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# An in-ground Natural Durability Field Test of Australian Timbers and Exotic Reference Species

## I. Progress Report After More Than 10 Years' Exposure


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### Contents



### 1. Introduction

For most of Australia's recent history, supplies of well known highly durable timbers, such as the ironbarks and boxes among the eucalypts, have been adequate for outdoor heavy construction. These include poles, fence posts, rail sleepers and bridge timbers. Due to slow growth rate, increasing demand and the practice of using shorter rotations with exotic species, supplies of premium timbers can no longer meet our needs. In their place a wide range of less common species is now being used, and more information is needed

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* Full credit for the concept of this test must be given to Mr. N. E. TAMBLYN (retired) and Dr. E. W. B. DA COSTA (retired), both of whom, as members of the former CSIRO Division of Forest Products, planned this test, in conjunction with Miss. N. DITCHBURNE (retired), CSIRO Division of Mathematics and Statistics. The authors gratefully acknowledge also the contributions of:

(i) Mr. T. E. H. APLIN for his supervision of the collection of timber and specimen preparation;

(ii) the many government departments and their officers in Queensland, New South Wales and Victoria who are maintaining their exposure sites and are, therefore, continuing their invaluable assistance with this test;

(iii) those persons working in overseas institutions who kindly donated timber species from their authenticated stocks.

regarding their relative durabilities when exposed to environmental conditions closely representative of commercial service.

In order to provide rapid evaluation of the relative durabilities of species of immediate commercial interest, a series of laboratory tests of the relative decay resistance of different species was carried out (E. W. B. DA COSTA and T. E. H. APLIN, 1959; E. W. B. DA COSTA, T. E. H. APLIN and N. TAMBLYN, 1957) and the results were recently correlated by E. W. B. DA COSTA (1979). These early tests were at the time considered to provide – together with a consensus of opinion gathered in the 1950s from the combined experience of foresters, timber users and members of the former CSIRO Division of Forest Products – sufficient information to form a useful durability rating for timber species in Australian service. This information, for in-ground conditions, spanned all the species reported in this paper (exotics included) and was used within the former CSIRO Division of Forest Products, where it was known as 'the CSIRO internal, tentative, extended durability classification' (N. TAMBLYN and E. W. B. DA COSTA, unpublished data). For the purpose of the present report the values comprising this classification will be referred to as the 'tentative' durability rating. Those published natural durability ratings for Australian conditions have all essentially been derivations of the 'tentative' ratings (J. D. BOYD, 1961; H. KLOOT, 1965, Standards Association of Australia, 1979, 1980).

It should be noted that the early laboratory work concerned durability to basidiomycete fungi exclusively. E. W. B. DA COSTA (1975) emphasized the need for reproducible soft rot tests, an area only since researched for a small number of timber species (H. GREAVES, 1979). The laboratory tests using basidiomycetes were paralleled by field and laboratory tests of the termite resistance of many timber species, carried out by the CSIRO Division of Entomology (J. A. L. WATSON, personal communication).

Although laboratory tests against fungi may have provided a reasonably reliable method of assessing natural durability, on a limited and relative scale, it was recognized that outdoor exposure was needed to determine the relative (and to some extent absolute) life of these timbers and to determine the variability across a number of widely differing exposure hazards. Therefore a field test was devised with the intention of providing a direct measure of the natural durability of the more important timbers. This paper is the first progress report of that field test, installed in 1968 - 69 and comprising 77 timber species at five sites selected to provide a range of both decay and termite hazards in geographical locations ranging from cool temperate to wet tropical rainforest. About 3700 stakes were exposed. In this report values for average life are given only where at any one site all specimens of any species have become unserviceable. Future reports are intended to:

(i) provide additional data on average specimen life and

(ii) ultimately enable allocation of accurate durability ratings for species whose range of performance is sufficiently small or

(iii) demonstrate which species give widely variable performance.

## 2. Materials and Methods

### 2.1 Timber species and specimen preparation

A range of the most common commercial Australian timbers was chosen, encompassing both softwood and hardwood species. Exotic species were included in order that persons overseas could compare the performance of such well known timbers under Australian conditions, i. e. to provide 'yardstick' species which would be identifiable in many countries. The number of species tested was ultimately limited to those for which sufficient material was held in stock to allow what was considered adequate replication at all sites.

It was recognized that there was a wide variation of in-ground durability within any species, both between-tree and within-tree, as confirmed later by E. W. B. DA COSTA (1975). Wherever possible, five trees of each species were tested, the trees coming from five different localities representing as far as practicable the geographical range of the species. Between-tree variation was minimized wherever possible by testing the outer heartwood of the butt log, this part of the tree naturally representing the bulk of the merchantable timber for most trees and the important part of untreated poles and posts. The only possible difficulty posed by this method of selecting the heartwood for testing was the danger of including intermediate wood of lower durability than heartwood. However, because such material is usually very limited in extent in other than small trees and since it is often lighter in colour than normal heartwood, the danger of including such material in the test specimens was considered unlikely.

Timber species represented in this test are listed in Table 1. The botanical name and the common name of each species are as documented in Standards Association of Australia (1970, 1971). Durability ratings given in this table are the CSIRO 'tentative' natural durability ratings for in-ground service (see Introduction) and include the use of 'plus' and 'minus' qualifications in order to separate timbers within any one of the four durability classes. These classes, based on untreated heartwood of reasonable dimensions (at least 40 mm thickness) used in ground contact were as follows: Class 1, very durable, at least 25 years' service against both decay and termites; Class 2, durable, 15 - 25 years' service; Class 3, moderately durable, seldom give more than 15 years' service; Class 4, non-durable, a few years' or less service (Standards Association of Australia, 1980).

Normally two specimen stakes from each of five trees were allocated to each site, giving a total of ten specimens of each species per site. However, for some species, due to unavailability of the desired number of trees, eight specimens (representing four trees) or six specimens (representing three trees) or four specimens (representing two trees) were used (see Table 1). Altogether 77 species were exposed in the field, comprising 57 Australian myrtaceous hardwoods, 8 other Australasian hardwoods, 6 Australian softwoods, 2 exotic hardwoods and 4 exotic softwoods (Table 1). As a comparison with the untreated timber, creosoted *Pinus radiata* sapwood (175 - 210 kg of creosote per $m^3$, conforming to AS K55-1965) and copper-chrome-arsenic treated

Table 1. Timber species tested and their 'tentative' durability.

| Scientific name[a] | Common name[bc] | 'Tentative' durability[d] |
|---|---|---|
| | **Australian hardwoods** | |
| | Myrtaceae (*Eucalyptus*, *Syncarpia* and *Tristania* spp.) | |
| *Eucalyptus acmenioides* Schau. | White mahogany[b6] | 2 |
| *E. amygdalina* Labill. | Black peppermint | 3 |
| *E. astringens* Maiden | Brown mallet | 3 |
| *E. bosistoana* F. Muell. | Coast grey box | 1 − |
| *E. botryoides* Sm. | Southern mahogany | 2 |
| *E. calophylla* R. Br. ex Lindl. | Marri | 3 + |
| *E. camaldulensis* Dehnh. | River red gum | 2 + |
| *E. capitellata* Sm. | Brown stringybark[b] | 3 + |
| *E. cladocalyx* F. Muell. | Sugar gum | 2 |
| *E. cloeziana* F. Muell. | Gympie messmate | 1 − |
| *E. consideniana* Maiden | Yertchuk | 2 |
| *E. cornuta* Labill. | Yate[6] | 2 + |
| *E. cypellocarpa* L. Johnson | Mountain grey gum | 3 + |
| *E. diversicolor* F. Muell. | Karri | 3 |
| *E. dives* Schau. | Broad-leaved peppermint | 3 + |
| *E. elata* Dehnh. syn. *E. andreana* Naud. | River peppermint | 3 |
| *E. eugenioides* Sieb. ex Spreng.[a] | White stringybark[b] | 2 |
| *E. eugenioides* Sieb. ex Spreng.[a] formerly *E. wilkinsoniana* R. T. Bak. | Wilkinsons's stringybark[b6] | 2 |
| *E. fastigata* Deane et Maiden | Brownbarrel | 3 − |
| *E. gomphocephala* A. DC. | Tuart | 2 |
| *E. goniocalyx* F. Muell. ex Miq. | Long-leaved box[6] | 3 |
| *E. grandis* W. Hill ex Maiden | Rose gum | 3 |
| *E. guilfoylei* Maiden | Yellow tingle[6] | 2 |
| *E. haemastoma* Sm. | Scribbly gum[b] | 2 − |
| *E. jacksonii* Maiden | Red tingle[6] | 2 |
| *E. leucoxylon* F. Muell. | Yellow gum | 1 − |
| *E. longifolia* Link et Otto | Woollybutt | 2 |
| *E. macrorhyncha* F. Muell. ex Benth. | Red stringybark | 3 + |
| *E. maculata* Hook. | Spotted gum | 2 − |
| *E. maidenii* F. Muell. | Maiden's gum | 3 + |
| *E. marginata* Donn ex Sm. | Jarrah | 2 + |
| *E. megacarpa* F. Muell. | Bullich[4] | 3 − |
| *E. melliodora* A. Cunn. ex Schau. | Yellow box | 1 − |
| *E. microcorys* F. Muell. | Tallowwood | 1 |
| *E. moluccana* Roxb. | Grey box[b] | 1 + |
| *E. muellerana* Howitt | Yellow stringybark | 2 |
| *E. obliqua* L'Herit. | Messmate | 3 |
| *E. paniculata* Sm. | Grey ironbark[b] | 1 + |
| *E. patens* Benth. | Western Australian blackbutt | 2 − |
| *E. pilularis* Sm. | Blackbutt | 2 − |
| *E. polyanthemos* Schau. | Red box[4] | 2 |
| *E. radiata* Sieb. ex DC. | Narrow-leaved peppermint[b] | 3 |
| *E. regnans* F. Muell. | Mountain ash | 4 |

contd.

| | | |
|---|---|---|
| *E. resinifera* Sm. | Red mahogany[b] | 2+ |
| *E. rubida* Deane et Maiden | Candlebark | 3− |
| *E. saligna* Sm. | Sydney blue gum | 3+ |
| *E. salmonophloia* F. Muell. | Salmon gum | 2D, 3T |
| *E. sideroxylon* A. Cunn. ex Woolls | Red ironbark | 1 |
| *E. sieberi* L. Johnson | Silvertop ash | 3+ |
| *E. stjohnii* (R. T. Bak.) R. T. Bak. | Tasmanian blue gum | 3+ |
| *E. tereticornis* Sm. | Forest red gum[b] | 2+ |
| *E. viminalis* Labill. | Manna gum | 3 |
| *E. wandoo* Blakely | Wandoo | 1+ |
| *Syncarpia glomulifera* (Sm.) Niedenzu | Turpentine | 2 |
| *S. hillii* F. M. Bail. | Satinay | 2 |
| *Tristania conferta* R. Br. | Brush box | 3D, 1 or 2T |
| *T. suaveolens* (Sol. ex Gaertn.) Sm. | Swamp box | 1 |
| **Australasian hardwoods other than Myrtaceae** | | |
| *Acacia acuminata* Benth. | Raspberry jam | 2 |
| *A. harpophylla* F. Muell. ex Benth. | Brigalow | 2 |
| *Anisoptera polyandra* Bl. | Garawa | 3+ |
| *Casuarina luehmannii* R. T. Bak. | Bull oak[4] | 1 |
| *Intsia bijuga* (Colebr.) O. Ktze | Kwila | 1 |
| *Litsea reticulata* (Meissn.) F. Muell. | Bollywood[b] | 3 |
| *Nothofagus cunninghamii* (Hook.) Oerst. | Myrtle beech | 4 |
| *Pterocarpus indicus* Willd. | New Guinea rosewood | 2+ |
| **Exotic hardwoods** | | |
| *Quercus alba* L. | American white oak[4] | 4 |
| *Tectona grandis* L.f. | Teak (Burmese) | 1 |
| **Australian softwoods** | | |
| *Agathis palmerstonii* (F. Muell.) F. Muell. ex F. M. Bail | Kauri pine[b] | 4 |
| *Athrotaxis selaginoides* D. Don | King William pine[4] | 2 |
| *Callitris columellaris* F. Muell. sens. lat. | White cypress pine | 2 |
| *Dacrydium franklinii* Hook f. | Huon pine[4] | 2 |
| *Phyllocladus asplenifolius* (Labill.) Hook f. | Celery-top pine[4] | 2 |
| *Podocarpus amarus* Bl. | Black pine | 4 |
| **Exotic softwoods** | | |
| *Pinus radiata* D. Don | Radiata pine | 4− |
| *Pseudotsuga menziesii* (Mirb.) Franco | Douglas fir | 4+ |
| *Sequoia sempervirens* (D. Don) Endl. | Redwood | 1 |
| *Thuja plicata* D. Don | Western red cedar | 1 |

[a] They now form the one species *E. eugenioides*. At the time of selection for this test *E. eugenioides* and *E. wilkinsoniana* were considered to be separate species.

[b] Indicates that the same common name is applied to species other than the one listed here under its scientific name.

[c] The number indicates the number of replicates in test at each site, if other than 10.

[d] Tentative durability rating (see Introduction): 1, highly durable; 2, durable; 3, moderately durable; 4, not durable; +, more durable than most of this class; −, less durable than most of this class. Where decay resistance and termite resistance were expected to vary markedly, durability in termite hazard areas (T) is given separately to that in areas where only decay hazard (D) is present.

*P. radiata* sapwood (12 kg of dry salt per $m^3$) were also included. For comparison with these two treatments, the untreated specimens of *P. radiata* were selected on the basis of comprising sapwood only, but three specimens comprising heartwood only were included at the Pennant Hills site.

Stakes were cut to give a finished, air-dry size of 50 × 50 mm cross-section and 450 mm length. Stakes were numbered, and although intentionally free of any defect, each was later examined visually and scored separately for presence and severity of any physical defect as well as the presence of sapwood.

## 2.2 Test exposure sites

### 2.2.1 Choice and location of sites

No single site could be expected to represent adequately the full range of hazards facing a service timber exposed in ground contact in Australia. For this test five sites, all believed to include both decay and termite hazards, were chosen on the Australian mainland as follows:

In the State of Queensland (two sites): at Jolly's Lookout (a site belonging to the Queensland Forest Service) 19 km north-west of Brisbane (27° 30′ South, 153° 00′ East), a sub-tropical site with a relatively dry soil on a well drained ridge. A second site is located 10 km west of Innisfail (17° 30′ South, 146° 00′ East), a very wet tropical rain forest area.

In the State of New South Wales: One of the Forestry Commission of New South Wales test sites, 25 km north-west of Sydney, at Pennant Hills (33° 42′ South, 151° 06′ East).

In the State of Victoria (two sites): at the Victorian Department of Agriculture field station, in the dry north-west at Walpeup (35° 07′ South, 142° 00′ East), and the other on CSIRO-owned land at Mulgrave, 26 km east of Melbourne (38° 00′ South, 145° 20 ′ East).

All these test sites except Brisbane and Mulgrave were already being used for the exposure of a stake test of wood preservatives (J. Beesley, 1978).

It should be noted that, since no test site was selected within the dry tropical regions, the termite hazard from the giant northern termite *Mastotermes darwiniensis* Froggatt will therefore be absent from the present test. The dry tropical regions can also contain areas with a higher hazard from *Coptotermes acinaciformis* Froggatt than has so far been shown to occur in the area around Walpeup (see J. Beesley, 1978).

### 2.2.2 Characteristics of test sites

Features of rainfall and temperature for each site are given in Tables 2 and 3 respectively.

The site at Brisbane has a reasonably high rainfall with relatively even, warm temperatures. The soil is a hilltop loam and is well leached with many roots and loose rocks, the latter often making routine specimen replacement a time consuming exercise at each and every inspection.

Table 2. Rainfall distribution.

| Site | Years recorded | Mean rainfall (mm) Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Brisbane | 30 | 265 | 272 | 191 | 83 | 64 | 103 | 70 | 55 | 43 | 129 | 109 | 121 | 1498 |
| Innisfail | 15 | 446 | 676 | 737 | 414 | 372 | 148 | 111 | 73 | 80 | 84 | 134 | 304 | 3556 |
| Pennant Hills | 15 | 127 | 112 | 138 | 62 | 57 | 101 | 32 | 43 | 53 | 75 | 78 | 66 | 944 |
| Walpeup | 69 | 19 | 28 | 24 | 22 | 33 | 30 | 31 | 34 | 34 | 37 | 26 | 23 | 340 |
| Mulgrave | 25 | 52 | 64 | 58 | 76 | 107 | 64 | 77 | 83 | 89 | 94 | 83 | 72. | 919 |

Table 3. Temperature distribution.

| Site | Years recorded | Extremes | Mean daily temperatures (°C) Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Brisbane | 30 | Max | 25 | 23 | 23 | 21 | 18 | 16 | 16 | 18 | 20 | 23 | 23 | 24 |
| | | Min | 18 | 18 | 17 | 15 | 12 | 10 | 9 | 10 | 11 | 14 | 15 | 17 |
| Innisfail | 15 | Max | 30 | 28 | 27 | 25 | 23 | 21 | 21 | 23 | 25 | 27 | 30 | 30 |
| | | Min | 23 | 23 | 22 | 20 | 19 | 16 | 16 | 16 | 18 | 19 | 21 | 22 |
| Pennant Hills | 13 | Max | 28 | 28 | 26 | 24 | 20 | 17 | 17 | 19 | 21 | 23 | 25 | 28 |
| | | Min | 18 | 18 | 16 | 13 | 10 | 8 | 6 | 7 | 9 | 12 | 14 | 16 |
| Walpeup | 41 | Max | 32 | 31 | 28 | 23 | 18 | 15 | 14 | 16 | 19 | 22 | 26 | 29 |
| | | Min | 15 | 15 | 13 | 10 | 7 | 5 | 5 | 5 | 7 | 9 | 11 | 13 |
| Mulgrave | 25 | Max | 26 | 27 | 24 | 20 | 16 | 13 | 13 | 14 | 16 | 19 | 21 | 23 |
| | | Min | 13 | 14 | 12 | 10 | 8 | 6 | 5 | 6 | 7 | 9 | 10 | 12 |

Innisfall is by far the wettest site and is warm to hot and humid for most of the year. This site has an unbroken canopy of tropical rainforest (see J. Beesley [1978] for a photograph of another test at this site). The soil is a loose, friable forest loam, of high moisture absorbency, with a clay fraction beneath.

Pennant Hills is a site with peak rainfall in the hot sommer months. The soil is a clay loam containing a little gravel.

Walpeup is by far the driest site, with a hot summer. It is in the 'Mallee' vegetation zone (comprised of low-growing multi-stemmed eucalypts, providing little shade, with sparse grass cover beneath). The soil is a shallow, light sand overlying a calcareous clay pan that is almost impervious (see J. Beesley [1978] for a photograph of another test at this site).

Mulgrave has its highest levels of monthly rainfall in the winter season. The soil is a clay loam with dense grass cover, on a well drained slope.

## 2.3 Specimen installation

Two specimens from each tree of each species were required for exposure at each site. Every site was divided into two blocks, each block having one stake from each tree of every species. Within each block all stakes were randomly distributed. Stakes were numbered according to their allocated position and installed approximately 600 mm apart in rows consisting of from 80 to 100 stakes, depending on the dimensions of the area available at each site. The distance between rows was approximately 900 mm. One block at each site consisted of either three or four full rows and one part row. The second block commenced at the beginning of the fresh row and likewise ended in a part row. Minor alterations to the spacings were sometimes necessitated due to large buried rocks or tree roots. The 450 mm long stakes were installed so that two-thirds of the length of each was in the ground. The installation of the test was completed at four sites within the period May to July 1968, although the fifth site (Mulgrave) was not completed until July 1969.

### 2.4 Inspection procedure

The years of exposure at each test site, at each of the four inspections so far carried out, are shown in Table 4. The expense of travelling considerable distances has meant that inspections have been somewhat variably timed at the different sites. In future it is hoped to carry out inspections at intervals of two years.

Table 4. Frequency of field inspections.

| Site | Years from installation | | | |
|---|---|---|---|---|
| | First inspection | Second inspection | Third inspection | Fourth inspection |
| Brisbane | 2.0 | 4.2 | 6.2 | 10.9 |
| Innisfail | 2.3 | 4.2 | 6.2 | 10.9 |
| Pennant Hills | 3.1 | Not inspected | 6.3 | 10.9 |
| Walpeup | 2.1 | 4.5 | 6.2 | 11.4 |
| Mulgrave | 2.3 | Not inspected | 6.4 | 10.2 |

At each inspection, every specimen was lifted from the ground, examined for the incidence and extent of both decay and insect attack and replaced. A sharp knife was used to probe carefully each stake, after the removal of any adhering soil which would otherwise make visual inspection difficult. Each stake was separately assessed for decay and for termite damage on a scale ranging from '4' (sound) down to '0' (failed) in half points. This field rating system is, of course, subjective. It should be noted that, between successive inspections, decayed wood from the earlier inspection may possibly be removed by termites before the next inspection. Likewise the extremities of termite tunnelling, present at one inspection, may be subsequently eroded away by decay (or by other insect activity) so that little evidence of the full extent of such termite attack may remain by the next inspection. For these reasons, as a matter of policy, any apparent improvements in the score of a specimen against any one hazard are brought to the inspector's attention by the person recording the data. In nearly all cases, a lower score at the previous inspection will be considered by the inspector as the correct score for the present inspection. Numbers recorded on the field cards are then doubled at the time of punching onto the computer card, a transformation performed simply for quicker punching and to take up only two columns of a computer card with the data from each inspection. This final computer rating system is

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shown in Table 5, which includes a description of the condition believed by the authors to be representative of each assessment value.

After each inspection the data are added to the particular computer card allocated to each specimen. Each card contains coded information on: the timber species, the number of the tree from which the stake was cut, the site, the position in the site, any defects prior to installation, and ratings of the condition of the specimen (with respect to both decay and termite hazards) at each and every inspection.

Table 5. Computer rating system used for handling the condition of each stake at inspection.

| Rating[a] | Description of the condition of the stake |
|---|---|
| 8 | Completely sound |
| 7 | Breakdown to 2 mm depth around much of the stake |
| 6 | Nearly quarter of cross-section seriously affected by biological agents |
| 5 | Quarter of cross-section seriously affected by biological agents |
| 4 | Nearly half of cross-section seriously affected by biological agents |
| 3 | Half of cross-section seriously affected by biological agents |
| 2 | More than half of cross-section seriously affected by biological agents |
| 1 | Three-quarters of cross-section seriously affected by biological agents |
| 0 | Whole of cross-section seriously affected by biological agents |
| ** | Failed at any one of the previous inspections |
| * | Missing as a result of causes other than the single biological agent under consideration |

[a] Rating numbers are those used for computer analysis of the data. See text for numbers actually recorded in the field.

No attempt was made, at any inspection, to identify specific species of termites attacking the specimens. However, positive identifications have been made of several termite species present in nearby test plots at Innisfail, Pennant Hills and Walpeup (J. Beesley, 1978). Similarly, no attempt has so far been made to record the types of rot present in the specimens. However, at all future inspections the authors will attempt to classify the types of rot and these designations will be recorded on the field cards.

## 2.5 Recording and handling of inspection data

In the authors' opinion the presence of any sapwood, being non-durable, may increase the decay susceptibility of the remaining heartwood portion of a stake. Therefore, those stakes known to contain sapwood (see Section 2.1) were excluded from subsequent analysis. This resulted in the omission of 67 stakes ranging in total from 10 to 17 at each site, not counting the untreated *P. radiata* sapwood stakes. Those species known to have more than one specimen containing sapwood at any one site were always those with the full complement of 10 replicates per site. Furthermore, only on one occasion were more than two specimens of the one species involved, viz five specimens containing sapwood of *E. salmonophloia* at the Pennant Hills site.

For each inspection, a mean decay value and a mean termite value for each species was produced by computer print-out. In order to obtain a mean score the following points had to be taken into account in the computer program:

(i) When a stake scores '*' (i. e. missing, Table 5) no value is then used for the purposes of calculating the mean.

(ii) When a stake scores '**' for a particular hazard (i. e. it failed at any previous inspection due to that particular hazard, Table 5), then that stake is counted as scoring zero for that hazard at all subsequent inspections, and is included in the calculation of the mean at all subsequent calculations.

(iii) Any stake which fails due to one hazard is subsequently deemed to be missing with respect to the other hazard and is not included in the subsequent calculation of the mean for that other hazard.

Essentially what the above considerations mean is that Table 6, which describes the condition of species at the fourth inspection only, will provide mean scores (out of a maximum, sound, computer rating of 8.0) by including all specimens which are not missing, and incorporating a value of zero for any stakes previously failed due to the particular cause.

In order to obtain some measure of the variability and, therefore, the reliability of individual mean scores, confidence limits were also calculated.

## 2.6 Statistical analysis and species life values

Statistical analysis was performed in order to produce an average specimen life value within species ('ASL') under Australian conditions. A stake having a decay or termite score of '3' or less (out of a sound, maximum computer rating of '8', Table 5) was considered unserviceable. The ASL at any site, was (or will be) therefore the mean time (in years) for replicates to reach a score of '3' against any one hazard. No estimate of ASL was calculated for any species at any site where any specimens were last recorded as having scores of either 4, 5, 6, 7 or 8. The ASL was calculated using a value of the time for each stake to reach unserviceability as 'halfway between an inspection at which it gave a score from 4 to 8 and the next inspection at which it scored 3 or less'. This is done to prevent over-estimation of ASL and is considered most necessary for the less durable species in this test, since in these early stages, inspections were carried out less frequently than they are intended to be in the future.

Where most specimens at one site become unserviceable primarily as a result of one hazard, then an ASL value with respect to the other hazard cannot, obviously, be determined. One would expect, however, that occasionally sufficient specimens would be rendered unserviceable by each of the two hazards, resulting in an ASL value becoming available to each hazard separately. For the purposes of this paper the minimum number of specimens from which an ASL value was calculated was three for any one hazard at any one site.

However, it must be noted that ASL values resulting from one hazard may be conditioned by interaction with the other hazard and they do not necessarily reflect what the ASL value would have been had the other hazard not been present at that site. In practical terms the fact that decay and termite hazards are present in varying mixes is precisely what gives the different sites their overall biological hazards. Nevertheless, in Tables 7A and 7B an attempt has been made to give ASL values separately against the decay and the termite hazards of a particular site. However, as the headings to these tables clearly state, with the exception of the Mulgrave site, the ASL value against a particular hazard is in fact an value obtained in the presence of the alternative biological hazard.

There are two sources of errors involved in the estimate of ASL: firstly, the intrinsic variability of the wood, termite attack and decay, and secondly, the uncertainty in time of failure resulting from the long intervals between inspections in the early years of this test. Statistical analysis shows that these two sources lead to errors of similar magnitude and so it was necessary to incorporate both in the analysis.

The standard deviation of the ASL was not given by the usual formula, but a correction had to be applied, to allow for measurement error, as follows.

Since the exact time of failure is not known, the ASL values are effectively grouped into a small number of intervals. When the mean and standard deviation are calculated from grouped data, allowance must be made for the effect of the grouping. When the grouping interval is small compared with the variability of the data, the effect can generally be ignored, but when, as in the present case, the grouping intervals are of the same order as the variation in the data, a correction must be made.

If the form of the distribution of the data were known then its parameters could be estimated directly from the grouped data, and the mean and standard deviation calculated from these estimates. Since nothing is known about the distribution, we shall use a simple model which is likely to give reasonably accurate results.

We shall suppose that the probability density function is constant within each grouping interval. Thus if the ith interval is $j_i = (c_i \tfrac{1}{2} l_i,\ c_i + \tfrac{1}{2} l_i)$ where $c_i$ is the mid point of $J_i$ and $l_i$ is the length of $J_i$, then the density $f(x)$ of a single observation $X$ is given by

$$f(x) = \frac{P_i}{l_i} \quad \text{for } x \text{ in } J_i$$

where $p_i$ is the probability that $X$ lies in $J_i$.

The values of $c_i$ and $l_i$ are known exactly, and so only the $p_i$ have to be found from the data.

The maximum likelihood estimate (MLE) of $p_i$ is

$$\hat{p}_i = \frac{N_i}{N}$$

where $N$ is the total number of observations and $N_i$ is the number lying in $J_i$. The mean of $X$ is easily shown to be

$$E(X) = \Sigma\, c_i\, p_i$$

all intervals,

and the variance of $X$ is

$$\text{var}(X) = \Sigma \left( c_i^{\,2} p_i + \frac{1}{12} p_i\, l_i^2 \right) - (E(X))^2$$

all intervals.

Thus the MLE's of $E\,(X)$ and var $(X)$ are

$$\hat{E}\,(x) = \Sigma\, c_i\, \hat{p}_i$$

$$\text{and} \quad \hat{\text{var}}\,(x) = \Sigma \left( c_i{}^2 \hat{p}_i + \frac{1}{12}\, \hat{p}_i\, l_i^2 \right) - (\hat{E}\,(x))^2$$

The expression for the mean can be shown to be the mean of the observed values if a value lying in $J_i$ is taken to occur at $c_i$. The expression for the variance (if adjusted as usual for the bias in the MLE) is the usual estimate of the variance modified by an additional term

$$\frac{1}{12}\, \Sigma\, \hat{p}_i\, l_i^2$$

While this deviation depends on the form assumed for $f\,(x)$, it is likely to give a closer approximation than simply taking the observed values to be at the mid points of the intervals.

The calculation of a standard error for the estimated mean causes further difficulty since the estimated variance of $\hat{E}\,(X)$ when all observed values lie in the same interval is zero. A heuristic argument for using the correction found above for the estimated population variance can be given by treating the correction term as the variance of the error in the calculated mean resulting from the grouping.

$$\text{The 'true' value of } X \text{ was} \quad X_t = X + e$$

where conditional on $X$, $X + e$ is uniformly distributed on the interval $J_i$ containing $X$. Then, given the observed values $X$, the average of the 'true' values has mean $\hat{E}\,(X)$ and variance $(12\,N)^{-1}\, \Sigma\, p_i\, l_i^2$. Thus taking $l/N$ times the corrected population variance as the variance of the estimator gives a plausible correction for grouping.

It must be stressed, however, that this approach is applicable only when the variability of ASL is of the same order as the length of the intervals. If the lifetime distribution is highly concentrated within a single interval these estimates may be misleading. (In such a situation more frequent inspections would be essential.)

## 3. Results and Discussion

The condition of the stakes at the last (fourth) inspection is given in Table 6. Mean values are presented, the computer rating for a sound specimen being 8.0. Values in parentheses are means for which the length of the 95 per cent confidence interval is 3.0 or greater and these values are, therefore, to be viewed as less reliable data than the unbracketed values. From the results presented in Table 6 it is apparent that decay and termite hazards have varied considerably in severity from site to site. For the Brisbane site, the mean scores have indicated the decay hazard to be greater than the termite hazard. At Innisfail, termites have appeared to be the major hazard, though one cannot discount the possibility that, between inspections, the surface wood may have been softened by decay before the termites harvested the softened wood. Decay has been the major hazard at Pennant Hills, whereas at Walpeup, termites have apparently been a rather greater hazard than decay. At the Mulgrave site the presence of termites has not been detected.

The earliest information on durability to come from this test will, naturally, concern the least durable timbers. However, as many persons may look to this paper for information on the durable timbers, some evaluation of the most recent data (Table 6) is warranted. *E. wandoo* ('tentative' durability 1+, Table 1) so far appears to be performing slightly better than all other timbers. *E. leucoxylon* (1−), *E. melliodora* (1−), *E. microcorys* (1), *E. moluccana* (1+), *E. paniculata* (1+) and *E. sideroxylon* (1) are all performing well. However, *E. acmenioides* (2), *E. cladocalyx* (2), *E. gomphocephala* (2), *E. longifolia* (2) and *E. polyanthemos* (2) are apparently not yet readily separable from the aforementioned timbers (Table 6). Similarly, *A. acuminata* (2), *A. harpophylla* (2) and *C. luehmannii* (1) are all performing well. However, the within-site variation of *I. bijuga* (1) has been high and resistance to decay is poor.

Individual pieces of information coming from the early stages of this test could be interpreted as supporting the following statements:

(i) The decay hazard is higher in some areas of Australia than in some test sites employed by other workers overseas. For example, there is no similarity between the predicted average life value in excess of 73 years (D. F. Purslow, 1976) for *S. glomulifera* and the performance of this species against the decay hazard of the Brisbane site (Table 6). Also, *E. pilularis* gave a predicted average life in excess of 30 years (D. F. Purslow, 1976) compared to an average life of just over 5 years at the Brisbane site (Table 7 A).

(ii) Those representatives of the Australian Myrtaceae showing high durability in this test (Table 6) are in fact considerably more durable than some other timbers rated overseas as very durable. Certainly the exotic species *T. grandis* does not justify its reputation when one considers the performance of this species against the decay hazards of the Brisbane and Innisfail sites.

However, a further explanation for the relatively poor performance of, for example, *E. diversicolor* and *S. glomulifera* under Australian conditions (Table 6) in comparison to that for European conditions (D. F. Purslow, 1976) is open to suggestion by the reader of this paper. It could be postulated that the method of assessing the condition of the specimens used in this test could for some reason be far more severe/destructive than those methods

Table 6. Condition of heartwood stakes with respect to decay and termite

| Species | Mean rating[a] — Site and hazard: Brisbane Decay | Brisbane Termites | Innisfail Decay | Innisfail Termites | Pennant Hills Decay | Pennant Hills Termites | Walpeup Decay | Walpeup Termites | Mulgrave[b] Decay |
|---|---|---|---|---|---|---|---|---|---|
| **Australian hardwoods Myrtaceae** (*Eucalyptus*, *Syncarpia* and *Tristania* spp.) | | | | | | | | | |
| *E. acmenioides* | 5.6 | 7.8 | 5.8 | 5.0 | 6.5 | 7.8 | 6.2 | 6.3 | 7.2 |
| *E. amygdalina* | 0.0 | 8.0 | 0.0 | 0.0 | (2.9) | 6.4 | 6.2 | 2.7 | 1.8 |
| *E. astringens* | (2.3) | 5.9 | 6.2 | (1.4) | 6.2 | 7.4 | 5.6 | 4.1 | 6.4 |
| *E. bosistoana* | 4.9 | 6.2 | 7.2 | (2.9) | (5.6) | 7.2 | 7.0 | 5.0 | 6.4 |
| *E. botryoides* | 1.0 | 7.6 | (3.7) | 0.7 | 4.0 | 7.8 | 6.0 | 5.6 | (5.3) |
| *E. calophylla* | 0.7 | (6.0) | (3.6) | 1.1 | 4.6 | 7.1 | 5.7 | 3.7 | (4.0) |
| *E. camaldulensis* | 2.6 | 7.5 | 5.6 | 3.7 | (5.2) | 7.6 | 6.0 | 6.6 | 5.9 |
| *E. capitellata* | 0.1 | (6.5) | 0.0 | 0.0 | (2.6) | 7.0 | 5.8 | (3.3) | (4.2) |
| *E. cladocalyx* | 4.6 | 7.0 | 6.3 | 4.4 | 6.4 | 7.9 | 6.6 | 6.3 | 6.2 |
| *E. cloeziana* | 5.6 | (6.3) | 6.0 | (2.1) | 6.0 | 7.9 | 6.5 | 6.2 | 6.3 |
| *E. consideniana* | 2.5 | 6.7 | 5.5 | 0.6 | (3.9) | 7.8 | 5.8 | 4.7 | 5.7 |
| *E. cornuta* | (4.1) | 6.7 | 6.0 | (1.1) | 5.1 | 7.0 | 5.7 | 3.5 | (5.4) |
| *E. cypellocarpa* | 0.6 | 7.0 | 0.0 | 0.0 | (4.1) | 6.6 | 6.0 | (2.8) | 4.0 |
| *E. diversicolor* | (1.6) | (7.0) | 0.0 | 0.0 | 5.0 | 7.5 | 5.1 | (2.5) | 5.2 |
| *E. dives* | 0.4 | (6.0) | 0.0 | 0.0 | (3.6) | 6.4 | 5.5 | 4.4 | 3.8 |
| *E. elata* | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | (5.3) | (4.6) | 1.2 | (1.6) |
| *E. eugenioides* | 0.3 | (6.4) | 6.0 | 0.0 | (2.3) | (7.3) | 5.8 | 5.1 | 5.0 |
| *E. eugenioides* (formerly *E. wilkinsoniana*) | (1.3) | (4.5) | 6.0 | 0.4 | (2.8) | 7.0 | 5.8 | (3.2) | 4.7 |
| *E. fastigata* | 0.0 | 7.5 | 4.0 | 0.1 | 2.0 | (5.8) | 4.3 | (2.6) | (2.1) |
| *E. gomphocephala* | 5.2 | 7.3 | 6.7 | 1.1 | 5.3 | 7.3 | 6.7 | 4.8 | 6.4 |
| *E. goniocalyx* | (2.6) | (6.1) | 6.3 | 0.4 | 4.0 | 7.5 | 6.0 | 5.3 | 5.9 |
| *E. grandis* | 1.1 | 6.7 | (4.9) | 1.2 | (2.8) | 7.8 | 6.0 | 4.5 | (3.8) |
| *E. guilfoylei* | (4.1) | (2.3) | (7.0) | 0.8 | (4.5) | 7.7 | 6.4 | 4.4 | (3.8) |
| *E. haemastoma* | 0.2 | (5.3) | (2.5) | 0.4 | 4.4 | 7.8 | 6.0 | 5.2 | 4.1 |
| *E. jacksonii* | 0.0 | (4.0) | 0.0 | 0.0 | (1.8) | 6.4 | (5.4) | 1.1 | (3.3) |
| *E. leucoxylon* | 4.7 | 7.3 | 6.7 | (2.7) | 3.4 | 7.7 | 6.7 | 6.2 | 6.6 |
| *E. longifolia* | 5.7 | 6.9 | 6.8 | 1.2 | 6.9 | 7.7 | 6.7 | 5.4 | 6.8 |
| *E. macrorhyncha* | 3.2 | 5.0 | (5.2) | (1.4) | (4.2) | 7.3 | 6.4 | (5.0) | (4.9) |
| *E. maculata* | 3.0 | 6.4 | (5.0) | (1.7) | (4.2) | 7.6 | 6.4 | 5.1 | 6.1 |
| *E. maidenii* | 0.6 | (6.0) | 0.0 | 0.0 | (5.1) | (6.4) | 5.6 | 4.8 | 4.5 |
| *E. marginata* | 0.7 | 6.8 | (3.1) | 0.9 | 4.9 | 7.7 | 6.4 | 5.8 | 6.2 |
| *E. megacarpa* | (1.8) | (3.8) | 0.0 | 0.0 | (4.0) | (4.0) | 5.7 | (2.5) | 5.5 |
| *E. melliodora* | 6.1 | 7.0 | 6.4 | (4.4) | 7.1 | 7.9 | 6.9 | 6.0 | 7.0 |
| *E. microcorys* | 5.7 | 7.2 | 6.4 | (4.3) | 5.8 | 7.9 | 6.2 | 6.5 | 6.6 |
| *E. moluccana* | 5.8 | 7.4 | 6.8 | (3.8) | (6.1) | 7.3 | 6.9 | 6.2 | 6.2 |
| *E. muellerana* | 1.2 | (5.9) | 0.0 | 0.0 | (3.1) | 7.3 | 6.0 | (4.3) | (4.7) |
| *E. obliqua* | 0.9 | (3.5) | 0.0 | 0.0 | 1.6 | (5.7) | 6.0 | (2.5) | 1.9 |
| *E. paniculata* | 6.1 | 7.1 | 6.5 | (4.7) | 7.4 | 7.9 | 6.3 | 6.6 | 6.8 |
| *E. patens* | 2.6 | 5,8 | 6.0 | 0.3 | (5.0) | 7.7 | 6.4 | 5.9 | 5.5 |
| *E. pilularis* | 1.2 | (5.0) | 6.3 | 0.8 | (5.0) | 7.6 | 6.7 | 5.4 | 5.0 |

ı respect to decay and termite

| :ard | | | |
|---|---|---|---|
| ills | Walpeup | | Mulgrave[b] |
| r- tes | Decay | Ter- mites | Decay |
| | | | |
| ıae | | | |
| :ia spp.) | | | |
| 8 | 6.2 | 6.3 | 7.2 |
| 4 | 6.2 | 2.7 | 1.8 |
| .4 | 5.6 | 4.1 | 6.4 |
| .2 | 7.0 | 5.0 | 6.4 |
| .8 | 6.0 | 5.6 | (5.3) |
| .1 | 5.7 | 3.7 | (4.0) |
| .6 | 6.0 | 6.6 | 5.9 |
| .0 | 5.8 | (3.3) | (4.2) |
| .9 | 6.6 | 6.3 | 6.2 |
| .9 | 6.5 | 6.2 | 6.3 |
| .8 | 5.8 | 4.7 | 5.7 |
| .0 | 5.7 | 3.5 | (5.4) |
| .6 | 6.0 | (2.8) | 4.0 |
| .5 | 5.1 | (2.5) | 5.2 |
| .4 | 5.5 | 4.4 | 3.8 |
| .3) | (4.6) | 1.2 | (1.6) |
| .3) | 5.8 | 5.1 | 5.0 |
| .0 | 5.8 | (3.2) | 4.7 |
| .8) | 4.3 | (2.6) | (2.1) |
| .3 | 6.7 | 4.8 | 6.4 |
| .5 | 6.0 | 5.3 | 5.9 |
| '.8 | 6.0 | 4.5 | (3.8) |
| '.7 | 6.4 | 4.4 | (3.8) |
| '.8 | 6.0 | 5.2 | 4.1 |
| ;.4 | (5.4) | 1.1 | (3.3) |
| '.7 | 6.7 | 6.2 | 6.6 |
| '.7 | 6.7 | 5.4 | 6.8 |
| '.3 | 6.4 | (5.0) | (4.9) |
| '.6 | 6.4 | 5.1 | 6.1 |
| ;.4) | 5.6 | 4.8 | 4.5 |
| '.7 | 6.4 | 5.8 | 6.2 |
| l.0) | 5.7 | (2.5) | 5.5 |
| 7.9 | 6.9 | 6.0 | 7.0 |
| 7.9 | 6.2 | 6.5 | 6.6 |
| 7.3 | 6.9 | 6.2 | 6.2 |
| 7.3 | 6.0 | (4.3) | (4.7) |
| 5.7) | 6.0 | (2.5) | 1.9 |
| 7.9 | 6.3 | 6.6 | 6.8 |
| 7.7 | 6.4 | 5.9 | 5.5 |
| 7.6 | 6.7 | 5.4 | 5.0 |



hazards at the fourth inspection (between 10.2 and 11.4 years after installation).

| Species | Mean rating[a] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Site and hazard | | | | | | | | |
| | Brisbane | | Innisfail | | Pennant Hills | | Walpeup | | Mulgrave[b] |
| | Decay | Termites | Decay | Termites | Decay | Termites | Decay | Termites | Decay |
| *E. polyanthemos* | 6.5 | 7.5 | 5.8 | 4.8 | 6.8 | 8.0 | 7.0 | 7.5 | 6.5 |
| *E. radiata* | 0.3 | (4.0) | 0.0 | 0.0 | 2.0 | 7.0 | 4.9 | 3.6 | 1.7 |
| *E. regnans* | 0.8 | 8.0 | 0.0 | 0.0 | (2.0) | (4.0) | 5.9 | 0.4 | (2.1) |
| *E. resinifera* | (3.9) | 6.3 | (4.7) | (2.6) | 5.1 | 7.9 | 6.0 | 6.0 | 6.7 |
| *E. rubida* | 0.1 | 7.7 | 0.0 | 0.0 | 1.5 | (4.5) | (4.5) | 1.8 | (1.9) |
| *E. saligna* | 0.0 | (7.3) | (1.2) | (1.3) | (3.6) | 6.7 | (5.3) | (5.1) | 5.7 |
| *E. salmonophloia* | 6.1 | 7.1 | 6.5 | (1.4) | (6.0) | 7.4 | 6.1 | (4.5) | 6.8 |
| *E. sideroxylon* | 6.5 | 7.3 | 6.8 | (5.3) | 5.6 | 7.9 | 6.7 | 5.9 | 7.0 |
| *E. sieberi* | 1.5 | (5.3) | 0.0 | 0.0 | (3.8) | (5.7) | 6.1 | 3.4 | 4.4 |
| *E. stjohnii* | (1.8) | (4.9) | 0.0 | 0.0 | (4.6) | (6.1) | 6.9 | 2.4 | 4.4 |
| *E. tereticornis* | 4.8 | 7.2 | 6.2 | 4.1 | 6.4 | 7.6 | 6.6 | 6.7 | 6.9 |
| *E. viminalis* | 0.0 | 0.0 | 0.0 | 0.0 | (2.1) | 0.5 | (3.0) | 0.5 | 0.8 |
| *E. wandoo* | 6.7 | 7.5 | 6.7 | 5.8 | 7.5 | 8.0 | 6.7 | 6.7 | 7.2 |
| *S. glomulifera* | 3.7 | 6.5 | 5.7 | 3.1 | 5.1 | 7.8 | 6.5 | 5.8 | 6.2 |
| *S. hillii* | 1.5 | 6.9 | 5.3 | 2.8 | (4.2) | 7.6 | 6.6 | 7.3 | 5.8 |
| *T. conferta* | 0.1 | 8.0 | 0.0 | (2.0) | (2.0) | 7.0 | (3.2) | 7.0 | (2.5) |
| *T. suaveolens* | 3.8 | 7.4 | 1.1 | 7.0 | (5.4) | 7.7 | 7.1 | 8.0 | 6.3 |
| **Australasian hardwoods other than Myrtaceae** | | | | | | | | | |
| *A. acuminata* | 6.3 | 7.2 | 6.2 | (4.1) | 7.2 | 7.9 | 7.2 | 6.6 | 7.1 |
| *A. harpophylla* | 5.9 | 7.9 | 6.3 | 6.0 | 6.7 | 7.9 | 6.8 | 6.1 | 7.0 |
| *A. polyandra* | 0.7 | 6.8 | (1.3) | (2.4) | (1.9) | (6.3) | 3.7 | (3.9) | (1.4) |
| *C. luehmannii* | 6.3 | 8.0 | 7.3 | 7.0 | 7.0 | 8.0 | (5.3) | 6.0 | (5.3) |
| *I. bijuga* | (1.2) | 8.0 | (3.4) | (2.9) | (3.5) | 7.9 | 6.1 | 6.1 | 5.4 |
| *L. reticulata* | 0.0 | 7.0 | (2.8) | 0.0 | (2.5) | 7.3 | (3.4) | 5.4 | 2.7 |
| *N. cunninghamii* | 0.0 | 7.3 | 0.0 | 0.0 | (2.6) | (2.3) | 7.0 | 0.0 | (2.3) |
| *P. indicus* | 1.0 | 6.6 | 1.8 | (2.4) | (2.5) | 7.8 | 6.7 | 6.8 | 4.9 |
| **Exotic hardwoods** | | | | | | | | | |
| *Q. alba* | 0.0 | 0.0 | 0.0 | 0.0 | (1.8) | 7.8 | 6.7 | (1.5) | 1.0 |
| *T. grandis* | 3.8 | 7.0 | (3.0) | 5.3 | 5.8 | 7.8 | (6.8) | 7.3 | 6.5 |
| **Australian softwoods** | | | | | | | | | |
| *A. palmerstonii* | 0.0 | 6.0 | 0.0 | 0.0 | 0.0 | 0.0 | (3.5) | (2.2) | 0.0 |
| *A. selaginoides* | (1.0) | 7.5 | (1.5) | (3.0) | 3.3 | 7.5 | 7.5 | 6.8 | (6.3) |
| *C. columellaris* | (3.3) | 7.0 | (2.9) | (3.3) | (3.7) | 7.4 | 6.8 | 7.3 | 6.6 |
| *D. franklinii* | (2.3) | (5.5) | (3.0) | 0.0 | (3.5) | 7.3 | (5.8) | 2.0 | (6.0) |
| *P. asplenifolius* | (3.0) | (6.7) | 0.0 | 0.0 | (2.5) | 8.0 | (4.5) | (4.8) | 6.0 |
| *P. amarus* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | (3.7) | 5.9 | 0.5 |
| **Exotic softwoods** | | | | | | | | | |
| *P. radiata*[c] | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *P. menziesii* | 0.0 | 8.0 | 0.0 | 0.0 | 0.0 | (1.3) | 0.0 | 0.0 | (3.2) |
| *S. sempervirens* | 0.9 | 8.0 | (1.3) | (2.0) | (2.2) | 8.0 | 7.5 | 6.8 | (5.8) |
| *T. plicata* | 1.6 | 7.9 | (2.3) | (3.0) | 1.2 | (7.3) | 6.8 | 5.5 | 5.1 |

[a] Figures in parantheses are means for which the length of the 95 per cent confidence interval is 3.0 or greater. These values are, therefore, to be viewed as less reliable data than the unbracketed values.

[b] No termite activity has yet been recorded for the Mulgrave site.

[c] Most of the *P. radiata* stakes in this test were sapwood (for comparison with the preservative treatments). However, at the Pennant Hills site three stakes comprising all heartwood were included.

in use elsewhere. However, the authors feel that this possibility can be largely discounted since the CCA-treated and creosoted *P. radiata* stakes at the fourth inspection showed a minimum mean score for any site of 7.2 with respect to termites and 6.8 with respect to decay. These treated softwood stakes are, therefore, still largely sound and so far are performing better than any of the untreated species in test. (The condition of these treated stakes will be discussed more thoroughly in future reports.)

The former *E. wilkinsoniana* (now included within *E. eugenioides*) and *E. eugenioides* clearly are performing in a similar manner, perhaps providing confirmatory evidence of the suitability of their recent amalgamation as a single species.

It seems likely that examples of different durabilities, with respect to termites and decay, will come to light as this test progresses. For example *T. suaveolens* (1) justifies its durable reputation in terms of termite hazard, but definitely not in terms of decay hazard (Table 6).

None of the softwoods tested are showing a high degree of decay resistance (Table 6). This is a surprising result in the case of *C. columellaris*, bearing in mind the reputation of white cypress pine as a most suitable species for utility poles in certain localities. However, this reputation was probably achieved for service in the drier regions of Australia (J. E. BARNACLE pers. comm.) and it is interesting that *C. columellaris* is performing very well at the Walpeup and Mulgrave sites (Table 6), the two driest sites used (Table 2). Neither *S. sempervirens* nor *T. plicata* appear to justify their 'tentative' durability rating of 1, and neither compare favourably with those Australian hardwoods of similar reputation (Tables 1 and 6).

Values of the estimated average specimen life within species ('ASL') resulting from the decay hazard (Table 7 A) and the termite hazard (Table 7 B) have been obtainable for those species under test for which specimens have all become unserviceable with respect to either or both these hazards. Obviously it is not appropriate to devote lengthy discussion on the limited amount of ASL data so far obtained. Only two timber species have so far yielded ASL values for each of the two hazards present at the same site. These are *E. viminalis* at Pennant Hills with values of 4.1 years against decay and 7.1 years against termites, and *P. amarus* at Innisfall with values of 1.1 years against decay and 1.7 years against termites (Tables 7 A and 7 B). However, it must be emphasized that, with the exception of the Mulgrave site, the decay hazard is always occurring in the presence of termites. Similarly, at the four sites with termites present, the termite hazard is always occurring in the presence of a decay hazard.

It is interesting to note that of those timbers for which an ASL value has been calculated with respect to decay (Table 7 A), some were originally

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m score for any site of 7.2
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far are performing better
condition of these treated
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within *E. eugenioides*) and
manner, perhaps providing
recent amalgamation as a

rabilities, with respect to
st progresses. For example
n terms of termite hazard,
6).

degree of decay resistance
of *C. columellaris*, bearing
a most suitable species for
reputation was probably
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Table 7A. Estimated years of average specimen life within species (ASL) resulting from the decay hazard, while in the presence of a termite hazard[a].

| Species and tentative durability | Brisbane | Innisfail | Site Pennant Hills | Walpeup | Mulgrave |
|---|---|---|---|---|---|
| *E. amygdalina* (3) | 4.5 (1.0)[b] | | | | |
| *E. botryoides* (2) | 6.0 (1.0) | | | | |
| *E. capitellata* (3 +) | 4.8 (0.9) | | | | |
| *E. dives* (3 +) | 5.2 (0.9) | | | | |
| *E. elata* (3) | 1.2 (0.3) | | 5.0 (1.0) | | |
| *E. fastigata* (3 −) | 4.7 (1.0) | | | | |
| *E. haemastoma* (2 −) | 6.1 (0.8) | | | | |
| *E. jacksonii* (2) | 4.0 (0.8) | | | | |
| *E. maidenii* (3 +) | 5.2 (1.0) | | | | |
| *E. megacarpa* (3 −) | 6.3 (1.4) | | | | |
| *E. obliqua* (3) | 4.6 (1.1) | | | | |
| *E. pilularis* (2 −) | 5.3 (1.0) | | | | |
| *E. radiata* (3) | 4.0 (0.9) | | | | |
| *E. regnans* (4) | 2.3 (0.5) | | | | |
| *E. rubida* (3 −) | 2.8 (0.9) | | | | |
| *E. saligna* (3 +) | 4.6 (0.8) | | | | |
| *E. viminalis* (3) | | | 4.1 (0.8) | | |
| *T. conferta* (3 D) | 2.7 (0.5) | 4.2 (0.9) | | | |
| *A. polyandra* (3 +) | 5.1 (1.1) | | | | |
| *L. reticulata* (3) | 3.5 (0.5) | | | | |
| *N. cunninghamii* (4) | 2.6 (0.8) | | | | |
| *P. indicus* (2 +) | 7.0 (0.8) | | | | |
| *Q. alba* (4) | 2.6 (1.0) | | | | 5.3 (1.2) |
| *A. palmerstonii* (4) | | | | | 4.1 (0.7) |
| *P. amarus* (4) | 1.2 (0.3) | 1.1 (0.4) | 3.2 (0.6) | | |
| *P. menziesii* (4 +) | 3.6 (0.7) | | 4.8 (0.6) | | |

[a] Note that no termites have yet been detected at the Mulgrave site.
[b] Estimated standard error of mean.

classified as durable (*E. botryoides*, 2; *E. haemastoma*, 2 −; *E. jacksonii*, 2; *E. pilularis*, 2 −). Similarly with respect to species life against termites (Table 7B), both *E. eugenioides* and *E. guilfoylei* were designated Class 2 durability. These findings must, even at this early stage of test exposure, be considered as evidence leading to doubt about the accuracy of the tentative durability ratings of at least some of the species under test.

## 4. General Discussion

It is not the purpose of this paper to attempt a comprehensive review of the world literature on natural durability. Nevertheless, the final information obtainable from the present Australian test will need to be placed

Table 7B. Estimated years of average specimen life within species (ASL) resulting from the termite hazard, while in the presence of a decay hazard.

| Species and tentative durability | Site | | | | |
|---|---|---|---|---|---|
| | Brisbane | Innisfail | Pennant Hills | Walpeup | Mulgrave |
| *E. calophylla* (3 +) | | 4.8 (1.0)[a] | | | |
| *E. dives* (3 +) | | 2.6 (0.6) | | | |
| *E. eugenioides* (2) | | 3.9 (0.7) | | | |
| *E. goniocalyx* (3) | | 3.6 (1.0) | | | |
| *E. guilfoylei* (2) | | 4.2 (1.3) | | | |
| *E. viminalis* (3) | | | 7.1 (1.1) | | |
| *N. cunninghamii* (4) | | | | 2.8 (0.8) | |
| *D. franklinii* (2) | | | | 8.0 (0.8) | |
| *P. amarus* (4) | | 1.7 (0.5) | | | |
| *P. radiata*[b] (4 –) | | | 2.6 (1.9) | | |
| *P. menziesii* (4 +) | | | | 3.0 (0.6) | |

[a] Estimated standard error of mean.

[b] Most of the *P. radiata* stakes in this test were sapwood (for comparison with the preservative treatments). However, at the Pennant Hills site three stakes comprising all heartwood were included.

into context with whatever information has by then been accumulated on this topic. The authors feel, therefore, that it is pertinent to make some comment both on the assessment of the condition of field test specimens and on durability ratings, as applied throughout the world. Discussion of the former topic will, of course, include reference to work carried out with preservative-treated wood.

Currently some concern is being expressed by other workers about the need for the production of an inspection method of a quantitative nature for use with routine field tests (H. Friis-Hansen, 1981). However, the additional time involved in using such an inspection method would, we feel, almost certainly render any quantitative method impractical for use with the large numbers of specimens currently exposed at many sites around Australia and Papua New Guinea (Anon., 1968). Furthermore, exactly how such a method would separately quantify the decay and insect factors has not been elucidated. Neither of the present authors are too concerned that there are in use markedly different scales for the subjective scoring systems (R. A. Zabel and R. A. Moore, 1958; A. Purushotham et al., 1968; R. Cockcroft, 1976; R. H. Colley et al., 1976 J. Krzyzewski, 1976; H. L. Davidson, 1977), even though a world standard for uniformity has been put forward (G. Becker, 1972). It is in the interpretation of the data gathered from these inspection methods that the authors express concern. D. F. Purslow (1976), concerned with a decay hazard, used a mathematical formula to predict the life for species whose replicates had not yet all failed. For the present

life within species (ASL)
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| ıt | Walpeup | Mulgrave |
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study, involving both a decay and a termite hazard, we feel uncertain about the validity of entering into any predictive analysis because of the unpredictable pattern of termite attack. This uncertainty is, evidently, also shared by some workers who are dealing only with a decay factor (Ö. BERGMAN and B. HENNINGSSON, 1979; B. HENNINGSSON and Ö. BERGMAN, 1979), although in their case they have the additional factor of different preservatives at various retention levels.

Durability classifications are in use which differ between workers in terms of both the total number of classes employed (A. PURUSHOTHAM and M. J. MASCARENHAS, 1952; D. F. PURSLOW, 1976; W. LIESE, 1977; Standards Association of Australia, 1980) and the description of how many years of life are to be expected from timbers of the 'highest durability' (A. PURUSHOTHAM and M. J. MASCARENHAS, 1952; J. D. BOYD, 1961; N. R. DAS, L. P. CHANDOLA and B. C. RAMOLA, 1965; W. LIESE, 1977). It may be expected that much of this variation for the life of the most durable timbers would directly reflect the different climatic conditions under which the timbers may be exposed. However, the Australian requirement for 'very durable timbers' of 'at least 25 years service' (Standards Association of Australia, 1980) would appear to contrast markedly with the requirement of 'greater than 10 years' (Y. FORTIN and J. POLIQUIN, 1976), bearing in mind that both of these requirements should relate to those apparently similar tropical exposure conditions which can be encountered.

Though a world standard comprising seven durability classes has been proposed (W. LIESE and H. WILLEITNER, 1980), a major problem appears to lie in the separation of any proposed number of classes. Whilst the mean value for specimen life may fall within one particular class of durability, the specimen life values of individual replicates could overlap two or even more classes. One can argue that, if individual replicate values span more than one class of durability, then the mean value of those replicates is, in isolation, of little meaning for the use of, say, the specifying engineer or designer. Whilst the test reported here is still in its early stages, and final information on the most durable timbers will not be obtained for several years, it is worth considering that a measure of the variation of the mean durability of each timber species may be of more use to the end user than would the continued use of distinct durability classes. We recommend more consideration of these points, since mean values without consideration of variation cannot be countenanced in any scientific interpretation of either laboratory or field data.

## 5. Summary

Between May 1968 and July 1969, a graveyard test of some 3700 heartwood stakes was installed at five sites in Australia. A total of 65 native hardwood species and 6 native softwoods were included together with 2 exotic hardwoods and 4 exotic softwoods. Though all sites were selected to provide both decay and termite hazards, at one site no specimens have so far been attacked by termites. After more than 10 years (between 10.2 and 11.4 years) in test those hardwoods previously rated 'highly durable' are performing well and cannot yet be readily separated from certain of the species previously rated 'durable'. However, some of the other 'durables' are performing nowhere near as well as would have been expected, and a number of these species have deteriorated to a degree where an average specimen life ('ASL') value has been calculated with respect to either or both of the termite and decay hazards. The 'highly durable' exotic species, both softwood and hardwood, are not comparing favourably with those Australian hardwood species of similar reputation. A general discussion section stresses the authors' concern about the need to take notice of the variability of performance of test specimens when producing durability ratings for individual species.

## Zusammenfassung

### Ein Erd-Eingrabe-Versuch zur Prüfung der natürlichen Dauerhaftigkeit australischer Hölzer und ausländischer Vergleichsholzarten

### I. Fortschrittsbericht nach mehr als 10 Jahren

Zwischen Mai 1968 und Juli 1969 wurde ein Erd-Eingrabe-Versuch mit ca. 3700 Kernholzstäben auf 5 Versuchsfeldern in Australien begonnen. Insgesamt 65 einheimische Laubholz- und 6 Nadelholzarten sowie 2 ausländische Laubholz- und 4 Nadelholzarten wurden verwendet. Obwohl alle Versuchsfelder sowohl für Pilz- als auch für Termitenbefall ausgewählt wurden, sind auf einem Versuchsfeld die Stäbe noch nicht von Termiten angegriffen worden. Nach mehr als 10 Jahren (zwischen 10,2 und 11,4 Jahren) sind jene Hölzer, die vorher als „äußerst dauerhaft" eingestuft wurden, noch in gutem Zustand. Einige der Arten, die als „dauerhaft" eingestuft wurden, unterschieden sich von den ersteren kaum. Andere der „dauerhaften" Holzarten sind jedoch nirgends in so gutem Zustand wie erwartet, und eine Reihe dieser Holzarten sind so weit zerstört, daß die durchschnittliche errechnete Lebensdauer einer Probe (‚ASL') sowohl im Hinblick auf kombinierten Termiten- und Pilzbefall als auch auf getrennten Befall inzwischen erreicht wurde. Die „äußerst dauerhaften" ausländischen Holzarten, sowohl Nadelhölzer als auch Laubhölzer, schneiden im Vergleich mit den australischen Laubhölzern mit ähnlicher Einstufung der Beständigkeit schlecht ab. Der Abschnitt „Allgemeine Diskussion" unterstreicht die Wichtigkeit, die die Verfasser der Notwendigkeit zumessen, die unterschiedliche Dauerhaftigkeit der Prüfhölzer bei der Erstellung von Bewertungsklassen für die einzelnen Holzarten zu berücksichtigen.

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## Résumé

### Un essai sur le terrain de la durabilité naturelle dans le sol de bois de construction australien et d'espèces exotiques

### I. Constat après plus de 10 ans d'exposition

Entre mai 1968 et juillet 1969, un essai d'enfouissement dans le sol de quelques 3700 pieux de bois de cœur a été organisé sur cinq sites en Australie. On y a inclus un total de 65 espèces de feuillus indigènes et de 6 conifères indigènes en même temps que 2 feuillus exotiques et 4 conifères exotiques. Bien que tous les sites avaient été choisis pour des conditions d'attaque par la pourriture et les termites, à l'un de ces sites, aucun échantillon n'a été jusque là attaqué par les termites. Après essai de plus de 10 ans (entre 10,2 et 11,4 années), les feuillus préalablement reconnus comme « hautement résistants » se sont bien comportés mais ne peuvent cependant être facilement distingués de certaines espèces préalablement réputées « résistantes ». Toutefois, quelques unes des autres espèces « résistantes » ne se comportent pas aussi bien que prévu et un certain nombre de ces espèces a été déterioré à un degré tel qu'une valeur de vie moyenne d'échantillon (« ASL ») a été calculée d'après l'attaque de pourriture ou des termites ou des deux à la fois. Les espèces exotiques « hautement résistantes », à la fois feuillus et conifères, n'apparaissent pas aussi bonnes que les espèces de feuillus australiennes de réputation semblable. Une section de discussion générale souligne la préoccupation des auteurs en ce qui concerne la nécessité de tenir compte de la variabilité de la performance des échantillons d'essai lorsque l'on établit les degrés de durabilité des espèces individuelles.



## Resumen

### Ensayo de enterramiento destinado a examinar la durabilidad natural de maderas australianas y de especies de referencia extranjeras

### I. Informe sobre el progreso al cabo de más de 10 años

Entre mayo de 1968 y julio de 1969 fue iniciado en Australia un ensayo de enterramiento con unas 3700 estacas de duramen repartidas entre cinco campos experimentales. Fueron sometidas a prueba, en total, 65 especies indígenas de maderas de fronda y 6 de coníferas, así como 2 especies de maderas de fronda y 4 de coníferas procedentes del extranjero. A pesar de que todos los campos experimentales elegidos se hallaban expuestos a infestación, tanto por hongos como por termitas, en uno de ellos las estacas aún no han sido atacadas por las termitas. Al cabo de más de 10 años (entre 10,2 y 11,4 años), aquellas maderas clasificadas previamente de « altamente duraderas » permanecen en buen estado y no permiten todavía una clara separación de ciertas especies clasificadas previamente de « duraderas ». Por lo contrario, otras especies « duraderas » se hallan en peor estado de lo esperado, y cierto número de ellas presenta tal grado de deterioro, que se ha procedido a calcular respecto de las mismas la duración media de la prueba (Average Specimen Life – ASL), tanto en relación a una infestación combinada por termitas y hongos, como por cada uno de los agentes destructores por separado. Las especies extranjeras «altamente duraderas», tanto coníferas como maderas de fronda, dan peor resultado que las maderas de fronda australianas de clasificación similar. En la discusión general se resalta la importancia que atribuyen los autores a la necesidad de tener en cuenta la diferente durabilidad de las pruebas al proceder a la clasificación de especies individuales de madera.

## References

ANON: Field tests of wood preservatives. CSIRO For. Prod. Newsl. No. 355 (1968) 1 - 4.

BECKER, G.: Suggested standard method for field tests with wooden stakes. Pestic. Artic. News Summ. 18 (1972) 137 - 142.

BEESLEY, J.: An Australian test of wood preservatives. Part 1, Preservatives, principles and practices. Material und Organismen 13 (1978) 31 - 50.

BERGMAN, Ö. and HENNINGSSON, B.: (Field tests with different preservatives applied by pressure.) Revised 1976. (Swed.; Engl. summ.) Medd. Svenska Träskyddsinst., Stockholm, No. 134, 1979, 22 pp.

BOYD, J. D.: Efficient engineering with round timbers. J. Inst. Eng., Australia 33 (1961) 27 - 36.

COCKCROFT, R.: A survey of motorway fencing in England. BRE Curr. Pap. CP61/76. Build. Res. Establ. UK, 1976, 7 pp.

COLLEY, R. H., HENRY, W. T., LEACH, C. W. and WEBB, D. A. 1958 Co-operative Creosote Project. – IX: Field tests with stakes and posts, a progress report after sixteen years in test. Proc. Amer. Wood-Pres. Assoc. 72 (1976) 183 - 189.

DA COSTA, E. W. B.: Natural decay resistance of wood. In: LIESE, W. (Editor): Biological transformation of wood by microorganisms. Berlin (Springer-Verl.) 1975, 103 - 117.

— Comparative decay resistance of Australian timbers in accelerated laboratory tests. Austral. For. Res. 9 (1979) 119 - 135.

— and APLIN, T. E. H.: The resistance to decay in laboratory tests of twenty-three durable or moderately durable Australian timbers. CSIRO, Div. For Prod. Proj. P 13 - 5, Progr. Rep. No. 2, 1959, 17 pp.

—, — and TAMBLYN, N.: The comparative resistance to decay of eight Australian timbers under different conditions of testing. CSIRO, Div. For. Prod. Proj. P 13-5, Progr. Rep. No. 1, 1957, 25 pp.

DAS, N. R., CHANDOLA, L. P. and RAMOLA, B. C.: Data on the natural durability of timber species (installed in the test yard at New Forest, Dehra Dun) according to 1964 inspection. J. Timb. Dev. Assoc. India *11* (1965) 6 - 12.

DAVIDSON, H. L.: Comparison of wood preservatives in stake tests (1977 progress report). USDA For. Serv. Res. Note FPL-02, 1977, 81 pp.

FORTIN, Y. and POLIQUIN, J.: Natural durability and preservation of one hundred tropical African woods. Rep. Internat. Dev. Res. Cent. Ottawa, No. IDRC-017e, 1976, 131 pp.

FRIIS-HANSEN, H.: Quantitative assessment of the condition of field specimens. Internat. Res. Group on Wood Pres. IRG Doc. No. IRG/WP/2154, IRG Secretariat, Stockholm, 1981.

GREAVES, H.: The natural durability of various Australian wood pole species to soft-rotting microfungi. Internat. J. Wood Pres. *1* (1979) 15 - 20.

HENNINGSSON, B. and BERGMAN, Ö.: International field test with treated pine stakes. Revised 1976. Swed. Wood Pres. Inst. Rep. No. 133, 1979.

KLOOT, H.: Revised strength grouping system. CSIRO For. Prod. Newsl. No. 324, 1965, 1 - 4.

KRZYZEWSKI, J.: Wood preservative evaluation of stake tests. East For. Prod. Lab., Ottawa, Rep. OPX 171E, 1976, 17 pp.

LIESE, W.: Natural durability of timber. Proc. Internat. Workshop on Wood Pres. Ibadan, Nigeria, 1977, 39 - 40.

— and WILLEITNER, H.: Wood preservation research in the Federal Republic of Germany. Proc. Amer. Wood-Pres. Assoc., 1980, 182 - 190.

PURSLOW, D. F.: Results of field tests on the natural durability of timber (1932 - 1975). BRE Curr. Pap. CP6/76. Build. Res. Establ., UK, 1976, 17 pp.

PURUSHOTHAM, A., DAS, N. R., SINGH, S., SUBRAHMANYAM, I. V., SHIVARAMAKRISHNAN, V. R., PILLAI, S. R. M., BADOLA, K. C. and GAHLOT, H. S.: Natural durability of commercially important timber species and efficacy of preservatives on land (Part I). Ninth Commonw. For. Conf., For. Prod. Spec. Meet. (Wood-Pres.). Insp. Gen. of For., New Delhi, India, 1968.

PURUSHOTHAM, A. and MASCARENHAS, M. J.: Standardization of accelerated durability tests on timber species. Commonw. For. Conf., Ottawa, Canada, 1952.

Standards Association of Australia: Australian standard specification for creosote oil for the preservation of timber. Stand. Assoc. of Aust., Sydney, NSW, AS K55, 1965.

— Nomenclature of Australian timbers. Stand. Assoc. of Aust., Sydney, NSW, AS 02, 1970.

— Nomenclature of commercial timbers imported into Australia. Stand. Assoc. of Aust., Sydney, NSW, AS 1148, 1971.

— Timber poles for overhead lines. Stand. Assoc. of Aust., Sydney, NSW, AS 2209, 1979.

— Preservative-treated sawn timber, veneer and plywood. Stand. Assoc. of Aust., Sydney, NSW, AS 1604, 1980.

ZABEL, R. A. and MOORE, R. A.: Relative effectiveness of several oil-soluble wood preservatives. Condition of dip-treated stake and boardwalk assemblies exposed one year to decay and termite attack. For. Prod. J. 8 (1958) 1 - 7.

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