Management of Spruce Budworm Populations

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Introduction

The definitions and implications of the management of pest populations have been explained and reviewed by Geier (1966). Briefly, when we speak of pest management we imply some manipulation of the environment to adversely affect an organism that is utilizing it in a way that is incompatible with our own use. The manipulation is brought about through cultural practice, or by the addition of a regulatory agent such as a predator or an insecticide. Ideal management will of course be specific, the manipulation not adversely affecting any organism but the pest. Unfortunately we do not have a specific regulator for the spruce budworm and manipulation with insecticides regrettably leads to side-effects in the ecosystem. Proper choice of chemical dosage and application technique will mitigate these, but there is an appreciable margin of error and risk of environmental contamination. The fact remains however that the use of insecticides is the only practical method of crop protection available when we are faced with a large outbreak of this pest. The alternative is to concede the forest to the budworm, reducing losses as much as possible by salvage cutting — a small consolation at best, and to look for alternate sources of supply. In some parts of Canada this course of action is still economically acceptable but in most areas it is not tolerable.

Spraying in New Brunswick

The greatest effort to protect the crop from the budworm has been made in New Brunswick over the past 15 years. An outbreak started in the northern part of the Province in the late 1940's and aerial spraying was initiated in 1952. Spraying continued in northern New Brunswick until 1958 when the epidemic in that region collapsed. The epidemic con-

tinued in the central portion of the Province, however, and spraying was resumed there in 1960 and has continued to 1967. Over 9,000,000 acres have been sprayed one or more times to date. The spray program has undoubtedly been a successful venture in management. Most of the sprayed forests are in good condition and although there are dead trees scattered throughout the region, in no case was a major operating unit destroyed or a long-term management plan disrupted by severe tree mortality. In contrast over 65 per cent of the forest is dead in two check areas, covering approximately 60 square miles each, that were reserved from spraying.

The spray program has been equally successful in terms of cost-benefit. It is estimated that under normal circumstances forest production in central New Brunswick should exceed 500,000 cunits annually by 1980. If the spray program from 1960 to the present had not been undertaken some 400,000 cunits would be lost annually from production by 1980, resulting in the annual loss of some 2400 man-years employment in an area that is already severely handicapped economically in relation to the rest of Canada (Macdonald, 1966). Production would increase gradually but it would not return to its full potential until sometime after the year 2000. The cost of protecting the forests, \$11,600,000, 1952-1958, and \$10,200,000, 1960-1967, has been but a small fraction of the value of the resource and a very real investment in the future.

Between 1952 and 1958 spraying was recommended only when a further year's defoliation would threaten the life of the trees. This criterion was relaxed for the central New Brunswick operation because such delays often resulted in damage from top- and root-rots and prolonged reduction in increment. Also, many of the trees had been weak-

ened by earlier defoliation in the area overlapping the 1950-1958 outbreak, and others by infestations of the balsam woolly aphid. Accordingly there has been a tendency to spray earlier and more often since 1960. At no time however has there been a policy of insect eradication; crop protection has remained the foundation of the operating policy in this program against the budworm.

Use of DDT and Other Insecticides

DDT has been the primary insecticide in all operations. It was applied at 1 lb. per acre in 1952 and at $\frac{1}{2}$ lb. from 1953 to 1958. Unfortunately, at these dosages it caused severe reductions in the youngest age-classes of Atlantic salmon and in many species of aquatic insects. Collaborative investigations on various insecticides by the Chemical Control Section of the Department of Forestry and the Fisheries Research Board led to the adoption of a $\frac{1}{4}$ lb. DDT per acre dosage which was compatible with forestry and fisheries interests. This has been the standard dosage since 1960. Organophosphate insecticides have been field-tested at various times. Phosphamidon was found to be effective against the spruce budworm and fish toxicity tests indicated that the margin of safety for this insecticide in the aquatic environment is 300 times that of DDT. Phosphamidon was tested operationally in 1963, when it was used in 1-mile wide blocks along major salmon rivers while DDT was applied to the remaining area. This technique, developed by Forest Protection Ltd., provided protection to the trees near the river and avoided the risk of spraying DDT directly onto the water. The general operating procedure since 1964 has been to spray strips approximately $\frac{1}{2}$ -mile wide with Phosphamidon along the major salmon produ-

cing rivers within the spray plan. Phosphamidon unfortunately caused measurable bird mortality (Fowle, 1965) at the $\frac{1}{2}$ lb. per acre dosage but a series of operational experiments revealed that $\frac{1}{4}$ lb. per acre resulted in much lighter bird mortality. In the past two years this insecticide has been applied along the buffer strips in two applications of $\frac{1}{4}$ lb. per acre each, four or more days apart.

The search for alternative insecticides to DDT is a continuing function of the Chemical Control Research Institute of the federal Forestry Branch. Their results suggested that Sumithion would be an effective insecticide against spruce budworm with fewer side-effects. Operational tests indicated that a satisfactory reduction in budworm densities could be achieved with $\frac{1}{2}$ lb. Sumithion per acre with minimal adverse side-effects on fish and birds. This insecticide was used in 1967, both alone and in combination with Phosphamidon, on 200,000 acres.

The testing and operational use of other insecticides, does not necessarily mean that DDT is no longer regarded as a satisfactory insecticide, against the spruce budworm in Canada. It causes very good population reduction at dosages between $\frac{1}{4}$ and $\frac{1}{2}$ lb. per acre, and when used in concert with insecticides that break-down in water, such as Phosphamidon, there is little damage to the aquatic fauna providing reasonable precautions are used. Prolonged use in a small portion of the outbreak area in New Brunswick has led to some resistance to DDT in localized populations but this is not yet an important factor over the entire outbreak. This insecticide is considerably safer for the mixing and ground crews and the pilots than most of the organophosphate insecticides that are effective against the budworm and it is much cheaper. DDT is rightly criticized for its persistence, but it should

be acknowledged that many of the problems attributed to it arise from the use of heavy doses. There are many situations where its use is still warranted, since it is an exceptionally effective insecticide, although its impact on the ecosystem has never been fully assessed. This situation is now being remedied in New Brunswick where a 1,000 acre block in a small area that has been sprayed in 10 of the past 12 years has been reserved by the New Brunswick Department of Natural Resources for pesticide residue studies. Chemists, entomologists, and fisheries and wildlife biologists from several federal and provincial government departments and three universities are co-operating in studies to assess the distribution of DDT residues in the plants, soil and water, and their effect on key fauna.

Spraying has created a new ecological situation in New Brunswick that must be watched very carefully. The extensive overmature forests, which in earlier outbreaks would have been destroyed, have been preserved and still have the potential to generate another outbreak during periods of favourable climate. An extrapolation of Greenbank's (1965) analysis of climate before the recent outbreak in the northern part of the Province suggests that a similar weather sequence should occur within the next decade. Thus, while spraying is a pragmatic approach to budworm management, it does little to alleviate the basic problem. Budworm outbreaks will probably recur at more frequent intervals following a spray program unless the forest conditions that fostered the development of the outbreak are drastically modified.

Over the past 40 years forest entomologists have been making general recommendations for the prevention of budworm outbreaks and the reduction of damage, and these have become classic platitudes in forestry literature. In essence they reflect the basic concepts of good silvicultural practice: short rotation and intensive exploitation of balsam fir; separation of susceptible types into small compartments broken up by areas of non-susceptible forest and younger age classes; and the encouragement of other species. The validity of the cultural recommendations has been shown in the intensive investigations of the post-budworm forests of Ontario by Turner (1952) and in the population studies in New Brunswick (Morris *et al* 1963). Management foresters, however, have been discouraged by the immensity of the problem from doing anything that is not compatible with the immediate cost-supply requirements of their local economic units. This short-term approach inherently accepts the risk of extensive spraying operations and harmful side-effects, and is a doubtful economic substitute for long-term pest management.

It remains then for the forest entomologist to suggest ways in which the classic concepts can be applied in a practical manner.

Preventive Management for Spruce Budworm

The first step in the preventive management process is to recognize that spruce budworm outbreaks may eventually extend over 10,000 to 20,000 square miles of forest. Therefore spruce budworm

management must be practiced throughout major regions within a province, such as northern New Brunswick, the Saguenay in Quebec, or Algoma in Ontario. For each of these it will be necessary to decide whether or not the regional economy can afford to suffer another destructive spruce budworm outbreak. The economic and social interactions must be considered along with the more obvious effects of decreased productivity and increased fire-hazard.

In some regions it is already obvious that another destructive outbreak cannot be tolerated and preventive measures should be initiated immediately. In other regions the need for prevention is not clear cut and in these cases all the tools of sophisticated decision making should be employed to determine the course of action to be taken against the budworm. Mathematical models will have to be developed to simulate the results of cutting policies, of budworm outbreaks, and of the attendant interactions.

The provincial governments, which are responsible for the great bulk of the forest, must play a major role in initiating and administering any budworm prevention management plan. They will have to work closely with local industrial consortiums since actual implementation will finally depend on the cooperative actions of the individual companies within the region. The spraying program in New Brunswick is an excellent example of several industries and the Province co-operating to meet the immediate threat of a budworm outbreak. It would be a logical progression for this group to initiate a preventive program in the forest that they have already protected.

The next step in the preventive management process is to prepare a regional hazard map locating all areas of overmature balsam fir and spruce forest (Balch 1946, Morris and Bishop 1951, Morris 1958). The hazard area should then be examined carefully for areas where the spruce budworm is most likely to erupt first. Although epicenter prediction has not been the subject of any specific research project to date, I believe that we are now in a position to define in considerable detail where outbreaks can be expected to erupt. These potential epicenters will be areas where conditions are most frequently ideal for budworm growth and survival. In eastern Canada they will have a high proportion of overmature balsam fir, and will be characteristically dry and sunny in relation to the surrounding forest. Techniques for locating such areas have been described by Wellington (1965) who showed that differences in topographic relief produce recurrent patterns of cloudiness during turbulent or convective weather. Thus certain areas experience predictably lower frequencies of cloudiness and rain than others and these can be mapped from the ground or from the air. Wellington (1965) prepared a climatic map of the Saanich Peninsula on Vancouver Island showing cloudy and cloud-free zones and followed the population trends of the western tent caterpillar, *Malacosoma pluviale* (Dyar), in each. He found significant differences in population den-

sity between climatic zones over an eight-year period. Similar differences should occur in endemic spruce budworm populations and climatic maps of the high hazard areas would indicate the potential budworm epicenters. The delineation of the potential epicenter areas would considerably reduce the area that must be manipulated initially and could make cultural practices a practical preventive technique, since cutting would render these areas unsuitable for budworm population growth.

A major portion of the regional annual cut should come from these high risk areas, although the actual percentage in any one local industrial unit should be commensurate with local problems. It must be emphasized, however, that once the preventive program is undertaken within the region no large area of forest can be exempted from the treatment plan.

Reducing the hazard by cropping the potential epicenters will be a long-term program that may not be completed before the next period of favourable weather, therefore population trends should also be followed in selected high risk areas to give early warning of potential population explosions. Annual analyses of air mass movements (Wellington 1954) will also provide information on climatic trends affecting budworm survival and will be of predictive value on an inter-regional basis. If surveys reveal that the insect is increasing to outbreak densities then further direct manipulation will be warranted. Aerial spraying with DDT has already been used successfully to suppress populations in a small residual outbreak in Quebec (Blais 1963) and in two outlying infestations in New Brunswick. The key to success in these situations has been to delimit and treat the entire infested area. The aim of such programs should become population control rather than crop protection, and the insecticides and dosages should be chosen to give the greatest possible reduction in the numbers of insects, even at the risk of some temporary side-effects.

Research in New Control Methods

Research is progressing on alternative control methods that should be very effective against incipient outbreaks in the future. The production and release of sterile male moths offers promise in these localized situations, especially when used in concert with larvicides. Similarly research on sex attractants and mating inhibitors currently underway may lead to the development of techniques which will confuse the male moths and depress the reproductive potential of the population. Investigations are now being initiated by the federal Forestry Branch into new methods of reducing the reproductive capacity of insect populations by the use of juvenile hormones, or other disruptions of the insect's endocrine system, and it is hoped that the principles developed will be applicable to the spruce budworm.

Treatment of Large Outbreaks

In the early stages of a long-term preventive management program it is quite probable that the population will escape all control attempts and a full blown outbreak will develop. Entomologists should be quick to concede this and to switch from at-

tempts at population control to a program of crop protection, spraying only when and where it is necessary to avoid serious damage and tree mortality. Valuable guidelines can be taken from the New Brunswick experience, and the control strategy should be developed very early in the outbreak utilizing the models that are available in simulation studies to test various courses of action. I have outlined elsewhere the research work that is still needed to refine these models (Macdonald, 1966).

From this rapid sketch of our experience and thoughts on the spruce budworm problem it is evident that we have the ability to prevent the massive destruction of the spruce-fir forest when it is threatened by a major spruce budworm outbreak. Our research work has also provided the foundation for a practical program to reduce the vulnerability of the spruce-fir forests of eastern Canada and this could eventually lead the way to a true management of spruce budworm populations.

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