TECHNICAL NOTE

The importance of woody debris in New Zealand's indigenous forests

Glenn H. Stewart* & Rob Allen**

Introduction

Woody debris, in the form of standing dead trees (snags), fallen logs, and large branches, forms a major structural feature of many natural forest and stream ecosystems (Figure 1.). There is an increasing awareness that it performs many important ecological functions: acting as habitat for organisms, playing a part in energy flow and nutrient cycling, and influencing sediment transport and storage (Harmon & Hua 1991, Samuelsson et al. 1994). Despite its functional importance, the quantity and dynamics of woody debris have been described for few forests, and most of these from the northern hemisphere. In New Zealand,anthropogenic influences (e.g., timber harvesting, introduced browsing animals) are modifying the quantity and dynamics of woody debris in indigenous forests. This may be having important consequences for ecological processes that drive changes in these forests. To address the lack of information on woody debris in southern hemisphere forests, and the way it is being modified, has resulted in several recent studies (e.g., Stewart & Burrows 1994, Allen et al. 1997). In this article we summarise what is known about woody debris in our indigenous forests, discuss the likely impacts of its removal from forest ecosystems, and outline some of the key areas in need of research.

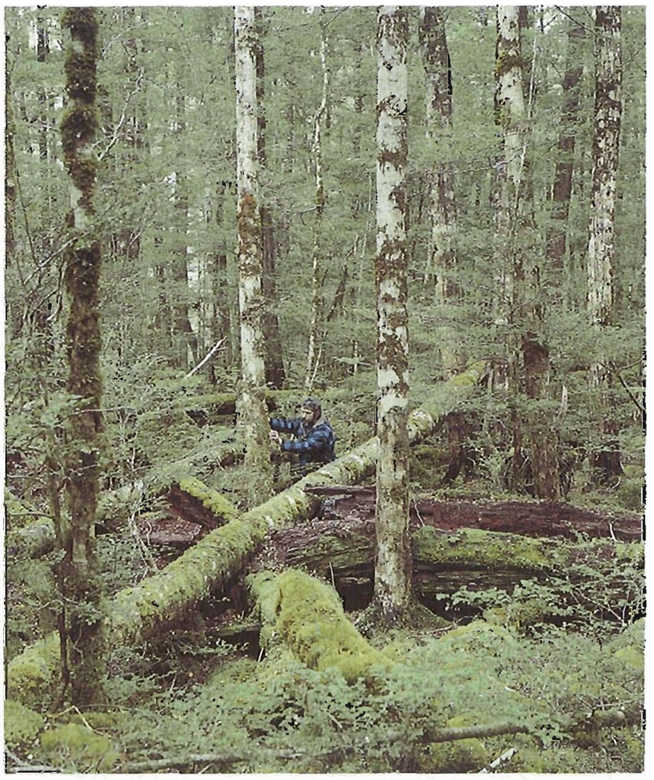

Figure 1. Down logs in red-silver beech forest, Maruia Valley, north Westland. Photo: New Zealand Forest Research Institute

Woody debris mass in New Zealand indigenous forests

We have summarised the available published information on woody debris in New Zealand forests in Table 1. What is immediately apparent is that we have data for only a few forest types, and most of this is from a handful of studies in beech forests. There are apparently no data, for example, from lowland podocarp forests or the giant kauri forests of the far north. In old-growth forests dominated by large red and silver beech trees the biomass of woody debris can be considerable, in the order of 150 to 300 Mg ha^{-1} for forests of north Westland (30 to 34% of total above ground biomass). If these amounts are typical of our forests then the woody debris component is unusually high compared to northern hemisphere temperate hardwood forests and approaches that of northern hemisphere conifer forests. The highest amounts of woody debris so far recorded were in old-growth rata-kamahi-totara forests of central Westland (Table 1). This is partially the result of recent forest dieback (commonly attributed to possum browsing) but also because of slow decay of the dense and durable rata wood.

Clearly there is considerable variability in woody debris mass found in New Zealand forests (Table 1). At any one point in time the amount of woody debris at a site will depend on the balance between (1) rate of input and (2) rate of decay, these in turn being influenced by factors such as the disturbance regime, stage of stand development, substrate (wood) quality for decomposer activity, the decomposer communities present, and climate. The differing disturbance regimes of red-silver beech and mountain beech forests provide an interesting contrast in the quantity and dynamics of woody debris. In red-silver beech forests characterised by small-scale gap regeneration, rates of woody debris input vary markedly (Figure 2.) but these forests contain large and persistent stores of woody debris (red beech logs may remain on the forest floor for up to 150-200 years, Stewart and Burrows 1994). In contrast, because mountain beech forests often regenerate in even-aged stands after catastrophic disturbances large amounts of woody debris is only a feature of young stands and, for no more than the first century of development (Table 1). These differences have major implications for nutrient cycling during stand development and will be discussed below.

In red-silver beech forests, the large mass of red beech woody debris can be partially explained by the differences in decom_

* *Reader in Ecology, Soil, Plant & Ecological Sciences Division, Lincoln University, P.O. Box 84, Lincoln, Canterbury, NEW ZEALAND.*
** *Scientist, Landcare Research, P.O. Box 69, Lincoln, Canterbury, NEW ZEALAND.*

TABLE 1. Summary of published information on woody debris in New Zealand's indigenous forests

Dominant tree species (mm/yr)	rainfall (degrees C)	Temp. (cm)	lower limit (m3 ha-1)	volume (Mg ha-1†)†	d.m. (Mg ha-1)	C (kg ha-1)	N	Reference
old growth red-silver beech	2,000	9	10	401	130	66	181	Stewart & Burrows 1994
old growth red-silver beech	2,255	9	10	796	296	149	368	Stewart & Burrows 1994
old growth red-silver beech	2,500-2,700	9	10	418	146	73	180	Stewart & Burrows 1994
old growth red-silver beech-rimu	2,600	11	25		52			Beets 1980
old growth red-silver beech-rimu-kahikatea	2,500-3000	10	10	365	c.130			Stewart & Burrows 1994, Stewart et al. 1993
old growth rata-kamahi-quintinia-miro	2,000	11	1		67			Levett et al.1995
old growth rata-kamahi-totara ('dieback')	6,000-10,000	7	5		576 (standing dead only)			Bellingham et al. 1996
mountain beech (10 years old)	1447	7		579	169	90	236	Allen et al. 1997, Clinton (unpublished data)
mountain beech (25 years old)	1447	7	10	416	99	59	188	Allen et al. 1997, Clinton (unpublished data)
mountain beech (120 years old)	1447	7	10	80	25	14	34	Allen et al. 1997, Clinton (unpublished data)
mountain beech (150+ years old)	1447	7	10	81	24	27	33	Allen et al. 1997, Clinton (unpublished data)
manuka-heath (16, 21, 33yrs) manuka-kamahi (45, 57yrs)	1450		10		2, 16, 2 2, 9		8. 41. 6	Egunjobi 1969

position rates of logs that may be due to differences in fungal composition of the red and silver beech logs (Stewart & Burrows 1994). Slow decay of red beech can be attributed to the presence of brown-rot fungi that degrade only cellulose, increasing the proportion of decay-resistant lignin as decay proceeds. Conversely, this may also account for the rapid decay of silver beech which is readily colonised by white-rot fungi capable of both lignin and cellulose decay (Gilmour 1965). It is likely that decomposer community composition (and therefore decay rate) will vary not only with substrate type (as in this example) but will also vary with climate. It would be intriguing to know if decomposer communities and hence decay rates in red beech, for example, are similar under different climates.

Woody debris as a store of nutrients (including carbon)

Carbon and nutrients stored in woody debris can be a significant component of the total stand nutrient pools (Harmon et al. 1986). There have been very few New Zealand studies characterising the proportion of forest stand carbon in woody debris. Yet this information is essential for developing carbon budgets for forests under international obligations such as the Framework Convention for Climate Change (FCCC). Recent estimates of carbon storage in New Zealand's indigenous forests have not incorporated carbon stored in woody debris (e.g., Tate et al. 1997). No published study has compared the major nutrient pools for live and dead wood components of the forest. Although nutrient concentrations in woody debris are low compared to other detrital inputs (e.g., foliage), nutrient storage is high because of the large amounts of woody debris present in forests. Low nutrients, in combination with the high carbon content of woody debris, means it is a poor substrate for decomposer activity. Thus, woody debris can be important in regulating nutrient cycling. Natural disturbances deposit a large amount of poor quality substrate on the forest floor . This can have a major influence on the immobilisation of nutrients such as nitrogen in woody debris (Zimmerman et al. 1995). Removal of logs (e.g., by timber harvesting) could reduce immobilisation potential and increase leaching of nutrients at the critical stage of seedling development. There are in fact very few studies that have linked the cycling of nutrients between dead and live biomass. In a New Zealand example, after catastrophic disturbance in mountain beech forests, there is a large store of carbon and nutrients in woody debris and very little in live biomass (Allen et al. 1997). During stand development there is a progressive movement of nutrients (e.g., Ca, Mg) from woody debris into the soil, from where these nutrients are taken up and sequestered in aggrading live biomass (Allen et al. 1997). As the amounts of woody debris decline (Table 1), and the live biomass increases, there is a decline in soil nutrient availability. This decline may be a factor contributing to decreased productivity as stands age (Gower et al. 1996).

Woody debris and the maintenance of diversity

Woody debris at various stages of decay contributes to a high level of habitat heterogeneity. In particular, the incidence and characteristics of logs and snags appear crucial for the maintenance of populations of many plant and animal species. For example, the threatened long-tailed bat (*Chalinolobus tuberculatus*) selects roost sites in beech forest snags based on the number of cavities, trunk surface area, and canopy cover (Sedgeley & O'Donnell in press). In south Westland, O'Donnell and Dilks (1986) found that scattered standing dead trees were vital to kaka (*Nestor meridionalis*) who used them for foraging for invertebrates. Many studies have shown the importance of logs on the forest floor for the establishment, growth, and survival of tree seedlings (June & Ogden 1978, Stewart & Rose 1990). One rea-

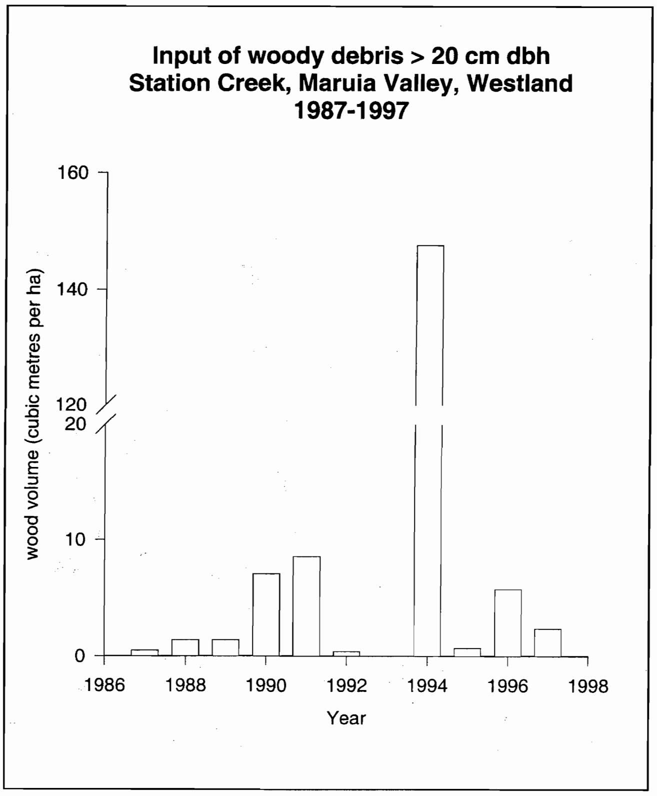

Figure 2. Annual inputs of woody debris > 20 cm dbh, in red-silver beech forest, Station Creek, Maruia Valley, Westland, 1987-1997 (Stewart, unpublished data).

son for the importance of logs as establishment sites is that they provide a raised surface for tree seedlings to avoid competition with ferns and other dense herbaceous layers. We know little about the log properties that may control the tree seedling species that establish on logs. Clearly log chemistry varies with stage of decay and it would seem likely that logs vary in suitability as a habitat.

Future research directions

Even though there is a paucity of information on woody debris in our forests it is obvious from the few studies that it is a key component that has been largely overlooked. Some areas requiring further investigation include:

- The amount of woody debris in a range of forest types and explanations for it's variability. For example, this information is needed for reporting on carbon storage and dynamics in indigenous forests.
- The consequences of log removal on the amounts and turnover of woody debris. For example, this will have important consequences for nutrient cycling if forests are managed for timber production.
- Given that woody debris is an important source of biodiversity, we need to understand the dynamics of woody debris and dependent biota to practice appropriate conservation management. For example, the abundance and distribution of rare bat populations may well only be understood with an appropriate understanding of woody debris dynamics.

References

Allen, R.B., P.W. Clinton, and M.R. Davis. 1997. Cation storage and availability along a *Nothofagus* forest development sequence in New Zealand. Canadian Journal of Forest Research 27: 323-330.

Beets, P.N. 1980. Amount and distribution of dry matter in a mature beech/podocarp community. New Zealand Journal of Forestry Science 10: 395-418.

Bellingham, P.J., S.K. Wiser, G.M.J. Hall, J.C. Alley, R.B. Allen, and P.A. Suisted. 1996. Impacts of possum browsing on the long term maintenance of forest biodiversity. Landcare Research Contract Report LC 9697-047 for Department of Conservation.

Egunjobi, J.K. 1969. Dry matter and nitrogen accumulation in secondary successions involving gorse (*Ulex europaeus* L.) and associated shrubs and trees. New Zealand Journal of Science 12: 175-193.

Gilmour, J.W. 1965. The pathogenic fungi of beech. In: Beech Forestry in New Zealand. Vol 2. New Zealand Forest Service, Forest Research Institute Symposium 5. pp. 79-84.

Gower, S.T., McMurtrie, R.E., and D. Murty. Above ground net primary production decline with stand age: potential causes. Trends in Ecology and Evolution 11: 378-382.

Harmon, M.E., and C. Hua. 1991. Coarse woody debris dynamics in two old-growth ecosystems. Bioscience 41: 604-610.

Harmon, M.E., Franklin, J.F., Swanson, F.J., Sollins, P., Gregory, S.V., Lattin, J.D., Anderson, N.H., Cline, S.P., Umen, N.G., Seddell, J.R., Lienkaemper, G.W., Cromack, K. Jr., K., & Cummins, K.W. 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research 15: 133-302.

June, S.R., and J. Ogden. 1978. Studies on the vegetation of Mt Colenso, New Zealand. 4. An assessment of the processes of canopy maintenance and regeneration strategy in a red beech (*Nothofagus fusca*) forest. New Zealand Journal of Ecology 1: 7-15.

Levett, M.P., J.A. Adams, and T.W. Walker. 1985. Weight and nutrient content of above-ground biomass and litter of a podocarp-hardwood forest in Westland, New Zealand. New Zealand Journal of Forestry Science 15: 23-35.

O'Donnell, C.F.J., and P.J. Dilks. 1986. Forest birds in south Westland: status, distribution, and habitat use. New Zealand Wildlife Service, Occasional Publication no. 10, Department of Internal Affairs, Wellington.

Samuelsson, J., Gustafsson, L., and T. Ingelog. 1994. Dying and dead trees: a review of their importance for biodiversity. Swedish Environmental Protection Agency Report 4306.

Sedgeley, J.A., and C.F.J. O'Donnell (in press). Roost site selection by the long-tailed bat, *Chalinolobus tuberculatus* in a temperate New Zealand rainforest and its implications for the conservation of bats in managed forests. Biological Conservation.

Stewart, G.H., and A.B. Rose. 1990. The significance of life history strategies in the developmental history of mixed beech (*Nothofagus*) forests, New Zealand. Vegetatio 87: 101-114.

Stewart, G.H., and L.E. Burrows. 1994. Coarse woody debris in old-growth temperate beech (*Nothofagus*) forests of New Zealand. Canadian Journal of Forest Research 24: 1989-1996.

Stewart, G.H., L.R. Basher, L.E. Burrows, J.R. Runkle, G.M.J. Hall, and R.J. Jackson. 1993. Beech-hardwood forest composition, landforms, and soil relationships, north Westland, New Zealand. Vegetatio 106: 111-125.

Tate, K.R., D.J. Giltrap, J.J Claydon, P.F. Newsome, I.A.E. Atkinson, M.D. Taylor, and R. Lee. 1997. Organic carbon stocks in New Zealand's terrestrial ecosystems. Journal of the Royal Society of New Zealand 27: 315-335.

Zimmerman, J.K., W.M. Pulliam, D.J. Lodge,V. Quinones-Orfila, S. Guzman-Grajales, J.A. Parrotta, C.E. Asbury, L.R. Walker, and R.B. Waide. 1995. Nitrogen immobilisation by decomposing woody debris and the recovery of wet tropical forest from hurricane damage. Oikos 72: 314-322.