THE MANAGEMENT OF STORM DAMAGED WOODLAND AT TOY'S HILL, KENT (poster)

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Summary

The storm of 16 October 1987 caused severe damage to the ancient woodland and remnant heath of Toy's Hill near Sevenoaks, Kent. The gales destroyed large areas of oak and beech high forest.

The owners of the site, the National Trust, have implemented several management schemes in various parts of the wood in an attempt to mitigate storm damage.

The aim of this study was to examine the effects of various post-storm management regimes on the flora of the woodland, with special reference to the natural regeneration of native tree species. The major management types were taken to be:

- Complete non-intervention (no clearance or replanting)
- Clearance and replanting
- Clearance and leaving to natural regeneration
- Careful clearance, with a view to managing as heathland

Toy's Hill provides a rare opportunity to study the process of natural regeneration alongside the effects of storm damage clearance and replanting.

Introduction

Toy's Hill lies 7.2 km southwest of Brasted, near Sevenoaks in Kent. The land, now in the possession of the National Trust, includes 154 hectares of ancient woodland, remnant heath and semi-improved pasture. The woodland of Toy's Hill lies within the Scord's Wood and Brockhoult Mount Site of Special Scientific Interest and has also been designated as an area of Special Significance for Countryside Conservation.

The storm of 16 October 1987 caused widespread damage to the woodland. The aim of this study was to examine the effects of various post-storm management regimes on the flora of the woodland, with special reference to the natural regeneration of native tree species (King 1993). The major management treatments were taken to be:

	Compartment No.
- Complete non-intervention (no clearance or replanting).	6a (Minimum Intervention Zone)
- Clearance and replanting.	3a; 4b
- Clearance and leaving to natural regeneration.	6b
- Selective clearance with a view to managing as heathland.	3b; 8a; 8b

The study was based on and close to the plateau of Toy's Hill which previous to the storm consisted mostly of beech and oak high forest. Further downslope, soil conditions and pre-storm vegetation types were markedly different, so could not be used to compare management treatments.

Methods

Plotless sampling, the preferred method of investigation, was impossible to carry out due to the density of vegetation which rendered some areas impenetrable. Therefore a sampling technique was devised using existing paths (the only way to penetrate some compartments) as a basis for transects in each compartment. At each sampling site (of which there were between 20 and 25 per compartment) a 1 x 5 m strip was measured from the transect and details were recorded, including:

- Soil depths at 0, 2.5 and 5 m intervals along the strip.
- Tree species and the quantity of each species.
- Tree description (seedling, sapling, standard, pollard or coppice).
- Tree condition (if windblown or felled and if so whether the tree is still alive).

Ground vegetation was also recorded using the DAFOR system (Dominant, Abundant, Frequent, Occasional, Rare), at each sampling site. Dead wood, bare ground and areas of severe compaction were also noted. Species names are given in Table 1.

A random sample of 80 planted trees in 3a and 4b was also examined to assess their survival after two years.

Table 1 Latin names and abbreviations used in the text

Latin name	Abbreviation	Common name
Betula pendula	Bp	silver (warty) birch
Betula pubescens	Bpu	hairy (downy) birch
Chamaecyparis lawsoniana	Cl	lawson cypress
Fagus sylvatica	Fs	common beech
Ilex aquifolium	Ia	holly
Pinus sylvestris	Ps	Scots pine
Quercus petraea	Qp	sessile (durmast) oak
Quercus robur	Qr	pedunculate (English) oak
Salix caprea	Sc	goat willow (sallow)
Sorbus aria	Saria	whitebeam
Sorbus aucuparia	Sa	rowan (mountain ash)
Ulex europaeus	Ue	gorse
Viburnum lantana	Vl	wayfaring tree
Calluna vulgaris	Calluna	ling heather
Chamaenerion angustifolium	Chamae	rosebay willow-herb
Pteridium aquilinum	Pteridium	bracken
Rubus fruticosus	Rubus	bramble
Vaccinium myrtillus	Vaccinium	bilberry

Results

Average soil depth by compartment

The shallowest soils were in compartment 3a which had been cleared partially in 1987/88 and more thoroughly in 1990 (Figure 1). Compartments 4b and 6b also exhibited denuded soil profiles due to clearance in 1987 and 1990 respectively. The deepest soils occurred where disturbance had been kept to a minimum in compartments 3b/8 and 6a.

Machine-cleared areas suffered compaction and erosion which left the mineral layer exposed in many places. The burning of windthrow has destroyed leaf litter and humus. In compartment 6b compacted ground made up 31.7% of the area sampled. Little vegetation had colonised these areas since clearance in 1990/91. Where intervention was less extreme, soil profiles remained largely intact with a good cover of humus and leaf litter.

<u>Density of seedlings and sapling trees by compartment</u>

Machine-cleared compartments 3a, 4b and 6b showed high densities of young trees due to extensive colonisation by birch seedlings (Figure 2). The number in 4b was lower because strong intra-specific competition caused their density to reduce over time. 3a and 6b had a shorter history of colonisation, and birch seedlings made up a large proportion of the total number of trees.

The non-intervention zone 6a had a low density of seedlings and saplings. Possibly the shade cast by dead wood may have suppressed germination. The condition of the seedbed also played a vital role - soils covered by leaf litter are not suitable for colonisation by birch and this may have contributed to the lower density of juveniles in compartments 6a, 3b/8.

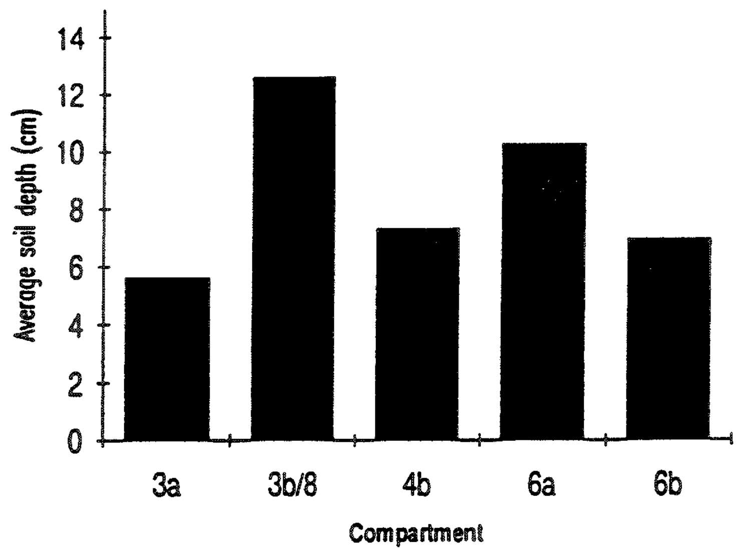


Figure 1 Average soil depth by compartment.
6a non-intervention, 3a/4b clearance and replanting, 6b clearance only, 3b/8 selective clearance.

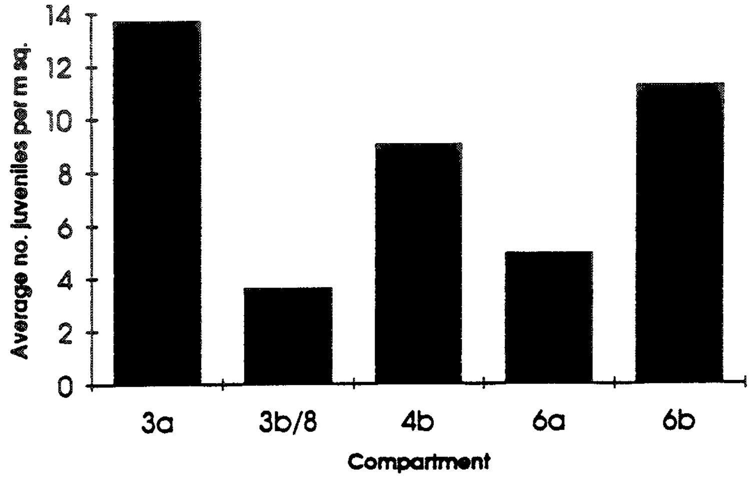


Figure 2 Average number of juvenile trees (seedlings and saplings) per square meter, by compartment.

Tree species by compartment

In all compartments birch (*Betula pendula* and *Betula pubescens*) was the dominant regenerating species (Table 2). The high proportion of birch (over 90%) in compartments 3a, 4b and 6b exemplify the ability of birch to colonise disturbed ground. Where the soil remained intact the proportion of birch was less being 70.4% in compartments 3b/8 and 56.3% in the Non-Intervention Zone 6a. *Betula pendula* was the more common of the two species: a higher growth rate and a more efficient seed mobility was probably the key to its dominance at Toy's Hill (Grime *et al.* 1988).

Table 2 Percentage of different species among juvenile trees by compartment in 1992

3a, 4b clearance and replanting, 3b/8 selective clearance, 6a Non-intervention, 6b clearance only.

Compartment	3a	3b/8	4b	6a	6b
Oak	0.3	7.5	0.7	2	0.5
Beech	2.2	3.2	2.9	2	1.0
Birch	94	70.4	92.5	56.3	93
Holly	3.5	13.6	3.4	36.4	4.4
Other	0.0	5.3	0.5	3.3	1.1
Total number of juvenile trees recorded	1776	368	1081	558	1342

The proportion of holly (*Ilex aquifolium*) was relatively high in 3b/8 and 6a. It is not possible to say however whether this was due to unfavourable seedbed conditions in cleared areas, the method of seed dispersal which may limit the extent of holly colonisation, or simply to higher populations prior to the storm.

The proportion of beech seedlings (*Fagus sylvatica*) was similar throughout the site despite differences in the number of young trees of other species in each compartment. In compartments 3b/8 the greatest proportion of beech juveniles was found where selective felling has taken place. In compartments 4b and 3a the severe compaction and denudation of the potential seedbed was probably offset by the high proportion of mature beech growing in these compartments before the storm. In compartment 6b, the most recently cleared area, relatively low amounts of beech regeneration might also be due to severe compaction which restricts beech seedling establishment (Watt 1923).

The greatest proportion of oak seedlings (*Quercus petraea* and *Quercus robur*) was found in remnant heathland, compartments 3b/8. Low figures in compartments 3a and 4b correspond to conditions before the storm when beech was the dominant species on the plateau. Compartment 6b however did contain a large number of oaks before the storm, and in this instance poor seedbed conditions may have prevented seedling establishment.

The results suggest that oak and beech regeneration were most successful where the soil profile is intact, so retaining the seed bank, and a seedbed which was suitable for germination.

Amongst the planted stock in compartments 3a and 4b after two years around 20% of beech seedlings were lost compared to 1% of oak seedlings, although it is not known whether the severe compaction noted above was a contributory factor in this differential loss.

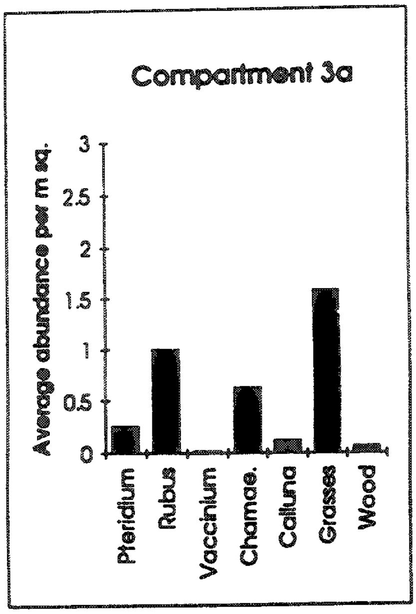
Ground vegetation changes

Mean abundances for different ground vegetation classes are summarised in Figure 3.

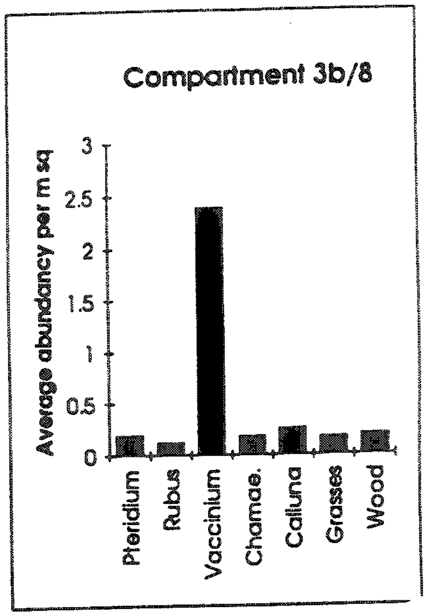
The opening up of the canopy at Toy's Hill has inevitably allowed the rapid growth of bramble (*Rubus fruticosus*) and in some areas (notably compartments 6b and 4b) bramble growth may have been exacerbated by clearance. However the abundance of bracken (*Pteridium aquilinum*) did not appear to bear any relation to the management schemes. Its prevalence in 3b/8 may have been due to the deep acid soils on which bracken thrives (Grime *et al.* 1988). However bracken was also common on the thin, denuded soils in compartment 4b.

The prevalence of bilberry (*Vaccinium myrtillus*) in compartments 3b/8 supports the findings of Watt (1919) and Shaw (1974) who commented that bilberry provides good conditions for the germination of oak seedlings. Juvenile oak with a ground cover of bilberry were found to grow to a density of up to 20 seedlings per metre square in compartment 3b/8 where clearance was minimal.

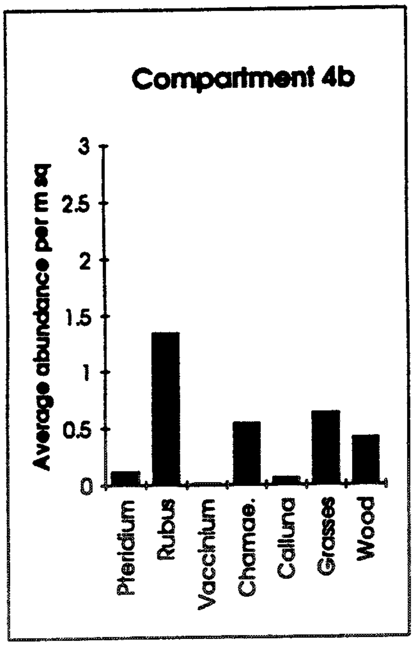
Rosebay willow-herb (*Chamaenerion angustifolium*) proved to be a good indicator of disturbance. It quickly colonised bare ground in the cleared compartments and areas around the roots of upturned trees in the Non-intervention zone where dead wood had suppressed other vegetation. In contrast areas disturbed by heavy machinery were often colonised by grasses. Heather (*Calluna vulgaris*) was most common in compartment 6b. Its appearance is probably the product of dormant seeds which are capable of long term survival.



Ground flora :
Average abundance
per square metre



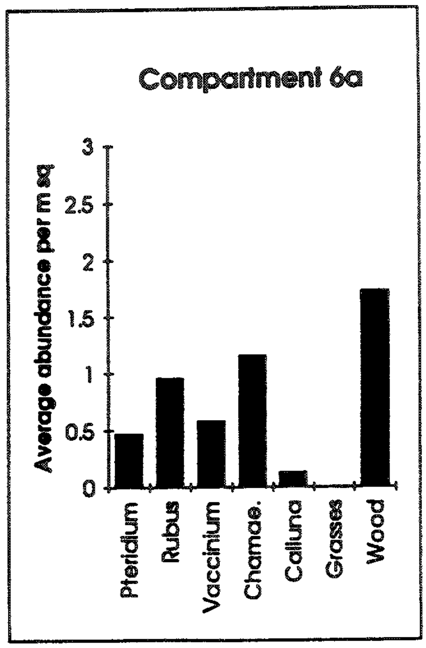
(Wood = Dead wood)

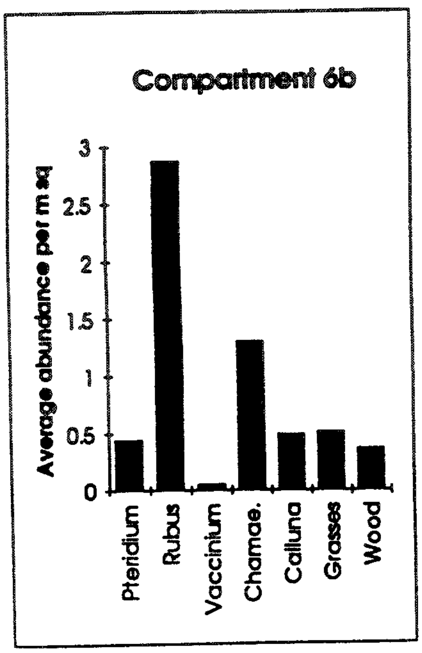


Ground flora :
Average abundance
per square metre

Figure 3. Vegetation differences in the compartments:

Clearance and replanting 3a 4b
Clearance/natural regeneration 6b
Minimum intervention 6a
Selective clearance to heathland 3b/8





Ground flora :
Average abundance
per square metre

Discussion

The most striking difference between the Non-Intervention zone (6a) and compartments which had been cleared (3a, 4b, 6b), was the amount of birch regeneration that had taken place. Areas selectively cleared (3b/8) were also markedly different, having a higher density of oak and beech juveniles and a relatively low density of young birch. As well as affecting regeneration clearance also affects the ground vegetation.

Bramble, bracken and grasses compete with beech seedlings for light, water and nutrients. Oak, however, has the advantage of a long tap root which allows it to compete more successfully with established vegetation. If this is the case, oak is more likely to become the dominant species in compartments already well colonised by ground vegetation.

The regeneration cycle

The extent to which a canopy is opened up or dead wood cleared has a bearing on the vegetation types that later grow on the woodland floor, influencing the diversity and the type of tree generation (Jones 1945; Watt 1947).

The current abundance of birch as a coloniser may thin out with age, and allow enough light to reach the forest floor to enable oak or beech succession. However Rackham (1980) suggests that birch, once dominant, may remain for several generations. The idea of beech or oak woodland as a permanent feature on this site may be incorrect. On acid soils (such as those found on the plateau of Toy's Hill) beech may have a degrading effect (Dimbleby & Gill 1955). Beech is less able to replace itself on the acid soils it has created, and becomes a transient species (Watt 1925).

Birch has the ability to increase pH and is often quoted as a soil improver (Dimbleby 1952). Holly has a similar effect.

The appearance of birch and holly may be an essential part of the cycle of an oak/beech wood. On poor soils, beech regeneration may decline until a gap phase gives the opportunity for self-replacement or for colonisation by species which may improve soils and prepare the way for the re-establishment of beech in future years.

Conclusions

At first sight the impact of the storm at Toy's Hill must have been one of complete devastation - in places 95% of the mature trees had fallen. However prior to the storm the majority of the trees on the plateau were old, possibly beyond peak reproduction age, and a dense oak/beech canopy prevented the establishment of seedlings. By chance 1987 was a good seed year for beech and oak. The storm thus gave the opportunity for these seeds to germinate by allowing sufficient light to reach the forest floor.

Colonising species such as birch quickly established themselves whilst there was ample light for them to do so. The appearance of birch in such great numbers has not been welcomed by the public or the National Trust - a young birch wood does not have the same attraction and amenity value as ancient beech/oak woodland.

The clearance and replanting programmes after the storm were partly instigated by public pressure, the aim being to tidy up storm damage and see the reinstatement of oak/beech woodland as soon as possible. However, in trying to improve or speed up the cycle of regeneration, more harm may have been done than good. Birch colonisation is far more extensive than it might have been had intervention been less drastic and the likelihood of natural oak and beech establishment has been reduced as a result.

Further information could be provided in order to make the public more aware of the issues governing management decisions. This may help to reduce the pressure for action to reinstate high forest of a particular composition before its time.

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THE EFFECTS OF THE 1987 STORM ON WOODLAND VEGETATION IN KENT (poster)

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Summary

Five areas were studied: Bitchet Common, Fawke Common, Knole Park, Scords Wood and Sevenoaks Common, to assess the effects of the 1987 storm on woodland vegetation in Kent.

Twelve transects were established in areas that had received different levels of post storm treatment:

1. Undamaged
2. Damaged but untreated
3. Cleared
4. Cleared and replanted

The type and abundance of vegetation were recorded along the transects using one metre square quadrats. The data were analysed using the numerical classification method TWINSPAN (Two-way Indicator Species Analysis), which arranged the quadrats into groups based on the similarity of their composition.

The areas that were undamaged or damaged but untreated, usually contained a large proportion of bare ground and a low species diversity. In treated areas species diversity was greater and there was less bare ground.

Introduction

The effects of the 1987 October storm on woodland vegetation were studied in five areas in the Sevenoaks region (Kent): Bitchet Common (1 cleared, 1 cleared-replanted transect), Fawke Common (1 damaged untreated, 1 cleared, 2 cleared/replanted), Scords Wood (1 undamaged, 1 cleared transect), Sevenoaks Common (1 cleared, 1 cleared/replanted) and Knole Park (2 cleared/replanted transects).

The aim was to compare growth in various woods that have been managed differently since the storm, in order to try to establish links between the type and amount of vegetation present and the post-storm treatment.

Methods

The transects, 50 m long, were established at each site in areas which had received different levels of post storm treatment (no treatment, damaged but untreated, cleared only and cleared and replanted) to give a total of 12 transects spread over the five sites.

Along each transect, at 5 m intervals, the vegetation type and percentage cover were recorded in 1 m^2 quadrats (ten quadrats per transect). Two 1 m^2 quadrats were also established at each of the five sites in an area of undamaged woodland to record the vegetation type and abundance. Soil samples were taken and tested for pH, and data recorded for the altitude, aspect, geology, slope angles and light levels of each site.

The data was analysed using TWINSPAN (Two-way Indicator Species Analysis, Hill 1979) which arranged the set of quadrats into groups based on the similarity of their species composition. Possible correlations between environmental factors and quadrat groupings were sought. Post-storm treatments were also compared in terms of extent of bare ground and species diversity. Ten quadrat groupings were derived from the TWINSPAN table.

Each group has its characteristic species (those occurring in more than 50% of a group) and companion species (those occurring between 25-49% of a group). Table 1 shows the species present in each of the groups, in which quadrats they were present and their percentage constancy. There was no clear-cut separation of the groups between the treatment types, but bare ground and species diversity did vary.

Both amount of bare ground and species diversity showed highly significant differences between post-storm treatment types. Similar taxa appear to occur in both undamaged and damaged areas so long as they remain untreated suggesting that the environmental conditions were similar in both. Light levels were often low and there may have been few nutrients and water available for pioneer and herb layer species due to the presence of standing or fallen trees. These three factors created difficult conditions for the invasion of new species, and may be why bare ground was abundant. One species characteristic of untreated sites was *Rubus fruticosus* (bramble) possibly because it can tolerate low light levels.

There was a greater species diversity and less bare ground in areas which had received post-storm treatment possibly because the light levels were higher due to the partial absence of a tree canopy, and also because the soil had been disturbed and more nutrients are available for the plants (Bormann & Likens 1979). Species characteristic of treated sites include:

Epilobium (Chamerion) angustifolium (rosebay willow herb). This favours habitats such as open or felled woodlands, and is a light demanding species.

Betula sp. (birch) invades disturbed sites and demands light. It colonises areas easily because its seeds are light and mobile.

Deschampsia flexuosa (wavy hair grass) and *Holcus* sp. favour clearings in woodlands.

Digitalis purpurea (foxglove)	)	
Agrostis sp.	)	Light-demanding species
Ulex europaeus (gorse)	)	
Poa nemoralis (wood meadow grass)	)	

Discussion

It was difficult to find evidence to connect the environmental variables affect the vegetation type and abundance, possibly because not enough data were collected. However the type of post-storm treatment has influenced the regeneration of woodland vegetation. Areas which were undamaged or damaged but untreated, usually contain a lot of bare ground and a low species diversity; in treated areas species diversity is greater and there is less bare ground because natural regeneration is stimulated.

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Table 1 The TWINSPAN quadrat groups and their corresponding species and taxa

Group	Number of quadrats	Quadrat numbers	Characterising species and taxa	Percentage constancy by group >50%	Companion species and taxa >25%
A	7	27,81,32,33, 42,43,44	*Epilobium angustifolium*	100%	
			Bare ground	57%	
			Betula sp.		42%
			Bryum capillare		28%
B	6	1,5,6,7,39, 49	Bare ground	100%	
			Rubus fruticosus	100%	
			Betula sp.	50%	
			Vaccinium sp.		33%
C	18	3,21,22,23, 24,31,34,35, 36,37,38,45, 56,61,68,69, 70,94	Bare ground	100%	
			Rubus fruticosus	100%	
			Betula sp.	77%	
			Epilobium angustifolium	66%	
D	17	48,50,62,41,46, 47,55,57,108, 116,117,52,53, 54,58,59,60 58,59,60	Bare ground	100%	
			Digitalis purpurea	88%	
			Betula sp.	76%	
			Epilobium angustifolium	70%	
			Rubus fruticosus	52%	
			Agrostis sp.		41%
E	21	65,66,67,84,91, 92,95,82,85,86, 87,90,93,96,97, 99,100,88,89, 126	*Rubus fruticosus*	90%	
			Bare ground	85%	
			Ulex europaeus	80%	
			Betula sp.	76%	
			Pteridium aquilinum		47%
			Epilobium angustifolium		38%
F	6	2,10,121,127, 128,123	Bare ground	100%	
			Pteridium aquilinum	50%	
			Dicranum scoparium		33%
			Hedera helix		33%
			Rubus fruticosus		33%
G	26	13,15,25,30,98, 102,104,129, 130,4,8,9,14, 16,17,18,20,26, 28,29,40,64,79, 80,101,122	*Pteridium aquilinum*	100%	
			Bare ground	84%	
			Rubus fruticosus	65%	
			Betula sp.		26%
H	10	72,74,75,76, 114,125,124, 11,12,71	*Deschampsia flexuosa*	100%	
			Bare ground	80%	
			Betula sp.	80%	
			Pteridium aquilinum	70%	
			Poa nemoralis		30%
			Rubus fruticosus		30%
I	12	19,103,73,105, 107,109,115, 118,119,120,63	*Pteridium aqulinum*	100%	
			Betula sp.	91%	
			Amphidium mougeotti	58%	
			Deschampsia flexuosa	50%	
			Digitalis purpurea		33%
			Epilobium angustifolium		33%
			Bare ground		33%
J	7	51,111,112, 113,78,110,77	*Deschampsia flexuosa*	100%	
			Galium sp.	57%	
			Agrostis sp.		42%
			Potentilla erecta		42%
			Juncus effusus		28%
			Pteridium aqulinum		28%
			Holcus sp.		28%

STORM DAMAGE EFFECTS ON TWO CHALK WOODS (poster)

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Permanent transects were set up at Noar Hill Hanger (a predominantly beech woodland in Hampshire) and Eagleshead Copse (an ash-hazel wood on the Isle of Wight).

The nature of the damage caused by the 1987 Great Storm was recorded in both woods. Subsequently studies of the ground flora and regeneration of woody species were made. Preliminary results indicate that some plant species showed a clear change in abundance, and could be divided into four groups:

Opportunists

These plants showed a rapid increase in abundance in the open areas created by the storm for the first three years. After this they rapidly decreased and in most cases have disappeared after six years. They include *Euphorbia amygdaloides, Cirsium arvense, Taraxacum officinale, Prunella vulgaris* and *Geum urbanum.*

Decreases

These plants were those present in some abundance before the storm, but which have gradually declined in abundance in the open areas since the storm. They include *Mercurialis perennis, Brachypodium sylvaticum* and *Clematis vitalba.*

Neutral Species

These species showed no significant increase or decrease in the glade created by the storm. They include *Rubus fruticosus.*

Increases

These species showed a significant increase in abundance in the open areas and include *Hedera helix.*

The regeneration of ash was locally prolific in the open areas created by the storm. Field maple and dog rose showed moderate regeneration at first, but after five years have not been relocated in the quadrats. Hazel has generally shown a slight but persistent regeneration from seed. Despite beech being the dominant canopy tree in Noar Hill Hanger, it has not shown any signs of regeneration in the quadrats studied.

STORM DAMAGE IN THE MENS (poster)

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Summary

Studies of damage in The Mens, an ancient woodland, after the storm of October 1987, suggest that such disturbances are a major factor influencing the distribution of species in woodland. The ratio of oak to beech is probably influenced by differential storm damage, and the distribution and abundance of shrubs and invasive species such as ash may depend on the formation of canopy gaps.

Introduction

The Mens, a Sussex Wildlife Trust Reserve between Petworth and Billingshurst, is an ancient woodland 155 ha in area. Formerly used as wood pasture and for other traditional purposes, The Mens has been neglected since about 1880 and is now under minimum-intervention management.

The vegetation was surveyed in 1988/89 to assess the effects of the storm of 16 October 1987. Details were recorded of some 6000 trees and shrubs in 155 evenly spaced circular 10 m radius quadrats, as well as ground flora, mosses, lichens, and fungi. Selected sites were re-surveyed in 1992/93, the most striking finding being that ash seedlings were flourishing in areas opened up by the storm.

Storm Damage

The storm brought down 7.7% (as basal area) of the trees in The Mens. Oak-dominated stands were the least damaged, followed by beech-dominated, with mixed stands the worst affected. Beech suffered both more windthrow and more windsnap than oak. Oak suffered more windsnap than windthrow, but the reverse was true for beech (Table 1).

The expected spurt in growth by the trees remaining standing in areas opened up by the storm had not begun at the time of the 1992/93 re-survey. The effects of the storm are shown in more detail in the following table and figures and in Cooke (1994).

<u>Changes in individual stands</u>

The details that are picked up by looking at an individual stand are also informative (Figure 2). The storm created a great deal more variety in stand structure. A closed canopy mixed stand was changed to a canopy gap with standing and fallen trees, suffering varying degrees of damage, and with other features like exposed root pits not previously present. Five years later dead wood had increased considerably, two more trees had fallen - one still alive - many saplings had regenerated and trees had put on significant growth. Shrubs, previously a more minor component of the stand, had increased in number and grown considerably. Of further interest is a large pulse of regenerating ash seedlings (Figure 2). The apparently random distribution of mature ash in The Mens may therefore be the result of ash regeneration in canopy gaps following disturbance.

Table 1 **The Mens: Effect of storm on different species**

Results expressed as basal area (m^2/ha, columns 1-3) and % (column 4), summed over the 155 quadrats of total area 4.7 ha.

1 = Stems brought down by the storm, alive in winter 1988 (i.e. windsnap).
2 = Brought down by the storm, mainly as branches, dead by winter 1988.
3 = Total brought down by the storm (1 + 2).
4 = Wood brought down by the storm and still alive in winter 1988 (1) as a % of trees of that species living before the storm.

Acer campestre and *Sambucus nigra* were not significantly damaged by the storm.

Species	1	2	3	4
Betula pendula	0.011	0.024	0.035	6.4
Betula pubescens	0.003	0	0.003	14.5
Castanea sativa	0.089	0.055	0.144	17.6
Corylus avellana	0.007	0.020	0.027	3.5
Crataegus spp.	0.005	0.001	0.006	1.6
Fagus sylvatica	2.308	0.814	3.122	12.0
Fraxinus excelsior	0.001	0.031	0.032	0.1
Ilex aquifolium	0.075	0.039	0.114	6.4
Prunus spinosa	+	0.002	0.002	0
Quercus petraea	0.120	0.097	0.217	2.2
Quercus robur	0.044	0.411	0.455	0.4
Quercus sp.	0.503	0.659	1.162	29.
All *Quercus*	0.667	1.167	1.834	3.6
Salix capraea	0.010	0.008	0.018	10.5
Sorbus torminalis	0.009	0	0.009	6.9
Taxus baccata	0.014	0	0.014	3.5
Others	0.095	0.013	0.108	63
Totals	3.294	2.174	5.468	7.7

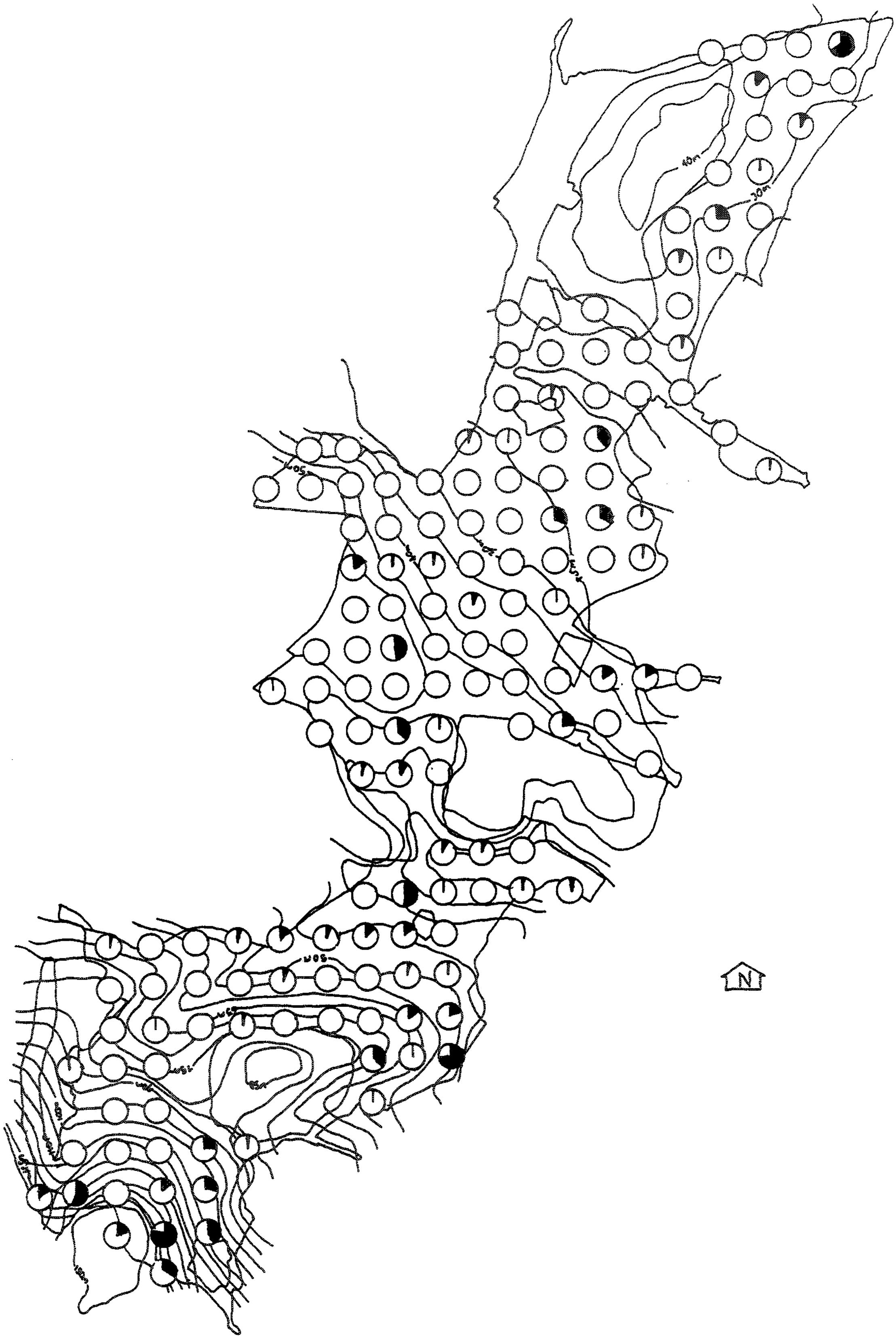

Figure 1 Pie diagrams show proportion of living wood (as basal area) brought down by storm and remaining alive. ⟼ = 100 m

Discussion

The analysis of data from The Mens before the storm has given an accurate picture of the structure and principal species composition of the site at one point in time and the analysis of size distributions provides information on possible changes underway prior to the survey. The site is predominantly a beech/oak mixture, with varying amounts of other species. Beech is more frequent on the sandy soils to the south, pedunculate oak more frequent on clayey soils to the north and sessile oak predominates in between.

The relationship of the oak species and beech is interesting and study of the size distributions may indicate whether there is some cyclic change between woodland types. In oak-dominated woodland beech seems to regenerate freely, whereas oak does not, leading to the development of mixed stands. In mixed woods again beech appears to increase in abundance at the expense of oak. However, in beech-dominated woods oaks become more frequent in the smaller size classes. Thus oak remains within the mixture and there may be some cycling back to mixed or oak woodland.

Both mixed stands and beech-dominated stands experienced more damage than oak stands, and in all categories beech suffered more than oak. Thus any progression towards beech dominated woodland is interrupted by disturbance which affects beech more than oak.

In spite of being susceptible to wind damage, beech grew most after the storm and this was true of relatively undamaged as well as severely damaged stands. The rate of growth of beech in a storm-damaged area was usually lower than in an undamaged stand, unlike in other studies (Merrens & Peart 1992) where trees in disturbed stands responded by growing faster than those in an unaffected area. The five year period of this study may be too short: the individuals take some time to respond to the increased resources available, whilst in the short term they suffer from the physical effects of disturbance and the loss of branches and hence of photosynthetic area.

Thus in the absence of disturbance there may be a progression towards beech woodland, but as oak still regenerates under beech wood there would be some tendency back to mixed woodland. When a disturbance occurs mixed and beech woodland types are affected most, and beech trees generally are affected more than oak. However beech then responded by putting on more growth after disturbance than did oak.

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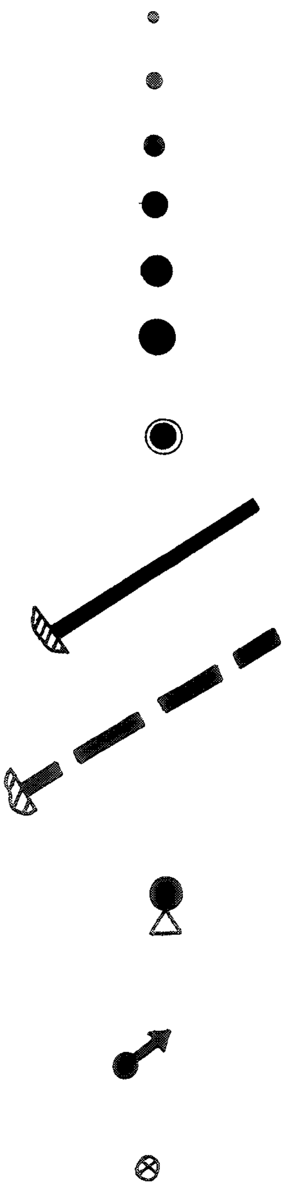
Figure 2 An examination of one stand (quadrat 84) from just before the storm to five years after.

KEY

Cm = Crataegus monogyna
Cox = C. oxyacanthoides
Fe = Fraxinus excelsior
Fs = Fagus sylvatica
Ia = Ilex aquifolium
Qp = Quercus petraea
Qr = Q. robur

Girth size categories



< 9cm

10 - 24

25 - 49

50 - 99

100 - 149

150 - 200

Tree showing sigificant growth

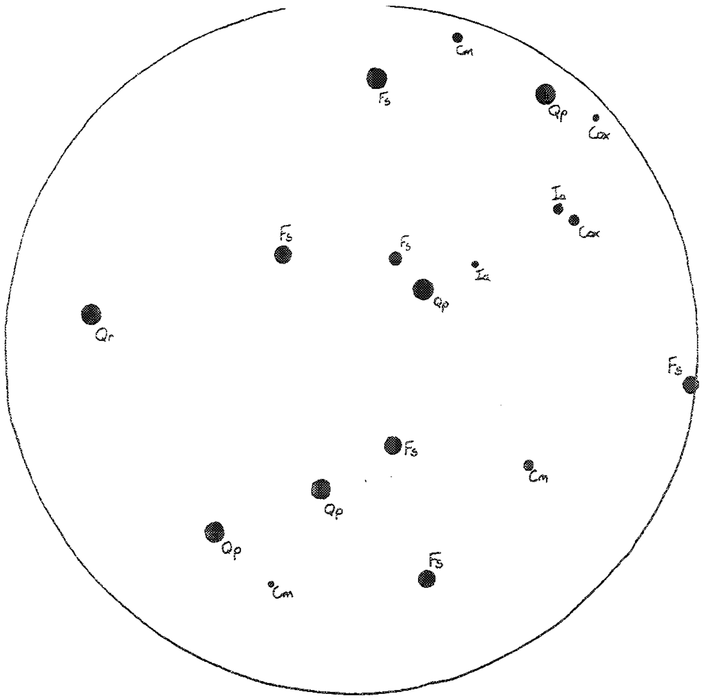
Fallen tree, alive

Fallen tree, decaying

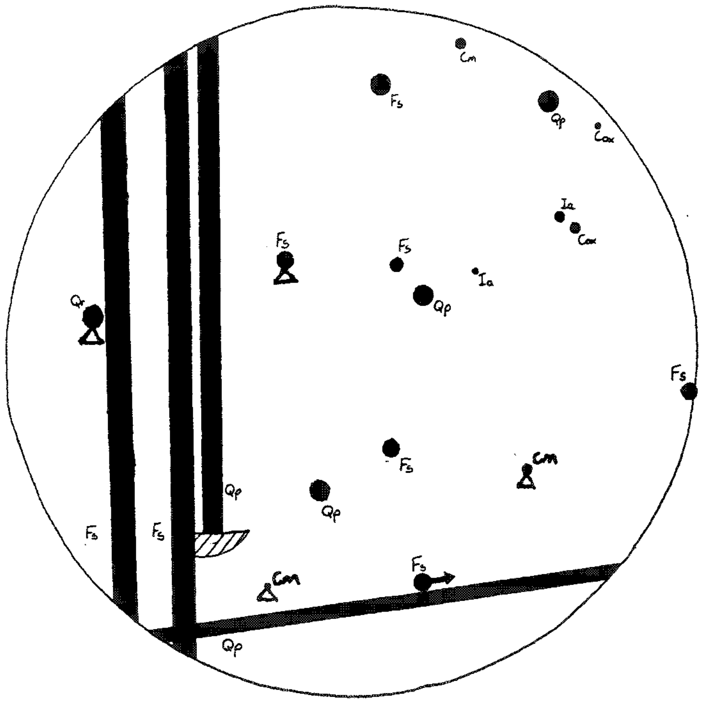
Standing damaged tree

Leaning tree

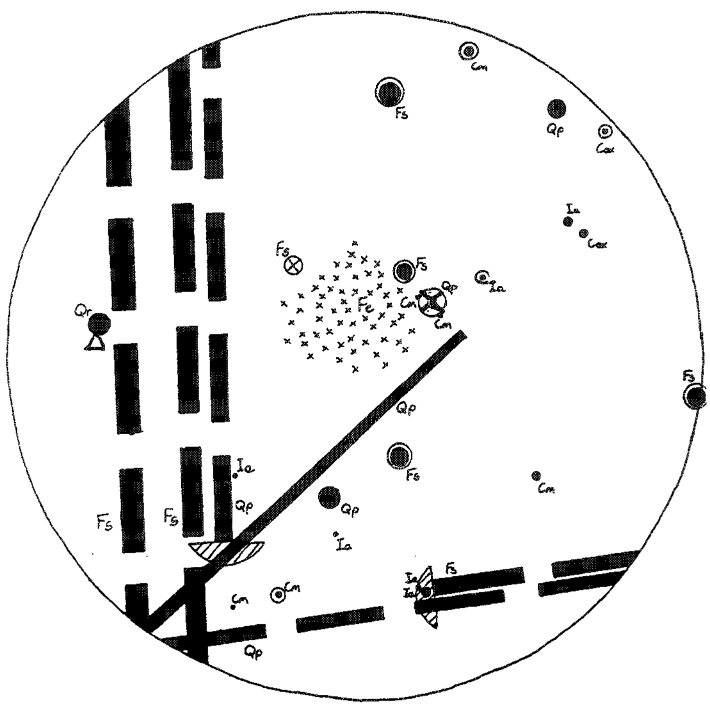
Standing dead tree



a) Reconstruction of the stand before the storm.



b) The stand in winter 1988/89



c) The stand in winter 1992

MONITORING OF VEGETATION CHANGES IN A MINIMAL INTERVENTION AREA, RENDLESHAM FOREST, SUFFOLK, FOLLOWING 1987 STORM DAMAGE

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Summary

Following severe storm damage, which left 50% of the total area of Rendlesham Forest windblown, opportunities for monitoring studies were ready made. A windblown part of a sub-compartment, comprising a 1.3 hectares area of 59 year old Scots pine at Hatchley Barn, was retained for research purposes.

In a series of permanently marked plots, measuring 16 m x 16 m, randomly located throughout the area, the density of dead wood and vegetation cover and frequency were recorded. 50% of the plots were fenced to exclude deer (roe and muntjac) and rabbits, and 50% of fenced and unfenced plots were sprayed annually with Asulox, at a rate of 5 l/ha, to control bracken growth. Assessments were been undertaken in 1991 and 1992.

The diversity of ground flora was very restricted, with bracken and bramble forming a dense layer between and over the fallen and decaying stems. Where these two species were less dominant, climbing corydalis or rosebay willowherb became locally abundant. Where bracken was treated with herbicide, areas of bare ground were created, often covered with a loose layer of brash and needle litter. In only a few places was this bare ground exploited by ruderal plant species, mainly where the plots were fenced. Occasional birch seedlings were found, but there were no signs of any of the pre-afforestation heathland species becoming re-established.

Significant differences in vegetation composition were found between sprayed and unsprayed control plots, due to a reduction in the cover of bracken and a concomitant increase in bare ground. No significant differences have yet been recorded between fenced and unfenced plots.

Introduction

In England, 16 counties were affected, in whole or in part, by the 1987 storm (Lamb 1989; Hopkins 1994; Whitbread 1991), over the area in which broadleaved woodland is most abundant (DoE, MAFF and FC, 1988). In total about 15 million trees, amounting to 3.9 million cubic metres of timber, were windblown (Forest Windblow Action Committee 1988). Slightly under half of these were conifers, mainly Scots pine, *Pinus sylvestris*, and Corsican pine, *P. nigra* var. *maritima*. Storm gusts reached a recorded maximum of 114 mph at Shoreham-by-Sea (Burt & Mansfield, 1988), and gusts exceeding 92 mph occurred over an extensive area South and East of a line from Poole to King's Lynn.

Rendlesham Forest, near Woodbridge, Suffolk, suffered extensive windblow, with over 50% of its total area blown. The combined figure for Rendlesham, Tunstall and Dunwich forests was 1,500 ha of windblow and the resulting clear-up operation lasted several years.

This study was set up at the suggestion of a former District Forester (Suffolk Forest District), with the objective of looking at vegetation changes in an area of windblown pine, to be retained indefinitely following the storm. The results are from assessments carried out in 1991 and 1992.

Site description

The site is a windblown part sub-compartment at Hatchley Barn, Rendlesham Forest (OS Grid Reference TM 309489). Formerly stocked with Scots pine planted in 1928, the majority of trees were uprooted or snapped by the storm. The area is triangular in shape, bounded on one side by a forest road, a wayleave area with overhead powerlines on another, and a narrow ride on the third side (Figure 1). The adjacent areas have since been cleared, destumped, windrowed, and replanted with Corsican pine.

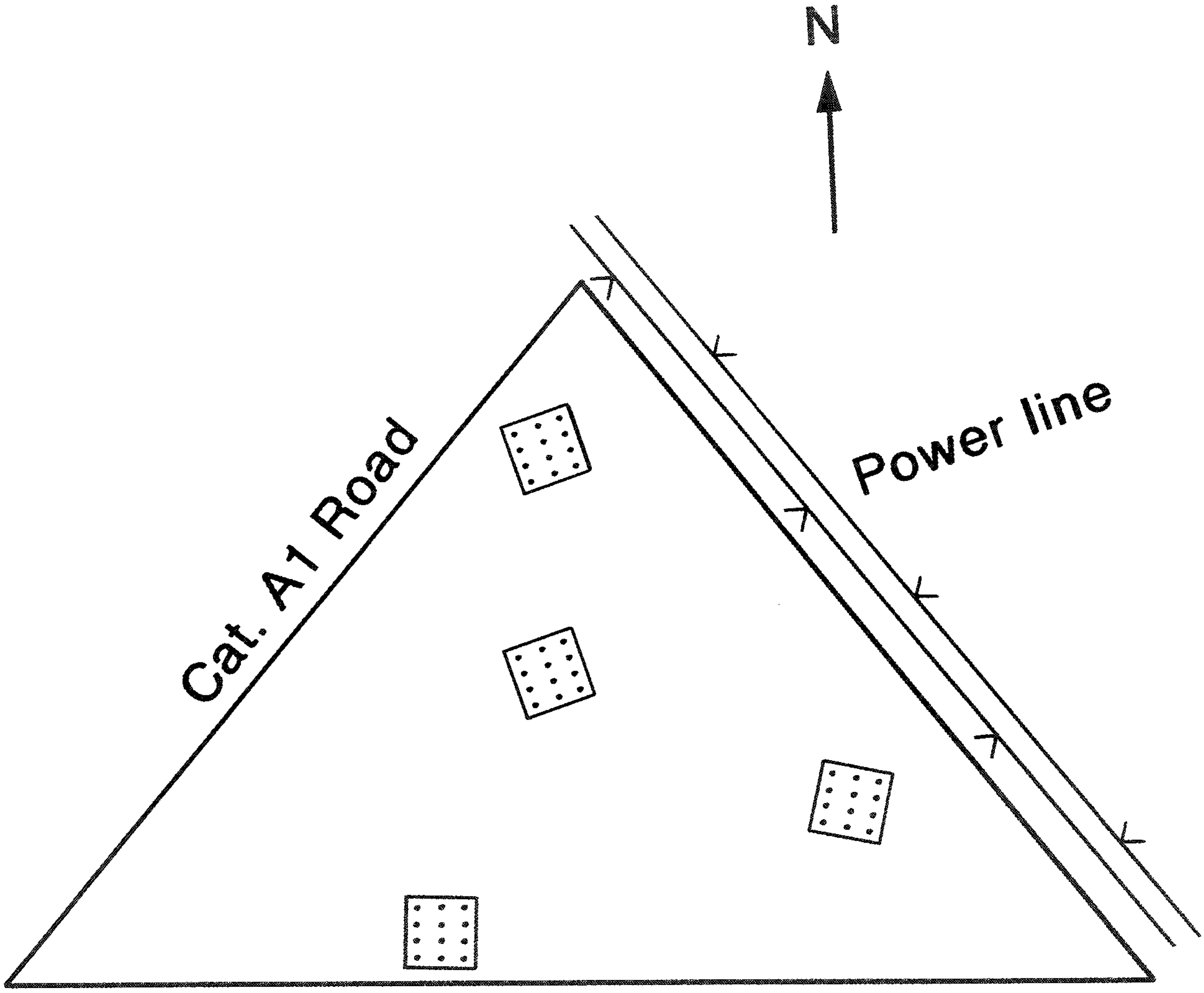

Figure 1 Site layout at Hatchley Barn, Rendlesham Forest, Suffolk. Total area = 1.3 ha.

Intervention has been kept to a minimum in this area, which is now recorded on Forest Enterprise District plans as a Research Area. A small amount of clearance work was necessary in order to create sufficient area for the erection of fenced plots and some trampling has resulted from access to spray some plots. In early 1993, it was decided to erect a fence, using 31 mm hexagonal mesh, around the entire area, in order to minimise the impact of rabbits from the research area on the adjacent restocked areas.

Methods

The experiment was laid out in a split plot design, comprising four permanently marked blocks measuring 16 m x 16 m. These were randomly located within the 1.3 ha study area, at no particular orientation.

Half of each block was fenced (i.e. an area of 16 m x 8 m), using 31 mm hexagonal mesh to a height of 1.05 m (Pepper 1992), to exclude rabbits and muntjac deer, *Muntiacus reevesi*. In half of both the fenced and unfenced halves in each block Asulox (a.i. asulam) was applied during July of each year (from 1990 onwards) at a rate of 5 litres per hectare to control bracken, *Pteridium aquilinum*. This arrangement produced four treatments, replicated four times (four separate blocks), as follows:

Unfenced and unsprayed (non-intervention Control)

Fenced and unsprayed

Unfenced and treated with Asulox at 5 l ha^{-1}

Fenced and treated with Asulox at 5 l ha^{-1}

Following herbicide application, dead bracken stems were hand-cut.

Vegetation assessments were carried out using 1 m x 1 m quadrats, randomly located in each of the four 'segments' (treatments) within each block, and replicated four times. Although the intention had been to use permanently marked quadrats, the difficult nature of the terrain made this an impractical, if not impossible option. Assessments of plant frequency, by recording presence/absence within 16 0.25 m x 0.25 m sub-quadrats, were made within each quadrat. Plant species cover was estimated visually within each quadrat, using the Braun-Blanquet scale of abundance (Ferris-Kaan & Patterson 1992). A crude measure of vegetation structure was made by measuring the height of the tallest individual plant within the quadrat.

Frequency and cover of bare ground and brash/log debris were also assessed using these methods.

Fallen dead wood on each of the four blocks was assessed, using a line-intercept sampling method described by Warren and Olsen (1964) for measuring logging waste. In this study, diagonal line transects were run from corner to corner of each 8 m x 8 m plot (i.e. two intersecting transects, each approximately 11 m in length). At intervals of 1 m along each transect, the diameter of any fallen dead wood bisecting the line was recorded. This did not allow an accurate assessment of the quantity of dead wood in each of the plots, but comparisons between plots can be made of the relative amounts of dead wood both in terms of numbers of fallen logs and their diameter at the point of intersection with the transect.

Standing dead wood in the plots was assessed by measuring the top height of any snags, using a Sokkia telescopic measuring pole (Sokkisha UK Limited, Crawley, West Sussex). A count of all standing trees, including snags, was also made (January 1992).

Statistical Analysis

Frequency data for each of the assessment dates (May 1991, September 1991, and September 1992) were subjected to analysis using multivariate ordination techniques. Principal Components Analysis (PCA) was used in most cases, with Redundancy Analysis (RA) employed with treatments considered as environmental variables (Kent & Coker 1992).

Non-parametric tests were performed on the data for the most constant 'species'. Friedman's 2-way analysis of variance, using ranks, was carried out on the frequency data for bracken and bare ground.

Cover data, although not analysed, were used to give an indication of the dominance of the communities by particular vegetation types, and provide a more detailed picture of the distribution patterns of certain plant species.

Results and discussion

On all three assessment dates, there was very little difference in the species composition or frequency of occurrence between fenced versus unfenced plots, across all four blocks.

Regeneration of birch, *Betula pendula*, might have been expected to be greater within the fenced plots, free of browsing by rabbits or deer. By September 1992, birch was found in two of the sprayed and fenced plots, one of the unsprayed and fenced plots, and one of the sprayed and unfenced plots. However, in the latter, there were clear signs of browsing by rabbits (the top had been taken out of the birch sapling, with further damage to the shoot tip). Further assessments may see greater differences beginning to occur between fenced and unfenced plots.

Application of Asulox for bracken control, irrespective of whether plots were fenced, produced significant differences, particularly in the percentage frequency of bracken (Table 1). The reduction in frequency of bracken on sprayed plots was most apparent in September 1991 and 1992, when fronds were fully expanded on the unsprayed plots. There was a corresponding increase in openness of the plots, but the frequency of bare ground did not differ between sprayed and unsprayed plots, as much of the ground was covered with a layer of small diameter brash and needle litter (as distinct from 'bare ground').

The significant results for percentage frequency of bracken indicate a rejection of the null hypothesis that there is no difference between the four treatments. An inspection of the Rank Sums indicates that this is due to reduced frequency of bracken in sprayed plots, and not due to any difference between fenced and unfenced plots.

Bracken control also resulted in some increase in percentage frequency of bramble, *Rubus fruticosus*, compared to unsprayed plots. Rosebay willowherb, *Chamerion angustifolium*, was often more frequent in sprayed plots, which is to be expected for a species producing large quantities of wind-dispersed seeds and readily able to colonise open ground. *C. angustifolium* seedlings are highly susceptible to dominance by established vegetation, and establishment is therefore usually restricted to circumstances where bare ground is created and disturbance immediately thereafter is minimal (Grime *et al.* 1988).

Table 1 **Friedman Two-Way Analysis of Variance by Ranks (Non-Parametric), performed on percentage frequency of bracken and bare ground (Untransformed replicate means).**

<u>May 1991</u>		
Bare ground	$X^2 = 2.1$	NS (p=0.649)
Bracken	$X^2 = 9.675$	Highly significant (p<0.0069)
<u>September 1991</u>		
Bare ground	$X^2 = 1.5$	NS (p=0.754)
Bracken	$X^2 = 9.675$	Highly significant (p<0.0069)
<u>September 1992</u>		
Bare ground	$X^2 = 2.33$	NS (p>0.524)
Bracken	$X^2 = 9.6$	Highly significant (p<0.0069)

In only one plot (sprayed and fenced) on the third assessment date (September 1992) was there any sign of regeneration of heathland vegetation, in this case heather, *Calluna vulgaris*. Seeds of *C. vulgaris* are known to be long-lived, and a large and persistent bank of buried seed may be formed (Grime *et al.* 1988). Seedling establishment appears to depend upon the creation of bare ground, and it may be that insufficient ground disturbance has accompanied the removal of the bracken canopy for seed to be brought into optimal conditions for germination to occur. The seedbank may also have been severely depleted by herbicide treatment at the time of crop establishment, leaving few propagules from which to re-establish.

The ordination diagrams using PCA and Redundancy Analysis (Figures 2 and 3), based on the mean percentage frequency data for all three assessment dates, show a clear dichotomy between sprayed and unsprayed plots in terms of their vegetation composition. These are related to differences in the frequency of bracken and increased relative frequency of rosebay willowherb, bramble, and birch (coupled with an increase in apparency, and hence recorded frequency, of 'brash/log debris') through time (note the positions of 'Time 1 - Time 2 - Time 3' on Figure 3).

There is little distinction drawn between fenced and unfenced plots, supporting the results reported earlier.

Given that the major factor affecting vegetation composition appears to be the application of Asulox, continued use each summer might be expected to accentuate these differences. The conditions for colonisation and establishment by other species might improve as the brash and needle litter begins to break down, and ground disturbance in addition to removal of dominant bracken might be beneficial. However, in the absence of repeated bracken control with herbicide, recolonisation of the sprayed plots is likely to be rapid, since the plots are relatively small areas surrounded by bracken-dominated vegetation.

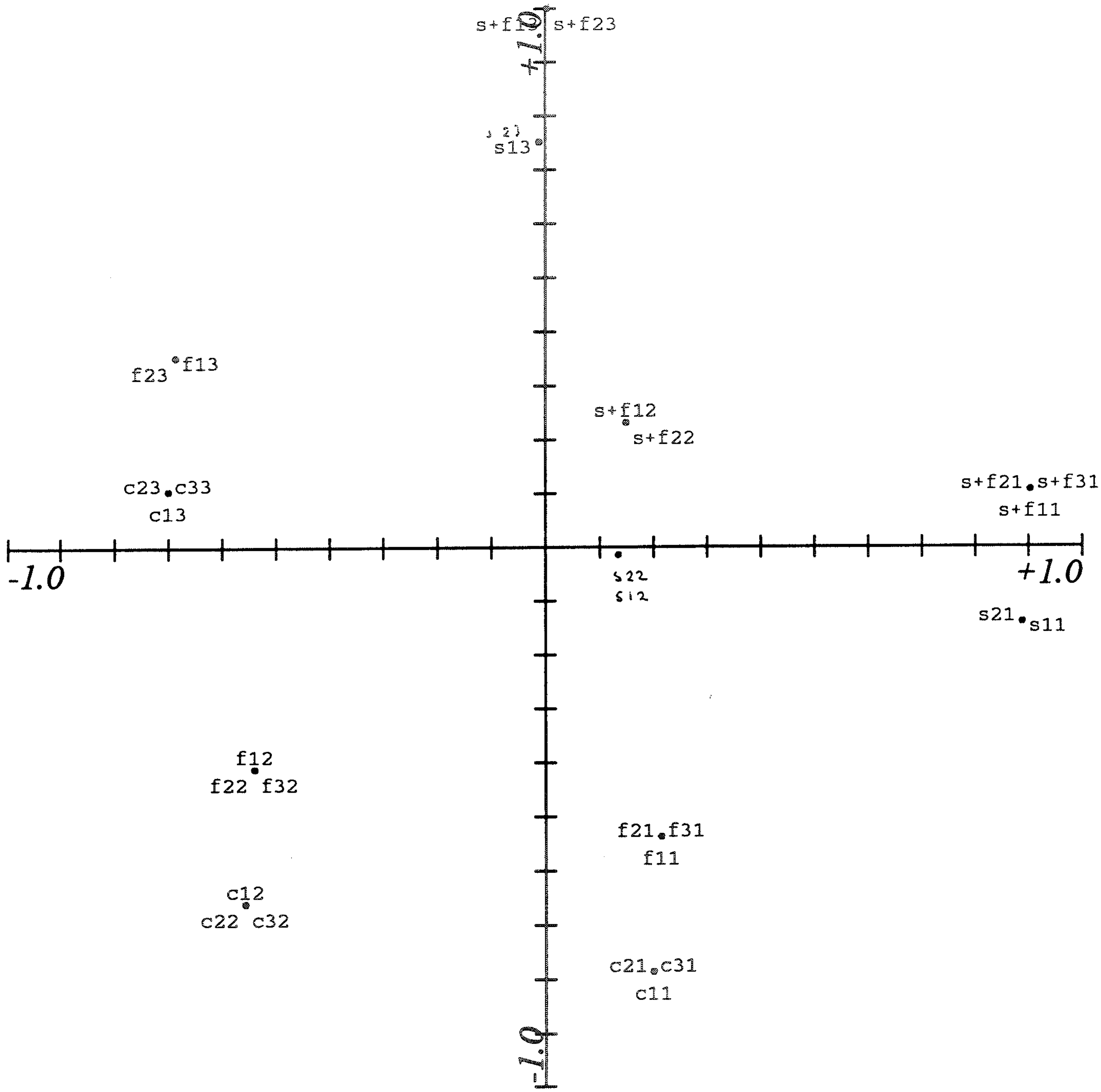

Figure 2

Principal Components Analysis (PCA) diagram, using percentage frequency data, showing relationships between Treatment Plots and Blocks over three assessment dates.

Key: C - control (unfenced and unsprayed); F - fenced and unsprayed; S - unfenced + sprayed; S+F - fenced + sprayed. First number refers to Block, second number refers to assessment date.

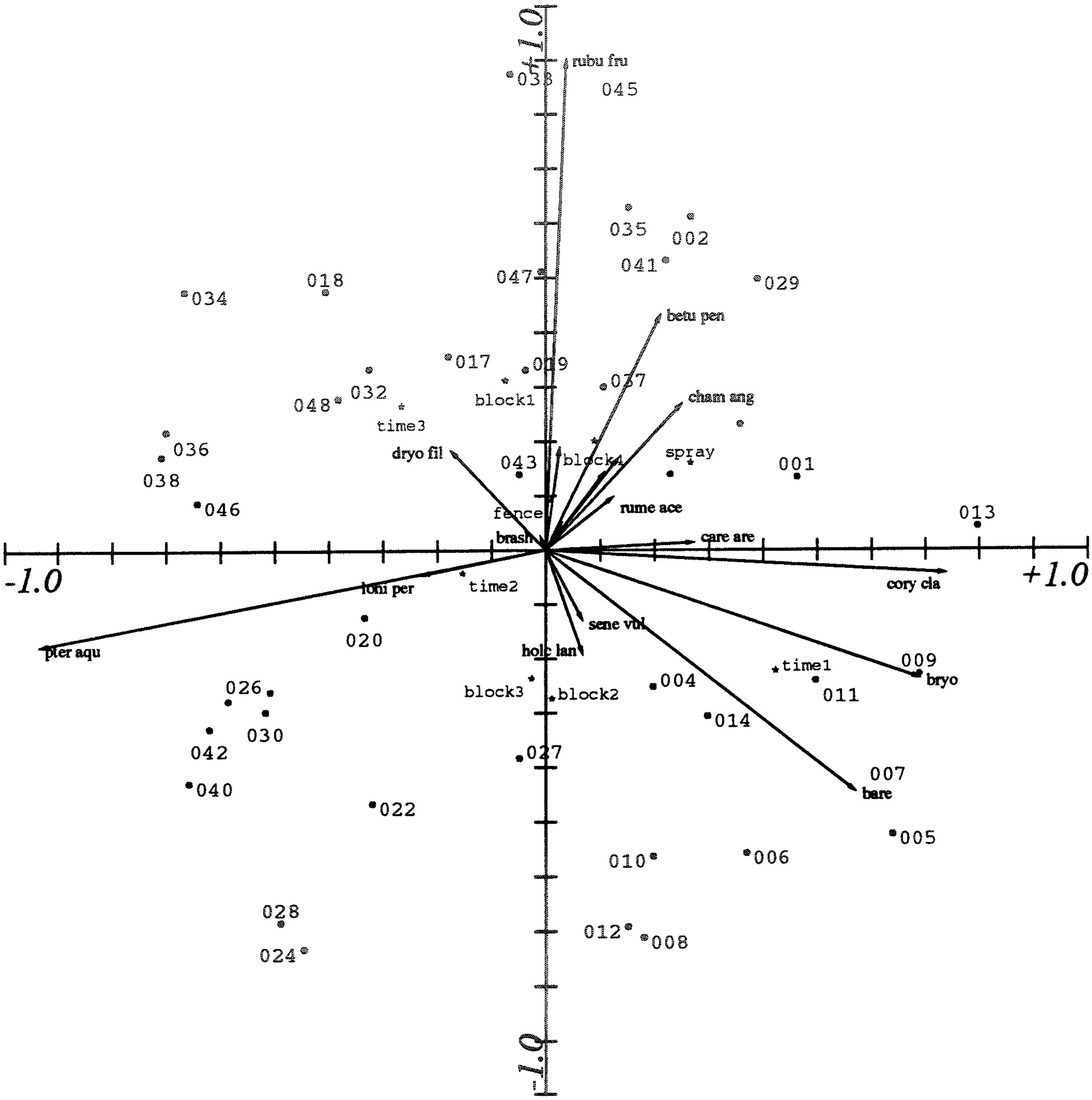

Figure 3

Principal Components Analysis (PCA) diagram, using mean percentage frequency data (mean of three assessment dates), showing plant species - quadrat - treatment - time associations.

Quadrat numbers are arranged as follows: Block 1 - S+F - Quadrats 1,2,3,4 (001-004); Block 1 - F - Quadrats 1,2,3,4 (005-008); Block 1 - S - Quadrats 1,2,3,4 (009-012); Block 1 - C - Quadrats 1,2,3,4 (013-016); Block 4 - C - Quadrats 1,2,3,4 (045-048).

Dead wood

There were no significant differences recorded in the amount of dead wood found in each of the four plots (in terms of either number of fallen logs or their diameter). The number of standing trees or snags recorded in each of the plots was variable, with six in Plot 1, four in Plot 2, and two in each of Plots 3 and 4; but no significant differences were found. Diameters at breast height (dbh) were recorded and did not differ significantly between plots, ranging from 66-102 cms, with a mean of 79.8 cms.

Changes in the quantity and 'quality' of dead wood might be expected over the next few seasons as a result of differences in exposure and hence decay rates. Plots on which bracken control has been practised may see a drying-out of the fallen logs and brash, leading to colonisation by a different assemblage of invertebrates and fungi. Fallen deadwood in plots in which no control of vegetation is undertaken, might be expected to retain moisture for a greater length of time, and hence undergo a rather different decay process. Further monitoring of the condition of the dead wood resource is underway and is expected to continue for a 5-10 year period.

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LONG TERM MONITORING OF STORM-DAMAGED SMALL WOODLAND IN WEST SUSSEX

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In October 1988 a research project was initiated by West Sussex County Council and English Nature to study short and long term ecological effects of the 1987 storm (Roberts 1989). Five small, semi-natural woods on a variety of geological types, characteristic of West Sussex were chosen for study. All were privately owned, received at least some management and have sizeable areas of storm damage which will remain uncleared. Initial assessment of the woods took place in early 1989.

Storm damage categories were plotted on 1:2,500 maps and 20 m x 20 m permanent quadrats were set up in both damaged and undamaged areas of the woodlands.

Within the quadrats a range of data was recorded including physical features such as aspect, slope and soil type, the degree and nature of 1987 storm damage and the features and location of trees and shrubs over 1.3 m in height. The natural regeneration of tree seedlings and saplings, and the species and abundance of ground flora were also recorded. Fixed point photographs were taken of all the quadrats.

In 1993 selected aspects of the woodland quadrats were studied again, jointly funded by West Sussex County Council and the Sussex Downs Conservation Board (Dolphin Ecological Surveys 1993). Repeat recordings were undertaken for natural regeneration of tree seedlings, saplings and ground flora species and a second set of fixed point photographs were taken.

Most regeneration recorded in 1989 was found to have been superseded by vigorous growth from windthrown, living trees and shrubs. Few significant changes in the composition or abundance of ground flora were observed.

Most of the changes in data from 1989 to 1993 were fairly minor which implies that four years is a minimum period for the re-assessment of many aspects of woodland dynamics.

The results so far indicate that the effects of storm damage are in many ways comparable to those of active coppice management.

It is hoped that regular follow-up studies of these sites will yield information that will improve our understanding of the benefits and disadvantages of management and help to produce guidelines on the most appropriate management of storm damaged woodlands.

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THE FATE OF STORM-DAMAGED TREES IN HAM STREET NATIONAL NATURE RESERVE, KENT

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Summary

This paper quantifies the survival and regrowth, after five years, of a sample of trees wind-damaged in the 1987 storm at Ham Street National Nature Reserve, Kent.

There were major differences between species in terms of survival of windthrown trees and regrowth from snapped stems (natural pollarding). Of the former, less than a fifth of birch, less than half the oak and over two-thirds of willow, chestnut and hornbeam survived. Virtually all of the hornbeam regrew after snapping as did about three-quarters of the oak. There were few snapped birch or chestnut stems recorded.

Most of the windthrown coppice was still alive after five years.

Introduction

Most publicity material written immediately following the 1987 storm concentrated on the damaging effects of strong winds on woodland. The tone was negative and most copy drew attention to the short-term impacts. There was little discussion of the long-term implications of such a major event or the possibility that the woods could survive even if in a slightly different form.

In woodland, ecological processes operate slowly and biological monitoring should continue for many years after a catastrophic event such as the 1987 storm. This paper examines the fate of a sample of trees wind damaged in 1987 and is one of a series of studies initiated in 1987 (Whitbread 1991).

Study Site

Ham Street National Nature Reserve lies on the southern edge of the Wealden clay, about four miles south of Ashford in Kent and seven miles from the Channel coast. This ancient wood supports stands of sweet chestnut, hornbeam and oak which can be classified as W10 *Quercus robur-Pteridium aquilinum-Rubus fruticosus* woodland of the National Vegetation Classification (Rodwell 1991). Sub-communities W10a, typical and W10b, *Anemone nemorosa* are widely represented in the wood. Two streams flow through the reserve cutting through the clay to produce valleys which give a variety of aspects and exposure. The wood is divided into 40 compartments managed as minimal intervention, high forest and coppice-with-standards.

The storm of 16 October 1987 uprooted or snapped standard and maiden trees and toppled coppice stools.

Methods

During 1988 and 1989 three separate records of the impact of the storm were made: an assessment of the structural damage to the canopy (Knott & Petley-Jones 1988); compartment surveys of the extent and type of tree loss (Knott & Petley-Jones 1988); and permanent transect records (Knott & Petley-Jones 1991). Many of the canopy gaps created were small and had a minor effect on the ground flora and understorey.

Compartment studies

In 1987/88 Knott and Petley-Jones plotted the location of all wind-damaged trees within each compartment. They also recorded the species, girth at breast height, 1.3 m above ground level (GBH), type of damage and direction of throw (Table 1). In spring 1993 all trees and coppice stools within seven sample compartments (Numbers 4, 9, 11, 15, 16, 18 and 19) were re-recorded. The compartments selected were all located in the same part of the wood and were therefore on similar soils and subject to similar pressures from the storm. They were subject to minimal intervention or high forest management but had received no attention since October 1987.

Each damaged individual was re-examined noting whether it was alive or dead. The location and species of any trees which had fallen since 1987 were also noted.

Permanent transect records

In 1988/89 a permanent transect, 160 m long, was marked out which ran through compartments 15, 19 and 24. It was divided into eight sections each measuring 20 x 20 m. A second 160 m transect running through compartments 15 and 19 was subsequently set up in 1989. All trees along each transect were plotted noting species, whether the individual was alive or dead, girth at breast height, angle of fall, single or multi-stemmed, crown size (small, medium, large) and whether the individual had epicormic shoots.

In 1993 each transect was re-examined and any changes to individual trees noted. Scientific names for the species concerned are given in Table 2.

The four most abundant species, hornbeam, oak, chestnut and birch, were divided into three damage categories; snapped, fallen or leaning, and other. This final category is composed of 22 individuals which were either dead before the storm or, as they were located at the edge of compartments, were felled for safety reasons during subsequent months. This category is not considered further.

Results

Compartment studies

262 storm damaged trees (Appendix 1) were recorded from the seven sample compartments (Table 2). Thirty-three individuals including one willow and two aspen could not be found. These were located at the edge of the wood or along rides sides and had been cleared away immediately after the storm to allow access. An additional 14 trees had fallen since 1987 (5% of the total number recorded).

The snapped trees (51) were mainly hornbeam and oak. Most snapped at between 2 and 3 m above ground level representing a natural form of pollarding. Survival was generally good although slightly better for hornbeam (94%) than oak (73%). Trees that were still alive resprouted from the remaining stem. Overall, the oaks were larger, mean girth at breast height of 102 cm, and probably older than the hornbeam (mean girth 63 cm) and may represent the standards from a former mixed coppice with standards system. The chestnut had previously contributed to the coppice, which may explain the absence of windsnap in this species. Although disturbed, the root system of snapped trees remained largely intact which contributed to their survival.

Table 1 Example of a 1988 Compartment Record (Knott & Petley-Jones 1988)

Compartment 11
C. = Coppice

Tree No.	Tree Species	Bearing on line	Girth at 1.3 m above ground (GBH) in cm	Notes
247	Birch	301°	70	
248	Hornbeam	027°	37	
249	Oak	000°	72	Snapped off at 4 m
250	Birch	038°	85	Edge of wood
251	Hornbeam	340°	70	
252	Hornbeam C.	050°	Av. 90	
253	Hornbeam	046°	43	Snapped at 3 m
254	Hornbeam	054°	60	Snapped off at 2 m
255	Hornbeam	028°	43	Snapped off at 2 m
256	Hornbeam	020°	47	
257	Hornbeam	036°	60	Snapped at 3 m
258	Hornbeam C.	057°	Av. 35	
259	Hornbeam C.	013°	Av. 40	Edge of wood
260	Hornbeam	032°	55	Edge of wood
261	Hornbeam	010°	47	
262	Hornbeam	052°	49	
263	Hornbeam	328°	32	
264	Willow	072°	71	
265	Chestnut	120°	56	
266	Cherry	038°	56	
267	Oak	043°	147	
268	Hornbeam C.	068°	Av. 50	
269	Hornbeam C.	022°	Av. 40	
270	Oak	040°	148	
271	Hornbeam C.	166°	Av. 70	On boundary
272	Oak	036°	130	Steel tree No. 43
273	Hornbeam C.	072°	Av. 75	
274	Hornbeam C.	012°	Av. 50	

The majority of wind-damaged trees either blew over entirely or were left leaning on other individuals in the canopy. This category therefore incorporates trees with a wide range of root system damage but more than that of snapped trees. The four most abundant species show differences in their ability to withstand this level of disturbance. Hornbeam and chestnut survived well (79% and 87% respectively) but oak and birch show poorer survival rates (37% and 9% respectively). The survival rate of oak was poorer for trees that had blown over than for those snapped (37% compared to 73%).

Individual trees responded in different ways to wind damage. In some the original crown of the tree was still alive but there was no new growth, so survival may only be short term. In others the crown was still vigorous and new shoots had sprouted from the trunk. In the long term these new shoots may root directly into the soil forming a row of saplings.

Table 2 Condition of storm-damaged trees in 1993

	Total	Snapped		Fallen or leaning		Other		Not found	Additional individuals found
		Alive	Dead	Alive	Dead	Alive	Dead		
Hornbeam	80	33	2	19	5	4	5	8	4
Oak	71	11	4	16	27	-	2	11	-
Chestnut	45	-	-	20	3	6	4	9	3
Birch	29	1	-	2	20	1	0	2	3

	Total	Alive	Dead	Not found	Additions
Willow	12	6	2	1	3
Cherry	10	4	5	-	1
Aspen	7	-	5	2	-
Ash	2	1	1	-	-
Maple	2	2	-	-	-
Hawthorn	1	1	-	-	-
Alder	1	-	1	-	-
Beech	1	1	-	-	-
Hazel	1	1	-	-	-
Total					

Scientific names for species:

Hornbeam	*Carpinus betulus*
Oak	*Quercus* sp.
Chestnut	*Castanea sativa*
Birch	*Betula* sp.
Willow	*Salix* sp.
Cherry	*Prunus avium*
Aspen	*Populus tremula*
Alder	*Alnus glutinosa*
Ash	*Fraxinus excelsior*
Maple	*Acer campestre*
Hawthorn	*Crataegus monogyna*
Hazel	*Corylus avellana*
Beech	*Fagus sylvatica*

Permanent Transect Record

Very little change was recorded along these two transects (Appendix 2). Most individuals that were alive when the transect was set up were still alive five years later and only four additional trees or limbs had fallen. Three oak trees had been snapped but were still alive. Of the three fallen trees only one, a hornbeam, was still alive.

Discussion

Press coverage of the effects of the October 1987 storm tended to draw attention to the damage (from a human perspective) that had been done to woods in south-east England. There was little consideration of wind as a natural agent influencing woodland ecosystems. Even with estimated return periods of about 200 years (Hopkins 1994) many broadleaved stands grown as high forest are likely to be subject to at least one storm of this sort of magnitude. The system should thus be adapted to respond to its effects.

Initial responses may also have been coloured by the experiences of foresters working in the north and west where strong winds are much more common and most of the forests are even-aged, shallow-rooted plantations. In such forests wind throw tends to be progressive: small gaps whether created by thinning or some other cause are subsequently enlarged by wind and this can lead to damage of much of the crop. At Ham Street NNR Knott and Petley-Jones (1991) suggested that a stand thinned just before the storm suffered more damage than unthinned crops. However, relatively few additional trees have been blown since 1987 and the small gaps created initially have not been enlarged. This seems to be the pattern at other sites in the south-east also.

Most of the trees blown down in the part of Ham Street NNR studied are still alive and some are putting on new growth. Survival rates vary according to species and type of damage. Individuals which were pollarded by the wind survived better than those blown over or partially uprooted. The slightly greater survival rate of snapped hornbeam, compared to oak, parallels experienced elsewhere that suggests hornbeam recovers better after pollarding (Sisitka 1991). Of those blown over, chestnut and hornbeam survived better than oak and birch. Birch is a shallow-rooting species with a rapid growth rate and consequently does not tolerate root disturbance well. Conversely chestnut and hornbeam are more stress tolerant and so may be better able to survive disruption of their root systems.

This study only looked at part of the reserve and only one aspect of the storm's effects - damage to the trees (see also Buckley *et al.* (1994) for some effects on the flora). Casual observations suggest however that these results are typical of the whole. In nature conservation terms the storm has not caused significant damage, rather the gaps and opportunities for regeneration, the increase in fallen dead wood and new niches created around rooted plates and in the boles of snapped trees can all be regarded as beneficial.

It is to be hoped that the state of the damaged trees and other effects of the storm on the reserve will be reviewed again in 5-10 years time.

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Appendix I Individual tree records from compartments 4, 9, 11, 15, 16, 18 and 19 at Ham Street NNR.

(Tree numbers are those used in Knott and Petley-Jones (1988)).

Tree No	Tree Species	Bearing of lie	Girth at Breast Height in cm	Notes and 1993 Records
Compartment 4				
94	Birch	025°	104	Dead
95	Oak	330°	96	Alive
96	Oak	055°	107	Dead, but alive after storm
97	Willow	030°	40	Alive
98	Willow	334°	90	Alive
99	Willow	333°	67	Alive
100	Birch	012°	74	Alive
101	Willow	065°	58	Alive
102	Chestnut	062°	51	Part of stool alive
103	Oak	060°	157	2 stems one fallen dead one snapped alive
104	Chestnut	060°	51	Part of stool, alive
105	Chestnut C.	006°	Av. 100	Alive
106	Willow	032°	97	Dead
107	Cherry	046°	86	Alive, coppice 3 stems
108	Cherry	058°	61	Alive
109	Cherry	064°	100	2 stemmed tree both alive
110	Oak	094°	104	Dead
111	Chestnut	086°	110	Alive
112	Alder	009°	68	Dead
113	Hazel C.	054°	-	Alive
114	Oak C.	326°	Av. 80	Alive
115	Ash	084°	Av. 50	Alive
116	Hornbeam	028°	79	Alive
117	Oak	026°	105	Top snapped off at 20 m, dead
118	Hornbeam	044°	80	Dead
119	Hornbeam	115°	52	Dead
120	Oak	040°	98	Top snapped off at 18 m, dead but had grown since storm
121	Hornbeam C.	096°	One main stem of 60 cm Not found	

Tree No	Tree Species	Bearing of lie	Girth at Breast Height in cm	Notes and 1993 Records
122	Hornbeam	242°	70	Dead
123	Chestnut C.	010°	Av. 60	Dead before storm. Not found
124	Chestnut	004°	64	Alive
125	Birch	105°	124	Not found
Additional trees recorded 1993:		Willow x 3 Hornbeam Cherry		
Compartment 9				
179	Aspen	013°	89	Dead
180	Aspen	030°	89	Dead
181	Hornbeam	041°	70	Part of coppice, alive
182	Aspen	015°	93	Dead
183	Ash	-	Av. 40	Dead
184	Aspen	038°	70	Dead
185	Birch	342°	78	Dead
186	Birch	350°	50	Alive
187	Birch	048°	59	Dead
188	Birch	048°	73	Dead
189	Birch	048°	62	Dead
190	Field maple	285°	75	Alive
191	Birch	028°	83	Dead
192	Chestnut C.	005°	Av. 60	Alive
193	Birch	020°	61	Dead
194	Hornbeam	036°	Av. 70	Alive
195	Oak	345°	157	Dead
196	Oak	012°	111	Alive (hung up)
197	Oak	017°	100	Dead
198	Oak	070°	147	Dead
199	Oak	013°	160	Dead
200	Oak	031°	110	Dead
201	Hornbeam	078°	50	Dead - felled at stump
202	Birch	051°	60	Alive, felled at stump
203	Hornbeam	064°	64	Not mapped
204	Hornbeam	070°	68	Not mapped

Tree No	Tree Species	Bearing of lie	Girth at Breast Height in cm	Notes and 1993 Records
205	Hornbeam	018°	70	Alive
206	Birch	003°	190	Dead
207	Chestnut	042°	78	Part of coppice, not found
208	Oak	040°	120	Dead
209	Oak	057°	140	Dead
210	Oak	031°	74	Dead
Additional trees recorded 1993:		Birch x 2 Chestnut Hornbeam		
Compartment 11				
247	Birch	301°	70	Dead
248	Hornbeam	027°	37	Snapped, alive
249	Oak	000°	72	Snapped off at 4m, alive
250	Birch	038°	85	Edge of wood. Not found
251	Hornbeam	340°	70	Alive, regrowth
252	Hornbeam C.	050°	Av. 90	Dead, cut across fence
253	Hornbeam	046°	43	Snapped at 3m, alive regrowth
254	Hornbeam	054°	60	Snapped off at 2m, alive regrowth
255	Hornbeam	028°	43	Snapped off at 2m, alive regrowth
256	Hornbeam	020°	47	Dead
257	Hornbeam	036°	60	Snapped at 3m, alive
258	Hornbeam C.	057°	Av. 35	Alive, cut across fence
259	Hornbeam C.	013°	Av. 40	Edge of wood. Dead
260	Hornbeam	032°	55	Edge of wood. Alive, regrowth
261	Hornbeam	010°	47	Alive
262	Hornbeam	052°	49	Alive
263	Hornbeam	328°	32	Alive
264	Willow	072°	71	Alive, leaning
265	Willow	120°	56	Alive, leaning
266	Cherry	038°	56	Dead
267	Oak	043°	147	Alive, vertical regrowth
268	Chestnut	068°	Av. 50	Alive, vertical weak regrowth
269	Hornbeam C.	022°	Av. 40	Alive, vertical regrowth
270	Oak	040°	148	Alive, vertical regrowth

Tree No	Tree Species	Bearing of lie	Girth at Breast Height in cm	Notes and 1993 Records
271	Chestnut	166°	Av. 70	On boundary. Alive, vertical regrowth
272	Oak	036°	130	Steel tree No 8? Snapped. Alive
273	Chestnut	072°	Av. 75	Alive, regrowth from root plate
274	Hornbeam C.	012°	Av. 50	Alive fallen, vertical regrowth
Additional trees recorded 1993:		Chestnut x 2 Hornbeam		
Compartment 15				
407	Oak	344°	77	Not found
408	Oak	020°	140	Not found
409	Hornbeam	044°	126	Not found
410	Chestnut	050°	93	Part of coppice. Not found
411	Chestnut C.	030°	Av. 80	Not found
412	Chestnut	202°	85	Dead before storm. Not found
413	Oak	002°	101	Not found
414	Hornbeam C.	-	Av. 60	2 main stems, snapped off at 2m, not found
415	Chestnut	032°	70	Alive, leaning
416	Chestnut	018°	81	Not found
417	Hornbeam	346°	62	Not found
418	Oak	017°	83	Alive
419	Birch	054°	75	Dead
420	Oak	018°	136	Dead
421	Oak	010°	101	Alive
422	Oak	007°	75	Dead
423	Oak	352°	102	Dead
424	Oak	013°	120	Alive
425	Chestnut C.	025°	Av. 50	Alive
426	Oak	012°	99	Snapped at 6½m, alive
427	Hornbeam	034°	46	Snapped at 2m, alive
428	Hornbeam	026°	46	Snapped off at 4m, alive
429	Chestnut C.	021°	One major stem of 60 rest small. Alive	
430	Chestnut C.	012°	Av. 70	Alive
431	Oak	036°	80	Not found
432	Hornbeam	000°	60	Part of coppice. Alive
433	Oak	030°	121	Snapped off at 4m, dead

Tree No	Tree Species	Bearing of lie	Girth at Breast Height in cm	Notes and 1993 Records
434	Beech	010°	178	Alive
435	Hornbeam	312°	62	Alive, leaning
436	2 Cherry	037°	Av. 70	Dead, felled
437	Chestnut	048°	75	Dead, felled
438	Cherry	028°	68	Hung up. Dead felled
439	Oak	033°	97	Snapped off at 6m, alive
440	Oak	351°	108	Snapped off at 2-4m, dead
441	Oak	004°	90	Dead
442	Oak	356°-028°	Av. 65	Alive, both stems
443	Hornbeam	024°	65	Dead, felled
444	Chestnut	293°	86	Dead, felled
445	Chestnut	046°	100	Alive, vertical regrowth
446	Hawthorn	052°	72	Alive, regrowth
447	Hornbeam	022°	71	Dead, felled
448	Hornbeam	026°	50	Snapped off at 4m, alive
449	Hornbeam	012°	62	Snapped at 1½m, alive
450	Hornbeam	000°	61	Snapped off at 4m, alive
451	Hornbeam	015°	65	Snapped off at 4m, alive
452	Hornbeam	060°	65	Snapped off at 2½m, alive
453	Hornbeam	014°	93	Snapped 2½m, alive
454	Birch	037°	76	Dead
Compartment 16				
455	Hornbeam	052°	63	Alive, fallen horizontal
456	Hornbeam	354°	76	Snapped at 4m, alive
457	Hornbeam	007°	70	Snapped off at 1½m, alive
458	Hornbeam	353°	55	Snapped off at 2½m, not found
459	Hornbeam	044°	65	Snapped off at 2m, alive
460	Hornbeam	045°	79	Snapped off at 3m, dead
461	Hornbeam	008°	59	Nest box 17. Alive
462	Chestnut	016°	90	Dead
463	Hornbeam	027°	60	Snapped off at 4m, alive
464	Hornbeam	056°	62	Snapped off at 4½m, alive
465	Hornbeam	022°	65	Snapped off at 5m, alive

Tree No	Tree Species	Bearing of lie	Girth at Breast Height in cm	Notes and 1993 Records
466	Hornbeam	027°	60	Snapped off at 3m, alive
467	Aspen	346°	114	Snapped off at 3m, dead
468	Oak	057°	40	Snapped at 2m, alive
469	Birch	332°	51	Dead
470	Oak	350°	72	Dead
471	Chestnut	012°	55	Dead
472	Birch	017°	95	Dead
473	Chestnut	070°	95	Old coppice. Dead
474	Chestnut	007°	95	Old coppice. Dead
475	Hornbeam C.	018°	Av. 45	Alive
476	Hornbeam	326°	70	Snapped off at 5m, alive
477	Oak	033°	130	Dead
478	Birch	026°	62	Dead
479	Chestnut	339°	75	Alive, fallen horizontal
480	Chestnut	299°	76	Alive, fallen horizontal
481	Oak	358°	136	Alive
482	Hornbeam C.	-	Av. 70	Alive
483	Hornbeam C.	-	Av. 60	Alive
484	Oak	090°	90	Dead before storm
485	Oak	050°	72	Dead
486	Oak	000°	64	Dead
487	Cherry	000°	94	Dead
488	Oak	030°	145	Alive
489	Chestnut C.	004°	Av. 80	Alive
490	Chestnut C.	315°	Av. 75	Alive, felled but regrowing
491	Birch	017°	70	Dead
492	Chestnut	027°	67	Not found
493	Oak	070°	68	Alive, snapped 6m
494	Hornbeam	031°	70	Alive
Additional trees recorded 1993:		Birch Hornbeam		
Compartment 18				
682	Oak	022°	140	Not found
683	Willow	009°	44	Not found

Tree No	Tree Species	Bearing of lie	Girth at Breast Height in cm	Notes and 1993 Records
684	Oak	345°	85	Not found
685	Oak	342°	144	Not found
686	Oak	050°	110	Not found
687	Oak	036°	95	Dead
688	Chestnut C.	344°	Av. 75	Regrowth from stool and lower stems
689	Chestnut	312°	65	Alive - vertical regrowth
690	Hornbeam C.	061°	Av. 90	Dead, felled across fence
691	Oak	042°	100	Dead, felled by path
692	Hornbeam C.	046°	Av. 45	Alive
693	Chestnut C.	000°	Av. 65	Alive, vertical regrowth
694	Willow	012°	70	Dead
695	2 Birches	014°	30	Dead
696	Oak	062°	105	Alive, hanging
697	Oak	051°	87	Alive, fallen
698	Oak	052°	100	Dead, fallen
699	Oak	031°	100	Dead, fallen
700	Oak	359°	125	Snapped 10m, alive
701	Oak	101°	101	Snapped 7m, alive
702	Oak	022°	85	Dead
Compartment 19				
703	Oak	057°	59	Not found
704	Hornbeam	047°	68	Snapped at 2½m, alive
705	Hornbeam	027°	62	Snapped off at 3m, alive
706	Hornbeam	005°	91	Snapped off at 3m, alive
707	Hornbeam	025°	72	Alive, leaning
708	Hornbeam	022°	59	Snapped off at 2½m, alive
709	Oak	020°	75	Alive
710	Hornbeam	046°	80	Snapped at 3ms, alive
711	Hornbeam	043°	74	Snapped at 5m, alive
712	Hornbeam	051°	75	Snapped off at 2½m, alive
713	Hornbeam	351°	64	Snapped off at 2½m, alive
714	Aspen	020°	72	Not found
715	Aspen	076°	85	Not found

Tree No	Tree Species	Bearing of lie	Girth at Breast Height in cm	Notes and 1993 Records
716	Birch	042°	80	Snapped 3m, alive
717	Birch	036°	58	Dead
718	Field maple	355°	55	Alive, vertical regrowth
719	Oak	024°	60	Snapped at 4½m, not found
720	Oak	078°	85	Dead
721	Chestnut C.	358°	Av. 80	Alive
722	Birch	311°	48	Dead
723	Chestnut	000°	90	Singled from coppice. Alive
724	Chestnut	020°	147	Vertical growth from stem. Alive
725	Chestnut C.	-	Av. 95	Alive, vertical regrowth
726	Chestnut	010°	117	Not found
727	Oak	082°	55	Not found
728	Chestnut	077°	90	Not found
729	Oak	024°	85	Top snapped 6m, alive
730	Hornbeam	005°	70	Fallen, alive
731	Hornbeam	012°	89	Snapped 4.5m - snag alive dead top
732	Oak	350°	85	Alive
733	Oak	033°	75	Dead
734	Oak	031°	107	Snapped at 4m. Just alive - pos dead
735	Oak	078°	65	Dead
736	Hornbeam	033°	70	Snapped at 2m, aalive
737	Hornbeam	002°	60	Snapped at 2m, dead
738	Hornbeam	006°	60	Snapped at 3m, snag alive
739	Chestnut	014°	103	Alive
740	Oak	037°	144	Dead
741	Chestnut	014°	99	Dead
742	Birch	044°	78	Dead
743	Hornbeam	028°	75	Snapped at 2m, snag alive top dead

Appendix II Ham Street NNR - Storm damage recording along permanent transects

Field notes were transcribed on to copies of the section maps. Only change was recorded, except where no change might be significant, such as wind snapped oaks still alive. Abbreviations eg. QLC* 141 are those used on the original transect maps held by English Nature.

Transect 1 (sections are as in the original report)

Section 1 No change.

Section 2 Live windthrow (*Castanea* c76 cm) now dead.

Section 3 No change. (*Quercus* with crown broken at 17m is still alive).

Section 4 Oak (QLC* 141) has lost a bough, the long standing dead oak (QLSD-B 107) has fallen into section 5. 130 degree bearing.

Section 5 No change apart from addition of fallen dead oak from section 4.

Section 6 Chestnut stool ("horizontal but living stem with shoots") was not found. Hornbeam (CbLSD "stump at 0.2m high") recorded as dead is now living, alternatively an adjacent living pole from the same stool has had its top blown out at 0.2m. Dead oak (QLSD 66) is now alive, with abundant epicormic growth - it also supports a hung up branch in its canopy.

Section 7 Fallen oak (Q c156 "living but fallen on 16/10/87"), now dead and swamped with bramble.

Section 8 Oak (Q 121) has shed a limb. 60 degree angle from trunk.

Transect 2 (incorporating the Steele plot)

Section 1 Oak (Q 152, St 57) has now lost its hanging bough. Poles on two adjacent chestnut stools at bottom centre left of plot (24 and 8 respectively) are dead. Third chestnut stool along bottom centre left of plot - poles 52 and 56 are alive with epicormic shoots. The long standing dead oak, Q91, St 64, is now leaning on Q 114, St 65.

Section 2 Oak Qmc*epi 154, St 80 has lost a bough, and is leaning on Qnc*epi 94, St 76.

Section 3 Oak snapped at 9m (Q 128, St 83) is still living, as is the Q 154, St 86 which had lost 75% of its crown.

Section 4 Oak Q 150, St 94 is now dead but still standing. Hornbeam stool at top centre right of plot; pole 47 - the attached limb is dead. The 'hornbeam' over the stream is hazel, and is sprouting from the root plate.

Section 5 Oak Q 150, St 10 - the storm damage is still hanging.

Section 6 No change.

Section 7 Hornbeam on right edge of plot, midway up, "partially uprooted" is still alive. Long standing dead oak QLSD 56, St 39 has fallen. Long standing dead oak QLSD 71, St 41 is still standing.

Section 8 No change.

The overall impression is that very little damage has occurred since the storm - a few boughs have (apparently) been lost and a couple of previously dead trees have fallen. Most windthrow that was alive has remained so, with the exception of some oaks and one chestnut stool. Severely damaged oaks (snapped or high percent of canopy loss) have survived if the trunk and root plate have remained intact.