Not just waste wood: decaying logs as key habitats in Tasmania's wet sclerophyll *Eucalyptus obliqua* production forests: the ecology of large and small logs compared

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Abstract

Large diameter decaying logs are a characteristic feature of unmanaged wet sclerophyll forests in Tasmania. In production coupes, however, rotation lengths of around 80 years will eventually lead to their elimination. This paper describes an on-going study into whether small diameter logs derived from small trees left at the end of the rotation are likely to follow the same successional pathways as large diameter logs, thus supporting the same range of decay types and fungal and invertebrate biodiversity. The study's findings may indicate whether some concerns over the use of dead wood as industrial fuelwood are justified. It may also indicate whether there is a need to cater specifically for the maintenance of large diameter trees and logs in managed coupes, or whether smaller ones will suffice.

Introduction: coarse woody debris as a key resource in managed forests

The importance of coarse woody debris (CWD) in Australian forests has gone largely unrecognised apart from a few recent studies (Meggs 1996; Grove and Stork 1999; Lindenmayer *et al.* 1999; Grove 2002). This dearth of research interest in CWD may be attributed to the cryptic nature of the organisms that inhabit it, the short-term nature of most research funding relative to the decay process, and a general attitude that wood left on the forest floor is 'waste'. Yet decaying logs on the forest floor are an extremely valuable biological resource. They support a rich diversity of invertebrates and fungi, as has been documented repeatedly in the scientific literature (Elton 1966; Harmon *et al.* 1986; Franklin *et al.* 1987; Speight 1989; Andersson and Hytteborn 1991; Parson *et al.* 1991; Esseen *et al.* 1992; Kirby and Drake 1993; Kaila *et al.*1994; Jonsson and Kruys 2001). Coarse woody debris provides habitat for saproxylic (dead-wood dependent) insects (Key 1993) and for wood decay fungi (basidiomycetes), which are the primary decomposers of dead wood and hence contribute to nutrient cycling (Edmonds and Eglitis 1989; Speight 1989; Edmonds and Marra 1999).

In many Northern Hemisphere forests, the dynamics of CWD recruitment have been

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grossly altered across the landscape due to centuries of timber harvesting and the removal of firewood (Gore and Patterson 1986; Edmonds and Marra 1999). This has contributed to the decline and in some cases extinction of a range of insect and fungal species reliant on CWD (Kirby and Drake 1993; Väisänen *et al.* 1993; Økland *et al.* 1996; Hågvar and Økland 1997; Kaila *et al.* 1997; Martikainen *et al.* 1999; Sippola 1999; Eriksson 2000; Köhler 2000). In these regions, a disproportionately large percentage of CWD dependent species are either red-listed or considered rare and threatened (Kirby and Drake 1993; Ranius and Jansson 2000; Ehnström 2001). Coarse woody debris is now the subject of extensive conservation research, with many recent studies confirming the particular value of larger diameter logs for biodiversity conservation (Wood 1978; Araya 1993; Edmonds and Marra 1999; Kruys and Jonsson 1999; Kolström and Lumatjärvi 2000; Ranius and Jansson 2000). Forest management agencies in Europe and North America increasingly recognise the need for modification of forest practices (Kaila *et al.* 1997; Bragg and Kershner 1999; Hagan and Grove 1999; Grove 2001; Ehnström 2001; Schiegg 2001). These include the development and implementation of action plans for red-listed species (Jonsell 1999; Key *et al.* 2000; Sverdrup-Thygeson 2001), and active management to maintain or restore CWD levels, particularly for larger diameter material (Harding and Alexander 1994).

Production forestry in Tasmania has a relatively short history (*c.* 150 yrs), meaning that its long-term impacts may not yet be apparent. However, it is clear that successive logging of native wet sclerophyll regrowth forests on planned rotations will alter CWD quality and quantity (Meggs 1996). Inevitably only smaller diameter (< 60 cm) CWD will be left on the forest floor, with no larger diameter (> 100 cm) CWD being produced within the forest coupe. If there are suites of species in these forests that are dependent on larger diameter CWD, then the risk that they may be extinguished from harvested areas within production forests is only too apparent.

The ecology of log decay

The decomposition of CWD is an extremely complex process, varying amongst different tree species (Schwarze *et al.* 2000) and according to prevailing environmental conditions. As CWD decomposes, it passes through various stages, from solid wood to material devoid of any structure. The metabolic and physical actions of the wood decay fungi chemically and structurally change the wood, resulting in a characteristic rot type. For example, brown rotted wood arises when so-called brown-rot fungi selectively remove cellulose and hemicellulose from the wood, leaving a residue of slightly modified lignin. By contrast, white-rot fungi utilise all components of the wood cells, removing lignin, cellulose and hemicellulose and leaving the wood bleached, with a spongy, stringy or laminated structure (Kaarik 1974; Gilbertson 1984; Schwarze *et al.* 2000).

Rot types can be difficult to define, as they can vary in colour and texture depending on the decompositional stage. Different types are often defined by visual and other subjective characteristics. A log is generally invaded by a succession of fungi, attacking it at different positions dependent upon environmental conditions. Therefore, across time and space, a log can exhibit many rot types; for example, a single cross-section can have a particular heartwood rot, sapwood rot and rot pockets. To add to the complexity, several fungi may bring about similar types of rot, and each fungus is not confined to one type of rot (Parkin 1942), thus posing many challenges in studying rotted wood.

In old living trees, a suite of fungi may be present and may initiate decay of the heartwood before the tree dies. However, such fungi may not be present in a younger, smaller diameter tree, such that when a young tree dies it may follow a different decompositional pathway. This potential difference between large and small logs may well influence faunal diversity, as saproxylic insects have specific microhabitat requirements. For example, some lucanid and prostomid beetles are only found in red-brown rotted wood in advanced stages of decay (Araya 1993; Lawrence and Britton 1994). By contrast, some tipulid flies live only in wood invaded by white rot fungi and with a very high moisture content, and some elaterid beetles prey on these tipulids (Dajoz 2000). Therefore, understanding the relationships between rot types and the associated fauna is a prerequisite for developing meaningful indicators with which to monitor and manage CWD dependent communities in production forests.

Project objectives

The three-year project described here was set up by the University of Tasmania, Forestry Tasmania and Gunns Limited, and is based at the Cooperative Research Centre for Sustainable Production Forestry in Hobart.

The four objectives of the project are, in regard to *Eucalyptus obliqua* CWD in Tasmania's wet sclerophyll forests:

1. To better understand the ecology of decomposing CWD, in terms of the associated wood decay fungi and saproxylic insects.
2. To investigate differences in fungal and insect biodiversity between small and large diameter logs. Small logs range from 30–60 cm diameter, representative of a tree felled at 60–80 years age, and large logs have a diameter greater than 100 cm, representative of a 150-year-old tree.
3. To provide a checklist of the fungal and insect species dependent on *E. obliqua* CWD in wet sclerophyll forests.
4. To look for direct associations between decayed wood, wood decay fungi and saproxylic insects.

The research is being conducted in wet sclerophyll *Eucalyptus obliqua* forest, in Tasmania's Southern Forests about 60 km south-west of Hobart (Figure 1). Of the ten sites selected, six are in the Warra Valley (a focus for long-term ecological research, as described elsewhere in this issue), and four in the West Picton Valley. Half the sites are in regrowth and half in mature-age oldgrowth forests. Regrowth sites were 20–40-year-old forests regenerated following clearfelling in the 1960s–1970s. All sites have soils derived from Jurassic dolerite, and all have a similar slope/aspect, with elevation ranging between 100 m and 150 m above sea level.

In this study, investigations have been restricted to *E. obliqua* logs of an intermediate decay stage. The visual characteristics of this stage are the lack of bark, coupled with the presence of decayed sapwood, heartwood showing distinct rot type patterns and colour, and some solid wood. At this stage, log shape is retained. This stage was chosen because:

1. Insects occurring in this intermediate decompositional stage have been shown to be the most vulnerable to logging effects (Heliövaara and Väisänen 1984).
2. It is at this intermediate decompositional stage that the actions of wood decay fungi are most prominent, exhibiting a characteristic rot type.
3. This choice thereby complements the on-going Warra LTER log decay study, which is looking at *E. obliqua* logs in an early decay stage (Bashford *et al.* 2001).

The insect component of the research has also been confined to the beetles (Coleoptera). Amongst the complex assemblage of saproxylic insects present in any forest, beetles are numerically a very important group, exceeding all other insect groups in terms of numbers of families, species and individuals. Functionally, they are also very important, with members in a range of feeding guilds, including wood feeders (xylophages), fungus feeders (mycophages), detritivores and predators (Gilbertson 1984; Dajoz 2000; Speight 1989). Many beetle species share an intimate relationship with wood decay fungi

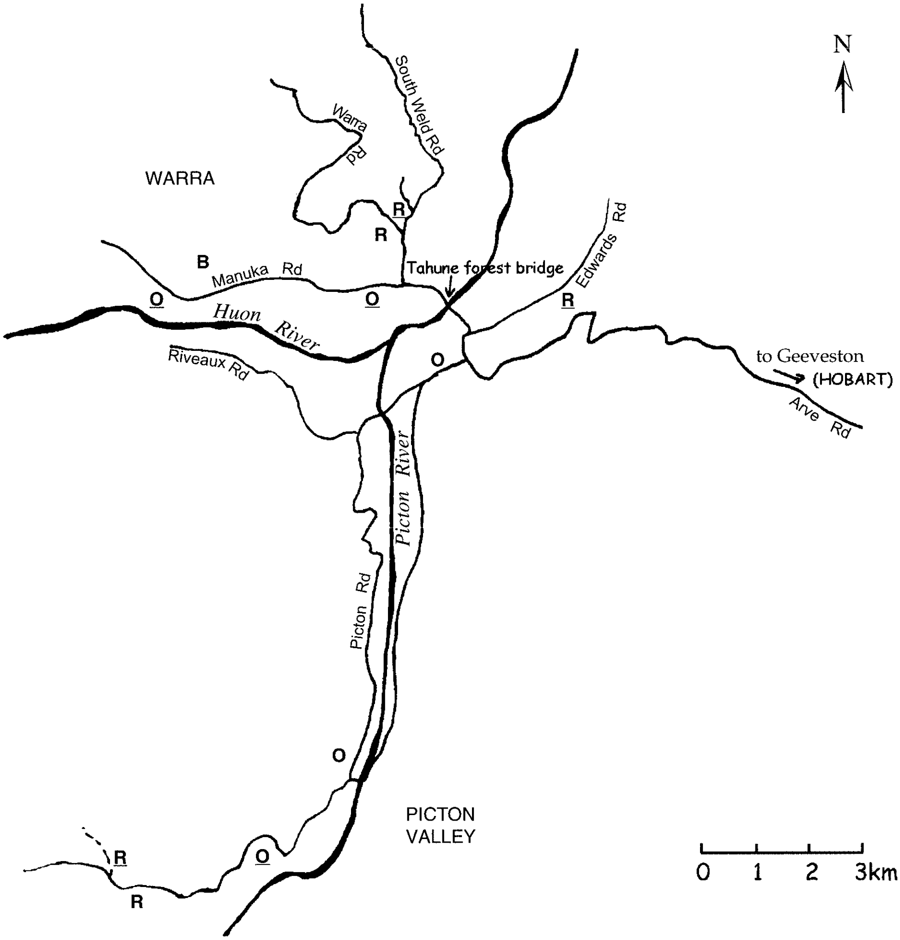

Figure 1. Location of study sites in Tasmania's Southern Forests. R = regrowth; 0 = oldgrowth forest. B = location of the Warra LTER log decay study. Destructive sampling was conducted at sites that are underlined.

and dead wood (Gilbertson 1984; Haack and Slansky 1987; Lawrence 1989; Dajoz 2000), for instance, carrying spores on their body surface or dispersing spores via their frass (Paine *et al.* 1997; Garcia and Morrell 1999). In addition, beetles have a relatively well-understood ecology at the family level and are relatively easy to identify, especially to morphospecies (Oliver and Beattie 1996). They are also robust for transport and handling. For all these reasons, they have been the subject of more comprehensive research elsewhere than have other groups, thus allowing this study to be more readily comparable.

Research objective 1.—*Developing a better understanding of the ecology of decomposing CWD*

This research objective is being conducted in six of the ten study sites (3R and 3O: Figure 1). At each site, three large and three small *E. obliqua* logs have been destructively sampled, totalling 18 in each size class. Each log was sawn into three (1 m length) sections at the apical, middle and basal positions. A 5 cm cross-sectioned disc was taken from each end of the 1 m long section, giving six discs per log. Each disc was photographed and coded, and the rotted wood described. To

Table 1. The rot type classification for Eucalyptus *spp. fallen logs used in the present study, compared with earlier classifications based on logs and mature trees. Rot types in the same row are thought to be the same rot type. Where available, information on the location of the rot type is indicated as (H) – attacking heartwood, and (SF) – attacking surface/sapwood.*

Rot type	This study (2001) *E. obliqua*	Meggs (1996) various *Eucalytus* spp. including *E. obliqua*	Mesibov (1988) *E. obliqua*	Parkin (1942) *E. regnans*	Refshuage (1938) *E. regnans*
1	Red-brown wet blocky muddy rot (H)	Red blocky rot	Blocky rot	Brown cubical rot	Brown cubical rot (H)
		Red blocky rot with seams of white fungal hyphae			
		Orange/red clayey rot	Mudgut rot		
2	Brown dry crumbly chalky rot (H)	Orange/red/brown crumbly rot	Friable/crumbly rot		
		Yellow crumbly rot			
3	Yellow stringy surface rot (SF)	Soft yellow fibrous rot	Spongy/fibrous rot	Yellowish stringy rot	
4	White stringy/spongy rot (H)	Spongy white rot			White spongy rot
					Large white pocket rot of white stringy type
5	Brown stringy rot (SF & H)	Orange/red/brown fibrous rot		Yellow brown spongy rot (H)	Brown stringy rot (H)
6	White jelly rot (SF)	Other (includes blue stain fungi and wet, jelly-like rot)	Skeletal rot		Large white pocket rot (H)
7	White/brown pocket rot (SF)			White pocket rot	Small white pocket rot (H)
					Small brown pocket rot (H)
8	Other – discoloured/stained wood (H)				Brown stain associated with small white pocket rot (H)

Table 2. The 15 beetle species most commonly found in seventy-two 1 m log sections. Species marked with an asterisk are those particularly associated with the red-brown blocky muddy rot type (Type 1).

Species	Family	Feeding Guild
*Prostomis atkinsoni**	Prostomidae	xylophagous
Parablax spp.*	Elateridae	predatory
Pycnomerus sp. 1*	Zopheridae	xylophagous
Dryopthorus sp 1.*	Curculionidae	xylophagous
Coripera deplanata	Tenebrionidae	xylophagous
*Cossonus simsoni**	Curculionidae	xylophagous
Lissotes cancroides	Lucanidae	xylophagous
Aleocharinae (STAPH 35)	Staphylinidae	predatory
Toxeutes arcuatus	Cerambycidae	xylophagous
SCIRT6*	Scirtidae	detritivorous
*Philothermus tasmanicus**	Cerylonidae	mycophagous
Chrysophtharta bimaculata	Chrysomelidae	other
Cryptorhynchinae (CUR3)	Curculionidae	xylophagous
TEN9*	Tenebrionidae	xylophagous
Syndesus cornutus	Lucanidae	xylophagous

isolate the wood decay fungi (Basidiomycete), samples of the rotted wood were taken to the laboratory, excised, and incubated on selective media. The three 1 m sections were intensively examined for beetles, noting where and in which rot type any beetles occurred.

A classification scheme for rot types has been devised, based on general appearance, colour, texture and position. As mentioned above, the classification of rot types can be extremely subjective, partly because there are so many variables involved. The scheme developed for this study aims to build on past studies in this field while reducing the ambiguity and confusion that has arisen from such studies (Table 1).

So far in this study, eight rot types have been found, and approximately 700 basidiomycete isolates have been obtained from material grown on selective media. At this stage, isolates have been identified to morphospecies based on colony morphology and biochemical tests. Molecular techniques will be used to assist in identifying isolates to species level. This will involve comparing the rotted wood isolates with isolates derived from identified basidiocarps collected from the field, and from reference collections held at Forestry Tasmania and CSIRO Forestry and Forest Products Clayton Laboratories. The results of this study will be compared with those of two earlier studies (Refshuage 1938; Parkin 1942) that looked at the fungal species responsible for particular types of rot.

So far, about 104 beetle morphospecies have been hand-collected from the log sections. Thirty-six per cent have been identified to genus level, and further efforts will be made to identify these to species level. The most common rot type found in the large diameter logs has been Type 1 (red brown blocky muddy heartwood rot). Of the 15 most commonly found beetles, eight are primarily associated with this rot type (Table 2), which appears to arise through the enzymatic activities of two unidentified basidiomycete species (coded LF213 and LF485). Early results indicate that the muddy rot sub-type (also known as clayey rot or mudguts: Meggs 1996; Mesibov 1988) is the later decay stage of the blocky rot sub-type (also known as cubical rot: see Table 1). As this rot type is most consistently found in large logs, successive short rotations resulting in small logs could potentially impact on beetle communities dependent on this rot type. This rot type was rarely present in small diameter logs, so the

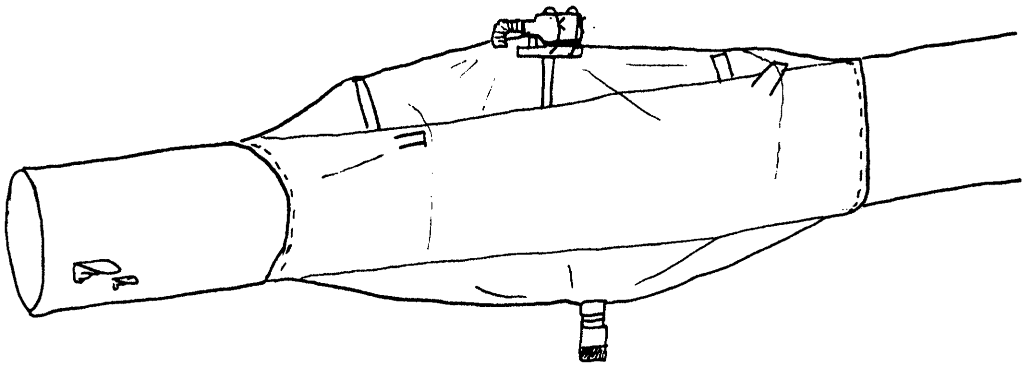

Figure 2. The log emergence trap design used in this study.

conservation of this particular beetle community may be difficult unless specific measures are taken to ensure its survival.

Research objective 2.—*Investigating differences in fungal and insect biodiversity between small and large diameter logs.*

This research objective is being conducted at all ten study sites (Figure 1). The aim is to assess whether smaller diameter logs support fungal and beetle assemblages similar to those of larger diameter logs. For the beetle component, log emergence traps are being used to monitor beetle emergence from decaying logs over 16 months. Trapping has advantages over hand sampling in that it provides a quantitative method of collecting saproxylic beetles, it can collect over extended periods (thus providing information on seasonality), it is non-destructive, and it requires less effort for data retrieval. It is also relatively unbiased in terms of operation error.

At each site, six traps have been erected, three on larger diameter logs and three on smaller diameter logs (60 traps in total). The log emergence traps used (Figure 2) are modified from the design used in the Warra LTER log decay study (Bashford *et al.* 2001). A two-metre long section of the log is encased with gauze net material (Broadway Textiles: Trilobal cloth). A collecting bottle is positioned at the top of the trap, to catch beetles whose behaviour is to move towards the light, and there is a container at the base to catch those that drop when emerging. Material was attached to the log using a staple gun, and wooden stakes were placed within the trap to keep the material off the log. Ethylene glycol was used as the preserving fluid. Traps were erected in September–October 2000 and will be monitored for 18 months, until April 2002. Samples are being collected monthly during summer and bimonthly during winter.

At the end of the trapping period, particular logs that have specific beetles emerging will be cut up to identify the wood rot type from which they emerged. Fungi will be isolated from the various rot types derived from this destructive analysis and grown in culture for DNA extraction and profiling. In this way, the beetle-fungi-rot type associations identified from Research Objective 1 can be validated.

Research objective 3.—*Providing a checklist of the fungal and insect biodiversity dependent on* Eucalyptus obliqua *CWD*

A comprehensive checklist of insect and fungal species associated with *E. obliqua* CWD will be compiled from specimens found and identified during this study. This baseline information will prove valuable for future studies at the Warra LTER Site. As a key resource demonstrating the ecological value of CWD, it should also prove valuable in forest planning. This is especially relevant given the current debate over the intensification of management of the Southern Forests and the prospect of CWD ('biomass, residue, waste') being used for power generation.

Research objective 4.—*To look for direct associations between decayed wood, wood decay fungi and saproxylic insects*

Basidiomycete fungi have been isolated from the frass of *Toxeutes arcuatus* larvae and other selected beetles. It is possible that such species may act as dispersers for fungi, as has been recorded elsewhere (Paine *et al.* 1997; Garcia and Morrell 1999). Looking for direct relationships between beetles and fungi will provide a deeper understanding of the nature and ecological significance of this association.

Outcomes for the forest industry

The ecological information from this research will contribute to assessing whether current forest practices are ecologically sustainable, developing appropriate indicators for monitoring forest biodiversity, and proposing prescriptions that ensure the conservation of these diverse dead wood-associated communities. Key issues to which this research relates include how best to conserve CWD at the coupe level and in the managed landscape. For instance, what is the best arrangement for retaining habitat trees so that they can continue to fulfil their ecological function in managed coupes long after their death? Is a landscape-level approach to CWD management (incorporating informal or formal reserves) sufficient, or will prescriptions also be required within coupes to ensure the survival of larger diameter material? Most critical, at present, is the issue of how best to minimise any threat to dead wood-associated biodiversity posed by the intended harvesting of CWD as a biofuel for power generation.

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