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The Spruce Budworm Problem in Ontario -- Real or Imaginary?

Proceedings of a Symposium sponsored by the Ontario Ministry of Natural Resources and the Great Lakes Forest Research Centre under the auspices of the Canada-Ontario Joint Forestry Research Committee

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Proceedings O-P-11

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Timmins, Ontario
14-16 September, 1982

C. J. SANDERS and J. R. CARROW, COCHAIRMEN

DEPARTMENT OF THE ENVIRONMENT

CANADIAN FORESTRY SERVICE

GREAT LAKES FOREST RESEARCH CENTRE

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FOREWORD

This symposium on the spruce budworm problem in Ontario was held in Timmins, Ontario, 14-16 September, 1982. It was the twelfth in a series of symposia conducted under the auspices of the Canada-Ontario Joint Forestry Research Committee (COJFRC). These symposia are intended to provide a forum for discussion and an interchange of ideas among provincial and industrial forest managers, educators and researchers in the field of forestry in Ontario.

The purpose of this symposium was to improve understanding of the nature of the spruce budworm problem in Ontario, and to generate discussion on five theme questions relating to the importance of the problem in Ontario in the future (1982-2000).

The five questions were:

1. How important will the spruce-fir component be?
2. What are the attitudes of forest industry towards future utilization of balsam fir?
3. In what forest use patterns will the spruce budworm be important?
4. What management actions should be taken now to reduce future impact?
5. What information is needed to facilitate management of the spruce budworm problem?

The program was arranged so as to encourage participants to attempt to answer these questions; the very title of the symposium deliberately raised a contentious issue, an issue which was developed by the keynote speaker, K.A. Armson.

As background to the problem, the program provided a review of the biology of the budworm, its history and impact ("Setting the Stage", moderated by C.D. Fowle). This was followed by a discussion of current and possible future techniques for coping with the problem ("Living with the Budworm", moderated by J.R. Carrow). The next session reviewed the importance of the budworm's hosts (balsam fir and white spruce) in Ontario, and the effect the spruce budworm has on policy and planning at the provincial level ("The Ontario Overview", moderated by D.E. Ketcheson).

The field trip to Kirkland Lake District east of Timmins was designed so that participants might view at first hand some of the problems presented by the budworm.

On the final day the program began with summaries by representatives of each of the five northernmost regions of the Ontario Ministry of Natural Resources (OMNR)--i.e., the regions most affected by the budworm--of how the spruce budworm problem is viewed in each of these regions (Regional Impact of Spruce Budworm--Past and Present", moderated by D. Schafer). Presentations were then made by representatives from Quebec, New Brunswick and Nova Scotia, who told how the problem has been handled in their jurisdictions ("Approaches to the Spruce Budworm Problem in Other Provinces", moderated by C.J. Sanders). "Task groups" representing each of the five northernmost regions of OMNR met separately in the afternoon to review the five theme questions as they apply to each of the regions ("Regional Impact of Spruce Budworm-Future"). While these task groups were meeting, the remainder of the participants at the symposium viewed and discussed two films which relate to the spruce budworm problem and how it can be handled: "The Forest in The Valley" and "Decisions" (moderated by G.W. Green).

Finally, at a plenary session, the five regional task groups reported their conclusions (moderated by J.R. Carrow). Much of the content of the two sessions dealing with the regional impact of the spruce budworm overlapped. Therefore, in these proceedings they have been included under the single heading "Regional Impact of Spruce Budworm-Past, Present and Future".

A total of 105 delegates attended the symposium. They were officially welcomed on the first morning by J.H. Cayford, Director of the Great Lakes Forest Research Centre, and A.H. Peacock, Chairman of COJFRC and Executive Coordinator of the Forest Resources Group, OMNR, Toronto.

The papers in these Proceedings, with the exception of the correction of typographical errors and misspellings, the checking of references, and the redrawing of some figures, appear as they were submitted by the authors. However, in the interest of brevity, the scientific names of the spruce budworm (*Choristoneura fumiferana* [Clemens]) and of tree species mentioned in the Proceedings have been omitted. Common names of tree species are those given in "Native Trees of Canada" by R.C. Hosie.

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WHY ARE WE HERE?

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It is my observation that titles for meetings or of scientific and professional papers fall into one or other of three categories. They may be prosaic and specific, telling the reader exactly what they are about in no uncertain terms, apart from the use of jargon. These may be categorized as honest but usually dull. A second category uses the time honored "carnie" or medicine man technique. The title attracts by titillating the fancy of the onlooker. A mundane study of the chemical content in the component organs of six sample pine trees may be titled "The Dynamics of Nutrient Cycling in Conifers - a Systems Approach". As with "Little Egypt" much less is revealed by the performance than the viewer anticipated. A third technique is to shun both the prosaic and the overblown and use the rhetorical gambit. This is obviously the category into which both the meeting title and that of my paper fall. It is a simple pedagogical device developed by a number of Greek teachers and philosophers. The objective is to develop a line of reasoning from one or more starting points or perspectives, that perhaps at first sight do not appear obvious. If they achieve their effect by turning you around -- they are revolutionary. In that case they have been very successful. You now think thoughts and relate things in ways you had either not considered or had rejected out-of-hand as inadmissible.

More frequently, this third ploy results in a glancing blow rather than delivering a knockout to our mental solar plexus.

Do we have a spruce budworm problem in Ontario? If I consider the main topics to be dealt with at this meeting then the answer would appear to be yes. Whether the problem is real or imaginary hinges on the degree to which the speakers deal in fact or fiction. None of them to my knowledge are authors of best-selling novels, and most, if not all are employed, presumably gainfully, by organizations which are not noted for employing writers of fiction. This last point, it has been suggested to me, may be debated by some! Superficially it would seem then that we have a budworm problem and it is a real one. If this is the assertion and I am on my professional mettle then I cannot accept the assumption without further substantiation. After all one difference between a layman on one hand and a professional or scientist on the other is that the first perceives the obvious, recognizes it as such and proceeds to deal socially with those who challenge the obvious, especially when the challengers question that which is embedded in culture, religion and politics. Historically the challengers have often met with imprisonment, torture and other forms of mistreatment. In our modern civilized world the mistreatment has often become inverted so that the challengers to accepted ways, instead of going to the rack, are paid to inhabit universities, with library racks and carrels instead of cells, or are entertainment personalities in the media. These latter generally employ skirmishing tactics rather than the deeper penetrating armament of persistent logic.

But back to the business at hand. The question is, "Why are we here?", and related to it is the assumption of the existence of a real budworm problem in Ontario.

First, many though not all problems arise because something that did not exist before, or did so in a limited manner, now occurs in significant amounts.

The spruce budworm, we are told (Swaine and Craighead 1924, Blais 1968) has occurred as a component of our natural forests for many hundreds, if not thousands of years. Although its numbers and therefore its impact as a consumer of forests has varied cyclically its presence is not novel. It cannot be classed as a pest in the same way as introduced ones such as the gypsy moth (*Porthetria dispar* L.) or the European pine shoot moth (*Rhyacionа buoliana* Schiff.); related to a large degree to the fact that it is indigenous, the budworm is part of the sequence of natural ecological processes going on in our boreal forests. It is part of the dynamics of this forest system, including the increased susceptibility to fire following upon mortality caused by budworm, although this susceptibility may be only for a short period.

As a competitor for wood, the budworm can hardly be construed as threatening the raw material supply to the forest industry in Ontario, as it does in New Brunswick. Over the past several years balsam fir has constituted only 3-6% of the wood harvested from Crown lands in Ontario.

Where it is a competitor for "our" wood in local areas, where it reduces growth of spruce or more importantly our harvest of spruce cones and seed, we have control measures which can be applied to at least minimize these losses on a local basis. What are these control measures? Many exist although few are used. The aerial application of a pesticide--DDT---was first developed in Ontario in the 1940s. Since then, and largely in response to the need for control in the northeast, many other measures have been employed, a number of which have proven relatively satisfactory. Over the best part of half a century the materials to control budworm have been well developed. The effects these materials have on other components of the forest system, including man, have been and are the subject of major concern by scientists, professional foresters and others.

The budworm itself has been an object of major scientific study, primarily by staff of federal government agencies, for over 40 years. Its life history, anatomy, physiology, reproductive behavior, feeding habits and preferences, flight patterns, parasites and so on have been documented, almost *ad nauseam*. It has been viewed, photographed, counted, trapped, bottled, dissected, crushed, analyzed and otherwise scrutinized as perhaps no other Canadian forest insect pest has been.

Why are we here? It isn't because:

- the budworm is a new pest about which we have little knowledge,
- the budworm is a new and unknown factor in the dynamics of our forests,
- balsam fir is a significant component of Ontario's industrial wood supply,
- the budworm causes damage, unsightly or otherwise, to trees in our communities,
- control measures are difficult or unknown,
- there are no management practices, including the shifting of conifer growing stock to less susceptible species, which will minimize the budworm problem.

Yet, the program before you at this meeting seems to deny my conclusions as to the reasons why we are here. If so much is already known, why are we gathered here to listen to one another talk about what either most of the concerned professionals already know about the budworm or if they do not know they could readily find out?

There are five theme questions which have been placed before you and which are the focus of this meeting:

1. How important will the spruce-fir component be?

2. What are the attitudes of forest industry towards future utilization of balsam?

3. In what forest use patterns will the spruce budworm be important?

4. What management actions should be taken now to reduce future impact?

5. What information is needed to facilitate management of the budworm problem?

These questions lead us down an interesting path, and I am certain that during the next three days they will be addressed and to a very large degree answered with scientific and professional competence. I do not believe, however, that these questions and the competent answering of them, no matter how rewarding to you as scientists and professionals, totally answer the fundamental question of "Why are we here?"

It is my view that we are here, in large measure, because the decisions and actions which have been and are used by industry and governments to address the spruce budworm problem are now challenged as never before. The challenges are made by persons who with dedication have called into question the actual practices employed and by implication raised the greater question of credibility and competence to make decisions and undertake such practices.

While initially the challenges related to the effects of such practices on the environment, they have more recently involved the possible damage to humans as a main argument for preventing the use of many materials and practices used in the protection and management of eastern Canadian forests, including herbicides.

The five theme questions implicitly make one basic assumption. It is that our society will allow the resolution of these questions on the basis of scientific, professional and economic facts, and knowledge related to defined forest management objectives. I suggest to you that that basic assumption cannot be made, and the reactions of certain governments to prohibit or limit the use of materials and practices during the past few years is ample evidence of this, despite the fact that in many instances there is no scientifically based justification for such prohibition or limitation.

Earlier this year the Ontario Professional Foresters Association featured the topic "Forest Protection" at their annual meeting. In the summary of the papers and discussions on forest insect control, the following statement is reported as a consensus of the panelists:

> *"Criticism of insect spraying projects will continue... As long as qualified authorities, both within and outside the regulatory agencies continue to assure us that forestry use poses no significant hazard to the environment or to human health, we should accept this professional judgement and get on with the job of insect control, even if it means taking some criticism".*

Here is an example of one profession--forestry--relying upon one or more others, yet the final decision to undertake spraying is a political one. We would be remiss if we failed to recognize that the final decision will always be subject to influences and arguments, that, unacceptable as they may be on scientific or professional grounds, can restrict practices otherwise deemed necessary.

The countering of these adverse influences requires a sustained effort to educate those who make the final decisions, and the forestry related community in the broadest sense, to the factors involved and the rationale for what we are doing or what is proposed. Those who challenge our forest management practices, particularly the use of pesticides, are articulate and frequently raise the spectre of harm to humans in what are best described as scare tactics. Neither logic nor scientific fact will sway them from their crusade; what must be countered is the influence they have on others, for the most part people who are open to reason. The forestry and scientific professions have been in the main inarticulate in the public arena, and therefore have consistently suffered. They have often countered emotion with logic and jargon and it doesn't work! Both industry and governments have made easy targets because of their large size and the fact that much of the concern involves Crown or public lands.

Many of you, I am sure, have made the point that use of pesticides in forestry is demonstrably less hazardous than in agriculture or other areas of human activity. But keep in mind that to attack those uses involves attacking farmer Jones who sprays his crops and Mrs. Brown who has a weed-free lawn. Small may or may not be beautiful but it sure makes for a smaller and less acceptable target.

We are here because, whether we think it deserved or not, we are under attack. The attack takes many forms but essentially calls into question our professional competence and judgment in managing the public forests. We and those whom we work for and with--government and industry--make a large target, often unwieldy and often characterized by being passive or reactive rather than by taking the initiative and being assertive.

Let me suggest that, rather than being a multicolored bull's eye target, we move forward bearing a standard and demonstrate, rather than remonstrate, to the public how we indeed are managing and can manage their forest lands on their behalf for the gain of all. The symbol of a standard is I think rather apt and in keeping with it I would parody a speech from Richard II which best sums up what I mean.

For God's sake let us sit upon the ground
And tell sad stories of the death of trees
How some have been disposed in harvest cut,
Some eaten by those insects and diseases they have host'd
Some consumed by forest fires, some windthrow killed
All felled; for within roots, boles and crowns
That round the being of our forest estate
Keeps Death his court, and there we foresters sit
Scoffing his state, and calculating our allowable cuts,
Allowing those a breath, some little scene
To publicize, confound and foil our plans
Infusing with their demi-truths and deceit
The world at large and those who make our laws.
Our knowledge and our logic is not impregnable
For those who emotionally restrict can with a little pin
Bore through our professional conceit, and farewell trees.

It is not enough to be concerned only with our professional competence and scientific verities; we have now as never before to articulate our position before our public. In order to do this we shall have to put our credibility on the line.

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SETTING THE STAGE

Moderator: C.D. Fowle

THE IMPACT OF SPRUCE BUDWORM ON THE FOREST COMMUNITY

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Abstract.--The spruce budworm has been an integral component of the spruce-fir forest ecosystem in northeastern North America for thousands of years. At irregular intervals, epidemic populations develop which destroy much of the balsam fir and some of the spruces. The new forest growing up after an outbreak is derived mainly from advance growth or from survivors, depending on the age of the forest.

This paper describes the sequence of impacts on the forest community in the cycle of development and decline of an outbreak. The significance of budworm damage in relation to fire hazard and some recreational uses of the forest is discussed.

Résumé.--La tordeuse fait partie intégrante de l'écosystème des forêts d'épinette et de sapin du nord-est de l'Amérique du Nord depuis des milliers d'années. À intervalles irréguliers, ses infestations détruisent la plus grande partie du sapin baumier et certaines épinettes. La nouvelle forêt qui pousse à la suite d'une infestation provient surtout d'une régénération préexistante ou de survivants, selon l'âge de la forêt.

La communication décrit la suite des répercussions sur la communauté forestière tout au long du cycle d'une infestation. On discute de l'importance des dommages causés par la tordeuse en relation avec le risque d'incendie et certains usages de la forêt à des fins de loisirs.

It may be a cliché to say that the forest is a dynamic community but, like most clichés, it expresses a profound, if obvious, truth--this one, a keystone of forest management. The dynamics of the forest are reflected in its history, the integration of all the interactions through time which together have determined the current species composition of plants and animals and have influenced their population parameters such as density, reproductive rate, growth and age distribution. We can all think of important interacting factors such as moisture regime, local climate, soil fertility and availability of seed trees but in spruce-fir stands and in the boreal mixedwood generally, we must emphasize the roles of fire, budworm and stem and root-rot fungi. The mosaic of types which is so characteristic of the forests of northern Ontario is the result of constant disturbance by these natural influences (Blais 1965, 1968; Rowe and Scotter 1973; Wright and Heinselman 1973; Kelsall et al. 1977; Alexander and Euler 1981; Basham 1981; Whitney 1981). The adaptive characteristics of the major tree species and other plants show that they have evolved in this dynamic environment and are well adapted to it. The serotinous and semiserotinous cones of jack pine and black spruce, the suckering of aspens, and the longevity of seed banks of species coming in after fire are all adaptations to survival in a fire-dependent community. Moreover, it has been suggested that natural selection has favored the evolution of fire-prone communities in providing combustible fuel in species such as white birch (Mutch 1970, Kershaw 1977, Day and Harvey 1981).

Of course, the budworm is also subtly adapted to spruce-fir stands where its periodic outbreaks ensure the maintenance of its own prime habitat. Baskerville (1975a) has called the budworm a *super silviculturist* in recognition of (and grudging admiration for) this ability. Like fire, the budworm is a permanent integral component in the dynamics of the boreal and acadian forests. It is not an occasional intruder (Blais 1965, 1968; Mott 1974; Baskerville 1975b).

Thus, from the long-term viewpoint the original boreal forest was a stable community in the sense that it was in a dynamic equilibrium of disturbance and regeneration, with parts of it being destroyed or set back periodically by fires every 75 to 125 years and by budworm outbreaks somewhere between 25 to 70 years (Blais 1965, 1968; Loucks 1970; Dix and Swan 1971; Carleton and Maycock 1978; Howse *et al.* 1980; Day and Harvey 1981). Maps prepared by Sippell (1982) show that about 90% of northern Ontario and the Algonquin Region has been infested with budworm at least once since 1937. The historical impact of budworm in New Brunswick is somewhat easier to detect than it is in Ontario and Quebec where a higher frequency of fires complicates the picture and may wipe out some of the effects of budworm (Baskerville 1975a). This short-term cycle of disturbance and regeneration has been such a feature of the mixedwood and boreal forests generally that it might be said that the climax of the region is really a hypothetical concept. Plant ecologists can only speculate and argue about its nature because the forest just does not survive long enough to let us see what a climax might look like.

Although fires and budworm are continuing as they have for thousands of years, the situation today is quite different from what it was even 100 years ago. Logging and fire protection have altered conditions over large areas and here and there we have attempted to check the budworm by chemical spraying. It is not surprising, therefore, that with so much human intervention, the processes fostering long-term stability have been upset and new equilibria are developing. This means that we must anticipate dealing with unstable systems or, at least, different regimes of ecological processes when addressing the practical problem of establishing the next commercial forest. It is important for us to keep this in mind since this symposium is concerned with predicting the role of the budworm in the future forest and in the management plans for stands yet to be harvested. Is it destined to play a significant role? How will it fit into the next forest? Is it a problem? What are the priority questions? It is certainly not my business to tackle questions like these for they are the substance of the symposium. My assignment is simply to describe how we think budworm affects the forest and suggest how its impacts may be significant.

Let me begin then with a hypothetical but, I hope, realistic description of the sequence of events accompanying a budworm outbreak. Because my example is an idealized and generalized scenario, it may not fit particular forests or outbreaks with which you are familiar, but it will give us a framework within which to consider impacts.

First of all, a quick review of the species composition of the forest affected by budworm in northern Ontario as shown in Table 1. Clearly, the major species are black spruce, jack pine and poplars. Balsam fir and white spruce, the budworm's favored host trees, make up less than 10% of the stand.

Most of the time the budworm is so scarce as to be very difficult to find, but occasionally as a consequence of a combination of factors not very well understood, there is a marginal increase of 2 or 3% in annual survival which, if sustained over three or four years, results in an enormous increase in the order of hundreds or even thousands of times. Miller (1975) reports increases from about five larvae per tree at the endemic level increasing in four years to 2000 and then to 20,000 or more in the fifth and sixth years. The population is then in an epidemic or outbreak phase. This level may be maintained for 6 to 10 years or more. Host trees, particularly balsam fir, may lose their new needles as well as some older growth each year to the successive instars of the larvae. The sixth instar is the most voracious feeder and may remove over 85% of the total foliage consumed in one season (Miller 1977; Sippell 1982). Fir start to die after 4 or 5 years of severe defoliation and continue to do so up to 7 to 9 years of attack. White and black spruce can hold out for 6 to 8 years (Baskerville 1960, 1975a;

Table 1. Species composition (percent) based on volume in forests affected by budworm in Ontario.

	Region				
	Northwestern	North Central	North	Northeastern	Algonquin
Balsam fir	3.3	6.4	6.9	8.1	5.1
White spruce	1.2	1.8	3.1	4.6	2.6
Black spruce	47.3	48.3	48.2	17.4	1.7
Jack pine	25.5	14.8	9.6	11.6	0.3
White pine	0.4	0.1	0.4	5.4	7.2
Poplar species	15.8	17.1	19.8	17.9	10.3
White birch	5.6	9.9	8.6	16.9	5.1
Other	0.9	1.6	3.4	18.1	67.7

From: Howse et al. 1982

Miller 1975; Baskerville and MacLean 1979). Those which survive are weakened and their growth is checked. Fir suffers the most, followed in order of decreasing damage by white, red and, finally, black spruce, which is rarely seriously affected. Dense populations may spill over and attack other species such as larch and eastern hemlock (Crummey and Otvos 1980; Sippell 1982). As the infestation develops in the upper parts of the tall trees the larvae drop down and feed on suppressed pole-growth and young fir and spruce below.

After perhaps 6-10 years, mortality of trees reaches a peak and the budworm population declines to a low level, again in response to a complex of factors varying in time and place, and the population declines to an endemic level. Food shortage, disease and adverse weather are thought to be important contributors, but the reasons for some declines are a mystery (Miller 1975; MacLean 1980; Ives 1981).

How and why does an outbreak get started? This question has prompted much speculation and various attempts to synthesize the field experience of many observers to reveal common factors associated wth explosive population increases. The factors seem to fall into two groups: those relating to habitat and those relating to ambient weather and microclimate in the trees. As far as habitat is concerned, most outbreaks seem to be associated with extensive, mature, dense spruce-fir stands over 60 years of age with a high proportion of fir and considerable advance growth located on certain topographic sites. Communities of this kind have been designated *highly susceptible* (Mott 1963) and outbreaks appear to originate in them and then spread to other types where the proportion of spruce and balsam is less and where there may be a substantial population of broad-leaved trees (Turner 1952; Greenbank 1963; Batzer 1969; Van Raalte 1972; Baskerville 1975a; Crook et al. 1979; MacLean 1980; Lawrence and Houseweart 1981).

Given the appropriate habitat and topographic location, weather also seems to have an important influence. A succession of three or four warm dry early summer periods (June and July) while larvae are feeding seems to contribute to that essential slight increase in survival which starts the upward trend in numbers (Wellington et al. 1950; Greenbank 1956; Pilon and Blais 1961; Blais 1968; Ives 1974).

There is evidence that microclimate might be important. Wellington et al. (1950) suggested that warm sunlit midcrown and crown environments with high evaporation rates favor larval survival. This led to the suggestion that, in mixedwoods, defoliation of poplars by the forest tent caterpillar (*Malacosoma disstria* Hbn.) would produce favorable conditions by removing shade from overtopped conifers, but this hypothesis was not confirmed in field studies by Ghent (1958a). He suggested that defoliation and death of poplars might make fir more susceptible to attack, but defoliation was not related to the origin of epidemics. It has also been suggested that loss of white birch to dieback in the Maritimes might improve microhabitat conditions in shaded spruce and fir, but this also has not been confirmed (Mott 1963).

Across the geographic distribution of the budworm in eastern North America the combinations of climatic and habitat conditions vary. In the Maritimes, the climate is generally cooler and wetter, but there are more extensive, older spruce-fir stands with high proportions of balsam than there are in Quebec and Ontario where dry warm springs are more common, but vulnerable habitat is more restricted (Pilon and Blais 1961; Blais 1968). These differences may be related to the varying frequency of outbreaks in the west and east.

There is no clear-cut evidence for the way in which epidemics originate and spread. There is some suggestion that they develop in *epicentres* or relatively small local areas in which favorable environmental conditions release the population (Sanders 1976, 1982). Centres of this kind have been described near Lake Nipigon and Lac Seul (Elliot 1960), Shebandowan Lake and Burchell Lake in northwestern Ontario and at St. Maurice and Temiscouata in Quebec (Sippell et al. 1969; Miller and Varty 1975). On the other hand, there seem to have been some cases where the population began to increase simultaneously over large areas (Miller 1975).

The outbreak spreads by the remarkable dispersal mechanisms of budworm which involve both larvae and moths. First instar larvae freshly emerged from eggs in summer and second instars emerging from overwintering hibernacula in the spring are wind-borne on extruded silk strands for short distances to nearby trees. In these stages there is a huge mortality among those failing to reach suitable sites for overwintering or feeding (Miller 1963). The dispersal of moths has been demonstrated by the imaginative research of Greenbank and his associates in which laborious day-long and evening observations above the forest canopy and the use of radar and aircraft at night have shown that vast numbers of females carrying about half their complement of eggs regularly take off at night and fly with the assistance of prevailing winds over long distances up to 90 km per night (Greenbank 1973; Greenbank et al. 1980).

This habit accounts for the marked tendency for infestations to spread in the direction of the prevailing wind (Elliot 1960; Pilon and Blais 1961) as well as for the prompt reinfestation of areas in which larval populations have been repressed by aerial application of insecticides. It probably also contributes importantly to gene flow among regional populations (Baskerville 1975b). Indeed, it now seems clear that a persistent power of dispersal is the key factor in the maintenance of outbreaks over long periods and large areas. In the sprayed forests of New Brunswick it could account for the persistence and constant shifting of the focus of the outbreak from one area of favorable habitat to another (Anon. 1976; Greenbank et al. 1980).

There are several ecologically important consequences of the attack. While the trees are alive and infested with budworm they are physiologically weakened, their growth is checked (Mott et al. 1957; Blais 1958a,b; Baskerville and Kleinschmidt 1981), rootlets die (Redmond 1959; Stillwell 1960), and they fail to produce flowers and seed (Ghent 1958b). In mixtures of fir and spruce the preferential feeding on fir leads to differential mortality and alters the age and species composition. As the trees die they are attacked by beetles, decay fungi and lichens (Belyea 1952a, 1952b; Turner 1952; Stillwell 1956; Basham and Belyea 1960). Depending on the type of stand, there may be a tendency after four or five years' feeding for some of the advance growth and subdominant suppressed trees to die first while the tops of the larger trees are dying (Stillwell 1956; Mott 1974). Some survivors such as white spruce may recover but die later because of loss of rootlets (Baskerville and MacLean 1979). Gradually, many of the large trees are killed and begin to fall (Hatcher 1964). As the forest opens up, windthrow removes some of the survivors and thereby increases the opening. Physical conditions are suddenly changed with the loss of canopy and there is rapid growth of shrubs such as raspberry, mountain maple, pin cherry, hazel, and a few herbaceous species (Ghent et al. 1957; Mott 1974). If the stand is old enough, the advance growth of seedlings established before the budworm arrived is briefly released, but it is soon immersed in competing shrubs which appear to threaten its survival (Day and Harvey 1981). Conventional wisdom has it that spruce suffers in the competition, but Ghent et al. (1957) showed that on their sample plots over a five-year period (1950-1955) following release there was no difference in growth of spruce and balsam, but that numbers were substantially reduced, up to 12,000 to 14,000 per ha in some cases. However, over 70% of the losses were attributable to the cover provided by broken and downed tree trunks and branches and fewer than 20% were attributable to competition with shrubs. Fye and Thomas (1963) examined the same areas in 1961, about 15 years after release, and reported a general decline in fir in relation to spruce, but variation among the plots was too great to show a clear-cut trend. By 1961, the trees which had survived the budworm had contributed additional seedlings from their seed. If the attack is in a young stand lacking advance growth the destruction is often less than in a mature forest, but there will be severe thinning, reduction in volume and many dead tops. The new forest grows up from survivors and seedlings from their seeds (Baskerville 1975a).

The question of the degree to which budworm increases balsam in forests growing up after outbreaks remains open although there seems to be some opinion that it does encourage balsam regeneration at the expense of spruce (Howse 1981). It is unlikely that in uncut forests budworm would have this effect. If it did, balsam would be more abundant than it is. However, in many areas we are no longer dealing with the undisturbed natural forest and it is now apparent that cutting is what promotes the production of fir (Blais 1965; MacLean 1980; Flowers 1981; Young and Fry 1981). Burning of cutovers and forest devastated by budworm also seems to lead to increased balsam on many sites. Thus, it is probably not budworm, but man who is increasing balsam and we are doing it in an area where climate tends to favor outbreaks. Are we setting the stage for more frequent budworm epidemics? In the absence of human intervention it is the budworm which releases the stored up balsam and spruce and thereby perpetuates its habitat and sets the stage for the next outbreak.

There is no doubt that the loss in volume to budworm is considerable (Blais 1958b, 1964; Howse 1981; Sterner and Davidson 1981). It has been estimated that loss to mortality and reduced growth since 1967 in the current outbreak in Ontario exceeds 70 million m^3. The loss in 1981 was about 16 million m^3, including balsam and white and black spruce. On sample areas in the Northeastern Region average mortality in black spruce was 17% (with a high of 36%), 10-15% in white spruce and up to 85% in balsam (Meating et al. 1982). Elliott (1960) estimated that between 1937 and 1955 about 17 million cords of pulpwood were lost in the Lake Nipigon area and that about 60% of the host trees died. Losses of this kind have naturally prompted attempts to save trees by aerial spraying with insecticides which, on the whole, has been quite successful. However, it usually does not stop continuing annual defoliation which checks growth and results in a considerable loss in volume. Sprayed forests stay green, but they are by no means as productive as those free from budworm (Baskerville and Kleinschmidt 1981).

The extent of mortality varies in relation to the composition and age of the stand. As has been pointed out, the most susceptible stands contain a high proportion of mature fir. They are probably the most vulnerable in that there is a high probability of extensive mortality (Mott 1963). The level of mortality has been shown to be correlated with the basal area of fir (Turner 1952; Batzer 1969), but the relationship between vulnerability and other stand characteristics is still not understood (Miller 1977; MacLean 1980). Young coniferous stands are less vulnerable in that a high proportion of trees survive in spite of top kill and considerable thinning (Baskerville 1975a; Baskerville and MacLean 1979). Mixedwood stands with a significant component of hardwoods are the least susceptible.

Obviously, the period of attack and the few years following peak tree mortality is one of rapid change in the forest community. Species diversity and age composition change, there are dramatic changes in physical conditions and a period of new growth and succession is initiated. I have emphasized the vegetational features, but we should remember that there are parallel responses to change among populations of insects, birds and mammals (Welsh 1982).

Whether or not you consider the sequence of changes significant depends on your point of view. Foresters and forest industries primarily interested in black spruce and jack pine in northern Ontario may see little need to be concerned. Balsam is not a commercially important species and white spruce constitutes only a small proportion of the forest. However, if you are interested in moose the budworm is an important element in your habitat management strategy. Wildlife managers will be concerned to retain sheltering balsam and spruce in winter deer yards. If you are concerned with fire control you will want to know where the damaged stands are and the degree to which they may be a hazard. If you are a park manager, you may wish to protect your campsites and other amenity values in your park. Parks infested with budworm stand to lose much of their scenic value and the destruction of trees in campsite areas and picnic grounds may reduce their utility or render them useless, to say nothing of the hazard of falling trees. The loss may be considerable when the large development costs are considered. The Chapleau District has had serious problems of this kind in at least three parks where some spraying was undertaken and proposals were made for the removal of infested trees in critical areas and for rehabilitation by planting nonsusceptible species. If you are responsible for a wilderness area you face the dilemma of whether you should do anything about budworm. Silviculturists will be concerned to protect selected stands of seed trees, seed orchards and nurseries. We know that budworm attack suppresses or stops flowering and seed production in white spruce and fir by destroying buds and flowers or by weakening the tree. Black spruce is usually thought to be relatively immune, but recently it has been recognized in Ontario that budworm may be very important in preventing seed production in black spruce. Twenty-five years ago, Blais (1957) noted that in nonflowering years mortality of budworm was higher on black spruce than on white spruce and fir and he put this down to the later opening of buds on black spruce. However, in flowering years some black spruce had higher populations of larvae than adjacent white spruce and fir and there was a high survival and serious damage to flowers. If this is a general situation, it could be a major problem at a time when we need black spruce seed. I cite these concerns simply to suggest that loss of wood is not the only thing to consider in deciding how the budworm fits into forest management plans.

There are several other ecological consequences of budworm attack which are at present somewhat speculative but may deserve more attention.

One of the consequences of the collapse of a severely infested forest is an increase in beetles and fungi. Little attention seems to have been given to the effect of pests in the dead trees moving to survivors, especially those weakened by defoliation. Belyea and Prebble (1951) and Thomas (1958) reported that bark beetles increased during a budworm epidemic in the Lake Nipigon region and probably killed weakened white spruce which might otherwise have survived.

It is often said that one of the important consequences of budworm infestations is the fire hazard created by the dying forest (Fleiger 1970; Prebble 1975; Otvos and Moody 1978), but there is little or no documentation of this. Wein and Moore (1979) comment that there are no records of fire following the extensive outbreak between 1910 and 1920 in Cape Breton, Nova Scotia. They suggest that this may be due to the humid climate. The fact is that we just do not know for sure if budworm creates a major fire hazard and at what season it may be most significant. The research on this problem now going on at the Great Lakes Forest Research Centre will help us answer the question.

This has been a brief review of the impact of budworm on the forest prepared by someone who is neither a forester nor an entomologist and for that reason is undoubtedly incompletely and possibly ill-informed on some points. On the other hand, from my position as an outsider I may have detected a few things which I may comment on by way of conclusion.

My first comment relates to the published record. There is an enormous volume of publications of various kinds in government reports and the refereed journals dealing with the biology of the budworm itself and with attempts to control it but there is really not very much on its impact on the forest. Some of what has been said about impact is speculative and perhaps inaccurate, for example, the significance of devastated forests as fire hazards, or the relative immunity of black spruce. There must also be a few thousand kilograms of government reports on the annual status of outbreaks and the details of aerial spraying programs. These are surely a valuable long-term record but somebody should be analyzing these masses of data to see if they are statistically significant and make biological and ecological sense. Can they really help us improve management?

My second point could be applied to many biological problems and applications to resource management. It is that we are slow learners. Rigidity of mind-set and casual acceptance of the conventional wisdom in the daily rush of events somehow prevents us from being sharply analytical and getting to the nub of the problem. We have been studying budworm for over 40 years, but I suspect that for many of us it is only in the last half dozen years that we have developed a fairly clear mental model of the interaction of budworm and the forest and have begun to use it in a coherent management strategy. Because of its persistence, maximizing our effectiveness in coming to terms with budworm is like coming to terms with the weather. We are not going to beat it. We should be trying to come to some sort of détente.

A review of our knowledge would show that we know an awful lot about some things which are not very important in a management strategy and we are lacking crucial information on other aspects. No one has yet invented a way of steering research to give us the answers we need as quickly as we would like. This is due to the lack of a guiding model at the outset and to the tendency of scientists to start with details which later reveal the model. It's a problem, but I think we should still ask if we are using all we know to guide management strategy and to direct research along the most fruitful lines. Should we still be without a clear strategy after 40 years?

Finally, with respect to basic biological data, it was instructive for me to discover that the biological base of what we now use is virtually all in that wonderful volume edited by Frank Morris and published in 1963, nearly 20 years ago. Most of the comprehensive quantitative data on succession following outbreaks is contained in the papers by Arthur Ghent and his associates published 25 years ago. Many of the other key papers are at least 20 years old. Now that we have progressed to the point where we probably have a pretty good model to guide us, would it not be a good idea to confirm and extend some of these earlier studies? There are still some myths to be dispelled and we are a long way from coming to terms with budworm which, like the weather, is not likely to improve and is certainly not going to go away.

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A REVIEW OF THE SPRUCE BUDWORM AND ITS OUTBREAK HISTORY

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Abstract.--*To help encourage desirable exchanges of views between foresters and scientists, the biology and dynamics of spruce budworm are reviewed. Concepts of importance to forest managers are emphasized. The history of outbreaks is outlined with the aid of three original cumulative damage maps showing parts of Ontario affected over the past 45 years.*

Résumé.--*Pour favoriser les échanges de vues entre les forestiers et les scientifiques, on fait le survol de la biologie et de la dynamique de la tordeuse. On souligne les notions importantes pour les aménagistes forestiers. L'historique des infestations est illustré à l'aide de trois cartes originales des dommages cumulatifs dans les régions de l'Ontario touchées au cours des 45 dernières années.*

Introduction

Full participation in this symposium will require a basic knowledge of the biology of the spruce budworm. With this introductory statement some forest managers for whom this symposium has been arranged may already be screwing up their faces because they consider entomology relatively unimportant in achieving management objectives. For you in particular, this paper avoids unfamiliar entomological terms, or if they are used, attempts to make their meaning clear. It also purposely avoids description of the current spruce budworm situation in Ontario and Canada. That is adequately described in Canadian Forestry Service publications such as the Forest Insect and Disease Survey Bulletins by Howse and Applejohn (1982), the spruce budworm situation reports, the latest of which was by Meating et al. (1982), and the annual report of the Forest Insect and Disease Survey of Canada compiled by Sterner and Davidson (1981), which I feel confident come across your desks on a regular basis or are available through the Forest Insect and Disease Survey technician in your area.

The spruce budworm needs no introduction to forest management in Ontario. So much has been written about the insect and its relationship to the forest, most of it in published and available form, that a review must have a specific purpose. The purpose of this paper, then, is to refresh your minds about the features and outbreak history of the subject insect which reveal it to be the most adaptable, hardy and "victorious" of forest insects frequenting North America. Since most of you have had the biology of the spruce budworm reviewed in the recent past, my intention is to skip through the biology quickly, covering what you once knew but have perhaps forgotten. Also, I wish to stress some background concepts concerning the insect which are needed to comprehend more fully the papers which follow, points likely to be covered in our deliberations over the next three days, and the five theme questions this symposium is to address.

Biology and Dynamics

Balsam fir and white spruce are the main hosts of the spruce budworm in Ontario. When occurring in infestation proportions the spruce budworm also attacks black spruce, eastern hemlock, tamarack and a wide variety of other conifers. In the more easterly provinces red spruce is an important host tree as well.

Balsam fir is most vulnerable in the sense that it is prone to being killed by repeated attack. White spruce comes under severe attack as well but frequently survives owing in part to the larger complement of foliage retained. Black spruce trees growing in mixture with the more favored hosts may die following infestation but in pure stands black spruce appears almost immune.

The spruce budworm occurs naturally in a wide arc from the Atlantic seaboard of Canada and northeastern United States across the Great Lakes Region to the Mackenzie River Basin. Details on its relationship to other species in the genus *Choristoneura* are presented by Freeman et al. (1967).

The adult is a small grey or in some instances reddish mottled moth. Males and females which resemble one another in gross features occur in roughly a 50-50 proportion. Male moths tend to appear first and mating takes place soon after the female moths emerge. The eggs are laid from late June through July, the female moth ovipositing ca 200 fertilized eggs in several clusters, one or two clusters before much flight takes place and the remaining following local or more distant flights. The eggs hatch in about 10 days and the emerging first instar larvae (L_1) wander until suitable sites are located in which to overwinter. The L_1 stage does not feed. Because of their light weight, their positive response to light and their habit of dropping on silken threads, they are frequently dispersed by the wind over wide areas. This is the first of two important periods of larval dispersal which may result in major concentrations of populations such as in valleys or on the lee side of hills. In the same way, budworm numbers may be relatively low on the windward side of hills or ridges where dispersal losses exceed dispersal gains. Upon settling into a suitable overwintering site such as in staminate flower cups, under lichen pads or crevices in the bark, the budworm spins a silken protection, a so-called hibernaculum, in which it moults, giving rise to the second instar (L_2). It is in this stage that the budworm overwinters.

Early in May of the following year the L_2 budworm emerge from their hibernacula. This is the second period of larval dispersal when larvae again drop on silken threads and are carried by wind currents up to several kilometres or more. Budworm may land on an adjacent branch or tree, on nonhost trees, or disperse to more distant locations which may be favorable or unfavorable for continuing development. Dispersal results in a mixing of populations, and often a vastly different distribution from that shown by egg mass counts or overwintering population measurements. These periods of dispersal are emphasized to help explain the problems that exist in forecasting precisely levels of budworm and associated damage and to help explain the enormous variation in the intensity of infestation found in various parts of Ontario.

L_2 budworm begin feeding in the expanding flower buds of balsam fir (the preferred sites) or, if flower buds are not available, they will mine 1-year-old needles or mine directly into the enlarging vegetative buds. Moulting to the L_3 stage (third instar) takes place at feeding sites in the flowers or about the time the L_2 moves from a mined needle to a vegetative bud. Budworm again show preference for flowers by remaining there to feed until tissue dries out, i.e., through the L_2, L_3 and even L_4 stages.

Budworm continue to feed in the expanding buds and later the opening shoot, developing and moulting into the L_4, L_5 and L_6 larval stages. L_5 and L_6 budworm consume by far the greatest amount of foliage and it is at these stages particularly that the supply and quality of food are critical to the level and vigor of the subsequent generation.

Reviewing the feeding habits of L_4 to L_6 budworm from the aspect of telltale presence, budworm larvae lay down a fine thread of silk as they move. Also, they devote much time to spinning silk among the needles surrounding them. This silk contracts somewhat as it dries, pulling needles together to form a kind of feeding shelter. Budworm are wasteful feeders in that they cut off needles near their base rather than consuming all green tissue. The result is that the new shoots quickly become defoliated but the severed needles remain attached to the shoot held by the silken threads referred to above, and in that position the needles gradually turn brick red in color. In a severe infestation the new shoots become defoliated before budworm have completed their feeding, in which case the larvae move back and feed on the foliage produced in preceding years. This is referred to as "back-feeding". You are reminded of the transitory and changeable nature of the condition in which dead needles, both new and old, adhere simply by silken threads. A heavy rain will cause this foliage to drop off so that trees may lose much of the discoloration caused by budworm feeding in a few days. In another instance white spruce trees may be heavily defoliated for the first time following many budworm-free growing seasons. In this case the proportion of the total foliage which discolors is very small and the evidence of infestation is inconspicuous.

L_6 budworm moult at their feeding sites or elsewhere on the host tree, giving rise to pupae. After about 10 days male and female moths appear. The life expectancy of a moth may be as much as 2 weeks. This is the stage at which a third period of dispersal occurs and has by far the greatest influence on infestation and damage patterns.

Female moths lay a portion of their egg complement on needles in the periphery of the crown of the host tree near their site of emergence. The remaining eggs are laid following periods of flight. Too little is known about the long-range displacement of female moths carrying a residual complement of one-third to one-half their eggs.

An elaborate study involving observation platforms, the use of radar and specially equipped aircraft carried out in the Maritime provinces by Greenbank et al. (1980) showed that moths in flight made vertical exits from heavily populated stands on a massive scale and that moths flying downwind above the forest canopy became concentrated at various zones of wind convergence. Using examples they reasoned that displacement of up to 240 km was likely to be quite common and they provided convincing evidence that under specific conditions involving a moving warm front moths may be displaced a distance of 450 km into Newfoundland from infestations in the Maritimes. This kind of moth dispersal was recently confirmed by Raske[1] who in July 1982 found budworm moths on the west coast of Newfoundland before any moths whatever had emerged in local populations. Immigrant moths were also captured in traps across the central portion of Newfoundland during July.

Owing to the inherent difficulties involved in following moth flights, which begin late in the day and persist after dark, and in obtaining relevant scientific data, you will understand why entomologists are prevented from applying long-range dispersal concepts to budworm dynamics on an operational basis. Few examples of extensive flight have been fully substantiated. However, conceptually at least, movement of moths including females with a partial complement of eggs over distances of up to several hundred kilometres from areas of heavy damage and high populations is now gradually being accepted as a feasible and common natural phenomenon. Accordingly it is important for foresters and practising entomologists to become familiar with budworm conditions in the area surrounding a management unit for which damage forecasts are required, particularly towards the north and west from which directions inflights are most likely to occur.

Finally, on the aspect of biology and dynamics, a generalized survivorship curve from Miller (1963a) is shown in Figure 1. This figure depicts generation survival by stages from egg through the various larval instars 1 to 6 and through the pupal stage. Mortality factors affecting moths are not included. It will be noted that, typically, mortality of the order of 80% occurs during the interval of first to third larval instars, most of it as a result of dispersal during the first instar. Another decline in density occurs during the second period of larval dispersal following overwintering emergence as described earlier. This curve would of course vary considerably by stand type, elevation, and year but the point made is that L_1 and L_2 losses account for a considerable amount of generation mortality in relative terms.

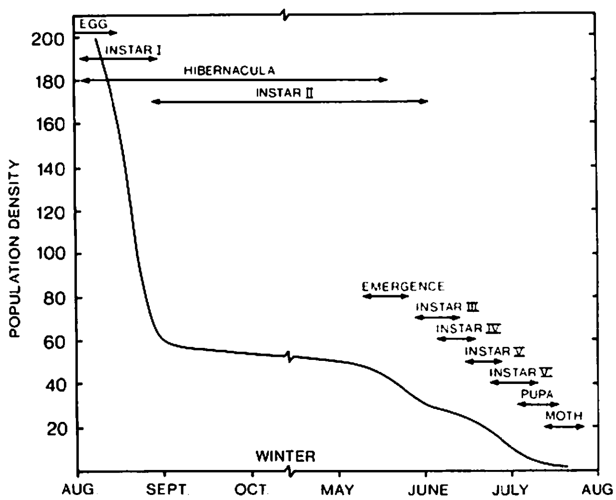

Figure 1. A generalized survivorship curve for the spruce budworm, from Miller (1963a).

Extensive studies have been carried out on the insect parasites of spruce budworm.

[1]A.G. Raske, Newfoundland Forest Research Centre, St. John's, Nfld. 1982 (pers. comm.)

McGugan and Blais (1959) reported finding 30 primary parasitic species. Some of the more common insect parasites of the spruce budworm in Ontario are listed below.

Stage attacked	Insect parasite
egg	*Trichogramma minutum* Riley
young larvae	*Apanteles fumiferanae* Vier.,
	Glypta fumiferanae (Vier.)
	Tranosema rostrale (Brischke) (Vier.)
late larvae	*Meteorus trachynotus* Vier.
	Actia interrupta Curr.
	Aplomya caesar (Ald.)
pupae	*Apecthis ontario* (Cress.)
	Itoplectis conquisitor (Say)
	Phaeogenes hariolus (Cress.)

The purpose of including the above incomplete list of parasites simply is as a reminder that considerable attention was given to this mortality factor in the early research in Canada.

It is probably fair to say that entomologists who have studied the parasite complex in relation to changes in spruce budworm population densities are in agreement with Miller (1963b) who concluded that it is only during the final phases of an outbreak, after density has been considerably reduced by other factors, that parasites kill an appreciable proportion of the population and help to bring about the collapse. More recently, interest has grown in the investigation of the specific circumstances under which one or more of the parasites may be manipulated to bring about control by biological means. Emphasis appears to be on the egg parasite *T. minutum*.

Other natural factors credited for killing spruce budworm such as predators, diseases, weather factors, starvation, even cannibalism, anywhere along the survival curve are or have been under investigation by Canadian scientists.

Damage Maps; A Record of Outbreak History

Owing to the severe impact spruce budworm infestation had on the forests of eastern Canada earlier this century, entomologists began recording areas of damage largely for the benefit of the forest industry. Scouting on the ground was soon replaced by aerial observation from aircraft. The first aerial reconnaissance was carried out in 1920 by Swaine and Craighead (1924) north and west of Lake Temagami in Ontario. A HS2L Curtis flying boat was flown out of Haileybury and the observations proved so productive that surveys were repeated in subsequent years.

Since the budworm is no respecter of jurisdictional boundaries and because observations require skilled and experienced workers covering large land masses, responsibility for mapping and reporting on infestations over the years settled with government agencies. At the present time in eastern Canada various combinations of federal and provincial forestry agencies and their representatives are involved. In Ontario the responsibility lies with the Forest Insect and Disease Survey Unit of the Great Lakes Forest Research Centre in Sault Ste. Marie working closely with headquarters, regional and district offices of the Ontario Ministry of Natural Resources, which provide aircraft time for aerial reconnaissance and mapping.

Defoliation caused by the feeding of spruce budworm is described in various ways and consequently should be briefly defined to avoid confusion in our discussion. *Current defoliation* refers to the loss of foliage on the current shoots of a tree or stand. When mapping feeding damage from the air, light current defoliation is barely detectable and not easily discernible without frequent ground checks. Current defoliation in excess of 25% of the foliage is usually mappable and is referred to as moderate-to-severe defoliation, moderate referring to 26-50% and severe to 51-100% of the new foliage. Moderate-to-severe current defoliation is generally the category of damage mapped by one individual covering large areas. Moderate and severe categories may be used in mapping damage for more specific purposes.

Cumulative defoliation refers to the loss of the total complement of foliage normally held by a tree or stand. This may result from consecutive years of current defoliation which, following 4-5 years of severe current defoliation, results in the beginning of mortality among balsam fir trees.

In surveys of infestation, discoloration supported by ground checks to confirm cause is used as a basis for mapping areas affected. Color is also a key element in the mapping of budworm associated tree mortality. The presence of totally grey trees supported by ground checks to confirm that some trees are dead, i.e., brown cambium on both sides of the bole, is the criterion used for identifying tree mortality.

The following points concerning the mapping system should be recalled.

1. The precise timing of flights is critical and must coincide with the peak of discoloration.
2. The information that can be recorded by an observer differs considerably whether mapping a small infestation of, say, 200 km^2 or part of an extensive area covering 800,000 km^2 or more.
3. The symptoms of damage are less clear at the start of an infestation and during a period of collapse. Some of the factors which may cause problems are damage by other pests, heavy crops of flowers or cones and frost damage. Frequent ground checks are essential.
4. Agreement must be reached along district, regional and provincial boundaries to ensure that lines of demarcation coincide.
5. Mapping of tree mortality is difficult in that trees appearing grey in color from the air are not necessarily dead. Also, the identity of host tree as to species may be doubtful when severe cumulative defoliation is involved. Tree mortality often occurs in patches, and parts of tree crowns may die. Again frequent ground checks are the rule. With few exceptions, in Ontario tree mortality is not classified as to degree from the air. Rather, emphasis is given in aerial surveys to determining the year when tree mortality begins and the degree of mortality is determined subsequently on the ground.
6. Damage maps are included in spruce budworm cartographic histories such as that compiled by Brown (1970).

The provincial history of spruce budworm infestations is naturally skimpy and understandably incomplete before 1936, the year the Forest Insect and Disease Survey was founded. Widespread damage is known to have occurred across northern Ontario between 1920 and 1940. Before that a severe outbreak is known to have swept through eastern Canada, including parts of Ontario, between 1910 and 1919. Also, evidence of previous infestation appears in the form of suppression patterns on the radial growth of surviving host trees, and dates back into the 1800s as well as the 1700s, the earliest being in 1702 in the Lake Nipigon Region (Turner per Blais 1968).

Concentrating on that part of the history for which fairly concrete and complete information is available for Ontario, a long history depicted by annual infestation maps since 1936 has been condensed for this symposium and herewith is presented on three maps. Cumulative areas of moderate-to-severe defoliation and cumulative areas of moderate-to-severe host tree mortality apply. Figure 2 covers the period 1937-1951 for northeastern Ontario; Figure 3, 1943-1962 and Figure 4, 1967-1981 for the entire province. It must be assumed that the spruce budworm was relatively quiescent in intervening years. If in your mind's eye you overlay the three maps, one on the other, you gain appreciation for the small proportion of the spruce and balsam fir growing area of Ontario that has been unaffected over the past 45 years. The maps also reveal that outbreaks follow an irregular pattern of time and location, an observation which supports a similar conclusion reached earlier by Blais (1968) who studied available evidence of outbreaks occurring over a period of 200 years. Northeastern Ontario appears to be something of an exception in that the bounds of infestation in 1937-1951 were much the same as for the current outbreak of 1967-1981. History will reveal the consistency or inconsistency of this pattern.

Conclusion

The reality of this history of spruce budworm infestation is that despite many years of excellent scientific research aimed at controlling the spruce budworm and despite the outstanding achievements of Canadian scientists, man has not prevented a natural spruce budworm outbreak from occurring in Canada. In reality, outbreaks appear to be more frequent and more prolonged. We in the forestry community must in some way shift some of our attention from the passive mode, i.e., studying and recording events and relationships, towards an active mode in which we apply what is known in the form of best possible management action to prevent outbreaks from occurring. Much was learned and accomplished in northwestern Ontario during the period 1968-1975 about abating and postponing an incipient outbreak as described by Howse and Sippell (1975) but the kinds of information and control tools were inadequate. This is an area that requires renewed inspiration and hope and for which a more imaginative yet realistic management strategy is required.

For the forest manager, the unit you are managing may be relatively free of spruce budworm; it may be threatened by advancing infestation; it may be under active attack; or it may have passed through the worst of the current outbreak. The next few days represent an opportunity to decide or adjust,

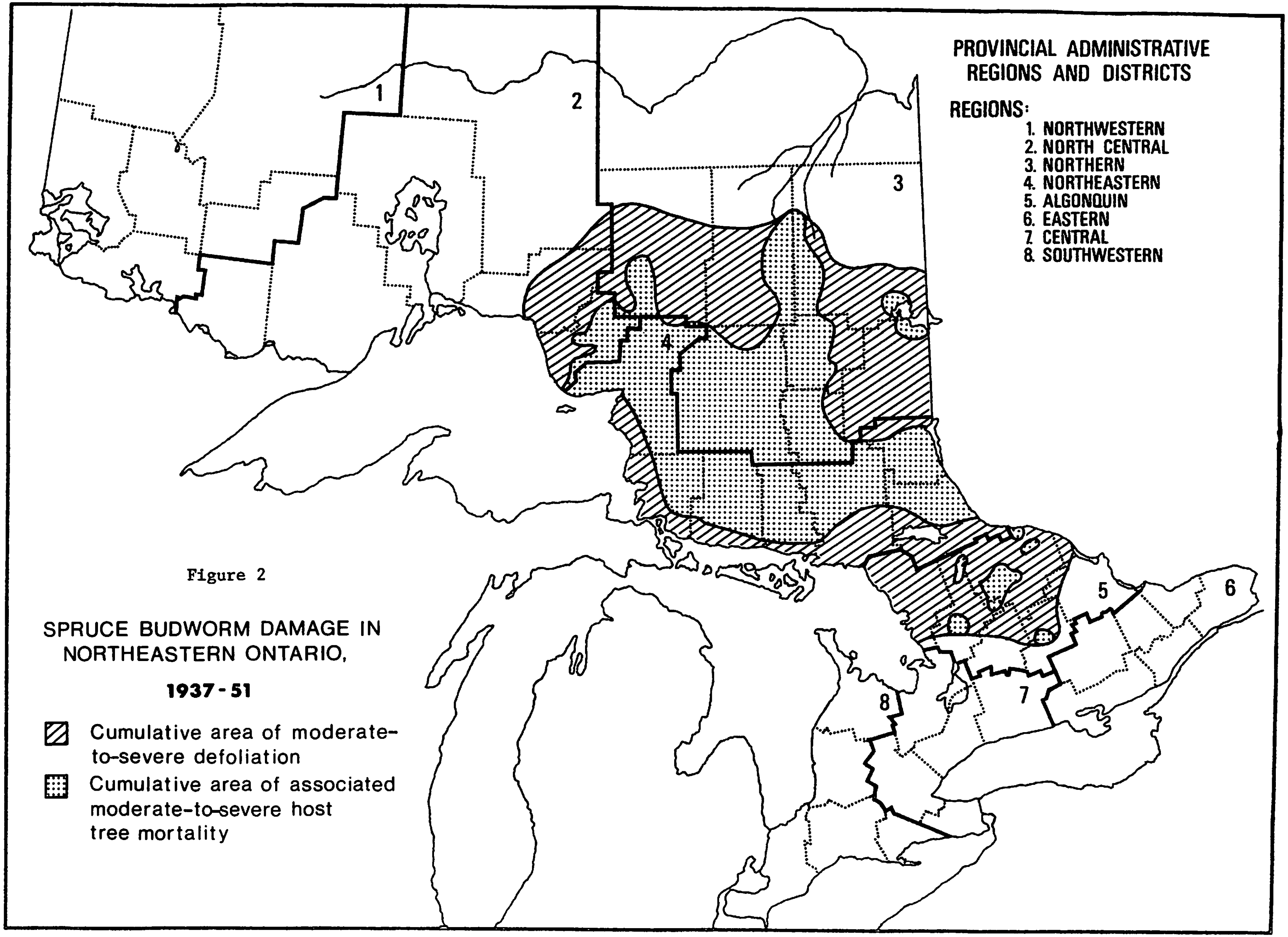

Figure 2

SPRUCE BUDWORM DAMAGE IN NORTHEASTERN ONTARIO, 1937-51

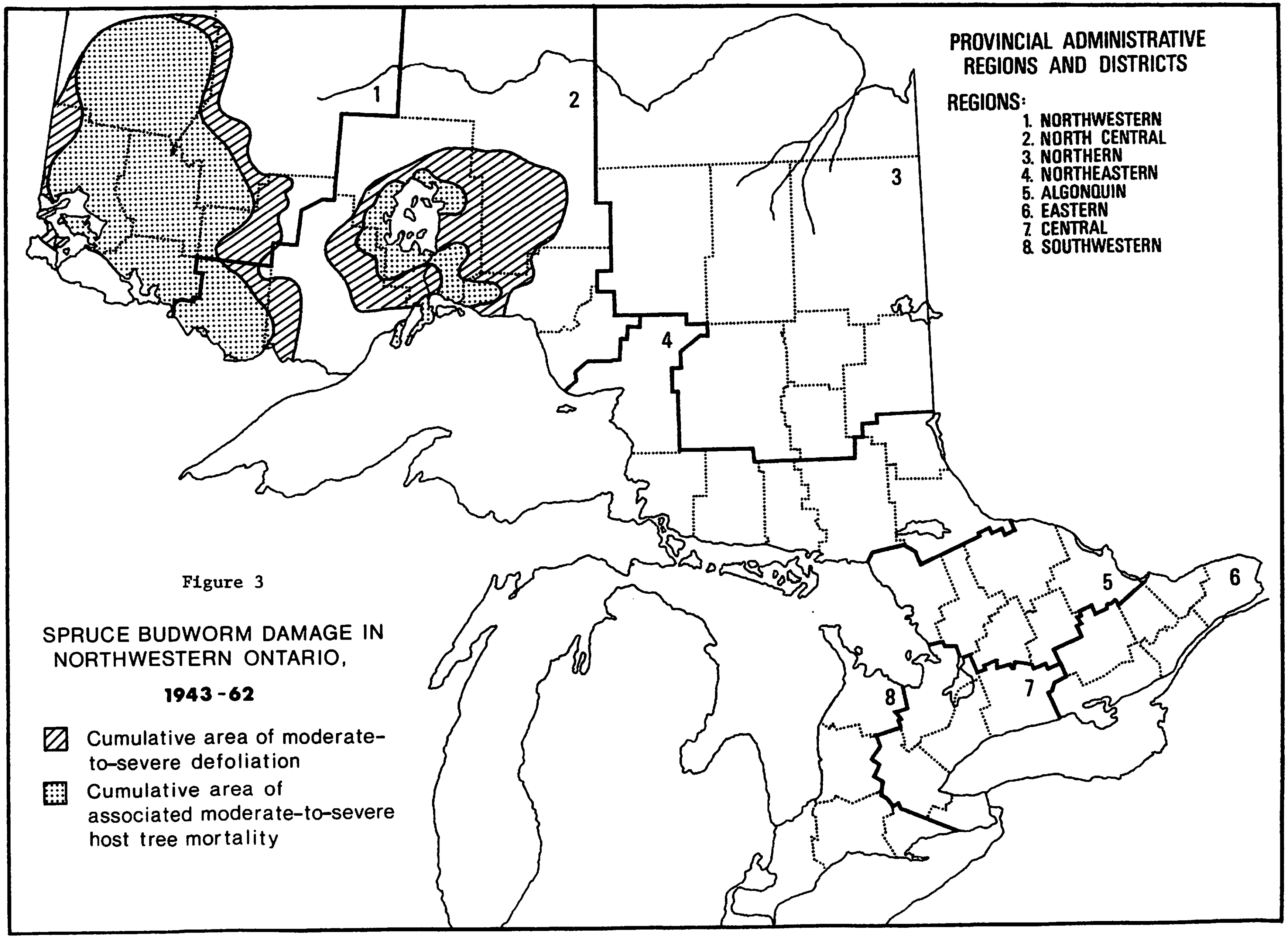

Figure 3

SPRUCE BUDWORM DAMAGE IN NORTHWESTERN ONTARIO,

1943 - 62

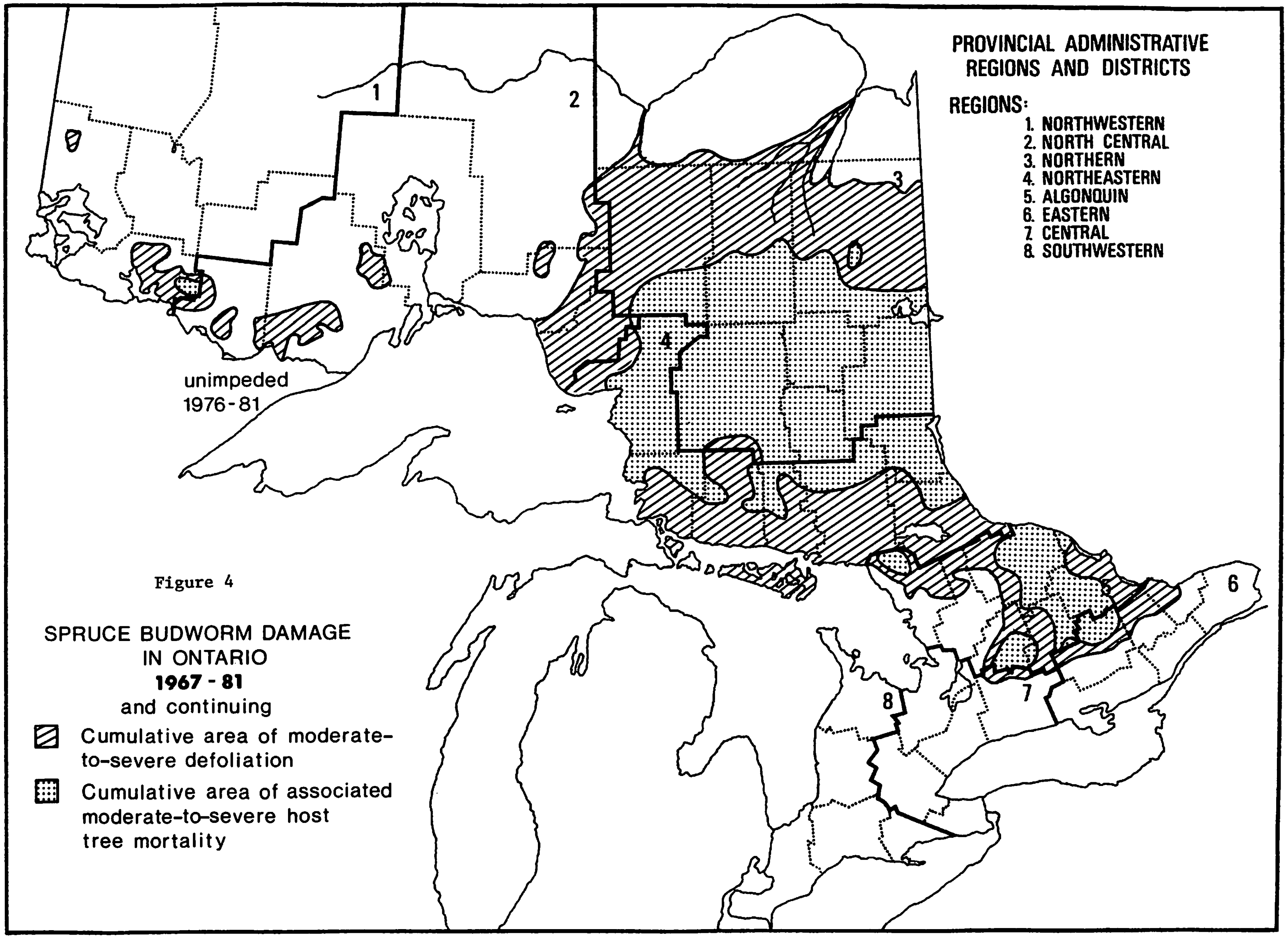

Figure 4

SPRUCE BUDWORM DAMAGE IN ONTARIO **1967 - 81** and continuing at least tentatively, until more promising plans of action surface, the best course of action to deal with spruce budworm infestation in the management unit under your care. You are encouraged to document your views in written form particularly for the management foresters who will follow you. The time span associated with this spruce budworm history alone strongly implies that subsequent outbreaks will indeed occur and that the next outbreak will involve new personnel who are unfamiliar with the pest and its impact. Rather than starting over, future managers when faced with difficult decisions concerning the most appropriate management attitudes to deal with the budworm should at the very least have available for their management unit a prepared statement describing the decisions reached by a predecessor faced with similar spruce budworm problems along with a logical rationale as to how the decisions were reached.

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THE RELATIONSHIP BETWEEN SPRUCE BUDWORM AND WILDLIFE

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Abstract.--Interactions between wildlife and spruce budworm have positive and negative effects on both groups. Moose (Alces alces) *are most affected indirectly by changes in forest structure, while birds are impacted directly by changes in food resources and by changes in the forest. Bird predation is recognized as an important regulator of insect numbers in many parts of the world. Evidence is presented suggesting that they are probably a significant control mechanism for endemic spruce budworm populations.*

Résumé.--Les interactions entre la faune et la tordeuse ont des effets positifs et négatifs sur les deux groupes. L'orignal (Alces alces) *est surtout affecté indirectement par les modifications de la forêt, tandis que les oiseaux sont directement touchés tant par les modifications de la forêt que des sources de nourriture. Dans beaucoup de parties du monde, les oiseaux prédateurs sont reconnus comme des agents importants de régularisation du nombre d'insectes. Des faits sont présentés, qui montrent qu'ils sont probablement un mécanisme notable de répression des populations endémiques de tordeuses.*

I've chosen an open-ended title because like most Ottawa based civil servants I like to have things both ways.

In reviewing our own studies and literature it is obvious that budworm is both good and bad for wildlife and that wildlife is both good and bad for budworm. This has made it difficult to develop a single strong theme for this paper.

Since it is clearly unnecessary for me to talk about the importance of the 'budworm problem' to the forest industry, I will confine my comments to the enormous impact budworm has on the boreal ecosystem and its wildlife, particularly the warm-blooded vertebrates. I've organized the talk into two main sections: The Effect of Budworm on Wildlife, and The Effect of Wildlife on Budworm.

The subject matter of the talk is a personal selection of important interactions and is not by any means an exhaustive review. The emphasis on birds is a reflection of both my own biases plus the fact that there has been almost no work done on mammals in relation to budworm. In general, studies relating budworm and wildlife have concentrated on small animals because they are easier to work with and because their home ranges or territories are sufficiently small that they can be directly related to forest stands.

Effect of Budworm on Wildlife

(a) Mammals

Having said that, I'll begin with the only mammal in northern Ontario worth talking about--the moose *(Alces alces)*.

Moose and budworm both eat balsam fir so it is not difficult to imagine a conflict situation, although some might argue that it is not a fair fight. In Ontario, balsam fir is an important browse species for moose in both uncut and cut-over forests, especially in late winter in deep snow areas. There are as many ways of measuring utilization and importance of browse as there are biologists, so it's difficult to say exactly how important--perhaps 10% of their winter diet on average. It is well established that moose eat more balsam fir in Quebec than Ontario and as you move eastward the trend continues until in Newfoundland in many areas more than 80% of the winter food is balsam fir. Whether balsam fir tastes better in Newfoundland or not is not really critical to my arguments.

In most areas moose tend to be creatures of habit and return to the same areas to feed each winter. These so-called 'yards' are areas with both numerous shrubs and young balsam fir to provide an abundant food supply and some adjacent old timber for cover. In general the animals range widely in young stands early in winter and feed in a more confined older forest with increased cover late in winter.

In Newfoundland, a cooperative program between the Newfoundland Division of Wildlife and Canadian Forestry Service (J. Hancock, pers. comm.) is trying to determine the effect of budworm on moose. A number of permanent plots have been set up in areas of different moose density to measure changes in browse production and utilization in relation to budworm. Although it will be several years before the study is complete it is clear that in areas of high utilization by moose, food supply is being drastically reduced by budworm. Interestingly, though, in other areas of dense spruce-fir forest with a heavy canopy and low moose density, budworm defoliation is opening up the stands, allowing shrubs and small balsam fir to grow. In the long run these areas are being improved as moose range, so both damage and improvement of moose range is occurring.

In Ontario there is a strong association between moose and mixedwoods. As the balsam fir component is damaged or destroyed there will generally be more food and less cover. To date the effects of these changes in range condition have not been quantified in terms that can be related directly to the question of more or less moose. The magnitude of the impact on moose populations will be determined in the short run by the effect of interspecific competition for reduced resources and in the long run by the effect of altered forest composition.

There have been several studies on the effect of budworm outbreaks on small mammals but the results over all have been equivocal (Morris et al. 1958). It appears that, with the exception of arboreal foraging species, it is only when budworm fall to the ground in sufficient numbers to become an important food that they are likely to have any immediate impact.

Probably much more important is the effect of changing habitat through alteration of the overstory. As well, a number of small mammals like deer mice (*Peromyscus maniculatus*) and red squirrels (*Tamiasciurus hudsonicus*) are dependent on conifer seeds for food, particularly in winter. As the budworm outbreak reduces cone production these populations will obviously suffer.

(b) Birds

The effect of budworm on birds is a particularly interesting question because of the intricacy of the relationship between forest structure, food resources and the bird community and because of the oft made suggestion or hope that birds may provide some control of insect populations. As the forest goes through succession from young herbaceous to mature and over-mature old-growth stages its suitability as a place to live for different species of birds changes also, so there is a successional pattern in the avifauna reflecting the changes in the forest structure.

Budworms affect bird populations most obviously during epidemics by initially increasing the availability of food and by ultimately dramatically altering forest structure. Understanding the relationship of birds to forest structure is extremely important, because if we ever want to modify bird density or species composition it will most likely be done through habitat manipulation.

Although there has been little detailed study of the structure of budworm ravaged forests from an ornithological point of view we do know what characteristics of vegetation birds respond to. There are now over a hundred papers illustrating the non-random distribution of birds and detailing the different ways they divide up habitat. Features such as the number of and density of foliage layers (often expressed as foliage height diversity), the volume of foliage, plant species diversity, horizontal and vertical spatial distribution of plants, number of snags, and so on can all be used to develop predictive descriptions of which species will live in any particular forest stand. So, theoretically at least, we do have the capability of predicting the effect if we know how the forest changes.

As well as large changes in structure, seemingly minor changes may have considerable effects on some species. Lichens of the genus *Usnea* and other epiphytes undoubtedly increase in some budworm damaged stands. The Parula Warbler *(Parula americana)* is well known to nest almost exclusively in hollowed-out cups in large clumps of *Usnea*. I think it reasonable therefore to assume that Parula Warblers benefit from spruce budworm.

Not all birds are equally affected by the fortunes of the budworm. In general thick-billed species are poorly suited to foraging on conifer foliage, whereas warblers with their thin bills are well adapted or pre-adapted to feeding in conifers and are the primary conifer foliage-gleaning insectivores in the boreal forest. It is only at times of very high budworm density when there is a feast for all, that thick-billed birds like grosbeaks are really affected. As well as bill size other physical features of the avian predator are important. For example, when foliage density increases with forest age there is a strong correlation with decreasing body size of foliage gleaners, suggesting that it is advantageous to be small in some circumstances.

The birds most affected by budworm are those which make a living harvesting insects from the surface of foliage, particularly conifers. This group includes species like Golden-crowned Kinglet *(Regulus satrapa)*, Ruby-crowned Kinglet *(R. calendula)*, Red-eyed Vireo *(Vireo olivaceus)*, Orange-crowned Warbler *(Vermivora celata)*, Parula Warbler, Yellow-rumped warbler *(Dendroica coronata)*, Redstart *(Setophaga ruticilla)*, Cape May Warbler *(D. tigrina)*, Magnolia Warbler *(D. magnolia)* and Bay-breasted Warbler *(D. castanea)*. In most cases, due to the difficulties in sampling bird populations, we don't know when we observe a density change whether it is the result of a behavioral response through immigration or emigration or actual changes in survival rates or other reproductive parameters.

Kendeigh (1947), studying the spruce budworm outbreak in 1945 at Black Sturgeon Lake, reported a density of 783 breeding pairs of birds/km^2 and several other studies have found comparable densities (Hensley and Cope 1951, Stewart and Aldrich 1951, 1952, Cheshire 1954) at high budworm levels. Sanders (1970), studying plots similar to Kendeigh's 20 years later at Black Sturgeon Lake, found densities of about 300 pairs/km^2, less than half the earlier number. Based on a comparison of his species lists and Kendeigh's, he pointed out that most of the difference was due to changes in Bay-breasted, Cape May, and Tennessee Warblers *(Vermivora peregrina)* and that the rest of the 35-50 species had made changes that could probably be attributed simply to differences in forest structure.

The question of which species will respond to the increase in budworm seems to have several answers. We know that during a budworm epidemic avian population density will increase from several times to even an order of magnitude above density at endemic budworm levels and that some of the group of Cape May, Bay-breasted, Tennessee, and Blackburnian Warblers *(Dendroica fusca)* will normally show the most dramatic increases.

Elsewhere Morse (1978) has found relatively low densities of Cape May and Bay-breasted Warblers during budworm outbreaks in Maine and noted increases in other Dendroica Warblers. He suggests that substitution or displacement may sometimes occur with increasing budworm populations. Zach and Falls (1975) found that Ovenbirds *(Seiurus aurocapillus)*, a ground foraging warbler, fed regularly in trees during a budworm outbreak in Algonquin Park. During the outbreak they laid larger clutches as well and their territories were reduced by almost 50% and were more densely packed. Our own studies during an extreme budworm outbreak in Mildred Township (Welsh and Fillman 1980) in northeastern Ontario in 1978 found levels of over 2,000 pairs of breeding birds/km^2, and although 40% of the birds were Tennessee Warblers, almost all species were well above normal levels.

In subsequent work near Manitouwadge (Welsh, unpublished), where we moved to escape the effect of budworm, we have found rather dramatic changes in bird numbers on some plots with increasing budworm numbers; one plot has gone from 270 pairs/km^2 in 1979 to 1450 pairs/km^2 in 1982. The major increase has been in Red-eyed Vireo, Tennessee Warbler, Nashville Warbler *(Vermivora ruficapilla)*, Magnolia Warbler, Yellow-rumped Warbler, Chestnut sided Warbler *(Dendroica pensylvanica)*, Bay-breasted Warbler and White-throated Sparrow *(Zonotrichia albicollis)* all of which have more than doubled. Other plots in the area have shown smaller but nonetheless significant increases but only Tennessee, Bay-breasted and Cape May have shown major increases. We believe that the difference is due to structural limitations of the habitat. In the first case all of the species that increased were food limited while on the other plots the structure of the stand itself is imposing the limit on numbers for several species.

Habitat use and foraging behavior by warblers varies from species to species as some are specialists with stereotyped foraging patterns while others are generalists with very plastic behavior. MacArthur (1958) suggested that some species like Cape May and Bay-breasted Warblers, which are both budworm specialists, are opportunists adapted by flexibility in clutch size to capitalize on superabundant foods.

As a final impact of budworm on wildlife, I'll briefly mention spraying. Since the early days of heavy DDT doses in New Brunswick, the effect of spraying on wildlife has been studied. There have been at least 50 major studies in the last decade as well as an enormous amount of work on impact assessment. It is impractical and would be rather tangential to try to provide a review here. In the 1980s there is not and will not be a clear answer about the impact of spraying on wildlife. As our technological skill increases we create better and safer chemicals and find better and more sensitive ways of measuring their effects. We know that as well as the chemical itself we have to look at forest stand age and composition, time of season, dosage rate, carrier and so on. All of these factors make reaching conclusions complicated. For example, one recent study (Buckner and MacLeod 1975) found no detectable effect of Orthene on wildlife when applied at 0.56 and 1.4 kg/ha while another study (Richmond et al. 1979) found decreases in numbers of birds and evidence of prolonged ChE (brain cholinesterase) depression in some bird species at similar spray levels. The differing results seem to be primarily due to differences in assessment procedure.

Clearly one of the major effects of spraying is drastic food reduction for insectivorous animals regardless of the toxicity question. The joint Canada/United States Spruce Budworms Research Program (CANUSA) is presently funding a major study in Maine on the effect of reduced food availability on birds. Preliminary results (CANUSA Newsletter No. 19) suggest major changes in foraging behavior by some warblers after spraying and in some cases abandonment of areas used before spraying.

Effect of Wildlife on Budworm

Although it is clear that budworm eruptions can have dramatic effects on wildlife populations it is much less certain that vertebrate predation has any real effect on budworm populations. Yet in many ways finding the answer to that question has never been more important.

The realization that current methods of pest control lead to degradation of the environment and increased hazards to human health and often provide short term benefits followed by even greater problems has provided impetus for a more serious look at biological control. In the attempt to reverse the loading of the environment with toxic and polluting pesticides there is an increasing effort to couple restrictive use of chemicals with maximum natural regulation.

Although the following comments emphasize birds, many of the same principles may apply to other vertebrates. In the case of spruce budworm the red squirrel and perhaps bats are the only mammals that seem to have any real potential as predators.

There are numerous examples of effective regulation of insects by birds, and in many countries in Europe strong efforts are made to encourage birds in forest plantations. In Spain the forestry department installed and maintains over 400,000 nest boxes and an equal number are maintained in other western European countries (Thomas et al. 1975). Bruns (1960) and Franz (1961) have extensively reviewed the European literature on bird-insect interactions and biological control. Otvos (1979) has reviewed the literature fully in the proceedings of a symposium on the role of insectivorous birds in forest ecosystems.

The English Sparrow *(Passer domesticus)* was introduced into the eastern United States to control shade tree pests (Forbush 1921 *in* Otvos 1979), a fact that provides a double lesson about biological control. Whether the shade tree pests were successfully controlled or not I don't know, but we are all aware of the extensive and disastrous spread of the introduced predator. It is reported that sparrows and starlings *(Sturnus vulgaris)* control fall webworm *(Hyphantria cunea* [Drury]) in Hungary, and in Germany the pine looper *(Bupalus piniarius)* is clearly kept under control in woodlots with nestboxes and requires chemical control in those without (Herberg 1965). In North America Kroll and Fleet (1979) report that woodpeckers are significant predators of the southern pine beetle *(Dendroctonus frontalis)*.

At endemic levels woodpeckers consume 20-30% of spruce beetle *(Dendroctonus rufipennis* [Kirby]) (Koplin 1969) and at moderate to high levels eat 24-98% (Baldwin 1960, McCambridge and Knight 1972). Mattson et al. (1968) have shown that birds remove 40-65% of late instar larvae and pupae of jack pine budworm *(Choristoneura pinus pinus*

Free.) in some woodlots. Rather than continuing the catalogue of successes, I will briefly go over a few ideas about predation and try to relate them to the spruce budworm.

In general, predators consume a small fraction of their available prey. In order to provide effective biological control it is essential that there be density-dependent feeding. Unless birds eat more budworm when there are more budworm available then all we have is control by chance and birds are no more effective than weather.

There are three different ways birds could provide a density dependent response. There could be a functional response, in which birds increase the number of budworm they eat as more become available; more birds could move into an area because there is more food--a behavioral numerical response; and there could be a true numerical response in which more young are born or more survive when more prey are available; hence there are more birds. The examples of great changes in bird numbers in the last section are examples of numerical response both through true increase and immigration. Undoubtedly most resident foliage gleaners have a functional response to increased budworm; otherwise they would not show a numerical response to a surfeit of food.

Several studies (Kendeigh 1947, Morris et al. 1958, and others) have demonstrated that birds have no effect on high density budworm populations. At the other end of the scale, work on the dynamics of budworm suggests that predation may provide an important extrinsic control at endemic levels. What remains to be proven is that birds are effective density-dependent predators at low prey levels. Recently Wypkema (1982) has shown that birds remove a sufficiently large percentage of budworm larvae and pupae at endemic levels to suggest that some real control must be occurring. Campbell and Torgerson (CANUSA Newsletter No. 16) have shown that avian predation is responsible for important pupal loss in western spruce budworm (*Choristoneura occidentalis* Free.) but to date no one has provided solid data demonstrating effective density-dependent predation.

I suspect that we may have gone as far as we can reasonably expect to go unless we're willing to spend a lot of additional money on research. The major reasons that we don't have concrete proof of effective predation at low levels are logistic: the labor of sampling the budworm alone is enormous, especially when you need life-cycle stage-specific dynamics and when there are 15-20 species of avian predators that should be sampled in most stands. Most of the predators of interest are feeding at treetop level and to properly answer the question you would need a representative sample of each at each of the late stages of the budworm life cycle, 4th, 5th, and 6th instar, pupa and adult and all of the above would need replication at several different budworm densities. To further compound the problem the bird sampling should be non-destructive to avoid total disruption of the bird community.

In reviewing the evidence, we know that 15-20 species of birds eat budworm at endemic population levels (summarized in Wypkema 1982), and that at epidemic budworm levels all show a functional and numerical response. As well, it is likely that some density-dependent extrinsic factor, like bird predation, normally represses budworm and it is only when everything is in its favor that budworm takes off or erupts. I believe the circumstantial evidence is sufficient for us to accept the arguments made over 30 years ago by Kendeigh (1947) that bird predation reduces the frequency and extends the interval between outbreaks. It is interesting to note that the extensive spruce-fir forests of New Brunswick have naturally low-density, simple bird communities.

If birds do control low level budworm populations it is important to know which species. Holling (unpublished) has suggested on energetic grounds that his class two (17-33 g) and class three (45-89 g) birds which are medium and large passerines are the most likely to provide effective control. Wypkema's data (1982) and my own suggest that Holling's class one (6-11 g), including most of the foliage gleaners, is a much more likely group.

The species showing the greatest response to budworm--Tennessee, Bay-breasted and Cape May Warblers--are all basically specialists on budworm and are normally unlikely to be present in sufficient numbers to have the major role in control when budworm populations are low. It seems much more likely to me that the other dozen or so foliage gleaners with more general feeding habits will provide any control that occurs. The generalists have the capability to provide an immediate functional response while the specialists presumably require a greater lag time to capitalize on increases in prey through numerical increase.

Accepting the argument that birds regulate budworm in some circumstances, it is interesting to speculate how we might enhance the forest to maximize the number and diversity of desired birds. Based on what we know about their need for structural diversity it is clear that we should avoid monocultures and stands of the same age and height. The best protection will occur when the ratio of the number and diversity of desired bird species to conifer foliage volume is high. The trick is to provide high foliage diversity so as to have larger and more diverse bird communities. Obviously if we eliminate most of the habitat we lose most of the birds. A cutover with residual mature trees and advance growth after cutting can support many more birds than a flattened fully scarified clearcut. As well, retention of snags is extremely important because they are nest sites for many species, only some of which will accept nest boxes. As an aside, I think it extremely unlikely that an extensive nest box scheme like Spain's would work here simply because we do not have sufficient hole-nesting bird species to respond.

Some people in the audience would be better able than I to say whether we have more and/or worse budworm outbreaks now than we used to, but it is interesting to speculate briefly on the effect man's activities have had on bird populations. One major result of forest cutting is that we now have much more area in early successional stages than ever before. Most of the bird species that live in the simplified early seral vegetation never occupy older stands. If one of the important means by which birds regulate insects is to move into an area as the prey increases then forest fragmentation may have reduced the chance of that happening. There is no place to move from!

Fragmentation due to cutting has another major effect as well; that is that bird density is likely to fluctuate much more than it would in relatively continuous forest. If, because of migration and overwinter mortality, birds don't return to a particular piece of habitat there will be little immigration into that stand if the surrounding forest is of a different age and has a different bird species composition.

Really, all I'm suggesting is that in any given year we are now more likely than before to have a low number of budworm-eating birds present in a stand. Additionally, if the budworm are having a good year, recent forest harvesting may well have reduced the likelihood that birds from adjacent areas will move in and control the outbreak. While it can be argued that forest managers don't manage wildlife it is clear that they do manage habitat. All of their decisions affect habitat, and forestry practices will to a large extent determine what kind of birds live where and in what numbers. If we decide that we want lots of unspecialized insect-eating birds to reduce pest problems then we will have to consider their needs in forest management plans.

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LIVING WITH THE BUDWORM

Moderator: J.R. Carrow

HARVESTING BUDWORM INFESTED BALSAM STANDS:

ONTARIO PAPER COMPANY'S EXPERIENCE

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Abstract.—*In 1976 the Ontario Paper Company moved an operation to the Shining Tree Management Unit. This move coincided with the firm entrenchment of the spruce budworm in the area. The following paper describes the evolution of the logging techniques used to combat the problems of harvesting infested balsam fir.*

Résumé.—*En 1976, l'Ontario Paper Company a établi un parterre de coupe dans le Shining Tree Management Unit. Au même moment, la tordeuse s'est fermement établie dans la région. La communication décrit l'évolution des techniques de coupe utilisées pour juguler les problèmes d'exploitation du sapin baumier infesté.*

Introduction

The Shining Tree Management Unit is in the Gogama District of the Northern Region of the Ontario Ministry of Natural Resources, approximately 105 air kilometres south of Timmins.

Ontario Paper Company has a volume agreement for approximately 99,000 cubic metres of black spruce, white spruce, balsam fir and jack pine per year on this 3,212 square kilometre Management Unit.

The terrain of this area is predominantly rolling to hilly upland of sand, gravel and bedrock with some lowland deep peat soils. For the most part, the balsam is growing on sandy soils of varying depths that once supported stands of jack pine, but due to the lack of wildfires were naturally converted to balsam fir. Where wildfires did occur, there are now excellent stands of 40 to 70 year old jack pine.

When Ontario Paper made the decision to move to this area, budworm defoliation was visible over most of the Management Unit, but forecasts had populations declining to the extent that it wasn't expected to be a serious problem. These forecasts, however, did not prove to be correct and the infestation continued to grow worse up to the present time with abatement finally taking place due to the virtual destruction of the balsam fir working group on the Management Unit.

Harvesting

By the time Ontario Paper had its contractor operation, Morard Pulpwood, set up ready to begin harvesting, it was evident that the balsam fir was in trouble and that special attention would have to be given to the species if we were to harvest significant volumes rather than let it rot on the stump. As a result, it was decided to concentrate on the balsam fir working group at the expense of other working groups.

Once harvesting began, one of the initial problems we encountered was the varying stages of advancement of the budworm in any one particular stand. Certain trees or a section of the stand would be relatively free of budworm attack while other adjacent sections might vary from slightly infested right up to the mortality stage.

The problem this caused was that harvesting the green balsam presented few difficulties while harvesting the dead balsam resulted in considerable loss due to stem breakage at the various stages of the logging process.

Logging Technique No. 1

Existing logging equipment from the previous operating area was used initially for the harvesting start-up. This consisted of two Drott 40 feller bunchers felling full trees in bunches. The major problem here was that productivity became very low in the poorer stand which contained as little as 40 m^3 per ha. Only in stands that contained 100 m^3 per ha or more was productivity thought to be acceptable. These bunches were then skidded full tree to roadside by four Timberjack 550 (170 H.P.) skidders where they were delimbed with a flail delimber mounted on a Hydro Axe. Due to the fact that some of this timber had reached mortality and become very brittle coupled with the fact that even green balsam is a brittle tree species by nature, this limbing technique resulted in considerable breakage and lost fibre.

After limbing, the tree-length timber was loaded butt and top by a Poclain hydraulic boom loader and trucked to the processing plant at Ostrom on the CNR main line south of Gogama. Here the tree-length material was unloaded using a Cat 966 front-end tree-length loader with a non-tilt grapple. Since the timber was loaded butt and top, this type of grapple caused considerable breakage during the unloading process. Once again breakage was due mainly to the brittle nature of the dry balsam. After unloading, the timber was either stockpiled for later processing or immediately barked tree length, using two Cambio 45.5 cm barkers, and then slashed to 2.54 m lengths for rail shipment to our mill in Thorold, Ontario. During the barking process there was still more breakage due to the quality of the balsam fir.

Due to our fear of fibre loss through breakage, the wood was 100% scaled in the full-tree form at roadside. The total volume on the first 36,000 stacked m^3 was then followed through the entire logging process and scaled once again after being loaded on railcars as 2.54-m peeled wood. The scale on railcars compared to the 36,000 stacked m^3 we started with was a shocking 28,600 stacked m^3 or a fibre loss of over 20%. It was evident that we either had to terminate the harvesting of this balsam or attempt other logging systems.

In order to carry on with changes to our logging system, it was felt that a lower salvage rate for this timber was necessary to offset some of the additional logging costs. After considerable negotiations with the Ontario Ministry of Natural Resources, the salvage rate was reduced from \$0.3300 to \$0.0033 per m^3 for the balsam.

Logging Technique No. 2

As it was determined that the flail delimbing system led to a major portion of the fibre loss, this system was abandoned and replaced by Timmins Head delimbers. Also, two of the Timberjack 550 skidders were replaced by smaller, less powerful Timberjack 230 machines. Although scaling tests now indicated that we had reduced our fibre loss to approximately 15% from the initial 20.5%, it was obvious this was still unacceptable. The causes for the continued fibre loss, that had to be improved upon if logging was to continue, were in the limbing, truck unloading and barking processes. Cutting productivity was also proving to be unacceptable with the slow-moving tracked Drott 40 in the low-density stands.

Logging Technique No. 3

To combat some of the above problems, it was decided to revert to conventional logging. Hence ten chainsaw logging gangs were hired to cut, limb, and skid to roadside. Due to the nature of the timber, however, namely low density stands, limby and short wood, the last gang had disappeared within one month. A possible solution to the limbing and cutting productivity and fibre loss in the limbing process, therefore, never materialized. Another change made at this time was the addition of a Weldco tilt grapple mounted on a Hough 100 for unloading the tree length at the barking complex. This solved most of the problem of breakage at this stage. In the barker, improvements to the feed system and better control over the knife pressures also reduced breakage considerably.

Logging Technique No. 4

With the disappearance of the conventional cutting gangs, it became necessary to try different cutting and limbing methods. Two machines were then brought into the operation: a John Deere 743 tree harvester which felled, limbed, and somewhat erratically bunched tree length, and a Forano B.J. 20 harvester which, although it used different techniques, carried out the same functions of felling, limbing and erratically bunching the timber. The tree-length timber was then forwarded to roadside using a John Deere grapple skidder, a FMC clam bunk skidder and a Kokum clam bunk skidder. Although from a fibre loss point of view, this appeared to be an acceptable system, productivity was low, resulting in costs that proved to be unacceptable, and this system had to be abandoned.

Logging Technique No. 5

In a last attempt to find an acceptable system, a Koehring Feller Forwarder was brought onto the operation. This machine cuts the tree, places it in its bunk keeping it entirely off the ground, and forwards it to roadside, thereby minimizing the amount of abuse the tree must take in the cutting and forwarding stages. Also since the machine is on wheels, maneuverability and speed of the machine gave respectable production. To delimb, a Harricana delimber mounted on a Cat 215 was brought in and due to the extra support in holding the tree while delimbing and the different limbing technique, breakage was reduced significantly.

Results at last proved to be encouraging and although logging costs were higher than, say, cutting in normal spruce or pine stands, it was decided that there would be an attempt to live with the costs in order to salvage as much of the balsam as possible.

Approximately four months after obtaining the first Koehring, a second machine was obtained and a second delimber in the form of an existing Drott 40 fitted with a Denis Model T delimber. For delimbing balsam, the Denis proved to be even better than the Harricana in keeping breakage to a minimum.

Basically, this logging system has continued to the present time, although the two delimbers are now the Denis Model K, which is simply an improved model using the same delimbing technique. These delimbers are now mounted on Linkbelt 228 carriers.

Now that a system is in place to harvest this type of balsam, the balsam on this Management Unit has pretty well been laid to waste by the budworm and the balsam cut is down to a small percentage of the total cut. From 1976 to the present (March '82) approximately 2,746 net ha and 98,700 stacked m^3 of balsam have been harvested.

The above logging system remains in place and is working out very well in cutting pine and spruce although there are problems with the Koehrings in the wetter sites, even in the winter months.

Ideal Logging Technique

Although not acceptable to Ontario Paper Company's newsprint mill, an ideal logging system would consist of full tree chipping at roadside as is currently being used by Domtar at Redrock to obtain chips for their kraft mill. Domtar is utilizing a Morbark 55 cm chipper at roadside, blowing chips into vans for delivery to the mill. In stands that would be uneconomical to harvest in any other fashion due to tree size, Domtar is realizing 140 m^3 per ha in young balsam stands. These stands are then site prepared and planted.

SILVICULTURE AND THE SPRUCE BUDWORM

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Abstract.--*Past forest management practices in Ontario are discussed in relation to the vulnerability of the forest to spruce budworm outbreaks. Improved practices are suggested to reduce the vulnerability of the forest, including the development of a budworm vulnerability rating system to be used regularly to monitor each forest. Present public attitudes to the use of insecticides should assist managers in using silvicultural methods to help reduce the budworm problem. Forest Management Agreements provide a useful means of implementing the changes required.*

Résumé.--*Les méthodes d'aménagement forestier utilisées par le passé en Ontario font l'objet d'une discussion en rapport avec la vulnérabilité des forêts face aux infestations de la tordeuse. Des améliorations sont proposées pour réduire cette vulnérabilité, y compris la mise au point d'un système d'évaluation de la vulnérabilité qui serait utilisé de façon suivie pour contrôler chaque forêt. Actuellement, les attitudes du public face à l'utilisation des insecticides devraient aider les aménagistes à utiliser des méthodes sylvicoles afin de résoudre le problème de la tordeuse. Les Accords d'Aménagement Forestier constituent un moyen utile pour réaliser les modifications nécessaires.*

We have all known for many years how to manage forests to discourage the spruce budworm, but we have not done it. Is there any reason to think that things may be different now? I believe there is. As world demands for forest products are projected to increase, public awareness of our past poor management performance also increases. The public attitude to our actions is much more critical, particularly in the use of chemicals to combat the spruce budworm, as has been demonstrated recently in the Maritimes. We should be able to get some public support for silvicultural aids in our territorial dispute with the budworm.

In addition, we have a new vehicle in the Forest Management Agreements (FMAs) to help us improve forest management through the participation of the forest industry in a much more direct way than in the past.

What have we been doing wrong and what steps should we be taking?

Let us imagine for a moment what the situation might be if a spruce budworm were to write the plan for management to supply its survival needs from the forest. First of all, naturally, it would call for a good forest fire suppression system. It recognizes that its preferred crop, fir, is easily killed by fire and does not regenerate as well after fire as other boreal tree species.

Some cutting would have to be permitted to assure a series of new stands of fir.

Since fir regenerates best under shade (Anon. 1965), partial cutting would be recommended. Take out the unappetizing jack pine and black spruce to reduce the seed source. Leave the poplar and a good scattering of the older fir for shade and seed, and, of course, protect the clumps of advance fir growth. The white spruce does not regenerate well without careful planning, so it can all be taken.

Fir regenerates well on almost any seedbed, even deep litter if it is moist, so no site preparation is needed.

This cutting operation leaves a seed source for fir, a suitable seedbed, and shade to protect the fir germinants and to help reduce unwanted competition. The young fir will survive under dense shade and be ready and able to respond immediately to any openings in the forest canopy as they develop.

A series of cuts of this sort will assure the future food for the budworm.

The operating plan must look after the budworm's immediate needs as well. The cutting should bypass as much as possible the decadent stands which are heavy to fir. Road access should go to the nearest best stands of jack pine and black spruce and not be extended to open up the whole area. Fringes of forest should be left around shorelines and along rivers and highways. These, along with a good network of parks where cutting is not permitted, provide numerous centres for food and overwintering.

So far the plan has not looked after the equally tasty white spruce. It is not essential for survival but a few should be kept for emergency and diversity. The best means is planting. Some site preparation is usually needed but care must be taken not to damage the advance fir growth and seed trees, or too much of the poplar. Prescribed burning must be absolutely prohibited. A release spraying should be delayed as long as possible to maintain the advantage of the fir, while still allowing a few spruce to become established.

Finally, two long-term measures should be introduced. The media should be encouraged to give coverage to the views that monocultures of budworm resistant species are bad and that the natural, untouched (but with fire excluded) overmature mixed stands are good.

The second long-term measure is a hard one which will be opposed by many budworms, but it is for the good of the species. There should be a little insecticide spraying done, perhaps just in parks and a few special areas, to develop and keep a nucleus of spray-resistant budworms in case of emergencies.

This management plan ought to ensure a good supply of overmature stands of fir, and an increasing fir content in the future stands for the continuing benefit of the budworm.

Since this is exactly what we have been doing for many years, I wonder who has been setting our forest management policy anyway, us, or the budworm?

What is our forest like as a paradise for budworm? The rating of vulnerability to budworm attack (MacLean 1982) developed for New Brunswick and Nova Scotia is not directly applicable to Ontario but it can help us judge our forest. It gives high vulnerability marks to the proportion of white spruce plus fir in a forest. The last comprehensive forest inventory figures available (Dixon 1963) for Ontario show that, in the exploitable forest which covers most of the budworm range, white spruce plus fir represented only 11.3 percent of the total inventory volume. This does not seem high, so our natural forest was probably, on the average, not too vulnerable. However, it was not uniform and would have been made up of large areas of more vulnerable forest to support the budworm outbreaks of the past.

We can only conjecture on what has been happening since, because Ontario does not see fit to release recent provincial inventory data or allowable cuts. Our harvest of fir was only 18 percent of the allowable cut in 1979-1980 (Anon. 1981), so much of the fir must be left. Many of our highgraded, mixed stands are left untreated, encouraging an increase in fir. Advance fir growth is usually protected during site preparation, and few prescribed burns are done. Until 1976 (Anon. 1981) more than 70 percent of our spruce planting was the vulnerable white spruce rather than the resistant black spruce. Only in the last five years has that proportion fallen, and then only to about 45 percent. Our management, or lack of it, has tended strongly to increase this aspect of budworm vulnerability.

The next main factor in vulnerability is the maturity of the fir. Our forests have all tended to be predominantly mature to overmature, and while we vocally encourage the cutting of the oldest age classes first, we have not enforced the policy. Our low cut of fir and our skimming of the mixedwood stands for spruce and pine tend to leave overmature fir. We don't usually develop a network of roads to access all parts of the forest, but push out from the mill, leaving the distant overmature forest for the budworm.

These two factors, the proportion of fir and white spruce, and the maturity of the fir, tend to be increasing, leading to ever greater vulnerability to budworm attack.

So what should we do? The answer seems simple: just do the reverse of what we have been doing. Reduce the proportion of white spruce and fir, and the maturity of the fir in the forest. However, there is no way we can change the character of the forest and correct 40 years of forest practices overnight. It will take stand-by-stand action and a great deal of time. There are no instant panaceas so we have no more time to waste.

We must be much firmer in our policy of cutting the oldest age classes first. This is a requirement in the allocation of stands for cutting in the FMAs and it is strongly supported with an access road payment. If stands are bypassed they cannot be replaced with other stands. This policy should be made a requirement for Crown forests and non-FMA licenses as well. The policy must be applied equally strongly to vulnerable stands in our system of shoreline and road reserves. There is no excuse for deliberately setting up safety zones all through the forest for the budworm.

We must intensify our management to favor the less vulnerable species. In the boreal forest that means jack pine, black spruce and even aspen. Fir must be cut cleaner. Much more use must be made of prescribed burning for site preparation in the mixedwood sites to reduce the fir content in the future stand.

The proportion of white spruce in our planting program must be reduced still further until such time as more budworm-tolerant or even resistant strains of white spruce can be developed. Little has been done as yet in this aspect of genetic improvement but the geneticists and entomologists are now looking into the possibilities. For the present, probably no more than 10 percent of our spruce planting should be white spruce, and then only in well distributed sites, carefully selected for the best growth.

For now, and in the foreseeable future, we will still have immature stands with a high proportion of fir. It is impractical to consider destroying them all and starting over. We must, therefore, start to manage the fir we have. We have only just recently done some research in this field but we know fir will respond well to release and spacing. This will shorten the time until it can be harvested and thereby reduce its vulnerability.

All these measures for improved forest management are necessary in Ontario, not just for spruce budworm control, but in order to meet our production targets and supply the mills to take care of our future needs. We cannot afford to neglect our most important renewable natural resource.

Finally, I believe we should have our own vulnerability rating system. Every FMA and every Crown unit should be rated every five years. This should be a part of the normal review of management progress at the start of each new operating period, so that we can monitor our progress in achieving a less vulnerable forest.

In conclusion, we are going to have to live with the budworm. If we continue to manage our forests as we have in the past, the effect will be devastating. We know the silvicultural techniques and we have to start now on the long, slow corrective process to achieve a forest that will supply our needs and be far less vulnerable to the inroads of the spruce budworm.

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SPRUCE BUDWORM CONTROL OPTIONS - CURRENT AND FUTURE

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Abstract.—*The spruce budworm will continue to plague forest managers in Ontario as long as spruce and fir remain significant components of the province's forests. Spruce budworm control options currently available to forest managers are outlined in this paper and predictions are made concerning new pest control products and techniques which may become available in the 1980s through continuing research and development.*

Résumé.—*La tordeuse continuera à hanter les aménagistes forestiers de l'Ontario tant que le sapin et l'épinette constitueront en grande partie les forêts de cette province. L'auteur décrit l'arsenal antitordeuse actuel et fait certaines prédictions concernant l'apparition sur le marché, au cours des années 80, de produits et techniques antiparasitaires, résultats de la recherche incessante consacrée à ce problème.*

Introduction

The theme of this particular session of the Symposium has as its title "Living with the Budworm", and this implies to me that the Symposium organizers believe, as I most certainly do, that the budworm is here to stay, and at some level or other, will continue to plague forest managers as long as spruce and fir remain significant components of Ontario's forests. With this fact established, it then remains for us to learn how to live with this insect and to keep the losses that it occasions at levels that are considered acceptable to forest managers by utilizing techniques that are efficient, economical and environmentally acceptable. My specific role in this session is to describe for you control options that are currently available; to comment on their effectiveness and their shortcomings; and to do a little crystal gazing vis-à-vis other options that may become available for operational use in the 1980s and beyond, through research that is now ongoing within the Canadian Forestry Service (CFS) and elsewhere. This is a relatively tall order in the short time available and only a superficial treatment of the subject will be possible. Furthermore, I will deal only with direct control approaches and will leave such subjects as silvicultural control to others more expert and perhaps more optimistic of the potential of such approaches than I happen to be where the highly adaptable and intractable spruce budworm is concerned.

Control Options Currently Available

Currently, there are only three viable and proven options available for budworm control--or more properly, forest protection from the budworm during its outbreak stage--

no protection, foliage protection with chemical insecticides, and foliage protection with *Bacillus thuringiensis (B.t.).*

The No-protection Option

The no-protection option is a viable alternative and is one that always must be considered--it certainly has been over much of Ontario during the current outbreak. The consequences are entirely predictable with extensive mortality of fir and somewhat less of spruce, which culminates several years after the collapse of the outbreak when the budworm has eaten itself out of house and home. Other consequences of such an approach are a significant elevation of the fire hazard and regeneration of extensive areas to more or less even-aged fir and spruce once more, unless silvicultural methods are utilized to alter the natural regeneration picture. While this has been considered, to date, a viable approach over much of northeastern and north-central Ontario given the current value of fir in Ontario's forest economy, it has not been considered a viable alternative in New Brunswick or in much of Quebec, and acceptance of this option has created a forest disaster over much of the Highlands of Cape Breton. As noted above, this is a reasonable option depending upon the economics involved, and the particular wood supply needs of the area concerned between the time the option is selected and the next rotation. Where intensive forest management of spruce and fir is being practised, however, it ceases to be a viable alternative.

Protection with Chemical Insecticides

Foliage protection with chemical insecticides is a proven method of protecting spruce-fir forests from extensive mortality during an outbreak. It has been used effectively in New Brunswick almost continuously, for the past 30 years, and while there is little question that it has perpetuated outbreak conditions through assuring a continuing supply of foliage for the budworm to feed upon, it has allowed at least doubling of the forest industry through the period 1952 to 1976, and if the same level of protection currently practised is maintained, it will sustain the same industrial capacity past the turn of the century. Without protection, it has been projected that by 1990, no spruce-fir stand in New Brunswick would be over 40 years of age and the total growing stock would be only about 10% of the current level (Baskerville 1978)!

Where chemical insecticides are concerned, fenitrothion and aminocarb have been the main pesticides used over the past decade. They are both about equal in terms of effectiveness and overall cost, and when applied carefully, have been used over some 40 million ha of spruce-fir forest with no significant disruption of any major ecological process or reduction of a resource population attributable to this use being found, despite extensive monitoring activity (Irving and Webb 1981). Nor has there been any proven effect on bystander health, despite continuing allegations to the contrary by anti-spray groups.

Three other chemical pesticides--acephate (Orthene), carbaryl (Sevin-4 oil), and trichlorphon (Dylox)--are also registered for forestry use in Canada against the budworm. The Canadian experience with Sevin-4 oil against the eastern spruce budworm has been minimal, largely, I think, because of the higher volumes of application (2.2 L/ha) required, but the material has been used broadly and with good success in Maine, and remains a currently viable alternative for use in Canada. Orthene has been used to only a very limited extent also. However, because of its relatively low toxicity to fish and to other aquatic organisms, it remains a good alternative for special situations including buffer areas along productive water courses. Dylox also has been used to a limited extent. It must be applied in relatively large amounts and in rather high volumes, but because it is of relatively low toxicity to pollinators, it does have potential for use, especially in areas contiguous to blueberry fields, or in other similar situations.

That is the current situation vis-à-vis the chemical insecticides available for use against the spruce budworm in the forest management category. It is not a spectacular array of options for the forest manager, but it does provide the tools required to do an adequate job of protection, provided the politics involved in any forest protection program are such that the forest manager is allowed to utilize the chemical tools currently registered and available to him.

For the future, where chemical insecticides for use against the spruce budworm are concerned, there are a few new materials or new formulations of existing materials in the research and testing mill that are at various stages along the lengthy and expensive road to registration.

The Forest Pest Management Institute (FPMI) and other cooperating agencies have been involved for the past three years in efficacy, environmental impact and chemical accountability testing of a new aminocarb flowable formulation, which has just recently been submitted for registration. This new formulation utilizes a finely ground component of the active ingredient suspended in a carrier mixture, which eliminates the need for nonylphenol as a primary solvent for the active ingredient, a solvent which had caused some concern to fisheries interests because it was shown to be more toxic to Atlantic salmon than was the active ingredient itself. This new flowable formulation can be used either with insect diluent 585 or, with a suitable emulsifier, as an aqueous mixture. All of our tests to date have shown that it is at least as effective as the current nonylphenol formulation against the spruce budworm, causes no increased impact on non-target terrestrial components of the forest ecosystem and is less toxic than the nonylphenol formulation to non-target aquatic organisms, including fish. We are very optimistic that aminocarb flowable will be registered and available for operational use by 1983.

We have also initiated tests on a new fenitrothion flowable formulation that is under development by Sumitomo Chemical Inc. Some early problems with separation and/or in-flight encapsulation of the original formulation were detected but now appear to have been overcome and if no unforeseen problems are encountered in the future, this new formulation may be registered and available for operational use by 1985. In a similar vein, we have begun testing of a new formulation of carbaryl-Sevin FR which shows promise of overcoming some of the problems noted earlier with Sevin-4-oil in the Canadian context. If no unforeseen problems are encountered, this product should be available for use in the 1980s.

Where the more or less classical chemical insecticides are concerned, we have a few other organophosphates and carbamates in the screening and testing mill at FPMI. These are at the stage of laboratory screening for toxicity to budworm larvae, and by and large, are relatively comparable to existing organophosphates (e.g., fenitrothion) or carbamates (e.g., aminocarb). There is nothing spectacular here, and their further development for forestry use will depend largely on whether or not the pesticide industries concerned decide that the economics of their further development is warranted in view of their predicted use.

Moving away from these more or less classical insecticides, we have done a great deal of work with the synthetic pyrethroids, concentrating on permethrin as a representative of the generic group. After some 6-7 years of experience with permethrin, we have reached the conclusion that this material, because of its very high toxicity to fish and to aquatic insects, is not a candidate for broad-scale forestry use against the budworm, although we do support its use against budworm and other pests in the woodlands management category. The same can probably be said for the relatively wide range of other synthetic pyrethroids and these materials will not likely find broad-scale forestry use unless it is possible to develop specific ones that are much less toxic to fish and other aquatic organisms.

On the brighter side, where the less classical chemical insecticides are concerned, we have just recently begun laboratory tests on an experimental compound from the amidinohydrazone group. This particular material has been used effectively in fire ant control in the United States and is unique in that it is predominantly a stomach, as opposed to a contact, insecticide. This is exciting because it would have to be ingested to be toxic, and therefore it should have much less impact on non-target species, including parasites and predators, birds, mammals and aquatic organisms. It is much too early to make any firm predictions, but the potential would seem to be there for development of a significant breakthrough in chemical insecticides for budworm, and other uses.

Still on the less classical side are the benzoyl-urea moult inhibitors. These are materials that interfere with chitin synthesis and, in effect, destroy an arthropod's ability to synthesize its supporting skeleton. They, too, for the most part, have to be ingested to be effective, and they go a long way in providing us with materials that are specific in their effect on a much narrower range of organisms in the forest environment. Some of you may have heard of Dimilin and this is the class of materials that I am referring to. One of the experimental compounds we have worked with is particularly effective against the spruce budworm, and if production rights can be established, and the pesticide industry is supportive of further development, we may have another completely new class of compound available for use against the budworm and other insects during the 1980s.

Now, I hope I have not lost the specific theme in this presentation. I am still commenting on current, viable, direct options for budworm control or management, or whatever you might want to call that process that involves direct application of materials that will reduce the level of damage that spruce budworm imposes on spruce and fir during an outbreak. I have mentioned the 'no control' and have discussed the present and near future where chemical insecticides are concerned. The only other remaining topic here is the use of *Bacillus thuringiensis (B.t.)*.

Protection with Bacillus thuringiensis (B.t.)

Outside of chemical insecticides, *B.t.* is the only other material that currently can be used effectively and economically against the spruce budworm. Currently, there are seven different formulations of this material available for registered operational use against the spruce budworm in the forest category: Thuricide 16B, Thuricide 32B, Thuricide LV, Dipel F, Dipel SC, Dipel 88, and Novabac 3.

A coordinated field-trial approach under the auspices of the Canada-United States Spruce Budworms Program (CANUSA) has resulted in the broad-scale testing of this material against the eastern spruce budworm throughout Canada and the United States over the past three years. This, plus continuing research and development by the CFS and cooperating agencies has, to a very large degree, brought *B.t.* of age where spruce budworm is concerned and has demonstrated that if this material is applied carefully with proper timing, and under acceptable meteorological conditions, it can be as effective as chemical insecticides in achieving desired foliage protection against the spruce budworm. There is no question, I think, that it is currently more difficult to use, and its cost is several times that of chemical insecticides, yet in its present form it has been used, and will continue to be used, in selected areas where the use of chemical insecticides may not be appropriate for a variety of reasons. It has little or no effect on beneficial, non-target organisms, its activity being restricted for the most part to Lepidoptera, few of which are considered beneficial where forestry is concerned. Research that has been ongoing within the CFS and in cooperation with provincial and American colleagues under the aegis of CANUSA over the past few years is providing us with better information on dose- and volume-response curves for this material and how best to deliver the material to the target to achieve optimal results. Work done, primarily by the CFS in Quebec, shows good promise of providing *B.t.* in a more concentrated formulation which, by reducing the volume of material shipped from the manufacturer, will reduce the delivered cost of the material significantly, and by reducing the volume of the material that must be dispersed by aerial applications, will reduce these costs as well. My prediction would be, that within the 1980s, the cost of *B.t.* utilization could be reduced to a figure approaching that for chemical insecticides; that the control inconsistency which has plagued its use to date will be largely overcome and that it will become an even more viable alternative to chemical pesticides, especially in cases where the use of the latter is not appropriate. My enthusiasm here must be tempered by the fact that *B.t.* as it exists, or even as it may become in more concentrated formulations, will perhaps always be logistically somewhat more difficult to utilize than chemical insecticides where very broad-scale protection programs are required. However, this gap will be narrowed, and the remainder of the 1980s should see much more extensive use of this environmentally benign material.

Nor does the future of *B.t.* end here. The possibility still exists that strains significantly more toxic to spruce budworm will be found through ongoing screening, and possibly through genetic manipulation. Ongoing research on the parasporal, crystalline, toxic component of *B.t.* at FPMI should allow us to identify the truly active moiety of the toxic proteinaceous crystal, and this information, in turn, should allow either for the development of synthetic mimics of this natural material, or through biotechnology, for fermentation of the toxic element in *E. coli* or other micro-organisms, much more cheaply than it is currently produced in *B.t.* itself. In summary, where *B.t.* is concerned, the more distant future looks bright, but success will be achieved only through continued research and development on this bacterial pathogen.

To this point, we have considered only the 'no protection option', chemical insecticides, and *B.t.*, both with respect to the current 'state of the art' and what the immediate future (i.e., up to the 1990s) appears to hold. But what of the other approaches to direct control that are in the wings at various stages of development?

Control Options for the Future

Insect Parasites

The eastern spruce budworm is affected by a number of native insect parasites which affect the egg, early-larval and late-larval and pupal stages. A good deal is known of their roles in the dynamics of budworm populations during the outbreak stages. Although parasite abundance increases with increasing budworm abundance during an outbreak, parasites by themselves do not appear capable of terminating an outbreak but simply contribute to it by hastening the collapse already initiated by other factors. Because of the extremely large areas that are involved in a typical outbreak of the eastern spruce budworm, inundative releases of parasites such as *Trichogramma minutum*, a hymenopteran parasite attacking the egg stage, and *Agria affinis*, a dipteran parasite of the late larval stage, are not considered to be either economically or logistically practical even though these particular species can be mass produced with relative ease. Introduction of exotic parasites from Japan and Europe has been attempted at intervals during our long experience with the budworm in Canada, but with no success to date. Although one cannot rule out the approach, and while more successful exotic parasites than those tested to date might be found, particularly in areas with climatic conditions that approach those of eastern Canada, the chances of introduction of one or several exotic species controlling outbreaks is considered, by most, to be relatively slim. I think this is understandable, given the tremendous capacity of the budworm for numerical increase, together with its mobility which contributes so effectively to the rapid spread of budworm outbreaks.

The potential for the use of parasites against the spruce budworm would appear best in the case of outbreak prevention, possibly through the introduction of exotic species that might be particularly effective at low host densities, or through inundative releases of parasites like *Trichogramma* or *Agria* in incipient outbreak areas if, indeed, discrete and localized areas of incipient outbreak exist, and if continuing research provides us with techniques for identifying such areas with some degree of precision. Some of you are probably aware of the field testing of inundative release of *T. minutum* carried out cooperatively by the CFS, the Ontario Ministry of Natural Resources (OMNR), and the University of Guelph in the Hearst area this summer. The results of this test are not available as yet, but are expected to shed some light on the potential of such an approach.

Budworm Predators

Where predators of the eastern spruce budworm are concerned, only limited and sporadic research and testing have been carried out in Canada to date. Of the relatively broad range of budworm predators known, birds would appear to have the best potential for exploitation. However, for many of the same reasons that appear to limit the potential for parasites in budworm control, only manipulation of bird populations, perhaps by enhancing the numbers of selected species through introduction of nesting boxes or by stand manipulation, will likely have any chance of success and only as a preventive technique in association with other approaches in a coordinated or integrated pest management system.

Insect Pathogens

Like most insect species, the eastern spruce budworm is affected by a number of insect pathogens, none of which, except in a few very localized instances, have been reported as instrumental in the collapse of budworm populations. Despite this, insect pathogens do have potential for use, and a good deal of research on them has been under way within the CFS for the past three decades and will continue into the foreseeable future. I have already commented on *Bacillus thuringiensis* which, I think, can be considered a pretty spectacular success story, where the spruce budworm is concerned. But now I would like to spend a little time on other insect pathogens with potential either as microbial insecticides or as agents capable of producing true epizootics--viruses, fungi, and protozoa.

The eastern spruce budworm is affected by three baculoviruses that occur naturally within it--nuclear polyhedrosis virus (NPV), cytoplasmic polyhedrosis virus (CPV) and granulosis virus (GV). It is also susceptible to an entomopox virus (EPV) which was discovered several years ago in the western budworm. A good deal of research on these viruses has been conducted over the past 30 years at FPMI and a good deal of cooperative field testing with OMNR has gone on. In the past decade, most budworm-related research and field testing have been with NPV and somewhere in the neighborhood of 200 ha have been treated experimentally with this virus in Ontario with varying degrees of success. NPV, as it currently exists, acts primarily like a microbial insecticide and, although some carry-over in the remains of virus-killed larvae and pupae, which remain on the foliage over winter, has been recorded, and contributes to some foliage protection for several years following application, no epizootic which spreads broadly through budworm populations has resulted from such applications. To date, most of the field testing with NPV has been against third- and fourth-instar budworm larvae. Initial testing against the early instars (i.e., as they emerge from overwintering hibernacula) has shown some promise of increasing the effectiveness of this material and this possibility will be investigated further in the immediate future. With NPV, most of the biochemical and safety testing information required for a registration petition has been generated, but this virus has not been submitted for registration for a number of reasons, which will be considered later.

Research and testing on CPV, GV and EPV has also progressed to the stage where we have a fair knowledge of their potential for use against the eastern spruce budworm. Very briefly, CPV at the moment does not appear to have much potential for use against the budworm. While it is relatively infectious, it is not particularly virulent. EPV, which, following its discovery, appeared particularly promising on the basis of laboratory tests, proved disappointing when applied under field conditions for reasons which are not completely clear, although there is now evidence that this particular virus should be applied to the early instar stage (i.e., second-instar larvae leaving the overwintering hibernacula) to be most effective. In addition, this virus has some morphological similarity to the vertebrate pox viruses, and, although this similarity should not be taken as evidence of potential adverse effects on vertebrates, including human beings, the possibility of misinterpretation is there and has cooled to a certain degree our immediate interest in this particular virus.

Research and testing with GV have not yet proceeded as far as they have with the other viruses. GV is slower acting on eastern spruce budworm than the other viruses mentioned, but there is some evidence that the same kill may be possible with significantly lower doses than with the other viruses. This particular virus appears much more effective against the western than the eastern budworm and research with it, for the immediate future, will concentrate on the western species to determine its potential there and also to investigate means of increasing its effectiveness against the eastern spruce budworm.

Because insect viruses can be replicated only in living cells, either host insect larvae or insect cell cultures must be used to produce them. At the present state of development, tissue culture has not proceeded to the stage where budworm viruses can be produced in the amounts required for operational use, and hence they must be produced in the laboratory using spruce budworm larvae. This is a labor-intensive and expensive approach where the eastern spruce budworm is concerned (It takes about 3,000 infected budworm larvae to produce enough NPV to treat .4 ha). We estimate the cost of this production at approximately $240 per ha and, given other methods of control available, viruses at the moment must be considered uneconomical for use against the eastern spruce budworm, certainly during its outbreak phase. Research at the moment to reduce production costs is directed at determining if suitable, much larger hosts can be found within which to produce budworm virus, and at ways and means of utilizing cell cultures for mass production. It is doubtful if any significant breakthrough will occur in these particular areas during the 1980s.

Another approach to this overriding problem is to increase the infectivity and virulence of existing viruses, and research along these lines is continuing at FPMI. We currently have one of our virologists on development leave at the University of Cologne in West Germany where he is investigating, with a world authority in the field, genetic manipulation and cloning of baculoviruses including those infecting the eastern spruce budworm. Thus, we are actively investigating the potential of the burgeoning new field of biotechnology for possibilities where the production of new or modified viruses with improved characteristics is concerned. This field is so technical and developing so rapidly that it is difficult to predict what application it will have in virology. However, the future does look particularly bright and my bet would be that we will see marked advances in the use of viruses and other microbials against the spruce budworm and other insects before the end of the 1980s, through utilization of these new, exciting and rapidly developing approaches in biotechnology.

Where fungal pathogens are concerned, technology is not yet as advanced as it is with either *B.t.* or baculoviruses. We now know a great deal of the biology of the entomogenous fungi and there is no question that some of them form important elements in the disease complex of the eastern spruce budworm (e.g., *Zoophthera radicans* and *Entomophthora egressa).* Researchers at FPMI in cooperation with colleagues at the Great Lakes Forest Research Centre, the Newfoundland Forest Research Centre, Memorial University and other universities, are now concentrating on factors influencing the development of resting spores which are considered to be the most appropriate life stage of the fungi for use as microbial insecticides, and on the epidemiology of the fungi in host populations in the field. Significant advances have been made in these areas over the past few years and the stage is rapidly being reached where meaningful field trials with these microbials can be mounted against the spruce budworm and the hemlock looper. Until such trials have been conducted and mass production techniques developed, the full potential for use against the spruce budworm cannot be determined. Suffice it to say here that the apparent potential warrants continued research and development over the near future, and that by the end of the 1980s we will either have another option for budworm management available or will know why entomogenous fungi are not appropriate for budworm control.

A very small portion of biological control research within the CFS is devoted to protozoan parasites and is carried out at FPMI. This research is concerned wih the microsporida which commonly occur in a wide range of lepidopteran and hymenopteran pests. These organisms are usually very persistent in populations, increasing in abundance as the population ages. They are not normally highly pathogenic but adversely affect larval and pupal vigor and reduce adult longevity and fecundity. One of these microsporida, *Nosema fumiferanae*, is the most common parasite of the eastern spruce budworm, and another one, *Pleistophora schubergii*, will also readily infect budworm. They can be artificially introduced into budworm populations by applying spore suspensions and the level of infection can be increased substantially. Our research has shown that *N. fumiferanae* is transmitted transovarially and from spores from infected hosts occurring in frass or in regurgitations. Research in this area has recently moved to the epizootiology of microsporida in natural spruce budworm populations. The direct control potential of these protozoans is likely to be low where budworm outbreaks are concerned, but they may have potential for application in outbreak prevention. It is considered essential, however, that we understand the role they play in budworm population dynamics and their influence on host reaction to both chemical insecticides and other entomopathogens. The 1980s should see elucidation of these relationships.

Pheromones

A good deal of research and development within the CFS has been and is being done on pheromones of the eastern spruce budworm, primarily at FPMI, the Great Lakes Forest Research Centre and the Maritimes Forest Research Centre. Other research and testing are under way at the University of New Brunswick, McGill University, and the New Brunswick Research and Productivity Council. Through CANUSA, cooperative field trials are in progress utilizing the pheromone to monitor spruce budworm populations. The sex pheromone has been isolated, chemically identified and is now available commercially. Techniques have been developed and are under development to provide the pheromone in a controlled-release formulation (e.g., Hercon Flakes, Microcapsules, Conrel fibres) for use in pheromone traps or for application in the mating disruption technique. An extremely sensitive and rapid technique for detecting the pheromone at nanogram levels has been developed under the auspices of CANUSA. Excellent progress has been made in the use of the pheromone to monitor budworm populations at low levels, an expensive and time-consuming undertaking using the older foliage sampling techniques. Attempts at using the pheromone in the mating disruption approach have been made upon numerous occasions over the past years and while there is little question that the mating of natural populations can be reduced (based on male catches in pheromone traps), difficulties have been experienced in assessing the effect of the disruption technique on the subsequent generation because of reinvasion of treated areas by mated females from outside.

Currently, the pheromone can be used effectively in adult trapping to monitor spruce budworm populations and this will be a very useful technique for monitoring numerical changes during the post- and pre-outbreak stages and in determining the locations and extent of budworm epicentres, if these indeed exist as localized areas. With respect to the use of the pheromone as a direct control agent, further field trials will be required to resolve the potential. My own personal opinion, based upon what I have seen to date, is that, by itself, the technique will not be useful during the outbreak stage of the budworm. However, used in an integrated manner with chemical or microbial insecticides, it could prove to be a useful approach in specific situations. The pheromone has, I think, its greatest potential as a preventive technique during the pre-outbreak stage, used either alone or in concert with other control agents.

Genetic Mechanisms

Until very recently with the move of the researcher to management duties, FPMI had a project investigating genetic approaches to the management of insect pests. A major part of this work was aimed at the spruce budworm. Chemosterilants and Co^{60}- irradiation were utilized to produce sterility in male spruce budworm adults. Chemosterilants were found to have adverse effects on male mating behavior and viability but low level irradiation appeared promising in that it induced chromosome damage and resulted in inherited sterility and reduced population fertility in laboratory tests. This work is now in abeyance and no field releases have been made. Again, as with a number of other approaches already mentioned, the sterile male technique, if it is to be useful at all, will likely find its application as a preventive approach, at pre-outbreak levels, and used either by itself or as an integrated approach with other techniques.

Summary

In summary, and excluding the no-protection option, chemical insecticides and *Bacillus thuringiensis* are our only currently available, direct-control options for use operationally against the spruce budworm during its outbreak stage. Where chemical insecticides are concerned, we can expect to see available for registered use prior to the 1990s some new and improved formulations of some of the existing compounds (e.g., aminocarb flowable, fenitrothion flowable and perhaps the carbaryl line). It is possible that up to two new organophosphates or carbamate materials may also come on stream before 1990 and that, if control potential is verified, we will have one of the relatively new amidinohydrozones and one of the benzoyl-urea moult inhibitors available for use.

On the microbial insecticide side, I think we can forecast significant improvement in *B.t.* and perhaps its derivatives, in terms of both effectiveness and economics of use. If the biotechnology bubble does not burst, and there is no apparent reason that it should, we might possibly have a virus that is both effective and economically practical for use against the spruce budworm. Thus, in terms of materials for application, we can expect to see a modest increase in the number and type of specific materials available for use, but we will still be highly dependent upon chemical insecticides and on *B.t.* where treatment of outbreaks is concerned. Through continuing research by FPMI, the National Research Council, the New Brunswick Spray Efficacy Research Group and others in the field of application technology, we can expect to see rather significant advances in ways and means of formulating both chemical and biological pest control products that will allow us to produce spray clouds that will impinge more effectively on specific target areas, thus improving efficacy against the spruce budworm and reducing drift and contamination of non-target areas. Where microbials are concerned, this same approach should lead to economies of use and extension of the active leaf-life of these materials.

As we move into more intensive forest management including major thrusts in forest renewal, the need to protect the new forests will increase and we will have to use all options available either singly or in imaginative, integrated approaches aimed at preventing outbreaks from occurring or minimizing damage if outbreaks occur. This will require a whole new approach to budworm/forest management and will force much closer cooperation and planning among forest managers, silviculturists, forest economists, and protection specialists than is the case currently, or has been the case in the past. Where the new forests are concerned, forest protection must become an integral part of forest management in its broadest context.

Despite any advances that we can make through continuing research in the development of new and/or improved pest control products and in methods for utilizing them more effectively and safely against the spruce budworm, these advances will be to no avail unless forest managers are allowed to utilize these tools in a responsible way where and when they are required to achieve management objectives. Forestry use of pesticides, be they chemical or biological, is currently being challenged out of all proportion to other accepted uses of the same or similar pesticides by well-meaning but vociferous and, unfortunately, often ill-informed environmentalists and other public interest groups. Political over-reaction to these challenges is then resulting in decision making which denies the implementation of forest protection practices where these are required to manage the forest resource base in an intelligent and responsible manner and to allow it to contribute optimally to the socio-economic well-being of all Canadians. The challenge of the future, therefore, is no more critical in the development of new and improved pest control products and procedures than it is in the development of a more conscious and well-informed Canadian public where forestry and forest protection are concerned such that decisions with respect to the forestry use of pesticides of any kind can be made on objective as opposed to emotional grounds. This is a challenge which faces every forester in this room.

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RESEARCH ON THE SPRUCE BUDWORM--

UNDERSTANDING POPULATION DYNAMICS

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Abstract.--Successful prevention of spruce budworm outbreaks requires an understanding of how and why outbreaks occur. If epicentres exist (discrete areas of high population density which generate sufficient dispersing insects to cause outbreaks in the surrounding forest) then their suppression would lead to prevention of outbreaks. If populations build up simultaneously over extensive areas then prevention is more difficult. Simulation modelling of the processes affecting budworm survival will greatly assist our understanding without our having to resort to long-term, expensive field studies.

Résumé.--Pour bien prévenir les infestations de la tordeuse, il faut comprendre comment et pourquoi elles surviennent. Si des épicentres, c'est-à-dire, des secteurs bien localisés de populations denses d'où suffisamment d'insectes se dispersent pour infester la forêt environnante, en sont à l'origine, alors la suppression de ces épicentres permettrait de les prévenir. Si les populations prolifèrent de façon simultanée sur des superficies plutôt étendues, alors la prévention est plus difficile. La modélisation des processus qui influent sur la survie de la tordeuse nous aidera grandement à comprendre le phénomène sans que nous ayons à recourir à des études à long terme sur le terrain, qui sont coûteuses.

Dr. Green, Director of the Forest Pest Management Institute (FPMI) of the Canadian Forestry Service (CFS), has given you an overview of the CFS research effort aimed at developing new, and less environmentally hazardous, techniques of controlling spruce budworm numbers. Other aspects of the federal research effort on the spruce budworm problem have been dealt with in the earlier session, "Setting the Stage", moderated by Dr. C.D. Fowle. Yet other research topics are illustrated in the poster displays.

Numerous other aspects of budworm biology and impact are also under investigation, but one area of research which I believe deserves emphasis here is that on population dynamics.

The study of population dynamics is aimed at determining how and why population densities fluctuate from year to year. If we can understand the processes leading to outbreaks then we may be able to intervene, and either prevent outbreaks or at least minimize their impact.

Attempting to determine why outbreaks occur is not easy. After an outbreak is well established the evidence of its early buildup and spread is obscured and lost. Trying to follow an outbreak from its early beginnings is time consuming and chancy. Since we do not know the factors leading to outbreaks we do not know where to watch for one to start. As a result there are very few hard data, but there are lots of theories. Let us take the epicentre theory, for example, since it well illustrates how an understanding of population dynamics could affect forest management.

Between outbreaks spruce budworm populations are so low that they are practically undetectable, but it is almost certain that there are constant, minor fluctuations taking place every year. It is probable that some areas support higher rates of growth in good years than others, so that a transect of spruce budworm population densities taken across a wide stretch of forest would show ups and downs like a mountain range (Fig. 1A). As conditions for survival improve, numbers will increase everywhere, but they will increase fastest in the more favorable areas, so that the 'mountain range' will rise over large areas and some of the peaks will become visible as isolated pockets of defoliation (Fig. 1B) such as were found in northern Ontario in 1967.

The critical question, then, is: "Does the whole mountain range continue to rise (Fig. 2A) or do the peaks of high population density erupt and distribute moths and larvae into the surrounding forests (Fig. 2B)?" If spruce budworm populations in the surrounding forests would not have reached outbreak level without invasion by these insects, then the peaks are epicentres, and prevention of dispersal will prevent the outbreak from spreading. If they exist, epicentres are probably discrete centres of forest having recognizable features of stand composition, age, site and topography. If these traits can be identified then potential epicentres could be removed by cutting. Alternatively, populations in these areas could be monitored carefully, and if population densities increase dramatically they could be suppressed by spraying. Such a program of prevention would involve spraying smaller areas, and spraying less often, than is the case with current crop-protection spraying in the Maritimes.

On the other hand, if populations rise inexorably over wide areas, then removal of the epicentres would not prevent an outbreak (although it might slow the rate of spread which could buy precious time for accelerated harvesting). In such a case prevention of outbreaks would be far more difficult, and would involve far larger areas in need of treatment. Our only hope would lie in finding out what factors were operating or were failing to operate in allowing the populations to increase; then it might be possible to redress the balance.

Do epicentres exist? This is a moot point. In two instances, isolated pockets of high population density were treated with

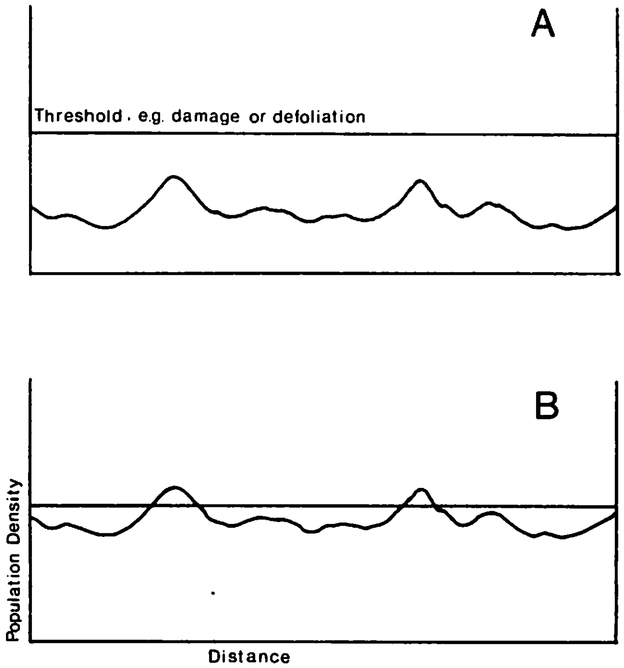

Figure 1. Diagrammatic representation of spatial differences in spruce budworm population densities over a forest transect of several hundred kilometres.
(A) Populations at low density throughout the area.
(B) Following increased survival rates throughout the area, populations become detectable in isolated areas (i.e., they exceed the damage or defoliation threshold).

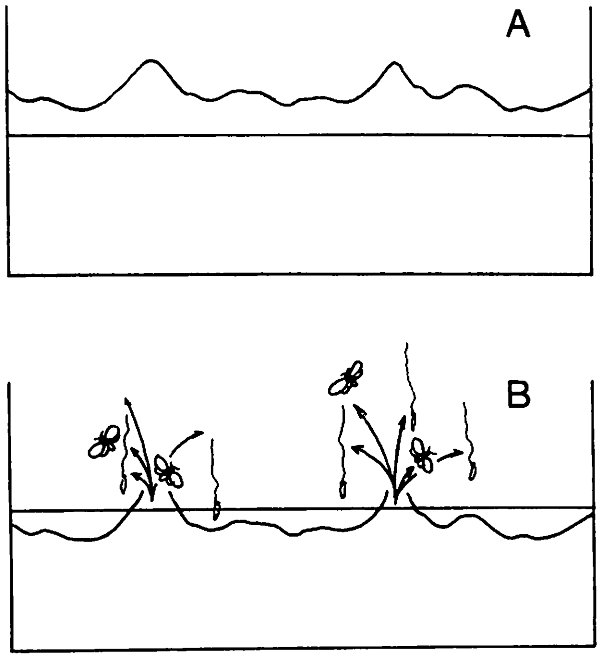

Figure 2. A continuation of Figure 1. Do outbreaks occur by (A) a continued rise in populations throughout the area, or (B) insects spreading out from the centres of high population (= epicentres)?

insecticide, one in 1963 in eastern Quebec at Lake Kedgwick (Blais 1964) and one in northwestern Ontario at Burchell Lake in 1968 (Howse and Sippell 1975). Subsequently no outbreak occurred in the surrounding forests in either instance. Were these, then, epicentres? We cannot be certain since in neither case was there a 'control area' where pockets of high density were allowed to develop unchecked. In other instances such as in northeastern Ontario in the late 1960s outbreaks occurred almost simultaneously over such large areas that it is difficult to imagine that they could have started from isolated pockets. In some situations where forest composition, topography and site are quite variable, epicentres may be critical. In other more homogenous areas they may be less important.

It is not my intention here to resolve the question of whether epicentres exist or not, but to illustrate the impact that the answers would have on the management of the spruce budworm problem. Because of this, we in the CFS believe that it is crucial for us to try and resolve the processes operating in population dynamics. The last concentrated attempt was made in the Green River project in the 1950s in New Brunswick. This study involved a large research staff which had the advantage of working in high population densities in which insects are easy to find and sampling is relatively easy. But even with these advantages, it is clear after the event that some important parameters were not adequately studied. Moreover, it is also clear that some of the crucial events take place when populations are at very low densities, making study extremely difficult and costly. How, then, can we hope to make any headway in our understanding with our present limited resources? Following the Green River study very little headway was made and our understanding of spruce budworm population dynamics virtually stood still. However, recently we have begun to move ahead again, with the advent of computer simulation modelling. Computers enable us to build complex models of the processes that we believe are operating on budworm populations in the real world. These models can then be pieced together and allowed to interact, simulating what will happen to a budworm population over several years. If the outcome of these simulations appears reasonable, then we can design experiments to check our assumptions, leading to modifications in the process models as necessary. This interaction of theory, model building and experimentation allows us to make maximum use of our research dollars and I have every hope that we will make rapid progress in this complex but important area of research in the immediate future.

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THE ONTARIO OVERVIEW

Moderator: D.E. Ketcheson

THE EFFECT OF THE SPRUCE BUDWORM PROBLEM ON POLICY AND PLANNING

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Abstract.--Although a few annual plans at the district level incorporate plans to control the spruce budworm, currently approved Forest Management Plans for Ontario contain no long-term or medium-term control strategies. This is because, on the provincial scale, depletions due to the budworm are difficult to predict and represent only a fraction of the losses due to burns, blowdowns, insects and diseases, which collectively represent only 6% of the total annual depletions.

Résumé--Même si quelques plans annuels de district prévoient la répression de la tordeuse des bourgeons de l'épinette, les plans d'aménagement forestier de l'Ontario approuvés à l'heure actuelle ne renferment pas de stratégies de répression à longue ou moyenne échéances. C'est, qu'à l'échelle provinciale les pertes dues à la tordeuse sont difficiles à prévoir et ne représentent qu'une fraction des pertes attribuables aux incendies, aux vents, aux insectes et aux maladies qui, globalement, ne constituent que 6% des pertes annuelles totales.

My assignment for this seminar is to comment on the effects of the spruce budworm problem in Ontario on policy and planning. I would like to begin with an outline of how planning is carried out in Ontario by the Ministry of Natural Resources.

The Planning Systems

Planning is an exercise which seeks the answers to "why", "what", "where" and "how" we are doing things. Generally planning systems will deal with all of these questions; however, emphasis and detail may differ between systems. The Ontario Ministry of Natural Resources employs a number of planning systems which can be categorized as follows:

Policy Planning	"why"
Land Use Planning	"where"
Resource Management Planning	"what"
Work Program Planning	"how"

Policy planning attempts to establish policy within a legislative mandate and determines goals and objectives on a macro-scale which can be striven for across the province. An example is the Forest Production Policy approved by Cabinet in 1972 which set a forest management goal of producing 9.1 million cunits of wood fibre per year by 2020. Another example on a somewhat lesser scale is the Spruce Budworm Spray Policy which sets out the purpose and the conditions under which spraying can be carried out in the province.

Land use planning attempts to rationalize the land requirements for the existing land uses and establish zones for single and multiple uses of land. It has been carried out in the province for more than 10 years and has introduced the concept of public involvement in the planning process, a concept which has now been adopted for resource management planning as well.

Resource management planning deals with the resources on or in the lands and waters of the province. It establishes management objectives to regulate resource use, renewal and/or rehabilitation and it sets out practices and standards by which the objectives can be achieved. Resource management planning is particularly sensitive to regional and local socio-economic and biological conditions; as a result, planning takes place on smaller units of land as, for example, the Forest Management Units in Ontario. Therefore, the development and use of standard provincial planning procedures and manuals is a prerequisite of resource management planning.

Work program planning, in the true sense is operational planning. It translates objectives, standards and practices as set out in resource management plans into annual operations with measurable outputs and matches these with inputs of dollars, manpower and equipment. In Ontario, work program planning is carried out in each forest district and is aggregated by region and for the province to arrive at a provincial budget and the allocation of provincial expenditures. The process is complicated due to the integrated nature of the Ministry programs and it takes some 15 months to complete.

The importance of the interrelationship between the planning systems cannot be overemphasized. The annual forest operations, no matter how efficiently planned and implemented, can only be effective if they lead to the achievement of a longer term objective enunciated in a forest management plan. Similarly, the objectives in a forest management plan must be the result of policy decisions and must fully recognize the existence and values of other land uses.

All planning systems have three closely related activities in common. First, there is the collection of data which will establish the facts concerning the biological, physiographic and socio-economic conditions of the forest estate. Second, there is the determination of a course of action. Traditionally, forest plans presented the facts and the decisions, but did not include a critical analysis of the options available for action. This weakness must be recognized and future plans must include a middle part which bridges the descriptive and the prescriptive parts of the plan. Third, there is the preparation of one or more planning documents which describe the conditions under which management takes place and contain the management prescriptions in various detail depending on the plan period.

To be useful, a plan should be used, which means that it should be adaptable to change. However, it is unwise to respond to what may be a temporary change in circumstances without considering what the long-term effect of the response may be. It is therefore necessary to strike a balance between flexibility and continuity. The more fundamental objectives should not easily be changed until a new situation is judged to be stable, but when this is recognized the revised objectives should be stated clearly and unequivocally.

In forest management planning the solution has been to prepare more than one planning document. A long term plan (20 years) reflects the long term policy objectives which can only be varied when a substantive permanent change in circumstances is apparent. A more detailed medium term plan (5 years) can be compared with the headlights of a car which light up the road for a constant distance ahead. These plans can be revised periodically as new information or techniques become available. A short term plan (one year) takes the more temporary changes into account and can be adjusted accordingly. A prerequisite for this type of planning system is that highly skillful staff should be available to carry out the planning exercise as well as the implementation of plans. Without the necessary expertise management will move from one crisis to another and degenerate into a series of ad hoc expediencies.

Having made a plan, it is necessary that it be implemented. There are two types of control. The first is exercised continually throughout the implementation of the proposed operations to ensure efficiency whereby unit costs are continually compared with the budget estimates. The second type measures effectiveness whereby the results are compared with the plan objectives. Therefore, a record system must be put in place which will facilitate comparison of achievement with long term as well as short term objectives. To be useful, a record system must consider what data are necessary, how and when to collect them and how they should be processed and communicated.

The Forest Management Planning System

The forest management planning system used in Ontario by the Ministry of Natural Resources is the oldest resource planning system. The fundamental requirements and techniques were published in 1948 in part 3 of the Manual of Timber Management. Subsequent to the Forest Resource Inventory program carried out between 1948 and 1959 new planning techniques were adopted which were outlined in the Manual of Management Plan Requirements published in 1960 and revised in 1961, 1962 and 1977. Until the early 1970s it was the only official planning system in use, and as a result, it contains some of the elements of what presently are recognized as separate planning systems.

With the advent of Forest Management Agreements between the Ministry and forest companies in 1979 a new Manual of Forest Management was published. It contained basically the same requirements as in the Manual of

Table 1. Forest Management Planning System.

Documents	Contents	Source
Data Bank	(FRI ledgers & maps (OPC ledgers & maps (Topographical data & maps (Site classification & maps (Insect & disease data (Fire data (Socio-economic data (Recreational data (Fish & wildlife data (Historical data (Analysis of past management	) Surveys) Reports) Studies) Existing plans
Management Plan (20 years)	(Summary description (Wood requirements (Other use requirements (Management objectives (Calculated AAC (Silviculture system & standards (Provisional AAC allocation (Access plan (Protection plan (Plan maintenance schedule	) Data bank) Policy directives) Licences) Wood flow directives) Land use plans
Operating Plan (5-10 years)	(Final AAC allocation (Silviculture prescriptions including harvesting (Management prescriptions for other uses (Cutting schedule & licensing schedule (Silvic. improvement schedule (Access schedule (Insect & disease control schedule	) Management plan) Procedure directives) Bulletins) Guidelines
Annual Plan (1 year)	(Access constr. & maintenance plans (Cutting operations (Silviculture operations (Insect & disease control operations	) Operating plan) Procedure directives) Bulletins
Annual Records	(Depletion records (Silviculture records (Assessments (stocking, survival, FTG)	) Photography) Surveys

Management Plan Requirements but the emphasis on certain parts was changed to bring it in line with the Agreement document (silviculture ground rules). Both manuals are presently in use to guide the preparation of management plans throughout the province.

The elements of the forest management planning system are outlined in Table 1. The system consists of a data bank which contains all relevant facts; a long term plan usually called the management plan or management plan report which covers a period of 20 years; a medium term plan called the operating plan which covers a period of 5 or 10 years; a short term plan called the annual plan for a period of one year; and a record system which is updated annually. When the system is used properly, it provides a framework by which forest policy and objectives are translated into a continuity of treatments for a management unit.

The Effects of the Budworm Problem on Forest Management Planning

The budworm problem is a specific forest problem. It will affect the old forest which is scheduled for cutting as well as the new forest which has been established after cutting and is in various stages of development. The location, size and significance of current and future outbreaks are important factors in the decision for control, either by aerial application of chemicals or by management prescriptions which will remove the susceptible stands before the outbreak takes place (i.e., change of allocation; accelerated cutting, crush and burn). Finally, when the outbreak has taken its toll, again location, size and significance of the damage will decide what management prescriptions are necessary to regenerate the forest.

Planning systems are decision making tools, and the forest management planning system is no exception. As can be seen from the outline in Table 1, the system provides for data input, evaluation and opportunity for decisions at all levels of planning. It is interesting to note that the currently approved plans do not contain much information in regard to the spruce budworm infestation and its control. With the exception of a few annual plans which describe planned control measures, no long term or medium term control strategies appear in the management or operating plans, which leads us to the conclusion that either there is no spruce budworm problem or it is only of local significance. The following offers in part an explanation.

The major aspects of forest management planning deal with planning for the depletion of the old forest and planning for the establishment and maintenance of the new forest. Table 2 depicts the elements of forest depletion and the percentages in area of the allocated allowable cut. As can be seen, the larger part of the depletion consists of stands cut and stands bypassed during the harvest due to economic and operational reasons. Only a minor part deals with other types of depletion including those areas depleted by spruce budworm infestation.

Table 2. Forest Area Depletion

Harvest cut	70%
Stands bypassed (operability factor)	18%
Forest reserves and roads	6%
Burns Insects and diseases Blowdown	6%
Total allocated AAC area	100%

Since depletion in terms of location and site conditions sets the stage for the subsequent renewal operations, management practices, techniques and standards have been developed for those conditions perpetrated by the cut as the first priority, and very little attention has been given to management practices for other types of depletion. Furthermore the conditions after cut, where the forest has been accessed and most of the trees removed, are more conducive to subsequent silvicultural operations than for instance a stand devastated by the spruce budworm, which must be accessed and the trees removed before regeneration techniques can be applied. Finally, depletion due to natural causes such as fire, wind and pathogens is difficult to predict in terms of location, size and severity, and therefore not conducive to long or medium term planning.

In conclusion it can be safely stated that the spruce budworm problem has had little effect on forest management planning and that any future effect will depend on the proportion of the total forest depletion as a result of the spruce budworm.

BUDWORM AND THE ONTARIO FOREST RESOURCE INVENTORY--

CALIBRATIONS FOR A CRYSTAL BALL

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Abstract.--Forest Resource Inventory data are used to show the relative occurrence of species susceptible to spruce budworm. A model which integrates the effects of depletions, regeneration and forest growth is described. This simulation model can be used to evaluate different forest management policy decisions.

Résumé.--Les résultats des inventaires forestiers sont utilisés pour montrer la fréquence relative des essences vulnérables à la tordeuse. On décrit un modèle qui tient compte des effets de l'épuisement des forêts, de leur régénération et de leur croissance. Ce modèle de simulation peut servir à évaluer les différentes options en matière d'aménagement forestier.

I grew up with certain definitions. An *objective* was "a statement of explicit measurable end result(s) which is (are) feasible to attain as the result of particular actions." *Policy* was "a once-and-for-all *internal* decision which deliberately sacrifices the flexibility of tactical decisions for other aims," and a *strategic decision* was "one that concerns itself with the allocation of resources (time, money, manpower, materials) for the achievement of important future aims."

Ontario has a production policy of "33.9 million cubic metres (allowable cut?) by 2020". This is a combination of objectives and policy as defined above. To implement that *policy* we have both *management plans* and an *implementation schedule,* i.e., statements of our strategic decisions. Management plans primarily describe the planned-for future depletion of the forest (the allowable cut calculation and allocation) and the implementation schedule primarily describes the planned-for future replenishment of the forest.

Today's Static Data

Knowledgeable people will speak during this symposium about the budworm. I will speak about forests. Data about the forests come from the Forest Resource Inventory (FRI) which collects and portrays forest statistics about parts of Ontario on a 20-year cycle. Summing the data from all these parts provides an approximation of the forests of the province.

In Ontario's FRI, productive forest land is subdivided into stands. Each stand is uniquely identified and classified by a variety of characteristics. Included in these characteristics are:

Working group	- usually the predominant species in the stand
Age	- approximate age of predominant species

Species composition	- estimate of percentage composition of the stand by species (by basal area)
Stocking	- ratio of actual basal area to Normal Yield Tables basal area
Volume/area	- volume (gross total) of all species found in that stand.

Under *working group* Ontario recognizes balsam fir but generally adds all the spruces together as *spruce all*. From FRI data we can show the relative incidence of *balsam* and *spruce* working group area coverage compared to other softwood working groups in OMNR's Northern Region (Fig. 1 - Crown land only).

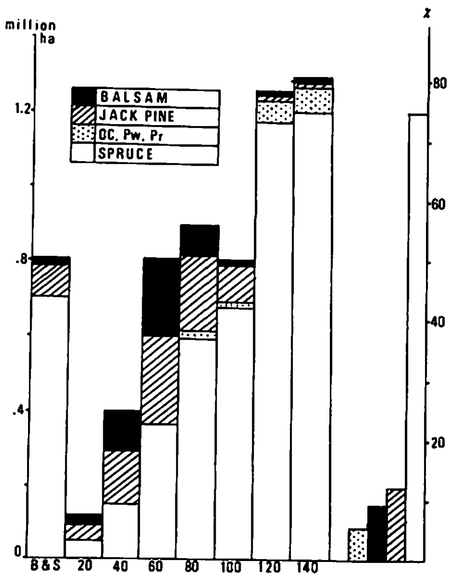

Figure 1. Areas of working groups by age classes of production forest in OMNR's Northern Region.

Policy makers and planners also like to work with end products--in our case wood--so they like to know about volumes. The current status of the balsam species' gross total (GT) volume and the white spruce species' volume (GT) in the Northern Region is shown in Figures 2 and 3 for the *spruce all* and *balsam* working groups, respectively. Figure 4 shows balsam and white spruce volumes (GT) in the *poplar* working group. These data reflect the net result of past history: growing, cutting, burning, dying, being eaten--and they are derived from the existing FRI.

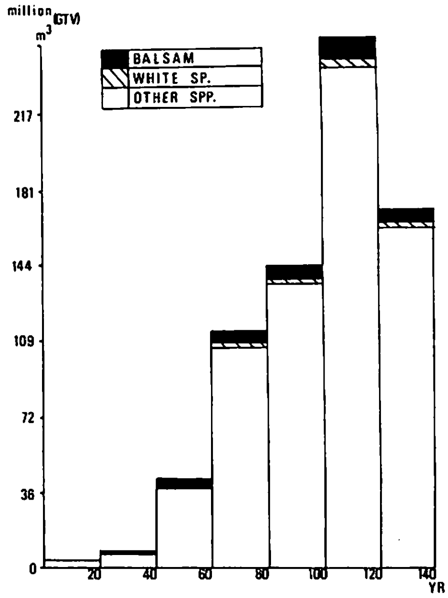

Figure 2. Volumes (GTV) of species by age classes in the *spruce all* working group of OMNR's Northern Region.

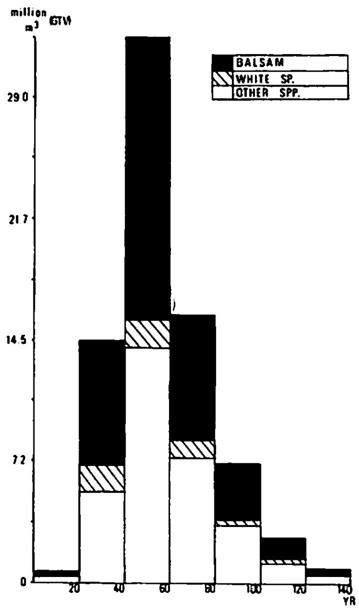

Figure 3. Volumes (GTV) of species by age classes in the *balsam* working group of OMNR's Northern Region.

Today's Dynamic Data

Knowing you have $10,000 in your account is heartening but finding it is only earning 1% interest is sickening. In forestry the static data, or the inventory in the account, are called the growing stock. Growth on this stock, or the trees' increment, constitutes the dynamic data resembling the interest. Forest planners talk of allowable cuts, and

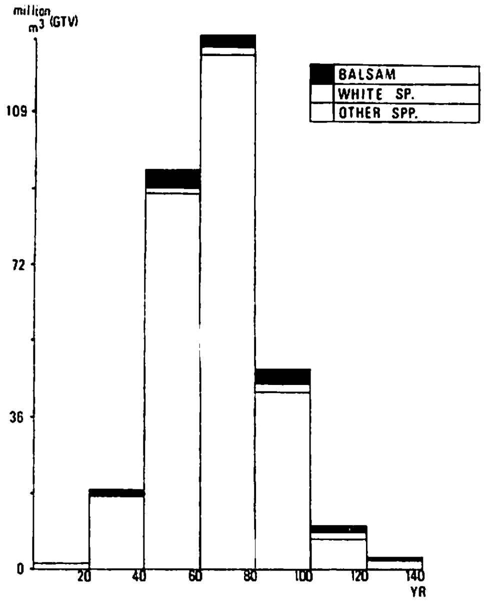

Figure 4. Volumes (GTV) of species by age classes in the *poplar* working group of OMNR's Northern Region.

in theory the allowable cut, like an interest rate, should be sustained as high as possible--which means that the increment of the forest should be as high as possible. By way of comparison the softwood working groups' current annual increment (CAI) and allowable cut in OMNR's Northern Region are: 8.40 million cubic metres GT/year and 11.08 million cubic metres GT/year, respectively.

Crystal Balls

The little old lady with the gypsy earrings and Calvin Klein jeans has a lot in common with the forest policy analyst in Levis with a diamond stud in his ear. The fortune-teller massages the crystal ball, interprets the pictures seen therein and with a modicum of mumbo-jumbo relates them to the user.

Our crystal ball is a forest simulation model. It is being used right now to study the existing production policy. The massaging that we do is really calibration.

The model primarily takes the existing forest and "grows" it through time under a certain series of assumptions. Before we look at that--and before we focus on the fifth question of this symposium--we need a few more definitions:

old forest = *today's existing growing stock*

new forest = *growing stock on areas reforested from today onwards*

depletions = *reductions in growing stock because of:*
- *cutting*
- *natural disasters (burn, windblow, flood)*
- *zoning out to other land uses*
- *"eating" by pathogens*
- *dying*

yield curves = *estimated volumes per unit area at different ages (see Fig. 5)*

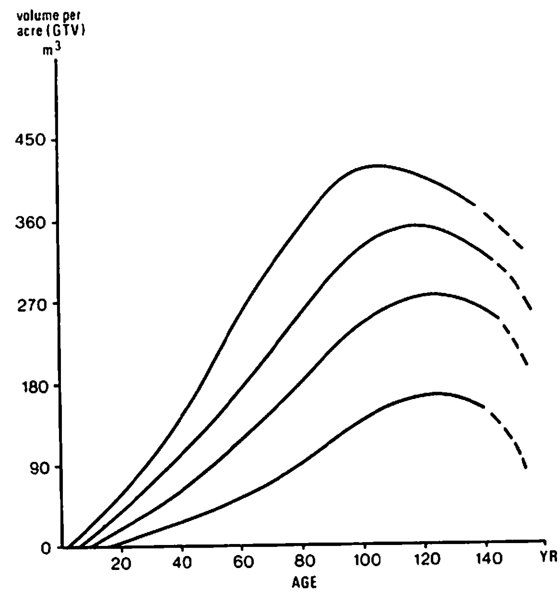

Figure 5. Yield curve of a species showing volume per ha by age class.

From the data of Figure 1 (the age class distribution of working group areas in the Northern Region) and the data of Figure 5 we can calculate the existing growing stock of the *balsam* working group = the old forest. Using the same data we could calculate the estimated growing stock on these same areas if all the trees grew five years more. This shows as the gross growing stock (GS) curve in Figure 6. These data can all be derived from the existing FRI.

However, in those five years this part of the forest experiences depletions and the resultant net growing stock is also shown in Figure 6. Certain areas of the old forest change age class status as they are depleted. Very simply, apart from the areas zoned out for other uses, all the depleted areas are available for creating the new forest. In the FRI we classify them as "barren" and "scattered".

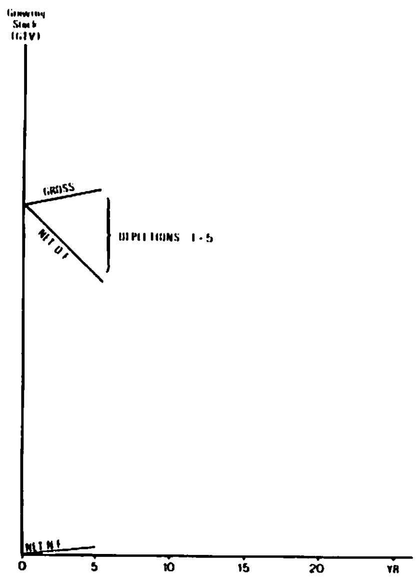

Figure 6. Changes to hypothetical forest's present growing stock (GTV cubic metres) over the next 5 years.

The present management planning "allowable cut" calculations compute the future permissible depletions. In light of the above list of depletions it may be better to rename this calculation algorithm "potential allowable depletions" rather than allowable *cut*. The latter term infers it is all out there available for the loggers.

In the five year period (0-5) management practices of different intensities result in growing stock on those young areas. The production policy analysis will include four levels of new forest management practices. These four levels will be entitled:

extensive = Level 1

basic = Level 2

intensive = Level 3

elite = Level 4

Each of these has its own yield curves. As with the old forest the areas treated will grow along their respective curves. Some depletions will occur in this new forest and the curve shown in Figure 6 is net growing stock. This planned series of future treatments is currently tabulated in the Implementation Schedule which is in the process of being extended to 1992.

Figure 7 shows the process of depletions and replenishments continued for another five-year period. The old forest growing stock potentially grows but is depleted, resulting in its gradual diminution. The new forest continues to grow, despite some minor depletions. We can repeat this at five-year intervals as in Figure 8, showing the possible future 20 years from today.

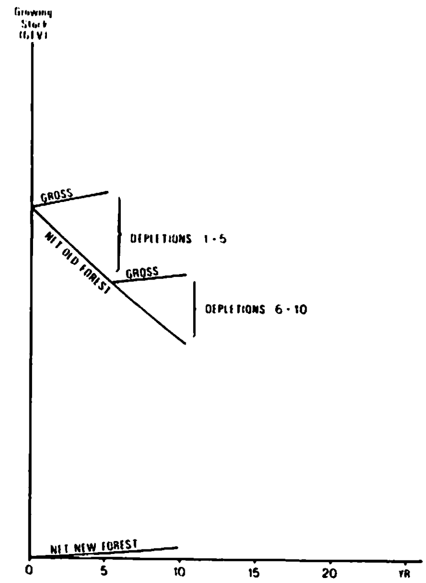

Figure 7. Changes to hypothetical forest's present growing stock over two 5-year periods.

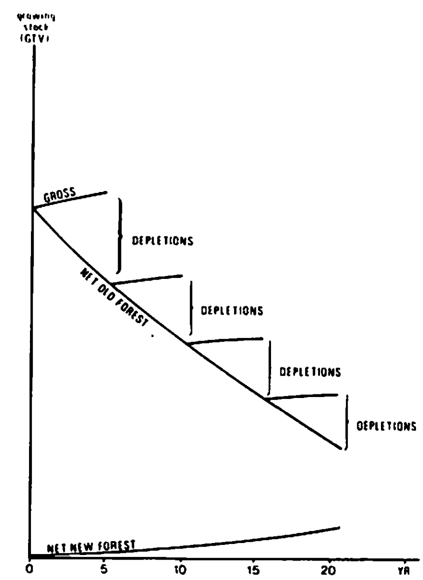

Figure 8. Changes to hypothetical forest's present growing stock over four 5-year periods.

Using growing stock as the dependent variable we can see a scenario from the crystal ball in Figure 9. At this stage we can add a new line--the entire forest--old forest and new forest combined.

Perhaps more illustrative is Figure 10. The future events used to create the results in Figure 9 were those of depletion and replenishment. Figure 10 looks at the depletion forecasts. This really focuses on the types of data that are necessary to calibrate this crystal ball.

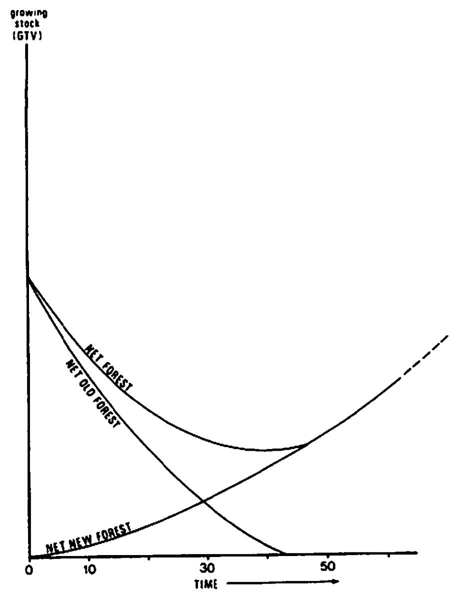

Figure 9. Changes to hypothetical forest's present growing stock over time.

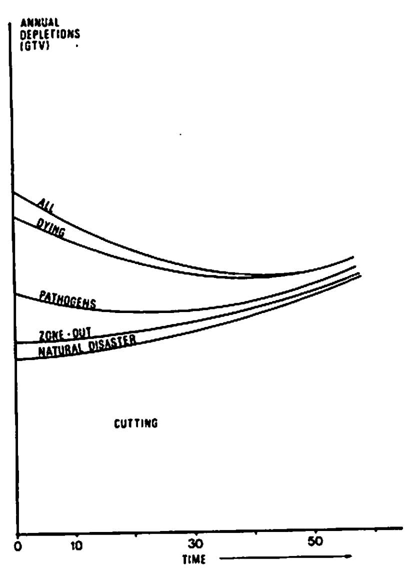

Figure 10. Changes to hypothetical forest's annual depletions over time.

In the section above the description of the existing forest comes from FRI data. Undoubtedly these data can be improved but at this macro level of planning and decision making they are considered adequate. Using the empirical *yield* curves as deduced from FRI data is a poor approximation of genuine *growth* curves. Nevertheless, these yield data must serve this purpose until we derive more realistic growth relationships.

Calibration Data

We have cited several causes of depletion. Whereas we may be able to forecast estimated roundwood consumption (future cuts) there are difficulties in forecasting the other depletions. Historic records of burns can be used as our first approximations of the future losses due to fire. Other future natural disasters will be more of a problem to estimate. Predictions of future rezoning which will reduce the production forest land base will be very difficult to make. Land use planning's past rezoning could provide a guide. However, the identification of which working group, which age class, and when such rezoning will occur will obviously be somewhat speculative. The future pathological effects are perhaps the component of greatest interest here at this symposium. Just think for a moment what it is we are trying to derive.

At time 0, now, the FRI has the areas of any working group by age class. Applying the appropriate yield curve (Fig. 5) the estimated volume of the existing forest can be derived, as shown in Figure 6. How did we arrive at the net volume estimate of the forest at time 5? Specified areas of the forest at time 0 (specified areas by age class) were assumed to change age classes because the trees were either cut, burned or killed by pathogens, or they died and the entire areas were assumed to be age 0, i.e., barren and scattered, and available for regeneration. In addition, areas were zoned out of production but the actual trees remained standing.

So the pathological data of direct importance here are those that say in this five-year period which stands (blocks of trees) on what areas (by age class) will die, i.e., for all intents and purposes the entire stand is written off and reverts to age 0. But what of the pathological effects which kill only some trees in the stand, or only slow down the trees' growth? This latter effect, this reduction in the trees' growth or actual volumes per unit area, is partially accounted for in the *empirical* yield curves. These empirical yield curves are an average of previous natural happenings in the forest but they obviously do not reflect catastrophic happenings. Hence there are really two effects we are trying to predict with respect to the depletions: the areas which change from the existing age class to age 0, and the areas where the volumes per unit area are different from the empirical yield table value built into the model. In the use of pathological data both these effects are important.

There is one other depletion effect that should be mentioned and this is an example of the interdependencies of these depletion components. Included in the list of depletion components is "natural" death. Stands do die. The model needs to have an age (for any given working group) above which stands will automatically revert to age 0. The pathological surveys may well contain data which help establish this "age of stand death".

One final comment should be made about depletions. Many of the causes of depletion --in fact all except the cutting--can and will occur in the young new forest. As explained above, Figures 7, 8, 9 and 10 show the net growing stock of the new forest. Natural catastrophe, pathological effects and the zoning of land out of production forest will occur in young stands. These effects will become of ever-increasing importance as the new forest growing stock constitutes more and more of the total forest.

Policy and Planning Implications

Two items emerge from the above which have relevance to the objectives of the symposium and the effects of the budworm on policy.

Looking at Figure 10 you can argue that all those depletions are variables--we can control all of them, including the "eating of the trees". Hopefully this symposium will speak to how we can control this cause of depletion. The model lets us look at the possible impacts of any forest protection policy level. If we keep the bugs and bird spotters and the beachcombers out we will have more trees for the pulp pile. Eliminate spraying and salvage operations and the volume available for industry may be severely reduced.

The second item springs from the above remarks. The cryptic statements are only as good as the calibrations and the fundamental biological principles of the model. We need to have yield curves better defined but more importantly for this symposium we need to be able to forecast depletions. Notice that this depletion forecast must not only be how much but also from what age class and which geographic location!

Summary

Forest management practices in Ontario to achieve the production policy objective of 33.9 million cubic metres by 2020 follow management plans and the implementation schedule. FRI data are used to describe the existing occurrence of balsam fir, white spruce and black spruce both in terms of working group areas and species volumes. For example, in OMNR's Northern Region the balsam fir working group currently covers 9.6% of the softwood production forest.

By using the inventory data as proxy growth relationships a forest simulation model can be created to investigate possible effects of different depletions and regeneration strategies. This approach highlights the need for depletion forecasts which identify which working groups, which areas, and which age classes will die because of spruce budworm. Refinement in the calibration of this model will make it a more useful policy analysis tool which in turn will help estimate the relative importance of spruce budworm and help explain our policies on spruce budworm treatment to scientists, managers and administrators.

SPRUCE BUDWORM SPRAYING -- ONTARIO'S APPROACH

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Abstract.--*In response to potential localized wood shortages in the Northern Region in the late 1970s, the Ontario Ministry of Natural Resources developed a policy on protection of commercial wood supplies from spruce budworm damage. A Ministry Policy and Procedure, approved in 1979, authorizes the Ministry to carry out spruce budworm spraying programs for epicentre suppression, outbreak containment, or protection of high-value or commercially operable forests. The current spraying program is designed solely to protect designated forest areas, not to control budworm populations. Under this policy and procedure, commercial forest areas may qualify for protection, provided that they satisfy selection criteria relating to species composition, harvest schedule and species utilization. If a designated area is to be protected, the protection area must be accessed and harvested within five years, with no more than three years of spraying. This approach combines short-term protection spraying with directed and/or accelerated harvest. Implementation of this policy in Hearst district is reviewed and some of the problems encountered are discussed.*

Résumé.—*Devant la possibilité de pénuries locales de bois dans le nord de l'Ontario à la fin des années 70, le ministère des Ressources naturelles de cette province a élaboré une politique de protection du bois commercialisable contre la tordeuse. En vertu de cette politique et de ses modalités d'application approuvées en 1979, le Ministère a été autorisé à effectuer des pulvérisations contre la tordeuse pour supprimer les épicentres, localiser les infestations ou protéger les forêts de grande valeur ou commercialisables. Le programme actuel de pulvérisations a pour seul but de protéger des territoires forestiers désignés, et non pas de réprimer les populations de tordeuse. En vertu de la politique et de ses modalités d'application, les territoires forestiers commerciaux peuvent être protégés pourvu qu'ils satisfassent aux critères de sélection relatifs à la composition et à l'utilisation des essences et au calendrier de récolte. Si un territoire est désigné la superficie à protéger doit être rendue accessible et être récoltée dans les cinq ans, et les pulvérisations ne pas dépasser trois ans. Cette façon de procéder allie la protection à court terme à la récolte dirigée ou accélérée. Le présent document examine l'application de cette politique dans le district de Hearst et discute de certains des problèmes rencontrés.*

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Introduction

The current spruce budworm outbreak, which is distributed throughout much of northern Ontario, began in 1967 in two widely separated locations--Chapleau and Thunder Bay Districts. In northwestern Ontario, the Ontario Ministry of Natural Resources (OMNR), in consultation with the Great Lakes Forest Research Centre, decided to suppress and contain the outbreak by carrying out annual spraying programs. The objective of this program, which lasted from 1968 to 1976, and covered areas ranging from 9,000 ha to 100,000 ha, was to suppress the outbreak and prevent it from becoming widely distributed. Protection of the wood supply in the spray area was not a primary objective. The program was generally considered successful, but in 1976, the outbreak expanded dramatically and to carry on would have required a spraying program of about 400,000 ha in 1977. At this time, OMNR decided that containment was no longer a reasonable undertaking, and so discontinued the program.

An entirely different situation existed in northeastern Ontario. A task force, headed by Mr. Dennis Schafer, studied the situation and concluded in 1970 that in view of the generally low economic importance of balsam fir to the forest industry, extensive spray programs to suppress the budworm or to protect future wood supplies were not justified. The task force recommended that spraying be carried out only to protect designated high value forests from budworm feeding damage. This approach was followed throughout the 1970s, with protection spraying directed primarily at provincial parks and nurseries. However, as the decade passed, budworm damage became more severe, tree mortality increased and the wood supply situation in OMNR's Northern Region began to tighten in certain districts. It first became critical in 1978, when the 10-year wood supply for the new Normick Mill in Kirkland Lake was threatened by spruce budworm. This wood supply, located in the Abitibi Management Unit, consisted of approximately 40% balsam, which had suffered 3 to 4 years of moderate to heavy feeding damage. The competition between man and the budworm for a forest resource, so long a reality in Atlantic Canada, had finally become a reality in Ontario. Protection spraying was carried out over 10,000 ha in 1979 to preserve this wood supply, but it became immediately apparent that a policy was needed to define the conditions under which future protection spraying of commercial forests would be conducted.

The Policy

A Policy and Procedure for Budworm Spraying in Ontario[2] was developed in 1979 by a task force made up of provincial and federal representatives. The policy established that OMNR may conduct spraying programs in Crown and Agreement forests, and forests covered by the Woodlands Improvement Act for the following purposes:

1. Suppression of epicentres
2. Containment of outbreaks or developing outbreaks
3. Protection of high value or commercially operable forest areas

Because the current outbreak is so extensive, the objectives of suppression and containment in Ontario are not feasible; however, they will likely be of use in the future. Given the nature of the present outbreak, protection spraying of high value or commercial forests is the only reason for spraying in Ontario.

There are three categories of high value forests:

1. <u>Investment protection</u>
   - seed orchards, Seed Production Areas (SPAs)
   - spruce regeneration -- regeneration that meets the standards of the Ontario Stocking Standards, or the ground rules of the Forest Management Agreements (FMAs)
   - tree nurseries
   - research areas
2. <u>Aesthetic value</u>
   - provincial parks
   - official park reserves
   - unstructured Crown land (canoe routes)
3. <u>Ecological value</u>
   - unique forest areas--gene pool value
   - demonstration spruce/fir forests
   - fish or wildlife habitat

The current budworm spraying program in Ontario includes many of these high value forests--seed orchards, SPAs, spruce regeneration, nurseries, parks, and wildlife habitat--all intended to preserve the integrity and resource value of these areas. There is, however, one major problem, and that is the spraying of spruce regeneration. We are reasonably confident that spruce regeneration will be able to survive the current outbreak,

[2]Spruce Budworm Spraying in Ontario, Ministry of Natural Resources. 1979.

but we do not know what effect the loss of 25%, or 50%, or 75% of the current year's needles has on the volume increment of spruce regeneration. Studies are needed to determine the effect of various levels of defoliation by budworm on annual increment of spruce. Having determined this, OMNR will then have to define how much annual increment can be lost before this loss becomes unacceptable--in other words, define a loss or damage threshold, beyond which protection spraying should be undertaken. Without this, there is a very real danger that protection spraying of spruce regeneration could become extensive without any economic justification.

The other main type of forest that qualifies for protection spraying is commercially operable forest. In order to qualify for protection the commercial forest must satisfy the following selection criteria.

Selection Criteria

1. Area must be scheduled for harvest within the 10-year operating plan, or projection thereof.
2. Balsam and spruce component must be essential to the wood supply for the mill.
3. Combined balsam and spruce must exceed 40% of the merchantable stand volume or value.
4. There must be no alternative short-term wood supply for the mill.

If a forest area qualifies for protection, then spraying can be initiated, subject to the following constraints, which are intended to limit both the extent and the duration of spraying in any one geographic area.

Constraints

1. Construction of access roads within the spray area must be initiated within 1 year and completed within 3 years of the start of spraying.
2. The company must commit itself in writing to complete harvesting of the sprayed area within 5 years of the start of spraying.
3. Spraying may be conducted in these forests for a maximum of 3 years in the 5-year protection period, if required.
4. Budworm larval populations in the spray area must be assessed in the spring to establish whether the populations are high enough to cause serious damage. If not, spraying in all or part of the area may be cancelled.
5. Conduct an annual review of the program to determine the necessity for and extent of next year's program.

This approach, then, is one that combines short-term protection spraying with directed or accelerated harvest. OMNR is committed to protect areas which are seriously threatened by the budworm, provided that the industry agrees to modify its harvesting plans to remove this high risk wood within 5 years. It is an approach that requires a good information base on budworm populations and forest damage, as well as a willingness to modify plans for extraction.

Implementation of Policy/Procedure—Commercial Forests

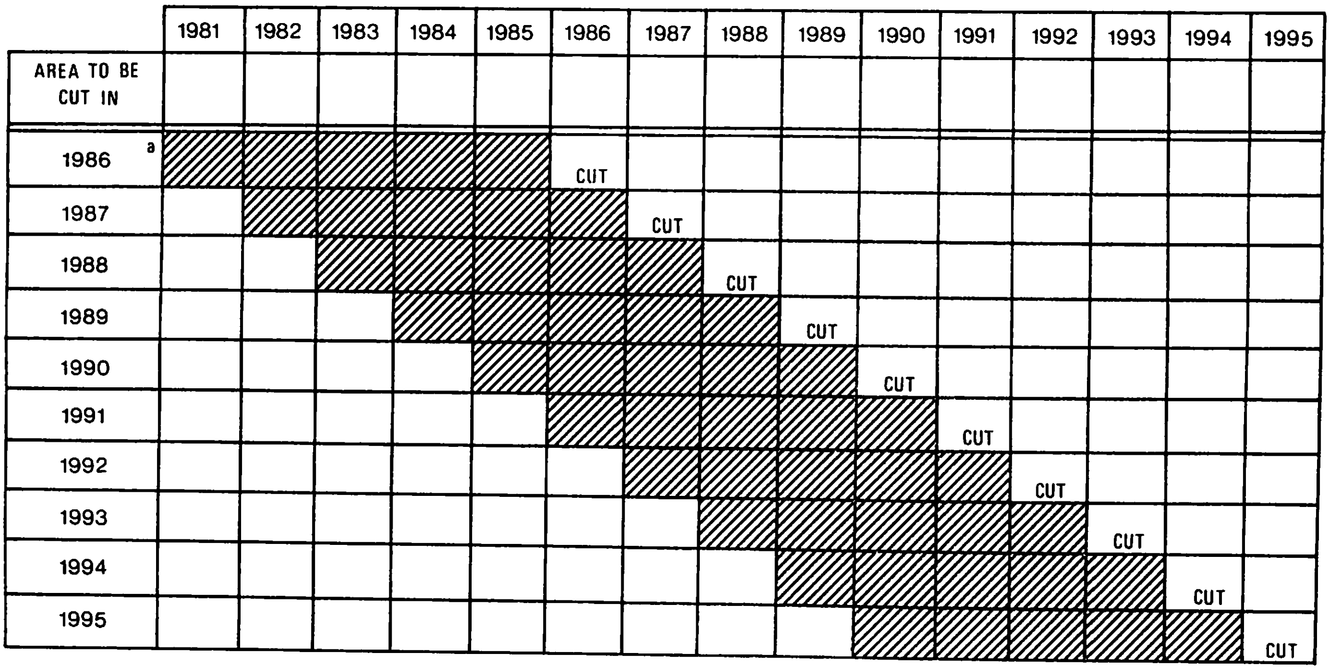
OMNR's budworm spraying policy for commercial forests has been implemented in two management units: Abitibi in Kirkland Lake District and Pitopiko in Hearst District. The policy was issued in late 1979, *after* the operating plan for Abitibi had been developed, and it has been difficult to revise that plan to satisfy the policy completely. Nevertheless, spraying has been carried out twice in this unit since the policy was introduced and it has succeeded in stabilizing and improving the condition of the trees, so much so that, in 1980, an excellent white spruce cone crop was produced in the protected area. However, because of declining sales and mill operations, it may be very difficult to complete the harvesting of the protected area within the 5-year period.

In Pitopiko, however, the operating plan was developed with the policy in mind and this has led to a harvesting schedule which complies with the policy and allows for effective protection spraying.

Figure 1 is a guide as to how spraying and harvesting can be planned in accordance with the policy.

Note:

1. Years of spraying and harvesting.
2. 5-year protection period: e.g., area to be cut in 1986 can be protected from 1981 to 1985, maximum of 3 sprays.
3. Areas to be cut are selected so that most heavily damaged areas are cut first.
4. Cumulative buildup of spray area for 5 years (1981 to 1985), then a roll-over of areas beginning in 1986.



[a] High-risk areas (based on accumulated damage) should be harvested first.

Figure 1. Spruce budworm spraying policy (TM 13-04): guide for spraying and harvesting (shaded area indicates five-year protection period: maximum of three sprays).

AREA TO BE SPRAYED IN / AREA TO BE CUT IN	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1985	865				CUT								
1986	578					CUT							
1987		582					CUT						
1988			661					CUT					
1989				596					CUT				
1990					269					CUT			
1991						341					CUT		
1992							442					CUT	
1993								318					CUT
1994									371				

Figure 2. Guide for spraying and harvesting - Pitopiko Management Unit.

Figure 2 shows the actual spraying-harvesting schedule in the Pitopiko Management Unit.

Note:

1. Spraying began in 1982, covering the areas scheduled for harvest in 1985 and 1986: 865 ha and 578 ha.
2. In 1983, the cut for 1987 (582 ha) will be added.
3. Annual additions until 1985, when the maximum 5 years of harvesting will be protected: 3,282 ha.
4. In 1986, area 1 will be dropped from protection, and the 1990 harvest will be added.
5. Thus spraying may continue in this management unit until 1994, if required, but no one area will be sprayed more than three times, and the size of the spray area will never exceed five years of harvesting: ca. 3,300 ha.

This approach is not without problems, but I believe it represents a good starting point for industry and government to develop cooperatively an approach whereby short-term protection spraying can be used intelligently to preserve an essential wood supply until it can be harvested. For it to work effectively, requires planning of harvesting and road construction *before* the budworm has inflicted widespread serious damage in the operating area. Waiting until the budworm has caused moderate-to-severe feeding damage for several years over a large area seriously reduces flexibility in harvesting and may require larger scale protection spraying programs than are authorized under the policy. One of the most serious obstacles with the policy is the commitment to harvest within five years. With the fluctuating market conditions that are so common, it is very difficult for an industry to commit to harvest a certain area five years in the future, not knowing what market conditions will prevail then. Effective implementation of the policy will also require up-to-date, stand-specific information on budworm populations and accumulated forest damage. Considerable progress has been made by the Ontario Centre for Remote Sensing in developing a photographic system for classifying budworm damage. In summary, the policy is a good starting point and if difficulties do arise in implementing it in an operating area, then we should strive to modify the policy so that it can achieve the desired objectives, and yet remain practicable.

APPROACHES TO THE SPRUCE BUDWORM PROBLEM IN OTHER PROVINCES

Moderator: C.J. Sanders

APPROACHES TO THE SPRUCE BUDWORM PROBLEM IN NOVA SCOTIA AND NEW BRUNSWICK

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Abstract.--*The softwood supply to mills in eastern Nova Scotia and New Brunswick is compared under the respective situations of no protection, and protection, from spruce budworm. Uncontrolled budworm-caused mortality renders management of the resource impossible. The harvest made by budworm must be controlled, or the harvest taken by man reduced; otherwise, the forest will be overexploited.*

Résumé.--*L'approvisionnement des usines de pâtes et papiers de l'est de la Nouvelle-Écosse et du Nouveau-Brunswick en bois de résineux fait l'objet d'une comparaison entre ce qui se passe lorsque les forêts sont protégées contre la tordeuse des bourgeons de l'épinette et ce qui se produit lorsque aucun moyen de lutte n'est pris. Dans ce dernier cas, la gestion de la ressource forestière devient impossible. Pour éviter que les forêts ne soient surexploitées, il est nécessaire soit de limiter les dommages causés par la tordeuse, soit de réduire la coupe.*

It is really very simple to summarize provincial approaches to the budworm problem, and it is also very dangerous. The context of the problem is far too variable for simple explanations. The New Brunswick and Nova Scotia budworm stories involve such a complexity of indicators, such a complexity of decisions, so many players, and so many perspectives it simply is not possible to characterize either situation in a few words. On the other hand, both situations have been so badly, and so persistently, misrepresented in the media that some summary statement is needed. The following is an attempt to provide a thumbnail sketch of the *forest management* implications in two very complex situations. The comments here deal only with the relationship of protection against budworm to forest management in the two provinces.

The "budworm problem" is in reality a problem of controlling forest dynamics to maintain the supply of wood, wildlife habitat, and recreation. The issue is one of who controls the timing and amount of the harvests made from the forest, the budworm or man. Where there is no competition for the use of the forest, i.e., where wood supply, wildlife habitat and recreation are abundant, there is no problem. Both man and budworm can use the forest without depleting it. Where competition does exist, i.e., where the sum of the harvests by the budworm and by man limits the sustainability of the use by man, there can be a monumental problem. This is particularly serious in that haphazard forest destruction by the budworm renders futile any planned management of the forest by man. The size of the problem depends on the degree of competition.

When man and budworm compete for the right to choose the amount and location of the harvests that ultimately control forest development, the result is not the same in all jurisdictions. Even if the budworm biology were the same from place to place, the degree of competition between the insect and man is not the same from place to place, and therefore the problems are different. Since the problems are not the same, the solutions, or approaches to solutions, adopted by various jurisdictions need not be the same. There is no room for--and indeed no sense in--arguing along the lines of "because they did it". No jurisdiction should protect its forests from budworm because New Brunswick does. Nor should any jurisdiction not protect its forests from budworm because Nova Scotia doesn't. Each jurisdiction must choose a line of action which is appropriate to its own situation and, having made that choice, it must live with it. When the choice is made on grounds other than forest management a jurisdiction will have to adjust its forest use patterns with respect to wood, wildlife, and recreation to suit the consequent realities.

There is a wide range of possible reactions to a spruce budworm infestation. At one end of the scale where there is no wood supply problem, or where the wood supply problem could be addressed by transferring wood from other locations, the appropriate action is no action. Where there is no real problem in terms of total wood supply, but the budworm interferes with the scheduling of the use of the forest by man, some limited action may be appropriate. Where a wood supply problem exists, rising intensities of action are appropriate, with the actual intensities employed being related to the nature of the wood supply problem. Clearly, there are no absolutes in this matter, and each problem must be viewed in its specific context.

Nova Scotia

Budworm has been an influence in the forests of eastern Nova Scotia in the past, but the crunch came with rising insect populations in 1969 on the mainland and in 1973 on Cape Breton Island. The problem was concentrated in the seven eastern counties of Nova Scotia, particularly on Cape Breton Island. The major user of the softwood forest in this area was Nova Scotia Forest Industries Ltd. This company had a well planned intensive management program built around spacing of natural regeneration with limited planting. Based on the early availability of wood from the new forest that was being created by silviculture, Nova Scotia Forest Industries had accelerated its harvest of the old forest. The old forest was being harvested at a rate that would remove the last of it just as the new forest became available. This accelerated harvesting (often called the allowable cut effect) was based on the presumptions that there would be a continuity in availability of wood from the old forest, and that wood from the spacing and planting activities would become available exactly on schedule as the old forest was eliminated (Reed 1978).

A comparison of the actual harvest and the sustainable harvest levels for the Cape Breton Region, Eastern Region, and Nova Scotia as a whole for the period 1970 to 1975 just prior to the budworm outbreak shows over-harvesting (Fig. 1). Softwood harvests at that time were running at 125 percent of the sustainable level in the Cape Breton Region, 170 percent of the sustainable level in the Eastern Region and 120 percent of the sustainable level for Nova Scotia over all. Hardwood production was substantially below the sustainable level. The key point here is that before the budworm reached epidemic levels the harvest of softwoods by man exceeded the basic allowable level without intensive management.

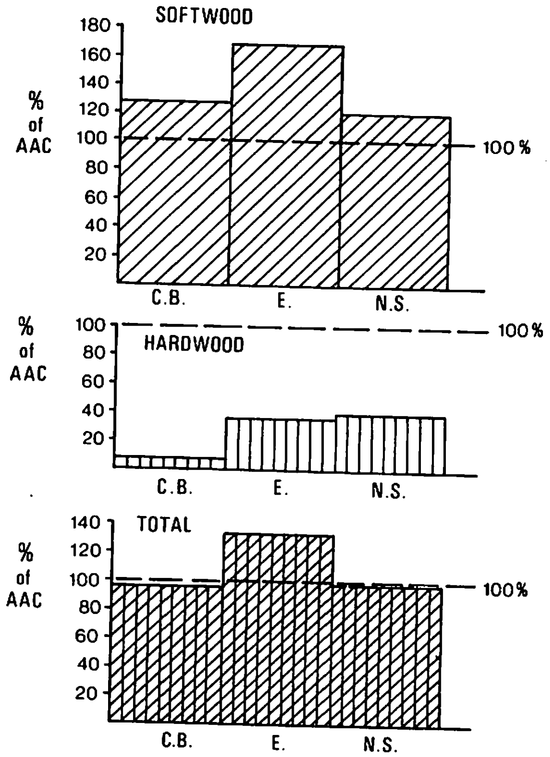

Figure 1. Actual harvest of softwoods and hardwoods compared with the sustainable level (AAC = allowable annual cut) for Cape Breton Region (C.B.), Eastern Region (E) and Nova Scotia as a whole (N.S.). The data are averages for the period 1970-1975 immediately prior to the budworm outbreak. Adapted from Anon. (1977).

The Nova Scotia Department of Lands and Forests published an analysis of the wood supply on Cape Breton Island in 1977. The projected wood supply from 1977 onwards for Cape Breton Island forests under management showed sustainability (Fig. 2). The then current softwood harvest levels, which were above the sustainable level without management, would result in slight over-harvesting in the first three decades but would thereafter be in balance. The projected wood supply for Cape Breton Island from 1977 onwards assuming a 25 percent loss of growing stock as a result of budworm-caused mortality is illustrated in Figure 3. In this situation, the maintenance of current softwood harvest levels is not possible beyond the first decade, and the wood supply problem becomes worse over time. In theory, it would be possible to maintain the current softwood mill capacity by converting a portion of that capacity to hardwood use. To do this would necessitate total displacement of all existing hardwood industry and would involve the assumption that the basically mature hardwood forests could sustain that harvest level, and that they would not fall prey to pests. The projected wood supply for Cape Breton Island from 1977 onwards assuming a 50 percent loss of growing stock to budworm-caused mortality is shown in Figure 4. With such losses it is not possible to maintain current softwood harvest levels beyond the first decade and the available wood services only one-half the existing mill capacity in the third decade. Even with a total conversion to hardwood it would not be possible to maintain the existing softwood mill capacity. The projected wood supply from 1977 onwards assuming a 75 percent loss of growing stock is illustrated in Figure 5. There is insufficient wood to sustain production at existing softwood mill capacity beyond the first decade and the available softwood would meet less than one-third of existing mill needs in the second decade.

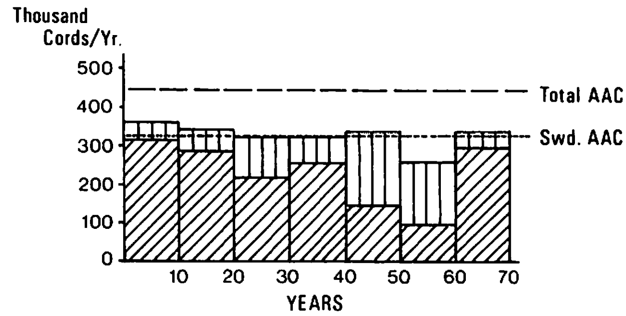

Figure 3. The projected wood supply from Cape Breton assuming a 25% loss of the 1977 growing stock to budworm-caused mortality. Diagonal hatching = softwoods, vertical hatching = hardwoods, and SWD AAC = softwood annual allowable cut. Reproduced from Anon. (1977).

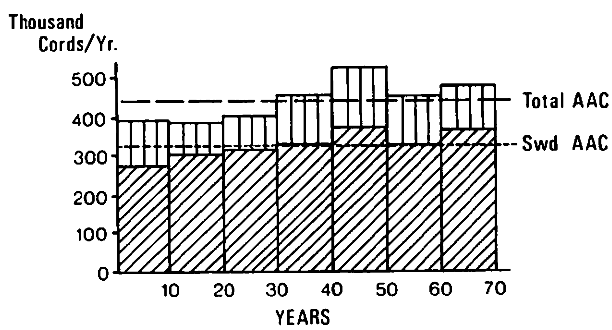

Figure 2. The projected wood supply from Cape Breton under normal managed conditions as forecast by the Nova Scotia Department of Lands and Forests. Diagonal hatching = softwoods, vertical hatching = hardwoods. Reproduced from Anon. (1977).

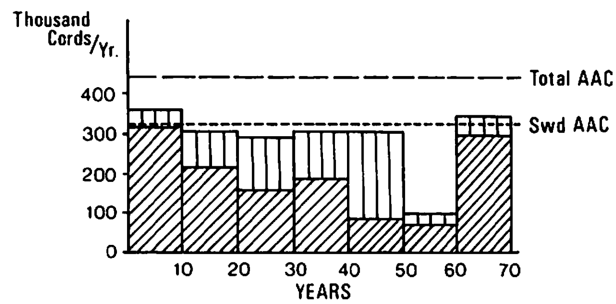

Figure 4. The projected wood supply from Cape Breton assuming a 50% loss of the 1977 growing stock to budworm-caused mortality. Diagonal hatching = softwoods, vertical hatching = hardwoods and SWD AAC = softwood annual allowable cut. Reproduced from Anon. (1977).

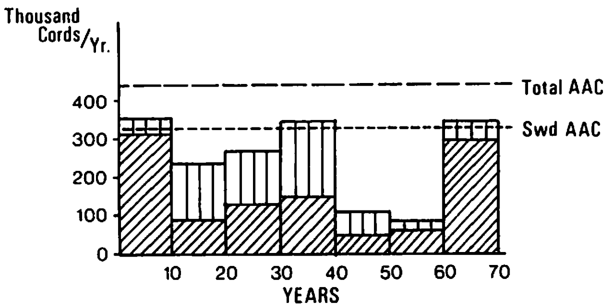

Figure 5. The projected wood supply from Cape Breton assuming a 75% loss of the 1977 growing stock to budworm-caused mortality. Diagonal hatching = softwood, vertical hatching = hardwood and SWD AAC = softwood allowable annual cut. Reproduced from Anon. (1977).

No protection was extended to the forests of Cape Breton Island during the outbreak of the 1970s and 1980s and losses did occur (Ostaff 1982). A comparison of the losses forecast in 1978 with the actual measured loss in 1981 was given by van Raalte (1981). Losses were forecasted to total 80 percent of the Highlands growing stock and about half that in the Lowlands by 1981. In actuality, 78 percent of the Highland stock was dead by the end of 1981. The accuracy of such forecasts is not surprising. Of the 200 million ha of budworm-infested forest in northeastern North American in recent years, less than 10 percent has been protected, and consequently the greatest experience, by far, is with the accumulation of mortality in uncontrolled situations. Bailey (1982) has provided an analysis of losses for the combined Highlands and Lowlands of Cape Breton Island based on permanent sample plots used for inventory purposes by the Nova Scotia Department of Lands and Forests. His data are consistent with those of van Raalte, and show that the total losses of fir and white spruce for the four Cape Breton counties (Highlands and Lowlands combined), up to 1981, amounted to 53 percent of the fir and white spruce growing stock. Although the budworm outbreak on Cape Breton Island appears to be subsiding in 1982, the substantial experience elsewhere suggests that there will be continued mortality for at least another three years.

Taking the known mortality accumulated to 1981, it is clear that the wood supply situation on Cape Breton Island is at least as bad as that illustrated in Figure 4. That is, softwood production at mill capacity levels can only be maintained for the current decade, and beyond that time there will be insufficient softwood to maintain more than about 60 percent of the current existing softwood mill capacity without over-exploiting the forest.

The above analysis indicates a number of problems. First, it is clear that continuing the softwood harvest at current levels on Cape Breton Island amounts to over-exploitation, and is not sustainable. There will be sufficient softwood to maintain the current harvest rates for the first decade, but beyond that the options are either to reduce drastically the softwood mill capcity, or else dramatically over-exploit the forest. As mortality accumulates in the next few years the wood supply situation for Cape Breton Island will move closer to that illustrated in Figure 5, which indicates less than one third of the necessary softwood available beyond the current decade. The above analysis does not account for the fact that the loss of fir in a fir-spruce stand often reduces the total volume to a level such that the entire stand becomes inoperable. It may no longer be feasible to harvest the low residual spruce volume, and the budworm has in effect economically eliminated the entire stand. The analysis does not account for the disruption that took place with respect to the forest management program on Cape Breton Island. This program was one of the most advanced on Crown lands in Canada (Reed 1978), and a substantial portion of the accumulated spacing and plantation area has been destroyed by the budworm while the surviving silviculturally treated areas suffered severe setbacks in growth. Silvicultural effort was withheld during the outbreak, since it was not possible to protect these high value areas. The analysis does not account for the disruption of normal harvest scheduling and the associated relocation of men and equipment in order to adapt to the management pattern forced on the forest, and on man, by the budworm.

The province of Nova Scotia and Nova Scotia Forest Industries made an effort to salvage a portion of the budworm-killed forest. The volumes involved were small in comparison with the total losses and there have been major difficulties in maintaining quality of the salvaged material. Rot is seriously degrading the wood for pulping purposes.

The silvicultural program of Nova Scotia Forest Industries and the Nova Scotia Department of Lands and Forests on Cape Breton Island must now begin again from scratch. Since it takes a minimum of 30 to 50 years to grow new plantations, assuming that the plantations are weeded and protected from further budworm attacks and other insects and diseases, it is clear that the wood supply problem illustrated in Figures 4 and 5 cannot be corrected by silviculture. To be cured by silviculture, this would require that the silvicultural program have started 20 to 30 years ago and been protected through the budworm outbreak. The difficulty is one of timing, in that the wood supply problem occurs in 10 years, and it takes 40 to 50 years to grow new wood.

In summary, it is possible to maintain the current softwood mill capacity on Cape Breton Island in the short run, but that level of softwood harvest is not sustainable beyond the present decade. Neither is it possible to sustain current softwood mill capacity by switching to hardwoods. In the longer run, the current softwood mill capacity is not sustainable even with the most prodigious silvicultural effort. If softwood mill capacity is not reduced in the current decade the eastern Nova Scotia softwood forests will be over-exploited by 30 to 60 percent in the second decade, and by 40 to 60 percent in the third decade.

New Brunswick

The budworm outbreak in New Brunswick began in the north and central parts of the province in the early 1950s. The outbreak collapsed where it was intensively sprayed in the northern third of the province in 1958, but persisted in the central lowlands where it was also sprayed. In the 1970s budworm populations increased over the entire province including the southern third which had been unaffected until then. This outbreak occurred over some 150,000,000 ha in northeastern North America.

The problems posed by budworm relative to continuity of the wood supply in New Brunswick were similar to those in Cape Breton Island. The actual history from 1952, when protective spraying began, to 1976, and a 50-year projection from 1976 onwards assuming the current protection policy, are illustrated in Figure 6. Over the period 1952-1976 the annual consumption of softwood in New Brunswick doubled, as new mills were built and older ones expanded, and the full capacity of the forest to sustain a harvest is now being used by man. The pattern of insect, forest and industrial development that might have ensued had no protective action been taken in New Brunswick is illustrated in Figure 7. The forecast of probable losses in terms of growing stock, and the behavior of the budworm, is qualitatively similar to what actually occurred in Nova Scotia and in the other areas in eastern North America where no protection was undertaken. Had this circumstance prevailed it would not have been possible to sustain the mill capacity existing in 1952 without over-exploiting the forest. The pattern of forest and industrial development which might now ensue with cessation of protection in New Brunswick is illustrated in Figure 8. Again the figure carries a budworm and forest mortality pattern similar to that actually experienced in Nova Scotia and elsewhere. As in the Cape Breton Island case it would be possible to maintain the existing mill capacity for some period of time, but only at the expense of substantial over-exploitation of the forest.

The wood supply situation in New Brunswick has virtually no flexibility (Baskerville 1982). The current harvest levels can be sustained provided that the current management inputs, which are proportionately the highest in the country, are also maintained. There is, however, no room for further industrial expansion until the benefits of the intensive management program become available in some 30 years' time. In the interim, it is crucial that the existing softwood growing stock be maintained as an available wood supply. Put simply, every tree that will be harvested in the next 30 to 40 years in New Brunswick is already growing in the forest today. Every one of those trees is already committed to a processing plant sometime in the next 30 to 40 years. Any losses of that growing stock resulting from budworm-caused mortality will be a direct reduction in the wood supply available to processing plants over the next four decades.

Following a trial protection program in 1952, New Brunswick adopted a policy of protecting its softwood forest from unscheduled harvest by the spruce budworm. This policy has evolved, but its essential character has been maintained for 30 years. The policy uses insecticides to limit the amount of defoliation of trees by the budworm in order to prevent budworm-caused mortality. The areas treated in each annual program are those where the risk of mortality is highest. These are annually redefined by mapping defoliation in the previous year, historic defoliation, and the distribution of budworm egg masses which indicates the probability of damaging budworm populations for the following year. Each year, maps of past defoliation and egg distribution are combined to

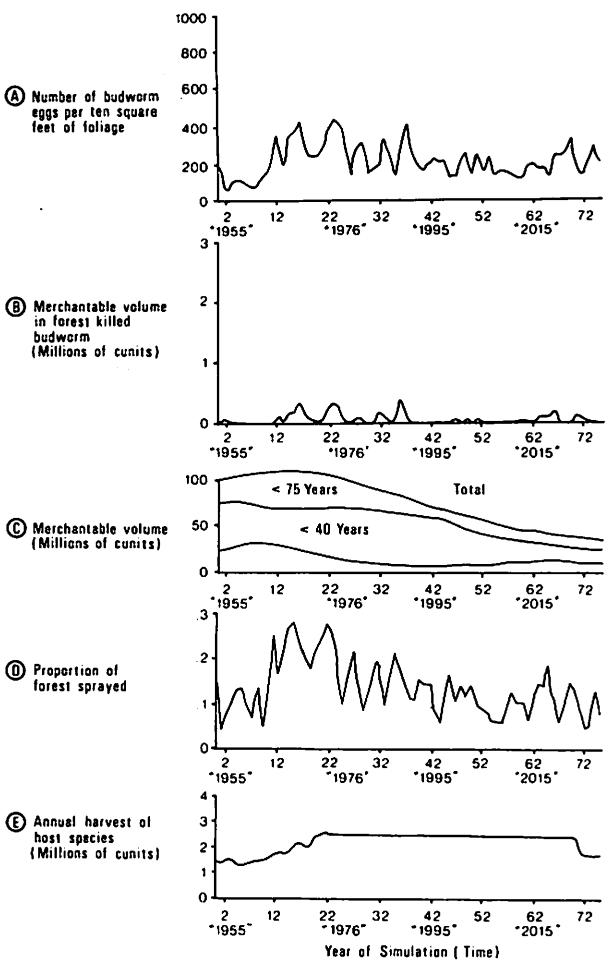

Figure 6. A summary of budworm and forest development in New Brunswick from 1952 to 1976 with a projection based on maintenance of the protection policy. The figure prints the provincial picture but there were dramatic regional variations. A - number of budworm eggs, B - merchantable volume killed, C - total growing stock, D - proportion of the forest sprayed, E - industrial consumptions. Adapted from Baskerville (1976).

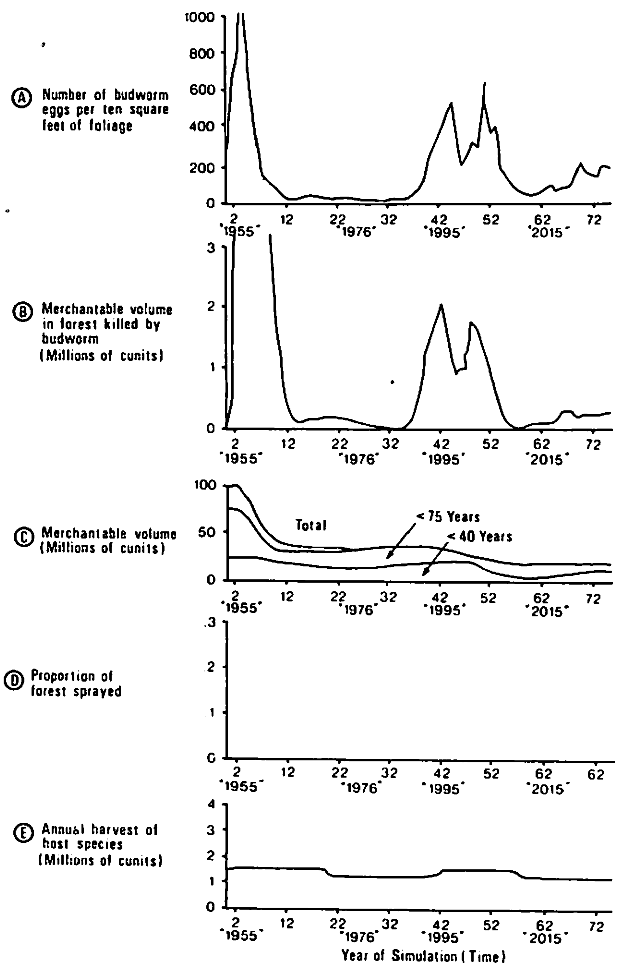

Figure 7. A forecast of budworm and forest development in New Brunswick from 1952 onwards, had no protective action been taken. A - number of budworm eggs, B - merchantable volume killed, C - total growing stock, D - proportion of forest sprayed, E - industrial consumption. The forecast is based on a simulation of budworm/forest dynamics. Adapted from Baskerville (1976).

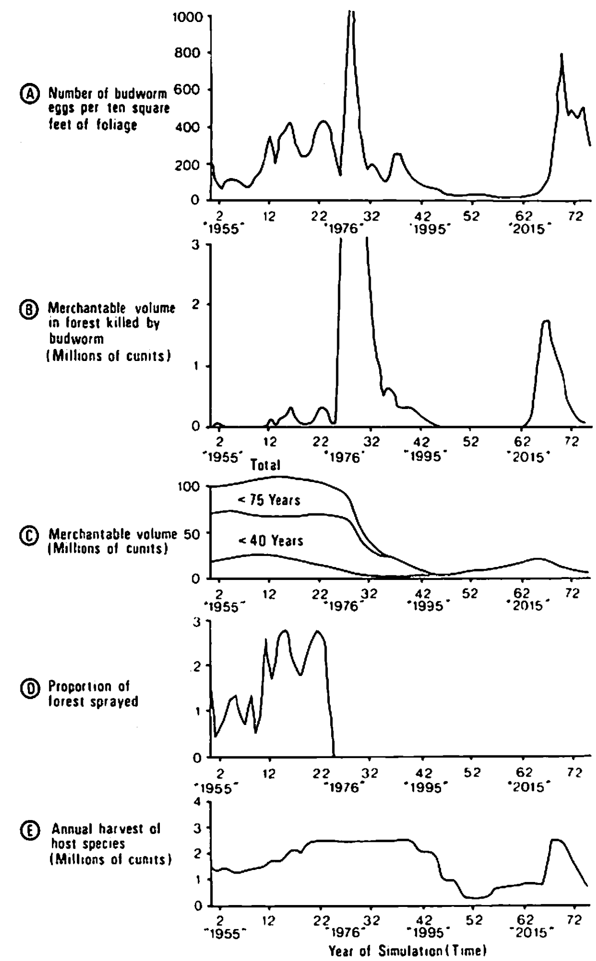

Figure 8. A forecast of budworm and forest development in New Brunswick from 1952 onwards with full protection as occurred from 1952 to 1976 but no protection for 1976 onwards. A - number of budworm eggs, B - merchantable volume killed, C - total growing stock, D - proportion of the forest sprayed, E - industrial consumption. The forecast is based on a simulation of budworm/ forest dynamics. Adapted from Baskerville (1976).

yield a hazard map indicating the portions of the forest where the risk of mortality in the following year is greatest. This hazard map is then overlaid on a forest cover map showing the location of the susceptible parts of the forest. The actual spray program is then designed to target the susceptible parts of the forest where there is risk of mortality. The proportion of the total forest treated in any one year has ranged from 0% in 1959 to a high of 68% in 1976. Until the early 1970s the proportion of the forest sprayed was about 17 percent. With the widespread northeastern North American outbreak in the 1970s the infestation spread to the entire province, and the proportion of the forest sprayed has risen to an average of about 30 percent in the late 1970s and 1980s. Analyses of the actual spray programs have shown that there is a 10 to 20 percent chance of a particular location in the forest being treated in two successive years, and a 5 to 10 percent chance of treatment occurring in three years in a row (Eidt and Fisher 1982).

The protection program has worked. The amount and location of budworm-caused mortality in the forest has been largely controlled so that planned management scheduling of the harvest could be maintained. In areas where protection was withdrawn, such as within 1.6 km of habitation, budworm-caused mortality has been substantial and has resulted in major disruption of the harvesting plans in order to 'chase' the budworm.

There has been much argument with respect to the issue of eradicating the budworm or suppressing the population to normal endemic levels. These goals are patently unattainable. The area of forest under the protection program in New Brunswick accounts for about 5 percent of the total infestation area in northeastern North America, and it is unreasonable to think that a pest that disperses as rapidly, and as far, as the budworm could be locally eradicated on such a small portion of its range. Suppression of insect populations was identified as unrealistic by entomologists at the beginning of the program in 1952 (Balch 1952). Each adult female lays some 200 eggs from which only two need survive to adulthood to maintain the population fully. With literally millions of insects per hectare there is no possibility of an insecticide spray killing in excess of 99.5 percent of the population which would be necessary to suppress an outbreak. The New Brunswick program has aimed, and does aim, at keeping stands alive so that a normal pattern of forest management can be maintained.

There has also been considerable argument that the protection program has generated a continuous outbreak. It can be argued that there have been at least three distinct outbreaks in New Brunswick over the past 30 years. It is likely that one of these would not have occurred had the first budworm outbreak been allowed to destroy the forest in the early 1950s. The fact that the New Brunswick forest has been maintained at a full growing stock level has meant that budworm populations have more or less continuously had suitable habitat available to them. The protection program may not have caused the continuous outbreak but it certainly permitted it.

There have been both gains and losses with respect to the protection against budworm in New Brunswick. The gains have been expansion of the forest-based industry to the level of sustainable production of the forest, and freedom of decision to introduce this nation's most comprehensive forest management program on Crown land. Neither of these would have been possible if budworm had been allowed to harvest the forest over the past 30 years in its own haphazard manner. Despite the overall success of the program in restricting mortality, there have been losses in the protection zone where some patches were too small to protect economically. There have been substantial losses in stands along streams and around lakes inside the protection zone where spraying is restricted. The most substantial losses have been in the area within 1.6 km of habitation which was not protected from 1976 to 1980 and received only limited protection in 1981 and 1982 (Clowater and Andrews 1981). Major difficulties posed by the losses (in addition to the actual mortality) are the fact that the losses disrupt normal management patterns, and that partial loss in damaged stands has often rendered the remainder of the stand inoperable for economic reasons.

Some Lessons

Care must be taken in comparing these two situations, but several points can be drawn from each case history of forest management. The events in Nova Scotia in the past six years have verified the accuracy of forecasts of loss. Losses of the scale incurred on Cape Breton Island have rendered current softwood harvest levels there non-sustainable. Further, the damage has totally disrupted the geographic pattern of management in respect to harvesting and silviculture. By any definition, the softwood forest on Cape Breton Island is not currently under management. Major silvicultural efforts can provide a better long-term future on Cape Breton Island, provided that silviculturally treated stands are protected until they are harvestable. However, no amount of silvicultural effort can bridge the gap between removal of the old forest at the current rate, and the availability of the new forest.

The protection program in New Brunswick has demonstrated that it is possible to limit budworm-caused mortality. The protection program in new Brunswick has made it possible for man to execute the annual harvest in locations of his choice. The large contiguous areas of susceptible forest that existed in the early 1950s are no more. The forest in the province has been dramatically changed in geographic pattern, and now consists of a highly variable pattern with the susceptible parts of the forest intermingled with non-susceptible forest and with recent cutovers supporting developing regeneration. Protection has permitted the systematic introduction of major planting and spacing programs without the threat of losing these high value stands before they reach harvestable age. The protection program in New Brunswick has permitted the implementation of a comprehensive management scheme that extends forest management to every hectare of Crown land in the province, the only province in Canada where this is true.

The information presented here has been widely available, and is not new. It would be comforting if it were possible to say that the two forest management futures described above had been consciously chosen by the two societies involved. Unfortunately, there is little evidence in either case that there is any public understanding of the role of protection in forest management. In simplest terms, forest management consists of scheduling the future harvests on a stand-by-stand basis, distributing the products from each stand as the harvest is made, carrying out silvicultural renewal effort on each cutover as required and protecting the forest. These four tools of management are used in an integrated manner. A stand may be scheduled for harvesting in 1990, to yield 300 m^3 per ha of pulpwood and 100 m^3 per ha of sawlogs, scarified in 1991, planted in 1992, treated with herbicides in 1995 and 1997 as needed, and scheduled for harvesting of 600 m^3 per ha in the year 2034. None of this is possible unless the stand is protected until 1990 so that the scheduled harvest volumes are available then, and the new plantation is similarly protected as needed throughout its life so that the forecast volume is available on schedule. To manage a forest it is absolutely essential that these four kinds of action be integrated.

Because trees take time to grow, the results of forest management are delayed. It is crucial that the public comprehend that no amount of silviculture can resolve a wood supply problem that occurs in the next 30 to 40 years, since no plantation established today can be available in that time frame. Similarly, there are delayed effects with respect to protective actions, and the absence thereof. Protection can be turned on or off at will, and while this does not immediately affect the forest resource base, it has major impact on the development of the resource over a period of decades. Similarly there are delayed effects on the use of the forest by man whether for wood, wildlife habitat or recreation. As with all decisions, forest management decisions are choices between alternative futures. The real question, then, is: Does the public have a reasonable comprehension of the alternative futures it can choose for its forest?

The decisions with respect to forest protection in both Nova Scotia and New Brunswick were taken by governments representing people. One must conclude that both were "right" decisions in that they appear to have been taken on behalf of a majority of the people. It is doubtful that either society, or either government, comprehends the meaning of the protection decision with respect to management of the forest. One government chose not to protect the forest and thereby rendered forest management problematical, if not impossible. One government chose to protect the forest and, while this has facilitated orderly management of the forest, the means of protection has become a subject of controversy. Without arguing the rightness or wrongness of either choice, one has to question the comprehension of the choice that was being made. Forest management decisions last a long time and take a long time to recover from. Protection has become separated from management in the decision process and while forest management is not the only basis for choice, it is a necessary context for protection. If there is a lesson from these two cases it is that much better public information and education are needed with respect to forest management so that knowledgeable choices can be made reflecting the realities of forest management as well as the other inevitable considerations.

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THE SPRUCE BUDWORM IN QUEBEC: THE SITUATION TODAY[1]

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Abstract.--The spruce budworm outbreak began in 1967 in western Quebec. In 1975, it covered 35 million ha. In 1982, the infested area is estimated to be 18 million ha. To date, about 90 million m^3 of marketable wood have been killed by budworm in public and private forests. Insecticide sprayings were begun in 1970 to minimize budworm-caused mortality. Salvage programs were also initiated by forest industries and the Quebec government and more efforts are expected in forest management in the management units where the situation is most critical. The Ministère de l'Énergie et des Ressources du Québec is closely following developments in research.

Résumé.--L'infestation de la tordeuse des bourgeons de l'épinette a commencé dans l'ouest du Québec en 1967. En 1975, elle s'étendait sur une superficie de 35 millions d'hectares. En 1982, la superficie des régions infestées est évaluée à 18 millions d'hectares. Jusqu'à maintenant, environ 90 millions de mètres cubes de bois marchand situés sur des terres publiques et privées ont été détruits par la tordeuse. Les épandages d'insecticides ont commencé en 1970 afin de réduire les ravages causés par l'insecte. Les entreprises forestières et le gouvernement du Québec ont également entrepris des programmes de récupération, et d'autres efforts seront déployés au niveau de la gestion forestière dans les secteurs où la situation est la plus critique. Le Ministère de l'Énergie et des Ressources du Québec suit de très près les progrès de la recherche dans ce domaine.

Introduction

First of all, my sincere thanks to the organizers of this symposium for their kind invitation. It has been a genuine pleasure to follow your discussions over the past few days. Protection policy, inventory of damage and damage impact assessment, spraying programs, simulation models, ecological impact of spraying--these are the same issues we are talking about in Quebec. Unfortunately, time will not permit me to discuss our situation on all these fronts.

Rather, I shall attempt to point out the ways in which the situation in Quebec differs from that in Ontario. My text will be devoted to four subjects:

1. a short background of the outbreak development in Quebec
2. an assessment of the damage caused and its impact
3. the principal measures of control (spraying programs) and forest management
4. a few words on research being done on the budworm problem.

The Spruce Budworm Outbreak in Quebec

Figure 1 illustrates how the spruce budworm epidemic has spread in this province. The first epicentre was discovered in 1967 in Low, in western Quebec. The prevailing winds quickly carried the budworm from west to east. Two other epicentres were later discovered in eastern Quebec, one in Temiscouata (1970) and a second near Baie des Chaleurs

[1]Translated from the French by R. Clive Meredith; revised by Marcia Theriault and Germain Paré.

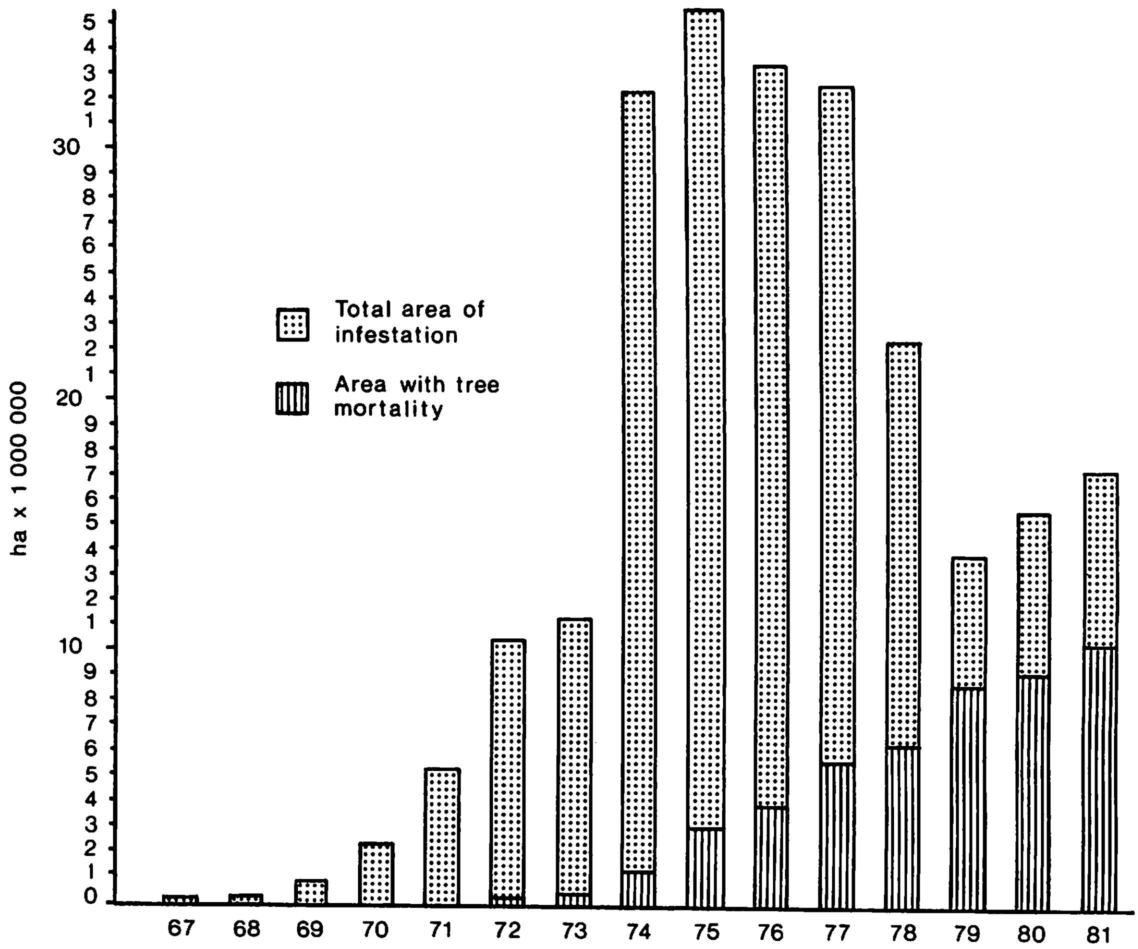

Figure 1. Areas infested by the spruce budworm in Quebec: 1967 to 1981.

(1972). These epicentres contributed to the spread of the outbreak. The year 1975 saw the peak: more than 35 million ha were affected. The outbreak then gradually regressed until 1979, although in 1980 a slightly larger area was infested. In 1982, some 18 million ha were infested, and the experts expect the outbreak to regress swiftly, and to end in 1986.

Mortality and Impact

Figure 1 also illustrates the spread of mortality in terms of area. Figure 2 shows the situation as it stood in 1981. The first trees to die were in the Outaouais region; these were noted in 1972. The number of trees killed increased steadily and, by 1981, they covered 10 million ha.

In terms of volume, Quebec's Ministère de l'Énergie et des Ressources has calculated that, on the accessible land of the public forest, there were dead balsam fir and white spruce for over 87 million m^3 in 1981. In private forests this figure was 2.6 million.

It is estimated that by 1986 this loss will be over some 150 million m^3 on public land. As a comparison, the 10-year forest inventory shows that, on the same territory, we find 813 million m^3 of marketable balsam fir and 132 million m^3 of marketable white spruce. The total marketable volume of conifers (balsam fir, spruces and jack pine) is about 2,714 million m^3. Still as a comparison, the annual harvest of conifers totals about 22 million m^3 (see Fig. 3). Losses by 1986 in private forests are estimated at 10.7 million m^3.

When these figures are seen in a provincial perspective, it is not easy to grasp from them the extent of the destruction. In Quebec, the public forest is subdivided into 44 management units, and these in turn are combined into nine administrative regions. It is in this regional perspective that the impact of the spruce budworm outbreak must be

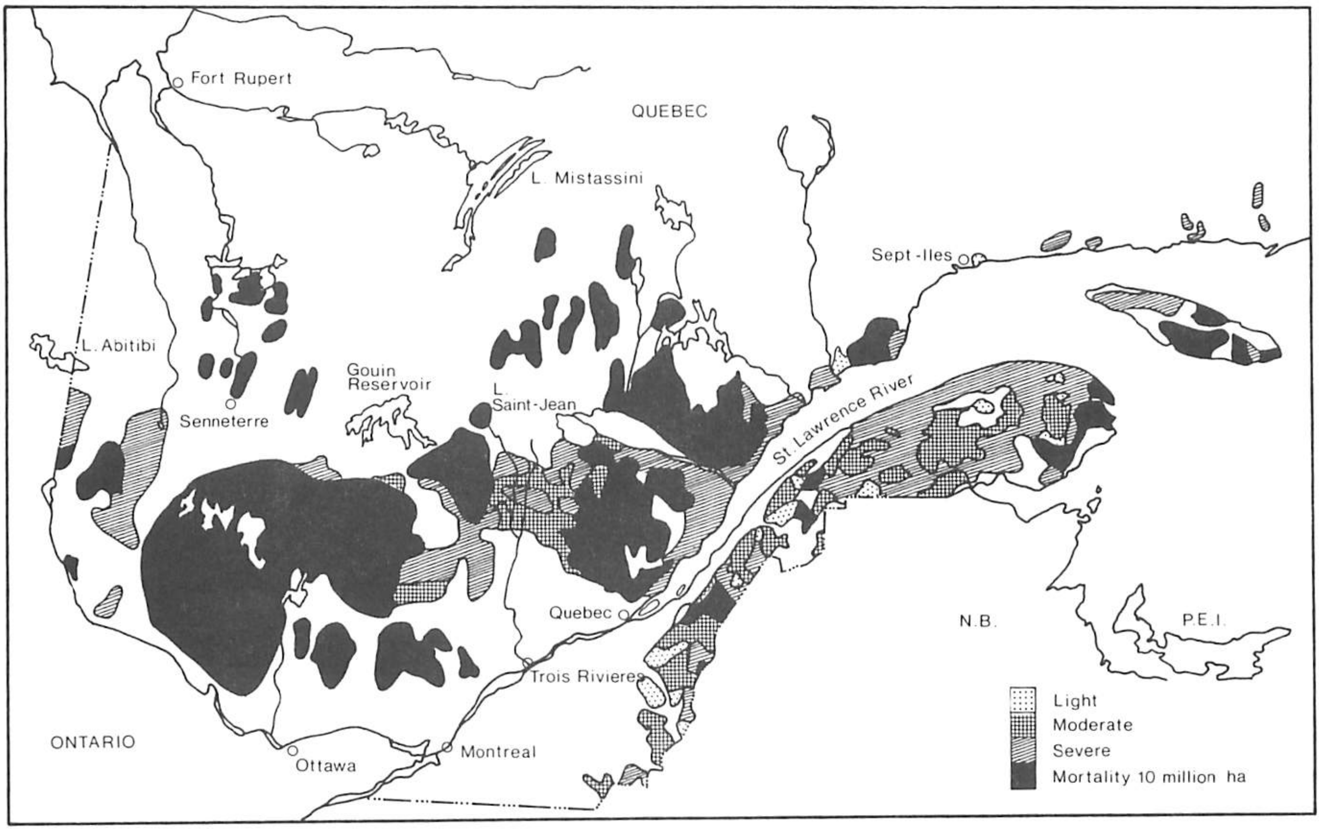

Figure 2. Infestation by the spruce budworm--Quebec, 1981.

situated. To give an example, in the Coulonge and Noire management unit (near where the epidemic first broke out), the results of a remeasuring of the permanent sampling plots set up in 1978 showed that the stock of balsam fir dropped by 83% and that of white spruce by 43%. In the neighboring (Basse-Gatineau) management unit, standing stock was reduced by 54% (fir) and 17% (white spruce).

To sum up, by killing the trees it does, the spruce budworm also reduces annual allowable cuts and leads to supply shortages in a number of management units. The situation is particularly serious in some of the management units in southern Quebec, where it is estimated that supply shortages will occur over such a short term (15 to 25 years) that even an increase in intensive management will not suffice to compensate.

But there is not just mortality. When defoliation occurs repeatedly over a number of years, there is a noticeable slowdown in growth, both in diameter and in height. Even though the trees survive, they yield less wood. There are a number of stands where,

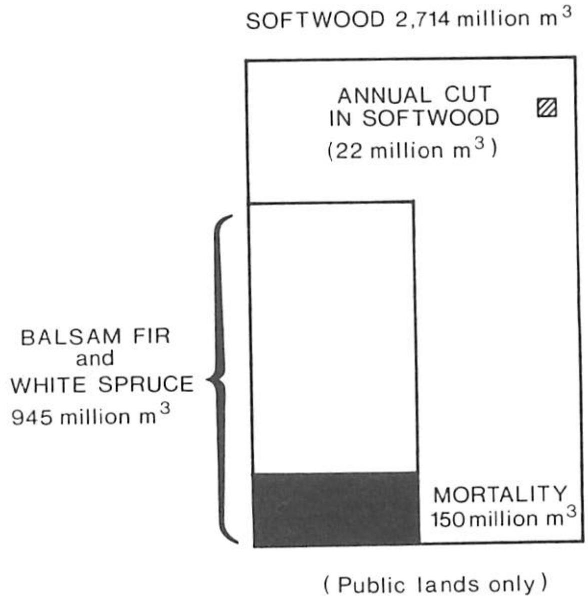

Figure 3. Annual harvest of conifers.

because a major proportion of the trees have died, the stands themselves are no longer economically operable. As a result, much more wood is lost than has died. Also among the budworm's victims are young stands, or regenerating stands. The losses here are minimal in volume now, but future repercussions will be considerable. A final side effect of the budworm infestation is an increase in the price of wood, brought about by shortages, increased transportation costs, etc.

Spraying and Forest Management Programs

In 1970, three years after the beginning of the outbreak, the government of Quebec decided to begin insecticide spraying. Table 1 shows how the spraying programs developed. Until 1976, spraying was done primarily in western Quebec. Since then, given the extent of the outbreak and the priorities established, it is restricted mainly to southern Quebec (the Gaspé region) where it has contained mortality.

In Quebec, the spraying policy is generally to take action after one year of severe attack, and to continue treatment until infestation is substantially reduced by such natural factors as climate and parasitism. The main objective of the treatments is to minimize the mortality caused by the insect. Selection of areas for treatment is based on the commitment of government wood to the forestry industry. In a few cases, spraying is done in zones where there is already a slight mortality (less than 25%); this is to keep down the mortality rate and in order to extend salvage operations over a greater number of years.

Spraying is done only on public land, primarily in southern Quebec. Most of the time, a chemical insecticide is used. In sensitive areas (near settled areas or bodies of water) *Bacillus thuringiensis (B.t.)* is used. Quebec has been using *B.t.* every year, on an experimental or an operational basis, since 1971.

Considering the gravity of the damage caused and anticipated, one important aspect of the budworm battle is salvage of wood which has been attacked. Some license holders have had their own recovery programs for a number of years now, and such programs are also enforced on some of the Crown land. Recently, with a view to increasing volumes saved and reducing the impact of mortality, an effort has been made to plan these salvage programs. The private forests have been given priority: they are not covered by the

Table 1. The spruce budworm in Quebec: development of infestation and of insecticide spraying.

Year	Area infested (ha)	Area treated (ha)	(%)
1969	809,370		
1970	1,428,110	11,635	0.5
1971	5,260,905	867,300	16.5
1972	10,400,404	759,254	7.3
1973	11,412,117	3,929,720	34.4
1974	32,212,926	2,563,508	8.0
1975	35,373,515	2,882,015	8.2
1976	33,149,367	3,649,647	11.0
1977	32,788,792	1,393,301	4.3
1978	22,554,219	1,294,160	5.7
1979	13,815,251	582,965	4.2
1980	15,477,213	188,511	1.2
1981	17,099,688	705,164	4.1
1982	17,915,579	1,156,249	6.5

spraying program and, for a private owner, budworm-related mortality can have a considerable impact. To give some idea of the scope of these programs, in 1982-1983 on public lands, the volume from salvage cuts amounted to 12.4 million m^3 (2.3 million m^3 of which were dead wood) representing 46% of all wood cut in these same forests (about 26.8 million m^3). Again in 1982-1983, salvage cuts on private land should yield 1.5 million m^3. To sum up, for the next few years salvage will lead to an increase in the relative proportion of private wood used to keep the mills going. The recovery program will be revised each year, depending on how the outbreak progresses.

More effort is also expected in forest management in the management units, where the situation is most critical. In reforestation, for instance, 19 million additional seedlings will be used in the public forests and 12.5 million in the private forests. Considerable changes are also expected in forest management, to avoid the appearance of vast fir stands. In order to plan forest management programs more effectively, the Ministère de l'Énergie et des Ressources is closely following developments in research.

Research

Never before has so much research been devoted to one insect. Given the scope of the problems caused by the budworm outbreaks, research specialists must push on: they must study possible solutions and become better acquainted with the phenomena involved. Briefly, in Quebec, research is continuing on epidemiology (the epicentre and 'abundance zone' theories); insecticides and spraying methods (including the use of *B.t.* which has already been the subject of major experiments); simulation models for the budworm-forest system (including Holling's) to study means of action, economic aspects of forest management dependent on the budworm, and other subjects.

Conclusion

Because of the nature of Quebec's forests, we shall doubtless always have the spruce budworm with us. The protection policy is intended solely to reduce the impact, so as to allow increased, more rational use of the forest resources, for the socio-economic development of Quebec.

REGIONAL IMPACT OF SPRUCE BUDWORM--
PAST, PRESENT AND FUTURE

Moderator: D.W. Schafer

IMPACT OF THE SPRUCE BUDWORM IN THE ALGONQUIN REGION--PAST AND PRESENT

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Abstract.--*Generally, spruce and balsam are commercially unimportant in the region. The budworm impact is basically in "high value areas" on other than the timber resource. Protection has been carried out over the years in these areas.*

Résumé.--*En général, l'épinette et le sapin baumier n'ont aucune importance commerciale dans la région. Les répercussions de la tordeuse s'exercent fondamentalement dans les secteurs de grande valeur, dont la ressource principale n'est pas le bois de sciage. C'est vers ces secteurs qu'on a orienté la protection au cours des ans.*

The spruces and balsam fir are not now nor have they ever been particularly important to the forest industry of this region, with two exceptions. One exception is the Beachburg/Douglas strain of white spruce which has constantly shown superior growth characteristics and is widely recognized, as indicated by the demand for the seed of this strain. The other is the white spruce found as scattered individuals in both tolerant hardwood and pine stands throughout the region. Though not particularly sought after, these trees, which are usually large and of good quality, enrich the mixture of species found in these working groups. They are usually harvested as encountered.

Basically, no pulpwood-type market has ever existed for spruce or balsam fir. More importantly, the predominant forest industry is based on a continuous supply of the high quality, high value tolerant hardwood and red and white pine sawtimber.

The spruce budworm can best be considered a nuisance and a frustration. It is a nuisance because of its impact on the aesthetics of the forest, because of the inconvenience produced for tourists and recreationists and because of the staff time required to service office and field visits to explain the pest and the problems it creates.

It is a frustration in terms of attempts to salvage damaged or vulnerable timber in the light of no markets, in terms of the problems of attempting to apply control measures within the patchwork of Crown/private ownership, and the problems and complications involved in attempting to generate an acceptable control program within the bounds of public concern for the environment and restrictions on the use of pesticides.

The budworm has come and gone on a somewhat irregular basis over the last 20 years. While the pest has been under continuous surveillance over that time by Environment Canada, the information provided has been little used because of the relative unimportance of balsam fir, particularly, and white spruce to the forest management program.

Some years ago there was some spraying in the Algonquin Park recreation corridor with good results. More recently a deer yard and provincial park were sprayed in the Parry Sound District, also with good success. The last spraying, however, was done in 1981.

All of the control effort in the region has been toward protection of other than the timber resource in "high value areas". These high value areas have been monitored in the past and must continue to be monitored. The major consumptive forest resource value in the region remains the tolerant hardwoods and pines (red and white). The growing stock of the region is 46% tolerant hardwood, 23% pine and only about 5% spruce-fir. The problems of management of these two major working groups require all and more of the Ministry staff effort.

IMPACT OF THE SPRUCE BUDWORM IN THE ALGONQUIN REGION--THE FUTURE

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Abstract.--*Spruce and balsam fir are minor components of the forests of the region. With a sawtimber economy in the region and no pulpwood use facilities, the species are generally unimportant. An exception will continue to be the scattered white spruce found within the tolerant hardwoods and pines. Protection and management of the spruce and fir are unlikely.*

Résumé.--*L'épinette et le sapin baumier sont des éléments mineurs des forêts de la région. Comme l'économie de cette dernière est basée sur le bois de sciage et qu'il n'y a aucune installation qui utilise le bois de pâte, ces essences sont en général peu importantes. L'exception restera les épinettes blanches disséminées dans les peuplements tolérants de feuillus et de pins. La protection et la gestion de l'épinette et du sapin sont peu probables.*

The spruce and balsam fir working groups make up considerably less than 10% of the growing stock in the Algonquin Region. They tend to occupy poorly drained (swamp) sites and are low on the priority list for harvest or silvicultural treatment.

The harvest of spruce (mostly white spruce) was just over .5 million m^3 in 1980-1981, and balsam fir was approximately 2,000 m^3. The harvest volume of spruce is deceptive since the bulk of this was upland white spruce picked up in routine partial cutting (selection and shelterwood) harvest operations in tolerant hardwoods and red and white pine. Approximately 150,000 white spruce seedlings are planted in the region annually.

In short, the spruce and balsam fir working groups represent a low priority, low productivity situation relative to the more valuable tolerant hardwood and pine working groups, except for the spruce found as scattered individuals in these groups. A further exception is the high(er) value Beachburg/Douglas strain of white spruce found on the east side of the region. These trees appear as scattered individuals in other working groups.

Our responses to the five theme questions[1] are given on the following page:

[1]The theme questions are as follows:

1. *How important will the spruce-fir component be?*
2. *What are the attitudes of forest industry towards future utilization of balsam fir?*
3. *In what forest use patterns will the spruce budworm be important?*
4. *What management actions should be taken now to reduce future impact?*
5. *What information is needed to facilitate management of the spruce budworm problem?*

1. Basically answered in the introduction: spruce and fir are relatively minor in this region. Other working groups, particularly the tolerant hardwoods and pine working groups, are far more important. White spruce as a component of both working groups is still important. There is probably more spruce and fir on private land in the region than on Crown land. Management of these species on private land is less likely than on Crown land.

2. The forest economy of the region is based on sawtimber. Pulpwood and other low value products are usually by-products of sawtimber harvesting. Balsam fir is not a sought-after species now, and is unlikely to be in the foreseeable future. White spruce will continue to be an incidental component of the future harvest. Sugar maple and white pine will continue to represent the long term value from the forest harvest. There are no pulpwood-use facilities in the region now and it is unlikely that they will appear in the foreseeable future. Facilities that do exist outside the region are too far away to be viable marketplaces. There is the possibility of fibre-use facility in the future to utilize a recognized surplus of low quality material, particularly poplar, white birch and tolerant hardwoods. Such a facility could provide an outlet for budworm-damaged timber also.

3. The spruce budworm could be an important factor in the management of "special use areas." Those that have had attention in terms of controls to date are deer yards, parks and recreation corridors. Controls may be necessary in the future. However, the cost of such action must be borne by the use groups such as wildlife or recreation, and not timber. Various control restrictions will also mitigate against full control.

4. Control action as indicated above is possible in special use areas. Any control action for timber production in terms of cost effectiveness is extremely doubtful.

   Some action to "salvage" damaged timber is warranted if markets can be developed or if adequate incentives to the private sector can be provided. The principle here is that a healthier or altered growing stock may be less susceptible to heavy damage in the next inevitable cycle.

5. Continuous detection is mandatory particularly for identified special use areas and to provide basic information for decisions concerning management within these areas. The budworm, with consequence against basically only two lower value species in this region, would probably not be managed regardless of additional information available.

IMPACT OF THE SPRUCE BUDWORM IN THE NORTHEASTERN REGION -- PAST, PRESENT AND FUTURE

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Abstract.--Current management practices and past spruce budworm epidemics have increased the proportion of balsam fir in much of the Northeastern Region. Estimates of losses caused by budworm are inconclusive, but they will become more crucial as forest land is lost to other uses. Current research and management activities show little prospect of coping with the budworm problem. Management aimed at creating less suitable budworm habitat could alleviate the problem. Large scale aerial photography can be used to locate areas vulnerable to budworm damage, which could then be harvested followed by prescribed burning to reduce the proportion of balsam fir in the next rotation.

Résumé--Les pratiques actuelles d'aménagement et les épidémies de tordeuse des bourgeons de l'épinette que le Nord-Est a connues se traduisent par une proportion plus forte de sapin baumier dans la majeure partie de la région. Les estimations des pertes causées par la tordeuse ne sont pas concluantes, mais ces pertes prendront une importance de plus en plus grande à mesure que le territoire forestier sera grugé par d'autres utilisations. Il semble peu probable que les recherches et pratiques d'aménagement puissent, à l'heure actuelle, régler le problème de la tordeuse. Des pratiques visant à créer un habitat moins propice à la tordeuse pourraient l'atténuer. On pourrait, au moyen de photographies aériennes à grande échelle, localiser les endroits vulnérables à la tordeuse, pratiquer une coupe à ces endroits puis un brûlage dirigé afin de diminuer la proportion de sapin baumier dans le nouveau peuplement.

Introduction

An attempt was made to compare the 1950 Forest Inventory and the 1972 Inventory. The purpose of this was to ascertain if the incidence of balsam fir had increased over the 22-year period. Since the 1972 inventory data were not available for every management unit, the comparison was limited to six management units across the Region. These are the Abitibi, Ranger Lake, Peshu Lake, Wanapitei, Temagami and Latchford Units (Fig. 1).

In making the comparison, both balsam fir and poplar were considered. These two species often grow together and in the early stages of regeneration, one may supplant the other. The data are summarized in Table 1.

Comments on these data are as follows:

a) Abitibi Unit. Large clearcuts were made since 1950. This should have favored the balsam fir but the sites actually favored the expansion of poplar.

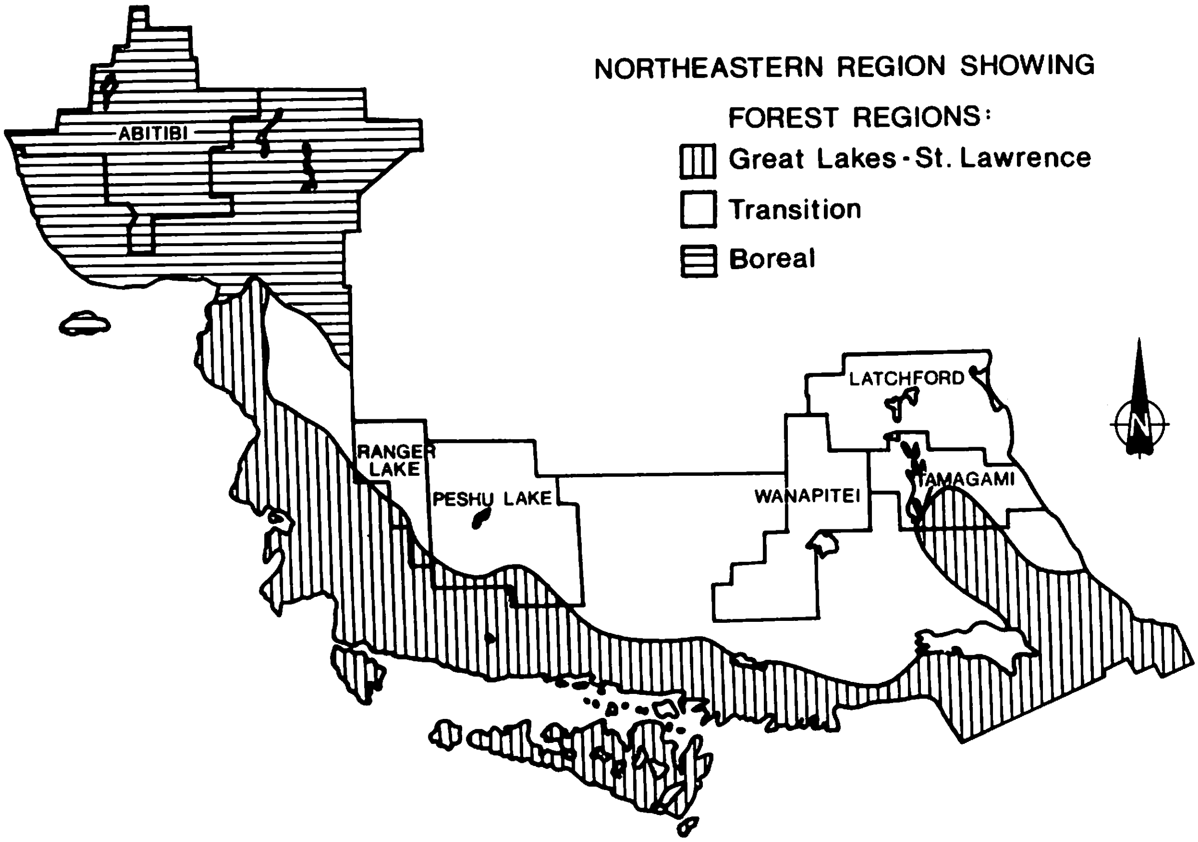

Figure 1. Map of Northeastern Region, showing forest regions and location of Management Units listed in Table 1.

Table 1. Change in proportions of balsam fir and poplar in six Management Units in the Northeastern Region from the 1950 Forest Inventory to the 1972 Inventory.

Management Unit	% by Volume			
	Balsam fir		Poplar	
	1950	1972	1950	1972
Abitibi	12	7	45	58
Ranger Lake	12	23	13	14
Peshu Lake	12	8	13	34
Wanapitei	7	16	40	37
Temagami	8	14	32	35
Latchford	8	21	32	42

b) Ranger Lake Unit. The increase in balsam fir is likely due in large part to balsam fir regeneration which followed the 1941-1946 epidemic entering the 10- to 18-cm diameter class (i.e., it became large enough to measure).

c) Peshu Lake Unit. There is no apparent reason for the decrease in balsam fir. The increase in poplar is quite likely due to the poplar regeneration following the 1948 Mississaugi Fire entering the 10- to 18-cm range during the 22-year period.

d) Wanapitei Unit. Increase in balsam fir is attributed to regeneration following the 1941-46 epidemic reaching measureable size, 10-18 cm.

e) Temagami Unit. Partial white pine cuts favor balsam fir growth.

f) Latchford Unit. Partial white pine cuts favor balsam fir growth. Also, this unit is the best poplar producing unit in the Region.

It should be noted that the great bulk of the balsam fir is in the relatively small size class. This will be borne out in later information.

The results from this analysis are somewhat inconclusive, but time was short and data were scarce. This type of information deserves a more thorough examination.

A recent land use planning exercise to evaluate the loss of wood to companies by various restrictions was carried out by the Unit Foresters of northern Ontario.

The losses attributed to budworm in the Northeastern Region are shown in Table 2. No names or units are given to avoid embarrassing any particular forester, but consider the two extreme estimates, 0% loss and 100% loss.

Table 2. Numbers of Management Units in Northeastern Region estimating various percentage losses of balsam fir to spruce budworm.

Estimated losses due to budworm	Number of Management Units
0%	3
1%	4
2%	2
3%	1
5%	4
8%	1
10%	2
12%	1
20%	2
100%	3

At 0%, one of the units is hardwood and therefore may not have very much, if any, loss. However, the other two units were very badly hit by budworm and cannot be described as having 0% loss.

At 100%, it is indicated that three units are involved. This is just not so. A casual overview of these units or a walk through them would quickly show that there are considerable losses - probably not much more than 50% - certainly not 100%.

The overall conclusion is that *we just do not know what losses have been sustained.* No Unit Forester knows, no District Supervisor knows, no Regional Forester knows nor does the Executive Director of Forest Resources for the province know.

Budworm Present

The present budworm infestation which began in 1968 would now appear to be waning. However, there are other losses sustained in forestry which mean that any loss to budworm damage is that much more significant.

The Forest Resource Inventory for the Northeastern Region shows 5.8 million hectares of productive forest land. The results of our Forest Land Productivity Survey show a decrease of 8%. This decrease is only for shallow soil and rock. There is no decrease shown for rough topography. What losses of productive forest land are we likely to suffer to other resources? Probably there will be losses to agriculture. Long-range forecasts indicate that the production of food will be moving northward as the climate warms up. There will be losses to mining, particularly in the area of aggregates. There may also be losses as peat harvesting takes place, for some organic soils could well support good forest crops. Losses of forests to other resources make forest losses to budworm that much more significant.

Budworm Future

What is the future of this insect? It would appear to be very good. Like a racehorse on a track, it goes around and around, always coming back to the same place. It doesn't pay attention to people and that means CFS and OMNR staff. But it does keep people employed. How many high salaries depend on it? We think more people should be employed - employed in reducing the losses of a natural resource to a larval teenager with a teenager's appetite.

It would seem that over the past few years, the effectiveness of the Canadian Forestry Service work with respect to budworm has been virtually nonexistent. Since 1950, there have been a number of new approaches such as new types of spray, sex hormones and the introduction of radar to trace the flights of the moth. Few of these have yielded any practical results. Why is the Canadian Forestry Service in this state? Quite likely because the Ministry of Natural Resources is also not doing anything. Research and practice must go hand in hand. One is no good without the other.

The Ministry of Natural Resources has sprayed a small area to protect the forest industry, has sprayed a park or two, has carried out a salvage operation in Gogama, and a smaller one in Wawa. But all this amounts to is the fact that we are chasing the budworm with a fly swatter.

The working group convened for this Symposium in the Northeastern Region discerned a parallel between the budworm and fire. This is not the usual conclusion that a bad budworm infestation creates bad fires, but a parallel in the fact that they both devastate the forest resource.

A bad fire creates a tremendous overreaction of activity. This was certainly true following the 1980 fire season which was extremely bad in northwestern Ontario. In the upper levels of the Ministry and the upper levels of the forest industry, the fall of 1980 and the spring of 1981 were times of great activity and soul searching. But six, eight or ten years of budworm engender nothing more than a typical ho-hum approach towards its resolution.

Fire areas are devastation areas. It was amazing to see the number of tourists stopped along Highway 17 between Dryden and Kenora in the fall of 1980, not taking pictures of the scenery, not taking pictures of someone with a large fish, but taking pictures of burned over areas. This devastation had caught their attention. How many of these same people would stop to look at a budworm infestation? The public is not interested in crawling insects. If we really want to catch the budworm, we are going to have to be there ahead of time, when he, she, or it arrives.

There has been a lot of talk about forest management as a means of combatting budworm. Every time this sort of talk arises, the person doing it is generally laughed out of the room. The time span required can be mind-boggling. But we must start somewhere.

If there is one thing that foresters should know by now it is that every species in the animal kingdom and the vegetable kingdom has an optimum habitat. If the Ministry of Natural Resources could manage to rearrange the budworm habitat so that the budworm cannot survive or survive only in part, we might just be able to exercise some control over it. We will never eradicate it. But why should we? It is more important that we work towards control of it.

There are two basic tools we have at our disposal to help us control the budworm - the match and the axe. The match can be used to start prescribed burns. The axe can represent a chain saw or a Koehring harvester; only the source of energy is different, the end result is the same. We suggest that the Ministry of Natural Resources' staff should try using these tools.

Last spring, a two-page document received from the Maritimes was circulated throughout OMNR. It outlined a method for rating a forest for vulnerability to the spruce budworm. We decided to try this out. A computer program was written to rate full townships as well as stands. The basic datum for this program was the Forest Resource Inventory of Ontario.

Using a system like this, the forester could lay out or direct his annual allowable cut into the highly vulnerable areas and harvest them quickly. In fact, he could accelerate his cut considerably, if the situation warranted. Harvesting alone is not sufficient. It is necessary to follow up with a prescribed burn (the match) *or* a clean-up of the area (the axe). A prescribed burn has preference in this situation, as balsam fir does not easily regenerate after a fire.

Measuring Damage

Last year (1981), Dendron Resource Surveys of Ottawa carried out a large-scale photography program near Wawa, Ontario. This work was done for the Forest Resources Inventory Section in Toronto. Since Dendron already had the photos, we asked them to evaluate the area for budworm damage.

From the inventory photos made in 1981, Dendron had 300 plots. To this, they added another 150 for the purpose of the budworm evaluation. We asked for three damage classes: no damage, some damage, and dead. Dendron gave us four classes and grouped them into *survival* and *loss* on the basis that "no damage" or "light damage" would survive, and "heavy damage" or "dead" was a loss. Balsam fir was classified into 10-18 cm DBH and 18+ cm DBH. Spruce was classified into 10-18 cm, 20-28 cm and 30+ cm DBH. The reason for the three-level classifications for spruce as opposed to two for balsam was that there were insufficient balsam fir over 30 cm to give a reliable sample. Those that were found were grouped into the 18+ cm class.

Estimated losses from this exercise are as follows:

VOLUME LOSSES M^3

Balsam	394.400	60% of G.T.V.
Spruce	1,763.700	34% of G.T.V.
Total	2,158.100	37% of G.T.V.

Here we have a definitive area with a quantifiable loss that can be comprehended. This is needed if we are to understand budworm losses and to become serious about the budworm problem. A large fire area can be seen and appreciated. Budworm infestations in Ontario are not so readily seen and are not understood. When one reads in the media that we have lost a tremendous number of cubic metres of wood to budworm, it does not serve any useful purpose. Most people rate this about three steps below their concern for the fiscal policies of the Republic of Madagascar and ignore it. We are not going to wipe out the budworm, but each of us must try to control it in our own area. The present infestation is gone. It is now time that we mounted our attack on the next infestation.

One final bit of information: in asking a few questions, it would seem that the northern two-thirds of the Northeastern Region, that is the Transition Zone and the Boreal Forest, could be surveyed and interpreted by using large-scale aerial photography annually for approximately $150,000 (1982 $). We should take advantage of this very cheap type of survey to identify our losses, to measure our losses, to derive a comprehensible figure for those losses, and to keep a camera's eye on the movements of the spruce budworm.

The time for wheel-spinning is past. Forward progress is essential.

Acknowledgments

This report was prepared under the auspices of a committee consisting of W.C. Stevens, OMNR (Chairman); M.R. Innes, Abitibi-Price; C.K. Sumi, OMNR; and R. Beny, OMNR.

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IMPACT OF THE SPRUCE BUDWORM IN THE NORTHERN REGION -- PAST AND PRESENT

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Abstract.--The Northern Region has been extensively infested by spruce budworm during the past 15 years. Impacts on forestry, recreation, and fire behavior have been locally significant particularly in the southern half of the Region. From an overall regional viewpoint, however, budworm impact has been moderate because of the relatively small percentage of productive forest land occupied by balsam fir and white spruce working groups.

Résumé.--Au cours des 15 dernières années, la région du Nord a été infestée sur de vastes étendues par la tordeuse des bourgeons de l'épinette. Localement, dans le sud de la région surtout, les effets sur la foresterie, les loisirs et les incendies en ont été notables, mais dans l'ensemble, ils ont été modérés à cause du pourcentage relativement petit de terres forestières productives constituées de sapin baumier et d'épinette blanche.

Introduction

The current spruce budworm infestation has affected the Northern Region more than any other region in the province of Ontario. Beginning in 1967 in the southern portions of Gogama, Chapleau and Kirkland Lake Districts, spruce budworm populations have expanded steadily to cover a peak area in 1981 of almost 10 million ha of moderately to severely defoliated forest land. Extensive fibre loss estimated at 50 million m^3 has occurred, primarily in the four southern districts[1].

Recently, the infestation has shown definite signs of collapse, as a result of the combined factors of reduced food supply, successive cold spring weather, and parasites and diseases normally found in overpopulated situations. In fact, the area of moderate-to-severe infestation declined by 92% between 1981 and 1982.[2]

Major impacts of the current outbreak include merchantable timber mortality, forest growth reduction, loss of aesthetic values, alteration of wildlife habitat and creation of extensive fire hazard areas.

Reaction to budworm predation has been limited primarily to selective spraying of high-value forests and direct conversion of affected stands to less susceptible tree species.

Impact on Forestry

The major impact of the spruce budworm has been a reduction of forest growing stock primarily through direct mortality of balsam

[1,2]Howse, G.M., Head, Forest Insect and Disease Survey Unit, Dep. Environ, Can. For. Serv., Sault Ste. Marie, Ont., 7 Sept. 1982 (pers. comm.).

fir and reduced growth of white spruce and black spruce.

Given that estimation is difficult because of frequently inaccurate or outdated forest inventories and mortality due to other factors, cumulative fibre losses in the Northern Region during the current outbreak have been estimated as follows[3] (Table 1).

Table 1. Cumulative volume loss by species as a result of budworm infestation in the Northern Region (1982).

	Net merchantable volume (millions)	
	m^3	Cunits
Balsam fir	36.8	13.0
White spruce	5.3	1.9
Black spruce	7.2	2.5
TOTAL	49.3	17.4

Assuming the above volume would otherwise have been utilized, this represents a direct economic loss to industry of $870 million (calculated at $50 per cunit) and some $118 million in basic Crown dues. In actual fact, however, the true figure should be far less since the often small diameter, short length and frequent stem decay of balsam fir render it economically undesirable in many instances.

The majority of spruce budworm-induced mortality in the Northern Region has occurred in the Chapleau, Gogama, Timmins and Kirkland Lake districts. Actual economic effects vary within this area according to the proportion of conifer allowable cut comprised of balsam fir and the dependence of local forest industries on that species.

On a regional average basis, balsam fir accounts for only 6.9% of total growing stock according to Ontario Forest Resource Inventory data. However, in Kirkland Lake District the figure increases to 17.3%, contributing to the necessity of protection spraying operations on a 5260 ha commercial forest area in Elliott Township beginning in 1979 (Meating et al. 1982). As in the Gogama District where balsam fir comprised 13.8% of the total growing stock at time of inventory, extensive salvage cutting and stand conversion operations have also been conducted. Prescribed burning has been a major tool in stimulating natural succession to budworm-resistant pioneer species such as jack pine, black spruce and poplar.

Less affected districts have confined activities to selective spraying of white and black spruce seed orchards, seed production areas, seed tree areas and high-value plantations using a variety of chemical, bacterial and viral compounds (Meating et al. 1982). Total area sprayed represents less than 0.1% of the 1981 outbreak area, while 68% of the total spray area was treated with biological insecticides (Carrow et al. 1982).

Effectiveness of the spray program has been variable, depending on timing, weather, choice of insecticide, method of application and rate. Generally, chemical insecticides such as Matacil have provided better control than biological agents such as *B.t.*, particularly on white spruce (the primary target in high-value spraying). The current decline in budworm populations has led to suspension of most Northern Region spray programs with the exception of Hearst District where damage potential is still high.

Over all, spruce budworm damage does not appear to have drastically altered the regional wood supply picture since local mills depend primarily on jack pine and black spruce. Major negative effects have been confined to inhibition of cone production in seed orchards and seed production areas through sustained defoliation of white spruce.

Impact on Wildlife

Wildlife habitat modification has been a direct consequence of spruce budworm infestation in the Northern Region. Defoliation of large areas of mature balsam fir has resulted in loss of cover and the proliferation of shrub and herbaceous growth as a result of increased availability of light.[4]

In general, however, the effect has been beneficial, in that pockets of early seral habitat have been created in an otherwise mature forest landscape. Mixed conditions which result support a greater variety of

[3]Howse, G.M., 7 Sept. 1982 (pers. comm.).

[4]Greenwood, C., Regional Moose Biologist, Ont. Min. Nat. Resour., Northern Region, 7 Sept. 1982 (pers. comm.).

wildlife, particularly mammals dependent on abundant hardwood browse and roots, such as moose and bear. Taken to extremes, however, winter yarding areas for moose can be threatened with defoliaton as in the Hearst District where protection spraying is currently in limited practice.[5]

Insectivorous upper canopy feeders such as warblers have also prospered through direct consumption of budworm larvae, which in turn increases activity along the entire food chain.

Man's activities in controlling budworm have had varying effects on wildlife. For example, spraying of aminocarb insecticides may be directly toxic to songbirds, salmonid fish populations and surface aquatic invertebrates. In practice, however, these effects have been minimal because of the short duration of Northern Region spray programs and the use of budworm-specific bacterial sprays along watercourses.[6]

Conversion of balsam fir stands through prescribed burning is expected to affect wildlife favorably through nutrient release, hardwood browse production and forest edge creation.

Impact on Recreation

Impacts of spruce budworm on recreation in the Northern Region have been limited mainly to reductions in aesthetic values in provincial parks and along highways. Large areas of defoliated or dead balsam fir occur along Highway 560 in Gogama and Kirkland Lake districts, and along highways 101 and 129 in the Chapleau District, with similar situations in provincial parks in Chapleau, Kirkland Lake and Hearst districts.

Beginning about 1967, Chapleau District undertook spraying of chemical insecticides in developed areas within five provincial parks. Aerial application of Fenitrothion and Zectran continued with limited success for approximately eight years, followed by more effective ground application of Malathion and Orthene. District parks personnel would in future recommend a more integrated approach involving species and age class interspersion through small-scale stand conversion[7].

Hearst District recently undertook the protection of two relatively large areas in Nagagamisis and Fushimi Parks using aerially applied *B.t.* Plans are to maintain these programs should budworm populations fail to decline.[8]

Aesthetic impacts of budworm defoliation along highways are being countered primarily in the Gogama District through salvage cutting, prescribed burning and replanting to jack pine. Prominent signs explaining the program have recently been erected to foster public understanding of forest renewal.

Impact on Forest Fire Management

The current budworm infestation has significantly affected fir susceptibility patterns. Extensive areas of budworm-killed balsam fir up to several thousand hectares in size frequently occur in Chapleau, Gogama and Kirkland Lake districts, creating high fire hazard situations.

Regular spring droughts accentuate the problem through rapid drying of fire fuels before deciduous leaf-out occurs. Spread potential is often explosive because of flaking balsam fir and birch bark thrown far ahead of the fire front. Such fires, if not detected and confined early, may be virtually impossible to control under drought conditions.

Management of the problem has focused on three major fronts: identification of potential hazard areas, fire behavior prediction research and hazard reduction through salvage cutting and prescribed burning in conjunction with forest regeneration programs. A fourth approach, that of allowing wildfires in budworm-killed timber to burn under surveillance, may be considered in future should fire behavior prediction and suppression technology permit.[9]

Conclusions

In summary, the impact of the spruce budworm from an overall regional standpoint

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[5]Pinto, F., Unit Forester, Ont. Min. Nat. Resour., Hearst District, 7 Sept. 1982 (pers. comm.).

[6]Greenwood, C., 7 Sept. 1982 (pers. comm.).

[7]Dingee, G.W., Parks and Recreation Supervisor, Ont. Min. Nat. Resour., Chapleau District, 7 Sept. 1982 (pers. comm.).

[8]Pinto, F., 7 Sept. (pers. comm.).

[9]White, D., Reg. Fire Training Officer, Ont. Min. Nat. Resour., Northern Region, 7 Sept. 1982 (pers. comm.).

can only be described as moderate. Certainly infestation and damage have been heavy in local situations, creating potential wood shortages, high fire hazards, loss of wildlife cover and reductions in aesthetic appeal. Tree mortality and growth loss roughly equivalent to eight years' coniferous allowable cut have also been suffered regionally. However, considering the fact that the balsam fir working group accounts for less than 8% of the productive regional land base, that local industries rely primarily on spruce and jack pine, and that the current infestation appears on the brink of collapse, the spruce budworm should not be perceived as a major threat to resource management in the Northern Region.

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IMPACT OF SPRUCE BUDWORM IN THE NORTHERN REGION--FUTURE

The following statement was prepared by R.F. Calvert, Regional Forest Improvement Specialist, OMNR, Northern Region, from comments made by:

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1. <u>HOW IMPORTANT WILL THE SPRUCE-FIR COMPONENT BE?</u>

- spruce by itself will continue to be important
- use of balsam depends on the product and the ability of a company to harvest relatively small trees
- in spruce-balsam stands, the volume of spruce is often too low to make the stand merchantable; it is often the balsam volume which determines if the stands will be logged
- balsam fir is not preferred by industry but can be used especially in some types of pulping processes
- in some districts in 10 years' time there will be virtually no merchantable living balsam in the Northern Region -- perhaps some for pulpwood, no sawlogs
- the conversion of balsam working group stands to a different working group is expensive but will be a major forest management activity to the year 2000
- when dead and dying balsam is cut much of it does not get to the skidway because of cull and breakage; cutters being paid piece work do not like to cut balsam partly because of the high incidence of cull

2. <u>WHAT ARE THE ATTITUDES OF FOREST INDUSTRY TOWARDS FUTURE UTILIZATION OF BALSAM?</u>

- balsam is not a preferred species but if it is available in commercial quantities it will be used
- there should not be any management for balsam
- some sawmills cut fir only if the lumber market is good; others will not cut fir at all
- often cannot get fir cut even at salvage rates
- a change in technology to enable young balsam to be full-tree chipped with a possible chip-bark separation after harvest would make balsam more desirable
- some companies discriminate against balsam
- the smashing of balsam fir advance growth is acceptable in most people's eyes
- merchantable balsam left standing and pieces, broken or whole, left on the ground are often ignored by some districts; i.e., cleanups are not ordered
- industry would prefer to see spruce, pine or aspen growing on land occupied by balsam

3. IN WHAT FOREST USE PATTERNS WILL THE SPRUCE BUDWORM BE IMPORTANT?

- balsam is important to moose management and in some recreational areas but it has to be sprayed or it dies
- if balsam were eliminated it is unclear if outbreaks would be as frequent or as devastating
- if balsam is important to the triggering of an outbreak it indirectly affects the supply of seed from both white and black spruce; perhaps the wild forest cannot be relied upon as our main source of seed
- spruce mortality may be less in stands with a low balsam content
- balsam should be harvested from reserves to eliminate as much of the seed source as possible

4. WHAT MANAGEMENT ACTIONS SHOULD BE TAKEN NOW TO REDUCE FUTURE IMPACT?

- public education about forest values
- design silvicultural programs to reduce the amount of balsam although some consider balsam regeneration a desirable species when carrying out regeneration cruises
- increase supply of spruce & pine
- some do not consider balsam a desirable species when deciding if a stand requires tending or retreatment
- in young even-aged stands with spruce the budworm will probably kill the first crop of balsam before the spruce is merchantable
- today's standards were based on what is known today; a scarcity of wood in the future and a change in harvesting technology may make the fir thicket valuable
- much old mixedwood cutover is coming back to balsam--scarification discourages balsam fir
- budworm damage in spruce plantations is observed in mixedwood stands with spruce in corridors; balsam is present in the untreated strip
- 7 of the 10 present did not think the budworm was a limiting factor in white spruce plantation management

5. WHAT INFORMATION IS NEEDED TO FACILITATE MANAGEMENT OF THE SPRUCE BUDWORM PROBLEM?

- how do we get rid of the budworm?
- how do we reduce the amount of fir in a stand?
- what effect does the budworm have on white spruce plantations?
- what is the effect of budworm on spruce seed crops?
- continued monitoring of budworm populations and predictions of outbreaks.

IMPACT OF THE SPRUCE BUDWORM IN THE NORTH CENTRAL REGION --

PAST, PRESENT AND FUTURE

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Abstract.--Spruce budworm history and control measures are discussed for the North Central Region. The importance of the spruce-fir component as a whole to the Region is described and future utilization and potential problems are discussed. Short- and long-term remedies are suggested and information gaps are highlighted.

Résumé—L'historique des infestations et les mesures antitordeuse sont décrits pour le Centre-Nord. L'importance pour cette région du groups épinette-sapin est soulignée, et des utilisations prévues et problèmes potentielles sont discutées. On propose des correctifs à court et long termes et on met en évidence les principales lacunes des connaissances.

Introduction

Spruce budworm, because it feeds on the primary pulpwood species, black spruce, white spruce, and balsam fir, represents a serious threat to the economy of the North Central Region where forest industries use large combinations of these species. The questions that need to be answered are: do we really have a budworm-susceptible forest according to Van Raalte's (1972) standards, and if so, is the regional budworm problem real or imaginary?

This paper deals with the budworm history in the North Central Region, summarizes recent control measures, elaborates on the five theme questions and updates the status of past suggestions that have been implemented to various degrees.

History of Spruce Budworm in the North Central Region

Major spruce budworm outbreaks have occurred as follows (Howse 1981): in 1704 - near Lake Nipigon, in 1802 - by Lake Nipigon, in 1911 - by Lac des Milles Lacs, from 1940 to 1962 - near Nipigon.

Major outbreaks usually occur at 35- to 100-year intervals (Brown 1970) and sometimes may occur as early as 21 years apart (Blais 1968). If the gap between major outbreaks is between 42 and 100 years, then 42 years from between 1940 and 1962 would signal the start of a major outbreak. Increases and decreases in spruce budworm populations in different parts of the North Central Region in 1981 cannot substantiate that another major outbreak of spruce budworm is occurring or is about to occur (Howse et al. 1981). The presence of second-growth stands in the Black Sturgeon (Nipigon), Mattawin, and Dog River areas does, however, indicate that the spruce budworm problem could worsen in the future.

Control of Spruce Budworm in the North Central Region

In Northwestern Ontario, starting in 1968, OMNR adopted a policy of attempting to eliminate incipient infestations or to suppress outbreaks (Howse and Harnden 1978).

Annual aerial spraying operations ranging from 4,452 to 111,291 ha in size were conducted from 1968 to 1976 jointly in the North Central and Northwestern regions. Since then no operational spraying of insecticides has been conducted to control spruce budworm in the North Central Region. Wholesale spraying to control the budworm in the future is not envisioned by industry or government although on a short-term basis spraying will be necessary until susceptible high-value stands are harvested.

No matter which insecticide or alternative spraying agent is being used, opponents of spraying will say, "Prove it is safe" and proponents of spraying will say, "Prove it is unsafe". The heart of the problem is balancing the risks and this is especially hard when these risks cannot be quantitatively assessed, and furthermore, it is not clear whose responsibility it is to do so. With these problems facing them, many forest managers have, are, and will hesitate to spray against the budworm. Biological agents such as bacteria and sex attractants still do not look attractive to the North Central Region. Very good results with the bacteria will be questionable if costs and operational difficulties make their use complicated and unlikely. Also public acceptance of spraying germs will be just as unlikely as is their present acceptance of certain pesticides. Pheromone use, on the other hand, seems to be presently limited by its high production costs and specialized dispersion requiring long-lasting evaporation. The Region agrees with Stevens' and Schabas' (1978) opinion and foresees no operational use of this product at the present or near future.

Importance of Spruce-Fir Component

The spruce-fir component is part of a much larger forest - the boreal mixedwood forest. The recent symposium on this forest type has presented some valuable background information on wildlife needs (McNicol and Timmerman 1981) on utilization trends (Opper 1981, Flowers 1981) and on the impact of spruce budworm (Howse 1981). This section of this paper will deal with seven ways in which the spruce-fir forest is considered important.

The first item that needs clarification is how vast is the spruce-fir resource in the North Central Region. Old Forest Resource Inventory (FRI) reports summarized by Dixon (1963) show that there are approximately 2.7 million ha of productive forest that support the mixedwood forest in the North Central Region (Table 1). This land base is 38% of the total land base and it once contained 52, 37 and 11% mature, immature and young growth stands, respectively (Table 2) which have shifted in proportion during the last 30 years. Out of the 810 million m^3 of primary growing stock balsam fir (9%) and white spruce (6%) have represented 15% of the total fibre available in the past (Table 3). The true present and future representations of these fibre sources are still unknown although approximations can be made but are not attempted for this paper.

In 1973, there were eight sawmills and five pulpmills in the North Central Region that required balsam fir (Anon. 1973). These mills utilize balsam fir for newsprint, specialty paper, kraft paper, lumber pallets, studs, turpentine and tall oil. Secondary

Table 1. Summary of distribution of cover types within the productive forest of the North Central Region (by old districts).

District	Thousands of hectares of productive forest	Percentage of productive forest classified as		
		Conifer	Hardwood	Mixedwood
Geraldton	2,534	57	5	30
Port Arthur	3,201	42	13	35
White River	1,565	27	11	56
Regional total	7,300			
Regional averages		44	10	38

Table 2. Summary of distribution of age classes for the mixedwood cover type within the productive forest of the North Central Region (by old districts).

District	Thousands of hectares of mixedwood	Percentage of mixedwood cover type attributed to following age classes		
		Mature	Immature	Young growth
Geraldton	766	60	30	10
Port Arthur	1,106	47	38	15
White River	872	50	41	9
Regional total	2,744			
Regional averages		52	37	11

NOTE: Values obtained from Tables 2 and 3 and converted to metric from FRI reports 1 to 23 published from 1953 to 1959.

Table 3. Summary of distribution of primary growing stock within productive forest of the North Central Region (by old districts).

District	Millions of cubic metres of primary growing stock	Percentage of total volume attributed to		
		Balsam fir	Black spruce	White spruce
Geraldton	294	8	38	7
Port Arthur	349	10	30	5
White River	167	8	25	9
Regional total	810			
Regional averages		9	32	6

NOTE: Values obtained from Table 8 and converted to metric from FRI reports 1 to 23 published from 1953 to 1959.

wood-using industries also consume balsam fir (Anon. 1981), but from the 1981 directory it is impossible to discern which industry actually uses balsam fir.

The allowable cut for the spruce-fir forest of the North Central Region has been estimated at 13% (Table 4) of the 14 million m^3 of primary growing stock (Dixon 1963). From 1947 to 1971, balsam fir has represented annually 1.38 to 4.21% of the wood cut for all species on Crown land (Tucker and Ketcheson 1973) with the average provincial use being 3.37%. Today, however, in the Thunder Bay District balsam involves approximately 30% of the current allowable cut. With 65% of the old cuts having reverted to the balsam fir working group (Flowers 1981) it is conceivable that the balsam fir allowable cut could increase even more than the dreaded 30% level.

The balsam fir resource presented in Table 2 alone or mixed with white spruce represents potential heavy infestation areas. The most prominent of the potential danger areas are the second growth stands located in the Black Sturgeon, Mattawin, and Dog River areas. One Timber Management Supervisor has estimated that there are 200,000 ha south of Highway 11 ready for the budworm and a second one foresees 400 km^2 of potential heavy infestation surrounding Lake Nipigon.

Table 4. Summary of distribution of allowable cut for the primary growing stock within the productive forest of the North Central Region (by old districts).

District	Thousands of cubic metres allocated for allowable cut	Percentage of allowable cut volume attributed to		
		Balsam fir	Black spruce	White spruce
Geraldton	4,551	7	26	6
Port Arthur	6,587	9	19	4
White River	2,872	6	19	4
Regional total	14,010			
Regional averages		8	21	5

NOTE: Values obtained from Tables 11 and 12 and converted to metric from F.R.I. reports 1 to 23 published from 1953 to 1959.

If the devastations predicted in the Nipigon and Geraldton districts come true, the devastated areas could pose substantial fire hazards to towns such as Jellicoe and Beardmore. Fire hazards could also occur in cottage areas such as Lake Shebandowan and the many others that exist within the Region.

Devastated budworm forests with various degrees of mortality will also reduce municipal, recreational, and canoe route aesthetics.

The second-growth spruce-fir stands have been obtained at little or no expense and to date have not warranted silvicultural work. If these second-growth stands are to fill voids in the 41- to 60-year age classes of other conifers serious consideration will have to be given to investing some monies in these stands to improve conifer yields by techniques such as thinning and conifer-release by herbicides before these stands are harvested within two decades.

The spruce-fir forest is quite important to wildlife. Bakuzis and Hansen (1965) have described quite fully the wildlife aspects associated with balsam fir and have listed the common animals and birds that are found in the spruce-fir forests. For further details people should examine their monographic review of balsam fir.

The Regional Moose Biologist asks all other services not to forget that balsam fir provides cover for moose *(Alces alces)* and other wildlife, and also late winter food. He has also expressed some concern about moose populations starving on isolated islands on larger lakes if the budworm devastates the balsam stands on these islands. There is also a suggestion that marten *(Martes americana)* populations might dwindle when red squirrels *(Tamiasciurus hudsonicus)* decrease in dead balsam stands thus affecting the economy of local trappers.

The last but not the least important contribution that balsam fir makes is its more than adequate fibres. First, balsam fibres are the best suited of all conifer fibres in the enhancement of brightness of paper. Second, without balsam fir, the folding endurance of paper would decrease substantially. Third, without balsam fibre content, paper bags, such as grocery bags, will not stretch and are more liable to burst. These three facts have been documented by Bakuzis and Hansen (1965). Also, foresters should be aware that kraft paper produced with specific decayed and stained balsam fir does not fall significantly below the established standards for burst and tear strengths (Hunt and Whitney 1974).

Over all, in the North Central Region the spruce-fir component is not considered very important now, but when the 20-year management plans come up for the next revision, this type of forest will be very important.

Industrial Attitude to Future Utilization of Balsam Fir

Future utilization of balsam fir will depend on the 2.3% annual increase for wood demand as predicted by Manning and Grinnell

(1971) plus the needs of the energy and plastics industries for wood as a raw material. As the preferred conifer resources become fully utilized, demand for balsam fir should greatly increase. Already there is evidence that the gross annual cuts of white spruce, black spruce, and jack pine are exceeding the gross mean annual increment (Table 5). Balsam fir is the sole exception. If the mean annual forest drain is considered and no other fibre demands arise, then in Ontario it will probably take 48, 15 and 39 years, respectively, to exceed the allowable cuts for balsam fir, the spruces and jack pine. With these wide time gaps it is hard to envision how industry will react.

Present indications are that industry will utilize balsam fir with reservations. Domtar Newsprint Ltd. has tried full-tree chipping of balsam fir and poplar in the Nipigon District. Other major companies will also be attempting this technique. Some advance growth and hidden seedlings, however, will survive the chipping process to start new stands. Salvage harvests after fire have shown some potential but the available time to remove damaged stands is limited after mortality. Industry is also targeting budworm epicentres for immediate harvest if possible and accessible. Harvesting of balsam fir for essence of balsam has started on a small scale.

The only major drawbacks to increased future utilization of balsam fir are cutters and mill managers. The cutters, as many of the symposium speakers have pointed out, do not like to cut trees that break easily or that contain rot. If the first cut shows a trace of rot, the rest of the tree is discarded. This is a wasteful practice since root rots don't extend far up into trees and trunk rots are localized in part of the bole and do not normally extend all along the bole. Mill managers, on the other hand, blame all breakages of paper rolls on the presence of higher content of balsam fir fibres rather than the presence of short fibres that weaken sections of paper. No one really knows how many times people have actually stopped to identify the exact fibres which caused the paper to separate. It is perhaps time to return to the old beaker-glass rod and pulp mixture routine of university days where microscopic perusal can identify all types of fibres.

Over all, the North Central Region envisions mills using considerably more balsam provided that the blended mix is kept constant.

The North Central Region task force formed during the present symposium concurred that there is a strong need to change the attitudes of mill managers, union and cutters. This can only be achieved through education which should start as soon as possible.

Use Patterns Contributing to Spruce Budworm

Man's chief activities in the forest (harvesting wood, restricting fire and applying insecticides) aid the development of a highly competitive climax species such as balsam fir. This means that, as time goes on, foresters will be faced with increasing quantities of fir, on both specific areas and more extensive areas. Horse-logging in the past has restricted damage to advance growth which later produces seeds annually to regenerate more balsam fir. Any given balsam fir may produce seeds for several consecutive years with seed quantity and quality fluctuating considerably. Lack of site preparation and other disturbances after current logging will continue to favor the establishment and survival of balsam fir.

In the future, the North Central Region will mechanically break up large areas of balsam fir and will invest funds to convert these areas into jack pine stands. This approach will not totally remove or eradicate the balsam fir but it should serve to decrease the budworm's food supply.

Management Actions Required to Reduce Future Impact

Man's chief activities in the forest must be modified drastically to alter the use patterns which contribute to spruce budworm. Two of the three activities are easy to change. Each of the activities, however, has ecological, sociological, and other implications which must be seriously weighed before any changes are attempted.

Fire is the best tool to eliminate balsam fir. It has been used successfully to remove balsam fir seed source from overstorey. However, in mixedwood forests, fire cannot be used as successfully, because crowns of trees are much closer together and spruce is readily mixed with balsam fir. Even when fire is set under controlled conditions or occurs naturally, the practice has been to suppress the fire early. The Canadian public does not like to see the forests burn since trees purify the earth's air. Unless the communications media and the general public can be educated to accept fire as a means of preventing future budworm devastations, there seems little likelihood that anyone will really want to use fire to eliminate balsam fir in northern Ontario.

Table 5. Comparison of supply, demand and drain of primary growing stock on all Crown lands in Ontario.

	Balsam fir	Spruces	Jack pine
Gross mean annual increment ('000 m^3)[a]	3,992	17,002	9,302
Gross mean allowable cut ('000 m^3)[b]	3,946	18,598	11,707
Net merchantable allowable cut ('000 m^3)[c]	1,985	8,693	7,540
Mean annual actual cut ('000 m^3)[d]	346	5,430	2,512
Minimum annual actual cut ('000 m^3)[d]	266	3,802	1,648
Maximum annual actual cut ('000 m^3)[d]	456	7,130	3,438
Depletion factor (%)[e]	50	90	80
Mean annual forest drain ('000 m^3)[f]	692	6,034	3,140
Minimum annual forest drain ('000 m^3)[f]	532	4,225	2,060
Maximum annual forest drain ('000 m^3)[f]	912	7,924	4,293
Forest drain as a percentage of the net merchantable allowable cut on the basis of the:			
mean	35	69	42
minimum	14	49	27
maximum	46	91	57

NOTE: [a] Values from Tables of FRI reports
[b] Values from Tables 11-12 of FRI reports
[c] Values from Table 7 of Tucker and Ketcheson (1973)]
[d] Values from Table 6 of Tucker and Ketcheson (1973)] taken from Dixon (1963) and Ont. Dept. Lands For. (1967)
[e] Values from Table 7 of Tucker and Ketcheson (1973)]
[f] Values from Table 8 of Tucker and Ketcheson (1973)]

Eliminating the use of insecticides and other agents such as predators, parasites, fungi, growth regulators, pheromones, viruses and bacteria will allow the budworm to spread, provided that early spring frosts do not occur annually to kill the fourth instar of the spruce budworm. Eventually the food supply will disappear and the budworm will disappear to resurface in the future. The economic consequences of this scenario are, however, drastic. A much better alternative would be to use chemical and biological sprays if the trees are to be used by industry in the near future. All spray operations should, however, be accompanied by professional public relations campaigns which tell all sides of the story, listing the consequences.

Spraying to save wood which might or might not be used is no longer feasible if millions of hectares are involved. The dollars should always be directed where the best returns can be achieved and targets can be altered within reason. Spraying should be used only to save high-value areas for 5 years or less. If, however, a total knockout of the budworm is desired, it is envisioned that regional insecticide caches might have to be established if deemed necessary.

The best means of reducing the present and future impact of spruce budworm is to harvest the balsam fir totally. This means the cutting of all second-growth stands with priority being given to infested areas. No balsam fir should be left. If this is the objective, then full-tree chipping would be ideal to destroy the balsam resource totally provided that all sizes of fir can be cut and used. Research and development are still needed on how to chip the residual advance growth trees.

Another alternative that the forester has for fighting the spruce budworm is to reduce the rotation age of balsam fir. The standard rotation age is 90 years. However, reducing it to 60 or 40 years is not inconceivable. Such a step, however, will mean that smaller trees will be available to stud mills. If the rotation age is reduced by 30 to 50 years, alternatives will have to be examined to increase the volume production of balsam fir to compensate for other losses. Thinning and conifer release programs will have to be given serious consideration. If the fir is not desired, then it could be removed in precommercial thinnings. Funds will have to be diverted from other current forest management practices, such as tree planting and scarification to permit the management of a resource that has cost almost nothing. This step has not yet been considered in any region but none of the regions, including the North Central Region, can discard any viable alternative when wood supplies are dwindling.

The final alternative is to break up the spruce-fir stands and convert them to other conifers. This is the long-term option which will involve silvicultural steps to prevent recurrence of balsam fir. The costs will be high when site preparation is used to destroy balsam seed sources and the area is then planted with non-susceptible tree species. This costly route, however, is preferred by many foresters and will be carried out until it can be proven a wasteful practice and a damaging one to the conifer age-class distribution inventories.

Information Needed to Facilitate Management of Spruce Budworm Problem

The spruce budworm problem has many sides, and it is characteristic that people consider only part of one or, at very best, part of a few of these sides. Such approaches are doomed, because something was left out and what you leave out is what gets you into trouble. Research into the balsam resource and into the budworm problem has also been limited to narrow areas where a team work concept has not always worked. For example, balsam fir grows in combination with the two spruces and both trembling aspen and white birch in boreal mixedwood forests. Yet very few researchers will look at the total picture to explain the influence of the total forest on total growth and biomass production. The Northern Forest Research Unit (OMNR) does not yet have this approach. Also entomology and silviculture have not yet married to yield better information for the forest manager. Foresters still do not know the true relationship between budworm and forest structure. In reports of spraying operations, data are given on the amount of material applied together with a measure of success in killing the target organism. However, there is usually no mention of the exact nature of the forest, i.e., height, density, age classes, etc., so that the results can be related to the forest structure.

There are six distinct areas where additional information will help to facilitate the management of the spruce budworm problem. Each of these areas will be discussed very briefly.

The first need is for better maps. Balsam fir age-class distribution maps will indicate where the pest is likely to pop up and where decay problems will be expected. These maps in turn can reflect budworm outbreaks relative to high-value areas such as spruce stands, canoe routes and communities. With the balsam fir age-class maps, the wildlife people should use outbreak overlays and moose corridor and habitat overlays to determine the true impact of the budworm on the moose resource.

Once the balsam age-classes are identified, there will be a need to inventory these areas and to gather reliable growth and yield information for second-growth stands which may or may not have been managed. Also there will be a need to identify the clay sites on which balsam fir can be left to grow and from which balsam fir could be eliminated because it grows poorly.

Two other items that need clarification are the relationship between infestation and mortality of balsam and the true impact of keeping trees green. In the first instance existing budworm data could be related to tree mortality survey data that should be obtained over a short time period (several years). The second aspect needs quantification so that a true cost-benefit analysis can be conducted to determine whether or not it is economically justified to continue to spray against the spruce budworm so that trees will be kept green.

The last aspect that needs improvement is mill technology so that more balsam fibre can be accepted in final products. This problem could be looked at by industry or by educational or research institutes.

Status of Past Suggestions

The last item that needs to be discussed in this paper is the status of past suggestions. In the mid-1960s Burgar (1965) proposed silvicultural control for the spruce budworm in northwestern Ontario. This is the only tool that makes any attempt to change the basic conditions which permit a buildup and subsequent explosion of budworm populations. The forest manager, therefore, would be well advised to look to silvicultural control rather than relying on chemical and biological factors solely to overcome the spruce budworm problem. Burgar's proposal was implemented six years later with the OMNR draft of silvicultural control of spruce budworm being reviewed by the supervisor of the Northern Forest Research Unit. These guidelines still exist but how much they are followed is anyone's guess.

The last milestone in the North Central Region was the spruce budworm meeting that was held in Thunder Bay on 20 June 1978. Here six research needs were spelled out. To date very little significant progress has been made on any of the six research needs.

Conclusion

The spruce budworm problem in the North Central Region is real but the true impact will not be felt until after the year 2000. The spruce-fir component is and will remain important to the timber, wildlife, parks, lands and other people that are in daily contact with this resource. Industry will continue to use this resource in the future with balsam representing higher ratios in constant blends. Better education of cutters, mill managers and unions will help to improve the acceptance of balsam fir. Future use patterns will restrict the development of vast second-growth stands but will not completely eliminate the species from our forests. Short-term and long-term management actions will both be attempted to reduce the future impact of spruce budworm. Other alternatives will also be examined. The six areas where information is needed to facilitate the management of the spruce budworm problem will need to be monitored much more closely than have been the past suggestions which have barely been implemented.

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IMPACT OF SPRUCE BUDWORM IN THE NORTHWESTERN REGION--

PAST, PRESENT AND FUTURE

The following notes were prepared by a Task Force convened in the Northwestern Region in response to the five theme questions of the Symposium.

A statement representing the Northwestern Region was presented at the Symposium, but is not available for inclusion in these proceedings.

1. HOW IMPORTANT WILL THE SPRUCE-FIR COMPONENT BE?

The Task Force thought that the fir component is not very important in the Northwestern Region, either from the point of view of percentage of fir working group or the percentage of volume of fir in the Region.

To test this general impression, the exact figures (from fir ledgers) for each management unit in the Northwestern Region will be examined. The following will be requested from each unit:

- total productive area of unit
- total production area of unit
- area of fir working group of unit
- total volume all species in unit
- total volume balsam in unit
- total volume spruce in unit

From this an overall regional picture will be put together.

2. WHAT ARE ATTITUDES OF FOREST INDUSTRY TOWARDS FUTURE UTILIZATION OF BALSAM?

Balsam is used as it occurs primarily under rotation ages (management) for other conifer species being utilized. No change is visualized for the future.

3. IN WHAT FOREST SITUATIONS WILL THE BUDWORM BE IMPORTANT?

- where balsam is a prevalent species of the forest to be managed
- where balsam is being managed per se
- where conversion to balsam occurs, either through stand decadence or regeneration
- specialty areas, e.g., seed orchards, research areas
- non-harvested areas (e.g., parks) could serve as source of budworm buildup and subsequent spread to adjoining forest.

4. WHAT MANAGEMENT ACTIONS SHOULD BE TAKEN NOW TO REDUCE FUTURE IMPACT?

- utilization of balsam as encountered, not bypassing any areas with high concentrations of balsam
- earmark potential future problem areas for harvest on priority basis
- policy (program) of conversion of balsam to other species
- special attention needs to be given to budworm-killed balsam with regard to forest fire since these areas present a difficult control problem

5. <u>WHAT INFORMATION IS NEEDED TO FACILITATE MANAGEMENT OF THE SPRUCE BUDWORM PROBLEM?</u>

- maintain existing field technician annual surveys by FIDS Ranger
- determine what proportion of balsam in the stand is necessary for initial budworm buildup into epidemic proportions
- regional survey at periodic intervals (perhaps every 10 years) to pinpoint potential outbreak areas