



## Host selection behaviour of deathwatch beetle, *Xestobium rufovillosum*: Oviposition preference choice assays testing old vs new oak timber, *Quercus* sp.

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### Abstract

In a choice bio-assay adult female deathwatch beetles were offered two dendrochronologically dated wood blocks from oak timber to study oviposition preference behaviour. There was a clear preference for ovipositing on old wood dating from the 13th to 19th centuries rather than new wood from the 20th century. Control, same-century choice, experiments showed that beetles will oviposit on young wood and that the age of the wood does not alter the overall oviposition potential. Oviposition frequency varied with insect age. Fecundity of insects collected from an infested building was similar to that of insects maintained in culture.

### Introduction

The deathwatch beetle, *Xestobium rufovillosum* de Geer (Coleoptera: Anobiidae), is well known for its tapping noise that is now reliably known to be a mating call (Birch & Keenlyside, 1991; White et al., 1993; Goulson et al., 1994). Its pest status is well documented (Fisher, 1937; Hickin, 1963; Cymorek, 1984) with the first description of the beetle in 1668 (Wilkins, 1668; Allen, 1698). The use of insecticides to control deathwatch beetle has proven ineffective (Bravery, 1977; BRE, 1987) and alternative methods of control are lacking (Hickin, 1960). The deathwatch beetle can cause extensive timber damage in old buildings (Baines, 1914; Hickin, 1974; Maxwell-Lefroy, 1924; Coleman, 1975). Despite this damage, knowledge about the insect's habitat, life cycle, physiology and behaviour remains mainly anecdotal (Kimmins, 1933; Fisher, 1935, 1937).

It has been previously argued that the deathwatch beetle prefers old oak wood, *Quercus* sp. for oviposition (Fisher, 1941). However, it was not known

whether beetles could discriminate among wood of different ages. The aims of the present study were to compare the oviposition potential of deathwatch beetles from a standardised laboratory culture with that of a field-collected population and to determine if the deathwatch beetle female demonstrates host selection oviposition preference with regard to the age of its preferred host.

### Materials and methods

Two populations of female adult deathwatch beetles were used in this study. One population was collected daily on emergence from a laboratory-maintained culture (21 °C, 75% r.h.) during March 1996. The other population was collected weekly from Bishopstone Church, Wiltshire, UK at the beginning of the emergence season which in 1996 occurred in April. Until now, the lengthy larval development time (1 to 12 years) and the short adult emergence season (1 to 2 months per year) has discouraged culturing the beetle

in the laboratory for use in standardised experimentation (Fisher, 1935, 1937). The laboratory colony of beetles was maintained on fungal decayed blocks of oak by adapting a method used by Cymorek (1975) to rear *Anobium punctatum*. The females used in experiments had been previously exposed to males for five days to allow mating to occur, but had not yet oviposited. Insects were sexed by gently squeezing the abdomen to expose their genitalia (Harris, 1959; Goulson et al., 1993).

Oak heartwood, (*Quercus petraea*, *Quercus robur*) of known dendrochronological age that represents timber felled in every century, from the present back to and including the 13th century, was cut into blocks 2.5 cm<sup>3</sup> (Table 1). Dendrochronologically dated wood was provided by Dan Miles, UK. Choice assay experiments tested new (20th century) oak against old (13th to 19th century) oak and the data were analysed using the Wilcoxon matched-pairs signed-ranks test. Wood blocks were standardised for the absence of physical traits such as cracks or insect damage and blocks representing a century were cut from timber from the same source. Two blocks were placed in a clear polystyrene arena 22 cm × 12 cm × 8 cm (Stewart Plastics Ltd.), into which one mated female was placed. The blocks were placed with either their longitudinal or transverse face upwards and the orientation of the blocks within a replicate was the same. The experimental arenas were kept in a dark quiet room at ambient temperature (21±1 °C and 35±5% r.h.). The number of egg clusters and the number of eggs per cluster found on each wood block were counted daily until the adult female died. Participation in the experiment was determined by the oviposition of at least one egg. Control experiments involved testing two wood blocks from the same century, for example, 20th vs 20th century. In order to analyse the data from these control 'choice' experiments, the blocks within a replicate were assigned as either control 1 or control 2 and the difference in the number of eggs laid on each control block was recorded.

## Results

A preliminary experiment showed that there was no difference in the number of eggs laid by the laboratory cultured insects and the number laid by beetles obtained from Bishopstone Church (Mann–Whitney U-test,  $U < 1.4$ ,  $n = 30$ ,  $P > 0.05$ ). Insects from both

the culture and Bishopstone Church were therefore used in the oviposition experiment.

Under the experimental conditions, oviposition commenced 5 days after adult emergence and ceased after 22 days (Figure 1). The mean number of eggs oviposited by a female was 40.6±2.22 (mean±sem,  $n = 140$ ). Fifty percent of the total number of eggs laid had been oviposited by day 13, at which time insects were halfway through the oviposition period.

Females laid their eggs in clusters, ovipositing 2.3±0.11 clusters during the adult life span (mean±sem,  $n = 140$ ). The mean number of egg clusters laid per female and the number of eggs in each cluster varied with insect age (Figure 2). The mean number of egg clusters laid increased from day 5 to day 10 and then decreased from day 16 to day 22. As the number of egg clusters oviposited increased, the number of eggs per cluster also increased. The mean number of eggs in a cluster was 16.4±1.30 (±sem) and the mean number of egg clusters laid per female per day was 0.14±0.021 (±sem). The age of the females had a significant influence on the day-to-day variations in the number of egg clusters laid per female and number of eggs per cluster (non-linear regression, clusters/insect  $F = 22.04$ ,  $P < 0.001$ ,  $r^2 = 0.8151$ ; eggs/cluster  $F = 15.02$ ,  $P < 0.001$ ,  $r^2 = 0.7503$ ; Figure 2).

In the choice experiments the mean number of eggs laid per wood block was always significantly higher on the old wood than on the new wood block (Wilcoxon matched-pairs signed-ranks test  $Z > 2.8$ ,  $n = 10$ ,  $P < 0.001$ ; Figure 3). The daily records of the position of oviposited egg clusters on the wood blocks showed that eggs were always preferentially laid on the old wood before the new wood.

The results from the control 'choice' bio-assays show that females laid the same number of eggs on both wood blocks (Wilcoxon matched-pairs signed-ranks test,  $Z < 0.77$ ,  $n = 10$ ,  $P > 0.05$ ). The total number of eggs laid by females exposed to the control same-century 'choice' replicates (mean±sem number of eggs was 39.1±3.17,  $n = 50$ ) did not differ significantly from that of females in the old vs new choice replicates (mean±sem number of eggs was 41.6±3.82,  $n = 90$ ) (Mann–Whitney U-test,  $U < 1.5$ ,  $P > 0.05$ ).

Table 1. Description of oak wood, *Quercus spp.*, samples used in host selection experiments testing old (13th–19th century) timber against new (20th century) timber

Building and location in UK	Location of timber in building	Date tree cut down
The Cottage, Aston Tirrold, Oxon	wallplate	1284
Manor Cottage, Sutton, Courtenay, Oxon	wallplate	1317
All Saints, Lydiard Millicent, Wilts	collar	1341
Trees Cottage, Froxfield, Hants	rafter	1350
Abbey Farmhouse, Great Missenden, Bucks	inner wall plate	1406
The Queen's Head, Crowmarsh Gifford, Oxon	wallplate	1400
17–19 The Street, Crowmarsh Gifford, Oxon	floor joist	1435
Wolverton Manor, Salop	tie beam	1570
Real Tennis Court, Oriel College, Oxford	top plate	1637
Park Farm Barn, Mapledurham, Oxon	purlin	1722
Low Barn, New Farm, Mapledurham, Oxon	main post	1739
Cutt Mill, Watlington, Oxon	beam	1820
All Saint's, Lydiard Millicent, Wilts	collar	1860
Unused and untreated timber	from timber merchant	1976
Unused and untreated timber	from timber merchant	1986
Unused and untreated timber	from timber merchant	1995

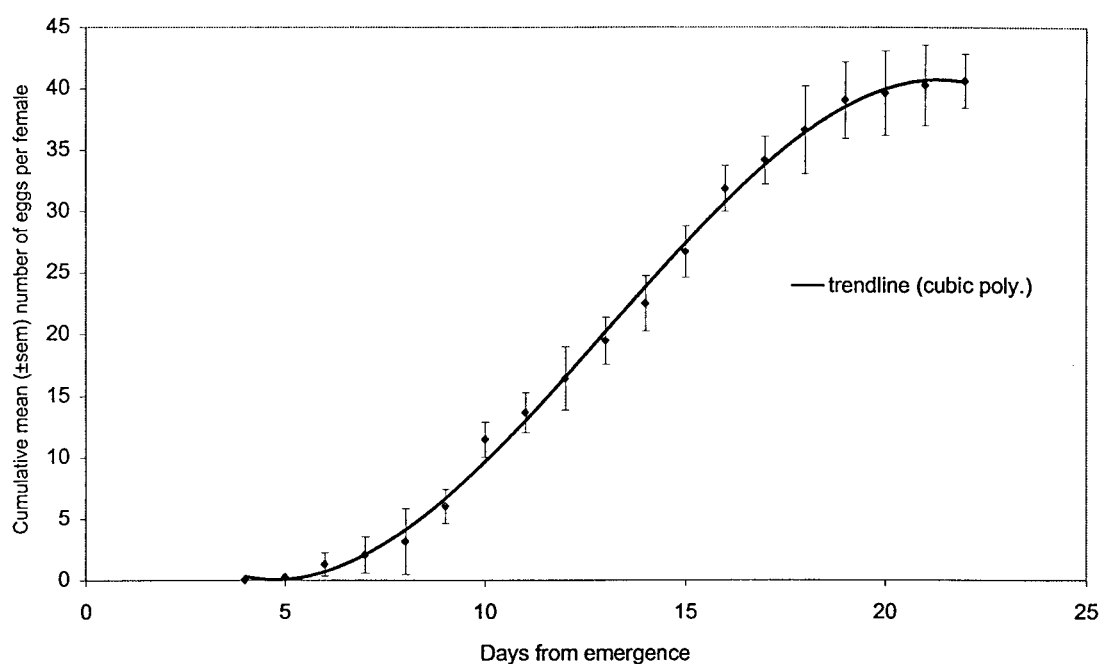


Figure 1. Oviposition activity during the lifetime of female deathwatch beetles (mean  $\pm$  sem,  $n = 140$ ). Trendline was fitted by applying a cubic polynomial equation to the data.

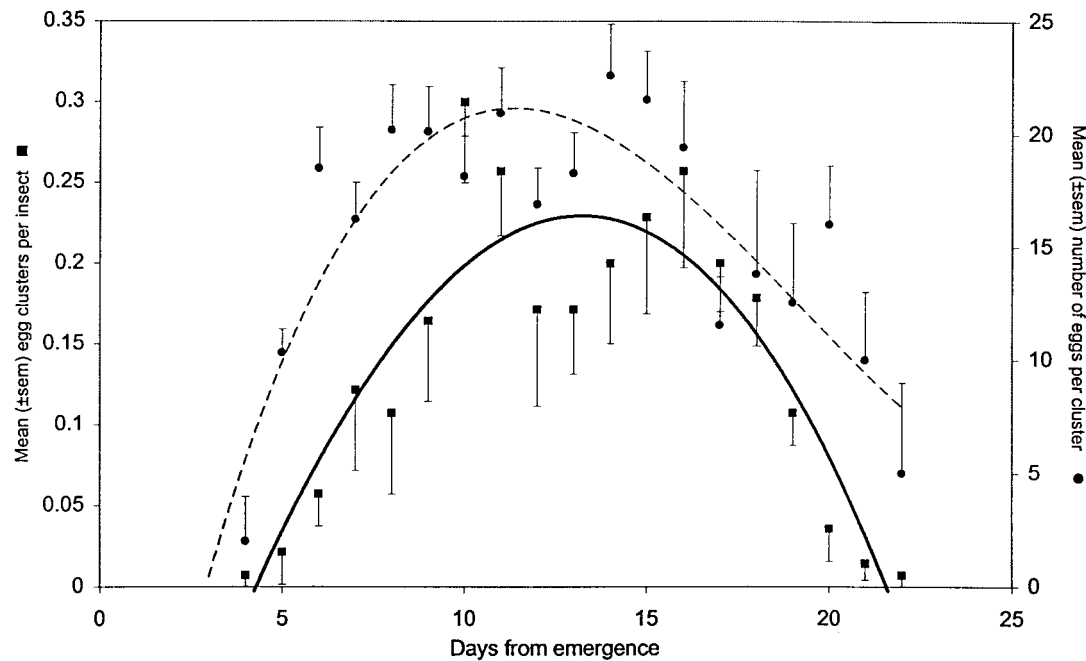


Figure 2. Effects of insect age on the number of egg clusters (mean±sem) and the number of eggs in each cluster (mean±sem). ■ mean egg clusters per insect ( $n = 140$ ), ● mean number of eggs per cluster. — clusters per insect (cubic poly),  $r^2 = 0.82$ , ..... eggs per cluster (cubic poly),  $r^2 = 0.75$ .

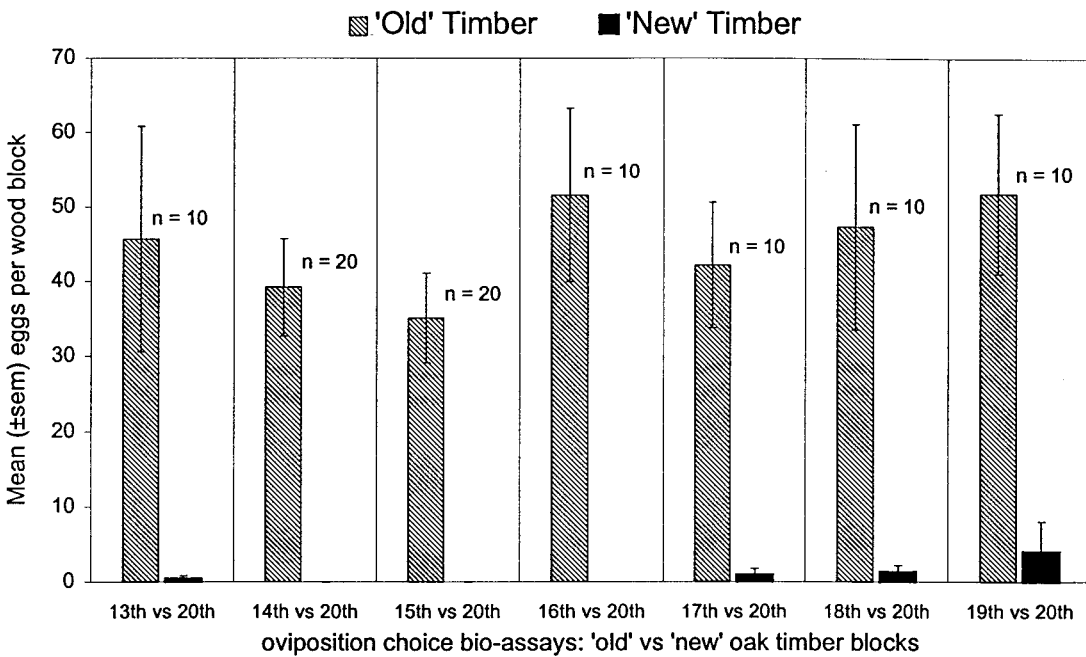


Figure 3. Distribution of eggs laid by deathwatch beetle females when presented with a choice between old and new blocks ( $2.5\text{ cm}^3$ ) of oak wood.

## Discussion

These experiments show that female deathwatch beetles exhibit oviposition host selection behaviour, and lay more eggs on old wood rather than new wood when given a choice between old and new blocks of wood. Although beetles will oviposit on new wood, when presented with two blocks of new wood, if given a choice they will oviposit on old blocks before ovipositing on new blocks. Whether this host selection behaviour is related to chemical or physical characters in the wood is not known. The results suggest that beetles are attracted to old wood rather than being repelled from new wood.

The total number of eggs laid by females was not influenced by the age of the wood in the choice experiments. Therefore, the age of the wood did not alter the overall oviposition potential. Research on the deathwatch beetle's nearest relative, *Anobium punctatum*, would suggest that the nutritional quality of wood eaten during larval development plays a primary role in insect fecundity (Bletchly, 1966). The nutritional quality of the wood the deathwatch beetle adults emerged from was unknown and most likely differed between the church and laboratory populations. However, the fact that the number of eggs laid by the laboratory-reared insects did not differ from that of beetles obtained from a wild population, suggests that under the experimental conditions used in the choice experiments, fecundity was not greatly influenced by larval diet. However, further experiments would need to be undertaken with wood of known nutritional quality to determine the role wood quality has on the fecundity of deathwatch beetles. The data also shows that although the numbers of batches of eggs and numbers of eggs per batch did vary with insect age the preference behaviour of the adults did not vary. Thus if further preference experiments were carried out it might be possible to decrease the duration of the bio-assay from 22 days, which represented the life-span of the adult, to only 2–4 days; especially if experiments were undertaken with beetles aged between 7–15 days, their peak oviposition period.

The natural deathwatch beetle habitat is hypothesised to be limited to dead or dying trees, mainly of oak and willow, but infestation can be found in a range of hardwood species (Fisher, 1937, 1940). In order to optimise survival within a restricted habitat, it would be helpful for the deathwatch beetle to be able to distinguish between healthy and dying trees. Practical experience in historical building conserva-

tion programmes suggests that in a building comprised of timbers which vary in age, the deathwatch beetle is more likely to attack mediaeval oak than more modern oak (B.V. Ridout, personal communication) and that the beetle is often, but not exclusively, found in fungally attacked timber (Altson, 1922). Previous research in artificial situations, suggests that increasing fungal decay of wood decreases the development time of deathwatch beetle larvae (Fisher, 1940, 1941; Campbell, 1941). Thus levels of deathwatch beetle damage in buildings might be greater in areas containing fungal infected timber.

The precise histories of the old wood used in the current study are not known. Although all the old wood samples used in this study appear free of fungal attack, it may be that the wood had been exposed to fungi centuries ago. For example, 18th century samples may indeed be more decayed than 13th century samples. However, the 20th century samples used in the experiments had not been exposed to fungal infection. If all the old wood used in the choice experiments had been attacked by fungi then the results might reflect the ability of the insects to select between fungal decayed and undecayed wood rather than between old and new wood.

The factors responsible for the observed host selection behaviour of beetles are unknown. Previous experiments have shown that the extent of decay in any given timber does cause differences in the chemical (Medda & Nandi, 1991; Ejechi et al., 1996) and physical (Singh et al., 1992; Winandy & Morrell, 1993) condition of the wood (Faix et al., 1991; Mulder et al., 1991; Tsujiyama et al., 1993; Homolka et al., 1994; Yamamoto & Hong, 1994; Adaskaveg et al., 1995). Current research has shown that oak experienced relatively little mass loss when exposed to oak rot fungi, but there were differences in the chemical profile between decayed and undecayed wood and negligible differences in the chemical profiles among decayed wood samples (P. Esser, personal communication).

Chemical analyses are currently being undertaken on the wood blocks used in the choice experiments to see if there are differences in their chemical profiles. If there are differences it is planned to use choice experiments to determine whether any specific compounds in the wood attract or deter beetles. Such information could help establish the role of chemicals in the observed host selection behaviour and may lead to the development of baited traps for monitoring or control of deathwatch beetles in historical buildings.

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