Pacific Science (1983), vol. 37, no. 4

Dieback in New Zealand *Nothofagus* Forests[1]

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ABSTRACT: Dieback has been observed in New Zealand *Nothofagus* forests for some time, and a number of causal factors have been recognized. Some understanding of the effects of dieback on forest structure has been gained in a study of events after snowfalls had caused partial damage to an area of mountain beech forest. The results of this study are used to interpret the structure of beech forests elsewhere in New Zealand.

Nothofagus FORESTS in New Zealand are generally associated with mountain environments and are consequently subjected to frequent disturbance, often of climatic origin. The effects of these are usually local and contained, but sometimes a relatively minor event may predispose the forest to damage by other, often biotic, agents causing extensive dieback of the forest canopy. As yet, there is little information on the long-term effect of canopy dieback on forest structure or on the characteristics that make one stand vulnerable and another not. An understanding of these factors should make it possible to predict the susceptibility of stands to dieback. Such an understanding is important in the management of these forests.

HARPER STUDY

Two heavy, moist snowfalls in 1968 and 1973 caused extensive damage to the beech forests in some parts of Canterbury, New Zealand. Up to 35% of the trees on the southern facing slopes in certain areas were seriously damaged. Most of this damage involved canopy breakage, but uprooting, tilting, and main stem breakage occurred as well. Main stem breakage involved trees up to 20 cm or sometimes even 30 cm diameter.

Both snow storms caused extensive damage to the forests of the Harper catchment, a branch of the Rakaia River in inland Canterbury. These forests, which clothe the upper valley between 650 m altitude and the subalpine timberline at about 1350 m, cover an area of 5000–6000 ha. The forest is simple monotypic *Nothofagus solandri* var. *cliffortioides* (Hook. f.) Poole (mountain beech) and there are virtually no other tree species (Figure 1).

Two hundred and seventeen permanent plots, each 400 m^2, were established throughout the Harper forests during the 1970–1971 summer (before the second snow storm in 1973). In each plot, all stems of mountain beech were measured for diameter at breast height and permanently tagged with numbers for identity, giving a total of about 21,000 tagged stems. Seedling subplots were established within each permanent plot to estimate seedling densities by height classes. These permanent plots provided an opportunity to gauge the impact of the snow storms, particularly the 1973 storm, on the forests of the catchment as a whole, and to study the long-term effects on forest structure. Each of the plots has been remeasured four times at intervals of about 2 yr.

Significant structural damage from the two snow storms was recorded from nearly 30% of the 217 plots. The mean basal area of the Harper forests decreased from 51.9 m^2/ha to about 50.7 m^2/ha between 1970 and 1974, a loss of about 2.3%. Much of this initial loss could be attributed directly to mechanical damage from the 1973 snow storm, but there would also have been continuing mortality associated with the 1968 event. By the time

[1] N.Z.F.S. No. 1685/ODC 182.2. Manuscript accepted 5 October 1983.
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FIGURE 1. Interior of mountain beech forest. Note general absence of other species.

of the last measurement in the 1980–1981 summer, the basal area was still continuing to decrease substantially (Figure 2) and the mean had been reduced to 46.2 m^2/ha. This represents a net loss, over and above increment, of nearly 6 m^2/ha, or, in other words, 11% over the whole catchment, and it is expected from present trends that the basal area of the forest will continue to decrease further.

Relatively few of the trees that escaped discernible snow damage were responding in terms of growth to the reduced competition associated with these lower basal areas. Indeed, by 1980–1981, many of them were also dying. The incidence of wind damage throughout the catchment has increased since the snow break occurred, and undoubtedly this has accounted for some of the losses.

The initial snow damage was most pronounced in the forests on the lower slopes and river terraces, and many of the stands near timberline apparently escaped unscathed. Subsequent mortality was mostly associated with the areas where snow damage was most severe, but there are recent indications of increasing death of canopy trees in stands that escaped the initial damage. The mechanisms involved here have yet to be elucidated.

A large increase in seedling density has occurred in the catchment since the snow storms (Figure 2). This increase has been especially pronounced in the larger seedling categories. In 1970–1971, seedlings of mountain beech between 76 and 135 cm high were rare, averaging only about 1/ha. By 1980–1981, these had increased to about 43/ha. Seedlings between 46 and 75 cm high increased tenfold from about 34/ha to 390/ha,

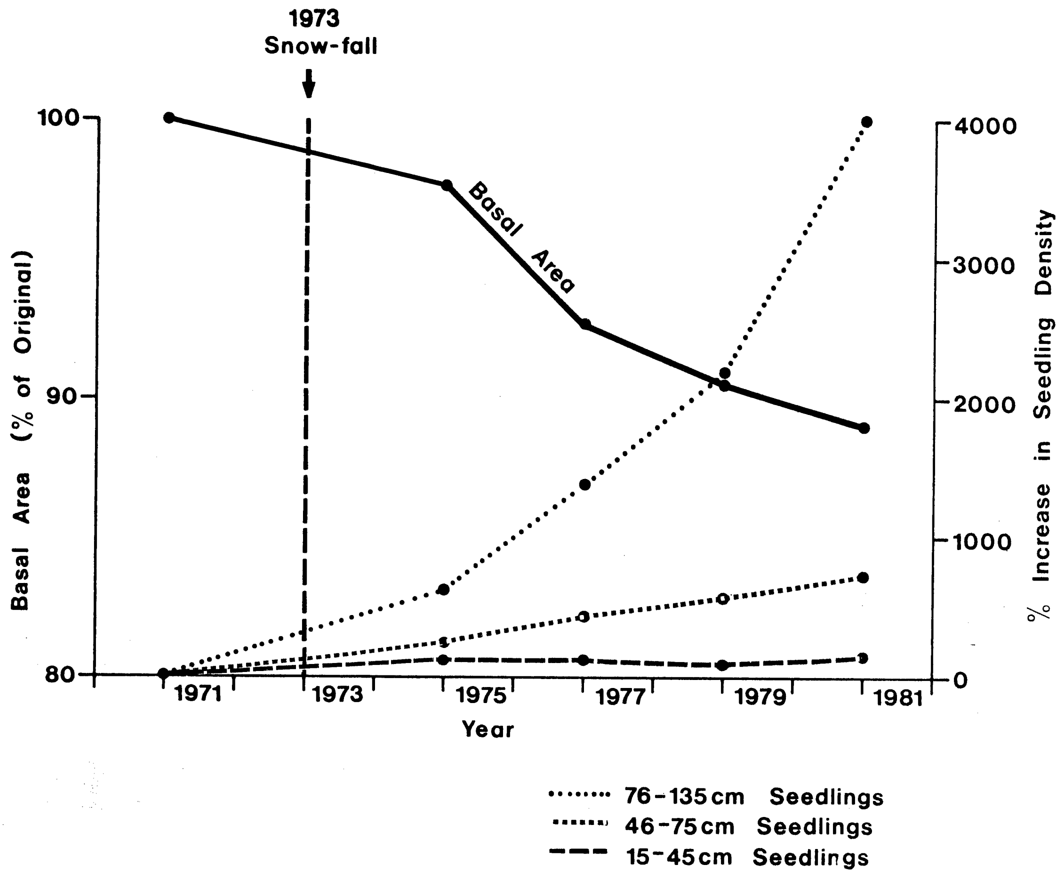

FIGURE 2. Structural changes associated with heavy snow storms in the Harper forests. The diagram shows the mean reduction in basal area of the forests over the whole catchment and growth responses in three height categories of mountain beech seedlings.

while the smaller seedlings (from 15 to 45 cm high) increased by little more than double, from 670 to 1680/ha.

Twenty-eight of the Harper plots suffered notable damage only during the 1973 snow storm. These, with a further 28 randomly selected from the plots which showed no damage either in 1968 or 1973, were studied further to evaluate changes in stand structure resulting from the snow damage. Final evaluation awaits more detailed analysis of the plot data.

The damaged plots showed a reduction in all stem diameter classes, particularly in the smaller classes, between the 1970 and 1974 measurements (Figure 3). Much of this could be attributed directly to the mechanical effects of the 1973 snowfall. In the undamaged plots there was loss during this period from the smaller size classes, but a slight increase in the larger ones. This loss can be attributed partly to competition-related mortality, and partly to through-growth to the larger size classes. There was no compensating recruitment into the smaller size classes from seedlings, since mountain beech is a light-demanding species and stands have a tendency to assume a normal bell-shaped diameter distribution as they develop. The smallest class (2–10-cm diameter) generally continued to show an annual loss of between 4% and 8% throughout the study

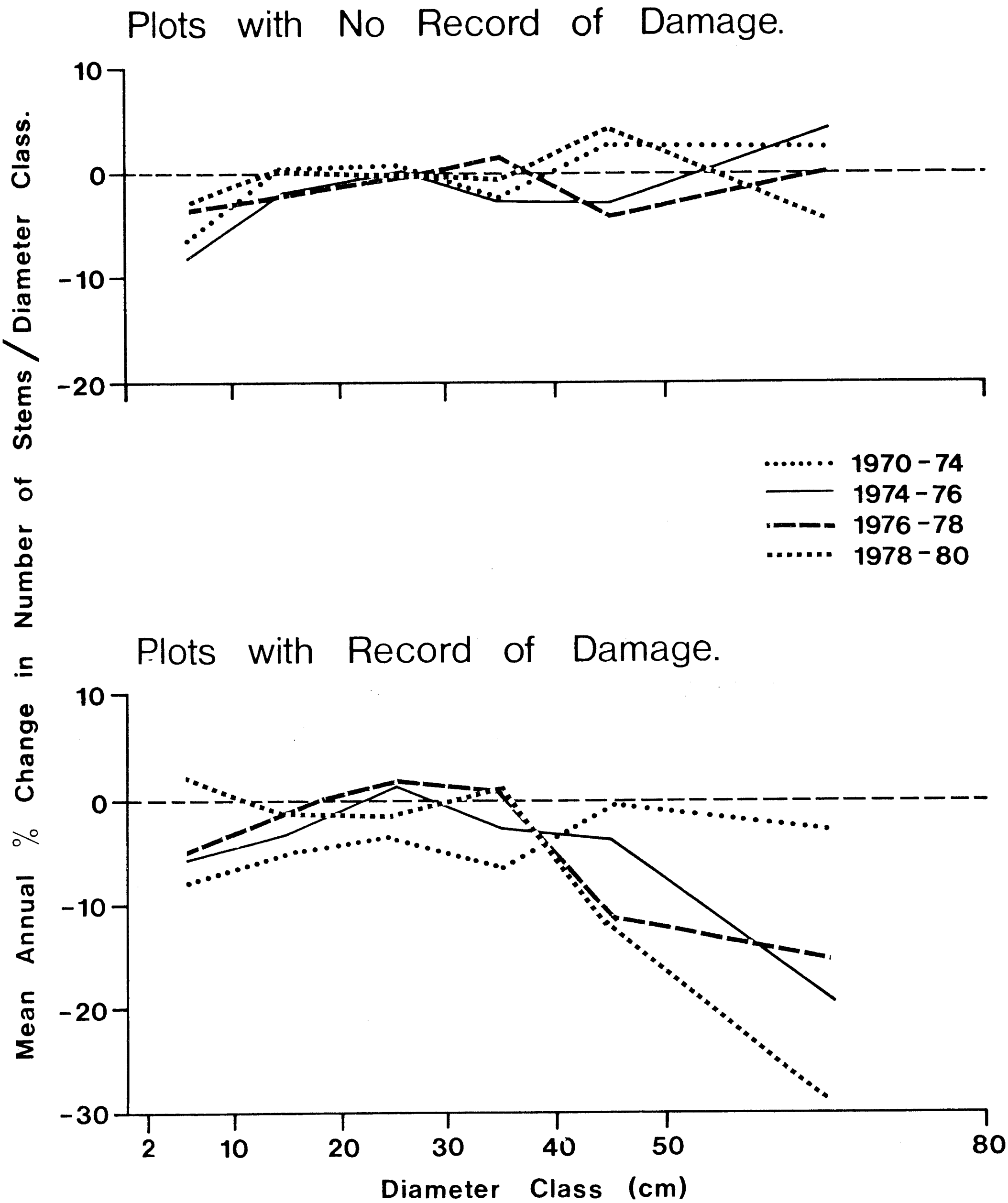

FIGURE 3. Comparison of structural changes that have occurred in snow-damaged and undamaged forests in the Harper branch of the Rakaia River. The data on each graph are based on 28 permanent plots, each 400 m^2.

period in both damaged and undamaged stands, presumably because of through-growth and intraspecific competition. However, the number of stems in the damaged plots actually increased between the last pair of measurements (1978–1980). By this time, the surge of seedlings released by the loss of basal area due to the snow break and related events was beginning to appear as ingrowth into the 2–10-cm class.

The main differences between damaged and undamaged plots occurred in the >40 cm size classes. The number of stems in these larger classes showed little change between measurements in the undamaged plots, with 50.9 stems/ha in 1970–1971 and 53.6/ha in 1980–1981 on the average. However, the number of larger stems surviving in the snow-damaged plots changed dramatically. During the same 10-yr period, the rate of mortality of these trees has increased progressively, until at the time of the last remeasurement, only 21.4 of the original 61.6 stems/ha were alive. Many, in fact probably most, of these larger trees that have died showed minimal evidence of direct mechanical snow damage.

This study indicates that a disturbance such as the 1973 snow storm can cause a reduction in the diameter range, and presumably therefore the age range, of the stems in the affected forest. The damage synchronizes mortality in the larger, older cohorts of the population, and also encourages synchronous regeneration. In this way, the range of ages in any one stand periodically becomes reduced, so that there is a tendency toward the development and perpetuation of an even-aged, or partial-aged, structure.

BEECH FORESTS IN OTHER AREAS

Where events in the past have led to a forest structure with stems uniformly large in diameter over extensive areas, we might anticipate that an event such as a heavy snow storm could lead to mortality rates of catastrophic proportions. Apparently, this has happened in another tributary of the Rakaia, the Moa catchment. In this catchment, most of the trees in the 1000 + ha of mountain beech forest have died. From various unpublished accounts, death in the standing trees seemed to originate in the upper reaches of the valley and then proceeded downstream over a number of years. Extensive areas of wind-damaged forest in the upper valley is the probable originating point for the dieback. The average stem size in the Moa catchment was large, indicating that the forests were old. Mortality was most severe where the trees were of large diameter, and the only areas of forest that escaped were some isolated pockets that had originated after recent disturbances.

Similar catastrophic mortality in mountain beech forest occurred in Tongariro National Park, and circumstantial evidence linked this with a period of relatively low precipitation (Skipworth 1981). There is also an example of extensive recent dieback in *Nothofagus fusca* (Hook. f.) Oerst (red beech) after a period of low rainfall in the Maruia and Inangahua valleys near Springs Junction, west of the Main Divide (C. Gleason, unpublished).

These are recent examples, but the dieback phenomenon in New Zealand beech forests has long been recognized. Early records of apparently excessive mortality in beech forests date back at least to the first decade of this century (Cockayne 1908). Extensive dieback affecting over 2000 km^2 of the beech forests in the Buller area was noted after the Murchison earthquake of 1929 (Rawlings 1953). Extensive dieback in beech forests was also reported after droughts in the 1945–1946 summer in the central North Island (Elder 1962, Grant 1963, Hocking 1946).

Many of our beech forests, especially in the drier mountain ranges, show structural evidence of synchronous regeneration. Many are composed of even-aged, or possibly two-aged, mosaics. Frequently, the sizes of these uniform stands are quite large, and sometimes there has been more or less synchronous development over entire mountain ranges or valley systems.

The mean structure of the mountain beech forests of the entire Wairau and Waitaki catchments (two large catchments in the eastern South Island) was calculated from large numbers of sample plots of the type described for the Harper study. The distribution of basal area by diameter size classes for these mountain beech forests were compared with those for mountain beech forest of the Harper catchment (Figure 4). Quite obviously, the structure of the mountain beech forests in these three areas was very different. From the data collected in the Harper catchment, a plausible explanation is that the dif-

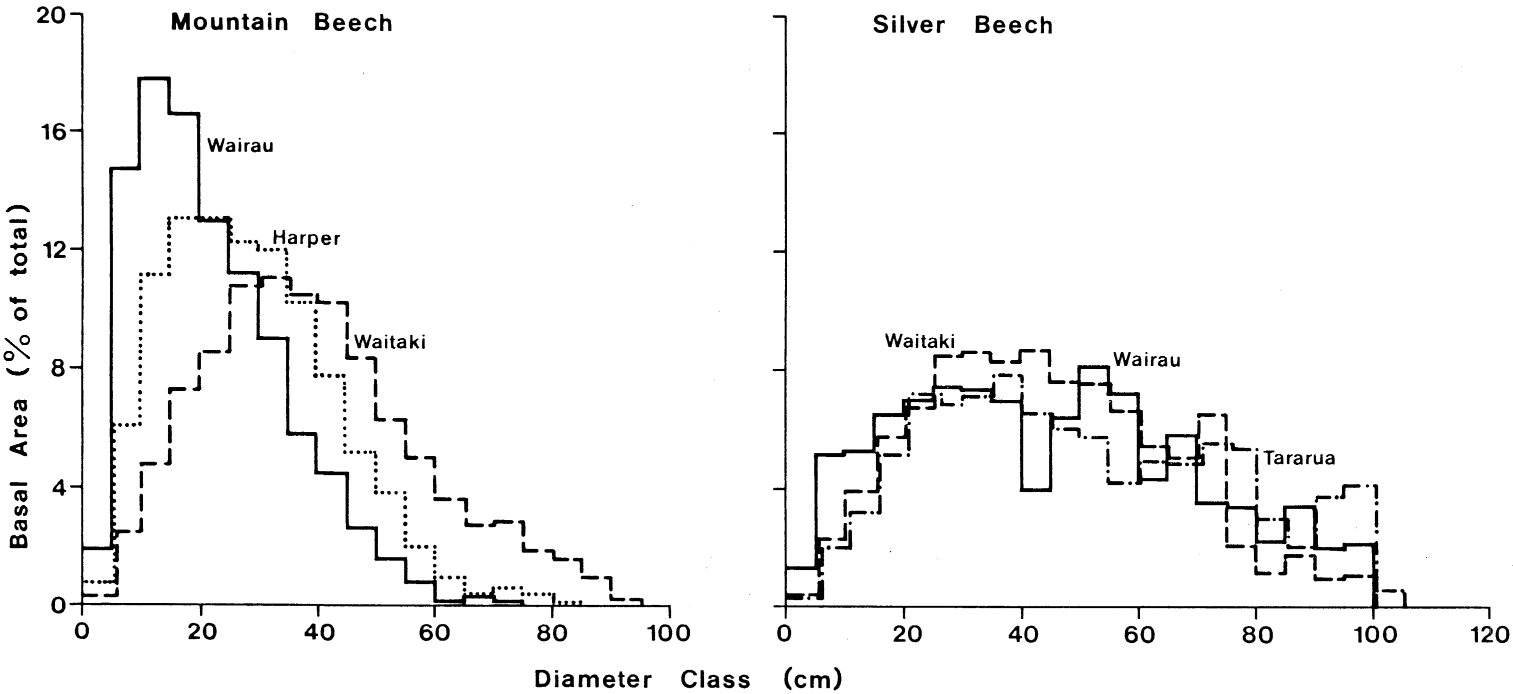

FIGURE 4. Distribution of basal area by diameter classes for all mountain beech stems in the Wairau (249 plots), Harper (214 of the 217 plots were used), and Waitaki (158 plots) catchments; and for all silver beech stems in the Wairau catchment (127 plots), Waitaki catchment (105 plots), and Tararua mountain range (85 plots). In each case, the structure is based on analysis of diameter class frequency distributions from 400 m^2 permanent sample plots.

ferences were associated with synchronous mortality of canopy trees after disturbance to the forest. The Waitaki forests were biased toward the larger size classes and were probably relatively old, whereas, the Wairau forests had a greater representation in the smaller size classes. These forests probably originated relatively recently. The Harper forests were intermediate in structure, and probably also age.

Data from the Harper study, as well as the observations from the Moa, indicate that it was the larger-diameter and presumably older trees in the stand that were most susceptible to the dieback phenomenon. Therefore, we might predict that the Waitaki mountain beech forests are particularly susceptible because they are generally old, and that some physical or climatic disturbance might well lead to extensive dieback. The Wairau forests are relatively young and therefore not so susceptible.

Nothofagus menziesii (Hook. f.) Oerst (silver beech) does not usually show the degree of structural differences between areas shown by mountain beech. The distributions of basal area by diameter classes of silver beech forest in the Waitaki and Wairau catchments were compared with those for the Tararua range in the southern North Island (Figure 4). The structure in all three areas was remarkably similar. Silver beech is relatively shade-tolerant in contrast to mountain and red beech, which are strongly light-demanding species. Silver beech tends to develop mixed-aged structure, even in stands that have originated at one time following disturbance, so that there is not the same potential for dieback to occur synchronously over large areas.

DISCUSSION

A number of examples of canopy dieback in New Zealand beech forests have been described, and an attempt has been made to illustrate its significance in stand dynamics. What ingredients must be present for dieback to occur? Why does relatively minor damage lead to extensive tree mortality in one forest, while in another forest, similar or even greater damage has relatively little effect?

First, the stand must be at a susceptible stage of development. It is suggested here that old, even-aged stands are particularly susceptible, while younger stands, or those with a greater mixture of age classes are relatively immune. There is some evidence from beech thinning trials that dense, competing pole stands represent another susceptible stage in the developmental history of the stand. Late thinning often leads to wind instability, poor growth rates on the retained trees, and excessive mortality.

The second requirement is some form of disturbance or stress. Examples include the snow damage in the Harper forests, possible wind damage in the Moa, drought in the Maruia and central North Island, and earthquake damage in the area surrounding Murchison. There are others. Dieback has been associated with rising water tables after damming of lakes for the production of hydroelectric power (Mark, Johnson, and Wilson 1977) and with felling operations.

The third ingredient seems to be a population outbreak of some pests or pathogens in response to the stressed condition of the trees, the buildup of dead or dying plant material, or for some other reasons.

The beech buprestid, *Nascioides enysii*, and the *Armillaria* root rot fungi have been the most frequently cited pest and pathogen associated with beech mortality (Morgan 1966, Rawlings 1953), but it has subsequently been found that outbreaks of *Nascioides* are secondary (J. S. Dugdale, unpublished). This insect is an inner bark feeder which, as far as is known, does not transmit toxic substances or pathogens to trees. It requires the death of the host tree to complete its life cycle, but does not seem capable of killing the trees itself. It now appears that most of the mortality formerly attributed to *Nascioides* in beech forest was caused by the fungal pathogen, *Sporothrix*, which is often introduced to the tree by ambrosia beetles of the genus *Platypus* (Faulds 1977, Milligan 1972, 1979). This combination of insect and fungal pathogen has been demonstrated experimentally to be capable of killing even healthy beech trees, and to be attracted to attacked trees by aggregating pheromones. It is often, if not usually, associated with the dieback phenomenon.

Undoubtedly, other pests and diseases may be involved. *Armillaria* has been demonstrated to attack beech (Campbell 1962), and high concentrations of fruiting bodies have been observed after forest disturbances (L. H. Roth, unpublished; W. Silvester, personal communication). The scale insect *Inglesia fagi* has also been associated with mortality (D. Kershaw, unpublished). However, the evidence for the association of either of these genera is still circumstantial.

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