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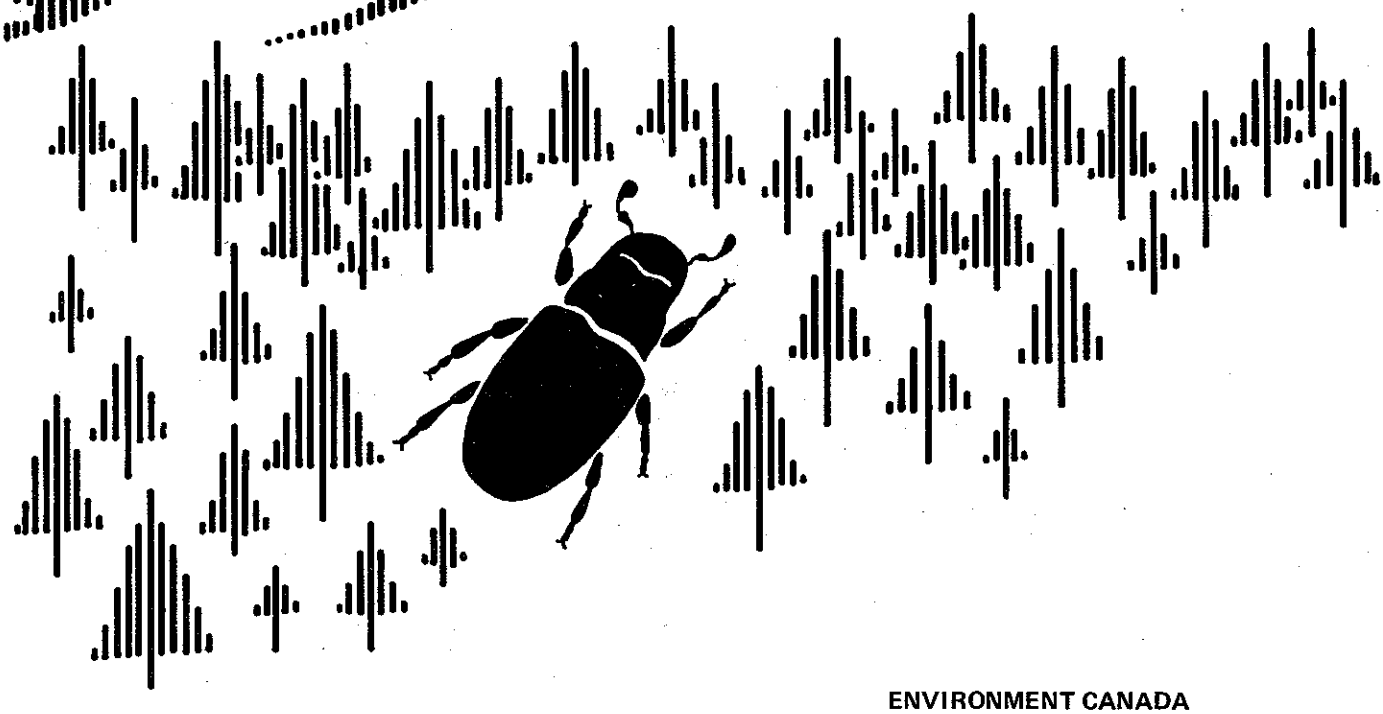
Position Paper on Mountain Pine Beetle Problems With Special Reference to the Rocky Mountain Parks Region



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PREFACE

Infestations of the mountain pine beetle have developed to crisis proportions in western Canada and the adjacent United States in recent years. The problem is particularly severe in the Rocky Mountain regions of Alberta and British Columbia where the beetle infestations present special difficulties to the agencies responsible for federal and provincial parks and recreation areas, watersheds, timber supplies and the other values of the forest resource. The Canadian Forestry Service has had a long history of research and technical service on the mountain pine beetle problem. Much of the in-depth research on the pest that was conducted in the 1950's and 1960's was done in areas that are again being infested or are threatened.

This position paper was prepared to brief senior officials in Environment Canada and other federal and provincial agencies on the magnitude of the current problem, the present state of knowledge, the needs for additional research and a potential action strategy. There is widespread interest and concern about the problem and therefore we are giving the paper wider distribution to assist in the general understanding of the issues involved. The paper was prepared by Drs. L. Safranyik, G.A. Van Sickle and G.H. Manning, Canadian Forestry Service Pacific Forest Research Centre, Victoria, B.C.

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SUMMARY

The mountain pine beetle, a native pest, is the most serious insect enemy of mature pines in western Canada. Infested trees usually begin dying within a few weeks after attack from the combined action of blue stain fungi carried into the tree by the beetles and girdling of the living bark.

Outbreaks by mountain pine beetle have been recorded from southern and central British Columbia at irregular intervals since 1910. However, prior to the current epidemics which started in the late 1960's and early 1970's, only one outbreak was recorded from Alberta (Banff National Park). Currently, infestations in British Columbia occur over 156,000 ha and the 1979 attacks alone killed more than 14 million trees with a gross volume 7.7 million m^3. In Alberta, infestations encompass more than 7 750 ha and recently killed trees total 1.5 million.

The most serious outbreaks in southeastern British Columbia, southwestern Alberta and the adjacent United States threaten pine forests under multiple use and ownership. Pine stands in Glacier National Park, Montana; Waterton National Park, Alberta; Cypress Hills Provincial Park, Alberta-Saskatchewan; and the Akamina-Kishinina Park reserve in British Columbia and adjacent commercial forests have already sustained severe losses. Also, initial infestations are evident in Kootenay, Glacier and Yoho National Parks in British Columbia.

The economic impact of these losses are largely dependent on the effects of epidemics on annual allowable cut, regeneration of affected areas, and increased fire protection costs. The potential economic impact of the 1979 attacks is $700 million in British Columbia.

Cumulative losses and the potential loss of mature, susceptible stands are many times greater. In addition to the socio-economic impacts of epidemics infestations, federal-provincial relations are involved, international concerns are raised and federal interdepartmental action is indicated.

Since mountain pine beetle epidemics tend to persist in place and time, most of the current epidemics will likely continue within their present boundaries for the next 1-2 years, with new spot infestations occurring nearby. The northward spread of infestations, especially in southwestern Alberta, will likely continue. Current epidemics on the White and Palliser River drainage in British Columbia pose a threat, respectively, to the pine stands of Kananaskis Provincial Park and Kootenay National Park, and small infestations in Glacier and Yoho National Parks threaten vast, adjacent pine forests. Based on past history the risk to Jasper National Park appears to be low.

A possible control strategy for the Rocky Mountain parks region involves priorizing stands based on socio-economic values and the probability of successful control. Immediate control action should be considered on infestations in the Cypress Hills and Yoho National Park. Intensive control action, including sanitation salvage and treatment of small infestations, should be considered along the northern boundaries of infestations in southwestern Alberta, the north fork of the White River, the Palliser River and the adjacent Kootenay River Valley in British Columbia. Infestations in Waterton Park should be immediately evaluated. It apears that, due to the heavy infestation in this park, control would likely be unsuccessful and should receive low priority.

The biology and management of the mountain pine beetle has been intensively researched in Canada and the United States. However, more research is needed to better understand the epidemiology of the beetle and to develop effective preventive and curative techniques for reducing losses. Future research should focus on: long and short-range dispersal; control techniques and strategy based on natural factors; synthetic attractants and chemical insecticides; improvements in stand hazard assessment and preventive management practices.

POSITION PAPER ON MOUNTAIN PINE BEETLE PROBLEMS WITH SPECIAL REFERENCE TO THE ROCKY MOUNTAIN PARKS REGION

OBJECTIVES

1. To review past and current mountain pine beetle outbreaks in western Canada, with particular reference to the Rocky Mountain parks region, economic impact, international concerns, and the state of knowledge concerning the biology and management of beetle populations; to develop an action strategy for containing the problem in the Rocky Mountain parks region and to identify gaps in knowledge and needs for future research.

THE PROBLEM

2. The mountain pine beetle, a native pest, is the most serious insect enemy of mature pines in western Canada. The beetles attack trees in mid-summer by chewing through the outer bark and cutting vertical egg galleries (tunnels) in the inner bark region of the main stem. Eggs are laid along the galleries. Upon hatching, the larvae feed circumferentially on the soft tissues of the inner bark and usually overwinter, becoming pupae the spring after attack. Pupae transform into young adult beetles by late spring-early summer and upon maturation, 2-3 weeks later, emerge to attack new trees. Thus, the length of the life cycle is normally 1 year. The beetles carry with them a number of microorganisms, including blue stain fungi which quickly infest and kill living cells in the bark and sapwood. Infested trees usually begin dying within a few weeks from the

action of the blue stain fungi and girdling of the living bark by the beetles.

3. Mountain pine beetle activity has been recorded in British Columbia since 1910, with major outbreaks at irregular intervals in various geographic locations. Outbreaks are persistant; on average, they last 8-9 years and severely deplete the pine component of forests, particularly the larger diameter (> 25 cm) trees. Groups of trees in the younger age classes (40-80 yrs) may also be attacked and killed. Other effects of the mountain pine beetle are a hastening of forest succession, change in age and diameter distribution of the pine component of forests, reduction in aesthetic values and an increase in fire hazard. Each of these effects can force changes in management plans. Additionally, marketing problems may result from the unplanned necessity to cut quickly large volumes of dead timber.

4. Because outbreaks usually develop in mature to overmature forests, especially in lodgepole pine, large reserves of these forests pose a constant hazard in areas climatically favorable for the beetle. Thus "storing" mature/overmature trees on the stump should be discouraged and management plans for parks should consider protection against destructive mountain pine beetle outbreaks.

5. Potentially, the most damaging current outbreaks are found in southeastern British Columbia, southwestern Alberta and the adjacent United States, centered on Glacier National Park, because they threaten pine forests under multiple use and ownership. Many of these forests are at high elevation, growing on environmentally sensitive sites. Pine stands in Glacier National Park, Montana, Waterton Park, Alberta and the Akamina-Kishinina park reserve in British Columbia have already sustained severe losses. During the

past 2 years, there was a marked northward spread of infestations on both sides of the British Columbia/Alberta Divide, posing an immediate threat to pine trees in Kootenay National Park and the new Kananaskis Provincial Park. Also, small infestations reported from Yoho National Park, the first since the 1940s, threatened extensive areas of mature lodgepole pine located within this Park as well as adjacent commercial pine stands. At the same time, an infestation was discovered in the Cypress Hills, indicating unexpected long-range dispersal and/or accidental transport of the beetles in logs or fire wood.

6. Owing to the destructive nature of mountain pine beetle outbreaks, the biology and management of this insect had been intensively researched in Canada (mostly in the Canadian Forestry Service) and the United States. Some of the key publications, which also form the basis of this report, are listed in Attachment 1.

Extent and history of mountain pine beetle outbreaks

7. Historically, in British Columbia, damage has been greatest in the south-central and southeastern interior, the Chilcotin and in an area between Hazelton and Stuart Lake. Prior to the current outbreak in south western Alberta, one outbreak has been reported from Banff National Park.

8. The current outbreaks started during the late 1960s and early 1970s. The majority of these are in lodgepole pine stands. In British Columbia they are found in diverse locations throughout the southern and central interior. By 1980, mountain pine beetle-killed pine trees occurred on more than 150 000 ha throughout the interior of British Columbia, from the international border north to

Williston Lake. In southwestern Alberta, infested trees occurred northward to the latitude of Claresholm, with outlying infestations in the Cypress Hills and in Lethbridge and Medicine Hat. In adjacent Montana, mortality has been extensive on more than 570 000 ha, particularly in Glacier National Park. In the Kamloops, Nelson and Cariboo Forest Regions, the area of forest containing recently killed trees is 1.4 to 2.2 times the total area logged in each region in 1979.

9. Infestations in British Columbia have expanded dramatically since 1974, when a total of only 3 300 ha (Fig. 1, Attachment 2) at 35 scattered locations (see map, Attachment 2) were affected. By 1980, infestations numbered more than 6 000 and encompassed 156 000 ha (see maps, Attachment 2) of mature lodgepole and other pine stands. There was a 22% increase in infested areas in one year. It is estimated that the 1979 attacks alone killed more than 14 million trees in British Columbia, with a gross volume of 7.7 million m^3. The volume of timber on the area under attack was 18.5 billion m^3. In Alberta, infestations encompass more than 7 750 ha, with 1.5 million recently killed trees.

Economic impact

10. The extent to which these volume losses in 1980 are real economic losses depends on several factors: 1) the extent to which these losses create a real decline in Annual Allowable Cut, 2) the extent to which the acreage affected is not adequately regenerated, and 3) the increased costs of fire protection.

11. The first of these may be addressed from a theoretical point of view. If, as Reed[a/] suggests, there is no economically available uncommitted allowable cut in British Columbia, each thousand m^3 decline in allowable cut results in a loss of 1.87 jobs in the logging and sawmilling industries, with an income loss of $35,230 from forest industry employment. Applying a local multiplier of 2, employment loss is 3.74, and dollar loss is $70,460. To this must be added lost revenue from stumpage ($0.30 - $16.16/$m^3$) and tax revenue losses (provincial losses of $3.45/$m^3$, federal losses of $3.42/$m^3$),[b/]) though these might not be incurred in total. On the basis of these values, and the estimated 7.7 million m^3 loss in 1980, the potential economic impact from this single year is estimated to approximate $700 million.

12. The cumulative loss to date, and the potential loss, considering the extent and volume of mature, susceptible stands, are many times greater. As 45% of the infestions mapped presently cover less than 20 ha each and 47% were less than 50 ha (Table 1, Attachment 2), the potential for expansion is considerable. Also, 67% of the area mapped was judged to be lightly or moderately infested (i.e., less than 30% of the susceptible host trees were recently attacked)(Table 1 Attachment 2); consequently, the potential is high for continued intensification of attacks within these stands.

13. The attached maps and area or tree counts (Attachment 2) are based on newly faded trees, most of which were attacked the year preceding

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a/ F.L.C. Reed & Associates Ltd. Aug. 1980. Recent Reductions in the Canadian Timber Base.

b/ Excluding personal income taxes.

the annual aerial survey. Recently killed trees that are still green or trees killed in earlier years are not reflected in the annual data. Results from 42 ground cruises may more clearly indicate the complete condition: in individual stands, from 2 to 52% of the trees were recently killed with red foliage still evident, 2 to 29% were currently attacked and still green, and 1 to 32% of the trees had been dead 2 or more years. In some stands, only 10% of the pine remain unattacked; this despite the fact that very severely affected stands were intentionally not surveyed.

14. The majority of infested stands in Canada are on provincial Crown Land, although major infestations occur in the Akamina-Kishinina park reserve and adjacent Waterton National Park, Cypress Hills Provincial Park and several British Columbia provincial parks, and initial infestations are evident in Kootenay, Glacier and Yoho National Parks.

15. In the Flathead River Valley in British Columbia, a few scattered infested trees were first recorded in 1976, adjacent to the infestation in Glacier National Park, Montana, which began before 1972. By 1980, in this area, more than 75% of the mature lodgepole pine on 15 000 ha had been killed. Similar, but slower, intensification of infestations has occurred since the 1950s in the Elk Creek and White River valleys just south of Kootenay National Park. Infested trees were first observed within the park in 1979, has occurred at five scattered locations in 1980. Within Yoho National Park, about 200 infested trees in three areas were evident during the 1980 aerial surveys and additional numbers will have been attacked but not yet turned color. In the latter cases, the

situation is similar to that during the 1930s following which up to 90% of the mature pine stands over 650 km^2 in Kootenay and Banff National Parks were killed by 1945.

STATE OF KNOWLEDGE

16. General Biology. Much of the general biology of the mountain pine beetle is known. The life cycle and factors affecting its duration and host specificity of the insect are reasonably well understood, with the exception of nutritional requirements for growth and development. However, the insect lives in a complex symbiosis with microorganisms and its host tree. This interaction is a dynamic process, evolving in response to changes in the environment, including man's actions in the practice of forest management and conservation. Thus, there are many aspects of this interaction which are relatively little known, and some where more detailed knowledge is required, as discussed below.

17. Behavior. Flight and dispersal, host finding and colonization behavior of the mountain pine beetle are major gaps in our knowledge. Little is known of the behavior of the beetle after it emerges until it has attacked (entered) a new host tree. Although secondary attractants (volatile chemical substances produced after initial attack) are known and an attractant (pheromone) has been synthesized and formulated for field use, this pheromone is weak in lodgepole pine stands. Only partially understood are the mechanisms involved in the finding of suitable host trees by the beetles and the possible role dispersal plays in this process and in the territorial spread of infestations.

18. Consequently, our knowledge of how to use synthetic pheromones to manage mountain pine beetle populations is limited.

19. Beetle-Host Tree/Stand Interaction. The physical characteristics of lodgepole pine trees likely to be infested by beetles are documented and their role in population ecology is well established. However, susceptibility of trees to colonization by beetles is poorly understood, as are stand characteristics affecting the course of epidemics. Therefore, our ability is poor relative to rating stands for outbreak hazard and subsequent depletion. We have a good understanding of the effects of beetle activity on the structure and dynamics of lodgepole pine stands, except for the roles of wild fires and tree disease in the interaction between beetles and lodgepole pine stands.

20. Interaction between lodgepole pine and the beetle with its associated blue stain fungi is well researched and the symbiotic relation between the fungi and the beetle with respect to host colonization is explained. However, other aspects of nutritional symbiosis are not well understood and, in particular, the possible nutritional role of associated fungi needs further investigation.

21. Natural Control Factors and Agents. The role climate may play in the survival of the beetle, in restricting infestations and in population regulation, is reasonably well known and has been used to do hazard rating in management guidelines. Several indigenous natural control factors and agents have been identified. However, the population biology of predators, parasites and disease agents

has been little studied. Neither the role of these agents in the regulation of beetle populations nor their potential as biocides in inundative programs of direct control are understood. The general role of intraspecific competition for food and space among mountain pine beetle larvae in the regulation of populations has been studied and explained, but little is known of the effects of interspecific competition.

PROBABLE FUTURE COURSE OF THE CURRENT OUTBREAKS IN THE EAST KOOTENAYS OF BRITISH COLUMBIA AND SOUTHWESTERN ALBERTA

22. Barring catastrophes such as extreme unseasonably low temperature, mountain pine beetle epidemics in lodgepole pine tend to persist in place and time. For example, the Elk Creek-White River infestation in the east Kootenays is about 20 years old. Thus, most of the outbreaks are not likely to subside for a few years since there is ample food supply (in terms of mature susceptible trees) available for the beetles. Decline of epidemics due to severe winter temperatures is more likely in some of the Alberta/Saskatchewan infestations than in the east Kootenays of British Columbia.

23. The current epidemics will likely continue within their present boundaries for the next 1-2 years, with spot infestations occurring mainly in stands located within a few km of the current epidemic areas. The northward spread of infestations, observed during the past 2 years, particularly in southwestern Alberta, will likely continue. Current epidemics on the north fork of White River and the Palliser River pose a threat to the pine stands of both Kananaskis Provincial Park and Kootenay National Park. Hazard to

pine trees in Kootenay National Park appears to be higher, since a few groups of infested trees have already been detected inside the southern boundary. Also, the only recorded outbreak in Kootenay and Banff National Parks, between 1931-1943, had its origins in pine stands along the Kootenay River drainage south of Kootenay National Park; many of these areas currently support epidemic infestations. Small infestations in Yoho National Park appear to threaten the extensive areas of mature pine located inside and adjacent to the Park. Epidemics further north in B.C., along the Columbia River-Canoe River drainages, occur a few km from the Alberta border and there is some concern regarding probable spread into Jasper National Park. Even though numerous outbreaks have been recorded from this area in the past, no infestations have developed in Jasper Park. However, weather conditions are generally suitable for supporting beetle populations and there are now extensive areas of mature lodgepole pine in this Park. Therefore, the pine stands inside and adjacent to Jasper National Park should be closely monitored.

RECOMMENDATIONS FOR CONTROL ACTION

24. Experience with direct control of mountain pine beetle epidemics has indicated that, regardless of the control technique used, success in suppressing infestations is dependent on certain conditions:

(1) The initial treatment over the entire area to be protected must be completed within one or two seasons. It is desirable that the control area be isolated from other sources of infestation. When the infested area(s) cannot be treated within the specified

time period, it is generally better to give priority to salvage operations over direct control strategy because control is not likely to be successful. This is partly because during epidemics there is usually a 2-to 5-fold increase in the number of infested trees. Therefore, the increase in infested trees will be greater than the number of trees that could be treated in any year. The other major complicating factors are the territorial expansion of infestations and the inefficiency in finding infested trees.

(2) Control work must continue as long as there is evidence of beetle activity as indicated by yearly stand surveillance. Surveillance must be performed to prescribed specifications.

(3) Success in direct control is dependent upon the thoroughness with which treatments are applied and the thoroughness of surveillance. The object is to treat every infested tree in the control area.

(4) The most satisfactory long-term management of the mountain pine beetle lies in reducing stand hazard. In light of our current knowledge, this could be achieved by planned harvesting of mature stands and regeneration in a mosaic of age classes, formation of mixed stands, or conversion to the successional forest type. New lodgepole pine stands should be harvested just before they reach susceptible age (about 80 years) because, thereafter, the risk of loss from mountain pine beetle infestations might outweigh the possible benefit from growing trees on a longer rotation.

25. Any, or a combination, of the following direct control techniques can be used:

(1) Large infestations

Sanitation salvage logging: This implies treatment of infested stumps and infested host material at landings, and millsites (e.g., utilization before flight, water sprinkling, ponding) and restriction on transport of infested materials, especially during the flight period of the beetle.

(2) Small infestations

(a) Use of pheromone-baited trap trees with, or without, pesticide treatment of the lower stem. When trap trees are not treated with pesticides, they must be treated after beetle attack by one of the techniques listed below.

(b) Treatment of individual currently infested trees and stumps:

i) with pesticides (sapwood injection or penetrating sprays); however, limited registrations of pesticides are major constraints

ii) burning (standing single tree burning or fell, pile and burn)

iii) bark peeling and burning of infested bark

iv) removal by hot-logging (see 1 above).

(3) Preventive treatments for trees

(a) Pesticides in water formulation, operationally proven.

(b) Pine oil - This by product of the pulping process has proven very effective experimentally in preventing attacks by three species of major bark beetles but its operational effectiveness has not been tested.

In addition to experience with using any of the above given direct control techniques, experience is also required in finding and recognizing the signs and symptoms of mountain pine beetles' presence in trees in order to mark these for treatment.

Control Strategy for the Rocky Mountain Park Region

26. Priorities for control action are based on the hazard to high value stands and the probability of success. Hazard to stands includes the susceptibility of the stands to mountain pine beetle infestation (based on age/size criteria) and the proximity of current infestations. Probability of success depends upon the isolation of stands being treated and the potential for severe climatic factors limiting damage in the next few years.

27. Based on present knowledge and intensive annual surveys, control strategy appears to be as follows:

(1) Lodgepole pine stands should be evaluated in terms of their susceptibility to mountain pine beetles and the apparent hazard from known infestations. Whenever control action is planned, it should be initiated immediately and continued until evidence of infestation disappears.

(2) The infestations in the Cypress Hills and Yoho National Park should be considered for immediate direct control action.

(3) The northern boundaries of the infestations in southwestern Alberta, the north fork of the White River and the Palliser River and the adjacent Kootenay River Valley should be considered for intensive control action, including sanitation salvage, and treatment of small infestations to the north of the boundaries, including those in Kootenay National Park and any that may be found in Kananaskis Provincial Park.

(4) The infestation in Waterton Park should be evaluated in the light of the heavy infestations there and in the surrounding area. It would appear that control action would likely be unsuccessful and that this area should receive a low priority.

(5) The threat to Jasper National Park, based on past history, appears to be low and control action should be limited to intensive surveillance until evidence of infestation occurs.

FUTURE RESEARCH NEEDS

28. Future research should focus on: long- and short-range spread (dispersal) of the beetle; control techniques and strategy based on natural factors, synthetic attractants and chemical insecticides; improvements in stand hazard assessment, and preventive management procedures.

(1) Dispersal: To date, knowledge of dispersal and its role in the spread of infestations is fragmentary. There is some scientific evidence indicating long-range dispersal of mountain pine beetle, but the magnitude, mechanisms and significance are unknown. Understanding of long-range dispersal characteristics would allow prediction of the likely mass-movement of beetles

and, therefore, initiation of stand surveillance and preparation for potential control action, and would provide the background for the feasibility of control through interception, decoy and other disruptive treatments of destroying beetles (e.g., by chemicals and other means such as microwaves).

(2) Host finding and colonization: Occurrence of short range dispersal is well established, but we cannot effectively predict the local expansion and spread of small infestations, mainly because we do not understand how beetles find susceptible trees and the effective range of their natural attractants. Such knowledge would allow an increase in efficiency of direct control techniques, including sanitation salvage logging.

(3) Attractants: (Pheromones) Improvements in the currently known pheromone complex of mountain pine beetle are needed to increase the efficiency of direct control techniques based on such chemicals and to help understand the nature of host tree-bark beetle interaction, especially colonization.

(4) Natural factors: Emphasis should be placed on understanding the effects of host tree resistance, stand factors and cultural practices on tree and stand susceptibility. Such work is basic to development of a stand hazard rating system and preventive stand management, which is the most satisfactory long-term approach to reducing losses from the mountain pine beetle. In researching biological control agents and their potential to prevent and/or control infestations, emphasis should be given to augmentation of indigenous agents.

(5) Chemical pesticides: Treatment of individual trees with chemicals alone or in combination with pheromones is an integral part of direct strategy against the mountain pine beetle. Owing to the continuous review of pesticide safety, changes in availability of suitable pesticides and anticipated adaptation and resistance, there is a need for testing alternative products.

FEDERAL-PROVINCIAL RELATIONS CONSIDERATIONS

29. The Canadian Forestry Service works closely with its British Columbia and Alberta counterparts to provide surveillance of the spread of the mountain pine beetle, to develop effective means of control and to provide such information to the provincial forest services and other interested parties.

30. As well as attacking stands on provincial-crown land, the mountain pine beetle is attacking stands in National Parks. The provincial forestry services are concerned that infestations might spread from these parks onto adjacent provincial-crown lands. In general, it is the policy of Parks Canada not to control insect infestations, as they are considered part of the natural system. However, control is not prohibited by the National Parks Act. Parks Canada has an obligation to take effective measures to minimize risk of spread to adjacent provincial-crown lands, just as it does for forest fires.

INTERNATIONAL CONCERNS

31. The outbreak of mountain pine beetle along the British Columbia-Alberta border was first recognized in 1976 adjacent to the

infestation in Glacier National Park, Montana, which began before 1972. Concerns have been expressed that migration of beetles across the International Border intensified and hastened the damage.

32. Efforts by the Province of British Columbia to salvage beetle-killed timber in the Akamina-Kishinina drainage led to queries by the United States concerning potential adverse impacts on transborder water quality, scenic quality and wildlife habitat. It is likely that these concerns would be expressed again in the face of increased salvage efforts, and could involve investigations by the International Joint Council.

INTERDEPARTMENTAL CONCERNS

33. At present, no other federal departments are involved. However, the European Economic Community is concerned over the spread of mountain pine beetle to Europe and has instituted regulations prohibiting import of "waney" lumber. This may bring the Departments of Industry, Trade and Commerce and External Affairs into the picture, as could transborder environmental concerns with the United States.

Attachment 1.

SELECTED BIBLIOGRAPHY OF MOUNTAIN PINE BEETLE PROBLEMS AND MANAGEMENT

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Composition board from standing dead white pine and dead lodgepole pine. 1976. Proceedings of the 10th Wash. State Univ., Symposium on Particle Board, March 1976, Pullman, Wash.

Attachment 2

TABLE 1. SELECTED STATISTICS ON MOUNTAIN PINE BEETLE INFESTATIONS IN BRITISH COLUMBIA IN 1980.

	Provincial Forest Region:					
	Nelson	Kamloops	Cariboo	Prince George	Prince Rupert	Vancouver
Proportional distribution of the 6300 infestations by region - %	57	17	23	1	2	0.1
Proportional distribution of the 156 000 ha in which mortality occurred, based on aerial surveys - %	21	24	40	5	9	1

Distribution of the number of infestations by size class:

Initial (<20 ha)	Small (21-50 ha)	Medium (51-250)	Large (251-1000 ha)	Extreme (>1000 ha)
45%	47%	7%	1%	0.1%

Distribution of affected forest area by proportion of susceptible trees killed, based on the 1980 aerial survey:

Light (1-5%)	Moderate (6-30%)	Severe (>30%)
30%	37%	33%

Attachment 2

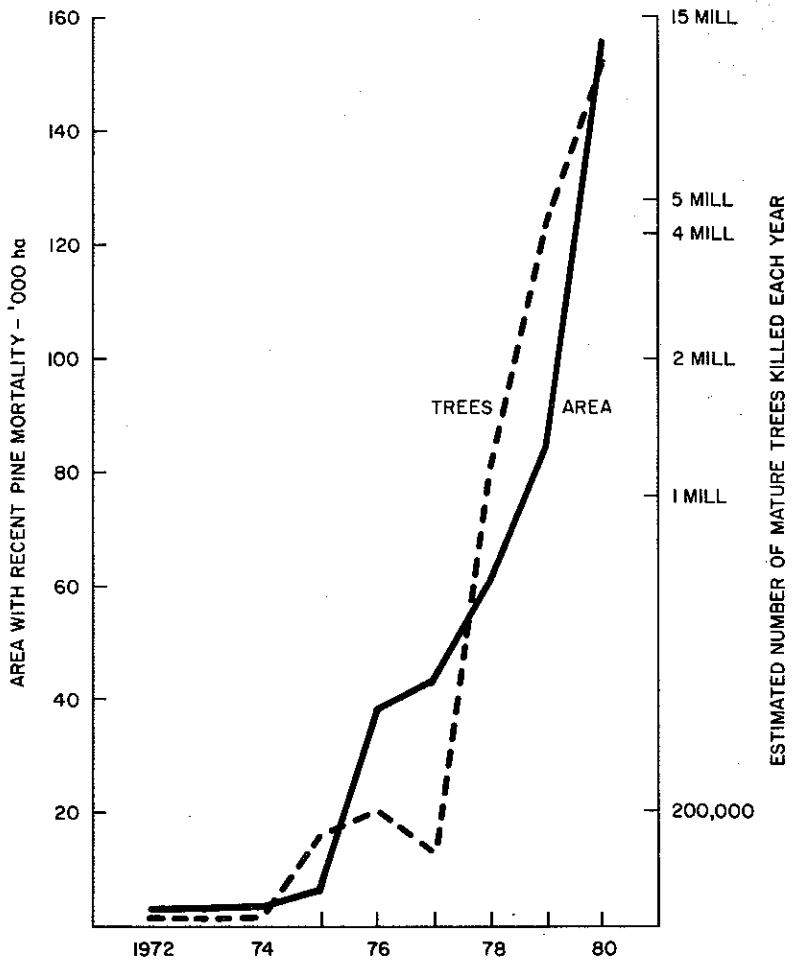
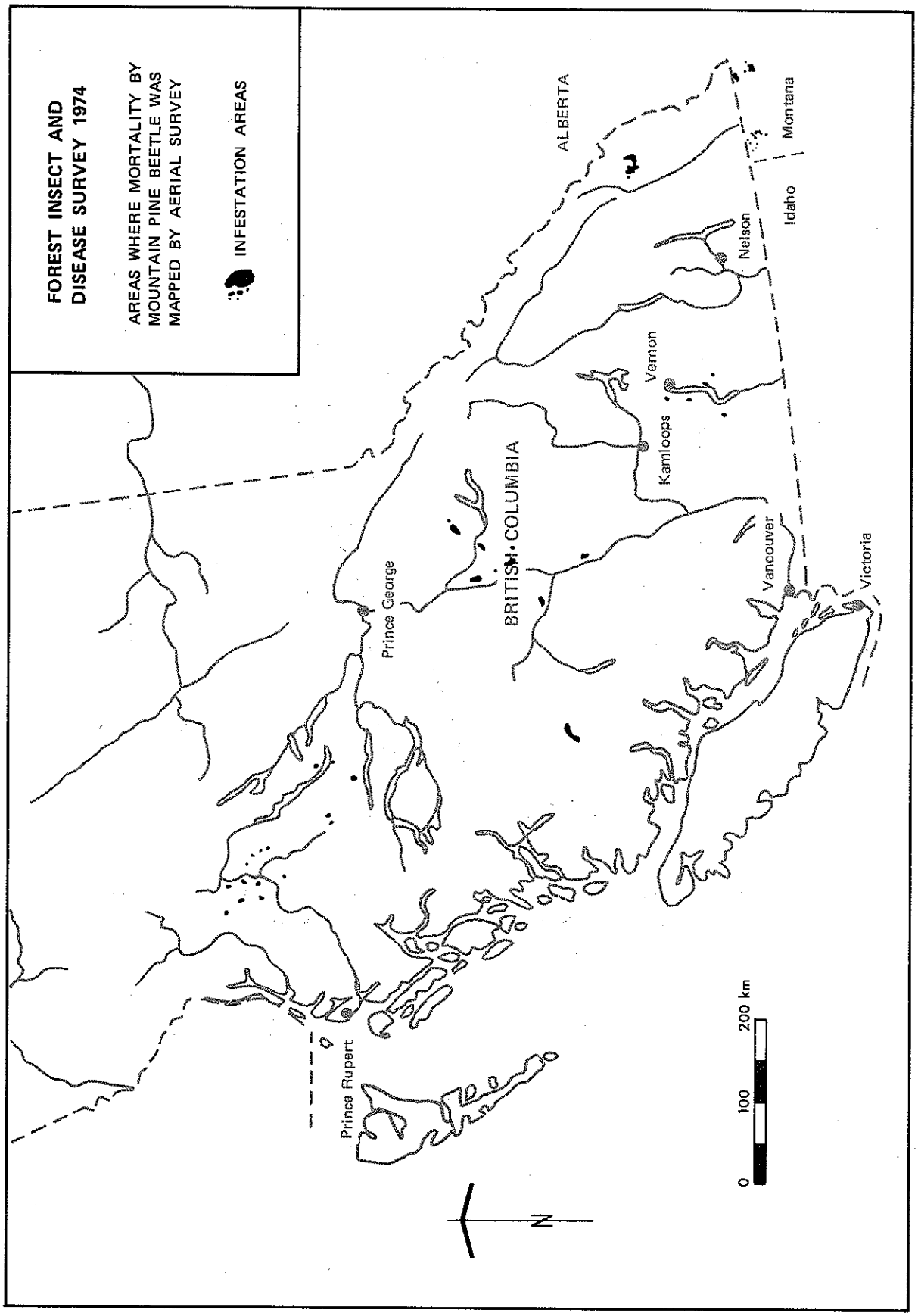


Figure 1. Number and area of recent pine tree mortality by mountain pine beetle in British Columbia based on annual aerial surveys.

Attachment 2



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