

Dead wood in the forest - alive and dynamic!

Peter K. Buchanan*, Peter W. Clinton**, and Rob B. Allen**

Introduction

Dead wood constitutes a large part of total biomass of indigenous forests, approximately 20 - 30% in mature forest ecosystems (Boddy and Watkinson 1995). In New Zealand beech (*Nothofagus*) forests, this component equates to 24 - 296 Mg/ha depending on forest composition and age of stand (Stewart and Allen 1998). Contained within this apparently dead material are large pools of carbon and nutrients (Allen *et al.* 1997). The recycling of these elements by substrate decomposition, necessary to maintain soil fertility and health of the forest, is effected primarily by fungi and bacteria, especially the basidiomycete and to a lesser extent the ascomycete fungi. "Dead wood" is thus a living system. In any piece of fallen wood, several fungal species compete for a common resource. Black "zone lines", frequently seen when decaying wood is split, demark the boundaries of territory occupied by adjacent colonies of different species or sometimes different individuals of the same species. In this article we discuss the role of fungi in decomposition of wood, focussing on New Zealand beech forests.

Number and roles of fungi

An estimated 22,000 species of fungi are thought to occur in New Zealand, based on ratios of fungi to plants from regions where constituents of both groups are well known. In New Zealand, knowledge of fungi has been gained at a slower rate than for plants. To date 6,500 species of fungi (est. 30% of total) have been documented in New Zealand (Pennycook and Galloway 2001, unpublished). Of these, 5,000 species are non-lichenised fungi while the remaining 1,500 form symbiotic relationships with algae (the "lichens").

In all forests, fungi fulfil a range of roles in addition to wood decomposition. Fungi assist in the nutrition of trees through mycorrhizal associations with roots, many species decompose dead organic matter other than wood (of plant and animal origin) in the soil, some live symptomless within leaves as endophytes and may confer on the host such benefits as resistance to disease, drought, and animal browse, and a minority are pathogenic on plants, animals, and other fungi. In New Zealand beech forests, the mycorrhizal fungi are mainly ectomycorrhizal basidiomycetes that form mushrooms and mushroom-like sporocarps, often fruiting in profusion each autumn (and to a lesser extent in spring). Among 838 species of fungi documented on beech in New Zealand (McKenzie *et al.* 2000), 185 species are

ectomycorrhizal. Apart from beech, *Kunzea* and *Leptospermum* (tea tree) are the only other native trees that have ectomycorrhizal fungal associates; almost all other native plants in New Zealand have a different, vesicular-arbuscular type of mycorrhizal fungal association.

In a biodiversity survey of wood-decomposing macrofungi on mountain beech (*N. solandri* var. *cliffortioides*) at Craigieburn Forest Park, Canterbury, Allen *et al.* (2000) recorded 80 and 151 fungal taxa on 75 selected fallen logs during one survey, in spring and autumn, respectively. Corticioid (crust) fungi and mushrooms made up the majority of species encountered (e.g., Figure 1). A correlation was identified between composition of fungi recorded on a log and the extent of decay of that log. The survey showed that a complex mixture of wood at different states of decay is necessary to maintain natural diversity of saprobic decay fungi.

Different types of wood rot

Wood decay occurs by fungal enzymatic dissolution of the wood cell walls that are composed of cellulose, hemicelluloses, and lignin. Two main enzymatic systems give rise to the two main kinds of wood rots: white, in which all three components of the cell wall are degraded; and brown, in which cellulose and hemicelluloses are degraded to leave a residue of brown lignin. For many people, the most serious (and sometimes all too frequent) brown rot fungus is "dry rot", which can cause major structural damage to untreated timbers in buildings, particularly when wood has been allowed to remain wet with inadequate ventilation; this fungus does not occur in forests. In forests and in particular on hardwoods, white rot fungi dominate, although Stewart and Burrows (1994) suggest that brown rots were common in red beech. Two other types of decay are also typical of the decomposition process but are less significant: non-wood decay caused by various microfungi that utilise simple carbon compounds in living cell walls resulting in staining, and soft rot caused by various ascomycetes which produce a localised decay.

Rate of decay

Little is known about the speed of decomposition of beech wood on the forest floor. Decay rates are likely to vary considerably depending on the combination of fungal species that colonise a particular log and the type of wood. Observations in the forest indicate that silver beech, for example, degrades more rapidly than red beech. Logs of the latter may remain on the ground for as long as 150-200 years (Stewart and Burrows 1994).

To gain a preliminary understanding of rates of decomposition we inoculated test blocks of wood of three species of *Nothofagus* with 12 beech-inhabiting fungi (Figure 2). Weight loss of the wood-fungal system after 16 weeks varied with fungal species from under 2% (on an oven dry basis) for *Postia pelliculosa* and *Australoporus*

*Scientist, Landcare Research, Private Bag 92170, Mt Albert, Auckland, New Zealand

**Scientist, New Zealand Forest Research Institute Ltd, Private Bag 4800, Christchurch, New Zealand

**Scientist, Landcare Research, PO Box 69, Lincoln, New Zealand



Figure 1. Sporocarps of two decay fungi on *Nothofagus*: A, *Pluteus velutinornatus*. B, *Australoporus tasmanicus*.

tasmanicus (Figure 1b), to up to 90% for *Trametes versicolor* (Figure 3) (Buchanan and Clinton, unpubl. data). It is important to note that the harvested weight of decomposed wooden test blocks is a combined measure of both the remaining decayed wood and the living fungal biomass. In a future experiment we plan to measure the fungal component in decayed blocks.

Decomposition rates under experimental conditions seem to reflect the ecological role of the fungi. For example, the most vigorous decomposer we tested, *T. versicolor*, is an early coloniser of fallen beech and can be seen among the first fungi to fruit in open sites. On the other hand *A. tasmanicus* (1.3% weight loss of inoculated blocks) is most commonly seen on well-decayed logs and may colonise the substrate only after decomposition by other fungi. Our results did not discriminate between rates of decomposition on the three *Nothofagus* species (Buchanan and Clinton, unpubl. data).

Sporocarp nutrients

Sporocarps are the most obvious sign of decomposing fungi on logs. Most fungal biomass, however, is hidden and occupies the substrate adjacent to the point of sporocarp initiation. Rarely in New Zealand is it possible to identify the fungus present in wood without

the sporocarp. Few species produce persistent sporocarps, while the majority fruit for only a short period and may not develop sporocarps every year. A comprehensive and long-term study of the fungi in decaying logs is needed to understand the composition and succession of decay organisms.

As decomposition of wood proceeds, fungi convert C to CO₂ and the relative concentration of N and P increases (Boddy and Watkinson 1995). However, a proportion of these elements are sequestered by fungi and utilised in growth such as the development of hyphal cords and rhizomorphs, which search out new food sources, and the production of sporocarps. Undecayed wood commonly has C : N ratios as high as 500 : 1, and occasionally up to 1,250 : 1 as has been measured in *Picea sitchensis* (Rayner and Boddy 1988). In studies reported by Boddy and Watkinson (1995), the C : N ratio of undecayed wood was 247 : 1, compared to that of decayed wood which ranged from 44 to 175 : 1, while that of fungal mycelium was only 35 : 1. Comparable C : N ratios for woody debris of New Zealand mountain beech are 500 : 1 for undecayed wood compared to 300 : 1 for decayed wood (Clinton, unpubl. data), and between 8 : 1 and 40 : 1 for sporocarps on decayed wood (Clinton *et al.* 1999).

We compared the nutrient composition of sporocarps

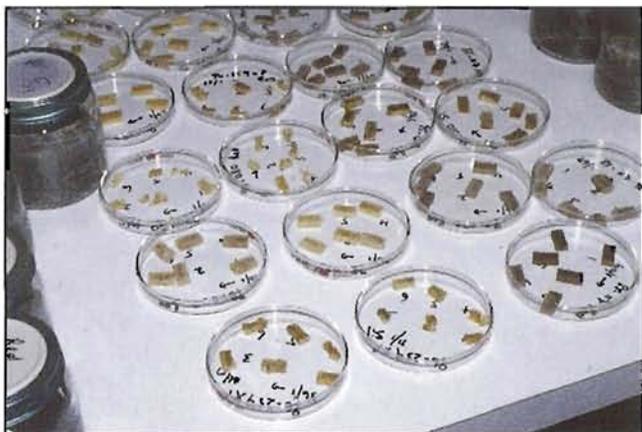


Figure 2. A laboratory experiment to measure rates of decomposition by 12 species of fungi of three species of *Nothofagus*.



Figure 3. Sporocarps of *Trametes versicolor*, the most efficient wood decay fungus on *Nothofagus* among 12 species tested under experimental conditions.

of 10 species of wood decay fungi on naturally decaying mountain beech logs with sporocarps of four species on the forest floor (Clinton *et al.* 1999). Nutrient concentrations of substrates of the forest floor were much greater than those of fallen wood, but sporocarp nutrient concentrations were variable and did not reflect their substrate origins. Sporocarp N concentrations ranged from 12 to 55 mg/g, while logs contained 1.5 mg/g N and the forest floor 8.7 mg/g. Sporocarps can be considered as nutrient packages and are important in nutrient cycling. Sporocarps may decompose after only a few days or weeks or be consumed by insects and grazing animals, including possums. Thus, the nutrients originally contained in the dead wood may ultimately be cycled locally or dispersed from the site of the log.

Future research initiatives to understand wood decomposition

Fungi control nutrient cycling in all forest ecosystems, yet we presently understand little of the great diversity of fungal species present and the nature of their individual roles in the decomposition of each host tree species. Our initial results for mountain beech suggest the decomposition process requires interaction between a broad range of fungal species. Does this hold for the other beech forest types and other forests? How is fungal biodiversity influenced by environmental factors?

We are largely ignorant of the effects of threats to the roles of indigenous fungal species from influences such as vertebrate pests, climate change, and fungal invaders. The widespread "orange pore fungus" (*Favolaschia calocera*) from Madagascar, for example, has become invasive in New Zealand where it colonises a broad range of woody substrates from Northland to Westland (Johnston *et al.* 1998) and appears to displace indigenous fungal species. What effect is this "weed fungus" having on nutrient cycling and on fungal diversity?

Decomposition rates *in vitro* require further investigation as do changes in nutrient cycling processes as wood decomposes. A more informed awareness of the complexities of wood decomposition in forest ecosystems requires an integrated research approach to create an understanding of both the diversity of fungal participants in wood decay as well as fungal and plant ecology.

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John Johns - A Memorial Calendar

Many Institute members will remember the late John Johns, who has for many years the Forest Service photographer. His work hung in every Forest Service office and he wrote and contributed to many books, notably with Geoff Chavasse and Lindsay Poole.

A group (Clive Anstey, Lindsay Poole, Jolyon Manning and John Purey-Cust) who knew him felt that a suitable memorial to him from the Institute would be a calendar of his work, and we put our proposal to the Institute's Council and have its support in principle. The calendar will be a large one, 42 x 59 cm (4 x A4), a page a month with two or three photos on each page. We will be advertising by word of mouth and in the journals of groups with a kindred interest, and we plan to get it out for \$30 and in time for overseas posting.

Any expressions of interest in the purchase of copies are welcome.

Contact:

John Purey-Cust

Campion Road

4 RD Gore

Fax: (03) 208 5200

Email: cust@esi.co.nz