FUNDY NATIONAL PARK REPORT

PHASE 1

Executive Summary

The Spruce Budworm Decision Support System Protection Planning System (PROPS) was implemented on the Fundy National Park (FNP), a total landbase of 19,356 ha. The FNP landbase is composed of 18,387 ha of productive federal forest. PROPS predicts the budworm-caused volume losses, or alternatively the marginal timber supply benefits of protecting stands against spruce budworm defoliation in a given year.

Because there was no quantifiable budworm defoliation on the FNP during the past 5 years and no predicted 1999 budworm populations from larval (L_2) surveys, actual budworm losses (priority values for budworm-caused volume loss) in 1999 were 0 throughout the landbase. In other words, with no expected defoliation in 1999, there would be no mortality or growth reduction.

The various tables and maps in this report allow evaluation of potential volume losses that would be caused by a budworm outbreak on FNP. A "normal" severity budworm outbreak, similar to that experienced in New Brunswick in the past, was estimated to result in 252,000 m^3 of mortality and growth reduction. A severe outbreak, similar to that in Cape Breton Island in the 1970-80's, would cause 626,000 m^3 of volume reductions. Maps will allow Park managers to anticipate natural disturbance effects on stands in FNP.

Fundy Model Forest

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The Fundy Model Forest…
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"The Fundy Model Forest (FMF) is a partnership of 38 organizations that are promoting sustainable forest management practices in the Acadian Forest region."

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Canadian Institute of Forestry
Canadian Forest Service
City of Moncton
Conservation Council of New Brunswick
Fisheries and Oceans Canada
Indian and Northern Affairs Canada
Eel Ground First Nation
Elgin Eco Association
Elmhurst Outdoors
Environment Canada
Fawcett Lumber Company
Fundy Environmental Action Group
Fundy National Park
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Maritime College of Forest Technology
NB Department of the Environment and Local Government
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Introduction

Outbreaks of spruce budworm (*Choristoneura fumiferana* Clem.) are natural disturbances that cause large-scale mortality of spruce (*Picea* sp.) and balsam fir (*Abies balsamea* (L.) Mill.) trees in northeastern North America (MacLean 1980). This results in large uncertainty in future forest structure and productivity (MacLean 1985, 1990). Three major spruce budworm outbreaks have occurred in the 20th century, beginning about 1910, 1940, and 1970, with maximum extents of about 11, 25, and 58 million hectares, respectively (Kettela 1983). Spruce budworm is the most destructive forest pest in Canada, causing about 40% of the 81-107 million m^3 of timber volume lost to insects and disease each year (Sterner and Davidson 1982, Power 1991).

Management actions to deal with budworm outbreaks include spraying insecticides to prevent defoliation and keep trees alive or to maintain growth increment; salvage harvesting of dead trees before they are no longer useable due to rot; planting nonsusceptible tree species such as jack pine (*Pinus banksiana* Lamb.) or hardwood species, or low susceptibility species such as black spruce (*Picea mariana* (Mill.) B.S.P.); forest restructuring using precommercial thinning or harvest scheduling to reduce the occurrence of the most susceptible fir and spruce species at the stand or landscape level (MacLean 1996b); or doing nothing and incurring the resulting growth reduction and mortality. Chemical insecticides are no longer used against spruce budworm, but the biological insecticide *Bacillus thuringiensis* (*B.t.*) or the insect growth regulator Mimic are now in use.

The Spruce Budworm Decision Support System (SBW DSS) was developed by the Canadian Forest Service (CFS) from 1992-95, to assist in spatial decision-making related to budworm management (MacLean and Porter 1994, 1995). The SBW DSS makes use of forest inventory and budworm monitoring data to describe the landbase and determine outbreak scenarios (MacLean et al. 1999); uses a stand growth model and timber supply (forest estate) model to determine stand- and forest-level effects of defoliation and protection (MacLean 1996a, Erdle and MacLean 1999); makes use of the ARC/INFO GIS and C programs for calculations and spatial data manipulation; and uses customized ArcView projects for map generation and a graphical user interface (GUI) (Porter and MacLean 1996).

The SBW DSS models the marginal timber supply benefits (m^3/ha) and forest structure consequences of alternative management actions. It thereby facilitates incorporation of effects of insect damage into forest management planning (MacLean et al. 1997, 1999). The DSS permits evaluation of costs, benefits, and consequences of management, assists in optimizing insecticide use (if desired), and improves visualization of the consequences of pest outbreaks and management strategies on forest performance indicators. From 1996-99, the SBW DSS has been operationally implemented, on a cost-shared basis with industry and the provincial government, for all forest in New Brunswick. It is also being implemented for test landbases in Alberta, Ontario, and Quebec.

The Protection Planning System (PROPS) is the component of the SBW DSS that quantifies the marginal timber supply benefits of protection. This procedure was proposed by Erdle (1989), and the initial version of PROPS was developed under contract to the CFS by Vanguard Forest Management Services Ltd. (1993). PROPS is a GIS-based system which quantifies the marginal timber supply benefit (m^3/ha) of protecting stands against spruce budworm defoliation, with the calculation made at the scheduled time of harvest. It provides the ability to determine the effects of different budworm protection strategies on forest development and sustainability.

The objectives of the present study were: 1) to implement PROPS on the Fundy Model Forest (FMF) and on each main ownership (Crown License #7, J.D. Irving Ltd., S.N.B. Forest Products Marketing Board, and Fundy National Parkn(FNP)); and 2) to conduct strategic planning analyses to determine costs, benefits, and forest development/ sustainability consequences of different budworm protection strategies. Separate reports will present implementations for J.D. Irving Ltd. Freehold, Crown License #7, S.N.B. Forest Products Marketing Board, and Fundy Model Forest.

This report will describe the procedures used to implement PROPS on the FNP, as well as summarize the consequences of different budworm outbreak scenarios on forest development.

Materials and Methods

Fundy National Park is a 19,356 ha landbase located in southern NB. This federally-owned landbase is composed of 18,386 ha of productive forest land, 715 ha of nonproductive forest land, 119 ha of roads, and 136 ha of water.

The distribution of forest stand types on the FNP is shown in Figure 1. The total landbase, ordered based on vulnerability to budworm, includes:

- 1% fir-spruce types
- 34% spruce-fir types
- 32% mixed spruce-fir/hardwood types
- <1% mixed spruce-fir/other softwood
- 25% hardwood/spruce-fir types
- <1% plantations and thinnings
- 3% nonsusceptible
- 4% nonproductive forest
- <1% water
- <1% roads

The colors in Figure 1 were selected such that the most vulnerable fir-spruce, spruce-fir stands, plantations and thinnings were red, pink or purple; moderately vulnerable mixed spruce-fir/hardwoods, and spruce-fir/other softwoods were yellow; low vulnerability mixed natural and thinned hardwood/spruce-fir and mixed other softwood/spruce-fir were green or blue; and non-susceptible hardwood and non-host species were gray. Using this general classification, areas in Figure 1 can be generally rated with respect to their vulnerability to spruce budworm as:

- 6,731 ha is highly vulnerable (red, pink or purple)
- 6,195 ha is moderately vulnerable (yellow)
- 4,844 ha has low vulnerability (green)
- 1,586 ha is non-vulnerable or non-productive (gray).

The forest inventory data were loaded onto a Unix workstation running ARC/INFO version 7.2.1 and a PC running ArcView version 3.1. ARC commands, INFO and AML programs, SAS, Excel, Word, and SigmaPlot were used to manipulate and analyze the data and to describe and present the results of different budworm-caused volume loss scenarios.

Database Construction - PROPS Setup

The bulk of the work in implementing PROPS on any landbase is the database setup.

There are two main databases that must be constructed in order for PROPS to work: the stand impact matrix and stand history file. PROPS implementaions on industrial forest also use a third database, the forest impact matrix, which estimates budworm-caused volume reductions at the future scheduled time of harvest.

Stand impact matrix

The stand impact matrix is a large lookup table that contains percent volume reductions, caused by budworm defoliation, to be applied to management plan volume yield curves. In the case of the FNP, Crown Timber License 7 (CTL # 7) yield curves were used and applied to the FNP landbase. The stand impact matrix is constructed once for all implementations of PROPS, and budworm impact classes are matched with volume yield curves (MacLean et al. 1999). Therefore, the stand impact matrix contains relative budworm-caused losses, and is transferable from one landbase to another. Percent reductions in the stand impact matrix were calculated based on STAMAN version 2.4 model runs for each budworm impact class by harvest period, for all possible future defoliation conditions over the next 10 years (MacLean et al. 1999).

A total of 54 budworm impact classes that will sustain different losses during a budworm outbreak were defined. Impact classes were delineated based on a combination of four stand factors: percent spruce-fir content, species composition, age class, and silvicultural treatment. The 54 budworm impact classes are listed in the first column of Table 1, and defined in columns 2-5 of Table 1.

Operationally, the stand impact matrix is an INFO file called SIMPACT, which contains 37,800 percentage volume loss records (for 54 budworm impact classes x 7 future time periods x 100 possible cumulative defoliation levels for periods 1 and 2). Periods cover 5-year intervals, such that period 1 is years 1-5 and period 2 is years 6-10. The stand impact matrix is used to determine the percent volume reduction caused by period 1 and period 2 defoliation levels, for that specific stand type (i.e., budworm impact class).

Percent volume loss as a function of the 100 possible cumulative defoliation values (10% intervals) can be depicted as a “surface” on a 3-dimensional graph. Such “surfaces” of percent volume loss for eight budworm impact classes (balsam fir-hardwood, balsam fir-spruce, spruce-hardwood and spruce-balsam fir; each presented for two age classes 11-15 years in the future) are presented in Figure 2. The highest percent volume losses occur in the older budworm impact classes: fir > 80 years old and spruce > 100 years old. The maximum percent volume loss values for these impact classes ranged from 91-95%. These older classes sustain the greatest volume loss because as trees age, their ability to withstand and recover from defoliation decreases. Younger classes (especially < 40 yrs old) do not sustain as high volume loss because the trees are more vigorous, increasing their ability to recover from defoliation.

Both mature (age 41-80 or 41-100 yrs) and overmature (age > 80 or > 100 yrs) stands sustained large losses to budworm (Figure 2).

For fir, the younger impact class (41-80 yrs) actually sustained greater volume loss than the older impact class (age > 80 yrs). Due to the natural mortality of balsam fir in the older impact classes, there is less of it to lose in the older BFHW class. The remainder of this class contains spruce and hardwood, resulting in the percentage losses being less than in the younger BFHW class. This did not occur in

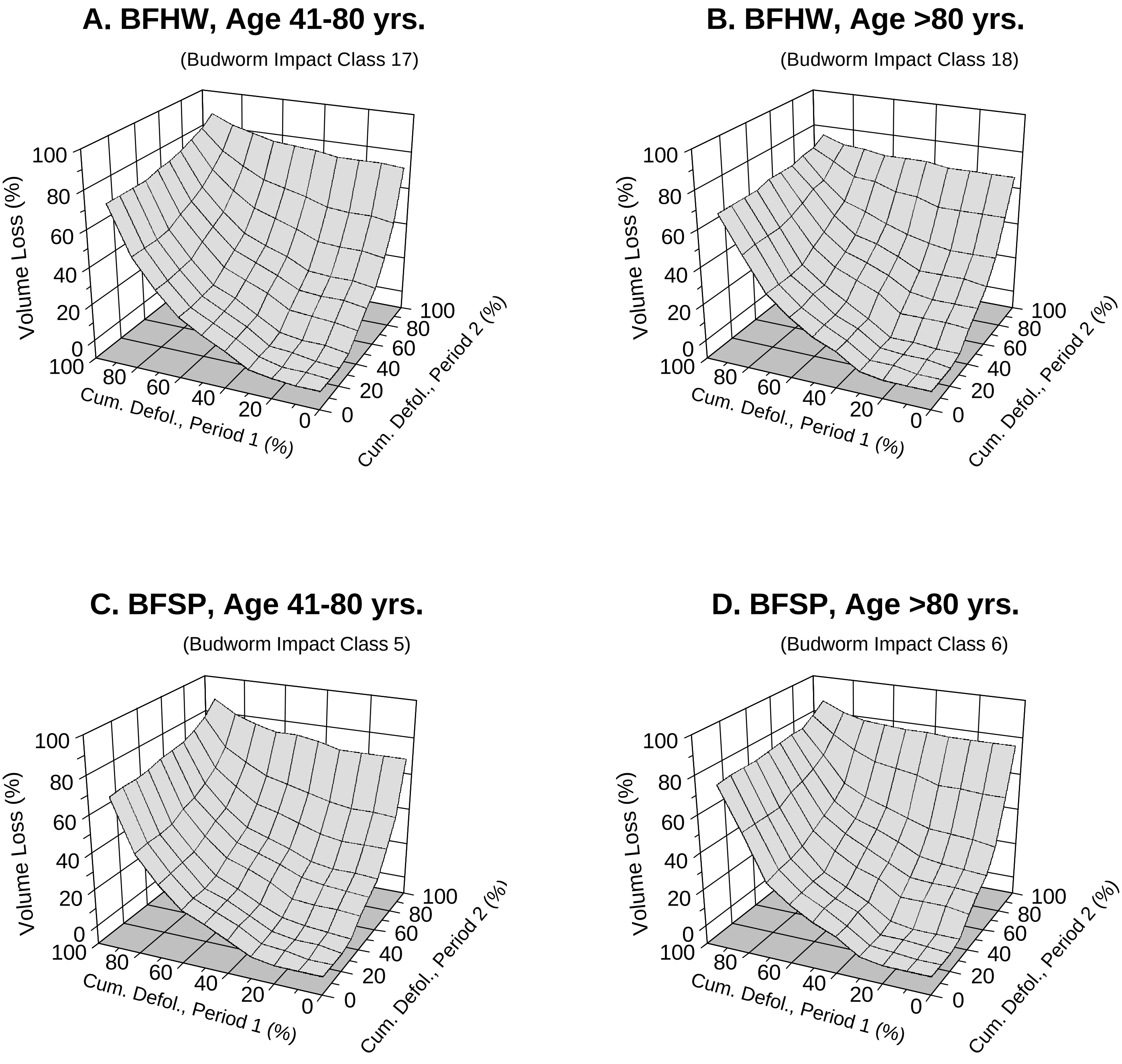

Figure 2. Budworm-caused volume loss (%), 11-15 in the future, expected as a function of cumulative defoliation in period 1 (years 1-5) and period 2 (years 6-10) for eight stand types: four species groups (BFHW, BFSP, SPHW, and SPBF) and two age classes (41-80 and > 80 years for fir; 41-100 and >100 years for spruce). Budworm Impact Class numbers refer to Table 1.

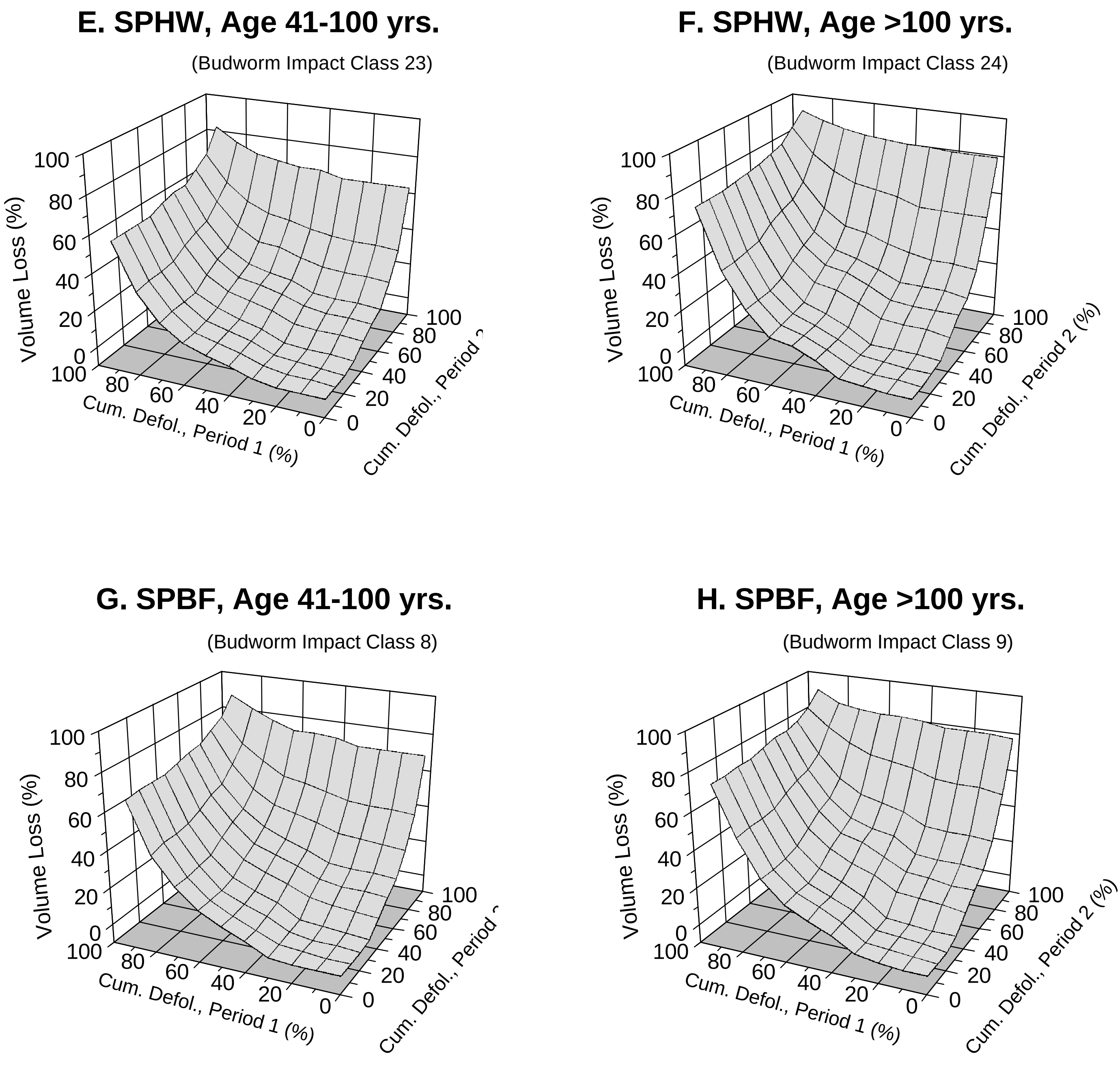

Figure 2. Continued.

the spruce impact classes because of its greater longevity; normally, spruce stand breakup does not occur until 180-200 years of age.

CTL #7 volume development (yield) curves were matched to budworm impact classes by species composition, age, and silvicultural treatment (column 6 of Table 1). This step assigned one of the 54 budworm impact class numbers to each forest class (yield curve no.) used for management planning on the License (Table 1). Since FNP is contained within the CTL #7 and does not include silviculturally treated stands, not all stand types (yield curves) listed in Table 1 are represented within FNP. Percent volume reduction, for a given budworm impact class, is a function of the time when the loss due to budworm is measured, and cumulative defoliation level in period 1 (1-5 yrs) and period 2 (6-10 yrs).

Stand history file

The stand history file is the other major database needed for PROPS setup. This file contains a unique stand identifier, budworm impact class number, harvest period, stand area, and 5 years of past and 10 years of future defoliation information. The detailed procedures undertaken in creating this INFO file called STANDHISTORY and assigning values to its attributes are described in Sections 2.8 - 2.24 of Appendix I of Vanguard Forest Management Services Ltd. (1993). This file also contains budworm-caused volume loss (protection priority) values determined within PROPS, which are used to summarize m^3/ha benefits by spray block and produce budworm loss (protection priority) maps.

Results and Discussion

The setup for PROPS was conducted such that it could be used to help evaluate potential spruce budworm-caused mortality on the FNP in the upcoming year (summer of 1999). However, there was no quantifiable defoliation in the past 5 years and no predicted 1999 population levels from 1998 budworm L_2 surveys. Therefore, budworm-caused volume loss was 0 in 1999, because no loss would occur with no expected 1999 defoliation.

Varying Budworm Outbreak Scenarios

Different budworm outbreak conditions were simulated by changing the defoliation conditions in the stand history file, to represent “normal” and “severe” spruce budworm outbreaks starting in 2000. The pattern of defoliation for normal and severe outbreak scenarios is presented in Figure 3. PROPS requires explicit assumptions about future budworm defoliation levels; these assumed defoliation values are based on past outbreak cycles in NB (Royama 1984; Steinman and MacLean 1994).

The normal outbreak scenario (Figure 3A) shows a 30-year cyclical pattern of defoliation and associated budworm population levels. There is a 12-year outbreak period of moderate-severe defoliation, followed by 18 years of nil-light (≤ 20%) defoliation. This scenario reflects lower defoliation, for a given budworm population level, in the declining phase (years 9-14) of the outbreak than in the increasing phase (years 6-8). This is because of the action of parasitoids and diseases that build up during the outbreak. The broken line shows a target defoliation limit of 40%, which corresponds to the N.B. Department of Natural Resources and Energy (NB DNRE) current protection strategy for balsam fir. The severe outbreak scenario (Figure 3B) was developed because analyses indicated that the normal scenario did not result in cumulative defoliation or tree mortality levels as high as past severe

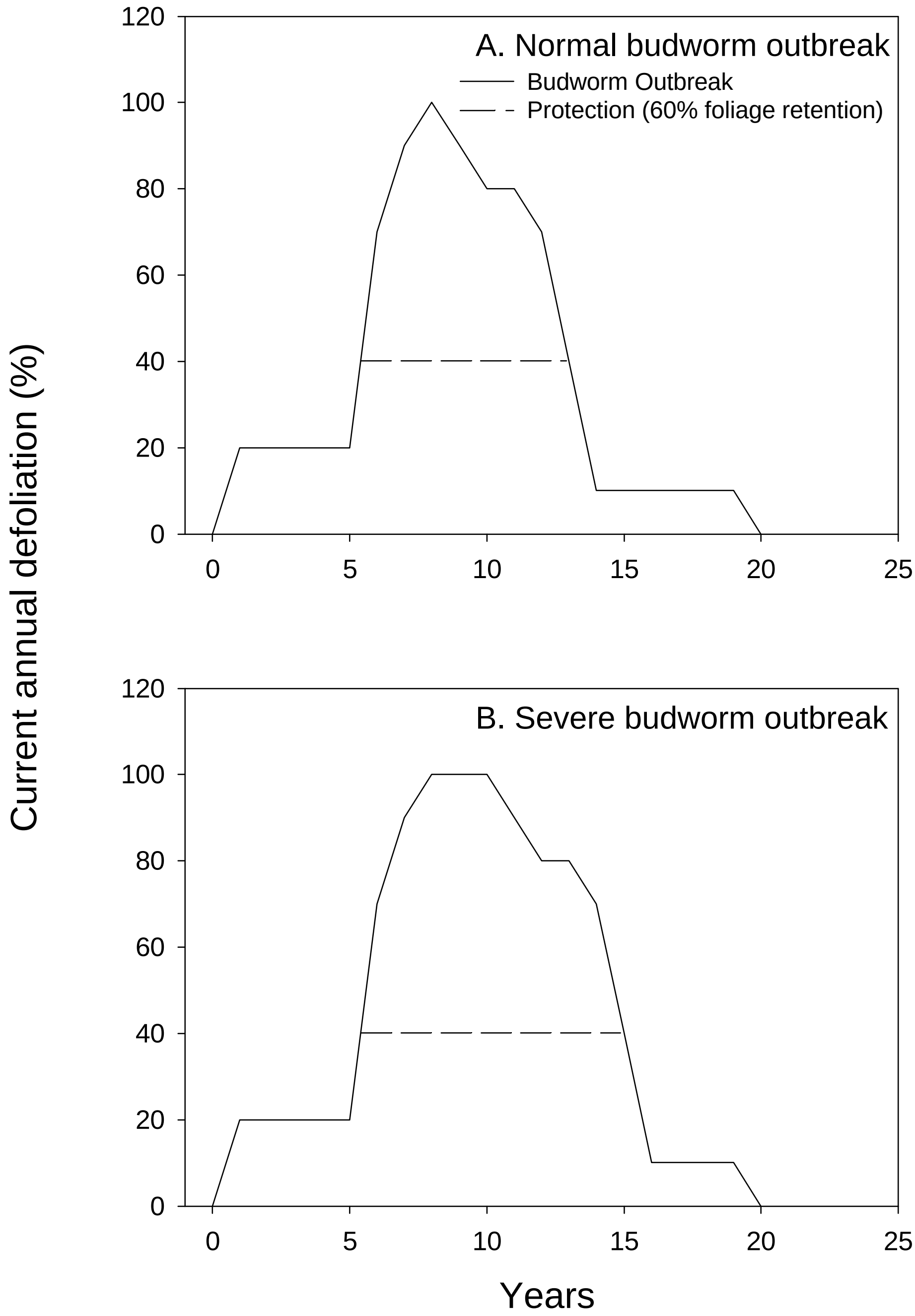

Figure 3. Current annual defoliation sequences for A. normal budworm outbreak, and B. severe budworm outbreak.

outbreaks, such as in northern NB in the 1950's (Baskerville and MacLean 1979) and Cape Breton from 1976-84 (MacLean and Ostaff 1989). Therefore, two more years of 100% defoliation were added at the peak of the outbreak scenario (Figure 3B). These two scenarios indicate probable future budworm outbreak patterns.

Table 2 summarizes results of the above two simulated defoliation scenarios on the FNP. This includes the mean and maximum budworm-caused volume reduction; the area of the landbase in 10 or 20 m^3/ha volume reduction classes; and the total forest-level m^3 of growth reduction and mortality for each scenario.

Normal budworm outbreak scenario

The normal budworm outbreak scenario assumed that defoliation would begin in 2000, follow the outbreak pattern in Figure 3A until 2008, and decline thereafter. Under these conditions, direct defoliation-caused losses total 252,000 m^3 (Table 2). Areas of 4,000, 4,300, 500, and 1,900 ha of the landbase would sustain mortality and growth reduction of 11-20, 21-40, 41-60, and 61-80 m^3/ha, respectively (Table 2). A total of 7,200 ha would sustain losses of 1-10 m^3/ha.

Figure 4 shows a budworm-caused volume reduction map for the normal outbreak scenario. This identifies those stands with the highest growth loss and mortality, in this case, stands mapped as yellow (41-60 m^3/ha loss) or red (>60 m^3/ha). In addition to the small scale map shown here, large scale (wall sized) maps could be produced if desired.

Severe budworm outbreak scenario

The severe budworm outbreak scenario assumed that a budworm outbreak would start in 2000, follow the pattern in Figure 3B until 2008, and decline thereafter. The two additional years of 100% current defoliation in this scenario (Figure 3B) resulted in increases in losses, which now reach 81-100 m^3/ha on 7,300 ha of the FNP landbase (Table 2). Under this scenario, defoliation-caused volume loss is 626,000 m^3 on the FNP (Table 2).

Figure 5 shows budworm loss values resulting from the severe outbreak scenario for the FNP. It is obvious that there is a lot more red, representing the extreme loss categories. The normal outbreak scenario results in stands that are in such poor conditions that two additional years of complete current defoliation, as in the severe outbreak scenario, "pushes them over the edge". This results in severe mortality. Overall projected losses were two and one-half times as great under the severe outbreak scenario.

Conclusions

A large proportion of the softwood forest in the Fundy National Park is comprised of budworm-susceptible spruce and mixed spruce-fir/hardwoods. This forest is still showing the effects of the last spruce budworm outbreak in the 1970's, which killed most of the mature balsam fir and some spruce. As a result, the next budworm outbreak, expected within five years or so, will cause partial mortality in most stands if similar to our "normal" outbreak scenario. If the outbreak is similar to our "severe" scenario, heavy mortality will occur on much of the FNP.

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