display most dramatically after forest fires. Buds in the trunk and branches produce 'epicormic' shoots, which develop rapidly and can fully restore the crown of a completely defoliated tree within 3–5 years. But the trees' capacity for revival has limits. They draw on reserves of starch to produce the new shoots. If these are attacked repeatedly almost as soon as they appear, sooner or later the starch reserves will run out and the trees will die.

A scientist who has been studying the interaction of insect populations and eucalypts for many years, Dr Phil Carne of the CSIRO Division of Entomology, says dieback is much more severe in New England than anywhere else he knows. But he fears that similar situations are developing elsewhere. He has found that serious damage by leaf-eating insects is rare in undisturbed forests and woodland, more common where the tree cover has been thinned for grazing, and most extreme where only the odd tree stands in pasture land. There are exceptions to the pattern, however; some grazing areas show no trace of dieback. Presumably local factors make the difference, but what those factors are remains uncertain.

Christmas beetles

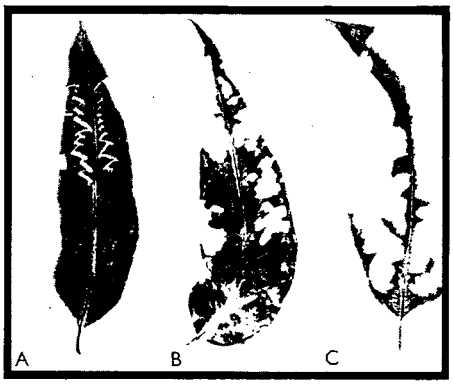
The leaf-eaters that Dr Carne has studied most closely are various species of Christmas beetle — the familiar large brown beetles that emerge from the ground and head for gum trees round about the festive season. These insects normally have a 2-year life cycle, most of it spent as grubs feeding on organic matter in the soil. They appear for a month or two in summer, to feed on gum leaves and to mate. Then the fertilized females burrow back into the soil.

By cutting down trees and increasing the area of grassland, graziers have reduced the amount of foliage that the adult beetles can graze and at the same time enhanced the survival prospects of the larvae. The result, almost certainly, is more Christmas beetles per tree.

The thinning of eucalypt stands also favours Christmas beetles in another way. Like many other leaf-eating insects, they choose foliage exposed to sunlight in preference to shaded leaves. Dr Carne's observations show that they will attack the outer trees of plantations adjoining pasture, but will rarely move into a stand with a closed canopy.

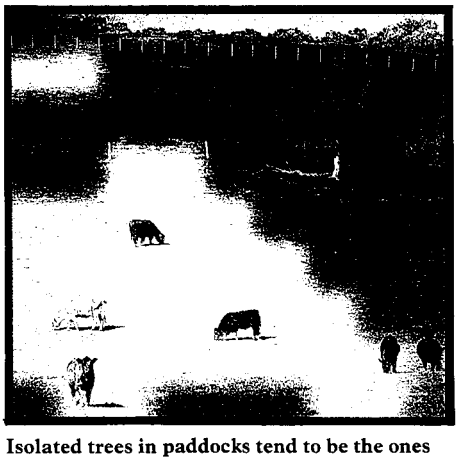
There are no immediate prospects for stopping the destruction.

A Christmas beetle on a diminishing leaf.



Stages in the destruction of a leaf by a Christmas beetle. The initial cuts commonly form zig-zag patterns like that in the left-hand leaf.

A scarab larva. Larvae of many scarab species, including Christmas beetles, are often present in large numbers in the soil under pastures.



Isolated trees in paddocks tend to be the ones most severely affected by insect attack.

. . . and soil conditions

In a study near Galong, 100 km north-west of Canberra, he and his colleague Mr Ray McInnes found a strong link between Christmas beetle numbers and the condition of the soil in summer. Numbers tend to be low in very dry summers, and also 2 years after a very dry summer.

The explanation seems to be that the soil in that part of the country becomes very hard — it virtually sets like concrete — when conditions are hot and dry. If these conditions occur early in the summer, beetles can't get out of the ground and head for the trees. If the soil hardens later, when the beetles should be returning to lay their eggs, the life cycle can again be interrupted. The effect shows up in a reduced crop of beetles two summers later.

Insects that used to exist in balance with the eucalypts are now killing them.

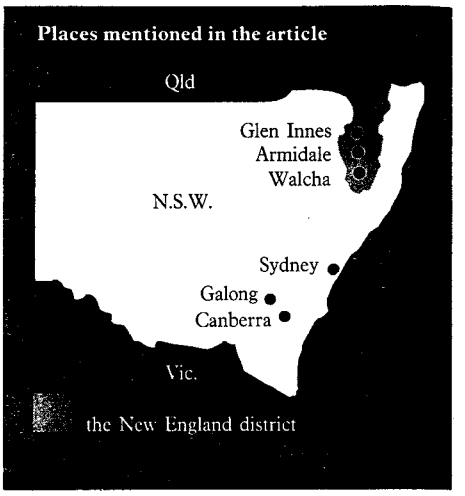
Ploughing up samples of pasture in search of Christmas beetle larvae, the researchers found them, after very dry summers, virtually restricted to pockets of soil that did not harden — notably around trees used by stock as camping sites. But after summers when rain kept the soil penetrable, larvae were spread throughout the paddocks; there was no obvious association between their distribution and the location of trees.

Near Armidale in the New England district, Dr Reg Roberts of the Division of Entomology has also found Christmas beetle larvae spread at random through paddocks. His sampling under improved pastures has produced a conservative population estimate of 24 000 per hectare. Except in occasional drought years, New England receives most of its rain in summer, so the beetles there will rarely be trapped by hard soil.

Other leaf-eaters

Although Christmas beetles make up only a small proportion of the insect species that attack eucalypt leaves, they appear to play a key role in dieback, at least in some areas. This is because many of the other leaf-eaters prefer fresh shoots to more-mature foliage. If Christmas beetles strip off most

These badly affected trees have produced many clumps of epicormic growth.



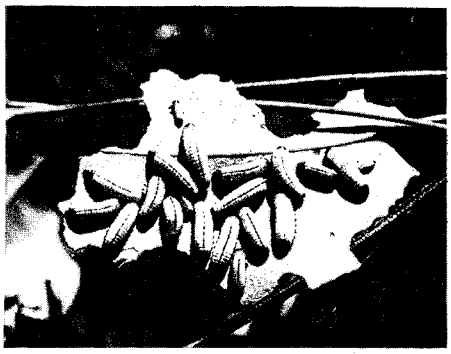
of the leaves in mid summer, trees have to put out copious quantities of new shoots in late summer and autumn to survive. Nothing could suit these other insects better.

Prominent among the eaters of fresh foliage is a group of insects known as chrysomelids, or leaf beetles. They are smaller than Christmas beetles, and often brightly coloured. As they go through two to three generations each spring-to-autumn growing season, their numbers can build up rapidly when conditions favour them. Both the grub and adult stages live on leaves, and they choose fresh shoots for egg-laying sites as well as for food. They drop to the ground only for the short time it takes the fully fed grubs to turn into beetles. Heavy weed growth around the base of trees seems to favour these beetles.

Dr Brian Selman, a leaf beetle specialist from the United Kingdom, recently spent a year with the Division of Entomology studying and classifying specimens collected between southern Tasmania and central Queensland. He found much greater numbers in former woodland and forest that had been extensively cleared than in undisturbed areas. He also found that beetle numbers increased with altitude.

On the tablelands of New England, which are 1000 m and more above sea level, he found trees being attacked by more leaf beetles of more species than trees anywhere else in Australia. He suggests that the following sequence of events may be the main immediate cause of the dieback there.

- ▶ Leaf beetles attack the flush of new growth in spring.
- ▶ The remaining foliage is attacked heavily by Christmas beetles.



Leaf beetle larvae on a partially eaten leaf.

- ▶ The trees then put out their secondary growth of juvenile foliage, and a large second generation of leaf beetles sets about removing it.
- ▶ Further secondary growth late in the growing season may be killed by early frosts.

However, insects of many types — not just Christmas and leaf beetles — attack eucalypts in New England and elsewhere, and their relative importance remains to be determined. So do the precise reasons why they have attained that importance. The problem is extremely complex and will take a great deal of unravelling.

Some complications

One fascinating aspect is the role of the oils in eucalypt leaves; some research suggests that, when trees are stressed, the composition of the oils changes, making the leaves more attractive to insects. It is possible that severe insect attack begins only after some environmental change — perhaps drought or a change in nutrient availability — has put the trees under stress.

To further complicate matters, some interesting differences exist in the way dieback manifests itself from place to place. In New England, the trees succumbing in greatest numbers are New England peppermint (*Eucalyptus nova-anglica*), Blakely's red gum (*E. blakelyi*), and boxes including the important honey-producer yellow box (*E. melliodora*). Stringybark species have proved the least susceptible. On the New South Wales Southern Tablelands, by contrast, a stringybark (*E. macrorhyncha*) is often the worst-hit species.

Also, in most areas very young trees are largely left alone by the insects. Trees that are a few years old and have grown into pole-sized saplings are generally the most heavily attacked. In New England, however, trees of all ages seem to face much the same onslaught.

Research

Virtually the only research now under way on the problem is a small effort in New England. This is coordinated by a working group brought together by the New South Wales Forestry Commission in 1976. The University of New England, the New South Wales Department of Agriculture, and CSIRO are involved.

The working group was set up in response to growing local concern about what is happening to the district's eucalypts. The New England Rural Development Association, a rural landholders' organization, started calling for research in the early 1960s. In 1965 Mr Robert Boyd, of the University of New England Botany Department, produced a booklet for the Association setting out current knowledge of the problem. Other local organizations that have pressed for action include the North and North West Regional Research Conference, which held a large seminar on dieback in Armidale in December 1975.

One of the first aims of the working group was to find out whether the severity

of dieback in different areas could be linked with characteristics of the country such as soil type, slope, and vegetation patterns. A series of map overlays prepared by Mr John Duggin of the University of New England's School of Natural Resources revealed no broad-scale associations when checked against a 1:250 000-scale dieback distribution map prepared by the Forestry Commission from road surveys.

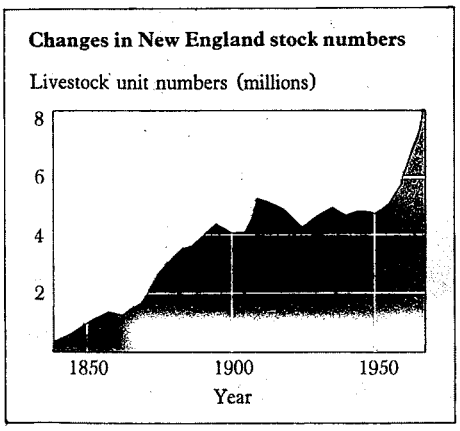
On a more local scale, Mr Rod Clark and colleagues from the Forestry Commission have examined trees on a statistically selected sample of 15 properties scattered throughout New England, trying to find associations between the degree of dieback and characteristics of both the trees and the country. On each property, they chose two typical 12- to 25-tree plots, one in dense timber and the other made up of scattered trees.

They recorded features of each tree including its height, trunk diameter, and maturity, and estimated the percentage of its crown that had been defoliated. They also looked closely at the epicormic growth prompted by defoliation, to assess the severity of attack by leaf-eaters in recent years and the extent to which trees had been able to recover.

All trees examined had lost parts of their crown to leaf-eaters. The foresters recognized up to three separate flushes of epicormic shoots on most trees, indicating that they had been defoliated repeatedly. Dominant, mature trees tended to be less severely affected than suppressed, immature ones.

Again no association between dieback and soil type could be detected. But a tendency showed up for damage to be worse on flat and poorly drained sites than on ridges and well-drained slopes. Whether this is due to characteristics of the sites or to the way the more- and less-susceptible eucalypt species are distributed remains to be determined.

Scores of Christmas beetles at work.



The graph shows how stocking in the New South Wales Northern Tablelands levelled off early this century, but then shot up with the introduction of improved pastures after 1950. The livestock unit used is the 'sheep equivalent': one head of cattle is assumed to exert the same grazing pressure as seven sheep.

Farm management link?

Looking for possible links between dieback and farm management practices, the Forestry Commission team obtained information from property-owners on current stocking rates, use of fertilizers, the proportion of their land sown with improved pastures, and so on. They also asked about the history of clearing, stocking, fertilizer use, and pasture improvement.

Once again, no clear pattern emerged. Dieback is particularly severe in some areas with a high proportion of improved pastures and high stocking rates but, to confuse matters still further, in similar areas the trees seem quite healthy.

European settlement of New England dates back to 1832, when the first grazier set himself up in the Walcha district. Stock numbers built up until about 1900, and then remained virtually steady until the early 1950s when pasture improvement by the spreading of superphosphate and the growing of nitrogen-fixing clover became general practice. Over large portions of the grazing land — typically 20–30% of the area of the properties surveyed by the foresters — native pastures have now been replaced by mixtures of exotic grasses and clovers. The result, on the most highly improved pastures, has been up to a doubling of pre-1950 stocking rates.

Part of the story of the eucalypt deaths in New England is the fact that survivors among the trees left standing when clearing began last century are growing old. The natural life span of a gum tree is around 150–300 years, so simple old age must be a factor in many of the tree deaths.

Grazing has put a stop to much of the natural replacement of these trees, as sheep and cattle eat eucalypt seedlings and the shoots produced by the stumps of felled trees. However, until the 1950s, one of the regular activities in the farmer's calendar was destroying regrowth in areas cleared of timber. The attention of stock was not enough to prevent regeneration; in fact up to 6 years' cutting was sometimes needed before suckers stopped appearing in cleared areas. Some new growth escaped both stock and the axe, and developed into mature trees.

Things changed with the introduction of improved pastures; farmers found they no longer had to clean up after clearing an area. The change was probably due partly to the greater density of these pastures, making it harder for eucalypt seedlings to become established. Also the impact of stock has probably increased — as a result of higher stocking rates and, possibly, of sheep and cattle seeking out gum shoots for roughage to supplement the lush pasture feed. Whatever the reasons, eucalypt regeneration in these pastures has virtually stopped.

Whether the use of superphosphate and introduced pasture species has increased the level of insect attack on the remaining trees, or adversely affected the trees in some other way, remains to be determined. The only evidence we have is circumstantial; local people say New England's dieback problem has become much worse since 1950, and particularly since the mid 1960s.

Possibly pasture improvement has increased Christmas beetle populations by making life in the soil easier for their larvae. Phosphate and nitrogen added to the soil by the superphosphate–clover combination may have made the trees more attractive to insects by changing the nutrient content of their leaves. Alternatively, they may have weakened the eucalypts directly; the soil

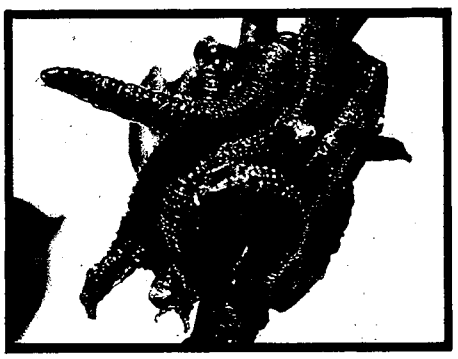
may now be too rich for the trees, which evolved in nutrient-poor conditions. Another possibility is that the replacement of native pastures with exotics has removed plant species that served as food sources for parasitic wasps and other insects that attack some of the leaf-eaters.

Before pasture improvement began, it was common practice to burn the dry grass off each winter. This encouraged lush growth in spring and reduced the risk of grass fires. The virtual abandonment of this practice in recent decades may be another factor tending to increase the leaf-eating insects' numbers. It may also have reduced the chances of eucalypt seedlings becoming established.

Saving some trees

Anyway, the eucalypts are dying rapidly and there are no immediate prospects of stopping the destruction. But it may be possible to protect prized individual trees, such as those around homesteads.

Forestry Commission scientists have greatly improved the condition of some trees by injecting insecticide into their sapwood. The chemical is carried through the



Sawfly larvae — another type of eucalypt leaf-eater.

trunk and limbs to the leaves, where it wreaks havoc among the feeding insects. The leaves remain toxic to insects for up to 3 months. As well as holding out the hope of saving particularly valued trees, the Commission's experiments tend to confirm the central role of insects in the dieback problem.

For tests that began in November 1977, the scientists chose six pairs of similar, partially defoliated trees at each of three sites near Armidale. One of each pair is treated with Nuvacon insecticide; these trees are already looking considerably healthier than their untreated neighbours. Treatment involves drilling holes about 5 cm deep and 1 cm diameter into the tree and pouring the chemical in.

One aim of the tests is to find out how often trees need the treatment to stay healthy. Another is to check that treatment can

A treated and an untreated tree in a Forestry Commission insecticide injection experiment. The treated tree is on the right.

continue indefinitely without damaging the tree. Each injection kills the wood around the hole out to a radius of about 1·5 cm, and the risk exists that repeated treatment may eventually weaken the tree.

Another potential problem being investigated by Forestry Commission scientists is the poisoning of bees along with leaf-eating insects. The risk of this seems small, as the dieback-affected trees that require treatment are unlikely to flower and produce nectar.

The chemical used for one treatment of a large tree costs about $1. Labour costs and the need for repeated treatment would push costs up, making it unlikely that the method will be used on a large scale.

Testing other eucalypts

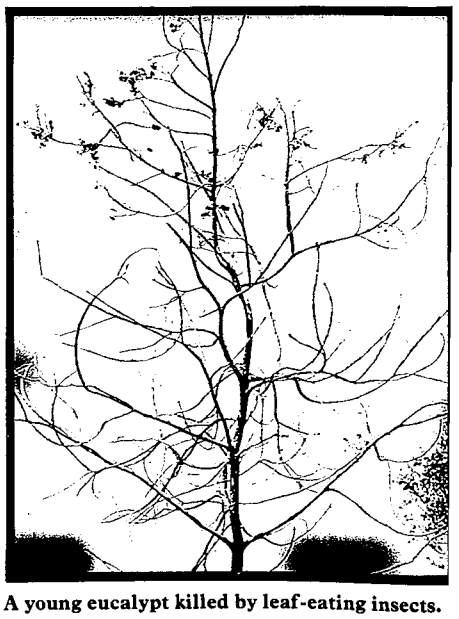
One of the working group's main projects is an attempt to find eucalypt species from other parts of Australia that will grow successfully in New England. If such trees exist, they can be recommended for planting in place of the dying local species. If none can be found, the only good prospects for planting will remain trees from abroad and a few non-eucalypt native species.

The Forestry Commission and CSIRO's Division of Forest Research have set up plantations near Walcha, Armidale, and Glen Innes. Twelve eucalypt species are being tested, together with a few acacias. It will be at least 10 years, probably more, before the scientists are able to say whether any species can be planted with confidence. But in the meantime they will accumulate information on the susceptibility of young plants to insect attack.

Dr Roberts began monitoring the impact of insects on the plantation seedlings in December 1977. Most of his observations so far are on the Walcha and Glen Innes plots, because some species in the initial planting at Armidale were wiped out by another of the hazards young eucalypts face in New England, frost.

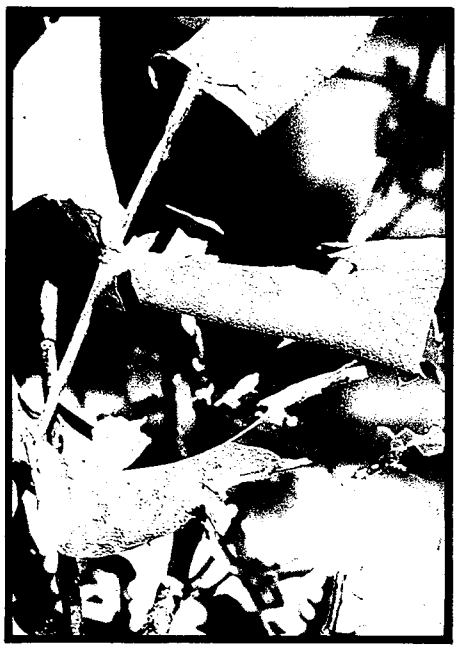
Insects attacked the plantations in force during the summer and autumn. Wingless grasshoppers were first on the scene in December. They do little damage to mature trees, but can have a big impact on young ones. They completely defoliated a few of the plantation seedlings.

Next up, in late December and January, were the Christmas beetles. Before these returned to the soil, species of caterpillars known as leaf tiers joined the attack. They tie the tips of leaves together with a sticky thread, and then settle down inside the bunch to eat the leaves. Leaf tiers caused most of the damage in February, but other insects, notably leaf suckers such as psyllids, also contributed.

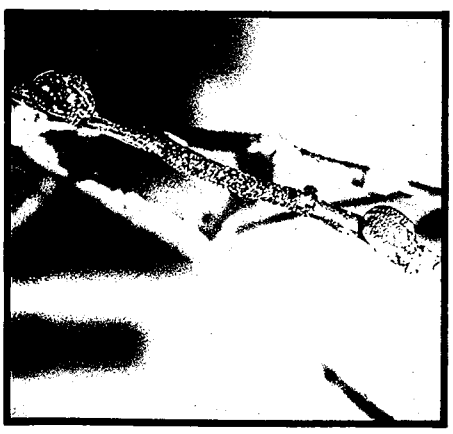


A young eucalypt killed by leaf-eating insects.

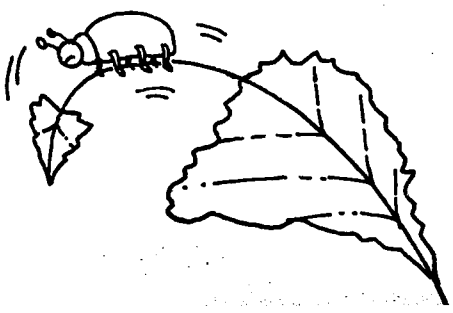
These cup moth larvae are leaf skeletonizers.



Skeletonizers remove the green matter from leaves.



Two species of leaf beetles. They come in many colours and patterns.



In March, large numbers of leaf beetles appeared at the Glen Innes plantation, but not at Walcha. Apart from that invasion, leaf skeletonizers — caterpillars that pick the soft tissue out of leaves — were the main insects carrying the attack into the winter.

The young trees at Walcha fared considerably better than those at Glen Innes, most of which were looking very unhealthy when winter brought a respite from insect attack. A difference between the plantations that Dr Roberts suspects may be significant is that the Walcha plot is quite close to some healthy stands of eucalypts, while most of the trees within sight of the Glen Innes plantation show severe dieback symptoms. He thinks the insects may have attacked the young plants there particularly severely because their favoured food was in short supply on older trees.

Among the species that have done best in the trials so far is the snow gum (*E. pauciflora*), which has also done well in recent street plantings in Armidale. The other strongest performers are Argyle apple (*E. cinerea*) and the swamp gum (*E. ovata*). The species that has had the hardest time is a blue gum (*E. bicostata*). It has proved very sensitive both to frost and to insect attack.

A glimmer of hope?

An interesting line of research that Dr Roberts is now following arose out of studies, conducted with Mr John George of the CSIRO Division of Animal Production, of insects that damage pastures in New England. That work showed that stocking rates have a big influence on the abundance of soil-inhabiting insects.

Dr Roberts later found that numbers of some insect pests, which reached damaging levels when stocking rates were held constant, declined steadily when they were alternated each year between higher and lower levels. This happened despite the fact that the average annual stocking rate remained unchanged.

The insects affected included Christmas beetles, so there is a possibility that the abundance of these important defoliators of eucalypts could be reduced by manipulating grazing regimes. Other leaf-eating insects would not be affected directly, but conditions might become less favourable for them if the level of Christmas beetle attack on the trees declined.

Whether alternation of stocking rates would have the same effect over large areas as it has had in small experimental plots remains to be seen, and farm-scale trials are now being organized. However, the results achieved so far bring a glimmer of hope to the generally dismal dieback picture.

Writing in 1965 about the death of eucalypts in rural areas, Dr Max Day, now Chief of the CSIRO Division of Forest Research, said: 'We see today a very large number of trees which are not going to live more than perhaps a decade or two in the future, and their place is not being taken by new seedling trees ... The Australian countryside is changing at an unprecedented rate. Our children will never see many of the things which we saw 30 or 40 years ago and the rate of change is increasingly rapidly.' There are few grounds for optimism that this trend will be reversed in the near future.

More about the topic

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