THE EFFECTS OF THE 1987 AND 1990 STORMS ON GREAT SPOTTED WOODPECKER *DENDROCOPUS MAJOR* NUMBERS AND NEST SITE SELECTION IN TWO HERTFORDSHIRE WOODS

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Summary

Breeding great spotted woodpeckers have been studied annually since 1984 in two mature oak woodlands in Hertfordshire, southern England. Although Hertfordshire was only on the fringe of the main area of damage of the 1987 storm there was considerable damage which was increased by further storms in January 1990.

Sample surveys of living and dead wood in the two study sites were carried out in 1986 and repeated using the same methodology in 1991. The numbers of great spotted woodpeckers breeding in the woods have been monitored by finding all the nests each year and, over the 10 years of the study, 121 nests have been recorded. These data have been used to examine breeding numbers and nest site selection over the period in relation to the changes caused by the storms.

Introduction

In the aftermath of the great storm of 1987 there was much advice offered to the managers of affected woodlands to leave dead wood for the woodpeckers. Although there are no data available on the extent to which this advice was heeded, there are two main ways in which it could have been of benefit to the birds.

1. Woodpeckers excavate their nesting cavities in dead or decaying wood either in the main trunks or in large limbs of trees. Many such sites would have been created as a result of damage caused by the storm.

2. Woodpeckers, particularly great spotted *Dendrocopos major*, feed for a large part of the year on invertebrates associated with dead or decaying wood (Cramp 1985). By leaving the timber resulting from storm damage to decay *in situ*, sites for invertebrates would be created eventually providing increased foraging opportunities for woodpeckers.

The damage from the 1987 storm was both severe and extended over a wide geographical area, but there is no evidence that it had any impact on woodpecker populations on the national scale (Marchant *et al.* 1990; Stroud & Glue 1991; Andrews & Carter 1993; Gibbons *et al.* 1993) although individual woods were clearly affected. In this paper I use data collected as part of a long term study of great spotted woodpeckers in two mature oak *Quercus* sp. woods in Hertfordshire, southern England between 1984 and 1993 to look for effects that could be attributed to the storms.

These woods were on the fringe of the main area affected by the great storm but nevertheless suffered considerable damage. This is one of the few studies with data on the composition of a woodland stand and its birds from both before and after the storms. In fact the woods were damaged by two storms, the first in October 1987 and a further one in January 1990, the combined effects of which are considered here.

Study sites

The two study sites were 94 hectares of Wormley Wood, an ancient semi-natural oak-hornbeam *Carpinus betulus* wood, owned and managed by the Woodland Trust and Hitch Wood, 65 hectares of mature oak, beech *Fagus sylvatica* and sweet chestnut *Castanea sativa* plantation. The two woods are managed very differently. A considerable volume of oak was removed from Wormley Wood in the 1940s and 1950s, but it is now managed on a low intervention basis apart from the dictates of public safety. On the other hand, Hitch Wood is actively managed by selective felling and has a long history of such management. During the period of the study a firewood merchant operated in Hitch Wood and was allowed to collect and sell fallen dead wood.

Methods

The stand composition of each woodland was characterised in 1986 and 1991 by measuring the diameter at breast height (dbh) of all trees within a 10 m radius circular area at a grid of sample points. In 1991, 94 points were counted in Wormley Wood and 65 in Hitch Wood, the points being on a regular 100 m grid. In 1986 a smaller number of points was sampled in each wood (23 in Wormley and 22 in Hitch Wood).

In 1986 and 1991 the volumes of dead wood within a sample of the 10 m circles was assessed by estimating by eye the length and diameter of each dead limb or trunk. Only limbs of 5 cm or greater diameter were counted. The results were grouped as dead wood lying on the ground, dead wood in living trees and dead wood on standing dead trees.

In both woods all trees blown down by the storms of 1987 and 1990 were counted by species and their dbh measured. In addition, in 1991, all trees counted at the sample points were assessed for major storm damage defined as loss or significant damage to a limb of 20 cm diameter or greater.

The breeding numbers of great spotted woodpeckers in each wood were determined by finding all the nests each year. For each nest site details of the tree species, dbh, whether the tree was alive or dead, the exact nesting location and whether it had been created as the result of storm damage were recorded.

Results

Changes in woodland composition

The stand compositions of the two woods in 1986 and 1991 are shown in Tables 1 and 2, together with the figures for the trees blown over by the storms in the intervening years. A large number of trees were blown down by the storms (730 in Wormley and 232 in Hitch Wood), but the overall changes to the stand composition were small and unlikely to be detectable by means of the sample surveys. In Wormley Wood the main changes were increases in standing dead oak trees and a small decrease in standing dead birch *Betula* sp. In Hitch Wood there were increases in standing dead oak and other species.

In both Wormley and Hitch Woods significant numbers of oak trees were damaged (usually involving the loss of one or more major limbs) (Table 3). The fraction of hornbeam trees damaged in Wormley was much lower than for those in Hitch Wood.

In both woods there were increased volumes of dead wood in 1991 compared with 1986 (Tables 4 and 5) but those for Hitch Wood were always lower than Wormley. As expected, the volume of dead wood on the ground increased in Wormley. There was also some increase in Hitch Wood but even by 1991 much of the fallen timber had been removed and the process has continued so, in 1993, little remained.

Table 1 The stand composition of Wormley Wood in 1986 and 1991 expressed as the basal area (m^2/ha) of living and standing dead trees, including trees falling in the intervening years

The figures for 1986 are based on a sample survey within 10 m of 23 points arranged on a regular grid through the wood. In 1991 94 points on a 100 m grid were sampled. The basal area of fallen trees was the result of a full count throughout the wood.

Living trees

Tree species	Basal area 1986 (m^2/ha) ± SE	Fallen trees (1986-91) (m^2/ha)	Basal area 1991 (m^2/ha) ± SE
Oak	14.86 ± 2.11	0.12	14.23 ± 1.12
Hornbeam	5.81 ± 0.98	0.30	6.62 ± 0.49
Ash	2.21 ± 1.10	0.03	1.95 ± 0.56
Birch	0.74 ± 0.51	0.08	1.04 ± 0.25
Other species*	0.24 ± 0.12		0.07 ± 0.02
Total	**23.86 ± 1.79**	**0.53**	**23.93 ± 1.00**

*Beech, sweet chestnut

Standing dead trees

Tree species	Basal area 1986 (m^2/ha) ± SE	Fallen trees (1986-91) (m^2/ha)	Basal area 1991 (m^2/ha) ± SE
Oak	0.37 ± 0.18	0.03	0.62 ± 0.16
Hornbeam	0.04 ± 0.02	0.003	0.18 ± 0.10
Ash	0	0.01	0
Birch	0.57 ± 0.15	0.07	0.40 ± 0.12
Total	**1.03 ± 0.41**	**0.12**	**1.20 ± 0.23**

Table 2 **Stand composition of Hitch Wood in 1986 and 1991**

Based on 22 sample points in 1986 and 65 in 1991.

Living trees

Tree species	Basal area 1986 (m^2/ha) ± SE	Fallen trees (1986-91) (m^2/ha)	Basal area 1991 (m^2/ha) ± SE
Oak	17.96 ± 2.71	0.19	17.32 ± 1.54
Beech	6.55 ± 1.75	0.16	5.24 ± 1.14
Sweet chestnut	2.03 ± 1.10	0.04	0.99 ± 0.41
Hornbeam	1.97 ± 0.71	0.09	1.48 ± 0.35
Sycamore	1.28 ± 0.61	0.007	1.73 ± 0.73
Other species*	0.57 ± 0.31	0.04	1.88 ± 0.69
Total	**30.37 ± 2.33**	**0.53**	**28.64 ± 1.53**

*Birch, ash, larch

Standing dead trees

Tree species	Basal area 1986 (m^2/ha) ± SE	Fallen trees (1986-91) (m^2/ha)	Basal area 1991 (m^2/ha) ± SE
Oak	0.03 ± 0.02	0.02	0.53 ± 0.20
Elm	0.30 ± 0.25	0	0.25 ± 0.15
Others	0	0	0.24 ± 0.13
Total	**0.33 ± 0.26**	**0.02**	**1.02 ± 0.30**

Table 3 **Percentage of trees showing evidence of major storm damage in 1991**

Tree species	Wormley Wood	Hitch Wood
Oak	22.8%	29.5%
Hornbeam	4.8%	17.6%
Ash	3.6%	-
Beech	-	25.0%
Birch	0	-

Table 4 **Estimated volumes of dead wood in Wormley Wood in 1986 and 1991**

Based on visual estimates for 10 m radius circles around a sample of 25 points

	1986 (m^3/ha)	1991 (m^3/ha)
Dead wood on ground	7.6	12.1
Dead wood on standing live trees	9.0	10.7
Standing dead trees	7.2	8.7
Total	**23.8**	**31.5**

Table 5 **Estimated volumes of dead wood in Hitch Wood in 1986 and 1991**

Based on visual estimates for 10 m radius circles around a sample of 22 points

	1986 (m^3/ha)	1991 (m^3/ha)
Dead wood on ground	2.8	5.5
Dead wood on standing live trees	10.8	9.5
Standing dead trees	0.7	6.8
Total	**14.3**	**21.8**

Changes in woodpecker numbers and nest usage

The numbers of great spotted woodpecker nests found each year are plotted in Figure 1. In Hitch Wood numbers have remained consistently around four nests (range 2-5) whereas in Wormley there has been an increase from two in 1984 to 12 in 1992 and 1993, although the numbers in 1984 were anomalously low. In that year great spotted woodpeckers suffered severe competition for nest sites from starlings *Sturnus vulgaris* and very few active nests were found. Many cavities were excavated only to be taken over by starlings. Starling numbers had fallen by 1985 and have continued to do so, so nest site competition has not been a problem since. However, even if the 1984 figures are excluded, there has been a consistent increase in numbers of great spotted woodpeckers in Wormley over the last nine years. There is general agreement in the direction of the year to year changes in the two woods, but there is no obvious relationship between the storm years and the changes. In Wormley Wood the overall rate of increase was around 9% per year with the biggest rise between 1991 and 1992.

Table 6 Nest sites 1984-93

Wormley Wood

	Living trees	Dead trees
Oak	27	5
Ash	10	0
Hornbeam	1	1
Beech	2	0
Birch	2	31
Elm	0	3
Aspen	1	0
Total	**43**	**40**

Hitch Wood

	Living trees	**Dead trees**
Oak	13	0
Ash	1	0
Hornbeam	3	1
Beech	6	2
Birch	1	1
Elm	0	8
Larch	0	1
Cherry	1	0
Total	**25**	**13**

The nest locations used in the two woods over the full ten years of study (Table 6) have been separated into those in living and those in dead trees although, even for nests in living trees, the actual site was often a dead limb. In Wormley Wood the main sites were live oak trees and dead birch. In Hitch Wood more of the sites were in live rather than dead trees. Oak was the most common species but a variety of other trees were used. Dead oak trees were rarely used in either wood.

One of the main effects of the storms was the major damage inflicted on a large fraction of the trees. In Figure 2 the fraction of the great spotted woodpecker nests that were in sites created by the storms is plotted against year. In Wormley Wood this fraction had only risen to around 30% in the last two years of the study in spite of there being a general increase in woodpecker numbers. In Hitch Wood, as early as 1988, 60% of nests were in sites created by the 1987 storm. This fraction has since remained high although there is a suggestion of a fall in 1992 and 1993. This rapid switch to newly created nest sites suggests a shortage of such locations in Hitch Wood before the storm. However the increased availability of nest sites has not been accompanied by any increase in breeding numbers in the wood.

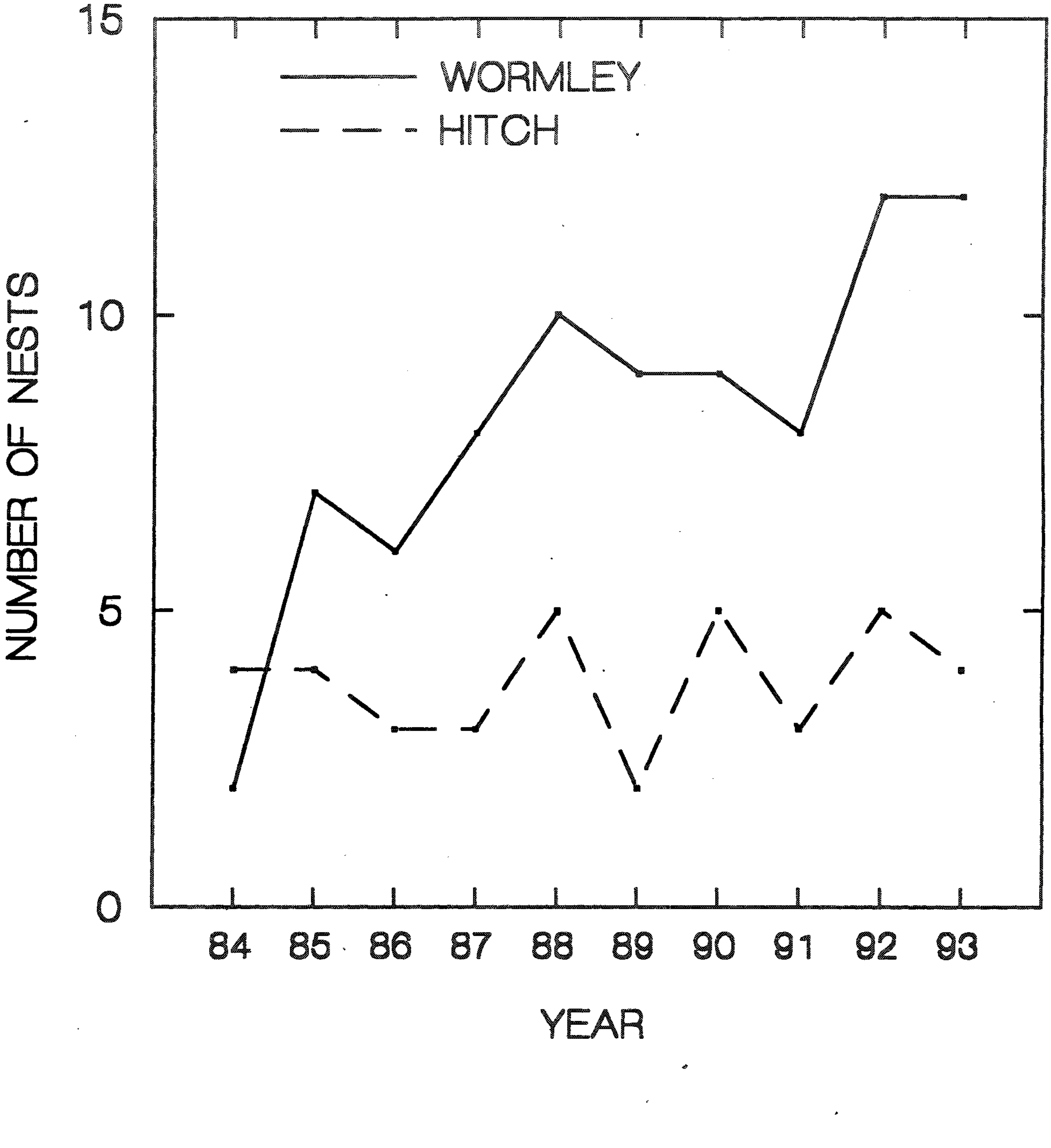

Figure 1 The numbers of great spotted woodpecker nests found in (a) Wormley Wood (94 ha) and (b) Hitch Wood (65 ha) each year from 1984 to 1993. As a result of competition for nest sites from starlings, the numbers of nests found in Wormley Wood in 1984 are known to be an under estimate of the number of pairs present.

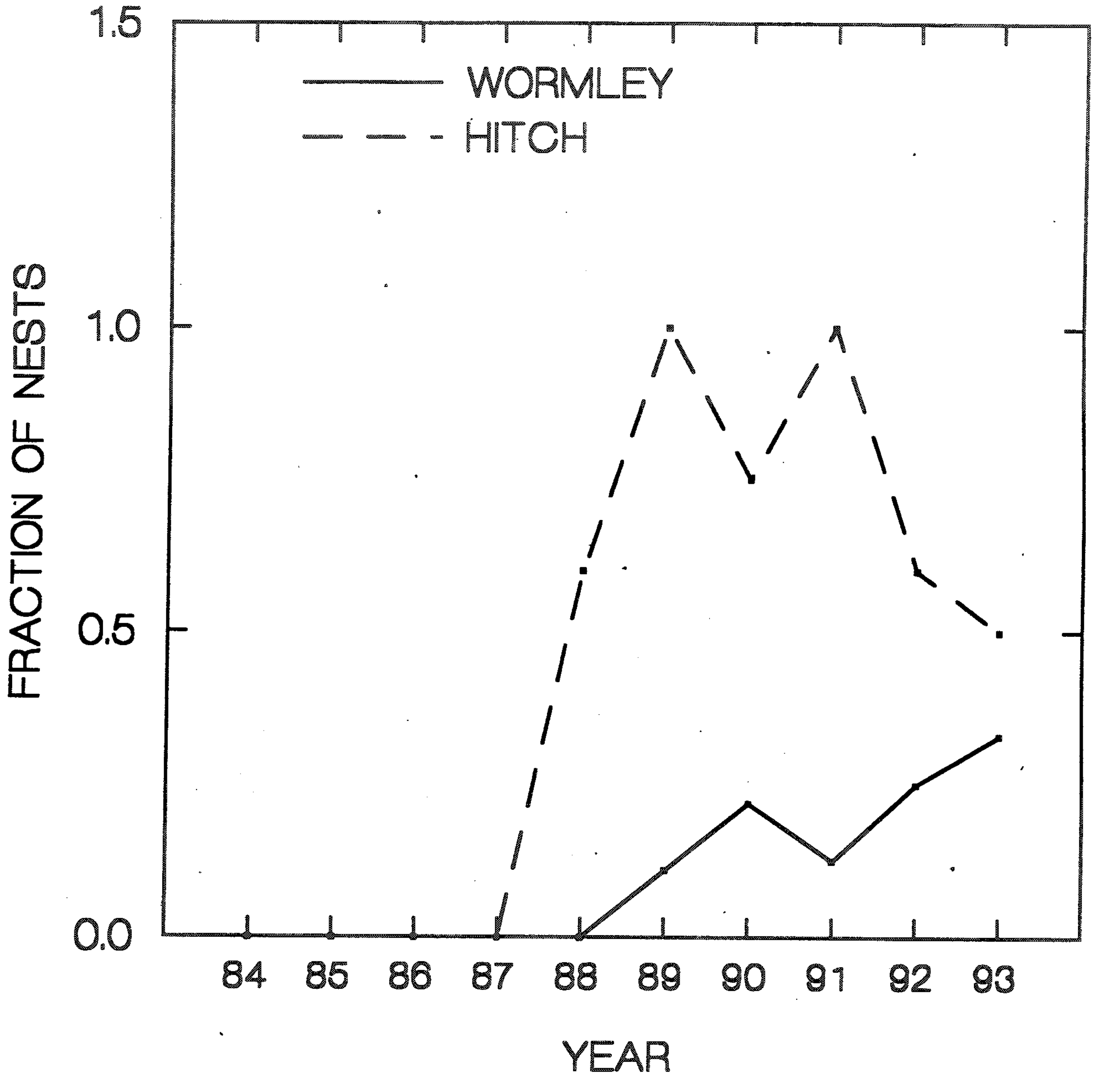

Figure 2 The fraction of nest sites used in (a) Wormley Wood and (b) Hitch Wood which were created by the storms of 1987 and 1990.

Discussion

Have the changes in the study woods brought about by the storms had any effects on nesting woodpecker numbers? The levels of storm damage were low so that the essential fabric of the woods remained intact; changes in stand composition were so small as to be virtually undetectable by the sample surveys. This was not the case in many other sites elsewhere in south-east England (Palmer 1990) and in sites where the majority of trees were blown down there would have been major losses of woodpeckers.

In both woods the volumes of dead wood were higher in 1991 than in 1986 although much of the fallen timber in Hitch Wood had already been cleared before the survey in 1991. The increase in the volume of standing dead trees in Hitch Wood was largely the result of dieback of oak trees, perhaps as a delayed indirect effect of the stresses induced by the storms and subsequent dry winters.

In winter great spotted woodpeckers from Hitch Wood tended to have large ranges and often left the wood entirely to feed (Smith 1987 and unpublished results) whereas in Wormley Wood winter ranges were small and of similar size to those in the breeding season. This difference may be related to the availability of winter feeding sites. That numbers have not increased in Hitch Wood even after more potential nest sites were created by the storms suggests that nest sites were not the limiting factor on numbers.

The volume of dead wood has been used as an indicator of the abundance of dead wood invertebrates on which woodpeckers feed. This is only a crude measure and there are probably systematic differences between the two woods in the relationship between the abundance of invertebrate food and the volume of dead wood. In Hitch Wood, what dead wood there is tends to show little obvious signs of decay even when it has been lying on the woodland floor for some years. In Wormley Wood there is much more rapid breakdown and evidence of woodpecker attack. It is not clear whether this is a result of different micro-climates in the two woods, differing management histories or many years of intensive management in Hitch Wood leading to an impoverished dead wood fauna.

Dead birch stumps were the main nest sites in Wormley Wood in the mid 1980s. They were probably the remnants of birch which invaded after the major felling of oak in the 1940s. One of the effects of the storms was that many of these birch stumps were blown over but this did not affect the numbers of nesting woodpeckers which were able to switch to alternative sites.

The increasing numbers of woodpeckers nesting in Wormley Wood is consistent with the hypothesis that they are benefitting from the increasing dead wood fauna resulting from more than a decade of low intervention management. What is less certain is the effect of the storm damage on this process. Most of the damage in Wormley was in the 1990 storm and this may have fuelled the large increase in numbers between 1991 and 1992. Monitoring for a few more years will be needed to see if numbers subsequently decline.

Great spotted woodpeckers occur at their highest densities in mature deciduous woodlands. In other types of woods where nest sites and feeding opportunities are more limited, storm damage could be highly beneficial. It is even possible that woodpeckers might take advantage of storm damaged sites for feeding whilst nesting elsewhere. For instance one of the favoured winter feeding sites for great spotted woodpeckers from Hitch Wood was an adjacent copse of larch and Scots pine which had suffered windthrow in the early 1980s and supported a good dead wood fauna. The birds never nested there.

Given the differences found in just two woods, it is not surprising that no overall national trend in woodpecker numbers emerged after the storms. Although there have been major behaviourial changes, most notably in nest site selection, these would not have been picked up by a national population index.

Acknowledgements

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References

ANDREWS, J. & CARTER, S.P. (eds) 1993. *Britain's Birds in 1990-91: the conservation and monitoring review.* Thetford, British Trust for Ornithology/JNCC.

CRAMP, S. (ed) 1985. *The Birds of Western Palearctic.* Oxford, Oxford University Press.

GIBBONS, D.W., REID, J.B. & CHAPMAN, R.A. 1993. *The New Atlas of Breeding Birds in Britain and Ireland: 1988-1991.* London, T. & A.D. Poyser.

MARCHANT, J.H., HUDSON, R, CARTER, S.P. & WHITTINGTON, P. 1990. *Population trends in British Breeding Birds.* Tring, British Trust for Ornithology.

PALMER, K.H. 1990. A tree by tree survey of the effect of the October 1987 storm on the Willett Memorial Wood, Petts Wood. *The London Naturalist* **69**, 35-51.

SMITH, K.W. 1987. Ecology of the great spotted woodpecker. *RSPB Conservation Review* ***1***, 74-77.

STROUD, D. & GLUE, D. (eds) 1991. *Britain's Birds in 1989-90: the conservation and monitoring review.* Thetford, British Trust for Ornithology/NCC.

THE USE OF FRESHLY-DOWNED TIMBER BY INSECTS FOLLOWING THE 1987 STORM

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Summary

The Great Storm of October 1987 produced, at a stroke, large quantities of timber which had been killed at approximately the same time. The opportunity was taken to carry out a preliminary study of the use of this material by a range of invertebrate groups. The study site selected was Hatfield Forest in Essex as this is known to be of particular interest for the range of relict old forest saproxylic invertebrates present.

Timber of two size classes from four tree species (oak, hornbeam, field maple and ash) were gathered and placed in Owen extraction traps in spring 1990, having lain in the open Forest for about two and a half years. Owen traps allow the dead timber to remain in more or less natural conditions throughout the extraction period, invertebrates only being captured once they have reached the adult stage and started to fly. The traps were dismantled the following autumn and the extraction samples collected for identification and analysis.

The objectives of the study were threefold:

1. to examine the value of freshly-downed timber to invertebrates;

2. to field trial the Owen trap and appraise its value to the study of saproxylic faunas and;

3. to extend our knowledge of the rich saproxylic fauna of Hatfield Forest.

Introduction

One of the few certainties about the invertebrate fauna of dead and decaying timber is that we know very little about it. The associated fauna is very rich - over 1000 species (Alexander in prep.), includes a very high proportion of rare species (Table 1), and many of these - if not most - are relict old forest species (Harding & Rose 1986; Alexander in prep.) but there is a great need to learn more about the ecology of this fauna.

How does the fauna of the different woody plant species differ, what is the succession of fauna as the timber decays and how do these differ in dead and decaying timber in different situations? What is the range of species using the timber across the year; not just the species which breed in it, but also those which depend on it for other purposes, such as temporary protection from desiccation, extremes of temperature? Which nocturnal species use it for shelter during the daylight hours and *vice versa*?

One of the great stumbling blocks to gaining this knowledge has been the difficulty of studying such cryptic and elusive species. However recently fogging techniques have been developed in order to produce species inventories relatively speedily and without directly damaging the habitat itself (Hammond & Harding 1991) and another invaluable addition has been the Owen Trap (Owen 1989, 1992).

The Owen Trap

The Malaise Trap is now a widely used sampling device (Southwood 1978) which uses the observed behaviour of flying insects inside tents to accumulate and capture them. The Owen Trap is a tent of fine mesh netting with a Malaise Trap-type collecting device. Dead timber - or other material under investigation - is placed within the tent, which is then sealed, and left on site for the fauna already within the timber to develop under fairly close to natural conditions. Adult insects emerging from the timber that are capable of flight accumulate in the top of the tent and are collected in a preservative-filled container for later examination.

Table 1 **Nationally scarce and Red Data Book saproxylic insects in Britain***

<table>
<tr><th></th><th colspan="4">Red Data Book (RDB)</th><th colspan="2">Notable (N)</th><th rowspan="2">Total RDB+N</th></tr>
<tr><th></th><th>1</th><th>2</th><th>3</th><th>K</th><th>A</th><th>B</th></tr>
<tr><td>Hemiptera</td><td>-</td><td>-</td><td>2</td><td>-</td><td colspan="2">3</td><td>5</td></tr>
<tr><td>Lepidoptera</td><td>5</td><td>-</td><td>3</td><td>-</td><td>6</td><td>9</td><td>23</td></tr>
<tr><td>Coleoptera</td><td>59</td><td>25</td><td>51</td><td>7</td><td>106</td><td>163</td><td>411</td></tr>
<tr><td>Diptera</td><td>32</td><td>25</td><td>29</td><td>9</td><td colspan="2">77</td><td>172</td></tr>
<tr><td>Hymenoptera Aculeata</td><td>3</td><td>3</td><td>8</td><td>-</td><td>4</td><td>2</td><td>20</td></tr>
</table>

*Rarity categories from Ball (1986) except where updated by Falk (1991a, b), Hyman & Parsons (1992), and Kirby (1992).

Notable A = species thought to occur in 16-30 10 km squares; B = species thought to occur in 31-100 squares; RDBK = candidates for RDB status but insufficiently known to confirm this.

This design has the advantage of isolating the dead timber from further colonisation by invertebrates, while at the same time allowing the dead timber to remain under close to natural conditions throughout the extraction period. Afterwards the extracted timber can be returned to the forest intact, to be used by later successional stage invertebrates. Extracted insects are, of course, captured in their adult stages, facilitating their subsequent identification.

Limitations are that flightless invertebrates are under represented in the catches. Some crawl up the netting and are captured, but presumably only a low proportion of the total individuals. Species that continue to breed in the timber and do not emerge are also under-sampled.

There may also be "contamination" from species that breed in epiphytic growths on the timber samples, or any adhering soil. Finally, the trap itself may break down with time because the extraction period is necessarily a long one.

Nevertheless the traps can be used to look at a wide range of factors such as the influence of the age of the dead-wood, its size, the degree of decay, the species of tree, the species of wood-rotting fungus present, sawn longs verses naturally split ones, the length of exposure to invertebrate colonisation, the situation of the dead-wood (level of shading, moist versus dry, etc.). Owen (1989) for example suggests that the attractiveness of dead wood to insect species at different stages of decay could be examined by cutting timber live, keeping it protected from insects for a year or two and then exposing it for a period before placing it in the trap. This paper describes use of the trap with material brought down in the 1987 storm.

<u>Opportunities created by the Great Storm</u>

One of the features of the storm of October 1987 was that it produced large quantities of timber which had been killed all within one night. This was thus a unique opportunity to carry out some studies of the use made of different types of freshly-downed material by invertebrates. Limited resources however meant that only preliminary trials were feasible.

Of the National Trust's sites known to be of national importance for the conservation of saproxylic invertebrates (Harding & Alexander 1993), fortunately only one was badly affected by the storm, Hatfield Forest in Essex. Retention of all fallen dead-wood on site is still rarely achievable within the Trust, but in this case the property managers were persuaded to leave everything, albeit with limited making safe of potentially dangerous trees, and movement of fallen material in order to restore access and pasture.

The retention of all of this material, together with its accumulation in identified locations, meant that timber which had died more or less simultaneously, and been subsequently left within the Forest to experience the same gross climatic and local weather conditions, was available in large supply for subsequent study.

The Study

On 11 April 1990, having been left undisturbed in the Forest for three winters and two growing seasons, timber of two size classes from four tree species was gathered and placed in eight Owen Traps. The four tree species were oak *Quercus robur*, hornbeam *Carpinus betulus*, field maple *Acer campestre* and ash *Fraxinus excelsior*, and the two branch diameter classes were approximately 5-6 cm and 21-23 cm. Branch lengths were in the range 60-100 cm. The timber was all living when windblown, with no obvious signs of heartrot and had also been lying undisturbed on the soil surface until collected for extraction. The branches were largely intact, with little signs of rot development or structural breakdown, except for the hornbeam material, where considerable peeling of the bark was evident.

The Owen Traps were set up close to the location of the timber, and in a sheltered position with some shading. Branches were stacked within the traps so as to fill them but not to touch the netting. It was not possible to find one location in the Forest with timber from all four tree species present, and this may have influenced the fauna extracted, particularly as regards the non-saproxylic species (see later). The traps were dismantled the following November and the sample containers collected for identification and analysis. The branches were not further examined, and so information is not available on which wood-rotting fungi had begun to develop.

<u>Objectives of Study</u>

The objectives of the study were threefold:

1. to examine the variety of insects using freshly-downed timber;

2. to field trial the Owen Trap and gain some experience of its usefulness to the study of saproxylic faunas; and

3. to extend our knowledge of the rich saproxylic fauna of Hatfield Forest, although the saproxylic fauna detected would be early successional species which can turn around one whole life cycle within two seasons after the death of the timber.

This study could have been conducted by cutting live branches of the same length and girth from a random selection of trees, making it easily replicable, perhaps even using material cut while re-pollarding the old pollards of Hatfield Forest. However, the storm provided a large quantity of fresh timber which had been generated "naturally". Sawn or axed timber might well provide a subtly different habitat for the fauna.

Results

The variety of insects extracted

So far, 124 species have been recognised (Appendix 1): 68 species of Coleoptera, 53 species of Diptera, one Neuropteran, common earwig (*Forficula auricularia*) and even one species of Plecopteran. Some Coleoptera and Diptera have not yet been identified to species level. Hymenoptera have not yet been tackled at all.

Presence on non-saproxylic species

The greatest surprise has been the abundance of non-saproxylic insects. This has also been the case in extractions carried out by Owen himself (1992) and surveys in Wytham Woods (Larkin & Elbourn 1964; Paviour-Smith & Elbourn 1993). Only 27 of the Coleoptera species found are saproxylics (c.43%), while for Diptera there were 12 (c.26%) specialist saproxylics plus a further 13 (c.28%) generalist fungus associates (Table 2).

Table 2 Incidence of saproxylic and non-saproxylic insects in Owen Trap samples during 1990

	No of species	% of total	No of individuals	% of total
Coleoptera				
Saproxylic	27	43	141	22
Overwintering	36	57	509	78
Diptera				
Saproxylics	12	26	19	28
Fungus breeding (not specialising in wood-rotters)	13	28	17	25
Pupation site only	20	44	32	46
Epiphyte associates	1	2	1	1

Owen (1992) used thick oak branches torn off by the October 1987 storm in Windsor Great Park, which already contained some heart-rot and so the results are not directly comparable. Nevertheless of 37 Coleopteran species obtained from an extraction lasting four years, twenty-six were saproxylics (c.70%). This higher percentage is largely due to the existence of rot within the boughs, which had been colonised by deadwood beetles prior to the storm. Larkin and Elbourn (1964) similarly found that oak branches that were in a state of decay contained greater numbers of saproxylic species.

Some of the non-saproxylics appear to be using dead wood as pupation sites, e.g. those Mycetophilidae which breed in soil fungi, the *Cordilura*, and the stonefly *Nemoura cinerea* - a species which breeds in rut puddles and ditches. Others are most likely using the dead wood as winter hibernation sites, eg the Chrysomelidae, Carabidae, weevils, and probably some of the Mycetophilidae. Larkin and Elbourn (1964) observed that hibernating animals are most noticeable in dead wood that is in the more advanced stages of decay.

The presumed winter hibernating species (Table 3) include many which are predominantly grassland species, rather than woodland or tree associates. This category was dominated by two common and widespread species: the chrysomelid beetle *Longitarsus luridus* and the weevil *Sitona lineatus*. The main foodplant of *L. luridus* is *Cirsium arvense* and the *Sitona* feeds on various Leguminosae including clovers. These two species were most numerous in the oak and hornbeam (Table 3), but this may relate more to the location in the Forest where this timber was accumulated rather than any real preference for these species.

This large presence of grassland Coleoptera may indicate that there are only limited hibernation sites available in grazed pastures and that some grassland insects need to enter adjacent habitats in order to find suitable hibernation sites. An investigation of such movement would be an interesting study.

Table 3 Locations of overwintering Coleoptera in the Owen trap samples

Lg = large; Sm = small; Hbm = hornbeam; Mpl = field maple

Species	Oak		Hbm		Ash		Mpl	
Timber size:	Lg	Sm	Lg	Sm	Lg	Sm	Lg	Sm
Carabus violaceus L.	1	-	-	-	-	-	-	-
Nebria brevicollis (F.)	-	-	-	-	-	-	1	-
Trechus quadristriatus (Schr.)	-	-	1	-	-	-	-	-
Pterostichus melanarius (Ill.)	-	-	-	1	-	-	-	-
Anotylus rugosus (F.)	-	1	-	1	-	-	-	-
Stenus impressus Germ.	-	-	-	-	-	-	-	1
Rugilus orbiculatus (Payk.)	-	-	-	1	-	-	-	-
Tachyporus chrysomelinus (L.)	1	1	5	5	-	-	-	-
T. hypnorum (F.)	4	-	3	11	-	-	-	-
T. nitidulus (F.)	-	-	-	-	1	-	-	-
Brachypterus glaber (Steph.)	-	-	-	-	-	-	1	-
Meligethes aeneus (F.)	2	-	-	1	2	-	-	-
M. nigrescens Steph.	1	2	-	-	-	-	-	-
Stilbus testaceus (Panz.)	-	1	-	-	-	-	-	-
Aridius bifasciatus (Reit.)	2	-	-	1	1	-	-	1
Oulema melanopa (L.)	-	-	-	1	-	-	-	-
Aphthona euphorbiae (Schr.)	-	-	-	-	6	2	1	-
Longitarsus luridus (Scop.)	5	59	18	147	-	-	-	1
L. melanocephalus (Deg.)	-	1	-	8	-	-	-	-
Batophila aerata (Marsh.)	1	-	1	2	3	-	2	-
Crepidodera ferruginea (Scop.)	-	-	-	1	-	-	-	-
Chaetocnema concinna (Marsh.)	1	1	-	-	-	-	-	-
C. hortensis (Fourcr.)	1	-	1	5	-	-	-	-
Psylliodes chrysocephala (L.)	-	-	-	-	1	-	-	-
Apion assimile Kirby, W.	-	-	-	2	-	-	-	-
A. loti Kirby, W.	-	5	-	1	-	-	-	-
A. nigritarse Kirby, W.	-	-	1	2	-	-	-	-
A. onopordi Kirby, W.	-	-	1	-	-	-	-	-
A. seniculus Kirby, W.	-	1	-	2	-	-	-	-
Barypeithes araneiformis (Schr.)	-	-	-	-	-	-	1	-
Barynotus obscurus (F.)	-	-	-	1	-	-	-	-
Sitona lineatus (L.)	4	63	8	86	1	-	-	-
S. sulcifrons (Thunb.)	-	-	-	1	-	-	-	-
Cidnorhinus quadrimaculatus (L.)	1	-	-	-	-	-	-	-
Ceutorhynchus assimilis (Payk.)	1	-	-	-	-	-	-	-
Miccotrogus picirostris (F.)	1	-	1	2	-	-	-	-

To confirm that species are using the timber solely as an overwintering hibernation site extraction samples should be collected periodically throughout the year, perhaps monthly, to discover in which season individual species are most often captured. Traps could also be set at different times of the year. The phytophagous species seem most likely to be hibernators. Ground-living predators such as nocturnal Carabidae and Staphylinidae could include species that were already active on the forest floor by the April collection date and were merely sheltering in the timber during the daylight hours.

The species thought to be using the timber just as a pupation site also show some bias towards field maple (Table 4), but, again, it is unlikely that field maple has any special quality in this respect. The timber of this particular tree lay in an area with a higher water table and so the insect larvae may have been driven upwards to pupation sites, which is consistent with the presence here of the stonefly!

Table 4 Locations of species suspected as having used timber for pupation only

Species		Oak		Hbm		Ash		Mpl	
	Timber size:	Lg	Sm	Lg	Sm	Lg	Sm	Lg	Sm
Plecoptera									
Nemoura cinerea (Retz.)		-	-	-	-	-	-	2	-
Neuroptera									
Wesmaelius betulinus (Strom, H.)		-	-	-	-	-	-	1	-
Diptera									
Pedicia immaculata (Meig.)		-	-	-	-	-	-	1	-
Limnophila nemoralis (Meig.)		-	-	-	-	-	-	1	-
Ilisia occoecata (Edws.)		-	-	-	-	-	-	2	-
Ormosia nodulosa (Macq.)		-	-	-	-	1	-	-	-
Molophilus sp.		-	-	-	-	-	-	5	-
Exechia fusca (Meig.)		-	-	-	1	-	-	1	-
E. contaminata group		-	-	-	-	-	-	1	-
E. parva group		-	1	-	-	-	-	-	-
Cordyla fissa Edw.		-	-	-	-	1	-	1	-
C. murina Winn.		-	-	-	-	-	-	1	-
Copromyza stercoraria (Meig.)		-	-	-	-	-	-	2	-
Crumomyia notabilis (Collin)		-	-	-	-	-	-	1	-
Ischiolepta denticulata (Meig.)		-	-	-	1	-	-	-	1
Limosina silvatica (Meig.)		-	-	1	-	-	-	-	-
Spelobia parapusio (Dahl)		-	1	-	-	-	-	-	2
Cordilura albipes Fall.		-	-	-	-	-	-	1	-

The saproxylic fauna

All of the four timber species were used by the Coleoptera (Tables 5 and 6), with ash being used by the least number of species. All timber species also supported at least one species not recorded in any other, although few of the Coleoptera concerned are known to breed specifically in only one of the species of timber extracted. The numbers of species and individuals extracted from oak and hornbeam are comparable, while field maple produced a comparable number of species but much lower number of individuals. Ash was poorer in both respects.

Except for maple, the smaller size category of branches produced the greatest numbers of individual beetles, but somewhat fewer species (Tables 5 and 6). This probably reflects the larger numbers of branch sections used in the extractions because subcortical Coleoptera, which predominate in the samples, have more breeding habitat available in a large number of smaller branches than in a few larger ones.

Table 5 Locations of the saproxylic Coleoptera

Species	**Oak**		**Hbm**		**Ash**		**Mpl**	
Timber size:	**Lg**	**Sm**	**Lg**	**Sm**	**Lg**	**Sm**	**Lg**	**Sm**
Anisotoma humeralis (F.)	-	-	1	-	-	-	-	-
Scaphisoma agaricinum (L.)	-	-	-	4	-	-	-	-
Phloeonomus punctipennis Thoms.	-	-	1	1	-	1	-	-
Lordithon trinotatus (Er.)	1	-	7	-	-	-	-	-
Denticollis linearis (L.)	-	-	-	-	1	-	1	-
Anobium punctatum (Deg.)	-	-	-	1	-	-	-	-
Malachius bipustulatus (L.)	-	1	-	-	-	-	-	-
Epuraea sp.	-	-	-	-	-	-	-	1
Rhizophagus bipustulatus (F.)	6	-	-	-	-	-	-	-
Aspidiphorus orbiculatus (Gyll.)	-	-	-	1	-	-	-	-
Aridius nodifer (Westw.)	1	1	2	2	3	-	-	1
Bitoma crenata (F.)	-	-	3	1	-	-	-	-
Rhinosimus planirostris (F.)	-	-	-	1	-	-	-	-
Pyrochroa serraticornis (Scop.)	-	-	-	-	3	-	-	-
Anaspis maculata Fourcr.	-	4	-	2	-	8	-	7
A. regimbarti Schils.	2	-	-	-	-	-	-	-
A. rufilabris (Gyll.)	-	-	-	-	-	-	1	-
Anaspis spp. (tenerals)	-	5	-	4	-	-	-	-
**Mordellistena neuwaldeggiana* (Panz.)	-	-	-	2	-	-	1	-
**Ischnomera cyanea* (F.)	-	-	-	-	-	-	1	-
**Aderus oculatus* (Payk.)	1	-	-	-	-	-	-	-
Grammoptera ruficornis (F.)	-	2	-	-	-	3	-	-
Alosterna tabacicolor (Deg.)	-	-	-	-	-	-	2	-
Leiopus nebulosus (L.)	-	28	2	14	-	-	-	-
Acalles turbatus Bohem.	-	-	-	-	-	-	2	-
Rhyncolus lignarius (Marsh.)	-	-	-	-	-	-	2	-
Dryocoetes villosus (F.)	3	-	-	-	-	-	-	-

*Nationally scarce species (Hyman & Parsons, 1992)

Table 6 Saproxylic Coleoptera sorted by timber species and timber size

Tree species	Oak	Hbm	Ash	Mpl
No of species of beetle	11	13	6	10
No of species exclusive to tree	5	6	1	6
Total individuals	55	49	19	19

Hbm = hornbeam; Mpl = field maple

Branch size category	Large	Small
No of species of beetle	15	13
No of species exclusive to size category	13	9
Total individuals	47	95

Some species clearly preferred the smaller size category branches: *Leiopus nebulosus, Grammoptera ruficornis* and *Anaspis maculata,* while others need larger boughs, e.g. *Dryocoetes villosus* which breeds in thick bark.

The saproxylic Diptera data (Tables 7 and 8) are notable for the number of species detected by only single individuals and the large number of species reared from large field maple logs. As suggested above, the field maple situation may be more significant than the species of the wood, as this site proved to be particularly good for Diptera overall. The large timber category was the most productive, generating nearly 90% of the species and the individual flies (Table 8), which may reflect the importance of moisture to many of the Diptera species; larger boughs retain more moisture than smaller ones.

Discussion

<u>Problems in the interpretation of the catch from Owen Traps</u>

The problem of using timber from different locations within the Forest is very apparent from the grassland fauna detected and the species using the timber for pupation. Some of the logs may also have been contaminated with soil as a number of the craneflies which emerged are known to be soil-breeding ones. This needs to be considered in any future work of this kind. Perhaps the wood should be hosed down with water before being placed in the extraction traps, or at least largely scraped clear of soil? Contamination by species associated with epiphytic growth was demonstrated by the capture of the cranefly *Tipula pagana.*

Table 7 Locations of the saproxylic and fungus-breeding Diptera

Species	Oak		Hbm		Ash		Mpl	
Timber size:	Lg	Sm	Lg	Sm	Lg	Sm	Lg	Sm
Tipula flavolineata Meig.	-	-	-	-	-	-	1	-
**Limonia decemmaculata* (Loew)	-	-	2	-	-	-	1	-
L. dumetorum Meig.	-	-	-	-	-	-	1	-
Epiphragma ocellaris (L.)	-	-	-	-	-	-	1	-
Austrolimnophila ochracea (Meig.)	-	-	10	-	-	-	6	-
Orfelia fasciata (Meig.)	-	-	1	-	-	-	-	-
O. nemoralis (Meig.)	-	-	-	-	1	-	-	-
O. nigricornis (F.)	2	-	-	-	-	-	-	-
Mycomya wankowiczii (Dz.)/*winnertzi* Dz. F	-	-	-	-	-	-	1	-
Phthinia humilis Winn./*mira* (Ostrov.)	-	-	-	-	-	-	1	-
Sciophila lutea Macq.	-	-	2	-	-	-	-	-
Acnemia nitidicollis (Meig.)	-	-	-	-	1	-	-	-
Ectrepesthoneura sp. (female)	-	-	-	-	-	-	1	-
Anatella simpatica Dz.	-	-	-	-	-	-	1	-
Allodiopsis excogitata (Dz.)	-	-	-	-	-	-	1	-
Allodia s.str.	-	-	-	-	-	-	1	-
Phronia conformis (Walk.)	-	-	-	-	-	-	1	-
Dynatosoma fuscicornis (Meig.)	-	-	1	-	-	-	-	-
Mycetophila curviseta Lundstr.	-	-	1	-	-	-	-	-
M. formosa Lundstr.	-	-	-	-	-	-	-	2
M. marginata group	-	-	-	-	-	-	1	-
M. occultans Lundstr.	-	-	-	2	-	-	-	-
M. trinotata Staeg.	-	-	-	1	-	-	-	-
Zygomyia vara (Staeg.)	-	-	-	-	-	-	2	-
Trichosia pilosa (Staeg.)	-	-	-	-	1	-	-	-
Total species in each category	1	-	6	2	3	-	13	1
Total species exclusive to category	1	-	5	2	3	-	12	1

*Nationally scarce species (Falk, 1991a)

Table 8 Saproxylic and fungus-breeding Diptera by timber size and species

Branch size category	Large	Small
No of species of fly	22	3
No of species exclusive to size	22	3
Total individuals	41	5

Tree species	Oak	Hbm	Ash	Mpl
No of species of fly	1	8	3	14
No of species exclusive to tree	1	7	3	13
Total individuals	2	17	3	21

Hbm = hornbeam; Mpl = field maple

Not all the invertebrate material is necessarily captured. Some species, especially the non-insects, are flightless although *Carabus violaceus* was taken, presumably having climbed up the netting walls of the trap. Others may not have completed their life cycle within the time period of the extraction; further species or individuals may remain within the timber to breed rather than fly off in search of mates and fresh oviposition sites. Owen (1992) tried an extraction period of three years, and was still capturing insects in the last year. These later arrivals were all saproxylics, the overwintering Coleoptera being all extracted in the first year. However, it was not possible to decide whether the later arrivals were from long-lived larval stages or whether earlier adults had mated and oviposited and gone through the life cycle again while still in the trap.

Improvement in knowledge of Hatfield Forest fauna

A high proportion of the species recorded were new to the Hatfield list. This emphasises how poorly recorded the fauna is at this site - as is the case for most of the best pasture-woodlands in the British Isles and elsewhere! Four species were "nationally scarce" (Hyman & Parsons 1992; Falk 1991b): the beetles *Mordellistena neuwaldeggiana, Ischnomera cyanea* and *Aderus oculatus*, and the crane fly *Limonia decemmaculata*. These are all saproxylics and only one of them, *I. cyanea*, was already known from Hatfield.

Comparisons with other studies

There have been very few detailed extractions of invertebrates from dead wood, apart from Owen's own work (1989, 1992) and those at Wytham Woods e.g. Paviour-Smith and Elbourn (1978, 1993) and Fager (1968). The Wytham Survey researchers have generally used heat extraction apparatus and so sampled flightless species and larval individuals, as well as full-winged adult insects. However larvae present great difficulties in identification to species level and heat extraction is not exhaustive (Larkin & Elbourn 1964). The Owen Trap allows the larvae in the samples to reach the adult stage before being captured, although at the expense of some of the fauna, as already explained, particularly flightless species.

The present study appears to be the first to attempt to extract solely from timber which had started off as live and undecayed.

Conclusions

Dead and decaying timber in pasture-woodland such as Hatfield Forest is not just important for sparoxylic invertebrates, but forms a well-used medium for winter hibernation and for pupation. These latter groups of species are best represented when the timber is lying in grassland and on ground with a high water table, respectively.

Even when fallen timber is abundant due to an unusually severe storm, freshly-downed timber which has no existing decay is used by a wide variety of insects, including nationally scarce species (see also Winter (1993)). However, the survival of these species on the site might not be threatened by the removal of some or even much of this fresh deadwood.

Despite a few problems, the Owen Trap offers a very useful means of furthering the study of the ecology of saproxylic faunas and hence of significantly improving our understanding of their nature conservation requirements.

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References

ALEXANDER, K.N.A. in prep. *An annotated checklist of British lignicolous and saproxylic invertebrates.*

BALL, S.G. 1986. *Terrestrial and freshwater invertebrates with red data book, notable or habitat indicator status.* Peterborough, Nature Conservancy Council (Invertebrate Site Register Report No. 66).

FAGER, E.W. 1968. The community of invertebrates in decaying oak wood. *Journal of Animal Ecology* 37 121-142.

FALK, S. 1991a. *A review of the scarce and threatened bees, wasps and ants of Great Britain.* Peterborough, Nature Conservancy Council (Research and survey in nature conservation No. 35).

FALK, S. 1991b. *A review of the scarce and threatened flies of Great Britain, Part 1.* Peterborough, Nature Conservancy Council (Research and survey in nature conservation No. 39).

HAMMOND, P.M., & HARDING, P.T. 1991. Saproxylic invertebrate assemblages in British woodlands: their conservation significance and its evaluation. In *Pollard and veteran tree management*, edited by H.J. Read, pp30-41. Burnham Beeches, Corporation of London.

HARDING, P.T. & ALEXANDER, K.N.A. 1993. The saproxylic invertebrates of historic parklands: progress and problems. In *Deadwood matters: the ecology and conservation of saproxylic invertebrates in Britain*, edited by K.J. KIRBY & C.M. DRAKE pp 58-73, Peterborough, English Nature (English Nature Science 7).

HARDING, P.T. & ROSE, F. 1986. *Pasture-woodlands in lowland Britain.* Huntingdon, Institute of Terrestrial Ecology.

HYMAN, P.S. & PARSONS, M.S. 1992. *A review of the scarce and threatened Coleoptera of Great Britain, Part 1.* Peterborough, Joint Nature Conservation Committee (UK Nature Conservation No. 3).

KIRBY, P. 1992. *A review of the scarce and threatened Hemptiera of Great Britain.* Peterborough, Joint Nature Conservation Committee (UK Nature Conservation No. 2).

LARKIN, P.A. & ELBOURN, C.A. 1964. Some observations on the fauna of dead wood in live oak trees. *Oikos* **15** 79-92.

OWEN, J.A. 1989. An emergence trap for insects breeding in dead wood. *British Journal of Entomology and Natural History* **2**, 65-67.

OWEN, J.A. 1992. Experience with an emergence trap for insects breeding in dead wood. *British Journal of Entomology and Natural History* **5**, 17-20.

PAVIOUR-SMITH, K., & ELBOURN, C.A. 1978. Some spiders of dead wood in living trees in Wytham Woods, near Oxford. *Bulletin of the British Arachnological Society* **4**, 213-220.

PAVIOUR-SMITH, K., & ELBOURN, C.A. 1993. A quantitative study of the fauna of small dead and dying wood in living trees in Wytham Woods, near Oxford. In: *Dead wood matters: the ecology and conservation of saproxylic invertebrates in Britain* edited by K.J. KIRBY & C.M. DRAKE, pp 33-57, Peterborough, English Nature (English Nature Science No. 7).

SOUTHWOOD, T.R.E. 1978. *Ecological methods, with particular reference to the study of insect populations.* 2nd Edition, London, Chapman & Hall.

WINTER, T. 1993. Deadwood - is it a threat to commercial forestry? In *Deadwood matters: the ecology and conservation of saproxylic invertebrates in Britain*, edited by K.J. KIRBY & C.M. DRAKE, pp 74-80, Peterborough, English Nature (English Nature Science 7).

Apppendix 1 Summary of whole data, together with an indication of the nature of the association with dead wood

Association codes

S saproxylic species
F fungus-breeding species not specific to saproxylic situations
P species using deadwood as pupation site only
W species using deadwood for winter hibernation purposes only
U species more or less ubiquitous in habitats
E species associated with epiphytes

Other codes

L large girth timber
S small girth timber
n material not yet identified or counted
* Nationally Scarce Species
Hbm hornbeam
Mpl field maple

Species	Association with deadwood	Oak		Hbm		Ash		Mpl	
		L	S	L	S	L	S	L	S
Dermaptera									
Forficula auricularia L.	U	18	2	2	14	-	3	2	5
Psocoptera		-	n	-	-	-	n	-	n
Plecoptera									
Nemoura cinerea (Retz.)	P	-	-	-	-	-	-	2	-
Neuroptera									
Wesmaelius betulinus (Strom, H.)	P	-	-	-	-	-	-	1	-
Coleoptera									
Carabus violaceus L.	W	1	-	-	-	-	-	-	-
Nebria brevicollis (F.)	W	-	-	-	-	-	-	1	-
Trechus quadristriatus (Schr.)	W	-	-	1	-	-	-	-	-
Pterostichus melanarius (I11.)	W	-	-	-	1	-	-	-	-
Anisotoma humeralis (F.)	S	-	-	1	-	-	-	-	-
Scaphisoma agaricinum (L.)	S	-	-	-	4	-	-	-	-
Phloeonomus punctipennis Thoms.	S	-	-	1	1	-	1	-	-
Anotylus rugosus (F.)	W	-	1	-	1	-	-	-	-
Stenus impressus Germ.	W	-	-	-	-	-	-	-	1
Rugilus orbiculatus (Payk.)	W	-	-	-	1	-	-	-	-
Quedius sp.		-	-	1	-	-	-	-	-
Lordithon trinotatus (Er.)	S	1	-	7	-	-	-	-	-
Tachyporus chrysomelinus (L.)	W	1	1	5	5	-	-	-	-
T. hypnorum (F.)	W	4	-	3	11	-	-	-	-

Species	Association with deadwood	Oak		Hbm		Ash		Mpl	
		L	S	L	S	L	S	L	S
T. nitidulus (F.)	W	-	-	-	-	1	-	-	-
Aleocharinae		3	-	18	1	5	2	2	2
Denticollis linearis (L.)	S	-	-	-	-	1	-	1	-
Anobium punctatum (Deg.)	S	-	-	-	1	-	-	-	-
Malachius bipustulatus (L.)	S	-	1	-	-	-	-	-	-
Brachypterus glaber (Steph.)	W	-	-	-	-	-	-	1	-
Meligethes aeneus (F.)	W	2	-	-	1	2	-	-	-
M. nigrescens Steph.	W	1	2	-	-	-	-	-	-
Epuraea sp.	S	-	-	-	-	-	-	-	1
Rhizophagus bipustulatus (F.)	S	6	-	-	-	-	-	-	-
Aspidiphorus orbiculatus (Gyll.)	S	-	-	-	1	-	-	-	-
Cryptophagus spp.		1	-	-	-	2	-	-	-
Atomaria sp.		-	-	1	-	1	-	-	1
Stilbus testaceus (Panz.)	W	-	1	-	-	-	-	-	-
Aridius bifasciatus (Reit.)	W	2	-	-	1	1	-	-	1
A. nodifer (Westw.)	S	1	1	2	2	3	-	-	1
Cortinicara ?gibbosa (Hbst.)	U	-	1	1	1	1	-	-	-
Bitoma crenata (F.)	S	-	-	3	1	-	-	-	-
Rhinosimus planirostris (F.)	S	-	-	-	1	-	-	-	-
Pyrochroa serraticornis (Scop.)	S	-	-	-	-	3	-	-	-
Anaspis maculata Fourcr.	S	-	4	-	2	-	8	-	7
A. regimbarti Schils.	S	2	-	-	-	-	-	-	-
A. rufilabris (Gyll.)	S	-	-	-	-	-	-	1	-
Anaspis spp. (tenerals)	S	-	5	-	4	-	-	-	-
**Mordellistena neuwaldeggiana* (Panz.)	S	-	-	-	2	-	-	1	-
**Ischnomera cyanea* (F.)	S	-	-	-	-	-	-	1	-
**Aderus oculatus* (Payk.)	S/W	1	-	-	-	-	-	-	-
Grammoptera ruficornis (F.)	S	-	2	-	-	-	3	-	-
Alosterna tabacicolor (Deg.)	S	-	-	-	-	-	-	2	-
Leiopus nebulosus (L.)	S	-	28	2	14	-	-	-	-
Oulema melanopa (L.)	W	-	-	-	1	-	-	-	-
Aphthona euphorbiae (Schr.)	W	-	-	-	-	6	2	1	-
Longitarsus luridus (Scop.)	W	5	59	18	147	-	-	-	1

Species	Association with deadwood	Oak		Hbm		Ash		Mpl	
		L	S	L	S	L	S	L	S
L. melanocephalus (Deg.)	W	-	1	-	8	-	-	-	-
Batophila aerata (Marsh.)	W	1	-	1	2	3	-	2	-
Crepidodera ferruginea (Scop.)	W	-	-	-	1	-	-	-	-
Chaetocnema concinna (Marsh.)	W	1	1	-	-	-	-	-	-
C. hortensis (Fourcr.)	W	1	-	1	5	-	-	-	-
Psylliodes chrysocephala (L.)	W	-	-	-	-	1	-	-	-
Apion assimile Kirby, W.	W	-	-	-	2	-	-	-	-
A. loti Kirby, W.	W	-	5	-	1	-	-	-	-
A. nigritarse Kirby, W.	W	-	-	1	2	-	-	-	-
A. onopordi Kirby, W.	W	-	-	1	-	-	-	-	-
A. seniculus Kirby, W.	W	-	1	-	2	-	-	-	-
Barypeithes araneiformis (Schr.)	W	-	-	-	-	-	-	1	-
Barynotus obscurus (F.)	W	-	-	-	1	-	-	-	-
Sitona lineatus (L.)	W	4	63	8	86	1	-	-	-
S. sulcifrons (Thunb.)	W	-	-	-	1	-	-	-	-
Acalles turbatus Bohem.	S	-	-	-	-	-	-	2	-
Rhyncolus lignarius (Marsh.)	S	-	-	-	-	-	-	2	-
Cidnorhinus quadrimaculatus (L.)	W	1	-	-	-	-	-	-	-
Ceutorhynchus assimilis (Payk.)	W	1	-	-	-	-	-	-	-
Miccotrogus picirostris (F.)	W	1	-	1	2	-	-	-	-
Dryocoetes villosus (F.)	S	3	-	-	-	-	-	-	-
Hymenoptera									
Aculeata									
Diptera									
Trichocera sp.	P	-	-	-	-	-	-	1	-
Nephrotoma quadrifaria (Meig.)	P	-	-	-	-	-	-	1	-
Tipula flavolineata (Meig.)	S	-	-	-	-	-	-	1	-
T. pagana Meig.	E	-	-	-	-	-	-	1	-
T. paludosa Meig.	P	-	-	-	-	-	-	2	-
**Limonia decemmaculata* (Loew)	S	-	-	2	-	-	-	-	-
L. dumetorum Meig.	S	-	-	-	-	-	-	1	-
L. tripunctata (F.)	P	-	-	-	-	1	-	-	-
Pedicia immaculata (Meig.)	P	-	-	-	-	-	-	1	-

Species	Association with deadwood	Oak		Hbm		Ash		Mpl	
		L	S	L	S	L	S	L	S
Epiphragma ocellaris (L.)	S	-	-	-	-	-	-	1	-
Austrolimnophila ochracea (Meig.)	S	-	-	10	-	-	-	6	-
Limnophila nemoralis (Meig.)	P	-	-	-	-	-	-	1	-
Illisia occoecata (Edws.)	P	-	-	-	-	-	-	2	-
Ormosia nodulosa (Macq.)	P	-	-	-	-	1	-	-	-
O. ?nodulosa (Macq.)		-	-	-	-	-	-	1	-
Molophilus sp.	P	-	-	-	-	-	-	5	-
Chironomidae		-	-	-	-	-	-	2	-
Macrocera angulata Meig.		-	-	-	-	-	-	2	-
Orfelia fasciata (Meig.)	S	-	-	1	-	-	-	-	-
O. nemoralis (Meig.)	S	-	-	-	-	1	-	-	-
O. nigricornis (F.)	S	2	-	-	-	-	-	-	-
Mycomya wankowiczii (Dz.)/*winnertzi* Dz.	F	-	-	-	-	-	-	1	-
Phthinia humilis Winn./*mira* (Ostrov.)	S	-	-	-	-	-	-	1	-
Sciophila lutea Macq.	F	-	-	2	-	-	-	-	-
Sciophila sp.		-	-	-	-	2	-	-	-
Acnemia nitidicollis (Meig.)	S	-	-	-	-	1	-	-	-
Synapha fasciata Meig.		-	1	-	-	-	-	1	-
Ectrepesthoneura sp. (female)	S	-	-	-	-	-	-	1	-
Anatella simpatica Dz.	F	-	-	-	-	-	-	1	-
Allodiopsis excogitata (Dz.)	F	-	-	-	-	-	-	1	-
Exechia fusca (Meig.)	P	-	-	-	1	-	-	1	-
E. contaminata group	P	-	-	-	-	-	-	1	-
E. parva group	P	-	1	-	-	-	-	-	-
Allodia s.str.	F	-	-	-	-	-	-	1	-
Cordyla fissa Edw.	P	-	-	-	-	1	-	1	-
C. murina Winn.	P	-	-	-	-	-	-	1	-
Phronia conformis (Walk.)	F	-	-	-	-	-	-	1	-
Dynatosoma fuscicornis (Meig.)	F	-	-	1	-	-	-	-	-
Mycetophila curviseta Lundstr.	F	-	-	1	-	-	-	-	-
M. formosa Lundstr.	F	-	-	-	-	-	-	-	2
M. marginata group	F	-	-	-	-	-	-	1	-
M. occultans Lundstr.	F	-	-	-	2	-	-	-	-

Species	Association with deadwood	Oak		Hbm		Ash		Mpl	
		L	S	L	S	L	S	L	S
M. trinotata Staeg.	F	-	-	-	1	-	-	-	-
Zygomyia vara (Staeg.)	F	-	-	-	-	-	-	2	-
Sciaridae indet.		n	-	n	-	-	-	3	-
Trichosia pilosa (Staeg.)	S	-	-	-	-	1	-	-	-
Cecidomyiidae		-	-	3	-	-	-	1	-
Copromyza stercoraria (Meig.)	P	-	-	-	-	-	-	2	-
Crumomyia notabilis (Collin)	P	-	-	-	-	-	-	1	-
Ischiolepta denticulata (Meig.)	P	-	-	-	1	-	-	-	1
Limosina silvatica (Meig.)	P	-	-	1	-	-	-	-	-
Spelobia parapusio (Dahl)	P	-	1	-	-	-	-	-	2
Cordilura albipes Fall.	P	-	-	-	-	-	-	1	-

MONITORING CHANGES IN WOODLAND AUCHENORRHYNCHA FOLLOWING THE STORM OF 1987 (poster)

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Summary

The immediate, short-term and long-term changes in leafhopper and planthopper populations in Perry Woods, Kent following the Great Storm of 1987 are described in relation to the life history traits of individual species. Examples from the field, shrub and canopy communities are discussed.

Species mobile at the time of the storm were able to move quickly from damaged to healthy plants as the quality of their habitat deteriorated. Early leaf fall precipitated by the storm was followed by early migration of *Empoasca vitis* (Göthe) to evergreen trees on which it overwinters.

The scale of the damage inflicted by the storm was localised and transient, so some of the changes were not detected by the monitoring programme. The most noticeable changes in leafhopper abundance occurred as a delayed response to changes in vegetational composition in the larger gaps. The planthopper *Ditropis pteridis* (Spin.) increased in areas subsequently dominated by bracken and the leafhopper *Graphocephala fennahi* Young increased in areas overgrown by rhododendron. Numbers of *Graphocephala* were closely linked to the numbers of flower-buds initiated under the unusually warm growing conditions experienced during 1989-91. Large swarms of *Graphocephala* were observed in 1990 and 1991.

Sampling of live, fallen oak trees in the year after the storm revealed that more nymphs of the cicadellid *Iassus lanio* (L.) occurred naturally in the crown and mid-canopy than on the lowermost branches.

Introduction

Few long term monitoring studies of insects in their natural habitat have been undertaken in the British Isles compared with studies of other groups such as birds. A monitoring programme was therefore started in 1984 to record the numbers of Auchenorrhyncha (frog-hoppers, leafhoppers and planthoppers) associated with various tree and shrub species occurring in Perry Woods, Kent, over an extended period. It was hoped that this study would provide base-line data on auchenorrhynchous insects similar to those obtained for other groups of insects such as the Lepidoptera (eg Rothamsted Insect Survey, Taylor 1986: Butterfly Monitoring Scheme, Pollard *et al.* 1986; Pollard & Hall 1988). The Environmental Change Network (ECN) launched in the UK in 1992 with the primary purpose of quantifying environmental changes associated with man's activities, includes the monitoring of populations of froghoppers, carabids and tipulids (Sykes 1992).

Perry Woods situated near Faversham suffered severe localised tree damage as a result of the Great Storm of 1987 owing to its exposed position high up on the North Downs of Kent. Losses of many mature standards and some chestnut coppice resulted in increased exposure of shrub and ground layer plants to sunlight. The opportunity was therefore taken to investigate any changes that might have occurred to populations of selected auchenorrhynchous species as a consequence of the storm.

Three time scales were investigated; the weeks immediately following the storm, the remaining autumn and winter of 1987-88, and the period to the present day. Five species representative of the field, shrub and canopy communities were studied and these are listed in Table 1, together with brief details of their biology.

Table 1 Auchenorrhyncha species studied in Perry Woods

Species	Host plant/community	Stage at time of storm
Ditropis pteridis (Spin.)	Bracken, field layer	Mobile nymph
Issus coleoptratus (Fab.)	Holly, shrub/tree layer	Mobile nymph
Empoasca vitis (Gothe)	Various shrubs and trees/overwinter as adults in evergreen trees	Mobile adult
Graphocephala fennahi Young (*G. coccinea* misident.)	Rhododendron, shrub layer	Egg + few adults
Iassus lanio (L.)	*Quercus* sp., canopy inhabitant	Egg

Study Area

The survey was carried out in Perry Woods, Selling, on the North Downs near Faversham, Kent (Grid reference TR045556) owned by Swale Borough Council.

The present woods of 60 ha, range from 80 m to 154 m above sea level. The lower, outer areas are situated on Thanet sand, while the two hills to the west and south are situated on Woolwich and Reading beds capped with a layer of Oldhaven deposits comprised mainly of small pebbles. The vegetation consists of chestnut coppice with occasional sessile oak standards and a mixture of underwood comprised of hazel, ash and field maple (Wilson 1911). The regions of high ground are composed mainly of planted Scots pine and Douglas fir, over bracken with patches of heather *Calluna vulgaris* (L.) along the rides. Peterken (1981) classified the woods as sessile oak-hornbeam (sub-type 9Bb) noting the occasional hornbeam and a scattering of birch (*B. pendula*) among the chestnut coppice. A mixture of *Rhododendron* species was planted as game cover in the chestnut coppice during the early part of the present century. The most common species, *R. ponticum* (L.), gradually expanded its range owing to lax management with the result that by the 1980s several large tracts of chestnut coppice had become overgrown by this shrub, with mature bushes standing as high as 4-5 metres.

The effects of the Storm

The coniferous plantations of pine and fir on the high ground suffered severe damage during the Great Storm of 1987, with upwards of 67% loss of standing trees. Damage to the chestnut coppice was less extensive (<5%) with older-age stands suffering disproportionately. Many mature beech on the northern slopes were either uprooted or lost major limbs. The Borough Council's policy of ensuring that the woods were safe for public use meant that clearance of fallen timber and damaged trees was undertaken fairly rapidly, in contrast with many other areas of Kent (Davies & Pritchard 1994). The conifers on the upper slopes were cleared except for a small area of standing pine and replanted by mid-summer 1988. Many clearings were created in the coppice as a result of timber removal. The loss or partial destruction of the canopy in areas where rhododendron was growing led to a great expansion in foliage growth, particularly of small to medium-sized bushes. Many of these were able to initiate flower buds in 1988 leading to a burst of flowering and further flower bud initiation in 1989.

Methods

The Auchenorrhyncha survey was started in 1984. Four deciduous and three evergreen tree species were sampled for insects every two weeks using a standard-sized beating tray (area 0.75 sq m). The tree species were beech *Fagus sylvatica* L., birch *Betula pendula* Roth., chestnut *Castanea sativa* Mill.

and oak (mainly *Quercus petraea* (M.)), holly *Ilex aquifolium* L., yew *Taxus baccata* L., rhododendron *Rhododendron ponticum* L. together with bracken *Pteridium aquilinum* (L.) as a field layer plant. Five 'beats' from separate plants were taken except for rhododendron and bracken where 10 samples were used. Leaf drop, relevant to the migration of overwintering Auchenorrhyncha to evergreen trees was recorded on a weekly basis during the autumn months.

Population numbers of each species were calculated by summing the numbers from individual counts made during the year. The number of eggs deposited by *Graphocephala fennahi* Young in rhododendron flower buds was determined by collecting buds at a height of approximately 1.5 m above ground at a single location. The total numbers of eggs laid in each bud was determined by dissection. In a separate exercise to compare the effect of light on leafhopper oviposition, buds were collected at a number of locations of differing light intensity within the wood. Measurements of photosynthetically-active radiation (PAR) were made using a standard light meter on a bright day.

The damage inflicted by the Storm presented a unique chance to study the distribution of insects in the upper canopy. At the time of the Storm, the cicadellid *I. lanio* (L.) had virtually completed its egg laying. By sampling live, fallen oak trees in leaf in the following summer it was possible to estimate the numbers of leafhopper nymphs that would have occurred naturally at different heights in the canopy. Well-separated large branches were chosen for study so as to minimise the chances of nymphs moving between branches. Five oak trees were sampled ranging in height from 13 to 20 m.

Results

Short Term Changes

A substantial number of holly trees were damaged or uprooted by the storm. Observations on the planthopper *Issus coleoptratus* (Fab.) which feeds on holly showed that the early instar nymphs (mainly II-III) present at the time were able to move from damaged to healthy bushes within days of the storm, providing there were suitable corridor plants in the immediate vicinity. Population counts of all instars during November showed that many individuals survived the storm, with total numbers higher than 1986 (Table 2). The number of *Issus* developing into adults in the summer of 1988 based on samples from all tree species was similar to that of the preceding years indicating reasonable survival. No major changes in *Issus* numbers could be directly attributed to the storm, although a reduction in total numbers in the woods must have occurred as a result of damaged isolated holly trees dying and others being removed by contractors.

Table 2 **Totals of Auchenorrhyncha in Perry Woods 1985-92**

Species	YEAR Stage	1985	1986	1987	1988	1989	1990	1991	1992
Issus	Adult	4	18	17	16	7	18	47	13
	Nymphs*	-	28	86	77	38	-	-	-
Ditropis	Adult (shaded area)	1	0	0	2	14	16	3	20
	Adult (canopy gap)	-	-	14	16	72	91	76	266
Iassus	Adult	2	1	1	4	2	6	2	6

Results based on 14 day counts of 7 tree and shrub species x 5 replicates, except for *Ditropis* which is based on 10 replicates from bracken only.

*No. of *Issus* nymphs recorded in November each year. Those for 1987 represent those surviving the storm.

Medium Term Changes

Each autumn, adults of the leafhopper *Empoasca vitis* (Göthe) migrate to yew and other evergreen species from a variety of shrubs and trees on which they have been feeding, in order to obtain shelter and sustenance during the winter. Adult migration begins in early or mid September and peaks in late October to early November. Migration is both by day and night. Peak periods tend to coincide with major changes in food (ie leaf) quality and availability, as leaves senesce and drop from their host plants.

At the time of the storm many trees were still largely in leaf and the force of the storm removed 20-40% of the leaves in a single night. Those leaves remaining but damaged by the storm (either by mechanical force or salt burn) senesced prematurely and dropped from the trees in the weeks immediately following the storm. The net result was that deciduous trees lost their leaves two weeks earlier than normal compared with 1986 (Figure 1). Field vegetation also suffered damage and died back earlier.

Migration of *Empoasca vitis* occurred up to 11 days earlier in 1987 than in 1986 presumably owing to a substantial loss of feeding and resting sites and the insects' increasing need for shelter (Figure 2). Leaf drop in most years follows a characteristic pattern with species such as birch and chestnut tending to lose their leaves earlier than oak. One effect of the storm was to condense this sequence so that leaf drop occurred at a similar rate between species (Figure 3). This meant that foliage of late-senescing species were not available as habitats for late-migrating *Empoasca.*

The reasons why *Empoasca vitis* prefers yew on which to overwinter are not fully known, although the needle-like leaves and dense foliage structure provide effective cover from the wind and cold. They have not been shown to feed on yew or imbibe water during the winter and it appears that the tree merely provides protection from bad weather. Equally large numbers of *Empoasca* were recovered from dying, snapped branches as from undamaged yew branches during the winter and it was only from the end of February 1988 onwards that there was a noticeable preference for live foliage (Table 3). A clear preference for live as opposed to dead yew leaves was shown by *Empoasca vitis* migrating in the following autumn, even though the dead leaves were still largely intact. Thus *Empoasca vitis* may acquire some benefit, possibly sustenance, from overwintering on live yew foliage.

Table 3 Mean numbers of adult *Empoasca vitis* on attached and broken yew branches based on five samples per tree with the range in brackets.

		1987-1988		1988-1989	
Month/week		Branches attached	Branches broken	Branches attached	Branches broken
October	4	10	-		
November	2	11.8	-	69.4 (20-136)	8.8 (7-18)
December	1	27.6	14.5		
	4	11	-	34.8 (14-96)	1
January	1	6	17.5		
	2	-	-	34.4 (12-70)	2.5 (1-5)
	4	6.4	8.8		
February	4	6.0	5.7		
March	2	12	5		
April	2	11.2	3.3		
	4	2.8	0.3		

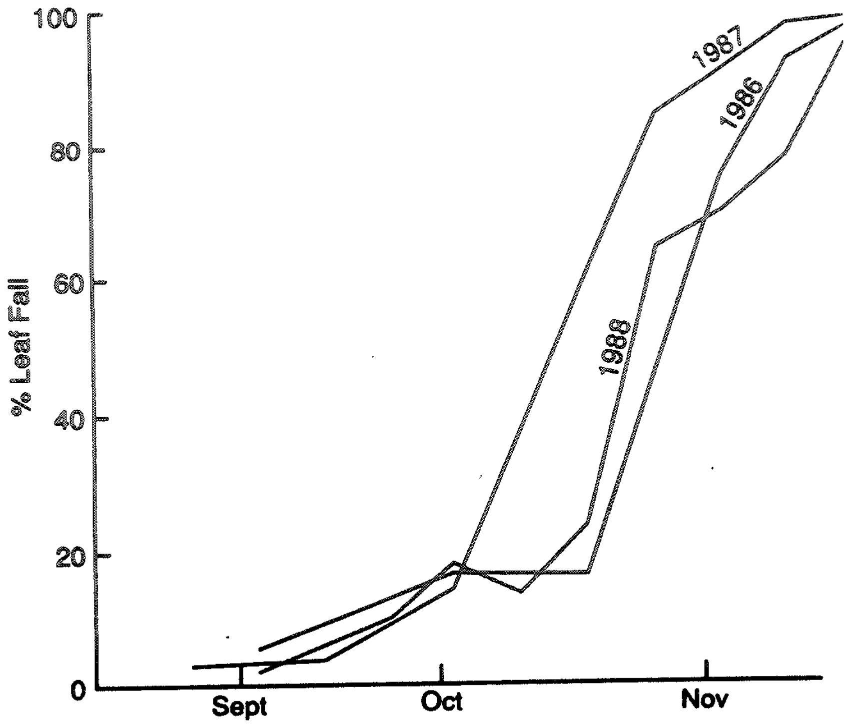

Figure 1 Leaf fall of sweet chestnut, Perry Wood 1986-1988.

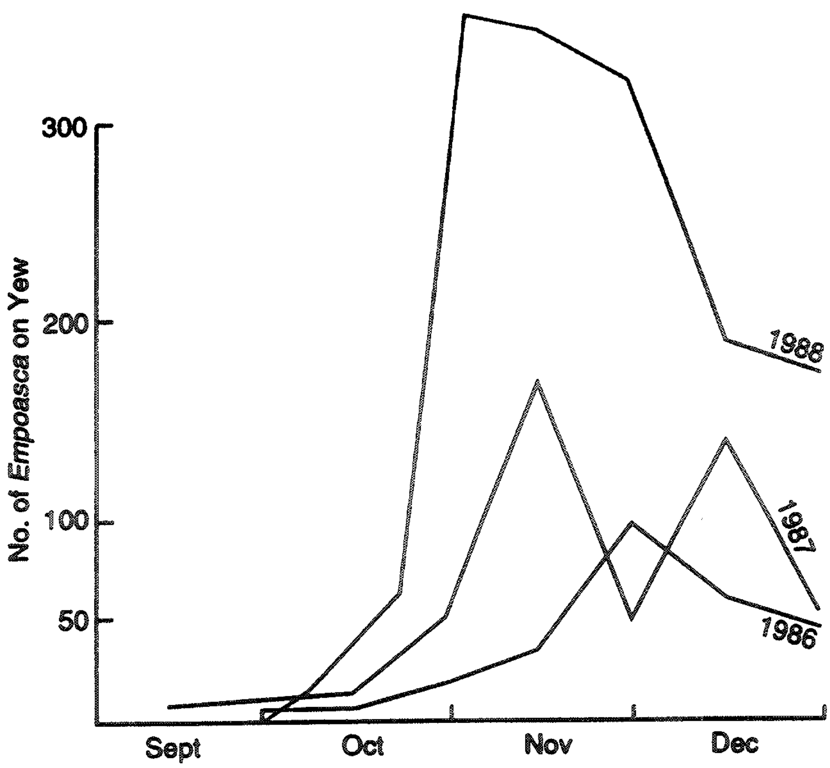

Figure 2 Numbers of adult *Empoasca vitis* overwintering on yew.

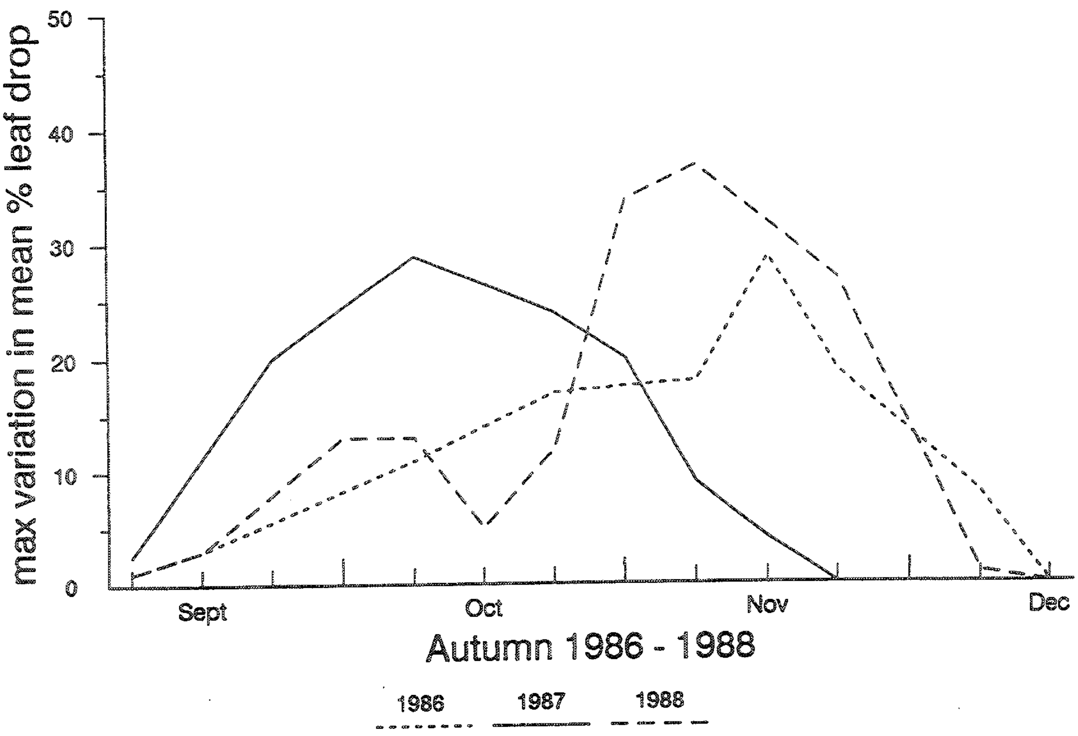

Figure 3 Maximum variation in leaf drop between species

Values were calculated as the maximum difference in mean % leaf drop between beech, birch, chestnut, oak and 1% die-back of bracken. High values indicate asynchrony between species. The large variation in leaf drop in early autumn 1987 prior to the storm was due to the early loss of leaves from birch relative to other tree species.

Numbers of adult *Empoasca vitis* showed a dramatic increase in the autumn of the following year as a result of reasonable adult survivorship during the winter of 1987-88; and an increase in abundance of field layer food plants growing in areas disturbed by the storm.

Migration in 1988 occurred earlier than in 1987 possibly as a result of many storm-damaged trees eventually dying and losing their leaves relatively early.

<u>Long Term Changes</u>

Ditropis pteridis (Spin.).

The only planthopper of the field layer community to be studied was the delphacid *Ditropis pteridis*. This species, which is normally brachypterous, feeds exclusively on bracken. Early instars feed at the base of the main stem amongst old bracken litter from late summer onwards, while the later instars and adults feed on the expanding pinnae in the following spring.

Bracken itself was hardly affected by the storm except where plants were uprooted next to fallen trees and many of these subsequently survived. Third instar *Ditropis* nymphs present at the time of the storm were able to move to adjacent undamaged plants to complete their life cycle, if required. The original stand of bracken under study was in a partially shaded area which remained relatively unscathed by the storm, but was subsequently cleaned up as part of the post-storm clearance programme. Numbers of adult *Ditropis* in 1988 (ie those present as nymphs during the storm) were similar to those of previous years (ie low) and it was only in 1989 and 1990 that an increase in numbers was recorded (Table 2). In a large canopy gap nearby, bracken subsequently became the dominant plant and here *Ditropis* showed a steady increase from low numbers under previously-shaded conditions (14 in 1987 and 16 in 1988) to a peak of 266 in 1993 (Table 2). This vast increase in population size was accompanied by a small increase in the numbers of macropterous (fully-winged) individuals.

Graphocephala fennahi Young

The rhododendron leafhopper *Graphocephala fennahi*, a bright red and green species from North America, was first recorded in England at Windlesham, Surrey in 1936. Since then it has spread across large areas of southern England and is now locally abundant in Kent (Badmin 1990). Nymphs and adults feed on a wide range of host plants, but adults lay their eggs exclusively in *Rhododendron*, inserting them into the scales of developing flower buds (Morcos 1953).

Adult leafhoppers lay their eggs mainly in August and September. At the time of the storm, egg-laying was therefore virtually complete and the size of the 1988 generation already fixed. The storm itself caused a slight reduction in the small number of adults remaining, but had little effect on developing eggs. Although many rhododendron bushes suffered minor damage with losses of branches and buds and hence some leafhopper eggs, few bushes were completely destroyed and the 1988 leafhopper population reached a level similar to that observed in 1987 (Figure 4).

Rhododendron bushes showed a marked increase in growth in 1988 in areas where the surrounding canopy had been destroyed. Mature plants increased in size and laid down a substantially larger number of flower buds in 1988 compared with 1987 and smaller plants, previously-suppressed by dense undergrowth, matured for the first time and also began to lay down flower buds for the next season. Scrub clearance took place in the following spring allowing a further group of rhododendron bushes in an adjacent area to initiate flower buds in 1988. There was probably a doubling of the number of new flower buds laid down in 1988 compared with 1987 in one large disturbed area (approx 100 m x 100 m) of the woods, resulting in a vast increase in the number of available oviposition sites for *Graphocephala* in this locality. The hot summers of 1989-91 also probably played a part in inducing flower bud initiation.

The open ground around the rhododendron bushes created by the storm proved ideal for *G. fennahi* as the leafhopper preferred to lay its eggs approximately 1 m above ground (i.e. the height of medium-sized bushes) in sunny, well-lit areas (Figures 5 and 6). More eggs were laid in large rather than small flower buds but there was no evidence that more large flower buds were being produced or that female *Graphocephala* selected their oviposition sites purely on bud size alone (Figure 7).

The numbers of *Graphocephala* increased by six-fold over the period 1988-1991 as a result of the favourable growing conditions for rhododendron and the concomitant increase in available oviposition sites. Removal of some of the rhododendron and some local shading from young emergent birch eventually led to a reduction in numbers in 1992. However no specific factors regulating the upper limit of the population size of *Graphocephala*, apart possibly from flower bud frequency were definitely identified. A small percentage of buds suffer bird damage (<5%) with some loss of viable eggs. No egg or larval parasites have so far been detected in the UK, despite repeated searches (1960s and 1980s present survey), nor has bird predation of nymphs been observed.

In post storm years with increasing adult numbers, leafhoppers dispersed to neighbouring plants, particularly bracken (Figure 4). Large swarms were evident in 1990 and 1991, with large numbers occurring on silver birch, a host association not previously recorded (Atkinson 1992).

Adult *G. fennahi* were easily disturbed, so that a walk through the woods in 1990 resulted in wave after wave of adults flying into the surrounding vegetation. This colourful scene was accompanied by a continuous "patter" as insects alighted and scurried over the vegetation, causing a sound similar to that of large raindrops in a brief summer shower.

Canopy distribution of the oak leafhopper *Iassus lanio*

Current knowledge of the distribution of arboreal insects on trees in the British Isles is based mainly on sampling of the lowermost branches and little is known about their occurrence in the canopy above. Many arboreal leafhoppers lay their eggs in next year's leaf buds in late summer. The vertical distribution and frequency of individual species is therefore largely determined by the egg-laying behaviour of females of the previous year.

Sampling of live, fallen oak trees in early summer of the year following the storm showed that more *Iassus* nymphs occurred in the crown and mid canopy than on the lower branches (Figure 8). These figures also suggested that nymphal density increased higher up the tree, since a common sampling unit (0.75 sq m tray) was used. Such differences may have been due in part to a noticeably higher leaf density in the crown than elsewhere.

Although the total number of *I. lanio* in Perry Woods decreased as a result of the storm owing to the loss of many mature oak trees, many individuals survived to complete the next generation on live fallen oaks and partially damaged trees. Regular sampling failed to show any major changes in *Iassus* numbers on surviving trees over the period 1988-92, although numbers were probably too low for useful comparison.

It is possible that egg mortality caused indirectly by bud blast *Pycnostysanus azaleae* (Peck) which kills developing flower buds may have been an important factor locally (Baillie & Jepson 1951).

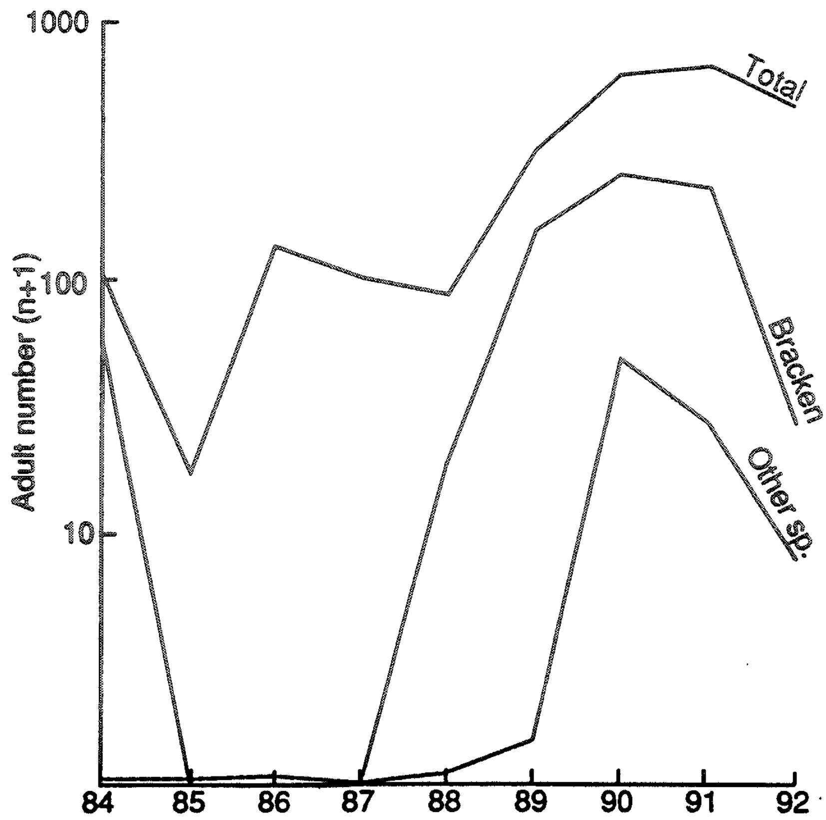

Figure 4 Numbers of Rhododendron leafhoppers, Perry Woods, 1984-1992

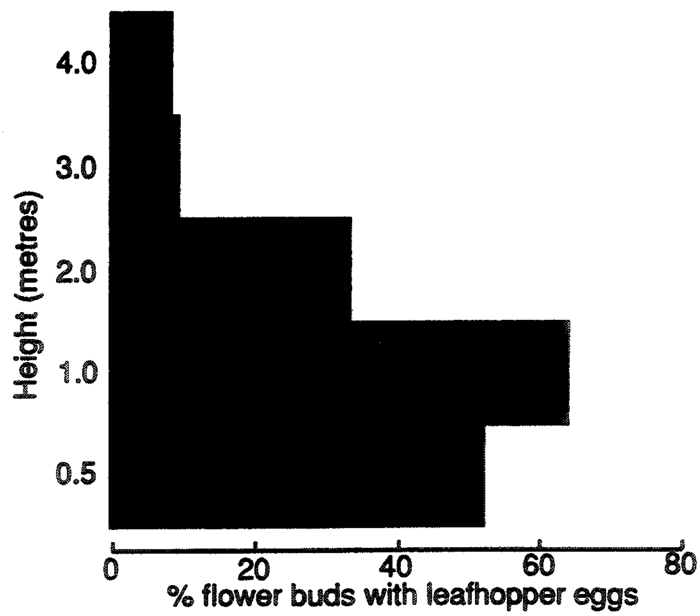

Figure 5 Frequency of flower buds with eggs of *Graphocephala fennahi* in relation to Rhododendron bush height.

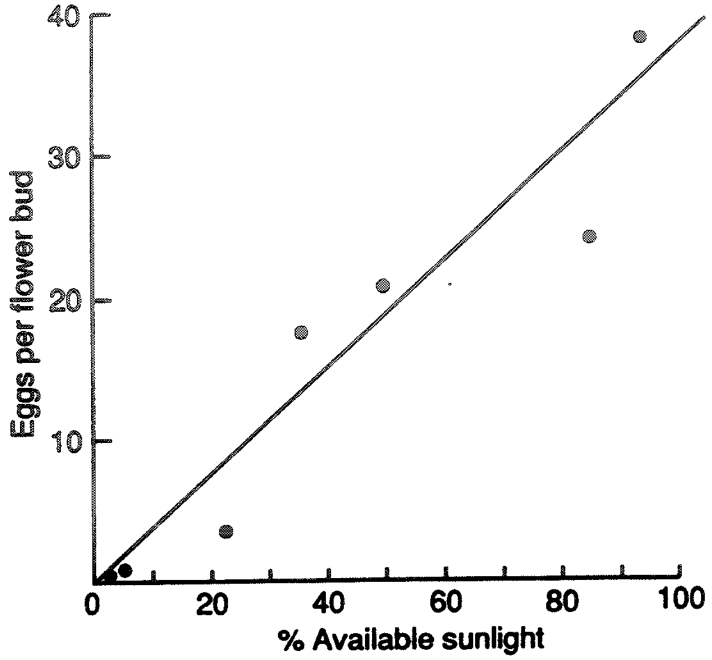

Figure 6 Relationship of leafhopper egg density with available sunlight.

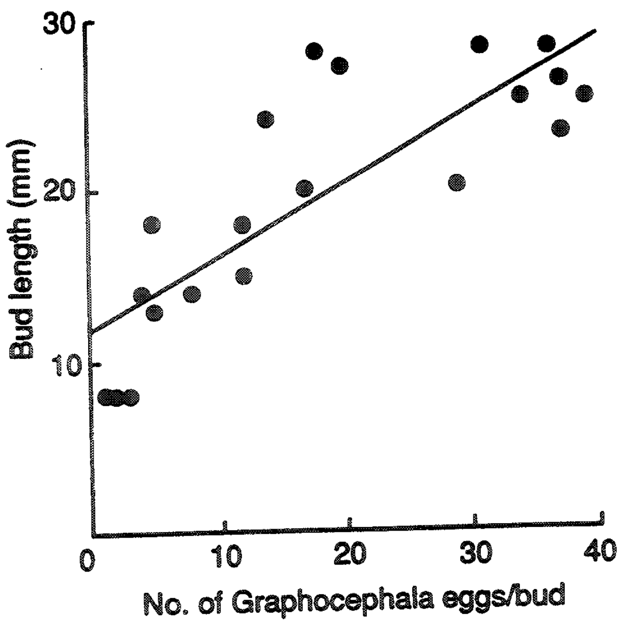

Figure 7 Number of *Graphocephala* eggs relative to Rhododendron bud size (mm)

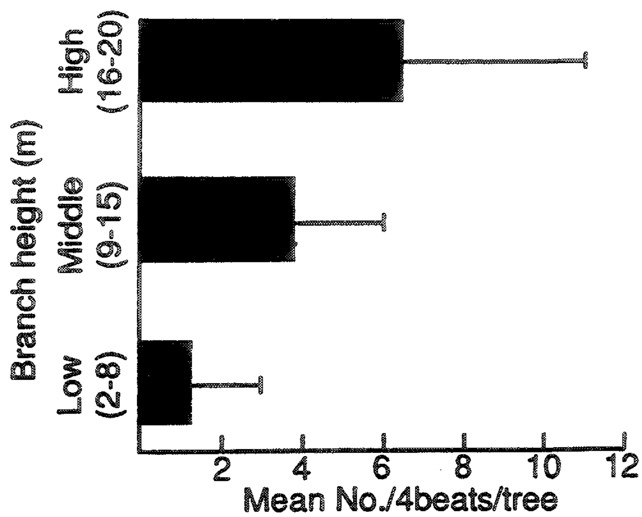

Figure 8 Mean numbers (range) of *Iassus lanio* nymphs on sessile oak at different canopy levels. Data based on five oak trees blown over by the storm in 1987 and sampled in 1988 soon after the leaves had expanded. Bars represent the maximum values recorded.

Discussion

The survey succeeded in its general aim of providing baseline data on species of woodland Auchenorrhyncha with counts before and after the storm. Mobile species were able to move relatively quickly from storm-damaged plants to new hosts as the quality of their habitat declined. Early leaf fall precipitated by the storm was followed by early migration of *Empoasca vitis*. However such trivial movements are not surprising if species are to survive.

The scale of the damage inflicted by the storm was localised and transient so that some of the changes were not detected by the monitoring programme. In the coppice area where monitoring was carried out less than 5% of trees were uprooted and few large canopy gaps were created despite much minor damage. No studies, apart from the bracken and Rhododendron survey were concentrated in gaps so that comparisons between damaged and undamaged areas went largely unmeasured.

The most noticeable changes in leafhopper abundance occurred as a delayed response to changes in vegetational composition in large canopy gaps and areas cleared after the storm. The abundance of *Ditropis pteridis* increased significantly in newly created gaps dominated by bracken to the extent that macropterous individuals, which tend to develop under crowded conditions, were recorded in 1991 and 1992. The effects were more noticeable in large than small gaps. Similarly the open habitat surrounding the Rhododendron plants proved ideal for vegetative growth and flower bud initiation, with the result that more ovipositional sites became available for *Graphocephala* in succeeding years, and numbers of *Graphocephala* reached epidemic proportions in 1990 and 1991 with adults swarming and moving on to nearby vegetation. The swarms were triggered by two separate events: canopy gaps created by the Great Storm of 1987 and the subsequent warmer than average summers of 1989-91, allowing both host plant growth and leafhopper numbers to expand virtually unchecked. Shading from surrounding vegetation in subsequent years subsequently led to a reduction in leafhopper numbers.

The study of leafhoppers on oak trees blown over in the storm showed that more *Iassus* occurred in the upper canopy at 18-20 m, a reminder that the apparent rarity of certain arboreal insects may be an artefact when only the lower, accessible branches are sampled. Comparable data for other groups are conflicting and depend on insect type, age and type of host tree and neighbouring tree species. For example, Moore *et al.* (1991), recorded greater leafhopper densities in the upper canopy of oak in an oak/spruce mixture but lower densities in an oak/alder mixture. Fewer species of invertebrates and a lower species diversity index were recorded in the canopy (5-6 m) of mature hazel coppice (Housego & Gormally 1993).

References

ATKINSON, M.D., 1992. Biological Flora of the British Isles No. 175. *Betula pendula* Roth (*B. verrucosa* Ehrh.) & *B. pubescens* Ehrh. *Journal of Ecology* **80** 837-870.

BADMIN, J.S., 1990. Rhododendron leafhopper in Kent. *Transactions of the Kent Field Club* **11**, 94-97.

BAILLIE, A.F.H. & JEPSON, W.F., (1951). Bud blast disease of the rhododendron in its relation to the leafhopper *Graphocephala coccinea. Forst. J.R. Hort. Soc.* **76** 355-365.

DAVIES, L. & PRITCHARD, C. 1994. An assessment of post-storm woodland action centred on two areas surrounding Sevenoaks and Canterbury in July 1990. In *Ecological responses to the 1987 Great Storm in the woods of south-east England*, edited by K.J. KIRBY & G.P. BUCKLEY, pp 13-23, Peterborough, English Nature (English Nature Science 23).

HOUSEGO, A.J. & GORMALLY, M.J., 1993. Investigation of the invertebrate communities associated with different ages of hazel coppice at Upper Hamble Country Park, Hampshire. *The Entomologist* **112** 3-9.

MOORE, R., WARRINGTON, S. & WHITTAKER, J.B., 1991. Herbivory by insects on oak trees in pure stands compared with paired mixtures. *Journal Applied Ecology* **28** 290-304.

MORCOS, G., 1953. The biology of some Hemiptera-Homoptera (Auchenorhyncha). *Bull. Soc. Fouad 1er Entom.* **37** 405-439.

PETERKEN, G.F., 1981. Woodland conservation and management. London, Chapman & Hall.

POLLARD, E. AND HALL, M.L., 1989. Butterfly monitoring in 1988. *The Entomologist* **108** 229-242.

POLLARD, E., HALL, M.L. & BIBBY, T.J. 1986. *Monitoring the abundance of butterflies, 1976-1985.* Peterborough Nature Conservancy Council (Research & survey in nature conservation 2) 280pp.

SYKES, J.M., 1992. *Environmental Change Network.* Merlewood Institute of Terrestrial Ecology.

TAYLOR, L.R., 1986. Synoptic dynamics, migration and the Rothamsted Insect Survey. *Journal of Animal Ecology* **55** 1-38.

WILSON, P., 1911. Plant distribution in the woods of north-east Kent. *Annals of Botany* **25** 857-902.

STORM-RELATED MONITORING IN A WIDER CONTEXT

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Summary

The 1987 storm was an exceptional event and the studies which it spawned reflect the concern that there should be a permanent record of its impact. There will be patterns in the structure and composition of 21st century woods that originate in the storm. Only if our records, the knowledge of them and the woods themselves, survive will ecologists in 80 years time be able to explain such patterns.

Recording the effect of catastrophic events that have a long-lasting imprint is one argument for making permanent records in woodland. However, gradual changes where almost no difference is detectable from year to year also benefit from such work. Our memories are fallible - are the blackthorn thickets really as dense in Wytham Woods as they were? How should records be set up so details are available before the next change occurs? Sometimes we know that a change is likely and where it will occur; at other times we know the location but not the type of change; sometimes vice versa, and sometimes we can predict neither. The nature of the record systems set up must vary accordingly.

Ad hoc simple records such as photographs scattered across a wide range of sites have proved useful, but can indicate only gross changes in the structure or management in woods. Relatively little can be learnt of the ground flora, fauna and soils. More quantitative records need to be made in the most cost-effective way, often leading to the use of systematic sampling designs within a wood. By analogy to increase the chance that the next big event will affect sites with suitable baseline records a more uniform distribution of sites across the country is needed than exists at present. English Nature should make more of its reserves available for this purpose.

The critical period in many long-term studies is the first ten years - do the details survive the first change of personnel, reorganisation, shift in research priorities? How many of the post-storm initiatives will be picked up? With hindsight could we have made better use of the resources available in 1987-88 by concentrating them on one or two sites or areas? The emphasis in the initial studies was on the woodland structure, with only a few studies on the ground flora response and birds, virtually nothing on invertebrates and nothing (known) on mammals. The opportunity to produce an integrated picture of responses to the storm has been lost. Again this reflects in part a failing on the Nature Conservancy Council's part to promote research on its reserves in a coherent fashion - a lesson English Nature has got to learn.

Introduction

The 1987 storm was for most of us and for the woods it hit exceptional although comparable events can be found in historical and pre-historic records (Allen 1992; Hopkins 1994). The structure and composition of many sites seem likely to bear its imprint well into the 21st century and possibly beyond. It was also unprecedented in the range of studies of its effects that were set up immediately afterwards, most of them stimulated by George Peterken, then Senior Woodland Ecologist with the Nature Conservancy Council (NCC) and supported by Dr Sarah Webster. The value of such work is that it may make it easier for our ecological successors to understand and interpret the patterns that they find in woods that were affected.

The 1987 storm is however only one particular example of such events. Long-term monitoring (or surveillance) may and has been used to understand both these and the more gradual changes that occur within woods. How may we improve our approaches to monitoring particularly on reserves and related sites? Are there lessons to be learnt from the way the studies were set up after the storm that we can use so we are better able to track the impact of future gales, drought, deer damage, disease or whatever?

Sudden events, cyclical change and gradual trends

The 1987 storm is considered to have an average return time of about 200 years (Hopkins 1994) in the south east, although almost as severe weather then re-occurred in January 1990. In the north-west heavy winds tend to be more regular but the scale of damage (at least to semi-natural woods) tends to be smaller. Other types of event may be more widespread in their impact, for example the 1976 drought, Dutch Elm Disease and sudden increases or decreases in grazing/browsing have all altered woods in the last 20 years. They may produce an immediate effect followed by gradual adjustment to a new state, gradual change initially then a sudden switch, or a more or less steady rate of change (Figure 1).

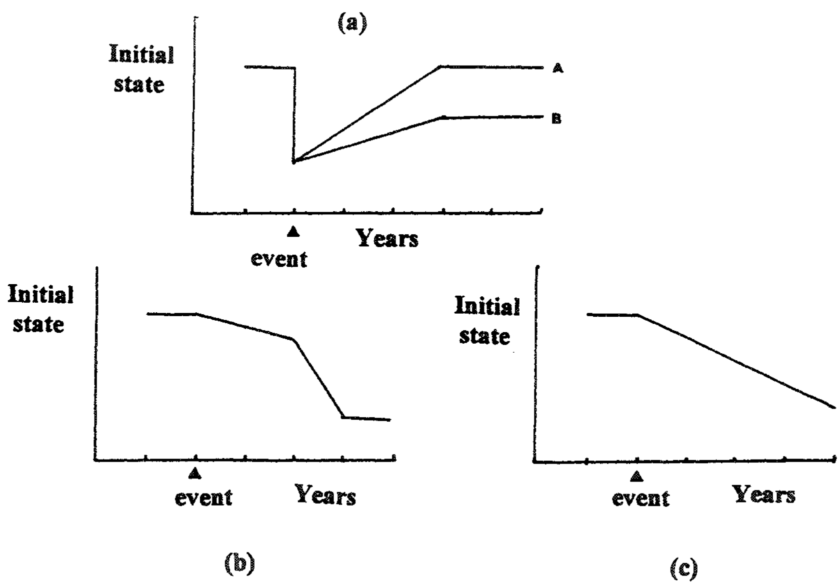

Figure 1 Model patterns in the response of woodland to events and their implications for monitoring.

Impact of:

a. sudden change followed by slow recovery either to the initial state (A) or a new state (B) such as followed the storm;

b. some initial impact but the major effects following a year or two later and continuing as weakened trees die, as for example after repeated droughts;

c. a gradual change which may not be obvious for many years typical of some forms of air pollution;

a. is likely to trigger studies of long-term change. By the time the need is realised for such studies of b. and c. the changes may be already well-advanced.

Our woods are also subject to forces that may produce little apparent effect year-on-year, but have a substantial impact over a long period - for example air pollution leading to soil enrichment, the effects of steady levels of grazing or recreation pressure.

Both sudden and gradual changes are superimposed on the cyclical changes that occur in all woodland as trees and the stands they form age and decay - for example the shifts from open stage to thicket floras, from the warbler-dominated bird fauna of young stands to the hole-nesters typical of old stands. Species differ in how they react to the changing conditions through a stand's life, some shifting their location within the wood, some plants retreating to the soil seedbank, while others rely on being able to survive conditions throughout the cycle.

In any habitat it is unwise to rely on a single survey, a single year's data as guide to the future state of the site but this is particularly so in woods. We must assume that any point is going to change within the lifetime of the stand even in the absence of exceptional events or long term trends, so how can we detect these latter?

The human memory is a very unreliable guide - is the feeling that there were more lily of the valley in Swanton Novers 20 years ago, that the blackthorn thickets in Wytham were denser, any more reliable than that the summer holidays were longer (and sunnier) when we were children? Long-term records are essential, not just to follow the impact of sudden events like the storm which triggered this burst of studies but for the slower changes that we may not recognise until they are well-advanced.

Some aspects of long-term recording

Dawkins and Field (1978), Peterken (1993) and Peterken and Backmeroff (1988) have stressed the key aspects of long-term monitoring in woodland and these are reiterated by Whitbread (1994); the sites must survive, the records must survive and so too must the knowledge of both. Much of the concern has however been with the changes in the structure of the trees and shrub communities and largely (though not entirely) in special minimum intervention sites. Peterken and Backmeroff point out the value of even the simplest records such as photographs - an important point given the limits on resources. However they work best in the open parts of a wood, rides and glades, rather than in the stand. They have limited use for ground flora, fauna or soil studies.

I would like therefore to emphasise more the need to record the ordinary and the managed sites and to include other aspects of the woodland system, not just the trees and shrubs. What is obvious and ordinary now may not seem so in ten, twenty or thirty years time. So which sites should be studied? This relates to the types of change envisaged. Can both its location and the likely nature of the changes of interest be predicted - for example the ground flora in a coppice block or in a grazing enclosure? Can only the location - a road is going through this wood - but not the nature of the main change be stated? Are we more certain of the likely change (increasing recreation leads to more paths) than of where this will occur (we cannot say where the paths will develop)? Over longer periods we can predict neither - storms may or may not occur, they may or may not affect particular regions or woods and if they do will it be the ground flora, trees or birds most affected?

Dawkins and Field (1978) pointed out the value of systematic sampling designs for detecting unforeseen change across a wood. Once an event exceeds a certain size it must be detected and in the same way monitoring efforts should be spread across the country. Greater encouragement for research on our reserves and in other sites where English Nature has some influence is desirable. Similarly if we want to be prepared for the unexpected we must move away from only recording tree and shrub layers. The Dawkins and Field model is again useful (Table 1) even if this level of detail is not always feasible. Different aspects of the wood at each plot were recorded and in different ways to increase the likelihood that one or other would be affected by some future change. This has proved to be the case in recent re-recordings of the plot system (Thomas & Kirby 1992).

Table 1 Records made for each 10 x 10 m plot

(Further details in Dawkins & Field (1978)

General plot characteristics	Slope Aspect List of all vascular plants in plot Features such as rides, banks, ditches
Tree layer (> 2.5 m height)	Total % cover (by tree species) Mean basal area (by tree species) Diameter of four largest trees
Shrub layer (0.5-2.5 m)	Total % cover (not divided by species)
Ground flora (< 0.5 m)	Total % cover (not divided by species) Cover for each of five major dominant species Occurrence of species in 13, 0.1 m quadrats within the plot
Soil	pH, major nutrients, loss on ignition

Monitoring as a basis for prediction/extrapolation

We can simply describe and interpret the changes we see at a point but in most cases consciously or unconsciously the aim is to extrapolate to other areas to predict what will happen. We can compare the development of storm-damaged and undamaged areas and some (but not all) of the studies took this into account when they were set up. Similarly studies have been done on both areas left alone and those where clearance took place. However without pre-storm records to show that two areas were the same we must be wary of using undamaged stands as "controls" for the damaged areas. Pre-existing differences may be the reasons why one area was damaged and the other not.

To overcome this difficulty we need to expand the quality and quantity of recording on sites so that we do have records of what places were like before major events occur.

Initiatives to expand woodland recording

Various initiatives are underway to improve our baseline data. At a European scale there are proposals to form a network of minimum intervention sites where standard records take place (Broekmeyer *et al.* 1993). In Britain the Environmental Change Network, coordinated by the Institute of Terrestrial Ecology has been established, one of its sites being Wytham Woods and other forest sites are being set up in Forestry Commission properties. The Biodiversity and Forest Action Plans deriving from the Rio conference on the environment have added to the impetus to the need for better understanding of long-term changes in woods. The Habitats and Species Directive will require us to monitor the condition of sites selected as Special Areas for Conservation as part of the European Commission's Natura 2000 series.

English Nature is trying to improve its record through better monitoring of SSSIs generally, though much of this will be concerned with fairly gross characteristics of a site. Other public bodies such as the Forestry Commission and MAFF are reviewing what monitoring they require to account for the nature conservation aspects of work done in woods under their grant schemes. If all these schemes can be coordinated there will be a much better set of data about woods in an area from which to judge change. On National Nature Reserves (NNRs) I hope we will see more encouragement for research, which was one of the original reasons for establishing reserves (Marren 1994), and in particular the development of a framework of studies for particular sites and suites of sites so that individual pieces of work can be fitted together (Table 2). The distribution of NNRs is however too patchy for these to be enough on their own: in south-east and south England which have the highest density of ancient woods in the country there are only four significant ancient woodland reserves.

Table 2 **List of woodland reserves for which the following records exist - a butterfly transect, a common Bird Census and a "long-term" vegetation or structural transect or plot record.**

	Butterfly	Bird	Vegetation/structural records
Avon Gorge	✓	✓	
Blean Woods	✓	✓	
Bovey Valley	✓		
Bure Marshes	✓	✓	
Castle Eden Dene	✓		✓
Castor Hanglands	✓	✓	
Chaddesley Wood	✓	✓	
Collyweston Great Wood	✓		
Colt Park			✓
Cotswolds			✓
Derbyshire Dales	✓		✓
Ebbor Gorge	✓	✓	
Finglandrigg Woods		✓	✓
Gaitbarrows	✓		
Golitha Falls	✓		
Hales Wood			✓
Ham Street	✓	✓	✓
High Halstow	✓	✓	
Kingley Vale	✓	✓	
Lady Park Wood			✓
Langley Wood			✓
Monks Wood	✓		✓
Park Wood	✓		
Rodney Stoke	✓	✓	✓
Swanton Novers	✓	✓	
Yarner Wood	✓	✓	✓
Wistman's Wood			✓
Wrens Nest	✓	✓	
Wyre Forest	✓		

The data in Table 2 underestimate the monitoring that is in place - there are many studies on individual species or features that have not been included as well as extensive photographic records. Nevertheless the impression remains that there is a need to try to expand both the coverage of structural/vegetation monitoring in particular to provide a context for work on other organisms.

Lessons from what was done after the 1987 storm

It is possible to build up the enthusiasm and get the resources to set up studies after major "events". The main credit for this is due to George Peterken of the Nature Conservancy Council. By contrast little work was done after the 1990 storms in the south-west (although see Sparshott 1991; O'Dare (1994); Van den Berge *et al.* (1993)) or on the effects of recent droughts other than Paul Harding's (1990) parkland study. However funding for any sort of long-term study is frequently difficult to obtain.

We are at the critical time for many of the projects established in 1987, the first change-over of staff, organisations and people's interest. Several contributors at the conference were uncertain whether they would be able to keep their projects going by themselves, yet we know that these short-term results are only the start of the story. Many of the other projects listed in Whitbread (1991) may not survive to be usable in 5 years or 10 years time. This conference provides a reminder of their existence and an encouragement to take them forward, but there is a need to improve our archiving of results and to update the register of projects.

With hindsight (this is intended not as a criticism but as a guide to how we should plan future campaigns) did we make the right disposition of the resources we had in 1987? The range of studies carried out from overviews to detailed studies of particular sites is very valuable, but I think an opportunity was lost to produce a more coherent picture. There appears to be little data on invertebrate changes (Key 1994) on lichens (O'Dare 1994; Rose 1988) or fungi (Boddy (1994)) and nothing so far noted on mammals. In very few instances have surveys for different species groups been combined on the one site or data from different levels of surveys been put together. Only some of the studies contain control areas and good statistical designs that enable extrapolation from the immediate area surveyed. There have been virtually no experimental studies -that by Ferris-Kaan (1994) is a notable exception, but it is not in the sort of site with which most ecologists and nature conservationists have been concerned.

Would it have been better to have identified one or two key sites and then actively encouraged a diversity of work on these rather than spreading the funding across often similar studies on different sites? Had the Nature Conservancy Council been better prepared by having in place an existing programme of research on the main reserves in the area such a key site approach might have been easier to implement. English Nature must learn from this.

Could there have been better coordination between the work done on ecological matters (largely run by the Nature Conservancy Council, universities, local wildlife trusts and local authorities) and the restoration programmes of Task Force Trees and the Forestry Commission? Could this be improved in future?

The value of hindsight is that we can learn how to do things better next time. The next storm may be only just round the corner.

References

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

BODDY, L. 1994. Wood decomposition and the role of fungi: implications for woodland conservation and amenity management. In *The rehabilitation of storm-damaged woods* edited by J.W. SPENCER & A. FEEST, pp 7-30, Bristol, University Department for Continuing Education.

BROEKMEYER, M.E.A., VOS, W. & KOOP, H. 1993. *European forest reserves.* Wageningen, Pudoc.

DAWKINS, H.C. & FIELD, D.R.B 1978. *A long-term surveillance system for British woodland vegetation.* Oxford, Commonwealth Forestry Institute (occasional Paper 39).

FERRIS-KAAN, R. 1994. Monitoring of vegetation changes on a minimum intervention area, Rendlesham Forest, Suffolk, following 1987 storm damage. In *Ecological responses to the 1987 Great Storm in the woods of south-east England* edited by K.J. KIRBY & G.P. BUCKLEY, pp 56-63, Peterborough, English Nature (English Nature Science 23).

HARDING, P.T. 1990. *Damage to ecologically important trees in selected pasture woodlands resulting from winter storms and summer drought in 1990.* Peterborough Nature Conservancy Council, (Commissioned Research Report).

HOPKINS, B. 1994. The storm. In *Ecological responses to the 1987 Great Storm in the woods of south-east England* edited by K.J. KIRBY and G.P. BUCKLEY, pp 1-11, Peterborough English Nature (English Nature Science 23).

KEY, R.S. 1994. The storms of 1987 and 1990: threat or opportunity for woodland invertebrates. In *The rehabilitation of storm-damaged woods*, edited by J.W. SPENCER & A. FEEST, pp 45-58, Bristol, University Department for Continuing Education.

MARREN, P. 1994. *England's National Nature Reserves.* London, Poyser.

O'DARE, A.M. 1994. The storms of early 1990: problems for the lichen flora. In *The rehabilitation of storm-damaged woods* edited by J.W. SPENCER & A FEEST, pp 31-38, Bristol, University Department for Continuing Education.

PETERKEN, G.F. 1993. Long term studies in forest nature reserves. In *European forest reserves* edited by M.E. BROEMEYER, W. VOS & H. KOOP, pp 35-48, Wageningen, Pudoc.

PETERKEN, G.F. & BACKMEROFF, C 1988. *Long-term monitoring in unmanaged woodland nature reserves.* Peterborough, Nature Conservancy Council (Research and survey in nature conservation 9).

ROSE, F. *Lichen surveys of sites in West Sussex to assess the effects of the hurricane of 16 October 1987.* Lewes, Nature Conservancy Council (unpublished report).

SPARSHOTT, R. 1991. *The response of the Nature Conservancy Council in south-west England to the storms of January 1990.* Taunton, English Nature.

VAN DEN BERGE, K, MADDELEIN, D. & MUYS, B. 1993. Recent structural changes in the beech forest reserve of Groenendaal (Belgium). In *European forest reserves*, edited by M.E. BROEKMEYER, W. VOS & H. KOOP, pp 195-198, Wageningen, Pudoc.

WHITBREAD, A.M. 1991. *Research on the ecological effects on woodland of the 1987 storm.* Peterborough, Nature Conservancy Council (Research and survey in nature conservation 40).

WHITBREAD, A.M. 1994. Surveys of storm-damaged woods set up in 1987-88. In *Ecological responses to the 1987 great storm in the woods of south-east England*, edited by K.J. KIRBY & G.P. BUCKLEY, pp 24-31, Peterborough, English Nature (English Nature Science 23).