SPRUCE BUDWORM IMPACT STUDIES IN SPRUCE FORESTS OF NORTHERN ALBERTA

By

H.F. Cerezke

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Northern Forest Research Centre
Canadian Forestry Service
Environment Canada
5320 - 122 Street Edmonton, Alberta, Canada

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ABSTRACT

Populations and damage by the spruce budworm, *Choristoneura fumiferana* (Clem.) were studied in several white spruce stands, *Picea glauca* (Moench) Voss, in northern Alberta and near Fort Smith, Northwest Territories. Relative abundance of young instar larvae is described to illustrate their distribution and bud damage within crowns of white spruce. Radial growth profiles of budworm-damaged and non-damaged trees are presented to illustrate growth differences within stems, between attacked and non-attacked trees and between trees of different age. Seasonal precipitation data are examined in an attempt to determine whether periods of low annual increment due to budworm defoliation can be separated from periods of relative drought. Data are presented that describe the development of dead tree tops in budworm-infested forests in relation to tree height class.

INTRODUCTION

Outbreaks of the spruce budworm, *Choristoneura fumiferana* (Clem.), in the Northwest Territories and northern Alberta were first reported in 1954 and have since been monitored annually by aerial and ground surveys (1). Most of the outbreaks have occurred in mature and overmature stands of white spruce, *Picea glauca* (Moench) Voss., along or adjacent to main river valleys (1). Although the western limit of balsam fir, *Abies balsamea* (L.) Mill., extends throughout much of northern Alberta, this tree species plays no significant role in the development of budworm outbreaks as in eastern Canada (20).

Annual aerial and ground surveys have provided a general historical account of the spread and intensity of budworm outbreaks since 1954, but comparatively little work has been done toward describing the impact of the budworm on northern spruce forests. In providing statements on impact assessment and hazard prediction, heavy reliance has been placed upon comprehensive studies made elsewhere in eastern Canada and in the United States (3, 4, 5, 7, 8, 9, 19, 20, 21, 25, 26, 27).

In Alberta, Brown (10) reported averages of 6.3% and 22.9% for tree mortality and dead tree tops, respectively, due to budworm defoliation. In his study, budworm populations had persisted for at least 10 years prior to the survey although annual defoliation had fluctuated widely during this period. In a similar study within the same outbreak area, Stevenson (23) provided data on accumulated tree mortality and tree top kill in two selected areas where budworm damage had been most intense. He reported mortality of dominant and co-domiant trees as high as 39%, top kill up to 49%, and estimated volume losses of merchantable timber between 10% and 50%. Radial increment profiles of white spruce from the outbreak area suggested that damaging budworm populations may have been present since about 1938. In addition, plots established in mature white spruce along the Mackenzie River in the Northwest Territories showed 31% to 57% tree mortality and 25% to 68% top kill (1).

Further information on the impact of the spruce budworm in northern spruce forests is presented herein. This report summarizes data on the distribution of young budworm larvae in spruce crowns and their feeding damage, and examines patterns of radial growth and tree top kill resulting from several years of accumulated defoliation.

METHODS AND MATERIALS

Eight locations, representing a variety of white spruce stand conditions were selected for study in northern Alberta and near Fort Smith, Northwest Territories. These locations are numerically coded for reference in the text and are shown in Fig. 1.

Bud Damage Pattern and Spruce Budworm Populations

Spruce foliage samples were collected in early June, 1971, at locations IV and V (Fig. 1) to examine the distribution and relative abundance of second to fourth instar spruce budworm larvae within spruce crowns. The stands at these locations were semi-mature (Table 1) and predominantly white spruce. Nine co-dominant trees were selected, 5 from location IV and 4 from location V (Table 1). Each tree was felled and the live crown was divided into four equal height levels, A, B, C, and D (A being uppermost). Four 46-cm (18-inch) branch tips were removed from each level. All live buds were counted on each branch sample and examined for budworm larvae and damage. Spruce budworm populations at these two locations have been at low levels since 1969; the budworm populations were expressed as a percentage of the live buds damaged.

At another location, VI (near Fort McMurray), a collection of 46-cm branch tips was made from mature white spruce in a mixed spruce-aspen stand in early 1973, to examine cumulative effects of defoliation injury and overwintering larval abundance. This stand had supported high budworm populations for at least three years prior to sampling. Two branch tips were clipped with pole pruners from the lower third of 26 tree crowns. Total numbers of buds were counted on each branch prior to placing them in containers to rear out any second instar larvae present. The tally of live buds included all terminal, lateral, and internodal buds, although not all of these may have produced new shoot growth in 1973. All buds, however, were considered potential spring feeding sites of the overwintering larvae. The larval population was expressed as numbers of larvae per branch tip and as a percentage of the potential number of buds which could have been damaged or destroyed.

Radial Growth on Budworm-damaged and Non-damaged Spruce

Profiles of annual radial increment were obtained from five stand locations (I, II, III, IV, and VII) represented by three stands (I, II, and III) having no recorded or recognizable budworm feeding history, and two locations (IV and VII) which had a history of budworm feeding (Fig. 1). Spruce trees at locations I, II, and III represented different age classes: stand I was semi-mature, even-aged (83 yrs old) white spruce with scattered trembling aspen, *Populus tremuloides* Michx.; stands II (44 yrs old) and III (30 yrs old) were immature and consisted of trembling aspen in the overstory and white spruce in the understory. The stand at location IV was similar (83 yrs old) to that at location I, while the stand at location VII was mixed spruce-aspen (52 yrs old).

Ten trees were sampled at each of locations I, II, and III, 11 trees at location IV, and 2 trees at location VII. Two stem discs were cut from the bole of each tree, one at breast height (B.H.) level, the other from the top-third of live crown. The top-third level was chosen because it is known to be more sensitive to defoliation damage, and thus reflects more strongly and accurately the growth reduction than at the B.H. level (8, 9, 15, 16, 19, 21, 26). The discs were sanded smooth, marked with four radii at right angles, and each increment along the four radii was measured to the nearest 0.01 mm with an Addo-X machine. An average growth profile was calculated for each stem level at each location. The paired growth profiles for B.H. and top-third levels were then plotted together to illustrate characteristic differences in growth pattern within trees, between B.H. and top-third levels, between attacked and non-attacked trees, and between trees of different age.

The interpretation of radial growth patterns for delineating periods of reduced growth due to budworm defoliation is complicated by temperature and precipitation influences. In northern Alberta, which has a dry and cool climate (11, 13), soil moisture is believed to be the main limiting factor to growth of white spruce (24). The relationship between radial growth and seasonal precipitation was therefore examined using data from stand locations I and IV, to determine whether periods of low annual increment due to defoliation could be separated from periods of relative drought. Rainfall records at Fort Vermilion (Fig. 1), the nearest meteorological station, were used to compute 5-year running averages of precipitation for the period May 1 to August 31. These were plotted against the mid-year taken in the summation.

Development of Dead Tree Tops in Budworm-infested Stands

Field plots were delineated in three budworm damaged semi-mature to mature white spruce stands located, respectively, at IV, VI, and VIII (Fig. 1). White spruce was the dominant species in all plot locations. At location VIII, nine 0.10-acre (0.04 ha) plots were established in which all white spruce were tallied for dead tops and measured for height (in feet). All spruce in two fifth-acre plots at locations IV and VI, were similarly tallied. Dead-top incidence was related to tree height class to illustrate the pattern of this injury in stands of different structure.

RESULTS AND DISCUSSION

Bud Damage Pattern and Spruce Budworm Populations

Populations of the spruce budworm at locations IV and V, as expressed as percentage of buds damaged, suggested that the young larvae were distributed throughout the crown in proportion to number of buds (Table 2). The percentage of buds damaged ranged between 7.8% and 14.9% for all crown levels in the two tree groups. Highest numbers of larvae were recorded in level A, which also had the highest numbers of live buds per 46-cm branch tip. The numbers of buds in the different levels of crown at the two locations were similar to that on similar sized trees which had no spruce budworm damage (12). Crown exposure, however, would no doubt influence the distribution of bud numbers down the crown.

Second instar spruce budworm larvae were reared from the 52 branch samples from location VI and produced an average of 16.4 larvae per branch tip or 16.3% potential of buds damaged or destroyed, assuming one larva per bud. Observations of buds containing second and third instar larvae have indicated one larva per infested bud in most cases. When entering buds, most larvae chewed entry holes between half to three-quarters of the way from the bud base. Little or no evidence of needle-mining by second instar larvae was observed at two locations as had been reported by other workers (2, 17, 18). This feeding behavior, however, may become prevalent at high larval densities or when terminal buds are destroyed during the previous season. The branch tips had an average of 101 (S.E. $\pm$ 5.7) buds per tip, which is 2-3 times more than were produced on the lower third of crowns at locations IV and V (Table 2), and from another study on undefoliated trees (12). This increase in buds probably resulted from accumulated defoliation which was moderate-to-severe for at least three years. Similar development of epicormic shoots has been reported on balsam fir and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) as a result of heavy larval feeding for several consecutive years (6, 22). There is evidence that continued stimulation of epicormic shoots can result in a dense three-dimentional branch form, characteristic of mature spruce crowns in several northern budworm-infested stands.

Batzer (6) suggested that the proliferation and subsequent elongation of shoots on balsam fir results in some compensation for leaf area lost to budworm feeding. The ability to produce epicormic shoots, however, appears to be more strongly developed in white spruce since this species suffers less initial and overall growth reduction and mortality during outbreaks than does balsam fir (5, 7, 9, 20, 25). In addition, the greater resistance of spruce has been partly attributed to its later date of spring flushing and because its shoots grow longer and thus provide more food per budworm larva (20). Proliferation of epicormic shoots, on the other hand, may help to maintain budworm populations in white spruce by providing more protection and spring feeding sites.

Radial Growth on Budworm-damaged and Non-damaged Spruce

Radial increment profiles from B.H. and top-third of crown levels are plotted for trees from locations I, II, III, IV, and VII (Figs. 2a to 2e). In general, growth patterns in the upper third of crowns follow closely that at B.H. levels but tend to fluctuate more widely and have characteristically more growth (Figs. 2a to 2e). Growth patterns show a marked reduction in the top-third of the crown for trees from locations IV and VII where spruce budworm outbreaks occurred (Figs. 2d and 2e), compared to those patterns from trees sampled at locations I, II, and III. For example, at location IV (Fig. 2d), the reduction begins in 1957 and about 1960 at location VII (Fig. 2e). This reduction in the upper crown is attributed to severe defoliation by the spruce budworm since this level reflects more exactly the time and degree of defoliation compared to B.H. level (8, 9). Moreover, severe spruce budworm outbreaks were recorded in the same region in 1960 (1). Blais (9) also reported suppression of radial growth at B.H. in white spruce commencing 2-4 years after the first year of severe defoliation, and that this suppression may continue for some years after defoliation has stopped.

The pattern of growth in the upper crown of trees at location VII (Fig. 2e) also suggests that budworm populations remained high for several consecutive years after 1960, whereas at location IV

(Fig. 2d) there was a brief recovery period from 1961 to 1962, followed by a period of intensified damage. This was verified to some extent by records of the Forest Insect and Disease Survey (1). While no survey records are available for location IV until 1965, severe outbreaks of budworm were described to the southeast along the Wabasca River and to the northwest and north along the Liard and Mackenzie rivers as early as 1954 and 1955 (1). Spruce budworm larvae were also collected at Fort Vermilion and Dunvegan in 1956. Therefore, 1957 is a reasonable date to consider for the start of the budworm outbreak at location IV. Survey records further indicate that budworm populations remained high at location IV from 1965 to 1967, then collapsed in 1968 and 1969 (1).

At location VII, survey records (1) first report a major outbreak of the budworm along the Slave River north of Fort Smith in 1956. This outbreak continued to advance southward, and by 1961 moderate-to-severe defoliation was extensive between Fort Smith and Great Slave Lake. Consequently, growth profile data indicate a beginning of severe defoliation at location IV in 1960, and this agrees well with survey records (1).

An interpretation of Figs. 2a to 2e suggests that radial increment from the breast height and top-third crown levels, when plotted separately, do not provide a clear separation of budworm outbreak periods. When plotted together, however, these measurements provide comparative growth curves which indicate the start and duration of severe defoliation. Periods of reduced radial growth increment measured at breast height may be more indicative of low moisture availability than of spruce budworm damage. Fig. 3 provides a comparison of radial growth pattern at breast height for stand locations I and IV and seasonal precipitation during the period 1933 to 1969. A comparison of the graphs for location I, which had no history of budworm feeding, and for location IV, which had a history of budworm feeding, provides no indication of growth loss due to defoliation. Rather, the data suggest that, in northern Alberta, precipitation during the growing season strongly influences the ring width of white spruce and should be taken into account when interpreting growth reduction due to defoliation.

Development of Dead Tree Tops in Budworm-infested Stands

The spruce plots at locations IV, VI, and VIII all contained semi-mature and mature trees in the overstory but represent different stand structures (Figs. 4, 5, 6). For example, few height classes are represented in Fig. 4a while in Fig. 5a, advanced regeneration is well represented due to selective logging several years earlier. The relationship between incidence of dead tops and height class, however, is similar in all stands; trees in the lower crown positions (e.g., intermediate and suppressed trees) suffer more severely than those in the upper canopy levels. This is mainly due to large numbers of larvae which drop down from adjacent larger trees. Small crowns of understory trees are often sparsely foliated and are frequently under competitive stress; these conditions enhance the feeding impact of budworm larvae and result in increased top-killing and mortality of understory trees. In Figs. 4b, 5b, and 6b, the main factors that appear to influence the level and slope of the curves are stand density and the duration and intensity of budworm defoliation.

Dead tops on the understory trees, including regeneration spruce, generally occur after the second year of severe defoliation, while tree mortality may follow after the fifth consecutive year. In contrast, dead tops and tree mortality of overstory trees may begin after three and 6-8 years, respectively, of severe defoliation (5, 7, 8, 14, 27). No data are available on the progression of spruce mortality in relation to tree height class with prolongation of an outbreak, but it is expected to progress in a similar manner to that of dead tops.

The history of the budworm outbreak in each stand represented in Figs. 4, 5, and 6 is only partially known, but high populations have persisted in each stand for at least three years. While merchantable size trees in these stands appear to have suffered the least height growth reduction, radial growth reduction has probably accumulated on all trees. The overstory white spruce (ie., crop trees) are therefore less vulnerable to the effects of spruce budworm feeding than are the understory spruce. This fact could be taken into account when prescribing control recommendations in mature and over-mature budworm infested timber. Decisions concerning suppression of budworm populations can be made during the first two to three years of severe infestation since little mortality and growth reduction will occur until after the third year of outbreak (5). This points out the need for maintaining annual surveillance of budworm outbreaks by aerial and ground surveys. During outbreaks of the budworm, curves similar to those in Figs. 4b, 5b, and 6b may be derived from surveys to provide a tool for predicting budworm hazard and for guiding management decisions in commercial spruce forests.

LITERATURE CITED

1. Anonymous. 1954-1975. Annual reports of the Forest Insect and Disease Survey. Environment Canada, Can. For. Serv., Ottawa.

2. Atwood, C.E. 1944. The feeding habits of young spruce budworm larvae. Can. Entomol. 76 : 64-66.

3. Batzer, H.O. 1967. Spruce budworm defoliation is reduced most by commercial clearcutting. Research Note NC-36. U.S. Forest Service, North Central Expt. Stn., St. Paul, Minnesota: 4 p.

4. Batzer, H.O. 1969. Forest character and vulnerability of balsam fir to spruce budworm in Minnesota. Forest Science 15: 17-25.

5. Batzer, H.O. 1973a. Net effect of spruce budworm defoliation on mortality and growth of balsam fir. J. Forestry 71: 34-37.

6. Batzer, H.O. 1973b. Defoliation by the spruce budworm stimulates epicormic shoots on balsam fir. Environ. Entomol. 2: 727-728.

7. Belyea, R.M. 1952. Death and deterioration of balsam fir weakened by spruce budworm defoliation in Ontario. Part II. An assessment of the role of associated insect species in the death of severely weakened trees. J. Forestry 50: 729-738.

8. Blais, J.R. 1958. Effects of defoliation by spruce budworm (*Choristoneura fumiferana* (Clem.)) on radial growth at breast height of balsam fir (*Abies balsamea* (L.) Mill.) and white spruce (*Picea glauca* (Moench) Voss.). For. Chron. 34: 39-47.

9. Blais, J.R. 1962. Collection and analysis of radial-growth data from trees for evidence of past spruce budworm outbreaks. For. Chron. 38: 474-484.

10. Brown, C.E. 1962. Damage to spruce by the spruce budworm. Can. Dept. For., Bi-Mon. Prog. Rep. 19: 2-3.

11. Carder, A.C.; Siemens, B. 1971. Climate of the Lower Peace River region. Can. Dept. Agri., Publ. 1434; 22 p.

12. Cerezke, H.F. 1977. Variation in shoot and needle growth patterns on 46-cm branch tips of healthy white spruce. Can. Dept. Fish. and Environ. Bi-mon. Res. Notes 33: 18-19.

13. Edmonds, T.C.; Anderson, C.H. 1960. Note on climatic trends in the Lower Peace River region of northern Alberta. Can. J. Plant Science 40: 204-206.

14. Elliott, K.R. 1960. A history of recent infestations of the spruce budworm in northwestern Ontario, and an estimate of resultant timber losses. For. Chron. 36: 61-82.

15. Koerber, T.W.; Wickman, B.E. 1970. Use of tree-ring measurements to evaluate impact of insect defoliation. *In*: Tree-ring analysis with special reference to Northwest America, J.H.G. Smith and J. Worrall (Editors). Univ. British Columbia, Faculty of Forestry Bull. No. 7: 125 pp.

16. Kulman, H.M. 1971. Effects of insect defoliation on growth and mortality of trees. Annu. Rev. Ent. 16: 289-324.

17. McGugan, B.M. 1954. Needle-mining habits and larval instars of the spruce budworm. Can. Entomol. 86: 439-454.

18. McKnight, M.E. 1968a. A literature review of the spruce, western, and 2-year-cycle budworms. U.S.D.A. For. Serv., Rocky Mountain For. & Range Expt. Stn. Res. paper RM-44; 35 pp.

19. McLintock, T.F. 1955. How damage to balsam fir develops after a spruce budworm epidemic. U.S. For. Serv., Northeastern For. Expt. Stn. Paper No. 75: 18 pp.

20. Morris, R.F. (Editor) 1963. The dynamics of epidemic spruce budworm populations. Memoirs Entomol. Soc. Can. No. 31: 333 pp.

21. Mott, D.G.; Nairn, L.D.; Cook, J.A. 1957. Radial growth in forest trees and effects of insect defoliation. For. Sci. 3: 286-304.

22. Silver, G.T. 1960. Notes on a spruce budworm infestation in British Columbia. For. Chron. 36: 362-374.

23. Stevenson, R.E. 1970. The spruce budworm in northern Alberta: with emphasis on the Wabasca outbreak. Canadian For. Serv., Edmonton. Internal Rep. A-28; 13 pp.

24. Stockton, C.W.; Fritts, H.C. 1971. An empirical reconstruction of water levels for the Lake Athabasca (1810-1967) by analysis of tree rings. *In*: Hydrological Investigations, Peace-Athabasca Delta Project, Sec. P., Vol. 1, 55 pp, 1973.

25. Turner, K.B. 1952. The relation of mortality of balsam fir, *Abies balsamea* (L.) Mill., caused by the spruce budworm, *Choristoneura fumiferana* (Clem.), to forest composition in the Algoma Forest of Ontario. Can. Dept. Agr., Publ. 875: 107 pp.

26. Williams Jr., C.B. 1967. Spruce budworm damage symptoms related to radial growth of grand fir, Douglas-fir, and Engelmann spruce. For. Sci. 13: 274-285.

27. Williams Jr., C.B.; Shead, P.J.; Walton, G.S. 1971. Population density of western spruce budworm as related to stand characteristics in the BItterroot National Forest. U.S.D.A. For. Serv., Pacific Southwest For. & Range Expt. Stn. Res. Paper PSW-72: 8 pp.

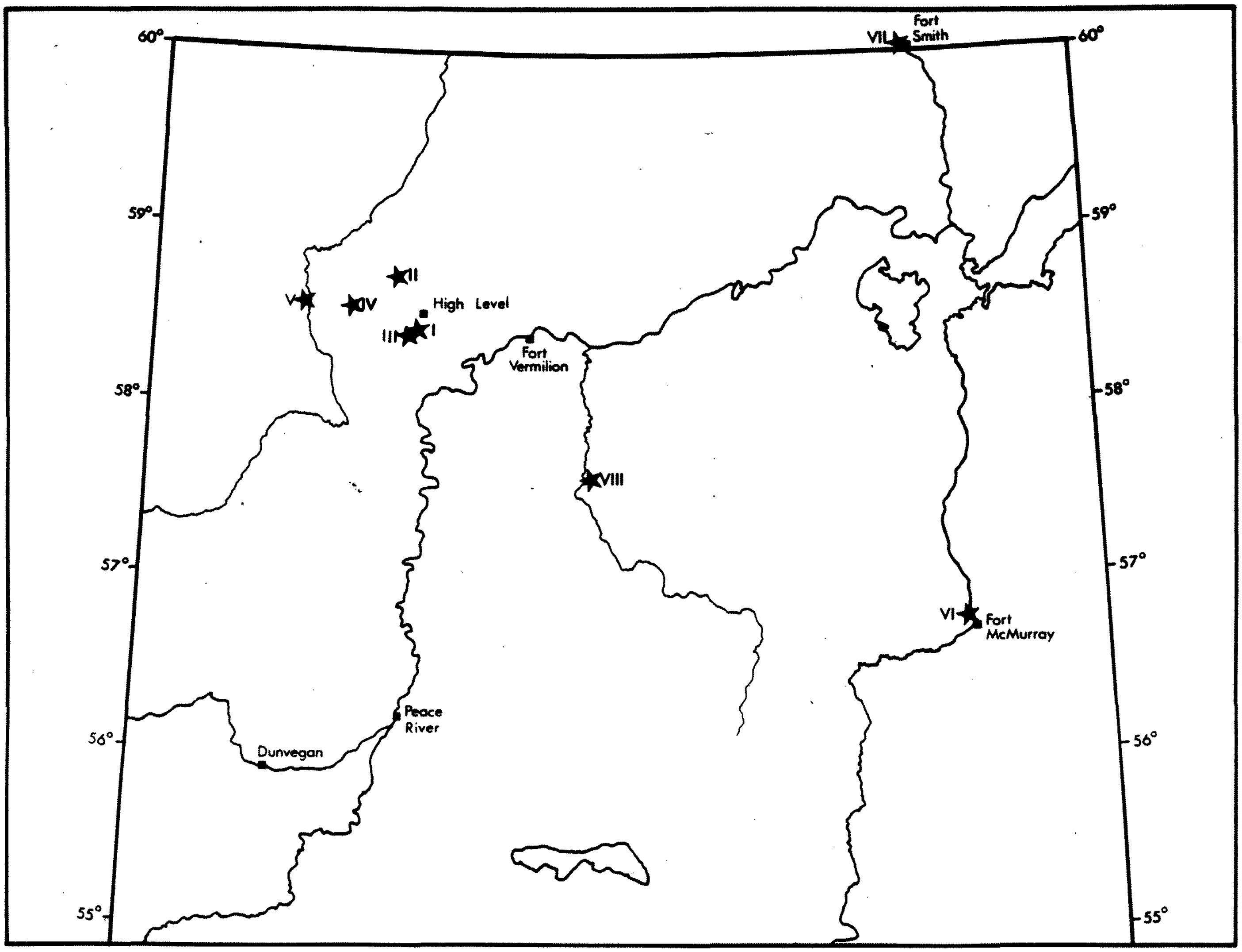
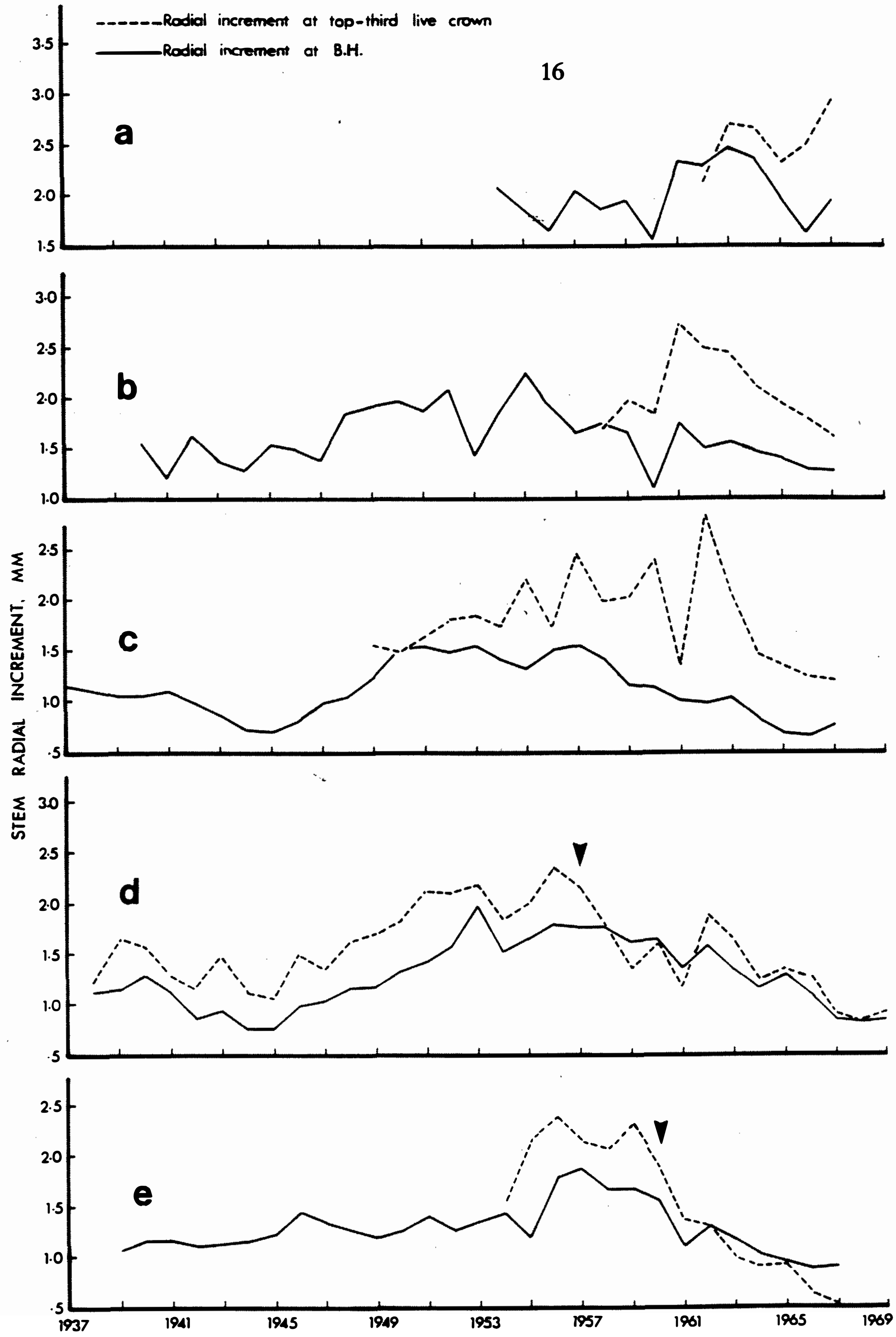


Fig. 1. Map of northern Alberta and southern Northwest Territories showing locations (I to VIII) of study sites in natural white spruce stands.



Figs. 2a to 2e. Radial growth profiles from breast height (B.H.) and top-third levels of stems of white spruce sampled at several locations (see Fig. 1 and Table 1 for locations and stand descriptions) in northern Alberta and southern Northwest Territories. Graphs 2a, b, and c summarize data from locations II, III, and I, respectively, and depict radial growth patterns on trees with no record of previous spruce budworm feeding. Graphs 2d and e summarize data from locations IV and VII, respectively, and depict radial growth patterns on trees with a known history of spruce budworm feeding. Arrows in 2d and e indicate probable year of first severe defoliation.

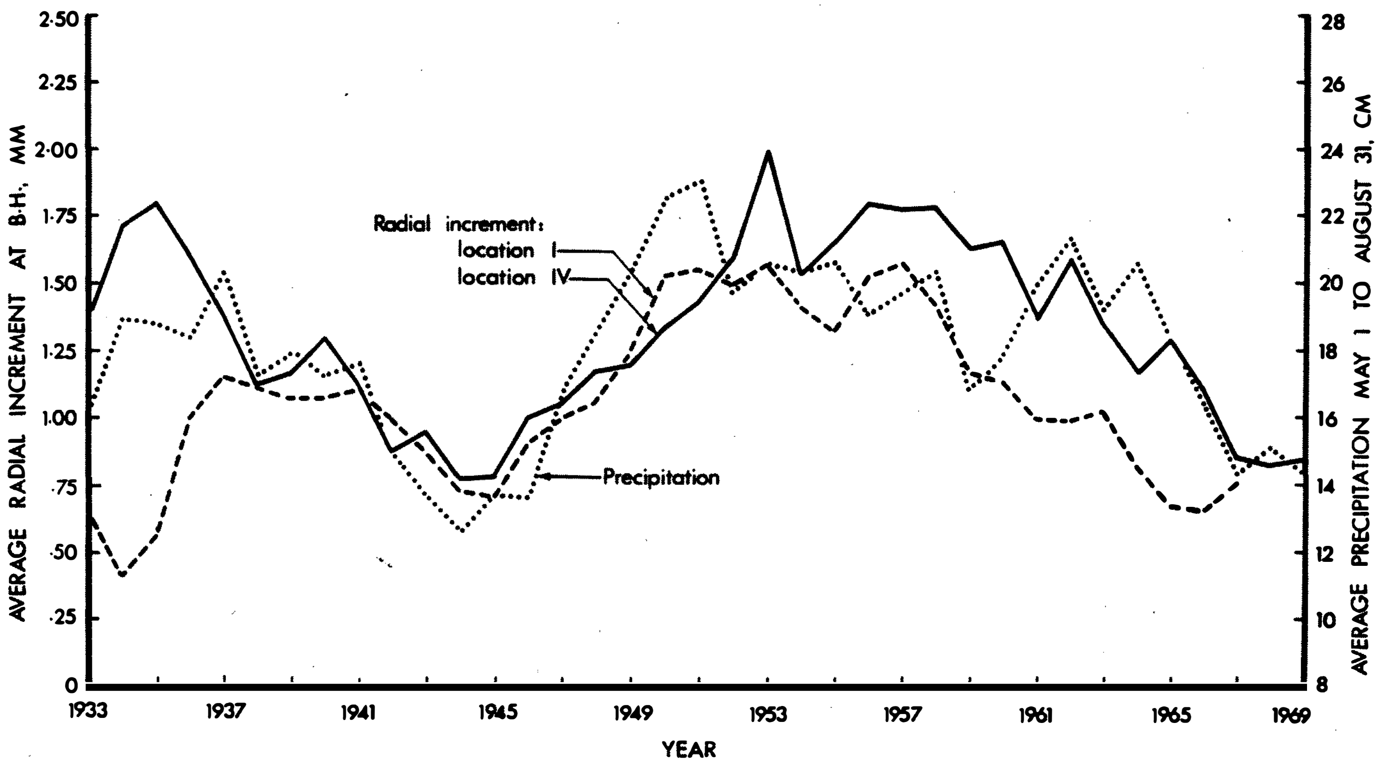
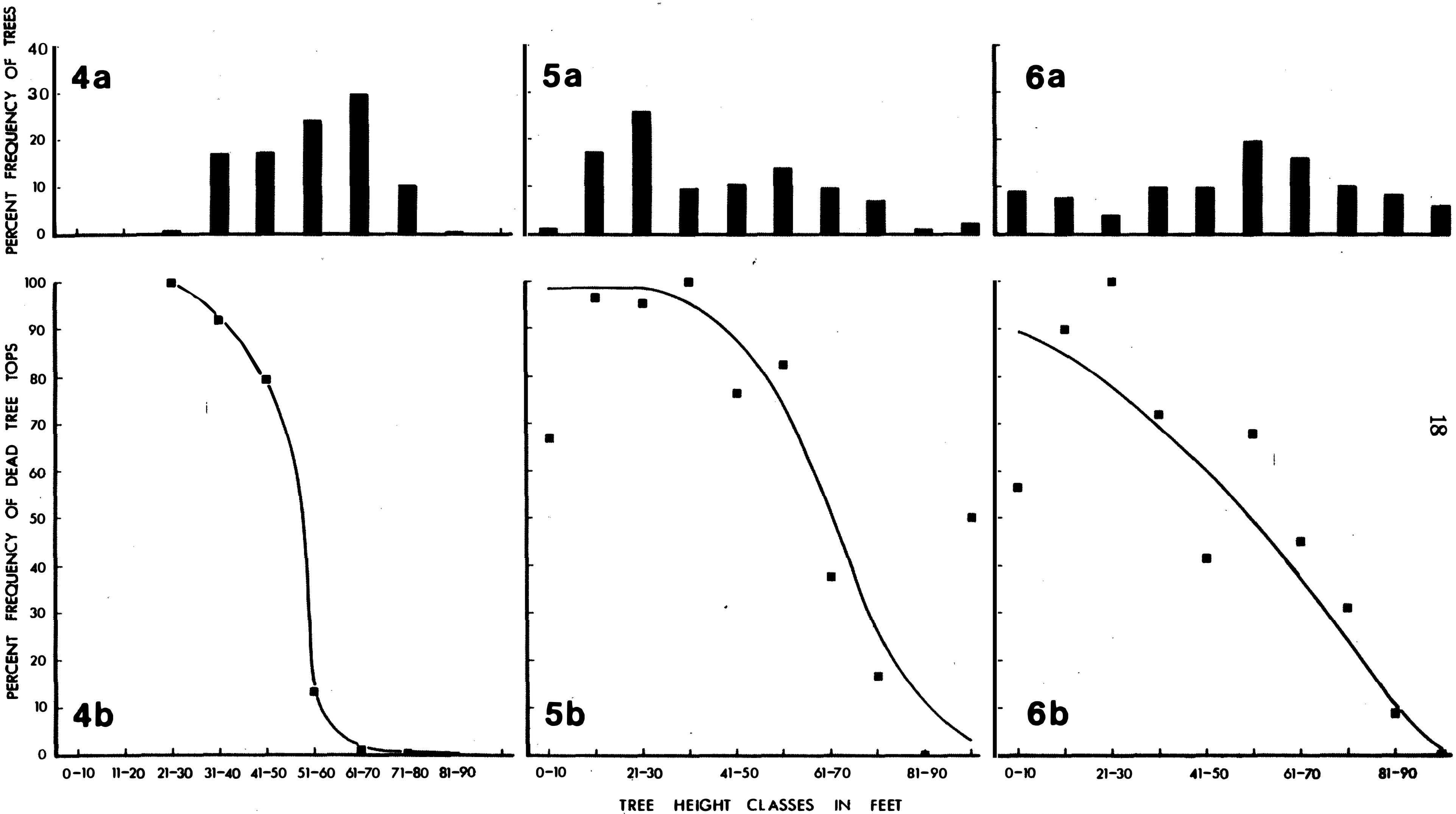


Fig. 3. Plot of 5-year running average precipitation for May 1 to August 31 (1933 to 1969), Fort Vermilion, Alberta, and radial increment profiles from breast height level of white spruce stems from locations I and IV (see Fig. 1 and Table 1 for locations and stand description).



Figs. 4a and b; 5a and b; 6a and b. Frequency histograms of tree height classes (4a, 5a, 6a) and the relation between tree top mortality and height class of trees sampled at locations IV (4b), VI (5b), and VIII (6b).

Table 1. Characteristics of white spruce trees sampled for spruce budworm populations and bud damage, June, 1971.

Stand location[a]	Number of tree crowns sampled	Ave. tree diameter at B. H. (cm)	Ave. tree height (m)	Ave. height live crown (m)	Average age
IV	5	24.0	19.8	9.6	83
V	4	25.5	21.0	9.0	103

[a] See Fig. 1 for locations of sampled white spruce stands.

Table 2. Summary of the total live buds and incidence of damaged buds on 46-cm long branch tips collected from four levels of white spruce crowns, June, 1971.

	Stand location[a] IV			Stand location[a] V		
Crown level	Ave. no. live buds[b] per 46-cm branch tip	Ave. no. damaged buds per tip	% live buds damaged per tip	Ave. no. live buds[b] per 46-cm branch tip	Ave. no. damaged buds per tip	% live buds damaged per tip
A	87 ± 11.3	9.20	10.6	81 ± 16.8	8.81	10.9
B	65 ± 14.4	9.75	14.9	52 ± 8.8	5.31	10.2
C	45 ± 10.7	4.90	11.0	26 ± 3.5	3.19	12.1
D	12 ± 6.0	1.10	8.9	12 ± 5.5	0.94	7.8
Mean per tree crown			11.35			10.24

[a] See Fig. 1 for map with stand locations.
[b] Mean ± one standard error.