Report Number
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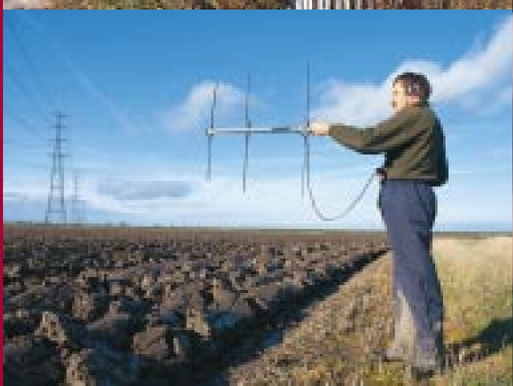
English Nature Research Reports



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Storm-damage and vegetation change in East Hampshire beechwoods
I. Ashford Hanger National Nature Reserve

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Preface

English Nature is grateful to Ed Mountford and Dave Ball for the opportunity to include this report in its research report series. This should help to ensure that knowledge of the permanent vegetation plots at the reserve 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.

Rebecca Isted, English Nature

Acknowledgements

Hampshire Country Council encouraged and supported this research. Geoff Farwell helped David Ball with the initial fieldwork, whilst Anne and Ed Mountford did the 2001 fieldwork jointly. Anne Mountford also input all the records onto computer spreadsheet. The fieldwork and this report form part of the NAT-MAN Project – Nature-based Management of Beech in Europe – financed by the European Community 5th Framework Programme.

Summary

Ashford Hangers National Nature Reserve is a semi-natural, beech-ash-yew woodland, growing on steep, narrow, chalk slopes in southern England. It suffered substantial storm-damage in 1987 and 1990, which was mapped across the reserve. This prompted the establishment of four 20x30m permanent plots, in which detailed records of trees, shrubs, ground vegetation and dead wood were made in 1988/9. Three of these, located in a minimum-intervention area on Ridge Hanger, were subsequently recorded in 1991 and 2001 to assess how they have developed.

Prior to the 1987 storm, much of the reserve was dominated by mature beech stands, though in places there were open areas and young stands. The storm caused widespread damage, with perhaps 1000 canopy trees lost. The most severe damage was in the south of the reserve where about 25% of the mature stands were lost. Damage was associated with large-sized canopy trees (and thus mature stands), which were located on exposed, south-facing, upper slopes and promontories, where the soils were shallow and provided little anchorage, and particularly within a band of ground running north-eastwards across the reserve. Most large trees in these situations were beech, so most downed trees were of this species. Further storm damage occurred in spring 1990, bringing down similar trees in exposed locations. However, total damage was less than in 1987 and it was less concentrated on south-facing slopes.

The impact of these storms on large canopy trees and dead wood was recorded in the three permanent plots on Ridge Hanger, which supported mature, intact beech stands beforehand. By May 2001, 75% of the original 29 large trees had been lost and the live standing basal area had declined by 80%. Tree loss had been both progressive and patchy: storms in 1987, 1990 or during 1991-2001, respectively accounted for about 50%, 30% and 20% of the losses, with the two plots higher up the slope losing nearly all large trees, whereas the plot on the mid-slope lost only three out of eight trees. Most losses were uprooted beech, none of which remained alive for long. They created several root pits/mounds and dramatically increased the amount of fallen dead wood. Many surviving canopy trees were invigorated following release, but on some surviving beech this was outweighed by dieback, poor foliage, bark damage/necrosis and/or squirrel debarking.

Tree and shrub regeneration was also recorded in the three permanent plots. A year after the storm, 1,333 small individuals per hectare were present. Most of these were in the two plots that had opened considerably. Ash was numerous, but nine other species were also present. A few of the individuals were large and must have formed a sparse understorey before the 1987 storm. Of the remainder, about 60% appeared to have been established before the storm as small, low-growing advanced regeneration. The remainder probably established during the 1988 growing season. Individuals were clustered possibly reflecting differences in the degree of ground shading before the storm. By 2001, 1489 individuals per hectare had grown to ≥1.3m height, nearly twice that in 1991. Ash remained most numerous, elder and hawthorn were occasional, and another ten additional minor species present. Two of the plots remained dominated by groups of ash with some elder and hawthorn and a few large individuals. Regeneration was limited in the other, but it included most or all of the few beech, broom, dogwood, hazel and rose. Of the individuals ≥1.3m height in 2001, 59% were survivors recorded in 1988, 12% established by 1991, and 29% established after 1991. In general, survival was highest amongst individuals recorded in 1988 and especially the largest of these.

However, some later recruits also grew large. The loss of mainly small-sized regenerants suggested competitive exclusion was a major cause of mortality, but in some cases other causes were responsible, including basal ring-barking probably by rabbits or bank voles, crushing by toppled trees or branches, and Dutch elm disease. Survival rates were low for elm (due to disease) and oak, moderate for holly, elder and beech, and highest for ash, birch, hawthorn, hazel and field maple. The most vigorous regeneration in 2001 was mainly of ash, along with some hawthorn and hazel and a few elder, maple, beech and birch. Squirrels had debarked a high proportion of surviving beech, birch and field maple stems, particularly the largest of these. Some ash had been debarked low-down probably by rabbits and/or bank voles, though few large stems were severely affected. Some individuals had been struck by canopy debris and severely damaged, including a few larger ash and field maple.

Changes in the ground vegetation were also recorded in the three permanent plots. The two main plants were *Mercurialis perennis* and *Rubus fruticosus.* In 1989 these both covered moderate amounts of the two most open plots, whilst only *Mercurialis* covered large areas in the plot that remained fairly closed. By 1991 *Rubus* had increased in all plots, but mainly the most open ones. *Rubus* remained abundant in 2001, having expanded where the ground had become well-lit and contracted where it had become shaded by tree/shrub regeneration. *Mercurialis* had decreased in many places, particularly where dense thickets of *Rubus* had grown up under gaps. Nevertheless, in some places with dense *Rubus* it remained quite abundant and generally it survived well where the ground remained shaded and *Rubus* was less vigorous. 25 minor plant species were recorded in 1989 and many others had established by 2001. Many were ruderals or other light-demanding plants. Most covered little ground, but *Clematis vitalba* had spread mainly amongst *Rubus*, *Hyacinthoides non-scriptus* had spread mainly below *Rubus*, and *Brachypodium sylvaticum, Pteridium aquilinum* and *Urtica dioica* had increased in open areas. Mosses also appeared to have increased, particularly *Hypnum cuppressiforme* (on fallen dead trunks and branches) and *Fissidens taxifolus* (on soil surface). Several minor species declined, apparently because of over-shading either by tree regeneration and/or *Rubus* thickets.

The implications for nature conservation and future research and site monitoring are discussed. The composition, variety and intermixing of the habitats that have replaced storm-damage beech stands are considered generally favorable in nature conservation terms. This has to be balanced against the loss of many mature trees and their associated habitats. Monitoring of the permanent plots on Ridge Hanger and general mapping of habitat changes across the reserve should be continued, and if at all possible expanded.

Contents

1. Introduction

The Great Storm of October 1987 damaged many woods in southern England (Grayson 1989; Whitbread 1991; Kirby & Buckley 1994; Peterken 1996). Some were virtually levelled (eg Mountford & Peterken 2000), some had large swathes blown down (eg Allen 1992), and many others had at least a few canopy trees uprooted or snapped off (eg Mountford & Peterken 2001). This was an exceptional storm, the likes of which had probably not been experienced for 200 years (Burt & Mansfield 1988). It attracted the attention of all involved in woodland management.

For woodland ecologists, this presented an opportunity to research the immediate and longer-term effects of such an intense, rare, natural event. Several baseline studies were established in a range of semi-natural woodland intended for management by minimum intervention (Whitbread 1991). These expanded on and contributed towards a national programme of long-term studies in untreated woodland nature reserves (Peterken & Backmeroff 1988; Hall and others 1999). Such studies aim to enhance our knowledge of woodland dynamics in Britain, and in turn to inform ecologists and policymakers interested in natural woodland and nature-based forest management. With this in mind a representative series of minimum intervention woodland reserves and a programme of long-term monitoring therein has been proposed (Mountford 2000, Peterken 2000). This report provides details of one of the studies set up after the 1987 storm at the initiative of Hampshire County Council (Farwell & Ball 1991; Whitbread 1991). It combines with similar studies conducted at Noar Hill Hanger (Mountford 2003, Mountford & Groome 2003).

2. Study area

Ashford Hangers National Nature Reserve (NNR) (grid reference SU 7326) is located slightly north of Steep village, near Petersfield in Hampshire. It covers 143ha in two blocks (Figure 1) and is managed by Hampshire County Council (Ball 1995). The reserve forms part of the East Hampshire Hangers, a collection of semi-natural woods running along the western edge of the Weald (Ockenden 1990). Many of these woods are designated as Sites of Special Scientific Interest and these combine as a Special Area of Conservation (SAC) under the European Union Habitats Directive. They 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.

Much of the reserve is or was covered by mature mixed beech-ash-yew woodland growing on steep, narrow, chalk slopes (Figure 2). The main tree species are ash (*Fraxinus excelsior*), beech *Fagus sylvatica*, and yew *Taxus baccata*. Less common trees are pedunculate oak *Quercus robur*, downy/silver birch *Betula pubescens/pendula*, sycamore *Acer pseudoplatanus*, wild cherry *Prunus avium*, and European larch *Larix europaea*.

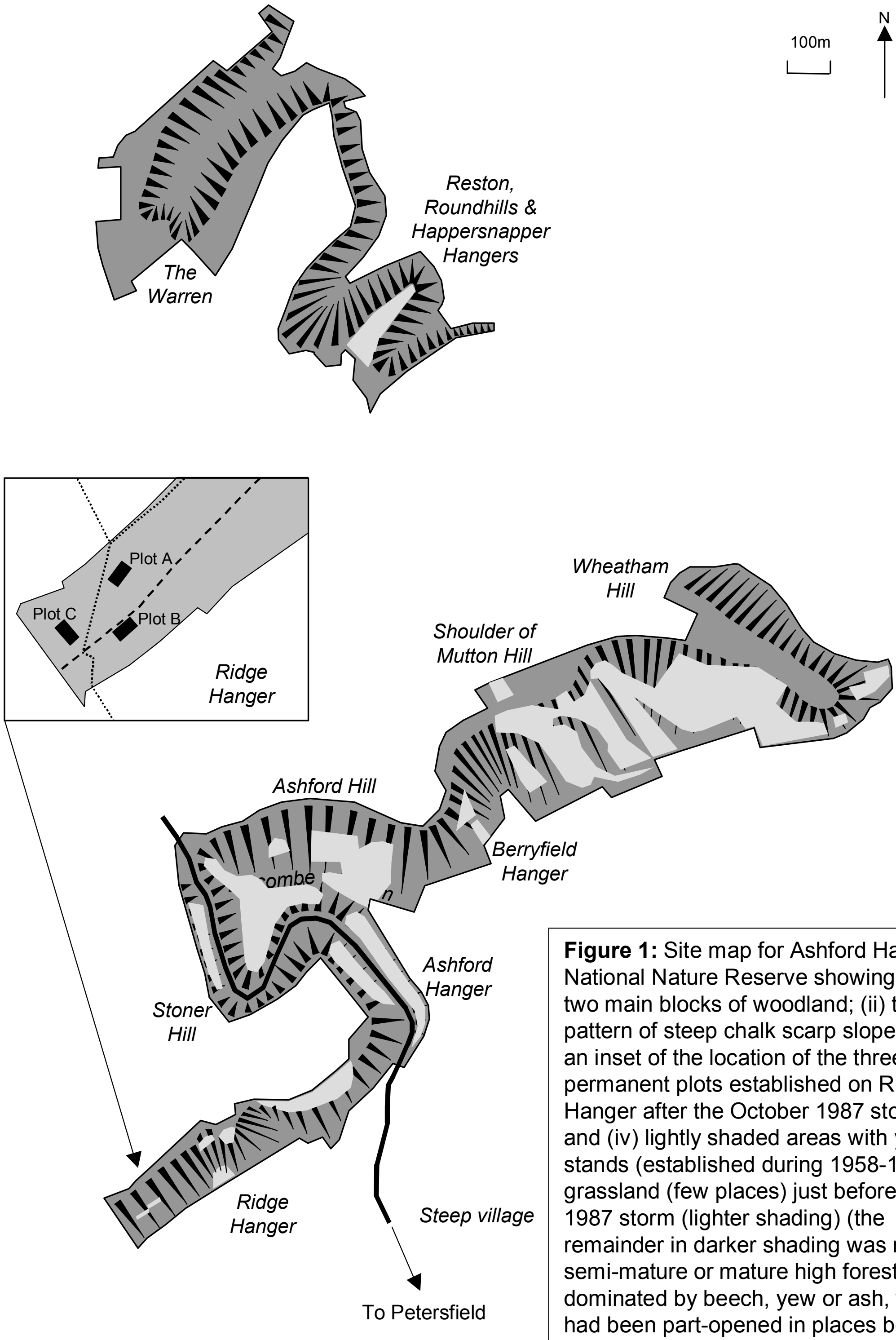

Figure 1: Site map for Ashford Hangers National Nature Reserve showing; (i) the two main blocks of woodland; (ii) the pattern of steep chalk scarp slopes; (iii) an inset of the location of the three permanent plots established on Ridge Hanger after the October 1987 storm; and (iv) lightly shaded areas with young stands (established during 1958-1981) or grassland (few places) just before the 1987 storm (lighter shading) (the remainder in darker shading was mainly semi-mature or mature high forest, dominated by beech, yew or ash, which had been part-opened in places before the 1987 storm by gales in 1974, beech losses after drought in 1976, Dutch elm disease, and localised felling).

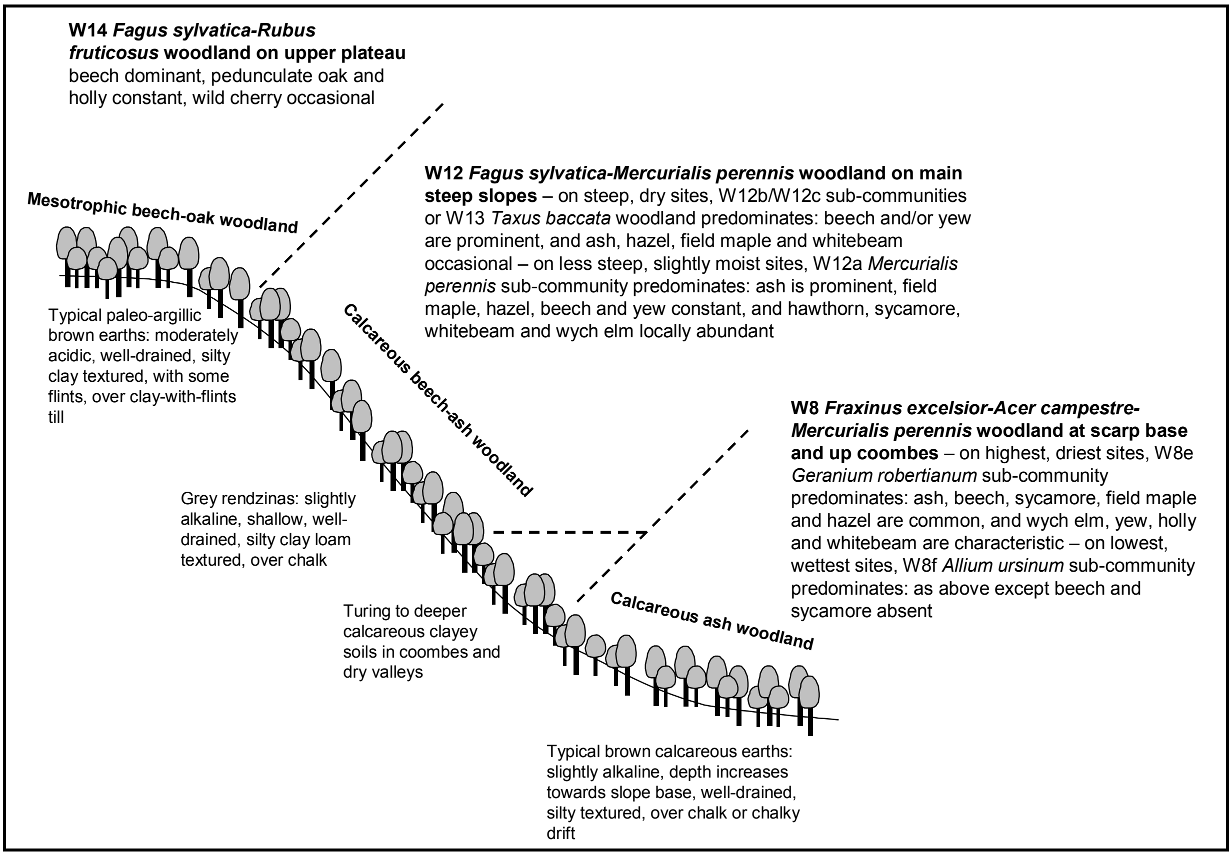

Figure 2: Typical zonation of woodland within Ashford Hangers National Nature Reserve in relation to topography down the steep chalk scarp slope. Based on a survey carried out by Jonathon Cox and Jane Barneveld in summer 1997 using the National Vegetation Classification (Rodwell 1991), and information from the Soil Survey of England and Wales (Mackney and others. 1983). On part of the clay-capped upper plateau on The Warren the woodland progresses into W15d *Fagus sylvatica-Deschampsia flexuosa* (*Calluna vulgaris* sub-community) woodland where beech, pedunculate oak and downy/silver birch are characteristic.

Shrub and medium tree species include broom *Cytisus scoparius*, dog rose *Rosa canina*, dogwood *Cornus sanguinea*, elder *Sambucus nigra*, field maple *Acer campestre*, goat/grey willow *Salix caprea/cinerea*, hazel *Corylus avellana*, hawthorn *Crataegus monogyna*, holly *Ilex aquifolium*, whitebeam *Sorbus aria*, and wych elm *Ulmus glabra*.

Like other East Hampshire Hanger woods (eg Webb 2002), it had developed extensive, mature stands of mainly beech before the 1987 storm. These had grown up from abandoned coppice/wood-pasture and/or plantings during the 19th century, which in turn had developed from areas of mainly arable or pasture use in medieval times (Ball 2001). For example, Ridge Hanger was common pasture before enclosure in about 1500. Conversion from sheep pasture to (beech) coppice occurred post-1600 with the decline in local cloth industry and to provide poles for hops grown below the escarpment. The stand only developed into (beech) high forest following promotion/planting when ownership changed in about 1860-65.

3. Recording & analysis

Damage to trees across the reserve as caused by severe windstorms on 16 October 1987 and during January-February 1990 was recorded shortly after these events. The method involved walking the main site paths and making use of viewpoints across the reserve to map the approximate location of large trees or blocks that were uprooted, snapped or lost major branches. However, the recording was rather quick (the original purpose was to identify the clearance work required to re-open access routes), it did not include every tree, and the centres of woodland blocks were less-well detailed. Nevertheless, it included the most severely damaged areas and gave a general impression of the storm impacts. It was supplemented by a series of photographs taken along the southern boundary of the reserve after the 1987 storm, which showed general views of the slopes. The composition of the stands prior to the 1987 storm was recorded by Rose and Marshall (1984) and Ball (1995).

Following the 1987 storm, four 20x30m, permanently marked plots were established on Ridge Hanger (plots A-C) and Ashford Hill (plot D) (Figure 1, Annex 1). The plot on Ashford Hill has not been recorded recently and is not included in this study. The Ridge Hanger plots supported calcareous beech-ash woodland, with plots A and C at the top and plot B in the middle of the main scarp slope (Annex 1, see also Figures 1-2). They were subsequently recorded on four occasions from 1988 to 2001, when the trees/shrubs, ground vegetation and/or dead wood were mapped and/or measured (Annex 2). The recording yielded information on almost 200 trees/shrubs, 600 stems (including about 340 stems whose fate was followed from 1988/91 to 2001), and numerous ground vegetation species. This was entered on to a Microsoft Excel spreadsheet to facilitate sorting, statistical analyses, and long-term storage. Most stems were confidently re-identified, but a few anomalies were detected and some adjustments had to be made to the record because individuals appeared to have been identified incorrectly, misplaced on the charts or omitted. Amendments were made only where the record seemed implausible by interpolating from the performance of similar stems located nearby.

In the analysis of the permanent plots, the stand composition before the 1987 storm was reconstructed based on measurements of standing and fallen trees in November 1988. Basal areas were calculated from girth measurements assuming stems were circular in cross section. In May 2001 live individuals/stems included those standing or fallen and with live leaves at or above 1.3m from the base, and losses included those that were reduced to alive below 1.3m height. The volume of fallen dead wood in November 1988 and February-March 1991 was estimated in each plot using the detailed charts of windthrown. This was done by calculating the cylindrical volume of the main trunk (ie excluding the smaller crown forks) on all large fallen trees (including those that fell into the plots), using the girth at ground measurements and measuring the trunk length off the scale-charts (including only those parts of the trunk within the plot). Downed trees were not measured in this way in May 2001, because *Rubus* had grown across many of these such that they could not be viewed without excessively trampling the ground vegetation. Instead the volume of fallen dead wood was estimated for the compartment using the line-intersect method and formulae given by Warren and Olsen (1964) and Kirby and others (1998) (see Annex 2). The ground vegetation mapping in May 1989 was quantified so that comparison could be made with other records. The cover of the two main plants (*Mercurialis perennis* and *Rubus fruticosus*) could be approximated because the mapping recorded the percentage cover of dominant species in different areas. Other species covered only small areas of ground: they were classified as 'scarce', 'occasional' or 'frequent' depending on how common and extensive they were.

4. General patterns of storm-damage across the reserve

The storm that swept through the area on the 16 October 1987 was exceptional. It caused widespread damage to trees along the East Hampshire Hangers, with major losses on sections of Noar Hill Hanger, Oakshott Hanger, Selborne Hanger, and the Ashford Hangers NNR complex (Ockenden 1990).

The mapping of storm-damage across the NNR is shown in Figure 3 (compare to topography and stand maturity shown in Figure 1). Trees were damaged in all parts of the reserve, with perhaps 1000 uprooted/snapped and many others crown-damaged. Little damage occurred on Stoner Hill, Shoulder of Mutton, in the northern part of the reserve, and areas of predominately young-growth. Most of the severe damage was in the southern half of the reserve, where about 25% of the mature stands were lost. The largest blow down was along the steep, south-facing, upper slopes and narrow plateau on Ashford Hill-Berryfield Hanger. The majority of the large, c.130-(150-180) year-old canopy (mainly beech) trees were lost, crushing some understorey individuals but leaving most of the well-developed understorey yew alive. Similar damage occurred on parts of Ridge Hanger, Ashford Hanger and Wheatham Hill. Many trees were lost across the south-west half of Ridge Hanger, ranging from scattered individuals to groups of ten or more trees. One of the largest blocks lost was on the upper slope at the south-western end of Ridge Hanger, where the permanent plots were subsequently placed. In a small coombe on Ridge Hanger, a small tornado-like turbulence (apparently) twisted/snapped the crowns off three large, *c*.100-135cm diameter, open-grown beech. The southern section of the road up Ashford Hanger was left with numerous trees across it and large root plates pulled out from the escarpment above – the road remained blocked for five weeks! On Wheatham Hill a proportion of the c.150 year-old beech on the crest of were lost, whilst further east a younger, dense, ash block up to about 50cm diameter were part-damaged. Only a small area of severe damage was recorded in the north of the reserve. However, a section of Oakshott Hanger was severely damaged, just south of the Happersnapper Hanger reserve boundary. This indicated that a band of severe gusts had crossed the area, running north-eastwards through Ridge Hanger, Ashford Hanger, Ashford Hill, Berryfield Hanger, and onwards down Oakshott Hanger.

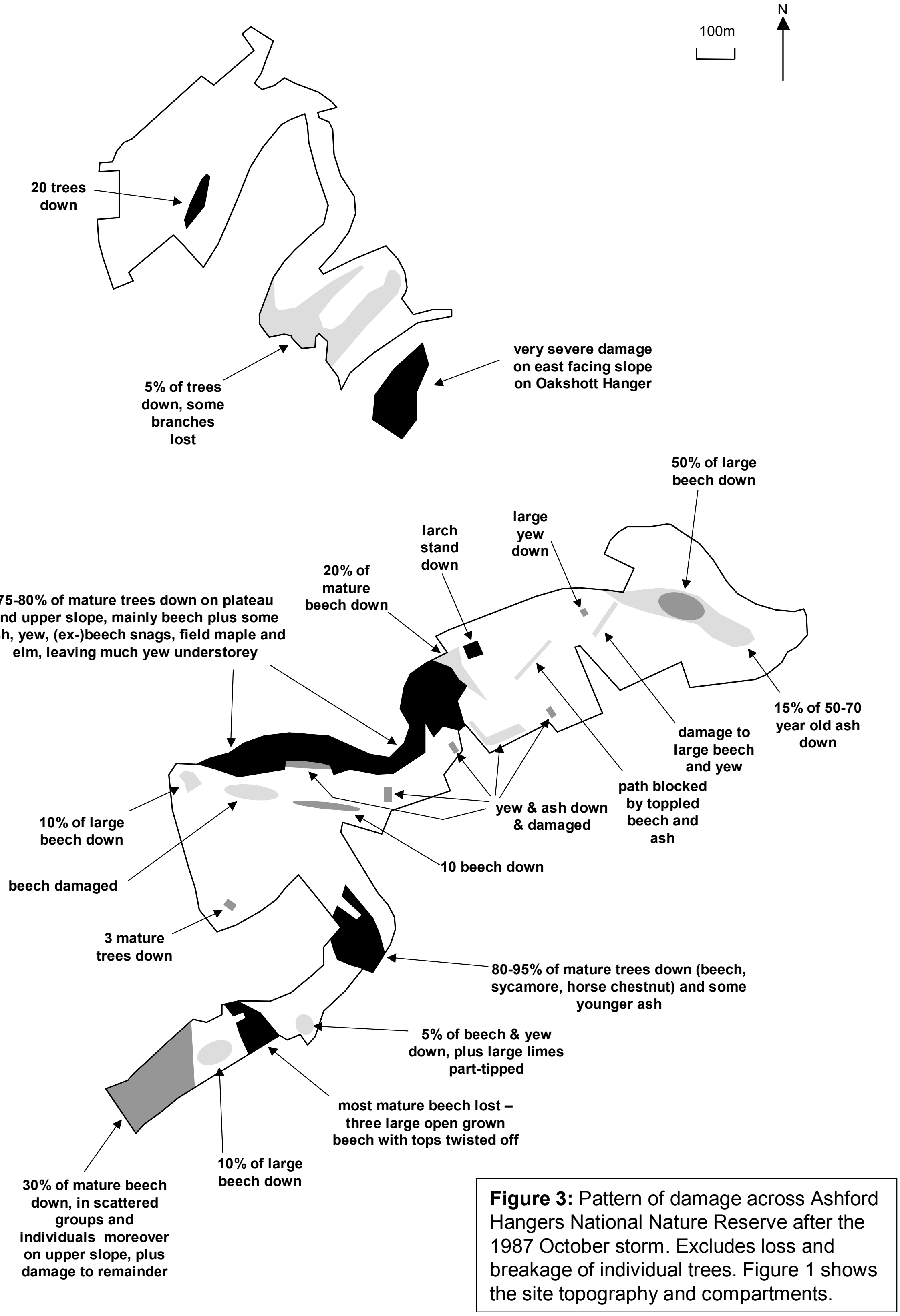

Figure 3: Pattern of damage across Ashford Hangers National Nature Reserve after the 1987 October storm. Excludes loss and breakage of individual trees. Figure 1 shows the site topography and compartments.

The most obvious factors accounting for the damage patterns were:

i. **tree size** – mature stands with large-sized canopy trees tended to suffer most, whereas adjacent younger stands suffered little – this was exemplified at the south-west boundary of Ridge Hanger where young stands adjacent to the reserve were left unscathed, whilst numerous large trees within the reserve were lost – similarly there was a lack of damage on Shoulder of Mutton where young plantations predominated, whilst heavy damage was sustained on Ashford Hill, Berryfield Hanger and the crest of Wheatham (see Figure 3) – most large trees were beech, so most of the downed individuals were of this species;

ii. **exposure to storm-winds** – the strongest storm winds (which were from the SW and left most fallen trees lying towards NE), impacted most on exposed, south-facing, upper slopes and promontories, particularly within a band running north-eastwards from Ridge Hanger across Ashford Hill-Berryfield Hanger – stands on 'protected' slopes that backed onto the main storm winds suffered little damage (eg in the coombes below Stoner Hill) (see Figure 3) – in some places it was apparent that (recently) exposed mature trees adjacent to gaps or young-stands consequently suffered damage – 'protected' understorey trees suffered little direct damage, but were vulnerable to crushing by thrown/snapped canopy trees;

iii. **anchorage** – the worst windthrow tended to be on (steep) upper slopes where the soils were shallow, directly over chalk, and provided little rooting depth – this was exemplified by the plots on Ridge Hanger (see section 5) – trees growing on deeper soils on the plateau above the main chalk slopes generally appeared more wind-firm (the survival of beech on the plateau at Ridge Hanger was conspicuous) – although most large trees growing on exposed upper slopes and promontories were beech, most of the root plates on these were upturned and had shallow-lateral plates with few large roots penetrating into the underlying bedrock.

The reserve suffered further storm-damage during spring 1990 (see Figure 4). Again, numerous large trees, particularly those in exposed locations and on shallow soils, were lost. Some had suffered root damage and/or were more exposed than in 1987. More large beech were brought down on Ridge Hanger, including most of the remainder on the upper slopes in the south-west end. Ashford Hanger had more beech blown onto the road and an adjoining line along the road were felled because they were left with their root plates rocking (interestingly, some in the same condition were kept and have remained standing) – the road was closed for 3 weeks this time. A band of trees of various species were damaged on the east-facing brow of Stoner Hill. The upper slope of Ashford Hill was badly affected again: most of the surviving standing beech were lost and several understorey yew were thrown, though they remained alive. An area of beech on Shoulder of Mutton Hill was windblown and many understorey yew were blown over, snapped or crushed. Some of the damage extended or further opened areas that had been severely damaged in 1987 (eg on Ashford Hill-Berryfield Hanger), but some of it created a few large new gaps (eg on Stoner Hill and Shoulder of Mutton).

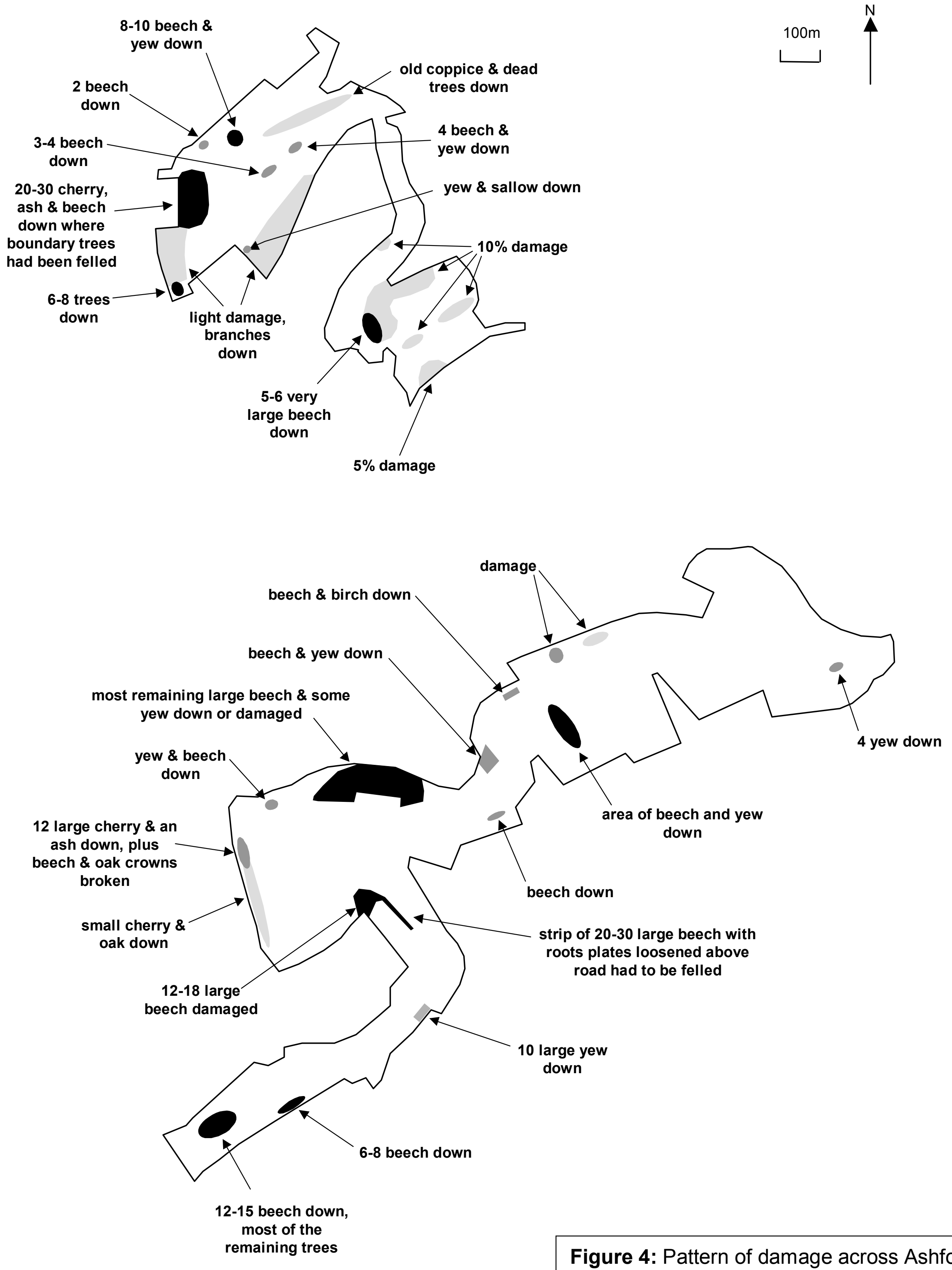

Figure 4: Pattern of damage across Ashford Hangers National Nature Reserve after the 1990 spring storms. Excludes loss and breakage of individual trees. Figure 1 shows the site topography and compartments.

In addition, many areas in the northern part of the reserve suffered light damage or had groups of beech, ash and other species brought down. However, the large windblown block on The Warren had been exposed by the (illegal) felling of (wind-firm) boundary trees, which exposed a band of tall, weakly-rooted, derelict coppice. Overall, the 1990 storms did much less damage than in 1987 (partly because there were less canopy trees standing and many had already proved their wind-firmness), and the damage was less concentrated on south-facing slopes. No specific storms caused such widespread damage during the 1990s, but further localized uprooting/ breakage continued to summer 2001.

5. Changes in large trees and dead wood in the permanent plots on Ridge Hanger

The cumulative impact of these storms on canopy trees and dead wood was recorded in the three permanent plots on Ridge Hanger. Before the 1987 storm struck, the stand here was mainly beech high forest with some oak, a few larch, Scot's pine and ash, and a sparse understorey. The dominant trees were about 125 years-old, and although the canopy was mostly closed, there were gaps where an extraction track had been built across the mid-slope in 1965/6 and in one place (roughly between plots A and B) where groups of trees alongside the track had been felled. The compartment surrounding the plots (*c*.3ha) had been mostly untreated for many years before the storm, and only the tracks have been cleared since.

Changes in large trees and dead wood in the plots are shown in Tables 1 and 2. Before the 1987 storm they contained 29 large trees, including 26 beech sized 82-248cm girth, a larch at 125 cm girth, an oak at 106cm girth, and a field maple at 88cm girth. The basal area and density of these ranged from 34-43 m^2 ha^{-1} and 133-200 ha^{-1} respectively. There was little standing or fallen dead wood. By November 1988, 10 beech had been uprooted, and another beech and the larch had been snapped off a few metres up and left dead standing. Most fallen trunks lay towards NE. Damage was confined to plots A (four of nine trees) and C (seven of 12 trees) at the slope top. Although all the uprooted trees had live foliage in November 1988, all but one had died by May 1989, and the dead wood volume had increased to about 200m^3 ha^{-1}, most of which was in fallen logs. By February-March 1991, a further six large beech had been uprooted towards NE to SE, and another beech was left leaning heavily. Though the plots at the slope top suffered most (three more trees in plot C and three in plot A), one tree in plot B on the mid-slope was uprooted. The volume of logs was now increased to about 320m^3 ha^{-1}. Although no other specific intense storms were recorded by May 2001, the last beech in plot A, two more beech in plot B, and the leaning heavily beech in plot C were toppled. The volume of logs was estimated for the whole surrounding minimum-intervention compartment at about 270m^3 ha^{-1}. The volume of snags in the plots was negligible.

Table 1 Change in the number and basal area (m^2 ha^{-1}) of large trees in the three permanent plots on Ridge Hanger from just before the 1987 storm to May 2001.

Plot A

Date	Status of trees	Number			Basal area		
		Beech	Oak	Larch	Beech	Oak	Larch
<1987 storm	Standing alive	7	1	1	42.8	1.5	2.1
1988 Nov	Standing alive	4	1	-	22.6	1.5	-
	Fallen alive	3	-	-	20.2	-	-
	Dead standing	-	-	1	-	-	2.1
1991 Feb/Mar	Standing alive	1	1	-	4.3	1.5	-
	Fallen alive	1	-	-	7.0	-	-
	Dead standing	-	-	1	-	-	2.1
	Dead fallen	5	-	-	31.4	-	-
2001 May	Standing alive	-	1	-	-	1.8	-
	Dead standing	-	-	1	-	-	1.4
	Dead fallen	7	-	-	42.7	-	-

Plot B

Date	Status of trees	Number		Basal area	
		Beech	Field maple	Beech	Field maple
<1987 storm	Standing alive	7	1	34.1	1.0
1988 Nov	Standing alive	7	1	34.1	1.0
1991 Feb/Mar	Standing alive	6	1	26.4	1.0
	Dead fallen	1	-	8.0	-
2001 May	Standing alive	4	1	13.9	1.8
	Dead fallen	3	-	21.4	-

Plot C

Date	Status of trees	Number	Basal area
		Beech	Beech
<1987 storm	Standing alive	12	36.5
1988 Nov	Standing alive	3	9.3
	Dead standing	1	4.6
	Dead fallen	8	22.5
1991 Feb/Mar	Standing alive	2	3.7
	Fallen alive	1	5.3
	Dead standing	1	4.6
	Dead fallen	9	22.5
2001 May	Standing alive	1	3.7
	Dead fallen	11	33.5

Table 2 Change in the volume (m^3 ha^{-1}) of large fallen (logs) and standing (snags) dead trees from November 1988 to May 2001. The snag volume is as recorded in the three permanent plots on Ridge Hanger. The log volume in 1988 and 1991 is as recorded in the three permanent plots, whereas the 2001 log volume is for the whole of the surrounding minimum-intervention compartment.

	Snags	Logs
1988 Nov	2.8	199.9
1991 Feb/Mar	2.6	319.2
2001 May	0.4	272.2

The condition of the seven live large trees that survived in the three permanent plots in May 2001 is shown in detail in Annex 3. The single oak had responded to release from severe competition from beech by developing a sheath of vigorous epicormic sprouts up the trunk. The surviving field maple had been struck by an uprooted beech and left on a lean, with one bough missing and damage to the trunk. However, it was now better lit and had developed numerous vigorous epicormic sprouts, though grey squirrels had debarked some of these. Three of the five surviving beech trees were responding well to release by shooting strongly in the crown, and two of these had formed new foliage low down off vigorous sprouts on the trunk or existing trunk branches. Nevertheless, all had suffered some bark loss due to squirrels or strikes from uprooted trees. The other two beech were also shooting in the crown, but this was outweighed by dieback in the crown, unhealthy foliage, bark necrosis and (in one tree) the recent snapping of large lower fork. Two of the beech appeared to be of coppice-origin, having additional smaller stems growing around the base. Although the larger of these stems were growing strongly in the increased light, two of the largest had been severely debarked by squirrels.

Thus, by May 2001 a total of 22 or 75% of the original 29 trees had been lost from the plots and the live standing basal area had declined by 80%. Tree loss had been greatest in plots A and C (where only a single live tree remained standing in each, and the basal area had fallen by 90-96%), compared to plot B (which retained four beech and a field maple, and declined in basal area by 55%). Most losses were beech, with the oak and field maple surviving, despite the field maple being part-tipped. Canopy tree loss had been both progressive and patchy: the 1987 storm accounted for about 50% of the losses, the 1990 storms for about 30%, and later storms for about 20%. The first storm affected canopy trees only in the two plots at the slope top and moreover in one of the plots. Losses in the 1990 storms were quite equally spread, whilst later losses affected only two plots. In summer 2001 the two plots at the slope top had only one surviving canopy tree between them, whereas the plot lower down retained 4 out of 7 original canopy trees. Most of the losses were uprooted (n = 20) rather than snapped (n = 2). This created several root pits and mounds and dramatically increased the amount of dead wood, particularly in downed logs (as opposed to snags). None of the uprooted trees remained alive in the long-term, and only a beech snapped at 8m up just outside one of plots managed to vigorously re-sprout at the base and up the trunk. Many of the canopy trees that were neither thrown nor snapped responded strongly to the release from competition and developed abundant new foliage on trunk or crown sprouts. However, on some surviving beech, crown dieback, poor crown foliage, bark damage/necrosis and/or squirrel debarking outweighed this.

The trends observed in the plots are considered indicative for many the mature beech stands in the south of Ashford Hangers NNR. They clearly demonstrate the rapidity with which many of the mature beech stands on steep terrain have broken up under the influence of windstorms, the dominance of uprooting in beech (as opposed to trunk snapping), the progressive and patchy nature of damage and localized survival and release of some trees/stands (part-related to site topography), and the associated decline in live standing basal area and large increase in dead wood.

6. Tree/shrub regeneration in the permanent plots on Ridge Hanger

With so much canopy disturbance, it was expected that trees and shrubs would regenerate in earnest. Detailed information on the progress of tree and shrub regeneration was recorded in the three permanent plots on Ridge Hanger.

6.1 General changes from November 1988 to May 2001

All small live trees and shrubs were recorded in the three plots in November 1988, one year after the storm (Table 3). 240 individuals (= 1333 ha^{-1}) from nine species were present. Ash was most numerous whilst beech and other species were scarce. The numbers included a few large (≥20cm girth at ground) ash, beech, elder, elm, field maple and hawthorn individuals, many of which were in plots A or B. These must have been well established and formed a sparse understorey before the 1987 storm. About 60% of the remainder were 5-<20cm girth at ground: most of these appear also to have been established before the storm, but as small, low-growing advanced regeneration. They included numerous ash in plot B and (to a lesser extent) plot A, plus a minority of beech, elder, field maple and hawthorn. The other 40% (n = 93), which were <5cm girth at ground, had probably established during the 1988 growing season. Again most were ash in plot A or B, but there were also several beech in plot C, and a few elder, field maple, hazel, holly and oak. Thus, plots A and B were quite similar in composition, whilst plot C had few ash but accounted for most beech and the few oak individuals.

The distribution of individuals in November 1988 is shown in Figures 5-7. Many were clustered in groups, partly related to the distribution of advance regeneration and canopy gaps before the storm. The areas between, where few or no individuals occurred, most likely marked ground that was strongly shaded before the storm.

Records for February-March 1991 are shown in Table 4. There had been very little overall change since November 1988, with recruitment and mortality of individuals virtually canceling each other out. Individuals became slightly more abundant in plot B and slightly less abundant in plots A and C. Amongst the species, ash became slightly more numerous; the others declined slightly or did not change; oak died out; and birch recruited. The changes hardly affected the distribution patterns across the plots (Figures 5-7).

Table 3 Number and girth (at ground) of small live trees and shrubs in the three permanent plots on Ridge Hanger in November 1988. Includes all individuals present irrespective of height or size. Multi-stemmed individuals are shown according to the size of the largest stem.

Plot A

Girth (cm)	Ash	Elm	Hawthorn	Elder	Field maple	Beech	Hazel	Total
0-<5	34	-	-	2	1	-	1	38
5-<10	24	-	1	-	-	1	-	26
10-<15	2	-	-	-	-	-	-	2
15-<20	-	-	1	-	1	-	-	2
20-<30	-	1	2	1	1	-	-	5
30-<40	-	1	-	-	-	-	-	1
40-<50	-	-	-	-	-	-	-	0
50-<60	-	1	-	-	-	-	-	1
60-<70	-	-	-	-	-	-	-	0
70-<80	-	1	-	-	-	-	-	1
Total	60	4	4	3	3	1	1	76

Note: the field maple at 24cm girth was growing laterally under an uprooted, large beech tree

Plot B

Girth (cm)	Ash	Elder	Hawthorn	Beech	Holly	Total
0-<5	33	-	-	-	-	33
5-<10	59	1	-	1	-	61
10-<15	21	-	2	-	1	24
15-<20	2	1	1	-	-	4
20-<30	2	1	2	-	-	5
30-<40	-	2	-	-	-	2
Total	117	5	5	1	1	129

Plot C

Girth (cm)	Ash	Elder	Field maple	Beech	Hazel	Oak	Holly	Total
0-<5	6	-	-	10	2	3	1	22
5-<10	3	1	-	2	1	-	-	7
10-<15	1	-	1	-	-	-	-	2
15-<20	-	2	-	-	-	-	-	2
20-<30	-	1	-	-	-	-	-	1
30-<40	-	-	-	1	-	-	-	1
Total	10	4	1	13	3	3	1	35

Table 4 Number and height (or length if growing laterally) of small live trees and shrubs in the three permanent plots on Ridge Hanger in February-March 1991. Includes all individuals present irrespective of height or size. Multi-stemmed individuals are shown according to the height of the largest stem. The bottom rows show the turnover of individuals since November 1988.

Plot A

Height (m)	Ash	Elder	Elm	Hawthorn	Field maple	Hazel	Birch	Beech	Total
0.1-<0.5	5	1	-	-	-	-	-	-	6
0.5-<0.9	19	-	-	-	-	-	-	-	19
0.9-<1.3	3	-	-	-	-	-	-	-	3
<1.3	16	2		-	1	-	1	-	20
>1.3	1	-	-	-	-	-	-	-	1
1.3-<2.0	15	-	-	-	-	-	-	-	15
2.0-<3.0	10	-	-	1	-	1	-	-	12
3.0+	1	1	4	3	2	-	-	-	11
Total	70	4	4	4	3	1	1	-	87
Recruits and losses since 1988	+23, -13	+1	-	-	-	-	+1	-1	+25, -14

Note: one of the field maple >3m long was growing laterally under an uprooted, large beech tree

Plot B

Height (m)	Ash	Hawthorn	Elder	Beech	Holly	Total
0.1-<0.5	13	-	-	-	-	13
0.5-<0.9	6	1	-	-	-	7
0.9-<1.3	17	-	-	-	-	17
<1.3	4	-	-	-	-	4
>1.3	5	-	-	-	-	5
1.3-<2.0	13	-	-	-	-	13
2.0-<3.0	31	1	-	1	1	34
3.0+	23	3	4	-	-	30
Total	112	5	4	1	1	123
Recruits and losses since 1988	+16, -21	-	-1	-4	-	+16, -26

Note: one of the ash >3m was growing laterally having been struck by a large fallen beech tree

Plot C

Height (m)	Beech	Ash	Elder	Hazel	Birch	Field maple	Oak	Holly	Total
0.1-<0.5	-	2	-	-	-	-	-	-	2
0.5-<0.9	4	-	-	-	-	-	-	-	4
0.9-<1.3	3	-	-	-	1	-	-	-	4
<1.3	1	-	-	-	-	-	-	-	1
>1.3	-	-	-	2	-	-	-	-	2
1.3-<2.0	1	5	2	-	-	-	-	-	8
2.0-<3.0	1	2	-	-	-	-	-	-	3
3.0+	1	-	1	-	-	1	-	-	3
Total	11	9	3	2	1	1	-	-	27
Recruits and losses since 1988	+2	+3, -4	+1, -2	-1	+1	-	-3	-1	+7, -11

Records in May 2001 are shown in Table 5. Unlike in November 1988 and February-March 1991 when all individuals were recorded, the threshold for inclusion was raised to 1.3m height. Over the three plots 268 individuals had grown to ≥1.3m height (= 1489 ha^{-1}), nearly twice the number of this size in 1991 (Table 4). This mainly reflected an increase in ash in plot A, where individuals of ≥1.3m height were now slightly more abundant than plot B (2067 v 1867 ha^{-1}), the reverse of November 1988/February-March 1991 (Tables 3-4). Withstanding the differences in recording thresholds, there had been very little change in the relative abundance of any species, though beech declined by the highest percentage. Ash remained most numerous with 1144 individuals ha^{-1} ≥1.3m height, and elder and hawthorn were occasional with 61-106 individuals ha^{-1} ≥1.3m height. Ten additional minor species were now present, with a few broom, dogwood and rose having established since February-March 1991. Hazel and maple were the only minor species to occur in all plots.

Table 5 Number and girth (at 1.3m) of small live trees and shrubs ≥1.3m height in the three permanent plots on Ridge Hanger in May 2001. Includes individuals ≥1.3m height. Multi-stemmed individuals are shown according to the size of the largest stem. The origin of individuals is shown in brackets [present November 1988 & ≥1.3m height in February-March 1991, present November 1988 & <1.3m height in February-March 1991, not present until & ≥1.3m height in February-March 1991, not present until & <1.3m height in February-March 1991, not present until & ≥1.3m height in May 2001]. * Bottom rows relate to individuals that attained 1.3m height in February-March 1991.

Plot A

Girth (cm)	Ash	Elder	Hawthorn	Field maple	Elm	Birch	Hazel	Beech	Total
<10	29 [1, 3, -, 3, 22]	2 [-, 1, -, -, 1]	-	1 [-, 1, -, -, -]	1 [-, -, -, -, 1]	-	-	1 [-, -, -, -, 1]	34 [1, 5, -, 3, 25]
10-<20	43 [7, 11, 1, 8, 16]	1 [1, -, -, -, -]	1 [-, -, -, -, 1]	-	1 [1, -, -, -, -]	-	-	-	46 [9, 11, 1, 8, 17]
20-<30	25 [8, 8, 4, 3, 2]	4 [-, 1, -, 1, 2]	2 [1, -, -, -, 1]	-	-	-	1 [1, -, -, -, -]	-	32 [10, 9, 4, 4, 5]
30-<40	6 [4, 1, -, 1, -]	-	-	2 [2, -, -, -, -]	-	1 [-, -, -, 1, -]	-	-	9 [6, 1, -, 2, -]
40-<50	-	-	2 [2, -, -, -, -]	-	-	-	-	-	2 [2, -, -, -, -]
50-<60	-	-	1 [1, -, -, -, -]	-	-	-	-	-	1 [1, -, -, -, -]
Total	103 [20, 23, 5, 15, 40]	7 [1, 2, -, 1, 3]	6 [4, -, -, -, 2]	3 [2, 1, -, -, -]	2 [1, -, -, -, 1]	1 [-, -, -, 1, -]	1 [1, -, -, -, -]	1 [-, -, -, -, 1]	124 [29, 26, 5, 17, 47]
* change from 1991	+76	+6	+2	+1	-2	+1	-	+1	+86
* Losses from 1991	-3	-	-	-	-3	-	-	-	-6

Plot B

Girth (cm)	Ash	Elder	Hawthorn	Field maple	Hazel	Holly	Rose	Beech	Total
<10	29 [11, 9, -, 3, 6]	8 [-, -, -, -, 8]	- -	1 [-, -, -, -, 1]	1 [-, -, -, -, 1]	1 [1, -, -, -, -]	1 [-, -, -, -, 1]	-	41 [12, 9, -, 3, 17]
10-<20	37 [25, 10, 1, 1, -]	1 [1, -, -, -, -]	1 [1, -, -, -, -]	-	-	-	-	-	39 [27, 10, 1, 1, -]
20-<30	19 [15, -, -, 1, 1]	-	1 [1, -, -, -, -]	-	-	-	-	-	18 [16, -, -, 1, 1]
30-<40	11 [10, -, 1, -, -]	-	2 [2, -, -, -, -]	-	-	-	-	-	13 [12, -, 1, -, -]
40-<50	-	-	-	-	-	-	-	-	-
50-<60	1 [1, -, -, -, -]	-	-	-	-	-	-	-	1 [1, -, -, -, -]
Total	94 [62, 19, 2, 5, 7]	9 [1, -, -, -, 8]	4 [4, -, -, -, -]	1 [-, -, -, -, 1]	1 [-, -, -, -, 1]	1 [1, -, -, -, -]	1 [-, -, -, -, 1]	-	112 [68, 19, 2, 5, 18]
Change from 1991*	+22	+5	-	+1	+1	-	+1	-1	+29
Losses from 1991*	-8	-3	-	-	-	-	-	-1	-12

Plot C

Girth (cm)	Beech	Ash	Rose	Elder	Hazel	Field maple	Birch	Hawthorn	Broom/ Dogwood	Total
<10	5 [1, 2, -, 1, 1]	2 [-, -, 2, -, -]	4 [-, -, -, -, 4]	-	-	-	-	-	2 [-, -, -, -, 2]	13 [1, 2, 2, 1, 7]
10-<20	2 [-, 1, -, -, 1]	3 [2, -, -, -, 1]	-	1 [-, -, -, -, 1]	2 [1, -, -, -, 1]	-	1 [-, -, -, 1, -]	1 [-, -, -, -, 1]	-	10 [3, 1, -, 1, 5]
20-<30	1 [1, -, -, -, -]	1 [1, -, -, -, -]	-	2 [-, 1, -, -, 1]	1 [1, -, -, -, -]	1 [1, -, -, -, -]	-	-	-	6 [4, 1, -, -, 1]
30-<40	-	1 [1, -, -, -, -]	-	-	-	-	-	-	-	1 [1, -, -, -, -]
40-<50	1 [1, -, -, -, -]	1 [1, -, -, -, -]	-	-	-	-	-	-	-	2 [2, -, -, -, -]
Total	9 [3, 3, -, 1, 2]	8 [5, -, 2, -, 1]	4 [-, -, -, -, 4]	3 [-, 1, -, -, 2]	3 [2, -, -, -, 1]	1 [1, -, -, -, -]	1 [-, -, -, 1, -]	1 [-, -, -, -, 1]	2 [-, -, -, -, 2]	32 [11, 4, 2, 2, 13]
Change from 1991*	+6	+1	+4	-	+1	-	+1	+1	+2	+16
Losses from 1991*	-	-	-	-2	-	-	-	-	-	-2

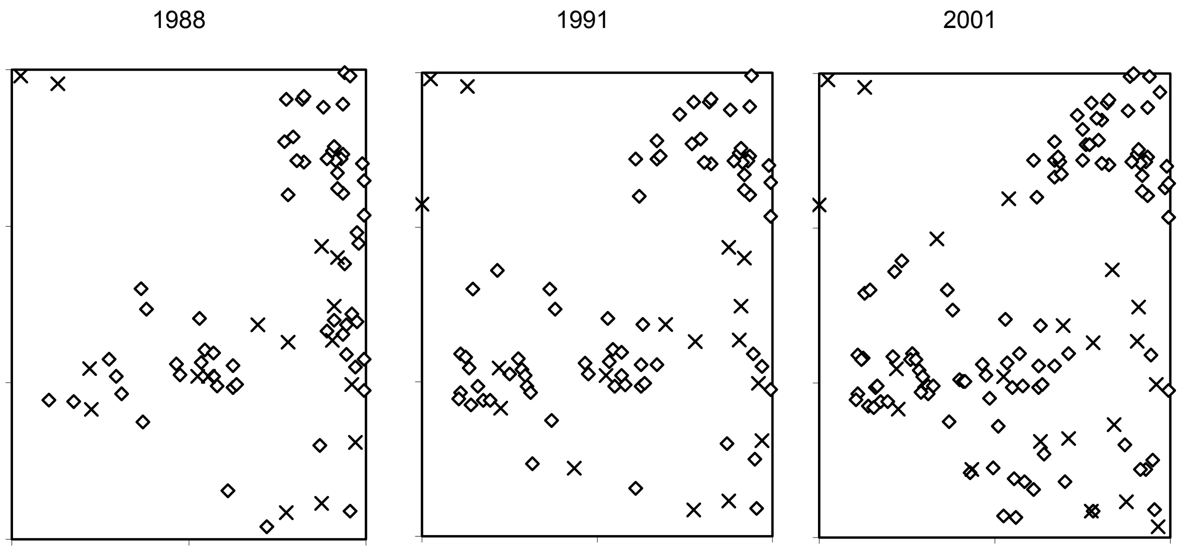

Figure 5: Distribution of small live trees and shrubs in permanent plot A in November 1988, February-March 1991, and May 2001. The plots measure 20x30m. Each point represents an individual. Ash individuals (diamonds) are shown separately from other species (x). All individuals were recorded in 1988 and 1991, whereas in 2001 only those attaining 1.3m height were included.

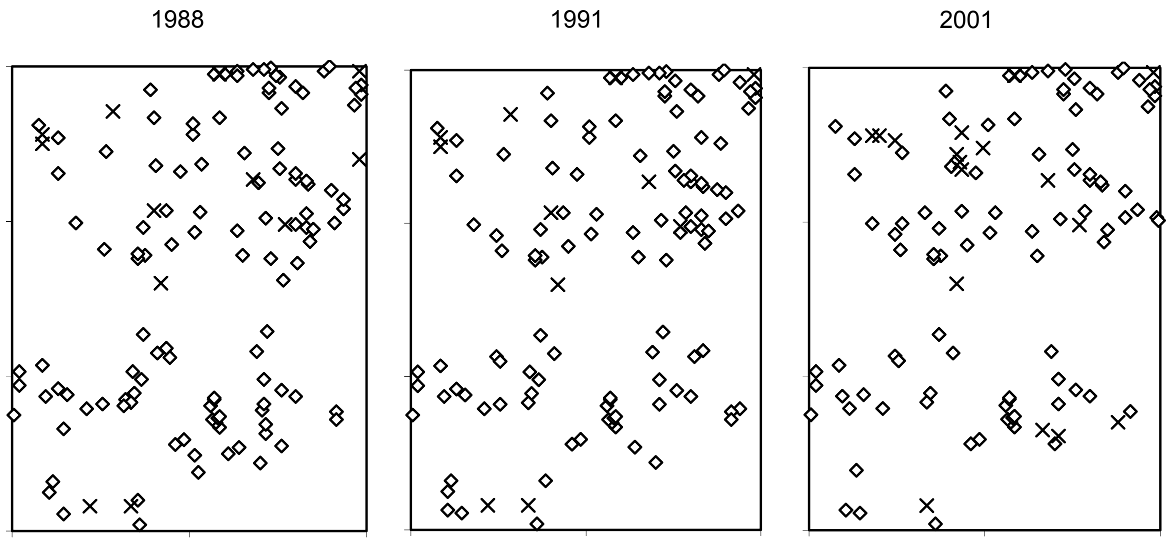

Figure 6: Distribution of small live trees and shrubs in permanent plot B in November 1988, February-March 1991, and May 2001. The plots measure 20x30m. Each point represents an individual. Ash individuals (diamonds) are shown separately from other species (x). All individuals were recorded in 1988 and 1991, whereas in 2001 only those attaining 1.3m height were included.

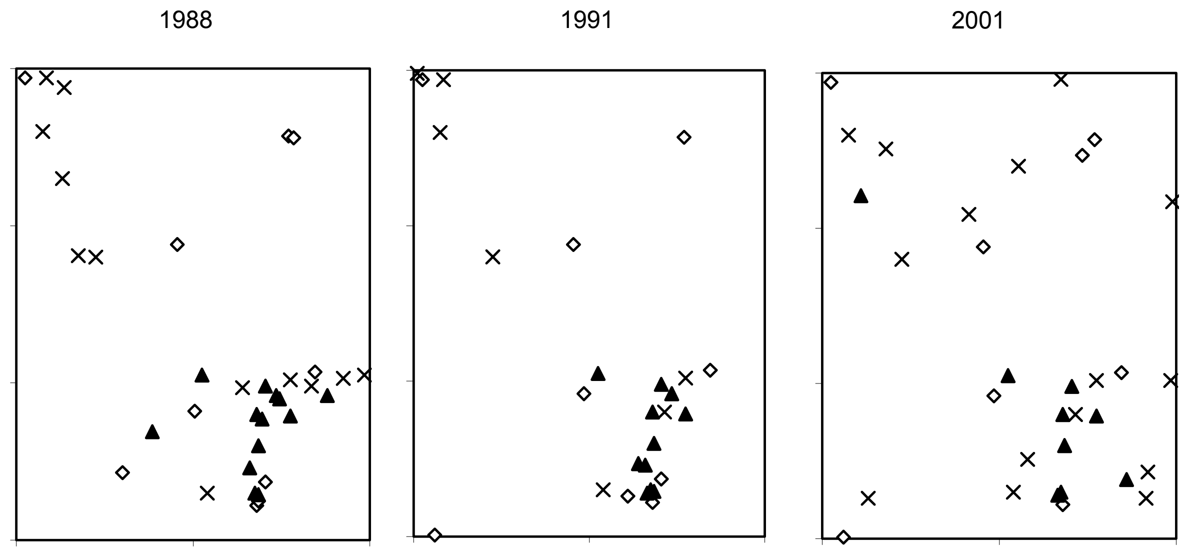

Figure 7: Distribution of small live trees and shrubs in permanent plot C in November 1988, February-March 1991, and May 2001. The plots measure 20x30m. Each point represents an individual. Ash (diamonds) and beech (triangles) individuals are shown separately from other species (x). All individuals were recorded in 1988 and 1991, whereas in 2001 only those attaining 1.3m height were included.

By May 2001, plots A and B differed only slightly in species composition and the size of individuals. Both were dominated by regeneration of ash, minor species were mainly elder and hawthorn, and a few individuals had grown large. There were slight differences in the abundance of large individuals: ash was more abundant in plot B, and field maple, hawthorn and elder in plot A. This mainly reflected differences in the survival (ash, field maple) or growth of pre-storm individuals (hawthorn), or the survival of post-storm recruits (elder). Otherwise, one or two beech, birch or elm occurred in plot A, whereas a single holly and rose occurred in plot B. Despite changes caused by mortality and recruitment, the distribution of individuals had changed only slightly since November 1988. Individuals were still aggregated leaving areas without regeneration (Figures 5-6). Plot C remained quite different in that recruits were limited, ash was scarce, and nine of the ten beech individuals occurred here. Four of the beech were pre-storm survivors, including a large coppice-type beech individual that had seven stems ≥13cm girth, the three largest at 30-47cm girth. All broom and dogwood, and most rose and hazel individuals were in plot C, but there were few elder or hawthorn, and no elm or holly. Many of the individuals, including most of the beech, remained clustered into one of the lower corners of the plot, whilst most of the others were scattered across the top of the plot (Figure 7).

6.2 Performance of seedlings established by November 1988

Of the 240 individuals recorded in November 1988, 189 survived to February-March 1991, and 156 grew to ≥1.3m height by May 2001 (Table 7).

Survival rates were highest for maple, hawthorn, hazel and ash (68-100%), moderate for holly, elder and beech (40-50%), and lowest for elm and oak (0-25%). Survival and mortality was related to initial size. This is demonstrated in Figures 8 and 9 for the ash population, which accounted for 78% of individuals in November 1988. Losses were concentrated amongst stems <10cm girth at ground, though the rate of survival was similar in the <5cm and 5-<10cm girth classes (Figure 8). The largest girth stems in November 1988 had generally grown tallest by February-March 1991, but only some of these were amongst the largest by May 2001 (Figure 9). In addition, they included some stems that started small yet after 1991 grew very rapidly. Many (100) of the individuals that survived were amongst those in November 1988 that appeared large enough to have been established before the storm. These included 12 individuals ≥20cm girth at ground in November 1988, and 88 sized 5-<20cm that were probably small advanced regeneration. Many (127) were already ≥1.3m height in February-March 1991. In fact only a small number (20) of such individuals failed to survive to May 2001. Similarly, few (13) of the 62 individuals from November 1988 that survived at <1.3m height in February-March 1991, failed to grow to ≥1.3m height by May 2001. Survivors accounted for 58% of the individuals that were ≥1.3m height in May 2001. 66 had grown to ≥20cm girth, including 50 ash and a few elder, maple, beech and hazel, which amounted to most of the large-girth individuals (85 were ≥20cm girth). Nevertheless, 90 remained <10cm girth (Table 7).

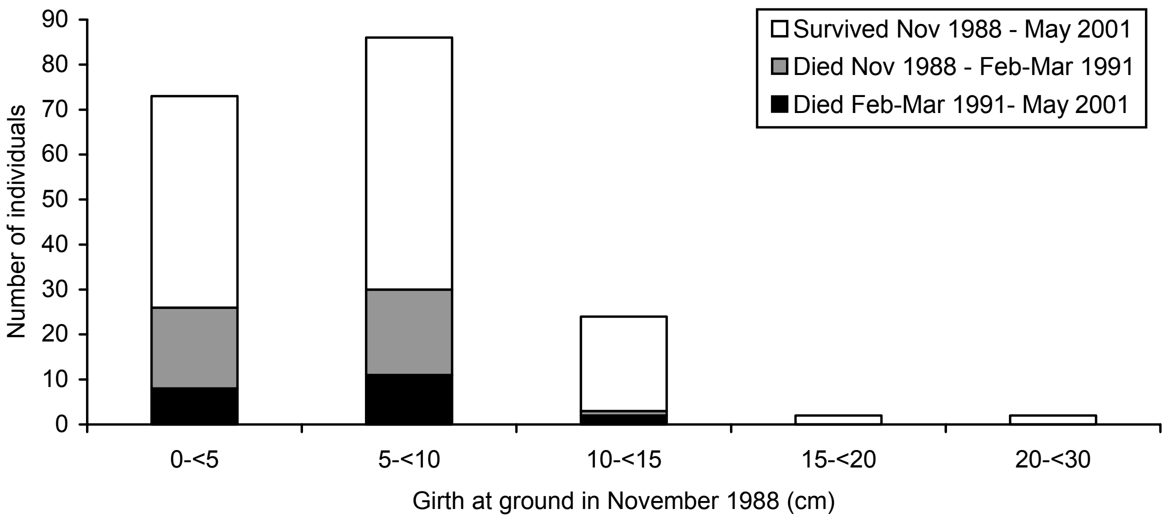

Figure 8: Mortality/survival of small ash individuals in the three permanent plots on Ridge Hanger from November 1988 to February-March 1991 and May 2001 in relation to their initial size.

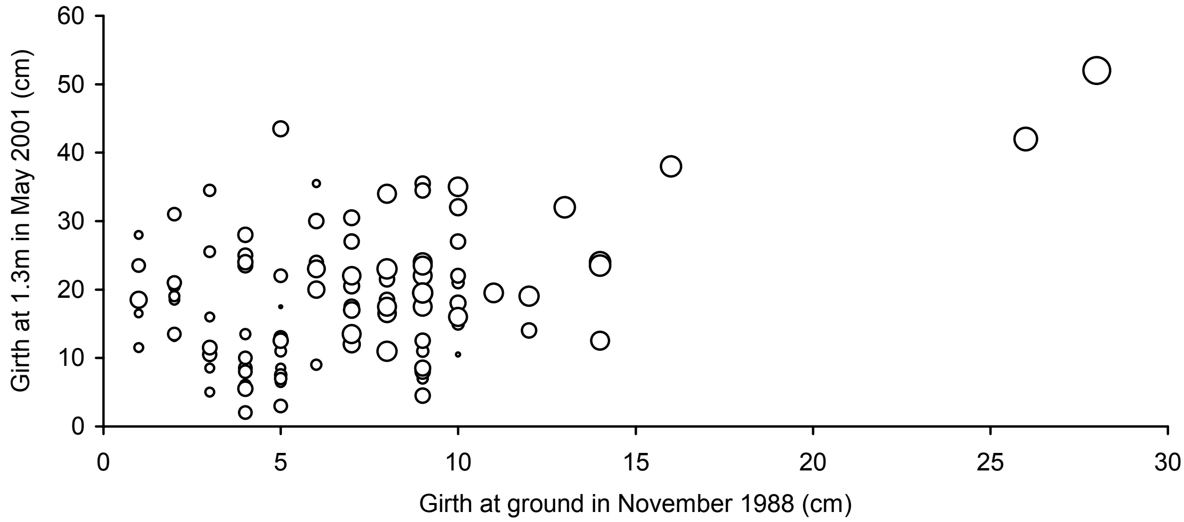

Figure 9: Size of small ash individuals in the three permanent plots on Ridge Hanger. The initial girth in November 1988 (x-axis), the height in February-March 1991 (area of the circular point; range = 0.1-7m), and girth in May 2001 (y-axis) are shown. Includes all available stems.

Losses included 51 individuals that died by February-March 1991, and 33 that died later or failed to grow to 1.3m height by May 2001. 59 were ash, nine were beech, seven were elder, three were oak, three were elm, and three were either hawthorn, hazel or holly. They accounted for 71 out of 187 individuals that were <10cm girth at ground in November 1988. Only eight were ≥15cm girth at ground in November 1988. In most cases the cause of mortality could not be identified with certainty because few or no traces of the individuals remained. Nevertheless, the loss of mainly small-sized individuals suggests competitive exclusion was a major cause of mortality. In some cases other causes were responsible: basal ring-barking probably by rabbits or bank voles killed at least two ash and one beech, and nine ash and one holly had died after being crushed by trees or branches that fell after November 1988. The eight losses ≥15cm girth at ground in November 1988, included two elder in plot C that died by February-March 1991, and three elder in plot B that died later evidently due to exclusion. The remaining three large individuals were all elm in plot A: these succumbed to Dutch elm disease following an outbreak in 1996. Another large elm in this plot was infected and by May 2001 had almost died.

6.3 Performance of seedlings established during November 1988–February/March 1991

Forty-eight new individuals established by February-March 1991, 10 of which had grown to ≥1.3m height by this time (Table 4). Most were ash, but a few beech, birch and elder established. 33 survived and were ≥1.3m height by May 2001, which was 12% of such individuals (Table 5). All birch survived, 69% of ash, and half the beech and birch. Nine survivors (all ash) were ≥1.3m height and 24 were <1.3m in February-March 1991. Some of these had grown large, including 10 ash, an elder and an beech that attained 20cm girth (Table 7). These included a mixture of tall and short individuals from February-March 1991, though the majority of short individuals remained small girth (Figure 10). Losses included 13 ash, a beech and an elder. Most losses were short individuals: only one was ≥1.3m height in February-March 1991. At least one ash loss was due to basal ring-barking probably by rabbits or bank voles.

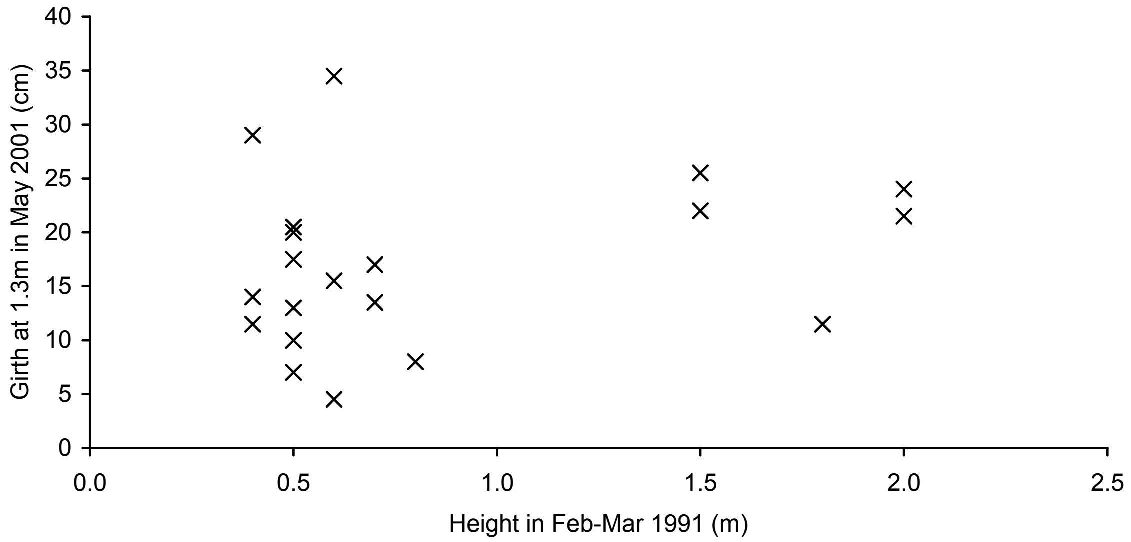

Figure 10: Growth of small ash individuals in the three permanent plots on Ridge Hanger that established during November 1988 - February-March 1991. The initial height is compared to the girth attained in May 2001. Includes all available stems.

6.4 Performance of seedlings established during February/March 1991–May 2001

Seventy-eight new individuals established and grew to ≥1.3m height during February-March 1991 and May 2001 (Table 5). These amounted to 29% of the 2001 population. Most were ash (48) or elder (13), but a few rose, beech, hawthorn, hazel, elm, maple, broom and dogwood established. Only a few ash, elder and hawthorn managed to grow to 20cm girth or more (Table 7). 49 remained small at <10cm girth.

6.5 Condition of surviving recruits

The stature and vigour of all live stems in the plots attaining 10cm girth at 1.3m height (n = 283) was recorded in May 2001 (Table 6). 178 stems were growing more-or-less erectly and at least quite vigorously. These appeared most likely of dominating the stand in the immediate future. Most were ash (139), but some were hawthorn (13) or hazel (10), and a few were elder, maple, beech, or birch. They included all the birch and 56-70% of the ash, hawthorn and hazel stems, but only 31-36% of the maple, beech and elder and none of the elm. 51 stems were classified as more-or-less erect and non-vigorous. These represented suppressed and diseased stems, which had become overtopped. They included 14-25% of the maple, hawthorn, ash, hazel and elder, and 50% of the elm. 54 stems were classified as growing on a strong lean or laterally, only 16 of which appeared at least quite vigorous. These included stems of ash, beech, elm, elder, field maple, hazel and hawthorn that had been hit/pinned under fallen trees/branches, were smoothed under *Rubus*, or were growing on an angle as forks or stool sprouts. They included a high percentage (64-67%) of the beech and field maple stems, though only beech had a high percentage (42%) that were leaning/lateral and still quite vigorous.

Table 6 Stature and vigour of live stems on small trees and shrubs in the three permanent plots on Ridge Hanger in May 2001. Only stems attaining 10cm girth (at 1.3m height) are included. The cells show the number of stems in four categories: [+/- erect and at least quite vigorous], [leaning or lateral and at least quite vigorous], [+/- erect and non-vigorous], [leaning or lateral and non-vigorous], eg ash stems at 10-<20cm girth had 41 stems +/- erect and at least quite vigorous, 2 stems leaning or lateral and at least quite vigorous, 13 stems +/- erect and non-vigorous, and 5 stems leaning or lateral and non-vigorous.

Plot A

Girth (cm)	Ash	Birch	Elder	Elm	Field maple	Hazel	Hawthorn	Total
10-<20	41, 2, 13, 5	-	0, 1, 1, 1	0, 0, 1, 1	0, 1, 0, 5	0, 0, 1, 0	0, 1, 3, 0	41, 5, 19, 12
20-<30	26, 1, 0, 0	-	5, 0, 0, 1	-	4, 0, 0, 0	0, 0, 1, 2	3, 0, 0, 0	38, 1, 1, 3
30-<40	7, 0, 0, 0	1, 0, 0, 0	-	-	1, 0, 0, 1	-	-	9, 0, 0, 1
40-<50	-	-	-	-	-	-	3, 0, 0, 0	3, 0, 0, 0
50-<60	-	-	-	-	-	-	-	-
Total	74, 3, 13, 5	1, 0, 0, 0	5, 1, 1, 2	0, 0, 1, 1	5, 1, 0, 6	0, 0, 2, 2	6, 1, 3, 0	91, 6, 20, 16

Plot B

Girth (cm)	Ash	Elder	Beech	Hawthorn	Total
10-<20	26, 2, 20, 9	0, 0, 0, 1	0, 0, 0, 1	2, 0, 0, 2	28, 2, 20, 13
20-<30	23, 1, 1, 0	-	-	0, 0, 1, 0	23, 1, 2, 0
30-<40	12, 0, 0, 1	-	-	2, 0, 0, 0	14, 0, 0, 1
40-<50	1, 0, 0, 0	-	-	-	1, 0, 0, 0
50-<60	1, 0, 0, 0	-	-	-	1, 0, 0, 0
Total	63, 3, 21, 10	0, 0, 0, 1	0, 0, 0, 1	4, 0, 1, 2	67, 3, 22, 14

Plot C

Girth (cm)	Ash	Beech	Birch	Elder	Field maple	Hazel	Hawthorn	Total
10-<20	0, 0, 3, 0	2, 2, 0, 1	1, 0, 0, 0	0, 0, 2, 2	-	7, 2, 1, 1	3, 0, 0, 1	13, 4, 6, 5
20-<30	0, 0, 0, 1	1, 1, 0, 1	-	0, 0, 1, 1	0, 0, 2, 0	3, 0, 0, 0	-	4, 1, 3, 3
30-<40	1, 0, 0, 0	0, 2, 0, 0	-	-	-	-	-	1, 2, 0, 0
40-<50	1, 0, 0, 0	1, 0, 0, 0	-	-	-	-	-	2, 0, 0, 0
50-<60	-	-	-	-	-	-	-	-
Total	2, 0, 3, 1	4, 5, 0, 2	1, 0, 0, 0	0, 0, 3, 3	0, 0, 2, 0	10, 2, 1, 1	3, 0, 0, 1	20, 7, 9, 8

Debarking and other damage was noted on all recorded live stems. Wherever possible the most likely cause of this was identified. Squirrel debarking on stems attaining 10cm girth at 1.3m height is shown in Table 7. Affected species were beech, birch, field maple and hazel. Debarking levels were generally higher for beech, birch and field maple (50-71% of stems) than hazel (33% of stems), though only two birch stems were available for comparison. Although stems of all sizes were debarked by squirrels, the severity of damage increased with stem size. Other debarking and damage than squirrel debarking is shown in Table 8. Affected species included ash, beech, field maple, hawthorn, hazel and holly, though 89 out of the 101 stems/individuals involved were ash, most of which were located in plots A and B. Much of this debarking was limited and affected small ash. It was attributed mainly to rabbits and/or bank voles. The rabbit population was high around the time of the 1987-90 storms, but had collapsed by 2001 probably due to myxomatosis disease. Only 8 (ash) stems suffered severe debarking: the largest at 23.5cm girth at 1.3m height had been debarked where it had been hit by a toppled beech, whereas the others were debarked lower down, probably by rabbits and/or bank voles. 26 stems/individuals from a range of species had been hit and damaged.

18 of these had been severely damaged, including 15 that were left growing laterally and three that had been snapped. Most of these were smaller stems/individuals, but a few larger ash and field maple were struck and severely damaged.

Table 7 Squirrel debarking damage on live stems on small trees and shrubs in the three permanent plots on Ridge Hanger in May 2001. Only stems attaining 10cm girth (at 1.3m height) are included. The cells show the number of stems in three damage categories [none], [limited/moderate], [severe/very severe], eg ash stems at 10-<20cm girth had 61 stems with no damage, 0 stems with limited/moderate damage, and 0 stems with severe/very severe damage. The damage categories are explained in the notes for Table 2.

Plot A

Girth (cm)	Ash	Birch	Elder	Elm	Field maple	Hazel	Hawthorn	Total
10-<20	61, 0, 0	-	3, 0, 0	2, 0, 0	4, 1, 1	0, 1, 0	4, 0, 0	74, 2, 1
20-<30	27, 0, 0	-	6, 0, 0	-	0, 2, 2	1, 1, 1	3, 0, 0	37, 3, 3
30-<40	7, 0, 0	0, 0, 1	-	-	0, 1, 1	-	-	7, 1, 2
40-<50	-	-	-	-	-	-	2, 0, 0	2, 0, 0
50-<60	-	-	-	-	-	-	1, 0, 0	1, 0, 0
Total	95, 0, 0	0, 0, 1	9, 0, 0	2, 0, 0	4, 4, 4	1, 2, 1	10, 0, 0	121, 6, 6

Plot B

Girth (cm)	Ash	Beech	Elder	Hawthorn	Total
10-<20	57, 0, 0	1, 0, 0	1, 0, 0	4, 0, 0	63, 0, 0
20-<30	25, 0, 0	-	-	1, 0, 0	26, 0, 0
30-<40	13, 0, 0	-	-	2, 0, 0	15, 0, 0
40-<50	1, 0, 0	-	-	-	1, 0, 0
50-<60	1, 0, 0	-	-	-	1, 0, 0
Total	97, 0, 0	1, 0, 0	1, 0, 0	7, 0, 0	106, 0, 0

Plot C

Girth (cm)	Ash	Beech	Birch	Elder	Field maple	Hazel	Hawthorn	Total
10-<20	3, 0, 0	3, 2, 0	1, 0, 0	4, 0, 0	-	8, 2, 1	4, 0, 0	23, 4, 1
20-<30	1, 0, 0	0, 1, 2	-	2, 0, 0	0, 2, 0	3, 0, 0	-	6, 3, 2
30-<40	1, 0, 0	0, 1, 1	-	-	-	-	-	1, 1, 1
40-<50	1, 0, 0	0, 0, 1	-	-	-	-	-	1, 0, 1
Total	6, 0, 0	3, 4, 4	1, 0, 0	6, 0, 0	0, 2, 0	11, 2, 1	4, 0, 0	31, 8, 5

Table 8 Other damage than squirrel debarking on small trees and shrubs in the three permanent plots on Ridge Hanger in May 2001. All stems attaining 10cm girth (at 1.3m height) and all individuals attaining 1.3m height are included. The cells show the number of stems in four categories: [limited debarking], [severe debarking], [hit but limited damage], [hit and severely damaged], eg ash stems at 1-<10cm girth had 13 stems with limited debarking, 1 stem severely debarked, 0 stems hit but with limited damage, and 1 stem hit and severely damaged. The damage categories are explained in the notes for Table 2. A few stems occurred in more than one category.

Plot A

Girth (cm)	Ash	Field maple	Hawthorn	Total
1-<10	13, 1, 0, 1	-	-	13, 1, 0, 1
10-<20	17, 0, 0, 3	0, 0, 0, 3	0, 0, 0, 1	17, 0, 0, 7
20-<30	3, 0, 1, 0	-	-	3, 0, 1, 0
30-<40	-	0, 0, 0, 1	-	0, 0, 0, 1
Total	33, 1, 1, 4	0, 0, 0, 4	0, 0, 0, 1	33, 1, 1, 9

Plot B

Girth (cm)	Ash	Field maple	Hawthorn	Holly	Total
1-<10	14, 3, 0, 4	1, 0, 0, 0	-	1, 0, 0, 0	16, 3, 0, 4
10-<20	12, 4, 3, 1	-	0, 0, 1, 0	-	12, 4, 4, 1
20-<30	1, 0, 1, 1	-	-	-	1, 0, 1, 1
Total	27, 7, 4, 6	1, 0, 0, 0	0, 0, 1, 0	1, 0, 0, 0	29, 7, 5, 6

Plot C

Girth (cm)	Ash	Beech	Hazel	Total
1-<10	2, 0, 1, 0	0, 0, 0, 1	-	2, 0, 1, 1
10-<20	2, 0, 0, 0	0, 0, 1, 0	1, 0, 0, 1	3, 0, 1, 1
20-<30	0, 0, 0, 1	-	-	0, 0, 0, 1
Total	4, 0, 1, 1	0, 0, 1, 1	1, 0, 0, 1	5, 0, 2, 3

7. Changes in the ground vegetation in the permanent plots on Ridge Hanger

It was expected that the ground vegetation in the plots would respond strongly where the canopy had been opened by storms. Changes were recorded in the three permanent plots on Ridge Hanger (Annex 2, Figure 2). The two main ground vegetation plants were *Mercurialis perennis* and *Rubus fruticosus.* Records of their cover are shown in Table 9. In May 1989 these both covered moderate amounts of the most open plots A and C, whilst in plot B, which remained fairly closed, *Mercurialis* covered large areas, but there was little *Rubus*.

Rubus cover was recorded again in February-March 1991. It had increased in all plots, but particularly in the most open plots A and C, where it now covered about two-thirds of the ground. It had colonised all squares in plot B, but only in small patches. *Rubus* remained as the most abundant ground species in May 2001, but it had expanded in some places and contracted elsewhere. Overall it decreased by only small amounts in plots A and C, whereas in plot B it increased by 12%. In 11 of the 18 squares it changed by 15% or less. Major increases (30-54%) occurred in squares A1, A3, B4 and B6, where the canopy had become open and the ground well lit. Major decreases (20-50%) occurred in squares A2, A5 and A6, where *Rubus* had become shaded by regeneration and left moribund.

Table 9 Change in the cover of the two main ground plants in the three permanent plots on Ridge Hanger from November 1988 to May 2001. The percentage cover for each 10x10m square within the plot is shown. *Mercurialis perennis* was not recorded in 1991. - = <5% cover or not present.

	Nov 1988	May 1989	Feb/Mar 1991	May 2001
Mercurialis perennis				
Plot A				
A1	-	75		30
A2	-	5		-
A3	-	80		-
A4	25	70		10
A5	-	-		-
A6	-	15		5
Plot B				
B1	25	90		70
B2	25	80		75
B3	50	80		60
B4	25	70		10
B5	35	80		50
B6	6	90		25
Plot C				
C1	-	50		30
C2	25	55		60
C3	-	-		-
C4	-	10		20
C5	-	40		20
C6	-	-		-
***Rubus fruticosus* agg.**				
Plot A				
A1	10	10	25	70
A2	45	60	90	70
A3	-	-	60	95
A4	5	5	45	60
A5	5	30	75	25
A6	20	50	85	40
Plot B				
B1	-	-	5	-
B2	-	-	9	-
B3	-	-	6	10
B4	-	-	6	60
B5	-	-	12	10
B6	-	-	10	40
Plot C				
C1	25	25	75	80
C2	6	5	45	40
C3	55	55	75	75
C4	-	-	15	15
C5	65	65	95	80
C6	90	90	95	80

By May 2001, *Mercurialis* had decreased in many places, particularly in squares A1, A3/4, B4 and B6, where dense thickets of *Rubus* had grown up under gaps. Nevertheless, in some places it remained quite abundant under *Rubus* (eg squares C1/2). It also survived well in many places in plot B where the ground remained shaded and *Rubus* was less vigorous. Overall it changed from 41 to 8% in plot A, from 82 to 48% in plot B, and from 26 to 22% in plot C.

Records for minor ground vegetation species are shown in Annex 3. In May 1989, 25 minor species were recorded. Only *Hyacinthoides non-scriptus* and *Urtica dioica* were regarded as occasional: the first covered 10-15% in squares C2 and C6, whilst the latter covered 5% in square C2. The remaining species occurred infrequently, as individual plants or in small groups. Although some species were typical of shady conditions (notably *Anemone nemorosa, Arum maculatum, Dryopteris dilatata, Dryopteris filix-mas, Hyacinthoides non-scriptus*), many were ruderals or other light-demanding plants (notably *Brachypodium sylvaticum, Carduus acanthoides, Chamaerion angustifolium, Chrysanthemum segetum, Cirsium palustre, Clematis vitalba, Digitalis purpurea, Epilobium montanum, Galium aparine, Mycelis muralis, Myosotis sylvatica, Scrophularia nodosa, Senecio jacobaea, Sonchus arvensis, Urtica dioica, Verbascum thapsus, Veronica montana*). More minor species were recorded in plots A and C, where the canopy was more open and the ground had been disturbed more through uprooting.

Numerous additional minor species were recorded in May 2001. *Pteridium aquilinum* had colonised and spread strongly onto open ground in the top corner of square A1. The other 18 new species remained scarce. Most were ruderals or other light-demanding plants (notably *Ajuga reptans Arctium lappa, Bryonia dioica, Cerastium holosteoides, Circaea lutetiana, Eupatorium cannabinum, Geum urbanum, Holcus lanatus, Plantago major, Poa annua, Rumex sanguineus, Solanum dulcamara, Taraxacum offiinale, Veronica serpyllifolia*). In addition, several species present in May 1989 had increased substantially. *Clematis vitalba* now covered 10-30% in squares B4, B5, C1 and C2 where it grew mainly amongst *Rubus* on well-lit ground. *Hyacinthoides non-scriptus* covered 40-50% in squares C3 and C6 where it grew mainly below well-lit thickets of *Rubus. Urtica dioica* remained at 5% cover in square C2, but had increased to 15% cover in square C6. *Brachypodium sylvaticum* covered 25% in square C4, where it grew mainly with *Mercurialis* in an open area where rabbits had apparently prevented *Rubus* from spreading. Otherwise, *Dryopteris dilatata, Myosotis sylvatica* and *Senecio jacobaea* had colonised all three plots. Although mosses were not recorded in May 1989, they nevertheless appeared to have increased substantially. In particular, *Hypnum cuppressiforme* had colonised many of the fallen dead trunks and branches, and *Fissidens taxifolus* had colonised widely on the soil surface. The number of minor species in the three plots was now quite similar (18-26 species, excluding mosses), with plot B having opened substantially and increased from six to 20 species.

The main declines in species recorded in May 1989 were: (i) the loss of *Carduus acanthoides, Carex sp., Chrysanthemum segetum, Digitalis purpurea, Verbascum thapsus* and *Veronica montana*, which could not be re-found; (ii) the loss of *Euphorbia amygdaloides* from two of the three plots it was recorded in, and (iii) the loss of *Scrophularia nodosa* and *Sonchus arvensis* from one of the two plots they were recorded in. In most cases the location of these species was marked on the 1989 charts and checked in the field in May 2001. The main causes of decline appeared to be over-shading either by tree regeneration and/or (where the canopy remained open) by *Rubus* thickets.

8. Implications for nature conservation

The East Hampshire Hanger woods are regarded as one of the finest series of semi-natural, beech-ash-yew woodland in southern England, protected under national and European designations. The character of these woods has changed considerably during the past 15 years, due mainly to the 1987 and subsequent windstorms.

The records of storm-damage and responses from Ashford Hangers National Nature Reserve and the plots on Ridge Hanger provide an indication of the scale and extent of these changes. Across all the Hanger woods, several thousand canopy trees (mainly beech) have been brought down. Although this has more-or-less destroyed some stands, the damage has been remarkably patchy. In the southern part of the NNR, which suffered far more damage than the north, only about one-third of mature beech blocks lost virtually all their canopy trees. Remaining stands have suffered less and in some places they remain more-or-less unscathed. This can be observed by visiting Ridge Hanger: on the upper slope at the south-western end virtually all canopy trees have been downed across several hectares, but further east and on the lower slopes and upper plateau many large trees and intact groups remain. Many surviving individuals have been invigorated with the loss of adjoining and overtopping beech, particularly suppressed individuals of oak, field maple, hazel and ash.

Where canopy trees have fallen a range of other habitats have been created, as exemplified by the changes recorded on Ridge Hanger. Where the ground has become well-lit, the variety of ground plants has increased as numerous light-demanding species have colonized. *Rubus* has grown over many of these areas, though it has also retreated wherever natural regeneration has developed strongly. Despite this leading to the displacement of some early colonizing ground plants, many have persisted. Gaps have also part-filled with tree and shrub regeneration, though this has varied greatly from one area to another. Some patches have become filled, whilst others have only scattered groups or individual trees or bushes. Others have no tree or shrub regeneration and look set to remain as semi-permanent open spaces filled mainly with *Rubus*. Ash has been the main colonist, though many other native trees and shrubs are present in at least small quantities. Overall there are far more tree and shrub species than before the storms. Most noticeable is the scarcity of beech regeneration, particularly from seed, though some old beech coppice-stools are regrowing strongly. However, even these are unlikely to grow into 'normal' canopy trees, as they are already being badly debarked by grey squirrels and most likely will have their tops killed (Mountford 1997). The loss of so many canopy trees has created a super-abundance of dead wood. Most of this is in large fallen logs and branches, which have been colonised widely by mosses. Although dead wood is presently abundant, much of this is unlikely to remain for long: most beech logs have already shed their bark and even the largest of these is unlikely to last longer than about 3-4 decades (Van Hees and Clerkx 1999). The root plates and hollows of uprooted trees have also provided a range of micro-conditions suitable for different types of plants (Buckley and others 1994). In other parts of the reserve, particularly on Ashford Hill and Berryfield Hanger, there was an extensive and well-developed understorey of yew, most of which has survived and prospered since the loss of the beech canopy. This has restricted the development of the ground vegetation and other tree/shrubs regeneration, though some pockets of both are present.

Thus, storm-damage stands are being replaced by a variety of habitats, mainly: (i) dense stands dominated by ash or yew; (ii) smaller mixed groups and individuals of ash plus other trees and shrubs; and (iii) open areas dominated mainly by *Rubus* scrub. All contain a number of large dead logs, some have large canopy trees and snags interspersed, and they are distributed in blocks of various sizes between extant mature stands. Much the same change has been recorded at Noar Hill Hanger (Mountford 2003, Mountford & Groome 2003). The composition, variety and intermixing of these habitats is considered generally favorable for nature conservation (Peterken 1993). Of course, this has to be balanced against the loss of many mature trees and their associated habitats – for example several moribund beech that were uprooted on Ashford Hill were of invertebrate interest. Nevertheless, by no means have all mature trees been lost, and where fallen trees have been retained this has created substantial dead wood habitat and opportunities for saproxylic species. There is also going to be a major change from beech-dominance to ash or yew or *Rubus* scrub. Even so, a minority of beech is regenerating (eg from old coppice stools and a few snapped trees on Ridge Hanger, and from seedlings alongside the Stoner Hill road), and despite the effects of grey squirrel debarking, this is unlikely to kill all younger beech. In time beech might establish as an understorey to ash, albeit limited by the distribution of seed and seed trees. In fact, to some extent the reduction in beech dominance has advantages for nature conservation. Fortunately the storms have not directly disturbed any rare or scarce plant species: in fact they have opened several areas of chalk scree onto which *Helleborus foetidus* has expanded.

9. Recommendations for research and monitoring

The information reported here offers a baseline from which to monitor long-term changes in Ashford Hangers NNR. It also combines with research from other minimum intervention reserves, which is starting to build up a more comprehensive picture of natural stand development in British woodland (Mountford 2000, Peterken 2000). It would therefore be useful to continue recording the plots at Ridge Hanger every decade or so, with any intervening impacts or events noted preferably by means of an annual inspection (when the state of the permanent markers can also be checked). These activities should be written into the management plan and the recorded information retained in the site archive and made available through summary publications.

It would also: (i) be useful to add to the existing monitoring plots, increasing the number and distribution, ideally make them representative of reserve, and at least to include other woodland types (eg beech-yew woodland on Ashford Hill); (ii) maintaining a standard methodology; and (iii) studying other features of interest (see Mountford 2000 for details). The minimum intervention on Ridge Hanger is rather small and vulnerable to edge effects. It would be valuable to the make any minimum intervention areas at least 20ha in area. These blocks would be valuable not only for research and monitoring, but would help increase the amount of old-growth habitat within the reserve. As a comparison, it would be interesting to select 'actively' managed parts of the reserve and establish similar plots in these so that comparisons can be made between different management regimes.

10. References

ALLEN, J.R.L. 1992. Trees and their response to wind: mid Flandrian strong winds, Severn Estuary and inner Bristol Channel, southwest Britain. *Philosophical Transactions of the Royal Society of London B,* 338, 335-364.

BALL, D. 1995. Ashford Hangers National Nature Reserve site management plan. *Unpublished report held by Hampshire County Council.*

BALL, D. 2001. *The Ashford Hangers NNR: an archaeological and landscape history survey.* Unpublished MA Thesis, King Alfred's College, Winchester.

BUCKLEY, G.P., BOLAS, M.J. & KIRBY, K.J. 1994. Some effects of treefall-induced soil disturbance on understorey vegetation development following the storm of 1987. *In*: K.J. KIRBY, & G.P. BUCKLEY, eds. Ecological responses to the 1987 Great Storm in the woods of south-east England. *English Nature Science*, No 23, 81-104.

BURT, S.D. & MANSFIELD, D.A. 1988. The Great Storm of 15-16th October 1987. *Weather,* 43**,** 90-108.

FARWELL, G. & BALL, D. 1991. Long-term monitoring of permanent plots in Ashford Hangers, Hampshire. *In*: A.WHITBREAD, ed. Research on the ecological effects on woodland of the 1987 storm*.* *Research and Survey in Nature Conservation*, No. 40, 70-72. Peterborough: Nature Conservancy Council.

GRAYSON, A.J. 1989. *The 1987 storm: impacts and responses.* London: HMSO (Forestry Commission Bulletin No. 87).

HALL, J.E., KIRBY, K.J. & MORECROFT, M.D. 1999. Minimum intervention woodlands and their use for ecological research in Great Britain. *Joint Nature Conservation Committee Report,* No. 295.

KIRBY, K.J. & BUCKLEY, G.P., eds. 1994. Ecological responses to the 1987 Great Storm in the woods of south-east England. *English Nature Science,* No. 23.

KIRBY, K.J., REID, C.M., THOMAS, R.C. & GOLDSMITH, F.B. 1998. Preliminary estimates of fallen dead wood and standing dead trees in managed and unmanaged forests in Britain. *Journal of Applied Ecology,* 35, 148-155.

MACKNEY, D., HODGSON, J.M., HOLLIS, J.M. & STAINES, S.J. 1983. *Soils of England and Wales* (1:250,000 Map and Legend). Harpenden: Soils Survey of England & Wales.

MOUNTFORD, E.P. 1997. A decade of grey squirrel bark-stripping damage to beech in Lady Park Wood, UK. *Forestry,* 70**,** 17-29.

MOUNTFORD, E.P. 2000. A provisional minimum intervention woodland reserves series for England with proposals for baseline recording and long-term monitoring therein*.* *English Nature Research Reports*, No. 385.

MOUNTFORD, E.P. 2003. Storm-damage and vegetation change in East Hampshire beechwoods. III. Stand change at Noar Hill Hanger. English Nature Research Reports, No. XXX.

MOUNTFORD, E.P. & GROOME, G. 2003. Storm-damage and vegetation change in East Hampshire beechwoods. II. Ground vegetation at Noar Hill Hanger. English Nature Research Reports, No. XXX

MOUNTFORD, E.P. & PETERKEN, G.F. 2000. Natural developments at Scords Wood, Toy's Hill, Kent, since the Great Storm of October 1987. *English Nature Research Reports*, No. 346.

MOUNTFORD, E.P. & PETERKEN, G.F. 2001. Long-term changes in an area of The Mens, a minimum intervention woodland reserve damaged by the Great Storm of 1987. *English Nature Research Reports*, No. 435.

OCKENDEN, J.K. 1990. *The East Hampshire Hangers Project 1985-1990.* Petersfield: East Hampshire District Council.

PETERKEN, G.F. 1993. *Woodland Conservation and Management.* 2nd Edition. London: Chapman and Hall.

PETERKEN, G.F. 1996. *Natural Woodland: Ecology and Conservation in Northern Temperate Regions*. Cambridge: Cambridge University Press.

PETERKEN, G.F. 2000. Natural Reserves in English Woodland. *English Nature Research Reports,* No. 384.

PETERKEN, G.F. & BACKMEROFF, C.E. 1988. *Long-term monitoring in unmanaged woodland nature reserves. Research & Survey in Nature Conservation,* No.9. Peterborough: Nature Conservancy Council

RODWELL, J.S. ed. 1991. *British Plant Communities Volume 1: Woodlands and Scrub.* Cambridge: Cambridge University Press.

ROSE, F. & MARSHALL, I. 1984. *Report on the biological survey of the Chalk Hangers N and NW of Petersfield in the ownership of Hampshire County Council*. Unpublished report held by Hampshire County Council.

VAN HEES, A. & CLERKX, S. 1999. Dood hout in de bosreservaten. *De Levende Natuur,* 5, 168-172.

WARREN, W.G. & OLSEN, P.E. 1964. A line intersect technique for assessing logging waste. *Forest Science,* 10, 267-76.

WEBB, C. 2002. *An archaeological and historic land use survey of Selborne Common.* Unpublished MA Thesis, King Alfred's College, Winchester.

WHITBREAD, A. ed. 1991. Research on the ecological effects on woodland of the 1987 storm. *Research and Survey in Nature Conservation*, No. 40. Peterborough: Nature Conservancy Council.

11. Annexes

Annex 1 Location and main features of the four plots established to monitor vegetation changes in Ridge Hanger following the 1987 storm. Vegetation types are based on Rodwell (1991). Soil information is based on Mackney and others (1983) and soil pits.

Plot	Grid reference	Main features
A	SU 72852561	Plot starts just on the edge of the upper plateau and runs across the top of the scarp on 19-24° slopes – soils are transitional from clayey brown earths at top to shallow rendzinas down the scarp – vegetation type mainly W12a calcareous beech-ash woodland, just transitional to W14 mesotrophic beech-oak woodland towards the top
B	SU 72862554	Plot on the middle of the scarp on 28-33° slopes – soils are shallow rendzinas[2] – vegetation type W12a calcareous beech-ash woodland
C	SU 72762555	Plot starts on the edge of the upper plateau and runs down the scarp slope starting at 20° and ending at 30° – soils and vegetation type as per Plot A

Note

The soil on main scarp was a grey rendzina, with a dark brown, calcareous, crumbly, moderately sticky, silty clay loam textured, pH 7.5 topsoil, and a chalky subsoil. The soil on the upper plateau was a typical paleo-argillic brown earth, with a mainly brown, flinty, poorly structured, sticky, silty clay textured, pH 6.5 topsoil, and an orange brown clay-with-flints subsoil.

Annex 2 Recording of the four permanent plots established to monitor vegetation changes in Ridge Hanger following the 1987 storm. All plots were recorded in 1988/89/91, but only plots A-C in 2001. The main recorders during 1988-1991 were Geoff Farwell and David Ball; Ed and Anne Mountford undertook the 2001 recording.

Date	**Tree/shrub recording**	**Ground vegetation recording**
November 1988	Location of all standing and uprooted individuals and seedlings/saplings –measurement of girth on fallen and standing trees at 1.5m height and seedlings/saplings at base – detailed map of windthrow	Estimate of % cover of *Mercurialis perennis* and *Rubus fruticosus* in each 10x10m subplot
May 1989	Not recorded	Mapped main ground vegetation units listing dominant species – list of minor species
February-March 1991	Repeat recording as in November 1988	Estimate of % cover of *Rubus fruticosus* in each 10x10m subplot
May 2001	Location of all standing and live fallen individuals attaining 1.3m height – measurement of girth at 1.3m height on all stems attaining 10cm girth and a brief description of the condition of each stem[1] – estimate of fallen deadwood level for the compartment using the line-intersect method[2]	Estimated % cover of main species in every 10x10m subplot – mapped main ground vegetation units listing dominant species – list of minor species

Notes

[1] included notes on stature, forking, vigour, crown condition, epicormics, damage, debarking, climbers, cause of death, and origin; longer descriptions were made for large canopy trees; dead stems (including those alive only at the base) had the height estimated to the nearest m, the decay state categorised as solid or part-rotten, and remaining bark estimated to the nearest 10%; squirrel debarking 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; other debarking caused by rabbits, bank voles or deer, when stems had been hit by falling trees/branches, or by other unidentifiable causes was classified in a similar way; possibly some debarking caused by squirrels might have been attributed to other causes and vice versa; stems that had been hit by falling trees/branches were classified as severely damaged if they had been snapped &/or left growing laterally

[2] based on methods described by Warren and Olsen (1964) and Kirby and others (1998); ten equal length line-transects covering 200m (t) were spread throughout the compartment containing the plots; 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 estimated using the formula, $V = \sum(\pi^2 d^2/8t)$ ($m^3\ ha^{-1}$)

Annex 3 Condition of seven surviving large live trees in the permanent plots on Ridge Hanger in May 2001. Squirrel debarking scores are explained in the notes for Table 2.

Plot	Sp.	Girth (cm)	Description	Squirrel debarking
A	Oak	117	Tall erect tree apparently much suppressed before storm – now with upper crown +/- completely lost/dead, but whole tree now sheathed in long, vigorous epicormic sprouts from base to top and +/- all round but most vigorous into space below	None
		14	Vigorous lateral trunk sprout low down on trunk	None
		11	Vigorous lateral trunk sprout low down on trunk	None
B	Beech	176	Tall +/- erect tree – now shooting in the upper crown, though the crown is rather small and has some dead parts, the low/mid-trunk has some dead bark patches, and a large fork has snapped out on lower side maybe a few months ago	None
	Beech	162.5	Tall erect tree – now shooting in the crown, though all upper branches are dead/poor, overall the crown is very poor and small for the size of tree, and has a lot of dead bark to 8m up, including ring at base on lower side (has probably suffered due to drought and/or excessive opening of the stand)	None
	Beech	153	Tall erect tree probably promoted from coppice with several additional coppice-type stems (see below) and apparently moderately suppressed before storm – now with upper crown shooting and several vigorous sprouting branches on mid-trunk/lower crown forming new crown, though some branches are dead in places, at some branch ends the foliage is poor, and some squirrel damage present	Limited
		43.5	Leaning basal stem – now vigorously spreading and rising with much side light, but debarked low down by squirrels	Moderate
		30.5	Leaning basal stem – now vigorously spreading with much side light, but base and trunk top debarked by squirrels	Severe
		28.5	Leaning basal stem – now with strongly spreading with much side light, but branch tops debarked by squirrels	Limited
		15	Leaning basal stem growing down slope	None
	Beech	142.5	Tall erect tree apparently much suppressed before storm – now with upper crown shooting strongly and numerous vigorous sprouts all up trunk, but tops of some laterals have been debarked by squirrels and root debarked where struck by uprooted beech	Limited
	Field maple	109.5	Tree leans partly down slope and upper crown was much suppressed before storm – now with crown released and numerous vigorous sprouts up trunk and into crown, though many sprouts (including some that have died) and have been debarked by squirrels and bark also damaged low down where hit by toppled beech, also had a bough snapped out when beech fell,	Moderate
		33.5	Erect basal stem with spreading and rising top	Limited
		26	Leaning basal stem with crown much suppressed and lower parts dead	Moderate
C	Beech	156	Erect tree with part curved twisting trunk – crown branches shooting well, but no strong epicormic sprouts and has large scars to 6m up on topside where struck	None
		56.5	Leaning basal stem with several spreading trunk branches out along ground and laterally below spreading and rising vigorously, but badly debarked by squirrels to 2m up and numerous debarked patches in upper branches	Severe

Annex 3 Occurrence of minor plant species in the ground vegetation in the three permanent plots on Ridge Hanger in May 1989 and May 2001. + = scarce; ++ = occasional; +++ = frequent. Mosses were not recorded in May 1989. Excludes *Mercurialis perennis and Rubus fruticosus* agg. (see Table 11).

	May 1989			May 2001		
	Plot A	**Plot B**	**Plot C**	**Plot A**	**Plot B**	**Plot C**
Present both dates						
Arum maculatum	+	+	+	+	+	+
Galium aparine	+	+	+	+	+	+
Euphorbia amygdaloides	+	+	+	-	+	-
Dryopteris filix-mas	+	+	-	+	+	-
Hyacinthoides non-scriptus	+	-	++	+	-	+++
Epilobium montanum	+	-	+	++	+	+
Chamaerion angustifolium	+	-	+	++	-	++
Dryopteris dilatata	+	-	+	+	+	+
Scrophularia nodosa	+	-	+	-	-	+
Senecio jacobaea	+	-	+	+	+	+
Sonchus arvensis	+	-	+	-	-	+
Urtica dioica	-	+	++	+	+	++
Anemone nemorosa	+	-	-	-	+	-
Rubus idaeus	-	+	-	-	-	+
Brachypodium sylvaticum	-	-	+	+	++	++
Cirsium palustre	-	-	+	-	+	+
Clematis vitalba	-	-	+	+	+++	+++
Fragaria vesca	-	-	+	-	-	+
Mycelis muralis	-	-	+	-	-	+
Myosotis sylvatica	-	-	+	+	+	+
Ribes sylvestre	-	-	+	-	-	+
Present 1989 only						
Digitalis purpurea	+	-	+	-	-	-
Veronica montana	+	-	+	-	-	-
Carex sp.	+	-	-	-	-	-
Chrysanthemum segetum	+	-	-	-	-	-
Verbascum thapsus	+	-	-	-	-	-
Carduus acanthoides	-	-	+	-	-	-
Present 2001 only						
Hypnum cuppressiforme	-	-	-	+++	+++	++
Other mosses	-	-	-	++	++	+
Fissidens taxifolus	-	-	-	++	-	++
Pteridium aquilinum	-	-	-	++	-	-
Circaea lutetiana	-	-	-	+	-	+
Geum urbanum	-	-	-	-	+	+
Holcus lanatus	-	-	-	+	-	-
Lonicera periclymenum	-	-	-	+	-	-
Plantago major	-	-	-	+	-	-
Primula vulgaris	-	-	-	+	-	-
Phyllitis solopendrium	-	-	-	-	+	-
Rumex sanguineus	-	-	-	-	+	-
Veronica serpyllifolia	-	-	-	-	+	-
Ajuga reptans	-	-	-	-	+	-
Arctium lappa	-	-	-	-	+	-
Cerastium holosteoides	-	-	-	-	+	-
Bryonia dioica	-	-	-	-	-	+
Eupatorium cannabinum	-	-	-	-	-	+
Galeobdolon luteum	-	-	-	-	-	+
Poa annua	-	-	-	-	-	+
Solanum dulcamara	-	-	-	-	-	+
Taraxacum offiinale	-	-	-	-	-	+

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Middle left: Co_2 experiment at Roudsea Wood and Mosses NNR, Lancashire.
Peter Wakely/English Nature 21,792
Bottom left: Radio tracking a hare on Pawlett Hams, Somerset.
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