies

Measurements of salinity and temperature were made twice a year using thermo salinometer. Ten replicates were taken during each inspection per site.

## Statistical analysis

Measurements were made on 40 replicates in each assessment for each timber species. The results were presented as means and standard deviations. The results were analysed using GLM ANOVA. Correlations between borer holes and wood density and internal damage were established using the Pearson correlation test. MINITAB 15 was used.

## RESULTS AND DISCUSSION

### Hydrographic studies

Salinity, temperature and abundance of food are the most important factors related to the intensity of marine borer activity. Other factors include sea current, pollution, dissolved oxygen, hydrogen ion concentration and the amount of dissolved hydrogen sulphide (Horonjeff & Patrick 2000).

The water temperature which was observed every 6 months ranged from 27 to 29 °C for Lumut and 22 to 25 °C for Endau-Rompin (Table 1). Water salinity and pH were higher at Lumut (27 to 32 and 8.0 to 8.4 ppt respectively) than Endau-Rompin (13 to 18 and 7.5 to 7.8 ppt respectively). According to Culliney (1970) and Saraswathy (1974), water salinity gave big impact on the distribution of teredinids in estuaries.

## Species

Nineteen species of marine wood borers were identified. A total of 11 species were from the family Teredinidae (*Teredo navalis*, *T. bartschi*, *T. mindanensis*, *T. clappi*, *Bankia gouldi*, *B. gracilis*, *B. rochi*, *B. campanellata*, *B. cieba*, *Barnea destructa* and *Bactronophorus thoracites*), five from the family Pholadidae (*Martesia striata*, *M. nairi*, *Barnea dilatata*, *B. manilensis* and *Xylophaga* sp.), two from the family Sphaeromatidae (*Sphaeroma terebrans* and *S. walkeri*) and one from the family Limnoriidae (*Limnoria* sp.) (Table 2). Of the 19 species, 17 were found at Lumut while only 11, at Endau-Rompin. The reason could be the more saline conditions at Lumut, as evidenced by the salinity data. The families of Teredinidae and Pholadidae were the most common marine borers at both jetties. This is in agreement with previous studies (Tan 1970, Chong 1979). Both families are common in Malaysian marine and brackish water. *Teredo navalis*, *B. gouldi* and *M. striata* were the most dominant species with over 70% of test panels at both test sites being attacked. This agreed with previous studies in India (Nair 1964), Australia (Lamprell & Healy 1998, Turner 1998) as well as North Carolina, Texas and Brazil (Tunnell et al. 2010). Even though *T. navalis* is one of the most dominant species, it is also present in warm waters and almost every English port (Smith 1979). This species causes high wood deterioration. *Bankia destructa* is native to the Caribbean but has been reported in Singapore waters (Chou et al. 1994), a location that is not far from Endau-Rompin. However, the record of *B. cieba* in Endau-Rompin is possible since it has also been reported by Mata and Siriban (1976) in Philippines waters and Menon (1957) in Malayan waters.

**Table 1** Hydrographic conditions at the two test sites in Peninsular Malaysia

Parameter	Lumut, Perak	Endau-Rompin, Pahang
Temperature (°C)	27–29 (0.89)	22–25 (1.11)
pH	8.0–8.4 (1.24)	7.5–7.8 (0.65)
Salinity (ppt)	27–32 (2.22)	13–18 (1.87)

ppt = Parts per thousand; mean ( $\pm$  SD) of five replicates

**Table 2** Marine wood borers recorded from the two sites in Peninsular Malaysia

Class	Family	Species	Location	
			Lumut	Endau-Rompin
Phylum: Mollusca				
Bivalvia	Teredinidae	<i>Teredo navalis</i>	+	+
		<i>Teredo bartschi</i>	+	–
		<i>Teredo mindanensis</i>	+	–
		<i>Teredo clappi</i>	+	–
		<i>Bankia gouldi</i>	+	+
		<i>Bankia gracilis</i>	+	+
		<i>Bankia rochi</i>	+	–
		<i>Bankia campanellata</i>	+	–
		<i>Bankia cieba</i>	–	+
		<i>Barnea destructa</i>	+	+
		<i>Bactronophorus thoracites</i>	+	–
	Pholadidae	<i>Martesia striata</i>	+	+
		<i>Martesia nairi</i>	+	+
		<i>Barnea dilatata</i>	+	–
		<i>Barnea manilensis</i>	–	+
		<i>Xylophaga</i> sp.	+	–
Phylum: Arthropoda				
Crustacea	Sphaeromatidae	<i>Sphaeroma terebrans</i>	+	+
		<i>Sphaeroma walkeri</i>	+	+
	Limnoriidae	<i>Limnoria</i> sp.	+	+

+ = present, – = absent

A few of the Teredinidae (*T. bartschi*, *T. mindanensis*, *I. clappi*, *B. rochi*, *B. campanellata* and *B. thoracites*) and two species from Pholadidae (*B. dilatata* and *Xylophaga* sp.) were not found at Endau-Rompin. This could be because Lumut is located on the west coast of Peninsular Malaysia with extensive mangrove coastline (Darus & Haron 1988). Mangrove has significant impact (source of food through production of detritus) on the abundance of Teredinidae and Pholadidae (Singh & Sasekumar 1994) due to its tolerance to water salinity (Lugo & Sneadaker 1974). The result showed more molluscs with increasing salinity. In addition, the temperature of water at Lumut was higher compared with Endau-Rompin (Table 1). Uniform high water temperature allows for continuous breeding of marine borers (Singh & Sasekumar 1994).

Crustaceans (Sphaeromatidae and Limnoriidae) occurred at both test sites. Pillai (1965) stated that Limnoriidae are distributed world-wide, while Rotramel (1972) noted that

Sphaeromatidae groups especially *S. annandalei*, *S. terebrans*, *S. walkeri* and *S. quoyanum* are common in tropical and subtropical harbours around the world. Their low intensity at Endau-Rompin could be due to limited sources of food as Endau-Rompin is not a mangrove area (Ong 1978).

The potential for introduction of new species to Lumut is likely low as reported by Singh and Sasekumar (1994). As stated by Ruiz et al. (2000), most estuarine and marine species introductions are associated with shipping and man activities. They may be transported on ship hulls, navigational buoys, floatation devices, anchors, chains, ropes and flotsam or jetsam (Carlton 2001).

### Resistance to Teredinidae

Figure 2 shows that none of the timber samples were free from borer attack at Lumut or Endau-Rompin. The intensity of attack was



quite severe at both test sites especially against terenids and pholadids. *Shorea maxwelliana* had only slight attack against Teredinidae after 24 months exposure at both jetties, followed by *D. platysepalum* and *C. malaccensis* (Figure 3). The damage to these three timber species was mostly due to bivalve molluscs (shipworms and pholads). Teredinids (shipworms) were most destructive among the marine borers. The high resistance of these timber species could be due to their high extractive contents (Wong et al. 2005). *Shorea maxwelliana* was reported to have a service life of more than 5 years at Naval Dockyard in Singapore (Ong & Lee 1972). Southwell and Bultman (1971) described a range of timbers with interesting heartwood extractives. Silica content is another important characteristic. *Dialium platysepalum*, which is one of the most siliceous timbers, showed better performance against both terenids followed by pholads at both sites.

*Kompassia malaccensis* and *Eugenia* sp., the two medium hardwood species, were badly attacked by shipworms after 6 months exposure (Figure 2). The seawater in Lumut was more saline than Endau-Rompin, thus, more blocks were attacked. The abundance of teredinids was probably due to water salinity (Hoestland & Brasselet 1968).

The burrows were usually straight in lightly attacked samples of 6 months exposure but twisted and turned in any direction in heavily-attacked samples of 24 months exposure. The teredinids (shipworms) which belong to the phylum Mollusca, order Myoida, are the most widespread and destructive marine-boring organisms. These teredinids continuously lengthen their burrows and do extensive internal damage to the wood (Cragg & Levy 1979, Harinder 1995).

### Resistance to Pholadidae

Pholads are commonly found in areas of the world. No timber was found to be naturally resistant to attack by this borer (Southwell & Bultman 1971). Pholad damage normally weakens the wood surface to the point where waves can erode the damaged wood. Test panels exposed at Lumut were more badly attacked by this type of marine borer than at Endau-Rompin as shown in Figures 2 and 3. Judging from the

number of borer holes, *S. maxwelliana* was the most resistant timber against Pholadidae with only 35 (Lumut) and 27 (Endau-Rompin) borer holes after 24 months exposure. *Cynometra malaccensis* had a similar performance with *D. platysepalum*. Both *K. malaccensis* and *Eugenia* sp. test samples were badly attacked which indicated that both timber species were not resistant to Pholadidae.

*Martesia striata* and *S. terebans* badly attacked *K. malaccensis* and *Eugenia* sp. (Figures 4 and 5 respectively) compared with *C. malaccensis*, *S. maxwelliana* and *D. platysepalum* (Figures 6, 7 and 8 respectively). In one study, it was found that *K. malaccensis* was moderately attacked in 2 years at south Johore, while *Eugenia* sp. was lightly attacked in 11 months at Kuantan, Pahang (Menon 1957). The borer enlarged its original entrance hole up to 4 mm in diameter, which was visible to the naked eye but the interior diameter was about four times greater than the diameter of the entrance hole.

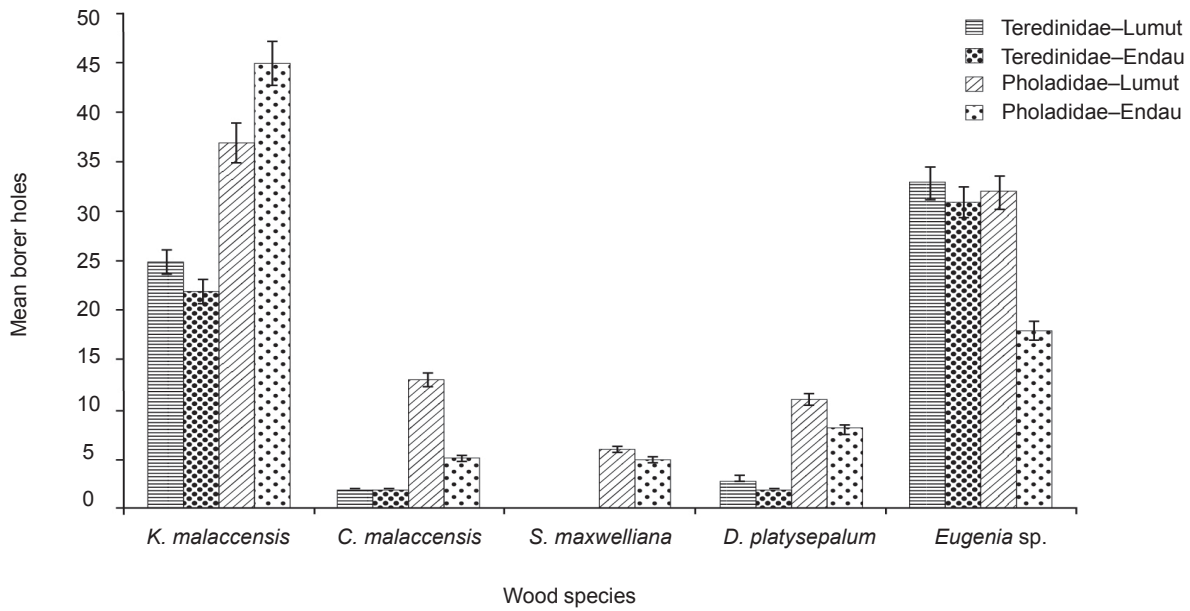
### Resistance to crustaceans

Except for one hole on *K. malaccensis*, no test blocks were attacked by crustaceans (Sphaeromatidae and Limnoriidae) after 6 months exposure at both jetties. Less than 10 entry holes were found on test panels after 24 months (results not shown).

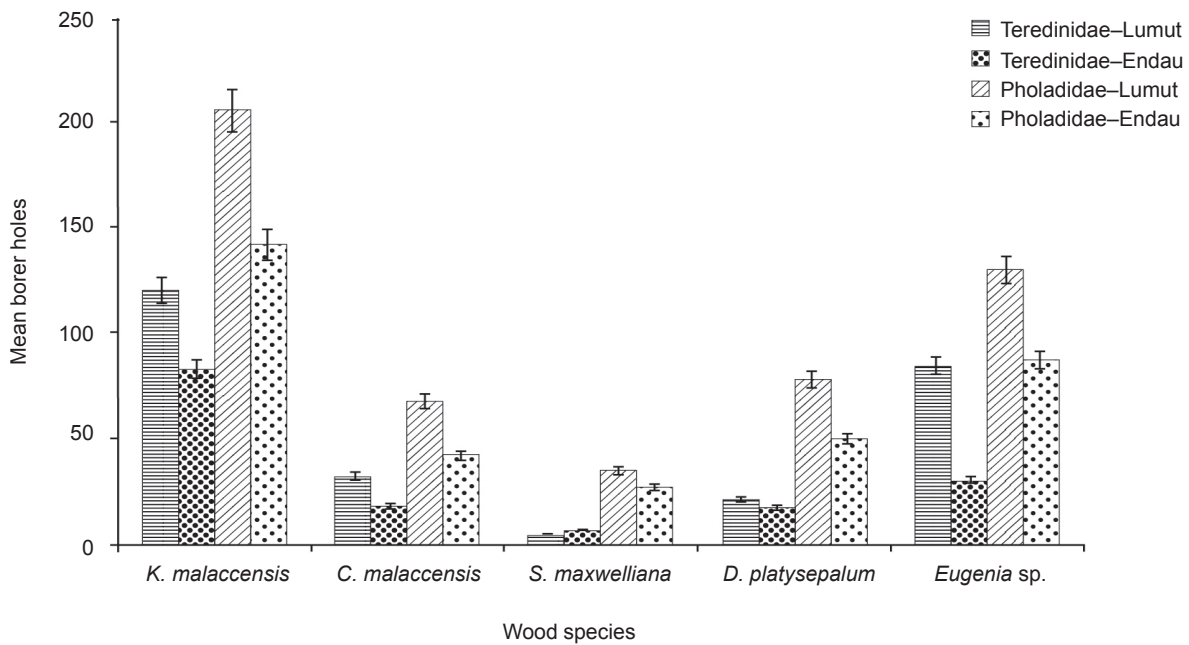
The intensity of attack by *Limnoria* was more in Lumut compared with Endau-Rompin. Endau-Rompin has no significant limnoriid problem due to salinity tolerance. The absence of crustaceans at both test sites is not unusual because they are most active between tides. Crustaceans especially *Limnoria* sp. is not a pest and it is neither abundant nor destructive (Menon 1957). *Limnoria* prefers marine and high salinity water and cannot survive in low salinity. This means that reducing salinity has great effect on boring activity of *Limnoria* at low temperatures (Eltringham 1961).

### Correlation between borer holes and wood density and internal damage

Figures 9 and 10 show that the number of borer holes and wood density appear highly significantly inversely related for Teredinidae at both test sites (Lumut:  $y = -1.0375x + 1027.3$ ,  $r^2 = 0.9733$ ; Endau-Rompin:  $y = -0.6946x +$



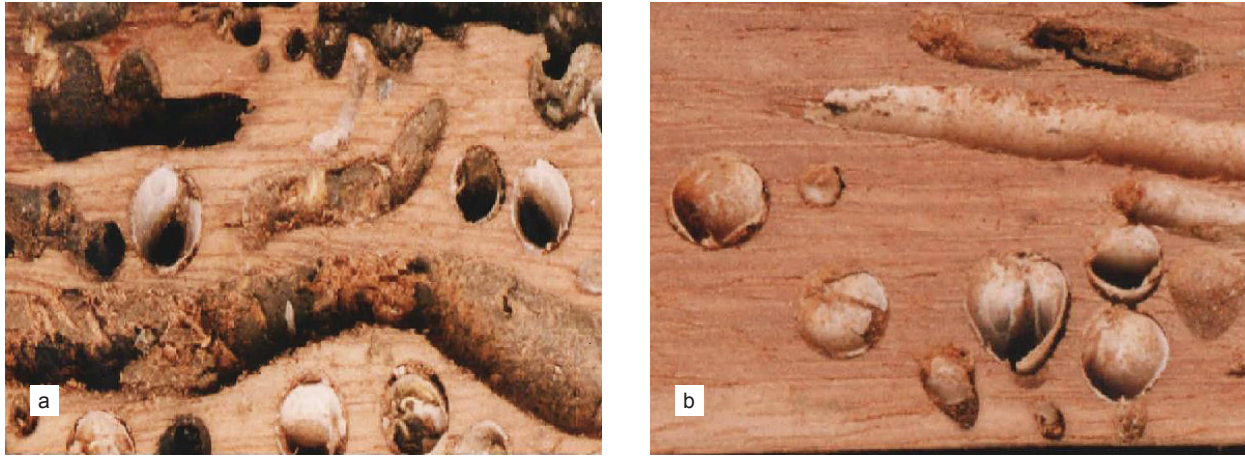
**Figure 2** Extent of destruction caused by borers at Lumut, Perak and Endau-Rompin, Pahang after 6 months exposure



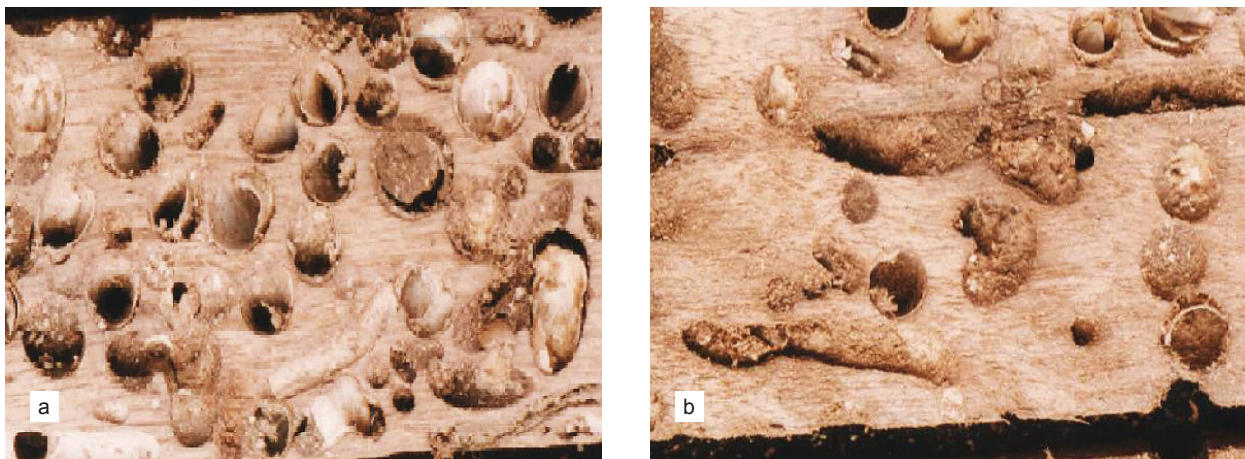
**Figure 3** Extent of destruction caused by borers at Lumut, Perak and Endau-Rompin, Pahang after 24 months exposure

687.98,  $r^2 = 0.986$ ). However, the correlation of the above variables were not significant for Pholadidae (Lumut:  $y = -0.6046x + 658.85$ ,  $r^2 = 0.460$ ; Endau-Rompin:  $y = -0.4052x + 441.1$ ,  $r^2 = 0.457$ ). Although high wood density did not assure resistance, *C. malaccensis*,

*S. maxwelliana* and *D. platysepalum* were found to be highly resistant to Teredinidae and Pholadidae. Their wood densities are categorised as extremely hard and dense ( $> 900 \text{ kg m}^{-3}$ ). However, other factors such as hardness and extractives content are also involved in wood



**Figure 4** Panels of *Koompassia malaccensis* exposed for 24 months, split open to show internal destruction; a = Lumut b = Endau-Rompin



**Figure 5** Panels of *Eugenia* sp. exposed for 24 months, split open to show internal destruction; a = Lumut b = Endau-Rompin

durability (Borges et al. 2008). Significant but limited resistance of these three wood species to marine crustaceans and bivalve borers matched the resistance measured in tests using termites, white-and brown-rot fungi (Ani et al. 2005, Wong et al. 2005).

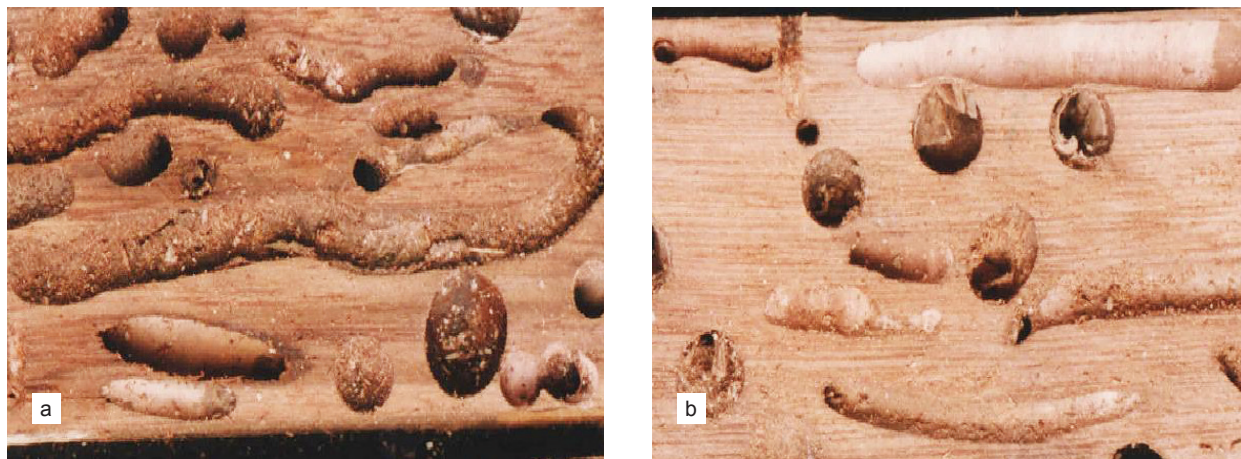
Figures 2 and 3 reveal that there is no definite correlation between the number of borer holes and the internal damage caused to the timbers. For example, even though species such as *C. malaccensis* had a large number of borer holes, the actual internal damage was about 50%. In comparison, although *D. platysepalum* had less number of borer holes, its damage was found to

be nearly 40% (Table 3). Santhakumaran (1970) also reported this trend in his study on 85 species of Indian timbers.

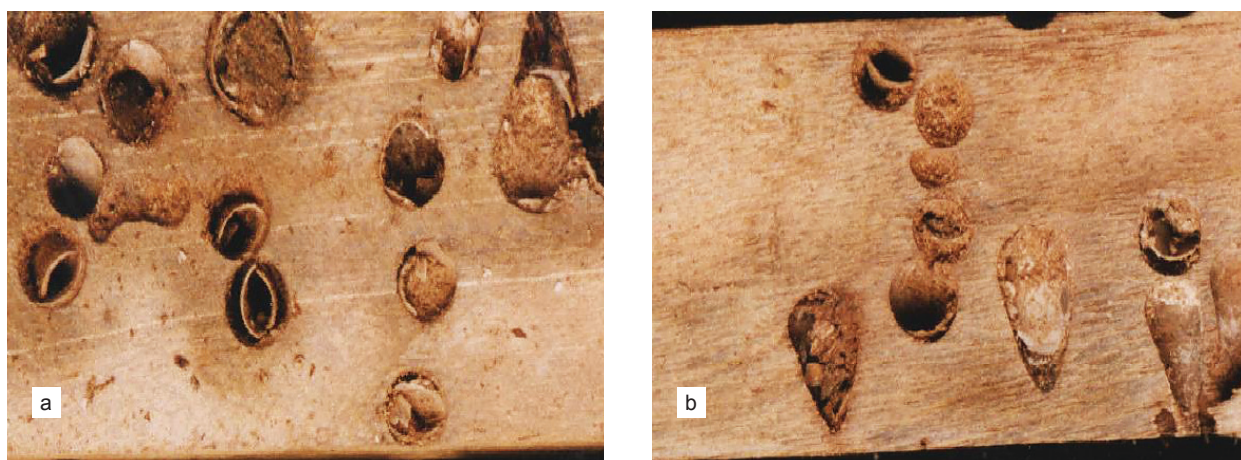
### Correlation between borer holes and wood extractives

Results of wood extracts of *K. malaccensis*, *C. malaccensis*, *S. maxwelliana*, *D. platysepalum* and *Eugenia* sp. were obtained from Azizol et al. (1990). For purpose of comparison, the timber species tested in this study are provided in Table 4. Result showed that there was correlation between wood extractives and

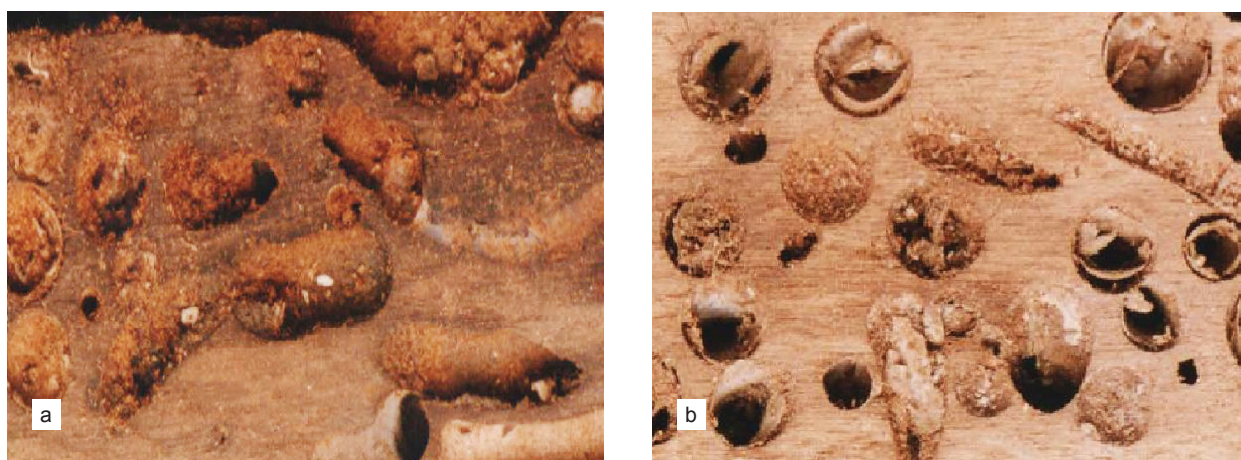




**Figure 6** Panels of *Cynometra malaccensis* exposed for 24 months, split open to show internal destruction; a = Lumut b = Endau-Rompin

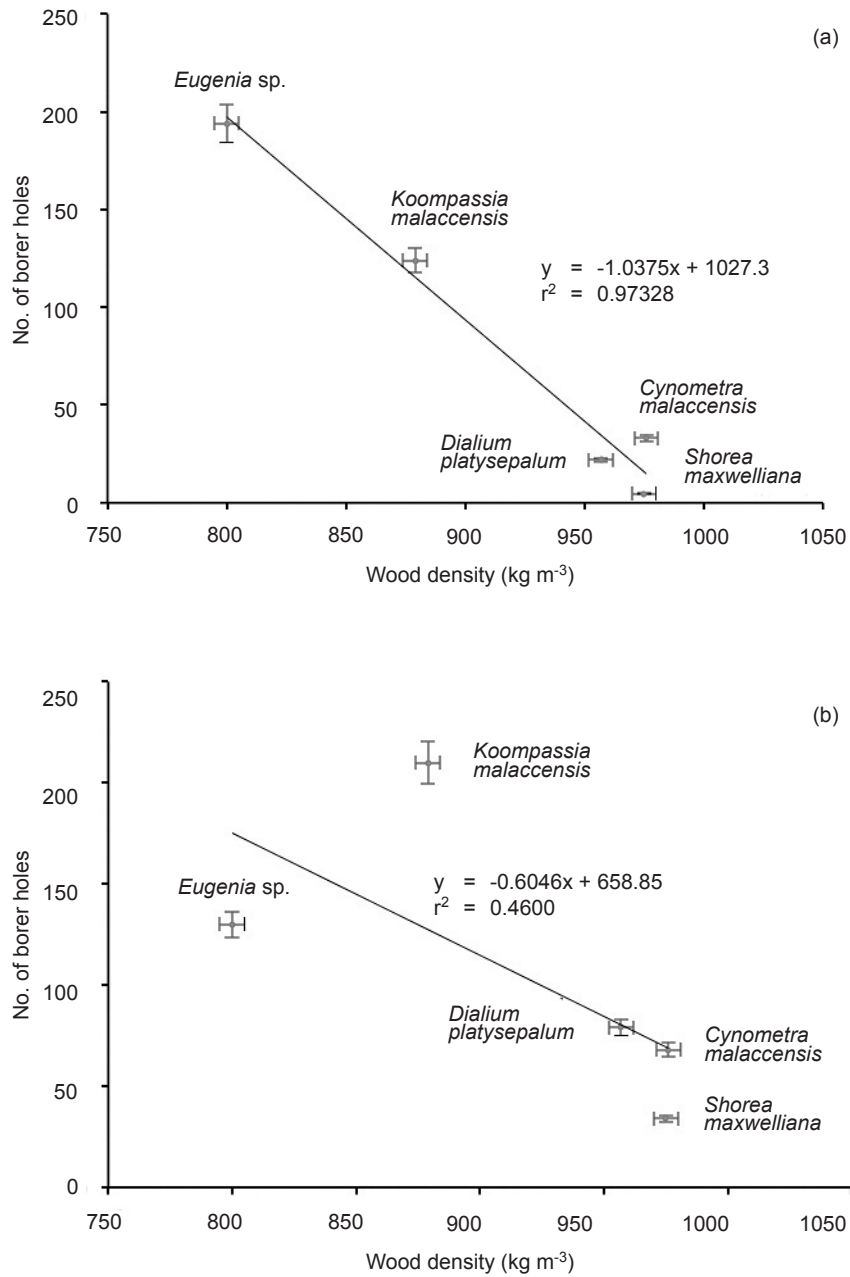


**Figure 7** Panels of *Shorea maxwelliana* exposed for 24 months, split open to show internal destruction; a = Lumut, b = Endau-Rompin



**Figure 8** Panels of *Dialium platysepalum* exposed for 24 months, split open to show internal destruction; a = Lumut b = Endau-Rompin

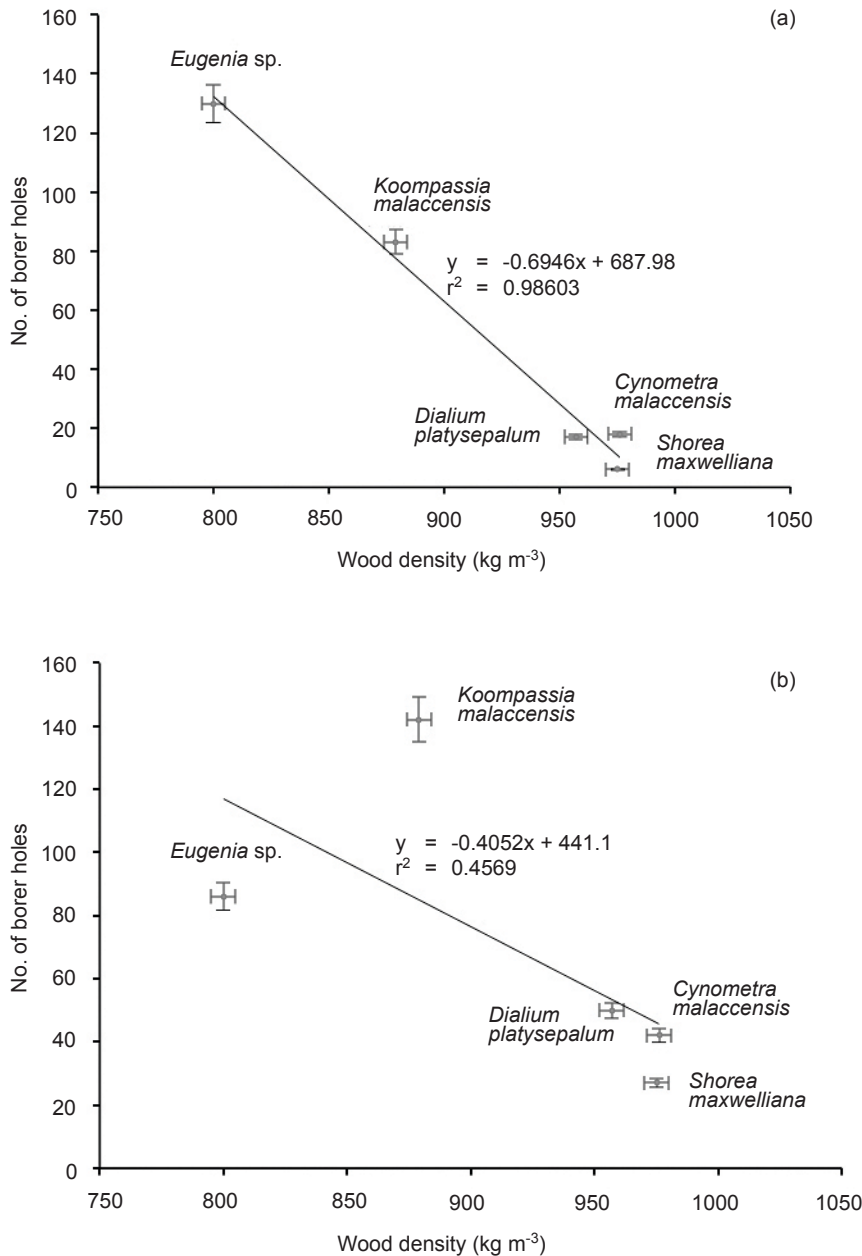




**Figure 9** Correlation between wood density and number of borer holes of (a) teredinids and (b) pholads in a range of Malaysian timbers exposed at Lumut, Perak; error bars denote standard errors; n = 40

percentage of damage by the marine borers. Wood species with high wood extractive content (*S. maxwelliana* and *D. platysepalum*) have more protection against marine borer compared with those with less wood extractive content. As indicated by Borges et al. (2008), extractives may disrupt digestion in *Limnoria*. However, not all extractives are toxic to marine borers. In the case of *C. malaccensis*, there is possibility that its wood extractive is not toxic to marine borer although

it is found in significant amount. In addition, wood hardness also influences durability against marine borers. A combination of wood extractives and wood hardness will improve the durability of wood against marine borer (Sivrikaya et al. 2009). On the other hand, compounds such as terpenoids, minquartinoic acid and alkaloids have been found toxic against arthropods (Rasmussen et al. 2000, Staerk et al. 2000, Han et al. 2004, 2005).



**Figure 10** Correlation between wood density and number of borer holes of (a) terenids (b) pholads in a range of Malaysian timbers exposed at Endau-Rompin, Pahang; error bars denote standard errors; n = 40

## CONCLUSIONS

The results from this study revealed hazards to timber caused by molluscs (Teredinidae and Pholadidae) with slight attack by crustaceans (Sphaeromatidae and Limnoriidae). *Teredo navalis*, *B. gouldi* and *M. striata* were the main destructive organisms at both sites. Water salinity played a major role in terms of marine borer intensity and distribution. Wood extractive content played a role in determining resistance of

wood to marine borer. Although the duration of the study was limited to 24 months, it is possible to classify the timber species, segregating non-resistant species and recommending promising ones.

## ACKNOWLEDGEMENTS

The authors are grateful to the Ministry of Defence (Naval Base, Lumut, Perak) and Ministry of Fisheries for providing the necessary sites and

**Table 3** Marine borer attack (number of borer holes, 25 mm<sup>2</sup>) on timber panels exposed at the two sites in Peninsular Malaysia for 24 months

Timber	Lumut			Endau-Rompin		
	Teredinidae	Pholadidae	Damage (%)	Teredinidae	Pholadidae	Damage (%)
<i>Koompassia malaccensis</i>	15.00 (1.20) b	25.75 (2.22) a	89.3	10.38 (0.43) b	17.75 (0.99) a	94.1
<i>Cynometra malaccensis</i>	4.00 (0.65) c	8.50 (0.05) c	50.0	2.25 (0.76) c	5.25 (0.04) c	46.0
<i>Shorea maxwelliana</i>	0.40 (1.44) d	4.38 (0.66) d	21.8	0.75 (1.32) d	3.38 (0.86) d	18.0
<i>Dialium platysepalum</i>	2.63 (0.08) c	9.75 (0.01) c	38.3	2.13 (1.63) c	6.25 (1.31) c	32.6
<i>Eugenia</i> sp.	23.13 (3.25) a	16.25 (2.11) b	93.5	16.25 (0.78) a	10.88 (2.01) b	92.4

Mean ( $\pm$  standard deviation) of 40 replicates for each timber species; similar alphabets mean values within the same column are not significantly different at the 0.05 level

**Table 4** Correlation between borer holes and wood extractives

Timber species	Destruction (%)		Wood extractives yield (%)
	Lumut	Endau-Rompin	
<i>Koompassia malaccensis</i>	89.3	94.1	} Azizol et al. (1990)
<i>Cynometra malaccensis</i>	50.0	46.0	
<i>Shorea maxwelliana</i>	21.8	18.0	
<i>Dialium platysepalum</i>	38.3	32.6	
<i>Eugenia</i> sp.	93.5	92.4	

facilities for the study. Thanks are also due to the staff of the Forest Products Division, Forest Research Institute Malaysia for field assistance. The study was funded by an IRPA grant from the Ministry of Science, Technology and Innovation, Malaysia.

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