INSECT EPIDEMICS ON FOREST TREES IN NEW ZEALAND

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FOREWORD

This paper, which does not set out the results of any particular piece of research, was presented as a contribution to a symposium on Forest Communities at the Second Annual Meeting of the New Zealand Ecological Society held in Wellington in May 1953. It was written largely for botanical ecologists, to illustrate the important part played by insect epidemics in the normal development of forest communities, a point which tends to be overlooked by most botanists. As it had to be restricted in length to keep within the time limits set for reading papers, it may be found wanting in detail and also over-positive in certain unproven statements. Nevertheless it is felt that, even removed from its context, it may prove sufficiently useful to practical foresters to justify its publication.

I. INTRODUCTION

Before dealing with specific cases of insect epidemics in New Zealand forests, it is proposed to treat briefly with the causes of epidemics and the sequence which they may be expected to follow. As this sequence is complicated and too varied to be discussed fully the generalisations made must not be applied unreservedly to specific cases.

An insect may normally maintain its population at a high level or at a low level, and the level will fluctuate both throughout the year and as between one year and another. Fluctuations within normal limits usually pass unnoticed, but occasionally abnormally large numbers of insects are produced, giving rise to the condition known popularly as an epidemic or plague.

Such epidenics may be brought to the notice of the casual observer through the defoliation or killing of plants, the pollution of reservoirs or even through the stopping of trains. Many epidemics of small harmless species, such as Psocids, pass entirely unnoticed. Epidemics are transitory in nature and have a recognisable course characterised by a rapid rise in population, a peak period, and a sudden decline.

In the conventional treatment of insect epidemics it is usual to recognise a number of developmental stages which may be summarised as follows:—

1. *The biotic balance*; this is the normal state, previous to the epidemic, in which a balance is maintained at approximately the normal level.

2. *The preparatory stage* ; in which there is an increase in insect population but no visible damage.

3. *The podromal stage* ; in which damage is visible but not of economic importance, though there is a definite increase in insect numbers.

4. *The eruptive stage* ; in which the population rapidly attains epidemic proportions and severe damage may be caused.

5. *The crisis* ; at which point the epidemic breaks down.

6. *The decline* ; in which the population falls to or below the normal level. The biotic balance is then restored.

Such epidemics must not be confused with the sudden outbreak of a newly introduced inset, which may maintain a high level of population until the food supply becomes adjusted to the new biotic factor, or until native or introduced controlling factors such as insects or virus, bring about a balanced condition. Distinction must also be made between a typical epidemic and a new and more permanent high level of population due to the permanent failure of a controlling factor. Such conditions may arise through the development of immune strains or of resistant mutations, where a virus has been the main controlling factor.

The cultivation of a tree outside its natural range, particularly in large areas of one species and age, may also favour a high level of insect population. Similar results may occur where the balance of tree species in a mixture is upset through the milling of one species.

II. CAUSES OF EPIDEMICS

The predisposing causes of insect epidemics are numerous and often obscure. To initiate an outbreak a combination of peculiar circumstances may be required and it becomes extremely difficult to assess the relative significance of the various factors. In most cases the factors of greatest importance are climatic and should be, therefore, to a certain extent, predictable. Epidemics may be initiated by positive factors favourable to the insect or unfavourable to the tree ; or by the temporary partial cessation of those controlling factors which maintain the population within normal limits. There is a certain periodicity which may be observed in that epidemics are liable to occur in insects of the same order in the same period. This is particularly noticeable in orders having different feeding habits, such as Lepidoptera, Hemiptera and Coleoptera. This periodicity is probably associated with larval feeding habits.

The majority of outbreaks of forest insects may be placed in one of two groups depending upon the predisposing causes. In the first group the outbreak is brought about by the temporary failure of controlling factors and is independent of any debility within the tree itself. Such outbreaks may be influenced by increase in biotic potential owing to changes in the quality of the food; which is influenced, in turn, by the amount and quality of the sunlight. In the second group, at least in the initial stages, the outbreak is dependent upon some debility within the tree. This debility increases the availability of the food supply; and when once the epidemic is under way the vast numbers of individuals may themselves be capable of producing debility through concentrated or repeated attack.

INCREASE AND SPREAD:

Increase and spread tend to work in opposite directions, increase in numbers produces greater damage, while the rate of spread determines the concentration or the dissipation of the attack.

The rate of increase is determined partly by the biotic potential, or ability of the female to produce eggs, and partly by the extent to which controlling factors have ceased to operate.

The sex ratio is also important. If males greatly out-number females few eggs will be laid, but these are more likely to be fertilised, and, in the case of facultatively parthenogenetic species, will produce a greater proportion of females in the next generation. In a dense population, if climatic and other conditions are suitable, copulation is more likely to take place and either more eggs will hatch or more females will result. Another most important factor is the number of generations in a year.

Rate of increase is in geometrical progression and the number of individuals will reach astronomical figures if uncontrolled for three generations. In most cases the *controlling factors are not completely inoperative* and many generations may be required before the crisis is reached.

Increase is soon rendered impossible owing to the limitations of the food supply; spread is therefore necessary away from the centres of attack. Most frequently outbreaks spread from one or a few centres of infestation.

If the rate of spread is slow, damage is likely to be concentrated and more severe; rapid spread may disperse the population and reduce the severity of the damage. Spread may occur in the larval or adult stage and may be random or directional. Random spread takes place in more or less concentric circles from the point of origin; directional spread may be towards or away from light, up or down hill, with or against the wind or towards fresh food supplies. These factors are equally important with regard to predators and parasites.

The combined biotic potentials of predators and parasites is normally greater than that of the host, and, unless increase is inhibited, they should attain numerical supremacy in the fourth generation or at least by the end of the eruptive stage.

If the spread of the host is greater than that of the predators and parasites, then these cannot overtake the wave of advance of the host.

In New Zealand spread is limited by the relatively small areas of forest of any one type, so that advance of even a few miles each year will result in all available territory being occupied in a short time. Epidemics are likely, therefore, to be of short duration. In countries where tracts of uniform forests may extend for a thousand miles, epidemics may advance foı many years without reaching the limits of spread.

THE CRISIS AND DECLINE

The decline of an epidemic is brought about by the factors of natural control which restore the balance at or below its previous level, or adjust it at a new level in harmony with new conditions. Apart from food supply the most important controlling agents are climatic and biological factors.

Climatic factors operate through their action on the tree, on the insect, or on other controlling factors. They tend to be cyclic and have been associated with sun spot cycles. They are also cumulative in their action, as for example when periods of consecutive dry years occur. Storm frequency and storm tracks have been shown to be significant in some cases. The paths followed by centres of high and low pressure are probably of prime significance in New Zealand.

Biological control may come through a general increase in parasites and predators, through the dominance of one species, or through a bacterial or virus disease. In some cases control has been attributed to lethal genetic factors.

The net result is an adjustment of the balance between rate of reproduction and the rate of mortality prior to oviposition, so that the population is first reduced and then maintained at about its normal level.

In general it may be said that the insects will either exhaust their food supply, or else will be controlled by parasites, predators, disease or climatic agencies.

III. EXAMPLES OF OUTBREAKS IN NEW ZEALAND FORESTS.

As already mentioned outbreaks fall naturally into two groups, according to whether they are independent of, or dependent upon, some debility within the tree. Insects causing outbreaks in the first group are termed primary and those in the second group secondary. It is then convenient to subdivide groups according to whether the insect and host are of indigenous or exotic origin.

We have, therefore two main divisions each of which has four subdivisions. This classification is of the greatest importance in the consideration of the economic problems arising out of epidemics. Predictions as to the duration of an epidemic, the probable amount of damage and the possibility of control, can only be made after due consideration of all the factors involved; and their accuracy is largely dependent upon the correct classification of the epidemic.

GROUP A. OUTBREAKS INDEPENDENT OF ANY DEBILITY WITHIN THE TREE

A.1. *Indigenous insect on indigenous forest:*

Epidemic outbreaks of caterpillars of the Oecophorid moth, *Proteodes carnifex* Butl., occur at intervals in forests of *Nothofagus cliffortioides.*

These outbreaks have not been studied and no details are available regarding parasites, predators or other controlling agents.

A.2. *Indigenous insect on exotic forest:*

On 3rd December 1951 an outbreak of the Boarmid moth, *Selidosema suavis* Butl., was reported defoliating sixteen year old *Pinus radiata* at Eyrewell State Forest in Canterbury. The larvae pupated early in December by which time the trees over some 500 acres had suffered defoliation of the lower half of the crown. Vast numbers of adults emerged towards the end of December and spread over 4,000 acres. Eggs were laid and young larvae appeared in January, 1952. These caused considerable defoliation before they pupated in February and March 1952. Adults, which appeared again in April and May, oviposited and died. The eggs hatched in September 1952 and larvae appeared in great numbers over some 6,000 acres.

A similar outbreak was reported at Balmoral State Forest in February 1952 which spread over 2,000 acres by September. No conclusive evidence is available to indicate the exact factor responsible for these outbreaks, control was effected through aerial spraying with D.D.T. and on a heavily infested area of 1,000 acres in Balmoral left untreated, control came through disease. The eggs of *Selidosema suavis* are parasitised by a species of *Trichogramma*, the larvae by a species of *Rogas*, and the pupae by several Ichneumonids and a Chalcid. Several predators were active, particularly the Pentatomid, *Cermatulus nasalis* Wwd., spiders and birds. The net result of parasites and predators was neglible in reducing the population in the first three generations but it is probable that control would have been effected by the end of the fourth generation if disease had not intervened.

A second species of Boarmid, *Declana floccosa* Walk, was present on the trees and it is an interesting point that this species showed no noticeable increase in numbers above normal.

A.3. *Exotic insect on indigenous forest :*

No outbreak of this group has yet been recorded in New Zealand. The introduction of a primary insect from Tasmania or South America could have serious results to our *Nothofagus* forests. Such outbreaks are not strictly epidemics but uncontrolled populations at a high level. There are many examples from overseas ; in Canada the European spruce sawfly, *Diprion polytomum* Hartig, and the pine sawfly, *Neodiprion serifer* Geoff., caused extensive damage and were not controlled by the many parasites introduced to check them. Both have now been controlled by virus diseases, introduced accidentally in the case of the spruce sawfly and intentionally for the pine sawfly.

A.4. *Exotic insect on exotic forests :*

No true outbreak coming within this group has yet been recorded here. However, the destruction of *Eucalyptus globulus* by the combined action of many exotic insects may possibly be included.

Another border-line example is the elimination of the genus *Picea*, as forest trees, by the spruce aphid, *Neomyzaphis abietina* Walk., and the spinning mite *Paratetranychus ununguis* (Jacobi).

In these examples there is some doubt as to whether the insects should be considered as primary. Control has been attempted through the introduction of predators and parasites but there is little evidence that any beneficial results have been achieved.

GROUP B. INSECTS DEPENDENT UPON SOME DEBILITY WITHIN THE TREE

B.1. *Indigenous insect on indigenous forest :*

Outbreaks of the Buprestid beetle, *Nascioides enysi* Sharp, are of fairly frequent occurrence.

The eggs are laid on the bark of trunks of species of *Nothofagus* and the larvae bore in towards the cambium.

Successful attack depends upon the ability of the larvae to destroy the cambium. In a rapidly growing healthy tree with a plentiful water supply the larvae fail to develop. With successful attack the tree is killed and the larvae reach full size and pupate, usually in the bark.

Predisposing causes are :—overcrowding of trees ; root injury due to trampling of stock or deer ; attack by *Armillaria mellea* ; silting ; flooding ; drought ; earthquake ; fire ; felling operations.

Once an epidemic has started, progressively more healthy trees may be killed through repeated mass attacks. All mature trees may be killed over considerable areas but (in pole stands the epidemic usually stops when 25-30 per cent of the trees have been killed.

Control comes through the elimination of susceptible trees, and, in pole stands, through the temporary relief from severe competition consequent upon the reduction in numbers of the trees. The return of climatic conditions more favourable to the trees increases host resistance and lessens the chances of successful attack.

The Buprestid larvae are parasitised by a Colydid beetle, *Bothrideres obsoletus*, and a Braconid, *Doryctes pallidus*. The most severe outbreak recorded culminated ten years after the Murchison earthquake and covered som 800 square miles of forest.

B.2. *Indigenous insect on exotic forest :*

No outbreak in this group has yet been recorded in New Zealand.

B.3. *Exotic insect on indigenous forest :*

No outbreak in this group has yet been recorded in New Zealand.

B.4. *Exotic insect on exotic forest :*

Outbreaks of the sawfly, *Sirex noctilio* Fabr., occur at intervals in forests of *Pinus radiata* (and to some extent with other species of the same genus).

Eggs are deposited, between January and March, in the wood of living trees and at the same time fungus spores are inserted.

Successful attacks depends upon the ability of the fungus to invade the wood and cut off the water supply to the crown. With a plentiful water supply the fungus is unable to kill the tree, invaded areas are surrounded by resin barriers, the fungus dies and eggs or young larvae fail to develop.

There is one generation each year, at least in the North Island, and an epidemic can develop in three years.

Predisposing causes are overcrowding and drought conditions continuing for three years. In addition to the favourable conditions within the tree, an epidemic may be accelerated owing to the drought conditions being favourable to copulation and so increasing the proportion of females in the next generation. Copulation may also be favoured, in this case, by the assembly of large numbers of individuals. Populations of between 250,000 and 500,000 per acre may occur, and, through mass attack, comparatively healthy trees may be killed.

Control is through the reduction in stocking by 25-30 per cent and by the return of favourable climatic conditions.

Sirex noctilio is parasitised by the introduced Ichneumonid, *Rhyssa persuasoria* L. ; by the Cynipoid, *Ibalia leucospoides* Hoch., introduced but not yet established ; and by the native Orussid *Guiglia schauinslandi* (Ash) Bens.

These parasites are of little value in preventing or controlling epidemics under existing conditions, but with improved silvicultural methods they should assist in maintaining the balance at a level low enough to prevent serious damage to forest stands.

IV. DISCUSSION

The most interesting points arising out of what has been said, centre round the negative, rather than the positive records.

Thus, we have had primary and secondary insects epidemic in indigenous forest; and we have had epidemics of a primary indigenous insect and a secondary exotic insect in exotic forests. But we have had no epidemics of a primary exotic insect, or of a secondary indigenous insect in exotic forests; nor have we had an exotic insect of either group in indigenous forest.

The most serious risk with the native forest, lies in the introduction of primary insects. For example, were some species of insect doing controlled damage to a species of *Nothofagus* in South America to be introduced, it could, in the absence of host resistance and natural controls, easily eliminate one or more species of *Nothofagus* from the forest in this country.

Similarly the most serious risk with exotic forests lies in the introduction of primary species (such as a defoliating sawfly attacking *Pinus radiata*), which attacks the trees in their native habitat or, what is even more dangerous, trees of the same genus elsewhere.

It appears inevitable that many more exotic insects will be introduced, in spite of quarantine regulations, and it is probable that many more indigenous insects will adapt themselves to exotic forests but the operation of natural controls should prevent exhaustive damage from native species.

Normal and natural insect epidemics have a role to play in the ecology of natural forests, and, in the final count, when the forest recovers it is in a better state, from a health point of view, than it was before. It is only when these processes conflict with human requirements for managed forests, in which the forester is, or should be, the dominant ecological factor, that control measures need be applied.

Abnormal outbreaks may be due to the emergence of a new species of insect, or to the acquisition by an insect of immunity to disease; or to long term changes in climate, from any cause; or to the introduction (usually by human intervention) of new factors into the forest. These outbreaks are all very different from typical epidemics in their impact upon the forest and may necessitate a permanent change to readjust the forest to the new conditions before a new balance is achieved.

V. SUMMARY

A brief account is given of the causes of insect epidemics and the course which they may be expected to follow. Insects causing epidemics are classified as primary or secondary and indigenous or exotic, and trees are classed as either indigenous or exotic. Examples are given of outbreaks in New Zealand and the significance of the absence of outbreaks in certain groups in the classification adopted, is discussed.

FARM WOODLOTS IN THE WAIRARAPA

By D. M. BLITHE

(Paper tabled at Annual Meeting)

In 1951 I was one of three departmental officers who shared the organising and judging of a Best Tree Planted Farm competition, sponsored by the district branch of Federated Farmers. During the course of the competition, the first of its kind in the Dominion, most of the farms in the district were visited and the judges' notice was constantly directed to the value a planned woodlot contributed to a farm's economy. My aim in presenting this paper is to bring forth for discussion the need of the planned woodlot in the national economy and also, the assistance we, as technical and practical foresters, can contribute. With our indigenous timber resources rapidly dwindling, conservation becomes more necessary and the fostering of the planned woodlot, in my opinion, essential.

The original indigenous private holdings in the Wairarapa have been over exploited for many years and as all the local State Forests are now regarded as protection forest, a large percentage of the timber requirements have to be imported from the central North Island. At the present time there are approximately 10 small milling plants cutting 50% each of exotic and indigenous timber. The exotic timber, predominately *Pinus radiata,* is being drawn from farm shelter belts and the present royalty rate ranges from 10/6d. to 14/6d per hundred board feet. The foresight of the early settlers can be seen in the excellent shelter belts still on some initial farm properties, but much of this has been milled and this source of supply was of great value during the war years. It is most regrettable that so little has been done by the farming community to replace this asset. Many of the plantings in the Wairarapa date from the 1920's when the Forest Service made available free or low-priced tree stocks.