



FOREST RESEARCH REPORT

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IMPACT OF THE 1974-81 SPRUCE BUDWORM INFESTATION ON THE FORESTS OF CAPE BRETON ISLAND

INTRODUCTION

The latest spruce budworm [SBW] (*Choristoneura fumiferana* (Clem.)) infestation on Cape Breton Island, Nova Scotia began in 1974 (NSDLF, 1977; Ostaff and MacLean, 1989). The infestation reached a peak in 1976-1977 causing widespread mortality of balsam fir (*Abies balsamea* (L.) Mill.), white spruce (*Picea glauca* (Moench) Voss), and black spruce (*Picea mariana* (Mill.) B.S.P.) throughout Cape Breton (NSDLF, 1983). The budworm population declined to endemic levels by the fall of 1982 (Kettela, 1982). To minimize losses, an extensive harvest and silvicultural program was undertaken to salvage the dead and dying stands and restore their productivity. During the period 1974 to 1989, 11 million m³ (5 million cords) of softwood were either harvested or salvaged from Cape Breton Island (NSDNR, 1993).

What were the overall effects of the SBW infestation on the Island forests? A comparison

of forest inventories for 1970 and 1985 (NSDLF 1970, 1985) shows that the standing volume of merchantable spruce/fir was reduced from 38.8 to 13.8 million m³ over this period (excluding Cape Breton Highlands National Park; HNP). This gives rise to a number of questions:

- How much of this reduction was due to the budworm infestation?
- How much can be attributed to normal mortality?
- How much growth was lost?
- Was fir more susceptible to budworm damage than spruce?
- Were mixedwood stands less vulnerable than softwood stands?
- Did softwood mortality result in an increase in hardwood growth?

To help answer these questions, an analysis of data from the Nova Scotia Forest Inventory Permanent Sample Plots (PSPs) was carried out.

A total of 357 PSPs were randomly established by NSDNR on Cape Breton Island between 1965 and 1970 (NSDLF, 1976). Since then, the plots have been remeasured at 5 year intervals. As of the last remeasurement, seventy-three of the plots have been totally or partially harvested and are not included in these analyses. An additional 26 plots were rejected because they contained no merchantable trees prior to the SBW attack (for example, cutovers and immature stands). Data collected from the remaining 258 plots (Figure 1) provided the basis for determining what happened to trees that were merchantable prior to the SBW attack.

It should be noted that only a small proportion (3%) of these PSPs were protected using pesticides during the SBW infestation.

To obtain an estimate of growth loss attributable to the SBW infestation, it was first necessary to establish projections of growth and mortality unaffected by the SBW. Data from the 233 PSPs remeasured prior to the onset of the SBW were used for this purpose. The projections were obtained by regressing 5 year volume and density changes with stand age by covertype and species. The results of these regressions, applied to the initial measurements of merchantable trees in the 258 PSPs, provided the basis for projecting their "SBW-infestation-free" status 20 years into the future (Appendix I). Projected stand values for the 258 plots were then compared with the actual 1985-1990 measurement values to obtain an estimate of volume and density changes attributable to the SBW infestation.

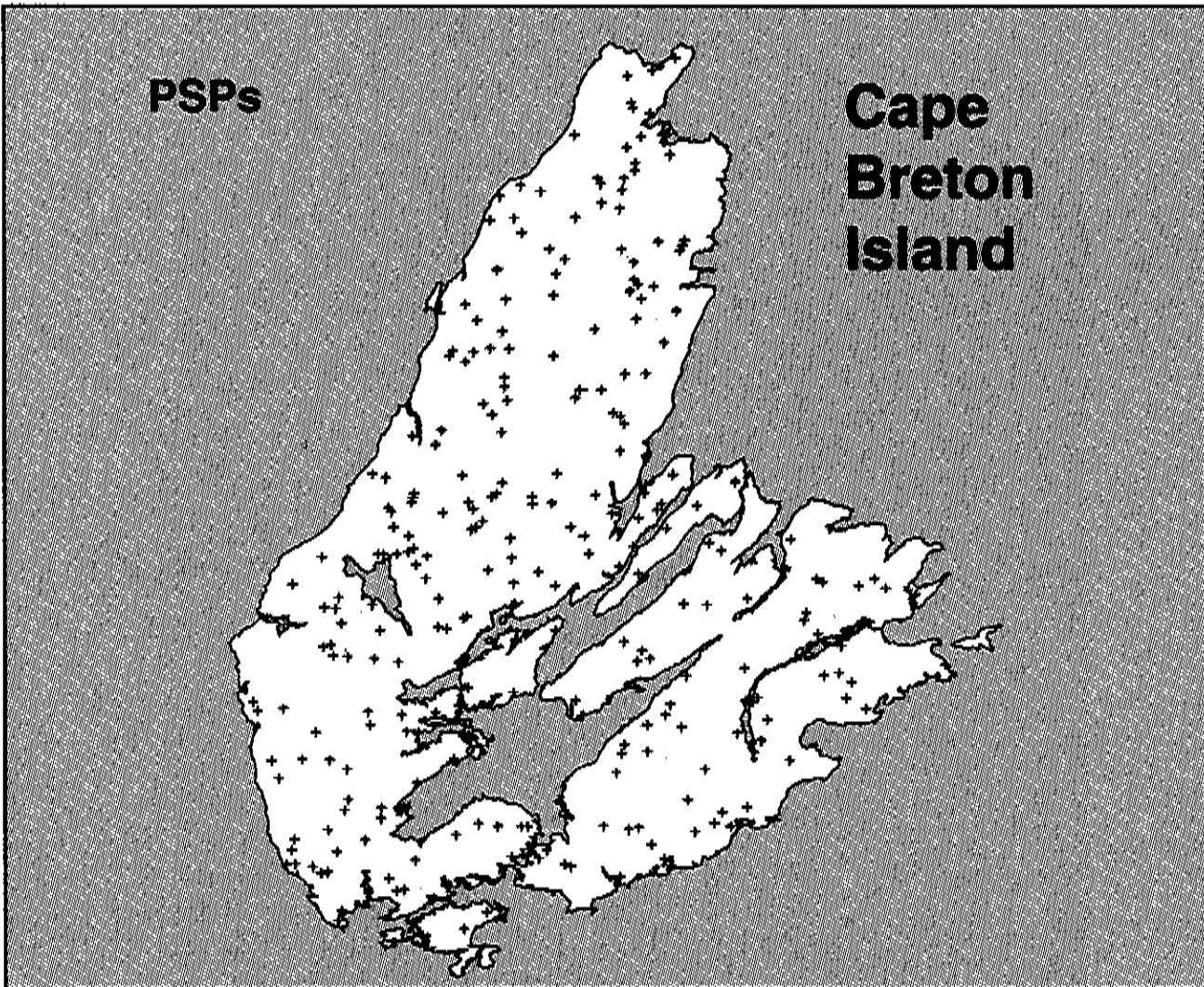


Figure 1. Location of the 258 Permanent Sample Plots (PSPs) used for this study.

RESULTS

Unlike the forest inventories referred to in the Introduction, the results discussed below apply only to the unharvested stands that contained merchantable trees prior to the SBW attack. No assumptions or calculations were made regarding SBW induced damage to harvested stands. Also, ingrowth into the merchantable category which occurred during and after the infestation was excluded from these analyses.

Volume of Merchantable Spruce/Fir

There were 31 million m³ (14 million cords) of merchantable spruce/fir (Table 1) prior to the 1974 SBW infestation on 629 910 ha of Cape

Breton Island forested land (including HNP). Allowing for natural growth and mortality, and with normal background populations of SBW and spruce beetle, it is estimated that this number would have increased to 45 million m³ (20 million cords) by 1985-90. However, following the SBW attack, the volume of living merchantable spruce/fir trees was only 13 million m³ (6 million cords); a 70 % reduction over predicted levels.

It is interesting to note that while the largest proportion of the Cape Breton Island forest prior to the SBW was classified as mature

Table 1. Estimated volume and density losses due to the budworm infestation of 1974-81, by coverype and species on Cape Breton Island.

Coverype / Species	Stand Age at Plot Establishment (years)	Area Occupied (%)	Density of Merchantable Trees						Merchantable Volume							
			Pre ²		Post ³ Budworm		Loss (Projected - Actual)		Pre Budworm		Post Budworm		Loss (Projected - Actual)			
			Actual		Pro-jected ⁴		Per Hectare		CBI		Actual		Per Hectare		CBI	
			(trees/ha)	(trees/ha)	(trees/ha)	(trees/ha)	(%)	(millions)	(m ³ /ha)	(m ³ /ha)	(m ³ /ha)	(m ³ /ha)	(%)	(million m ³)	(million cords)	
Pure Balsam Fir Stands																
Balsam Fir	61	20	941	606	111	495	82	62	69	32	10	72	88	9.1	4.1	
Spruce			52	37	24	13	35	2	5	7	2	4	67	0.5	0.2	
Spruce/Fir			993	670	135	535	80	67	74	88	12	76	86	9.6	4.3	
Pure Spruce/Fir Stands																
Balsam Fir	58	22	566	397	128	269	68	37	32	55	13	42	76	5.8	2.6	
Spruce			321	232	147	85	37	12	33	54	21	33	61	4.5	2.0	
Spruce/Fir			887	633	274	359	57	50	66	106	34	72	68	10.0	4.5	
Softwood Stands																
Spruce/Fir	58	56	882	631	257	374	59	132	62	93	27	66	71	23.3	10.6	
Hardwood			45	39	38	1	3	0	5	8	7	1	15	0.4	0.2	
Mixedwood Stands																
Spruce/Fir	59	28	534	351	159	192	55	34	47	72	19	52	73	9.2	4.2	
Hardwood			371	272	304	-32	-12	-6	46	50	62	-11	-22	-2.0	-1.0	
Hardwood Stands																
Spruce/Fir	61	16	119	46	40	6	13	1	7	7	4	3	46	0.3	0.1	
Hardwood			605	493	484	9	2	1	92	148	117	31	21	3.1	1.6	
All Stands																
Balsam Fir	59	100	471	292	96	196	67	123	32	48	10	38	79	23.8	10.8	
White Spruce			79	67	40	27	40	17	9	27	7	20	75	12.6	5.7	
Black/Red Spruce			109	79	57	22	28	14	8	11	5	6	54	3.7	1.7	
Spruce/Fir			660	432	194	238	55	150	49	71	21	49	70	31.1	14.1	
Hardwood			228	183	185	-2	-1	-1	30	43	40	3	8	2.1	1.0	
Island Wide⁵ - Spruce/Fir (millions)			416	272	122	150			31	45	13	31				

- 1 Coverype Based on the first measurement period (Appendix II).
 2 Pre Based on establishment measurements of 1965 - 1970 inclusive.
 3 Post Based on measurement periods 1985 - 1990 inclusive.
 4 Projected Based on regression equation or average change. (Appendix I).
 5 Island Wide Based on 629 910 ha of unharvested Cape Breton Island forest. Density expressed in millions of trees and Volume expressed as million m³.

Note: Values may not add up because of rounding and use of separate equations to project individual species and species groups.

(Figure 2), it had not reached a state of decline. Spruce/fir was predicted to continue to grow in volume until the year 2000 (Figure 3, and 'Peak Age' Appendix I). According to these predictions, net losses in volume, in the absence of major SBW attacks, would not have occurred,

on average, before 85 years of age. This is contrary to the discussion in an earlier report (NSDLF, 1977: pg. 20)

On an Island wide basis, the SBW infestation reduced the average spruce/fir volume in unharvested stands by 70%, from 71 m³/ha to

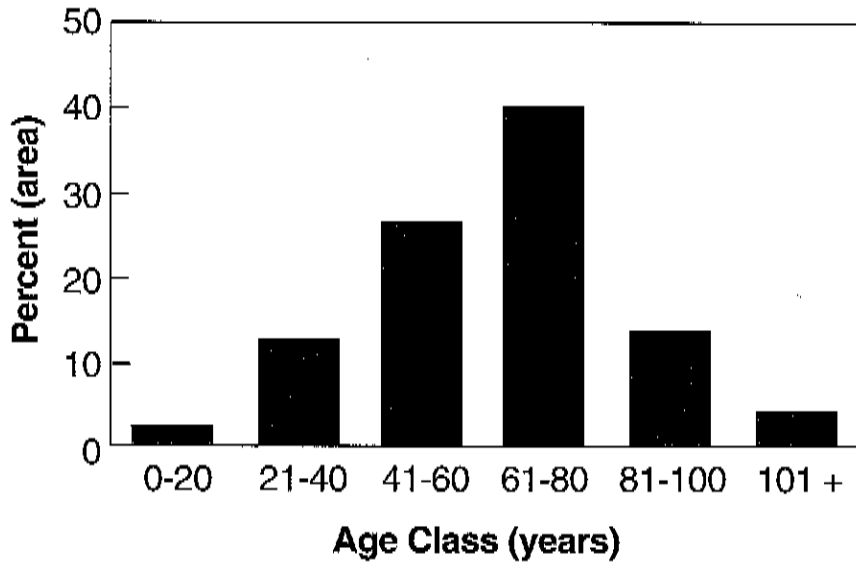


Figure 2. Age class distribution of the Cape Breton Island forest prior to the budworm (based on 258 PSP's).

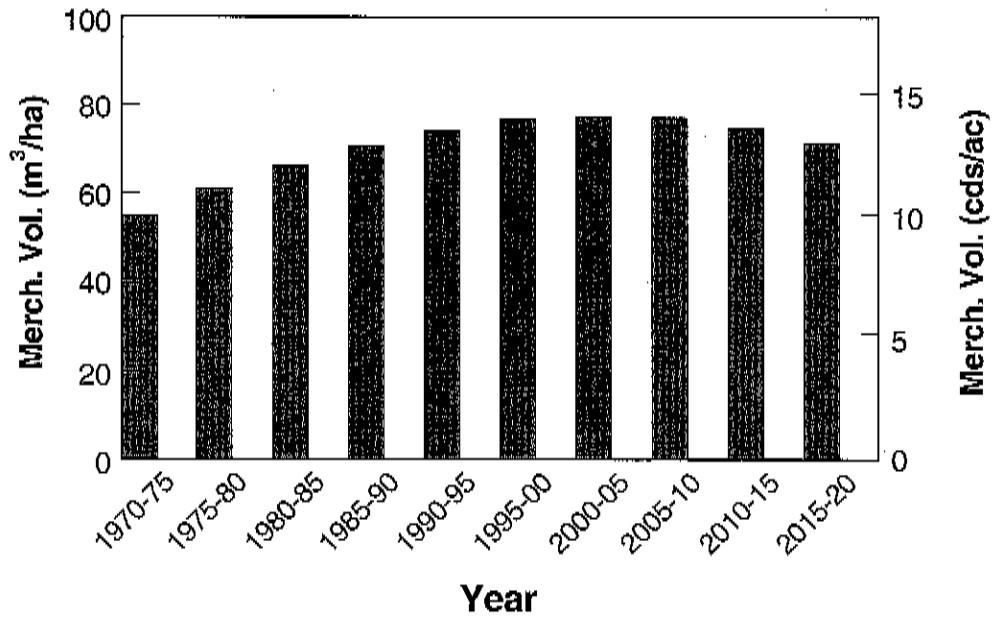


Figure 3. Predicted spruce/fir yields (all covertypes) in the absence of the SBW infestation based on pre-budworm PSP data.

21 m³/ha (3.9 cords/acre)(Figure 4).

Were spruce and fir in mixedwood and hardwood covertypes more, or less susceptible than in softwood stands? Based on analyses of the PSP data (Table 1), the greatest reduction in volume of merchantable spruce/fir occurred equally in softwood and mixedwood covertypes (71 and 73 % respectively). In hardwood stands the spruce/fir was reduced by almost half (46 %).

Within the softwood coertype, fir was hardest hit, but spruce was also damaged severely. In stands classified as spruce/fir (39 % of the area occupied by softwood forest), the fir volume was reduced by 76 %, while spruce dropped 61 %. Combined, these losses lowered the average volume of merchantable spruce/fir by 68 % from 106 m³/ha to 34 m³/ha (6.3 cords/acre).

In the pure fir stands (36 % of area occupied by softwood forest), volume loss was substantially higher. Fir volume was drastically reduced by 88 %, while spruce dropped 67 %. Combined, these losses of spruce/fir added up to an 86 % reduction, effectively lowering the volume of merchantable fibre, for this stand type, from 88 m³/ha to only 12 m³/ha (2.2 cords/acre).

On a species basis, irrespective of stand type, balsam fir showed the highest rate of mortality (79 %).

Volume of Merchantable Hardwood

The reduction in spruce/fir volumes were not accompanied by an overall increase in hardwood volume. Hardwood volume fell by 15 and 21 % from predicted levels in softwood and hardwood

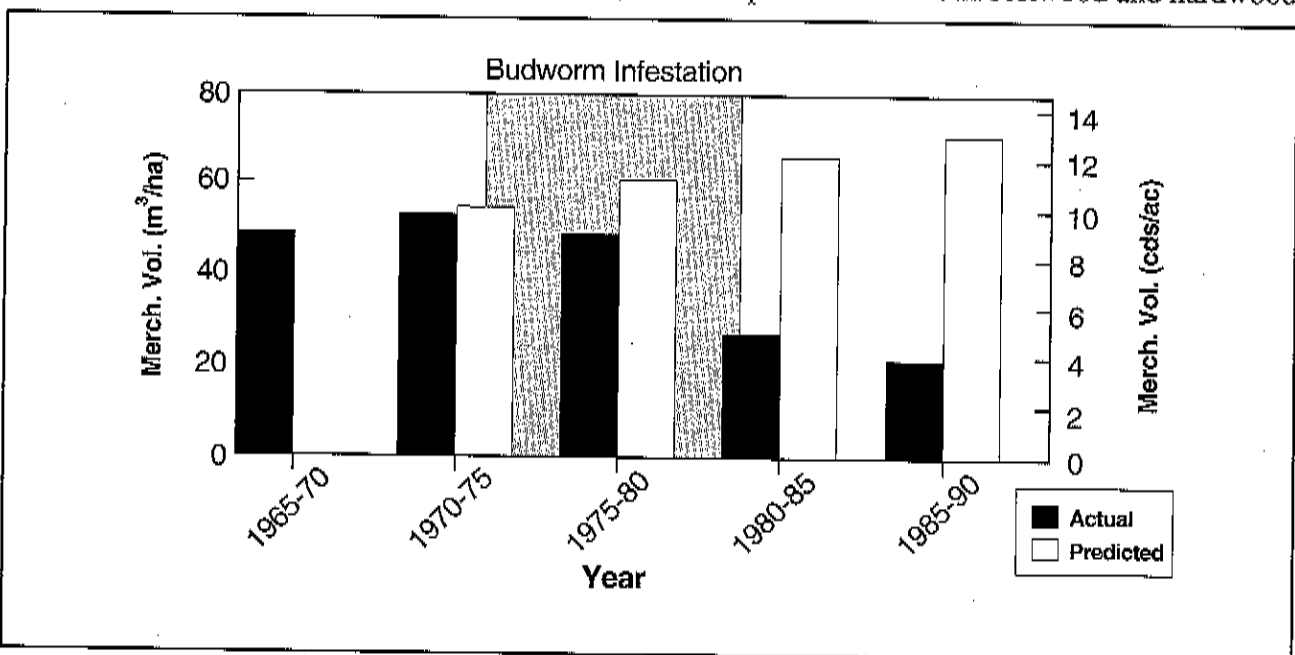


Figure 4. Reduction in merchantable spruce/fir volume based on a comparison of actual versus predicted volume (in the absence of SBW infestation). The SBW infestation began in 1974, peaked in 1976-77 and ended by 1982.

stands respectively, but rose by 22 % in mixedwood stands. The actual hardwood volume in 1985 - 1990, on the Island averaged 40 m³/ha (8.2 cords/acre), a decrease of 8 % over predicted levels of 43 m³/ha (8.8 cords/acre).

Density

Prior to the SBW (1965-1970), there were an estimated 416 million mature spruce/fir trees on 629 910 ha (unharvested forested area containing

merchantable trees). By 1985-90 our prediction equations indicate that this number, as a result of normal stand dynamics, would have decreased to 272 million. Following the SBW attack, the actual number of living-merchantable spruce/fir trees remaining (excluding ingrowth) was 122 million, which is equivalent to a 55 % loss over predicted levels. Considering the softwood coertype only, the density of spruce/fir fell by 59 % to 257 trees/ha. In mixedwood

and hardwood stands, spruce/fir density, declined by 55 and 13 %, respectively. This is equal to an overall average reduction for all 3 covertypes of 55 % (194 trees/ha).

Did the SBW favour fir over spruce? On average, the number of merchantable balsam fir trees for the entire forested area of Cape Breton Island fell 67 % from a predicted 292 trees/ha to an actual 96 trees per hectare (Table 1). White spruce and red/black spruce densities were reduced by successively smaller increments of 40 and 28 %, respectively.

Within softwood covertypes, balsam fir again suffered the greatest density losses. In pure fir stands, the average number of living merchantable fir trees fell by 82 % from predicted levels as opposed to spruce which fell

only 35 %. In spruce/fir stands, the spread was similar, although less mortality was experienced. Fir suffered a 68 % reduction in average density, while spruce lost 37 %.

Covertypes

Although there was minimal change in hardwood stand density from predicted levels (Table 1), the tremendous losses of spruce/fir both in softwood and mixedwood stands dramatically changed the distribution and proportion of covertypes on Cape Breton Island.

Figure 5 illustrates the diminishing softwood cover. For example, fir comprised 20 % of the cover in 1965-70 and only 7 % in 1985-90. Alternately, the hardwood coertype escalated in area (16 % in 1965-70 to 36 % in 1985-90).

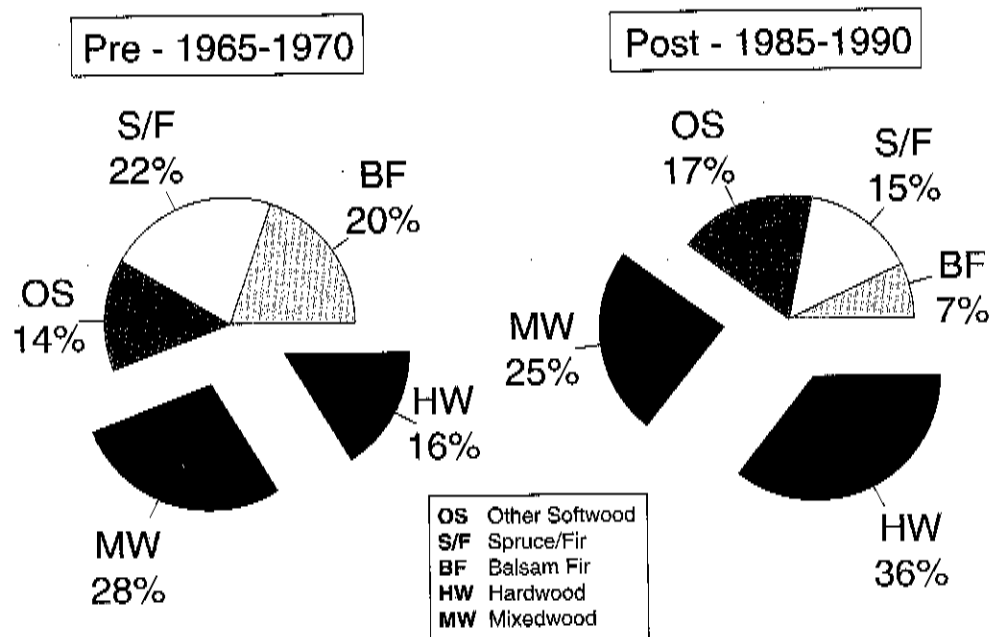


Figure 5. Cape Breton coertype distribution prior to and following the budworm infestation based on the 258 PSPs.

SUMMARY

In this report, spruce budworm (SBW) induced changes to the merchantable component of the Island forests were based on analyses of data collected from 258 unharvested randomly established Permanent Sample Plots. The major results are as follows:

1. The volume of merchantable spruce/fir growing stock on Cape Breton Island was reduced by 70 % from a projected volume of 45 million m³, to 13 million m³ (6 million cords), resulting in a 31 million m³ loss (14 million cords). On a species basis, the loss in volume was greatest for balsam fir (79 %), followed by white spruce (75 %) and red/black spruce (54 %).

2. The degree of damage varied by coartype. The volume of merchantable spruce/fir in pure fir, spruce/fir, softwood, mixedwood and hardwood stands declined by 86, 68, 71, 73, and 46 % respectively. It is noteworthy that the damage to spruce/fir was approximately equal in softwood and mixedwood stands.

3. Over half (55%) of the projected living merchantable spruce and fir trees died either

during or immediately following the SBW attack reducing their numbers from 432 to 194 trees/ha on average. By species, the density of fir, white spruce and red/black spruce was reduced by 67, 40 and 28 % respectively.

4. Density reduction varied by coartype. Within spruce/fir stands and pure fir stands, fir suffered greater density losses (68 and 82 % respectively) than spruce (37 and 35 % respectively). The loss in density for spruce/fir combined was 80 % for pure fir, 59 % for softwood, 57 % for spruce/fir, 55 % for mixedwood and 13 % for hardwood stands.

5. The growth of hardwoods did not increase as a result of the decrease in softwood. In fact, hardwood volume decreased by 8 % from predicted levels.

6. The large decrease in the volume of merchantable spruce/fir resulted in a dramatic increase in forested area classified in the hardwood coartype (16 to 36 %) and a corresponding reduction in the softwood coartype (56 to 39 %).

LITERATURE CITED

Kettela, E.G. 1982. *Spruce budworm infestations in Nova Scotia in 1982 and a forecast for 1983.* Can. For. Serv., Marit. For Res. Cent. Tech. Note 63. 6 pp.

NSDLF. 1970. *Cape Breton Island subdivision, Nova Scotia forest inventory.* N.S. Dept. of Lands and Forests, Halifax, N.S. 36 pp.

NSDLF. 1976. *Provincial forest inventory metric specifications: Part V; Permanent Sample Plots.* Forest planning division, Forest inventory subdivision, Truro, Nova Scotia. 27 pp.

NSDLF. 1977. *Nova Scotia's spruce budworm situation...* Nova Scotia Department of Lands and Forests. 39 pp.

NSDLF. 1983. *Submission to the Royal Commission on Forestry.* Nova Scotia Department of Lands and Forests. 331 pp.

NSDLF. 1985. *Information report: forest inventory Cape Breton Island 1984 - 85.* Forest Resources Planning and Mensuration Division, N.S. Dept. of Lands and Forests, Halifax, N.S. 77 pp.

NSDNR, 1993. *Unpublished data.* Forest Resources Planning and Mensuration, Nova Scotia Department of Natural Resources.

Ostaff, D.P. and D.A. MacLean. 1989. *Spruce budworm populations, defoliation, and changes in stand condition during an uncontrolled spruce budworm outbreak on Cape Breton Island, Nova Scotia.* Can. J. For. Res. 19: 1077-1086.

APPENDIX I

Basis for density and volume projections in the absence of the spruce budworm infestation by coertype and species.

Coertype ¹	Age ²	Species	Number of Plots	Peak Age ³ (yrs)	Merchantable Density				Merchantable Volume			
					Change ⁴ (%)	r ²	a ⁵	b ⁵	Change (%)	r ²	a	b
Balsam Fir	61	Balsam Fir	48	76	-9.5	0.035	0.140	1.004	12.0	0.332	-0.00783	1.59
		Spruce	34	88	-7.4	0.002			12.3	0.080	-0.00475	1.42
		Spruce/Fir	48	76	-9.4	0.025			11.9	0.322	-0.00756	1.58
Spruce/Fir	58	Balsam Fir	49	87	-7.5	0.113	0.126	-0.046	18.2	0.403	-0.00678	1.59
		Spruce	49	87	-8.0	0.021			15.5	0.235	-0.00580	1.50
		Spruce/Fir	49	85	-7.4	0.085	0.097	1.572	16.1	0.423	-0.00631	1.54
Softwood	58	Spruce/Fir	132	82	-7.5	0.045	0.104	1.338	16.0	0.388	-0.00691	1.57
		Hardwood	65	91	-3.5	0.032			15.8	0.145	-0.00543	1.49
Mixedwood	59	Spruce/Fir	62	85	-9.0	0.000			17.2	0.071	-0.00675	1.57
		Hardwood	62	na	-7.5	0.026			7.4	0.014		
Hardwood	61	Spruce/Fir	30	na	-23.8	0.049			0.4	0.029		
		Hardwood	39	78	-5.0	0.067			25.8	0.139	-0.01510	2.18
All	59	Balsam Fir	210	87	-11.3	0.000			14.9	0.076	-0.00559	1.49
		White Spruce	90	114	-3.8	0.001			35.4	0.080	-0.00576	1.66
		Red/Black Spruce	98	95	-7.5	0.000			12.8	0.062	-0.00410	1.39
		Spruce/Fir	244	84	-10.1	0.003			14.2	0.119	-0.00589	1.49
		Hardwood	166	86	-5.4	0.000			15.0	0.059	-0.00588	1.51

¹Coertype: Based on percent Basal Area prior to the budworm infestation.

²Age: Average stump age of plot at time of establishment.

³Peak Age: Stump age at which net merchantable volume growth becomes negative.

⁴Change: Percent change in volume or density over 5 year period preceding the budworm infestation.

⁵a and b: Regression equation coefficients in linear model $y = a * x + b$, where x is the average plot age expressed in years.

y is the ratio of merchantable volume at the year remeasured to the initial merchantable volume.

If no coefficients are shown, projections were based on average change prior to budworm.

APPENDIX II

Definitions

PSP

Prior to establishment, the permanent sample plot locations were determined by using a computer to randomly generate latitudes and longitudes. Each year, between 1965 and 1970 inclusive, plots were established at these randomly selected locations throughout the entire province. The circular plots are 0.0404 ha in size. All trees greater than 9.0 cm at Breast Height are numbered with paint and metal tags. The DBH point is marked with paint on each tree. Measurements taken included: DBH to 0.1 cm, top merchantable diameter, stump

height, total and merchantable height, species, tree condition, crown class, and tree status (alive or dead). In addition, the age of 3 codominant trees were measured. Each plot is remeasured every 5 years.

Coertype

A particular association of trees defined on the basis of the species or species group comprising at least 75% of the merchantable basal area, for example, fir, spruce/fir or hardwood. For mixedwood coertypes, stands contain 26 to 74% softwood or hardwood.

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