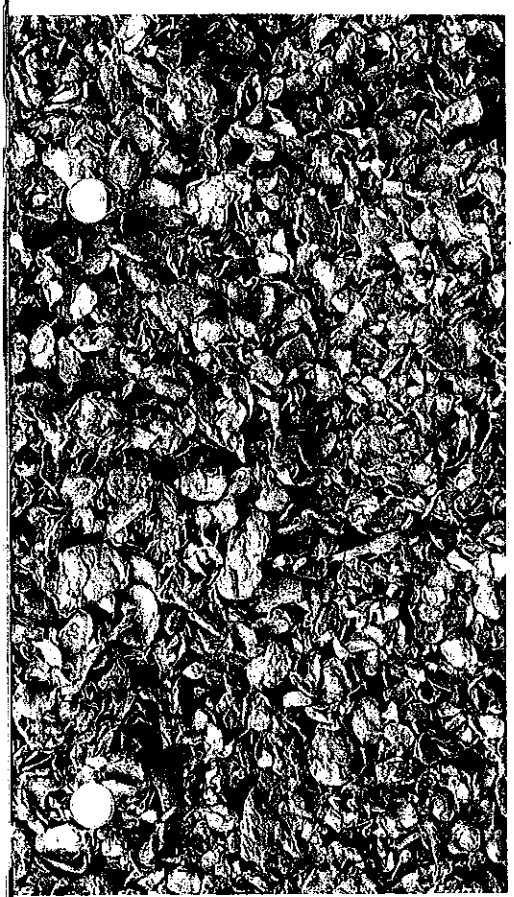
ISSN 0127-659X

TRTTC TECHNICAL REPORT

NO. TR/18

JUNE 1996

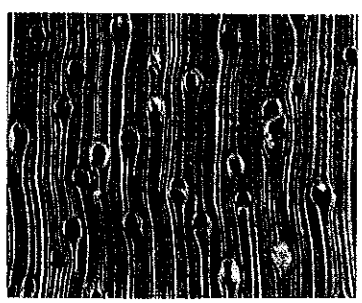


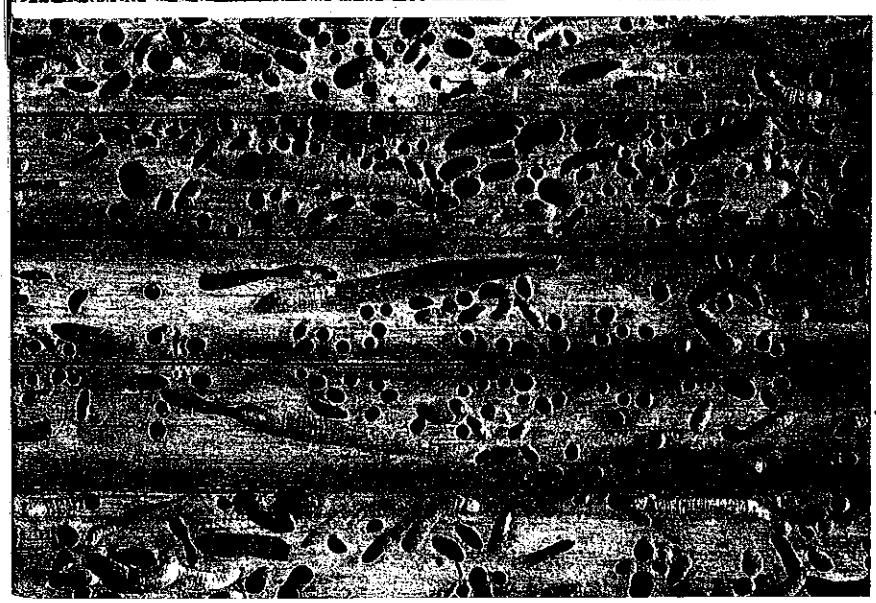
LABORATORY STUDY ON THE NATURAL DURABILITY OF SARAWAK TIMBERS AGAINST MARINE BORERS

BY

LIM CHONG WANG CHOON

LAURIE J. COCKSON





LABORATORY STUDY ON THE NATURAL DURABILITY OF SARAWAK TIMBERS AGAINST MARINE BORERS

by
LING WANG CHOON
LAURIE. J. COOKSON

Timber Research and Technical Training Centre
Forest Department
Kuching, Sarawak,
Malaysia.
1996

LABORATORY STUDY ON THE NATURAL DURABILITY OF SARAWAK TIMBERS AGAINST MARINE BORERS

Ling Wang Choon[1] and Laurie.J. Cookson[2]

[1] Timber Research and Technical Training Centre, Forest Department, Sarawak.
[2] CSIRO, Division of Forest Products, Australia.

INTRODUCTION

Earlier work showed that certain species of marine borer could be successfully reared and studied in laboratory aquaria (Cookson, 1990), and that after a one year comparison certain treated timbers could be attacked more severely than in the seas at Townsville and Port Stephens (Cookson and Woods, 1995).

The aquaria bioassay system should also prove useful for rapid assessment of the natural durability of various woods. This report describes the assessment of 41 untreated Sarawak timbers. The information gained should allow Sarawak to utilise more efficiently its timber resource for the marine end use. The project might also identify rain forest timbers worthy of further study as a potential source of naturally occurring wood preservatives. Such a possibility was demonstrated by Bultman and Parrish (1979), when they isolated obtusaquinone from the naturally resistant timber *Dalbergia retusa* (cocobolo), and found that it possessed anti-borer activity.

The timber from Sarawak was exposed to the crustacean limnoriid marine borer *Limnoria tripunctata* Menzies, and the teredinid *Lyrodus pedicellatus* (Quatrefages) for one year in laboratory aquaria.

MATERIALS AND METHODS

Preparation of blocks

The timber species sent from Sarawak are shown in Table 1. Seasoned timber from three different trees of each species was fumigated and sent to Australia. The samples were of size 200 x 38 x 38 mm or 200 x 38 x 30 mm. The timber was cut from the outer heartwood of trees with mean breast height diameter of 643 mm (standard deviation 15.2). Belian (*Eusideroxylon zwageri* Teijsm) was obtained from a commercial yard in Sarawak as sawn timber. The first four digits of the tree identification numbers provided in Table 1, indicate the year and month that the trees were collected. After shipment to Melbourne, blocks were conditioned to 12% moisture content, measured accurately and weighed, to determine air dry

densities (Table 1). Blocks 25 x 10 x 5 mm were cut from each sample, with longest dimension in the grain direction. Similar blocks of *Pinus radiata* D. Don sapwood were obtained from local sources and included for comparison.

Blocks were numbered with white ink, and artificially weathered by vacuum impregnation with water by weighing blocks down in jars, filling jars with tap-water, applying a vacuum of -98 kPa for 30 minutes, releasing vacuum and allowing them to soak for 30 minutes. Each species was in a different jar, containing blocks from the three trees. A record was kept of whether blocks for each timber species sank or floated. Blocks were then leached in tap water at 35°C for 14 days on a shaking water bath. The water was replaced with clean water ten times. Blocks were then vacuum oven dried at -90 kPa and 40°C for five days, and leached for a further seven days in sea water at 35°C. The sea water was changed five times. The blocks were air dried to 12% MC, weighed, and then attached with rubber bands in random order to a series of glass rods that were to be placed in the tanks with marine borers.

Marine borers and bioassay

Three sets of three replicate 401(600 x 300 x 300 mm) glass aquaria were used in this test, with each set containing a different species of marine borer:

Limnoria tripunctata Menzies is a crustacean with world-wide temperate and tropical distribution, and a high tolerance to creosote. The population was collected from creosote-treated *P. radiata* from Sydney Harbour, and supplemented at the start and mid-way through the bioassay with animals freshly collected from Melbourne's Port Phillip Bay in untreated pine bait blocks. Water in tanks containing this species was maintained at 24°C.

Lyrodus pedicellatus is a molluscan 'shipworm' with world-wide temperate and tropical distribution. Pine bait blocks collected from Port Phillip Bay were introduced into the tanks at the start and mid-way through the bioassay. The original bait blocks were then removed, as were any *Limnoria* that had moved from the bait blocks to the feeder blocks or test blocks. Water in tanks containing this species was maintained at 20°C.

Each tank contained a biological filtration system. This consisted of 71(7.7 kg) of crushed mollusc shells with diameters of 2.4 - 8.0 mm. The crushed shell, which supports bacterial attachment, was placed on a mat of synthetic 'filter fibre' that covered a plastic mesh base supported on glass Petri dishes. The water entrance to the biological filter was loosely packed with 'filter fibre'. This system prevented clogging of the shell grit with the large amount of frass produced by borers. All frass was siphoned from the floor of the tank, and sea water replaced with local sea water from Port Phillip Bays one and three weeks after bioassay commencement, and monthly thereafter. To avoid blockage from frass, the 'filter fibre' at the

entrance to the biological filter was replaced bimonthly. Water circulated through the system at about 20 - 30 l/h, by use of an airlift pump. Water was kept at a salinity of 30 ppt, and distilled water used to replace that lost by evaporation.

The limnoriid borers were fed throughout the test with untreated *P. radiata* boards (230 x 130 x 6 mm) hung from glass hooks in the tanks. *L. pedicellatus* was maintained in *P. radiata* feeder blocks having a smaller surface area (150 x 90 x 35 mm), to help prevent the formation of surface contaminating microbial growths. All borer species bred in the tanks. Throughout most of the bioassay period, *L. pedicellatus* continued to release larvae from the feeder blocks, and these would migrate to test blocks. For *Limnoria*, specimens were often observed to have eggs or larvae in the brood pouch.

One block from each tree was exposed in each tank, so there were three blocks of each timber species in each tank. Against each marine borer species, a total of nine replicate blocks were exposed. Test blocks on glass rods were placed on the floor of tanks containing *L. tripunctata*, and about 50 mm below the water surface (and above the *P. radiata* feed stock) in tanks containing *L. pedicellatus*.

After 12 month's exposure in the tanks, blocks were removed, air dried to 12% mc, and weighed to determine mass loss. Blocks were then X-rayed (20 seconds at 18 kV) to help determine the extent of internal damage. The X-rays aided the visual assessment of attack. After being X-rayed, blocks were viewed under a binocular microscope, and subjectively rated on a scale of 0 to 4, where:

4.0 = no attack.

3.5 = trace attack. *Limnoria*: etchings on wood surface only. *Lyrodus*: burrow initiations, where hole is less than pediveliger diameter of about 0.35 mm, indicating full metamorphosis into adult was unsuccessful.

3.0 = light/moderate attack. *Limnoria*: 1-3 burrows. *Lyrodus*: hole depth 1-2 times shell diameter.

2.5 = moderate attack. *Limnoria*: 4-6 burrows, or more than 4-6 burrows but burrows confined to edges of block. *Lyrodus*: hole depth 2-3 times shell diameter.

2.0 = moderate/heavy attack. *Limnoria*: 7-12 burrows over general surface. *Lyrodus*: several holes with depths 2-3 times shell diameter, or with several holes with depths 4-5 times shell diameter.

1.5 = heavy attack. *Limnoria*: 13-24 burrows over general surface. *Lyrodus*: many holes 1-2 mm in length.

1.0 = heavy/severe attack. *Limnoria*: many burrows over general surface. *Lyrodus*: some holes 3-8 mm long.

0.5 = severe attack. *Limnoria*: numerous burrows, block beginning to lose outline of shape. *Lyrodus*: many holes up to 10 mm long.

0.0 = destroyed. *Limnoria*: block lost shape. *Lyrodus*: entire cross section honeycombed with burrows.

RESULTS AND DISCUSSION

The condition of each block after exposure is shown in Table 1. The performance rating given to each block is listed, along with its mass loss. Table 2 provides a summary of the results for each timber species, and lists those species in order of resistance. This ranking of species was obtained after combining the ratings given after exposure to both species of marine borer. However, as teredinids are the greater hazard in Sarawak than *Limnoria*, it might be prudent to give greater weight to the *L. pedicellatus* data.

During the artificial weathering cycle, the heartwood blocks were vacuum impregnated with water. Table 2 lists those timber species where blocks sank, floated or did both after treatment. This property is a function of both density and wood treatability. However, the information is included to give cursory indication of treatability. Blocks with density over 1000 kg/m^3 sink whether water impregnated or not. Blocks that float, would tend to indicate that the timber species was not easy to treat.

Mass loss did not provide a useful indication of the level of marine borer attack, especially when attack was light or moderate. While mass was lost to marine borers, several other variables add to mass loss, making correlation difficult. Mass would also have been lost through leaching, and through the activities of marine fungi in the aquaria. Marine fungi were very active on blocks in tanks containing *L. pedicellatus*, and surface mycelium was observed on most blocks. However, surface mycelium was not observed on blocks in tanks containing *L. tripunctata*. This borer probably grazes on surface mycelium, keeping blocks clean, while *L. pedicellatus* is unable to leave its burrow. This difference in behaviour also explains why there was usually higher mass loss of blocks in aquaria exposed to *L. pedicellatus* than those containing *L. tripunctata*. Marine fungal activity in aquaria with *L. pedicellatus* also caused greater surface erosion (and mass loss) of blocks. In the sea, various non-wood boring invertebrates other than *Limnoria* would also be able to graze on surface fungal mycelium, so reducing the mass loss that could potentially result from these microorganisms .

The least resistant timber examined was *P. radiata* sapwood. This was almost completely destroyed during the exposure period (Table 2), and shows that the bioassay conditions were favourable to marine borer activity. Those Sarawak

timbers heavily attacked were entuyut, ramin telor, tekalong, and pitoh paya (Table 2).

The most resistant timber from Sarawak was belian. This timber species is commonly used for marine structures in Sarawak (Ling, 1994). Selangan batu, selumar and teruntum merah were also quite resistant. Teruntum merah is used for marine structures in Sarawak (Ling, 1994), but these results suggest that selangan batu and selumar may be slightly more resistant (Table 2). Selangan batu is sometimes used for marine piling in Darwin.

REFERENCES

Bultman, J.D. and Parrish, K.K. (1979). Evaluation of some wood-extractives and related compounds as anti-borer, anti-fungal, and anti-termitic agents. Int. Biodeterior. Bull. 15: 19-27.

Ling Wang Choon, (1994). Response to IRG questionaire, unpublished.

Cookson, L.J. (1990). A laboratory bioassay method for testing preservatives against the marine borers *Limnoria tripunctata, L. quadripunctata* (Crustacea) and *Lyrodus pedicellatus* (Mollusca). Internat. Res. Group on Wood Pres. Document No. IRG/WP/4 1 60.

Cookson, L.J. and Woods, T.L. (1995). Laboratory method used to test the effectiveness of chlorothalonil against marine borers. Wood Protection 3: 9-15 (in press).

Table 1 Rating and mass loss of each 1.25 cm^3 block after one year's exposure to marine borers in aquaria. Three replicates for each tree.

x-ray	Timber species	Tree sample number	Air dry density kg/m^3	*Limnoria tripunctata* Rating (and mass loss) of each block	*Lyrodus pedicellatus* Rating (and mass loss) of each block
42	Radiata pine *Pinus radiata*		526	0.5(48.5),0.5(59.2),0.5(43.9) 0(70.9),0.5(41.9),0.5(52.3) 1(32.4),1(28.4),1(38.3)	0(55.4),0(45.4),0(52.1) 0(68.9),0(57.8),0(35.9) 0(58.1),0(37.3),0.5(57.9)
1	Keruing puteh *Dipterocarpus caudiferus*	8110-01 8110-02 8110-03	779 735 777	4(0.2),2.5(0.7),1.5(2.2) 3(1.0),3(0.1),3(0.6) 2.5(2.3),3.5(1.4),1.5(2.6)	3(7.4), 2.5(10.4), 2.5(8.7) 3(7.5),3(9.7),2(14.0) 2.5(11.1),2.5(13.7),2.5(7.5)
2	Keruing ternek *Dipterocarpus palembanicus*	8106-07 8106-08 8106-09	785 882 812	3.5(0.1),1.5(8.1),2(1.0) 1.5(4.4),2.5(0.1),0.5(36.8) 1.5(3.6),1.5(3.3),3(0.4)	2.5(8.0),2(12.6),2.5(10.0) 1(16.3),1.5(14.2),1(16.9) 2 (6.9),1.5(11.3),2(10.8)
3	Keruing utap *Dipterocarpus rigidus*	7905-007 7905-008 7905-009	883 1019 812	2.5(1.7),3(0.4) 2.5(0.3) 3(0.8),0.5(45.6),2(1.9) 3(0.6),3(0.2),3.5(0.1)	2.5(5.8),2(9.8),2.5(9.2) 1(12.5),1(17.2),0.5(23.1) 2(5.3),2(13.4),2(14.5)
4	Kapur paji *Dryobalanops lanceolata*	8203-06 8203-08 8203-09	651 735 690	4(1.3),3.5(0.4),4(1.7) 3(0.1),3.5(0.2),3(0.3) 3.5(0.4),2.5(1.3),3(0.1)	3.5(10.9),3(11.1),3(8.6) 3(9.3),3(7.5) 3(5.7) 2.5(11.7),3(11.7),3(7.1)
5	Raruk *Shorea ochracea*	7905-001 7905-002 7905-003	490 464 452	2.5(1.6),4(0.3),4(1.1) 3(1.7),2.5(0.2),4(1.0) 4(0.5),3.5(1.2),3.5(0.6)	3(9.6),3(15.0),3(15.4) 3(8.4),2.5(16.3),2.5(13.3) 2.5(13.3),2.5(16.8),3(8.3)
6	Meranti binatoh *Shorea argentifolia*	8104-05 8104-12 8104-13	512 300 484	3.5(1.5),4(2.6),4(3.7) 1.5(0.6),2.5(0.8),3(1.4) 3.5(2.2),4(6.4),4(5.2)	3(7.1),2.5(5.4),3(11.6) 2.5(22.9),2(14.0),2.5(25.7) 2.5(8.7),3(11.5),2.5(5.6)
7	Engkabang jantong *Shorea macrophylla*	8202-01 8203-05 8203-07	411 413 365	4(0.7),3(3.9),4(2.7) 3(1.5),3(0.7),4(0.7) 4(0.4),4(2.3),2.5(1.3)	2(14.4),2(17.9),2.5(9.8) 2(10.0),2(18.0),2.5(19.0) 2.5(22.0),2(13.4),2(21.0)
8	Meranti sarang punai *Shorea parvifolia*	8203-02 8203-03 8203-04	397 480 620	1.5(2.0),4(0.0),3(1.4) 4(2.3),3.5(1.1),4(3.2) 4(1.4),4(1.2),4(1.0)	2.5(18.2),2(16.3),2.5(8.3) 2.5(10.8),2.5(8.4),2.5(6.6) 3(9.7),3(3.1),2.5(26.4)
9	Meranti bulu *Shorea pilosa*	7905-010 7905-011 7905-012	397 390 339	3(1.6),3(0.4),3.5(3.4) 4(2.9),3(1.8),3(0.6) 2.5(2.0),2.5(1.5),3(0.2)	2.5(14.1),2.5(9.8),2.5(17.4) 2.5(9.0),2.5(14.6),2.5(12.9) 2(19.7),2(11.0),2.5(24.7)
10	Meranti langgai bukit *Shorea pinanga*	8106-11 8106-14 8106-15	401 488 558	1.5(2.2),3.5(3.0),3(1.0) 2.5(0.6),0.5(23.9),3(0.6) 4(2.6),3(0.7),3(0.5)	2(15.1),2(9.3),2.5(17.3) 2(17.2),2.5(14.4),2(9.4) 2.5(9.6),2.5(12.7),2.5(7.0)
11	Meranti merah kesumba *Shorea rubra*	8106-05 8106-10 8106-13	572 581 535	4(1.4),2.5(2.9),4(2.3) 3(1.4),3.5(3.6),4(2.9) 3(3.6),4(0.6),2.5(0.2)	2.5(5.1),2.5(11.4),3(12.2) 2.5(11.9),2.5(11.4),2(4.5) 2.5(12.6),2.5(8.9),2.5(5.1)
12	Meranti daun mata lembing *Shorea sagittata*	7905-013 7905-014 7905-015	495 589 374	4(2.3),4(2.2),4(1.7) 4(1.6),4(2.7),3.5(1.6) 3(6.5),3.5(7.5),4(2.6)	2.5(11.3),3(4.5),3(8.1) 3(8.8),3(2.7),3(8.8) 2.5(9.5),2.5(5.4),2.5(13.9)
13	Meranti paya bersisek *Shorea scaberrima*	7804-001 7804-003 7804-009	432 454 437	4(0.3),3(2.7),2(0.2) 3(2.7),3.5(2.2),4(3.4) 3.5(1.7),2.5(0.8),4(2.0)	2.5(9.5),2.5(17.9),2.5(13.8) 2.5(11.8),2.5(14.9),2(8.0) 2.5(17.0),2.5(8.8),2.5(15.5)
14	Resak m'bangan *Vatica oblongifolia*	7809-004 7809-006 7809-007	884 968 972	1.5(5.1),1.5(0.9),2.5(0.3) 1.5(4.2),2.5(0.7),1.5(11.8) 1.5(9.2),1.5(1.8),2.5(0.2)	3(2.5),3(4.2),2.5(8.8) 2.5(7.4),3(3.9),2.5(6.4) 1.5(7.6),1.5(4.7),1.5(4.6)
15	Durian burong *Durio carinatus*	7704-014 7704-015 7704-017	532 703 747	1.5(13.1),2(2.6),2.5(3.7) 3(3.2),4(1.1),4(1.9) 4(1.7),1.5(4.8),3(0.3)	1.5(25.1),1(20.7),1(19.1) 2.5(15.2),2.5(16.2),2.5(9.8) 1(12.4),1.5(14.6),1(9.7)

16	Bajan	8106-01	971	4(0.5),3.5(0.2),3.5(0.4)	2.5(5.1),2.5(9.5),3(6.9)
	Kokoona reflexa	8106-04	1028	4(0.5),3(1.4),2.5(0.8)	1.5(9.6),1.5 (7.7),1(6.1)
		8106-12	1024	3.5(0.4),3(0.2),4(0.5)	2(7.5),2(5.4),1(10.0)
17	Perupok paya	7903-005	513	3(1.3),3.5(0.4),3(1.6)	2(15.6),2(12.4),2(18.3)
	Lophopetalum	7903-006	480	3.5(1.9),2(0.3),3(1.2)	1.5(15.2),1.5(17.4),1(23.8)
	multinervium	7903-007	508	1(10.0),1.5(3.5),3.5(2.0)	1(13.7),2(17.0),1(19.7)
18	Teruntum merah	7703-001	752	4(0.2),3(0.8),4(1.4)	3(10.4),3(6.4),3(9.0)
	Lumnitzera	7704-003	798	4(1.0),4(0.3),4(0.0)	3(4.7),3(7.5),3(9.4)
	littorea	7704-007	869	3.5(0.3),4(0.7),4(0.2)	3(8.2),3(29.1),3(7.9)
19	Geronggang paya	8007-004	536	3(0.8),4(1.3),2.5(1.6)	2(6.4),2(9.6),2(14.4)
	Cratoxylum	8007-005	456	3(2.7),2.5(0.9),3(0.8)	2(8.2),2(16.5),2(14.6)
	arborescens	8007-006	441	3(1.7),2(3.3),2.5(0.2)	1.5(20.1),1(17.8),1.5(12.2)
20	Belian	1	1038	4(1.9),4(2.3),4(1.7)	3.5(0.7),3(2.1),3.5(2.6)
	Eusideroxylon	2	1132	4(2.3),4(2.1),4(2.2)	3.5(1.7),3.5(1.2),3.5(0.2)
	zwageri	3	1023	4(1.8),4(2.0),4(2.3)	3(1.1),3.5(2.0),3(2.4)
21	Tapang	8104-01	975	4(1.2),4(1.5),2(0.6)	2.5(5.3),2.5(8.3),2.5(5.5)
	Koompassia	8104-04	1001	3.5(0.8),2.5(1.2),1.5(1.2)	2.5(9.5),2.5(4.5),2(7.8)
	excelsa	8104-09	934	3.5(0.2),2(1.2),3.5(1.0)	2.5(8.7),2(5.7),2(9.2)
22	Menggris paya	7806-012	995	4(0.9),3.5(0.8),3.5(0.9)	3(7.1),2.5(6.3),2.5(4.6)
	Koompassia	7806-013	873	4(0.9),3.5(1.4),3(0.9)	2.8(8.5),3(5.8),2.5(5.1)
	malaccensis	7806-014	987	3(1.2),4(1.0),2(1.5)	1.5(10.9),1.5(9.4),2(4.9)
23	Petai belalang	8110-07	701	4(1.4),4(1.3),2(0.6)	3(3.4),3(5.7),3(7.5)
	Pithecellobium	8110-08	708	4(2.7),4(2.8),4(2.3)	3(3.0),3(5.6),3(5.7)
	ellipticum	8110-12	734	4(1.3),3(1.9),4(2.8)	3(3.2),3(6.6),2.5(6.5)
24	Ramin telor	7612-013	611	1.5(5.8),2.5(2.8),1(5.1)	1(20.0),1(19.4),1(20.6)
	Gonystylus	7704-012	657	1(7.0),1(7.0),2(6.2)	1(25.4),1(28.6),1(18.3)
	bancanus	7704-013	664	2.5(3.8),2.5(3.8),3(3.7)	2(17.5),2(17.3),2(13.6)
25	Keruing sol padi	8707-01	792	1(26.2),0.5(15.9),1(19.9)	2(14.9),1(9.9),1(19.0)
	Dipterocarpus	8707-02	772	3.5(1.2),1.5(2.5),3(0.7)	2.5(8.0),2.5(6.1),2.5(10.7)
	pachyphyllus	8707-03	769	3.5(0.6),3.5(1.0),2(3.6)	2(12.3),2(7.5),2(12.6)
26	Selangan batu	8707-04	1075	4(0.7),4(1.2),4(0.6)	3(2.7),3.5(5.1),3(5.0)
	Shorea	8707-05	989	4(1.1),4(1.3),4(0.6)	3(5.9),3.5(5.4),3(2.5)
	pluricostata	8707-06	1119	4(0.8),4(0.8),4(1.0)	3(2.2),3.5(4.3),3(5.4)
27	Kumus	8211-08	779	4(0.5),4(2.3),4(1.8)	3(7.7),3(7.8),3(4.7)
	Shorea laevis	8211-10	791	4(1.5),4(1.1),4(0.7)	3(9.2),3(8.7),3(4.6)
		8211-11	651	2.5(1.7),4(2.3),4(3.3)	2.5(7.9),3(6.6),2.5(4.3)
28	Meranti luang	8306-03	419	3(1.6),4(1.9),3(1.2)	2(9.5),2.5(16.9),2(11.5)
	Shorea ovalis	8306-13	450	2(1.1),3(3.6),4(1.1)	2.5(9.5),2.5(11.4),2.5(15.6)
		8306-24	537	3.5(2.1),4(1.3),2.5(0.8)	2(9.7),2(8.8),1.5(12.8)
29	Meranti buaya	8610-06	648	4(2.7),1(3.3),3(1.9)	2.5(5.0),2.5(13.1),2.5(10.6)
	Shorea uliginosa	8610-08	654	3.5(1.8),3(2.8),2(0.7)	2(7.9),2(11.9),2(4.3)
		8611-16	844	3(1.0),2(1.7),2(1.0)	2(6.4),2(9.4),2(4.9)
30	Pitoh paya	8903-05	647	1(10.8),1(31.6),2(8.2)	0.5(40.5),1.5(16.5),1(21.5)
	Swintonia glauca	8903-06	647	3(1.2),2.5(2.2),3(0.8)	1(8.9),1(17.5),2.5(15.0)
		8904-08	731	3(0.0),1(18.4),3(1.2)	1.5(15.2),1(14.1),2.5(13.9)
31	Bengang	8806-10	Missing		
	Neesia borneensis	8806-11	564	4(2.4),2.5(1.3),3(1.1)	2(12.4),1.5(15.8),2(17.0)
		8806-12	643	3(0.9),3(1.4),3.5(2.7)	2.5(9.0),3(14.2),2.5(15.5)
32	Empenit	8211-13	1111	4(1.6),4(1.2),4(1.5)	3(5.8),2.5(2.7),2(6.2)
	Lithocarpus	8211-14	1071	4(2.3),4(1.2),4(1.4)	2(6.6),2(3.2),2(5.8)
	cantleyanus	8211-15	1036	4(1.8),4(1.0),3(1.1)	2(7.5),2.5(4.2),2.5(2.7)
33	Bintangor	8406-03	718	4(0.8),4(2.4),4(1.9)	3(2.1),2.5(6.7),3(10.0)
	Calophyllum	8406-06	724	4(2.8),4(2.0),3.5(2.3)	2.5(7.7),3(5.7),missing
	retusum	8406-11	725	4(0.7),4(2.0),3.5(0.6)	3(11.9),2.5(11.7),2.5(6.5)

34	Keranji	8504-04	967	3(0.1),4(0.1),4(0.5)	2.5(3.6),3(6.0),3(4.8)
	Dialium indum	8504-05	935	3.5(0.5),3(0.1),3.5(1.5)	3(6.6),2.5(8.0),2.5(4.3)
		8504-08	1105	3.5(1.5),2.5(1.2),3(0.8)	1.5(12.4),2(7.0),2(4.8)
35	Litoh	8007-010	776	4(1.6),3.5(0.4),4(1.2)	2(7.2),2(7.4),2(9.9)
	Ctenolophon	8007-015	857	4(0.0),4(1.1),4(0.4)	2.5(6.4),3(8.2),2.5(9.9)
	parvifolius	8007-016	767	4(0.8),4(0.1),3(0.8)	2.5(11.3),2.5(11.7),2.5(6.2)
36	Jelungan sasak	8903-03	961	4(1.5),4(2.4),4(1.3)	3(5.9),3(2.4),3(5.9)
	Amoora	8904-16	938	4(2.0),4(2.2),4(2.6)	3(2.2),3(6.4),3(5.1)
	rubiginosa	8904-17	789	4(1.9),4(1.3),3.5(2.8)	2(4.6),2.5(8.2),2(8.3)
37	Tekalong	8806-13	490	1.5(5.6),1.5(6.9),3.5(1.2)	1.5(14.7),1.5(7.7),1.5(13.0)
	Artocarpus	8806-14	419	1.5(10.0),3(0.4),1(19.2)	1(22.0),1(20.3),1(21.2)
	odoratissimus	8806-15	593	4(1.1),2(1.3),1.5(7.4)	1.5(13.9),1.5(16.4),1(20.1)
38	Selumar	8904-09	913	4(1.1),4(1.5),4(1.9)	3(5.7),3(3.3),3(6.2)
	Jackia ornata	8904-10	1026	4(0.6),4(0.9),4(1.3)	3.5(4.8),3(4.0),3(5.2)
		8904-12	905	4(1.1),3.5(0.4),4(1.2)	3(5.7),3(5.1),3(3.7)
39	Jadap	8806-03	1005	3(0.2),4(0.7),4(0.3)	2.5(7.2),2.5(6.4),2.5(4.9)
	Mussaendopsis	8806-08	969	2.5(0.3),1(19.6),2(0.0)	1(12.1),1(9.5),1(13.7)
	beccariana	8806-09	1034	2.5(0.9),4(0.7),4(0.1)	2.5(5.4),2(7.3),2.5(6.5)
40	Nyatoh	8707-07	735	3(2.2),4(2.8),3.5(2.2)	3(8.5),3(3.3),3(6.3)
	Palaquium	8707-08	746	4(2.3),3.5(2.5),4(2.3)	3(7.1),2.5(4.2),3(6.7)
	rivulare	8707-12	724	4(2.4),3.5(1.9),4(1.4)	3(4.1),3(7.5),2.5(7.9)
41	Entuyut	8306-47	738	1(23.6),2.5(0.1),2(1.6)	2.5(7.4),2(13.1),2(11.3)
	Tetramerista	8306-48	825	0.5(43.4),1(10.9),1(13.4)	1.5(15.8),1(7.8),1.5(14.8)
	glabra	8306-57	707	1(15.2),1(20.9),0.5(53.9)	1.5(15.7),1(11.8),1(25.7)

Table 2. Summary of results, listing timber species in descending order of marine borer resistance. Mean of nine replicate blocks (three trees) for each species.

Timber species	Mean air dry density of trees kg/m^3	After water impregnation S = all sank F = all float I = some sank some floated	*Limnoria tripunctata* Mean rating (standard error)	*Lyrodus pedicellatus* Mean rating (standard error)	Total of rating means
Belian *Eusideroxylon zwageri*	1064	S	4.0(0.0)	3.3(0.1)	7.3
Selangan batu *Shorea pluricostata*	1061	S	4.0(0.0)	3.2(0.1)	7.2
Selumar *Jackia ornata*	948	S	3.9(0.1)	3.1(0.1)	7.0
Teruntum merah *Lumnitzera littorea*	806	S	3.8(0.1)	3.0(0.0)	6.8
Kumus *Shorea laevis*	740	F	3.8(0.2)	2.9(0.1)	6.7
Bintangor *Calophyllum retusum*	722	I	3.9(0.1)	2.8(0.1)	6.7
Meranti daun mata lembing *Shorea sagittata*	486	F	3.8(0.1)	2.8(0.1)	6.6
Petai belalang *Pithecellobium ellipticum*	714	I	3.7(0.2)	2.9(0.1)	6.6
Jelungan sasak *Amoora rubiginosa*	896	I	3.9(0.1)	2.7(0.1)	6.6
Nyatoh *Palaquium rivulare*	735	F	3.7(0.1)	2.9(0.1)	6.6
Kapur paji *Dryobalanops lanceolata*	692	I	3.3(0.2)	3.0(0.1)	6.3
Raruk *Shorea ochracea*	469	F	2.8(0.1)	3.4(0.2)	6.2
Meranti sarang punai *Shorea parvifolia*	499	F	3.6(0.3)	2.6(0.1)	6.2
Empenit *Lithocarpus cantleyanus*	1073	S	3.9(0.1)	2.3(0.1)	6.2
Litoh *Ctenolophon parvifolius*	800	S	3.8(0.1)	2.4(0.1)	6.2
Meranti binatoh *Shorea argentifolia*	432	F	3.3(0.3)	2.6(0.1)	5.9
Meranti merah kesumba *Shorea rubra*	563	F	3.4(0.2)	2.5(0.1)	5.9
Engkabang jantong *Shorea macrophylla*	396	F	3.5(0.2)	2.2(0.1)	5.7
Meranti paya bersisek *Shorea scaberrima*	441	F	3.3(0.2)	2.4(0.1)	5.7
Menggris paya *Koompassia malaccensis*	952	S	3.4(0.2)	2.3(0.2)	5.7
Keranji *Dialium indum*	1002	S	3.3(0.2)	2.4(0.2)	5.7
Meranti bulu *Shorea pilosa*	375	F	3.1(0.2)	2.4(0.1)	5.5

Meranti luang *Shorea ovalis*	469	F	3.2(0.2)	2.3(0.1)	5.5
Bengang *Neesia borneensis*	604	S	2.3(0.2)	3.2(0.2)	5.5
Keruing puteh *Dipterocarpus caudiferus*	763	S	2.7(0.3)	2.6(0.1)	5.3
Bajan *Kokoona reflexa*	1008	S	3.4(0.2)	1.9(0.2)	5.3
Tapang *Koompassia excelsa*	970	S	2.9(0.3)	2.3(0.1)	5.2
Meranti langgai bukit *Shorea pinanga*	482	F	2.7(0.4)	2.3(0.1)	5.0
Jadap *Mussaendopsis beccariana*	1003	S	3.0(0.4)	1.9(0.2)	4.9
Meranti buaya *Shorea uliginosa*	715	F	2.6(0.3)	2.2(0.1)	4.8
Geronggang paya *Cratoxylum arborescens*	478	I	2.8(0.2)	1.8(0.1)	4.6
Durian burong *Durio carinatus*	661	S	2.8(0.3)	1.6(0.2)	4.4
Keruing utap *Dipterocarpus rigidus*	905	S	1.7(0.2)	2.6(0.3)	4.3
Perupok paya *Lophopetalum multinervium*	500	S	2.7(0.3)	1.6(0.2)	4.3
Resak m'bangan *Vatica oblongifolia*	941	I	1.8(0.2)	2.3(0.2)	4.1
Keruing sol padi *Dipterocarpus pachyphyllus*	778	S	2.2(0.4)	1.9(0.2)	4.1
Keruing ternek *Dipterocarpus palembanicus*	826	S	1.9(0.3)	1.8(0.2)	3.7
Pitoh paya *Swintonia glauca*	675	S	2.2(0.3)	1.4(0.2)	3.6
Tekalong *Artocarpus odoratissimus*	501	F	2.2(0.4)	1.3(0.1)	3.5
Ramin telor *Gonystylus bancanus*	644	S	1.9(0.3)	1.3(0.2)	3.2
Entuyut *Tetramerista glabra*	757	I	1.2(0.2)	1.6(0.2)	2.8
Radiata pine (sapwood) *Pinus radiata*	526	S	0.6(0.1)	0.1(0.1)	0.7

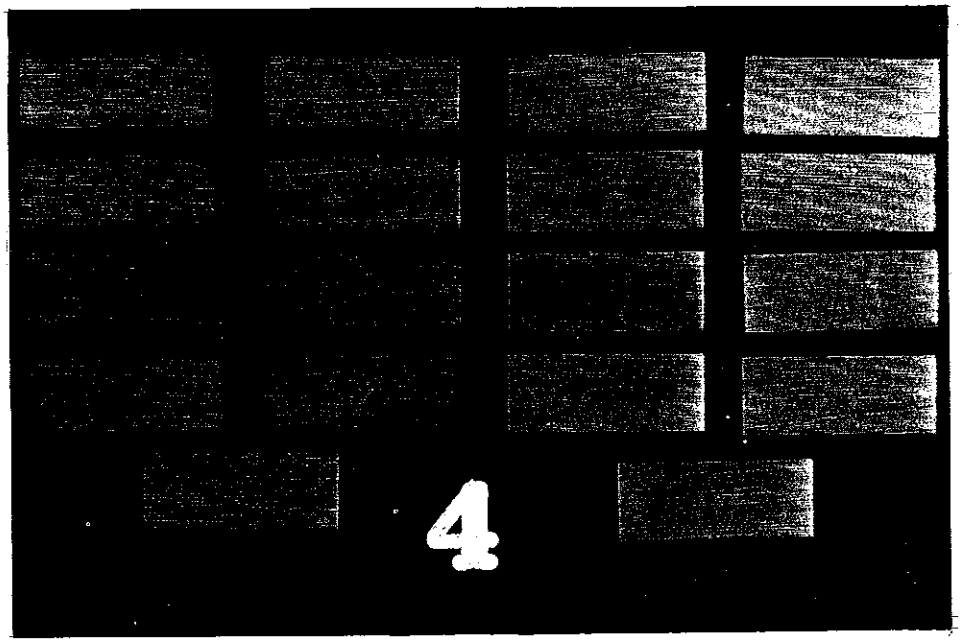


Fig. 1 X-ray photo 4 showing 2 sets of Kapur paji blocks attacked by borers of *Lyrodus pedicellatus* *[3.5(10.9),3(11.1),3(8.6),3(9.3),3(7.5),3(5.7),2.5(11.7),3(11.7),3(7.1)] and *Limnoria tripunctata* [4(1.3),3.5(0.4),4(1.7),3(0.1),3.5(0.2),3(0.3),3.5(0.4),2.5(1.3),3(0.1) on left and right respectively

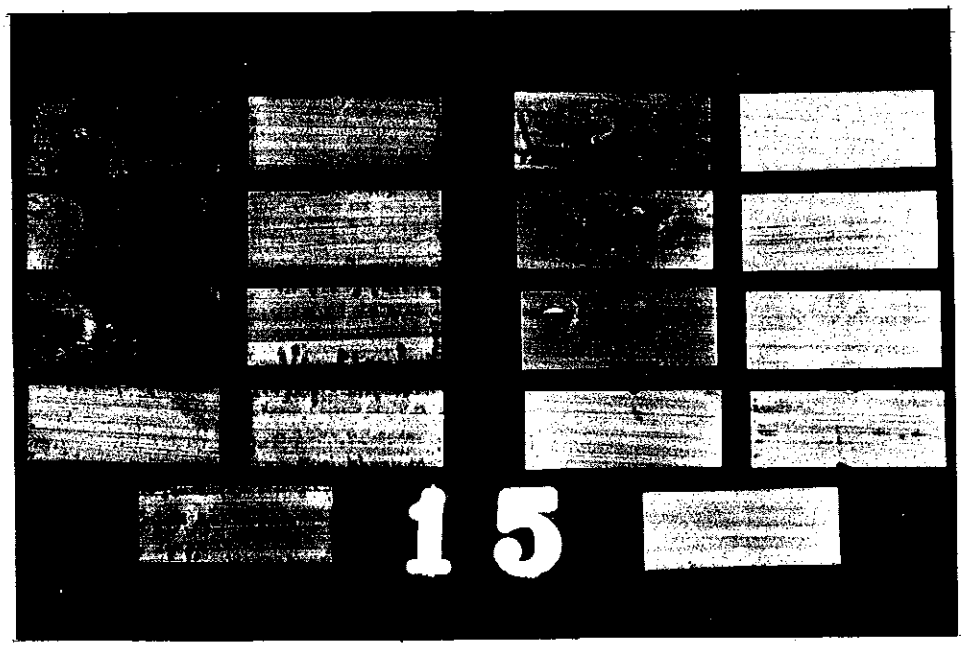


Fig. 2 X-ray photo 15 showing 2 sets of Durian burong blocks attacked by borers of *Lyrodus pedicellatus* [1.5(25.1),1(20.7),1(19.1),2.5(15.2),2.5(16.2),2.5(9.8),1(12.4),1.5(14.6),1(9.7)] and *Limnoria tripunctata* [1.5(13.1),2(2.6),2.5(3.7),3(3.2),4(1.1),4(1.9),4(1.7),1.5(4.8),3(0.3)] on left and right respectively

* Figures in square bracket indicate the rating (and mass loss) of each block and should be read from top left to bottom right

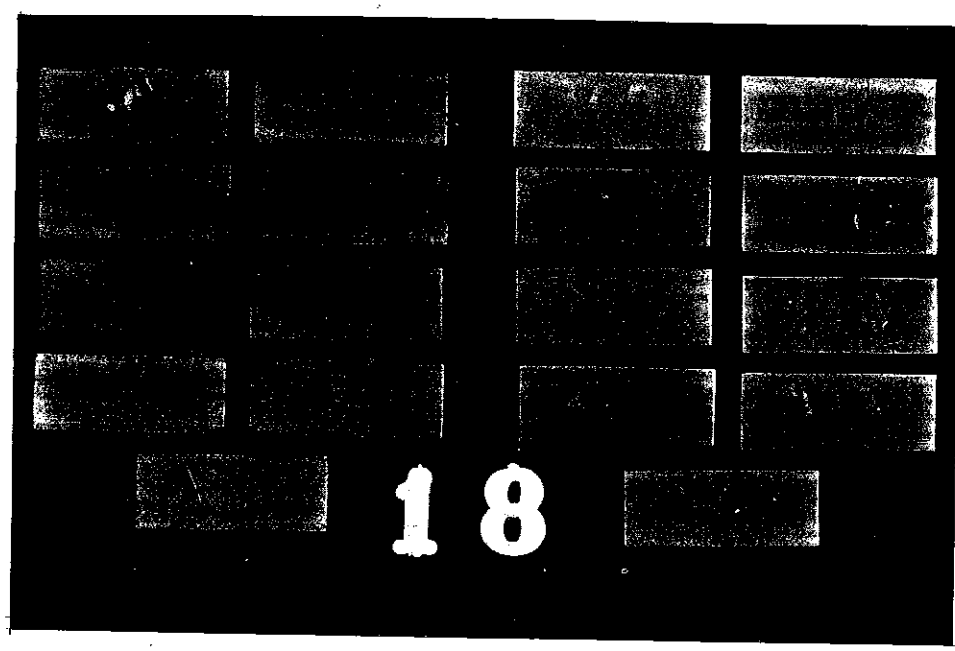


Fig. 3 X-ray photo 18 showing 2 sets of Teruntum merah blocks attacked by borers of *Lyrodus pedicellatus* [3(10.4),3(6.4),3(9.0),3(4.7),3(7.5),3(9.4),3(8.2),3(29.1),3(7.9)] and *Limnoria tripunctata* [4(0.2),3(0.8),4(1.4),4(1.0),4(0.3),4(0.0),3.5(0.3),4(0.7),4(0.2)] on left and right respectively

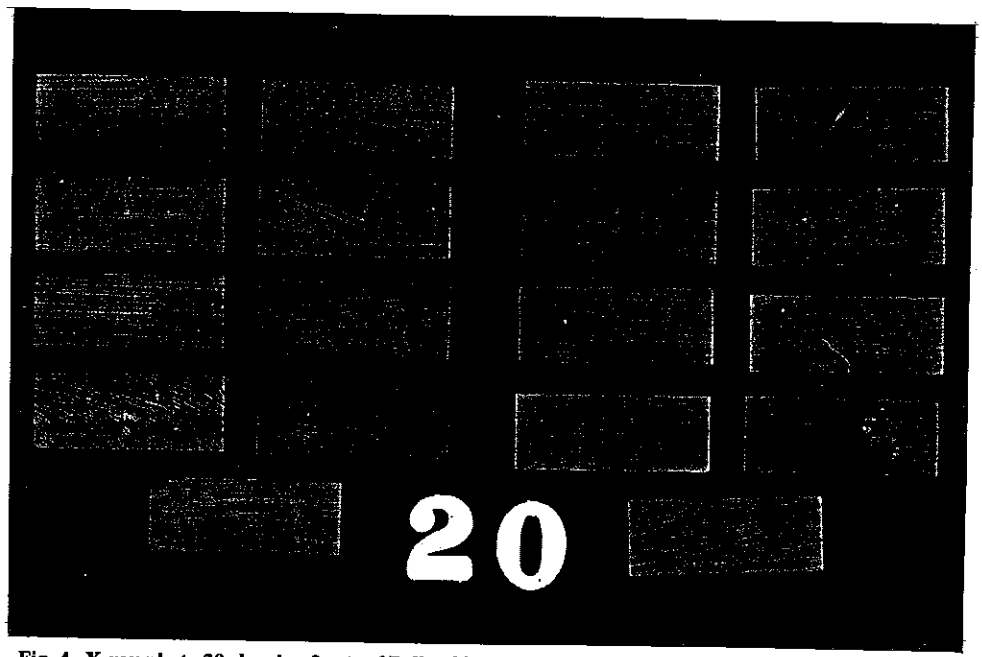


Fig. 4 X-ray photo 20 showing 2 sets of Belian blocks attacked by borers of *Lyrodus pedicellatus* [3.5(0.7),3(2.1),3.5(2.6),3.5(1.7),3.5(1.2),3.5(0.2),3(1.1),3.5(2.0),3(2.4)] and *Limnoria tripunctata* [4(1.9),4(2.3),4(1.7),4(2.3),4(2.1),4(2.2),4(1.8),4(2.0),4(2.3)] on left and right respectively

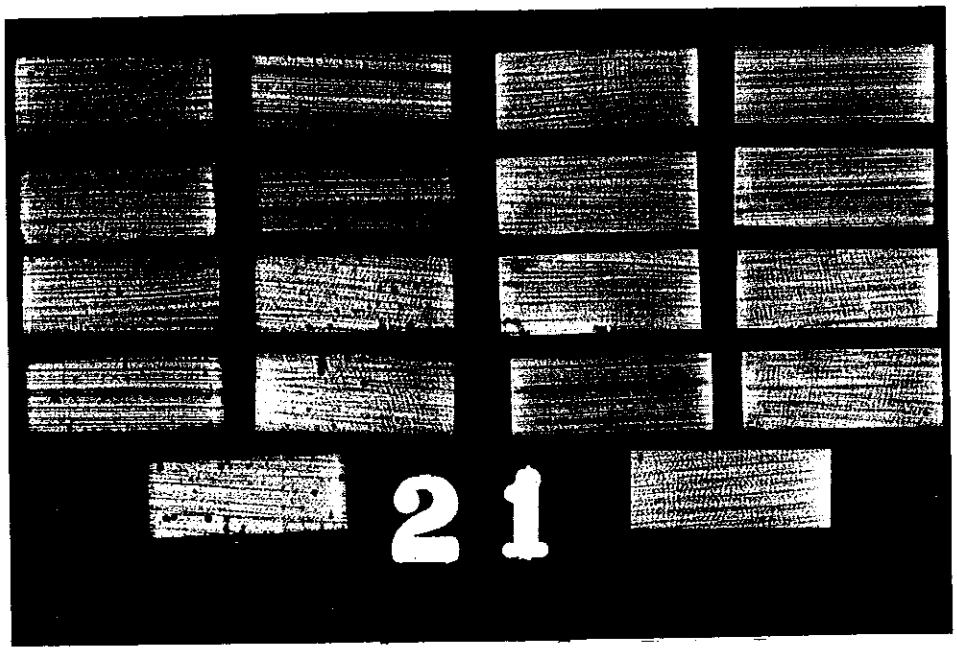


Fig. 5 X-ray photo 21 showing 2 sets of Tapang blocks attacked by borers of *Lyrodus pedicellatus* [2.5(5.3),2.5(8.3),2.5(5.5),2.5(9.5),2.5(4.5),2(7.8),2.5(8.7),2(5.7),2(9.2)] and *Limnoria tripunctata* [4(1.2),4(1.5),2(0.6),3.5(0.8),2.5(1.2),1.5(1.2),3.5(0.2),2(1.2),3.5(1.0)] on left and right respectively

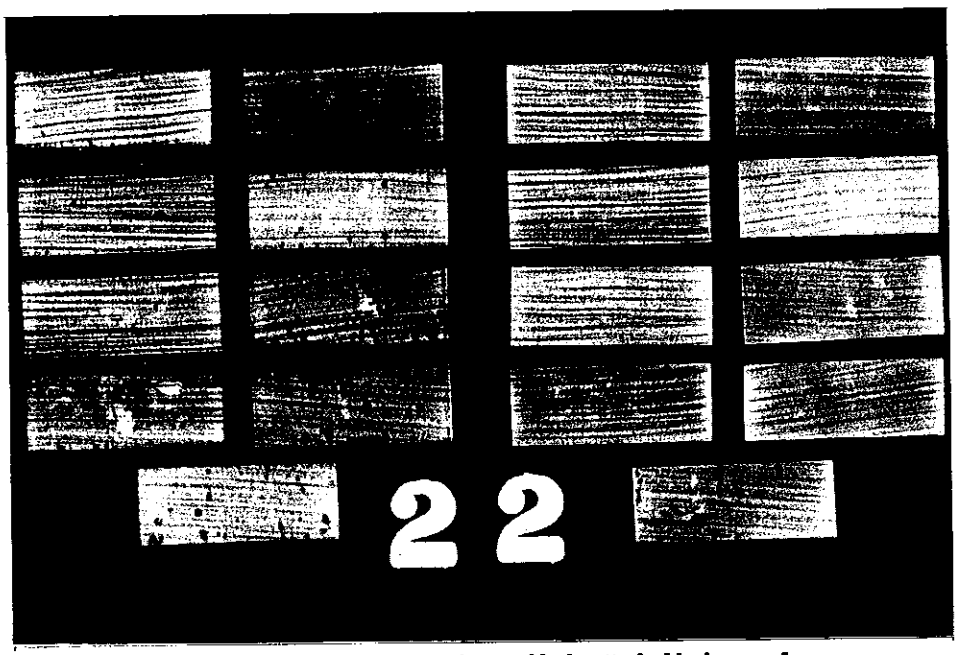


Fig. 6 X-ray photo 22 showing 2 sets of Menggris paya blocks attacked by borers of *Lyrodus pedicellatus* [3(7.1),2.5(6.3),2.5(4.6),2.5(8.5),3(5.8),2.5(5.1),1.5(10.9),1.5(9.4),2(4.9)] and *Limnoria tripunctata* [4(0.9),3.5(0.8),3.5(0.9),4(0.9),3.5(1.4),3(0.9),3(1.2),4(1.0),2(1.5)] on left and right respectively

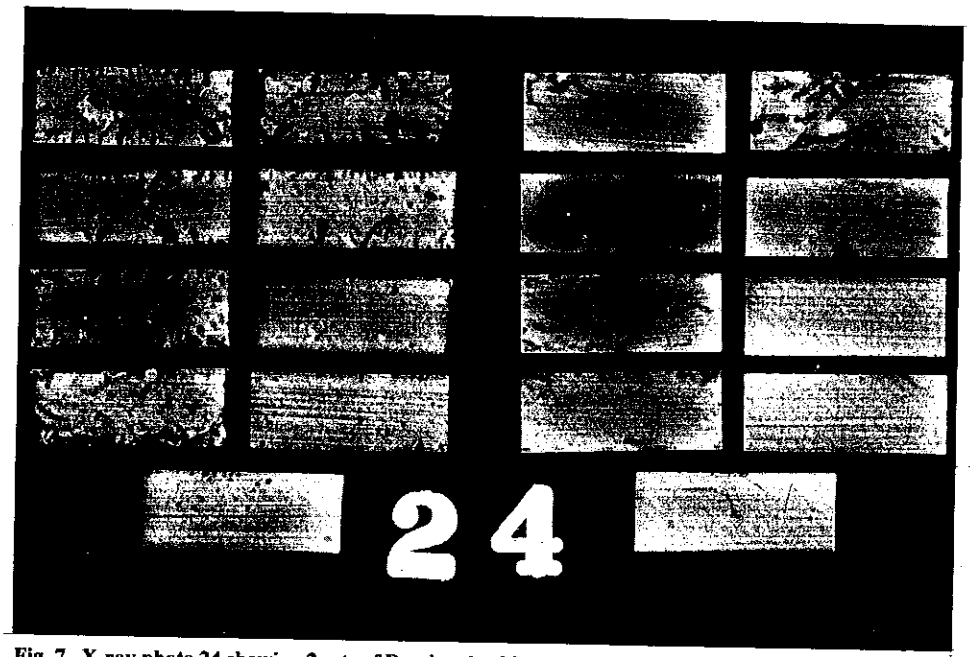


Fig. 7 X-ray photo 24 showing 2 sets of Ramin telor blocks attacked by borers of *Lyrodus pedicellatus* [1(20.1),1(19.4),1(20.6),1(25.4),1(28.6),1(18.3),2(17.5),2(17.3),2(13.6)] and *Limnoria tripunctata* [1.5(5.8),2.5(2.8),1(5.1),1(7.0),1(7.0),2(6.2),2.5(3.8),2.5(3.8),3(3.7)] on left and right respectively

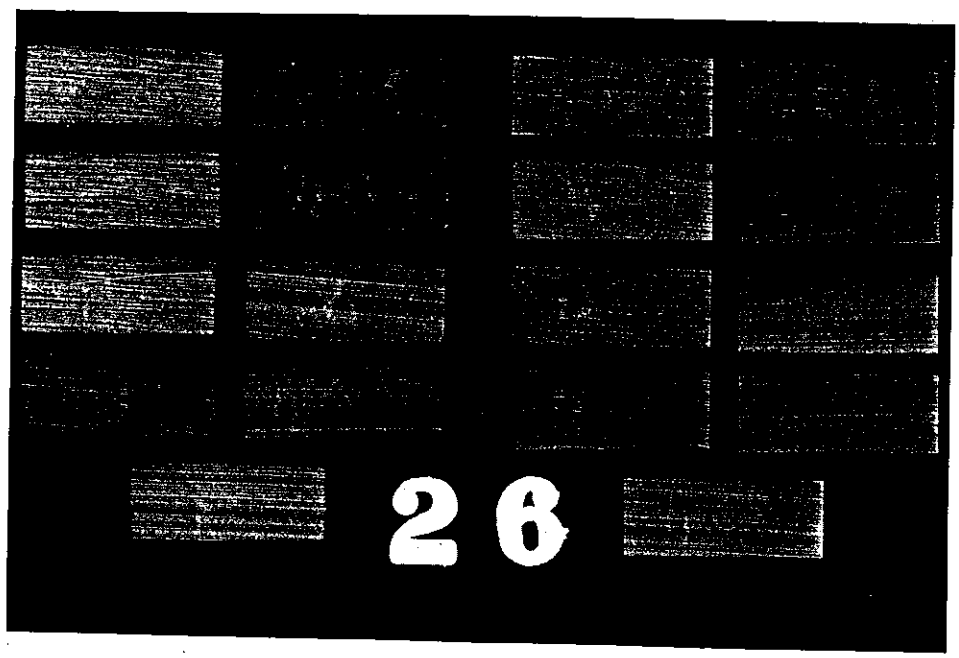


Fig. 8 X-ray photo 26 showing 2 sets of Selangan batu blocks attacked by borers of *Lyrodus pedicellatus* [3 (2.7),3.5(5.1),3(5.0),3(5.9),3.5(5.4),3(2.5),3(2.2),3.5(4.3),3(5.4)] and *Limnoria tripunctata* [4(0.7),4(1.2),4(0.6),4(1.1),4(1.3),4(0.6),4(0.8),4(0.8),4(1.0)] on left and right respectively

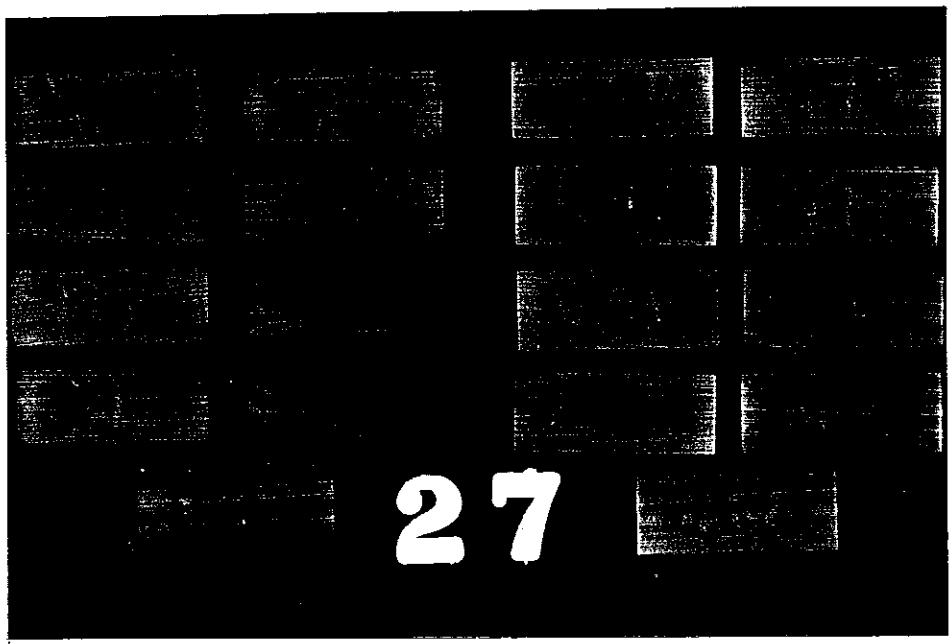


Fig. 9 X-ray photo 27 showing 2 sets of Kumus blocks attacked by borers of *Lyrodus pedicellatus* [3(7.7),3(7.8),3(4.7),3(9.2),3(8.7),3(4.6),2.5(7.9),3(6.6),2.5(4.3)] and *Limnoria tripunctata* [4(0.5),4(2.3),4(1.8),4(1.5),4(1.1),4(0.7),2.5(1.7),4(2.3),4(3.3)] on left and right respectively

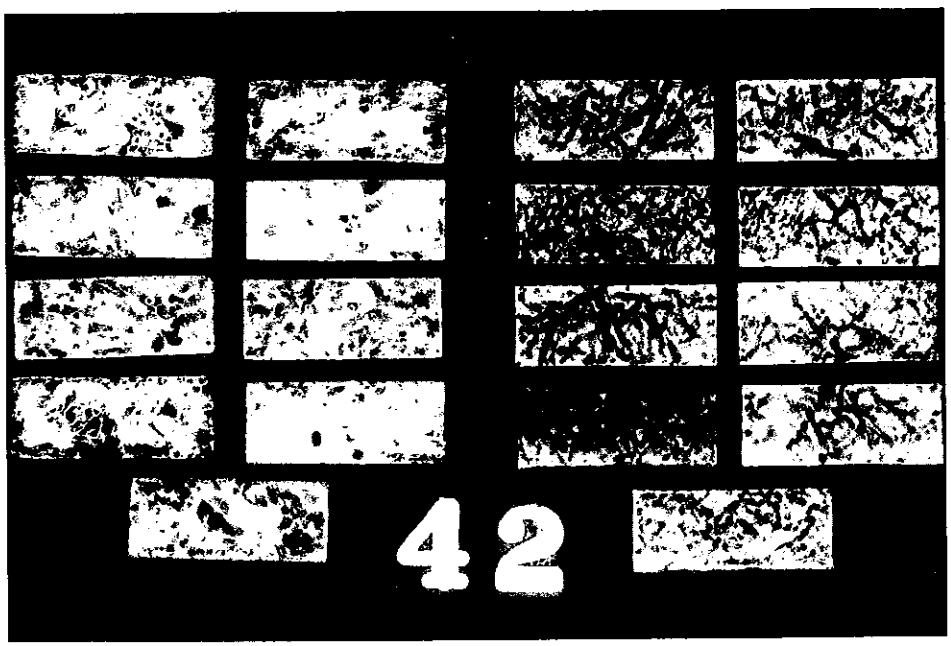


Fig. 10 X-ray photo 42 showing 2 sets of Radiata pine (sapwood) blocks attacked by borers of *Lyrodus pedicellatus* [0(55.4),0(45.4),0(52.1),0(68.9),0(57.8),0(35.9),0(58.1),0(37.3),0.5(57.9)] and *Limnoria tripunctata* [0.5(48.5),0.5(59.2),0.5(43.9),0(70.9),0.5(41.9),0.5(52.3),1(32.4),1(28.4),1(38.3)] on left and right respectively