Monitoring Forest Condition in Ireland (1988-91)

R. McCarthy

Research & Technology Division, Coillte Teoranta, Sidmonton Place, Bray, Co.Wicklow

Summary

A range of 878-995 trees were assessed for vitality status over the years 1988-1991, in two projects equally funded by the EC and the Forest Service, Department of Energy. Four species were studied in a total of 47 plots distributed around the country: Sitka spruce (*Picea sitchensis*), Norway spruce (*Picea abies*), lodgepole pine (*Pinus contorta*), and noble fir (*Abies nobilis*).

Forest damage levels, amongst the lowest in Europe, were very low in the spruces, and almost negligible in lodgepole pine and noble fir. Exposure and insects were the most common causes of damage, being influenced greatly by the position of the assessed tree (damage increasing as follows: internal > internal edge > external edge) and altitude, and less so by age, soil type, and nutrition.

Forest condition in the spruces improved from 1988 to 1991, the improvement being attributed largely to relief in climatic stresses, leading especially to reductions in insect populations (green spruce aphid, *Elatobium abietinum*) and water deficits. There was no evidence of long-term damage and, as such, the existence in Ireland of forest decline, as defined by continental Europeans, is questioned.

Introduction

In the late 1970s concern arose over the widespread decline observed in the general health or vitality of the forests in Central Europe. This condition became widely known as "forest decline". Concerns that forest decline may be occurring elsewhere led many countries to conduct surveys to monitor the condition of their forests.

Germany (formerly West Germany) was the first country to bring the so-called forest decline phenomenon to public notice, and it was also the first to institute surveys of forest decline. The methods they employed have largely been adopted by all countries participating in the co-ordinating action of the United Nations ECE, ICP Forests (International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests). Thus, European forests have been surveyed annually from the mid- to late 1980s, using a common methodology, which allows comparison of results between countries and detection of trends.

Three surveys of forest condition are ongoing in Ireland. They are being carried out by Coillte Teoranta (Irish Forestry Board), funding for which is

IRISH FORESTRY, 1993, Vol. 50 No. 1: 21-34

provided by the European Commission and the Forest Service, Department of Energy.

These surveys are being conducted annually, under Council Regulation (EC) No. 3528/86, a Community programme for the protection of forests against atmospheric pollution, and comprise the following:

(1) EC Forest Health Inventory, initiated in 1987 (22 "Periodic" Plots)

(2) Study of the Cause-Effect Relationships Underlying Forest Decline, initiated in 1988 (25 "Permanent" Plots)

(3) Study of Ways to Improve Methods of Measuring Forest Health, initiated in 1990 (33 plots).

This paper reviews the forest damage results, from the first two of these surveys, over the four-year period, 1988-91. The third survey will be referred to for the early results from it showing the stong relationship between the location of a tree, with respect to its partners, and the amount of damage sustained. More detailed information on the results for the individual years (1988-1990) for each survey is available in the annual reports published[6,7,8,9,10,11]. Annual reports are also published with the forest damage results for the whole of Europe[3,4].

Assessment Methods

Estimates of needle or leaf loss (defoliation) and discolouration are assumed to reflect the condition or health status of a tree. Trees in all plots are assessed for defoliation and discolouration in July-September of each year. The assessment is carried out by a single surveyor, who has attended international training courses on assessing forest damage.

The number of trees assessed in each plot varies according to the availability of trees suitable for assessment, that is, tree crowns which are sufficiently visible to assess accurately. In most plots, only trees located on plot edges were suitable, since the crowns of trees located elsewhere in a stand were generally not sufficiently visible, unless the stand had been thinned considerably. Thus, the number of trees assessed was largely dependent on the availability of "edge" trees. The number of trees assessed in each plot ranged from 10 to 25.

Before the start of the original survey all selected sample trees were numbered, so that a record of changes in condition over time can be obtained for each individual tree.

Each sample tree is assessed for degree of defoliation and discolouration in 5 % classes as follows: a tree with 0-5 % defoliatiion is recorded as 5 %, 6-10 % is recorded as 10 %, and so on. However, the data are transposed to broader classes, as shown in Table 1, for ease of interpretation. Details on the criteria used in defining defoliation classes are also shown in Table 1. Discolouration criteria are similar, except that there is no Class 4.

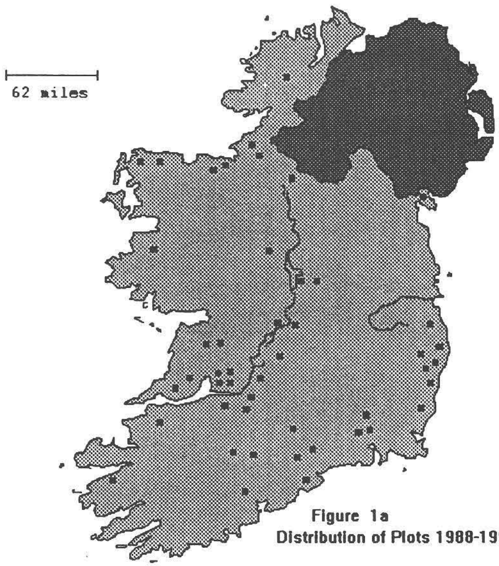

Figure 1a
Distribution of Plots 1988-1990

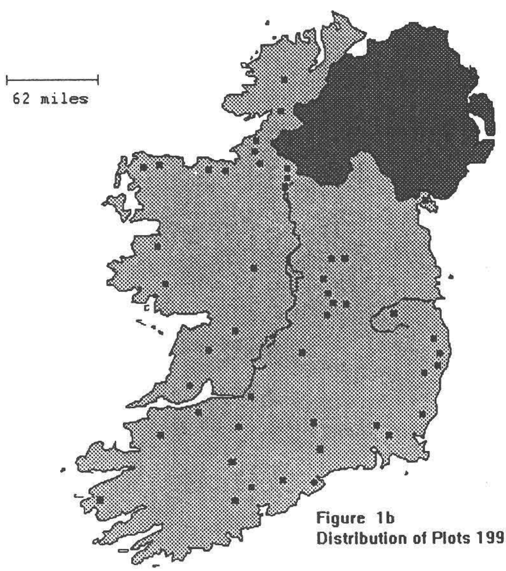

Figure 1b
Distribution of Plots 1991

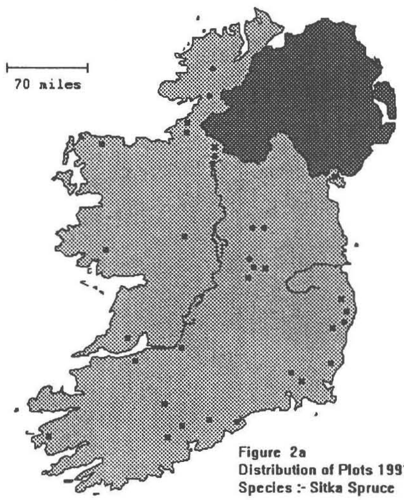

Figure 2a
Distribution of Plots 1991
Species :- Sitka Spruce

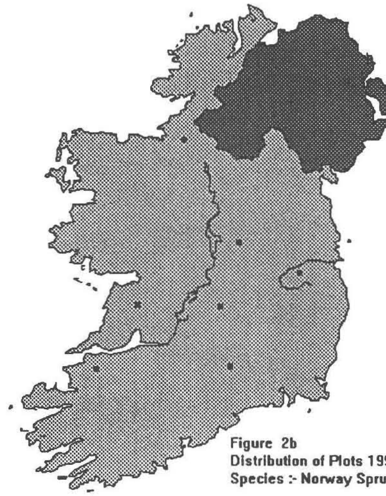

Figure 2b
Distribution of Plots 1991
Species :- Norway Spruce

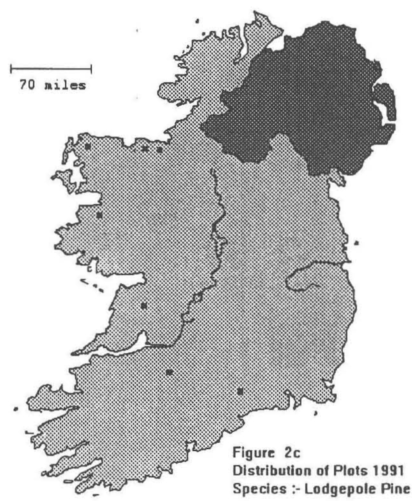

Figure 2c
Distribution of Plots 1991
Species :- Lodgepole Pine

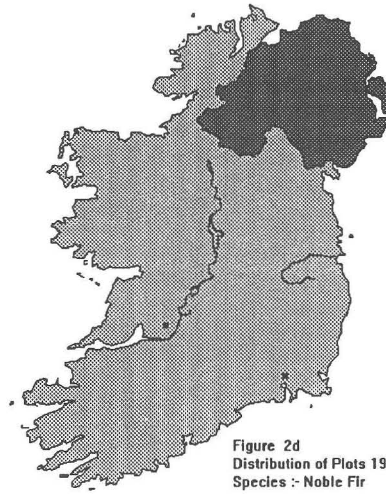

Figure 2d
Distribution of Plots 1990
Species :- Noble Fir

Table 1: Defoliation criteria.

CLASS	DEGREE OF DEFOLIATION	NEEDLE LOSS (%)
0	None or negligible	0-10
1	Slight	11-25
2	Moderate	26-60
3	Severe	> 60
4	Dead	

When possible the probable cause(s) of the forest damage was recorded for each tree. The surveys were confined to four of the more important coniferous species in this country, that is, Sitka spruce (SS), Norway spruce (NS), lodgepole pine (LP), and noble fir (NF).

Location of Plots

The distribution of plots was the same in 1988-1990. However, in 1991, in the "Study of Cause-Effect Relationships Underlying Forest Decline" project, 15 of the original plots were replaced to obtain a network with better representation of forest regions, age classes, and altitudes (Figure 1).

Figure 2 shows the distribution of plots by species in the "EC Forest Health Inventory" project. The 22 plots in this project have remained unchanged over the four years being reviewed (1988-1991).

The number of plots and trees for each species is shown in Table 2.

Table 2: Plot numbers by trees and species composition.

SPECIES	PLOTS		TREES	
	1988-90	1991	1988-90	1991
SS	26	33	447	676
NS	12	7	231	156
LP	7	7	164	163
NF	2	0	36	0
Total	47	47	878	995

Results

Results for defoliation and discolouration are presented for a combination of all the plots from both the "EC Forest Health Inventory" and "Study on Cause-Effect Relationships Underlying Forest Decline" projects. In this paper emphasis will be placed on the "0" and "1" classes of defoliation and discolouration, since it is generally accepted that trees assessed in those classes are undamaged[2,5]. Indeed, Becker[1] has produced evidence to show that foliage losses of up to 40 percent may occur in some species without affecting annual increment.

I. Defoliation

Sitka Spruce

The assessments of defoliation in Sitka spruce show that there was very little needle loss in any year of the surveys. This is illustrated in Figure 3a, where the percent of trees in the undamaged classes (0+1) never went below 73 percent, and reached as high as 90 percent in 1991. There was a clear improvement in the crown density from 1988/89 to 1990/91, which reflects a decrease in the occurrence of the green spruce aphid *(Elatobium abietinum)*, of which there were significant outbreaks in the early years of the surveys.

Norway Spruce

The defoliation results for Norway spruce are somewhat similar to those found in Sitka spruce, undamaged trees (classes 0+1) ranging from 65 to 83 percent of total trees assessed, the improvement in crown condition increasing in the course of the survey period (Figure 3a).

Lodgepole Pine

Defoliation in lodgepole pine was even less than in the spruces (Figure 3a). The crown density remained relatively constant over the four years, the proportion of trees in the undamaged classes being in the 85 to 93 percent range.

Noble Fir

There were only two plots of noble fir, and these were discontinued after the 1990 survey. For the three years (1988-90) that it was assessed, the crown density of noble fir was, like lodgepole pine, relatively unaffected, all trees being classed as undamaged except for 5 percent of trees in 1988 (Figure 3a).

II. Discolouration

Sitka Spruce

The pattern of the results for defoliation in Sitka spruce is found also with regard to discolouration. This applies not only to the high proportion of trees in undamaged classes, but also to the improvement in the results through the survey period (Figure 3b).

Norway Spruce

The discolouration assessments for Norway spruce were very similar to those found for Sitka spruce, with more than 80 percent of all trees assessed as being in the (0+1) classes (Figure 3b).

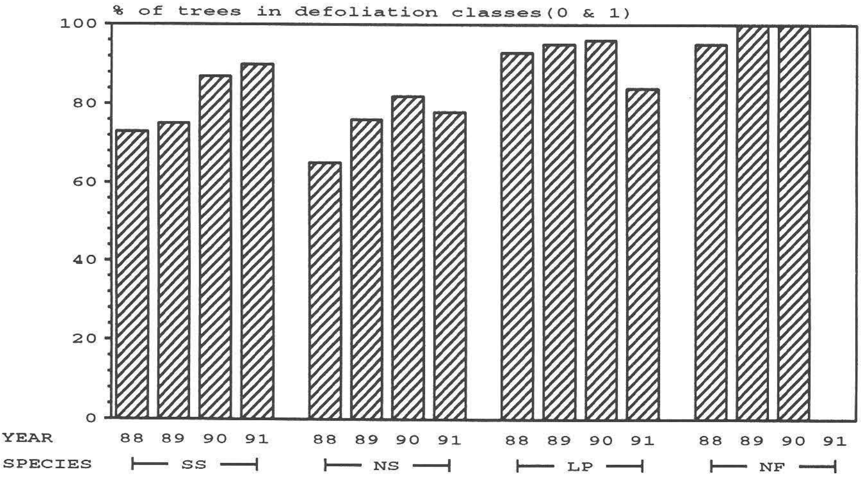

Figure 3a: Defoliation (1988-1991)

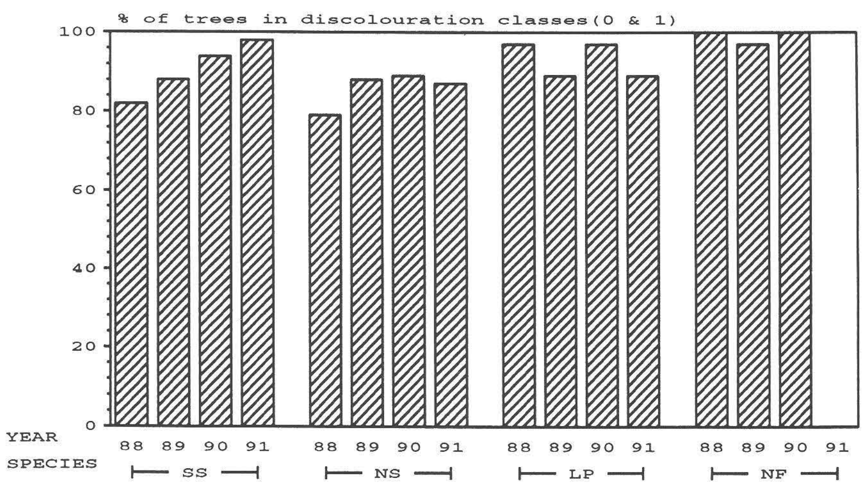

Figure 3b: Discolouration (1988-1991)

Lodgepole Pine

Discolouration levels for lodgepole pine were minimal for all years (Figure 3b). The levels fluctuated, with slight increases in 1989 and 1991.

Noble Fir

As with the defoliation assessments, the discolouration levels for noble fir were very stable over the three years that the species was monitored (Figure 3b), being the least affected of all the species surveyed.

III. Foliage Analysis

In the "Study of the Cause-Effect Relationships Underlying Forest Decline" project a representative number of trees in each plot (25 plots) were selected each year for analysis of the current year's foliage, in order to see if nutrient levels were limiting growth and/or causing damage, particularly in the context of discolouration. The nutrients analysed were: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg).

The average results for all plots, for each species, is shown in Table 3 for three of the four years of the survey, the results for 1991 not yet being available.

Table 3: Mean foliage analysis results for SS, NS, and NF in 1988-90 (percent of dry matter)

		SPECIES			
NUTRIENT	YEAR	SS	NS	NF	MEAN
N	1988	1.80	1.90	1.71	1.83
	1989	2.06	1.95	1.75	1.99
	1990	1.47	1.48	1.31	1.46
P	1988	0.18	0.19	0.17	0.18
	1989	0.19	0.17	0.17	0.18
	1990	0.15	0.16	0.14	0.15
K	1988	0.89	0.61	0.65	0.77
	1989	1.01	0.74	0.73	0.89
	1990	0.78	0.54	0.54	0.68
Ca	1988	0.45*	0.47	0.73**	0.49***
	1989	0.53	0.64	0.37	0.56
	1990	0.56	0.74	0.41	0.61
Mg	1988	0.11*	0.14*	0.06**	0.12***
	1989	0.10	0.17	0.13	0.13
	1990	0.09	0.11	0.10	0.09

Note:

* = analysis from only 4 plots (from a total of 14 SS and 9 NS plots)

** = analysis from only 1 plot (from a total of 2 NF)

*** = mean analysis from 9 plots (from a total of 25)

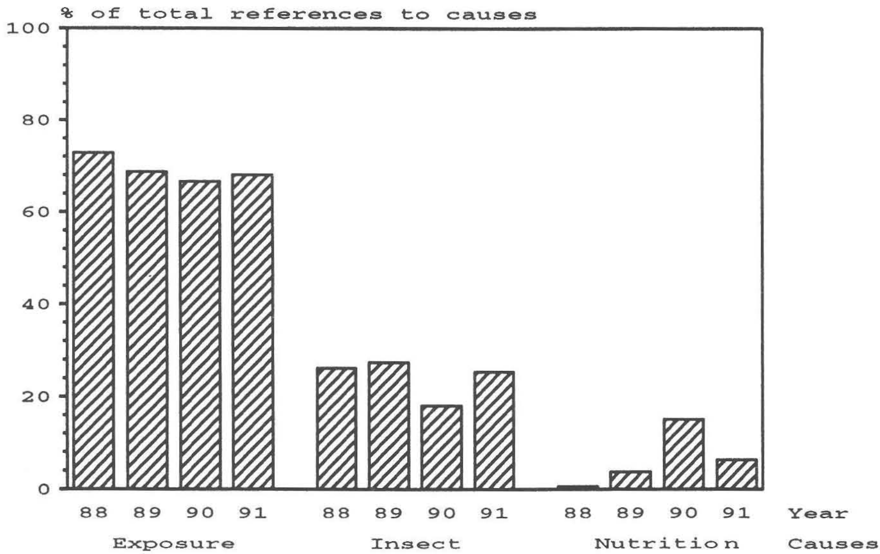

Figure 4: Causes of Defoliation
Class 2 Defoliation, SS(1988-1991)

The pattern of foliage analysis for all species was similar. There was an increase in N, K, and Mg from 1988 to 1989, followed by a decrease in 1990 to levels below those in 1988.

For P, there was little difference in concentrations between 1988 and 1989, but there was a decrease in 1990. Of the five nutrients analysed, Ca was the exception in that it alone increased from 1988 to 1990, in the spruces, but not in noble fir where the pattern was uneven.

IV. Easily Identifiable Causes of Damage

The most frequently enumerated causes of damage for all species, in order of importance, were : (1) exposure, (2) insects, and (3) nutrient deficiency. This is illustrated by the results which were obtained with Sitka spruce for the moderate defoliation class 2 (26-60 percent needle loss), which was typical for the other species also (Figure 4).

The data on "damage type" only records the presence of a cause, or causes, contributing to the damage, but does not indicate the scale of the effect attributed to the cause(s). The usefulness of the damage type records is limited to giving only general indications of the scale of the damage from different causes. This is because some trees can be subject to several types of damage, and thus will be represented more than once in the damage type records. In addition, a cause of damage to a tree is only recorded where there are identifiable symtoms of damage.

The influence of changes in soil moisture availability to the general improvement in forest condition can only be speculated upon. However, meteorological records show that soil moisture deficits, expressed as the number of 10-day periods with 50 mm or more in June-September, were less in 1990 than in 1989.

V. Effect of Altitude, Soil, Age and Position of Trees

Site (altitude and soil) and crop (age and position of tree) characteristics were recorded for each sample in the following categories:

(1) **Altitude** – in 50 m categories, up to 400 m.

(2) **Soil** – (i) Wet Mineral, (ii) Dry Mineral, (iii) Blanket Bog, (iv) Midland Bog, (v) Old Red Sandstone, (vi) Limestone.

(3) **Age of Tree** – in 20 year categories, up to 60 years.

(4) **Position of Tree** – (i) External Edge, (ii) Internal Edge, (iii) Internal (no edge).

A General Linear Models statistical procedure was used to estimate the significance to tree damage by the four factors above. The results for the relationship between defoliation (in Sitka spruce, Norway spruce, and lodgepole pine), as the dependent variable, and altitude, soil, age and position, as the independent variables, are shown in Table 4.

The R-Square values show that the combination of the four factors of altitude, soil, age and position of tree, account for 60, 68, and 49 percent respectively of the variation in defoliation damage in Sitka spruce, Norway spruce, and lodgepole pine, respectively. The highly significant F-values indicate the over-riding importance of position of sample tree, especially for Sitka spruce and lodgepole pine.

Three categories of trees were identified in terms of their position and susceptibility to forest damage:

(1) trees on forest boundaries (external edges) – most susceptible

(2) trees on forest edges within the forest (internal edges) – moderately susceptible

(3) trees within the forest, away from edges – least susceptible.

The small number of plots represented on each soil type makes it difficult to comment reliably on the effect of soil. Results indicate that damage has been worst on the gleys and least on the old red sandstone soils. It is hoped to determine if this is a real or a circumstantial effect.

Table 4: Statistics on relationships between defoliation and altitude, soil, age and position of tree.

		SITKA SPRUCE	
R-Square	0.60		
Source		F Value	Prob > F
Altitude		4.62	0.0002
Age		8.98	0.0003
Position		31.79	0.0001
Soil		3.86	0.0062
		NORWAY SPRUCE	
R-square	0.68		
Source		F Value	Prob > F
Altitude		7.72	0.0002
Age		6.13	0.0059
Position	6.41	0.0048	
Soil		2.47	0.0809
		LODGEPOLE PINE	
R-Square	0.49		
Source		F Value	Prob > F
Altitude		2.79	0.0370
Age		0.88	0.3560
Position		9.92	0.0040
Soil		1.53	0.2266

Discussion

The results clearly show that forest damage levels recorded over the four years of the surveys were very low in Ireland. The overall forest damage is probably not as as bad as even these levels indicate. This is because most of the sample trees were located on stand or forest edges, and so would be more vulnerable than internal trees to environmental damage, especially exposure. Early results from a separate ongoing study, into the effect that the position of a tree has on the amount of damage received, shows that internal trees had 10-20 percent more in the undamaged defoliation categories than had edge trees[12].

In making comparisons with the rest of Europe a few important points must be appreciated. These relate to differences not only to pollution levels produced, but more especially to the characteristics of forests in Ireland. Irish forests tend to be young, conifers rarely exceeding 50 years, and they are planted at relatively low altitudes. European coniferous forests, by contrast, have a wider age structure, and they occur over a wider altitudinal range. The high levels of forest damage occurring in Central and Eastern Europe, and indeed elsewhere, are undoubtedly hugely influenced by the high proportion of their old and/or high altitude forests.

Comparison with the rest of Europe shows that Ireland experiences relatively little forest damage[3]. In the 1990 ECE forest damage survey, Spain and Ireland had the lowest damage levels recorded amongst the 34 participating countries and regions[3]. Ireland had less than 6 percent of the sampled coniferous trees in defoliation damage classes (2+3+4), which comprise those classes with at least a moderate degree of needle loss. This level of damage (5.4 percent) is in stark contrast to the high of 57 percent for Byelorussia, 50 percent for Czechoslovakia, and 45 percent for the United Kingdom.

It is not possible yet to be specific as to the reasons for the wide differences in forest damage sustained between countries. This is not surprising, since it is not always even clear within countries what factors are involved in influencing forest condition, not to mind what their relative importance is, or how they might interact.

Air pollution is considered by their respective governments to be the most important factor leading to forest decline in Austria, Czechoslovakia, Germany, and Liechtenstein[4]. In Ireland air pollution can be considered as no more than a possible predisposing factor. Ireland is one of four countries – the others being Hungary, Spain, and the United Kingdom – which considers factors other than air pollution to be more important in determining the condition of its forests. The 1988-91 surveys reviewed in this paper indicate that the most important of these "other factors" in Ireland are environmental in nature or reflect climatic stresses, especially exposure and insects.

Exposure is a difficult factor to quantify, since it embraces the involvement of other site factors, such as, elevation, aspect, topography, landform, distance from sea, and wind. The approach taken in these studies follows the practice used in most other studies of this nature (that is, general to semi-intensive), which is to employ the simple expedient of allocating a plot to a general exposure class based on an assessment of the factors contributing to exposure.

Of the four species monitored in the surveys, Sitka and Norway spruce varied more in forest condition than lodgepole pine and noble fir. This is attributable to outbreaks of the spruce pathogen, the green spruce aphid (*Elatobium abietinum*), in 1988 and 1989, and the absence of any notable pest/pathogen on the other species. The improvement in the condition of the spruces from 1988 to 1991 is largely due to the decline of the green spruce aphid over that period. It is heartening to note that spruces which were observed to have been considerably defoliated in the early years of the survey period appear to have recovered to a healthy state, which is in conflict with the commonly-held view that such trees suffer long-term damage.

Trees subjected to stress, such as, pollution, are predisposed to some pest attacks. For instance, outbreaks of bark beetle (*Dendroctonus micans*) are common on drought-stressed trees. Thus, it is perhaps tempting to speculate that trees subjected to pest attacks in the studies reviewed here were already pollution-stressed. However, there is no basis for this speculation, since the green spruce aphid – the predominant pest encountered here – is generally indiscriminate in its occurrence with regard to the condition of the trees it attacks. Outbreaks of green spruce aphid are largely dependent on winter temperature and the nature of the amino acids in the tree foliage.

In view of the importance of the green spruce aphid to the condition of the spruces, albeit a short-term effect, and since outbreaks of this insect are related to climatic factors, such as, the occurrence of mild winters, we can assume that the damage levels of those species will fluctuate accordingly.

It is a moot point as to whether there is forest decline in Ireland at all. The forest decline first noted by the Germans is a phenomenon which implies a continuing decrease in the forest condition. On the evidence of these surveys, admittedly for only four years, long-term damage does not appear to be happening in Ireland, since the condition of our forests generally rises and falls according to variations in such factors as climate and insect attacks. It is a consolation to Irish foresters, and the Irish forest industry, that the mean damage levels recorded in these surveys are so low, with the result that normal fluctuations are unlikely to have serious consequences.

Conclusions

The forest damage levels for all species assessed in 1988-91 were very low, being amongst the lowest in Europe. Lodgepole pine and noble fir were very stable, being relatively unaffected when compared to Sitka and Norway spruce.

There was an improvement in the condition of Sitka and Norway spruce over the four-year period. This improvement is largely attributed to changes in climate, which became less conducive for insect outbreaks and water stress. However, it must be borne in mind that the improvement was made from a base in 1988/89 when forest damage levels were already very low.

Exposure and insects were identified as the most common causes of damage. The position of a tree in a stand and altitude were undoubtedly very important factors in influencing the effects of exposure and insect attacks. The extent of the interactions have yet to be established. Soil type and age of trees were less important factors influencing forest damage.

Nutrient concentrations were generally above threshold levels, even in 1990 when concentrations tended to be lower than those in 1989. Studies are ongoing to determine if this is a temporary decrease, but even so, it is clear that it has not had a deleterious effect on forest condition so far.

The results show that there is no evidence of a long-term decline in forest condition in Ireland. The yearly variation in forest vitality reflects more the influence of non-pollution factors, in particular climate and the stresses that result from its extremes, such as, exposure, water deficits, and insect attacks.

ACKNOWLEDGEMENTS

The studies which are the subject of review in this paper are carried out by Coillte Teoranta on behalf of the Forest Service, Department of Energy, for the European Commission, who co-funded the projects. Thanks are extended to the Forest Service for facilitating the administration involved, to John Hogan for carrying out the field survey work, to Oh Peng Lim for his assistance with computer analysis of the data and to Andrew Fitzgerald for laboratory analysis of the foliage.

REFERENCES

1. Becker, M. 1987. Bilan de sante actuel et retrospectif du sapin (*Abies alba* Mill.) dans les Vosges. Etude ecologique et dendrochronologique. Annales des Sciences Forestieres 44, 379-401.
2. Bengtsson, G. 1985. Approach and methodology of the health of forests in Sweden. In: Inventorying and monitoring of endangered forests; editor, P. Schmid-Haas, 205-208. Eidgenossische Anstalt fur das forstliche Versuchswesen, Birmensdorf.
3. Commission Of The European Communities. 1991. Directorate-General for Agriculture. Forest Health Report 1991. Technical report on the 1990 survey.
4. ICP Forests. 1990. International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests. Convention on Long-Range Transboundary Air Pollution. Forest Damage and Air Pollution. Report of the 1990 forest damage survey in Europe. Prepared by the Programme Co-ordinating Centres, with the assistance of the United Nations Environment Programme (UNEP) and the Secretariat of the United Nations Economic Commission for Europe (ECE).
5. Kauppi, P. 1988. Advantages and disadvantages of expressing forest damage on a percentage basis. In: Workshop on Methodologies; editors, K. Moisl and J. Zlinska, 37-39. Institute for Environment and Utilisation of Natural Resources, Prague.
6. Keane, M., J. Hogan, and R. McCarthy. 1988. EC Forest Health Inventory/Ireland. 1988 Report.
7. Keane, M., R. McCarthy, and J. Hogan. 1989. EC Forest Health Inventory/Ireland. 1989 Report.
8. McCarthy, R., M. Keane, and J. Hogan. 1988. Establishment of Permanent Plots to Study the Cause-Effect Relationships Underlying Forest Decline. EC Report (1988).
9. McCarthy, R. and J. Hogan. 1989. Study of the Cause-Effect Relationships Underlying Forest Decline. EC Project Report (1989).
10. McCarthy, R. and J. Hogan. 1990a. EC Forest Health Inventory/Ireland. 1990 Report.
11. McCarthy, R. and J. Hogan. 1990b. Study of the Cause-Effect Relationships Underlying Forest Decline. EC Project Report (1990).
12. McCarthy, R. and J. Hogan. 1990c. Study of Ways to Improve Methods of Assessing Forest Health. EC Project Report (1990).