WIND-CAUSED DISTURBANCE OF A RED/SILVER BEECH FOREST: TEN YEARS ON

GORDON HOSKING

Ministry of Agriculture and Forestry,
P.O. Box 2526, Wellington, New Zealand

and JOHN HUTCHESON

2 Wharetoroa Drive, Rotorua, New Zealand

(Received for publication 14 December 1997; revision 13 October 1998)

ABSTRACT

A 10-year study of the effect of wind damage on the health of residual *Nothofagus fusca* (Hook. f.) Oerst. / *N. menziesii* (Hook. f.) Oerst. (red/silver beech) forest showed tree mortality continued throughout the period in severely damaged forest. Forest with less than 30% canopy loss was much less affected by continued deterioration and showed little difference from undamaged forest at the end of the period. The two species showed different trends in mortality over time; the mortality rate of red beech levelled off after 7 years while that of silver beech was still increasing after 10 years. *Platypus* spp. pinhole borers were not a primary cause of tree mortality, attack being largely confined to trees that were already unhealthy. Blowdown debris harboured only a single generation of pinhole borers, decay being too advanced to support further broods.

Keywords: wind damage; forest decline; tree mortality; *Nothofagus fusca*; *Nothofagus menziesii*; *Platypus* spp.

INTRODUCTION

Natural disturbance has long been recognised as an integral part of the dynamics of New Zealand's indigenous forests (Thompson 1936; Allen & Wardle 1985; Stewart & Veblen 1983). In particular, beech forest has been the subject of a number of studies which focused primarily on the role of insects and disease in relation to disturbance-driven stand dynamics (Litchwark 1978; Faulds 1977; Hosking & Kershaw 1985; Hosking & Hutcheson 1986). One of the most common causes of disturbance in beech forests is wind, initiating changes which range from single damaged trees to tens of hectares of complete canopy destruction. Jane (1986) examined the direct effect of a wind event in *Nothofagus solandri* var. *cliffortioides* (Hook. f.) Poole (mountain beech) forest with reference to the distribution and nature of damage, and Shaw (1983) discussed the influence of wind storms on the composition and structure of New Zealand's indigenous forests. This paper records changes in the forest canopy over a 10-year period after a single disturbance event, with particular reference to the progression and cause of residual tree mortality.

Causes of residual tree mortality in beech forest after disturbance are of interest not only to managers of the conservation estate but also to managers of production beech forests. With increasing recognition that any future production from these forests will have to be sustainable, understanding the role of natural disturbance may provide the key to management strategies which emulate natural processes, and provide politically acceptable harvesting options (Attiwill 1994; Brown & Press 1992).

Tree mortality in red/silver beech forest has long been associated with attack by the native pinhole borers *Platypus* spp. (Faulds 1977; Milligan 1979). A number of other insects and diseases have been associated with tree decline in beech forests (Milligan 1972, 1974) and in some cases no obvious pathological cause of decline was evident (Skipworth 1981; Hosking & Hutcheson 1988). Wardle & Allen (1983) discussed the effect of severe snow damage on forest structure and documented the change in stem numbers and diameter classes over time after such damage. They suggested that insects and disease are commonly associated with such on-going decline. Cyclone Bernie, a major storm in 1982, provided the opportunity to monitor changes in residual stands with special reference to insects and disease of red/silver beech forest on two separate sites, one in the Northern Kaimanawa Ranges and the other in the Whirinaki Forest Park.

METHODS

The Easter 1982 storm caused damage throughout the Urewera National Park and southward through Whirinaki Forest Park and the Kaimanawa Ranges. Minor damage probably occurred throughout the entire area with extensive areas of moderate, and patches of severe, damage present in the southern and eastern parts of the National Park (Shaw 1983) and in parts of the Whirinaki Forest Park and Northern Kaimanawa Ranges. Two separate and well-separated areas were chosen for the study, one along Clements Mill Road into the Northern Kaimanawas (38° 50′S, 176° 10′E) and the other along the Whirinaki Track in the Southern Ureweras (38° 50′S, 176° 40′E).

Clements Mill Road Site. Wind effects in this area of mature red/silver beech forest ranged from virtually undamaged stands to almost complete destruction. Plots were established in three subjectively defined classes of damage: undamaged/slightly damaged (canopy essentially intact), moderate damage (at least 30% of canopy removed), and severely damaged (complete canopy destruction with only scattered trees remaining) (Table 1).

Whirinaki Track Site. Forest in this area lacked sites of intermediate damage. The forest type was similar to that along Clements Mill Road, in that it was dominated by mature red and silver beech, although relative size-class distributions of the two species varied by site (Table 2).

Plot Establishment

All plots were tree centred and circular with a 5.0-m radius. Beech trees over 10 cm dbh (Table 2) were permanently tagged and assessed for crown condition, stem damage, and insect and disease attack. Crowns were classified into five categories—viz healthy (no obvious damage, full and without wilt), intermediate (dead fine branches, small areas of wilt, breakage of major branches), unhealthy (clear decline and death of major branches, extensive wilting and crown contraction), dead, and windthrown. Problematical allocation

TABLE 1–Distribution of plots and trees by damage class and tree species

Damage category	Kaimanawa		Whirinaki	
	No. plots	No. trees	No. plots	No. trees
Undamaged	17		21	
Red beech		89		34
Silver beech		19		24
Subtotal		108		58
Moderate damage	6		0	
Red beech		26		
Silver beech		10		
Subtotal		36		0
Severe damage	28		13	
Red beech		29		7
Silver beech		42		14
Subtotal		71		21
Total	51	215	34	79

TABLE 2–Diameter class distribution of sample plot trees by species and site

Diameter class (cm)	Trees in each diameter class (%)			
	Kaimanawa		Whirinaki	
	Silver (n=71)	Red (n=144)	Silver (n=38)	Red (n=31)
10–20	22	18	41	7
21–30	21	27	24	2
31–40	17	24	11	10
41–50	19	18	8	10
51–60	10	8	0	10
61–70	7	1	8	10
>71	4	4	8	51

of occasional trees was not of concern since subsequent assessments recorded the progression or otherwise of decline. *Platypus* attack was noted and recorded as adult or larval activity according to frass characteristics. The density of attack was recorded as absent, low (less than 1 attack per 100 cm^2), moderate (1–5 attacks per 100 cm^2), or heavy (>5 attacks per 100 cm^2). The presence of Armillaria root rot was also noted. All plots were assessed at establishment immediately after the storm event in April 1982, and then in 1984, 1985, 1986, 1988, 1989, 1991, and 1992.

Although subjective, the categories of tree health proved to be practical in application and biologically meaningful in the context of forest decline.

RESULTS

Some decline was apparent in residual red and silver beech in all damage categories on both sites. However, there were important differences in the severity of decline between the two beech species and between damage classes over the 10 years of the study.

Decline Over Time

After 10 years, 41% of silver beech trees were recorded in one or other disease-affected class compared with 32% of red beech (Fig. 1). Individual tree decline in red beech plots had begun to level out after 6 years, and was scarcely increasing in any category by 1991, but decline in silver beech was continuing. The period of greatest decline was 3 to 6 years after disturbance for both species, with very little change prior to this.

Ten years after the disturbance 17% of residual red beech had died compared with 8% of silver beech (Fig. 2). However, only 17% of red beech deaths occurred in the last 4 years of the study compared with 44% for silver beech.

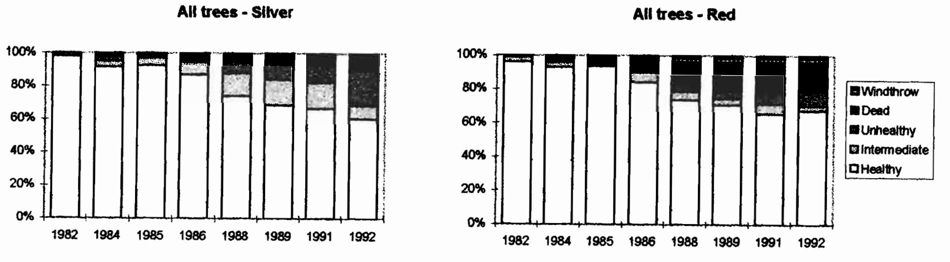

FIG. 1–Change in condition classes of all trees by species over the 10 years of the study.

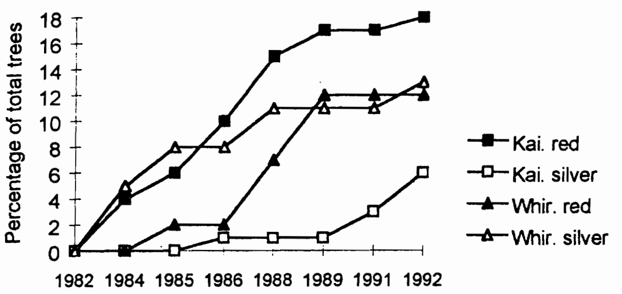

FIG. 2–Cumulative tree mortality by species and site (Kai = Kaimanawa, Whir = Whirinaki)

Canopy Damage and Decline

Plots located in relatively undamaged canopy suffered very low levels of subsequent decline, although red beech was more affected than silver beech (Fig. 3). Silver beech in the undamaged Kaimanawa plots showed a distinct pulse of ill health (Fig. 3b) after which complete recovery occurred. Three plots in the transitional zone of moderately damaged forest at the Kaimanawa site also showed no ongoing increasing mortality of either species (Fig. 4).

Almost all decline subsequent to the wind event was found within the severely damaged plots. This was consistent on both sites for both species (Fig. 5). Decline was most rapid for red beech, with a steady deterioration through intermediate and unhealthy categories to death over 6 years. By the end of the study period less than 30% of the original post-event population in damaged plots was considered healthy.

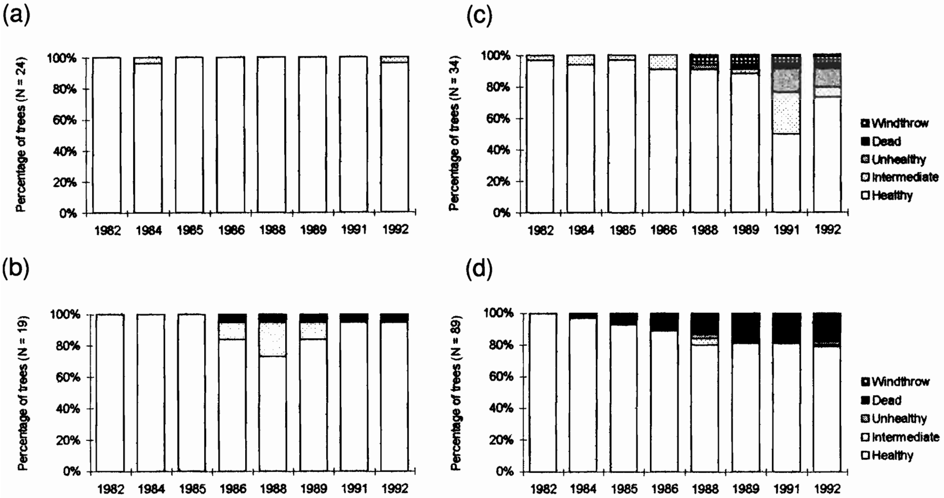

FIG. 3—Change in tree health categories by species and site in the undamaged plots over the duration of the study. (a) Whirinaki silver beech; (b) Kaimanawa silver beech; (c) Whirinaki red beech; (d) Kaimanawa red beech.

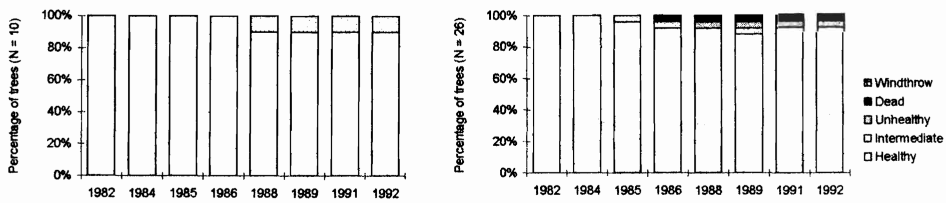

FIG. 4—Change in tree health categories by species in the transitional plots at Kaimanawa over the duration of the study—(left) silver beech, (right) red beech.

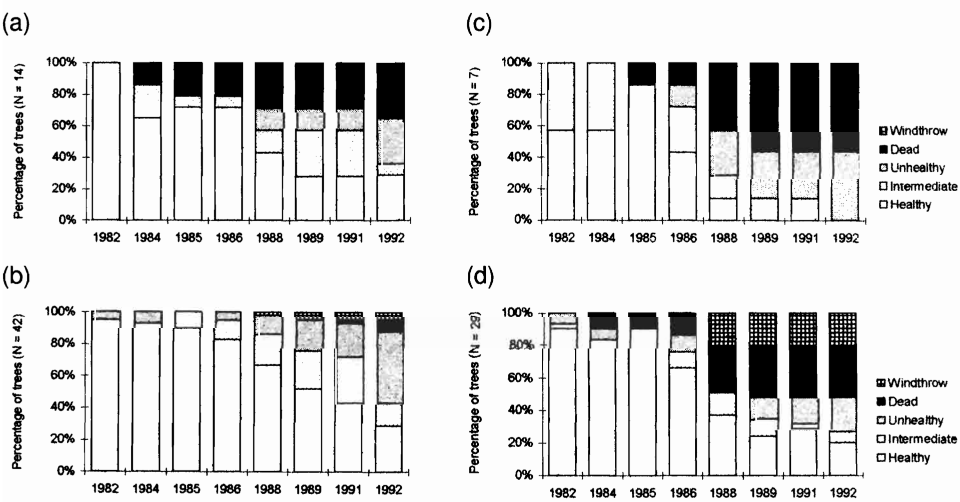

FIG. 5—Change in tree health categories by species and site in the severely damaged plots over the duration of the study. (a) Whirinaki silver beech; (b) Kaimaniwa silver beech; (c) Whirinaki red beech; (d) Kaimaniwa red beech.

Decline and Site

Clear differences existed between the Whirinaki and Kaimanawa areas in both the rate and intensity of decline (Fig. 5). Decline of both silver and red beech was more rapid, and resulted in proportionally greater mortality at Whirinaki (Fig. 5a, c). On the Kaimanawa site, progression of decline was initially slow but increased steadily throughout the study for silver beech, and into the late 1980s for red beech (Fig. 5b, d). Comparisons between the two sites were confounded by differences in diameter-class distribution particularly for red beech, with Whirinaki trees much larger (and almost certainly older) on average than Kaimanawa trees (Table 2). The Whirinaki site was unaffected by further windthrow during the study period, but there was a small localised windthrow event at the Kaimanawa site prior to the 1988 assessment.

Platypus spp. Attack

Although 68% of dead trees had been a target for *Platypus* spp. at some time during the course of the study, attack only rarely preceded decline, i.e., affected trees were generally already classed as unhealthy when attack occurred. Of the total 294 trees, only four showed attack after 2 years. This increased to 20 at 3 years, accompanied by the first appearance of larval activity. *Platyus* spp. attacks peaked earlier on the Kaimanawa site than at Whirinaki, with 1988 being the year of greatest overall activity (Fig. 6). At the conclusion of the study only 26% of trees classified as less than healthy had showed signs of attack by *Platypus* spp. The pattern of attack over time did not differ either by host species or by sites.

No other diseases or insects were found associated with the decline process, although *Armillaria* spp. mycelium and *Ganoderma* spp. fruiting bodies were common on long-dead trees and windthrown debris.

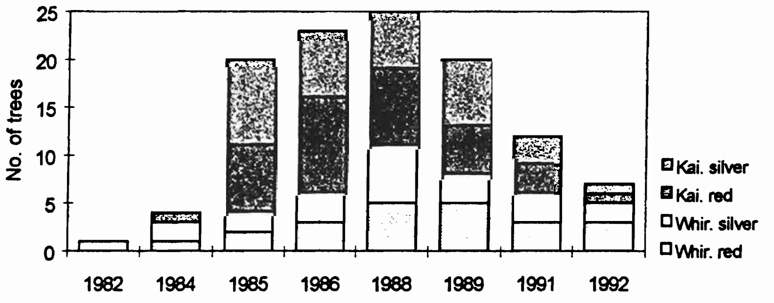

FIG. 6–Total number of trees showing evidence of *Platypus* spp. attack, by species and site, over the duration of the study.

DISCUSSION

Periodic disturbance, associated mostly with climatic events such as wind storms, is a common feature of New Zealand's shallow-rooting beech forests (Jane 1986; Grant 1984; Hosking & Hutcheson 1986; Allen & Wardle 1985; Ogden 1988; Cunningham & Stribling 1978). However, severe wind events causing widespread damage are not unique to New

Zealand's forest ecosystems, commonly occurring in a wide range of temperate and tropical forests (Attiwill 1994). The spread of residual mortality from centres of damage has been documented by Wardle & Allen (1983) for mountain beech, a species for which complete canopy collapse after damage appears intimately linked with its regeneration strategy (Hosking & Hutcheson 1988). Red/silver beech forests in less-exposed environments appear to generally utilise smaller gap dynamics in their replacement strategy (Stewart *et al.* 1991), but these forests also suffer periodic extensive damage due to major climatic events (Shaw 1983), often followed by secondary damage from biotic agents (Hosking & Kershaw 1985; Hosking & Hutcheson 1986). The present study is the first we are aware of that examines the long-term fate of residual forest undergoing different levels of damage, with particular reference to the involvement of *Platypus* spp.

Period of Decline

The general environment of forests is dramatically modified during severe damaging events, and stress-related decline might well be expected. The prolonged influence of a major wind disturbance event on tree health was clear from the study, with some trees in severely damaged areas beginning to decline 10 years after the event.

Damage Severity and Decline

For both beech species, damage involving up to 30% canopy loss did not initiate significant decline in the remaining stand. It is likely that this level of damage is closer to the small gap regeneration processes (Stewart *et al.* 1991) which do not appear to initiate decline of surrounding trees. Ill health of trees, evident as canopy thinning and foliage yellowing, may be a temporary phenomenon, as seen for silver beech (Fig. 3b). Results from this study suggest protracted decline occurs only after damage to canopy trees exceeds 30%. The difference between the two sites in the progression of decline may relate to the nature of the damage. At Whirinaki a single large area was devastated, with a few surviving trees within the damaged area; in the Kaimanawas, although areas of several hectares suffered a similar fate, they were separated by a mosaic of less damaged and undamaged stands. Whirinaki therefore represented the more extreme case and suffered more rapid initial decline of surviving trees.

Species Differences

Although decline occurred in both beech species, according to the data red beech declined more rapidly than silver. This was particularly evident if each site was considered separately. Patterns of cumulative mortality differed for the two species (Fig. 2) with an increased rate of death occurring earlier for red beech. This suggests that red beech is more sensitive to environmental change than silver beech. Hosking & Kershaw (1985) found that drought effects on red beech were more severe than on silver beech in the Maruia Valley, where an associated insect epidemic preceded extensive mortality of red beech. The data do suggest, however, that decline may continue to affect silver beech over a longer period, with mortality still occurring on both sites after 10 years. The position of silver beech in the original canopy is not known, but G.H.Stewart (pers. comm.) found subcanopy trees affected by natural gap formation still dying after 10 years at Maruia.

Platypus spp. Attack

Platypus spp. have long been considered the primary cause of tree death after disturbance in beech forests (Milligan 1974). A study by Litchwark (1978) concluded there was preference for attack on red beech over silver of about 9 to 1. While there is no doubt *Platypus* spp. introduce a pathogenic fungus to hosts (Faulds 1977; Milligan 1979; Payton 1989), these and other pathogens such as *Armillaria* spp. are thought to contribute to, rather than act as primary causes for, tree decline (Hosking 1993). In the present study *Platypus* spp. attack was present in less than 70% of dead trees, it generally occured after trees were classified as unhealthy, and total activity peaked in 1988, declining steeply thereafter. The sharp increase in attack in 1985 (Fig. 6) reflected the first emergence of brood from the 1982 storm debris, a process which continued through to 1987 and was reflected in the 1988 peak (Milligan 1979). The subsequent decay of the debris led to a decline in populations as the material became unsuitable for reinfestation.

The study indicates that the critical factor limiting *Platypus* spp. populations is availability of suitable host material. Major wind events such as those discussed in this paper may result in the production of a large amount of host material that cannot immediately be fully utilised by background populations of the insects. By the time the first generation emerges the outer sapwood of this material is largely decayed beyond suitability for infestation. High *Platypus* spp. populations and associated death of healthy trees (Milligan 1979) result when a continual and contiguous supply of breeding material is made available, either from a series of natural events, or through human activity. The latter was typified by the effects of post and batten splitters in the 1950s and 1960s in the Northern Kaimanawas. Then beech trees killed by *Platypus* spp. were a common sight because ongoing activity provided stumps and head logs to boost populations. Pulses of saprophytic fungi which may be weakly pathogenic, such as *Armillaria* spp., inevitably accompany damage such as that discussed here, but subside rapidly once suitable host material has been utilised. No ongoing tree death attributable to insect or disease was evident over the course of the study.

Implications for Beech Forest Management

A key question in the management of beech forests for both production and conservation is the influence of disturbance on the health of the residual forest. The present study suggests disturbance separated by at least 6 years from subsequent disturbance events does not support populations of *Platypus* spp. sufficient to cause mortality in otherwise healthy trees. It does show, however, that damage affecting more than 30% of the canopy may lead to ongoing decline of residual forest. Management of red/silver beech forest for timber production should focus on eliminating a continuous supply of breeding material for *Platypus* spp. through the separation of harvesting coupes in space or time. Although on-site reduction of potential breeding material may also contribute to this end, research is needed to identify the relative importance of the components of logging residue and the most appropriate treatments to reduce breeding of *Platypus* spp. in them. Light selection logging, where less than 30% of canopy trees are removed, should not lead to ongoing decline.

The study also indicated that scattered trees surviving severe disturbance, or left as seed trees after harvesting, may remain alive for some years, but are unlikely to survive in the long term.

It is possible that extensive disturbance in red/silver beech forest may also lead to a change in species composition. Ogden (1988) suggested extensive canopy openings may ultimately favour red beech, the more rapidly growing and less shade-tolerant of the two species, while lack of disturbance favoured the more shade-tolerant silver beech. It might appear, therefore, that small coupe harvesting may favour red beech dominance, while undisturbed forests may tend towards silver beech dominance assisted by an apparently greater resistance to extrinsic stress by this species (Hosking & Kershaw 1985) and the higher susceptibility of red beech to attack by *Platypus* spp. (Litchwark 1978). However, Stewart (pers. comm.) has found red beech outgrowing silver beech even in small gaps.

Little is known of the factors affecting the development of regeneration and the ecological relationship it has with existing trees. The present study showed a protracted decline of the sparse residual trees after major disturbance. Some trees showed little sign of ill health until 5–7 years after the event, by which time regeneration was over 6 m tall and very dense. It is possible that changes in the soil environment brought about by dense advanced regeneration may be implicated in the decline of the residual trees. Transpiration rates of dense advanced regeneration must overtake those of residual trees in wind-damaged forest, and it is possible to speculate that a transference of mycorrhizal associates occurs from the residual canopy trees to the advanced regeneration. Fruitful areas for future investigation might include monitoring changes in soil moisture, soil organisms, and mycorrhizal associations after disturbance and through the regeneration phase.

ACKNOWLEDGMENTS

We are grateful for the very helpful comments of Dr Glen Stewart, Dr John Herbert, and Mr Bill Faulds who reviewed the manuscript.

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