Mountain Beech Mortality in the West Ruapehu Forests

J. P. Skipworth, Palmerston North

Introduction

With some localised exceptions, the mountain beech forest of western Ruapehu appears to be in poor health. A large percentage of the standing trees are clearly dead, and substantial expanses of forest appear unsightly with intertwining masses of silvery, leafless, lichen-covered branches. Various aerial photographs suggest that this so-called dieback was not generally in evidence prior to 1967.

The present inquiry involves an attempt to account for this situation and in order to do so several approaches have been taken. It was first of all necessary to understand the general biology of mountain beech. Second, in case the Ruapehu forests happened to be structurally old with many trees having reached senility simultaneously, the age structure of the forest needed to be appraised.

Third, a quest for the cause of what is presumed to be accelerated mortality needed to be undertaken.

General Biology

Wardle (1970 a, b, c, d, 1974) has subjected mountain beech to detailed investigation and the following four paragraphs are based in large measure on his findings.

Mountain beech *(Nothofagus solandri* var. *cliffortioides)* is one of two varieties of an unusually ubiquitous New Zealand tree species. It is associated with a wide range of generally poor soil types and evidently possesses wide climatic tolerances. Throughout much of New Zealand it is the forest at the upper forest/grassland or forest/scrubland ecotone, the mountain beech on the south side of Mt Ruapehu probably being the highest forest in the country. In various parts of New Zealand it occurs at intermediate altitudes yet it descends to sea level in Fiordland. Individual trees may be in excess of 20 m tall but even at maturity they may be very much smaller. At the highest altitude on Ruapehu for example, ring counts indicate that some trees more than 100 years old may be little more than a metre in height.

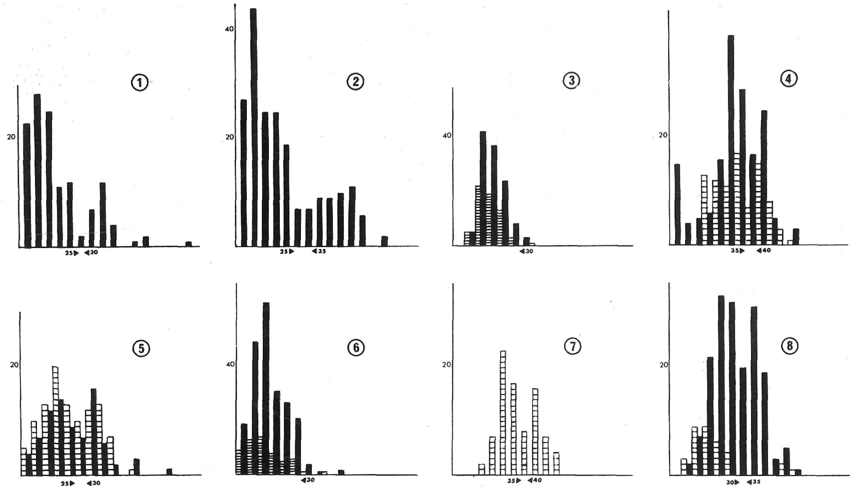
It is the dominant species in a number of distinctive associations, that at higher altitudes on west Ruapehu being representative of one which contains *Phyllocladus alpinus, Griselinia littoralis, Coprosma foetidissima, C. pseudocuneata, Pseudopanax colensoi* and *Astelia nervosa* as common understorey trees and shrubs.

Flowering is an irregular phenomenon. It usually follows a hot dry summer and occurs towards the end of October. Profuse flowering is not necessarily followed by prolific seeding, and the quality of such seed as is produced varies greatly from year to year. Indications are that good years from the point of view of production of an abundance of viable seed occur about once in a decade, with perhaps two or three minor mast years in between.

Seedfall occurs in late summer or autumn and germination takes place the following spring. Seeds are dispersed by wind and are rarely thrown more than a few metres from the tree on which they originate. An important exception to this generalisation is that seeds may be borne by water and germinate on stream banks. Germination conditions are peculiar and perhaps precise, light shade (neither full sunlight nor heavy shadow) being necessary to effect the quick emergence of the embryo and/or early post-embryonic development. The chances of germination and early survival seem much greater if the seed should fall in beech litter. Although seedlings soon become capable of an annual increase in stem length of 30 or 40 cm, the usual situation in a forest with a closed canopy is for seedlings to enter a semi-dormant state during which height increase may be little more than 1 cm per year. A mountain beech plant in a forest may therefore be less than 50 cm in height yet more than 20 years old. Such a plant is of shrublike form and said to be at an "advance growth" stage. Apparently this semi-dormancy can be broken only by the advent of high light intensity, which usually occurs upon the death of canopy trees. Rapid growth characterised by strong apical dominance follows as poles are produced. The larger among these shade the smaller and also outcompete them for soil nutrients with the consequence that only the most vigorously growing survive. Competition, growth and death continue as the new canopy is formed. Theoretically, the only ultimate survivor will be that which spatially replaces the one whose death 100 or more years previously allowed light to break the dormancy of perhaps dozens near the forest floor. As unsuccessfully competing trees die the crowns of the survivors expand and canopy branches become larger. These branches, partly owing to their own weight, finally break, and death of the tree usually follows, probably because infections enter the wound. Mountain beech is probably less deeply rooted than most other tree species.

Age Structure

Relative age structure within stands has been determined from diameter at breast height (D.B.H.). In the literature three are numerous cautionary statements concerning the assumption that age and size are closely related. However, Ogden (1971) has discussed this with respect to New Zealand beech forest, and it seems that providing size classes are not too small, and that there is no attempt to extrapolate from one species or from one site to another, nor any attempt to use size for absolute age correlation, meaningful information can be obtained.



Histograms representing size class distribution at each of the eight sites. Vertical axes = number of trees; Horizontal axes = size classes (5 cm D.B.H. intervals); Solid blocks = living trees; Hatched blocks = standing dead trees.

Trees were measured at eight sites chosen so as to encompass a range of altitude and of aspect and to include both severely damaged and relatively unaffected stands. The sites are summarised in the following table:

Site	Altitude	Aspect	Slope	General
1	1320m asl	NW	10°	Damage light
2	1240	NE	40°	Near ridge top — steep
3	1210	SW	8°	Shady
4	1120	NW	2°	In continuous bush — widely representative
5	1070	NW	1°	Isolated copse
6	1060	N	5°	On stream bank
7	1030	W	2°	In continuous bush
8	890	—	flat	Part of large isolated stand

Thus site 1 is the highest, and trees are apparently least damaged. Site 2 is quite steep, site 3 particular shady, and site 4 is in a large expanse of continuous forest and probably the most nearly symbolic of the forests of the area. Site 5 is a large part of an isolated copse, site 6 might have received seed from a riparian source, at site 7 mortality is total, and site 8 is the lowest. At sites 2, 4 and 8 trees were sampled randomly by the point quarter method with centres along arbitrary lines, and at each of the others all trees in variously circumscribed quadrats were counted. Subsamples were obtained at sites 3, 4, 5, 6, and 7 by separately assessing standing dead trees (with no leaves) and living trees (including those apparently dying but still with some leaves). At each site an assessment of number of seedlings (including plants at the advance growth stage) was made.

All trees in a 50m square quadrat were measured at site 1. There were 128 in total, including nine which had recently died but were still standing. As the histogram (Fig. 1) reveals there was generally an increase in the number of trees in successively smaller classes, although there were fewer than might be expected in the 25-30 cm class. There was no sign of small beech seedlings although some advanced growth plants were present.

Size distribution was similar at site 2 where 199 trees were sampled. There was again a dearth of trees of moderate size, this time in the 25-35 cm classes. There was a higher number of seedlings than at any other site and most of them were at the advance growth stage.

At site 3 trees seemed to be younger. Of 162 only three were over 30 cm and none over 40. There were relatively few in the two smallest size classes. It seemed that mortality had occurred at all ages and in fact in each of the three classes represented by more than 35 trees, the proportion dead was very similar (40.7%, 41.3% and 35.1%). Relative to most other sites seedlings were abundant.

More trees might have been expected in the three smaller size classes at site 4 where 246 trees were sampled, 33.4% of which comprised a standing dead subsample. Mortality was not this time evident in the smaller classes, although both subsamples revealed a dip in the histogram in the 35-40 cm class. Seedlings, particularly young ones, were quite well represented.

More than half of the 189 trees at site 5 were dead though still standing, and in both subsamples there was a suggestion of paucity among smaller classes and in the 25-30cm class. There were very few seedlings.

Site 6 was another at which there were virtually no larger trees. Fifty-three (20%) of the 271 trees measured were dead, and mortality seemed spread throughout the size classes. No small seedlings were noted, although there were some young plants at the shrub stage.

All 83 trees were dead at site 7, where again there were no trees in the smaller classes and an evident scarcity in a medum-sized group (30-35 cm). More trees than at any other site fell into the larger size classes (over 30% were in excess of 40 cm). There was no sign of any individual less than 15 cm.

Two hundred and nine trees were measured at site 8. Once more there seemed a partial lack of trees both in the smallest classes and that embracing 30-35 cm. The majority of the dead trees were small. Some seedlings were present.

Suggestions which arise from this information on size classes will be discussed later, but two features worth summarising at this stage are that there is apparently a regeneration gap among trees of medium age (and perhaps another in the immediate past), and that mortality in all size classes has indeed been high recently.

Boring Insects

Dead trees, apart from some in the smallest size classes, seem almost invariably to have round or slightly oval shaped holes in the bark about 2 mm across. These enter at right angles to the surface and ramify but generally run tangentially, principally in the sapwood. They are evidently caused by both adults and larvae of the indigenous beetle *Platypus*. This species has been known for some time to be associated with *Nothofagus* although the general belief has been that only dead or weakened trees are attacked (Miller 1971). There is strong evidence from marked trees at Ruapehu, however, that the beetles also attack living trees, at least at times of heavy infestation, and indeed this has been demonstrated experimentally in red beech by Milligan (1972). The chances of healthy trees being attacked seems to depend on their proximity to large numbers of infected trees. That is, where there has been widespread mortality, trees initially surviving in, or adjacent to, affected areas, are particularly vulnerable. There is a strong suspicion that fungal infections enter these tunnels, quite possibly via the bodies of the insects. More than one species of fungal pathogen may become established (Faulds 1973) and it could well be that the extraction of nutrients from the ascending xylem flow and the release of poisonous metabolic by-products are more detrimental than the tunnels themselves. *Platypus* has been said by Milligan (1974) to feed on yeasts which become established on the tunnel lining and not on the wood itself.

Rainfall

The facet of the physical environment most amenable to investigation is climate. From 1937 onwards records for precipitation at Chateau Tongariro are complete; prior to that time they are very sparse. Climatic data of other kinds seems not to exist in worthwhile quantity.

Examination of monthly precipitation reveals a very wide range. Over 1000 mm of rain, for example, fell in January and February of 1940, almost twice as much as in those two months in any other year. The February rainfall (1937-1973) has been from 18 mm (1970) to 607 mm (1940), but despite this high February figure, mean values indicate that January, February and March are the driest months (average 1937-1973, 193 mm/month) and May, June and July (average 260 mm/month) probably the wettest. The lowest monthly mean was March (172 mm) and the highest June (275 mm). The figures seem to suggest that monthly precipitation is irregular, but that on average there is not a great deal of difference between wettest and driest times of the year.

The available information permits comparison of years and of groups of years. The total rainfall in the period 1968-72 was 8.8% lower than in the period 1943-67. Summer rainfall in the period 1960-69 was also 8% lower than the period 1940-59. It would be dangerous to attempt to draw too much by way of conclusion from the available figures but some suggestions can be offered. The reduced rainfall in summer (when evapo-transpiration is at a maximum) and the reduction in annual precipitation may, during the 1960's, have caused a drop in water tables and thereby imposed new stresses on trees.

Discussion

Various inferences can be drawn from the information gathered on age structure.

First, at all sites apart from the two at which larger trees were absent, and in all subsamples, there was a partial absence of trees in one or other of the medium-size categories. This suggests a period of low recruitment at some time in the past. Precisely when is not easy to say, and may well vary from site to site. Core borings from trees in the 20-25 cm class suggest an age of something like 100 years for this group and 150 years for the 35-40 cm group. The figures of Wardle (1970 d), which are based on much larger samples collected all over the country, give ages greater by some 25%, however.

At sites 1, 2 and 6 there seems to have been a rise in recruitment rates in the 15-25 cm class, i.e. in trees 75-100 years old. At site 8 recruitment seems to have accelerated about 110-120 years ago and at sites 4 and 7 something like 140-150 years ago. (Extrapolation from Wardle's graph gives somewhat longer periods). Even the minimum of these times is too far into the past for the forest of the time to be remembered, and reliable ecological writings from the turn of the century hardly exist. There is, however, a report on Tongariro National Park by Cockayne (1908). With special reference to mountain beech Cockayne stated that "dead trees still standing and prone are a feature", and that "seedlings and saplings are in abundance". A photograph supports the former comment. One should not of course expect an "abundance" of saplings unless there had been a recent increase in light on the forest floor, an event which would logically follow accelerated death of canopy trees. Neither should one expect dead trees to be a "feature".

It is very doubtful that either comment could be construed as applying to an average mountain beech forest. Was indeed Cockayne's survey undertaken during a period of widespread regeneration following excessive tree mortality? Was the regeneration gap suggested by the absence of medium-sized trees in the present survey a consequence of a period of low recruitment which might well have preceded that excessive mortality?

The second point to arise from present measurements is that at the majority of sites there was an apparent shortage of plants in the smaller size classes. A histogram produced by Wardle (1970 d) based on 49 plots over the whole range of *Nothofagus solandri* in New Zealand also reveals a partial lack of small trees (< 2.5" in diameter), which he attributed to browsing mammals. Wardle's next largest size class (2.5-4.5") was his most prolific, followed by the 4.5-6.5 class. These, which correspond roughly to 5-10 cm and the 10-15 cm classes, differ sharply from the present findings at most Ruapehu sites, and the situation with respect to young trees at sites 3, 4, 6, 7, 8 and perhaps 5 must therefore be looked upon as unusual. A logical explanation could be that the forest at these sites has for some decades prior to the mid 1960's been a maturing one with light mortality and low replacement.

The third point is that mortality to approximately the same extent occurs in young, medium-aged and old trees. Of course there is physically simply not enough room for all seedlings to become mature trees so mortality in all size classes must be expected. Ogden (1971) and particularly Wardle (1970 d) have demonstrated this with *Nothofagus*. What is of interest in that even at a time of accelerated mortality there is little evidence of larger trees being more vulnerable. That mortality is, or has recently been, excessive can hardly be doubted. Of 1,465 standing trees at all eight sites, 450 (30.7%) were dead and perhaps a further 10% were dying. Although dead trees doubtless remain standing for several years, the values are greatly in excess of the 3% per year determined by Wardle (1970 d).

A fourth point concerns seedling density. The evaluations made of this were subjective and it is very easy to arrive at under-estimations unless precise counts are made. Nevertheless it seems certain that there were none at site 7 and that seedling density (including plants at the advance growth stage) was probably less than 1/square metre (10,000/hectare) at sites 4 and 6. At the other sites it was almost certainly above this figure, although it is very doubtful if anywhere maximum densities recorded for red beech of 103,000/hectare (Ogden 1971) or 210,000/hectare (Kirkland 1961) are approached. Based on his figure Ogden has calculated that only 1% of seedlings would need to survive to maturity if the forest was to be maintained. Disregarding the site from which seedlings are absent I estimate that where they are at their lowest density (sites 4 and 6) there are still 5-10 times as many as are necessary to replace the tree crop.

With respect to the boring beetle, pathogenic fungi and precipitation levels, Milligan (1974) has suggested that an important contributary cause of *Platypus* eruption is in fact drought. He saw reduction of wood moisture as something which favoured fungi — "During seasonal drought . . . advance of the fungus may be accelerated." It is not of course certain that the dimunition in precipitation was sufficient to promote the insect and the fungi, but the variation is in the appropriate direction.

It does seem that the forests near the Chateau are old. Over 70% of the trees from the 49 plots in different associations in both North and South Island considered by Wardle (1970 d) were less than 6.5" (16.6 cm) in diameter. In the present study some 37% were less than 15 cm in diameter. Less than 6% of Wardle's samples were over 12.5 cm (31 cm), while nearly 30% from the sites involved in this account were over 30 cm.

Where the proportion of old trees is higher than usual it should follow that a higher-than-usual percentage are susceptible to whatever agent causes trees to die of "old age". In this case it is suggested that the agent of death is *Platypus* and associated fungi, the effects of which have been aggravated by several years, summers in particular, of lower precipitation. Admittedly trees of all ages are dying, but beetle holes, which are universal among dead and dying trees over 15 cm in diameter, are not commonly present in the dead trees from the two smallest size classes. Perhaps the fact that trees in all classes seem approximately equally vulnerable amplifies the suggestion of a reduction in ground water availability because this is one stress factor which would affect young trees as much as old.

The tentative explanation for the present high level of mortality is therefore that reduced precipitation in the 1960's led to lowered water tables, and that this placed trees under extra stress and produced ideal conditions for an eruption of *Platypus* and associated fungi. The magnitude of this was probably accentuated by the unusually high percentage of trees in the more vulnerable larger size classes. Accelerated mortality of small trees is attributed to reduced water alone.

The key to the future of the west Ruapehu mountain beech lies in the seedlings, the survivors, and a return to more average precipitation levels. Where mortality is total and there are no seedlings, as at site 7, there can only be gradual re-establishment over scores of years; there might at best be the typically slow migration into the devastated area from its periphery. There are other sites in the locality similar to 7 but they are not widespread in the region as a whole. At all the other sites examined there were seedlings and survivors which should continue to shed viable seed at least in some years. These areas should all remain as beech forest, although they will not look healthy until the dead trees have fallen. The possible impediment is a further deterioration in soil water availability, although figures since 1973 indicate that there has been a return to the 1940-60 average.

Reference has been made to a possibility based on the observations of Cockayne (1908) that mortality similar to that of the immediate past may have occurred some 80-100 years ago. Another has been made to a possible regeneration gap preceding that period. An hypothesis based on these suggestions would be that the present-day visitors who find dying beech so commentworthy might simply be witnessing a phase in a cycle which is repeated ever 100-150 years.

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