Forest&Wood Products Australia
Knowledge for a sustainable Australia

MARKET ACCESS & DEVELOPMENT

PROJECT NUMBER: PNA023-0809

AUGUST 2010

Pine timber roof environments in Western Australia and its susceptibility to European House Borer

This report can also be viewed on the FWPA website
www.fwpa.com.au
FWPA Level 4, 10-16 Queen Street,
Melbourne VIC 3000, Australia
T +61 (0)3 9927 3200 F +61 (0)3 9927 3288
E info@fwpa.com.au W www.fwpa.com.au

Pine timber roof environments in Western Australia and its susceptibility to European House Borer

Prepared for

Forest & Wood Products Australia

by

R.J. Cunningham, D. Collins, L. Vagg and M. Grimm

Publication: Pine timber roof environments in Western Australia and its susceptibility to European House Borer

Project No: PNA023-0809
This work is supported by funding provided to FWPA by the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF).

This work is supported by funding provided to FWPA by the Department of Agriculture, Fisheries and Forestry (DAFF).

ISBN: 978-1-921763-06-9

Principal Researcher:
R.J. Cunningham, D. Collins, L. Vagg and M. Grimm
Research and Technical Services, EHB Response, Department of Agriculture and Food WA (DAFWA), 3 Baron-Hay Crt, South Perth, WA 6151

Final report received by FWPA in August, 2010

Forest & Wood Products Australia Limited
Level 4, 10-16 Queen St, Melbourne, Victoria, 3000
T +61 3 9927 3200 F +61 3 9927 3288
E info@fwpa.com.au
W www.fwpa.com.au

Executive Summary

Objectives and Results

The key finding of this project is that that EHB adults can mate, lay eggs, the eggs hatch, and larvae bore into kiln dried structural pinewood. Peak air temperatures of 53ºC were recorded in the "hot" tile roof spaces, and 43ºC in the "cool" metal clad roofs. The maximum temperatures did not prevent egg laying and infestation. Significantly, core temperatures in test pine and pine roof framing did not reach the values required to kill EHB in quarantine treatments or used in Europe to control EHB in buildings by application of heat. The temperatures required for quarantine disinfestations of pine wood specifies it should be heated in accordance with a specific time-temperature schedule that achieves a minimum wood core temperature of 56°C for a minimum of 30 minutes.

The key objective was to test if European House Borer (EHB) beetles (*Hylotrupes bajulus*) can initiate and sustain infestations in untreated pine framing in roof spaces under Perth climatic conditions. The experimental program tested whether or not high temperatures in summer when adult beetles are actively laying eggs can prevent egg laying and successful initiation of infestations. The results show clearly that temperature of itself does not prevent infestation of pine by EHB.

Since EHB was found in Perth in January 2004, only one infestation has been found in a house roof or wall framing. One possible explanation for the low rate of infestation is that EHB may not successfully lay eggs that hatch and survive as larvae in pine timber and emerge as adults that are capable of re-infesting untreated pine wood, because of perceived extremely high temperatures in roof spaces; this projects shows this not to be the case. Another explanation is that the widespread use of pine framing in WA began in the year 2000 and there has not been sufficient elapsed time for EHB infestations to become evident.

Pine timber producers and users ("Industry") and the national Scientific Advisory Panel (SAP) to the containment and eradication program recommended that the effect of summer roof temperatures needed to be investigated experimentally under house roof conditions, giving rise to this project.

Three pairs of test houses were constructed at three locations around the Gnangara pine plantation, on Perth's northern outskirts. Dead wood in the *Pinus pinaster* plantation is infested with EHB and is a risk to expanding housing development around the plantation. Two roof space temperature conditions were set up, one "cool" and the other "hot". The cool roofs were clad with thermally reflective corrugated sheeting ("Colorbond^{TM}") with insulating sarking and the hot roofs were clad with black clay roofing tiles and water vapour barrier sarking.

Test pieces of commercial kiln dried structural pine were held in cages placed in the roof spaces and unmated pairs of EHB adults introduced. The roof spaces were extensively monitored with temperature data loggers to measure temperature profiles in the roof spaces. Duplicate cages were set up in the constant temperature airconditioned rooms below the roofs to act as controls. The hottest roof environment, black tile roof, resulted in fewer eggs being laid and a lower rate of egg hatching, than in the cooler metal roof. This result suggests that EHB may cause more damage in roof spaces with better thermal insulation. Internal stud walls are likely to be at greater risk again, based on EHB egg laying and hatching in the living areas.

Borer activity has continued in the test wood up to the last assessments in June 2010. However, no adult borers have emerged to this time, because the lifecycle of the insect is 3 to 7 years and will not be completed within the timeframe of this project.

Benefit to the Industry

The results of this work show that EHB are capable of infesting pine framing under current Australian construction practices. This information makes it clear that the use of insecticide treated timber to AS 1604 will need to be used in areas where EHB are established.

Currently, EHB have been confined to parts of the Perth Metropolitan and peri-urban areas. However, the shutting down of the eradication and containment program, and with it the regular surveillance of the spread of EHB, means that all of WA will now be deemed at risk of infestation, and the spread to other States over coming decades is likely. Therefore the use of suitable pine timber protection measures will be necessary.

Use of treated timber will have additional benefits in protection against other pests, particularly subterranean termites.

Industry uptake of results

The pine timber production industry, building industry and pest control industry need to take into account the risks to untreated pine in service posed by EHB. They need to make decisions on the need to invest in timber treatment facilities to produce H3 grade structural timber, and if needed, how to treat existing pine framing in structures to protect against EHB attack. The main manufacturer of pine timber in WA (Wespine) has installed equipment to apply envelope treatments of either permethrin or bifenthrin as per AS 1604 to structural timber produced in its mill at Dardanup. Other producers supplying the WA construction market may need to do likewise.

Table of Contents

Introduction

Background

European House Borer (EHB), (*Hylotrupes bajulus*) is an exotic pest that was first found in Perth's eastern suburbs in January 2004. EHB is a pest of seasoned, untreated pine wood and timber and can infest dead parts of pine trees, pine furniture as well as structural pine timber in buildings. EHB larvae can cause serious damage to pine timber and wood, including untreated structural pine timber to the point where it can cause collapse. Structural collapse may take several generations of infestation and could take between 15 and 25 years.

The Government of Western Australia initiated an Emergency Pest Response Plan which focussed on surveillance and containment of the pest, while cost benefit analyses and regulatory impact assessments were being conducted. Response activities from 2004 to 2007 indicated EHB was confined to the greater Perth metropolitan area, mainly in the Mundaring hills to the east, Gnangara and Ellenbrook to the north as well as several smaller outlier sites to the south. Between 2004 and 2007, the Western Australian Government spent $9.7 million on EHB surveillance and containment, as well as treatment of host material. An EHB Emergency Plant Pest Response Plan (EHB EPPRP) was Nationally agreed and funded in 2006 to contain and potentially eradicate EHB.

In 2010 the eradication program was deemed not viable and the project will be wound down over 2010-11.

A key issue identified by the softwood timber industry and by the Scientific Advisory Panel appointed to the eradication program was to experimentally investigate the ability of the strain of EHB in Perth to initiate infestations in structural pine in houses. The FWPA project reported here had its genesis in these recommendations

Pest Details

EHB is found in Europe, the Middle East, North Africa, South Africa, South America, USA, China and Asia Minor. EHB has been detected several times in the eastern part of Australia but the infestations have been successfully eradicated by fumigation of infested buildings or items of infested furnishings.

In Western Australia (WA), EHB is found in the greater Perth metropolitan area, in 2 main clusters in the Mundaring hills and in and around the Gnangara pine plantation, as well as several outliers to the south

EHB is known to attack seasoned softwood of the genera *Pinus*, *Abies*, *Picea* and *Pseudotsuga*, namely pine, spruce and fir. Host material can include dead trees, dead branches on trees, untreated timber used in the building industry, furniture and other (mainly pine) articles. Literature shows that EHB mainly attacks roof timbers, but in WA it has been mainly found in dead pine trees, or dead parts of living pine trees. In 2009 EHB infestations were found in structural framing in two houses, thus following the international experience. The most significant house infestation occurred adjacent to the Gnangara pine plantation and resulted from exposed packs of framing timber being left in the open under a weather cover for two years before being installed.

In Western Australia, the pattern of infestation is most comparable to the experience in South Africa in the period 1879–1940, where large infestations of EHB first developed in pine plantations before infesting structural pine in houses and other buildings in suburbs adjacent to the infested plantations (Durr 1954; Durr 1957). More than 90 per cent of infestations in WA have been found in dead pine trees, logs and branches. Furniture items and stored pine timber have also been found infested with EHB. Commercially produced kiln dried pine can be infested, and is used to rear EHB in laboratory colonies.

The surveillance data suggest that the incursion in WA has been detected before the borer has made the transition from the 'external' dead tree environment to the 'internal' structural timber environment. Untreated pine was not commonly used in the construction of buildings until 2000, when logging of hardwoods declined.

Objectives

The key objective of this project was to test if European House Borer beetles can initiate and sustain infestations in untreated pine framing in roof spaces under Perth climatic conditions. Softwood timber industry members and the national Scientific Advisory Panel (SAP) considered that high temperatures in house roof spaces in summer when adult beetles are actively laying eggs may prevent egg laying and successful initiation of infestations. This line of reasoning was prompted by the observation that infestation rates of EHB in structural pine framing were very low, while significant infestations of EHB were found in dead pine trees. The question then was why were infestation rates in roofs so low?

One possible explanation for the low rate of infestation of structural timber is that EHB cannot successfully lay eggs that hatch and survive as larvae in pine timber and emerge as adults that are capable of re-infesting untreated pine wood, because of high temperatures in roof spaces. Another explanation is that the widespread use of pine framing in WA began in the year 2000 and there has not been sufficient elapsed time for EHB infestations to become evident.

If the research work showed that EHB could initiate infestations in commercial kiln dried timber in Perth buildings, then the pine timber production industry, building industry and pest control industry needed to consider how to deal with the risks to untreated pine in service posed by EHB. This would entail decisions on the need to invest in timber treatment facilities to produce H3 grade structural timber, and if needed, how to treat existing pine framing in structures to protect against EHB attack.

Research plan

Six proxy house roofs were constructed and placed in pairs at three sites adjacent to the Gnangara pine plantation in the northern metropolitan area of Perth. The plantation is being encroached by suburban housing, and contains dead pine wood infested with EHB. Based on international experience, the highest risk of house infestation is adjacent to infested pine plantations.

Two types of roof cladding were fitted to the roofs, to provide “hot” and “cool” thermal fluxes into the roof spaces. The three replicates of “hot” and “cool” roofs were located to the west, south and east of the pine plantation. Roofs were constructed using methods typical for house construction in Perth and WA.

Temperatures in roof voids and timbers in the test roofs were monitored with data loggers.

Test pieces of untreated commercial kiln dried pine were held in cages and exposed to pairs of female and male EHB adults, and monitored for egg laying, hatching and survival of larvae. Control experiments were replicated in the constant temperature airconditioned rooms below the test roofs. The tests were repeated each summer over the course of the project.

Methodology

Overall experimental design and layout

Main effects

The main experimental effect of interest in this experiment is the contrast between “hot” (Bristile^{TM} Marseilles Graphite black clay tile roof) houses and “cool” (Colorbond™ Classic Cream^{TM} corrugated steel roof) houses. A further main effect is the contrast within each of these house types between the naturally variable roof space environment (notably being hotter in the summer) and the cooler “living spaces” (maintained at 24°C), these two environments being nested inside each PR house.

PR house design

The PR houses were designed with input from both the Building Commission of WA (previously Department of Housing and Works) and from the Scientific Advisory Panel (SAP) which oversees scientific aspects of the EHB Response programme. PR house designs were sought that provided the greatest likely thermal environment contrast between roof types and between roof and living spaces, and that would be expected to be found in the current (where pine timber is likely to be used for framing) housing market. One of the consequences of this is the apparent paradox seen with older literature where tin roofs have been regarded as hot roofs, while tile roofs are cooler. The need to have prefabricated transportable structures meant that unlike most houses the PR Houses were elevated off the ground.

Each PR House is essentially a large single room “living area” with a single door, two windows (kept shut for the most part) and two split-system air conditioners. The roof space above each “living area” represents a full normal roof apex but at reduced size. Access to the roof space is via stairs which lead to an elevated working platform and an array of access panels which together allow safe access to a work area on the ceiling where most experiments were conducted. A large area around the work platform was covered with metal mesh to act as a work platform and allow access to more peripheral parts of the roof.

Houses roofs were standard ridge and hip style, with boxed eaves, a roof pitch of 18°and no gutters. The ridges were generally oriented along a east-west axis with the major roof slope areas facing north and south. A southerly aspect being of particular interest as it was likely to experience the least thermal load. Each of the roof types was randomly positioned to the east or west of the other.

Internally the roof structure was standard untreated pine structural framing with full and part queen post roof trusses.

All PR houses had R3.0 insulation batts (Greenstuf® 100% polyester with 185mm nominal thickness) installed atop the ceiling as is typical of most modern houses and also provides the greatest contrast between roof and living spaces. This insulation mean that the cooler roofs are likely hotter than would otherwise be the case in a roof with no insulation.

Study sites

The three pairs of PR houses were all located adjoining the *Gnangara Pine Plantation*, with pairs at:

- Lexia Water Treatment Plant (-31.75646°, 115.94334°),
- Wanneroo Water Treatment Plant (-31.72112°, 115.85415°),
- Gnangara Forest Product Commission site (-31.79357°, 115.88978°)

Figure 1: "PR houses" - EHB proxy roof buildings at the Gnangara site, showing design and construction overview.

These sites form a triangle around the *Gnangara Pine Plantation* with a mean distance of ≈ 8 km between sites. Figure 1 illustrates the design of the buildings.

These three sites were chosen as they fell into areas known to be infested with *H. bajulus* and so were subject to existing regulations and management to contain *H. bajulus* as well as being in areas subject to possible infestation by *H. bajulus*. These sites also had high levels of physical security (barbed-wire fences, alarms and CCTV) in order to ensure the PR houses were not subject to vandalism or other interference.

A wider distribution of replicate sites would have been preferred, especially a site providing data for hills sites (where *H. bajulus* is the greatest problem and also where topography provides the greatest opportunity for temperature contrasts between roofs, regardless of type), but this was not possible.

Environmental monitoring

Internal air temperature and relative humidity

Data loggers ("Tiny Tag"™ Ultra 2) were centrally placed in the cool and hot spaces in all PR houses to monitor air temperature and relative humidity. Each data logger was positioned around the middle of each space suspended by fishing line (see Figure and Figure 7). Temperature and RH were logged every 15 minutes with the data downloaded to a laptop as required.

External air temperatures

Each site had a Radiation Gill Screen (Unidata Pty Ltd) set up housing two thermocouples (YSI44016 thermistor 10K @ 25°C) each logged to a "Smart Reader Plus 8" data logger (128KB capacity) in each house, data being logged at 15 minute intervals. Screens were mounted on a star picket at height of 1.3m, they were sited so as to never be affected by shadows cast from the PR houses and to generally avoid shadows from other structures, though large trees and long shadows means they were not completely shade free.

Long term climate data

The “Patched Point Dataset” (www.longpaddock.qld.gov.au/silo/ppd/index.frames.html) was accessed and climate data for the Wanneroo site (Station ID=9105, Lat.=-31.7333°, Long.=115.7917°), downloaded to provide daily weather data for the general area over the 1889–2010 period.

Proxy beam and related temperatures

Proxy beam design

Proxy beams, similar in dimensions to the split-beams and also similar to proxy beams used in another experiment where roof temperatures are monitored in volunteer houses, were fitted with thermocouples in order to monitor temperatures experienced in PR houses. Each proxy beam was fitted with a core (distance ≈ 30 mm and ≈ 17 mm from each face) and a surface temperature probe both being located medially along the length of the beam.

Proxy beam and other thermocouple locations

Each house had an array of six “Smart Reader Plus 8” data loggers (128KB capacity) logging data at 15 minute intervals from 21 thermocouples as well as recording the air temperature of the datalogger itself. Dataloggers were situated (and so monitored the air temperature) are given in Table 1.

Table 1: Positioning and layout of proxy beams and temperature probes within the PR house structure

Section	Host element	No. proxy beams	details
W roof	ceiling joist	1	N-S orientation
W roof	rafter	1	
W roof	queen post	1	
E roof	ceiling joist	1	N-S orientation
E roof	rafter	1	
E roof	queen post	1	
N roof	ceiling joist	1	E-W orientation
N roof	rafter	1	
S roof	ceiling joist	2	E-W orientation
S roof	rafter	2	
Central roof	ceiling joist	2	proxy element (details below), E-W orientation
Central roof	ridgeline	2	
Living area	ceiling joist	1	proxy element (details below) located in the S section with a N-S orientation
Living area	rafter	1	proxy element (details below) located in the S section with a N-S orientation
Living area	floor joist	1	proxy element (details below) located in the S section with a N-S orientation

As the roof space access doors prevented structural ceiling joists in the central section of the roof a non-fixed proxy joist was installed and proxy beams attached to this.

In order to collect data on temperatures that might be experienced by pine timber in furniture or as exposed beams a proxy ceiling joist was suspended immediately below the ceiling (in the living area) and a proxy rafter was suspended by monofilament fishing line in the living area (lower beam end at ≈ 1.2 m and upper beam end at ≈ 1.6 m, with the thermocouples at ≈ 1.4 m).

The structural floor joists were metal and so a proxy beam was positioned *inside* (outside adding extra complications) the living area as a proxy for floor joists.

Note that as the southern aspects of the houses are expected to be the least affected by heat issues there is a sampling bias towards this part of the PR houses.

Hylotrupes bajulus trials

Cages

“Tunnel” cages (250 mm × 230 mm × 900 mm) were constructed with an aluminium frame and floor, metal insect screen arched walls and roof, and with surgical cloth sealed end-access points, bound with elastic bands to house the split-beams and pairs of adults during testing (see Figure 3, Figure 5, Figure 6 and Figure 77). Two silicone beads were laid across the floor perpendicular to the cage’s long axis to elevate (≈ 2-3 mm) the split-beams off the floor to allow adults access to the underside of the beams both as potential sites from which to oviposit as well as to hide/shelter.

Split beams

Three slightly different designs of split-beam were used, different ones used in each of the three trials.

In the first trial split-beams were constructed from commercial kiln dried structural pine timber purchased from a retail timber merchant (Bunnings) with 70 mm × 35 mm pieces being docked to 800 mm lengths. Each length was then sawn 500 mm along the length, then the remaining 300 mm was split with a tomahawk to create two pieces ≈ 35 mm × 35 mm × 800 mm which were then bound together with black cloth tape at two points, the basal sawn end and just distal to the start of the split. The result was a reconstituted split-beam that pivots around the end of the cut-split section junction to produce a tapering groove along the sawn section and an expanding crack in the split section. Figure 2 shows a split-beam as used in the first trial.

The second trial used split-beams as described above with the following variations:

1. beams were sourced from a softwood timber mill (Wespine)
2. beam dimensions were 86 mm × 35 mm
3. split pieces were bound with yellow cloth tape
4. binding points were ≈ 30 mm distal to the basal sawn end and just distal to the start of the split

The third trial used split-beams as described for the second trial but the split pieces were bound with black cable ties.

All split-beams were labelled so provenance could be matched. Strict selection criteria (requirement for 90% sapwood, no checking, no knots or other wood faults that could provide alternative oviposition sites) and irregular or jagged splitting resulted in a high (> 70%) rejection rate for material drawn from a pack of timber and processed to produce a proxy-beam.

Figure 2: Typical split-beam (trial 1 design) showing tape binding with the left part being the sawn groove and the right part the split section (Photo: RJ Cunningham)

Hylotrupes bajulus

One hundred and eight pairs of adult *H. bajulus* were used in three separate trials. Adults were collected from cages in a colony maintained as part of ongoing EHB programme activities. Pairs were matched for similar post-emergence age, provenance and appropriate size (not too disparate). This is the same practice as used in colony pairings. Matching was less rigorous for the second and third trials as there were fewer adults from which to select well matched pairs.

Adult *H. bajulus* were usually collected from cages within twenty-four hours of emergence from colony timber. Mating can occur soon after emergence and particularly at the height of the emergence season (around the time of trial 1) there may be many potential mating partners. These factors mean that the mating status of adult *H. bajulus* used in the trials cannot be known. Unfortunately adults from colony rearing blocks (where mating status could be certain) were not available for these trials.

Females that were "underweight", for their size, were excluded with those "overweight" being preferred. Heavier females were chosen as they are less likely to have oviposited previously.

Adult, cage and split-beam layout

Six tunnel cages were placed in each PR house, three in the cool living space on the floor surface and three in the hot roof space on the ceiling surface (see Figure 3), giving a total of thirty-six cages. Each cage had one split-beam and a pair of colony *H. bajulus* placed in it. Pairs of adults were case-matched as pairs, one pair of each pair placed in the hot roof and the other in the cool living area. Similarly split-beams from the same source length were paired with parts of each pair placed in the hot roof and the other in the cool living area.

Figure 3: **Roof space with cages and split-beams from trials 1 and 2 visible** (Photo: L Vagg)

Adult survival, oviposition, hatching and long-term survival assessments

Adult survival

In the first trial adult survival was monitored by near daily visits, for a period just over three weeks, to inspect the caged adults to visually determine (general look and shining a torch into and under the split-beam) if the adults were alive and where they were to be found in the cage, the date on which an adult was found to be dead noted as the date of death.

No effort was made to monitor survival in the latter two trials as it required too much time and effort for only secondary data and we were also concerned the regular visits may disturb the adults behaviour.

Assessment of oviposition

After a period of 4-8 weeks the bindings of the split-beams were cut and the pieces taken apart to inspect for egg clutches and/or signs of early larval feeding (see Figure 4, Figure 5 and Figure 6). Any clutches found had the following parameters recorded:

- distance from the basal end of the groove
- likely direction (top, bottom, or end) of oviposition assessed
- state (hatched, feeding, unfertilised) of the clutch assessed
- clutch size (length ≈ width), as a proxy for fecundity (egg counts), was measured using digital callipers

Digital callipers were used to measure the width of the most distal part of the sawn groove for 24 split-beams, these data being used to estimate the groove width at the point of oviposition.

Long term assessment of survival

Assessment of larval development to adulthood has not been conducted and it is likely to be several more years before adult *H. bajulus*, or their exit holes, can be expected to be found.

A number of provisional methods have been used to try to assess ongoing larval survival, *viz*

- paper sheets that may catch any excess frass (not usually produced) were placed around the split-beams and are monitored
- prototype acoustic emission sensors (s13, s14, s15, s17), and a trained human ear, were used to try to detect feeding sounds from two beams, from the Lexia site known to have been infested during trial one. The sensors were placed directly over areas where clear initial feeding has been noted, sensors remained in place for 75 and 40 minutes. AED was attempted during summer 2010 (≈ 12 months after initial infestation) and during the period around noon (to ensure any quiescent morning period was avoided).

Should the infested split beams not be able to be maintained to make a final assessment of adult survival the beams should be sawn and chopped to search for larvae.

Figure 4: Cutting split-beams open for inspection in a roof space. A "Tiny Tag"™ datalogger can also be seen (Photo: L Vagg).

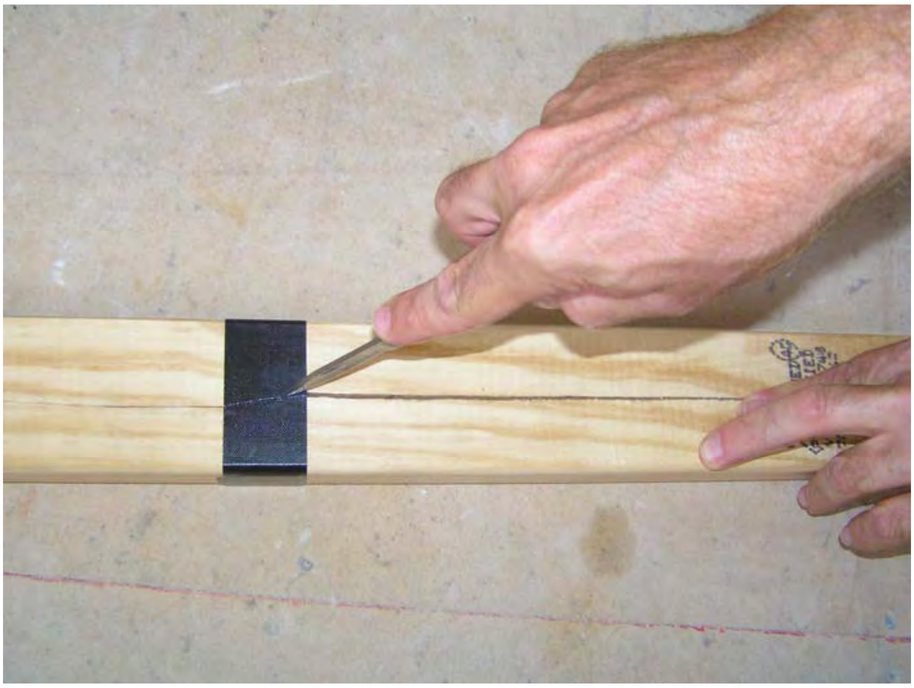

Figure 5: Dissecting a split-beam (Photo: L Vagg)

Figure 6: Opening and examining a split-beam in a living space (Photo: L Vagg)

Figure 7: Measuring clutch size and position in split-beams in a roof space (Photo: P Scanlon)

Year and seasonal differences

Three trials have been conducted, two during the 2008 *H. bajulus* emergence season (September-April) and one during the 2009 emergence season.

The two 2008 emergence season trials were conducted during the later part of the peak *H. bajulus* emergence season (pairs introduced 2009-01-13) and the other late in the emergence season (pairs introduced 2009-02-06).

The 2009 emergence season trial was conducted during the peak *H. bajulus* emergence season (pairs introduced 2010-01-13). The different split-beam designs for each trial means that some care is needed in interpreting any “seasonal”/annual variation.

Data management and analysis

Data loggers

Each of the types of data loggers, Tiny Tag™ “Ultra 2” for air temperatures and RH, and ACR “Smart Reader Plus 8” for thermocouples both require proprietary cables, software drivers and management software (TinyTag Explorer V4.1 and ACR TrendReader Standard V1.31c respectively). Immediately following download all proprietary binary datalogger files were exported to ASCII CSV files.

Data entry and management

Data entry and simple management was largely done with Excel™spreadsheet files. awk and sed were used for more complex batch processing and collation of datalogger files files.

Data analysis

Data analysis was done entirely with *R* (R Development Core Team, 2009). Assorted transformations for counts, heteroscedastic data and the like were applied as necessary. Mosaic plots (with extensions) were used to summarise and examine the significance of deviations from expectations in categorical data (Hartigan and Kleiner, 1984; Friendly, 1994).

Results

Environmental characteristics

PR House air temperatures

As per the original design goals the PR houses present a range of thermal environments consisting of *cool* living spaces under tile and tin roofs and *hot* conditions in roof spaces under both tile and tin roofs. Furthermore tile roof spaces had observed maxima temperatures about 10°C hotter than tin roof spaces, with tile living spaces also being marginally warmer than tin living spaces (Table 2).

In addition to the observed maxima the same gradient of thermal environments (coolest → hottest: living spaces < tin roof spaces < tile roof spaces) is seen when considering maxima temperature exceeding critical thresholds. Only roof spaces experienced maximum temperatures exceeding 45°C while only tile roof spaces experienced temperatures exceeding 50°C (Table 3). Three of the events (=days) exceeding 50°C occurred during a single heatwave period, 17-19 January 2010.

Table 2: Summary of maximum temperatures observed for each location, space and roof type

Location	Space	Roof type	Date/Time	Temperature (°C)
Gnangara	living	tile	2009-12-30 17:03:20	26.37
Gnangara	living	tin	2010-01-19 15:39:09	26.69
Gnangara	roof	tile	2010-01-17 15:42:04	52.15
Gnangara	roof	tin	2010-01-17 15:14:37	42.46
Lexia	living	tile	2009-03-15 12:22:31	28.17
Lexia	living	tin	2009-03-15 12:20:31	28.20
Lexia	roof	tile	2010-01-18 13:59:27	53.05
Lexia	roof	tin	2010-01-18 14:31:53	43.66
Wanneroo	living	tile	2009-11-04 15:03:25	26.61
Wanneroo	living	tin	2009-11-04 15:09:38	25.71
Wanneroo	roof	tile	2010-01-17 15:27:46	53.70
Wanneroo	roof	tin	2010-01-18 13:03:34	42.48

Table 3: Days with maximum temperatures exceeding critical values (40°C, 45°C, 50°C)

Location	Roof type	Space	days > 40°C	days > 45°C	days > 50°C
Gnangara	living	tile	0	0	0
Gnangara	living	tin	0	0	0
Gnangara	roof	tile	105	34	6
Gnangara	roof	tin	8	0	0
Lexia	living	tile	0	0	0
Lexia	living	tin	0	0	0
Lexia	roof	tile	117	40	7
Lexia	roof	tin	10	0	0
Wanneroo	living	tile	0	0	0
Wanneroo	living	tin	0	0	0
Wanneroo	roof	tile	102	34	7
Wanneroo	roof	tin	4	0	0

Examining the the critical periods with temperatures exceeding 50°C in further detail shows a wide range of exposure durations ranging from 15 minutes to four hours (Table 4). This table also shows that these critical temperature events typically occur during late December to mid January, though the Wanneroo site showed one very "late" 75 minute exposure period on 2010-03-01 (Table 4).

Table 4: Exposure duration to temperatures above 50°C (maximum minutes)

Location	Date	Exposure duration (minutes > 50 °C)
Gnangara	2009-01-11	75
Gnangara	2009-12-28	15
Gnangara	2010-01-03	15
Gnangara	2010-01-17	135
Gnangara	2010-01-18	30
Gnangara	2010-01-19	90
Lexia	2009-12-28	45
Lexia	2010-01-03	75
Lexia	2010-01-05	75
Lexia	2010-01-17	180
Lexia	2010-01-18	165
Lexia	2010-01-19	165
Lexia	2010-01-29	30
Wanneroo	2009-02-11	75
Wanneroo	2009-12-28	90
Wanneroo	2010-01-03	90
Wanneroo	2010-01-17	240
Wanneroo	2010-01-18	210
Wanneroo	2010-01-19	120
Wanneroo	2010-03-01	75

Proxy beam temperatures

Proxy beam data show, like ambient air temperatures, that tile roof spaces were hotter than tin roof spaces, experiencing greater numbers of critical events at different temperature levels (Table 5).

Similarly it is clear that beams higher in roof spaces were hotter than those lower in the roof structure, ridge beams in tile roofs being notable in having the only critical events exceeding 55 °C (Table 5).

The heatwave period noted earlier provided an ideal opportunity to examine differences between different beams in different roof types during critical high temperature periods. Figure 8 shows the situation in the southern sections of Wanneroo roofs during the period 2010-01-17 to 2010-01-18. It is notable that *only* rafters and ridge beams in tile exceeded ambient air temperatures, all beams in tin roofs were less that ambient air temperatures and ceiling joists in tile roofs also did not exceed ambient temperatures (Figure 8). Rafters and ridge beams in tile roofs, while hotter that the ambient air temperatures, did follow closely air temperatures experienced under tile roofs, with ridge beams slightly warmer than the air temperature and rafters slightly cooler (Figure 8). Figure 8 also shows a slight buffering effect of the proxy beam wood with core beam temperatures slightly lower than surface temperatures.

Examining detailed data for the four hottest days experienced during the proxy beam monitoring allows us to estimate (for high temperature periods) the temperatures of different roof types, beam types, roof sections and core vs surface proxy beam temperatures relative to ambient temperatures (Figure 9). Again it is clear that high beams in tile roofs, such as ridge beams and rafters, are much warmer (+5 °C) than other beams and tile roofs are generally hotter than ambient air temperatures. Figure 9 also shows clearly that there are beams in different sections of each roof type that are well below ambient temperature, indeed the majority of beams.

Table 5: Events (datalogger-days) with maximum temperatures exceeding critical values (40°C, 45°C, 50°C, 55°C)

Roof type	Section	Beam	core/surface	events > 40°C	events > 45°C	events > 50°C	events > 55°C
Tile	central	ridge	surface	235	132	39	7
Tile	central	ridge	core	195	90	24	2
Tile	west	rafter	surface	159	59	13	0
Tile	east	rafter	surface	154	52	9	0
Tile	south	rafter	surface	149	49	9	0
Tile	west	rafter	core	142	40	7	0
Tile	east	rafter	core	137	37	6	0
Tile	south	rafter	core	135	41	6	0
Tile	west	vertical	surface	131	35	5	0
Tile	north	rafter	surface	118	36	8	0
Tile	west	vertical	core	117	28	3	0
Tile	east	vertical	surface	116	31	4	0
Tile	east	vertical	core	107	27	2	0
Tile	north	rafter	core	106	29	7	0
Tile	central	ceiling	surface	88	18	1	0
Tile	central	ceiling	core	87	19	1	0
Tin	central	ridge	surface	40	6	0	0
Tin	central	ceiling	surface	32	4	0	0
Tin	central	ridge	core	24	0	0	0
Tin	central	ceiling	core	19	0	0	0
Tin	north	rafter	surface	12	0	0	0
Tin	south	rafter	surface	12	0	0	0
Tin	west	rafter	surface	12	0	0	0
Tile	west	ceiling	core	11	0	0	0
Tin	west	rafter	core	11	0	0	0
Tin	west	vertical	surface	10	0	0	0
Tin	east	rafter	surface	9	0	0	0
Tin	east	rafter	core	9	0	0	0
Tin	east	vertical	surface	9	0	0	0
Tin	north	rafter	core	9	0	0	0
Tin	south	rafter	core	9	0	0	0
Tin	west	vertical	core	9	0	0	0
Tin	east	vertical	core	8	0	0	0
Tile	north	ceiling	core	6	0	0	0
Tile	south	ceiling	core	5	0	0	0
Tile	east	ceiling	core	3	0	0	0
Tile	north	ceiling	surface	1	0	0	0

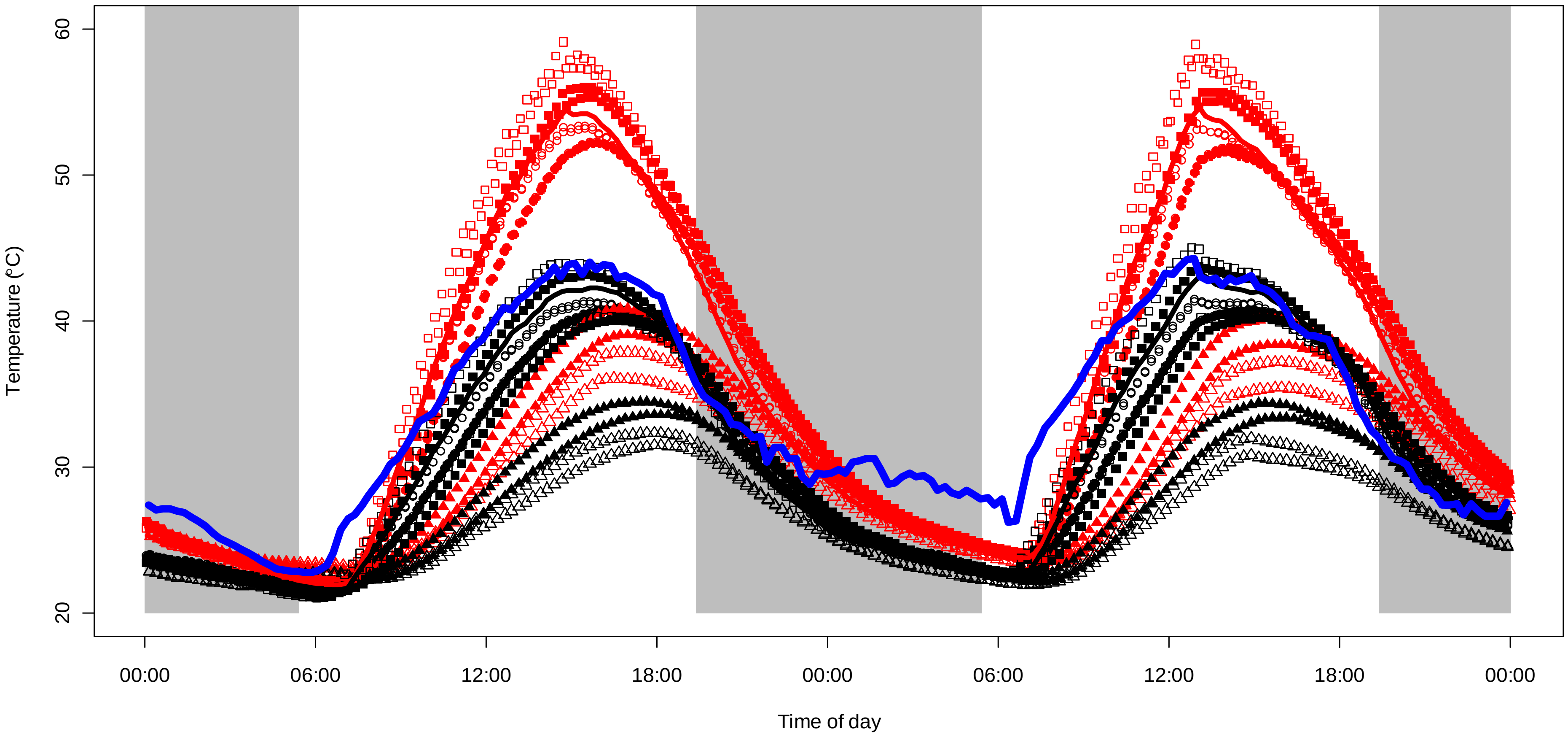

Figure 8: Diel temperature variation over two days of a head wave period (2010-01-17 - 2010-01-18). Legend:- circle: rafter; triangle: ceiling; square: ridge; filled symbols: surface; open symbols: core;red points: tile roofs; black points: tin roofs; red line: air temperature in tile roofs; black line: air temperature in tin roofs;blue line: ambient air temperature

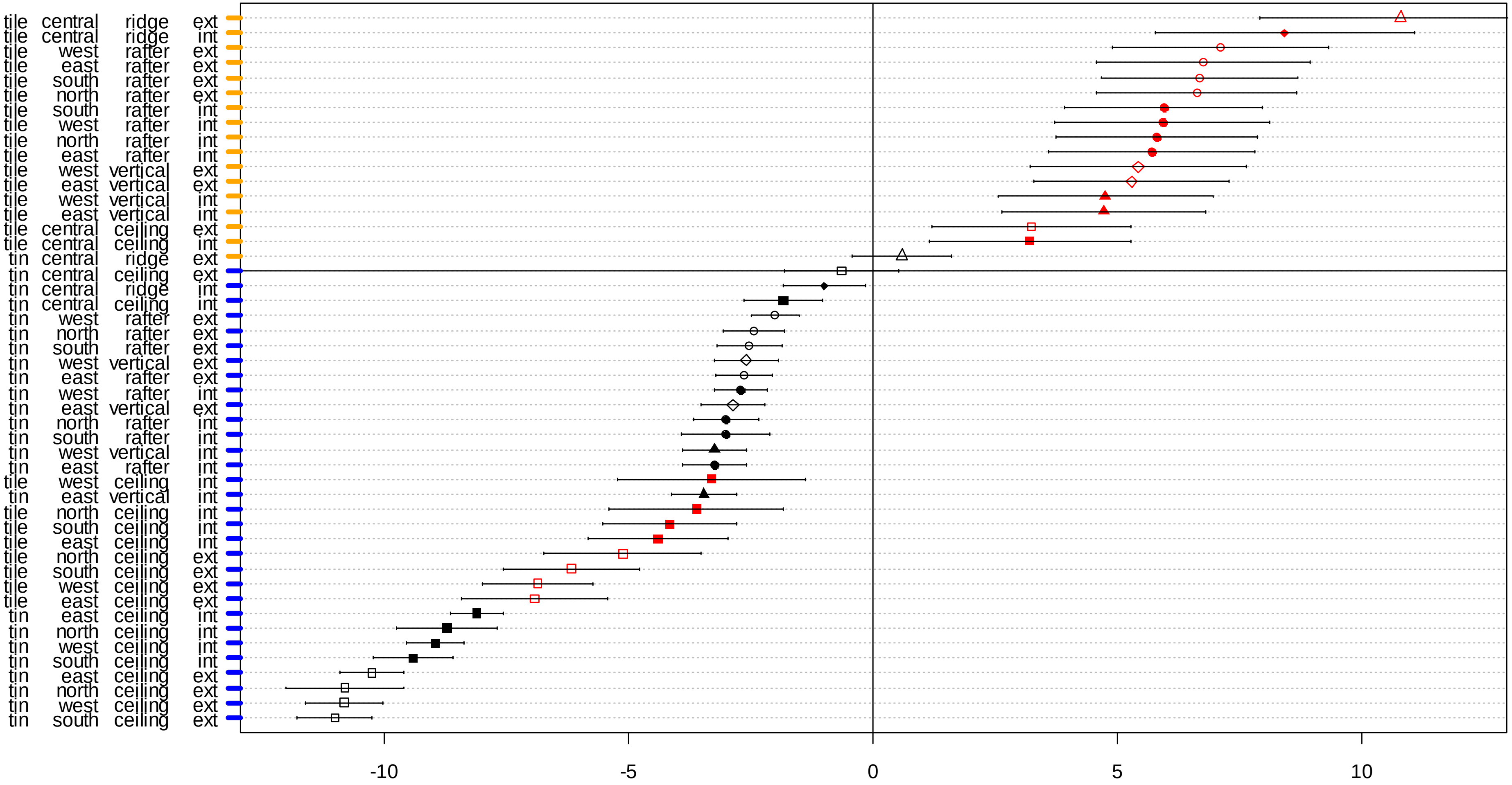

Figure 9: Estimated temperature differential (mean \pm 95% confidence interval relative to ambient air temperatures) for all roof type, section, beam type and surface/core treatement combinations. Legend:- circle: rafter; ridge: diamond; triangle: vertical; square: ceiling; open symbols: surface; closed symbols: core; red: tile roofs; black: tin roofs. Coloured tags on the y-axis highlight beams relatively cooler (blue) and hotter (orange) than ambient air temperatures

Long term climate data

There is a strong relationship between long-term observed maximum temperatures and maximum temperatures seen in PR house roof spaces (Figure 10). Over the range of available data the relationship is well approximated as a linear model (*PRhouse* = (1.24 × long-term observed maximum) + 0.503, $F_{[1,\ 1719]}$= 12974, p < 0.001 and *PRhouse* = (0.914 × long-term observed maximum) + 3.65, $F_{[1,\ 1707]}$= 21795, p < 0.001 for tile and tin roof spaces respectively), though the tile roof space, in particular shows, deviations towards the extremes. Tile and roof spaces had a mean temperature of 6.54°C above observed long-term maxima, while tin roof spaces had a mean temperature 1.49°C above observed long-term maxima.

Figure 10 also shows that the first observed critical event (temperature exceeded 50°C in a roof space) occurs when long-term maxima exceeded 36.5°C, and that the long-term maxima must exceed 42.0°C before *all* observed PR house roof space observation exceed 50°C.

Data for the 122 years since 1889 shows that only 18 years had daily maxima where PR house tile roof spaces would *all* be expected to exceed the 50°C critical value. The highest observed long-term maximum temperature was 46°C, this temperature would result in a predicted tin roof space temperature of ≈ 48°C so *no* tin roof spaces would have been expected to experience critical temperatures (>50°C) over thee last 122 years.

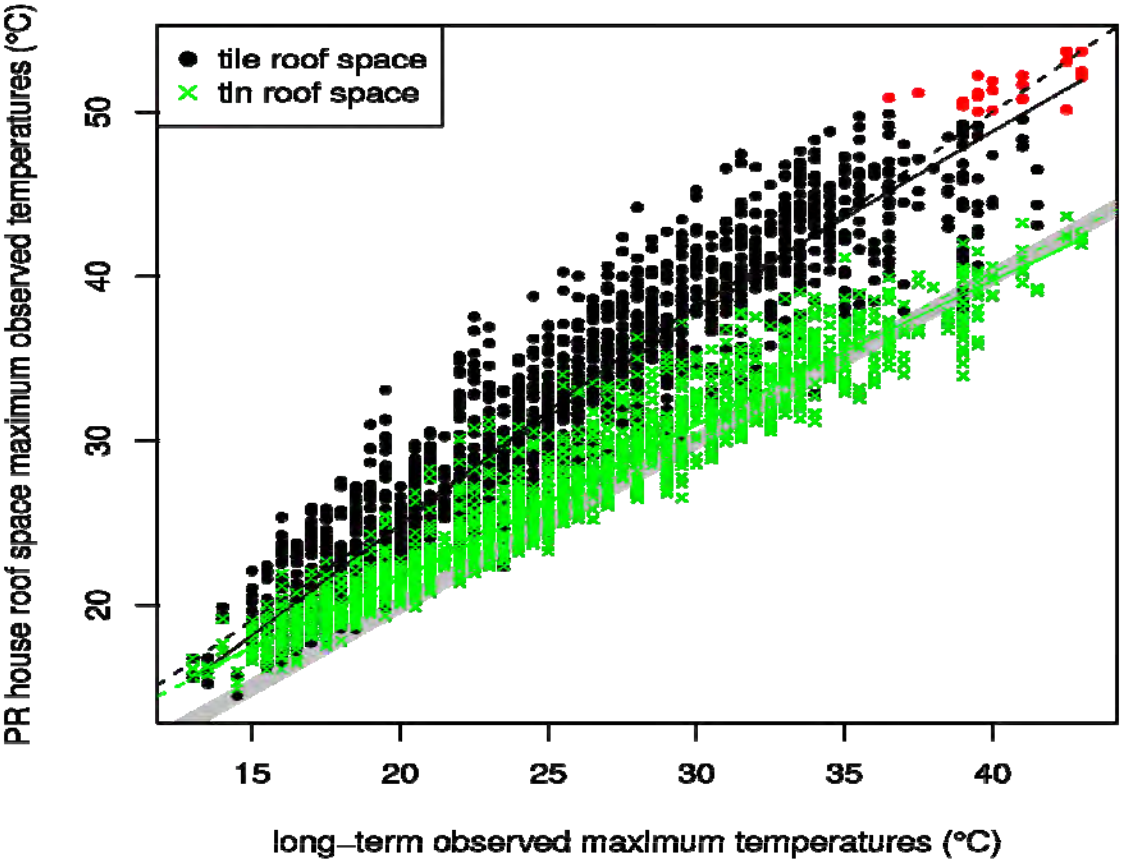

Figure 10: Relationship between long-term observed maxima from the Wanneroo station (No. 9105) and tile and tin roof space data from all PR houses. Red points mark roof space temperatures > 50°C, solid lines represent fitted splines and dashed lines linear fits for each roof type. The grey band shows parity

Hylotrupes bajulus trials

Adult survival

Adult *H. bajulus* lived for a mean time just over two weeks following their introduction to the test cages (2009 trial one data) thus allowing more than enough time for mating and oviposition to take place (often mating and oviposition takes place within hours of pairs being introduced to each other), 17 of the 72 adults survived beyond the 23 days the cages were monitored. Survival rates (proportion surviving the entire caged period) for males were much higher than seen for females (36% vs 11%, OR=4.43, $p < 0.001.0246$, Fisher's exact test). Male *H. bajulus* also survived longer that females (17.2± 2.25 days vs 13.8± 2.07 days, paired-$t_{[27]} = 3.44$, $p = 0.0064$, and Table 6).

Table 6: ANOVA table examining details of adult survival times following introduction to PR houses, contrasting sex, roof type and space

	SS	df	F	***P(>F)***
Sex	3.63	1	7.39	0.0084
Roof type	0.08	1	0.17	0.6858
Space	19.87	1	40.43	0.0000
Sex * Roof type	0.67	1	1.37	0.2459
Sex * Space	0.27	1	0.55	0.4625
Roof type * Space	0.99	1	2.01	0.1610
Sex * Roof type * Space	0.17	1	0.35	0.5582
Residuals	31.46	64		

Survival rates were much lower in roof spaces than in living spaces and no adults survived the entire caged period in the hottest treatment combination of the roof space of the tiled roof (Table 7) though these effects were not significant (OR=∞, $p < 0.001.23$, Fisher's exact test). There was no significant difference in survival times between tile and tin roofs, nor a significant interaction term involving these factors (Table 6). There was, however, a highly significant difference between survival times in different spaces with adults surviving longer in living spaces than roof spaces (19.4± 1.77 days vs 11.6± 1.83 days, Table 6).

Table 7: Numbers of adults that survived the entire twenty-three days of observation in different roof types and spaces (trial 1).

	living	***Roof***
tile	7	0
Tin	7	3

Oviposition behaviour and fecundity

Oviposition behaviour

H. bajulus successfully oviposited in all of the treatment combinations (living/roof space and tile/tin roof). Figure 11 shows a typical clutch as oviposited inside a grooved section crack of a split-beam. All three trials had clutches laid in every treatment combination with the exception of living spaces under tin roofs in trial 2, trial 2 being marked by overall low rates of oviposition (Table 8). Aside from the low rate of oviposition during trail 2 there was no consistent, nor statistically significant, effect seen, and in particular no bias towards particular roof or space types (Figure2).

Figure 11: Hatching clutch. Pictured are eggs ready to hatch, egg casts and unfertilised eggs **(Photo: RJ Cunningham)**

Table 8: Numbers of clutches found in different trials, roof types and spaces

		trial		
roof	space	1	2	3
tile	living	3	4	12
	roof	9	2	6
tin	living	12	0	12
	roof	8	3	5

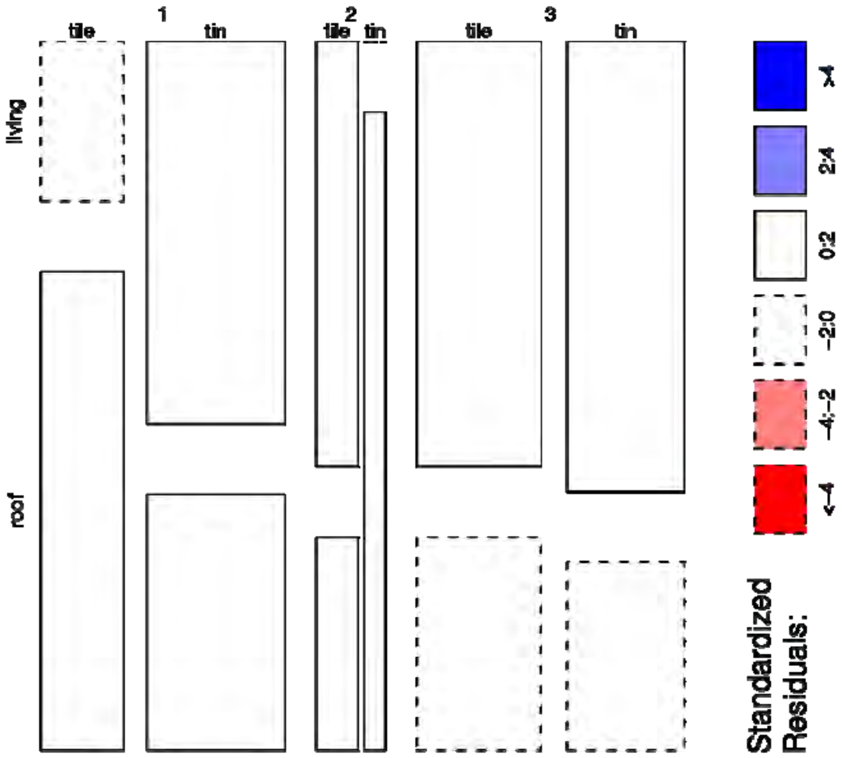

Figure12: Mosaic plot showing clutch numbers contrasting trials, roof types and spaces. Standardised residuals were tested within each trial. Standardised residuals shaded red and in broken boxes represent observations less than expectations while those shaded blue with solid boxes represent observations exceeding expectations. Residuals < 2 represent NS deviation, —2——4— represents $p < 0.05$, > 4 represents $p < 0.0001$

Oviposition site preferences

The oviposition sites of all clutches showed a marked non-random distribution (${}^2_{[\ 9]} = 178$, $p < 0.001$) over the length of the split-beams with a strong aggregation at the basal end of the sawn section (where the sawn groove narrowed near the binding tape or cable tie) and another aggregation in the cracked 300 mm section (Figure 3).

Neither space or roof type showed significant effects on the oviposition site of clutches, though there was a significant difference between trials (Table 9 and Figure2), with trial three clutches being more distal than those of trials 1 and 2.

Table 9: ANOVA table examining clutch position contrasting roof type, space and trial.

	SS	df	F	***P(>F)***
Roof type	25254.33	1	0.38	0.5414
Space	9359.97	1	0.14	0.7079
Trial	308245.32	1	4.60	0.0356
Roof type * Space	55835.57	1	0.83	0.3646
Roof type * Trial	49120.69	1	0.73	0.3949
Space * Trial	101297.10	1	1.51	0.2232
Roof type * Space * Trial	288432.89	1	4.30	0.0418
Residuals	4557302.68	68		

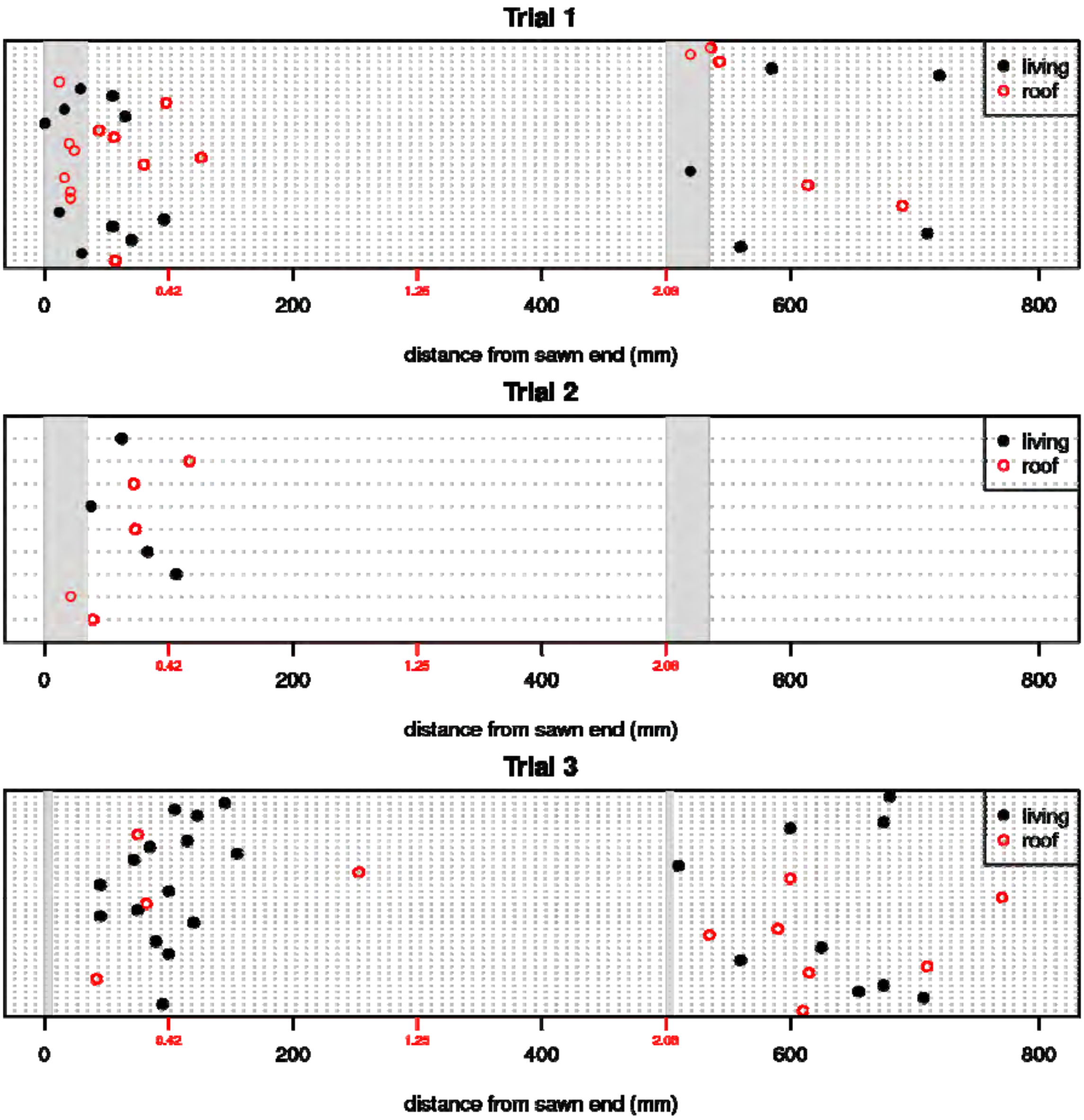

Figure 13: Spatial distribution of clutches in each of the three trials. Grey bands represent the locations of binding tape/cable tie. The minor axis (red text) shows the estimated crack width (no data available for the split section).

Using estimates of the groove width the mean crack width of oviposition sites in the grooved section of the split-beams was 0.29mm (± 0.054 mm), see also Figure 3.

Fecundity

Clutches in the roof spaces were larger (285mm ± 76mm) than those found in the living (243 mm ± 62mm) spaces. Similarly clutches in tile (290mm ± 84mm) roofs were larger than those in tin (236mm ± 54mm) roofs. However, these differences were not statistically significant (Table 10).

Table 10: ANOVA table examining details of clutch size contrasting roof type, space and site

	SS	df	F	*P(>F)*
Roof type	56576.35	1	1.36	0.2483
Space	20542.23	1	0.49	0.4851
Site	145840.29	2	1.75	0.1822
Roof type * Space	20341.02	1	0.49	0.4872
Roof type * Site	7805.67	2	0.09	0.9106
Space * Site	49861.92	2	0.60	0.5526
Roof type * Space * Site	98826.56	2	1.19	0.3122
Residuals	2497540.01	60		

.

Hatching and initial feeding

Clutches successfully hatched and commenced feeding in all treatment combinations (Table 11). Figure shows a recently hatched clutch with frass produced by feeding of early instar larvae entering a split-beam.

Hatching success was generally high and the highest rates were seen in the cooler treatment combinations (living spaces and/or tin roofs). The hottest treatment combination (tile roof space) showed the lowest successful hatching rate (41%) which was significantly lower than expectations (Figure).

Figure 14: Hatched clutch with frass indicating the newly hatched larvae have entered the split-beam and started feeding (Photo: RJ Cunningham)

Table 11: Clutch hatching status in different roof types and spaces (data pooled over all trials). Unhatched clutches either died or were unfertilised eggs

		clutch status	
roof type	space	hatched	unhatched
tile	living	16	3
	roof	7	8
tin	living	16	8
	roof	13	3

Ongoing survival

AED assessment

No *H. bajulus*-like waveforms were detected with the sensors from either of the two infested (had shown signs of initial feeding) split-beams monitored at Lexia. No feeding sounds were heard.

Frass production

Recent excess frass production was observed from 7 split-beams (four from trial 1, three from trial 2) infested during the 2008 emergence season trials (≈ 18 months and two summers post-infestation), see Figure 26. Excess frass production is probably not usual (most frass production will be contained in hidden galleries) so these data are only indicative of what may be happening. Nevertheless, it seems that as at July 2010 *H. bajulus* larvae are alive and actively feeding in both tile and tin PR houses and in the living and roof areas (Table 12).

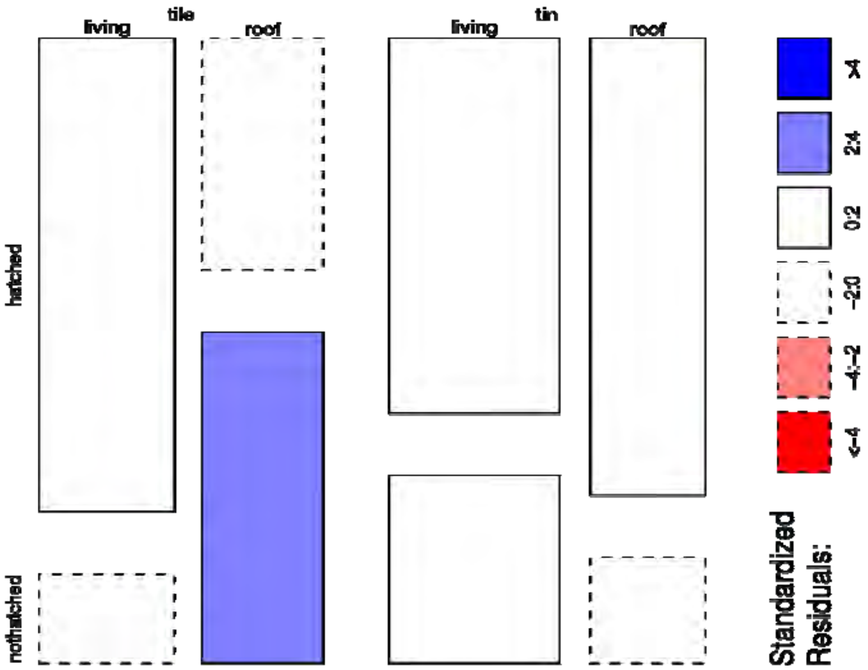

Figure 15: Mosaic plot showing hatching success contrasting roof type and spaces (data pooled over all trials). Unhatched clutches either died or were unfertilised eggs. Standardised residuals shaded red and in broken boxes represent observations less than expectations while blue with solid boxes represent observations exceeding expectations. Residuals < 2 represent NS deviation, —2—-—4— represents p < 0.05, > 4 represents p < 0.0001

Table 12: Numbers of split-beams (pooled from trials 1 and 2) found producing excess frass 18 months after initial infestation in the different roof types and different living spaces

	tile roof	tin
living space	2	2
roof space	2	1

Figure 2: An excess frass pile found under a split-beam 18 months after initial infestation. This frass pile was produced by ≈ 3 months feeding (April–July 2010). (Photo: RJ Cunningham)

Interesting observations

Wild H. bajulus attraction and access

During the trial one 15 dead adult *H. bajulus* were found on the floor of the living space at the Gnangara and Lexia sites with finds in both tin and tile PR houses.

Initially we suspected these were adults that had escaped from our trial cages, however all trial adults were accounted for and so these adults proved to be "wild" *H. bajulus* that had been attracted to, gained access to and had died in the houses. Following the initial serendipitous find we conducted a thorough search (LV and RJC on hands and knees) of living and roof spaces in all houses with no additional *H. bajulus* being found.

Observed matings

While we cannot be sure of the mating status of trial females we observed several matings within cages (roof and living spaces) thus showing mating can take place under these conditions, though we cannot know the success of these particular matings.

Female oviposition observations

Females were observed ovipositing on sites other than the split-beams, they were observed to oviposit on the metal cage surface and, more frequently, on the cloth ends of cages.

Discussion

Roof temperature environment

The objective of constructing 3 replicates of proxy roofs to provide a test environment for the mating, oviposition and infestation of pine wood was to have two treatments providing significantly hotter and cooler roof space environments, and a constant temperature control environment common to all sites. The data show that this objective was achieved. The black tile with water vapour barrier sarking was consistently approximately 10ºC hotter than the thermally reflective colorbond roof with R10 building blanket. Peak temperatures of 53ºC were recorded in the hot tile roof spaces, and 43ºC in the cool metal clad roofs. Both claddings were constructed following current building practice in Perth, and are believed to represent each end of a range of temperature conditions likely to be experienced in roof spaces currently being built in Perth.

Temperature profiles in the roof spaces compared to ambient temperature show that the reflective Colorbond metal roof with R1.5 building blanket insulation maintained temperature profiles that closely followed ambient temperature. The greatest difference was at night, when the metal roof space cooled to approximate the temperature in the airconditioned living space. By contrast, the tile roofspace temperature exceeded ambient temperatures by approximately 10ºC during the day before falling to temperatures approximating those in the airconditioned living space.

Significantly, core temperatures in test pine and pine roof framing did not reach the values required to kill EHB in quarantine treatments or used in Europe to control EHB in buildings by application of heat. The temperatures required for quarantine disinfestations of pine wood specifies it should be heated in accordance with a specific time-temperature schedule that achieves a minimum wood core temperature of 56°C for a minimum of 30 minutes (ISPM No. 15 (2002)).

The data show that the hottest point in the roof spaces were in the peak of the roof in the gable ridge beam, with the black tile roof hotter than the colorbond roof. Moreover, temperatures were coolest at ceiling level in ceiling joists. Rafters, especially on southern faces, were intermediate in temperature.

On the assumption that EHB would avoid the extremes of heat, infestations are more likely to be found in cooler timbers, at ceiling level and the lower ends of rafters and posts. It was not possible to test this hypothesis, as it would have required release of EHB into the roof space and monitor the locations most frequently chosen for oviposition.

The data obtained in the project differ from results published for South Africa (Durr 1954; Durr 1957), where tile roofs were found to be cooler than those clad with galvanized corrugated iron sheeting. The difference is most likely due to differences in the thermal properties of modern metal roofs in Australia compared to galvanized iron used in South Africa in the 1940 – 50’s. Colorbond sheeting is made of rolled steel sheeting with a passivating coating of zinc-aluminium, which is further protected with a paint coat (BlueScope Steel 2003). The paint colour used in this project (Colorbond™ Classic Cream$^{\text{TM}}$) has the highest thermal reflectance (solar absorbance <0.35) of the range of colours produced by the manufacturer (BlueScope Steel 2007). Sheeting coated in this way has a lesser radiation of heat into the interior of structures than those clad with galvanized iron. Darker Colorbond™ colours have higher solar absorbance values >0.75, and are likely to have higher roof space temperatures than those found in this experiment. In addition, the metal roofs used in this project have a building blanket with an insulation rating or R1.5 underlying the steel cladding. The building blanket comprises a layer of reflective aluminium foil bonded to fibreglass wool insulation (Permastop™ 436).

The black tile roofs used in this project have a high solar absorbance, being matt black, and have a high thermal mass, being a kiln fired clay tile. The sarking commonly used is an aluminium foil laminate (Sisalation™ 450) vapour barrier that reflects heat but with no insulation incorporated. The tile roofs in South Africa described by Durr (1957) note that they are cooler than steel clad roofs because ventilation through the tile overlaps allows heat build up in the roofs to escape.

A third difference between modern house roof construction in Australia compared to that reported from South Africa, is that eaves are lined and sealed, whereas in South Africa they were open where rafters overhang walls.

When the roofs for this project were being designed, little data could be found on roof temperature profiles in roof spaces with different claddings. A number of respondants to our enquiries regarding such data expressed a keen desire to see the results of the temperature monitoring, as the data may well have wider interest in thermal design of houses.

Mating and infestation of pinewood by EHB

The key finding of this project is that that EHB adults can mate, lay eggs, the eggs hatch, and larvae bore into the pinewood. Peak temperatures of 53ºC were recorded in the hot tile roof spaces, and 43ºC in the cool metal clad roofs. The maximum temperatures did not prevent egg laying and infestation. Significantly, core temperatures in test pine and pine roof framing did not reach the values required to kill EHB in quarantine treatments or used in Europe to control EHB in buildings by application of heat. The temperatures required for quarantine disinfestations of pine wood specifies it should be heated in accordance with a specific time-temperature schedule that achieves a minimum wood core temperature of 56°C for a minimum of 30 minutes.

The ranking of temperature environments found in this study, from hottest to coolest, was tile>steel>living area, and this gradient was reflected in the survival of EHB adults, oviposition and egg hatching. The results show clearly that temperature of itself does not prevent infestation of pine by EHB. The hottest roof environment, black tile roof, resulted in fewer eggs being laid and a lower rate of egg hatching, than in the cooler metal roof. This result suggests that EHB may cause more damage in roof spaces with better thermal insulation. Internal stud walls are likely to be at greater risk again, based on higher rates of EHB egg laying and hatching in the living areas.

Since EHB was found in Perth in January 2004, only one infestation has been found in a house roof or wall framing. This project has shown that temperature is not of itself a limitation to EHB infestation of pine wood in roof spaces. Another explanation is that the widespread use of pine framing in WA began in the year 2000 and there has not been sufficient elapsed time for EHB infestations to become evident. Under ideal conditions, EHB can complete a lifecycle in 3 years. However, factors such as the nutrient quality of kiln dried commercial pine, low summer moisture levels, and high summer temperatures in roofs, may collectively reduce development and survival rates of EHB to 5-7 years. If this is correct, then the earliest pine used in standard roof construction was about the year 2000 will not have shown emergence of adults until 2005-7. The damage caused in the first generation is likely to be insufficient to cause structural collapse. Damage from a second generation in the same wood will not be evident until about 2010-2014 at the earliest.

The methods of modern roof construction also mitigate against easy entry by adult EHB. The use of sarking and building blankets, and the closing of eaves and gutter lines, make ingress by adult beetles potentially more difficult than for the roof construction methods in use in South Africa last century.

While not a formal part of the experiments, the observation of “wild” EHB being attracted to the test roof buildings indicates that in the flight season, EHB can be attracted to buildings containing pine framing. The beetles found in the test houses are most likely to have come from the adjacent pine plantation, where high populations of EHB exist in dead wood not removed during plantation hygiene work. This re-enforces the observations overseas that the greatest risk to buildings is from populations in pine plantations and the dead pine wood in urban amenity pine trees.

Borer activity has continued in the test wood up to the last assessments in June 2010. However, no adult borers have emerged to this time, because the lifecycle of the insect is 3 to 7 years and will not be completed within the timeframe of this project. Following the fate of the infested timber in this project to measure the numbers of larvae that survive to adults is the best measure of the biological success of EHB in causing damage in roof temperature. It is unlikely that such an assessment will occur, since the project funding has ceased and the EHB program in WA is being wound down to a closing in 2011.

Conclusions

European House Borer (EHB) (*Hylotrupes bajulus)* adults are able to mate, lay eggs which can hatch, and the resultant larvae can bore into pine wood to initiate and infestation in kiln dried commercial structural pine timber in house roofs in summer conditions in Perth, Western Australia.

The larvae can continue to feed for at least two years. However it is not possible to show conclusively that larval development can continue to full development, pupation and emergence of adult beetles. The 3-year term of the research project is shorter than the life cycle of the insect, so observations were terminated before observations on the full lifecycle could be completed.

The results have shown that initiation of infestation is possible in roof spaces with summer temperature maxima peaking at 53ºC. This temperature is less than the internationally accepted heat treatment temperature of 55ºC for a minimum of 30 minutes core temperature required for quarantine disinfestation of EHB in pinewood.

Choice of roofing materials and construction methods have a marked influence on temperature profiles and EHB egg and larval survival. The peak temperatures were recorded in roofs clad with matt black clay tiles fitted in accordance with current building practice in Perth. Cooler peak temperatures, on average 42ºC, were observed in high heat reflectance steel roofs fitted with additional under-sheet insulation. This is also a standard roof construction method in Perth. EHB oviposition and egg hatching was higher at the lower roof space temperatures.

The highest egg lay, hatching and larval survival occurred in constant temperature conditions of 26ºC maintained by airconditioning the living space of rooms under both roof types. This is standard practice in current house construction in Perth. Internal pine stud walls are thus deemed to be at greatest risk of EHB survival and development. In Perth, most houses are build of brick, with the minority having internal stud walls. However in the non-metropolitan regional areas, brick veneer construction with internal framed stud walls is much more common. Likewise, in other States, the majority of construction is with internal stud walls.

The general observations during the containment and eradication program in WA are that as yet no extensive infestation of pine in houses has occurred. Most beetle populations occur in dead pine trees in the open environment, and the transition to the built environment is likely to be in the early stages. It is clear that temperature in roof spaces is of itself not likely to be limitation to infestation by EHB.

Recommendations

The pine timber production industry, building industry and pest control industry need to take into account the risks to untreated pine in service posed by EHB. They need to make decisions on the need to invest in timber treatment facilities to produce H3 grade structural timber, and if needed, how to treat existing pine framing in structures to protect against EHB attack. The main manufacturer of pine timber in WA (Wespine) has installed equipment to apply envelope treatments of either permethrin or bifenthrin as per AS 1604 to structural timber produced in its mill at Dardanup. Other producers supplying the WA construction market may need to do likewise.

Currently, EHB have been confined to parts of the Perth Metropolitan and peri-urban areas. However, the shutting down of the eradication and containment program, and with it the regular surveillance of the spread of EHB, means that all of WA will now be deemed at risk of infestation, and the spread to other States over coming decades is likely. Therefore the use of suitable pine timber protection measures will be necessary. Use of treated timber will have additional benefits in protection against other pests, particularly subterranean termites.

The results of this project should be communicated to the manufacturers of structural and other pinewood, to alert them to the risks posed by EHB to their products. They should consider the production of treated pine products compliant with the H3 standard in AS1604, for all pine timber sold into the WA market.

The risk of EHB spreading other States should also be factored in, now that the EHB containment and eradication program has been closed down and there is a higher risk of EHB spreading to other regions in WA and to other States.

The building and construction industry should be alerted as to potential risks posed by EHB. This is especially so for regions of Australia were ambient summer temperatures are lower than those in Perth and where peak roof space temperatures are likely to be lower than those used in this project. Additionally, building practices aimed at better thermal efficiency of house construction are likely to increase the ability of EHB to initiate infestations and survive in larger populations.

The pest control industry should be alerted so they can factor in expertise in recognising EHB damage when carrying out building inspections for insect attack.

References

BlueScope Steel (2003). General Guide to good practice in the use of steel roofing and walling products. Technical Bulletin TB-13. www.bluescopesteel.com.au

BlueScope Steel (2007). Classification of Colorbond steel colours for BCA and NSW BASIX. www.bluescopesteel.com.au

Durr, H.J.R., 1954. Die Europese huisboorder, *Hylotrupes bajulus* (L) (Coleoptera: Cerambycidae), en sy beheer in die Westelike Kaapprovinsie. *Bulletin* 337 (*Entomology series* 40) 78pp. Department of Agriculture, Union of South Africa. ***632.951***

Durr, H.J.R., 1957. The Morphology and Bionomics of the European Houseborer, *Hylotrupes bajulus* (Coleoptera; Cerambycidae). *Entomology memoirs* Vol. **4** (1): 136pp. Department of Agriculture, Union of South Africa.

Friendly, M. (1994). Mosaic displays for multi-way contingency tables. *Journal of the American Statistical Association,* **89**: 190–200.

Hartigan, J. and Kleiner, B. (1984). A mosaic of television ratings. The American Statistician, **38**: 32–35.

ISPM No. 15 (2002) International Standards For Phytosanitary Measures *Guidelines for Regulating wood packaging material in international trade* (2002) with modifications to Annex I (2006) Produced by the Secretariat of the International Plant Protection Convention Rome

R Development Core Team (2009). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org.

Acknowledgements

Funding

Thanks to Forest and Wood Products Australia (FWPA) for their funding of this research.

Contributors

In addition to the project team we thank the following for their contributions to this research:

1. Tristan Bruyn (EHB Response)
2. Jim Creffield (CSIRO Materials Science and Engineering)
3. Colleen Hendriksen (DAFWA)
4. Wayne Morris (DAFWA)
5. Fred Ramsden (DAFWA)
6. Pia Scanlon (DAFWA)
7. John van Schagen (DAFWA)
8. Adam Osseiran (Edith Cowan University—Joondalup)
9. Ivo Jacquemai (Edith Cowan University—Joondalup)
10. Water Corporation (WA) | two sets of PR houses are hosted on Water Corporation sites
11. Wespine Pty Ltd | donation of a pack (72) of 4.8m lengths of pine

Members of the Scientific Advisory Panel also acted as the steering committee for this project. Members made valuable contributions to the design and regular review to the project.

Rodney Turner, Chairman, (Plant Health Australia)
Robert Eldridge, (Dept Primary Industries NSW)
James Creffield*, (Private Consultant, Previously with CSIRO Wood Products Division)
Brenton Peters, (DPI Queensland)
Ross Wylie, (Private Consultant, Previously DPI Queensland)
John Bain, (MAF New Zealand)
Greg Mills (Allpest, Western Australia)

*Jim Creffield provided key technical assistance based on many years experience with EHB and testing of timber susceptibility to pests

Researcher’s Disclaimer (if required)

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products. All product names and trademarks cited are the property of their respective owners. The findings of this report are not to be construed as an official Department of the Agriculture and Food position unless so designated by other authorised documents.

Appendix

(Label each appendix in numeric sequence e.g. Appendix1, Appendix 2 etc)