Report Number
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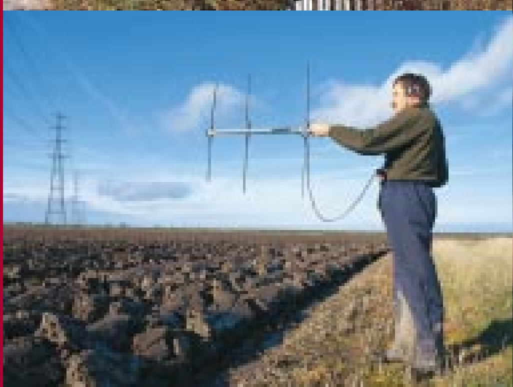
English Nature Research Reports



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Storm-damage and vegetation change in East Hampshire beechwoods
II. Noar Hill Hanger

Edward P. Mountford [1] and Giles Groome [2]

[1] Oxford Forestry Institute, c/o 4 Cheviot Close, Worcester, WR4 9EB
[2] Surrey Wildlife Trust, School Lane, Pirbright, Surrey, GU24 0JN

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Preface

English Nature is grateful to Ed Mountford and Giles Groome for the opportunity to include this report in its research report series. This should help to ensure that knowledge of the permanent ground vegetation plots at Noar Hill Hanger is maintained. The work was however done independently of English Nature and any views expressed are not necessarily those of English Nature and its staff.

Keith Kirby, English Nature

Acknowledgements

This study has relied on the input of several individuals and organisations. Sir James Scott of Rotherfield Park Estate and the Nature Conservancy Council/English Nature have retained Noar Hill Hanger as a non-intervention reserve since the storm of 1987. Recording was initiated as part of the NCC's interest in studying the ecological effects of the 1987 storm. This was supported by Hampshire Wildlife Trust and Farnborough College of Technology, and has benefited from the input of Ian Blair-Brown, Catherine Chatters, Jonathon Cox, Keith Kirby, Adrian Knowles, George Peterken and Tony Whitbread. Fieldwork was carried out by Giles Groome of Farnborough College of Technology in 1991; Patrick Stileman and Kevin Young of Hampshire Wildlife Trust in 1993; and Anne Hargreaves and Ed Mountford of Oxford Forestry Institute in 2000. Fieldwork in 1989/90 was carried out by lecturers and students from Farnborough College of Technology and volunteers from Hants and Isle of Wight Naturalist Trust, including R. Allen, R. Baker, Miles Brown and Chris Fairbrother. Anne Mountford input all the records onto computer spreadsheet.

Summary

Noar Hill Hanger is an ancient semi-natural beechwood, growing on a steep, chalk slope in southern England. It was severely damaged by the Great Storm of 1987 and part was consequently set-aside as a non-intervention area to allow the vegetation to develop naturally. Changes in the ground vegetation within this area were recorded in fifty, 1x1m quadrats positioned at 10m intervals along two permanently marked transects. Recordings took place in 1991, 1993 and 2000.

Prior to the 1987 storm much of the reserve was dominated by mature beech stands. The storm caused widespread damage, blowing down many canopy trees, though in some places the ground remained shaded where medium-sized trees and shrubs survived. More canopy trees were lost in storms in 1990 and by the time recording began in summer 1991, 64% of the quadrats were classified as open. By summer 2000, half of these had substantially closed over due to ash regeneration and/or the development of surviving shrubs and low branches/basal sprouts on canopy beech trees.

By summer 1991, plant cover and the number and density of species had apparently increased in most quadrats. Increases were greatest where the canopy opened most, but lesser increases were apparent even where an overhead canopy remained. Ground vegetation cover continued to generally increase up to at least the sixth growing season after the 1987 storm. Thereafter it plateaued in open areas and declined substantially where the overhead canopy had remained more-or-less closed. The total number of species present also declined. The decline was greatest in quadrats that had been open but had become over-shadowed, but also occurred in quadrats that remained open as *Rubus* and/or *Clematis* spread and displaced shorter, less-competitive species.

The total number and number of ground vegetation species per quadrat changed little during 1991-2000. However, turnover of species was substantial, probably reflecting the irregular dispersal and germination of seed and continued disturbance through tree fall (notably in 1990 storms) and root plate collapse. Species recorded in 1991-93 included many that tended towards a competitive/ruderal established strategy. Although these remained prominent in 2000, they had declined and the majority of the most abundant/frequent species now tended towards a stress-tolerant/competitive strategy.

Before the storm struck *Mercurialis perennis* probably formed several extensive colonial patches beneath the closed stands. There was little indication that it suffered due to canopy opening and had the highest cover of any species in 1991/93. However, by 2000 it had declined in occurrence and cover, and only at the base of the main slope where the canopy remained more-or-less closed did it still form substantial patches. Its demise was linked mainly with the spread of *Rubus/Clematis* in open areas and elsewhere with the spread of *Hedera* and/or development of ash regeneration or existing hazel bushes.

Rubus fruticosus agg. was probably present in small gaps before the 1987 storm. By 1991 it had colonised open quadrats widely, but growth was slow and its cover remained mostly limited. By 1993 its cover had increased substantially, and by 2000 almost half of the remaining open quadrats were covered by dense thickets of *Rubus*, especially those on the main steep slope. Trends in *Clematis vitalba* were similar to *Rubus*, except that it increased more slowly, to a lesser extent, and spread moreover on the clayey upper plateau. As *Rubus* and *Clematis* spread in open areas, they smothered and displaced other less-competitive

plants. The main limitation to both was shade from developing ash regeneration and/or shrub/sprout growth.

Hedera helix appeared to have been rather limited before canopy opening. During 12991-2000, it remained moderately frequent and increased in cover to the second most abundant species. It spread strongly in quadrats on the clayey plateau and main slopes where the canopy changed from open in 1991 to closed in 2000. This was linked with the development of ash regeneration, hazel/hawthorn bushes, or low branches on beech trees. It spread mainly at the expense of *Mercurialis perennis* and *Brachypodium sylvaticum*.

Two moss species also increased substantially: *Hypnum cupressiform,* which occurred primarily on fallen dead wood, and *Fissidens taxifolius,* which grew on bare soil.

Most of the other more frequent ground vegetation species that were recorded had spread into areas opened up by the 1987 storm. Most notable were *Geum urbanum, Euphorbia amygdaloides, Galium aparine, Brachypodium sylvaticum, Cirsium arvense*, *and Urtica dioica.* By 2000, however, these had declined. Many other ruderal species were present but never became frequent and several did not persist. Although many typical, gap-phase, ruderals associated with dry, calcareous beechwoods were recorded, some were less numerous than in other studies or went unrecorded.

Contents

1. Ground vegetation

1.1 Introduction

The Great Storm of 16 October 1987 damaged many woods in Hampshire and across southern England. Some mature woods were virtually levelled (eg Mountford & Peterken 2000), whilst others suffered lesser blow downs, occasional uprooting, or scattered crown breakage (Grayson 1989; Whitbread 1991; Allen 1992; Kirby & Buckley 1994; Peterken 1996). Mature stands that had been closed and heavily shaded for many years were opened, providing an opportunity for ground vegetation and tree regeneration to flourish.

Ecological interest into the immediate and long-term effects of the storm was co-ordinated into a programme of research lead by the Nature Conservancy Council (Whitbread 1991). A number of sites were identified where a policy of non-interference was adopted so that natural changes could be recorded and monitored over time. This report provides details of one such site in east Hampshire, and another study conducted at the Ashford Hangers National Nature Reserve (Mountford & Ball 2003). It adds to previous studies on the response of ground vegetation to canopy changes (eg Salisbury 1916, 1918, 1924; Adamson 1922; Watt 1925; Ash & Barkham 1976; Ford & Newbould 1977; Smith 1980; Kirby 1988), but specifically relates to beechwoods on chalky slopes and is based on records from permanent plots rather than chronosequence comparisons or general observations.

1.2 Study area

Noar Hill Hanger (grid reference SU 7326) is an ancient semi-natural beechwood, located between Alton and Petersfield, in Hampshire. It is owned by the Rotherfield Park Estate and forms part of a Site of Special Scientific Interest (SSSI) and candidate Special Area of Conservation (SAC). It is part of the East Hampshire Hangers, a series of mainly beech-ash-yew woods on steep chalky scarp slopes (Ockenden 1990). These are of particular significance as one the most extensive areas of mature, semi-natural, beech-ash woodland in southern Britain, and because they contain numerous plant and invertebrate species that are rare, restricted and/or associated with ancient woodland.

The wood covers about 20ha on the west Wealden chalk escarpment (Figure 1). Most of the ground is on steep 25-40º slopes, which face south-east and have thin, calcareous, well-drained, dark-brown, silty clay loam or silt loam textured, alkaline (pH 8), rendzina soils. Otherwise, there is some flat ground on the plateau above, on occasional ridges that extend down from this, and at the base of slopes, which have deeper, alkaline (pH 7.5) clay soils.

This study focuses on a 7ha minimum-intervention in the south part of the wood (Figure 1). This is mostly on steep 25-35º, south-facing slopes with shallow, well-drained, dark-brown, silty clay loam or silt loam textured, calcareous (pH 8), rendzina soils (Mackney and others, 1983). Some flat ground occurs on the plateau above the main slope, on occasional ridges that extend down from the plateau, and below the base of the main slope. The soils here are alkaline clays and they appear to be deeper than on the main slopes, particularly at the slope base. The vegetation on the main slopes and upper plateau conforms mainly to type W12 *Fagus sylvatica-Mercurialis perennis* woodland in the National Vegetation Classification (Rodwell 1991), whilst at base of the main slope it conforms to W8 *Fraxinus excelsior-Acer campestre-Mercurialis perennis*. Beech *Fagus sylvatica* and ash *Fraxinus excelsior* are the main canopy-forming trees on the slope and plateau. Small-medium trees and shrubs here include some substantial clumps of yew *Taxus baccata*, whilst minor species are represented by blackthorn *Prunus spinosa*, dogwood *Cornus sanguinea*, elder *Sambucus nigra*, field maple *Acer campestre*, goat willow *Salix caprea*, hawthorn *Crataegus monogyna*, hazel *Corylus avellana*, holly *Ilex aquifolium*, pedunculate oak *Quercus robur*, sycamore *Acer pseudoplatanus*, wayfairing-tree *Viburnum lanata*, and whitebeam *Sorbus aria*. Ash, field maple and hazel particularly abundant at the base of the main slope, whilst minor species include blackthorn, crab apple *Malus sylvestris*, hawthorn, pedunculate oak, spindle *Euonymus europaeus*, and wild cherry *Prunus avium*.

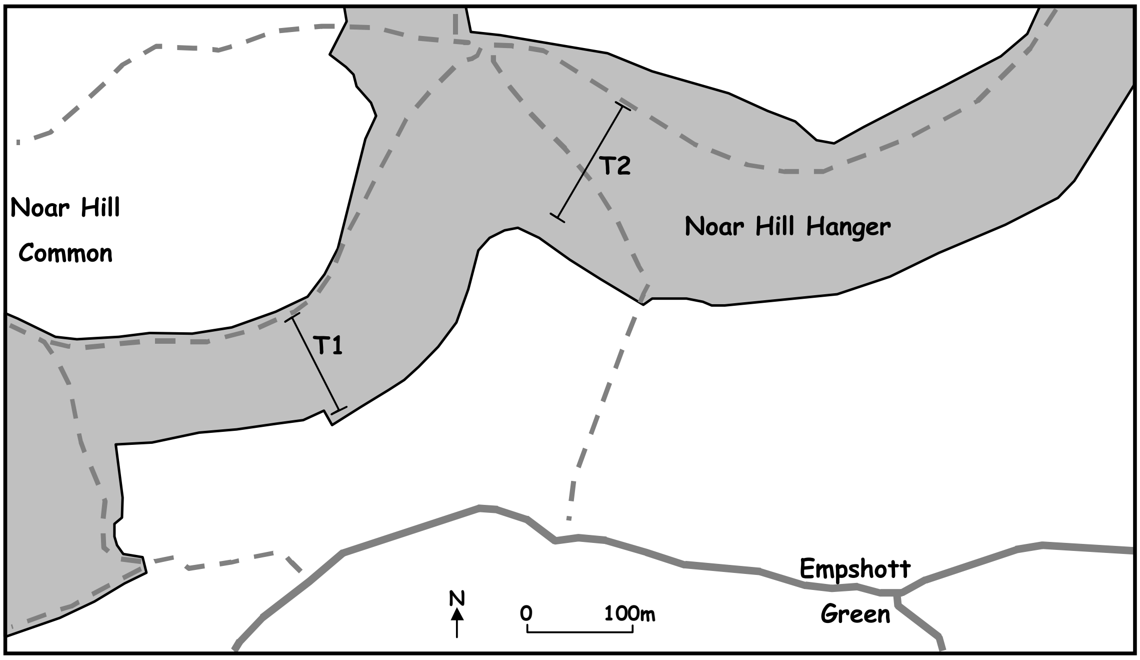

Figure 1: Map of Noar Hill Hanger showing the location of the two permanent transects (T1/T2). The area of beech woodland (shaded) occurs mainly on a steep chalk slope, whose base is close to or along the southern boundary. The route of a minor road through Empshott Green village and several tracks and footpaths are shown.

The most abundant/frequent ground plants are dog's mercury *Mercurialis perennis*, bramble *Rubus fruticosus*, false brome *Brachypodium sylvaticum*, clematis *Clematis vitalba*, cleavers *Galium aparine*, ivy *Hedera helix*, wood avens *Geum urbanum*, and wood spurge *Euphorbia amygdaloides*. Species frequency/abundance conforms most closely with the W12a *Mercurialis perennis* sub-community of the National Vegetation Classification (Rodwell 1991), which is associated with deeper, more moisture-retentive, calcareous soils.

Like other East Hampshire Hanger woods (eg Ball 2001, Webb 2002), most of Noar Hill Hanger developed into high forest during the 20th century. It appears to have been treated traditionally as wood-pasture, grazed by sheep and with beech pollards, and with areas of coppice. It was probably planted with beech/stored from coppice around 1900 and allowed to grow into high forest. As early as 1951, it was protected (as an SSSI) as a fine example of mature beech 'hanger' woodland. Since this time, only occasional selective felling of canopy trees has occurred. Before the stands recently broke-up, they contained a mixture of mainly maiden trees, combined with some of large, long-uncut, beech pollards, aged about 200-300 years, and occasional multi-stemmed ash, beech, hawthorn, hazel, whitebeam and yew, which were evidently long-uncut coppice. The stands began to deteriorate from the mid-1970s, as they were damaged by a windstorm in 1974 and by severe drought in 1976 and 1984, which caused localised dieback, bark disease and tree death (Ockenden 1990). Then in the Great Storm of October 1987, many mature canopy trees were downed and extensive openings were created. The study area has been more-or-less left untouched since this storm.

1.3 Recording & analysis

1.3.1 Recording and analysis of ground vegetation

Recordings within Noar Hill Hanger have been made on two permanent transects (T1 and T2). These are each 20m wide and 120m long. They are positioned about 400m metres apart and run straight down the chalk scarp (Figure 1). Each is divided into twenty-four 10x10m subsections, which are marked along the midline with galvanised metal stakes.

T1 started right at the edge of the upper plateau and for the first 100m ran down to the base of the main slope. However, the top right corner (from 5m out from the centre to 3m down the right transect edge) was on the upper plateau and formed part of a bridleway track. From 0-20m and 70-100m down, it crossed 26-31º slopes, but from 20-70m the slopes were 33-38º. T1 continued on across a strip of near-flat ground to 120m along. It covered 0.19925ha on the main slope and 0.04ha below the main slope.

T2 started on the upper plateau a few metres below the bridleway track. It ran across the plateau on 12-14.5º slopes for about 35m (34m on the left transect edge, 35m in centre, 37m on right), before descending down the main slope scarp to 120m along. It crossed a public footpath at about 77m down (80.5-82m on the left transect edge, 76.5- 78m in centre, 73.5m-75m on right), and stopped about 30m short of the slope base. It crossed slopes of 26-28º from about 35-80m down, but thereafter the slopes increased to 29-35º. T2 covered 0.0705ha on the upper plateau and 0168ha the main slope.

The timing and details of the transect recording are shown in Annex 1 and Figure 2. This started in July 1989 and was done last in September 2000. It has mainly involved mapping and measuring trees and shrubs present within the transects. However, a few individuals close to the transect edges were included, and in 2000 the main ground vegetation units were mapped within the transects and fallen dead wood was estimated for the compartment. Not all the transect subsections were included at each recording, and the detail and thoroughness varied considerably. The first recording took place over July 1989 to December 1990, but several subsections on T1 and T2 were not included or were only part-recorded. All subsections were covered in March 1993, though seven at the bottom of T2 were only part-recorded. Where these recordings were complete, they only included larger individuals and saplings and shrubs attaining 3m height. Much of the 1989-90 recording was done by students, who were generally not meticulous and sometimes skipped or inadequately recorded some features. Much the same applied to the 1993 recording, which mostly involved only checking the status of individuals on the 1989-90 records. The 2000 recording was the most detailed and thorough. It included all individuals attaining 1.3m height and all stems attaining 10cm gbh. Nevertheless, it proved impractical to record parts of the upper steep slopes on both transects, where the combination of dense bramble, large fallen trunks and steep ground made access hazardous, let alone near-impossible to lay out tapes and avoid excessive trampling of the bramble.

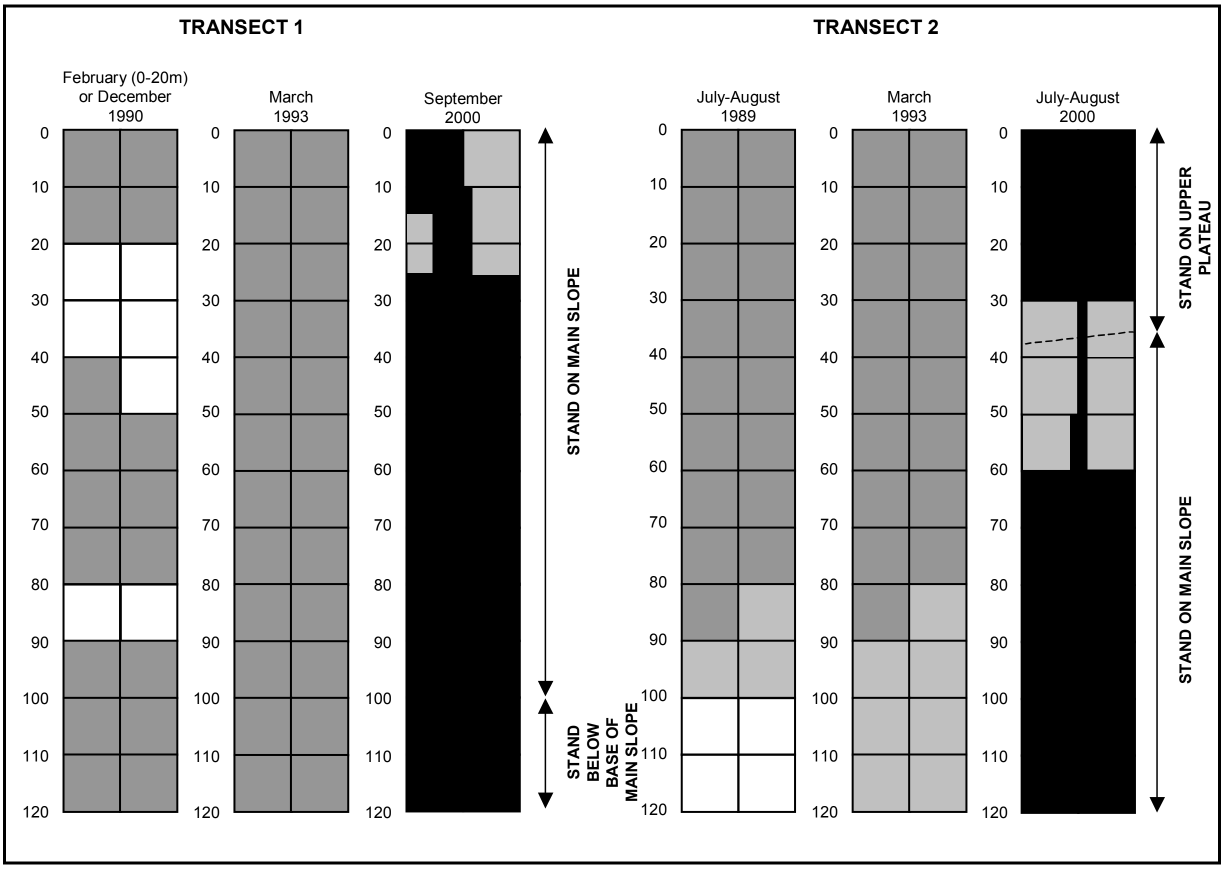

Figure 2: Recording on the two permanent transects at Noar Hill Hanger. The two transects are shown schematically with the distance down on the left in (m). Shaded areas had records made at the date shown above: light grey = only larger individuals recorded; dark grey = larger individuals and others attaining 3m height recorded; black = all individuals attaining 1.3m height recorded.

Annex 1 describes the exact details of what was recorded.

The records yielded information on just over 1800 individuals and 2500 stems. This was entered on to a Microsoft Excel spreadsheet to facilitate sorting, statistical analyses, and long-term storage. To carry out the analysis, some adjustments had to be made. Various anomalies were detected where individuals/stems appeared to have been omitted or incorrectly mapped, identified, measured or described. In particular, the coordinates of individuals measured in 2000 matched only partially with those made in 1989-93. This was mainly because tape measurements made in the early recordings were not done carefully. In most cases, probable matches were not that far away and could be reasonably agreed on. However, this posed a particular problem on T2 where there was dense regeneration with numerous similar-sized individuals. Occasionally, this made it difficult to decide which individuals matched or if an individual had been omitted early on. Secondly, the gbh measurements made early on were frequently inexact, particularly on large trees. Although they were good enough to use to match individuals between the recordings, only a minority were good enough to use in the analyses of stem growth, and some had to be changed to use in the size distribution and basal area analyses. Amendments were made only where the records seemed implausible and by interpolating from the size and performance of similar individuals located nearby.

In the analysis the transects were subdivided according to their topography and vegetation composition as described above, ie T1 main slope, T2 main slope, T1 below the main slope, T2 upper plateau. Stand composition before the 1987 storm was reconstructed by identifying which larger trees and shrubs were probably standing within the transects beforehand. Admittedly, some aspects of the record were difficult to interpret. The aim was to identify the general composition, size and position of individuals of each species, how closed the canopy was, and what impact the 1987 storm had. It was assumed that in general only individuals that attained 10cm gbh in 1989/90 were present before the storm struck, though smaller saplings and seedlings were undoubtedly present as discussed in the results section. The reconstruction tried to take into account that limited parts of the stands had been disturbed by wind-damage in 1974 and following the severe drought of 1976/1984. Recruitment of new individuals focused mainly on the records made in 2000. The 3m tall threshold and inconsistency of recording used during 1989/90/93 made any analysis of this aspect of the data unreliable.

Stem basal areas were calculated from gbh measurements and by assuming stems were circular in cross section. Snag volumes were calculated from gbh and height measurements and by assuming snags were cylindrical in volume. Live individuals/stems included those standing or fallen and with live leaves at or above 1.3m from the base. Individuals that were reduced included those that remained alive only below 1.3m height. The volume of fallen dead wood in 2000 was estimated from the line-intersect measurements and using the formulae given in Table 1.

1.3.2 Recording and analysis of trees and shrubs

In 1991 (11 July to 2 August), 1993 (19 June) and 2000 (24-26 July), a set of fifty 1x1m ground vegetation quadrats were recorded. These were positioned as pairs at 10m intervals along the transect mid-lines: 36 were on the steep chalk slopes (T1 1a-5b, T1 7a-10b, T2 4a-12b), ten were on the upper plateau (T1 0a+b, T2 0a-3b), and four were on level ground at the slope base (T1 11a-12b). They were numbered according to the transect (T1 or T2), position from the transect start (location 0 to 12), and location above or below a permanent metal marker-post (a or b). All but one pair of quadrats was relocated in 2000 (badgers appeared to have buried the post), so numbering went from T1 0a to T2 12b, excluding T1 6a+b.

Recording involved making a visual estimation of the percentage cover of all ground plants species, dead wood/leaf litter/bare ground, and low-sprout growth and seedlings of tree and shrub species up to 1.5m above the ground. In 1991 and 2000 the cover of the canopy/understorey above the quadrat was described and % cover estimated. In 1991 a DOMIN scale was used: 1 = <4% cover and rare, 2 = <4% cover and sparse, 3 = <4% cover and frequent, 4 = 4-10%, 5 = 11-25%, 6 = 26-33%, 7 = 34-50%, 8 = 51-70%, 9 = 76-90%, 10 = 91-100%. In 1991 and 2000 tree and shrub seedlings were counted and notes made of salient features, whereas the 1993 recording was briefer and excluded mosses, canopy cover above the quadrat, seedling counts and note taking.

The regularly-spaced quadrats provided a basis to reconstruct changes in the ground vegetation up to and following the 1987 storm. The analysis concentrated on quantifying changes in canopy cover and the occurrence and cover of ground plant species. All herbs, graminoids, ferns and mosses were included, but tree and shrub seedlings, low sprouts on trees and shrubs, and deadwood/litter/bare earth were excluded.

For comparisons, the DOMIN scale values recorded in 1991 were converted to percentages as follows: 1 = 0.5%, 2 = 1%, 3 = 2%, 4 = 7%, 5 = 18%, 6 = 30%, 7 = 42%, 8 = 63%, 9 = 83%, 10 = 95%. The descriptions and canopy/understorey cover values were used to assign each quadrat to one of three cover categories: *closed quadrats* (where the canopy overhead remained mostly closed); *open* → *closed quadrats* (where the overhead canopy was opened by the 1987 storm but by 2000 was much closed by understorey growth); and *open quadrats* (where the overhead canopy was opened by the 1987 storm and in 2000 remained mostly open). Records were accepted as written, except for a few adjustments where mistakes were apparent, particularly the precision of species identification. It was necessary to aggregate all records of *Viola*, which included *V.hirta, V.odorata, V.reichenbachiana,* and *V.riviniana*, because sometimes the species was not defined. *Rubus fruticosus* was treated as an aggregate, because it separated into sub-groups/micro-species during recording.

Statistical procedure followed Zar (1984) with sorting and calculations carried out using *Microsoft Excel Version 7.0* computer package. Two-factor Analysis of Variance (ANOVA) without replication was used to test the significance of differences in average values, and pinpointing was achieved by using Tukey Honestly Significantly Different tests. Species % cover values were arcsine transformed prior to ANOVA testing. Chi-square (χ^2) analysis was used to test the significance of frequency counts.

1.4 Changes in canopy cover

Before the stands began to break-up in the mid-1970s, they were mainly closed high forest, dominated by beech with some ash, yew, hazel, field maple, hawthorn and other shrubs. Opening began with storm-damage in 1974, and later drought-damage in 1976 and 1984, which caused deterioration, bark disease and tree death (Ockenden 1990). In the Great Storm of October 1987, many mature canopy trees were blown down, especially on the most exposed slopes. Nevertheless, some areas remained shaded, mainly where medium-sized ash, field maple, hazel, hawthorn or yew survived. More trees came down in storms in 1990, and by the time recording began in summer 1991, 64% of the regularly-spaced quadrats on the two permanent transects were classified as open.

During the next nine years several groups of ash-dominated regeneration developed, along with some of the surviving shrubs and low branches/basal sprouts on beech. By summer 2000, half the quadrats that had been open in 1991 had substantially closed over, ie only 32% remained open.

1.5 General changes in the ground vegetation

Much of the ground must have been heavily shaded, presumably with little cover or variety of plant species in the decades before the mid-1970s. Small gaps created before 1987 would have encouraged existing shade-tolerant plants and, where gaps were large enough, light-demanding species might have flourished. Nevertheless, the storm of October 1987 was the main cause of gap creation. It created many large gaps and greatly increased the amount of light and precipitation reaching the woodland floor.

General changes in the ground vegetation recorded in 1991, 1993 and 2000 on the two permanent transects are summarised in Table 1. Within a few years of the storm, plant cover and the number and density of species had increased in many places. Although increases were greatest where the canopy had been opened most, similar but lesser changes were detected in quadrats where the overhead canopy remained more-or-less closed, suggesting that sidelight increased widely. The actual change in cover was probably more gradual than the averages suggest because of the conversion of the DOMIN scores to percentages in 1991. Ground cover continued to generally increase up to at least the sixth growing season after the 1987 storm. Thereafter it plateaued in open area and declined substantially where the overhead canopy had remained more-or-less closed. At the same time there was a decrease in the total number of species present. The sharpest decline in species number was in quadrats that had been open, but became over-shadowed by dense pockets of ash regeneration or where existing shrubs or low branches/basal sprouts on mature trees developed. But species number also declined (though not cover) where the canopy remained open, as *Rubus* and/or *Clematis* spread and displaced shorter, less-competitive types (see below).

Table 1 Summary of general changes in ground plant species (excluding mosses) as recorded in fifty 1x1m quadrats in 1991, 1993 and 2000. There were 16 quadrats that remained open, 16 that changed from open → closed, and 18 that remained closed.

	Year		
	1991	1993	2000
Total number of species present			
All quadrats	35	33	30
Quadrats remaining open	29	24	22
Quadrats from open → closed	21	19	14
Quadrats remaining closed	16	11	16
Average number of species per quadrat			
All quadrats	5.1	4.5	4.9
Quadrats remaining open	6.2	6.5	6.5
Quadrats from open → closed	6.1	5.3	5.6
Quadrats remaining closed	3.2[a]	2.1[a b]	2.9[a]
Average % cover of ground plants per quadrat			
All quadrats	52.5	77.8[c]	81.4
Quadrats remaining open	59.1	102.0[c]	108.3
Quadrats from open → closed	47.1	86.9[c]	83.9
Quadrats remaining closed	41.3	48.3[d]	33.7[d]

NOTES: ANOVA and Tukey tests were used to determine the overall significance of differences between the average values, and differences between and within each year (see analysis): [a] significantly lower than open and open → closed quadrats ($P_{min}<0.001$); [b] significantly lower than in 1991 ($P<0.05$), [c] significantly greater than in 1991 ($P<<0.001$); [d] significantly lower than open and open → closed quadrats (1993 $P_{min}<0.05$; 2000 $P_{min}<0.001$).

Although the overall number of species changed relatively little, turnover was substantial with only 25 of the 46 ground plants recorded having been present at every recording date (Table 2). During 1991-1993, 12 species were lost (all had been scarce or uncommon in 1991) and ten recruited (into one or two quadrats). During 1993-2000, six species were lost (all recruited during 1991-93) and three recruited (again only into one or two quadrats). Only four species remained in >40% of quadrats throughout, many remained scarce, and in some cases shifted distribution between quadrats from one recording to another. The species recorded in 1991-93 included many that tended towards a competitive/ruderal established strategy (Table 3). By 2000 these had declined: 24 species became frequent or moderately frequent (ie recorded in at least 5 quadrats) but then declined and/or appeared only temporarily/intermittently, 15 of which tended towards a competitive/ruderal established strategy, five were intermediate competitive-stress-tolerant-ruderal, and only four tended towards stress-tolerant. Although competitive-ruderals remained prominent, the majority of the most abundant/frequent species in 2000 tended towards a stress-tolerant/competitive strategy. Thus, the ground vegetation community underwent considerable upheaval, even thought the total number (large scale diversity) and number of species per quadrat (small-scale diversity) remained relatively unchanged. Although the high turnover and maintenance of species richness might in part be due to the phenology of species and oversights during recording, it probably also reflected irregular dispersal and germination of seed and continued disturbance through tree fall (notably in 1990 storms) and root plate collapse.

Such a temporary flush in ground vegetation is commonly seen following canopy opening when a stand is coppiced or clear-felled (Salisbury 1916, 1918, 1924; Adamson 1922; Rackham 1975; Ash & Barkham 1976; Ford & Newbould 1977; Kirby 1988). The increase in light, soil nutrients and moisture creates opportunities for ruderal and competitive species to spread and establish amongst existing stress-tolerant types. After several years, shade returns or competitive species displace ruderal types, so cover and/or species richness declines.

Table 2: Occurrence of ground plant species out of fifty 1x1m quadrats as recorded in 1991, 1993 and 2000. The significance of changes in occurrence were determined using chi-square tests: [a] = P<<0.001, [b] = P<0.001, [c] = P<0.005, [d] = P<0.01, [e] = P<0.05.

	Occurrence (number of quadrats)			Change in occurrence		
	1991	1993	2000	1991-1993	1993-2000	1991-2000
Mercurialis perennis	46	41	40	-5	-1	-6
Rubus fruticosus	24	27	37	3	10[e]	13[e]
Hypnum cupressiforme	23	n.a.	32	n.a.	n.a.	9
Geum urbanum	22	5	1	-17[a]	-4	-21[a]
Hedera helix	21	21	25	0	4	4
Euphorbia amygdaloides	19	17	18	-2	1	-1
Clematis vitalba	14	22	27	8	5	13[d]
Galium aparine	13	15	9	2	-6	-4
Brachypodium sylvaticum	12	18	29	6	11[c]	17[b]
Fissidens taxifolius	12	n.a.	24	n.a.	n.a.	12[e]
Cirsium arvense	9	8	3	-1	-5	-6
Urtica dioica	8	3	4	-5	1	-4
Viola spp.	7	5	11	-2	6	4
Sonchus arvensis	6	5	2	-1	-3	-4
Taraxacum officinale	6	6	1	0	-5	-5
Circaea lutetiana	5	4	7	-1	3	2
Solanum dulcamara	5	3	6	-2	3	1
Senecio jacobaea	3	0	1	-3	1	-2
Epilobium montanum	2	6	3	4	-3	1
Galium odoratum	2	2	4	0	2	2
Arum maculatum	2	1	3	-1	2	1
Sanicula europaea	2	1	1	-1	0	-1
Chamaerion angustifolium	1	3	2	2	-1	1
Carex flacca, Dryopteris filix-mas	1	1	1	0	0	0
*Carex sylvatica**	1	1	1	0	0	0
Dactylis glomerata	1	0	1	-1	1	0
Potentilla sterilis	0	1	2	1	1	2
Unidentified moss on soil	0	n.a.	2	n.a.	n.a.	2
Agrostis spp.	0	0	2	0	2	2
Bryonia dioica, Daphne laureola, Stellaria media	0	1	1	1	0	1
Glechoma hederacea	5	0	0	-5[e]	0	-5[e]
Primula vulgaris	3	0	0	-3	0	-3
Geranium robertianum, Graminea spp., *Mycelis muralis, Prunella vulgaris, Veronica officinalis*	2	0	0	-2	0	-2
Poa annua, Tamus communis, Veronica montana	1	0	0	-1	0	-1
Anthriscus sylvestris, Arctium minus, Cirsium vulgare	0	1	0	1	-1	0
Festuca gigantea	0	2	0	2	-2	0
Ranunculus repens, Verbascum thapsus	0	1	0	1	-1	0

*assumed to have survived as an unidentified *Carex* in one quadrat in 2001.

Table 3: Categorisation of all ground plant species (excluding mosses) recorded in the permanent plots at Noar Hill during 1991-2000 and a list of their main attributes. Information is mostly from Grime and others (1988): under established strategy, C = competitor, S = stress-tolerator, R = ruderal, SC = stress-tolerant competitor, etc. Information on the ability to survive under closed stands of beech comes also from Smith (1980) and authors experience.

Species	Established strategy	Main regenerative strategies	Persistent seed bank	Seed dispersal	Ability to survive under beech
Species that were abundant but declined by 2000					
Mercurialis perennis	SC	Vegetative	No	Possibly ants	High
Species that became and remained (at least locally) abundant in 2000					
Rubus fruticosus	SC	Vegetative, buried seed	Yes	Animal	Moderate
Clematis vitalba	No info.	Seed	No info.	Wind	Low
Hedera helix	SC	Vegetative, perhaps buried seed	Uncertain	Animal	High
Species that became and remained frequent in 2000					
Brachypodium sylvaticum	S-SC	Vegetative, seed	No	Animal	Moderate
Euphorbia amygdaloides	No info.	Vegetative, seed	No info.	Animal	High
Hypnum cupressiforme	No info.	Vegetative, spores	No	Wind	High
Fissidens taxifolius	No info.	Vegetative, spores	No	Wind	High
Species that became and remained moderately frequent in 2000					
Viola spp.	S	Vegetative, seed	No	Ants	Moderate
Circaea lutetiana	CR	Vegetative, seed	No	Animal	Moderate
Solanum dulcamara	CSR-C	Vegetative, seed	No	Animal	Moderate
Species that became frequent but then declined by 2000					
Geum urbanum	CSR-S	Seed	No	Animal	Moderate
Galium aparine	CR	Seed	No	Animal	Low
Species that became moderately frequent but then declined by 2000					
Sonchus arvensis	CR	Vegetative, perhaps buried seed	No	Wind	Low
Taraxacum officinale	CSR-R	Widely-dispersed seed	No	Wind	Low
Epilobium montanum	CSR	Vegetative, widely-dispersed seed, perhaps buried seed	No	Wind	Moderate
Cirsium arvense	C	Vegetative, seed, perhaps buried seed	No	Wind	Low
Urtica dioica	C	Vegetative, buried seed	Yes	Animal	Moderate
Species that became moderately frequent but occurred only temporarily					
Glechoma hederacea	CSR	Vegetative, uncertain	Uncertain	Unspecialised	Moderate

Species	Established strategy	Main regenerative strategies	Persistent seed bank	Seed dispersal	Ability to survive under beech
Species that never became frequent but remained in 2000					
Potentilla sterilis	S	Vegetative, perhaps buried seed	Perhaps	Unspecialised	Moderate
Sanicula europaea	S	Vegetative, seed	No	Animal	Moderate
Carex flacca	S	Vegetative, buried seed	Perhaps	Unspecialised	Moderate
Carex sylvatica	S	Buried seed perhaps	Yes	Unspecialised	Moderate
Dryopteris filix-mas	SC	Vegetative, seed, perhaps buried seed	No	Wind	Moderate
Chamaerion angustifolium	C	Vegetative, widely-dispersed seed	No	Wind	Low
Galium odoratum	CSR-SC	Vegetative, seed	Perhaps	Animal	Moderate
Agrostis spp. (canina)	CSR-CR	Vegetative, buried seed	Yes	Unspecialised	Low
Arum maculatum	SR	Vegetative, perhaps seed	No	Animal	Moderate
Stellaria media	R	Buried seed	Yes	Unspecialised	Low
Bryonia dioica	No info.	Seed	No info.	Animal	Moderate
Daphne laureola	No info.	Seed	No info.	Animal	High
Species that never became frequent and occurred only temporarily or intermittently					
Poa annua	R	Seed, buried seed, vegetative	No	Unspecialised	Low
Senecio jacobaea	CR-R	Vegetative, widely-dispersed seed, buried seed	No	Wind	Low
Anthriscus sylvestris	CR	Vegetative, seed	No	Unspecialised	Low
Arctium minus	CR	Seed	No	Animal	Low
Cirsium vulgare	CR	Seed, perhaps buried seed	No	Wind	Low
Ranunculus repens	CR	Vegetative, seed	Perhaps	Animal	Low
Tamus communis	CR-C	Seed	No	Animal	Moderate
Geranium robertianum	CSR-R	Uncertain	Uncertain	Animal	Moderate
Verbascum thapsus	CSR-R	Buried seed	Yes	Wind	Low
Mycelis muralis	CSR	Widely-dispersed seed	No	Animal	Moderate
Prunella vulgaris	CSR	Vegetative, perhaps buried seed	No	Animal	Low
Festuca gigantea	CSR	Seed	No	Animal	Moderate
Dactylis glomerata	CSR-C	Seed	No	Unspecialised	Low
Veronica officinalis	CSR-S	Vegetative, buried seed	Uncertain	Unspecialised	Low
Veronica montana	CSR-S	Vegetative, buried seed	Uncertain	Unspecialised	Moderate
Primula vulgaris	S	Vegetative, perhaps buried seed	No	Animal	Moderate

1.6 Changes in individual ground vegetation species

Forty-six vascular plants and three mosses were recorded in the quadrats over the three recordings. Their frequency is summarised in Table 2, whilst Table 3 shows the main attributes of the species. The most widespread species were *Mercurialis perennis*, *Hypnum cupressiforme* and *Rubus fruticosus,* whilst *Brachypodium sylvaticum, Clematis vitalba, Euphorbia amygdaloides, Fissidens taxifolius, Galium aparine, Geum urbanum* and *Hedera helix* were the most common amongst the other species. Changes in their cover and occurrence are shown in relation to canopy cover in Tables 4 and 5.

Before the storm struck, *Mercurialis perennis* probably formed several extensive colonial patches beneath the closed stands, making use of the vernal light phase before trees come into leaf to initiate its vegetative growth and come into flower (Smith 1980). Thus, in 1991 its average cover was greatest in quadrats where the canopy remained closed, and only here did its average cover and presence at ≥60% cover remain high (Table 4). There was little indication that it suffered due to canopy opening. In 1991 and 1993 it had the highest cover of any species (Table 4) and was initially widespread in both open and closed quadrats (Table 5). Although it appeared to have increased in cover during 1991-93, this was confounded by the change in recording methodology (from DOMIN scores to % cover). It is commonly thought that *Mercurialis* responds poorly to increases in light after felling or coppicing (Grime and others 1988), with Salisbury (1924) providing figures that show a decline in the weight of *Mercurialis* plants after coppicing. However, plants in actively managed woods are prone to trampling and other damage during cutting operations, which might be responsible for the observed reduction in vigour of this essentially rhizomatic plant (Mukerji 1936). Despite performing well to 1993, by 2000 *Mercurialis* had disappeared from several quadrats and its average cover had declined to fourth in rank (Tables 2 and 4). Only at the base of the main slope, where the canopy had remained more-or-less closed, did it still form substantial patches. Its demise was linked mainly with the spread of *Rubus/Clematis* in open areas, and elsewhere with the spread of *Hedera* and/or development of thickets of ash regeneration or existing hazel bushes. It also suffered where root plates/dead fallen trunks collapsed and along paths created by badgers/deer.

Rubus fruticosus agg. and *Clematis vitalba* increased substantially and impacted strongly on other plant species. Both had probably developed in gaps created after 1974, but the 1987 storm created much greater opportunities for expansion. By 1991 both species had colonised open quadrats widely, but growth was slow and their cover remained mostly limited (Tables 4-5). However, by 1993 *Rubus* cover had increased substantially, and in 2000 almost half of the remaining open quadrats had at least 60% *Rubus* cover. These occurred as extensive spiny thickets to 1.5m high on open parts of the steep upper and lower slopes of transect 1, and more locally in open places along transect 2. Where *Rubus* thickets grew over large fallen trunks and root plates, access was virtually impossible. *Clematis* followed the same trend, albeit more slowly and to a lesser extent: by 2000 it attained 60% cover in five of the 16 open quadrats (Table 4). It spread particularly on the clayey plateau at the top of transect 2, where it formed an extensive, low-growing, sprawling mass. As *Rubus* and *Clematis* spread, they smothered and displaced other less-competitive plants (see below). No doubt the dry rendzina soils on the main slopes inhibited their growth, and *Rubus* (unlike *Clematis*) was certainly retarded by deer browsing on the plateau at the top of transect 2. Deer browsing might have been more widespread, but they seemed reluctant to forage on the steep slopes where large fallen trunks were abundant. Nevertheless, the main check to both species was shade (Tables 4-5). In 2000, it was especially noticeable how (once vigorous) *Rubus* thickets were moribund beneath dense, vigorous groves of ash saplings. Although *Rubus* had tried to escape shading by growing up through ash regeneration or basal sprouts, *Clematis* was far better adapted to achieve this and in places had grown into tall lianas.

Rubus is well-known as a robust, spiny plant capable of dominating and suppressing other plants in gaps in beechwoods several years after they open (eg Watt 1925). Kirby (1988) recorded the same time-lag spread in *Rubus* and decrease in plant species after coppicing in a mixed oak-hazel wood in Buckinghamshire, and (in two experimental clearances in East Anglian coppices) clearly demonstrated the extent to which *Rubus* can reduce the cover and diversity of other ground flora species. Both *Rubus* and *Clematis* have spread strongly in other chalky beechwoods opened by the 1987 storm: for example Westfield Wood (Parker and others 1993, Parker 1994), Wye Downs National Nature Reserve (Buckley and others 1994), and Ashford Hangers National Nature Reserve (Mountford and Ball 2003). Although it seems they are likely to recede at Noar Hill Hanger as more of the tree and shrub canopy re-establishes (accepting *Clematis* survival as lianas), several large areas have little or no regeneration of trees or shrubs and look set to remain open and become increasingly dominated by thickets of *Rubus* and/or *Clematis.*

Hedera helix remained moderately frequent and increased in cover during 1991-2000. It appeared to have been rather limited before canopy opening in 1987, and was evidently advantaged by this (Tables 4-5). It steadily increased in cover, and by 2000 was the second most abundant species (Table 4). Unlike *Rubus* and *Clematis*, it remained most frequent and spread particularly strongly in quadrats on parts of the clayey plateau and middle and lower sections of the main slopes where the canopy changed from open in 1991 to closed in 2000. This was where ash regeneration, hazel/hawthorn bushes, or low branches on beech developed, which limited the expansion of *Rubus/Clematis,* and left *Hedera* to spread mainly at the expense of *Mercurialis perennis* and *Brachypodium sylvaticum.* These quadrats probably represent some of the most heavily shaded parts of the wood in 2000, given the dense low canopy that had grown directly above them. These results generally support those reported by Barkham & Norris (1967, 1970), who studied ground vegetation patterns in two calcareous beechwoods in the Cotswolds. They found that, despite being patchily distributed, *Hedera* was strongly shade-tolerant, capable of replacing *Mercurialis perennis* as the dominant ground plant in dry, heavily-shaded areas. It appeared to establish early on rubble under beech and proceeded to prevent establishment of other plants by building up a thick mat of roots and shoots.

Mosses also increased substantially in occurrence. *Hypnum cupressiform* occurred in nearly half of the quadrats in 1991, and by 2000 had spread further. It occurred primarily on fallen dead wood, a substrate that was increased greatly by the 1987 storm. In a few cases it disappeared from quadrats because trunks or branches had rolled downhill between recordings. The other moss, *Fissidens taxifolius,* grew on bare soil. It was widely distributed in 1991 and by 2000 had spread mostly into quadrats that remained or had became shaded.

Table 4: Summary of changes in ground cover in relation to canopy cover for common plant species. Based on fifty 1x1m quadrats, 16 that remained open, 16 that changed from open → closed, and 18 that remained closed.

	All quadrats			**Quadrats remaining open**			**Quadrats from open → closed**			**Quadrats remaining closed**		
	1991	**1993**	**2000**	**1991**	**1993**	**2000**	**1991**	**1993**	**2000**	**1991**	**1993**	**2000**
Average % cover												
Mercurialis perennis	19.6[a]	28.9[a]	11.3[b]	16.8	31.7	5.2	10.4	14.3	2.0	30.1	39.6	25.1
Rubus fruticosus	5.8	13.3	23.1[c f]	10.7	21.3	46.0	7.1	18.6	23.9	0.4	1.4	2.2
Hedera helix	5.5	10.9	17.2[d]	0.5	3.8	9.4	15.9	29.3	44.1	0.6	0.8	0.2
Clematis vitalba	4.9	3.7	14.6[e g]	6.5	5.8	34.1	0.9	4.1	9.4	7.0	1.5	1.8
Brachypodium sylvaticum	6.1	8.1	2.9	12.3	15.3	5.9	6.8	9.1	2.0	0.0	0.7	1.1
Hypnum cupressiforme	2.9	n.a.	5.6	0.3	n.a.	4.3	4.8	n.a.	7.1	3.6	n.a.	5.3
Quadrats ≥60% cover (n)												
Mercurialis perennis	8	9	4	2	3	-	1	-	-	5	6	4
Rubus fruticosus	-	2	7	-	2	7	-	-	-	-	-	-
Hedera helix	2	2	8	-	-	1	2	2	7	-	-	-
Clematis vitalba	3	-	6	1	-	5	-	-	1	2	-	-
Brachypodium sylvaticum	2	2	-	1	1	-	1	1	-	-	-	-

NOTES: ANOVA and Tukey tests were used to determine the significance of differences between the average values for all quadrats combined: [a] significantly greater than all other species ($P_{min}<0.001$); [b] significant decrease from 1993 to 2000 ($P<<0.005$); [c] significant increase from 1991 ($P<0.001$) and 1993 ($P<0.05$) to 2000; [d] significant increase from 1991 to 2000 ($P<0.05$); [e] significant increase from 1991 ($P<0.005$) and 1993 ($P<0.025$) to 2000; [f] significantly greater than *Hypnum cupressiforme* and *Brachypodium sylvaticum* ($P<0.001$); [g] significantly greater than *Brachypodium sylvaticum* ($P<0.025$).

Table 5: Patterns of increase, recruitment, loss and decline between 1991-2000 in relation to canopy cover for the commonest ground plant species. Each cell shows the number of quadrats out of 16 (remained open), 16 (change from open → closed) or 18 (remained closed).

Species	Change in canopy cover over quadrat 1991-2000	Present 1991	Survived & cover change <20%	Recruited	Recruited & ≥20% cover in 2000	Survived & cover increase ≥20%	Lost	Survived & cover decline ≥20%	Present 2000
Mercurialis perennis	Remained open	14	10	2	-	1	-	3	16
	Open → closed	14	7	-	-	-	4	3	10
	Remained closed	18	9	-	-	2	4	3	14
Rubus fruticosus	Remained open	10[a]	2	4	1[b]	8[b]	-	-	15[c]
	Open → closed	13[a]	8	1	2	4	1	-	15[c]
	Remained closed	1	1	6	-	-	-	-	7
Hedera helix	Remained open	2	1	3	1	1	-	-	6
	Open → closed	13[d]	6	2	-	7	-	-	15[d]
	Remained closed	6	3	1	-	-	3	-	4
Clematis vitalba	Remained open	5[e]	1	3	7	2	-	2	15[f]
	Open → closed	7[e]	2	4	-	2	3	-	8
	Remained closed	2	-	2	-	-	-	2	4
Brachypodium sylvaticum	Remained open	8[g]	3	6	1	-	1[h]	4[h]	14[i]
	Open → closed	3	1	7	-	-	1	1	9
	Remained closed	1	1	5	-	-	-	-	6
Euphorbia amygdaloides	Remained open	5[j]	1	1	-	-	4	-	2
	Open → closed	13[j]	13	-	-	-	-	-	13[k]
	Remained closed	1	-	3	-	-	1	-	3
Fissidens taxifolius	Remained open	3	3	1	-	-	-	-	4
	Open → closed	6	6	3	1	-	-	-	10[n]
	Remained closed	3	3	7	-	-	-	-	10[n]
Galium aparine	Remained open	4	4	5	-	-	-	-	9
	Open → closed	3	-	-	-	-	3	-	-
	Remained closed	6	-	-	-	-	6	-	-

Species	Change in canopy cover over quadrat 1991-2000	Present 1991	Survived & cover change <20%	Recruited	Recruited & ≥20% cover in 2000	Survived & cover increase ≥20%	Lost	Survived & cover decline ≥20%	Present 2000
Geum urbanum	Remained open	9[m]	1	-	-	-	8	-	1
	Open → closed	10[m]	-	-	-	-	10	-	-
	Remained closed	3	-	-	-	-	3	-	-
Hypnum cupressiform	Remained open	4	4	3	1	-	-	-	8
	Open → closed	8	7	4	1	-	-	1	13
	Remained closed	11	8	2	-	1	2	-	11

NOTES: [a] significantly more frequent in open quadrats (χ^2 = 20.3, P<<0.001); [b] significantly more frequent in quadrats that remained open (χ^2 = 7.7, P<0.01); [c] significantly more frequent in quadrats that were initially open (χ^2 = 18.0, P<<0.001); [d] significantly more frequent in quadrats that changed from open → closed (χ^2_{min} = 13.7, P<<0.001); [e] significantly more frequent in open quadrats (χ^2 = 4.0, P<0.05); [f] significantly more frequent in quadrats that had remained open (χ^2 = 15.0, P<<0.001); [g] significantly more frequent in open quadrats (χ^2 = 5.2, P<0.025); [h] significantly more frequent in quadrats that remained open (χ^2 = 6.9, P<0.05); [i] significantly more frequent in quadrats that remained open (χ^2 = 8.4, P<0.005); [j] significantly more frequent in open quadrats (χ^2 = 12.6, P<0.001); [k] significantly more frequent in quadrats that changed from open → closed (χ^2 = 33.3, P<<0.001); [m] significantly more frequent in open quadrats (χ^2 = 8.5, P <0.005); [n] significantly more frequent in quadrats that remained or became closed (χ^2 = 5.0, P <0.05).

Most of the other more frequent ground vegetation species seemed to have spread at least moderately into areas opened up by the 1987 storm, but by 2000 had declined. *Brachypodium sylvaticum* was recorded as moderately abundant in 1991 and continued to recruit very widely, though it remained most strongly associated with open quadrats (Tables 2, 4-5). It developed most strongly close to pathways, probably from plants that were present here before the storm and which then provided a source of seed that continued to colonise widely. However, it failed to compete successfully in quadrats that remained open as *Rubus/Clematis* spread, and it retreated where *Hedera* spread and/or the canopy closed over. Despite being more frequent by 2000, it had generally declined in cover (Table 4), principally because in open areas it was unable to compete effectively wherever *Clematis* or *Rubus* spread. *Euphorbia amygdaloides* also remained moderately frequent (Table 2), but it occurred only as individual plants and so never covered much of the ground (Table 4). It spread rapidly into most open quadrats by 1991, and survived in many despite them closing over (Table 5). Nevertheless, by 2000 it had generally declined, having peaked in cover in 1991/93 in 21 of the 25 quadrats where it was recorded. Its decline was linked with the spread of *Hedera* (where the canopy closed over) and *Rubus/Clematis* (where the canopy remained open).

Geum urbanum spread very widely into nearly all open quadrats within a few years of the storm (Table 5). However, within six growing seasons it was much reduced, and by 2000 it survived in only one open quadrat. This implies a strong intolerance to shading and competition. *Galium aparine* followed a similar trend, but it spread less extensively and persisted better in quadrats that remained open (Table 5). It was helped as it formed sprawling mats, capable of growth up through other vegetation, which avoided excessive shading. *Solanum dulcamara* and *Circaea lutetiana* remained occasional, but six other species that became moderately frequent did not persist (*Cirsium arvense*, *Urtica dioica, Sonchus arvensis, Taraxacum officinale, Epilobium montanum, Glechoma hederacea*). Many other ruderal types that were never frequent did not persist also (Tables 2-3). These were presumably restricted mainly to the wood margins and internal paths before the canopy opened. They had a limited opportunity to colonise and expand, and did so mostly from animal- or wind-dispersed seed, with buried seed and vegetative expansion playing a lesser role (Table 3). Within a decade after the storm, they were declining because of increased shade from tree/shrub regeneration/ regrowth or competition mainly from rank growth of *Clematis* or *Rubus.*

The records from Noar Hill Hanger document many of the more typical, gap-phase, ruderals associated with dry, calcareous beechwoods. Admittedly, some species might have been ‘missed’ because they occurred outside the recording quadrats, or because recording did not start until the fourth growing season after the storm and was always undertaken well into the summer period (Kirby and others 1986). For example, *Verbascum thapsus* is regarded as a classic early coloniser of glades in chalk beechwoods, but which usually appears in profusion for a few years (Smith 1980). At Noar Hill, it was observed occasionally in open areas in 1991 and recorded in one open quadrat in 1993: it might have been more abundant in 1988 or 1989. The records expand on the ruderals given by Smith (1980) as colonisers of glades in chalk beechwoods. Most were recorded as part of ruderal flora on and around upturned root plates six years after the 1987 storm in calcareous beech woodland at Wye Downs National Nature Reserve (Buckley and others 1994). In study plots at the nearby Ashford Hangers National Nature Reserve, similar ground vegetation changes were recorded following storm-damage in 1987 storm (Mountford and Ball 2003). Nevertheless the minor species involved were slightly different, partly because the area studied included an area of moderately acidic clay soil. Although some minor species from Noar Hill were not recorded or were less abundant (notably *Hedera helix* and *Geum urbanum*), others that were present included: *Ajuga reptans, Arctium lappa, Carduus acanthoides, Cerastium holosteoides, Chrysanthemum segetum, Cirsium palustre, Digitalis purpurea, Eupatorium cannabinum, Holcus lanatus, Lonicera periclymenum, Myosotis sylvatica, Phyllitis solopendrium, Plantago major, Pteridium aquilinum, Ribes sylvestre, Rubus idaeus, Rumex sanguineus, Scrophularia nodosa and Veronica serpyllifolia.* Adamson (1922) also recorded a slightly different and richer array of ruderals three years after clear-felling a block of similar woodland on the north escarpment at Ditcham Park, Hampshire. The most abundant were *Arctium minus, Atropa belladonna, Cerastium holosteoides, Chamaerion angustifolium, Circaea lutetiana, Cirsium vulgare, Epilobium parviflorum, Hypericum hirsutum, Hypericum perforatum, Myostis arvensis, Ranunculus repens, Senecio jacobaea, Sisymbrium officinale, Urtica dioica* and *Verbascum thapsus.* Additional species that were occasional or local included: *Anagallis arvensis, Bryonia dioica, Carduus acanthoides, Cirsium arvense, Cynoglossom officinale, Dactylis glomerata, Dipsacus fullonum, Epilobium tetragonum, Eupatorium cannabinum, Fragaria vesca, Geranium robertainum, Heracleum sphondylium, Holcus lanatus, Leontodon hispidum, Poa annua, Prunella vulgaris, Sagina procumbens, Scrophularia aquatica, Scrophularia nodosa, Sinipis arvensis, Solanum dulcamara, Sonchus arvensis, Taraxacum officinale, Valerain officinalis, Veronica arvensis, Veronica officinalis, Veronica serpyllifloia* and *Vicia sepium.*

2. Stand change

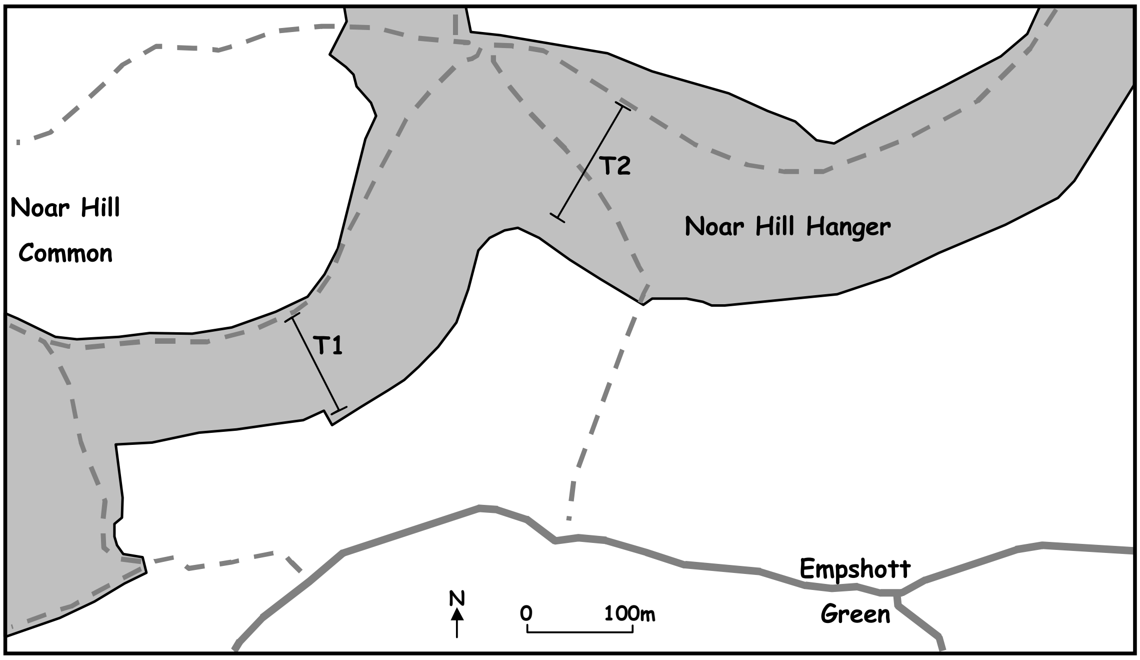

Figure 1: Map of Noar Hill Hanger showing the location of the two permanent transects (T1/T2). The area of beech woodland (shaded) occurs mainly on a steep chalk slope, whose base is close to or along the southern boundary. The route of a minor road through Empshott Green village and several tracks and footpaths are shown.

2.1 Changes in stand cover on the steep slope on transect 1

2.1.1 Stand condition when 1987 storm hit

T1:0-100m crossed the main steep slope. The reconstructed stand condition for this area when the 1987 storm hit is shown in Table 2.2 and Figure 3.

Table 2.2 Reconstructed density, basal area and size of live trees and shrubs on T1:0-100m on the main slope when the 1987 storm hit. The size of individuals is based on the largest stem on each. Figure 3 shows the position of individuals. Based on bushes and saplings that attained 10cm gbh in 1990.

	Beech	Yew	Elder	Ash	Hazel	Field maple	All species
Live individuals ≥10cm gbh (n ha^{-1})	141	25	141	80	10	5	402
Live stems ≥10cm gbh (n ha^{-1})	151	50	156	136	45	5	542
Basal area live stems ≥10cm gbh (m^2 ha^{-1})	43.2	3.1	0.6	1.2	0.1	0.3	48.5
Size of individuals (cm gbh)							
10-24.5	-	2	9	7	1	-	19
25-49.5	-	-	19	7	1	-	27
50-99.5	1	-	-	2	-	1	4
100-149.5	5	1	-	-	-	-	6
150-199.5	12	2	-	-	-	-	14
200-249.5	4	-	-	-	-	-	4
250-299.5	4	-	-	-	-	-	4
300-349.5	2	-	-	-	-	-	2
Total number individuals	28	5	28	16	2	1	80

The basal area was high due to mainly 28 large beech and three large yew. Most of the large beech were mature, single-stemmed maiden trees. However, a few were growing side-by-side or had additional smaller stems, suggesting that they were or might have been derived from coppice. An additional seven dead beech trees were present. These were apparently present before the 1987 storm struck either as snags or stumps, some of which were from recently felled trees, whilst others appeared to be possible victims of the 1976 drought or trees that had been excluded. The three large yew were mature, well-developed, sub-canopy trees, one of which appeared to have toppled downhill long ago. Most other individuals were sub-canopy or understorey ash or elder. These and a few hazel and field maple accounted for a moderate number medium- and small-sized individuals. The ash were mostly single-stemmed (or exceptionally twin-stemmed) maidens, but three large, multi-stemmed, coppice individuals were recorded, the largest stems on which were 27-65cm gbh. Elder included 28 single-stemmed and four twin-stemmed bushes. Both hazel were from sizeable coppice stools, whilst the field maple was a maiden tree growing in the sub-canopy.

Large beech dominated the first 20m of the transect and probably formed a near-complete canopy (Figure 3). There was virtually no understorey developed here, save for two elder that were growing at the transect start beside the bridleway track. A 143cm gbh beech snag at 10m down, which might have been excluded or killed following the severe drought of 1976, had probably left only a small gap.

Only two beech, both on the right side, were recorded from 20-30m down. These were both decayed stumps from trees sized 100cm gbh, which might have been victims of the 1976 drought. The presence of a sizeable gap of some age was reinforced by the presence of four elder bushes at 17-20cm gbh below the lower stump and a hazel at 30cm gbh at 21m down. In addition, there were two yew bushes in the vicinity, which might have impeded further regeneration of elder.

The absence of any developed understorey on the left side from 20-30m down (Figure 3), suggests there was not a sizable gap here. Admittedly, the absence of large beech here is somewhat anomalous. It might be explained because much of this part of the transect was recorded only in 1993 and there was already dense bramble making detection of dead trees difficult. Of course, there could have been a large beech just outside the transect with its canopy over the area, and the beech above and below this area could have encroached upon it.

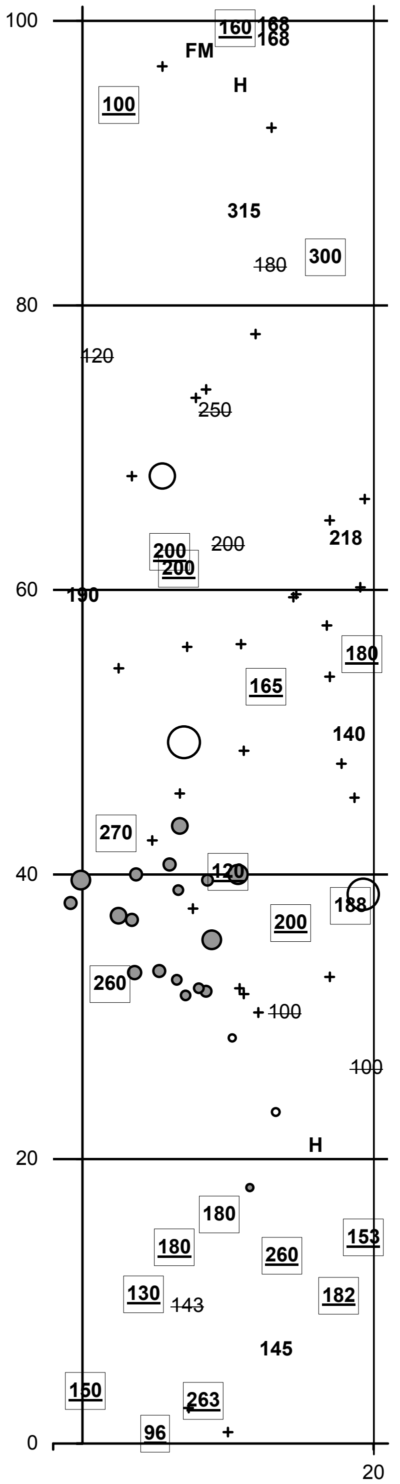

Figure 3: Reconstructed size and position of live trees and shrubs on T1:0-100m on the main slope immediately before the 1987 storm and fate of large trees by 2000

Values on left are distance (m) down from the top of the transect

Values within the diagram show the location and gbh (cm) of large beech trees: (a) non-bold values struck through = large stumps/snags dead before 1987 storm; (b) values underlined within boxes = standing alive before 1987 storm and uprooted after; (c) non-underlined value within boxes = standing alive before 1987 storm and snapped after; (d) values outside boxes = standing alive before and after 1987 storm (see text for details)

Circles and letters show location of other live individuals which attained 10cm gbh in 1989/90: grey circles = ash; white circles = yew; + = elder; H = hazel, FM = field maple; the width of circles is proportional to their gbh (range = 10-175cm)

Multi-stemmed individuals are based on the size of the largest stem

From 30-45m down, the canopy appeared closed on the right side by large beech and there was no developed understorey (Figure 3). On the left side, however, the majority of the ash on the transect, plus a couple of elder, were growing between a few large beech. The largest of the ash must have been a few decades old and possibly marked the location of a gap formed by the 1976 drought or even before this.

From 45m down, there were mostly scattered elder bushes in between groups of large beech (Figure 3). A couple of the large yew were also present, and the only field maple and other hazel occurred close to the base slope. The elder occurred mostly away from the beech and yew, and presumably marked gaps in the canopy or areas with good sidelight. There must have been a sizeable canopy gap at about 70-90m down. There were three stumps here within 30m of the slope base, all of which had marks to show that trees sized 120, 180 and 250cm gbh had been felled here sometime before the storm. Slightly above these was a probable snag of 200cm gbh, which would have contributed to the gap. This appeared to be dead already by 1987, if so probably due to the severe drought of 1976. Only a few elder were present, suggesting the gaps were quite recent or that regeneration had been limited. A similar gap was possibly present on the right side from 85-95m down, though this could have been part-filled by the large beech at 87m down or an unrecorded beech outside the transect.

2.1.2 Impact of 1987 storm

Eighteen of the 28 large live beech trees on T1:0-100m appeared to have been brought down by the 1987 windstorm (Figure 3). Two others at the top of the transect fell in the severe storms of January 1990. Possibly some of the presumed 1987 losses were not toppled until 1990. One further beech (sized 165cm gbh at 53m down) was lost during 1993-2000. This reduced the standing live basal area before the 1987 storm by 74% and left most of the transect open. All but one of the large beech at the transect top was lost, though another survived just outside on the right. All the large beech around the ash group at 30-45m had gone, and scattered large beech were lost thereafter down to the slope base. Losses were less on the lower half of the transect, with about the same number of large beech surviving as were lost from about 50m down. These survivors were isolated or in pairs, so even here the ground became far better lit. Trees of all sizes were lost, including the four smallest and four of the five largest. Sixteen were uprooted and five were snapped. Most uprooted trees fell towards N, NE or E and all fell within an arc from NW to SE. Recorded root plates ranged mostly from 2-4m wide/tall. One of the uprooted trees remained alive in February 1990, but this was dead by March 1993. One of the snapped trees broke low down at 1.5m, whereas the other four appeared to have broken at 4-9m up. None of the snapped trees re-sprouted. None of the seven large trees left standing had any major crown damage recorded.

The fallen trees knocked over the large yew at 68m and crushed or part-damage the two other yew, five elder, three ash and both hazel. There might have been more of this type of damage that was unrecorded, and some individuals might have been buried under fallen trees and unnoticed. Nevertheless, many of the understorey individuals appeared to be unscathed, including most of the ash group at 30-45m, and none of the large yew lost much of their crowns.

2.1.3 Condition of surviving trees/shrubs in 2000

The seven surviving beech trees in 2000 were generally healthy, though crown condition was variable. Most had responded well to the release from competition and had produced some or many vigorous trunk/crown sprouts and added new crown foliage. However, some trees (or at least substantial parts of the crowns on these) remained static, occasionally with poor, clustered foliage, dieback, and few or no signs of sprouts or crown expansion. There was a limited amount of squirrel debarking, mainly on the base of trunk sprouts, the tops of lateral branches or on root buttresses. A major fork on one of the larger trees had an old large split from 3-6m up which, despite healing well on the edges, had allowed rot to develop inside.

In 2000, all five yew were spreading vigorously in the open, though the uprooted individual had died back underneath and one of the smaller bushes was checked on top by a vigorous clematis mass. The ash group at 30-45m down was also responding strongly to the release from competition with canopy beech. The largest had grown to 60-90cm gbh and were suppressing nearby smaller individuals, one of which had apparently been excluded. Both hazel were also growing strongly, despite damage to and/or loss of some of the original stems, both had produced new vigorous shoots, particularly the one near the slope base that now had 22 stems size 5-32cm gbh. In contrast, few of the 28 elder recorded remained vigorous. Twelve had died because they had been overtopped and excluded, including three that had been overgrown and snapped by clematis. The remaining individuals (except one that was not recorded) had similarly been much reduced: many survived mainly as weak growth on lateral, snapped or fallen bushes, including those that had been struck by falling canopy trees, but a few remained moderately vigorous and several bore had a crop of berries. Otherwise, the field maple close to the slope base was leaning heavily and generally much suppressed, with a mainly contorted lateral crown growing above a large mass of ivy and clematis.

2.1.4 Recruitment of trees/shrubs by 2000 and condition of these

Recruits attaining 1.3m height were recorded on most of T1:0-100m in July-September 2000 (Figure 2). Those parts on the upper slope that proved impractical to record, were not dissimilar from the adjacent strips that were recorded. Table 3 shows the species, number and size of the recruits, whilst Figure 4 shows their location.

Table 2.3 Number and size of recruits on the main slope on T1:0-100m that had developed since the 1987 storm and attained 1.3m in height in 2000. Size is based on the largest stem on each individual.

	Ash	**Elder**	**Hawthorn**	**Beech**	**Field maple**	**Dog-wood**	**Hazel**	**Yew**	**Oak**	**Holly**	**All species**
Density recruits ≥1.3m height (n ha^{-1})	534	86	75	57	29	29	29	17	11	6	874
Size of individuals (n) (cm gbh)											
1-4.5	48	2	11	10	4	2	-	-	1	-	78
5-9.5	31	2	1	-	1	2	3	-	1	-	41
10-14.5	8	8	1	-	-	-	2	-	-	1	20
15-19.5	4	3	-	-	-	-	-	-	-	-	7
20-24.5	2	-	-	-	-	1	-	1	-	-	4
25-29.5	-	-	-	-	-	1	-	2	-	-	3
Total number individuals	93	15	13	10	5	5	5	3	2	1	152

The density of recruits was fairly low (874 ha^{-1}) and most were <10cm gbh. Ten species were present, though most were ash. Recruits were clustered in the first 20m or so of the transect, and scattered thereafter. Where the ground was not heavily shaded, bramble and clematis had developed strongly to form a dense cover, mostly 1-1.5m tall and in places virtually impassable. Where the ground was shaded, the ground vegetation was mainly dog's mercury, in places with some with false brome.

Ash accounted for 61% of the recruits. All were seedlings. Although most were small, a few had grown to saplings of 15-23cm gbh. Most were located on the upper part of transect from 0-21m down (Figure 4). Here they grew in dense groups, mixed with several other minor species between strips covered by large fallen beech logs. Nevertheless, only 33 out of the 83 ash saplings present were more-or-less erect and unchecked into the canopy, and only 6 of these attained 10cm gbh. Their growth was checked generally because the soils towards the slope top were very shallow and dry. However, this also limited the growth of bramble and clematis, which from about 10m down was visibly stronger and sufficient to grow over and smoother some of the saplings. There was also a surviving large beech tree at 7m down (Figure 3), which grew on a strong lean upslope, had some vigorous trunk sprouts present, and was overtopping several of the saplings and retarding their growth. The ash saplings from 31-41m down grew amongst, and were probably contemporary with, the ash group present here before the 1987 storm struck. They were all overtopped and strongly suppressed. The recruit at 43m down grew in the fork of a large beech snag and was also rather poor. The final three ash saplings at 63-64m down were only 3-8cm gbh. Two were smothered and bent over by clematis. The other arched up through bramble and was starting to get away. Thus, although the existing ash block had been expanded on, the lower half of the transect remained with hardly any ash individuals.

The nine other recruiting species accounted for 1-15 individuals each. Most numerous were elder, hawthorn and beech, with dogwood, field maple, hazel, holly, oak and yew scarce. All the beech, field maple, hawthorn, hazel and oak occurred within the first 22m of the transect, close to or amongst the ash recruits growing here (Figure 4). The beech recruits were all seedlings. They were only 1-4cm gbh and up to about 2m in height. All but one was grouped at about 5-8m down and 16-20m across. They appeared to have grown from seed off one of the two large beech that survived close to the transect top (Figure 3). They were supplemented by another ten beech seedlings, which grew amongst these but were only 0.8-1.2m in height. Nearly all these individuals were erect, stout, steadily growing and in the open. Even the isolated recruit at 19m down was healthy with good low lateral branches, though this was overtopped and had some clematis growing over it. The five field maple recruits were mainly located on the edge of the ash group to 7m down. They had probably developed from seed shed by trees in the hedgerow a few metres north of the transect start. The largest was only 7cm gbh. Four were erect, but three of these were being hampered by clematis, leaving only one in the open and unhampered. Thirteen hawthorn seedlings had recruited. Seven grew as part of the group on the right to 10m down, the others being just below from 10-20m down. Twelve were 6cm gbh or less and up to about 3m in height, but one had got to 11.5cm gbh. Eleven were erect and in the open or well lit, but one of these had clematis growing through it. The five hazel recruits were seedlings scattered within the first 20m down. Four were growing strongly in the open and were mostly multi-stemmed. The other had developed well and appeared to regrowth from an old coppice stool. However, this also had a lot of clematis and rose growing through it. Two oak seedlings were found at about 12m down, one of which was mostly overtopped and leaning under clematis/bramble. However, the other was erect, vigorous, in the open, and had got to 5cm gbh and 2.5m tall.

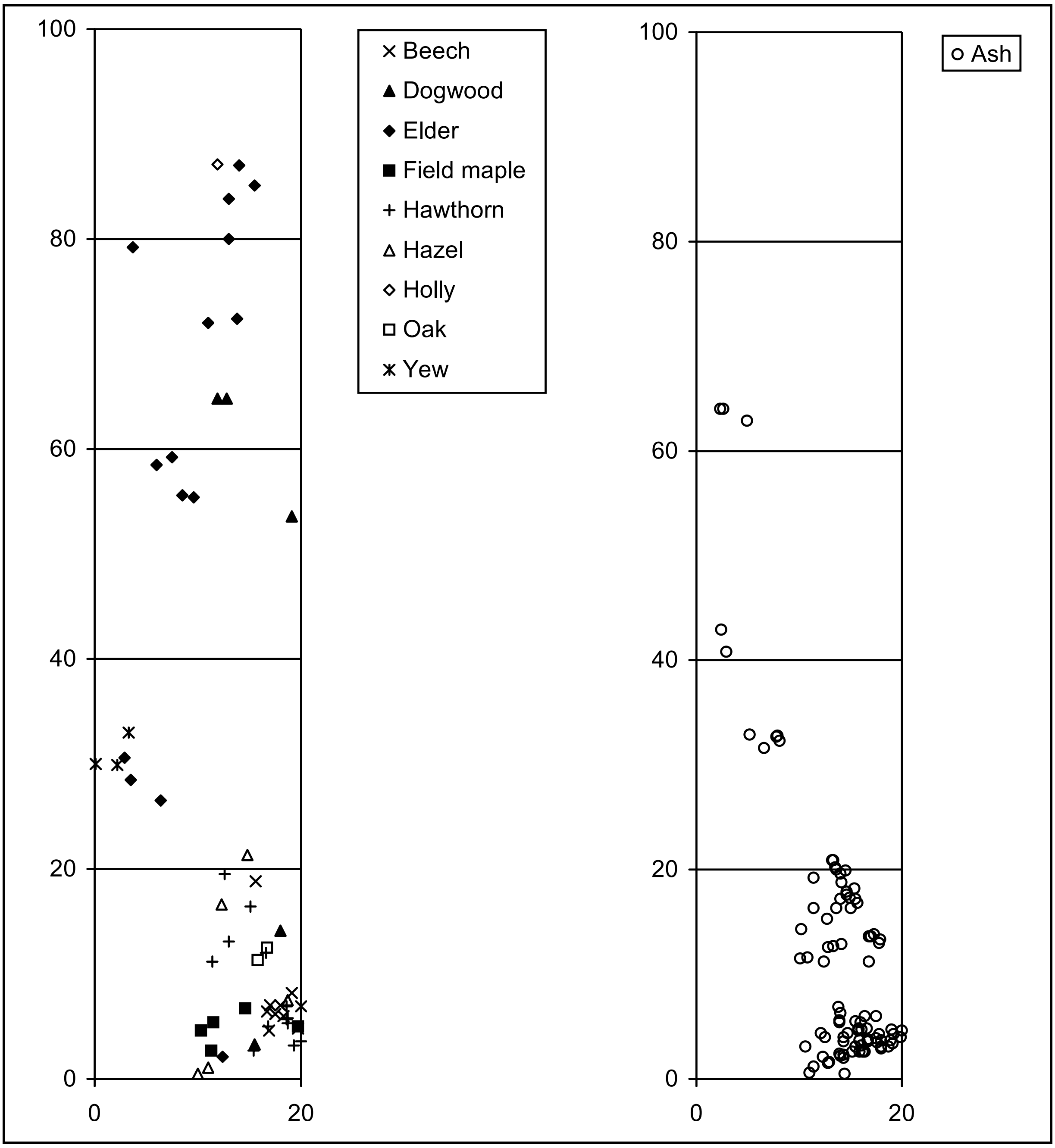

Figure 4: Location of recruits on the main slope on T1:0-100m that had developed since the 1987 storm and attained 1.3m in height in 2000. NB: not all parts of the first 25m of the transect were recorded (see Figure 2)

The elder, dogwood, holly and yew recruits occurred mainly around 30m or from 50m down the transect (Figure 4). Fifteen elder seedlings were recorded. They ranged from 4-18cm gbh, with 11 attaining 10cm gbh. Although they were scattered down the transect, many were on the lower half. Nine were overtopped by other trees and/or by clematis, and the remainder were similar but still had at least a few crown parts growing in the open. The five dogwood recruits included four seedlings and one layer from a bush just outside the transect. The two near the transect top were only 1-2cm gbh, one of which was over-topped and weak. The other three were at 50-65m down. They were sized 5, 7.5 and 21 gbh. Two were growing in the open, suckering, and had clematis growing through them, whilst the other was also not overtopped. The single holly recruit was a seedling growing from the between buttress roots of a surviving beech at about 90m down. It was possibly quite old and had been released. Some stems on this were erect and vigorous, but many were lateral and spreading down slope under clematis. The three yew recruits formed a small group at about 30m down, just before the block of surviving ash trees. They were of similar size (20.5-28cm gbh) and appeared to have established as small bushes before the 1987 storm, having since been released into vigorous or moderately vigorous growth. They were located not far away from and appeared to be contemporary with two other small yew, which had apparently grown to 10cm gbh by 1990 (Table 2.2, Figure 3).

2.2 Changes on the upper plateau on transect 2

2.2.1 Stand condition when 1987 storm hit

T2:0-35m crossed the upper plateau. The reconstructed stand condition for this area when the 1987 storm hit is shown in Table 2.4 and Figure 5.

Table 2.4 Reconstructed density, basal area and size of live trees and shrubs on T2:0-35m on the upper plateau when the 1987 storm hit. The size of individuals is based on the largest stem on each. Figure 4 shows the position of individuals. Based on bushes and saplings that attained 10cm gbh in 1989.

	Beech	Ash	Yew	Hazel	All species
Live individuals ≥10cm gbh (n ha^{-1})	156	128	57	14	355
Live stems ≥10cm gbh (n ha^{-1})	213	142	128	14	496
Basal area live stems ≥10cm gbh (m^2 ha^{-1})	16.0	7.5	2.5	<0.1	25.9
Size of individuals (n)					
10-24.5cm gbh	-	-	1	1	2
25-49.5cm gbh	-	-	1	-	1
50-99.5cm gbh	7	6	2	-	15
100-149.5cm gbh	3	3	-	-	6
150-199.5cm gbh	-	-	-	-	-
200-249.5cm gbh	1	-	-	-	1
Total number individuals	11	9	4	1	25

The basal area was moderate and accounted for mainly by eleven beech and nine ash. Many of these were medium-sized (55-140cm gbh) maiden trees, including nine of the beech and all the ash. One of the other beech was similar sized, in that it comprised four stems of 40-90cm gbh derived from coppice. Several similar sized trees were recorded just outside the transect, including three beech at 35-65cm gbh and three ash at 70-90cm gbh. The other two beech within the transect were larger. One was 140cm gbh and grew right beside another two near-same sized beech trees, which were located just outside the transect. The largest beech at 225cm gbh appeared to be a possible old pollard, pre-dating the other trees. Three dead beech trees were recorded within the transect that had apparently died before the 1987 storm. Two seemed small, at perhaps 50cm gbh, and had most likely been excluded by adjacent beech trees. The third was about 180cm gbh: this had more likely succumbed to drought, dying shortly before 1987 and leaving a small gap in which there were some ash saplings in 1989, all of which were less than 3m tall. The understorey included four yew within the transect and another just outside. Four were long-established, medium sized (44-90cm gbh) individuals. The other was a sapling at 10cm gbh. A single live hazel and a snag hawthorn were recorded near the transect start on the right side. The latter had apparently been excluded before the 1987 storm. Thus, the transect ran through the edge of two contrasting stands: the right side demarked the edge of an ash-dominated stand, whilst the left side was at the edge of a beech-dominated stand with some sizeable yew developed in the understorey.

2.2.2 Impact of 1987 storm

The 1987 storm appeared to have brought seven of the eleven live beech individuals down within the transect on the upper plateau (Figure 5). In addition, two of the four stems on the multi-stemmed coppice beech individual were snapped. This reduced the live standing beech basal area before the storm by 50%. Just outside the transect two of the five recorded live beech were also toppled. Considering all the recorded beech individuals that were toppled, most were medium-large sized trees. These included five uprooted trees sized 65 and 120-155cm gbh, and four snapped trees sized 60-111cm gbh. Trees left standing included the five smallest beech at 35-65cm gbh, another at 90cm gbh, and the large pollard at 225cm gbh. All five uprooted trees fell towards N, NE or NW. The snapped trees appeared to have broken at about 3-5m up. Three of the uprooted and two of the snapped trees remained with live foliage in 1989, but all were dead by 1993. None of the 12 ash recorded in the vicinity were toppled or suffered much crown loss in the 1987 storm. Indeed, few canopy trees on the right side of the transect were toppled, whereas most of the canopy beech on the left were lost, opening up the understorey or ground to far more light. No other large beech trees were lost by 2000, but the 1990 storms probably uprooted an 83cm gbh ash at 10m down (this was kinked and leaning before it fell and died) and half-uprooted another ash at 66cm (which survived). The toppled beech trees hit and partly broke and/or pushed over the four large understorey yew.

2.2.3 Condition of surviving trees/shrubs in 2000

In 2000 there were four surviving beech trees inside and three surviving beech trees just outside the transect, two of which were twin-stemmed. The condition of these was variable. None had suffered any major crown loss, though the large pollard was omitted in the 1989 and 1993 recordings and may well have been part-snapped at these dates. Moreover, this tree was in a poor state in 2000 with much of the lower trunk bark and crown dead (when it was visited in May 2001 the last surviving canopy fork had snapped off at the base and the tree appeared completely dead). Some of the other six medium-sized (45-100cm gbh) individuals had been released and were spreading into the gaps, whereas others remained overtopped and moderately suppressed by canopy ash trees. Two had been severely debarked by squirrels: consequently the top on one had been snapped out, and on the other twin-stemmed individual both crowns were yellowing prematurely. The other twin-stemmed individual also had one stem severely debarked by squirrels with large patches of bark missing from the base and crown forks. Nevertheless, most of these remained reasonably healthy.

Of the eleven ash surviving in 2000 (8 inside and 3 outside the transect): 7 were at least moderately vigorous and expanding into gaps; 3 remained much suppressed; and the other, which was half-uprooted, had a poor crown but a mass of well-developed trunk sprouts from 2m up, the lowest and largest of which had been badly debarked at base by squirrels.

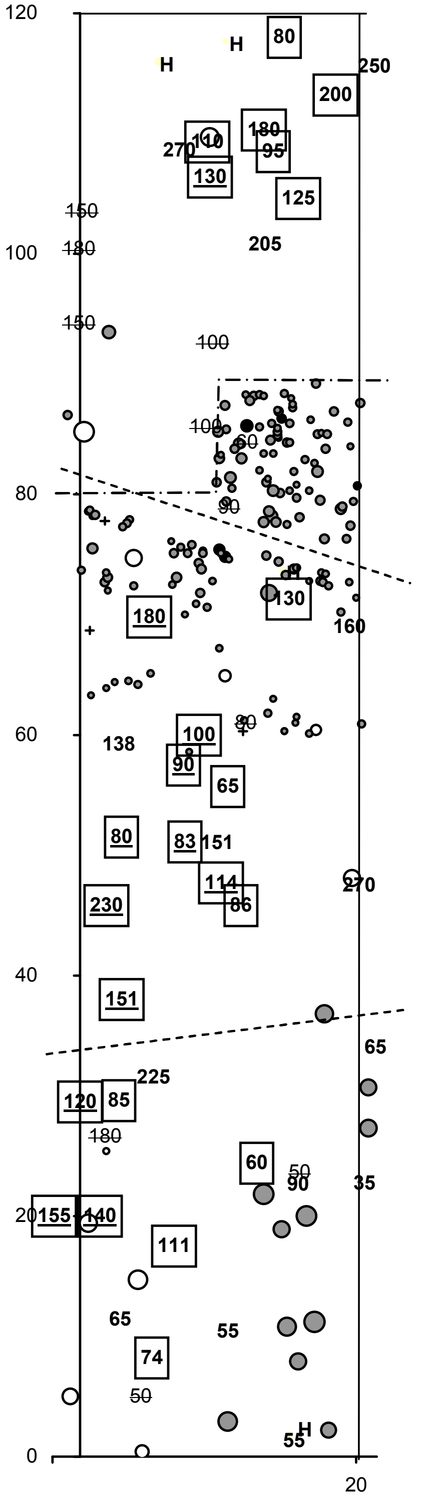

Figure 5: Reconstructed position of live trees and shrubs on T2:0-120m on the upper plateau (to 35m down) and main slope (from 35-120m) immediately before the 1987 storm and fate of large trees by 2000

Values on left are distance (m) down from the top of the transect. The dashed line at about 35m down shows the boundary between the upper plateau (0-35m) and main steep slopes (35-120m). The dashed line at about 80m down shows the position of the footpath.

Values within the diagram show the location and gbh (cm) of large beech trees: (a) non-bold values struck through = large stumps/snags dead before 1987 storm; (b) values underlined within boxes = standing alive before 1987 storm and uprooted after; (c) non-underlined value within boxes = standing alive before 1987 storm and snapped after; (d) values outside boxes = standing alive before and after 1987 storm (see text for details)

Circles and letters show location of other live individuals which attained 10cm gbh in 1989: grey circles = ash; black circles = goat willow; white circles = yew; + = elder; H = hazel; the width of circles is proportional to their gbh (range = 10-108cm); the pattern of ash/willow at 80-100m was probably repeated from 80-110m down on the left and 90-100m down on the right

Multi-stemmed individuals are based on the size of the largest stem

All four large understorey yew remained alive in 2000 and, along with the small yew individual, were spreading vigorously below gaps. One, however, was smothered in a mass of clematis. The hazel had also been released: it had developed numerous new stems, 16 of which attained 5cm gbh, but these were overtopped by trunk sprouts off an adjacent beech tree and were becoming suppressed.

2.2.4 Recruitment of trees/shrubs by 2000 and condition of these

In July-September 2000, recruits attaining 1.3m height were recorded on the first 30m of T2 on the upper plateau (Figure 2). Because of difficulties laying out tapes (and time constraints), only a central 2m-wide strip was recorded in this way from 30m down to the plateau edge. However, in this area the limits of the main block of dense ash regeneration was mapped and the only other recruit beyond this was recorded in full. Table 2.5 shows the species, number and size of the recruits in the first 30m of T2. Figure 6 shows the location and pattern of recruits to the plateau edge.

Table 2.5 Number and size of recruits on the upper plateau on T2:0-30m that had developed since the 1987 storm and attained 1.3m in height in 2000. Size is based on the largest stem on each individual.

	Ash	**Beech**	**Hazel**	**Holly**	**All species**
Density recruits ≥1.3m height (n ha^{-1})	3383	17	167	17	3583
Size of individuals (n)					
1-4.5cm gbh	69	1	6	1	77
5-9.5cm gbh	67	-	3	-	70
10-14.5cm gbh	34	-	1	-	35
15-19.5cm gbh	17	-	-	-	17
20-24.5cm gbh	13	-	-	-	13
25-29.5cm gbh	3	-	-	-	3
Total number individuals	203	1	10	1	215

The density of recruits was relatively high (3583 ha^{-1}), but they were clustered mainly into one of two groups on the left transect side. Where regeneration was lacking or limited and there was little canopy shading, bramble and clematis formed a dense but low cover, sometimes with limited amounts of dog's mercury and/or false brome. The ash regeneration groups extended beyond the transect into the adjacent stand, whilst the stand to the right of the transect similarly lacked regeneration. About two-thirds of recruits remained <10cm gbh, and although four species were present, ash was dominant, accounting for 94% of individuals and for all those that had grown to 15cm gbh.

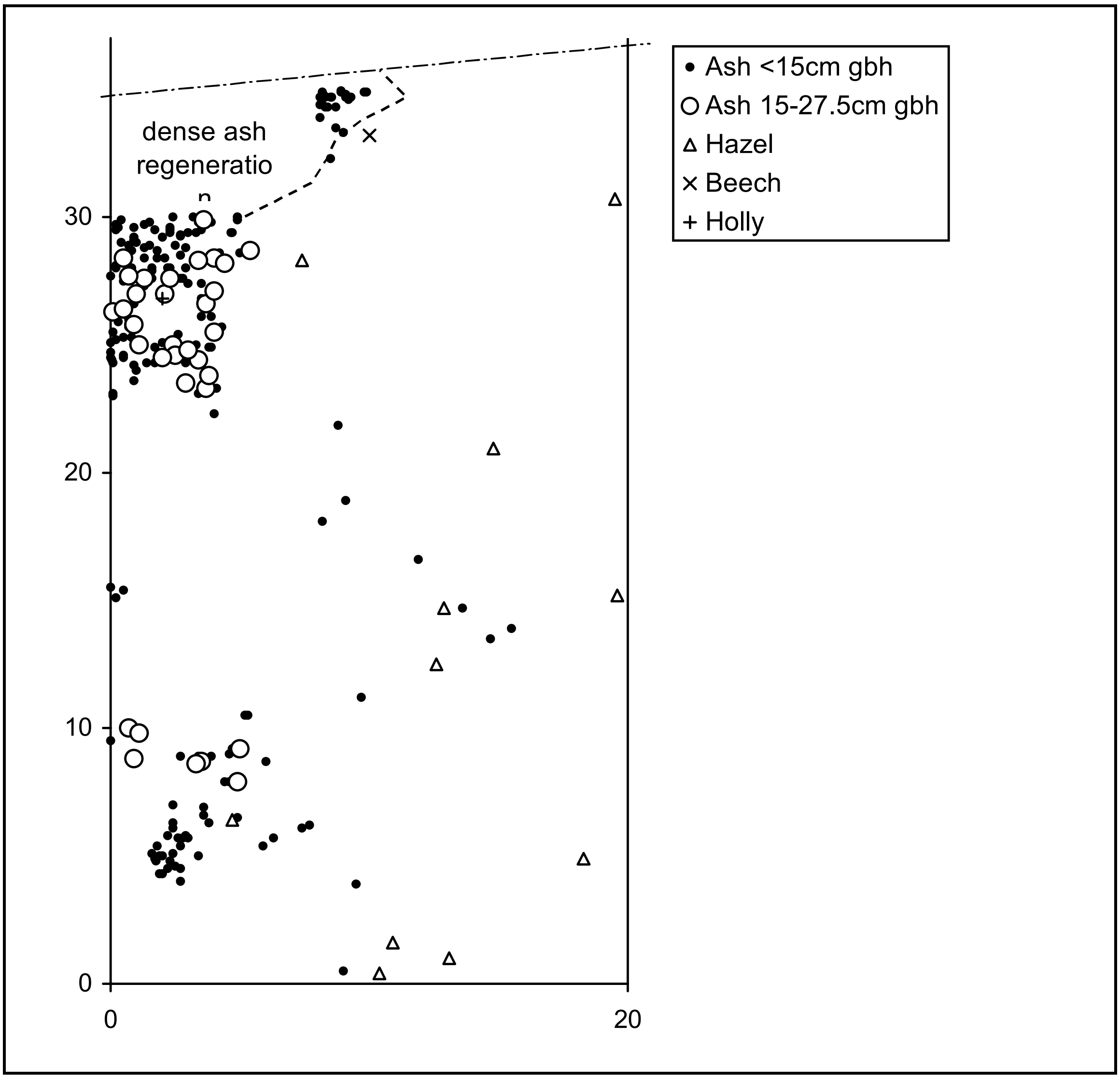

Figure 6: Location of recruits on the upper plateau on T2:0-35m that had developed since the 1987 storm and attained 1.3m in height in 2000. Values on axes are distance in metres. The left hand side beyond 30m along (marked dense ash regeneration) was not recorded in detail but contained similar regeneration as recorded immediately beforehand.

All the ash recruits were seedlings, derived from the stand of ash trees on the transect right and before the start. Although some were more widely scattered, most occurred in the two main regeneration groups from 4-10m down and 23m down to the plateau edge (Figure 6). The latter continued down the main slope in a similar form. The position of the two groups was linked with the survival of canopy trees and large understorey yew: where canopy trees or large understorey yew survived there was limited regeneration, but where gaps occurred between these it was copious. Both of the groups were virtual monocultures of ash, with a minority of saplings having grown to 15cm or more, leaving many of the others overtopped and suppressed. The first group had developed less strongly, partly because several yew bushes surrounded it and these had had expanded across and shaded several of the individuals, but also because clematis and sometimes bramble had grown over and bent saplings down. More of the saplings in the second group had grown vigorously and reached 15cm gbh by summer 2000. Surviving understorey yew and clematis troubled the saplings less here, though the group was punctuated towards the middle partly by the surviving small yew individual that was spreading vigorously, and clematis had grown through and suppressed a few saplings. Moreover, uprooted beech trees had covered the ground towards the middle, and had hit and damaged at least 25 surviving saplings and possibly another 22. These had characteristically been left bent over, and had reasserted themselves by either turning upright and/or by developing a new leading shoot part way along the trunk: this left them with a distinctive low kink or a lateral-growing base. Despite this damage, 14 of these individuals had still grown to over 15cm gbh by 2000. The ash saplings in this area were clearly present in 1989 (as revealed by a note in the field records), though they were not recorded individually. They were located around a probable beech snag, which died before the 1987 storm struck. Possibly, they had established shortly before the 1987 storm struck.

Eleven hazel seedlings were recorded before the plateau edge. These were scattered, but mainly occurred away from the dense ash groups, on the left transect side on the edge or under the surviving canopy ash trees (Figures 5-6). They were mostly small and had generally become overtopped and suppressed. Only one beech seedling was recorded. This was quite vigorous, but had only just got to 1.3m tall and was part-browsed by deer. A single holly seedling was recorded at 27m down in the large dense ash group. It was erect and growing on the top of an uprooted beech root plate.

2.3 Changes on the main steep slope on transect 2

2.3.1 Stand condition when 1987 storm hit

T2:35-120m crossed the main steep slope. The reconstructed stand condition for this area when the 1987 storm hit is shown in Table 2.6 and Figure 5.

Table 2.6 Reconstructed density, basal area and size of live trees and shrubs on T2:35-120m on the main slope when the 1987 storm hit. Data for ash and goat willow is limited to 35-80m on left and 35-90m on right (see Figure 5). The size of individuals is based on the largest stem on each. Figure 5 shows the position of individuals. Based on bushes and saplings that attained 10cm gbh in 1989.

	Beech	**Yew**	**Ash**	**Goat willow**	**Elder**	**Hazel**	**All species**
Live individuals ≥10cm gbh (n ha^{-1})	137	36	1416	43	18	24	1674
Live stems ≥10cm gbh (n ha^{-1})	155	95	1524	43	30	48	1895
Basal area live stems ≥10cm gbh (m^2 ha^{-1})	23.6	1.6	3.7	0.3	0.1	0.1	29.4
Size of individuals (n)							
10-24.5cm gbh	-	-	119	1	3	4	127
25-49.5cm gbh	-	2	11	3	-	-	16
50-99.5cm gbh	7	3	1	-	-	-	11
100-149.5cm gbh	7	1	-	-	-	-	8
150-199.5 cm gbh	5	-	-	-	-	-	5
200-249.5cm gbh	3	-	-	-	-	-	3
250-299.5cm gbh	1	-	-	-	-	-	3
Total number individuals	23	6	131	4	3	4	171

The basal area was moderately high. Most of it was accounted for by 23 beech trees, which ranged from 65-270cm gbh and were mainly single-stemmed maiden trees. However, three individuals appeared to be or might have been from coppice: one had two stems of 100 and 54cm gbh, another at 95cm gbh was on an old coppice stool, and another at 151cm gbh had two small basal sprouts. Two other live beech were recorded just outside the transect, including a large maiden at 250cm gbh and a large, 270cm gbh, long-uncut pollard at about 50m down on the right. In addition, eight dead beech were recorded, two of which were just outside the transect. These appeared to have been present before the 1987 storm as either snags or stumps and originally from trees sized 60-180cm gbh, many of which if not all appeared to be possible victims of the 1976 drought. Six yew were present in the understorey, including four well-developed, individuals with the largest stem on each sized 70-100cm gbh. A large cohort of ash was present, nearly all of which grew as single-stemmed maidens. The largest had got to over 30cm gbh, but 75% were <20cm gbh. Growing with these was a small number of goat willow ranging from 19-28cm gbh. Otherwise, only a few small elder and hazel bushes were recorded.

Large beech dominated most of the transect from the edge of the upper plateau to 60m down (Figure 5). These differed widely in size, from the smallest tree to the large, long-uncut pollard, and probably formed a near-complete canopy. Except for a large yew on the right edge at about 48m down, the understorey below these was largely undeveloped. There was a group of three large beech at about 70m down, and most of 100-120m was also dominated by medium-large canopy beech. Beneath the latter was one large understorey yew, whilst nearby were two hazel derived from old coppice stools.

There appeared to be gaps in the canopy from about 60m down. These were marked by small groups of ash saplings, and a couple of elder and yew bushes. The first gap on the right was associated with a beech stump from a tree of about 80cm gbh, which had died possibly following the severe drought of 1976. Close to the 130cm gbh beech at about 70m down was a canopy ash at about 70cm gbh, which was 30cm larger than any other recorded ash. This tree appeared to be a contemporary with the canopy beech (or at least much older than the other ash saplings) and had probably been released when the canopy immediately below had deteriorated following the 1976 drought (see below). The area from about 70m to 100m down appeared to have lacked any canopy beech before the 1987 storm struck. Instead, it was marked seven beech snags or stumps from trees originally sized 60-180cm gbh. These appeared to have died following the 1976 drought. To 80m down on the left and 90m on the right, ash regeneration was abundant. It grew around two large yew, and contained a few goat willow, hazel and elder saplings. Smaller trees and shrubs were largely unrecorded in the lowest seven quarter sections of the transect in 1989-93. However, field notes from this time show that 2-5m tall saplings, mainly of ash, were as numerous down to 100m on the right and 110m on the left as they were immediately before. The most vigorous ash saplings had grown to 30-40cm gbh, but many were smaller. In addition to 133 that attained 10cm gbh (see Figure 5), the 1989 records included 75 sized <10cm gbh from 53-90m along. These were all most likely part of the same cohort that had established several years before 1987.

2.3.2 Impact of 1987 storm

Fifteen of the 23 large live beech trees on the main steep slope on T2 appeared to have been brought down by the 1987 storm (Figure 5). This reduced the live standing basal area by 44%. Trees of all sizes were lost, including eight of the nine smallest and four of the six largest. Seven were uprooted and eight were snapped. Most uprooted trees fell within an arc from W to N, but one fell towards SW. Recorded root plates ranged mostly from 1-3m wide/tall. One uprooted tree remained alive in July-August 1989, but was dead by March 1993. One of the snapped trees broke low down at 1.5m, whereas the other four appeared to have broken at 4-9m up. Three of the eight beech left standing alive had 40-60% of their crown blown out, but the remainder and the two large beech recorded just outside suffered little damage. Otherwise, the larger ash at about 70m down was snapped at 12-15m up, possibly because the snapped neighbouring beech struck it. By March 1993 a further two beech at 48-51m down were uprooted: these were relatively small sized (83-114cm gbh), probably came down in the 1990 storms, and one remained alive on the ground. No more large beech fell by summer 2000.

The storm also appeared to have toppled a large yew on the left transect edge at 85m down. This was not recorded until 2000 when it was dead, fallen trunk. Because it had been uprooted, it was assumed that the 1987 storm brought it down. In addition, the two smaller yew (sized 28-35cm gbh) at 60-65m down were crushed by toppled beech trees: the smaller had the crown to the north snapped off, whilst the larger was left growing horizontally along the ground. The two hazel growing near the transect end and one of elder bushes, also suffered some limited damage from falling beech trees.

Falling beech trees/snags toppled in the 1987 storm damaged several of the ash saplings. Of the 195 recorded in 1989, 27 appeared to have been hit by falling trees/snags and another 35 might have suffered the same fate. These were left crushed, pinned and/or bent over. Two others were left growing laterally, as the beech root plate on which they were sited was upturned. None of the goat willow saplings appeared to have suffered such damage.

2.3.3 Condition of surviving trees/shrubs in 2000

Nine recorded beech sized 126-281cm gbh survived to 2000: seven were inside and two were just outside the transect. The condition of these varied. The two smallest (at 126-138.5cm gbh) had lost large parts of their crowns and the surviving parts were only slowly expanding (despite being in much space). Although the smaller tree had developed some large, vigorous, laterals on the lower trunk, these had being part-debarked by squirrels. Another tree at 165cm gbh had lost parts of its upper crown and suffered limited squirrel debarking, but the remaining crown forks were spreading well and, together with some developing vigorous lower crown sprouts, were reforming a new lower crown. Similarly, one the largest trees (at 279cm gbh) had lost one of its main forks and a large lateral on the surviving fork where it had been debarked by squirrels, but was spreading and shooting well downslope on the surviving fork. The largest surviving tree was the open grown possible ex-pollard: this had only one large trunk bough surviving (the other low lateral boughs appeared to have been shaded out before the 1987 storm struck), which was shooting/spreading slowly or quite vigorously in places, but had almost no trunk sprouts present and was debarked by squirrels in a few patches high up. Three of the remaining trees sized 173.5-260cm gbh had only superficial parts of the crown snapped out. The crown on the smallest remained healthy but was spreading little, and the only developing trunk sprouts were a few low lateral branches. The crown on the middle tree was released and slowly spreading all round, and this also had several developing trunk sprouts from 2m up. However, some branch tops had been debarked by squirrels. The crown on the largest tree was thin and dying back, but this was developing vigorously below mainly off trunk laterals. The other surviving tree was the uprooted 83cm gbh tree, which probably fell in the 1990 storms. This was dead beyond 12m along and had some new sprouts checked by browsing. Nevertheless, it had developed several low strong forks and new sprouts, some of which were erect and vigorous. Unfortunately, some of the stems had been badly debarked by squirrels and the foliage was consequently yellowing.

Three large yew survived to 2000 and were invigorated. The one on the right edge at about 50m down had grown up suppressed in the shade of beech, but was now far better lit and had become a vigorous, spreading and rising bush to 6m height. The one at 75m down was erect and vigorous with a broad, spreading crown below developing ash saplings. The last at 110m down was below a surviving beech, but was lit by side light and had many spreading laterals and a rising top. The two smaller yew were below a gap area and also released. The one that had the crown to the north snapped out, was otherwise mostly intact and had many vigorous, erect and spreading branches present. The other, which had been hit, uprooted, and seen most of the downside crown die off, had several erect, vigorous, replacement shoots developing from the upper forks and off the trunk.

The fate of 195 ash saplings recorded in 1989 by 2000 was determined. Only nine died completely: none of these were above 12cm gbh and two appeared to have been hit and crushed. Another persisted only as low live growth: it was beside the path and had been cut off. Surviving individuals ranged from 4-57.5cm gbh, but 124 remained <20cm gbh and only 16 had attained 30cm gbh. Although there were difficulties in matching some of stem size records, increment seemed to have been generally higher for the larger sized stems in 1989, though stems of all sizes exhibited high increment rates (Figure 7). Only 73 individuals remained in the canopy. The others were mostly overtopped and suppressed. Canopy individuals ranged from 9-57.5cm gbh, but included all the stems above 27cm gbh. Overtopped individuals included 98 of the 124 below 20cm gbh. The shape of canopy individuals differed: 40 were more-or-less erect throughout; 14 were similar but had noticeable kinks in the trunk (possibly because they been struck or suffered from terminal bud loss due to the ash bud moth); and 19 were more-or-less erect above but low down were leaning or growing off a short lateral base (most probably because they had been struck). Many of the overtopped individuals were growing on a distinct lean or laterally, at least low down, including 41 that appeared to or possibly had been struck in the past. Clematis was present in the crown of only 8 canopy and 8 overtopped individuals, and appeared to have impacted little on stand development.

All four of the goat willow saplings recorded in 1989 survived to 2000, but one, which was probably contemporary but sized 8cm gbh in 1989, had been excluded by adjacent ash. They had grown to 29-51cm gbh and by 0.9-1.5cm gbh per year. All survived as canopy trees, but with relatively small crowns. An additional five goat willow were recorded in 2000 at 82-91m down, on the part of the transect that was not recorded beforehand. These were undoubtedly contemporary with the others, having grown to 20-64.5cm gbh. The smallest of these had become overtopped and suppressed, whereas the largest remained in the canopy.

All four hazel survived to 2000. The two at 74-79m down had both developed several new stems. Ash saplings had overtopped and suppressed one already. Although the other had developed more strongly and was still generally vigorous, it too looked set to become overtopped in the same way. The two hazel near the transect end were invigorated old stools, which had developed and recruited many new stems by 2000. However, they were becoming part-overtopped by the surviving canopy beech, deer were browsing most basal sprouts, and a spruce tree had fallen across and part-damaged one of them.

Two of the three elder had died by 2000 and the other was near-dead. All were growing amongst and over-topped by developing ash saplings, though one had also been hit by a fallen beech and had clematis growing over it.

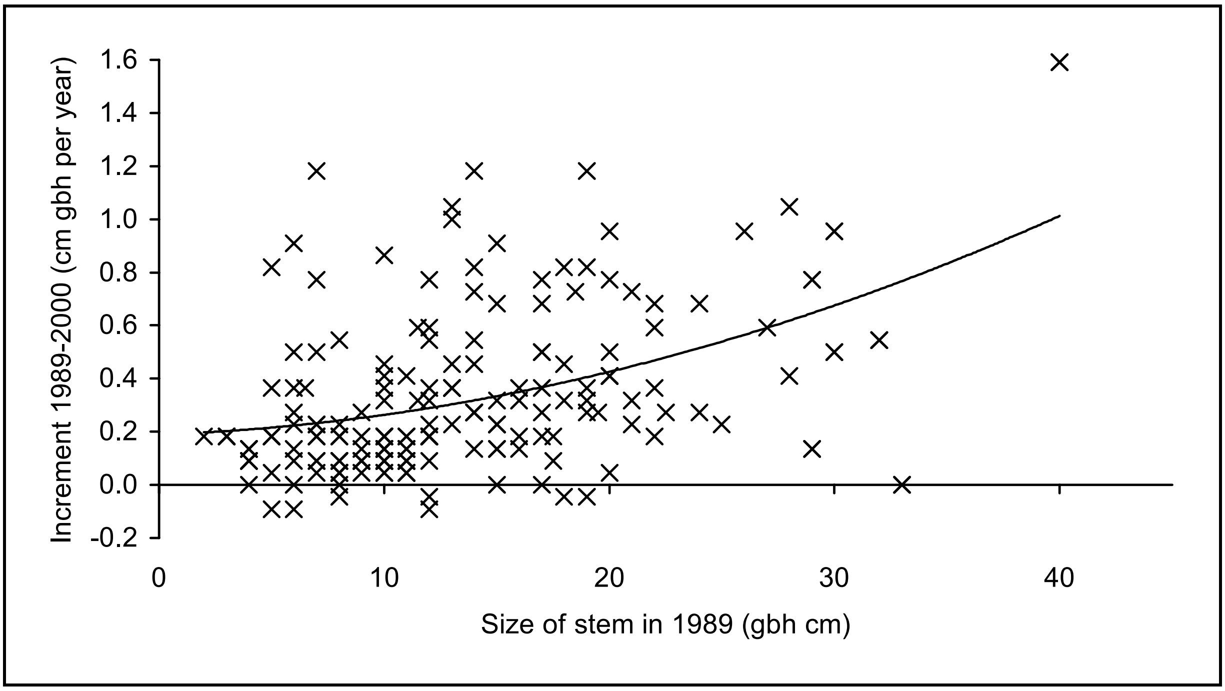

Figure 7: Increment of ash saplings on the main slope on T2 from 1989 to 2000 in relation to initial size. Some points represent more than one stem. The quadratic regression line equation is: $y = 0.0004x^2 + 0.003x + 0.1896$, $P<0.0001$, $R^2 = 0.210$. Includes only stems with stem size measurements that appeared realistic.

2.3.4 Recruitment of trees/shrubs by 2000 and their condition

In July-September 2000, recruits attaining 1.3m height on the main steep slope on T2 were recorded on the whole transect from 60-120m down, and (due to difficulties laying out tapes) on representative strips from 35-60m down (Figure 2). The limits of the main blocks of ash regeneration were mapped from 35-60m down. Table 7 shows the species, number and size of the recruits in the parts that were recorded in detail. Figure 8 shows the location and pattern of recruits on the whole transect. Recruitment differed from other transect areas, in that there was abundant ash regeneration, much of which had apparently established several years before the 1987 storm. Although some of this attained 10cm gbh by 1989 and was considered above, much did not and/or went unrecorded before 2000 (see Figure 2). The analysis of ash (and willow) recruitment therefore was done on the basis of all apparent recruits that developed shortly before or since the 1987 storm and attained 1.3m in height in 2000.

The density of recruits recorded in 2000 was very high. They occupied most of the transect, but some parts on the upper slope and at the end remained largely devoid of recruits (Figure 8). The area on the upper slope was open, but had shallow, dry soil, several large beech logs, and had become overgrown with dense bramble and some clematis. The area at the end already had a couple of large hazel and a yew that had expanded, and was otherwise over-shadowed by surviving beech trees (Figure 5). About two-thirds remained <10cm gbh, but some had grown over 30cm gbh. Four species were recorded, with ash dominant.

Table 2.7 Number and size of recruits on the main steep slope on T2:35-120m that had developed shortly before or since the 1987 storm and attained 1.3m in height in 2000. Size is based on the largest stem on each individual. The size of some individuals in 1989 was assumed.

	Ash			Willow		Hazel	Yew	Beech	All species
	≥10cm gbh in 1989	<10cm gbh in 1989	Others present in 1989	≥10cm gbh in 1989	Others present in 1989	<10cm gbh in 1989	<10cm gbh in 1989	<10cm gbh in 1989	
Density all live recruits ≥1.3m height (n ha^{-1})	1008	4528	3102	31	39	110	47	8	8874
Size of individuals (n)									
1-9.5cm gbh	3	468	215	-	-	10	2	-	698
10-19.5cm gbh	65	103	123	-	-	4	2	1	298
20-29.5cm gbh	44	4	38	1	1	-	1	-	89
30-39.5cm gbh	14	-	17	1	2	-	1	-	35
40-49.5cm gbh	1	-	1	1	-	-	-	-	3
50-59.5cm gbh	1	-	-	1	1	-	-	-	3
60-69.5cm gbh	-	-	-	-	1	-	-	-	1
Total number individuals	128	575	394	4	5	14	6	1	1127

In total, 1097 ash recruits were recorded in 2000 (Table 7). 703 of these were from parts of the transect that were recorded in 1989. The remainder were from towards the end of the transect, where recruits were not recorded in detail then (see Figure 2), although they were evidently numerous to about 100/110m down. All the saplings were from seed, presumably derived from scattered ash trees within a short distance of the area. Despite some differences in density, they occupied much of the transect area (Figure 8). Where they were lacking on the upper slope, the area was open and contained some short ash seedlings, but these were struggling on the shallow soils in competition with mainly bramble. Further down, they had mostly grown through bramble well (which was now moribund under the saplings), but in some places they had been part-checked by this, or by expanding yew bushes or crowns on surviving canopy beech. In a few places, uprooted beech trunks and root plates/pits covered the ground, though these had generally not limited the saplings from closing the canopy. There were few ash recruits near the transect end, as this was shaded by surviving beech and expanding hazel and yew bushes (Figure 5). A minority of the saplings had grown larger, leaving many overtopped and suppressed. The gbh-distribution of the 703 survivors recorded in 1989 and which attained 10cm gbh or were smaller then (Table 7), confirmed that the largest recruits in 2000 had generally been amongst the largest sized in 1989. These had also generally grown most rapidly (Figure 7), and most were situated lower down the slope, mainly below the path and to 95m down, before surviving beech trees shaded the area. This was presumably part-related to differences in the ground conditions (the soil lower down being both deeper and receiving more drainage water), although the sapling group lower down had evidently established earlier (Figure 5). Of all the ash saplings recorded in 2000, 236 were in the canopy, the others being mostly overtopped and suppressed. Canopy individuals ranged from 2-57.5cm gbh, but included all but 8 of the 33 stems attaining 30cm gbh. Overtopped individuals included 807 of the 977 below 20cm gbh. The shape of canopy individuals differed: 128 were more-or-less erect throughout; 35 were similar but had noticeable kinks in the trunk (possibly because they been struck or suffered from terminal bud loss due to the ash bud moth); and 73 were rising above but low down were leaning or growing off a short lateral base (most probably because they had been struck). Many of the 861 overtopped individuals were growing on a distinct lean or laterally, at least low down, including 276 that appeared to or possibly had been struck in the past. Clematis was present in the crown of 36 canopy and 76 overtopped individuals, in some cases having apparently bent down branches and prevented stems from developing normally. In some cases towards the slope top, bramble had grown over and bent saplings down.

Nine willow saplings were recorded in 2000. These grew at 70-91m down (apparently marking deeper, moister soil) (Figure 8), were sized 20-64.5cm gbh, and six remained in the canopy. Hazel had formed 14 new recruits. The largest had grown only to 21cm gbh and appeared to have developed from an old stool, but most were new seedlings <10cm gbh. They grew mainly from 60m down, scattered amongst ash saplings. Four had some stems frayed or browsed by deer, and most had become overtopped and suppressed by ash saplings. There were six yew recruits. The two largest (27-30cm gbh) occurred at 58m and 71m down. These appeared to be old bushes, which were now released and spreading vigorously. The four smaller recruits (<15cm gbh) grew at 91-98m amongst ash saplings. They were overtopped but healthy, the two largest having spreading crowns. Only one beech recruit was present at 86m down. It was 11.5cm gbh, 4m tall, and most probably a seedling. Another beech recruit was recorded just outside at 67m down. This was a seedling at 22cm gbh. It was generally erect, and despite being overtopped was vigorous, spreading and rising on top.

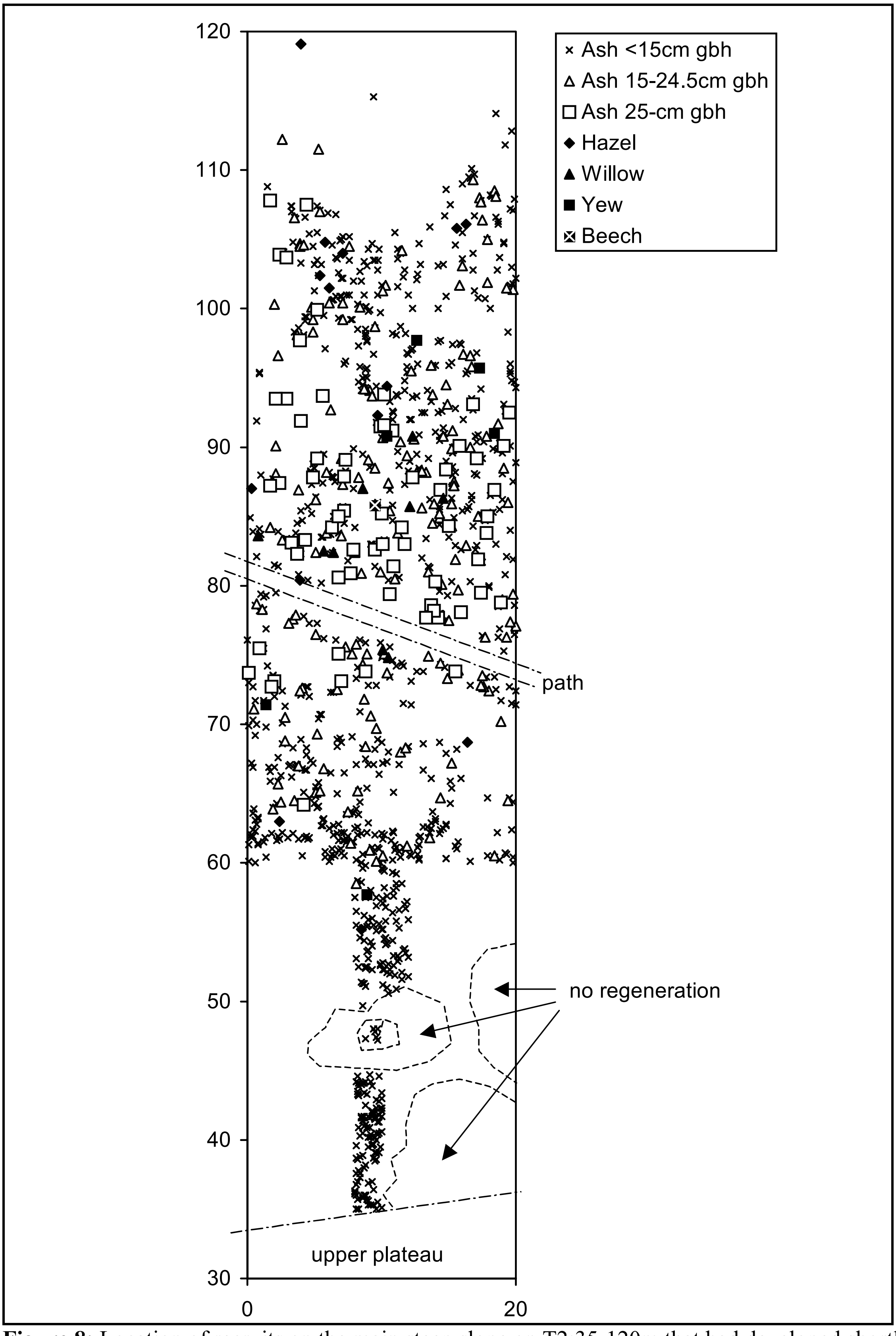

Figure 8: Location of recruits on the main steep slope on T2:35-120m that had developed shortly before or since the 1987 storm and attained 1.3m in height in 2000. Values on axes are distance in metres. Individual recruits were recorded only in representative central strips from 35-60m down, but the limit of the regeneration was mapped as shown.

2.4 Changes below the main slope on transect 1

The stand parameters for T1:100-120m in the stand below the main slope are summarised in Table 8. The main species remained as hazel, field maple and ash, most individuals of which were multi-stemmed and derived from coppice. Dogwood and crab apple were the only minor species within the area recorded, but a large cherry tree and a few small spindle were recorded nearby. The reduction in the recording threshold from all individuals attaining 3m height in 1990/93 to those attaining 1.3m height in 2000, probably had no effect on the comparison between dates because there were probably no short individual present in 1990/93.

Table 2.8 Density, size and basal area of live trees and shrubs and snags on T1:100-120m in the stand below the main slope in December 1990, March 1993 and September 2000. Recording of live individuals in 1990 and 1993 including those attaining 3m height, whereas in 2000 it included those attaining 1.3m height.

	Live individuals	Live stems				Snags		
	Density ($n\ ha^{-1}$)	**Density ≥10cm gbh ($n\ ha^{-1}$)**	**Density ≥50cm gbh ($n\ ha^{-1}$)**	**Max. size (gbh cm)**	**Basal area ≥10cm gbh ($m^2\ ha^{-1}$)**	**Density ≥10cm gbh ($n\ ha^{-1}$)**	**Max. size (gbh cm)**	**Basal area ≥10cm gbh ($m^2\ ha^{-1}$)**
1990 December								
Hazel	475	1325	175	75	12.8	100	37	0.8
Field maple	200	750	150	60	9.2	50	16	0.1
Ash	50	100	75	97	3.7	0	-	-
Dogwood	50	50	0	30	0.3	0	-	-
Crab apple	25	25	25	70	1.0	0	-	-
All species	800	2250	425	97	27.0	150	37	0.8
1993 March								
Hazel	475	1325	175	75	13.1	100	37	0.8
Field maple	200	750	150	70	9.6	50	16	0.1
Ash	50	100	75	105	4.1	0	-	-
Dogwood	50	50	0	30	0.3	0	-	-
Crab apple	25	25	25	72	1.0	0	-	-
All species	800	2250	425	105	28.0	150	37	0.8
2000 September								
Hazel	500	1225	125	67	10.2	475	33	1.9
Field maple	175	575	150	88	8.3	300	44	1.5
Ash	50	125	75	124.5	6.1	0	-	-
Dogwood	0	-	-	-	-	0	-	-
Crab apple	25	25	25	75	1.1	0	-	-
All species	750	1950	375	124.5	25.7	775	44	3.4

The basal area and size of the larger stems in December 1990 showed that this stand had been uncut for several decades. Snags were scarce and amongst the smaller stem sizes, indicating that they had probably been excluded. There was little evidence of any storm-damage, except that the 50% crown loss recorded on a field maple and two hazel stems might have been due to damage sustained by falling beech trees off the main slope. The stand changed little by March 1993.

By September 2000 the density and basal area of live individuals/stems had declined slightly, whilst snags had increased. The differences were mainly due to changes in hazel, field maple and dogwood. Hazel had 18 stems die (though including only 1 individual), nine of which were larger at 33-50cm gbh. 11 of the losses were replaced, but only by stems that grew to 10-16cm gbh. In addition, two hazel individuals re-established, but only from weak growth off an old crushed stem and an old stump. Field maple lost 9 stems (though only 1 individual died), six of which were 30-50cm gbh. Only two stems were replaced, and only by stems that grew to 11-13cm gbh. Both dogwood individuals recorded in 1990/93 died. Most of the hazel, maple and dogwood morality appeared to be due to exclusion, though a couple of stems were found cut off. Several hazel and maple stems remained standing, increasing the abundance of snags. The single crab apple tree survived but changed little in gbh. In contrast, all ash stems survived and the largest grew by about 15-20cm gbh each. Thus, the basal area of ash increased considerably. The large cherry outside the transect remained healthy. The ground vegetation remained heavily shaded and mainly comprised dog's mercury with some ground unvegetated.

2.5 Dead wood levels in 2000

The volume and length of dead wood was estimated on the main steep slopes and upper plateau in September 2000 (Table 9). Total volume and length were about 350m^3 ha^{-1} and 10500m ha^{-1} respectively. Most of this was beech and in fallen dead logs, reflecting the fact that storm damage had brought down most of the original beech dominated stand.

Table 9: Estimated volume and length of logs (fallen dead trees) and snags (standing dead trees) in September 2000 on the main steep slopes and upper plateau. Logs were based on line-intersect sampling (which extended into the compartment surrounding the study transects), whilst snags were based on measurements on the transects on the main steep slopes and upper plateau

	Logs		**Snags**	
Species	**Volume (m^3 ha^{-1})**	**Length (m ha^{-1})**	**Volume (m^3 ha^{-1})**	**Length (m ha^{-1})**
Beech	296.7	9173	40.5	180
Ash	10.2	377	0.1	80
Yew	1.9	440	-	-
Elder	0.4	188	0.2	80
Hazel	-	-	0.1	23
All	309.2	10179	40.9	363

2.6 Summary of results

The storm of 16 October 1987 was an exceptional event. It caused widespread damage to many mature woods along the length of the East Hampshire Hangers. Further storm-damage in spring 1990 brought down more trees. In some places, old-growth beech stands were all but leveled, literally over night. Noar Hill Hanger was one such wood. Fortunately, soon after the 1987 storm struck two permanent transects were established here. Although these were limited in terms of their representatively of the site as a whole, they nevertheless provided data from which it was possible to get an impression of what the stands looked like beforehand, and to what extent they were damaged by the storm and how this was related to site factors.

2.6.1 Stand condition before the 1987 storm

As with many woods along the East Hampshire Hangers, by the time the 1987 storm struck Noar Hill Hanger had largely developed into a high forest stand dominated by medium-large beech trees. Other trees were for the most part scarce, though in places ash was prevalent (see below) and on parts of the upper plateau and on the strip below the main slope it was the main canopy tree. The understorey was mostly limited, except on the strip below the main slopes where an understorey of mainly hazel and field maple was well-developed under an ash canopy. Below the closed beech stands, a few sizeable yew were present. However, there were some scattered canopy gaps on the main slopes that contained varying amounts of regeneration. The gaps had developed partly as a result of dieback triggered by the severe drought of 1976, but also because a few canopy trees had been selectively felled, no doubt including some drought-stricken individuals. They were detected on both study transects and on an aerial photograph of the site from 1984. They extended up to about 30m in diameter. On one of the study transects, the regeneration present mostly amounted to a scatter of elder bushes. However, one gap area here towards the middle of the main slope was filled with a small stand of medium-sized canopy ash. The canopy on the lower half of the other transect was much broken and contained a dense cohort of mainly small ash.

2.6.2 General patterns of storm-damage

The 1987 and (to a lesser extent) 1990 storms brought down many trees across the site. An aerial photograph of the site in August 1991 showed: (i) extensive heavy damage with limited survival of canopy trees across the upper and middle parts of the main steep slopes (some places, particularly at the western end at and lower down the slope, retained more canopy trees); (ii) survival of most trees on the part of the upper plateau that was set back from the main steep slopes, and also on the strip below the main steep slope.

These patterns were picked on the two study transects. The records helped quantify the amount of damage to canopy trees on the main steep slopes and adjoining parts of the upper plateau. Losses due to the 1987 storm amounted to about 65%, with the lower half of the main slope suffering slightly less. The 1990 storms brought down more trees, bringing the total to about 70% of those standing beforehand. Only a small number came down during the next decade. Most losses were of beech, as this was the dominant tree. Trees across the size-range were lost. About two-thirds were uprooted and one-third snapped. Most uprooted trees fell in a similar direction, generally uphill or across the main slope. Surviving beech were left mostly scattered as isolated individuals or small groups. Several had lost major parts of their crown, but others were largely unscathed. Several understorey individuals were crushed or part-damage, including several of the larger yew and about 30% of the young ash saplings. The group of medium-sized ash on the main slope survived largely unscathed.

The most obvious factors accounting for the damage patterns were:

i. **tree size** – the stands were dominated by large canopy trees, which because of their very size were vulnerable to uprooting or snapping – some trees were probably brought down as they were struck by larger trees – the surviving group of medium-sized canopy ash on the main slope proved that smaller canopy trees were less vulnerable;

ii. **exposure to storm-winds** – the stand grew on a steep, south-facing slope, which was directly exposed to the strongest storm winds in 1987 – the greatest impact was on the 'most exposed' areas (ie the upper and middle slopes and adjacent upper plateau) – stands 'protected' at the base of the main slope and set back on the upper plateau, and trees and shrubs 'protected' in understorey suffered less damage;

iii. **anchorage** – the majority of trees were uprooted and grew where the soils were particularly shallow, directly over chalk, and provided little rooting depth – trees growing at the base of the main slope and set back on the upper plateau were on deeper soils and proved more wind-firm – most of root plates on upturned beech were shallow and lateral with few large roots penetrating into the underlying bedrock.

2.6.3 Dead wood

With the loss of so many canopy trees, the amount of dead wood was substantially increased. In 2000, the total volume on the main steep slopes and upper plateau was about $350m^3\ ha^{-1}$, about 90% of which was in fallen logs. This was probably at least a threefold increase on the level before 1987, even allowing for some mortality of large trees following the 1976 drought.

2.6.4 Condition of surviving trees/shrubs and regeneration

The storms did not remove all canopy beech and ash trees on the main steep slopes and adjoining parts of the upper plateau. The beech on the study transects that survived to 2000 remained generally healthy, albeit that some had lost large forks. In fact, many had responded well to the release from competition and produced some or many vigorous trunk/crown sprouts and new crown foliage. Others remained static and occasionally had poor foliage and few signs of sprouting or crown expansion. Several had been partly-debarked by squirrels, but a few medium beech trees were more severely debarked and had consequently had the top snap out or suffered early crown-yellowing. Only one beech died back strongly (and was dead by May 2001). Hardly any beech toppled or snapped in the storms survived for long. Within the transects, only one uprooted beech survived in 2000. This was a medium-size tree, which had developed several low strong forks and new sprouts. Unfortunately, these had attracted the attention of deer and squirrels, some sprouts having been eaten back or badly debarked. The marginal trees in the surviving ash stand on the upper plateau were expanding well in 2000.

On the main steep slopes and adjoining parts of the upper plateau, most of the recorded yew and hazel that were established in the understorey before the 1987 storm, survived to 2000 and were growing strongly. The yew had developed vigorous, spreading crowns, even most of those that had been part-crushed or knocked over by falling canopy trees. A few had been part-checked by strong clematis growth. Most hazel had developed numerous new stems, though several were becoming overtopped and suppressed by surviving canopy trees or developing ash recruits. In contrast, few of the elder that were established in gaps before the 1987 storm remained vigorous in 2000. Some had been overtopped by ash regeneration or surviving canopy trees, some had been snapped by falling canopy trees, whilst others had been overgrown and/or snapped or by vigorous clematis growth.

2.6.5 Regeneration

Regeneration patterns recorded on the two study transects varied. On the main slope on the first transect, relatively few new recruits developed, even within gaps. Most that did remained small and were clustered at the top of the main slope. This included most of the ash (which accounted for 60% of the new recruits), and all the beech, field maple, hawthorn, hazel and oak. The largest ash had grown to 15-23cm gbh, but many were <10cm gbh. The beech were sized only 1-4cm gbh, though nearly all were well-established. Only a few field maple, hawthorn, hazel and oak remained erect and largely unimpeded. Growth at the slope top was notably slow because the soils were very shallow and dry, though this limited competition from bramble and clematis. On the mid-slopes, few recruits had developed. Rather, the dominant trees in the existing ash group were released and expanding strongly in 2000. On the lower half of the transect, which extended to the base of the main slope base, gaps had become largely been filled with dense low-growth of bramble and clematis, which was virtually impassable in places. Recruits here were few and mainly elder, many of which had been overgrown by clematis. Virtually no recruits established on the strip below the main slope. This remained closed and changed little by 2000, save for self-thinning in the understorey.

On the other study transect, many recruits developed in gaps on the upper plateau away from the surviving ash block and large understorey yew. Most were ash. The strongest had grown to 15cm gbh or more. A minority had been checked by clematis or bramble. Some had been struck by falling canopy trees, though several of these had reasserted themselves and were amongst the largest saplings in 2000. Probably, some of the ash recruits had established in gaps shortly before the 1987 storm struck. Only one beech seedling had recruited by 2000. Otherwise, a scatter of hazel recruits developed. These were positioned mostly around the edge of the surviving ash stand and had generally become overtopped and suppressed.

By 2000 much regeneration had established on the main slope on the second study transect. However, some places near the slope top, where the soils were especially shallow and logs abundant, remained without recruits and were instead filled mostly with bramble. Similarly, little new regeneration had established on the lowest part of the slope. Instead, surviving beech trees and hazel bushes had expanded here. Nevertheless, dense regeneration had established on the ground in between. This was dominated by ash, with a smaller number of goat willow, hazel, elder and yew, and only a very few beech saplings. It had grown up through bramble and for the most part had overcome any clematis lianas. Much of it was certainly established in gaps before the 1987 storm struck, and had subsequently been released. However, even higher up the slope where beech had formed a closed canopy beforehand, it had still developed reasonably well. Even so, these recruits remained smaller than those lower down, though this was partly because the soil was shallower higher up the slope and growth was accordingly retarded. Most of the dominant saplings in 2000 were ash. Several goat willow also remained in the canopy, but the beech, hazel, and small yew recruits were mostly overtopped. Surprisingly, about one-third of the ash saplings in the canopy in 2000 appeared to been struck by falling canopy trees in the past, yet had reasserted themselves.

2.7 Overview

This study combines with with similar studies conducted at the nearby Ashford Hangers National Nature Reserve where similar patterns of stand break-up and regeneration have been recorded following the 1987 storm (Mountford & Ball 2003). Together these demonstrate seven main points:

(i) mature beech stands on steep chalk slopes can break-up rapidly under the influence of severe windstorms;
(ii) canopy beech suffered predominately from uprooting (as opposed to trunk snapping);
(iii) storm-damage was patchy, partly related to site topography;
(iv) some surviving canopy trees and understorey individuals were released and invigorated;
(v) storm-damage reduced the live standing basal area and increased dead wood;
(vi) subsequent regeneration was patchy, predominately of ash, with little beech and oak, and included a minority of elder, goat willow, hazel and other species;
(vii) bramble and clematis succeeded in some gaps, rather than tree/shrub regeneration.

The implications for nature conservation and recommendations for research and monitoring are discussed in the report on Ashford Hangers National Nature Reserve (Mountford & Ball 2003). In general, the developments are considered favorable in nature conservation terms, albeit that this has to be balanced against the loss of many mature trees and their associated habitats. Monitoring of the permanent plots/transects at the two sites should be continued and, if at all possible, expanded.

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Annex 1 Recording on the two permanent transects at Noar Hill Hanger

Figure 1 shows which parts were recorded at each date.

Date	Features recorded
July-August 1989, February and December 1990	• All large trees/shrubs (including large uprooted trees and snags) and smaller saplings/shrubs attaining 3m height recorded, including their coordinates, species, status (as alive or dead), girth at breast height (1.3m) (gbh) of largest stem and sometimes subsidiary stems, and notes on the origin and form (mainly as maiden, coppice, pollard, shrub, canopy, ex-canopy, sub-canopy, shrub, sapling, forked, fallen, root plate dimensions, snapped, crown loss, snag, stump) • For most subsections various notes and salient features (eg large fallen trees) were included on a sketch map
March 1993	• As per above for newly mapped subsections • For subsections already mapped, only the status of individuals recorded before was checked
July-September 2000	• All trees (including large uprooted trees and snags), shrubs and saplings attaining 1.3m height recorded: including their coordinates (remeasured), species, status (as alive above or below 1.3m height or dead), girth at breast height (1.3m) (gbh) of all stems attaining 10cm gbh, and a description of their form, vigour, crown condition, sprouting, damage, debarking, cause of death, and origin (longer descriptions were made for large canopy trees and all large trees recorded in 1989/90/93 were checked) (snags attaining 1.3m height had the height estimated to the nearest m, decay state categorised as solid, part-rotten, rotten, and remaining bark estimated to the nearest 10%) (squirrel debarking to beech was scored using a five-point scale: 0 = *none* = no bark removed; 1 = *limited* = one or few small patches with <10% bark circumference removed; 2 = *moderate* = one large or few medium and/or many small patches with 10-50% circumference removed; 3 = *severe* = few large and/or many medium and many small patches with >50% circumference removed; 4 = *very severe* = as for severe but ring-barked; damage included that to the trunk and main forks, with the upper branches being viewed from the ground with binoculars; debarking was recorded first for the lower trunk (<2m height) and then for the upper trunk (>2m height), with the maximum score used to categorise overall damage, ie scores of 1/3, 3/3 and 3/1 were all categorised as severe damage) • Charts of 20x20m stretches of the transects were made showing the position of all individuals • The main ground vegetation units (listing dominant species) were mapped on the charts • Fallen dead wood was estimated for the whole compartment using 5x50m-long line transects and following the method described by Warren and Olsen (1964) and Kirby and others (1998): five equal length line-transects covering 250m (t) were spread throughout the compartment containing the transects; the number (N) of fallen dead stems attaining 5cm diameter and intersecting the line were counted, and their diameter (d) where they intersected the line was measured in cm and the species identified; each stem was assigned to a decay class (*solid* = no signs of decay, *part-rotten* = limited signs of decay, or *rotten* = decay advanced) and the % remaining bark was visually estimated; the volume (V) of fallen dead wood was then estimated using the formula, $V = \sum(\pi^2 d^2/8t)$ ($m^3\ ha^{-1}$)

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