Demography of treeline mountain beech as a guide to lahar events

G L Rapson, M Severinsen and A White
Department of Ecology
Massey University

Published by
Department of Conservation
Head Office, PO Box 10-420
Wellington, New Zealand

This report was commissioned by Tongariro/Taupo Conservancy

ISSN 1171-9834

Reference to material in this report should be cited thus:

Rapson, G.L., Severinsen, M. and White, A, 1998
Demography of treeline mountain beech as a guide to lahar events. *Conservation Advisory Science Notes No. 210,* Department of Conservation, Wellington.

Keywords: mountain beech, *Nothofagus solandri,* demography, lahars, Tongariro National Park

Abstract

Mountain beech (*Nothofagus solandri* var. *solandri)* trunk diameters were measured in each of two catchments, a control, and a stream catchment (a putative lahar path), to assess the vulnerability of a hut sited on the Wakapapaiti Stream, Tongariro National Park, to disturbance events. Beech forest margins were more abrupt, terraced, and were adjacent to rocky areas in the stream catchment, while high altitude forest lacked sapling classes, but had a higher density of seedlings. Erosive events appear to have occurred in the stream catchment in the past 100 years, indicating the hut site may be vulnerable to future disturbance. The most recent large past disturbances appear to have been flood events, and the site may be vulnerable to large lahar events flowing in unusual paths.

1. Introduction

Mt Ruapehu,Tongariro National Park, North Island, New Zealand, is an active volcano, which experienced minor eruption events of the phreatic (steam eruption) and phreatomagmatic type (explosive water and magma eruption) from 18 September - 14 October 1995, and 17 June - 27 July 1996 (ash eruptions). These generated a number of small lahar events, where water (either melted snow, or water from sources such as the Crater Lake of Mt Ruapehu), mixed with rock debris, ash and gravels, is ejected. On the upper slopes of the volocano, laharic material moves rapidly (e.g. 15-20 ms^{-1} Houghton *et al.* 1996) as a series of pulses down existing or dry stream beds. These may cause substantial damage during their passing, eroding gravel deposits and other material alongside streams (Palmer 1991; Cronin *et al.* 1997).

The Whakapapaiti catchment has been the primary north-western route for lahars from the Crater Lake of Mt Ruapehu for the past 9500 years (Palmer 1991). The recent lahars entering the Whakapapaiti basin (22 June 1969 and 24 April 1975 - Otway *et al.* 1995; and more recently 23 and 27 September 1995 - Houghton *et al.* 1996, and H. Keys, *pers. comm.)* progressed down to altitudes of 2200-1200 m, but larger events have occurred in the recent past (Palmer, 1991). Such events could threaten the safety of existing tramping huts which are often sited near streams. Whakapapaiti Hut is such a hut (Fig. 1), situated at 1360 m, just below treeline, on one of the three major tributaries draining the Whakapapaiti basin. In 1975 a lahar did pass the hut, having apparently crossed from another tributary of the Whakapapaiti where there was a larger flow (H. Keys, *pers. comm.).*

Because lahars may disturb vegetation surrounding their paths, such damage might be useful in dating the occurrence of lahars which are older than recorded events, but which have not left recognisable deposits (as found by Palmer, 1991, and Cronin *et al.* 1997). A potential source of evidence might be the dominant treeline-forming species, mountain beech *(Nothofagus solandri* var. *solandri),* which lives to 300 (and occasionally to 360) years and grows up to 1500 m on Mt Ruapehu (Wardle 1970, 1984). Demographic features of mountain beech, such as single-aged stands, missing cohorts, or forest edges which are more abrupt than normal ecotones, might indicate the past occurrence of lahars.

2. Objectives

1. To examine the size pattern in mountain beech trees near the treeline near Whakapapaiti Hut.

2. To assess whether this demography can be attributed to the effects of disturbance events.

3. On the basis of known lahar history/frequency (Palmer 1991; Otway *et al.* 1995) and disturbance patterns, to assess whether such disturbance events more likely to be due to lahars, rain-induced floods, mass movement or some other event.

4. On the basis of available information, to speculate on the vulnerability of the hut to the disturbance events.

3. Methods

Demographics of beech were compared in the Whakapapaiti basin on a pair of transects in each of two catchments - the eastern stream catchment beside the hut ("Stream"), and a small adjacent catchment ("Control") which enters the eastern stream bed just above the hut, but which has its own catchment head a few metres above treeline, and so is not exposed to lahar events (Photos 1-3). One pair of transects was sited just below treeline at about 1420 m and the other 40 m lower in altitude and 20 m above the existing hut. Each transect extended right across the gullies of the catchments, and at least 10 m into the beech forest on either side. The upper transect of the stream catchment was not fully aligned, as the nearby treeline is irregular, but both portions are only 5 m (horizontally) below the current treeline. The North-facing portion starts about 5 m horizontally and vertically from the stream bed (which is in a gorge at this point), while the south-facing transect is about 80 m further up the stream, 10 m higher in altitude, and is similarly displaced from the streambed, on a terrace 5 m above the stream.

In 2 m long segments along the transects, beech sizes (trunk diameter, at breast height, or lower where the trunk was branched) for all trees greater than 1 m in height were recorded in a 4 m wide belt during May 1997. Density of beech seedlings up to 1 m in height (and all <2 cm diameter at base) was also recorded for each transect.

4. Results

Maximum beech sizes on the two upper transects are smaller at this altitude (Table 1), and size classes differ between catchments (Fig. 2). The control transect's south-facing slope (on the right in Fig. 3) had a recently collapsed canopy, probably due to snow-break, and this is reflected in the relative paucity of seedlings (Table 1). The few larger trees and high proportion of saplings suggest similar disturbances have occurred in the past (Figs 2,3). Mean tree sizes are higher in the upper stream transect because of the relative lack of sapling classes, i.e., trees <15 cm diameter (Fig. 2); however, the density of seedlings is the highest recorded (Table 1), indicating healthy regeneration.

Both lower transects show good regeneration (Table 1), with a large number of saplings (Figs 4,5); the few very large stems possibly represent "relics" from a past forest cohort. There is no apparent difference in size classes between the two catchments, indicating that processes are similar in both at this altitude.

The lower control transect crosses a small wetland which is underlain by peat to a depth of at least 1 m, indicating the stability of the catchment; here there is apparently no marginal expansion of beech, as the beech adjacent into the wetland is dense and of uniform size (Fig. 5). The stream catchment has abrupt forest edges, and few saplings are present at or near the margin of the forest (Fig. 5). By contrast, the high density of seedlings in the stream catchment indicates good regeneration, and there is stream-ward expansion of the beech population from the forest margins.

The control catchment has smooth topography, apart from some gullying of the small drainage channel in its upper reaches. In contrast, in both upper and lower stream transects, the forest margins are on small terraces of 1-2 m in height above the adjacent surfaces. These surfaces, closer to the current stream bed, are vegetated with short turf, grass or shrub communities and contain a high proportion (60-90%) of stony and rocky material. By contrast, all the forested surfaces have well-developed soil profiles with a shallow litter layer (1-2 cm) overlying a 0.5 cm deposit of ash, apparently from the 1996 sequence of eruptions (Cronin *et al.,* 1996), and itself overlying more litter and buried organic horizons.

5. Discussion

Small lahar events in the Whakapapaiti catchment occurred in 1969, 1975, 1995 and 1996, the more substantial of these (1975, and 27 September 1996) reaching vegetated zones. Larger events have extended well below treeline, rendered highly mobile by water expelled from the Crater Lake (Palmer 1991; Cronin *et al.* 1996). These have left laharic deposits (chaotically sorted diamictons) on top of Taupo Tephra (i.e. more recently than 1850 years) at least down to 1200 m in the Whakapapaiti catchment (Palmer 1991). However,"snow slurry" lahars are particularly buoyant, and may contain little sediment (Cronin *et al.* 1996), travelling considerable distances without leaving (recognisable) deposits (Cronin *el al.* 1997). Since mountain beech lives up to 360 years (Wardle 1984) demographic patterns might be useful to date such lahar events and assess their impacts near treeline.

The two upper transacts sampled here have smaller maximum sizes than the lower transacts, possibly reflecting a gradual upslope movement of beech over the past few hundred years. Causes of past treeline depression might be volcanic disturbance, erosion, or climate change.

The mean tree size is higher in the stream catchment (Table 1) than in the control catchment, as the age structures differ due to the lack of sapling classes, and a bias towards more larger trees. This suggests that a mature cohort is moving through the population, particularly for the south-facing upper stream section. Similarly Skipworth (1981) shows a mean diameter at 1320 m on Mt Ruapehu of 17.3 cm (assigning diameters to the middle of each of his size classes) in a study of the extent of mountain beech dieback. Though he comments that his high altitude site is the least damaged, some size classes were under-represented, and seedlings were few. While he attributed such patterns to damage by the boring insect *Platypus* and associated entry by fungi, aggravated by drought periods, this cannot explain catchment-related differences here. These appear to suggest that beech demographic patterns have been reset some time in the past in the stream catchment.

Thus the stream catchment shows several signs of past disturbance compared with the control catchment. These signs are:

- occurrence of small terraces along the forested margins of the stream;
- presence of rocky or stony (apparently eroded) surfaces near the stream;
- distance of the ecotonal vegetation zone from the stream channel;
- abrupt margins to the forest vegetation;
- paucity of saplings in the upper transact;
- extensive recent regeneration via seedlings;
- presence of seedlings outside the forest margins;
- a cohort of apparently younger trees beside the stream.

Recorded diameter growth rates for mountain beech, probably over a range of altitudes, on Mt. Ruapehu are 0.33 cm/year (Wardle 1984), while Skipworth (1981) noted values ranging from 0.20-0.27 cm/yr in west Ruapehu forests (near those studied here), and probably also over a range of altitudes. This compares with 0.20 cm/yr at treeline in the Mangaturuturu catchment, on the southern side of Mt Ruapehu (V Nicholls, *pers. comm.).* Coring in the upper Whakapapaiti catchment gives a diameter growth rate of 0.15 cm/year

(A. White, *pers. data).* Thus growth rates are extremely slow in these high altitude environments.

There is an apparent under-representation of smaller size classes in the upper stream transect (saplings <15 cm in diameter). This suggests that a disturbance event could have occurred within 100 years, though none is recorded. In any case such an event must have been minor, as larger stems were not affected by it, and there is no sign of it reaching the lower catchment just above the hut. However, the high density of seedlings in the stream catchment may reflect a recent recruitment event, perhaps as a consequence of the 1975 lahar, as most seedlings (<1 m in height) are <25 years old (M. Severinsen, *pers. data).*

The terraces, eroded surfaces, margin location and abruptness, poor past recruitment of saplings, and recent marginal spread of beech suggest that such disturbance events were erosive in nature. Demographic evidence cannot determine whether the likely disturbance events were lahars (i.e. of volcanic origin) or large floods induced by heavy rainfall. In the adjacent forested areas there is no indication of gravel deposits and other laharic materials such as might be found on the trailing edges of a lahar track, particularly one nearing its terminus; however, the heavy rate of litter deposition could cover such materials within a few decades.

The Whakapapaiti Hut is situated on an open river flat about 30 m from the stream, and 1-2 m higher. Above it is a terrace (3 m higher again) covered in grassland-shrubland, and apparently the toe of an old landslip from the huge moraine ridge which runs parallel to the Whakapapaiti valley above the hut. Though the surface upstream of the but is forested, that adjacent the stream is covered in rocks and shingle, and it is unclear whether the openness reflects an erosive disturbance event or is a consequence of a frost pocket.

The primary Whakapapaiti stream path is, at the altitude of the hut, two small ridges of unknown origin and approximately 0.7 km to the north-west of the stream catchment examined here, merging with it about 1.6 km below the hut. This is the path which the recent (1995/96) lahars mapped on this part of the mountain would have followed, had they sufficient impetus (Fig. 1), and which has been the main lahar path off the Whakapapiti Glacier in the recent past (Palmer 1991). Observation of this valley indicates that it has received past erosive events, as the stream bed and surrounding surfaces are broad and lacking in forest. However, there is no obvious sign of the single-age cohorts of mountain beech which can be found in response to lahar damage which is extensive in nature, though low in frequency (return time of >50 years; V Nicholls, pers. comet.). Detailed examination might provide dates for some of the post-Taupo events recorded by Palmer (1991) for this lahar path.

To enter the eastern catchment and flow past the Whakapapaiti Hut, a lahar would have to overflow the primary stream path; this is most likely to occur 370-400 m in altitude above the hut, and 2.5 km further upstream, where the head of the eastern catchment abutts the main stream bed, and where there are only minor topographical barriers (Fig. 1). This implies that a lahar would need to branch at this point, contributing to both stream paths, as has occurred with past lahars from this volcanic centre (Houghton *et al.* 1996).

However, because of the steep and channelled nature of the main stream bed, only a large lahar would be able to overflow the primary Whakapapaiti Stream path, and enter the eastern catchment near the hut. A lahar entering the eastern upper branch of the main Whakapapaiti Stream would have a greater possibility of entering the catchment above the hut (area above circle on Figure 1). Though this route has not been recorded as a significant lahar path in the last two millennia (Palmer 1991), it was the site of the crossover which occurred in 1975, when a lahar flowed past the Whakapapaiti Hut (H. Keys, pers. comm.). It is unclear how frequent such an occurrence might be. Nor is it clear whether such probabilities would differ for the fluid, mobile "snow-slurry" type of lahar (Cronin et al. 1997) which is generated by large supplies of water (from the Crater Lake, or from a deep snow-pack), and a drier lahar containing a higher proportion of sediment and larger rock fragments, such as might occur later in an eruption episode, or during the warmer seasons or climatic periods.

6. Conclusion

Demographically, a past laharic event (i.e. an event outside the normal flood-based erosion events), would be indicated by a single-aged cohort of beech, perhaps with occasional larger trees, as relics or survivors of a previous forest cover, which acted as seed sources for recolonisation. While there is no such demographic evidence of a lahar affecting the region above the hut at least within the last 300-400 years, such an event is possible in the future. The current location of the but makes it vulnerable to an extreme erosion event whatever its source. Probably high rainfall events generate the greater risk, as El Nino Southern Oscillations in climate make extreme storm events periodically likely. Given this situation, consideration might be given to relocating the hut to a higher surface further from the stream, or to introducing some appropriate signage and early warning mechanism for hut occupants, especially since Ruapehu is considered "overdue for a very large eruption" (Otway et al. 1995), such as might jump catchments to affect the Whakapapaiti Hut.

7. References

Cronin, S.J. (1996). *Elemental deposition rates of the 17-19 June 1996 Ruapehu ash falls*. Contains *The distribution map of June 17-27, 199 Ruapehu ash falls*, by S.J. Cronin, VE. Neall, A.S. Palmer, and J.A. Lecointre. Department of Soil Science, Massey University, Palmerston North.

Cronin, S.J.; Neall, VE.; Lecointre, J.A.; Palmer, A.S. (1997). Changes in Whangaehu river lahar characteristics during the 1995 eruption sequence, Ruapehu volcano, New Zealand. *Journal of volcanology and geothermal research, 76,* 47-61.

Cronin, S.J.; Neall, VE.; Lecointre, J.A.; Palmer, A.S. (1996). Unusual "snow slurry" lahars from Ruapehu volcano, New Zealand, September 1995. *Geology, 24,* 1107-1110.

Houghton, B.; Neall, V; Johnston, D. (1996). *Eruption; Mount Ruapheu awakes!* Penguin Books, Auckland.

Otway, PM.; Hodgson, K.A.; Nairn, I.A. (1995). *Whakapapa skifields lahar study*. Confidential report prepared for the Tongariro/Taupo Regional Office of the Department of Conservation by the Institute of Geological and Nuclear Sciences, Wairakei Research Centre, Wairakei,Taupo.

Palmer, B.A. (1991). Holocene lahar deposits in the Whakapapa catchment, northwestern ring plain, Ruapehu volcano (North Island, New Zealand). *New Zealand journal of geology and geophysics, 34,* 177-190.

Skipworth,J.P (1981). Mountain beech mortality in the west Ruapehu forests. *Bulletin of the Wellington Botanical Society, 41,* 26-34.

Wardle, J.A. (1970).The ecology of *Nothofagus solandri.* 4: Growth, and general discussion to Parts 1 to 4. *New Zealand journal of botany, 8,* 609-646.

Wardle, J.A. (1984). *The New Zealand beeches: Ecology, utilisation and management.* New Zealand Forest Service, Christchurch. 447 pp.

8. Appendices

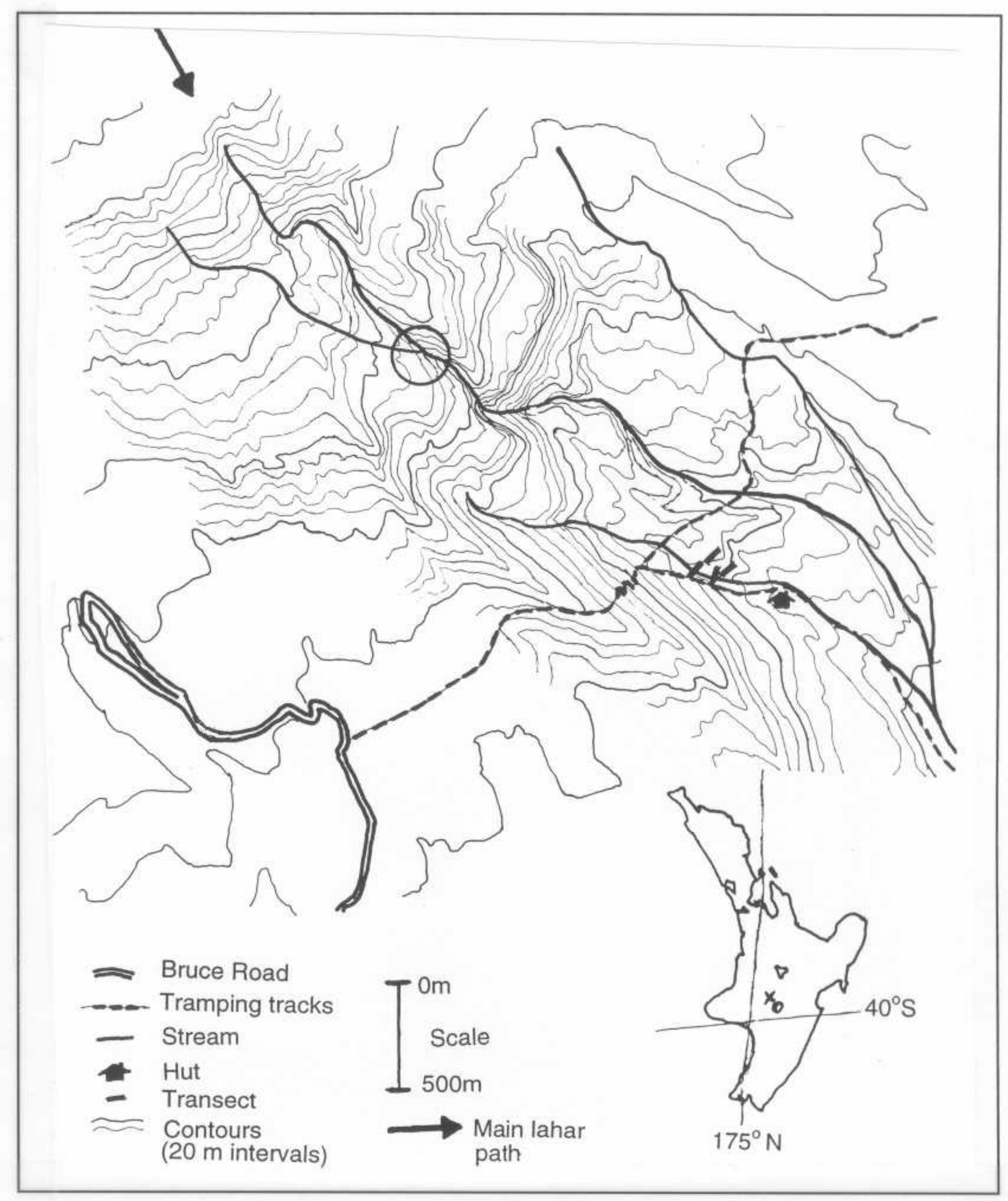

Figure 1. Topography of study area, showing stream catchment and control transects and hut in the Whakapapaiti basin. The main lahar path is arrowed, and the most likely site of a between-catchment `jump' before a lahar could threaten the hut is circled. Inset: Location of study site (x) in Tongariro National Park below the Crater Lake (o).

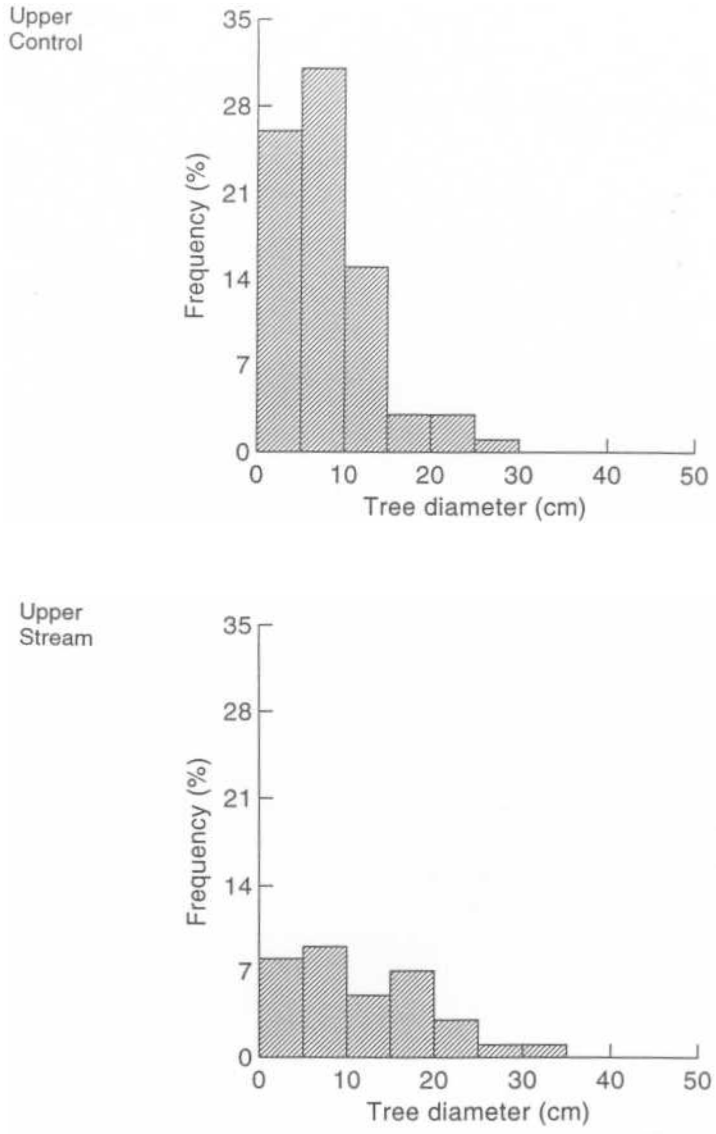

Figure 2: Frequency of beech trees in 5 cm diameter classes for the upper transects of the control (above) and stream (below) catchments.

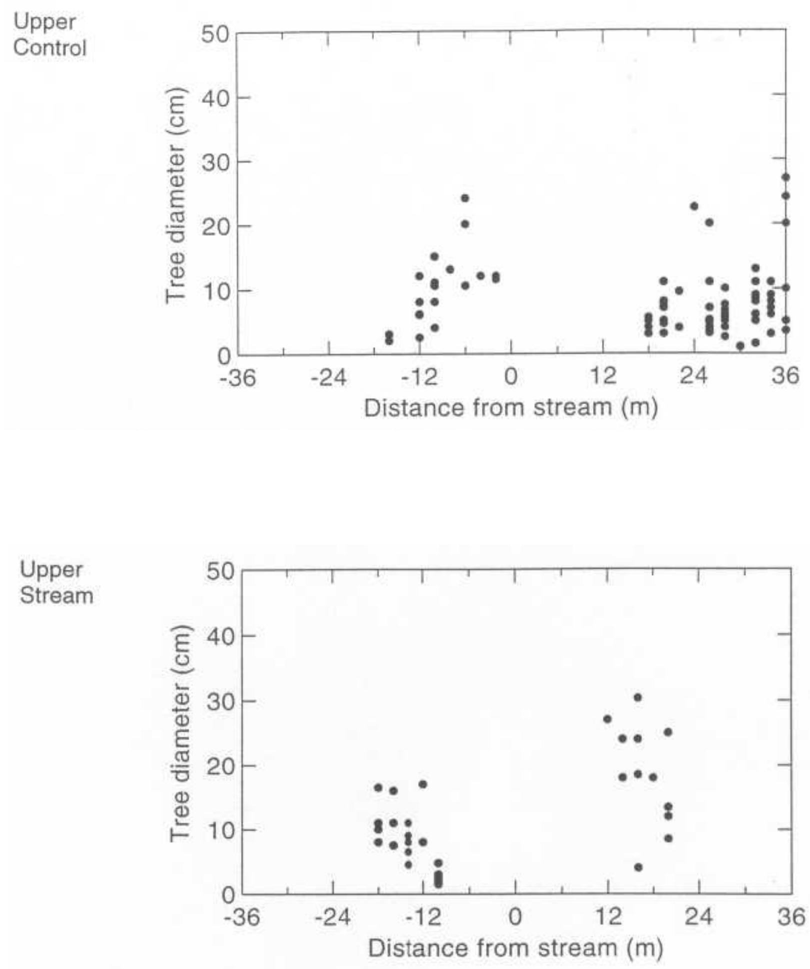

Figure 3: Beech tree diameters along the upper transects in the control (above) and stream (below) catchment, with the north-facing slope on the left, and the south on the right. Distances are plotted with respect to the centre of the gully, called "stream" even though water flow is minimal in the control catchment. Note that the stream transect is actually displaced from the stream and incompletely aligned (see Methods).

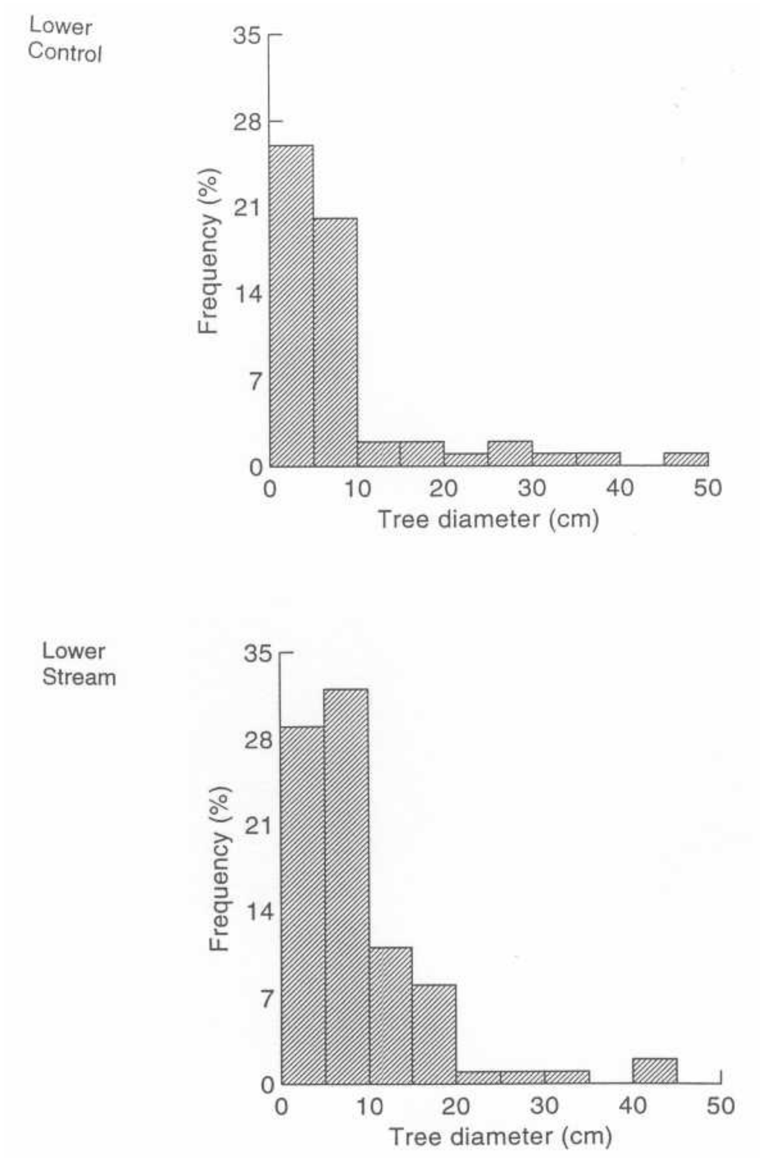

Figure 4: Frequency of beech trees in 5 cm diameter classes for the lower transects of the control (above) and stream (below) catchments.

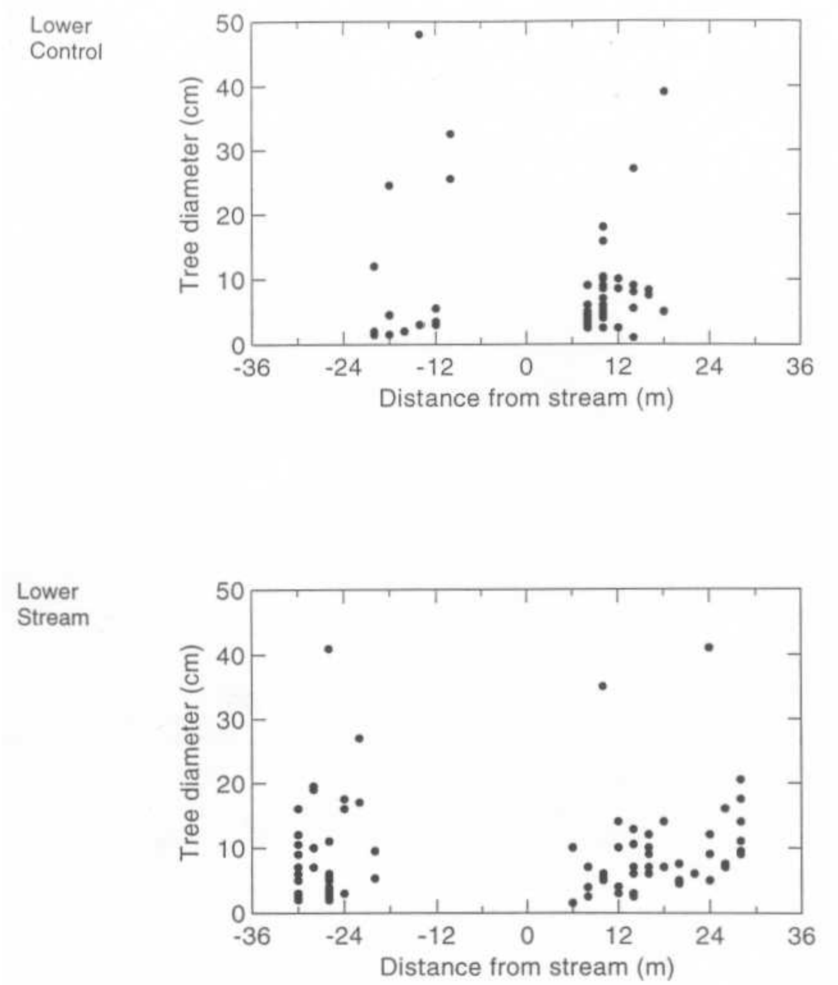

Figure 5: Beech tree diameters along the lower transects in the control (above) and stream (below) catchment, with the north-facing slope on the left, and the south on the right. Distances are plotted with respect to the centre of the gully, called "stream" even though the open area is a bog in the control catchment.

Table 1: Maximum and mean tree (>1m in height) diameter of all trees in each transect, and density of beech seedlings per square metre of the portion of each transect containing beech.

	Maximum tree size (cm)		Mean tree size + s.d. (cm)		Density of seedlings m^{-2}	
Catchment	Stream	Control	Stream	Control	Stream	Control
Upper transect	30	27	12.0 + 7.8	8.3 + 5.5	1.4	0.1
Lower transect	41	48	9.1 + 7.7	8.8 + 9.4	1.2	0.7

Continue to next file: casn210a.pdf