Marine Borers and Timber Piling Options

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CSIRO
AUSTRALIA

Revised and reprinted from
Division of Chemical and Wood Technology
Research Review 1986

PART 1. SELECTED TOPICAL ESSAYS

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Summary

About 5 million dollars worth of structural timbers is sold annually in Australia for use in the marine environment. CSIRO is conducting several marine tests on preservative-treated wood which have been in place for 9 to 26 years. The performance of timber varies in different hazard zones which are themselves distinguished by different species and activities of marine borers. The piling options likely to produce service lives of at least 20-30 years for a particular hazard zone are listed.

Introduction

Australia has about 350 000 timber marine piles along its 20 000 km of coastline. In addition, there are about three million oyster posts, and many sawn timbers are used for bracing, chafers, slipways, breakwaters and groynes. Because timber piles have fixed diameter sizes and will eventually deteriorate through attack by marine borers, their use in large structural docking facilities has been largely replaced by use of steel and concrete, although these materials also often require maintenance. However, wood continues to be used widely for mooring and fender piles because it can tolerate greater impact due to its high resilience. Timber piles tend to be 2-3 times cheaper than a similar sized steel or concrete pile.

If physical barriers such as plastic wraps or concrete are placed around timber piles, the pile service life extends to that of steel and concrete. These physical barriers kill marine borers by preventing fresh oxygenated sea-water from coming into contact with the pile.

Currently, about 4200 marine timber piles are sold annually in Australia, with a sale value of about 1.6 million dollars and a further installation cost of about 3.4 million dollars. Turpentine (*Syncarpia glomulifera* (Sm.) Niedenzu) is the major pile sold, with double-treated eucalypts (mainly *Eucalyptus maculata* Hook and *E. pilularis* Sm.) forming a rapidly expanding market (Table 1). Double treatment involves application by vacuum/pressure impregnation of copper-chrome-arsenic (CCA) followed by creosote.

About 450 000 oyster posts are also sold annually, mainly in New South Wales, with the main timber species used being untreated (but tar-coated) sawn turpentine, sawn brush box, and creosote-treated natural round eucalypts. The mussel farming industry in Victoria and Tasmania often uses CCA-treated *Pinus radiata* D. Don for framing. By combining these sales with the sales of other sawn timbers, the total sale value of timbers in contact with sea-water (not including decking or boats) would be about five million dollars annually.

The use of timber in the sea could increase further if more suitable preservative treatments were available. With CSIRO tests of pressure-treated timber which have survived in the sea now reaching 26 years (Table 2), and some commercially treated

TABLE 1 Number of timber marine piles sold annually. Based on figures obtained for the last one to four years.

Pile	Annual sales	Location of main users
Untreated turpentine	2000	NSW, Qld, SA
Double-treated eucalypts	1400	NSW, Vic, NZ
River red gum, yellow stringybark	210	Vic
CCA-treated jarrah	220	WA
CCA-treated messmate	170	Tas
Untreated jarrah	40	WA, NT
Other untreated eucalypts and CCA-treated pines	200	Australia
Total	**4200**	

TABLE 2 CSIRO marine tests with preservative-treated wood

Test	Age in 1986	Test Sites
P5-7 = K55 creosote, Celcure old, Celcure A, Boliden S25, Boliden K33, Tanalith C, Celcure A + K55 creosote**, turpentine timber	26	Sydney* Brisbane River Kwinana* Port Hedland
P5-9 = K55 creosote, CCA salt, CCA oxide	19	Sydney* Gladstone Cairns Weipa Darwin Port Hedland Carnarvon Port Moresby Lae Rabaul
P5-12 = K55 creosote, HTC, arsenical HTC, Tanalith C Tan. C + HTC**, Tan. C + arsenical HTC**	12	Sydney* Port Stephens* Cairns*
P5-13 = Various organic pesticides in CCA and/or HTC-treated wood	13	Sydney* Port Stephens* Cairns
P5-14 = (IRG test) CCA, CCB	9	Sydney*

* *Test sites where specimens are still present*
** *Double treatment*

timber piles in service for up to 23 years, we are now in a good position to suggest which timber treatments should give service lives of at least 20-30 years.

Marine Borers

The damage marine borers cause to man-made structures is worth about $20 million/year (based on timber replacement costs only). There are four main types of marine borers, two are crustaceans and two are molluscs. Figure 1 shows the animals and appearance of the damage they cause.

Limnoria are small (1-4mm long) crustaceans that bore into wood for food. They are one of the few invertebrates that can produce their own cellulase and therefore degrade the cellulose in wood without the aid of microorganisms (14). The closely related *Phycolimnoria* which bore into certain algae for food, appear to have evolved from *Limnoria*. *Limnoria* can attack wood anywhere from about mud-line to mid-tide, and produce burrows that closely follow the wood surface and which are punctured along their length by small ventilation holes. *Limnoria* rarely bore in locations where the salinity reaches below 25°/oo. (parts per thousand).

L. tripunctata Menzies is the limnoriid species which has been studied extensively throughout the world. It can form a symbiosis with certain creosote-degrading bacteria and rapidly attack creosote-treated softwoods (22). In Australia where the predominant piling timber used is hardwood, the important species of *Limnoria* are *L. tripunctata, L. quadripunctata* Holthuis and *L. indica* Becker and Kampf (2,5). *L. insulae* Menzies and *L. unicornis* Menzies have also been found in northern Australia, while there are five more new species from Australia and Papua New Guinea awaiting description (Cookson, unpublished data).

Sphaeroma is a larger crustacean than *Limnoria*, growing up to 8-14 mm long. The three important wood-boring species are *S. terebrans* Bate, *S. quoyanum* Milne Edwards and *S. triste* Heller. *Ptyosphaera alata* (Baker) (syn. *Exosphaeroma alata*) can lightly attack wood immersed in salinities down to 0.1°/oo. *Sphaeroma* bore for shelter into various materials such as wood, sandstone, poor grades of concrete, and polystyrene floats (Fig. 2). The burrows are usually short and at right angles to the surface. Because *Sphaeroma* is a filter feeder (15) and does not eat wood for food, it is fairly difficult to control with preservatives. Fortunately, it bores mainly in the tidal zone (3,7,21), and from about Sydney northwards where it is most active, attacked piles develop an hour-glass appearance. On Australia's southern coastline *S. quoyanum* is present, but generally bores too slowly and shallowly to produce the hour-glass effect that it can produce in Sydney. Necking of old piles in the tidal zone can still occur in southern Australia due mainly to *Limnoria*; however, by this stage the old piles are also usually heavily attacked below the tidal zone. *Sphaeroma* is euryhaline: it can actively bore in salinities ranging from 10°/oo to 35°/oo (21).

Because *Sphaeroma* bores mainly in the tidal zone, it can be controlled by the floating collar treatment. This involves placing a floating collar around the pile and filling the gap with a modified creosote that can float on sea-water. With the rise and fall of the tide marine borers are killed by the creosote. The creosote floating on the water surface is then recovered and the float removed until the next treatment about 18 months later (9). Alternatively, physical barriers (gunite concrete or plastic wraps and tapes) can be economically applied in the tidal zone specifically to control *Sphaeroma*. For some timbers these protection systems would almost double the service life of the pile.

Teredinids or shipworms are bivalve molluscs; however, the shells are small and cover

Fig. 1a. Limnoria tripunctata

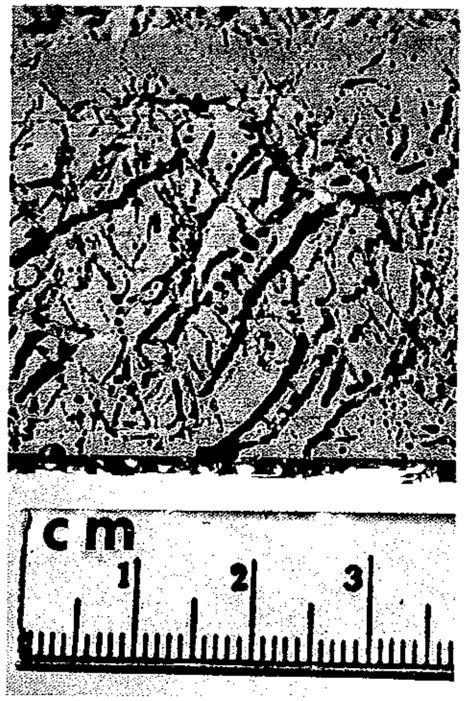

Fig. 1b. P. radiata *attacked by* L. tripunctata

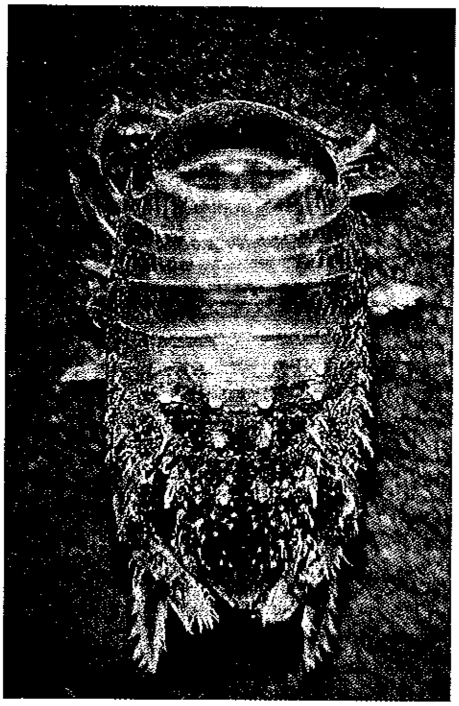

Fig. 1c. Sphaeroma terebrans

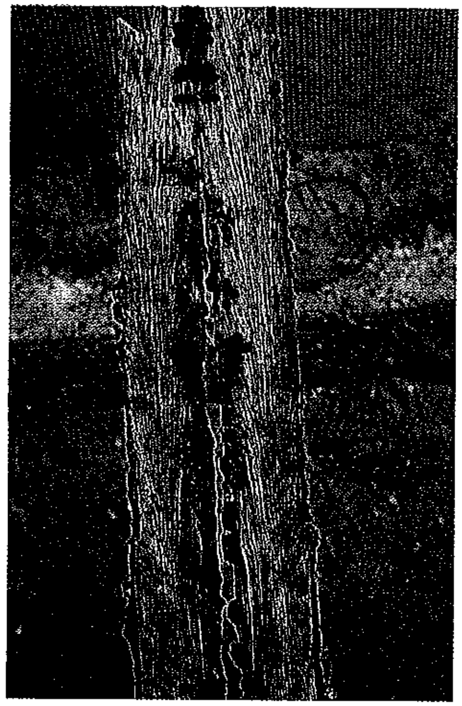

Fig. 1d. Eucalypt attacked by Sphaeroma

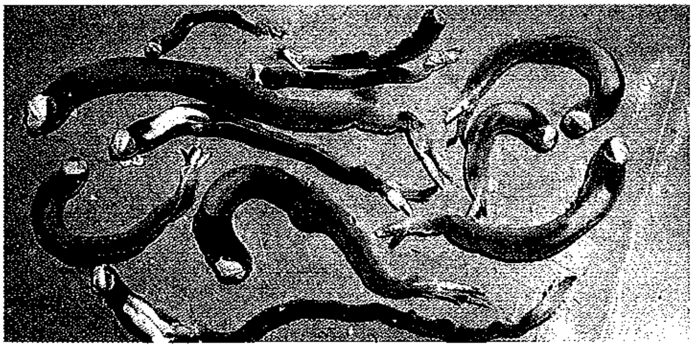

Fig. 1e. The teredinid Bankia australis.

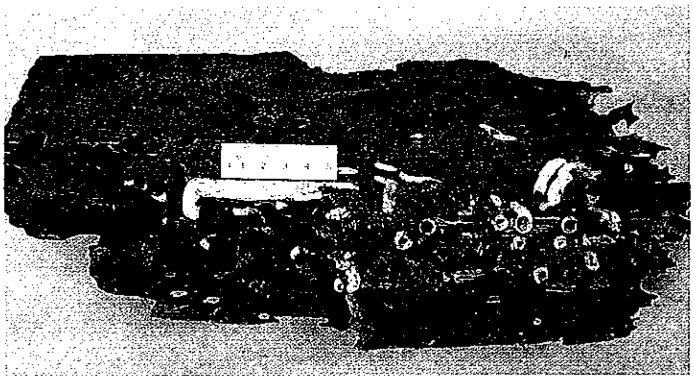

Fig. 1f. Eucalypt attacked by Nausitora dunlopei. *Note the calcareous lining of the teredinids tunnels*

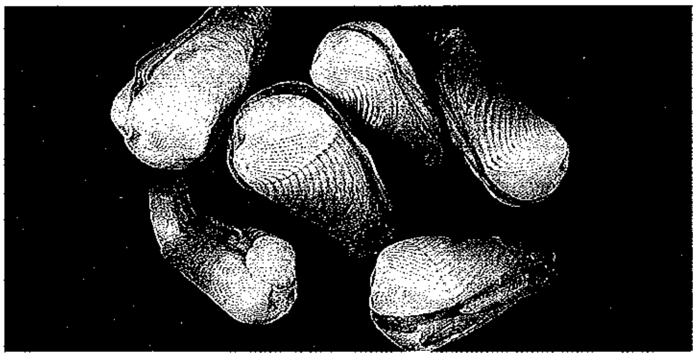

Fig. 1g. Martesia striata.

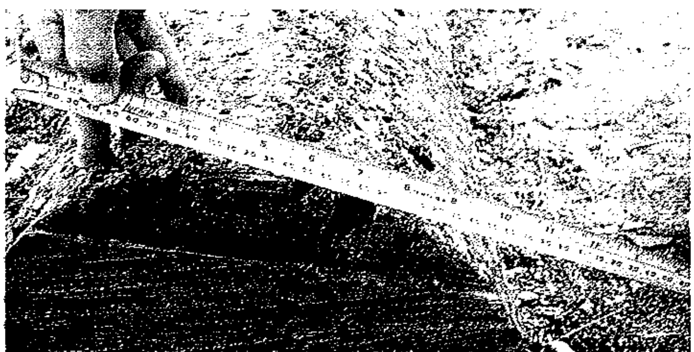

Fig. 1h. The pear-shaped hole produced by a large specimen of M. striata *in a turpentine pile.*

only the anterior end of the animal. The shells are used as rasps for boring into wood. About thirty species of teredinids have been found around the Australian coastline (18). Some of the genera found include *Lyrodus, Bankia, Teredo,* and *Nausitora.* Most species of teredinids appear able to both digest wood and filter feed. Recently, cellulolytic bacteria that can also fix nitrogen were isolated from teredinids (20). Teredinids release microscopic larvae into the sea-water, and depending on the stage of development at which the species releases its larvae, the larvae begin to bore 1 to 30 days later (18). Teredinids can attack wood from between the mud-line to mid-tide, often producing the most severe attack near mud-line. Some species are able to grow up to two metres in length. Teredinids take up the full length of their burrow, and cannot leave its confines. Only the incurrent and excurrent siphons and the hard calcareous pallets are exposed. The pallets can close off the burrow to protect the borer from predators and dehydration (at low tide). They are also valuable in species identification. The burrows can be distinguished by a white calcareous lining, which is secreted by the teredinid. This lining may break away in old disused burrows. Teredinids can grow rapidly and bore deeply into susceptible wood, but they themselves are susceptible to certain preservatives, although in the tropics they can still be very difficult to control. Most teredinids live in high salinity conditions; however, the low salinity teredinids *Nausitora* spp. are especially voracious and difficult to control. *Nausitora* is active mainly at salinities of about 1-10°/oo. Few data are available on the boring activity of *Nausitora* from sites other than the Brisbane River (21).

The other marine boring molluscs are the pholads, the main Australian species being *Martesia striata* L. *M. striata* occurs largely in the tropics and subtropics in high salinity conditions (18). The shells cover much of the borer's soft body, and the hole it produces is pear-shaped and only slightly longer than the body. *Martesia* bores into wood for shelter only as it is a filter feeder, like *Sphaeroma* (19). For this reason it is also difficult to control with preservatives. *Martesia* can bore between the mud-line to just above low-tide.

Figure 3 shows the main marine borer hazard zones around Australia. These zones are partly based on available sea-water temperature zones which are themselves greatly influenced by the sea's currents (10). Generally, the higher the temperature, the greater the number of species and activity of marine borers. For example, there are about twice as many species of teredinids in Queensland as in Victoria (18), and *Lyrodus pedicellatus* (Quatrefages) bores about three times faster in Townsville than in Sydney (8). Salinity is another major factor affecting distribution. Most available data on marine borer activity at low salinities come from Port Stephens (CSIRO tests P5-12 and P5-13) and the Brisbane River (21, P5-7).

Table 3 is a subjective listing of the relative marine borer hazards found around the Australian coast. The hazard terms represent the relative rates of attack caused on untreated wood within a particular location by certain marine borers or groups of marine borers.

Marine timber piling options

Table 3 also shows a tentative listing of the main timber marine piling options available, and the hazard zones under which they are likely to give service lives of at least 20-30 years.

Untreated turpentine

Turpentine is one of the most marine borer-resistant timbers known and has long been the traditional piling timber used in Australia. It is very resistant to teredinids, except *Nausitora* (hazard 7) (21). *L. tripunctata* also appears unable to attack sound turpentine heartwood,

TABLE 3 Tentative list of marine borer hazards and appropriate piling options that should provide service lives of at least 20-30 years

	Hazard Zone						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Salinity 0/00	**30-35**	**30-35**	**30-35**	**30-35**	**30-35**	**10-30**	**1-10**
Approximate Location	**Tas**	**Vic**	**SA**	**Sth WA NSW**	**Nth WA Qld NT**	**Port Stephens**	**Brisbane River**
Marine Borer :							
Limnoria tripunctata	-	low	mod	ext	mod	low	-
L. quadripunctata	mod	mod	mod	high	-	-	-
L. indica		-	-	high	high	-	-
L. unicornis	-	-	-	-	mod	-	-
L. insulae	-	-	-	-	mod	-	-
Sphaeroma terebrans	-	-	-	high	ext	ext	mod
S. quoyanum	low	low	mod	high	low	ext	-
S. triste		-	-	-	low	-	-
Ptyosphaera alata	-	-	-	-	-	low	low
High salinity teredinids	mod	mod	mod	high	ext	high	-
Nausitora spp	low	low	low	low	low	mod	ext
Martesia striata	-	-	-	mod	ext	low	-

mod = moderate, ext = extreme

Marine Pile	**Retention kg/m³** CCA	HTC	**Piles should last at least 20-30 years**						
Turpentine	-	-	+	+	+	+[2]	+[2]	+[2]	x
Jarrah	-	-	+	+	+	x	x	x	x
River red gum	-	-	+	+	+	x	x	x	x
Yellow stringybark	-	-	+	+	x	x	x	x	x
Jarrah	56	-	+	+	+	+	x	?	x
Other eucalypts[1]	32	-	x[3]	x[3]	x	x	x	x	x
Softwood	3.2 el Cu	-	+	+	+	+[4]	+[4]	x	?[5]
Eucalypt[1]	-	260	+	+	+	+	+[2]	+[2]	?
Softwood	-	320	+	+	+	x	?	?	?
Eucalypt[1]	32	260	+	+	+	+	+[2]	+[2]	?
Softwood	32	320	+	+	+	+[2]	+[4]	+[4]	?[5]
Any listed & full length barrier			+	+	+	+	+	+	+

1 = And possibly turpentine
2 = May require a barrier or floating collar treatment in the tidal zone
3 = Some piles will last 20 years, a higher retention may help
4 = Will require a barrier or floating collar treatment in the tidal zone. May also require knot protection
5 = P radiata *given this treatment were in good condition after ten years in the Brisbane River, but were then washed away by floods (P5-7)*

although it may attack sapwood, knots and pith. *L. indica* and *Martesia* can cause some deterioration; however, in hazard zones 4-6 *Sphaeroma* often causes most damage to turpentine piles. In Queensland (hazard 5), turpentine generally lasts about 12 to 20 years, although this service life could be almost doubled by applying a barrier in the tidal zone for protection against *Sphaeroma.* In Sydney Harbour, turpentine often lasts 32 years, or 70 years when *Sphaeroma* is killed by creosote applied by the floating collar technique (12). There are several examples in Tasmania of turpentine piles installed more than 80-90 years ago which are still in good condition. For these piles protection in the tidal zone was not needed due to the low *Sphaeroma* hazard found there.

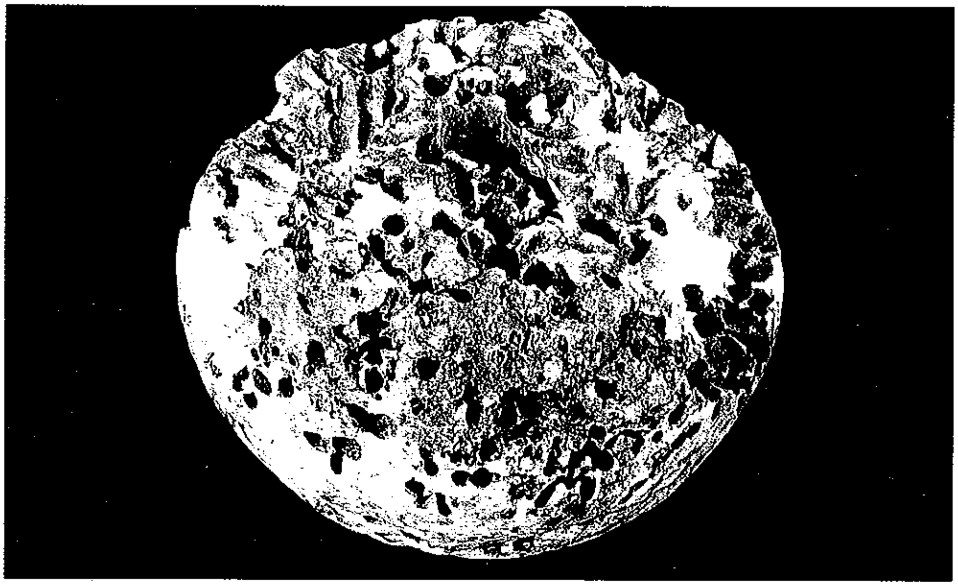

Fig. 2. A polystyrene float after about six months at Port Stephens. Attacked by S. quoyanum, S. terebrans *and* P. alata.

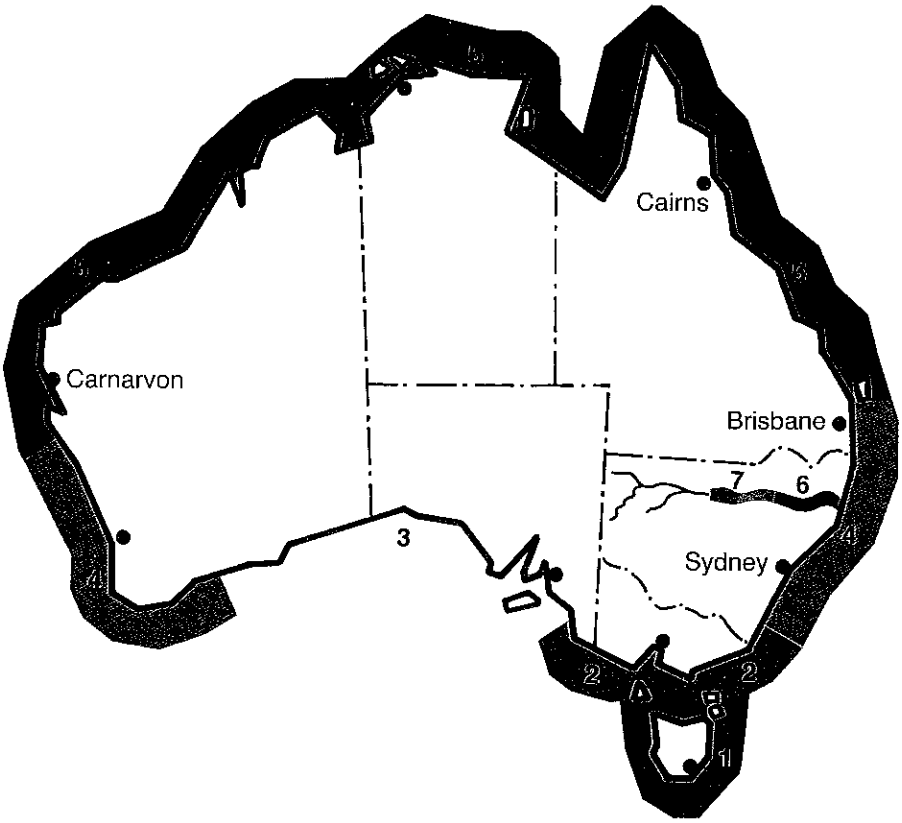

Fig. 3. Marine borer hazard zones of Australia. Generalised estuarine river (zones 6 & 7) not to scale.

Fig. 4. River red gum pile which supported a navigation light in Port Phillip Bay for 46 years. Light teredinid attack in the sapwood only.

Untreated eucalypts

Certain eucalypts such as river red gum (*E. camaldulensis* Dehnh.), yellow stringybark (*E . muellerana* Howitt) and jarrah (*E. marginata* Donn ex Sm.), while not particularly marine borer resistant, can provide long service lives in the cooler southern Australian waters (hazard zones 1-3). In Victoria, these piles are usually attacked by teredinids and *L. quadripunctata* rather than by *L. tripunctata* or *Sphaeroma*. Figure 4 shows one of several river red gum piles that supported a navigation light in Port Phillip Bay for 46 years. The pile was removed as the sand bar it marked had shifted and its concrete decking was corroded. The pile was only lightly attacked by teredinids in the sapwood. However, there are occasional examples of early failure. In the Gippsland lakes region in Victoria, with a hazard zone level of about 7 (although the region is less severe due to low temperatures), some river red gum piles were riddled by *Nausitora dunlopei* Wright within eight years (Fig. 5).

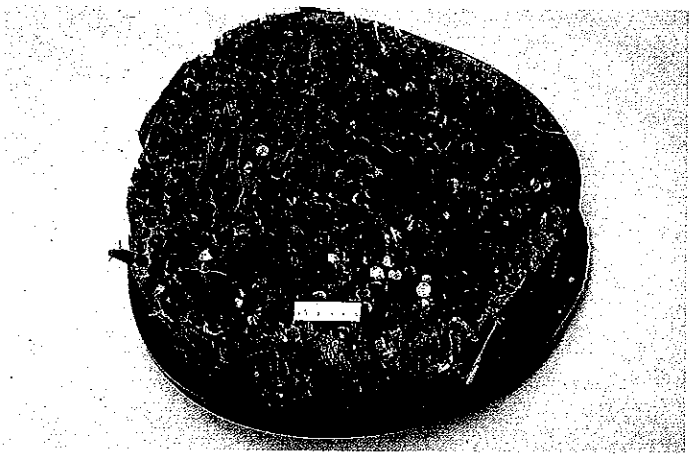

Fig. 5. River red gum pile attacked by Nausitora dunlopei *within eight years at Bairnsdale.*

Creosote-treated eucalypts

The oldest creosote-treated eucalypts in Australia are some red stringybark (*E . macrorhyncha* F. Muell. ex Benth.) stakes treated to 320 kg/m³ with K55 creosote and installed below the tidal zone at Sydney and Kwinana (P5-7) (1,4). After 26 years they are still virtually unattacked (Fig.6). K55 creosote is no longer commercially available and has been replaced with high temperature creosote (HTC) and the HTC-containing pigmented emulsified creosote (PEC) (6). Results from P5-12 show that HTC performs much better than K55. In this test, HTC-treated *E. pilularis* (250 kg/m³) stakes have only light *Sphaeroma* attack at Port Stephens (hazard 6) and light *Limnoria* attack at Sydney (hazard 4) after twelve years. Also at Port Stephens, many HTC-treated small diameter eucalypts were installed up to 15 years ago as oyster posts. Most of these are still in good condition, although there have been some failures mainly at knots, or where battens were nailed onto posts. In large piles knots are less common especially in the tidal zone where the butt end is situated. In hazard zone 5, five eucalypt specimens treated with HTC or HTC-containing arsenical creosote are also in good condition after eleven years at Cairns (P5-12), and an *E. maculata* pile treated to just 110 kg/m³ with HTC shows only light *Sphaeroma* attack in the tidal zone after fourteen years at Bowen (3).

Creosote-treated softwoods

It has been well documented in the USA that creosote-treated softwoods can be seriously attacked within a short period by *L. tripunctata* (11). In hazard zone 4 where *L. tripunctata* is most active, this treatment would probably not last 20 years. *P. radiata* stakes treated to 320 kg/m³ with K55 creosote have failed within six years at Sydney (P5-7, P5-9). Even very high retentions (500 kg/m³) of HTC in *P. radiata* have not prevented moderate *L. tripunctata* attack after 12 years (P5-12). However, in South Australia (hazard 3), K55-treated *P. radiata* piles installed 18 years ago still have only moderate *L. tripunctata* attack. Considering that HTC performs better than K55, HTC-treated *P. radiata* piles should last at least 20 years in hazard zones 1-3, especially in Tasmania where *L. tripunctata* appears to be absent. In tropical Australia, the hazard from *L. tripunctata* appears to be only moderate. Three specimens of *P. radiata* treated with very high creosote loadings (about 500 kg/m³) are still unattacked after 11 years below the tidal zone at Cairns (P5-12). In view of the low replicate number and overseas experience, the performance of HTC-treated *P. radiata* in the Australian tropics requires further evaluation.

CCA-treated eucalypts

In several CSIRO marine tests CCA-treated eucalypts have performed poorly. *E . macrorhyncha* treated to 27 kg/m³ with CCA (Tanalith C or Celcure A) was destroyed within 4-9 years at Port Hedland and within 16 years at Sydney (P5-7). *E. maculata* and *E. obliqua* L'Herit. stakes treated to 32 kg/m³ with a CCA salt were destroyed within 13-16 years at Sydney (P5-9). In 1969 at Bowen, about 50 *E. maculata* mooring piles treated to about 32 kg/m³ with CCA were destroyed by teredinids after only 3 years. This example turned many harbour authorities away from the use of treated wood. Also, in Tasmania *E. obliqua* piles treated to 22-32 kg/m³ with Tanalith C or Tanalith CA tend to last only 15-20 years, although some placed at the mouth of the Tamar River are in good condition after 23 years. Higher CCA retentions may produce longer service lives, but this remains to be proven. *E. maculata* and *E. pilularis* stakes treated with Tanalith C to about 37 and 57 kg/m³ respectively are still in good condition after 12 years at Sydney and Port Stephens (P5-12).

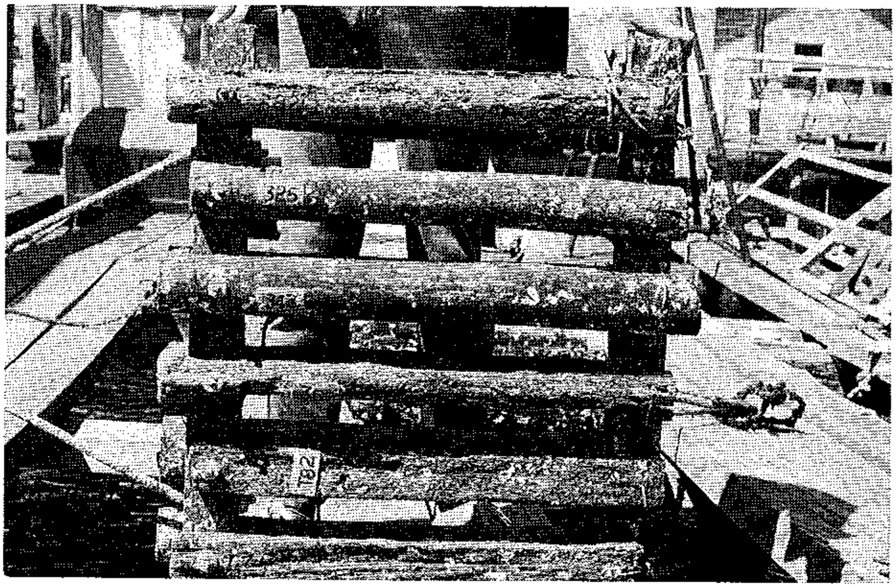

Fig.6. A P5-7 test frame after 26 years in Sydney Harbour.
*No. 382 (top) =27kg/m³ celcure old-*E. macrorhyncha *with severe attack.*
*No. 325 = 160kg/m³ high boiling fraction of K55 creosote-*E. macrorhyncha *with light attack.*
No. 343 = 320kg/m³ high boiling fraction of K55 creosote with no attack.
No. 367 = 27kg/m³ Boliden S25- E. macrorhyncha *with sapwood destroyed.*
T82 = untreated sawn turpentine with moderate attack.
T74 (bottom) = untreated sawn turpentine with heavy attack

An exception to the poor performance of CCA-treated eucalypts appears to be jarrah. Some of these piles treated to either 32 or 56 kg/m³ with Tanalith C are still virtually unattacked after 17 years at Fremantle, although in tropical Western Australia similar piles do not last as long (T. Leaver *pers. comm.* 1986).

CCA-treated softwoods

Treatments of softwood with CCAs which produce elemental copper loadings of at least 3.2 kg/m³ have performed well in positions or sites where *Sphaeroma* is not very active. Sawn *P. radiata* treated to 27 kg/m³ with Boliden K33 (Cu = 3.2 kg/m³) was only lightly attacked after 26 years below the tidal zone at Sydney. Similar stakes treated to 27 kg/m³ with Tanalith C (Cu = only 2.4 kg/m³) were moderately to heavily attacked by *Limnoria* and teredinids (P5-7). *P. radiata* rounds treated to 32 kg/m³ with a CCA oxide (Cu = 3.7 kg/m³) were in good condition after 9.3 years below the tidal zone at several PNG sites (17), and similar rounds at Sydney are still good after 18 years (P5-9). However, where *Sphaeroma* is very active (hazards 4-6) CCA-treated pine can be seriously attacked in the tidal region. CCA-treated *P. radiata* battens used for oyster farming at Port Stephens generally last only 3 to 4 years, although similar battens in Batemans Bay are still good after 8 years. At Bowen, two *P. elliottii* Engelm. piles (containing 45-54 kg/m³ CCA) were still serviceable after 14 years, although there was moderate to heavy attack by *Sphaeroma* in the tidal zone (3). However, a similar pile at Port Douglas had negligible *Sphaeroma* attack after 14 years. The most susceptible part of a softwood pile is the knots. These may need metal or plastic plates nailed over them to prevent entry of marine borers, or the problem could be avoided by choosing piles from trees that were high-pruned so that the knots were overgrown.

Double-treated eucalypts

The oldest available data for this treatment are for double-treated *E. maculata* piles installed 14 years ago at Pittwater (100 piles) and Port Stephens (24 piles). These piles are still virtually unattacked. CSIRO tests (P5-12) of double-treated *E. maculata* and *E. pilularis* rounds installed 12 years ago at Port Stephens and Sydney show that the rounds are also in good condition. Five similar P5-12 specimens placed below the tidal zone at Cairns are also in good condition after eleven years, as is the only double-treated *E. maculata* pile installed at Bowen fourteen years ago. No failures of double-treated eucalypts have yet been recorded in Australia. It remains to be seen if double-treated eucalypts perform better than eucalypts treated with HTC (or PEC) alone. Hopefully, future inspections of the P5-12 test will help to resolve this.

Double-treated softwoods

Double-treated *P. radiata* incorporating K55-creosote did not perform well against *L. tripunctata* at Sydney (P5-7). However, double-treatments incorporating HTC are still doing well after 12 years (P5-12). Two double-treated *P. radiata* piles (about 38 kg/m^3 CCA plus 240 kg/m^3 HTC) were still serviceable after fourteen years at Bowen. However, for these piles to reach a service life of twenty years, a barrier placed in the tidal zone would have been necessary to prevent further deterioration by *Sphaeroma*. *L. tripunctata* had also eaten out a knot in one of these piles (Fig. 7), but this could have been prevented by merely nailing a protective plate over the knot. Double-treated Douglas fir and southern yellow pine piles are still in good condition after 22 years in Hawaii (13). Double-treated softwoods can be expected to perform better than softwoods treated with CCA or creosote alone.

Fig. 7. A double-treated P. radiata *(not hoop pine) mooring pile after 14 years at Bowen. Knot eaten out by* L. tripunctata.

Further research efforts should be directed at better understanding and defining the marine borer hazard, and the mechanism of attack and preservative tolerances of the species. Alternative preservatives must also be found to fill the gap produced by any possible future reduction in the availability of naturally resistant timbers or by CCA or creosote preservatives being deemed environmentally unacceptable. Long term testing of alternative preservatives would be vital if they are to become accepted treatments in the future.

Acknowledgements

I wish to thank the Queensland Forestry Department, Forestry Commission of NSW, Koppers Australia Pty. Ltd., Brackish Water Fish Culture Research Station at Port Stephens, and the many harbour authorities, road construction authorities, and oyster farmers for providing information on the use of timber in marine structures. The help provided by the Maritime Services Board at Sydney, Brackish Water Fish Culture Research Station, the Western Australian Department of Conservation and Land Management, Cairns Harbour Board, and other port authorities for the maintenance of our marine tests is also gratefully acknowledged. Thanks also to John Beesley for providing Figures 1d and 1e, and to John Barnacle for providing Figure 7.

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ISBN 0 643 04997 5