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Beech tree health survey 1991-2

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University of London

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FORWARD

This Research Report is the third Beech tree health report produced by Imperial College for NCC/EN. The previous reports were produced in the NCC CSD series as numbers 949 and 1248 and included tree health surveys for the four years 1987-1990. This report takes the survey into its fifth year. It consists of two parts. The first is a summer survey when trees were scored for crown density and chlorosis. The second part contains the winter survey for crown architecture.

The survey was conducted on the same trees at the same sites by the same observers over the five year period. This consistency and detail is unique for tree health studies in the UK.

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Andrew Farmer
1992

BEECH TREE HEALTH IN SOUTHERN BRITAIN.

The Results of the 1991 summer survey

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SUMMARY

1. The health of beech in southern Britain has been assessed at sixteen sites for five successive years. There has been a marked deterioration in the density of tree crowns over the past three years, and in the summer of 1991, over 50% of the trees were found to be in the worst two categories for crown thinness.

2. This deterioration in health is not uniform across all sites. At some sites, poor health seems to be linked to damage resulting from the storms of 1987 and 1990. However, there are sites at which there is no obvious reason for the decline in crown density.

3. At an individual tree level, 44% of trees have shown no change in crown thinness between 1989 and 1991, whilst 46% have undergone a decline in health. however, 10% of trees have improved in health, suggesting that reductions in crown density are not irreversible.

4. There is no clear temporal pattern for crown chlorosis. Only 1.5% of all trees surveyed in 1991 were in the top two chlorosis categories, and these were restricted to sites with calcareous sub-soil.

1 INTRODUCTION

The Imperial College survey of beech tree health was set up in 1987 to assess the health of beech throughout its natural range in Britain, and to look for associations between tree health, local site factors (eg. soil type, slope, management etc.), meteorological and pollution levels. Emphasis was placed on woods of conservation value, and the majority of trees fell within the age range 80-140 years. In this initial survey, 24 sample trees were assessed at each of 72 sites, over the 2 year period 1987-1988. Several methods of health assessment were used, including summer and winter assessments (see below). The results of the analysis suggested that the health of beech was only moderate, and that it was greatly influenced by such factors as soil type, pH, disturbance, tree age and the openness of the crown. In addition, drought, sulphur dioxide, and various nitrogen compounds were found to be linked to different measures of tree health (Power *et al* 1989).

Sixteen of the original 72 sites were chosen for continued monitoring, and these have assessed annually since 1989. Six of these were assessed in 1987 and 1988, and as such now have 5 years of continuous data for the summer assessments. The others were assessed either in 1987 or 1988. The sites were chosen to represent a range of soil types and pollution climates, and the characteristics of each site are given in Appendix 1. Figure 1 shows the geographical distribution of these sites.

This report gives the results of the 1991 summer assessment of beech tree health, and puts this in the context of regional and local changes in health over the past 4-5 years.

2 METHODS

a) Tree Health Assessment

As in previous years, the health of the trees was assessed in the following way:

i) Crown thinness. Trees were assigned to one of four classes (0-3), corresponding to their percentage reduction in overall crown density, with category 0 representing minor (<10%) reduction and category 3 severe (>60%) reduction in crown density. Standard photographs of beech trees (Bosshard 1986), were used to aid assessment. In addition, a few trees which had lost all their leaves were assigned to crown thinness category 4.

ii) Crown chlorosis. The overall extent and intensity of chlorosis (yellowing) was recorded using a combined scale of 0-3, representing no chlorosis through to severe, widespread yellowing of the tree crown.

In addition, the following variables were recorded:

iii) Localised chlorosis. The intensity of yellowing of patches constituting less than 10% of the entire crown, on a 4 point scale (0-3). Much of the localised chlorosis observed was due to yellowing of leaf tips.

iv) Leaf roll. The overall extent and intensity of leaf roll was recorded on a 4 point scale (0-3).

v) Biotic leaf damage. Recorded on a presence/absence basis, and identified as holes in the leaves or necrotic patches.

vi) Mast. The amount of mast was recorded on a 4 point scale (0-3).

Figure 1.
Map showing the location of survey sites

Names of sites given in Appendix 1.

b) Lost Sample Trees

During the 1987-1991 period, a number of sample trees have been lost, either through felling, or as windblows, in particular as a result of the high winds of October 1987 and January 1990. In total, 38 of the original 384 trees have been lost, with just three of these lost between the 1990 and 1991 assessments (two as windblows, one through felling). Certain sites have been particularly hard hit, such as Denny Wood, where only 17 of the original 24 trees remain. The numbers of trees standing at each site is given in Appendix 2.

Power and Ashmore (1991) explored the possibility that trees in poor health were being preferentially lost as windblows, but found that at most sites where trees had been lost, the missing trees came from a cross section of health classes. At Denny Wood, all the trees lost were from the healthiest two crown thinness categories. However, to avoid any possibility of bias in the data, all analyses presented here have been carried out on data for only those trees standing in 1991. In addition, 5 trees still standing but with no leaves (crown thinness category 4) have been excluded from the crown chlorosis assessment.

3 RESULTS

The 1991 results for crown thinness, chlorosis and other variables assessed for all sites are given in Table 1.

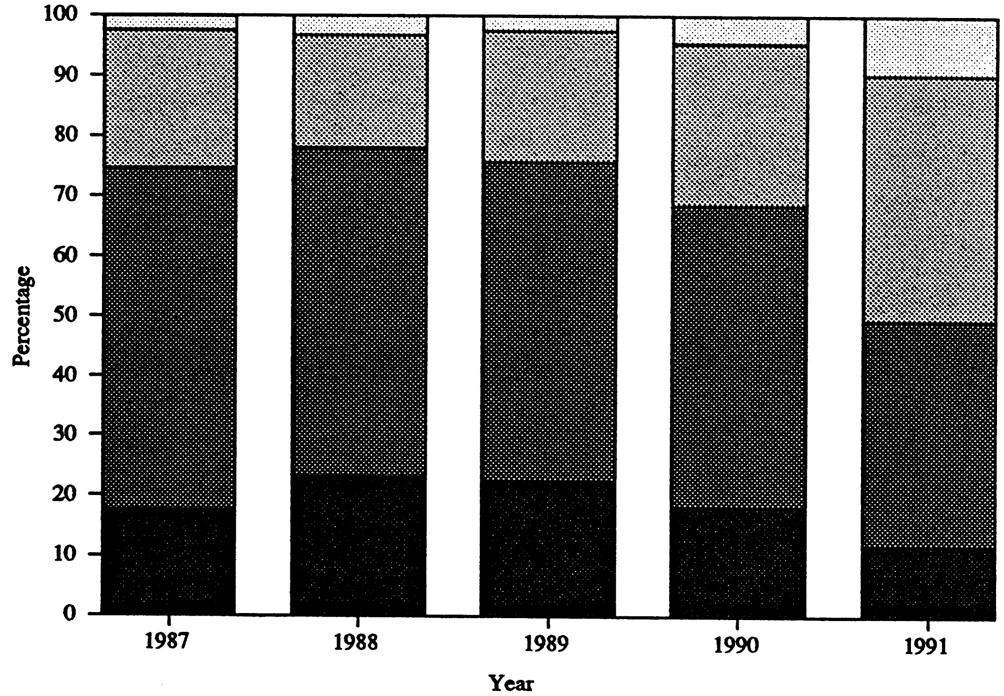
Table 1. Percentage of trees in each category for crown thinness and crown chlorosis as assessed in 1991.

	Category			
	0	1	2	3&4
Crown Thinness	11.8	37.6	40.8	9.8
Crown Chlorosis	66.6	31.9	1.5	0
Localised Chlorosis	36.1	56.6	7.3	0
Leaf Roll	38.6	54.1	7.3	0
Leaf Damage	78.8	21.2	0	0
Mast	83.9	16.1	0	0

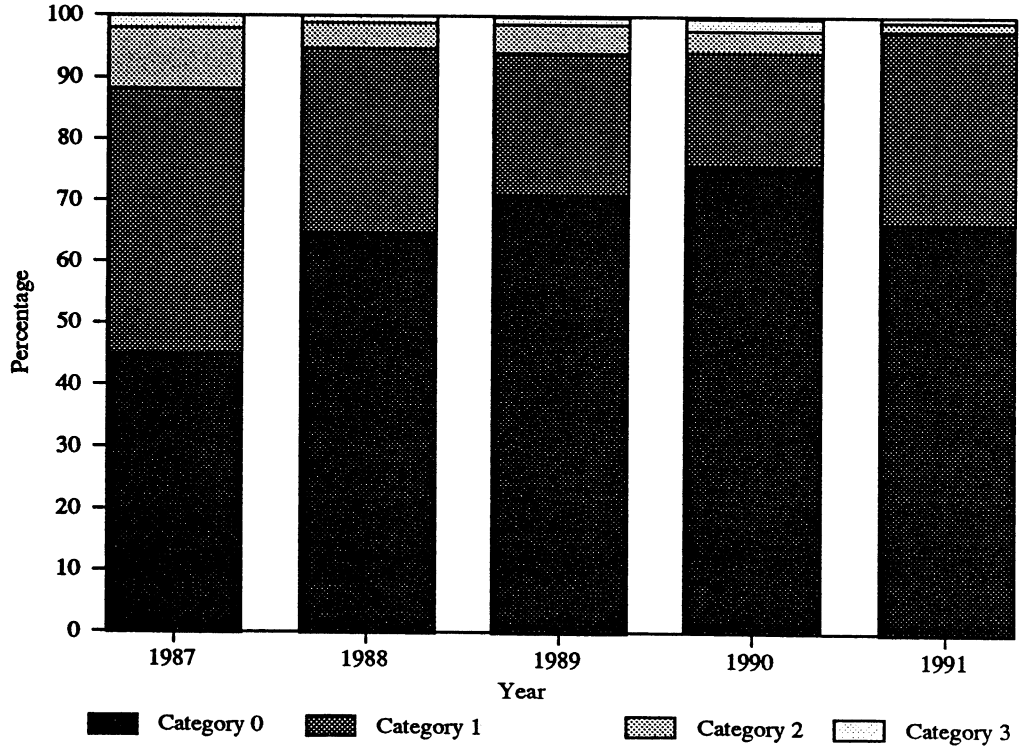
Figure 2 shows how these figures compare with assessments made between 1987 and 1990 (the percentage data is given at the end of Appendix 2). Crown thinness seems to have improved slightly in 1988, with 1989 results being broadly similar to those of 1987. However, in 1990 and 1991, the number of trees in categories 2 and 3 has increased dramatically, with approximately twice as many trees in these categories in 1991 as in 1987. This increase has been particularly sharp in 1991. For crown chlorosis, there is no clear temporal pattern, with levels of chlorosis encountered in 1991 being very similar to those of 1988. There are, however, slightly less trees in the top two categories than in previous years, and these were restricted to sites with calcareous sub-soil.

Figure 2. Changes in tree health between 1987 and 1991 for all sites

(a) Crown Thinness



(b) Crown Chlorosis



However, it is not strictly correct to compared the results from all sites over the whole 1987-1991 period, as not all the sites surveyed in 1987 were assessed in 1988 and vice versa. The improvement in health noted in 1988 could be due to the new sites having generally denser crowns. Figure 3 gives the results for the 6 sites which have been assessed every year. This shows the same temporal trend for crown thinness, although the overall health of these sites is worse than that of all 16 sites together.

The amount of localised chlorosis was light and generally restricted to the leaf tips, but was considerably more common than overall chlorosis. Its distribution shows no relation to soil type, being found to a greater or lesser extent at all sites. Like local chlorosis, the amount of leaf roll was widespread but generally light. Rolling was usually restricted to the top of the crown. Leaf damage was widespread but of low intensity, and was probably caused by the leaf miner *Rhynchaenus fagi* (Bevan 1987). The amount of mast was also very low, with only one tree meriting a score of 2.

A comparison of overall results, although revealing a pattern of worsening health for crown thinness, does not tell us anything about the changes that may have taken place at individual sites. The results for all years of survey at each site are given in Appendix 2. Power and Ashmore (1991) analysed the data on an individual site basis using the Wilcoxon signed rank test to compare tree health in 1987/8 and 1990. This exercise has been repeated on the 1990 and 1991 data, and the results of both analyses are presented in Table 2.

Power and Ashmore (1991) noted that those sites showing either no change in crown thinness, or an improvement, were generally on deep, well-drained soils of intermediate pH. When considering the changes which took place between 1990 and 1991 as well, it is harder to distinguish any clear patterns. The four sites where crown thinness has either improved or has not changed significantly (Kings Forest, Ash Hill, Castell Coch and Beechwoods) cover a wide range of soil types, pH and slopes (see Appendix 1). For some of the sites with significant reductions in crown thinness, deterioration in health can be linked to the extent and timing of disturbance in the wood, in particular the effects of the high winds of 1987 and 1990. For example, Chappett's Copse, Common Wood and Denny Wood all lost trees in the October 1987 storms and all underwent a decline in health during the 1987-1990 period. Burnham Beeches, Chappett's Copse, Denny Wood and Savernake lost trees in the 1990 storms, whilst felling in the vicinity of sample trees at Belleview Plantation in recent years has considerably opened up the canopy. All these sites, with the exception of Denny Wood, had a significant decrease in crown thinness score between 1990 and 1991. However, there are sites at which there is no obvious reason for the decline in crown density, such as Epping Forest and Cotswolds Beechwoods.

In 3 instances, a significant change in crown thinness score is accompanied by a similar change in crown chlorosis over the 1990-91 period. Otherwise, there seems to be no regional or soil-related trends in the changes witnessed.

Many scientists have argued that category 1 represents a warning stage whereas trees in category 2 have suffered a real deterioration in health. The Wilcoxon signed rank test gives equal weight to all category changes, whereas it can be argued that the most important changes are those between categories 0+1 and 2+3. Figure 4 illustrates how the percentage of trees in categories 2+3 have varied at each site over the survey period.

This data gives a quite different picture to that of the Wilcoxon test. For a number of sites, 1989 was a particularly good year, from which they have experienced either a steady increase in numbers of trees in category 2+3, or returned to levels approximating those when first surveyed. The significant reductions in crown thinness score given by the Wilcoxon test for Wychwood and Cannock Chase seem to be due to a particularly good year in 1990, rather than a real decline in health. However, there are certain sites, like Savernake, Chappett's Copse, Burnham Beeches, Denny Wood, Cotswolds Beechwoods and Belleview, where the increase in numbers of trees in these two categories has been dramatic and sudden.

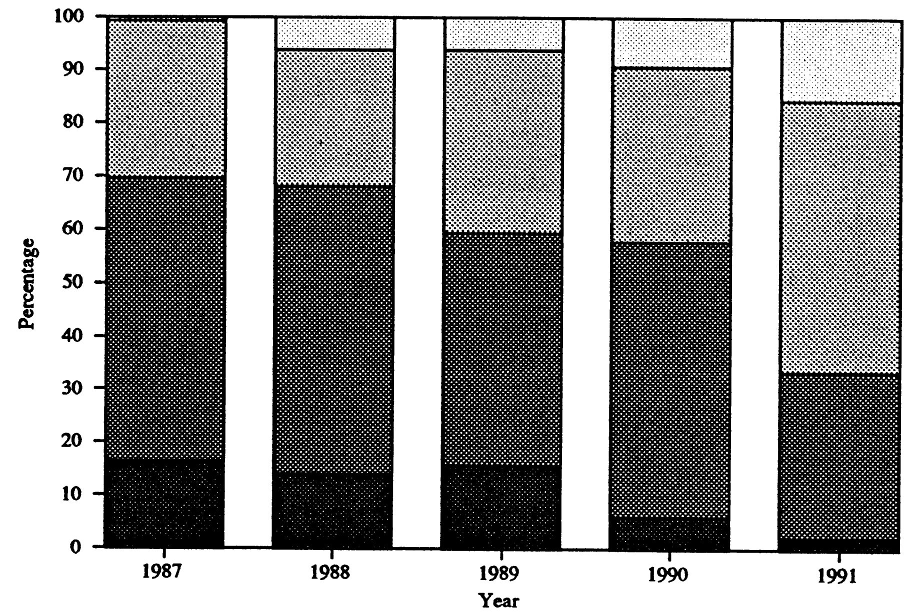
Table 2. Summary of significant changes in crown thinness and chlorosis score on a site basis between 1987/8 and 1990, and between 1990 and 1991.

Site	Crown Thinness		Crown Chlorosis	
Site	1987/8 to 1990	1990 to 1991	1987/8 to 1990	1990 to 1991
Cotswolds Beechwoods	-	---	n.s.	n.s.
Denny Wood	--	n.s.	+++	n.s.
Savernake	-	--	n.s.	--
Staffhurst	-	n.s.	++	n.s.
Common Wood	-	n.s.	++	n.s.
Kings Forest	++	n.s.	+	n.s.
Beechwoods	n.s.	n.s.	n.s.	+
Burnham Beeches	n.s.	--	++	n/a
Chappett's Copse	-	--	n.s.	+
Epping Forest	n.s.	--	n.s.	n/a
Belleview Plantation	n.s.	--	+++	--
Ash Hill	n.s.	n.s.	n.s.	n/a
Cannock Chase	n.s.	-	+	n/a
Forest of Dean	--	n.s.	+	n/a
Wychwood	+	--	n.s.	--
Castell Coch	n.s.	n.s.	-	n.s.

+/-, ++/--, +++/--- represent a significant improvement/deterioration in crown thinness scores at the $P<0.05$, $P<0.01$ and $P<0.001$ levels of significance. n.s. indicates no significant difference. n/a indicates insufficient differences to carry out the test.

Figure 3. Changes in tree health between 1987 and 1991
for those sites surveyed in both 1987 and 1988.

(a) Crown Thinness



(b) Crown Chlorosis

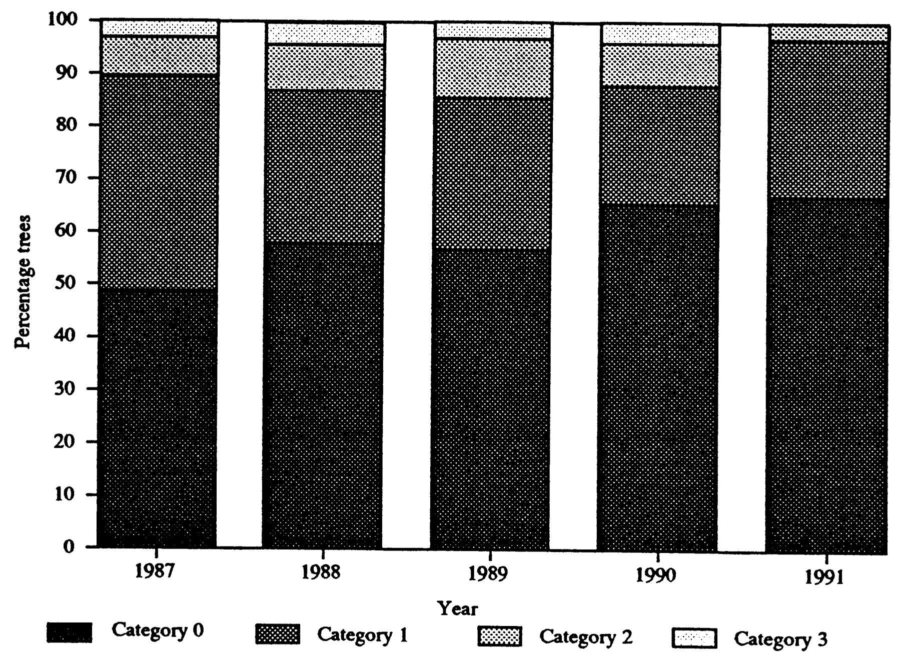
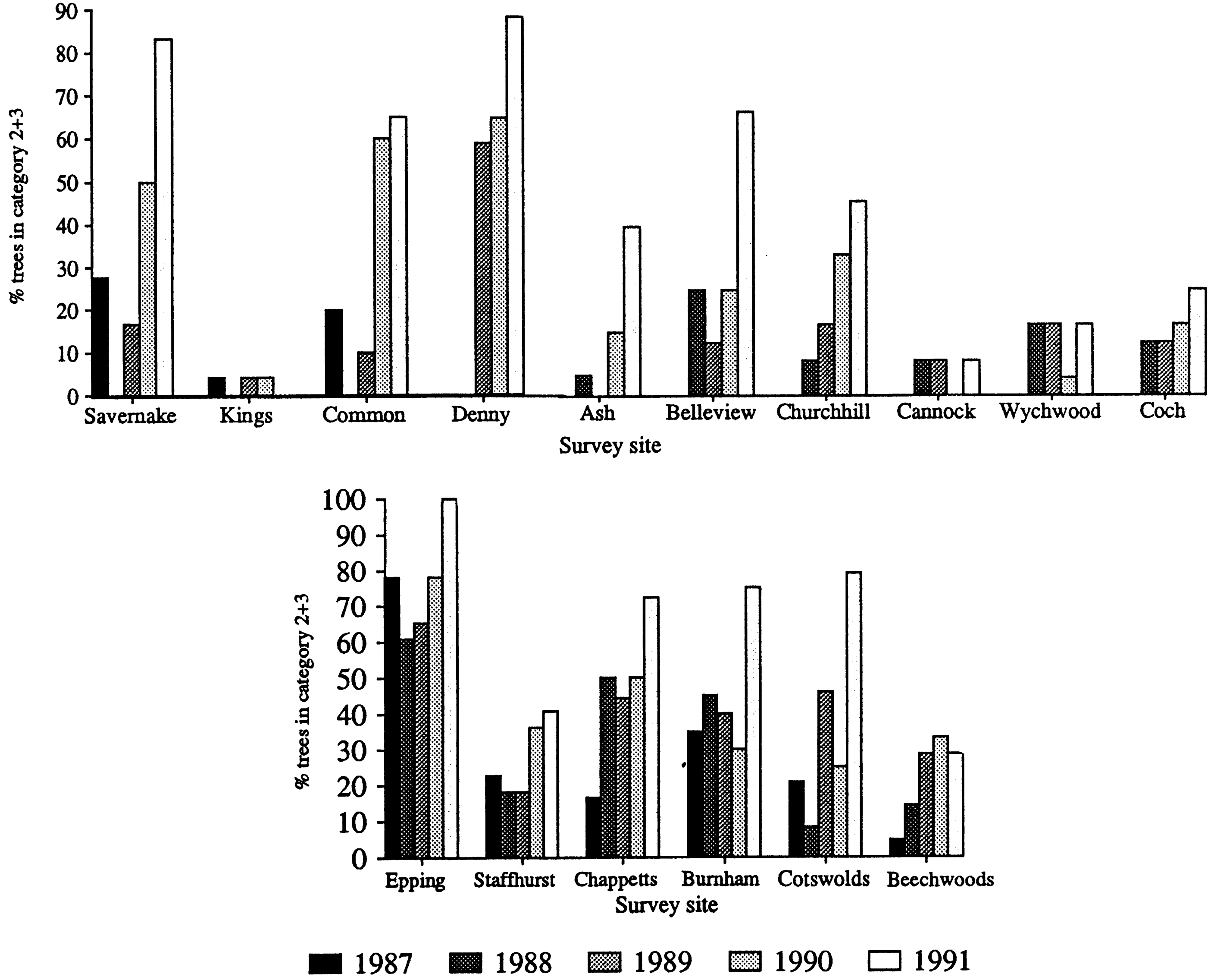


Figure 4. Changes in crown thinness score between 1987 and 1991 at each survey site.



It is also interesting to look at changes in health score at an individual tree level, to gain an idea of within-site year to year variability. Table 3 summarised the changes which have taken place between 1989 and 1991. Around 44% of all trees showed no change in crown thinness score over this period, 38% underwent a decline in score of 1 category, and 8% decreased by 2 or more categories. On the other hand, only 10% of trees improved in health, the majority of these moving from category 1 to 0. However, an appreciable number of trees changed from category 2 to category 1, suggesting that declines in health are not irreversible.

Table 3. Number of trees with given crown thinness scores in 1989 and 1991. n=346.

		Crown thinness score in 1991			
		0	1	2	3
Crown thinness score in 1989	0	22	38	15	2
	1	18	78	78	11
	2	0	14	47	14
	3	0	0	2	7

4 DISCUSSION

The dramatic increase in crown thinness witnessed in 1991 raises the possibility that this may be a reflection of observer bias, rather than a genuine decline in health. Whilst it is impossible to rule this out, it is important to note that in terms of numbers of trees in category 2&3 (Figure 4), some sites are the same, or have improved, with respect to their first crown thinness assessment in 1987/88. Also, the decrease in health witnessed in 1991 is a continuation of a trend which seems to have existed, in particular at the sites with a full 5 years of data, since the trees were first assessed. The Forestry Commission have suggested that forest condition oscillates from year to year, but overall maintains a steady state (Innes & Boswell 1990). Certainly, the results from this survey do not support this hypothesis.

Power and Ashmore (1991) found no relationship between tree health at these sixteen sites, and levels of air pollution in 1990. Whilst it is possible that chronic exposure to low levels of pollutant will contribute to some extent to the health of trees, annual variations in climate are likely to have a more obvious effect. The Forestry Commission has suggested that the marked improvement in health seen in their survey trees in 1989 was the result of wet summers in 1987 and again in 1988, combined with a mild winter in 1988/89, which resulted in excellent shoot growth and relatively high levels of foliage (Innes & Boswell 1990). It is known that many temperate, deciduous tree species undergo a lag in their response to perturbations, with the conditions prevailing whilst the buds are being formed being more important than those during bud burst and shoot extension (Kozlowski *et al* 1990). Studies of past patterns of shoot growth in beech in Southern Britain have shown quite clearly troughs for years following drought (Lonsdale *et al* 1989, Power & Ashmore 1991). Soil moisture deficit was particularly high at all sites in both 1989 and 1990, as were the summer temperatures, and it may be that the poor tree health found in 1991 was a reflection of near drought conditions which prevailed in 1990. If this is so, one might expect next year's growth to improve, following the mild and wet early part of the 1991 summer.

1989 and 1990 were also years of relatively high levels of ozone in southern Britain. A number of studies (Usher 1984, Ashmore 1984, Taylor *et al* 1989) in southern England have shown effects of filtration of ambient air on the growth or physiology of seedlings of broadleaved tree species, including beech. Although is is not possible to attribute these effects to a specific pollutant, there is little doubt that the major pollutant in rural southern Britain responsible for changes in plant performance is ozone (U.K. TERG 1988). Fumigation experiments, using realistic concentrations of ozone administered in episodes, showed significant growth effects on beech, with the direction of the response varing with the water status of the plant (Garretty & Ashmore 1991). Unfortunately, until modelling of ozone concentrations in the UK has improved, it is impossible to look for associations between the spatial distribution of beech health and the levels of this pollutant.

The relatively high amount of leaf roll (61%) seen was a feature of the 1991 summer assessment. Previously levels have been around 30% (Power *et al* 1989). The Forestry Commission survey has shown an increase in the incidence of leaf roll, from around 20% in 1987 and 1988, to over 50% in 1989 (Innes & Boswell 1987, 1989, 1990), and have suggested that it might be related to water stress, though they found no relationship with soil moisture deficit. They found that rolling was more extensive on trees with thinner crowns (Innes & Boswell 1990) and also noted a regional pattern to the distribution of leaf roll, with it being more frequent in the south east. This survey revealed no such spatial pattern, but a chi-squared analysis revealed a significant ($P<0.01$) relationship between crown thinness score and leaf roll. Both variables may be sensitive to the same environmental stresses, although it is also possible that the leaf roll is responsible, at least in part, for the thinness of the tree crown and thus is influencing this assessment.

5 ACKNOWLEDGEMENTS

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APPENDIX 1

Summary characteristics of survey sites

No.	Site	County	Grid Ref.	Status	Soil Type	Soil pH	Age Range
1	Cotswolds Beechwoods	Gloucs.	SO 898109	SSSI	Brown rendzina	6.7-6.9	120-125
2	Denny Wood	Hants.	SU 300100	SSSI	Typical stagnogley	3.8-4.4	100-110
3	Savernake Forest	Wilts.	SU 227644	FC	Stagnogleyic paleoargilic brown earth	4.1-4.9	95-100
4	Staffhurst Wood	Surrey	TQ 411487	SSSI	Typical stagnogley	3.8-6.0	120-130
5	Common Wood	Bucks.	SU 911950	-	Stagnogleyic paleoargilic brown earth	3.1-3.5	110-120
6	Kings Forest	Suffolk	TL 822760	FC	Typical brown calcareous sand	5.6-7.9	80-85
7	Beechwoods	Cambs.	TL 620597	LNR	Grey rendzina	7.8-8.0	110-125
8	Burnham Beeches	Bucks.	SU 950857	SSSI	Paleoargylic stagnogley	3.3-3.7	100-140
9	Chappetts Copse	Hants.	SU 654234	LNR	Grey rendzina	7.5-8.1	100-120
10	Epping Forest	Essex	TQ 420980	SSSI	Paleoargylic stagnogley	3.9-4.2	110-120
11	Belleview Plantation	Devon	SY 134972	-	Typical humic gley/Typical brown earth	3.6-4.2	100-120
12	Ash Hill	Devon	SY 065927	LNR	Typical brown earth	3.7-4.0	100-140
13	Cannock Chase	Staffs.	SK 053147	FC	Typical brown sand	4.1-5.1	85-95
14	Forest of Dean	Gloucs.	SO 631091	FC	Pelostagnogley	4.1-4.6	80-100
15	Wychwood	Oxon	SP 335165	NNR, SSSI	Typical argylic brown earth/Brown rendzina	5.4-7.1	80-100
16	Castell Coch	S. Glam.	ST 130827	SSSI	Typical brown earth/Brown ranker	5.4-7.3	100-140

SSSI - Site of Special Scientific Interest

NNR - National Nature Reserve

FC - Forestry Commission

LNR - Local Nature Reserve

APPENDIX 2

Percentage of trees in each health category for sites surveyed 1987/88 to 1991
NB. Only those trees standing in 1991 have been included.

Site	Year	Crown Thinness				Crown Chlorosis			
		0	1	2	3	0	1	2	3
Cotswolds Beechwoods	1987	33.3	45.8	20.8	0	70.8	20.8	8.3	0
	1988	12.5	79.2	8.3	0	66.7	29.2	4.2	0
Number of trees = 24	1989	8.3	45.8	41.7	4.2	25	54.2	20.8	0
	1990	4.2	70.8	25.0	0	66.7	20.8	8.3	4.2
	1991	0	20.8	75.0	4.2	79.2	16.7	4.2	0
Denny Wood	1987	35.3	64.7	0	0	0	55.6	44.4	0
	1988	-	-	-	-	-	-	-	-
Number of trees = 17	1989	0	41.2	58.8	0	66.7	33.3	0	0
	1990	0	35.3	52.9	11.8	66.7	33.3	0	0
	1991	0	11.8	76.5	11.8	66.7	33.3	0	0
Savernake	1987	11.1	61.1	27.8	0	100	0	0	0
	1988	-	-	-	-	-	-	-	-
Number of trees = 18	1989	22.2	61.1	16.7	0	94.4	5.6	0	0
	1990	0	50.0	44.4	5.6	100	0	0	0
	1991	0	16.7	61.1	22.2	44.4	55.6	0	0
Staffhurst	1987	18.2	59.1	22.7	0	13.6	77.3	9.1	0
	1988	31.8	50.0	18.2	0	40.9	45.5	13.6	0
Number of trees = 22	1989	22.7	59.1	18.2	0	77.3	22.7	0	0
	1990	0	63.6	31.8	4.5	63.6	36.4	0	0
	1991	4.5	54.5	40.9	0	36.4	63.6	0	0
Common Wood	1987	15.0	65.0	2.00	0	10.0	75.0	15.0	0
	1988	0	-	-	-	-	-	-	-
Number of trees = 20	1989	25.0	65.0	10.0	0	85.0	15.0	0	0
	1990	0	40.0	60.0	0	50.0	45.0	5.0	0
	1991	0	35.0	55.0	10.0	60.0	40.0	0	0
Kings Forest,	1987	21.7	73.9	4.3	0	47.8	52.2	0	0
Thetford	1988	-	-	-	-	-	-	-	-
Number of trees = 23	1989	52.2	43.5	4.3	0	100	0	0	0
	1990	65.2	30.4	4.3	0	82.6	17.4	0	0
	1991	43.5	56.5	0	0	65.2	34.8	0	0

Site	Year	Crown Thinness				Crown Chlorosis			
		0	1	2	3	0	1	2	3
Beechwoods	1987	28.6	66.7	4.8	0	69.6	30.4	0	0
	1988	28.6	57.1	14.3	0	78.3	21.7	0	0
Number of trees = 21	1989	38.1	33.3	28.6	0	65.2	30.4	4.3	0
	1990	23.8	42.9	33.3	0	60.9	30.4	8.7	0
	1991	9.5	61.9	28.6	0	91.3	8.7	0	0
Burnham Beeches	1987	0	65.0	35.0	0	35.0	60.0	5.0	0
	1988	5.0	50.0	45.0	0	75.0	25.0	0	0
Number of trees = 20	1989	20.0	40.0	35.0	5.0	80.0	20.0	0	0
	1990	5.0	65.0	25.0	5.0	85.0	15.0	0	0
	1991	0	25.0	65.0	10	80.0	20.0	0	0
Chappett's Copse	1987	16.7	66.7	16.7	0	6.7	40.0	26.7	26.7
	1988	5.6	44.4	27.8	22.2	0	40.0	40.0	20.0
Number of trees = 18	1989	5.6	50.0	33.3	11.1	0	20.0	53.3	26.7
	1990	5.6	44.4	27.8	22.2	6.7	26.7	40.0	40.0
	1991	0	27.8	38.9	33.3	6.7	73.3	20.0	0
Epping Forest	1987	0	21.7	73.9	4.3	80.9	19.0	0	0
	1988	0	39.1	43.5	17.4	76.2	19.0	4.8	0
Number of trees = 23	1989	0	34.8	47.8	17.4	80.9	19.0	0	0
	1990	0	21.7	52.2	26.1	95.2	4.8	0	0
	1991	0	0	52.2	47.8	90.5	9.5	0	0
Belleview Plantation	1987	-	-	-	-	-	-	-	-
	1988	16.7	58.3	20.8	4.2	29.2	70.8	0	0
Number of trees = 24	1989	25.0	62.5	8.3	4.2	91.7	8.3	0	0
	1990	8.3	66.7	20.8	4.2	100	0	0	0
	1991	0	33.3	41.7	25	50.0	50.0	0	0
Ash Hill	1987	-	-	-	-	-	-	-	-
	1988	30.0	65.0	5.0	0	90.0	10.0	0	0
Number of trees = 20	1989	35.0	65.0	0	0	100	0	0	0
	1990	15.0	70.0	15.0	0	95.0	5.0	0	0
	1991	20.0	40.0	40.0	0	80.0	20.0	0	0
Cannock Chase	1987	-	-	-	-	-	-	-	-
	1988	33.3	58.3	8.3	0	66.7	33.3	0	0
Number of trees = 24	1989	16.7	50.0	16.7	0	62.5	37.5	0	0
	1990	12.5	50.0	33.3	0	95.8	4.1	0	0
	1991	16.7	62.5	45.8	0	87.5	12.5	0	0

Site	Year	Crown Thinness				Crown Chlorosis			
		0	1	2	3	0	1	2	3
Church Hill Wood,	1987	-	-	-	-	-	-	-	-
Forest of Dean	1988	33.3	58.3	8.3	0	62.5	37.5	0	0
Number of trees = 24	1989	16.7	66.7	16.7	0	79.2	16.7	4.2	0
	1990	12.5	54.2	33.3	0	91.7	8.3	0	0
	1991	16.7	37.5	45.8	0	87.5	12.5	0	0
Wychwood	1987	-	-	-	-	-	-	-	-
	1988	20.8	62.5	16.7	0	83.3	16.7	0	0
Number of trees = 24	1989	20.8	62.5	16.7	0	37.5	58.3	4.2	0
	1990	50.0	45.8	4.2	0	87.5	12.5	0	0
	1991	20.8	62.5	16.7	0	33.3	62.5	4.2	0
Castell Coch	1987	-	-	-	-	-	-	-	-
	1988	54.2	33.3	12.5	0	91.7	8.3	0	0
Number of trees = 24	1989	20.8	66.7	12.5	0	83.3	16.7	0	0
	1990	50.0	50.0	16.7	0	54.2	41.7	4.2	0
	1991	20.8	41.7	25	0	83.3	16.7	0	0
All Sites	1987	17.9	58.3	23.3	0.5	45.1	43.1	9.8	1.9
	1988	23.1	54.9	18.7	3.4	64.9	29.8	4.1	1.1
	1989	22.5	53.2	21.7	2.6	71.2	22.9	4.7	1.2
	1990	18.2	50.3	26.9	4.6	76.5	18.6	3.5	2.0
	1991	11.8	37.6	40.8	9.8	66.6	31.9	1.5	0

Beech tree health in southern Britain.
The results of the 1991/2 winter survey.

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INTRODUCTION

In recent years there has been much interest in the health of Britain's native trees. Several surveys of tree health have been carried out by a number of different bodies during the past seven years. Since 1987, Imperial College has carried out detailed studies of beech *(Fagus sylvatica* L.) tree health throughout its natural range in southern and central Britain. In the initial survey (1987-1989), which included 72 study sites, the overall level of tree health was deemed to be relatively poor, with only a small proportion of trees having fully foliated crowns. Statistical associations were found between tree health, climate and certain air pollutants (Power *et al*, 1989). There was also an indication that the influence of pollution stress might be dependent on the soil type in which the trees were growing.

From 1989-1991, a second study of beech health was carried out, this time involving a reduced number of survey sites. Sixteen sites were selected for continued monitoring, and detailed above- and below-ground investigations were carried out at seven of these sites. The overall level of tree health was shown to have deteriorated substantially during 1989 and again in 1990 (Power, 1992; Power & Ashmore, 1991). This decline in health was attributed largely to the high soil moisture deficits that developed during the warm, dry summers of these two years. In addition, particularly unhealthy trees were found to have less vital root systems and, at acidic sites, were growing in soils with unfavourably low calcium/aluminium ratios. Whilst a lack of adequate data for the major air pollutants precluded a detailed analysis of their role in the deterioration in beech health, the involvement of pollutants such as ozone could not be ruled out.

Throughout these surveys, tree health has been assessed using both a crown thinness (and chlorosis) assessment during the summer months, and a crown architecture assessment in winter, when the trees have lost their leaves. The most recent survey of beech tree health, carried out in the summer of 1991 (Ling & Ashmore, 1991) revealed a dramatic further deterioration in the health of British beech. This report details the results of the fifth winter survey of beech health (1991/1992), and is a complement to the 1991 summer health survey (Ling & Ashmore, 1991). Temporal changes in tree health are examined across the country, and changes at individual survey sites are also considered.

METHODS

The locations of the sixteen survey sites assessed during 1991/2 are illustrated in Figure 1. For the winter assessments, sites were visited between the 4th and 16th April 1992, prior to the onset of spring bud burst.

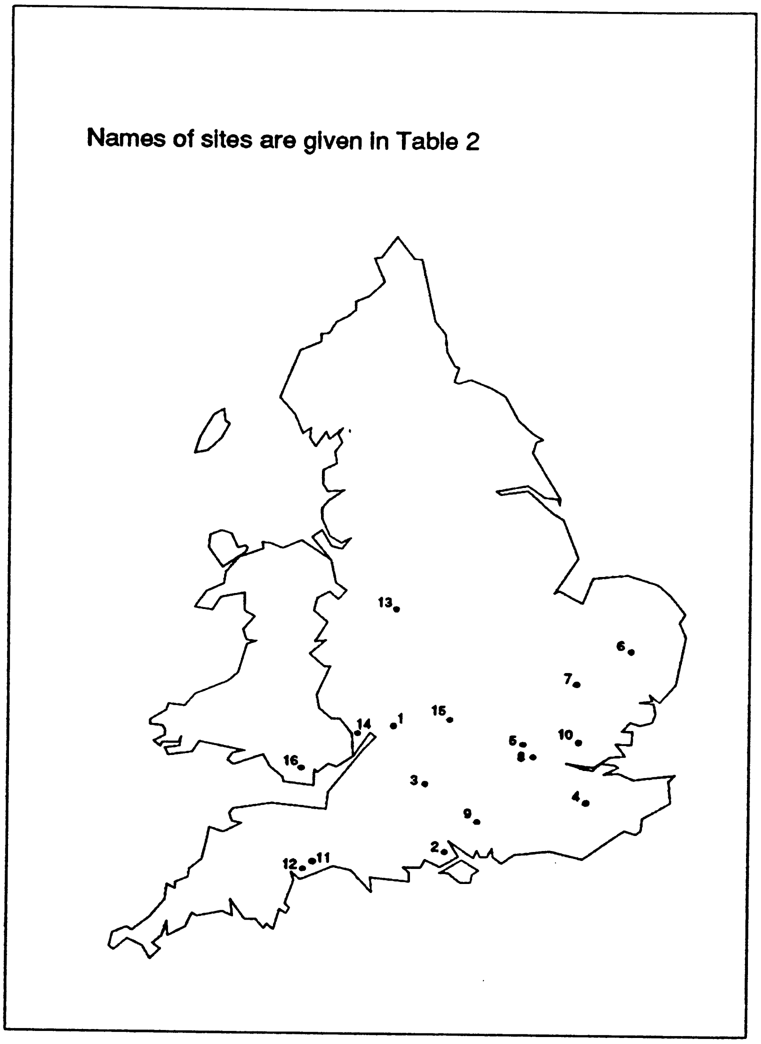

Figure 1. Location of the sixteen survey sites.

The winter survey of beech health uses the crown architecture assessment technique developed by Dr Andreas Roloff in Germany (Roloff, 1985a). Several studies (Dobler *et al*, 1988; Härdtle, 1991; Roloff, 1985a) have shown that the ratio of apical to lateral growth in the upper canopy of beech is a sensitive indicator of tree vitality, and is much less susceptible to year to year perturbations than the more commonly used crown thinness assessment.

Vigourously growing, mature beech produce in the region of 20-60cm apical (extension) growth each year (Evans, 1984) and approximately 3/5 of this amount as lateral growth (A. Roloff, pers. comm.). Roloff (1985a) has shown that with decreasing vigour, beech first reduce the amount of lateral growth and then the amount of extension growth, such that with a large decrease in vigour, very little growth is produced in either direction. No age-related loss of vigour would be expected for trees below approximately 140 years of age.

Four categories are recognised for the crown architecture assessment, representing progressively reduced vitality. Figure 2 illustrates the growth patterns of twigs in each of the four crown architecture categories.

Trees in category 0 typically have a rounded canopy, with a feathery appearance to the crown. Those in category 1 have reduced lateral growth, giving a spiky appearance to the crown, with many long 'spear-like' shoots protruding from the top. Category 2 corresponds to reduced apical as well as lateral growth, and results in the breaking up of the canopy, and the formation of gaps. The poor growth results in bent twigs ('claw twigs') and the overall result is a patchy appearance to the crown. Finally, a further reduction in vitality results in almost negligible growth in either direction. Twigs therefore become very bent over and brittle, and are prone to snapping off. This results in the loss of large numbers of twigs, giving the crown a very broken, ragged appearance.

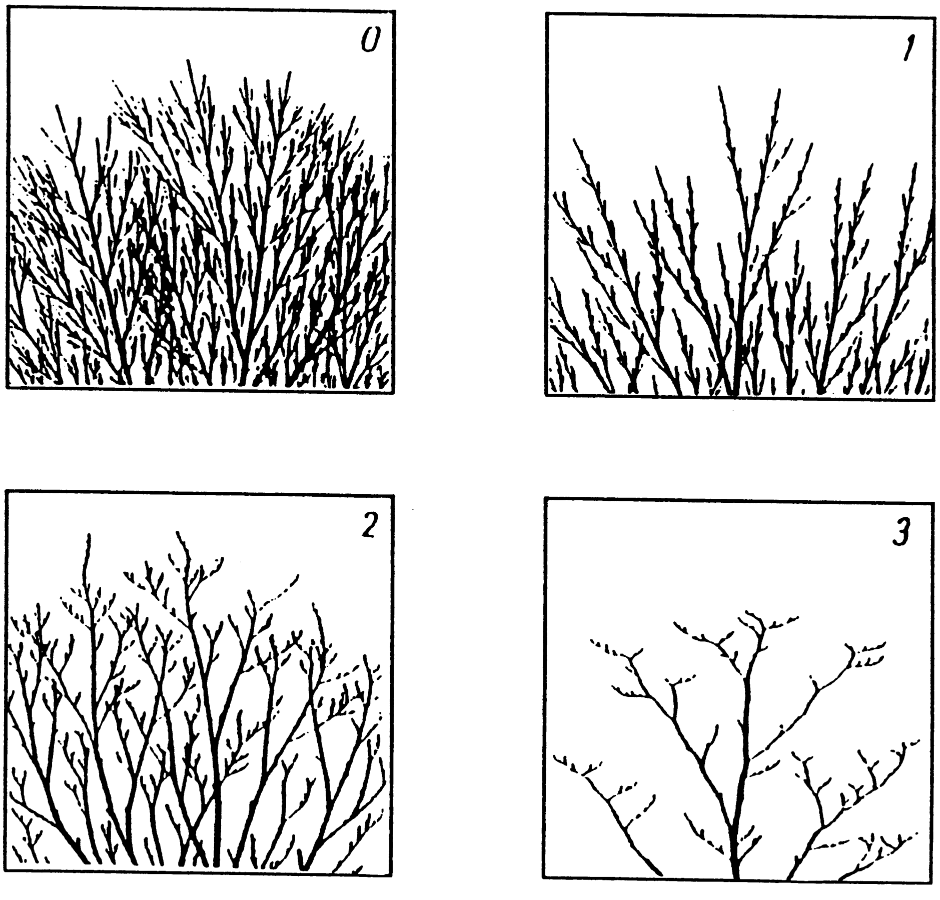

Figure 2. Examples of twig growth patterns corresponding to each of Roloff's (1985a) crown architecture categories.

Although in 1987, twenty four trees were assessed at each site, losses during the last five years have reduced the number of sample trees at many of the sites. In total, 346 trees were assessed this year; the same number for both the summer and winter surveys. In order to avoid any possibility of bias in the data, results presented in this report include only those trees that have been standing for all five years.

RESULTS

Table 1 presents the results for each of the past five survey years. There has been an overall shift towards higher (worse) crown architecture scores during the past year. Although not as great an increase as in 1990, the deterioration in tree health appears to be part of a trend towards declining health at a number of survey sites.

	Crown Architecture Category			
	0	1	2	3
1987	25.4	44.8	25.7	4.0
1988	25.1	42.8	27.7	4.3
1989	25.4	41.6	26.0	8.4
1990	14.2	41.6	35.3	9.0
1991	11.6	39.6	38.2	10.7

Table 1. Percentage of trees in each crown architecture category during the five year survey period.

Figure 3 illustrates the increasing numbers of trees in the top two crown architecture categories, representing moderately reduced and severely reduced tree vitality.

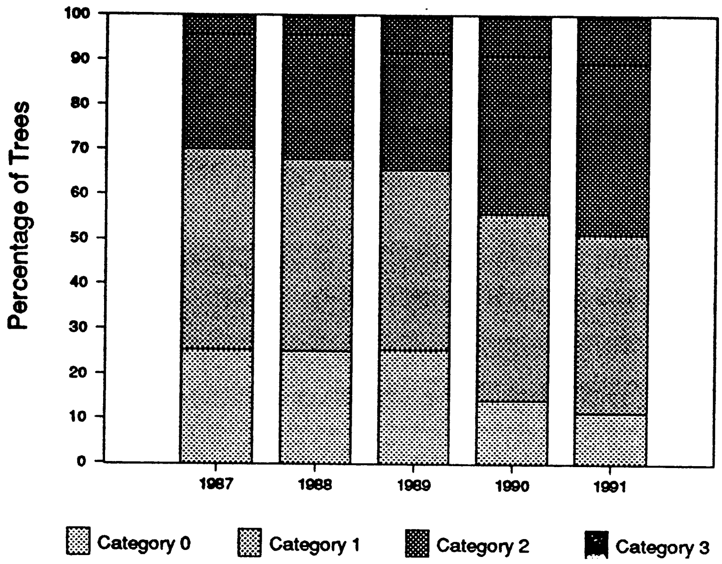

Figure 3. Proportion of trees in each crown architecture category from 1987 to 1991.

The significance of changes in health score at individual survey sites was determined using the Wilcoxon signed rank test. Individual tree scores are compared between two successive years, and the overall significance of changes at each site is calculated. This analysis has been carried out for all five survey years and the results are presented in Table 2.

No.	Site	87 & 88	88 & 89	89 & 90	90 & 91
1	CC&B	n.s.	n.s.	n.s.	n.s.
2	Denny Wood	+	n.s.	n.s.	n.s.
3	Savernake	n.s.	n.s.	n.s.	n.s.
4	Staffhurst	n.s.	--	n.s.	n.s.
5	Common Wood	+	--	n.s.	n.s.
6	Kings Forest	n.s.	n.s.	--	n.s.
7	Beechwoods	-	n.s.	-	n.s.
8	Burnham	n.s.	n.s.	n.s.	n.s.
9	Chappett's	n.s.	-	n.s.	n.s.
10	Epping	n.s.	n.s.	n.s.	n.s.
11	Belleview	n.s.	n.s.	n.s.	n.s.
12	Ash Hill	n.s.	n.s.	-	n.s.
13	Cannock	n.s.	n.s.	n.s.	n.s.
14	Forest of Dean	n.s.	n.s.	n.s.	n.s.
15	Wychwood	n.s.	n.s.	n.s.	n.s.
16	Castell Coch	n.s.	n.s.	-	n.s.

Table 2. Summary of the changes in crown architecture score between individual assessment years. Results are summaries of a Wilcoxon signed rank test between two survey years. +/-, ++/-- represent a significant improvement/deterioration in health in the second of the two years indicated, at the $p<0.05$ and $p<0.01$ level of significance. n.s. indicates no significant difference between the two years in question.

It can be seen that, whilst a number of significant changes took place at individual sites between 1987 and 1990, no significant improvements or deteriorations in tree health (vitality) were seen between 1990 and 1991. It appears, therefore, that the overall (slight) deterioration seen when data are averaged across all sixteen sites (Table 1) is the result of a number of non-significant changes at individual sites.

Since it has been argued that trees in categories 2 and 3 are of such reduced vitality that recovery is unlikely, but that trees in category 1 may recover if conditions improve, it is of interest to consider how the proportion of trees in the worst two categories have changed at individual sites during the past five years. Figure 4 illustrates these changes graphically for all sixteen sites.

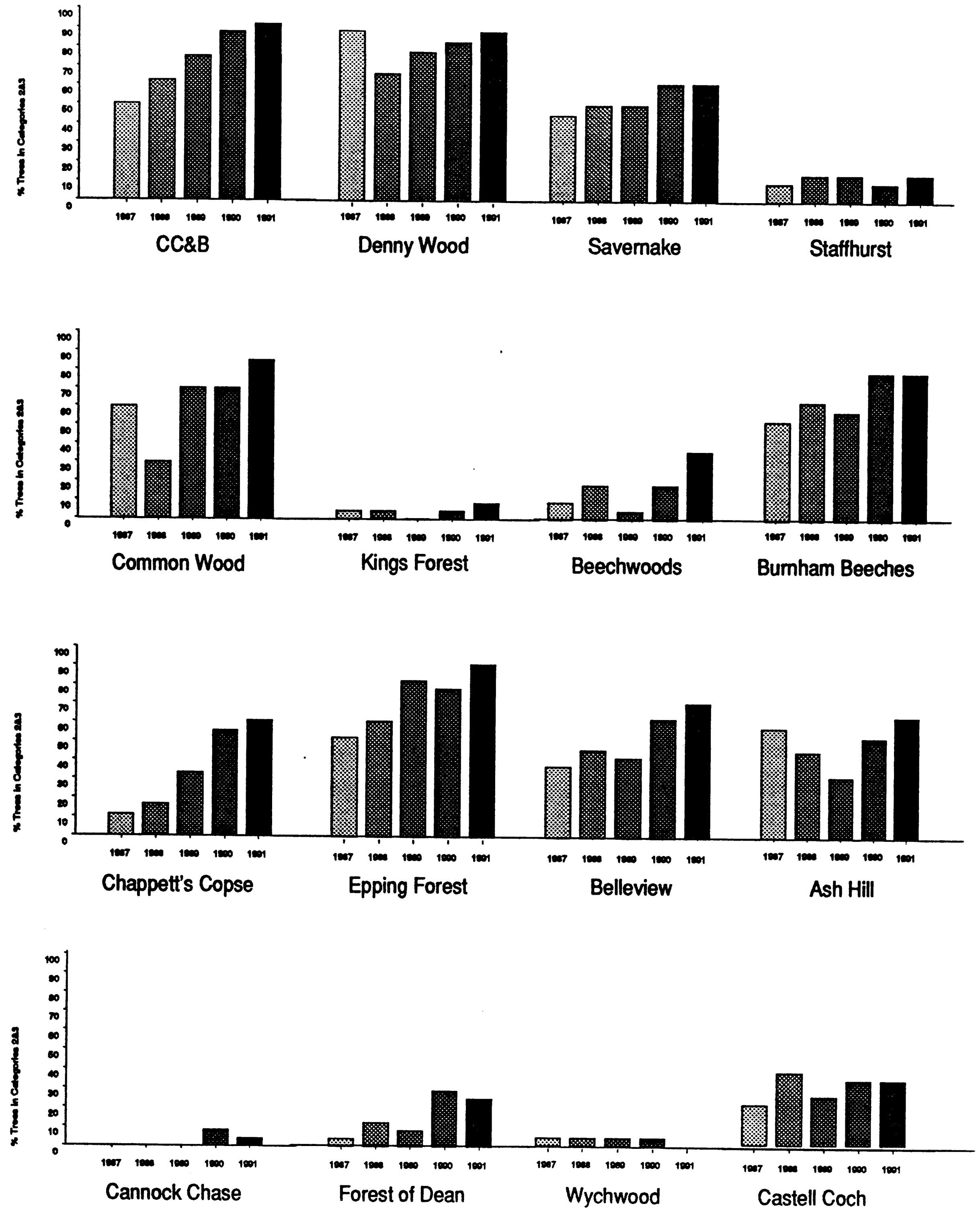

Figure 4. Annual variations in the proportion of trees in the worst two crown architecture categories.

The most consistent trend towards decreasing tree health over the past 5 years was found at the Cotswold Commons & Beechwoods (CC&B) and Chappett's Copse. However, a small increase in the proportion of trees in the worst two crown architecture categories was seen at several other sites. The greatest increases in the number of trees with poor crown architecture scores were seen at Common Wood, Beechwoods and Epping Forest. Two sites, the Cotswold Commons and Beechwoods and Epping Forest, currently have over 90% of their survey trees in the worst two categories for this health assessment.

Although not all sites suffered a deterioration in health during the past year, the fact that nearly 50% of all trees surveyed are currently of moderately or severely reduced vitality (crown architecture categories 2 or 3) indicates that the overall level health of beech in southern Britain is relatively poor.

DISCUSSION

The continued deterioration in health of the beech surveyed, both in the summer (Ling & Ashmore, 1991) and winter assessments, appears to be part of a trend towards decreasing vitality. Although five years of data is still rather short to make definitive statements about long term trends, continued monitoring of tree health for the next few years should provide the additional data necessary for this. Results of the Forestry Commission main surveys (Innes & Boswell, 1991a,b) support the observations from recent Imperial College surveys (Ling & Ashmore, 1991; Power & Ashmore, 1991) that there has been a decline in beech tree health in each of the last two years. The development of high soil moisture deficits during the warm, dry summers of 1989 and 1990 has been proposed as a possible cause of this recent decline (Innes & Boswell, 1991b; Innes *et al*, 1989; Power, 1992).

The crown architecture assessment is a measure of the long-term growth patterns of trees and, in theory, should be inherently less susceptible to annual perturbations than other assessments of tree health. Extension growth in beech is usually completed by early May (Roloff, 1985b), so droughts that occur during the summer period are unlikely to influence twig growth in that year, unless water stress had already developed during the spring growth period, or lag effects of water stress on extension growth exist.

The importance of drought on beech growth has been demonstrated in a variety of studies (Dobbler *et al*, 1988; Flückiger *et al*, 1986; Lonsdale *et al*, 1989; Power, 1992). In a study of beech twig growth at a number of the current survey sites, Power (1992), found particularly severe growth depressions in 1977 and 1985, years following the droughts of 1975/6 and 1983/4 respectively. Although the climatic conditions during 1991 were much more favourable for tree growth than the previous two years, it is possible that the continued deterioration in crown architecture score is a delayed response to the 1989 and 1990 droughts. If this is the case, an improvement, both in terms of crown thinness and crown architecture, might be expected in 1992, unless another unusually dry summer is experienced this year.

The fact that some trees varied in crown architecture score from year to year suggests that this assessment is more susceptible to short term influences than Roloff (1985a) proposed. Whilst a degree of observer error may be associated with these assessments, it is also possible that particularly good growth in just one year might tip a tree that was on the border between categories 0 and 1 or 1 and 2 into the healthier category. This should not be the case for trees which were clearly in the middle of one or other category, but may explain why crown architecture assessments vary somewhat from year to year.

Despite the fact that crown architecture scores may, in some circumstances, fluctuate a little from year to year, this technique is still considered to be a valuable method for assessing tree vitality. Used in conjunction with crown thinness and chlorosis assessments, a detailed picture of the overall state of tree health can be obtained, providing useful information on the condition of many sites of nature conservation interest. The results of the crown architecture assessment re-affirm the findings of the summer survey (Ling & Ashmore, 1991), that beech health has been declining steadily during the past five years.

There does not appear to be any consistent pattern amongst those sites which have deteriorated in health most since the survey began. Sites which are currently in the worst health cover a range of ages, soil types and exposures. Whilst a few of the sites in particularly poor health (Belleview, Denny Wood, Savernake and Chappett's Copse) did experience storm damage or management felling during the past 5 years, others (the Cotswold Commons & Beechwoods, Epping Forest and Burnham Beeches) have been relatively undisturbed over this period. In general, those sites which had the higher proportions of trees in the worst crown architecture classes in 1990 have undergone further (non-significant) deteriorations during the past 12 months.

Unfortunately, as in the summer survey, inadequate spatial and temporal resolution of existing pollutant data, precludes any statistical analysis of the involvement of air pollution in the recent decline in tree health.

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