

**Compilation Of Forest Health (Pest Management)
Projects Funded by
British Columbia Ministry of Forests Under The
1985-1990 Forest Resources Development Agreement**

**Silviculture Branch
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Table Of Contents

	Page
Foreword	i
Summary	ii
Table 1.	
Annual Activities and Expenditures for Forest Resources Development Agreement Forest Health (Pest Management) projects funded by Ministry of Forests.	ii
Table 2.	
Forest Resource Development Agreement Forest Health (Pest Control) Projects.	iii
Recommendations	v
Armillaria Root Disease (DRA) Projects	1
Blackstain Root Disease (DRB) Projects	7
Laminated Root Rot (DRL) Projects	10
Rhizina Root Disease (DRR) Projects	19
Tomentosus Root Rot (DRT) Projects	23
Multiple Root Disease (DR) Projects	32
Warren's Root Collar Weevil (IWW) Projects	44
Hemlock Dwarf Mistletoe (DMH) Projects	46
Larch Dwarf Mistletoe (DML) Projects	47
Lodgepole Pine Dwarf Mistletoe (DMP) Projects	48
Stem Rusts and Cankers (DS) Projects	55
White Pine Blister Rust (DSB) Projects	58
Black Army Cutworm (IDA) Projects	64
Porcupine (AP) Projects	66
White Pine Weevil (IWS) Projects	70
Vole (AV) Projects	77
Multiple Pest: Disease, Insect, Abiotic & Animal Projects	78
Air Pollution (NK) Projects	85
Bark Beetles (IB) Projects	88
Appendix 1	90

FOREWORD

This report is one of a series of reports distributed by Silviculture Branch, B.C. Ministry of Forests, to record accomplishments and interim or provisional results for the information of staff, colleagues, and others.

In the 1985 to 1990 Canada-British Columbia Forest Resources Development Agreement (FRDA), over 100 forest health (pest control) projects were directly funded by the province and administered by protection staff. Most of these projects have been reported—some as contractor reports—to expedite communication of new results and development of new techniques.

The current report to summarize all the projects was prepared by Graham V. Hawkins, Pacific Coast Biology, Victoria, and incorporated substantial input by branch and region forest health staff. The text was edited by John Muir.

For details or more information about reports or projects, please contact forest health staff at Silviculture Branch or at forest region offices.

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Summary

More than 100 forest health (formerly called pest management) projects were funded by the British Columbia Ministry of Forests, for the 1985-1990 Forest Resource Development Agreement. Projects were initiated or supervised by Protection Branch or forest region staff. Major achievements are outlined in Table 1. Each project entry includes the cost, dates, contractor, project objectives, a description of the work and an evaluation of project effectiveness. A total of \$1.1 million was spent over the five-year period.

Precise figures for the number of hectares treated were lacking because these data were not always included by each contractor. However, during this period 56,000 ha, 716 plots and 493 sites were surveyed for damage caused by disease, insects, abiotic factors and animals. In addition, 170 ha and ~~three sites were treated to reduce damage.~~

Treatments and activities per year for the agreement are summarized in Table 1.

Major accomplishments included development of effective and practical survey methods for laminated root rot, armillaria root disease, rhizina root disease, and multiple pests. Impacts and extent of lodgepole pine dwarf mistletoe, porcupine, white pine weevil, tomentosus root rot and other root diseases were determined over substantial areas in five forest regions. Effective control techniques and strategies were developed for laminated root rot, rhizina root disease and armillaria root disease. Root disease models were also initially developed as management tools. Several extension and demonstration activities were also initiated.

Recommendations — listed by insect or disease — encapsulate the findings, recommendations and evaluations from the projects contained in this document. Numerous recommendations resulted from most projects. Also, future work is suggested. Implementation of these should improve the direction and the effectiveness of forest health management.

Table 1: Annual Activities and Expenditures for Forest Resources Development Agreement Forest Health (Pest Management) projects funded by Ministry of Forests

Year	No. of Projects	Surveys			Treatments (ha)	Total Cost (\$)
		Area	Plots	Sites		
1985 - 86	11	47,200			16	230,200
1986 - 87	19	3,824	9	62	75	188,900
1987 - 88	18	227	264	40	24	188,900
1988 - 89	24	2,724	32	153	40	236,900
1989 - 90	29	2,180	411	238	18	239,900
Total	111	56,155	716	493	173	1,084,800

Table 2: Forest Resource Development Agreement Forest Health (Pest Control) Projects

Damaging Agent	Project Number	Year	Project Category	Area or No. Sites Surveyed or Treated	Cost	Achievement (s)	Page No.
Amarillaria Root Disease (DRA)	29	1987-88	Treatment	17.6 ha surv./11.9 ha treated	\$9400	Spacing trmt. performed & 60 PSP's est. to monitor effects	1
	34	1988-89	Survey	1321 ha surveyed	\$600	Incorporate amarillaria incidence/severity data in regen.	2
	53	1988-89	Survey	51.1 ha surveyed	\$14500	Disease incidence meas., area laid out for control trials	3
	55	1988-89	Survey	24 ha surveyed	\$8,800	Disease incidence meas., area laid out for control trials	4
	56	1988-89	Survey	20 ha surveyed	\$5300	Disease incidence meas., area laid out for control trials	4
	57	1988-89	Survey	None	\$4800	Travel to trial site only	5
	61	1988-89	Treatment	4.5 ha treated	\$1700	Excavations for control trials: push-over logging promising	5
	JM-101	1989-90	Survey	400 ha surveyed	\$9800	Compare pixel and line intercept surveys	6
Total Cost					\$54,900		
Blackstain Root Disease (DRB)	JM-072	1989-90	Survey	17 sites surveyed	\$18100	Established PSP's to determine disease spread & mort., recomm.	7
	JM-100	1989-90	Survey	22 sites surveyed	\$14900	Establish incidence & severity of disease, est. trends, recomm.	8
	JM-103	1989-90	Survey	13 sites surveyed	\$2400	Determine PSP ecosystems & soils for correlations with disease spread	9
Total Cost					\$35400		
Laminated Root Rot (DRL)	PB-4	1985-86	Survey	100 ha surveyed	\$38000	Efficacy of stumping equipment assessed, recomm. for ops.	10
	PB-1	1985-86	Treatment	16 ha treated	\$84000	Stumping equipment assessed on 2 sites	11
	228	1986-87	Backlog Research	9.3 ha surveyed	\$13000	Initial development of suitable survey method for rehab.	12
	228	1987-88	Backlog Research	108 has surveyed	\$25300	Complete survey method and guidelines for rehab. areas	13
	253	1988-89	Backlog Research	None	\$16000	Training video, handbook and sessions for DRL detection	13
	27	1987-88	Survey	260 PSP's surveyed	\$32,300	Data on ecological and site factors for stand risk rating	14
	JM-090	1989-90	Survey	188 ha surveyed	\$7600	Surveys of 5 spaced stands - data inconclusive	15
	JM-095	1989-90	Survey	32 PSP's surveyed	\$3,000	Test soil samples from 32 PSP's near Cowichan L.	16
	JM-096	1989-90	Survey	14 PSP's surveyed	\$2300	Ecological description of PSP's and soil sample collection	16
	JM-104	1989-90	Survey	20 ha surveyed	\$4200	Survey for establishment of DRL demonstration stand	17
	JM-106	1989-90	Survey	32 PSP's surveyed	\$700	Complete tests of soil samples from 32 PSP's	17
Total Cost					\$224,400		
Rhizina Root Disease (DRR)	54	1988-89	Survey	30 plantations surveyed	\$6,100	Survey method to measure disease incidence & severity, correl. factors	19
	JM-065	1988-89	Survey	Samples anal. from 40 plots	\$3300	Correlating factors & mgmnt. options determined for guidelines	20
	JM-088	1989-90	Survey	40 plots surveyed (1 site)	\$2100	Soil samples from 40 plots analyzed	20
	JM-092	1989-90	Survey	Overview of NFR	\$12700	Inoculations unsuccessful, recomm.	21
Total Cost					\$24,200		
Tomentosus Root Rot (DRT)	PB-12	1986-87	Survey	5 PSP's surveyed	\$3000	Establish PSP's to assess spread and impact	23
	PB-14	1986-87	Survey	5 ha surveyed	\$2000	Establish 2 PSP's to study spread and impact	24
	PB-16	1986-87	Treatment	60/18 ha surveyed/treated	\$6800	PSP's to measure spread & impact, recom.	24
	PB-21	1986-87	Survey	16.5 ha surveyed	\$5300	Survey control trial area for Proj. 30	25
	25	1987-88	Survey	33 sites surveyed	\$22300	Investigate extent, spread, duration, viability, inoculations	26
	30	1987-88	Treatment	8.8 ha treated	\$9100	Assess stumping equipment effacy and impact	27
	45	1988-89	Survey	8 sites surveyed	\$31,800	Investigate spread and infection	27
	49	1988-89	Survey	5 PSP's surveyed	\$1100	Analyze PSP data from Proj. PB-12	28
	59	1988-89	Survey	20 ha surveyed	\$10000	Survey and layout treatment areas	29
	JM-076	1988-90	Survey	8 sites surveyed	\$29100	Establish transfer rates, viability, make recom. for mgmnt.	30
	JM-079	1989-90	Treatment	4 ha treated	\$7500	Establish PSP's, conduct spacing treatment	31
Total Cost					\$128000		
Multiple Root Diseases (DR)	3.8	1985-86	Backlog Research	20 ha surveyed	\$15000	Develop Survey Methods for S. Interior	32
	3.8	1986-87	Backlog Research	17 sites surveyed	\$24000	Determine Disease Extent on S. Int. NSR sites, recomm.	33
	PB-5a	1985-86	Survey	Overview of 1 supply block	\$10000	Recom. multi stage survey method after review of other methods	33
	PB-5b	1987-88	Survey	10 ha (2 sites stem-mapped)	\$19,300	Assessed 3 survey methods as unsuitable for int. stands, recomm.	34
	PB-17	1986-87	Survey	As part of Proj. 3.8	\$4200	Produced an illustrated field guide, recomm. strip survey method	35
	38	1987-88	Modelling	2 sites simulated	\$10100	Eval. PROGNOSIS root dis. model for B.C. as useful, recomm.	36
	44	1988-89	Modelling	1 site surveyed & simulated	\$9800	Eval. PROGNOSIS root dis. model for IDF site as useful, recomm.	37
	51	1988-89	Survey	102 sites surveyed	\$18000	Developed site discrepancy method for disease assess. of TSA's	38
	58	1988-89	Survey	35.2 ha surveyed	\$25,000	Collected data on spread & mortality rates but analyses incomplete	39
	JM-064	1988-89	Survey	Overview of 2 sites	\$600	Initial air photo interp. & design of ground survey for verification	39
	JM-070	1989-90	Survey	1 site surveyed	\$4900	Conduct ground verification - method inaccurate, recomm.	40
	JM-084	1989-90	Survey	43 sites surveyed	\$9000	Prepare & interpret satellite image & choose discrepancy sites	40
	JM-087	1989-90	Survey	51.2 ha surveyed	\$14300	Collected data on spread & mortality rates but analyses incomplete	41
	JM-091	1989-90	Survey	43 sites surveyed	\$9300	Conduct ground truthing for disease-satellite image correlations	41
	JM-097	1989-90	Survey	43 sites surveyed	\$6100	Assess disease-satellite image correlations & note trends, recomm.	42
Total Cost					\$179,600		
Warren's Root Collar	JM-073	1989-90	Survey	1224 ha surveyed	\$13,000	Sporadic attack in pine plantations. Little Mortality.	44
Total Cost					\$13,000		
Hemlock Dwarf Mistletoe (DMH)	JM-093	1989-90	Survey	None surveyed	\$900	Measurement of 48 PSP's cancelled due to snow, no data	46
Total Cost					\$900		
Larch Dwarf Mistletoe (DML)	33	1987-88	Treatment	4 ha surv./2 ha treated	\$4900	Establish PSP's to determine impact of spacing on DML spread, recomm.	47
Total Cost					\$4900		

**Table 2: (Continued) Summary of 1985–1990 Forest Resource Development Agreement
Forest Health (Pest Control) Projects**

Damaging Agent	Project Number	Year	Project Category	Area or No. Sites Surveyed or Treated	Cost	Achievement (s)	Page No.
Lodgepole Pine Dwarf Mistletoe (DMP)	PB-2	1985-86	Survey	2476 ha & 293 plots surveyed	\$41500	Determined DMP incidence & damage, developed survey method, recom.	48
	PB-2a	1985-86	Survey	293 plots surveyed	\$4500	Perform initial analyses of plot data - no signif. DMR differences seen	49
	PB-22	1986-87	Survey	4 plots surveyed	\$9900	Measured shape of infected trees at different DMR's to assess impact	49
	PB-42	1987-88	Survey	4 plots surveyed	\$7800	Determined that BCFS volume equations sufficient for impact appraisal	50
	PB-48	1988-89	Survey	9 plots surveyed	\$600	Measured PSP's & analyzed data, effects of spacing not yet apparent	51
	PB-62	1988-89	Survey	10 sites surveyed (40 plots)	\$9800	Established plots to assess DMR effects for impact model, inconclusive	51
	PB-63	1988-89	Survey	1200 ha surveyed	\$15,000	Developed survey method for age class 1 stands, assessed 1200 ha	52
	JM-089	1989-90	Survey	5 sites surveyed (5 plots)	\$1700	Derived growth reduction factors for DMR's to assess impact, pending	53
	JM-102	1989-90	Survey	293 plots surveyed	\$4500	Summarized plot data for impact model to determine DMP impact	53
Total Cost					\$95,300		
Stem Rusts and Cankers (DS)	26	1987-88	Survey	7 sites surveyed	\$15000	Causal agents determined, recom. for detection and mgmnt.	55
	JM-060	1988-89	Survey	2 ha surveyed	\$4900	Spacing effectiveness not determined	56
	3.7	1985-86	Backlog Research	4 PSP's surveyed	\$4800	Spacing effectiveness not determined, recom.	57
Total Cost					\$24700		
White Pine Blister Rust (DSB)	NE-2	1986-87	Survey	1.5 ha surveyed	\$1500	SPA established, select possible resistant trees for breeding	58
	31	1987-88	Treatment	1.5 ha treated	\$4900	Conduct intensive mgmnt. of SPA	59
	32	1987-88	Survey	26.3 ha surveyed	\$4500	Determined effect of spacing & pruning, recom.	59
	47	1988-89	Treatment	34 ha treated	\$2500	Resistant trees selected, mgmnt. recom.	60
	JM-066	1988-89	Survey	12 ha surveyed	\$10000	Establishment of SPA and mgmnt. recomm.	61
	JM-086	1989-90	Treatment	1.5 ha treated	\$4500	Conduct intensive mgmnt. of SPA	62
	JM-094	1989-90	Treatment	12 ha treated	\$7000	Cone bagging of pos. resistant trees for seed collection	62
	JM-083	1989-90	Workshop	N/A	\$500	Demonstrate and discuss potential of SPA for breeding	63
Total Cost					\$35400		
Black Army Cutworm (IDA)	PB-24	1986-87	Survey	Overview of 70 sites	\$3200	No firm correlations, provided recomm. to improve BAC records	64
Porcupine (AP)	PB-15a	1986-87	Survey	20 sites surveyed	\$3000	Established 20 lines to assess attack levels & control methods	66
	23	1987-88	Survey	Literature review and interviews	\$10000	Assessed impact & correl., initial mgmnt. model & strategy, recom.	66
	24a	1987-88	Treatment	None	\$1800	Purchase of traps for live-trapping trials, trials terminated	68
	52	1988-89	Treatment	3 drainage areas	\$9000	Removed 300 porcupine to reduce damage in Kalum F.D.	68
	JM-078	1989-90	Treatment	3 drainage areas	\$15500	Removed 450 porcupine to reduce damage in Kalum F.D.	69
	24b	1987-88	Display	N/A	\$2400	Public display of porcupine problem improved public's perception	69
Total Cost					\$41700		
White Pine Weevil (IWS)	PR-1	1985-86	Survey	2600 ha surveyed	\$15000	Survey method, determined incidence & damage on 43 sites, recomm.	70
	PB-10	1986-87	Treatment	5.2 ha surv./3.4 ha treated	\$7200	Establish silvicultural control trial to assess effects of overstory	71
	PB-19	1986-87	Survey	9 ha surveyed (18 PSP's)	\$8100	Measured intensification & impact	72
	PB-20	1986-87	Survey	13 sites surveyed	\$9800	Determined incidence & damage on 13 sites, survey method	72
	26	1987-88	Survey	6.8 ha surveyed (9 PSP's)	\$3500	Measured intensification & impact	73
	43	1988-89	Treatment	5.2 ha surveyed	\$4600	Remeasure silv. control trial, no signif. effects seen	73
	JM-080	1989-90	Survey	291 ha surveyed (12 sites)	\$5800	Determined incidence & damage on 12 sites	74
	JM-082	1989-90	Survey	43 sites surveyed	\$21800	Measured & analyzed incidence & site data for 58 sites, no signif. correl.	74
	JM-099	1989-90	Survey	4.5 ha surveyed (6 PSP's)	\$4900	Measured intensification & impact	75
	JM-105	1989-90	Survey	1.3 ha surveyed	\$1800	Measured incidence in 3 sites to determine clipping efficacy, little effect	76
Total Cost					\$82300		
Vole (AV)	41	1988-89	Treatment	36 ha	\$2400	Purchased 2400 repellent devices for vole control	77
Multiple Pest: Disease, Insect, Abiotic & Animal	1.9	1985-86	Backlog Research	N/A	\$10000	Recom. for improved surveys re pest detection/appraisal	78
	PB-3a	1985-86	Survey	42000 ha surveyed	\$14200	Losses & method assessed, recommendations made	79
	PB-3b	1986-87	Survey	12 sites surveyed	\$11000	Causal agents identified	80
	PB-11a	1986-87	Survey	3214 ha surveyed	\$18,300	Determined damage levels & incidence in 41 plantations	81
	PB-11b	1986-87	Survey	520 ha surveyed	\$25000	Assess survey meth., determined damage lvs. in 104 sites, recom.	82
	PB-23	1987-88	Editing	N/A	\$6400	Editorial assistance and recom. for contract report formats	83
	40	1987-88	Backlog Research	1 TSA modelled	\$2000	Developed initial model for damage appraisal at two levels	83
Total Cost					\$86,900		
Air Pollution (NK)	46	1988-89	Survey	10 plots surveyed	\$23300	Determined efficacy of MEIS-II and LANDSAT for SO2 detection	85
	50	1988-89	Survey	8 plots surveyed	\$7,200	Correlated tree-ring data with visual est. of damage categories	86
Total Cost					\$30,500		
Bark Beetles (IB)	PB-18	1986-87	Treatment	54 ha surveyed/26 ha treat.	\$3900	Establish blocks & perform treatment	88
	35	1987-88	Survey	54 ha surveyed	\$2800	Resurvey treatments & controls	88
Total Cost					\$6700		

Recommendations:

General

The following recommendations in order of priority should be considered in future conduct and administration of F.R.D.A. forest health management and research projects:

1. Contract specifications should require project reports to follow standard B.C.F.S. guidelines (eg. Protection Manual, Vol. II, Chap. 16). For project reports or data summaries, electronic (floppy disk) copy in suitable PC or ASCII format in addition to "hard" copies is required. All original reports and data summaries should be filed by the contract administration officer, and copies sent to all concerned district and region staff.
2. Prepare an individual project summary and evaluation immediately after each project is completed. This practice would be beneficial for ongoing assessments of program/project directions and effectiveness with respect to detection and control, completion of objectives, delivery of results, and cost tracking.
3. Project information should be tabulated regularly on a system which should be shared and maintained between the regions, districts and branch for effective, rapid communication and updating.
4. Project numbers should be used on all invoices and other records for easy cost tracking. Project participants should be directed to use project numbers on all correspondence.
5. Contracts which are linked to one particular project or activity should be clearly mentioned in all related files in an ongoing manner. In this way, subject areas having more than one contract would be more easily assessed.

Armillaria Root Disease

Additional work is required for survey techniques and assessment of control methods (stumping or push-over logging) in the southern interior. The following activities are recommended in order of priority:

1. Continue push-over logging and stumping control trials initiated under F.R.D.A. I. Previously treated sites should be reassessed to determine subsequent disease incidence, treatment costs and resulting site disturbance for both techniques. Becker stumping equipment should also be assessed since this type of equipment appears promising. Surveys for root residues should be performed in order to determine treatment efficacy (i.e. amount of inoculum removed per treatment type) and remaining on-site risk. Selected treatment areas should cover the entire habitat range in which the pathogen is found.

2. Perform additional surveys of plantations to more accurately determine the extent and severity of armillaria in young stands in the southern interior and to refine survey methods. Observations of high disease incidence need to be substantiated and quantification of treatment thresholds over a wide range of ecosystems is required. Plantations assessed as having low levels of the disease should be regularly monitored. The effectiveness of establishing acceptable species mixes at reduced stocking should be substantiated. Preliminary evidence on host range suggests that this practice may only be useful as a temporary measure and should therefore be abandoned as a long-term solution.
3. Conduct additional trials of the pixel survey method using various pixel lengths to determine the optimum length for accurate disease measurement. A size of 30 m by 3 m may be optimal; this should be investigated. The pixel survey method might only be useful when disease levels are either high or low and, in any case, is only applicable to areas where mapping for follow-up treatment would not be required. This method might be suitable for mature and overmature stands.
4. The threshold for disease level (10 infected spots per ha) currently established for armillaria/regeneration surveys should be monitored and revised if required.
5. Verify root disease modelling and improve if necessary. Predictive thresholds for all types should be developed with respect to current disease levels and volume projections at rotation.
6. Produce the field guide initiated in Project PB-5b for field personnel, including colour illustrations and/or a training video.
7. Evaluate the prism method for survey of armillaria root disease in Interior stands.
8. Conduct trials and refine methods to evaluate disease impacts on large areas such as timber supply areas. Include other survey methods, such as the regeneration/armillaria technique for young stands, pixel method and inclusion of additional sample points to reduce variability.
9. In conjunction with armillaria root disease surveys, conduct additional satellite imagery analysis at 1:20,000 and ground truthing to confirm or refute correlation between degree of screening and disease incidence. Sampling could incorporate a further evaluation of the pixel method.
10. Modify the PROGNOSIS root disease model for B.C. stands, conduct further tests and im-

plement the model. Conduct extension and demonstration activities to transfer this model within the province. Assess the effectiveness of each management option with this model.

Black Army Cutworm

The information base for the black army cutworm should be improved for all regions for damage appraisal and management decisions:

1. Establish a separate file in each district office for recording black army cutworm infestation data. Allocate a data block for pest information within the History of Crop Establishment Record.
2. Conduct surveys of infested sites.
3. Train personnel in accurate black army cutworm identification, damage assessment and management considerations.

Blackstain Root Disease

1. Re-inspect all plots established under Project JM-072. Monitoring should be conducted every three years since disease spread is very rapid. Data collected should establish whether there is any host resistance, determining insect transmission rates, and mortality and rate of spread.
2. Establish additional plots in plantations near Campbell River and in the Qualicum River Valley, near Port Alberni, to determine mortality and disease spread rate in very young plantations (five years).
3. Conduct a soil survey to determine inoculum levels in affected and unaffected areas within the CWHb and CWHa biogeoclimatic zones.
4. Monitor susceptible plantations in the CWHb and CWHa biogeoclimatic zones.
5. Determine stress-inducing factors and the importance of insect vectors in disease spread and establishment.
6. Emphasize an integrated approach to blackstain studies since occurrence of this disease is probably the result of several factors acting synergistically.
6. Undertake extension and demonstration activities for field crews, emphasizing disease identification and awareness of susceptible plantations.

Hemlock Dwarf Mistletoe

1. Measure 48 plots to determine effects of different hemlock dwarf mistletoe infection classes on log grade, value and volume.

Laminated Root Rot (Coast)

Much progress has been made with respect to young stand survey methods, site risk rating and disease control. The follow-up activities below are recommended in order of priority:

1. Conduct additional stumping operations and regularly monitor for site impact (brush hazard, compaction, soil removal). As a modification of the preceding treatment, conduct preliminary push-over logging trials. This op-

tion, if effective, would be suitable for stands where average DBH is relatively small: heavily infected second growth stands at the commercial thinning stage or slightly older.

Efficacy of root removal, harvesting costs and site disturbance would have to be compared to conventional logging and stumping operations.

2. Conduct additional alternate species and species matrix trials, establish and regularly monitor plots on these sites. Western red cedar performance may be lower than originally anticipated when planted on some of the drier sites and, thus, should be closely assessed.
3. Implement the stand hazard ratings as developed during Pest Control Project 27. This knowledge could best be delivered by development of a pamphlet for field personnel, inclusion in Land Management Handbook No. 16 (R.N. Green et al, 1984) and workshops.
4. Conduct additional training of field crews with respect to proper survey techniques and disease recognition. On-site demonstrations of disease identification, accurate measurements of infection levels, precise mapping for treatments and control options should be stressed. Misdiagnoses and inaccurate estimates of infection levels and locations drastically affect stand management.
5. Perform more surveys of spaced stands to assess the post-spacing spread of laminated root rot in areas where infected trees have been left. Results from these surveys, especially applicable to the Port Alberni Forest District, can be used to evaluate future volume reductions. Appropriate treatments could then be implemented prior to projected harvest.
6. Evaluate a root disease impact model using operational situations. Refinement of such a model would enhance stand management when used in conjunction with the site hazard rating guidelines.
7. Establish and maintain a root disease demonstration stand near Stamp Falls, Port Alberni Forest District. The area is representative of infection at all stages and is readily accessible. Treatment blocks should be delineated, controls applied and plots established. The site could then be monitored for treatment effectiveness and practicality and disease impact (in the control). The stand would also be ideal for workshops.

Laminated Root Rot (Interior)

1. Evaluate the prism method for surveying diffuse laminated root rot in mature Interior stands.
2. Produce the field guide initiated in Project PB-5b in a format suitable for field personnel, including colour illustrations and/or a training video.

3. Conduct further trials and refinement of the site discrepancy method to evaluate disease impacts on larger areas such as timber supply areas. Refinement should include provision for other survey methods, such as the regeneration/armillaria technique for young stands, pixel method and inclusion of additional sample points to reduce variability.
4. Conduct additional satellite imagery analysis at 1:20,000 and ground truthing to confirm/refute correlation between degree of screening and disease incidence. Sampling could incorporate a further evaluation of the pixel method.
5. Modify the PROGNOSIS root disease model for B.C. stands, conduct further tests and implement the model. Conduct extension and demonstration activities of the model to transfer technique within the province. Assess the effectiveness of each management option with this model.

Larch Dwarf Mistletoe

1. Remeasure spacing trial blocks every five years, starting in 1992.
2. Establish additional plots on other sites.

Lodgepole Pine Dwarf Mistletoe

1. Perform a roadside and plot survey to determine lodgepole pine dwarf mistletoe incidence and impact in the Cariboo, Nelson and Kamloops forest regions.
2. If lodgepole pine dwarf mistletoe is a problem in the Cariboo, Nelson and Kamloops forest regions, then select suitable representative sites and perform a stem analysis to validate use of stand whole stem volume equations versus the Forestry Canada Program for determining volume and impact in dwarf mistletoe infected stands in these regions.
3. Remeasure the Prince George Forest Region spacing trials annually to determine efficacy of spacing in lightly infected versus heavily infected lodgepole pine stands.
4. Calculate impact using growth reduction factors from the recent Forestry Canada dwarf mistletoe program and incidence data from the 1985-86 roadside surveys and the 1988-89 Westlake PSYU survey of young stands. Results from these analyses should be compared to those derived from whole stem volume equations and the dwarf mistletoe impact plots.
5. Survey lodgepole stands, ages 1 to 20 years in Prince George Forest Region using 3.99m plots on 100 x 200m grids. Survey 10-20% of these stands per PSYU to estimate dwarf mistletoe incidence and damage during pre-stand tending surveys. Obtain an estimate of productivity and efficacy for the methodology developed in Project 63.
6. Train field crews to accurately identify dwarf mistletoes and to conduct either roadside surveys for forty year and older lodgepole pine

stands or 3.99m radius plots on 100 x 200m grids.

Multiple Pests

1. Conduct additional surveys in the Prince George Forest Region using the method developed in Project PB-11a to obtain a broader database.
2. Conduct additional surveys in the Prince Rupert Forest Region utilizing the same method as was employed in the Prince George Forest Region rather than the previously employed 100m plots. Evaluate the efficacy of the former method. Restrict surveys to sites that are 10 to 40 years of age, and of similar site and stand characteristics, and analyze any trends.

Porcupine

For the Prince Rupert Forest Region implement the following:

1. Resurvey 50km of permanent sample lines in the Interior and on the Coast to assess current and total impact and mortality. Continue monitoring until control programs are effective (in approximately 10 years). Establish plots in the Interior and continue plot monitoring on the Coast. Monitor porcupine population levels and movements annually, especially in the Kalum and North Coast Forest Districts to assess the effectiveness of the hunting program and predict future impacts and damage incidence.
2. Conduct further porcupine hunting trials with follow-up assessment. Other control options will probably require a longer time period to become effective in the most heavily attacked areas.
3. Assess fisher predation success on North Coast by re-introducing this animal and determining its efficacy over the next 5-10 years. Conduct and assess fisher predation trials in the Kalum Forest District.
4. Assess the effectiveness of a juvenile spacing trial and tree collaring control techniques. Results of spacing to different densities are inconclusive to date. This procedure may be too costly. Assess selection of balsam and western red cedar as crop trees over other stand components over the next five years.
5. Assess chemical repellents such as Ani-pel on the Coast and in the Interior.
6. Conduct further trials of live trapping pending the findings from a Pest Research Project currently under way in the Prince Rupert Forest Region.
7. Determine the impact of introduced wound parasites on volume at rotation.

For the Prince George Forest Region and Nelson Forest Region implement the following projects on a smaller scale:

1. Monitor porcupine damage incidence. Determine impact trends by assessing new versus

old attack in the same manner as the Prince Rupert Forest Region assessments.

2. Implement control trials, especially hunting, in heavily damaged stands for a short-term reduction in local populations.
3. Conduct population dynamics studies in the regions and assess other control options such as selection of less favoured hosts, predator introductions, live trapping and repellents. In general, hunting or trapping should be considered as very short-term solutions, predator enhancement as a short-term solution, and changes in silvicultural practices as a long-term solution.

Rhizina Root Disease

1. Assess the productivity and accuracy of the regeneration plot method for determining rhizina root disease incidence and severity and then implement this methodology on an operational basis. A grid pattern should be employed for complete coverage rather than the 10-15 plots/site previously employed.
2. Train field personnel in the identification of this disease and in the use of appropriate survey procedures and guidelines once these are fully developed.
3. Complete development of the guidelines for management of rhizina root disease. These guidelines should consist of a site risk assessment procedure based upon burn temperature, presence of infected fireweed and adjacent infected cutblocks, biogeoclimatic subzone and variant, amount of woody debris remaining on-site, and decadency of old-growth. Management options for moderate to high-risk areas should be listed as follows: mechanical site preparation, clean logging, perform low or high intensity burn, or plant in the third year following a medium intensity burn.
4. Develop suitable survey forms and transfer these to field personnel and managers, together with the management guidelines.

Subalpine Fir Decline

1. Standardize the multiple pest survey methodology. Use of a standard survey method would facilitate survey implementation and data comparisons between regions and districts. The Nelson Forest Region has already successfully used an armillaria/regeneration survey technique. A combination of pest/regeneration-type survey plus follow-up with specific pest surveys in areas with a high incidence of infestation would probably be the most appropriate strategy.
2. Train silvicultural survey personnel in pest identification, perhaps as part of the Silvicultural Surveys course currently offered.

Tomentosus Root Rot

Suitable detection and control techniques for this disease are still preliminary. Considerable follow-up projects are required before operational status is reached. An integrated approach for further work is recommended in the following order:

1. Develop an economical and accurate survey method which accounts for both even-aged (younger stands) and uneven-aged stands. The method must be suitable for use at the PHSP, survival and stocking, free-growing and stand tending stages. Stratification, site risk rating, treatment threshold and rigorous identification and mapping should be used to develop ecologically based prescriptions.
2. Conduct additional surveys of old-growth pure spruce and spruce-pine stands, using the methodology developed in Item 1, to adequately assess the extent and severity of the problem in the Prince George and Prince Rupert forest regions. Current information on occurrence applies to 49 sites. Disease distribution is patchy, with approximately 40% to 28% incidence in each region, respectively, according to K. Lewis and Forestry Canada F.I.D.S. estimates. These figures should be further substantiated. Observations that tomentosus root rot may be limited to moist or fresh habitats should be verified so that site stratification and risk rating procedures can be developed.
3. Assuming that disease incidence and levels are significant, conduct workshops on disease identification and appropriate survey methods for field crews, using available demonstration areas. Tomentosus is difficult to identify and accurately assess, especially in younger stands. Workshops should emphasize field assessments in stands 10 to 20 years of age as well as older stands.
4. Survey younger spruce and spruce-pine stands utilizing the preceding methods and training activities.
5. Evaluate treatments performed during F.R.D.A. I by means of regular monitoring of established plots in treated areas. To augment data for previous trials, conduct and regularly assess treatments on additional sites. Planting of alternate species should be stressed as an appropriate control if the disease is localized within moist to fresh habitats. Monitoring of Douglas-fir, lodgepole pine, balsam and spruce treatment blocks will provide accurate data on volume loss, mortality and spread. Excavation of infected spruce stumps is probably effective for removing most of the inoculum due to the shallow rooting habit of this species, but is likely less successful for pine. In general, stumping would prove less ecologically effective than alternate species establishment because excessive site disturbance (soil compaction and brush hazard) will occur

on moist to fresh areas. In any case, further stumping trials should employ smaller hydraulic excavators. In addition, those root removal operations already conducted should have follow-up assessments.

6. Examine the effectiveness of fertilization and pesticides as controls.
7. Survey subalpine fir stands to determine incidence and extent using the preceding methods.
8. Correlate root collar weevil activity with infection.

Stem Rusts/Cankers

Results of spacing as a control of stem rusts/cankers on lodgepole pine are preliminary at present. Substantiation of spacing as an effective control should be emphasized as a follow-up activity.

1. Continue monitoring of plots assessed under F.R.D.A. I to determine spacing treatment effectiveness. Additional areas should be delineated, treated and monitored to augment the data base and substantiate this treatment, if possible.
2. Develop, refine and implement the guidelines for prevention of Douglas-fir dieback as initiated under Backlog Research Project 3.7. Workshops should be conducted to deliver these guidelines. Field sessions should be emphasized to improve identification and prevention of this problem in interior plantations.

White Pine Blister Rust

Development of blister rust-resistant white pine should be emphasized since this is probably the most biologically effective means of control.

1. Perform regular intensive management of all western white pine seed production areas (SPA's) established under F.R.D.A. I. This management should include: monitoring of bark reaction trees, planting of *Ribes* to induce selective pressure, cone bagging and collecting, seed extraction, and in-planting of other white pine stock as desired. Results of this management would enhance efforts to produce blister rust-resistant stock in the Forestry Canada-B.C.F.S program currently underway.
2. Establish and intensively manage additional western white pine SPA's if suitable white pine stands can be located.
3. Continue assessments of white pine pruning/spacing trials as a blister rust control. Data on the costs and benefits for this treatment should be improved to determine if this control is practical. Established pruning/spacing control blocks should be regularly monitored and additional trials conducted.
4. Conduct on-site workshops on blister rust identification and control for field crews. This activity should reduce the incidence of infected leave trees and subsequent disease levels.

Armillaria Root Disease (DRA) Projects

Armillaria Root Disease: Pest Control Project 29

Title: Root Disease Spacing Trial.

Area Treated/Surveyed: 17.6 ha surveyed and 11.9 ha treated.

Contractor: Pathocora Consulting, Prince George.

B.C.F.S. Contact: H. Merler, Kamloops Forest Region.

Region: Kamloops Forest Region.

Date: August, 1987 to January, 1988.

Cost: \$9,400.

Objective:

1. Layout a trial and demonstration area to show the effects of spacing to different densities in young stands of Douglas-fir infected with root disease.

Description: Two stands in the Merritt Forest District were selected which had a high root disease incidence and were suitable for juvenile spacing or thinning operations. The sites were sufficiently far apart (3.7 km) and were large enough for delineation of three treatment blocks. Treatment units were laid out and ten 5.64 m radius (100 m²) plots were established per treatment type on each site, for a total of 60 plots. Of these plots, two types were established: five plots per treatment unit with no root disease and five per treatment unit containing at least one infected tree. Data on tree growth, stocking and infection status was obtained within these plots and stem maps were produced. Concurrently, a root disease survey was conducted in each area to determine pre-treatment disease levels and location for each site. General information was also obtained for the site and stand.

The initial survey determined that overall stocking was 1760 stems/ha in the first site and 3500 stems/ha in the second site, with density ranging from 5900 to 27800 stems/ha. Armillaria root disease levels were measured as 14.6% at Site 1 and 7% at site 2. Other pathogens were not present to any significant extent. Armillaria was diffuse in distribution at Site 1, with infection occurring mainly

as single trees, and was aggregated into distinct infection centres at Site 2. The following treatments were subsequently conducted in the winter of 1987-88: control (no spacing), spacing to normal standards, and spacing to normal standards plus removal of armillaria-infected trees and any trees within a 1 m radius of infection sources. Trees greater than 15 cm DBH or less than 2 m in height were not removed unless infected. Douglas-fir was favoured over the other stand components.

Contractor Recommendations:

- Resurvey sample plots to map stems removed and stems remaining after treatment
- Maintain each area and re-examine all plots regularly in order to assess post-treatment spread. This should be performed every one or two years.

Project Report: Schulting, J. 1988. Spacing in Armillaria obscura Infected Stands in The Merritt Forest District. Contractor Report. 12 pp plus stem maps.

Evaluation: All objectives were met during this project. Spacing probably aggravates armillaria root disease levels but firm data have been lacking. Thus, results from this work should prove useful in determining the effects of thinning operations. In addition, these sites will be useful demonstration areas for field crews. Suitable follow-up activities include:

- regular monitoring and maintenance of all plots to ascertain disease spread after treatment.
- perform on-site training for disease identification and appropriate control.

Project Status: Spacing probably does not control armillaria root disease but this assertion is yet to be proven. Operational Control Trial — method rated possible to fair chance of suitability for operational use; need data to precisely determine effectiveness and/or response to treatment.

Armillaria Root Disease: Pest Control Project 34

Title: Trial of a Regeneration Survey Modified to Assess Armillaria Root Disease.

Area Treated/Surveyed: 1321 ha.

Contractor: Laing, McCulloch Forest Management Services, Smithers.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: August to September, 1987.

Cost: \$14,500.

Objectives:

1. Test the feasibility of collecting armillaria root disease data in standard regeneration surveys or free-growing assessments.
2. Determine the extent and/or level of the disease in blocks where there was no previous record of disease presence.
3. Determine if correlations exist between armillaria root disease incidence and ecosystems, site productivity or other pests.
4. Determine what threshold levels of infection are acceptable.

Description: A total of 1088 regeneration survey plots were established in 1321 ha (16 openings) in the Golden TSA. Usual regeneration survey procedures were used, with data on armillaria root disease collected within plots and between plots. Plots were established on a 100 m grid to ensure adequate coverage. Causal agents were determined for all affected trees. Armillaria had not been recorded previously in any opening.

Of the 16 sites surveyed, 81% had confirmed or suspected armillaria. Ten blocks (63%) were confirmed for the disease, and six blocks (38%) had high infection levels, such that reforestation to required stocking standards was very problematic. Infection was also noted in stands adjacent to some of the infected blocks. Apparently two-thirds of the blocks will be severely damaged by root disease before they attain rotation age.

Blackstain root disease was found on Douglas-fir and lodgepole pine. Root collar weevils and various stem rusts were recorded on lodgepole pine. Frost, rodent damage and gall aphids were frequently noted. These agents may have exacerbated armillaria damage.

Armillaria root disease within regeneration plots was readily identified when crown symptoms were present. However, because of the occurrence of non-symptomatic trees, the estimated number of armillaria-infected trees per plot was less than actual numbers. Recording the disease between plots was possible but decreased survey productivity by 10%

to 15%. Assessment of armillaria root disease between plots was inaccurate because of brush and non-symptomatic trees. Numbers of trees recorded between plots could not be used for estimates because of missed trees and variations in infection centre distances. The cost of incorporating armillaria data gathering into a standard regeneration survey was found to be negligible.

Contractor Recommendations:

- Armillaria root disease should only be noted and mapped between plots and should not be quantified. Mapping will provide information on disease distribution for treatment purposes. Disease incidence should only be estimated within plots.
- Information on armillaria root disease should be incorporated into standard regeneration/free-growing surveys.
- Stands should not be assessed as free-growing if armillaria root disease levels exceed five contaminated spots per hectare or one or more percent of the plots.
- Contaminated growing spots per hectare should be used to measure disease levels between plots because this criterion is easily assimilated into the survey and gives a good description of disease intensity.
- Examine each block for residual timber and determine infection levels in these by means of a walk-through.
- Conduct stand development estimates in each block examined using root disease models.

Project Report: Laing, K. 1987. Armillaria-regeneration Survey: Golden TSA. Contractor Report. 13 pp.

Evaluation: This project achieved all objectives as outlined. However, quantitative correlations could not be made between armillaria and site index or presence of other damaging agents. This objective would probably best be accomplished with additional surveys and the application of root disease modelling. All contractor recommendations have since been implemented. The threshold for armillaria root disease levels needs to be reassessed, based on additional data from surveys over a broader range of ecotypes. Tentatively, this threshold has since been set at ten infected spots per hectare. Line intercept estimates and mapping should be dropped from the survey since heavily infected areas should be treated on a per stratum basis rather than selectively. Follow-up activities suitable under F.R.D.A. II include:

- additional surveys over a wider range of habitats.
- incorporation of columns for disease incidence on regeneration survey forms.

- training workshops at suitable field locations to transfer techniques to regeneration survey crews. Disease identification should be emphasized.
- reassess the sites surveyed in this project for future development of a suitable root disease model.

- correlations between armillaria root disease, other damaging agents and site factors.

Project Status: Operational Survey Trial: method fully practicable; need additional data for operational cost estimates and for a broader range of ecological conditions.

Armillaria Root Disease: Pest Control Project 53

Title: Knappen Creek Armillaria Control Trial: Area Survey and Layout.

Area Treated/Surveyed: 51.1 ha.

Contractor: T.M. Thompson and Associates Ltd., Victoria.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: October to November, 1988.

Cost: \$8,800.

Objectives:

1. Perform a line intercept/armillaria regeneration survey to map all infection centres.
2. Layout the area for treatments.
3. Provide a detailed map and brief report including treatment recommendations.

Description: A line intercept/armillaria regeneration survey was performed on a site near Knappen Creek, Boundary TSA, to determine infection levels, layout the site for treatment and map all infection centres.

The area was surveyed using techniques from Pest Control Project 34. Survey intensity consisted of strips spaced at 50 m and plots spaced at 100 m along all strips. Disease incidence was recorded within and between plots. Infected spots were verified for armillaria within plots and the start and end points of all infection centres were mapped along the transects. Data on topography, access, soils and timber type were also obtained.

Armillaria root disease was found throughout the site. Disease levels were estimated as 26.2% within plots and 13.3% between plots. This discrepancy between figures was probably caused by the occurrence of missed (non-symptomatic) trees along transect lines. Many small one- to three-tree centres were noted but all major infection centres were mapped. Selective logging was considered to have exacerbated the problem. No other damaging agents were noted.

Contractor Recommendations:

- Control armillaria root disease on the site by uprooting stumps to remove and expose the pathogen.
- Treat the site with an excavator since slopes are gentle and soils are deep and coarse-textured.
- Any treatment method employed should avoid soil erosion due to the proximity of the creek.

Project Report: Data summary with detailed map.

Evaluation: The treatment area was thoroughly covered and mapped. Disease incidence was measured in the same manner as in Pest Control Project 34, with similar results. Armillaria levels were greater within plots than between plots because of missed (nonsymptomatic) trees along each line. However, mapping along each transect was considered useful for locating major infection centres for future treatment. Thus, the modified survey method was judged as very practical.

Stumping operations were conducted on this site in November, 1989, using a feller/buncher equipped with a thumb and claw attachment. A total of 1584 stumps from 15 cm to 85 cm diameter were removed in three 0.5 ha test plots. As expected, time to pull stumps increased with increasing diameter. Slash affected productivity more than any other factor. Follow-up activities suitable under F.R.D.A. II include:

- regular monitoring of the site to assess treatment effectiveness and degree of site disturbance.
- performance of the survey and treatment methods conducted during this project on additional sites for thorough evaluation.

Project Status: This Project — Operational Survey Trial: method fully practicable; need additional data for operational cost estimate and for broader range of ecological conditions.

Follow-up Activities (Stumping with feller/buncher) — Operational Control Trial: method fully practicable; need additional data for operational cost estimate and for broader range of ecological conditions.

Armillaria Root Disease: Pest Control Project 55

Title: Quartz Creek Armillaria Root Disease Survey.

Area Treated/Surveyed: 24 ha.

Contractor: Klaus Roethel Forest Consulting Services, Vancouver.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: October to November, 1988.

Cost: \$5,280.

Objectives:

1. Conduct an armillaria root disease survey, using the line intercept/armillaria regeneration survey method, to establish infection levels and obtain data on other site factors.
2. Mark out the boundaries of suitable treatment blocks and produce a detailed map.

Description: A site 40 km north of Golden containing overmature western hemlock-spruce-fir-cedar was surveyed. The line intercept/armillaria regeneration method was employed on a grid of 50 m by 100 m to ensure adequate coverage. Data on armillaria infection were obtained within plots. Overall infection levels were estimated as 13%. The site was considered to be suitable for a control trial. Six treatment blocks were delineated for the control and proposed stumping with Becker or other excavation equipment.

Contractor Recommendations: The following recommendations were made for this site:

- Conduct Becker stumping on four blocks since this type of treatment would reduce inoculum levels while minimizing site disturbance (soil compaction).
- Also consider stumping with an excavator (backhoe) and push-over logging.
- Do not employ crawler tractor stumping because this equipment would create excessive disturbance.

Project Report: Roethel, K.E. 1989. Root Rot Survey at Quartz Creek Control Area. Contractor Report. 6 pp.

Evaluation: All objectives were achieved and control trials are to be conducted on this site in the near future. The survey method was effective for determining the amount of infection. Follow-up activities include studies of stumping and/or push-over logging trials, and follow-up monitoring, and performance and assessment of similar trials on other sites infected with armillaria root disease in the interior and on coastal areas infected with laminated root rot.

Project Status: Operational Survey Trial — method fully practicable; need additional data for cost estimate and broader range of ecological conditions.

Armillaria Root Disease: Pest Control Project 56

Title: Survey For an Armillaria Root Disease Control Trials.

Area Treated/Surveyed: 20 ha.

Contractor: Klaus Roethel Forestry Consulting Services, Vancouver.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: October to November, 1988.

Cost: \$4,800.

Objectives:

1. Survey a plantation near Quartz Creek to determine the suitability of the area for root disease control trials.
2. Conduct an armillaria/regeneration type survey on a portion of this site.

Description: A plantation was surveyed near Quartz Creek, 40 km north of Golden. Armillaria infection levels were measured within plots and suitability of the area for control trials was assessed.

The overall infection level was determined to be about 5% (moderate). Block boundaries were laid out for five adjacent treatment units plus a separate control area.

Contractor Recommendations: No control trial was recommended because disease incidence was only 5%.

Project Report: Roethel, K.E. 1989. Root Rot Survey at Quartz Creek. Contractor Rep. 4 pp.

Evaluation: All objectives were met during this project. Treatment units were delineated but control trials were not recommended because of low infection levels. The site should be regularly monitored for disease spread.

Project Status: Operational Survey Trial — method fully practicable; need additional data for operational cost estimate and broader range of ecological conditions.

Armillaria Root Disease: Pest Control Project 57

Title: Costs for Travel to Columbia West Stumping Trial.

Area Treated/Surveyed: None.

Contractor: None.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: October, 1988.

Cost: \$610.

Objective:

1. Travel to trial area for assessment of root removal operations for control of armillaria root disease.

Description: Funds were for travel to and from Columbia West armillaria root disease control trial area.

Contractor Recommendations: N/A.

Project Report: None.

Evaluation: This project number was part of a stumping assessment trial (Pest Control Project 61) and was for travel expenses only.

Project Status: Complete (4 D).

Armillaria Root Disease: Pest Control Project 61

Title: Columbia West Road Stumping Trial for Control of Armillaria Root Disease.

Area Treated/Surveyed: 4.5 ha.

Contractor: Darbyshire and Sons, Golden.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: October, 1988.

Cost: \$1,740.

Objective:

1. Assess a root removal trial at C.P.108, Columbia West Road to determine the amount and kind of roots left after stumping, and the degree of site disturbance for the four treatments.

Description: A root disease stumping trial was performed in 1987 by Evans Products, Golden, on a site with a high incidence (15.7%) of armillaria root disease. Four treatments were employed on the most heavily infected area (4.5 ha) within a 33.5 ha cutblock: push-over logging with a 235 backhoe, stumping with a 235 backhoe/thumb attachment, stumping with a crawler tractor, and control.

In 1988-89, 17 sample pits were randomly selected in these treatment units, and excavated using a 580S-type backhoe. Pits 1 cubic metre in size were excavated and examined for root residues in the upper and lower 0.5 m layers of each pit. Four diameter and length classes were used to classify root material recovered. Both armillaria and tomentosus infected roots were identified and separated for data analyses, but very few roots in the trial areas contained the latter disease.

Crawler tractor stumping and push-over logging were found to be almost equally effective in remov-

ing total root material (75% versus 69%, respectively). However, consistently less infected root material was left during push-over logging. Backhoe stumping resulted in twice as many infected roots being left in the soil. Backhoe stumping left infected stumps because of high slash levels and low visibility. Site disturbance was unacceptably high with the crawler tractor and was much less with the backhoe. Push-over logging appeared to produce the best results in terms of low site disturbance and amount of infected material removed from the site.

Contractor Recommendations:

- Ensure that control blocks are uniform perhaps by means of a pre-treatment root survey.
- Remove slash before treatment to ensure that all infected stumps are removed.
- Do not use crawler tractors for stumping since this equipment causes excessive site disturbance.
- Push-over logging with some yarding refinements is probably the best technique for most interior sites and, thus, should be further assessed.

Project Reports: Norris, D. 1988. Columbia West Road: Root Removal Trial. B.C.F.S. Internal Report (Pending). 13 pp.

Related (non-F.R.D.A.) Report — Taylor, B. 1988. An Analysis of Some Various Stumping

Trials for the Treatment of Armillaria Root Disease in the Golden Timber Supply Area. 36 pp.

Evaluation: The control area selected for this control trial assessment was probably not representative of the rest of the site. Further, additional pits could not be excavated due to funding constraints. However, preliminary results indicate that push-over logging was probably the best treatment

Armillaria Root Disease (DRA) Projects

since more duff was retained and relatively few infected root pieces remained in the soil. Further root removal trials and residue assessments should ensure that the control area is representative. In addition, more sample pits should be dug per treatment unit in order to have a truly representative data set. These concerns aside, further assessments of armillaria control trials should be conducted since excavations for root residues will probably give a

reasonable indication of the effectiveness of various stumping methods.

Project Status:

Operational Control Trial — methods rated fully practicable; need data for cost estimate and for broader range of ecological conditions for demonstration of feasibility.

Armillaria Root Disease: Pest Control Project JM-101

Title: Wickman Creek Armillaria Survey Assessment.

Area Treated/Surveyed: 400 ha.

Contractor: Kimmur Forestry Consultants Ltd., Cranbrook.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: February to March, 1990.

Cost: \$9,800.

Objectives:

1. Conduct a line intercept survey for armillaria root disease at Wickman Creek.
2. Compare armillaria root disease detection using the line intercept method versus a pixel survey of the same area.
3. Compare the results of the two survey methods.

Description: An operational timber cruise, using a 100 m grid, was employed on a 400 ha block infected with armillaria root disease. In addition to the standard cruise data, information was collected for armillaria and other damaging agents (dwarf mistletoe and Douglas-fir bark beetle). Armillaria damage was coded per tree as: 0 = no infection, 1 = crown symptoms only, 2 = 1% to 50% basal resinosis, 3 = 51% to 99% basal resinosis, 4 = recently killed, 5 = old kill.

A pixel survey, consisting of 3 m wide by 50 m long pixels (4 pixels / 100 m of strip), was performed between plots. Pixels were rated as either infected or healthy based on at least one infected tree

or stump per pixel. The line intercept method was used to determine the efficacy of the pixel survey.

Most armillaria damage consisted of trees with symptoms (code 1). A total of 67% of the pixels contained armillaria root disease versus an infection estimate of 66% for the line intercept method (measuring the length of infection centres). Subsequent observations by the Regional Forest Pathologist suggested that both methods did not overestimate the extent of the disease (D. Norris, 1990; pers. comm.). The pixel method was found to be 10% to 15% less productive than the line intercept method.

Contractor Recommendations: None. Push-over logging was recommended on the shallower slopes.

Project Report: Patterson, B. 1990. Wickman Creek Operational Trial — Contract No. PM89N00.05, Minor Services Contract 17558. Contractor's Report. 14 pp.

Evaluation: No specific recommendations were made for pixel surveys to determine armillaria infection levels. No detailed comparison of the methods, as outlined in the contract objectives, was performed. In any event, the pixel survey method would only be applicable in those areas where disease mapping is not needed. Additional evaluation of the two methods would be desirable. Any future assessments should compare lengths of pixel (30 m by 3 m may be optimal).

Project Status: Operational Survey Trial — method rated potentially suitable for operational use. Need additional data to determine effectiveness.

Blackstain Root Disease (DRB) Projects

Blackstain Root Disease: Pest Control Project JM-072

Title: Blackstain Root Disease Survey.

Area Treated/Surveyed: 17 sites.

Contractor: W. Jacobi, Visiting Scientist, Department of Plant Pathology, Colorado State University, Fort Collins, Colorado, U.S.A., 80523.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Vancouver Forest Region.

Date: May, 1989 to March, 1990.

Cost: \$18,100

Objectives:

1. Establish plots to monitor blackstain root disease to determine risk of planting Douglas-fir seedlings next to infected stumps, measure disease spread rate, role of insects as vectors, and determine host specificity.
2. Assess Douglas-fir trees in a provenance trial for resistance to blackstain.

Description: Mortality and spread of blackstain root disease were investigated in coastal Douglas-fir stands less than 30 years of age. The disease is a significant problem in Oregon and Washington under similar conditions; thus, investigation was strongly warranted in B.C.

Rectangular plots of variable area were established. Plots consisted of three to 239 trees per site to encompass infection centres. Each tree was numbered with an aluminum tag. Data collected included percent slope, slope position, aspect, topography, elevation, average tree age, height, DBH, species, disease code and radial growth increment. Foliage symptom codes were: 1 = healthy; 2 = green/yellow; 3 = yellow/green; 4 = yellow; 5 = 50-100% defoliation; 6 = dead one year or more.

A provenance trial, near Port Renfrew, was assessed for host resistance studies because this area had a high incidence of blackstain. Trees rated code 4 to 6 were examined for disease signs by cutting into the main roots and root collar.

Insect traps utilizing attractants were placed at each plot. On-site inoculations were also conducted by planting seedlings next to infected stumps. Root contact versus insect vectoring was assessed by placing half of these seedlings in an insect barrier.

Seventeen monitoring plots were established on Vancouver Island and the mainland to assess spread and mortality rates. Out of a total of 894 trees, averaging 20 years of age, 35% were symptomatic for disease and/or stress, and 16% were confirmed for blackstain. Blackstain mortality apparently occurred rapidly (within three years). Site topography generally did not vary, most plots being established on southern aspects. Many sites were assessed as poor and subject to periodic (summer drought) stress. In addition, most sites had been thinned.

A total of 1,189 trees was assessed in the provenance trial. Blackstain was found in 6.6% of these trees, but mortality prior to the study might have made this figure conservative. Armillaria root disease and laminated root rot were associated with some trees. There was a wide range of blackstain incidence between provenances, varying from 0% to 38%, and the disease had a clumped distribution. A trend toward possible resistance or susceptibility was noted between selections, but only one replication was available; thus, this observation is tentative.

To date, no results were obtained for the inoculations and proportion of insect transmissions. Several more years of observations are required to assess results.

Contractor Recommendations:

- Conduct more surveys for blackstain root disease.
- Assess management options such as: prevention of site degradation; removal of infected trees and control of associated armillaria and laminated root rot infection centres; creation of buffer strips of cut trees around disease areas (possibly helpful if insect vector populations are low); schedule thinning operations in

** Follow-up report by W. Jacobi, on file, rec'd Dec 19/94 (5yr re-measurement)*

Blackstain Root Disease (DRB) Projects

months when vector populations are low. The last two strategies would require accurate and regular monitoring of insect populations.

Project Report: Jacobi, W.R. 1990. Studies on Blackstain Root Disease on Douglas-fir in British Columbia. Contractor's Report. 16 pp, illus.

Evaluation: Seventeen permanent sample plots were established which will provide valuable information with respect to blackstain transmission, spread and mortality, and possible resistance in Douglas-fir. The disease is probably not an extensive problem in B.C. at present, but can have a serious impact in small, isolated locations. However, blackstain does cause severe localized damage, in similar stands in Washington and Oregon. Potentially,

the disease could increase rapidly in spaced stands because of insect transmission, and attraction to cut stumps. Thus, there is substantial cause for concern and data resulting from these plots should address many outstanding questions for the Suitable future work included:

- Regular monitoring of plots established during this project to obtain data on disease spread and mortality rates, insect transmission and possible host resistance.
- Establish additional study sites at Campbell River (Lost Lake and Boot Lake sites) and the Qualicum River Valley.

Project Status: Damage Appraisal Operational Trials — plot establishment and remeasurement.

Blackstain Root Disease: Pest Control Project JM-100

Title: Blackstain Root Disease Survey on Southern Vancouver Island.

Area Treated/Surveyed: 22 sites.

Contractor: Pacific Coast Forest Biology, Victoria.

B.C.F.S. Contact: J. Beale, Vancouver Forest Region; J. Muir, Silviculture Branch, Victoria.

Region: Vancouver Forest Region.

Date: March, 1990.

Cost: \$14,940

Objectives:

1. Develop and employ a survey method for determining levels and incidence of blackstain root disease in young Douglas-fir plantations on southern Vancouver Island.
2. Conduct an ecological assessment of all sites surveyed and analyze disease information with respect to site factors such as thinning operations and site class.
3. Provide a report with data analysis, location of disease and recommendations.

Description: The survey was designed to be as broad as possible: 22 representative sample units were surveyed within the CDF CWHa, CWHb and CWHd biogeoclimatic subzones. Within these zones, sites were selected based on stand age (less than 30 years), leading fir-type, and history of thinning operations. In addition to strip surveys of selected areas, road-side reconnaissance was performed in order to locate any additional infection.

Transects were run at 50m intervals and disease incidence was determined for 5m either side of each line. Area measurement was used to establish extent since the disease was observed to have an aggregated distribution. Lateral roots and the root collar were examined for confirmation of the disease. Crown symptom codes, as established in Project JM-072, were used to record disease incidence and se-

verity. Armillaria and laminated root rot were also recorded, together with evidence of insect activities.

Standard 3.99m silvicultural plots were used to perform the ecological assessments. The following information was collected: stand density and composition, number of stems (stocking), age, height, height and radial increment, EISG species, percent slope, slope position, aspect, soils, rooting zone, and indicators of stress. Analysis of variance and covariance was performed on area affected, disease proportions and incidence. A Kruskal-Wallis test was applied to disease proportions using site index, biogeotype, incidence of spacing, soil type and rooting depth. Chi-square analysis was performed to determine any correlation between blackstain and armillaria within stands and between trees, and to test any association of symptom severity with each disease.

The disease was found to be aggregated in distribution. Severity ranged from 0% to 48.7%. No significant differences were found between spaced and non-spaced areas and between biogeotypes due to large variations between sites. Blackstain and armillaria accounted for 90% of the infection, laminated root rot for the remainder. Trends indicated that the proportion was highest in the CWHb (mean of 13.6%) and lowest in the CWHd and CDF (0%) biogeoclimatic subzones.

In addition, there were no significant differences with respect to site index, soil type and rooting depth; however, trends indicated that disease incidence and severity may be greater in young spaced stands where shallow rooting and compactible silty soils are present. These factors are commonly associated with site disturbance.

Blackstain may occur as a result of the synergistic interaction of stand type and age, availability of inoculum, insect activity, stress, spacing and degree of host susceptibility. No relationship was seen between blackstain or armillaria, but either disease could initiate infection. Trends indicated blackstain

to be the initiator in most sites. However, results were too inconclusive to assess the long-term risk to coastal plantations. This was due to high variation rather than the survey method employed.

Contractor Recommendations:

- Conduct additional surveys, especially in the Campbell River area. Monitor the Lost Lake site to determine spread rate and mortality and verify the cause(s) of blackstain establishment in very young plantations.
- Perform a soil sampling survey to determine blackstain inoculum levels in affected and unaffected areas.
- Monitor susceptible plantations in the CWHb and CWHa biogeoclimatic subzones as part of regular stand surveying activities. At present, susceptible areas can be defined by proximity of known blackstain infection, site disturbance and stand characteristics in disease spread

since blackstain infection is probably affected by several factors acting in a synergistic manner.

Project Report: Bloomberg, W.J. and G.V. Hawkins. 1990. Survey and Evaluation for Blackstain Root Disease in Young Coastal Douglas-fir Plantations. 33 pp, illus.

Evaluation: Despite sampling 22 sites, results were inconclusive although some trends were observed. Disease incidence was tentatively established. Blackstain was similar in distribution to that in Washington and Oregon where the disease is aggregated in some areas, with severe damage occurring on occasion. Several new sites were discovered which may be suitable for future blackstain studies. Suitable follow-up activities are outlined in the preceding contract recommendations. Implementation of accurate disease recognition for field crews should also be considered.

Project Status: Damage Appraisal Operational Trials — Establish disease incidence and severity.

Blackstain Root Disease: Pest Control Project JM-103

Title: Ecological Description of Blackstain Root Disease Monitoring Plots.

Area Treated/Surveyed: 13 plots on 6 sites.

Contractor: Paul Bernardy, Vancouver, B.C.

B.C.F.S. Contact: J. Fournier (J. Beale), Vancouver Forest Region.

Region: Vancouver Forest Region.

Date: March, 1990.

Cost: \$2,382

Objectives:

1. Determine ecological site descriptions of blackstain root disease permanent sample plots (PSP's) at six locations on Vancouver Island using B.C.F.S. Ecological Classification Standards and site Diagnosis Procedures.

Description: Ecological descriptions were performed for 13 plots on Vancouver Island. Plots were located in the Cwha, Cwhb, or CDFa biogeoclimatic subzones. All measurements were done from plot centre. Vegetation was divided into four layers, and percentage cover was established and recorded for each species using the B.C.F.S. cover scale. Slope, drainage, micro-topography, soil and humus forms, soil moisture, soil colour, and nutri-

ent regimes were determined. Soil pits were dug to examine soil characteristics.

The following site factors were found:

- soils were well-drained and mostly coarse-textured.
- soil moist regimes varied from very dry (CDFa) to fresh (Cwhbl).
- soil nutrient regimes varied from poor to medium.
- all soils were podzolic.
- forest floors consisted of mor humus forms.
- salal was present as a dominant species.

Contractor Recommendations: None.

Project Report: Bernardy, P. 1990. Ecological Description of Blackstain Root Disease Monitoring Plots on Southern Vancouver Island. Contractor's Report. 26 pp.

Evaluation: All objectives were met. Ecological descriptions will be used in conjunction with ongoing measurement of mortality and volume at these plots, set up under Project JM072. Site factors will be considered in any future analysis of these plots. This project is thus complete.

Project Status: Complete — All work completed with respect to survey activities.

Laminated Root Rot (DRL) Projects

Laminated Root Rot: Pest Control Project PB-1

Title: Stump and Root Removal Trial for Root Disease Treatment.

Area Treated/Surveyed: 16 ha.

Contractor: Chew Excavating Ltd., Victoria.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Vancouver Forest Region.

Date: November, 1985 to March, 1986.

Cost: \$86,000.

Objectives:

1. Investigate the operational performance of a hydraulic excavator/bucket and thumb for removal of infected stumps from areas with a high incidence of root disease
2. Investigate the operational performance of an L.B. Foster Vibro Stump Puller mounted on an excavator for removal of infected stumps from areas with a high incidence of root disease.

Description: Stumping trials were performed at two sites near Shawnigan Lake and Duncan. A total of 37 days of machinery trials were conducted at the former site and seven days at the latter.

Although conditions appeared favourable for operation, the L.B. Foster Vibro Stump Puller was found to be ineffective. The Vibro Stump Puller was unable to remove infected stumps larger than 40 to 50 cm, and required as much as 10 to 15 minutes to remove smaller stumps.

The hydraulic excavator/bucket and thumb machine was evaluated for productivity and cost rates under the different conditions present at each site. A detailed time study method, performed by personnel from Silviculture Branch. A total of 56 timing plots was established and values for slash, slope and stump dimensions were recorded at the Shawnigan Lake site. Detailed timing was recorded within these plots and only major work activities were measured outside of plots.

The machine removed all visible stumps and piled these in windrows. The excavator worked in

two directions on relatively flat terrain but only operated upslope on steeper terrain. When significant slash was encountered the operator spent additional time removing debris to reach the stumps. In addition, more time was required to prepare a path upslope on the steeper terrain. The equipment was not considered to be operable on slopes in excess of approximately 30%.

All stumps less than 50 cm required less than one minute to remove while larger stumps between one and five minutes. All excavated stumps appeared to have intact root systems. Normal productivity values ranged from 0.15 to 0.045 ha/hour. The mean machine utilization, or the percentage of scheduled operating time that a machine is performing productive work, was 83%. On good, moderate and difficult sites average cost was \$2.10, \$3.07 and \$4.53 per stump, respectively. The preceding figures were based on removal of 500 stumps/ha and overhead and transportation costs were not included.

Contractor Recommendations:

- Further studies should explore excavator productivity over a wider range of site conditions.
- Greater emphasis should be placed on the silvicultural effectiveness of such treatments.

Project Report: Maxwell, J.A. 1987. Hydraulic Excavator Stump Removal Productivity Study. Project Report. 8 pp.

Evaluation: The operational effectiveness of stumping equipment was assessed on two sites. Operational trials were also performed on additional sites after this project had been completed. Subsequently, stumping with a hydraulic excavator/bucket and thumb was found to be cost-effective under a variety of conditions. Root residue surveys conducted under Project PB-4 and a Forestry Canada contract determined that the excavator removed a large portion of the infected root systems. However, some questions remain as to the degree and effects of site disturbance, particularly on wetter areas or sites with compactible soil types. Excessive soil disturbance and increased brush haz-

ard may result on some treated areas. Thus, a study should be initiated to quantify possible site effects. Results from a 25-year stumping trial near Skimikin indicated that trees on the stumped area grew 15% more in height than healthy trees in the non-stumped area. Similar results were reported from a

10-year trial in the United States by W. Thies. Thus, areas with a high incidence of root disease should be identified and stumped wherever feasible.

Project Status: Control Method Fully Practicable — implement method on an operational basis.

Laminated Root Rot: Backlog Research Project 2.28

Title: Root Disease Assessment in Coastal Rehabilitation Areas.

Area Treated/Surveyed: 2 sites (9.3 ha).

Contractor: Sterling Wood Group, Inc., Victoria.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Vancouver Forest Region.

Date: October, 1986 to February, 1987.

Cost: \$13,000.

Objectives:

1. Develop and evaluate survey methods to detect and assess laminated root rot in coastal rehabilitation areas.
2. To make recommendations for further work, including plans for extension and demonstration activities.

Description: To assess laminated root rot presence on sites considered for rehabilitation where susceptible tree species form only a portion of the second-growth and where there was potential disease carry-over from the first-growth, three survey methods were evaluated. These methods consisted of intensive pre- and post-harvest surveys and an extensive post-harvest examination.

Post-harvest surveys were conducted immediately after logging. During the intensive surveys, transects were run and all stumps were checked for symptoms, measured and mapped (if infected) for 3 m on each side of the lines. Wood chips were obtained from confirmed infection sources and incubated in order to evaluate effectiveness of the drilling procedure. In addition, plots were established to gather data on first- and second-growth stand composition, stems per ha, time since last harvest, site index, and soil particulars. First- and second-growth stand density, total basal area and infected basal area were calculated from this information. Two specialized survey forms were developed to record the data.

Laminated root rot was found at both sites at levels of 5.4% to 6.5% of total basal area infected, levels considered to be low to moderate. The pathogen was located in both first- and second-growth stumps during post-harvest surveys but was not found in first-growth stumps during the pre-harvest survey.

The power drill was found to be time consuming and unreliable for confirmation of infection, and was not recommended for further use.

Although detailed information was obtained on first- and second-growth inoculum sources, the intensive post-harvest method was found to be unproductive with respect to area covered. Further, the accuracy of this method was dependent upon the presence of trained observers and close coordination with logging activities.

The pre-harvest method did not require coordination with harvesting and was useful for obtaining data on infection in the second-growth. However, it was determined that this method would not be suitable for sites where the second-growth consisted almost entirely of non-susceptible species.

The postharvest extensive method allowed good coverage of both second- and first-growth inoculum sources, was relatively quick, and was accurate if strips were placed at 25 m intervals. However, this technique still required close coordination with logging and trained observers. In addition, productivity and accuracy could be adversely affected by slash levels.

A seminar was conducted for B.C.F.S., Forestry Canada and industry staff to communicate the project results and act as a forum to discuss the course of future development. The workshop was considered to be successful by those who attended. A major topic of discussion centered around pathogen survival in material from the original stand. Infected first-growth stumps were not considered to be a serious threat after 30 to 40 years due to localization of the pathogen around the root collar.

Contractor Recommendations: Recommendations from this project included prioritization of rehabilitation sites based on time since last harvest as well as stand composition and site index. Refinement of the survey method to increase productivity and extension and demonstration activities were also recommended.

Project Report: Hawkins, G.V. 1987. Root Disease Assessment in Coastal Rehabilitation Areas. Contractor Report. 26 pp.

Evaluation: This project was the first part of a two-part study to develop suitable survey methodology for laminated root rot in coastal rehabilitation areas. Such sites represent approximately 900 ha/year of the inventory in coastal stands within areas that could be potentially infected. Accordingly, a strategy was recommended for subsequent work

Laminated Root Rot (DRL) Projects

to improve survey procedures, prioritize rehabilitation areas for field assessment and conduct extension and demonstration activities to transfer the techniques.

Project Status:

Operation Detection Trial — method with a moderate to high probability of success but improvement(s) and additional data are required before implementation.

Laminated Root Rot: Backlog Research Project 2.28

Title: Root Disease Assessment in Coastal Rehabilitation Areas.

Area Treated/Surveyed: 8 Sites (108 ha).

Contractor: Sterling Wood Group, Inc., Victoria.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Vancouver Forest Region.

Date: September, 1987 to March, 1988.

Cost: \$25,300.

Objectives:

1. Develop suitable methods to assess root disease in coastal rehabilitation areas.
2. Communicate the project results by two preliminary workshops.

Description: Results from a 1986 trial indicated that laminated root rot could pose a significant threat on rehabilitation sites under certain conditions. However, disease detection would be difficult with few susceptible species in the second-growth. If areas were pre-stratified for risk and priority, they could be assessed with a more productive, less intensive version of the post-harvest survey technique initiated in 1986.

Survey guidelines were developed to rate areas as "high", "moderate", "low" or "nil" for risk. These guidelines were evaluated during trials on eight sites.

Disease was estimated by utilizing strips or plots. Information was recorded on specially developed field data forms but information was limited to disease intercept lengths to increase productivity. On five sites, post-harvest data on disease level and location was compared to information obtained before harvest to determine post-harvest survey accuracy. In addition, data were compared to disease incidence in the adjacent stand.

Post-harvest survey productivity was increased to operational levels of 24 to 30 ha/day for a two-person crew, but moderate to heavy slash decreased area covered by 20% to 50% and probably affected accuracy.

With one exception, less infection was found post-harvest. However, there was difficulty in directly comparing techniques and pre-harvest surveys may have over estimated disease levels. Some small in-

fection centres could not be relocated because of road and landing placement; however, all large centres were relocated post-harvest.

No correlation was found between perimeter disease level and on-site levels. Thus, hazard in the adjacent stand was dropped as a criterion for risk rating rehabilitation areas.

The effectiveness of pre-stratifying sites by means of the survey decision guidelines was verified. Areas designated as "nil risk" had consistently low infection levels, "low to moderate risk" areas contained low to high pathogen levels, and "high risk" sites had high disease incidence.

Workshops, which included handouts, discussions and field tours, were judged to be beneficial, especially for pathogen identification.

Contractor Recommendations:

- Conduct further extension and demonstration activities including a video production, field pamphlet and additional workshops
- Use the criteria outlined on the Survey Decision Guidelines form to pre-stratify all rehabilitation sites for risk and survey priority before conducting any surveys
- Conduct either pre- or post-harvest surveys, based on time since last harvest, and use a modified transect intercept method.

Project Report: Hawkins, G.V. 1988. Final Report on F.R.D.A. Project 2.28: Hazard Assessment Laminated Root Rot, *Phellinus weirii* (Murr.) Gilbertson, in Coastal Rehabilitation Areas. Contract Report. 49 pp.

Evaluation: Suitable survey methods were developed. Extension and demonstration activities provided a good forum for discussion on practicality and applicability for specific sites. It was felt that the techniques would augment existing survey methods. The methodology was considered to be operational provided that the Survey Decision Guidelines and field data collection forms were refined and printed and additional workshops held. These goals were later met under Backlog Research Project 2.53.

Project Status:

Operational — fully implement pending completion of technology transfer.

Laminated Root Rot: Backlog Research Project 2.53

Title: Extension and Demonstration Activities for Rehabilitation Site Assessment Procedure.

Area Treated/Surveyed: None.

Contractor: Sterling Wood Group Inc., Victoria.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Vancouver Forest Region.

Date: September to December, 1988.

Cost: \$16,000.

Objective:

1. Produce a training video, field identification pamphlet and survey forms and conduct five training sessions for B.C.F.S., industry and Forestry Canada personnel to transfer the procedures for assessing laminated root rot on rehabilitation areas.

Description: This project was implemented to transfer final results from Backlog Research Project 2.28. The survey forms were refined, drafted and printed. Form I consists of Survey Decision Guidelines for determining hazard rating, survey priority and appropriate survey method laid out in an easy-to-use format. This form was designed for use prior to conducting any field work. Form II consists of columns for disease incidence data collection per site stratum. Survey procedures are briefly outlined on Form I and were discussed in detail during the five workshops. The following methodology was presented for laminated root rot assessments in coastal rehabilitation areas:

- Stratify rehabilitation sites before any survey, using Form I

- Conduct root rot surveys as determined on Form I (time since last harvest, second-growth stand composition and edatopic grid)
- Use transects at 50 m intervals to determine disease incidence, and record data on Form II. Map infection centres on standard metric grid sheets. If the disease incidence is high, run additional transects at 25 m spacing
- Summarize disease incidence and hazard per stratum on Form II.

A training video, handouts, field demonstrations, and field pamphlets supplemented the training sessions.

Contractor Recommendations: Implement the procedures presented in the workshops.

Project Reports: Anon. February, 1989. Root Disease Assessment in Coastal Backlog Areas — Project 2.28. F.R.D.A. Research Memo No. 066. 3 pp.

Hawkins, G.V. 1988. Field Guide for Detection and Identification of Laminated Root Rot in Rehabilitation Areas. F.R.D.A. Pamphlet. 8 pp.

Hawkins, G.V. and G. More. 1988. Laminated Root Rot Identification and Detection in Coastal Rehabilitation Areas. F.R.D.A. Training Video. 12 min. 38 secs.

Field Form FS 313 PRO 88/11. Queen's Printer.

Field Form FS 314 PRO 88/11. Queen's Printer.

Evaluation: This project completed work initiated in Backlog Research Project 2.28, including transfer of the survey method, and preparation of field forms, training video and field identification pamphlet.

Project Status:

Project 2.53 Complete. Project 2.28 Fully Operational.

Laminated Root Rot: Pest Control Project PB-4

Title: Root Residue Surveys.

Area Treated/Surveyed: 100 ha.

Contractor: Sterling Wood Group, Inc., Victoria.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Regions: Vancouver and Nelson Forest Regions.

Date: January, 1986 to March, 1986 and November, 1986 to January, 1987.

Cost: \$36,000.

Objectives:

1. Evaluate the efficacy of root and stump removal to control root disease.

2. Make recommendations for field procedures to monitor the efficacy of stumping operations for root disease control.

Description: Two separate surveys were conducted on the coast (Jan. to Mar., 1986) and in the interior and on the coast (Nov., 1986 to Jan., 1987) to determine the effectiveness of stump excavations for removing infected material. Both surveys employed the same methods. Suitable stumped areas, treated from less than one year to 15 years before the survey, were selected for sampling and 11 were surveyed. The amount of residual material and its infective potential were determined and analyzed with respect to site factors such as soil type and moisture, depth, percent coarse fraction and terrain.

Laminated Root Rot (DRL) Projects

Strips and plots were established at regular intervals for uniform sampling at eight sites while non-random sampling was employed at three sites due to access restrictions and the desire to intensively sample infection centres.

A small backhoe was employed to excavate roots and soil at each plot. Excavations were performed down to the C-horizon. Dimensions, species and notes on any infection were recorded for all excavated root pieces, and suspected infected roots were incubated for confirmation. Site and soil factors were determined and also recorded per plot. Data on residual root material was analyzed by the percent of roots infected, the volume of infected roots per total volume of soil and the volume of all roots per total volume of soil. Site and soil factors were correlated with these analyses.

Results from both surveys indicated that statistically meaningful relationships could not be made between either total or infected root volume and the method of root removal or site age. Results indicated that root raking did not significantly reduce the amount of infected material. More root material was left on sites with high soil cohesion (silt and clay types) but relatively little of this material was infected due to the poor survival of pathogens under the wet conditions generally existing in these soil types. More infected material occurred in soils with greater porosity (sand types) but more material was also removed from these soil types.

In general, stumping operations were certainly effective in removing much of the infected material from heavily infected sites. Data from this project indicated that there was no significant difference in

removal efficacy between excavator and bulldozer equipment. (However, another study conducted for Forestry Canada in 1987 clearly showed that a large excavator is capable of removing more material than either a bulldozer or small excavator (1). Relatively few and smaller pieces of infected root material remain after treatment with a large hydraulic excavator/bucket and thumb.)

Contractor Recommendations: For improving the efficacy of root removal operations, infected areas... should be more thoroughly mapped and stumps should be conspicuously marked to assure their removal during treatment operations.

Project Reports: Hawkins, G.V. and N. Kunzli. 1986. Survey of the Efficacy of Root Removal Operations. 45 pp.

Kunzli, N. 1987. Survey of the Efficacy of Root Removal Operations. 19 pp.

Evaluation: Definitive information on root removal efficacy has been obtained, in part with this project, and also with a Forestry Canada study. The recommendation from Project PB-4 with respect to more accurate mapping has been applied to operations in order to improve delineation of infected areas and increase the amount of infected material that is removed. Thus, this study is complete.

Project Status: Completed.

1. Bloomberg, W.J. and G. Reynolds. 1988. Equipment Trials for Uprooting Root Rot-infected Stumps. Western Journal of Applied Forestry 3(3): 80-82.

Laminated Root Rot: Pest Control Project 27

Title: Laminated Root Rot Hazard and Yield Reduction in Coastal Douglas-fir Ecosystems.

Area Treated/Surveyed: 260 plots.

Contractors: Gordon Butt, Shawnigan Lake; Alan Ohs, Victoria.

B.C.F.S. Contact: S. Zeglen, Vancouver Forest Region.

Region: Vancouver Forest Region.

Date: June to September, 1987.

Cost: \$32,340.

Objectives:

1. Develop an ecologically based disease hazard classification system for laminated root rot in coastal Douglas-fir stands.
2. Determine the relationship(s) between the disease and ecological or site factors.
3. Develop yield reduction estimates for laminated root rot in coastal Douglas-fir stands.

Description: This project was implemented to obtain data on laminated root rot for an M.Sc. Thesis primarily aimed at risk rating coastal Douglas-fir stands and determining impacts for this disease. The expected benefits of this work include improved site prescription and stand management, quantitative disease hazard rating, classification by ecological association and evaluation of long-term impacts. Ecological and root disease assessments were conducted in 260 plots representative of coastal Douglas-fir stands in the CDFa, CDFb and CWHa biogeoclimatic zones. Age of sampled stands was between 40 and 110 years. The plots were established between 33 years and 13 years prior to the study date. At each plot root disease incidence was determined on an individual tree basis and was measured as percent basal area reduction. Vegetation and soil data had been previously obtained for most of the plots by MacMillan Bloedel staff. Additional soil and vegetation information was obtained during this project to supplement the preceding data.

Around each plot 25 basal area points were sampled on a systematic grid. In addition, 13 fixed radius plots were established to determine old growth species composition. Individual tree evaluations were conducted in 45 stem mapped plots, and full soil descriptions were performed in another 60 plots.

Soil samples from these locations were sent to the Environmental Laboratory of MacMillan Bloedel for analyses of the following: humus and soil pH, C:N ratio, total N, exchangeable bases (Ca, Mg, Mn, K, P and Na) and bulk density. Fourteen additional soil samples were collected from plots at Cowichan Lake for this study during Project JM-096, and 18 other outstanding soil samples were analyzed under projects JM-095 and JM-106.

As of December, 1990, all data are being subjected to a Chi-square analysis to assess variability between ecosystems, correlation analysis, possible multivariate analysis, and modelling of species in-growth rates in infected areas as appropriate. Yield reduction is to be measured by comparison of infected and uninfected volumes with stand age, using data obtained from similar observation periods. This strategy should narrow the range of stand conditions and minimize variability. Results from this project are pending publication of the M.Sc. Thesis.

Contractor Recommendations: Pending.

Project Report: Beale, J.D. 1992. M.Sc. Thesis. U.B.C.

Evaluation: All expected benefits, as mentioned above, will result from this project once data analy-

ses are complete and the results have been communicated to the district level. Enhanced disease detection and damage appraisal are two key results. The proposed follow-up activities listed below should enhance the operability of these findings:

- Continued assessments of disease impacts and expansion of the information base. To date, sampled areas have consisted of 90% fir, but additional data from mixed species and stand treatment plots should be obtained in order to better assess stand management and disease impact in other areas.
- Conduct extension and demonstration activities to transfer the findings, possibly through such publications as Operational Memos and/or modifications to the edatopic grid sheets for affected biogeoclimatic zones in the Vancouver Forest Region.

Such activities could be conducted as part of a proposed F.R.D.A. II to meet the following goals:

- Under the protection program, satisfy the requirement for the development of decision support tools and improve detection to enhance stand productivity.
- Meet the requirement to monitor sample plots and refine detection techniques.

Project Status: Project results still incomplete. Once all data analysis is completed, it is expected that the findings from this project should be fully implementable.

FSP?

Laminated Root Rot: Pest Control Project JM-090

Title: Root Disease Survey of Spaced Stands in the Port Alberni Forest District.

Area Treated/Surveyed: 186 ha.

Contractor: N. and R. Forest Management Ltd., Squamish.

B.C.F.S. Contact: S. Zeglen, Vancouver Forest Region.

Region: Vancouver Forest Region.

Date: November, 1989 to March, 1990.

Cost: \$7,600.

Objective:

1. Conduct root disease surveys of five spaced stands in the Port Alberni Forest District.

Description: Extensive Douglas-fir stands, from 37 to 54 years old, were juvenile-spaced in the 1970's and early 1980's. Some of these areas had high levels of laminated root rot which were not completely eliminated during thinning operations.

During this project, surveys were conducted in five stands considered to have significant disease

levels in order to augment 15 similar surveys performed by the district under regular funding. Follow-up surveys will be based on percent infection levels per stand. Data and maps from these projects are currently (October, 1990) being used to determine appropriate strategies for the more heavily infected sites. Proposed strategies include bridge tree removal or thinning to reduce inoculum prior to rotation within the next 20 years. Planting of alternate species may not be a viable option because of poor performance in affected areas due to site factors.

Strips were run at 50 m intervals to insure good coverage of infection centres. All infection centres within 25 m of the transects were confirmed as to pathogen, measured and mapped. Mapping accuracy was stressed and major timber types and topography were recorded for each unit. Recommendations for suitable stand treatment (selective or clear-cut harvesting, viability of stumping with respect to terrain, soil characteristics and slope) were to be formulated. Maps and summaries of all five areas were then submitted. Discrepancies were noted by district personnel following submis-

Laminated Root Rot (DRL) Projects

sion of this data. Consequently, project results are inconclusive at present.

Contractor Recommendations: None.

Project Report: None. Data summary pending.

Evaluation: The project is incomplete at the time of writing because of discrepancies between disease levels as measured by the contractor and those found by district personnel. Survey data should be available once a reassessment of the areas in question has been completed. Pending a resurvey, a pos-

sible F.R.D.A. II follow-up activity could include establishment and regular monitoring of permanent sample plots to determine efficacy of treatments (bridge tree strategy, thinning or push-over logging). Monitoring for laminated root rot would provide data for yield estimates, improve stand management and help reduce actual or potential NSR backlog.

Project Status: Incomplete.

Laminated Root Rot: Pest Control Project JM-095

Title: Soil Analysis for Laminated Root Rot Hazard and Yield Reduction Survey.

Area Treated/Surveyed: 32 plots.

Contractor: Environmental Laboratory, MacMillan Bloedel Ltd, Nanaimo.

B.C.F.S. Contact: S. Zeglen, Vancouver Forest Region.

Region: Vancouver Forest Region.

Date: January to March, 1990.

Cost: \$3,000.

Objective:

1. Perform laboratory analyses (physical and chemical) for soil and humus forms from 14 sample plots in the Cowichan Lake area and complete analyses on samples from 18 other plots examined previously.

Description: Laboratory analyses were performed on soils and humus from plots in the Cowichan Lake area. Soil samples were gathered during Project JM096. Laboratory analyses included: percent coarse fragments, particle size, bulk density, pH of humus and soil forms, mineralizable N, total N, total C, and exchangeable cations (Ca, Mg, K). Data from these tests were forwarded to J. Beale, Vancouver Forest Region, for analysis.

Contractor Recommendations: None.

Project Report: None. Data summary to be published as part of J. Beale's M.Sc. Thesis, U.B.C.

Evaluation: This project was implemented in order to obtain some additional ecological information for Pest Control Project 27: Laminated Root Rot Hazard and Yield Reduction in Coastal Douglas-fir Stands. As such, no follow-up activities are required with respect to Project JM-095.

Project Status: Complete.

Laminated Root Rot: Pest Control Project JM-096

Title: Ecological Assessments for a Laminated Root Rot Survey.

Area Treated/Surveyed: 14 plots.

Contractor: Paul Bernardy, Vancouver.

B.C.F.S. Contact: S. Zeglen, Vancouver Forest Region.

Region: Vancouver Forest Region.

Date: January to March, 1990.

Cost: \$2,250.

Objective:

1. Perform an ecological description (vegetation, soils, and humus forms) in conjunction with Project JM-095, for sampling of soils and humus forms for laboratory analyses.

Description: Ecological descriptions of vegetation, soils and humus forms were made at 14 plots in the Cowichan Lake area. Data on vegetation cover and

soil type were gathered at each location for subsequent analyses. Representative soil pits were dug at each plot. Equal amounts of soil and humus material were obtained from each pit for tests at the Environmental Laboratory of MacMillan Bloedel, Ltd. Humus (LFH) samples were removed from opposite sides of each soil pit and placed in plastic bags for shipment to the laboratory. Mineral soil was stratified into two levels: 0-20 cm and 21-40 cm. Soil samples were removed from each level from opposite sides of all pits. Laboratory analyses included the following: soil fertility, bulk density, pH of humus and soil forms, and exchangeable bases. This latter work was conducted under projects JM-095 and JM-106.

Contractor Recommendations: None.

Project Report: None. Data summary to be published as part of J. Beale's M.Sc. Thesis, U.B.C.

Evaluation: This project was implemented in order to obtain some additional ecological information for Pest Control Project 27: Laminated Root Rot Hazard and Yield Reduction in Coastal Douglas-fir

Stands. As such, no follow-up activities are required with respect to Project JM-096.

Project Status: Complete.

Laminated Root Rot: Pest Control Project JM-104

Title: Laminated Root Rot survey of the Stamp Falls Demonstration Area.

Area Treated/Surveyed: 20 ha.

Contractor: Chatla Forest Consulting, B.C.

B.C.F.S. Contact: S. Zeglen (J. Beale), Vancouver Forest Region.

Region: Vancouver Forest Region.

Date: March, 1990.

Cost: \$4,200.

Objectives:

1. Conduct a root rot survey and collect cruise data for a commercial thinning project at the proposed Stamp Falls demonstration area.

Description: A 20 ha area near Stamp Falls, Port Alberni Forest District, was surveyed using five prism cruise plots per ha. All cruise data collected were analyzed and evaluated for a commercial thinning project as part of the management plan for the area. Information collected per plot included: condition of all living and dead trees, total height, species, DBH, tree class, pathogen remarks and damage. Tree class was coded as: 1 = residual, 2 = standing dead, 3 = down, 5 = veteran. Damage due to laminated root rot was coded as: 0 = healthy, 1 = early crown symptoms, 2 = advanced crown symptoms, 3 = recently dead (< 2 years), 4 = dead 3 to 10 years, 5 = dead 11 years plus.

All plots and strips were marked, a survey map was produced and all root disease and cruise data were submitted for analyses, conducted by Reid Collins and Associates, Ltd. A recommendation was made to clear-cut most of the site based upon the

contractor's observations, but disease levels in the stand were later determined to be lower than those measured during this project.

Contractor Recommendations: None.

Project Report: None. Data summary submitted for cruise data analysis by Reid Collins and Assoc. Ltd., Vancouver. Evaluation of data included in: Hawkins, G.V. 1990. Stamp Falls Root Rot Demonstration Area — Proposed Management Options. Contractor's Report. 4 pp.

Evaluation: The cruise data was evaluated to determine appropriate stand treatments after re-evaluation and remapping of on-site disease levels. It is expected that the site will be a demonstration area for laminated root rot treatments and impacts for at least 10 to 15 years, depending upon future discussions with regional, district and Forestry Canada personnel.

Possible future activities for such a demonstration area include the following: layout of treatment blocks, spacing treatment(s), regular monitoring of treatment efficacy and disease impacts, sample collection and processing for a biocontrol program (Forestry Canada), additional stand management as required, and on-site extension and demonstration activities such as disease identification and control options/effectiveness.

Project Status: Survey Complete (4 D). Follow-up Operational Control Trial and Monitoring — rated moderately to highly practicable. Need data to substantiate operational use before method(s) are operational.

Laminated Root Rot: Pest Control Project JM-106

Title: Soil Analysis for Laminated Root Rot Survey.

Area Treated/Surveyed: 32 plots.

Contractor: Environmental Laboratory, MacMillan Bloedel Ltd, Nanaimo, B.C.

B.C.F.S. Contact: S. Zeglen (J. Beale), Vancouver Forest Region.

Region: Vancouver Forest Region.

Date: March, 1990.

Cost: \$700.

Objectives:

1. Complete laboratory analyses (physical and chemical) for soil and humus forms from 14 sample plots in the Cowichan Lake area, as initiated by Project JM-095.

Description: Laboratory analyses were performed on soils and humus forms from 14 sample plots in the Cowichan Lake area. The work was an extension of the soil tests initiated in Pest Control Project JM-095. Laboratory analyses included: 41 bulk density tests, 14 pH tests for soil and humus forms, and 20 CEC exchangeable bases. Data from these

Laminated Root Rot (DRL) Projects

tests was forwarded to J. Beale, Silviculture Branch, for his university thesis.

Contractor Recommendations: None.

Project Report: None. Data summary to be published as part of J. Beale's M.Sc. Thesis, U.B.C.

Evaluation: This project provided additional ecological information for Pest Control Project 27. All soil testing was completed.

Project Status: Complete.

Rhizina Root Disease (DRR) Projects

Rhizina Root Disease: Pest Control Project 54

Title: Rhizina Root Disease Surveys.

Area Treated/Surveyed: 30 blocks.

Contractors: Timberland Consultants Ltd., Nelson;
T.M. Thompson And Associates Ltd., Victoria.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: October to November, 1988.

Cost: \$6,100.

Objective:

1. Conduct regeneration type surveys to assess the incidence of rhizina root disease.

Description: Twenty-one plantations were surveyed by Timberland Consultants in the Kootenay Lake and Arrow TSAs. Nine blocks could not be surveyed because of snow coverage. Concurrently, nine plantations were surveyed in the Cranbrook TSA by T.M. Thompson Ltd. Remaining sites were covered in snow and could not be assessed.

All 30 blocks were sampled in the same manner. Between 10 and 15 regeneration type plots were spaced 50, 100 or 150 m apart along randomly placed strips, with plot spacing proportional to block size. Lines were run in a zigzag pattern in order to evenly cover each site. Within plots, each plantable spot was examined for dead seedlings, infected seedlings and rhizina fruiting bodies. Asymptomatic seedlings were considered to be infected if they were within 50 cm of a rhizina fruiting body.

Rhizina fruiting bodies were found on 10 of the 21 sites surveyed in the Arrow and Kootenay Lakes TSA's. No rhizina was observed on the nine blocks surveyed in the Cranbrook TSA despite assessing a wide variety of sites. Burn intensity varied from good to poor to unburned. Both planted and unplanted sites were examined. The majority of blocks were burned within one year of planting. Four sites were burned two years before planting and one

area was burned four years before establishment. The proportion of all trees with viable fruiting bodies ranged from 1.4% to 43.9%. Fruiting body incidence on dead or symptomatic seedlings and on vacant plantable spots ranged from 0% to 28.6% and from 0% to 100%, respectively. Rhizina was not found on the blocks burned more than one year before this survey.

Incidence of this disease appeared to be correlated with sites which had medium intensity or spotty burns. Areas which had high or low intensity burns did not show any evidence of the disease. Fruiting of rhizina may only have occurred where some litter of humus was present.

Contractor Recommendations: None

Project Reports: Timberland Consultants Ltd. 1988. Rhizina Root Rot Survey. Contractor Report. 3 pp.

T.M. Thompson And Associates Ltd. 1988. Rhizina Survey Report. Contractor Report. 4 pp.

Evaluation: The basic objectives were met but fewer sites were surveyed than originally planned because of snow or access problems on 15 of the blocks. However, extensive data were obtained on rhizina incidence, severity and possible correlated factors. The survey method was not assessed, but is probably effective and accurate. Suitable follow-up activities include:

- additional surveys, using the methods employed in this project.
- guidelines for detection and management of rhizina root disease.
- training of field crews in survey techniques and disease identification.

Project Status: Operational Detection Trial — method rated fully practicable; need data for cost estimate and for broader range of ecological conditions.

Rhizina Root Disease: Pest Control Project JM-065

Title: Soil Analysis of Plots Established to Determine Rhizina Root Disease Guidelines.

Area Treated/Surveyed: 40 plots (1 site).

Contractor: Pacific Soil Analysis Inc., Vancouver.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: February to March, 1989.

Cost: \$3,300.

Objective:

1. Analyze 80 soil samples for pH, total C and N, minimum N, available S, P and cations, and micronutrients to assess the effects of burning on rhizina root disease.

Description: A total of 80 soil samples from 40 plots at Giveout Creek were processed to determine pH, total C and N, minimum N, available S, P and cations, and micronutrients. The samples were collected to meet the requirements of Project JM-092 toward development of management guidelines for controlling this disease in new plantations. A pre-burn and post-burn soil analysis was performed on this site in order to determine burning effects on rhizina-caused seedling mortality. Findings were related to other investigations on burning and rhizina viability with the eventual goal of modifying the prescribed burning guidelines for the Southern Interior.

Survey work was subsequently completed under various F.R.D.A. and non-F.R.D.A. projects. Rhizina root disease incidence was observed to be related to the intensity of burning on a particular site. There was an increasing incidence of the disease on sites which had been subjected to a medium burn and decreasing incidence on sites which had been treated with low or high intensity burns. In addition, rhizina root disease was observed more frequently in the ICHa2i ESSFc and ICHc2 biogeoclimatic subzone variants. Slightly higher disease incidence on good sites was also noted.

As a result, management guidelines are currently being developed for PHSP's in the Nelson Forest Region. These guidelines rank sites for risk by the following weighted factors: aspect, burn intensity, decadency and composition of old-growth, and biogeoclimatic subzone. Recommended control options for moderate to high risk sites include clean logging, mechanical site preparation, burning at either very high or very low intensity, or planting in the third year after harvesting.

Contractor Recommendations: None.

Project Report: Summary

Evaluation: The soil analysis conducted in this project was part of a larger strategy toward management guidelines for rhizina root disease. As such, this work is complete. Suitable future activities consist of the following:

- Refine and produce the guidelines in a format suitable for forest managers and field crews. Field data collection cards will also be required as part of this package.
- Conduct Extension and Demonstration activities to transfer the guidelines and demonstrate the use of the field cards.
- Train crews in the accurate identification and assessment of rhizina root disease.
- Conduct regular monitoring surveys for this disease on sites considered to be higher risk. Employ standard 3.99m radius plots established on a uniform grid for complete coverage.
- Transfer these guidelines and survey methods to the Kamloops Forest Region if rhizina becomes a significant problem in this region.

Project Status: Survey work complete with respect to disease control.

Rhizina Root Disease: Pest Control Project JM-088

Title: Soil Sampling for Rhizina Root Disease.

Area Treated/Surveyed: 40 plots.

Contractor: Steve Thompson, Nelson.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: September, 1989.

Cost: \$2,140.

Objective:

1. Collect soil samples at 40 plots at Giveout Creek and photograph each plot.

Description: A total of 120 soil samples were collected from 40 plots on a burned site near Nelson. Subsequently, 80 samples were sent to Pacific Soil Analysis Inc. for determination of pH, total C and N, minimum N, available S, P and cations, and micronutrients under Project JM-065. An adjacent cut-block, approximately 300 m away, had a high incidence of rhizina (40% mortality rate). Results from the soil analyses were ultimately compared to

post-burn soil conditions in order to determine any relationship between rhizina root disease and the altered soil makeup. Findings were related to other investigations on slash burning (burn intensity, depth, coverage and temperature) and incidence of rhizina root disease in order to formulate modifications to the Prescribed Burning Guide for the southern interior.

Contractor Recommendations: None.

Project Report: None.

Evaluation: This project was part of a long-term study aimed at determining the extent and severity of rhizina root disease. As such, this project is complete.

Project Status: Complete — all survey work completed.

Rhizina Root Disease: Pest Control Project JM-092

Title: Rhizina Root Disease Pathology.

Area Treated/Surveyed: Overview of the Nelson Forest Region.

Contractor: Dr. S. Berch, Soil Science Department, University of British Columbia, Vancouver.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: September, 1989 to March, 1990.

Cost: \$12,720.

Objective:

1. Determine the pathology of rhizina root disease on lodgepole pine by reviewing pertinent literature, interviewing foresters and researchers, and conducting and assessing inoculations of seedlings with the fungus.

Description: All available literature was reviewed and Canadian and U.S. researchers were interviewed along with field personnel from the Nelson Forest Region.

Rhizina fruiting bodies and litter layer samples were collected from burned and unburned sites in the Nelson Region. Spores from fruiting bodies were cultured for use in inoculation tests using lodgepole pine seedlings. Five strains of *rhizina undulata* were subsequently isolated. In addition, serial soil dilutions were prepared using samples from the forest floor, burned forest floor, rotting wood, burned rotting wood, and burned LFH layer in order to determine rhizina inoculum density on burned and unburned sites. These dilutions were applied to containers in which lodgepole pine seedlings had been placed.

Pure rhizina cultures could be readily grown; however, no disease symptoms developed in any of the inoculations or dilutions despite exposure of the seedlings for several months. Spores were not considered to be responsible for causing infection. Rather, the disease was considered to occur due to the presence of fungal mycelium which requires a large woody food base such as logs or roots.

Interviews and examination of survey results revealed the following. Moderate burns caused sporulation. Spores may spread from adjacent areas that have been recently burned to unaffected forest

floors. Rhizina appeared at least 15 weeks after a moderate burn. Abundant fruiting bodies have been associated with areas of heavy seedling mortality but have also been located on sites where no mortality occurred.

Maximum mortality was correlated with alkaline soils or with light or high intensity burns. Mortality was greatly reduced in the second season. The fungus was not found on deciduous sites. Disease incidence decreased with time since burning and with increasing distance from stumps and roots. Sites with diseased seedlings often have fireweed which is stunted and nonreproductive compared to surrounding vegetation.

The disease developed in three stages, with symptoms appearing on seedlings shortly after a medium intensity burn as follows: chlorosis, bent tips, burnt needle tips, reduced growth, and needle loss except at the branch tips. It was postulated that a one year postponement of planting might reduce the risk of infection.

Contractor Recommendations:

- Continue rhizina research, to determine pathogenicity.
- Investigate fungi which might be antagonistic to rhizina.
- Determine if woody debris contains large amounts of inoculum.
- Evaluate seedling age and susceptibility by region.
- Determine if mycorrhizal seedlings show resistance.
- Attempt to isolate the fungus from suspect seedlings.

Project Report: Gamiet, S. and S.M. Berch. 1990. Rhizina Undulata on Conifers. Contractor's Report. 16 pp.

Evaluation: In general, the project objectives were met, however the inoculations were unsuccessful. Despite this problem some important considerations for management guidelines were developed. Suitable follow-up activities include:

- additional surveys to improve the data base,
- using the methods employed in this project.

Rhizina Root Disease (DRR) Projects

- guidelines for detection and management of rhizina root disease should be developed and transferred to field personnel and managers.
- field crews should be trained in the appropriate survey techniques and disease identification.

Project Status: Research Detection Trial — research requiring a scientific researcher and replications.

Tomentosus Root Rot (DRT) Projects

Tomentosus Root Rot: Pest Control Project PB-12

Title: Tomentosus Root Rot PSP Establishment.

Area Treated/Surveyed: 5 plots on 0.9 ha.

Contractor: Richard Reich, Prince George.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Prince George Forest Region.

Date: June to August, 1986.

Cost: \$3,000.

Objective:

1. Establish plots to investigate:
 - the effect of spacing on tomentosus root rot spread in a 60 year-old northern spruce stand
 - transmission of the disease by root contacts
 - resistance of white pine to the disease
 - suitable survey methods

Description: Five plots were established at 44 km on the Beaver Creek Road in the Prince George Forest Region. The sample area consists of a 60-year old spruce stand with considerable tomentosus root rot infection. Plots, each measuring .02 ha, were laid out around disease centres, with three plots in a spaced area and two plots in the untreated section.

All spacing slash was removed and the root systems of all plot trees were manually excavated to avoid damage. A string grid was established over the exposed roots and these were mapped to scale and sampled for disease at regular intervals using an increment corer. Roots were coded as healthy, stained or decayed and these data were recorded directly on the maps. Roots in all plots were then recovered with soil. Measurements of dbh, height, percent live crown, five-year radial increment and age were taken for all plot trees. Resinosis or evidence of root collar weevil (*Hylobius warreni*) activity were also noted. Plots were to be remeasured at five- to ten-year intervals.

Transects were run at 80 m intervals before spacing. Obvious crown symptoms and stand openings were noted along each transect. Trees within a one m strip were mapped, marked and drilled for wood chips which were later examined for tomentosus.

Results from the wood examination were compared to actual stump infection symptoms once the area had been spaced. A 14% misdiagnosis was found, of which 10% was an underestimate of disease level. In addition, crown symptoms were not easily seen, especially prior to thinning. Drilling was recommended since the amount of error was considered acceptable; however, it was advised that at least two major roots be sampled. A 100 m transect spacing and sampling of fewer trees was also proposed from preliminary surveys. More intensive surveys could then be implemented if required.

Project Report: Reich, R. 1986. in Lewis, K.J. 1988. Inonotus Tomentosus Plot Excavations Data analysis and Conclusions. Contractor's Report. 16 pp.

Evaluation: This project was intended to supply data every five to ten years over a substantial time period and is therefore still ongoing. The information obtained from the p.s.p.'s established in this project was subsequently analyzed under Project 49. All plots should be remeasured in 1991 or 1992 to obtain meaningful information on disease spread and impact and the effect of spacing treatment. Results of the survey method trial in PB12 are considered to be inconclusive since other studies have shown drilling to be too inaccurate and not cost-effective (projects 25 and 2.28). Thus, further work is still required to develop a reasonably accurate and cost effective survey method for tomentosus root rot.

Project Status: Damage Appraisal Operational Trials And Modelling — plot establishment and initial measurement.

Tomentosus Root Rot: Pest Control Project PB-14

Title: Tomentosus Root Rot Survey for Permanent Sample Plots (PSP's) and Demonstration Area.

Area Treated/Surveyed: 5 ha.

Contractor: Silvicon Services Inc., Smithers.

B.C.F.S. Contact: S. Zeglen (W. Martin to 1989), Prince Rupert Forest Region.

Region: Prince Rupert Forest Region.

Date: July, 1986.

Cost: \$2,000.

Objectives:

1. Establish plots to allow estimation of infected volumes in order to obtain accurate data on the spread rate and impact of tomentosus root rot in young spruce stands.
2. Locate and mark infection centres to aid field workers in the identification and control of the disease.

Description: A demonstration area incorporating ten plots was established at Jonas Creek in the Bulkley Forest District, Prince Rupert Forest Region. Out of a total of ten infection centres encountered on the site, eight were stem mapped and two prism plots were placed in centres adjacent to mature timber. Two additional plots were established in infection centres in the mature stand. All centres were marked for future relocation. Data on infected and uninfected volume and extent of decay were obtained in the two plots located in mature timber. A

total of 247 m³ and 590 m³ was recorded for infected and uninfected volume, respectively.

Transects were closely spaced to allow 100% coverage of the site and infection status was determined by observation of crown symptoms. In addition, a power drill was employed to gather wood chips for confirmation of infection status on 25% of the trees along each strip. All infected trees were marked and mapped.

Contractor Recommendations: Caution was recommended in interpreting wood chips as firm evidence of tomentosus root rot since misdiagnosis was observed in some cases. This finding agrees with that of projects 25, PB-12 and PB-21.

Project Report: Daust, D. 1986. Project Summary With Maps. 4 pp.

Evaluation: All contract objectives were attained during this project. Suitable follow-up activities include the following. The plots should be monitored at regular intervals to obtain valuable data on disease impact and spread, commencing in 1990 or 1991. Other areas should also be surveyed for plot establishment in order to enlarge the information base. Disease identification activities should be also implemented on this site since this pathogen is frequently misdiagnosed by field crews.

Project Status: Damage Appraisal Operational Trials — plot establishment and initial measurement.

Tomentosus Root Rot: Pest Control Project PB-16

Title: Tomentosus Root Rot Control Trial Area Survey and Layout.

Area Treated/Surveyed: 60 ha Surveyed and 18 ha Treated.

Contractor: Silvicon Services Inc., Smithers.

B.C.F.S. Contact: S. Zeglen (W. Martin to 1989), Prince Rupert Forest Region.

Region: Prince Rupert Forest Region.

Date: August to September, 1986.

Cost: \$6,800.

Objectives:

1. Establish permanent sample plots (PSP's) to monitor tomentosus-induced mortality and disease spread from infected stumps to young white spruce, lodgepole pine and Douglas-fir.
2. Assess the effectiveness of stumping in controlling disease spread.

Description: Five locations which had potentially high levels of tomentosus root rot were surveyed post-harvest near Tercer Lake and Burns Lake, Prince Rupert Forest Region. Transects were run at 60 m intervals and all stumps were checked for three m either side of line. In this manner, total coverage was 5% of each block. Stumps were examined with pulaskis for evidence of tomentosus. Subsequently, survey results indicated that the Tercer Lake area was better for the trials. Two control methods were proposed: uprooting of infected stumps or establishment of alternate species with possible resistance to the disease.

Results of the survey indicated that all sites were too wet wherever suitable disease incidence was encountered to allow reasonably cost-effective and non-disruptive stumping trials. Therefore, nine 2 ha treatment blocks were delineated for species resistance trials utilizing Douglas-fir, lodgepole pine and white spruce. These treatment blocks were lo-

cated over areas exhibiting relatively uniform and high levels of tomentosus (16% to 18%). Three 30 m by 30 m plots were established in each block to obtain long-term data on disease incidence and spread.

Contractor Recommendations: Although there was some difficulty with pathogen identification and slash, the post-harvest survey method was generally found to be productive and practical, with coverage of 184 m/hour. Similar procedures were recommended for future studies with the provision that disease centres should be located and marked before harvest to ensure complete delineation of infection centres. A combination of pre- and post-harvest surveys might be particularly useful for completely locating tomentosus in pure spruce stands since symptoms are often seen in spruce stumps whereas crown indicators are frequently absent, according to observations from projects 25, 45 and JM-076. However, this method would be much less useful in spruce-pine mixes or pure pine stands because stump symptomology is far less reliable in this species. In addition, sites should be stratified since this disease was more common in moist to wet areas than dry. This observation is in agreement with trends seen on other sites (projects 25, 45

and JM-076), where moist well-drained soils seemed to support greater disease development.

Project Report: Daust, D. 1986. Survey of Root rot (*Polyporus tomentosus*) and Block Layout for a Species Resistance Trial Near Tercer Lake and Burns Lake, British Columbia. Contractor Report. 25 pp.

Evaluation: Stumping trials were not conducted on this site since the area was too wet for effective treatment without excessive site disturbance. Stem mapping within infection centres is rudimentary and requires improvement in order to obtain meaningful information on disease spread and impact. Suitable follow-up activities include the following. Continued monitoring to next rotation performed at five year intervals to age 25 or 30, and thereafter, at ten year intervals. The first reassessment should be conducted in 1991 or 1992. Additional operational trials should be performed because stumping may be restricted if further surveys verify disease correlation with moister, more sensitive areas.

Project Status:

Damage Appraisal Operational Trials — plot establishment and measurement.

Tomentosus Root Rot: Pest Control Project PB-21

Title: Moricetown Spruce Root Rot Survey for Stumping Trial.

Area Treated/Surveyed: 16.5 ha.

Contractor: Silvicon Services Ltd., Smithers.

B.C.F.S. Contact: S. Zeglen (W. Martin to 1989), Prince Rupert Forest Region.

Region: Prince Rupert Forest Region.

Date: November to December, 1986.

Cost: \$5,300.

Objectives:

1. Conduct a survey for a tomentosus root rot control trial.
2. Determine disease extent and mark and map all infected trees within the trial area.
3. Locate tie-points in the treatment area so that all infection can be relocated after harvesting.

Description: An area 2.9 km northwest of Moricetown, Prince Rupert Forest Region, was suitable for stumping trials for control of tomentosus root rot. The site was stratified into areas which contained similar incidence of infection centres. The strata proposed for treatment were surveyed at 100% intensity.

Using a power drill, for obtaining wood chips, lateral roots were examined to determine which trees over 15 cm dbh were infected. Infected trees

were marked with highly visible orange paint near the base to ensure their relocation after harvesting. Data on disease incidence before treatment were obtained and a detailed stem map was produced showing the areas most suitable for stumping.

Disease incidence was determined to be 38% of the spruce checked. Disease was usually distributed in pockets. Some diseased trees under 15 cm dbh may have been missed because these trees were not checked. At least a 10% chance of incorrect diagnosis resulted from using the drill, a result similar to that from Project PB-12.

Contractor Recommendations: None.

Project Report: Daust, D. 1986. Summary of Survey Methods and Results With Maps. Contractor Report. 8 pp.

Evaluation: This project was the first phase of a tomentosus root rot control trial which was completed under Project 30. The trial area was delineated, all root rot centres were marked out for stumping treatment and then successfully relocated during the latter project. However, the survey technique employed during this project was not suitable for operational use. Drilling to determine infection status was inaccurate and time consuming.

Project Status: (Survey Completed)

Tomentosus Root Rot: Pest Control Project 25

Title: Tomentosus Root Rot Survey for Data on Occurrence and Infection.

Area Treated/Surveyed: 33 sites.

Contractor: Kathy Lewis, Prince George.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Prince George and Prince Rupert Forest Regions.

Date: June, 1987 to March, 1988.

Cost: \$22,300.

Objectives:

1. Determine the potential and probability of spread of tomentosus root rot from first-growth inoculum sources to the second-growth.
2. Make predictive assessments of the resultant disease severity by means of the following criteria (areas of study):
 - Determine the duration of viable inoculum in old-growth stumps and the colonization patterns and frequency of transmission
 - Determine the influence of chronological age, root size, host species (pine and spruce) and dynamic resistance mechanisms on pathogen establishment
 - Determine the relative importance of sporulation and vegetative spread with respect to infection in young stands.

Description: This project was the first of three contracts (25, 45 and JM-076) to investigate tomentosus root rot in northern stands. Significant progress was made in each of the areas of study during this project. A total of 33 areas were surveyed and five sites then selected for further data collection. Site choice was based on high incidence of tomentosus root rot, presence of on-site regeneration, time since last harvest and stand composition. A line intercept survey was conducted to obtain 20 infected old-growth stumps per strip. Infection was confirmed through excavations of the root collar and at least three main roots. Major roots were cut for examination of disease progression. A total of 340 samples of decayed or stained wood were removed, labelled, and later plated on malt extract agar to establish viability of the fungus during different stages of disease progression. The root systems of all old-growth stumps and the five closest associated second-growth trees were mapped. Visible infection and all root contacts were recorded.

Site infection appeared to be localized in fresh to moist areas, being rarely found in areas with wet or sandy, shallow soils. Colonization was patchy, ranging from 0% to 60%. Stands of pure spruce, as well

as spruce/pine mixtures, contained the disease but pure pine stands did not. Decay symptoms in stumps were more advanced in older plantations. Viable mycelium was found in stumps up to 26 years old but most of the advanced decay was localized around the root collar. Decay was observed to progress from narrow columns of stain in recently cut stumps to total advanced decay colonization with increasing age. Decay extended to the root surface or to a position just under the bark. The volume and area occupied by the pathogen was hypothesized to be low immediately after harvest, increasing steadily for approximately 20 years and then declining. Infected second-growth trees were seen but the extent of disease transfer was not quantified during this contract.

Drilling trees to determine infection status was found to be both time consuming and unreliable compared to excavation, cutting and on-site observations. Isolates of the pathogen were collected from four widely separate locations in both forest regions to insure the representation of two discreet populations. Isolation success was greatest with increasing age of decay (37% to 40%). Isolation from stained areas of wood was less successful (21%).

Inoculation trials were performed on spruce and pine seedlings using inoculum prepared from the isolates in order to determine species susceptibility and any differences in host response with respect to the different fungal populations. However, contamination problems forced discontinuation of these trials for 1987-88. Additional disease samples were obtained from eastern Canada, the U.S. and Europe. Pairings of vegetative isolates were initiated to determine population compatibility/incompatibility. Finally, a number of staining techniques were assessed for specificity to the presence of tomentosus root rot in host tissues.

Contractor Recommendations: Strategy for continued work in 1988-89.

Project Report: Lewis, K.J. 1990. Epidemiology and Population Biology of *Inonotus tomentosus* as a Pathogen of Young Forests in British Columbia. Ph.D. Thesis. Oregon State University. 199 pp.

Lewis, K.J. 1988. Tomentosus Disease Effects on Second-growth Spruce and Pine in the Prince George and Prince Rupert Forest Regions. B.C.F.S. Int. Rep. PM-PB-36. 25 pp.

Evaluation: This project was the first of three integrated contracts investigating tomentosus root rot in northern stands. Substantial progress was made in each area of study and was subsequently continued. An evaluation of all three projects as an entity can be found with the summary of Pest Control Project JM-076.

Project Status: Operational Detection Trial — rated possible to fair chance of suitability for opera-

tional use; need additional data to determine effectiveness.

Tomentosus Root Rot: Pest Control Project 30

Title: Moricetown Tomentosus Root Rot Stumping Trial.

Area Treated/Surveyed: 8.8 ha.

Contractors: D.C. Forestry Services, Smithers. Hudson Bay Construction and J. van der Deen, Smithers.

B.C.F.S. Contact: S. Zeglen (W. Martin to 1989), Prince Rupert Forest Region.

Date: September, 1987.

Cost: \$9,200.

Objective:

1. Determine the cost and effectiveness of stumping spruce and pine on a tomentosus-infected site.

Description: The site had been laid out and assessed for root disease under Project PB21. Three treatments were subsequently conducted on this site: D8H-brush blade (bulldozer) destumping, hydraulic excavator/bucket and thumb destumping, and control. Each treatment area was approximately 4.5 ha in size. Sites consisted of even terrain with moist to wet soil conditions and moderate to heavy slash. Equipment assessments were carried out by personnel from Silviculture Branch and the stumping operations were supervised by D.C. Forestry Services.

The average productivity and utilization for the bulldozer was 0.167 ha/hour and 85%, respectively. Site disturbance covered 97% of the area treated and was greater than that of the excavator, which disturbed 76% of its area. The hydraulic excavator was 50% more productive than the bulldozer, with a utilization of 88% and a productivity of 0.250 ha/hour.

Contractor Recommendations: The use of both types of equipment was not recommended on sites

with similar soil type and moisture because excessive compaction and brush problems would likely result. Instead, it was proposed that trials with a smaller bulldozer be attempted in future to determine what stump types and ground conditions can be effectively treated with minimal disturbance.

Project Report: Maxwell, J. 1988. Summary for the Moricetown Stump Removal Project. 9 pp.

Evaluation: Follow-up surveys are required on the two treatment areas and the control to quantify biological effectiveness and disturbance levels. These should be conducted at regular intervals of two to five years commencing in 1990 or 1991. Greater effectiveness of larger excavators over all other types of equipment has been demonstrated during Douglas-fir stump removal operations on less sensitive sites (for laminated root rot) (1). However, smaller bulldozers (DH6 or DH7) may prove effective in reducing site disturbance while removing much of the infection in spruce since this species exhibits shallow-rooting. Initial findings from projects 25, 45 and JM-076 indicate that tomentosus root rot might be more prevalent in moister, more sensitive areas. Thus, assessment of smaller bulldozers should be carried out on a limited basis. Alternate species trials should also be conducted since this strategy is expected to be the main treatment option if further surveys verify the preceding ecological correlation.

Project Status: Operational Control Trial — method rated possible to fair chance of suitability for operational use; need data to precisely determine effectiveness and/or response to treatment.

1. Bloomberg, W.J. and G. Reynolds. 1988. Equipment Trials for Uprooting Root Rot-infected Stumps. Western Journal of Applied Forestry 3(3): 80-82.

Tomentosus Root Rot: Pest Control Project 45

Title: Tomentosus Root Rot Survey: Data on Infection of Young Trees and Tests for Disease Responses to Infection.

Area Treated/Surveyed: 8 sites (33 surveyed during Project 25).

Contractor: Kathy Lewis, Prince George, B.C.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Prince George and Prince Rupert Forest Regions.

Date: June, 1988 to March, 1989.

Cost: \$31,800.

Objectives:

1. Determine the potential and probable spread of tomentosus root rot from first-growth stumps to second-growth trees.

Tomentosus Root Rot (DRT) Projects

2. Determine the duration and viability of inoculum in old-growth stumps and the colonization patterns and frequency of transmission
3. Determine the influence of chronological age, root size, host species (pine and spruce) and dynamic resistance mechanisms on pathogen establishment
4. Determine the relative importance of sporulation and vegetative spread with respect to infection in young stands.

Description: This contract was the second of a three part project investigating tomentosus root rot in northern spruce stands. Work during this phase included survey and selection of additional study areas, excavations at six selected field sites, continued tests of inoculation, fungal genetics (clonal studies) and virulence, and detailed microscopic examination of host-pathogen interactions.

Root to root contact patterns, decay progression and infection centre characteristics were elucidated during stump excavations. A total of 80 spruce seedlings, inoculated in 1987, were examined in 1988 for disease progression. In addition, 10 regenerated spruce and pine were inoculated per site with various strains of the fungus on 20 sites. Inoculum consisted of five isolates plus a control. Inoculated trees were marked and scheduled for reexamination in 1989.

Tomentosus root rot incidence (percentage trees) in the 41 sites surveyed was 42% and 29% in the Prince George and Prince Rupert Forest Regions, respectively. The number of infected stumps on sites excavated ranged from 20 to 71 per ha. Generally, infected stumps were found in small groups of two to six stumps in a clump. Individual disease centres ranged from single stumps to areas approximately 30 m in diameter. Clonal studies indicated that the smaller centres represented individual vegetative compatibility groups. This tentative finding sug-

gested that spore dispersal formed an important component of disease spread in northern stands.

Root contacts between infected stumps and trees were common, but decreased with increasing distance from the stump. The smaller roots of regenerated trees appeared to be more frequently infected. Disease transfer from infected stumps to second-growth trees was conservatively estimated to be 70% of the root contacts in spruce and 28% in pine. Advanced butt decay was more frequent and more extensive in older spruce stumps than in those of pine. During stump-top surveys on recently harvested sites, decay was less frequently observed in stumps of either species.

Contractor Recommendations: None.

Project Reports: Lewis, K.J. 1990. Epidemiology and Population Biology of *Inonotus tomentosus* as a Pathogen of Young Forests in British Columbia. Ph.D Thesis. Oregon State University. 199 pp.

Lewis, K.J. 1990. Final Report: Epidemiology and Population Biology of *Inonotus tomentosus* in Young Forests of British Columbia. Contractor Report. 97 pp.

Lewis, K.J. 1988. *Tomentosus* Disease Effects on Second-growth Spruce and Pine in the Prince George and Prince Rupert Forest Regions. B.C.F.S. Int. Rep. PM-PB-36. 25 pp.

Evaluation: This project was the second of three contracts investigating tomentosus root rot in northern stands. Substantial work still remained for 1989-90 in order to complete all studies and formulate suitable recommendations.

Project Status:

Operational Detection Trial — rated possible to fair chance of suitability for operational use; need additional data to determine effectiveness.

Tomentosus Root Rot: Pest Control Project 49

Title: Data Summary and Analysis From *Tomentosus* Root Rot Permanent Sample Plots.

Area Treated/Surveyed: 5 plots for 0.9 ha.

Contractor: Kathy Lewis, Prince George.

B.C.F.S. Contact: R. Reich, Silviculture, Prince George Forest Region.

Region: Prince George Forest Region.

Date: September to November, 1988.

Cost: \$1,050.

Objective:

1. Determine rates of infection, disease spread, and effects of tomentosus root rot on tree growth.

Description: This project was the second part of a study initiated in 1986 at Beaver Forest Road, Prince George Forest Region, in which five permanent sample plots were established and some preliminary survey methods were investigated (PB-12). All data from that project, including information and maps, were collated and analyzed.

The site summary included information on tree species, age, height, five-year increment, number and location of infected roots, infection rating up stem and infection rating in the roots. All trees were assigned a disease rating. Measurements of the last 15 years of growth were used to calculate basal area of infected trees over five year periods. Data were compared by means of an analysis of variance.

Root collar weevil (*Hyllobius warreni*) was found frequently associated with the presence of tomento-

sus root rot. The exact nature of this association was not established but it appeared that the role of the insect was secondary. Root collar weevils are probably not vectors of the disease, being attracted by stress due to infection instead. However, some infection courts may have been initiated by weevil activity.

Infection was frequent on the smaller (0.2 to 1.0 cm) roots. Larger roots caused much less transmission. Decay generally moved from the smaller roots toward the root collar. Roots with stain only and no advanced decay were observed to much less capable of causing infection. The fungus is more likely to be near the surface of the roots when roots are small or when advanced decay is exhibited. Trees which had stain without advanced decay in the root system had no decay in the stem even at the root collar. Observations on vegetative spread obtained during projects 45 and JM-076 support these findings.

Despite an observed trend, the analysis of variance found that five-year basal area increment was not significantly affected by the pathogen. However, significant differences in basal area increment are expected if the trend continues. Height increment of infected trees was found to be significantly

less than in the control, with mean growth over 15 years decreasing with increasing disease rating.

Contractor Recommendations: None.

Project Report: Lewis, K.J. 1988. Inonotus Tomentosus Plot Excavations Data Analysis and Conclusions. Contractor Report. 16 pp.

Evaluation: This project was established to determine long-term data on tomentosus root rot spread and impact. All five plots should be remeasured at five- to ten-year intervals. Ideally, these plots should be reassessed in 1991 or 1992 to detect any significant trends. Five similar but non-permanent sample plots surveyed in projects 45 and JM-076 supported the observations from Project 49. However, additional plots should be established in other representative locations in order to improve the data base since information on this disease is still rudimentary. Improved understanding of disease impact and spread and the effects of spacing will allow for more precise loss predictions and treatment decisions. This, in turn, will enhance long-term management of affected areas and should help reduce any future backlog.

Project Status: Damage Appraisal Operational Trials And Modelling — plot remeasurement and analysis.

Tomentosus Root Rot: Pest Control Project 59

Title: Knockholt Root Disease Control Trial.

Area Treated/Surveyed: 20 ha.

Contractor: Pathocon Consulting, Prince George.

B.C.F.S. Contact: S. Zeglen (W. Martin to 1989), Prince Rupert Forest Region.

Region: Prince Rupert Forest Region.

Date: November, 1988 to March, 1989.

Cost: \$10,000.

Objectives:

1. Conduct an intensive root disease survey on a 20 ha site to assess the effectiveness of glyphosate (Vision) in inhibiting the spread of tomentosus root rot in young spruce stands.
2. Prepare the area for treatment assessment.

Description: A 20 ha, 60-year old spruce stand was surveyed using the line intercept method. All infection centres were mapped and infected trees marked. A prestand tending survey was also conducted employing one plot/ha.

Nine treatment areas, each 1 ha, were delineated. Three treatments were randomly assigned: manually spaced, spaced using glyphosate, and control (untreated). Five growth and yield permanent sample plots (PSP's) were established within the three control areas following standard inventory practice. The infection status of all trees within these plots

was determined and recorded and stem maps were produced for infected trees. Infection centres varied from single tree sources to centres approximately one ha in size. A detailed map of the entire area was also produced. Approximately 25% of the area surveyed was infected. The line intercept survey method was recommended.

Contractor Recommendations: None.

Project Report: Schulting, J. and M. Schulting. 1989. Knockholt Root Disease Trial Area Layout. Contractor Report. 18 pp.

Evaluation: This site should be monitored at regular intervals for ten or more years in order to assess treatment effectiveness and disease impact. The line intercept survey method was recommended for tomentosus root rot; however, this method relies heavily on noticeable above-ground symptoms. It is probable that disease symptoms were readily observed in this case because of stand age and overstocking. In other instances, trees do not exhibit reliable crown symptoms, and infection centres would probably be missed. Therefore, development of a more reliable survey method is required for this disease.

Project Status: Operational Detection Trial — method rated possible to fair chance of suitability for operational use; need data to precisely determine effectiveness and/or practicality.

Tomentosus Root Rot: Pest Control Project JM-076

Title: Completion of Tomentosus Root Rot Survey: Data on Infection of Young Trees, Inoculations, Clonal Analyses and Infection Biology.

Area Treated/Surveyed: 8 additional sites (for a total of 49 sites surveyed during 3 contracts)-

Contractor: Kathy Lewis, Prince George.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Regions: Prince George and Prince Rupert Forest Regions.

Date: May, 1989 to March, 1990.

Cost: \$29,100.

Objectives: (See Project 45)

Description: This project was the final phase of a three year study investigating tomentosus root rot in young northern stands. All work implemented under the previous contracts was completed during this phase. Detailed excavation plots were established at the margins of infection centres on additional one- to five-year old sites to augment information on infection biology gathered in 1987-89. Regeneration trees inoculated the previous year were examined for infection response. The clonal tests for determining the importance of spore spread were completed. These analyses consisted of protein profiles and agar plating for observation of vegetative compatibility/ incompatibility patterns.

Observations from the previous two surveys (projects 25 and 45) were confirmed, with the following highlights:

- Tomentosus root rot was frequently found in young pure spruce or spruce-pine stands, ranging from 0% to 60% in the 49 stands examined. In the Prince George and Prince Rupert forest regions 40% and 29% respectively of the areas surveyed contained the disease.
- Distribution of tomentosus was patchy; some areas contained no disease while other parts of some sites had up to 40 infection centres per ha. Distribution appeared to be strongly influenced by soil moisture, the pathogen being limited to fresh to moist habitats. Tomentosus can be expected in 30% to 40% of such areas.
- Infection centres ranged in size from individual stumps to areas 30 m or more across. Most centres consisted of two to six old-growth stumps and associated regeneration.
- Clonal and vegetative compatibility tests indicated that spores are an important means of disease spread, although a quantitative assessment was not possible.
- The disease viability threshold in first-growth stumps was found to be 30 years, however ad-

vanced decay was generally localized around the root collar.

- More root contacts between regeneration trees and infection sources occurred in spruce than in pine, root contacts increasing with increasing plantation age and decreasing distance from the inoculum source. This is probably due to the deep-rooting nature of pine. Fine roots of either species frequently appeared to contain the fungus.
- Infectivity was greater in spruce than in pine, measuring 70% and 28%, respectively.
- Infected spruce stumps probably pose a greater hazard than infected pine stumps.
- Above-ground symptoms were not a reliable indicator of disease extent since not all infected trees exhibited noticeable crown thinning, reduced growth or chlorosis until at least 40% to 50% of the root system was decayed or stained.
- Stump top surveys located the disease much more reliably in spruce than in pine since visible decay columns were more frequent in the former species.
- Information from the detailed excavation plots indicated that the pathogen advances through the heartwood, extensively colonizing the root system, and then progresses radially toward the root surface at which time symptom expression starts.

Contractor Recommendations:

- Develop suitable and reliable survey methods and guidelines to determine infection levels and treatment thresholds. Possibilities include employment of wide (10 m) transects, post-harvest surveys of old-growth stumps in pure spruce stands (should provide accuracy within 10%), and coverage of at least 10% of each stand to assess extent. This type of survey will not give reliable results for pine stumps. Do not drill stumps to determine infection status.
- Survey additional stands in both forest regions to determine severity of the problem.
- Loss predictions should consider disease spread by spores as well as by vegetative means.
- Consider a plantation to be at risk from infected first-growth stumps for at least 30 years.
- Determine the relative susceptibility of pine. A 1987 study suggests that pine may be equally susceptible to infection 1.

Project Reports: Lewis, K.J. 1990. Epidemiology and Population Biology of Inonotus Tomentosus as a Pathogen of Young Forests in British Columbia. Ph.D. Thesis. Oregon State University. 199 pp.

Lewis, K.J. 1990. Final Report: Epidemiology and Population Biology of Inonotus Tomentosus in

Young Forests of British Columbia. Contractor Report. 97 pp.

Lewis, K.J. 1988. Tomentosus Disease Effects on Second-growth Spruce and Pine in the Prince George and Prince Rupert Forest Regions. B.C.F.S. Internal Report. PM-PB-36. 25 pp.

Evaluation: The many findings and recommendations from projects 25, 45 and JM-076 will be crucial in the formulation of effective management strategies for mitigating the effects of tomentosus root rot in young northern spruce and spruce-pine stands. The data obtained on disease incidence, spread and survival from one rotation to the next give a strong indication of the threat posed by this disease in some northern spruce and spruce-pine plantations. Implementation of reliable surveys, regular monitoring of plots and the use of effective controls should help reduce northern backlog NSR, a primary consideration of F.R.D.A. efforts.

Development of a suitable (i.e. more productive) survey method did not result from these projects. Much additional work is required to determine the extent of the problem, develop stand management guidelines and assess treatments and impacts. Fol-

low-up activities which would be suitable under F.R.D.A. II include:

- conducting additional investigations to determine the extent of tomentosus root rot in the Prince George and Prince Rupert forest regions.
- development of a more productive but accurate survey method for measuring tomentosus incidence and levels. Concurrently establish guidelines for survey intensity, treatment thresholds and stand management options.
- conducting workshops on proper identification, survey methods and management options.
- determining the relative susceptibility of pine through alternate species trials on infected areas. Evaluate control trial plots already established and set-up additional trials.
- additional population studies aimed at quantifying virulence and spread by spores.

Project Status: Operational Detection Trial — rated possible to fair chance of suitability for operational use; need additional data to determine effectiveness.

1. Schulting, P.J. 1987. Relative Susceptibility of Interior Spruce and Lodgepole Pine in Central British Columbia. M.Sc. Thesis. University of British Columbia.

Tomentosus Root Rot: Pest Control Project JM-079

Title: Knockholt Tomentosus Root Rot Spacing Trial.

Area Treated/Surveyed: 4 ha.

Contractor: Pathocon Consulting, Prince George.

B.C.F.S. Contact: S. Zeglen (W. Martin to 1989), Prince Rupert Forest Region.

Region: Prince Rupert Forest Region.

Date: November, 1989 to February, 1990.

Cost: \$7,500.

Objectives:

1. Manually space four 1 ha treatment blocks within the Knockholt tomentosus root rot control trial area.
2. Establish three growth and yield permanent sample plots within the spaced blocks.
3. Establish two 50 m by 50 m root disease rate-of-spread plots, one plot within the control blocks and one within one of the treated blocks.
4. Produce data forms and maps showing location of all plots and stems.

Description: A spacing crew manually spaced the four treatment units at the Knockholt root disease control area. One intensive forestry growth and

yield plot was established within each of the four treatment blocks. Two 50 m by 50 m root disease rate-of-spread plots were established. One plot was randomly placed in a control area and the other plot was located in a manually spaced treatment block. To date, this trial is incomplete pending a Pesticide Use permit for glyphosate (Vision) application within the treatment blocks.

Contractor Recommendations: None.

Project Report: None.

Evaluation: This project is incomplete to date. After chemical treatment, monitoring and maintenance of the plots should be performed at regular intervals for at least ten years to obtain data on treatment effectiveness and disease spread and impact. Presently, data is insufficient to adequately determine the effectiveness of this control strategy. Thus, follow-up monitoring should provide information that will benefit tomentosus root rot control efforts and help reduce backlog NSR in northern boreal spruce stands.

Project Status: Operational Control Trial — method rated possible to fair chance of suitability for operational use; need data to precisely determine effectiveness and/or response to treatment.

Multiple Root Disease (DR) Projects

Multiple Root Disease: Backlog Research Project 3.8

Title: Development of Root Disease Survey Methods for Southern Interior Stands and Plantations.

Area Treated/Surveyed: 20 ha.

Contractors: Pathocon Consulting Ltd., Prince George.

B.C.F.S. Contact: H. Merler, Kamloops Forest Region.

Region: Kamloops Forest Region.

Date: January to March 1986.

Cost: \$15,000

Objectives:

1. Conduct a root disease survey on up to six cut blocks of 15 to 20 ha each. Map and record all infected trees.
2. Analyze the survey data to develop root disease survey methods toward determining suitable management options for the Vernon-Salmon Arm area.

Description: Three sites, with mixed age and species and a history of selective harvesting, were selected for trials of survey methods. All three areas contained armillaria root disease and laminated root rot. All infected trees were mapped: species, size and infection code were determined and recorded. Infection class was coded as dead, heavy, medium and light. Trees were tallied by infection class and height class per species.

Two different sampling procedures were developed for each disease. Both clumped and diffuse infection was noted for laminated root rot, while armillaria rot disease was observed to have a clumped distribution. The transect infection method was not used. Instead, prism (BAF 2-6) and fixed area plots were considered in conjunction with a quick reconnaissance to stratify the area by infection levels. The fixed area plots were 10m x 20m or 20m x 20m in size and yielded good esti-

mates for laminated root rot. Data on armillaria root disease were obtained by running 10m wide strips at 50m intervals and recording all diseases within these strips. This method was found to be quite accurate for a clumped disease distribution, but was also time-consuming and therefore somewhat impractical. Armillaria root disease appeared to be associated with cut stumps, thus leading to the hypothesis that selective cutting is exacerbating the problem.

Contractor Recommendations:

- Conduct further assessments of the two proposed survey methods.
- Conduct extension and demonstration activities to deliver the final methodology.
- Examine additional stands to determine if armillaria infection centres are correlated to cut stumps and assess armillaria spread rate and delay period after cutting.

Project Report: Curran, M., and M. Schulting. 1986. FRDA Project 3.8: Development of Sampling Procedures for Root Disease in the Dry Interior - Douglas-fir Biogeoclimate Zone. Contractor Report. 44 pp, illust.

Evaluation: The project objectives were met, although a relatively small area was surveyed. The two proposed methods have since been greatly modified. The fixed plots covered too large an area and the 10m wide strip survey required an excessive amount of time. Follow-up to the contract recommendations occurred during the second part of this project in 1986-87.

Project Status:

Operational Detection Trial — Method rated possible to fair chance of suitability for operational use; need data to precisely determine effectiveness and/or practicality.

Multiple Root Disease: Backlog Research Project 3.8

Title: Survey of Root Disease on Backlog Non-satisfactorily Restocked Areas.

Area Treated/Surveyed: 17 sites.

Contractors: Pathocon Consulting Ltd., Prince George.

B.C.F.S. Contact: H. Merler, Kamloops Forest Region.

Region: Kamloops Forest Region.

Date: August, 1986 to March, 1987.

Cost: \$24,000

Objectives:

1. Examine representative backlog areas in the Southern Interior.
2. Compile a list of disease indicators and site hazard estimators suitable for field crews to evaluate and prescribe appropriate site treatments.
3. Develop and test root disease survey methods to determine disease incidence, hazard and symptoms in backlog non-satisfactorily restocked areas.

Description: Methods for determining the occurrence of root disease were evaluated on seven backlog NSR areas and 10 young stands. All but one site contained infected young trees and/or stumps or infected mature trees in adjacent stands. Incidence ranged from 0 to 15% in young stands and 0 to 6% in backlog areas; however, these estimates were considered to be conservative in the younger plantations. Thus, it was considered that armillaria

root disease and laminated root rot could increase the amount of backlog NSR.

A strip survey, at 3% to 5% sampling intensity, was employed to determine the percentage of trees infected. Hardwood shrubs were examined for use as disease indicators. In addition, mushrooms, debris, stumps, and residual conifers were examined. Ecological information was collected and adjacent stands were surveyed. Laminated root rot in the adjacent stand appeared to be correlated to on-site disease levels for the ICHm 1-5 biogeoclimatic subzone variants.

However, there was considerable variability. Examination of adjacent stands was unreliable for estimating on-site disease. Laminated root rot was difficult to detect in very young stands, but armillaria root disease was readily detectable even in two-year-old plantations. Thus, regeneration surveys were suitable for detecting armillaria but not laminated root rot.

Twelve different hardwood species were found to be indicative of armillaria root disease but infection of these species was not directly correlated with infection of commercial conifer species. Stump surveys were useful for areas with no conifer or hardwood regeneration, but this method was time-consuming. In addition, stump surveys had to be performed immediately after harvest. Sporophores (mushrooms) were not reliable indicators of armillaria root disease.

Treatment options were different for the two diseases. No treatment was required for low risk sites, while some options should be considered for high risk areas.

Multiple Root Disease: Pest Control Project PB-5a.

Title: Review of Root Disease Sampling Methods.

Area Treated/Surveyed: Overview of one supply block.

Contractors: T.M. Thomson & Associates, Ltd., Victoria.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Kamloops Forest Region.

Date: January to March, 1986.

Cost: \$10,000

Objectives:

1. Critically review root disease, inventory and silvicultural survey practices carried out by the B.C.F.S., Forestry Canada, industry and other agencies.

2. Recommend new or improved methods of sampling to determine disease losses and the benefits of control-treatment in TSA's.
3. Outline a disease sampling procedure to estimate disease impacts and control benefits in order to develop contract specifications for a selected sample TSA.

Description: Pertinent literature was reviewed and government and private agencies were contacted to determine which root disease survey procedures were being followed in order to determine their effectiveness and recommend suitable improvements. The following agencies were reached for input: Inventory Branch, Silviculture Branch, Vancouver Region, Duncan District, Sechelt District, Forestry Canada, C.I.P. and MacMillan Bloedel. The following information was received.

Multiple Root Disease (DR) Projects

Inventory Branch employed low level (mainly 70 mm) colour and infrared photography between 1981 and 1983. Results were satisfactory for discrete openings such as those caused by laminated root rot but were not satisfactory for diffuse disease occurrence as is the pattern for armillaria root disease in the Interior. Survey forms did not consider collection of root disease information. Silviculture Branch employed line intercept surveys if disease levels were estimated to be 10-20%. Planned silvicultural treatments would be adjusted accordingly if disease levels were found to be high. Disease survey results in the Vancouver Forest Region indicated that the line intercept method gave good results where infection centres are discrete, and could be used in pre-stratified TSA's.

Comments from the Duncan and Sechelt Forest Districts and Forestry Canada indicated that the line intercept method could not be used effectively in TSA's. Discussions with Forestry Canada revealed that the line intercept method would not be suitable for Interior stands since the openings are not discrete. A combination of sampling procedures using type maps, aerial photographs and ground verification would probably be satisfactory for TSA's. Industry employed the line intercept method in smaller areas but indicated that survey costs would be prohibitive in larger areas such as TSA's. Other problems included misdiagnosis and errors in disease measurement and the lack of a disease hazard rating system. It was generally agreed that root disease sampling in larger areas such as TSA's would require pre-stratification using type maps and large-scale aerial photographs.

From the preceding review, a twelve-stage survey methodology was proposed which utilized computer-assisted mapping, field sampling and large-scale aerial photographs. Areas were labelled as "risk" and "non risk" at the Biogeoclimatic subzone level within TSA's. Supply blocks and compartments were to be identified as to risk and marked on forest cover maps. All susceptible species site types would then be identified within "at risk" blocks and compartments. Large-scale photographic sampling would subsequently be conducted on 5% of the area identified as susceptible species/site types within these blocks and compart-

ments. The photographs would be analyzed and root rot levels assessed as absent, light, medium, or heavy. Ground surveys of 10% of the medium and heavy classes would be used to verify these estimates. Root disease loss factors would be compiled for the TSA and applied to the Region Volume Tables. The Okanagan TSA was used as a sample test area since this TSA was known to have a significant armillaria and laminated root rot problem. All phases of the preceding method, except ground sampling, were employed on a trial basis within Supply Block #6 of this TSA. Ground sampling could not be implemented due to insufficient funding. Costs were estimated at \$21,900 (1986) per supply block.

Contractor Recommendations:

- Carry out the developed procedures for root disease assessments within TSA's.
- Conduct ground verification of Supply Block #6, Okanagan TSA to complete evaluation of the method. Utilize the line intercept method or line plot method.

Project Report: Wallis, B.T., G. Wallis and E.G. Vaughan. 1986. Root Disease Survey Methods: Phase I, II and III. 3 part Contract Report. Total 38pp plus maps and appendices.

Evaluation: All objectives were met with the exception of actual ground verification. The line intercept method has not been effective for root disease estimation in the Interior since 1986. Thus, the ground sampling stage of the proposed method would have to utilize a different technique such as a pixel or a regeneration/armillaria survey. In addition, the proposed method did not consider any distinction between armillaria root disease and laminated root rot, and thus would not be useful for formulating management options in infected areas since these options differ between armillaria root disease and laminated root rot. Subsequent development of a site discrepancy analysis technique, still under revision, has also rendered the proposed multi-stage method unsuitable.

Project Status: Detection method not suitable for operations — Do not implement on an operational basis.

Multiple Root Disease: Pest Control Project PB-5b

Title: Evaluation of Three Root Disease Survey Methods for Interior Douglas-Fir Stands.

Area Treated/Surveyed: 10 ha stem mapped (2 sites).

Contractor: P.M. Wood, Vancouver.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Kamloops Forest Region.

Date: May, 1987 to March, 1988.

Cost: \$19,300

Objectives:

1. Compare the efficacy of three root disease survey methods by means of field trials.
2. Evaluate the feasibility, precision, costs and compatibility with current B.C.F.S. systems of the three methods for B.C.F.S. use.

Description: The efficacy and suitability of three root disease survey methods were compared. These

techniques consisted of a line intercept method, strip transect method and fixed radius plot sampling. Stem maps were produced in two mature interior Douglas-fir stands near Allison Lake, south of Merritt, and Turtle Valley, southeast of Chase. Stems were mapped as either infected or healthy.

Transects were placed at 50-70m intervals. The percentage of infected length was recorded along each transect. Strips were 10m wide and placed at 50m intervals. The area of root disease within the 10m wide strip was recorded. Fixed 5m radius plots were placed at 50 intervals and all disease within each plot was recorded.

Ten surveys for each of the three methods were simulated on each site. Each simulation was timed to estimate survey productivity. Survey results were compared by technique and by the known levels of root disease for the two areas to assess the effectiveness of each technique.

None of the tested methods was found to be biased. The plot method had the greatest precision and the line intercept method was the least precise. The strip method was generally slowest, while plot sampling was fastest to perform. The latter method required sketch mapping, thus taking longer and involving some amount of subjectivity. Extensive mapping was not included but would be required. However, neither laminated root rot nor armillaria root disease were distributed in discrete centres as on the coast; thus, all three methods were found to be inappropriate for interior stands unless applied strictly for stratification purposes. In addition, the survey methods evaluated were judged inappropriate for obtaining root disease data for entire TSA's

because of the cost and duplication of depletion estimates due to root disease in yield calculations. A yield point sampling method was considered to be more efficient than any of the preceding surveys.

Contractor Recommendations:

- Do not employ the survey methods evaluated in this project.
- Construct managed stand yield tables for areas treated for root disease.
- Although the plot method was best, a point sampling method (prism plot) would probably be more appropriate for mature Douglas-fir stands. This method should be tested.
- A technique for sketch mapping infection centres and point infection sources should be evaluated.

Project Report: Wood, P.M. 1987. An Evaluation of Three Root Disease Survey Methods for Interior Douglas-Fir Stands. B.C.F.S. Internal Report PM-PB-34. 39 pp.

Evaluation: Although all project objectives were obtained, the three methods were rated as unsuitable for interior Douglas-fir stands. However, plot sampling was the most efficient. This project did not address the question of suitability and accuracy of 70mm photography for root disease estimations. Suitable follow-up activities would include evaluation of a point sample survey for mature stands, in conjunction with pixel sampling and/or 70mm photography.

Project Status: Detection methods not suitable for operations — Do not implement on an operational basis.

Multiple Root Disease: Pest Control Project PB-17

Title: Root Disease Silvicultural Assessment.

Area Treated/Surveyed: Area surveyed as part of Project 3.8.

Contractors: Pathocon Consulting, Prince George

B.C.F.S. Contact: H. Merler, Kamloops Forest Region.

Region: Kamloops Forest Region.

Date: October 1986 to March 1987.

Cost: \$4,200

Objectives:

1. Develop a root disease survey procedure compatible with existing silvicultural assessments such as PHSP's, free-growing surveys and pre-spacing assessments.
2. Prepare a field guide to laminated root rot and armillaria root disease symptoms.
3. Demonstrate results to BCFS personnel.

Description: Strip surveys incorporating standard silvicultural plots were suitable for use. This

method is similar to the regeneration—armillaria survey method employed in some projects in the Nelson Forest Region. However, disease was tallied along transect lines only and two specialized field cards were developed for this purpose. A 25 page field guide was also produced. All symptoms of both diseases were illustrated with coloured photographs. Both "classic" and diffuse infection centres were illustrated. Disease estimates and recording procedures were explained together with correct use of the two field cards. Information to be included on these cards consisted of: total infected area, number of single trees infected, number of centres, species attacked and disease location. A demonstration was conducted for B.C.F.S. staff in the Merritt District.

Contractor Recommendations: None.

Project Report: Schulting, J, and M. Curran. 1987. A Field Guide to the Identification and Assessment of Root Disease in the Southern Interior of British Columbia. Contractor's Report. 25 pp, illus.

Multiple Root Disease (DR) Projects

Evaluation: All project objectives were attained. The survey method is probably suitable for use, although additional consideration of disease within standard silvicultural plots is probably more applicable since this method has been successful in the Nelson Forest Region during armillaria/regeneration survey trials. In this manner, disease measurements along transect lines would be suitable for assessment of discrete centres while measurements within standard fixed radius plots or use of the pixel method would be suited to estimates of more diffuse infection. Suitable follow-up activities include:

- production of the field guide in a suitable format (waterproof paper, rugged binder, compact size, etc.).
- conduct additional trials and demonstrations of the technique for field personnel.
- assess incorporation of disease information within the standard silvicultural plots in the same manner as the armillaria/regeneration survey procedure.

Project Status: Operational Detection Trial — Method rated moderated to highly practicable; need data to substantiate operational use, then should be fully practicable (2-2D).

Multiple Root Disease: Pest Control Project 38

Title: Evaluation of a Root Disease Model.

Area Treated/Surveyed: Modelling for two sites.

Contractors: ESSA Environmental and Social Systems Analysts Ltd., Vancouver.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria; D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: November, 1987 to March, 1988.

Cost: \$10,100

Objectives:

1. Assess PROGNOSIS root disease model from the U.S.F.S. for a pilot project in the Nelson Forest Region.
2. Evaluate the utility and applicability of this model for B.C. by using simulation of management options and disease levels on suitable stands and by gathering comments from the participants.
3. Make recommendations and identify information requirements and other needs for implementation of this model in B.C.

Description: A forest stand model that projects effects of root diseases, developed by the contractor in conjunction with and for the U.S.F.S., was assessed in B.C. The model, PROGNOSIS, simulates spread, mortality, and impacts on growth and yield due to armillaria and laminated root rot. The model was considered to inform foresters of the effects of different management practices and guidelines. The model was accessed at the Fort Collins Computing Centre, Fort Collins, Colorado to simulate scenarios on two selected sites. A graphical and written presentation was produced. Workshops were held for B.C.F.S. personnel to demonstrate the model and results for various management options.

Six management and three control scenarios were chosen for two armillaria-infected stands in the Golden Forest District at Quartz Creek and Beaverfoot. Estimates of armillaria root disease in these areas were believed to be conservative due to the

absence of pre-harvest data. Options included: no management ("doing nothing"), no root disease control, infected stump removal, planting resistant species, planting susceptible species at reduced stocking, overstory removal and establishment of natural regeneration, planting susceptible species at normal (1500 stems/ha) stocking, planting susceptible species at normal stocking and thinning to 750 stems/ha or less within 20 years. Final stand volumes and mortality were calculated for all treatments in both stands at age 90 for trees within infection centres, trees outside infection centres and the average.

Results were similar for both stands under comparable management regimes. Removal of infected stumps was the most successful scenario, the disease completely disappearing within 15 years of treatment. Overstory removal followed by natural regeneration was the least effective scenario. Projected growth of resistant species was poor, as was the establishment of residual species at reduced stocking. Precommercial thinning exacerbated the problem.

Two workshops were held and regional pathologists, silviculturalists, district managers and licensees (industry) attended. The following responses were received from participants with respect to utility and usefulness of this model in B.C.:

- The model would be able to perform a necessary role in determining stand management options, educating foresters on root disease control and forming an integral component of the timber supply planning process with certain refinements.
- The model should be made widely available.
- Modelling refinements are required because the model was designed for disease conditions in U.S.A. stands. Refinements must include laminated root rot and armillaria root disease together, effects of selective logging on disease spread, discrete outputs for mixed stands, and the effects on market values.
- Additional modifications would be required to simplify operation of the model for all users.

Contractor Recommendations: To implement the PROGNOSIS model in B.C.:

- Fully identify user needs.
- Refine the model for B.C. situations.
- Analyze model sensitivity for B.C. situations.
- Develop a more "user friendly" interface.
- Produce written packages for training and reference.
- Conduct extension and demonstration activities (workshops).

Project Report: Sutherland, G.D. and J. McNamee. 1988. Towards Technical Transfer of a Root Disease Model in B.C. — Model Demonstration and Evaluation. B.C.F.S. Internal Report. PM-PB-37. 72pp.

Evaluation:

All project objectives were attained. The PROGNOSIS root disease model is very useful for simulation of management options, training of foresters and appraisal of disease impacts. Modifications are required in order for this system to be used in B.C. Major benefits would be to evaluate effectiveness of management options now used in the province, to improve awareness of disease problems and subsequently enhance forest management.

Project Status:

Damage Appraisal Operational Trials and Modeling — Root disease impact management option simulations.

Multiple Root Disease: Pest Control Project 44

Title: Demonstration of a Root Disease Model in B.C.

Area Treated/Surveyed: Modelling for one site.

Contractors: ESSA Environmental and Social Systems Analysts Ltd., Vancouver.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria; H. Merler, Kamloops Forest Region.

Region: Kamloops Forest Region.

Date: April to June, 1988.

Cost: \$9,812

Objectives:

1. Simulate control and management scenarios for a representative Interior Douglas-fir stand in the Kamloops Forest Region.
2. Develop a permanent display of the model simulations and comparison of the management options for extension and demonstration use by the B.C.F.S.

Description: The PROGNOSIS root disease model of the U.S.F.S. was used to simulate management options and disease effects for a selectively-logged mixed-species (Douglas-fir leading) stand at Lanes Creek in the Interior Douglas-fir Biogeoclimatic Zone, near Kamloops. Twelve runs of the model over a 100-year period for eight management options plus four controls were produced. Data included a detailed stand inventory, infection from both standing (leave) trees and stumps, and location and size of laminated root rot infection centres relative to healthy stems.

Simulated scenarios included: no management; control (no root disease); no management plus simulated budworm outbreak; clear cutting with lodgepole pine regeneration; removal of infected stumps followed by planting of susceptible species at lower densities; clear cutting with establishment of resistant species; clear cutting with establishment of deciduous species; further selective cutting; and

shelterwood cut followed by natural regeneration. Mortality, growth and yield were generated for the whole stand during each simulation.

Results were that selective cut and shelterwood removal resulted in significant volume loss. Clear cutting and establishment of lodgepole pine produced a moderate merchantable volume. Spruce budworm outbreak did not affect root disease levels. Rotations of deciduous and resistant (ponderosa pine) species resulted in moderate yields, but these results were tentative because deciduous growth was estimated. Stump removal was most effective in maximizing yields but the model was insensitive to variation in the density of infected stumps.

A permanent display was designed and produced to demonstrate the results for the Kamloops Forest Region.

Contractor Recommendations:

- Treat results with caution pending refinement of the model for B.C. conditions.
- Low levels of laminated root rot will have a significant future impact, and detection and management activities should be conducted accordingly.

Project Report: Sutherland, G.D., and P.J. McNamee. 1988. Demonstration of a Model for Root Disease in B.C.: Example Scenarios for a Dry Site. Contractor's Report. 31 pp.

Evaluation: This project provided a useful preliminary demonstration of the capabilities and limitations of the PROGNOSIS root disease model. Suitable follow-up activities are discussed under Project 38.

Project Status:

Damage Appraisal Operational Trials and Modeling — Root disease impact management options and simulations.

Multiple Root Disease: Pest Control Project 51

Title: Site Assessment for the Arrow TSA.

Area Treated/Surveyed: 102 sites.

Contractors: Laing and McCulloch Forest Management Services, Smithers.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: September, 1988 to December, 1988.

Cost: \$18,000

Objectives:

1. Locate approximately 100 stands that have previously been identified on forest cover maps.
2. Measure site class and compare with inventory label. Recommend improvements to the method, record reason(s) for any discrepancy, summarize field observations and estimate potential gains of disease treatments.

Description: Field procedures included identification of pest problems and their effects on class, for the following types of inventory labels: deciduous species leading; coniferous species leading and poor site class; coniferous species other than western red cedar or true fir were leading and medium site class; labels where coniferous species were leading, and site class was good but crown closure was less than 50%.

Totals of 20, 20, 37 and 25 sites were sampled in the respective categories by running survey strips through each area. Three sample points were used per site. At each point the following was determined: ecosystem association, site index, presence of pathogens, insects, other problems affecting stand health, age, height, gross volume/ha, total merchantable stems, soils, and topography. Pest incidence was recorded by code. Regeneration information was also obtained for younger stands (age class 1 or 2).

All information was summarized per polygon (site) and collated. A type label was changed only if there was a change in the type group, leading species, site class, or height or age class of more than one level. A mean annual increment was calculated if the stand was satisfactorily restocked. Old labels were then removed from forest cover maps, where applicable, and polygons were colour-coded as to the reason for the removal.

Because sampling was restricted to small areas of the polygon and variations in site index per polygon were noted, data were interpreted only for general trends.

No changes were required for 65% of all sites sampled. For the 35% where the old type labels were removed, 31% of the changes were attributed to pests, 49% due to other causes and 20% due to

unknown cause(s). A total of only 11% of the sites had a discrepancy due to pests, even though pests were present in 36% of the sites examined. Pest incidence appeared to be strongly correlated with previous logging disturbance. Armillaria appeared to be the most common pest; larch disease, white pine blister rust, and bark beetles were also common.

Discrepancies were most often explained by suppression or shallow soils but pests had a greater impact than these factors. Laminated root rot was not noted to any significant extent. Potential gains in mean annual increment were apparent in the next rotation following implementation of pest treatments. The frequency of erroneous labels indicated a requirement for updated forest cover maps. This survey method was inexpensive, although accuracy was lower than for conventional disease surveys. Volume loss measurements were considered to be superior to conventional disease surveys.

Contractor Recommendations:

- Compare the site survey results with conventional survey techniques on the same areas.
- Refine the technique to include a greater number of point samples per site and record both total merchantable and unmerchantable stems over 3 metres in height.
- Do survey stands less than 20 years of age, because other survey techniques provide better results.
- Analyze mean annual increment plots evenly distributed throughout the stand.
- Develop field procedures to determine armillaria saprophytic or pathological subspecies.
- Establish correlation between above-ground signs and the actual extent of root disease fungi.

Project Report: McCulloch, L. 1988. Site Discrepancy Assessment: Arrow TSA. Contractor's Report. 10 pp.

Evaluation: All project objectives were satisfied. With refinements, the site assessment method might be feasible for large areas. Particular polygons would be targeted and a reasonable estimate of disease impact would be obtained using the method. Follow-up activities include:

- refinement and further trial of the technique on other sites.
- compare the accuracy of this method with that of conventional methods, using the same study areas. Formulation of specific site treatments should be included.
- develop field procedures for easily assessing the virulence of armillaria root disease on-site.
- conduct extension and demonstrations activities to transfer the results to field crews.

Project Status: Operational Detection Trial — Method rated moderate to highly practicable; need

data to substantiate operational use, then should be fully practicable.

Multiple Root Disease: Pest Control Project 58

Title: Salmon Arm Root Disease Survey.

Area Treated/Surveyed: 35.2 ha.

Contractor: Amabilis Forestry Services, Ltd., Vernon.

B.C.F.S. Contact: H. Merler, Kamloops Forest Region.

Region: Kamloops Forest Region.

Date: February to March, 1989.

Cost: \$25,000.

Objective:

1. Conduct a survey for incidence and level of laminated root rot.

Description: Surveys for root disease were conducted in the Salmon Arm Forest District in the Salmon Arm, Shuswap and Sicamous Sustained Yield Units (SYU). Areas were prioritized for survey using recent forest cover maps. Starting points for a 1964 root disease survey were relocated and new transects were run along 11 of the old strips. Each strip was 1.6 km length and 20 m wide for a total area covered of 3.2 ha per line. All strips were divided into 16 contiguous 20 m by 100 m plots. Data collected included a total tally of trees by di-

ameter class (merchantable, poles, advanced and suppressed), number of dead and living trees by species, DBH, presence of laminated root rot and other pathogens. In addition, biogeoclimatic factors and sample trees were assessed and recorded. Infection centres were mapped and all data were summarized per plot. Both laminated root rot and armillaria root disease were noted during this survey.

Disease incidence and levels were highly variable. Root disease had severe effects in some strips and virtually none on others. An attempt was made to compare the 1989 survey data with that obtained during the earlier survey. Unfortunately, analysis was difficult because only Douglas-fir was measured in 1964 and armillaria incidence was not recognised at that time.

Contractor Recommendations: None.

Project Report: Data and maps only.

Evaluation: This project has not been completed to date. Results are pending and no follow-up activities are recommended.

Project Status: Operational Damage Appraisal — appraisal of disease incidence and impact.

Multiple Root Disease: Pest Control Project JM-064

Title: Cariboo Root Disease Survey — Phase I.

Area Treated/Surveyed: 2 sites.

Contractors: Inland Timber Management, Ltd., Williams Lake.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Cariboo Forest Region.

Date: February to March, 1989.

Cost: \$645

Objective:

1. Review aerial photographs and determine criteria to identify forest stands with root disease. Design a program for field checks.

Description: Phase I (this project) consisted of a review and evaluation of 1:10,000 aerial photographs. Openings on aerial photographs were marked and later ground checked for root disease during Phase II. Disturbances such as bark beetle kill, selective logging, flooded areas and extensive blowdown were differentiated from areas with potential root

rot problems. Photographs were examined unaided and magnified at 2x power and 6x power. The test area had significant large affected patches, as indicated by a heavy disturbance of crown closure on 1:10,000 scale photographs. Indicators of disturbance included: skid trails, presence or absence of an understory, ground forms suggestive of drainage problems, wind throw, patch openings, bark beetle attack, and red foliage. Characteristics were examined in the following order: crown closure, coniferous understory, blowdown and terrain. The 1:10,000 scale was sufficient to readily discern areas with windthrow. A pattern of field surveys, with 7 transect lines, was designed for an area near MacIntosh Lake, 20km east of 150 Mile House. Transect lines were to be run at specified headings to intercept all disturbances marked on the aerial photographs.

Contractor Recommendations: Recommendations consisted of a proposal to conduct ground verification surveys. These were subsequently conducted.

Project Report: Fowler, R.A. Inland Timber Management. 1989. Cariboo Root Rot Disease Survey. Contractor's Report. 4 pp.

Multiple Root Disease (DR) Projects

Evaluation: Work was completed for this phase of the project. A complete evaluation can be found in Project JM-070.

Project Status: Complete.

Multiple Root Disease: Pest Control Project JM-070

Title: Cariboo Root Disease Survey — Second Phase.

Area Treated/Surveyed: 1 site.

Contractors: Inland Timber Management, Ltd., Williams Lake.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Cariboo Forest Region.

Date: June, 1989 to March, 1990.

Cost: \$4,835.

Objectives:

1. Ground check areas suspected of having root disease to test aerial photographic interpretation in Project JM-060.
2. Conduct a trial root disease survey at MacIntosh Lake and report on methods, results and recommendations for a large-scale inventory survey.

Description: In the first phase of the project (JM-060) suspect areas were delineated on aerial photographs and transferred to maps. In the second phase, ground checking was done to evaluate the accuracy of photographic interpretation with respect to root disease. Transect lines were run to intercept suspect areas. In suspect areas, trees were examined for root disease by exposing wood at the base of the tree. Disease incidence along each transect was recorded and later compared to the locations on the map.

Root rot centres could be identified from either 1:15,000 or 1:10,000 scale of photography but not accurately. Root disease in young (2 metres in height)

regeneration could not be distinguished at all on these photographs.

The area infected, as determined on the ground, was much larger than predicted from the map. Seven centres were located on the ground which were missed on the photographs. Of a total of 17 centres delineated, five could not be confirmed on the ground, seven centres were correctly identified and three areas predicted as having root rot had none. Ten areas not identified on photographs had root disease. Armillaria root disease and Warren's root collar weevil were the only disease or insect identified.

Contractor Recommendations: For a large-scale inventory project:

- Colour photographs (scale 1:10,000) should be used depending on cost.
- Suspected root disease centres should be transferred from photographs to forest cover maps.
- Areas should be prioritized and surveyed at predetermined intercept bearings.
- The need for further field surveys should be determined after an initial probe.

Project Report: Inland Timber Management. 1990. Cariboo Root Rot Disease Survey. 4 pp.

Evaluation: Results of using aerial photographs to survey for root disease were far less accurate than required, notwithstanding the contractor's recommendation for a large-scale inventory project. An unacceptable amount of root disease was missed at both scales examined. Ground surveys, employing pre-stratification from forest cover maps and surveys of targeted stands, would be a better approach. No follow-up work is recommended.

Project Status: Detection Method not suitable for operations — Do not implement on an operational basis.

Multiple Root Disease: Pest Control Project JM-084

Title: Satellite Imagery for Forest Disease Surveying.

Area Treated/Surveyed: 43 sites.

Contractor: Strathinnes Forestry Consultants, Ltd., Victoria.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: June to November, 1989.

Cost: \$9,000

Objectives:

1. Compare ground-based information to satellite images of the same area in the Arrow TSA, using maps from the site assessment analyses of Project 51.
2. Using correlations between disease sites and the satellite image for the Arrow TSA, conduct an image interpretation of the Boundary TSA and then a ground reconnaissance to determine the accuracy of the interpretation.

Description: This contract was the initial phase of a three-part study consisting of projects JM084, JM-

091, and JM-097. Satellite imagery (LANDSAT-5TM) at a scale of 1:1,000,000 was enlarged to 1:50,000. Clear acetate forest cover maps were superimposed. Each stratum sampled in Project 51 was identified and coded. Sites on the satellite image were rigorously inspected to determine similarities and differences in colours, texture of reflectance and brightness. Correlations between site conditions and corresponding image characteristics were attempted and three features were observed:

- Snow reflectance showed clearly on clear cuts and selectively logged areas.
- North aspect slopes were dark due to the low winter sun angle.
- A reddish coloration ("red casting") was seen at varying intensities over most of the image.

A total of 42 strata were chosen for ground surveys from the correlations established between the satellite image and the map. All survey areas were

within the Interior cedar-hemlock biogeoclimatic zone of the Boundary TSA and contained a broad range of species compositions and slope positions. Ground verification surveys were carried out in Project JM-091.

Contractor Recommendations: None for this phase.

Project Report: Horkoff, J. 1990. Boundary-Arrow Satellite Image Forest Disease Interpretation. Contractor's Report. 10 pp.

Evaluation: Initial image selection, overlays of forest cover maps, interpretation of the satellite image with respect to site discrepancies and selection of sites for ground truthing were completed during this phase. A comprehensive evaluation is presented in Project JM-097.

Project Status: This phase — Complete.

Multiple Root Disease: Pest Control Project JM-087

Title: Salmon Arm Root Disease Survey.

Area Treated/Surveyed: 51.2 ha.

Contractor: Amabilis Forestry Services Ltd., Vernon.

B.C.F.S. Contact: H. Merler, Kamloops Forest Region.

Region: Kamloops Forest Region.

Date: November, 1989 to March, 1990.

Cost: \$14,300.

Objective:

1. Conduct a survey of root disease incidence.

Description: This project was conducted to complete similar survey work in Pest Control Project 58 in the Salmon Arm Forest District. All work was conducted on 16 previously established survey lines.

All live and dead trees were tallied within sixteen 20 m by 100 m contiguous plots per strip. The following tree data were collected: species, DBH class, and pathogen remarks. Two sample trees per plot were selected for measurements of height, age, DBH, species, and health. Information was also

gathered on biogeoclimatic zone, ecosystem association, edatopic grid, slope, position, topography, aspect, elevation and stand history. All infection centres were mapped and data were summarized per plot.

Both armillaria root disease and laminated root rot were noted during this survey. Root disease levels and incidence were found to be highly variable: root disease had a severe impact on some strips and very little on other survey lines. Unfortunately, analysis is complicated since only Douglas-fir was measured in the 1964 survey and armillaria root disease was not recorded at that time. A complete analysis of the stem tally is still pending.

Contractor Recommendations: None.

Project Report: Data Summary.

Evaluation: Project results are still pending. Thus, to date this project is not complete. There are no recommendations for suitable follow-up work to this project.

Project Status: Operational Damage Appraisal — appraisal of disease incidence and impact.

Multiple Root Disease: Pest Control Project JM-091

Title: Satellite Imagery for Forest Disease Interpretation.

Area Treated/Surveyed: 43 sites.

Contractor: Strathinnes Forestry Consultants, Ltd., Victoria.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: November to December, 1989.

Cost: \$9,300

Objective:

1. For correlations between disease sites and the satellite image for the Arrow TSA, conduct a

Multiple Root Disease (DR) Projects

ground reconnaissance to determine the accuracy of the interpretation.

Description: This project was the second part of a three-part project consisting of projects JM-084, JM-091 and JM-097. Ground surveys in the Boundary TSA were conducted during this part of the study. A total of 43 sites were sampled. More were to be surveyed but weather conditions did not permit this. Field sampling consisted of reconnaissance of each area. Data collected on sample plots included: DBH, age, height, increment over the last 10 years, and presence and level of damaging agents.

The following features became apparent during these surveys:

- Every strata investigated had some insect or disease damage.
- All strata with a significant deciduous component contained root disease problems.

- The three most commonly encountered damaging agents were armillaria root disease, mountain pine beetle and dwarf mistletoe.

Field data were compiled for correlations and trends. This latter phase was completed in Project JM-097.

Contractor Recommendations: None for this Phase.

Project Report: Horkoff, J. 1990. Boundary - Arrow Satellite Image Forest Disease Interpretation. Contractor's Report. 10 pp.

Evaluation: All field work was completed during this phase in order to verify the image interpretation. A complete evaluation is presented in project JM-097.

Project Status: This phase — Complete.

Multiple Root Disease: Pest Control Project JM-097

Title: Satellite Imagery for Forest Disease Surveys.

Area Treated/Surveyed: 43 sites.

Contractors: Strathinnes Forestry Consultants, Ltd., Victoria.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: February, 1990.

Cost: \$6,100

Objectives:

1. Compare ground-based information with satellite images of the same area in the Arrow TSA using maps from the site analyses initiated in Project 51.
2. Conduct an image interpretation of the Boundary TSA once correlations are determined between disease sites and the satellite image for the Arrow TSA. Conduct a ground reconnaissance to determine the accuracy of the interpretation.
3. Set up and transfer a 1:50,000 image of the Boundary TSA to 1:50,000 forest cover maps.
4. Coordinate with Nelson Region Inventory so that polygons with stippled areas can be integrated into their data base.
5. Develop a data base program that will enable sorting by categories when stippled areas are digitized.
6. Report on the results with recommendations.

Description: Data from the ground-based surveys were analyzed for trends and correlations. The following characteristics were considered when comparing disease incidence with the satellite image: colour (degree of red on the image); screening (degree of white reflectance as high, moderate, low); leading species; leading cause of mortality (dis-

ease); disease incidence (as high, moderate, low); site class; and aspect.

No correlation was apparent between colours observed, i.e. intensity of red coloration, on the satellite image and actual disease conditions determined from the ground surveys. Screening was considered an appropriate indicator of crown closure, with high screening indicative of crown thinning and possible disturbance.

A trend was apparent between screening and disease occurrence. Armillaria root disease was found in 86% of the samples from polygons with medium to high screening. This correlation was even more (approximately 100%) if the corresponding type also had a high deciduous content. Other damage agents were found in 79% to 89% of the high screen zones. Correlation of disease incidence on northern slopes could not be determined due to the low angle of the sun in winter.

Contractor Recommendations: The following survey strategy was recommended based on results of this project:

- Obtain photographic satellite imagery at 1:10,000 scale.
- Select a suspect area for study and choose 30 to 50 strata for sampling in each screening zone.
- Sample each stratum with the pixel survey method at the same intensity.
- Compile information by site index, disease occurrence and incidence, degree of screening, etc.
- Statistically analyze the data.

Project Report: Horkoff, J. 1990. Boundary - Arrow Satellite Image Forest Disease Interpretation. Contractor's Report. 10 pp.

Evaluation: In general, there was no correlation between disease or suspect sites using shades or variations in colour reflectance on the satellite image. Thinning on winter satellite imagery detected disease with a 60% to 80% rate of success, but more sampling is required to confirm this trend. LAND-SAT-5TM images are efficient for broad image interpretation to stratify and target suspect areas and can be updated annually. However, significant limitations are the exclusion of northern aspects and inability to distinguish between causal agents on the image. Nevertheless, follow-up is warranted to refine the site analysis initiated in Project 51. Suitable follow-up work includes:

- sampling to verify the correlation between screening and disease incidence, using the contractor's recommended guidelines for future work.
- evaluation of pixel surveys for ground sampling.

Project Status: Operational Detection Trial — Method rated possible to fair chance of suitability for operational use; need data to determine effectiveness and/or practicability.

Contractor Recommendations:

- Stumps can be used to conduct hazard assessments for laminated root rot.
- Only qualitative estimates of risk can be made for adjacent stands.
- Conduct a reconnaissance survey to determine approximate on-site disease levels before formulating a backlog, site-treatment recommendation.
- Assess both laminated root rot and armillaria root disease.
- Plant alternate species for areas with high laminated root rot.

- Areas with high armillaria root disease should be treated or naturally regenerated rather than be replanted.
- Losses to armillaria root disease should be monitored every five years.

Project Report: Curran, M. and J. Schulting. 1987. Root Disease in NSR Lands in the Southern Interior of British Columbia: FRDA Research Project 3.8. Contractor Report. 47 pp plus appendices.

Evaluation: Project objectives were attained although discussion of root disease survey methods was included in an intended field guide rather than in the report for this project. The list of suitable indicators, together with the field guide, should be published in a format suitable for field crews. The survey methods developed under Project 3.a require further modification, trial, and assessment. A decision flow chart could be developed which would list the most applicable survey method depending upon disease distribution and occurrence of armillaria or laminated root rot. Transect intersect-type surveys are recommended for laminated root rot in discrete centres and a regeneration-type survey for young stands with diffuse armillaria infection. Fixed radius plot or pixel survey is appropriate for older stands exhibiting a diffuse infection pattern of either disease. Future work should include development and implementation of survey decision guidelines for the Southern Interior, and refinement of the survey procedures recommended in this project.

Project Status: Operational Detection Trial — Method rated moderately to highly practicable; need data to substantiate operational use.

Warren's Root Collar Weevil (IWW) Projects

1989-90 Project Number: Pest Control Project JM-073

Title: Root Collar Weevil Survey.

Area Treated/Surveyed: 1224 ha (30 plantations).

Contractor: Dr. J. A. McLean, Department of Forest Sciences, Faculty of Forestry, UBC, Vancouver.

B.C.F.S. Contacts: T. Ebata, Prince Rupert Forest Region; J. Muir, Silviculture Branch, Victoria.

Region: Prince Rupert Forest Region.

Date: May, 1989 to January, 1990.

Cost: \$13,000

Objectives:

1. Survey 30 lodgepole pine plantations in the Kispiox Forest District to assess damage by Warren's root collar weevil.
2. Sample one plantation intensively to establish weevil distribution and develop a survey method.

Description: A survey to assess root collar weevil damage was conducted in the Kispiox Forest District. Root collar weevil effects on stocking were a concern for many of the pine plantations in the District.

Two plot types were selected for evaluation: a 3.99m radius plot and a 2m x 25m strip plot. A 4 ha area, known to be infested, was selected for comparison. Plots were spaced at 25m intervals. The percentage of sample trees attacked was compared between sampling methods and circular plots were then selected for the remainder of the surveys.

Because of funding and time constraints, a sampling intensity of 1% (2 plots/ha) was used for the first 15 sites and 0.5% (1 plot/ha) was employed for the remaining 15 areas. Maximum area covered was 50 ha per plantation. Plantations selected had a predominance of lodgepole pine, and minimum tree age of five years.

The following information was collected within each plot: total number of trees by species and age class; DBH; height; number of dead lodgepole pine and hybrid spruce and cause of mortality; number of dying and chlorotic pine and cause; number of

healthy-appearing pine with root collar weevil damage; number of healthy trees; number of well spaced; number of weevilled potential well spaced; average LFH depth.

Each plantation was characterized by: total trees/ha; total well spaced/ha; total attacked/ha; attacked well spaced/ha; percentage of weevil-caused mortality; total number of chlorotic and dead trees due to other agents; and average DBH and height. Plot maps were produced per site. Site history records were examined to determine any correlations between site preparation method, original stand type, site index and plantation establishment.

A total of 30 lodgepole pine plantations were surveyed. Root collar weevil was found throughout the Kispiox Forest District. The percentage of pine attacked ranged from 0% to 100% of the trees sampled. Average weevil-caused mortality varied from 0% to 8.8% and was often clumped in distribution. Most mortality occurred in plantations less than 10 years of age. Average mortality was low, at 1.5%, in most plantations. Percentage of pine attacked increased with plantation age and tree height. Twenty plantations met minimum stocking standards. Plantations which were below minimum stocking had a variety of problems in addition to root collar weevil. The average amount of girdling was 50% in 15 of the sites surveyed. Weevil attack appeared to be randomly distributed within plantations.

Impact of the weevil was expected to be a loss of annual increment rather than reduced stocking (number of trees per hectare). No correlations were found between weevil damage levels and site preparation method, burning and scarification, ecosystem association, stocking elevation, slope, or aspect. A correlation was not found between LFH depth and weevil incidence, possibly because of the location of duff measurements within plots. Weevils appeared to be more abundant on moist, well-drained sites and on sites which originally had a lodgepole pine component. The 3.99m radius plot method was efficient since these plots minimize

edge calls and are used for standard silvicultural surveys. Thus, the survey method employed in this project could be readily integrated with current free-growing assessment surveys in areas with a high probability of weevil incidence.

Contractor Recommendations: None.

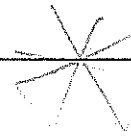
Project Report: Byford, G.T. and J.A. McLean. 1989. Survey of Warren's Root Collar Weevil in the Prince Rupert Forest District, Summer 1989. Contractor's Report. 91 pp.

Evaluation: All objectives were met during this study. Trials of the survey method should be imple-

mented as part of standard silvicultural surveys in districts where root collar weevil is suspected. Assessments of productivity and accuracy should also be made. Additional follow-up work should consist of training silviculture crews in root collar weevil identification and the damage assessment procedures outlined in this study.

Project Status: Operational Detection Trial — Method rated fully practicable; need data for cost estimate and for broader range of ecological conditions for demonstration of feasibility.

PSR established



Hemlock Dwarf Mistletoe (DMH) Projects

Hemlock Dwarf Mistletoe: Pest Control Project JM-093

Title: Hemlock-Dwarf Mistletoe Damage Assessment.

Area Treated/Surveyed: None.

Contractors: Canadian Pacific Forest Products, Qualicum Beach.

B.C.F.S. Contact: J. Beale, Vancouver Forest Region.

Region: Vancouver Forest Region.

Date: February to March, 1990.

Cost: \$900

Objectives:

1. Determine 9-class dwarf mistletoe rating, log grading and pathological indicators for each merchantable western hemlock in 48 permanent sample plots.
2. Describe site history, site ecology, and conduct an ANOVA on pooled data for stand, age and site versus disease infection class (healthy, low, medium, high).
3. Produce volume-age curves for each group and summarize log grades and values showing the effects of dwarf mistletoe infection on these.

Description: A survey of 48 pure western hemlock plots was commenced on southern Vancouver Island. These plots were to be measured in order to assess different levels of western hemlock-dwarf mistletoe infection on growth, log grades, and log values. After completion of all field measurements, data was to be summarized for similar stand, age, site and western hemlock-dwarf mistletoe infection classes. Unfortunately, snow conditions forced an early termination to this study before any plot data could be attained.

Contractor Recommendations: None.

Project Report: None.

Evaluation: This project would probably have yielded valuable data on western hemlock dwarf mistletoe impact in pure coastal western hemlock stands. Thus, suitable follow-up work consists of initiating this study again.

Project Status: Incomplete — Damage Appraisal not completed.

Larch Dwarf Mistletoe (DML) Projects

Larch Dwarf Mistletoe: Pest Control Project 33

Title: Larch Mistletoe Spacing Trial.

Area Treated/Surveyed: 2 ha treated/4 ha surveyed.

Contractor: Kutenai Nature Investigations Ltd., Nelson.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: June, 1987 to October, 1987.

Cost: \$4,900

Objectives:

1. Lay out four 1 ha blocks to Inventory standards to assess the effect of juvenile spacing on disease spread and determine threshold infection levels.

Description: Four 1 ha blocks were laid out, marked and assessed at Howser Creek, an area with light to heavy larch dwarf mistletoe infection. The long-term impacts on larch growth from given levels of infection will be determined by remeasurements every five years. Within each block five juvenile spaced (treatment) plots containing 12 trees, and five non-spaced (control) plots were established. Larch dwarf mistletoe infection occurred throughout two of the blocks, but was absent in the other two. Block and plot boundaries were marked and all plot trees were measured for height, leader length, DBH, age, and five-year and ten-year growth increments. Each plot tree was rated for

larch dwarf mistletoe using the six-point system and an overall dwarf mistletoe rating was determined for each plot. A map, showing the location of all plots, was submitted.

Contractor Recommendations:

- Clear a line-of-sight beside each plot to facilitate height remeasurement.
- Reconnoitre site types, infection sources such as larch veterans, and dwarf mistletoe infection before selecting control block locations. Aerial photographs and a low intensity strip survey should suffice for this purpose. Blocks would thus be situated on homogenous sites.
- It might be useful to locate plots radially around an infection centre in both treated and untreated areas in order to assess larch dwarf mistletoe spread.

Project Report: None. Plot map only.

Evaluation: This work initiated a long-term study of larch dwarf mistletoe spread and effects of spacing. Plots were to be remeasured at five-year intervals, beginning in 1992. Other projects for consideration would be replication of these plots on other sites following the contractor's recommendations for establishing these blocks.

Project Status: Operational Control Trial — Method rated possible to fair chance of suitability for operational use; need data to precisely determine effectiveness and/or response to treatment.

PSY

Lodgepole Pine Dwarf Mistletoe (DMP) Projects

Lodgepole Pine Dwarf Mistletoe: Pest Control Project PB-2

Title: Lodgepole Pine Dwarf Mistletoe in the Prince George Forest Region.

Area Treated/Surveyed: 293 plots and over 1238km of roadside surveyed (2476 ha).

Contractors: Industrial Forestry Service Ltd., Prince George.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria; R. Reich, Prince George Forest Region.

Region: Prince George Forest Region.

Date: December, 1985 to March, 1986.

Cost: \$41,500

Objectives:

1. Conduct a survey for lodgepole pine dwarf mistletoe infection in lodgepole pine stands.
2. Select survey areas and develop suitable survey methods in consultation with B.C.F.S. personnel.
3. Record stand data during a roadside survey, including timber type and age and stand mistletoe intensity. Record this data on maps.
4. Establish prism plots in lodgepole pine types at 5km intervals along survey roads. Record DBH, height and dwarf mistletoe rating (DMR six-class system) for each crown class and establish ecosystem and site quality.

Description: A roadside survey was conducted to determine lodgepole pine dwarf mistletoe incidence and levels in the Prince George Forest Region in stands consisting of at least 50% lodgepole pine. Areas covered were the Carp, Nechako, Kluskus, Stuart and Westlake PSYU, portions of the Prince George SSA, and the Crooked and Ootsa PSYU's. A total of 293 variable radius plots and 1238km of roadside survey were completed.

The plot dwarf mistletoe rating and the adjacent roadside rating system were based on an infection classification of 0 to 3. This code consisted of the following: 0 = 0% (none), 1 = 1-33% (low), 2 = 34-66%

(moderate), 3 = 67% (high). However, dwarf mistletoe ratings for individual trees in the plots were based on the six-class mistletoe rating system. Age, height, DBH and infection codes were recorded for dominant, co-dominant and intermediate trees in the plots. Site index estimates were attempted from ecological indicators but this may not have been accurate because the survey was conducted during winter.

Plot data were initially analyzed under PB-2a, but no significant effects of mistletoe growth were seen; i.e. there were no significant differences with respect to height and DBH between DMR. Data may have been too variable for the sample size obtained. A summary of roadside data gave the following incidence of lodgepole pine dwarf mistletoe. DMR 3 ranged from 0.1 to 41.4%, DMR 2 ranged from 1.3 to 30.3%, DMR 1 ranged from 7.5 to 25.2%, and DMR 0 ranged from 12.5 to 84.4%. Damage appeared to be most severe in the Westlake and Nechako PSYU's and the Prince George SSA.

Contractor Recommendations:

- Move plots to within the 20m strip rated by the roadside survey in order to facilitate comparisons between plot and roadside data.
- Rate plot trees using the same classification system as used in the roadside survey.
- Conduct surveys when no snow is on the ground in order to perform accurate site index assessment.
- Collect data from additional trees within the plot to obtain sufficiently large samples.
- Locate plots in similar stand and site types rather than at 5km intervals.

Project Report: Data Summary only.

Evaluation: Subsequent analysis of plot data by the contractor and the Prince George Region indicated that some changes in the survey methodology would be required. As a result, future sampling

techniques were altered with subsequent improvements in data collection.

Project Status: Operational Detection Trial — Method rated moderately to highly practicable; need data to substantiate operational use, then should be fully practicable.

Lodgepole Pine Dwarf Mistletoe: Pest Control Project PB-2a

Title: Analysis of Plot Data From a Lodgepole Pine Dwarf Mistletoe Survey in the Prince George Forest Region.

Area Treated/Surveyed: Analyses of 293 plots surveyed.

Contractor: Industrial Forest Services Ltd., Prince George.

B.C.F.S. Contacts: J. Muir, Silviculture Branch, Victoria; R. Reich, Prince George Forest Region.

Region: Prince George Forest Region.

Date: March, 1986.

Cost: \$4,500

Objective:

1. Analyze data on tree DBH, height and dwarf mistletoe infection rating in plots surveyed during PB-2.

Description: Data from 293 plots were analyzed. Height and DBH from domestic, co-domestic and intermediate trees were compared to the dwarf mistletoe rating (DMR) using the six-class system. There were significant differences between 0 (healthy) and the 1-6 ratings, indicating that presence or absence of lodgepole pine dwarf mistletoe has an effect on tree height. However, there were no significant differences in height and DBH between the six-class system DMR ratings. It was con-

sidered that modifications to the survey methodology with respect to plot placement and an analysis of plot volumes and stocking would improve impact studies in future. The appropriateness of using standard volume equations was questioned since taper could vary considerably between healthy and diseased trees; all preliminary analysis was performed using standard taper functions. In addition, losses due to deformity and decay were not considered in this analysis, although these are probably significant factors.

Contractor Recommendations: None — data summary only.

Project Report: None — data summary only.

Evaluation: Initial analysis of plot data indicated that increasing levels of lodgepole pine dwarf mistletoe infection did not cause a significant decrease in growth. This result was probably caused by variations in stand and site type and problems with plot placement and infection classification. It was recommended that coverage of the region be increased and additional plots be established in appropriate sites. Subsequently, future FRDA-funded dwarf mistletoe sampling projects were altered to improve data collection and analysis.

Project Status: Damage Appraisal Operational Trials — Appraisal of incidence and impact.

Lodgepole Pine Dwarf Mistletoe: Pest Control Project PB-22

Title: Stem Analysis to Determine the Impact of Lodgepole Pine Dwarf Mistletoe.

Area Treated/Surveyed: 4 plots.

Contractor: Industrial Forestry Service Ltd., Prince George.

B.C.F.S. Contacts: J. Muir, Silviculture Branch, Victoria; R. Reich, Prince George Forest Region.

Region: Prince George Forest Region.

Date: February to March, 1987.

Cost: \$9,850

Objectives:

1. Determine if a correction factor based on lodgepole pine dwarf mistletoe infection is required for whole stem volume equations.
2. Select a single stand suitable for stem sampling based on survey data from Project PB2.

3. Establish plots to determine DBH and stocking and select 25 dominant and co-dominant sample trees in each plot. Rate each tree for lodgepole pine dwarf mistletoe, fell trees, measure total tree height, and cut discs from the felled trees for radial measurements (sample points).
4. Analyze radial measurements to obtain stem profiles for each infection class and compare volumes for each infection class.

Description: This study was initiated to resolve the question of whether or not lodgepole pine dwarf mistletoe-infected trees have less taper than healthy trees. If dwarf mistletoe caused a decrease in height with respect to DBH then standard taper volumes could not be used for comparing dwarf mistletoe infection ratings unless a correction factor was derived. It was felt that this problem may have

Lodgepole Pine Dwarf Mistletoe (DMP) Projects

affected the earlier results of the PB-2a plot analysis. Samples were taken and analyzed to determine if tree shape was altered by dwarf mistletoe and to derive suitable correction factors for the standard whole stem volume equations used by the B.C.F.S.

From areas surveyed during PB-2, as single 60- to 80-year-old lodgepole pine stand on a medium site within the SBSk2 biogeoclimatic subzone variant was selected, and was considered to be the best representation of lodgepole pine stands in the area. Twenty-five trees were felled in each selected plot representing the following: healthy (DMR 0, 1 and 2), moderate (DMR 3 and 4), severe (DMR 5 and 6) and control (no dwarf mistletoe). After felling 100 suitable trees, discs were cut and two radii per disc were measured. Total tree height was also measured. Five-year radial increment was averaged and recorded for each disc.

Data were analyzed on a VAX computer to construct complete stem profiles of each tree. Average stem profiles were then determined for each infection class. Total (gross) volume for each year from age 20 to total age was calculated using Smalian's formula. These measured volumes per infection rating were then compared to the expected whole stem volume equivalents in order to derive volume correction factors.

There was very little difference between the observed (Smalian) volumes and the expected (whole stem volume equation) volumes, indicating that dwarf mistletoe had a very negligible impact on taper at any infection level. Thus, the resulting correction factor approximated unity (Project 42).

However, the impact of infection on volume at specific ages was not considered. In addition, variations in stand density were not accounted for.

Contractor Recommendations: None.

Project Report: Pousette, J. 1987. Impact of Dwarf Mistletoe on Growth in Lodgepole Pine Trees: FRDA Pest Control Project PB-22. Contractor's Report. 12 pp.

Pousette, J. 1988. Effects of Lodgepole Pine Dwarf Mistletoe on Tree Form. B.C.F.S. Internal Report PM-PB-39. 9 pp. (Project 42).

Evaluation: This project obtained data on tree shape (stem taper) and found that taper was not significantly altered by dwarf mistletoe at various infection levels. A subsequent study (Project 42) determined that correction factors approximated one. Thus, B.C.F.S. standard whole stem volume equivalents were shown to be satisfactory for determining the volume of dwarf mistletoe-infected lodgepole pine.

Project Status: Damage Appraisal Operation Trials — Database enhancement and appraisal of disease impact.

Lodgepole Pine Dwarf Mistletoe: Pest Control Project PB-42

Title: Stem Analysis to Determine Tree Volume Correction Factors.

Area Treated/Surveyed: Analysis of 100 trees from 4 plots.

Contractor: Industrial Forestry Service Ltd., Prince George.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria; R. Reich, Prince George Forest Region.

Region: Prince George Forest Region.

Date: March, 1988.

Cost: \$7,780

Objective:

1. Calculate tree volume correction factors and determine if standard B.C.F.S. tree volume equations are accurate for lodgepole pine infected by lodgepole pine dwarf mistletoe.

Description: PB-22. Data from 100 trees, collected and summarized under PB-22, were analyzed on a VAX computer to construct complete stem profiles of each tree. Average stem profiles were then determined for each infection class. Total (gross) volume for each year from age 20 to total age was calculated per infection rating using Smalian's formula.

These measured (observed) volumes were then compared to the expected whole stem volume equivalents in order to derive volume correction factors.

There was very little difference between the observed (Smalian) volumes and the expected (whole stem volume equation) volumes, verifying that dwarf mistletoe had a negligible impact on tree shape at any infection level. Thus, the resulting correction factor for whole stem volume equations was approximately one.

Contractor Recommendations: None.

Project Report: Pousette, J. 1988. Effects of Lodgepole Pine Dwarf Mistletoe on Tree Form. B.C.F.S. Internal Report PM-PB-39. 9 pp.

Evaluation: This study demonstrated that the standard B.C.F.S. whole stem volume equations are satisfactory for determining the volume of lodgepole pine trees infected with lodgepole pine dwarf mistletoe. Thus, volume and impact by lodgepole pine dwarf mistletoe could be determined using these standard equations.

Project Status: Complete.

Lodgepole Pine Dwarf Mistletoe: Pest Control Project PB-48

Title: Remeasurement of Lodgepole Pine Dwarf Mistletoe Sample Plots.

Area Treated/Surveyed: 9 plots.

Contractor: Kathy J. Lewis, Vancouver.

B.C.F.S. Contacts: J. Muir, Silviculture Branch, Victoria; R. Reich, Prince George Forest Region.

Region: Prince George Forest Region.

Date: September to October, 1988.

Cost: \$560.

Objective:

1. Remeasure trees to determine the effect of spacing in a young dwarf mistletoe-infected lodgepole pine stand.

Description: A spacing trial was established in a 30-year-old lodgepole pine stand at Pelican Road to determine the effectiveness of sanitation spacing compared to spacing without regard to dwarf mistletoe. Three blocks were laid out with and three permanent in each block. One block was located in a heavily infected area and two blocks (one spaced and one control) were established in lightly infected areas. The blocks were to be monitored every year for comparisons of DBH, height, number of infections and productivity between treated and non-treated areas. In September, 1988 the first remeasurements were performed. Height, diameter and percent live crown were estimated on all plot trees. Mistletoe infection was measured using the six-class rating method.

Photographs were taken in each block to record responses to treatment. The percentage of trees at-

tacked remained almost the same, except in the unspaced lightly infected block, which exhibited an increase of 26%. Significant differences in DBH, height and branch infections were noted between blocks, as had been previously noted during the establishment of this trial. In the heavily infected block the unspaced treatment had fewer branch infections. This increase was not observed in the lightly infected block. Tree height was shown to be an unreliable predictor of branch infection severity. Although initial differences were verified, results were considered to be tentative due to the brief two-year period after spacing.

Contractor Recommendations: None.

Project Reports: Lewis, K.J. 1988. Lodgepole Pine Dwarf Mistletoe Spacing Trials Plot Remeasurement — 1988. Contractor's Report. 11 pp.

Lewis, K.J. 1987. The Effect of Spacing in a Dwarf Mistletoe-Infected Stand of Lodgepole Pine — Establishment Report. B.C.F.S. Internal Report. PM-PG-9. 17 pp.

Evaluation: The Pelican Road trial was remeasured and differences between infection levels, noted in 1987 were substantiated in 1988. However, the results are considered tentative. Spacing in lightly infected stands, followed by sanitation activities, may keep dwarf mistletoe at an insignificant level. Spacing in heavily infected areas may exacerbate the problem.

Project Status: Operational Control Trial — Method rated moderately to highly practicable; need data to substantiate operational use, then should be fully practicable.

Lodgepole Pine Dwarf Mistletoe: Pest Control Project PB-62

Title: Dwarf Mistletoe Growth Effects.

Area Treated/Surveyed: 40 plots in 10 stands.

Contractor: Pathocon Consulting, Prince George.

B.C.F.S. Contacts: J. Muir, Silviculture Branch, Victoria; R. Reich, Prince George.

Region: Prince George Forest Region.

Date: December, 1988 to March, 1989.

Cost: \$9,800.

Objective:

1. Locate 10 suitable stands, establish four plots in each stand, mark plots, measure trees, and rate dwarf mistletoe infection.

Description: This project was conducted to determine the effect of varying dwarf mistletoe ratings

(DMR) on growth of lodgepole pine. The information was required to assess dwarf mistletoe impact in the timber supply area (TSA), using data from a previous dwarf mistletoe survey.

Ten even-aged lodgepole pine stands in the Prince George TSA were selected. Sites having high levels of other damaging agents were avoided. Four 5.64m radius (.01 ha) plots were established in each stand in such a manner that two plots had trees with high DMR and two plots, trees with relatively low DMR. All trees were measured for DBH and height and were tagged. The DMR was assessed for each tree. An average radius at age 30 was measured for all trees from increment core samples in order to have a standard benchmark. Radial and height increment of trees with high DMRs and those with low DMRs were compared.

Lodgepole Pine Dwarf Mistletoe (DMP) Projects

Data were analyzed on a VAX at Forestry Canada as part of Project JM-089. Height, age, current diameter and diameter at age 30 were correlated to the average DMR rating for each plot. The analytical program also analyzed effects of stocking, which may have adversely affected results in an earlier project (Project 42). Volume reduction values were also subsequently determined.

Five of the ten stands were too old to be evaluated by the existing program. Preliminary analysis of the data indicated that a mean DMR of 3.0 to 4.5 resulted in an average DBH of 90% of the expected DBH. A DMR between 4.5 and 6.0 resulted in DBH reduction to 88% of the expected value. More data were collected from lightly infected stands (Project JM-089) to quantify dwarf mistletoe effects.

Contractor Recommendations:

- Apply growth reduction values from the Forestry Canada analysis to incidence data collected in Projects PB-2 and 62 to assess dwarf mistletoe impact in the Prince George Forest Region.

Project Report: Schulting, J., and M. Schulting. 1989. Growth Reduction in Lodgepole Pine Due to Dwarf Mistletoe in the Prince George TSA: Preliminary Data. Contractor's Report. 12 PP

Evaluation: All project objectives were met. However, preliminary analysis following this study indicated the need for more data from lightly infected stands for determination of DMR effects.

Project Status: Development of a damage appraisal method — not yet operational. Required further development.

Lodgepole Pine Dwarf Mistletoe: Pest Control Project PB-63

Title: Dwarf Mistletoe Survey Procedure.

Area Treated/Surveyed: 1,200 ha

Contractor: Pathocon Consulting, Prince George.

B.C.F.S. Contacts: J. Muir, Silviculture Branch, Victoria; R. Reich, Prince George Forest Region.

Region: Prince George Forest Region.

Date: December, 1988 to March, 1989.

Cost: \$15,000

Objectives:

1. Survey young lodgepole pine stands to determine dwarf mistletoe incidence and levels using 3.99m radius plots established on a grid system.
2. Recommend dwarf mistletoe sanitation treatments or other suitable treatments for each stand.

Description: A survey procedure was developed and assessed for young lodgepole pine stands because current infection status in these stands was unknown. A suitable survey technique was required to determine incidence, to calculate volume reduction, and to identify sites for rehabilitation or treatment.

This study addressed the problem of determining dwarf mistletoe incidence in 5- to 20-year-old lodgepole pine. Nineteen stands were randomly selected within the Westlake PSYU. A total of 1200 ha was surveyed from the 1800 ha initially selected. Six of the stands had been juvenile spaced. These sites were included in the survey in order to obtain a representative sample.

The survey employed standard 3.99m radius plots established on a 100m x 200m grid to yield a sampling intensity of 0.5 plot/ha. Prestand tending survey cards were used to record information. The following data for each tree species was collected at

each plot: number per species, total number, number of well spaced trees per plot, and a tally by diameter class. A subsample was taken for age, height, DBH and percentage live crown estimates. Dwarf mistletoe incidence was recorded within plots according to the following criteria: 0 — no infection; 1 — less than 50% of branches infected; 2 — greater than 50% of branches infected; 3 — stem infected. Observations on dwarf mistletoe were also made while running the transects. Additional lines were established near stand edges to determine if any infection was entering from the adjacent stand. Adjacent infected trees were rated.

Spread from adjacent blocks was observed to be very limited. In most sites surveyed, very few trees were infected and these trees were usually located within 10m of an adjacent infected stand. Few infected residual lodgepole pine were noted. The overall infection rate was 0.22% by area. The proportion of trees infected was 4.8% within infected areas. The average infection level per tree was 1.8. An estimated 296 ha were infected within the Westlake PSYU. The removal of most infected residuals appeared to have reduced dwarf mistletoe spread. Western gall rust was also found during this survey and was considered to be at potentially damaging levels.

Contractor Recommendations:

- Survey young lodgepole pine stands in other areas of the Prince George Forest Region using the method developed in this project.
- Spacing for western gall rust should be more efficient if this disease is to be controlled.

Project Report: Schulting, J. and M. Schulting. 1989. FRDA Project JM-063: Incidence of Dwarf Mistletoe Infection in Young Lodgepole Pine Stands in the Westlake PSYU of the Prince George TSA. Contractor's Report. 4 pp.

Evaluation: All project objectives were met. However, an assessment of survey productivity and effectiveness was not performed. The technique is probably efficient and suitable for implementation in conjunction with pre-stand tending surveys but precise figures were absent in the results. Future employment of this method should consider an evaluation of its efficacy during surveys of lodgepole pine in other areas and over a broader range

of sites. Other suitable follow-up activities consist of training crews in this method and in the identification of dwarf mistletoe.

Project Status: Operational Detection Trial — Method rated fully practicable; need data for cost estimates and for broader range of ecological conditions for demonstration of feasibility.

Lodgepole Pine Dwarf Mistletoe: Pest Control Project JM-089

Title: Determination of Growth Reduction in Lodgepole Pine Due to Dwarf Mistletoe Infection.

Area Treated/Surveyed: 5 plots.

Contractor: Pathocon Consulting, Prince George.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Prince George Forest Region.

Date: December, 1989 to January, 1990.

Cost: \$1,700

Objective:

1. Establish five additional plots at sample sites initiated in Project 62 to obtain data from healthy or lightly infected trees for determination of dwarf mistletoe impact on growth.

Description: A preliminary evaluation of plot data from 10 stands surveyed in Project 62 indicated a requirement for additional data from healthy or lightly infected stands to quantify the impact of dwarf mistletoe at an earlier stand age.

Additional plots were established in lightly infected areas at five sites previously surveyed during Project 62. Trees were tagged and data on age, current DBH, height and DMR were obtained. DMR was averaged for each plot. All measurements were submitted to Forestry Canada for analysis.

Contractor Recommendations: None.

Project Report: Data Summary only.

Evaluation: A complete analysis of the survey data is still pending. Once growth reductions have been fully quantified for each DMR level, calculations of dwarf mistletoe impact can be performed throughout areas surveyed in the Prince George Forest Region during 1985-86 and 1988-89. Other follow-up activities consist of applying these results to dwarf mistletoe surveys in other regions and comparing them to results derived from whole stem volume equations. This comparison should also be made within the Prince George Forest Region and include impact data from established dwarf mistletoe sample plots.

Project Status:

Lodgepole Pine Dwarf Mistletoe: Pest Control Project JM-102

Title: Compilation of Lodgepole Pine Dwarf Mistletoe Survey Data Compilation (Project PB-2).

Area Treated/Surveyed: Data compiled for 293 plots and 2476 ha.

Contractor: Industrial Forestry Service Ltd., Prince George, B.C.

B.C.F.S. Contacts: J. Muir, Silviculture Branch, Victoria; R. Reich, Prince George Forest Region.

Region: Prince George Forest Region.

Date: March, 1990.

Cost: \$4,500

Objectives:

1. Compile lodgepole pine dwarf mistletoe data from the 1985-86 lodgepole pine dwarf mistletoe roadside survey.

Description: Data from the 1985-86 roadside survey (Project PB-2) was compiled and summarized. All dwarf mistletoe ratings were totalled and divided by the number of trees to derive average plot DMR's for 293 plots. Infected proportion of trees was also determined per plot. Data were grouped by type, PSYU and by DMR 0 to 2.99, 3 to 4.49 and 4.50 to 6. Data were stratified by good, medium and poor site class. Within good sites, data were further grouped by age class. Percentages of infected trees were plotted against average plot DMR for the Nechako, Westlake, and combined PSYU's. A list of plots with corresponding type label and roadside DMR was also provided. Data analysis using the Forestry Canada program has not been completed to date.

Contractor Recommendations: None.

Project Report: Data only.

Lodgepole Pine Dwarf Mistletoe (DMP) Projects

Evaluation: To date, data analysis is still pending. This analysis will use growth reduction factors as determined for dwarf mistletoe impact by Forestry Canada. Suitable follow-up includes application of growth reduction factors and this program to deter-

mine the impact of lodgepole pine dwarf mistletoe in other regions.

Project Status: Damage Appraisal Operational Trials: Appraisal of dwarf mistletoe impact.

Stem Rusts and Cankers (DS) Projects

Stem Rusts and Cankers: Backlog Research Project 3.7

Title: Remeasurement of Lodgepole Pine Stem Rust and Canker Permanent Sample Plots.

Area Treated/Surveyed: 4 Permanent Sample Installations.

Contractor: Dr. B. J. van der Kamp, U.B.C. Department of Forest Sciences, University of British Columbia, Vancouver.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Regions: Prince George and Nelson Forest Regions.

Date: July, 1985 to March, 1986.

Cost: \$4,800.

Objectives:

1. Remeasure lodgepole pine stem rust and canker permanent sample plots (p.s.p.'s) to determine the following:
 - the effect of altered stand conditions (post-spacing) and crown form on the rate of infection
 - the degree of damage resulting from infections recorded in 1980 in terms of deformity and mortality
2. Conduct routine maintenance of the plots during the remeasurement procedures.

Description: Four plots, established in 1980 in the Prince George and Nelson forest regions, were remeasured in 1985. Each plot consisted of two plots in the treatment area and two plots in an adjacent control area. Stem rust and/or canker infections were common on lodgepole pine in these areas prior to the 1978-79 spacing treatment and 1980 measurements of disease incidence. All trees were retagged and their DBH was recorded. Selected sample trees were remeasured for height. The height, location and condition of each occurrence of any of the four diseases was measured and recorded for both old (1980) and recent infections.

Remeasurements indicated that all trees responded normally to the thinning operation; average DBH increased while height increment was not

significant. The incidence of each disease was determined in three different ways: as a percent of trees infected, percent of trees with stem infections, and the number of infections per m² of basal area. The latter method of assessing disease incidence was considered to be independent of tree size, thus enabling comparisons between spaced and non-spaced areas. The incidence of all four diseases increased in both spaced and non-spaced areas. By 1985 a greater overall incidence (33.5% increase) of disease was found in thinned stands as compared to unthinned stands (19.0 % increase). Only 60.8 % and 74.8 % of the trees remained healthy in thinned and unthinned plots, respectively.

Western gall rust was the most common disease encountered but stalactiform and comandra rust accounted for a substantial portion of the losses. Damage due to atopellis canker was mainly in the form of deformity rather than mortality, especially in treated stands. However, an accurate assessment of impact by this disease will require remeasurement in 1990-95. These disease levels were found to be localized, the incidence being much lower at 14 other randomly selected sites. However, the losses in these four plots are substantial.

Contractor Recommendations:

- Diseased trees should be selected for removal during spacing. Thus, accurate identification of stem pathogens should be performed during thinning operations. In addition, considerable allowance should be made for further disease losses when establishing stocking standards for juvenile spacing.
- More stems should be left in areas where any of these pathogens are known to occur, particularly for comandra or stalactiform rust.

Project Report: van der Kamp, B. J. and M. Spence. 1986. The Incidence of Lodgepole Pine Stem Diseases in the Interior of British Columbia Following Juvenile Spacing. Department of Forest Sciences, University of British Columbia. Contractor Report. 21 pp.

Stem Rusts and Cankers (DS) Projects

Evaluation: More information on atopellis canker incidence and damage is required in order to accurately assess impacts from this disease. Spacing crews should be given training on pine stem rust and canker identification since the higher disease incidence in spaced plots may have been due to heavily infected leave trees. Training sessions should be conducted at the district level to account for the casual (intermittent work and high staff turnover) nature of spacing operations. A standard training

package offered through the regions might be a preferable approach. Training activities might ultimately assist in reducing backlog through more effective operational disease control.

Project Status:

Damage Appraisal Research Trials — development and evaluation of new methods requiring research and replications at the field stage.

Stem Rusts and Cankers: Pest Control Project 26

Title: Branch and Leader Dieback of Young Douglas-fir in the Central Interior.

Area Treated/Surveyed: 7 Plantations.

Contractor: Dr. B. J. van der Kamp, Department of Forest Sciences, University of British Columbia, Vancouver.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Cariboo, Prince George and Kamloops Forest Regions.

Date: May, 1987 to March, 1988.

Cost: \$16,500.

Objectives:

1. Determine the cause(s) and condition(s) which lead to dieback of young Douglas-fir in the central interior.
2. Develop guidelines that indicate which sites are at risk.

Description: Extensive surveys in the Cariboo, Prince George and Kamloops Forest Regions in 1985-86 demonstrated that dieback was occurring in some Douglas-fir plantations but the precise causes and conditions leading to this problem had not been verified. This project was initiated due to these concerns.

Work was conducted on seven plantations with severe levels of dieback. Dieback areas were delineated and sample plots were located within these areas. Trees in the plots were examined for frost damage, dieback progression and variation in severity from spring to late summer. Eleven damage classes were employed for recording and analysis purposes. The correlation between dieback damage and flushing date was determined by dissection of sample trees. Frost rings were clearly visible and provided an accurate record of extent and time of frost damage. Frost pockets were intensively grid mapped in order to determine damage distribution.

Frost was found to play a major role in the development of dieback. Two types of frost-related damage were noted. The less severe form consisted of leader mortality and occasional death of laterals due to early fall frosts. Forks and crooks resulted but no dieback was seen and only one weak patho-

gen, *Sclerophoma* spp., was associated with this type of damage.

The severe form of damage consisted of progressive dieback after initial frost damage and trees were lost as crop trees. As many as nine weak stem pathogens were isolated from a complex dieback pattern. Frost damage associated with these symptoms took place during late spring and was then accompanied by multiple occurrences of frost damage during the remainder of the growing season. Thus, late flushing trees were less seriously damaged than early flushing trees.

Dieback was restricted to trees growing in well delineated areas. These areas, or frost pockets, may have increased in size and depth due to impediment of cold, moist air with increasing vegetative cover as plantations aged. Therefore, the extent of frost damage may be increasing with time but this was not fully investigated. Frost pockets were noted with increasing regularity in shallow depressions and gullies in rolling terrain; at least 50% of the trees were damaged in such areas. The most severe damage occurred around the edges of depressions. Increased soil moisture was not confirmed as affecting damage incidence. High soil moisture may have been a contributing, but minor, factor. Spruce and subalpine fir were also heavily damaged but lodgepole pine remained unaffected.

Contractor Recommendations: Planting susceptible tree species in frost pockets. Instead, lodgepole pine should be planted in such areas wherever possible.

Project Report: van der Kamp, B. J. and R. Reich. 1987. Dieback of Douglas-fir in Central Interior Plantations. B.C.F.S. Int. Rep. PM-PB-35. 46 pp.

Evaluation: This project demonstrated that frost damage initiated dieback in Douglas-fir and was the overwhelming factor. However, other factors such as off-site planting, age and site moisture and nutrient content also contribute to the severity of the damage, as determined from two previous surveys.

These factors were quantitatively addressed in a subsequent project (F.R.D.A. Research 3.64) where 20 plantations in the Kamloops Forest Region were successfully risk-rated. In addition, other habitats

should be rated for risk and ground truthed to verify and refine the technique, if necessary.

Although further investigation into the causes of dieback is not required, a comprehensive guideline booklet or pamphlet should be developed, pending some additional surveys, so that field crews can risk rate plantations and identify frost pockets in the field on a regular basis. These guidelines, perhaps illustrated and consisting of a simple flow

chart type of format, should be transferred to field personnel by means of extension and demonstration activities.

Project Status: Operational Detection Trial — method rated fully practicable; need data for cost estimate and for broader range of ecological conditions for demonstration of feasibility.

Stem Rusts and Cankers: Pest Control Project JM-060

Title: Remeasurement of Forestry Canada Rust Spacing Trial at Ootsa Lake.

Area Treated/Surveyed: 2 ha.

Contractor: Pathocon Consulting, Prince George.

B.C.F.S. Contact: S. Zeglen (W. Martin), Prince Rupert Forest Region.

Region: Prince George Forest Region.

Date: December, 1988 to March, 1989.

Cost: \$4,900.

Objectives:

1. Assess the incidence and impact of atopellis canker, stalaciform blister rust and western gall rust in a spaced and pruned treatment area.
2. Establish three permanent growth and yield sample plots in both the treatment and control areas.
3. Resurvey a portion of 14 other stands which do not contain permanently marked trees.

Description: Trees were remeasured in an area which had been surveyed and treated (spaced and pruned) by the Forestry Canada in 1987. Trees were infected by three pine stem diseases but the incidence of each disease had not been recorded. In 1988-89 four stands in this area were re-examined with standard 3.99 m radius plots to ascertain the value of resurveying all 14 stands. In addition, walk-throughs were performed in an attempt to lo-

cate the original plots but these could not be relocated. However, a resurvey of all 14 stands was determined to be beneficial for improving knowledge of host-pathogen dynamics and the efficacy of control measures.

Within the treatment area all tagged trees were examined for stem pathogens. The spaced stands had a higher incidence of healthy trees (78.9 %) than the control areas (67.9 %). However, disease incidence did not vary significantly between the spaced, control and 1967 data. Thus, the results were inconclusive.

Contractor Recommendations: None.

Project Report: Schulting, J. and M. Schulting. 1989. Ootsa Lake C.F.S. Spacing Trial 1988-89 Remeasurements. Contractor Report. 8 pp.

Evaluation: The effect of spacing on incidence of the three diseases could not be determined. The plots established during this project should be re-measured at two to five year intervals and the remaining stands should be completely resurveyed. More data on the effects of spacing may enhance disease control methods and assist in reducing backlog, not-satisfactorily-restocked stands.

Project Status: Damage Appraisal Research Trials — development and evaluation of new methods requiring a researcher and replications at the field stage.

White Pine Blister Rust (DSB) Projects

White Pine Blister Rust: Pest Control Project NE-2

Title: Establishment of Ingersoll Creek (Whatshan Lake) White Pine Demonstration Area.

Damaging Agent: White Pine Blister Rust (DSB).

Keywords: White Pine Blister Rust, DSB, NE-2, N.

Contractor: Rod Martin Tree Improvement Ltd., Nakusp.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: July to October, 1986

Cost: \$1,500

Area Treated/Surveyed: 1.5 ha

Objectives:

1. Establish a demonstration and training area which contains a rare but very valuable white pine blister rust resistance mechanism.
2. Preserve from cutting all trees exhibiting resistance mechanisms.
3. Find, mark and record all trees exhibiting significant resistance to white pine blister rust.

Description: An area containing one known blister rust resistant (bark reaction) white pine was intensively surveyed using survey strips at 20 m intervals. The stand consisted of young (23 year old) mixed species where western white pine made up 20 % of the component. A total of 683 white pine were subsequently examined for blister rust incidence and possible resistance. Of these trees, 31 % were infected, 9 % were dead and 60 % were healthy. Six additional bark reaction trees were located and recorded within the stand immediately surrounding the previously identified blister rust resistant tree.

These individuals were considered to possibly be the offspring of a single parent (veteran) tree in the vicinity. The basal cankers of bark reaction trees varied in activity and all had inactive looking patches of sunken bark along the canker margins. The typical diamond-shaped yellow-orange margins seen in aggressive, girdling attacks were absent. Western

white pine individuals which can outgrow stem cankers have an important resistance mechanism since the rust can still complete its life cycle, thus reducing selection pressures for new and more virulent races.

Contractor Recommendations:

- Establishment of the area as a western white pine breeding source should be given high priority, along with continual monitoring.
- All other species should be removed to leave a stand of pure white pine in order to help identify other possible blister rust resistant candidates and facilitate cone collections from trees currently exhibiting bark reactions.
- The six bark reaction individuals should be cross pollinated with several U.S.F.S. resistance candidates to produce highly resistant seed orchard stock for very high risk areas. These individuals should also be pot grafted and planted in order to start a clone bank for blister rust resistant material to be used in future breeding work.

Project Report: Martin, R. 1987. Ingersoll Creek White Pine Demonstration Area. Contractor Report.

Recommended Report Format: B.C.F.S. Internal Report.

Related Projects: JM-031, JM-032, JM-047, JM066, JM083, JM085, JM086 and JM094.

Evaluation: Development of western white pine cultivars which are resistant to white pine blister rust should be given high priority. Development of improved white pine stock will be highly beneficial in large areas of the province where there are considerable losses from root rots, notably the CDF, CWH, IDF and ICH biogeoclimatic zones. If the blister rust problem can be ameliorated then white pine will be a productive and very desirable species for such areas. Currently, work on improvements to white pine stock is far from complete. Thus, intensive management, trials and monitoring of this area should be continued.

Project Status: Operational Control Trial — method rated moderately to highly practicable;

need data to substantiate operational use then should be fully practicable.

White Pine Blister Rust: Pest Control Project 31

Title: Detailed And Intensive Management of Possible Blister Rust Resistant White Pine at The Ingersoll Creek Demonstration Area.

Contractor: Rod Martin Tree Improvement Ltd., Nakusp.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: June, 1987 to September, 1988

Cost: \$4,900.00

Area Treated/Surveyed: 1.5 ha.

Objective:

1. Perform detailed, intensive management of the Ingersoll Creek (Whatshan Lake) demonstration area which contains six active bark reaction trees plus the probable parent tree. Primarily, management of the site was to encourage western white pine to produce cone, pollen and seed in order to preserve a possible resistant cultivar.

Description: This project was initiated, in part, due to the recommendations resulting from previous work performed on this site. Intensive management of the Ingersoll Creek Demonstration Area was conducted to enhance production of more desirable genotypes according to the project objectives.

The area boundaries were permanently marked and the site was hand-spaced to remove all species other than western white pine wherever possible. Slash was hand-piled throughout the site to reduce disturbance. All competing vegetation was removed near the bole of known bark reaction trees and these trees were then fertilized by hand. Spacing treatment was performed in order to enhance further spread of blister rust spores and possibly expose more bark reactions in the stand. In addition thinning, combined with fertilization, would probably accelerate growth, flower production and cross pollination of the desirable white pine genotypes.

Cones were collected from the parent tree for inclusion in Forestry Canada rust inoculation trials. Seed from the on-site veteran white pine was sown for 1990 outplanting in the demonstration area. Flower and pollen production on the bark reaction trees and parent tree were monitored and pollen was collected from the veteran and parent trees for a white pine pollen bank. Ribes plants were planted within the area to increase inoculum levels in order to expose additional bark reactions and place selective pressure on the stand.

Project Report: Martin, R. Ingersoll Creek White Pine Demonstration Area 1987 Progress Report. Contractor Report.

Contractor Recommendations: None.

Evaluation: Development of western white pine cultivars which are resistant to white pine blister rust should be given high priority as a control strategy. Development of improved white pine stock will be highly beneficial in large areas of the province where there are considerable losses from root rots, notably the CDF, CWH, IDF and ICH biogeoclimatic zones. If the blister rust problem can be ameliorated then white pine will be a productive and very desirable species for such areas.

The white pine breeding program will be enhanced through ongoing intensive management, re-measurement and analysis of the Ingersoll Creek (Whatshan Lake) site and related areas. In turn, genetic improvements of this species should assist restocking efforts in backlog areas and address the concerns of sustained yield, enhancement of biological diversity of forest ecosystems and promotion of biological solutions to pest problems. Thus, intensive management, trials and monitoring of this area should be continued.

Project Status:

Operational Control Trial — method rated moderately to highly practicable; need data to substantiate operational use then should be fully practicable.

White Pine Blister Rust: Pest Control Project 32

Title: Halfway White Pine Pruning And Spacing Trial — July 1987 Remeasurement.

Contractor: Rod Martin Tree Improvement Ltd., Nakusp.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: June, 1987 to January, 1988

Cost: \$2,500.

Area Treated/Surveyed: 26.3 ha

Objectives:

1. Remeasure plots established in an operational trial for pruning, spacing, and pruning plus spacing in a young western white pine stand.

White Pine Blister Rust (DSB) Projects

2. Compilation and analyse data to determine the efficacy of white pine blister rust control.

Description: This project, which was a continuation of a non-F.R.D.A. funded study initiated in 1983, tested the hypothesis that pruning and/or spacing of white pine crop trees will reduce white pine blister rust, (*Cronartium ribicola*), damage and mortality. The study area, located 24 km north of Nakusp, consisted of 22-year old mixed regeneration with western white pine being the major species.

Four treatments, conducted in 1983, were assessed in 1987: spaced white pine pruned, spaced and white pine not pruned, white pine pruned and no spacing, and control (no treatment). Thinning had been conducted at three metre intervals and pruning had consisted of removing both live and dead branches to three metres above ground or 50 % of tree height. Thirty-six plots, 250 m² or 125 m² in size, were established in order to obtain approximately 100 trees per treatment. In addition, treated areas and the control were located as adjacent, parallel plots running upslope in order to avoid variation in disease intensity due to slope position. The number of cankers present in 1983 also were recorded for later comparison.

The 1987 remeasurement and analysis of disease incidence, conducted during this project, revealed the following treatment results. Spacing increased the infection frequency especially if blister rust infected branches have not been removed. Pruning of spaced and non-spaced crop trees reduced the rust hazard and subsequent mortality, however pruning in highly infected areas, while reducing the rust hazard, probably will not reduce mortality. Slope effects were not statistically significant although

some variation in intensity was observed; infection intensity may rise with increasing slope, especially for susceptible areas located downslope.

Contractor Recommendations: Spacing should be confined to white pine stands with a low to moderate blister rust infection rate. Trees with the fewest infections should be selected for pruning. Heavily infected trees should be removed, not pruned. Trees less than 20 years of age should not be pruned, optimal treatment age being 20 to 30 years. These age criteria should be used in order to allow maximum selection pressure prior to treatment. Trees should be pruned to a minimum of three metres or up to the top whorl. A second pruning should be performed to remove new lethal infections as determined by periodic inspections of treated stands.

Project Report: Martin, R. Halfway White Pine Pruning And Spacing Trial. 1987. Remeasurement. Contractor Report.

Evaluation: A replicated trial should be established in the Kootenay Lake or Revelstoke districts to substantiate the findings of this project. In addition, the Halfway site should be remeasured every two years. Results obtained from further operational trials and remeasurements should form the basis of white pine blister rust management guidelines. These guidelines should include a site-specific risk assessment and some provision for training sessions.

Project Status: Operational Control Trial — method rated moderately to highly practicable; need data to substantiate operational use then should highly practicable.

White Pine Blister Rust: Pest Control Project 47

Title: Evaluate, Mark and Reserve White Pine Trees With Potential Genetic Resistance to White Pine Blister Rust.

Area Treated/Surveyed: 34 ha.

Contractor: Rod Martin Tree Improvement Ltd., Nakusp.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: June to October, 1988.

Cost: \$4,500.

Objectives:

1. Evaluate genetic resistance mechanisms to white pine blister rust found in the Beaver-mouth shelterwood area for use in operational trials and seed collections.
2. Select the most promising 25 to 30 trees for use in the Forestry Canada western white pine

screening trials and for use in planting and demonstration trials.

3. Evaluate white pine blister rust challenge and report on canker counts.
4. Assess the utility of the site for additional candidate seed production trees.

Description: A survey was conducted in the shelterwood block of the Beaver-mouth seed production area. Twenty trees averaging 80 years of age and showing a history of rust infection were chosen from the east side of the block. The selected trees exhibited blister rust tolerance, and had been exposed to the pathogen probably over a period of 60 years. The majority of cankers on these trees were dead and all trees were healthy. Candidate trees were measured, tagged and mapped. Protective bags were placed over developing cones. These cones were later collected and the seed extracted.

Contractor Recommendations:

- The area was considered suitable, provided some site maintenance. Non-candidate trees should be removed, along with all slash. The site should then be scarified to improve white pine regeneration.
- Further cone collections from candidate trees should be postponed until more white pine is regenerated. Selected seed should be planted on low hazard sites with two follow-up pruning sessions. Candidate seed should also be incorporated into a long-term progeny trial.

Project Report: Martin, R. 1989. Beavermouth White Pine Shelterwood Seed Production Area. Contractor Report. 15 pp.

Evaluation: Intensive management of this site should continue in order to enhance the white pine stock as part of the breeding program administered by the province and Forestry Canada. This, in turn, should ultimately enhance protection and silvicultural systems and thus reduce backlog. All recommendations resulting from this project should be implemented.

Project Status: Operational Control Trial — method rated moderately to highly practicable; need data to substantiate operational use then should be fully practicable.

White Pine Blister Rust: Pest Control Project JM-066

Title: Establishment of Texada Island Seed Production Area (S.P.A.).

Area Treated/Surveyed: 12 ha.

Contractor: Rod Martin Tree Improvement Ltd., Nakusp.

B.C.F.S. Contact: J. Beale, Vancouver Forest Region.

Region: Vancouver Forest Region.

Date: February to March, 1989.

Cost: \$10,000.

Objective:

1. Establish a western white pine S.P.A. on Texada Island, including tree evaluations, tagging and mapping of selected trees, removal of unsuitable western white pine, an estimate of rust incidence rate and hazard for the area, and observations of resistance mechanisms.

Description: A 12 ha 30-year old regenerated stand was surveyed on Texada Island for the most promising western white pine genotypes that express some degree of blister rust tolerance. All white pine were inspected in the area since many trees exhibited slow growth cankers.

A total of 493 trees greater than 20 cm DBH were classified into six groups, depending on degree of infection, and tagged. Slow stem canker growth was observed on 77 of these trees. Cankers were photographed for a record of disease progression. The location of any Ribes bushes was also recorded.

The site was marked out and divided into two blocks. A stand tending survey consisting of 18 plots was performed to estimate blister rust incidence on the site. Infection rates were determined

to be 71% for Block A and 52% for Block B. Trails were established to facilitate cone removal and future monitoring of candidate trees.

Contractor Recommendations:

- Monitor conelet development and collect cones
- Fertilize candidate trees to enhance cone production
- Conduct controlled breeding of candidate trees in order to produce highly resistant seed orchard stock for high blister rust risk areas
- Seed should be employed in long-term progeny trials and the Forestry Canada screening trials.

Project Report: Martin, R. 1989. Texada Island White Pine Seed Production Area. Contractor Report. 12 pp.

Evaluation: The stand represented a major discovery which could strongly influence the future course of the white pine breeding program. Management of this area should be considered a high priority and should continue in an ongoing manner since this site is extremely valuable to the western white pine breeding program. All of the preceding recommendations should be carried out in order to enhance the province's white pine stock. Future establishment of blister rust resistant stock should help reduce potential backlog.

Project Status: Operational Control Trial — method rated moderately to highly practicable; need data to substantiate operational use then should be fully practicable.

White Pine Blister Rust: Pest Control Project JM-086

Title: Management of White Pine Demonstration Area, Whatshan Lake.

Area Treated/Surveyed: 1.5 ha.

Contractor: Rod Martin Tree Improvement Ltd., Nakusp.

B.C.F.S. Contact: D. Norris, Nelson Forest Region.

Region: Nelson Forest Region.

Date: September, 1989 to March, 1990.

Cost: \$4,500.00

Objectives:

1. Conduct intensive management of the Whatshan Lake (Ingersoll Ck.) demonstration area.

Description: At Whatshan Lake (Ingersoll Creek), cones from the veteran and active bark reaction parent tree were bagged and collected. Seed was sent to Forestry Canada for testing. Active bark reactions were photographed. All white pine trees on the site were mapped. Ribes bushes were transplanted onto the site in order to increase selective pressure and expose additional bark reactions. Ten families of Priest Lake western white pine were

planted in openings created by previous removal of the other stand components. These families have shown proven resistance to blister rust. Scion bud material was collected for tissue culturing.

Contractor Recommendations: None.

Project Report: Project Summary and Data.

Evaluation: This project formed part of the ongoing intensive management of seed production areas established for long-term improvements to western white pine stock. Results from this breeding program, administered by the province and Forestry Canada, have been encouraging to date. Development of resistant stock should provide a practical long term solution since branch pruning has proven to be expensive. Western white pine is a highly desirable species particularly in areas infested by root disease. Thus, the white pine breeding program should be considered a priority.

Project Status: Operational Control Trial — method rated moderately to highly practicable. Need data to substantiate operational use. Then method should be fully practicable.

White Pine Blister Rust: Pest Control Project JM-094

Title: White Pine Cone Bagging at the Texada Island Seed Production Area (S.P.A.).

Area Treated/Surveyed: 12 ha.

Contractor: Rod Martin Tree Improvement Ltd., Nakusp.

B.C.F.S. Contact: J. Beale, Vancouver Forest Region.

Region: Vancouver Forest Region.

Date: January to March, 1990

Cost: \$7,040.

Objective:

1. Bag cones on 100 selected western white pine (79 showing blister rust resistant bark reactions and 21 exhibiting no rust infection) at the Texada Island S.P.A.

Description: A total of 88 white pine trees were selected for cone bagging at the Texada Island S.P.A. Twenty to thirty cones were covered per tree using cotton bags to protect developing cones from mam-

mal or insect damage. Seed from these cones will be used in the white pine tree improvement trials.

Report: None.

Evaluation: Management of the S.P.A. is an ongoing process. Bagged cones are scheduled for use for seed screening in the tree improvement program administered by the province and Forestry Canada. Fewer trees were selected than planned based upon availability of suitable bark reaction trees. Long-term results from this program should provide a practical solution to the blister rust problem since branch pruning has proven to be very costly. Thus, intensive management of this S.P.A., and others, should be given a high priority in order to provide a practical control method over the long term.

Project Status: Operational Control Trial — method rated moderately to highly practicable; need data to substantiate operational use then should be fully practicable.

White Pine Blister Rust: Pest Control Project JM-083

Title: Texada Island (Pocahontas) White Pine Workshop.

Area Treated/Surveyed: None.

Contractor: Rod Martin Tree Improvement Ltd., Nakusp.

B.C.F.S. Contact: J. Beale, Vancouver Forest Region.

Region: Vancouver Forest Region.

Date: June, 1989.

Cost: \$500.

Objective:

1. Conduct a demonstration tour of the Texada Island seed production area (S.P.A.) for B.C.F.S. and Forestry Canada representatives.

Description: The Texada Island S.P.A., surveyed and prepared by the contractor in 1988, was toured by B.C.F.S. and Forestry Canada representatives. Potential benefits of the site for the western white pine breeding program were discussed, along with

possible strategies for future management of the area and for white pine in general. The value of white pine establishment in areas heavily infected with root rot was highlighted. Because the species has a fairly broad ecological range, the opportunity for enhancing the western white pine rust resistance program was noted. The benefits of low branch pruning and the two-pass pruning were also noted.

Report: None.

Evaluation: The field demonstration and discussion were successful in focusing attention on this S.P.A., which was considered to be very valuable, and on the western white pine breeding program in general. Monitoring of bark reaction trees should continue and the management recommendations for this site, proposed in Project JM-066 should be implemented.

Project Status: Complete — demonstration.

Black Army Cutworm (IDA) Projects

Black Army Cutworm: Pest Control Project PB-24

Title: Investigation of Black Army Cutworm Infestations.

Area Treated/Surveyed: 70 sites (overview).

Contractor: Thomas Maher, Mountain Pacific Forestry Ltd., Clearwater.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Prince George and Prince Rupert.

Date: March, 1987.

Cost: \$3,215.

Objectives:

1. Review and compile available information on black army cutworm infestations in the Prince George and Prince Rupert Forest Regions.
2. Review relevant documents such as site preparation guides or burning reports, with particular concern for 1983 data, and analyze factors such as pre- and post-burn conditions.
3. Provide recommendations for data and/or procedures relevant to monitoring and recording infestations.
4. Provide a report with conclusions and recommendations for improvements.

Description: Interviews were conducted with district and licensee personnel from the Bulkley, Morice, Lakes, Prince George East and Prince George West Forest Districts. File records of 70 known black army cutworm infestations were examined in an effort to correlate black army cutworm occurrence with any site preparation techniques or characteristics. Cutting permit and block numbers were cross referenced to obtain opening files and all documents were examined, including the following: Site Preparation Guide, Prescribed Burn Analysis, Regeneration Survey Summary and Planting Report. All data and comments were summarized per district. Recommendations for improved record keeping were subsequently provided.

In general, it was perceived that the black army cutworm had not caused significant economic losses to date. However, it was a concern in all five forest districts with respect to potentially higher losses with increased spring burning. The majority of infestations occurred in the operating areas of only three licensees within three biogeoclimatic subzone variants, but this trend may simply have resulted from increased harvesting in these areas. The overall aspect of infested plantations was highly variable but a trend toward infestation of south aspect ridges and slopes with course-textured soils was noted. No other trends, including burning factors, were noted between site factors and incidence of black army cutworm. It was observed that infestations were not necessarily limited to sites where broadcast burning had been performed.

Observations were limited by the fact that only 30% of the files examined had detailed notes regarding black army cutworm infestations despite its occurrence having been noted. There was no consistency in the record keeping system, especially in terms of area infested and seedling damage levels. Thus, it was not possible to estimate total area affected and losses from the black army cutworm.

Interviews with district personnel revealed the following requirements for improved black army cutworm management: training of all district, contract and licensee staff with respect to identification and management considerations; performance of defoliation impact assessment; and determination of probability of infestation.

Contractor Recommendations: For improving black army cutworm records:

- Establish a separate file for recording infestation data in each district office. Records should include location, opening file number, month and year of planting, date on which black army cutworm was observed, a map of the infested area, descriptions of seedling damage, and an evaluation of impact one year after defoliation has occurred.

- Allocate a data block for damage information within the History and Crop Establishment Record.
- Develop a vegetation preference rating over a wide variety of habitats.
- Collect damage appraisal information to provide a data base for formulation of management options.

Project Report: Maher, T. 1987. Investigation of Black Army Cutworm Infestations in the Prince Rupert and Prince George Forest Regions. Contractor Report. 15 pp.

Evaluation: All project objectives were met. However few correlations could be made between site management factors and the black army cutworm within the areas studied. Important recommendations for improving the data base were put forth and these should be implemented on an operational basis as suitable follow-up. Additional activities should include the training of personnel in black army cutworm identification and damage assessment.

Project Status: Damage Appraisal Operational Trials — assess pest impact/incidence and establish methods for enhancing data base.

Porcupine (AP) Projects

Porcupine: Pest Control Project PB-15a

Title: Porcupine Survey in the Kalum Forest District.

Area Treated/Surveyed: 500 ha.

Contractor: Newcome Contracting, Terrace.

B.C.F.S. Contact: S. Zeglen (W. Martin to 1989), Prince Rupert Forest Region.

Region: Prince Rupert Forest Region.

Date: December, 1986 to January, 1987.

Cost: \$3,000.

Objectives:

1. Determine the incidence of porcupine damage in young stands in the Kalum Forest District.
2. Mark and map the location of all survey strips for resurveying in the future in order to assess the effectiveness of implementing a bounty to reduce porcupine numbers in affected areas.

Description: Due to persistently high damage levels, an objective was formulated which consisted of reducing the porcupine population by live-trapping and disposal or by shooting for bounty. However, the 1986-87 bounty kill project in the Kalum Forest District was unsuccessful because of a number of factors. Thus, a survey of tree damage was required in order to assess the probable future effectiveness of the bounty strategy before any attempt at population reduction.

The survey was conducted as follows. One transect line was run through each opening. Lines were of sufficient length to check and record at least 50

trees, but were not less than 800 m in length. All strips and trees were marked for resurvey after completion of the control program.

A total of 20 lines were established in 20 openings ranging from 10 to 20 ha in size, for a total of 16,068 m of line and 2941 stems checked. The percentage of trees attacked, by species, was as follows: lodgepole pine 0%, western hemlock 3.2%, balsam fir 0%, western red cedar 0%. The overall attack level was 2.36% with 0.44% being recent attack and 1.92% being old attack. A bounty program was implemented and all survey strips were subsequently reassessed under a non-F.R.D.A funded project.

Contractor Recommendations: None

Project Report: Data Summary.

Evaluation: Porcupine was determined to be a significant problem in the Kalum Forest District as a result of a resurvey of lines established during this project. The incidence of new damage increased over 100% in mixed hemlock-balsam stands and additional research work indicated that five or six trees may be attacked per animal per day. Data on damage incidence and levels will be used in a long-term quantitative assessment of control effectiveness and will be included in a TSA impact analysis. Thus, this survey is complete as part of a larger project.

Project Status: Complete — all survey work completed.

Porcupine: Pest Control Project 23

Title: Porcupine Problem Analysis.

Area Treated/Surveyed: 500 ha.

Contractor: Thomas Sullivan, Applied Mammal Research Institute, Langley.

B.C.F.S. Contact: S. Zeglen (W. Martin to 1989), Prince Rupert Forest Region.

Region: Prince Rupert Forest Region.

Date: August, 1987 to March, 1988.

Cost: \$10,000.

Objectives:

1. Describe the general population biology of the porcupine with respect to factors which determine levels of damage, stand disturbance, silvicultural factors, etc.
2. Assess the incidence of porcupine damage by region, district and biogeoclimatic zone by reviewing current and past records, including U.S. data.
3. Determine the effectiveness and practicality of control strategies in coastal and interior environments.
4. Determine the impact of feeding damage on non-stocked backlog areas, stand tending and yield analyses.
5. Develop a plan of action with an assessment of options for controlling damage in the Kalum and North Coast Forest Districts.
6. Develop a conceptual management model, incorporating factors and strategies resulting from the problem analysis.

Description: The population biology of the porcupine was covered in general terms. All available literature and records were reviewed and assessed. A survey questionnaire was developed and distributed in order to determine relative levels of porcupine damage, as observed by forestry personnel within B.C. and the northwestern U.S. Quantitative damage assessments were obtained from the North Coast and Kalum Forest Districts. Subsequently, estimates of impacts on stocking area, silvicultural practices, and yield were based on these limited data. Judgements on the effectiveness and practicality of various population and damage control options were made from a synthesis of available literature and discussions with experts.

This review resulted in the following salient points.

Porcupine populations have probably been increasing in recent years in response to favourable climatic conditions, an increase in the amount of preferred second-growth stands, and low predator populations. Population fluctuations occur over very long cycles and the range of individual animals is relatively small. Damage was observed to be increasing, particularly in second-growth western hemlock-Sitka spruce forests in the two districts reviewed. The overall damage incidence for B.C. is low (<5%) with severe damage (>50%) occurring only in the Prince Rupert Region. In the Kalum and North Coast districts, selection of the most vigorous pole-size stems for feeding would probably lead to non-stocked conditions in some areas and the impact on yield was seen to be incremental or catastrophic. Some changes in silvicultural practices were considered to be required in heavily attacked stands since present management practices may be

increasing the intensity of attacks. An initial management model was developed which considered favourable habitat and climate, stand age and type, stand management strategies, and predator reduction factors, as these affect the porcupine population, outbreak of damage and stocking.

Contractor Recommendations: A plan of action and a list of research and information requirements, included:

- Conduct surveys using 2 m wide strips in susceptible areas of the Kalum and North Coast districts in order to assess impact and the effects of population reduction methods.
- Implement a bounty system and continue and regulate hunting and trapping.
- Establish a control area to determine the efficacy of controls.
- Procure fishers and assess predator reduction in the North Coast Forest District, and curtail fur trapping in areas where the fisher is introduced.
- Where possible, leave or plant a greater number of stems per hectare (1200 to 1600 versus 900 after spacing and 2000 versus 1200 to 1400 at time of planting).
- Select less preferred species such as balsam and western red cedar wherever possible.
- Educate the local public on the porcupine problem and required solutions in the Kalum and North Coast districts.
- Establish and monitor growth and yield plots and analyze decay samples for wound parasites.
- Conduct a population study in the Kalum Valley to determine migration patterns and densities and the efficacy of hunting and trapping.
- Assess the effects of stand density manipulation.
- Assess porcupine preference for hardwood species compared to conifers.

Project Reports: Sullivan, T.P. 1988. Problem Analysis of Porcupine Damage in Young, Managed Forests in the Prince Rupert Region. B.C.F.S. Internal Report PM-PB-33. 76 pp.

Sullivan, T.P. and C. Cheng. 1989. Impact of Porcupine Feeding Damage on Intensive Forest Management in the Prince Rupert Forest Region: Problem Analysis. F.R.D.A. Report No. 083. 20 pp.

Evaluation: All objectives were attained during this project. A plan of action was subsequently developed and most of the contractor's recommendations are being implemented. All of these activities are suitable for follow-up work under F.R.D.A. II.

Project Status: Damage Appraisal Operational Trials And Modelling — problem analysis and first approximation of a management model.

Porcupine: Pest Control Project 24a

Title: Porcupine Control Trials.

Area Treated/Surveyed: None.

Contractor: Trapper Association, Terrace Local, Terrace.

B.C.F.S. Contact: S. Zeglen (W. Martin to 1989), Prince Rupert Forest Region, and Joe Katasonoff, Kalum Forest District.

Region: Prince Rupert Forest Region.

Date: July, 1987 to March, 1988.

Cost: \$1,800.

Objective:

1. Conduct trials for porcupine control using live trapping.

Description: A total of 40 to 50 traps were purchased for live trapping trials in the Erlandon Creek, Deep Creek, Lean-to Creek and Zimacord drainages near Terrace. Subsequently, only 50 animals were taken. The traps may have been ineffective due to

their small size, despite the use of several different baits. In addition, the time of trapping may have been inappropriate with respect to porcupine population dynamics. The project was terminated, partly because the bounty was too low. Thus, the porcupine population was not effectively reduced through this method in any of the study drainages.

Contractor Recommendations: None.

Project Reports: None.

Evaluation: This project was terminated but control efforts were later resumed at higher bounties and without live trapping. Suitable follow-up activities include a new trial and assessment of live trapping depending on the findings from a porcupine population dynamics study currently underway.

Project Status: Operational Control Trial — method rated possible to fair chance of suitability for operational use; need data to precisely determine the effectiveness and/or response to treatment.

Porcupine: Pest Control Project 24b

Title: Supply Information on Porcupine Damage and Control Requirements to the Public.

Area Treated/Surveyed: N/A.

Contractor: Trevor Jobb, Terrace.

B.C.F.S. Contact: S. Zeglen (W. Martin to 1989), Prince Rupert Forest Region; Joe Katasonoff, Kalum Forest District.

Region: Prince Rupert Forest Region.

Date: August, 1987 to March, 1988.

Cost: \$2,400.

Objective:

1. Educate the public with respect to porcupine damage in managed stands and the requirement for control methods to reduce losses.

Description: A communications plan was developed and implemented for the North Coast and Kalum Forest Districts in order to garner public support for porcupine control measures. Public groups reached included the following: the general public, industry, recreationists, the S.P.C.A., hunters, trappers, and the Ministry of Environment Meetings were held between the B.C.F.S. and members from the preceding

groups. A media field trip, school tours, mall display, and an "open house" were planned. An allotment of T.V. time was established and an information pamphlet was produced for distribution. Discussions were held concerning the impact of porcupine damage and the benefits of porcupine control. The display was held for two to three days in three malls in Prince Rupert, Skeena and Kitimat. This display was manned by B.C.F.S. staff. As a result, some level of public support was attained for establishing a bounty on porcupines in both districts, despite active lobbying by an animal rights group.

Contractor Recommendations: None.

Project Reports: None.

Evaluation: The mall display, pamphlet, meetings and tours were generally effective in garnering local public support for a porcupine control program. No further follow-up is required unless resistance is encountered in future control projects.

Project Status:

Complete — all demonstration work completed.

Porcupine: Pest Control Project 52

Title: Trial Porcupine Hunting Program.

Area Treated/Surveyed: 3 sites.

Contractor: Otto Lindstrom, Terrace.

B.C.F.S. Contact: S. Zeglen (W. Martin to 1989), Prince Rupert Forest Region, and J. Katasonoff, Kalum Forest District.

Region: Prince Rupert Forest Region.

Date: September, 1988 to March, 1989.

Cost: \$9,000.

Objective:

1. Control porcupine damage by conducting trial hunting.

Description: A trial porcupine hunting program was conducted in three areas with extensive porcupine damage: the Nass, Kalum and Kitimat valleys. Trappers involved with the hunt were either from the Northwest Trappers Association or from one of the local Native Band Councils. A bounty of \$30 per animal was established, with \$25 being paid to the individual trappers and \$5 going toward administrative costs. Porcupine noses were submitted for verification. The location, time of day and maturity of each kill was recorded. Porcupines were not hunted in an established study control area south of Terrace. The population was reduced by approximately 300 animals in the Terrace area, probably a small proportion of the local population.

Contractor Recommendations: None.

Project Reports: None.

Evaluation: The effectiveness of this control trial will not be known for at least five years. Thus, results are tentative but there are indications that hunting is effective. In one drainage removal of 40 to 50 animals appeared to reduce new damage significantly. However, a more accurate assessment requires consideration of population movements. A population dynamics study is currently underway. All hunting was suspended in 1990-91, pending observation of trends. For this reason, the region recommended continuation of hunting and monitoring for at least five more years. Additional follow-up activities include:

- establish monitoring plots in the Kalum Forest District.
- assess the effectiveness of spacing, selection of less susceptible species, and tree collaring in reducing damage levels.
- assess live trapping trials, pending findings from the population dynamics study now underway.

Project Status: Operational Control Trial — method rated possible to fair chance of suitability for operational use; need data to precisely determine effectiveness and/or response to treatment.

Porcupine: Pest Control Project JM-078

Title: Porcupine Hunting Program.

Area Treated/Surveyed: 3 sites.

Contractor: Otto Lindstrom, Terrace.

B.C.F.S. Contact: S. Zeglen (W. Martin to 1989), Prince Rupert Forest Region, and J. Katasonoff, Kalum Forest District.

Region: Prince Rupert Forest Region.

Date: September, 1989 to March, 1990.

Cost: \$13,500.

Objectives:

1. Control porcupine damage by conducting trial hunting.

Description: Further porcupine hunting trials were conducted in heavily damaged areas of the Kalum Forest District (Kalum, Nass and Kitimat valleys). Hunting activities were concentrated in the Kalum

Valley since this was the most severely affected area. A bounty of \$30 per animal was established and porcupine noses were supplied for verification. The population was reduced by 450 animals.

Recommendations: None.

Project Reports: None.

Evaluation: Tentative results indicated that hunting may be locally effective in reducing damage. Hunting was terminated, pending quantifiable results. Suitable followup activities include further evaluation of hunting and other control methods.

Project Status: Operational Control Trial — method rated possible to fair chance of suitability for operational use. Need data to precisely determine the effectiveness and/or response to treatment.

White Pine Weevil (IWS) Projects

White Pine Weevil: Pest Control Project PR-1

Title: White Pine Weevil Survey and Control in Southern Plantations in the Kitimat Valley.

Area Treated/Surveyed: 2,600 ha

Contractors: None — field crews paid by Kalum Forest District.

B.C.F.S. Contact: T. Ebata, Prince Rupert Forest Region.

Region: Prince Rupert Forest Region.

Date: November, 1985 to March, 1986.

Cost: \$5,300

Objective:

1. Survey Sitka spruce plantations to determine the extent and severity of white pine weevil infestation in the Kalum Forest District.

Description: Approximately 2600 ha of natural and established Sitka spruce plantations were surveyed to determine white pine weevil incidence and damage levels. These surveys were a follow-up to clipping operations conducted in 1983 and 1984 to assess the effectiveness of this procedure in reducing weevil damage. A continuous 10m wide strip survey method was employed, yielding an average sampling intensity of about 4% of the area of each plantation. All trees were tallied within 5m of either side of the transect line to obtain weevil damage and stocking data. Total number of trees, and current and previous years' attack were recorded every 25m.

A total of 43 plantations containing Sitka spruce as the leading species were surveyed in the Kitimat, East and West Skeena valleys and in the vicinity of Lakelse Lake and Cranberry River. Three biogeoclimatic subzone variants were encountered: CWH1l, CWH1f and ICH1l. Stocking was found to be highly variable, but most areas were satisfactorily stocked. Average current attack levels were approximately 5% with some plantations exhibiting 23%. The level of current attack was highest in the lower Kitimat Valley and declined to less than 1% in the upper Kitimat Valley. Levels in the Skeena and Lakelee areas

varied from 0% to 21%. Attack distribution was usually clumped and appeared to be stationary over time. It could not be determined if this patchy distribution was the result of site factors, but high site moist leading to stress was strongly implicated.

The effects of a deciduous overstory on weevil populations were not quantified. It appeared that shading did not reduce weevil attacks in sampled plantations although other site factors may have obscured this phenomenon.

The effects of the extensive clipping conducted in 1983-84 were highly variable. The level of attack either decreased, increased or stayed the same. In virtually all plantations clipping did not have any significant effect on the population after one summer had elapsed.

This treatment might have been more effective if adjacent infected stands also were clipped. Clipping might be useful for encouraging apical dominance and thus reducing long-term damage. However, subsequent results from clipping trials indicated that this control method is too expensive and has negligible benefits.

The strip method was not accurate enough to properly assess incidence because too few strips were employed and many sites exhibited too much variability. Future surveys should use a minimum of 20 uniformly spaced sample strips in order to improve accuracy.

Contractor Recommendations:

- More intensive surveys will be useful for identifying high risk sites and determining the role of site factors on the incidence of weevil populations.
- Low-intensity weevil surveys could still be used on an annual or biannual basis for assessing damage at the TSA, subzone or variant level.
- Monitoring surveys must also be conducted after the free-growing stage.
- Weevil hazard zones and sites should be determined together with species selection guidelines for the region.

- The effects of weevil attack on wood quality and value should be determined.

Project Report: Ebata, T. 1987. Results of Four Leader Weevil Surveys on Sitka Spruce: Kalum Forest District 1982 to 1986. B.C.F.S. Internal Report PM-PR-5. 37 pp.

Evaluation: All objectives were met. This project was part of an ongoing assessment of the weevil problem in the Prince Rupert Forest Region. Results from this study indicate that leader clipping is ineffectual. Therefore, this treatment should be discontinued as a control technique. Suitable follow-up

activities include implementation of further monitoring at higher sampling intensities in order to correlate site factors and develop a site hazard system. Additional surveys for damage incidence should be conducted at the lower sampling intensity.

Project Status: This project: Detection Method Fully Practicable — Implement methodology on an operational basis.

Follow-up control activities: Control Method Not Suitable for Operational Use — Do not implement clipping on an operational basis.

White Pine Weevil: Pest Control Project PB-10

Title: White Pine Weevil Silvicultural Control Trial Establishment.

Area Treated/Surveyed: 3.4 ha treated/5.2 ha surveyed.

Contractor: Integrated Silviculture Services Ltd., Prince George.

B.C.F.S. Contact: R. Cozens, Prince George Forest Region.

Region: Prince George Forest Region.

Date: April, 1986.

Cost: \$7,200

Objective:

1. Establish a white pine weevil control trial to assess weevil control efficacy.

Description: Chemical and biological control methods were believed to be of limited success in the near-future, thus silviculture control techniques required investigation. Subsequently, an area was established to assess the long-term viability of manipulating naturally occurring deciduous overstory as a method of weevil control. The effect of this overstory on weevil populations and stand vigour will be examined in an ongoing manner.

A control trial consisting of three 1.72 ha plots was established approximately 50km east of Prince George. The site was 15 years old and contained an active weevil population. Three replications of each plot were established. Plots consisted of one of the following: an undisturbed plantation with a relatively continuous overstory; a completely brushed plantation with no overstory; alternate brushed and non-brushed natural strips oriented so that the spruce in the brushed strips were in the shade created by the unbrushed strips.

All spruce were stem-mapped, measured and tagged within the plots. DBH, height, and leader growth were recorded and all trees were assessed for weevil damage. stem maps were supplied. Reduction in the number of weevil attacks due to

shading had been previously observed. However, weevil population reductions had to be studied under controlled conditions where is grown under an overstory of trembling aspen, red alder and/or western white birch. Spruce is expected to grow well under this understory. However, silviculture methods will only be practical if additional work is minimized.

Weevil activity will be assessed annually in the three plots. Annual measurements taken for each tree include: total height, current year's leader growth, presence/absence of white pine weevil, number of weevil exit holes and height of branch whorl below weevil attacks. In addition, electronic data logging equipment was placed in each replicate to record temperature and moisture of the duff between May and October for determination of the conditions under which weevil populations and spruce exist. All data is to be stored on computer.

Contractor Recommendations: None.

Project Report: Cozens, R.D. 1987. Silvicultural Control of Damage by Spruce Weevil *Pissodes strobi* Peck (Coleoptera: Curculionidae) in the Central Interior of British Columbia: Establishment Report. B.C.F.S. Internal Report. 16 pp.

Evaluation: The establishment of this control trial area was the initial phase of a long-term study and this portion is thus complete. Expected benefits consist of guidance in the prescription of brushing and weeding operations to minimize weevil impact while optimizing stand production. Suitable follow-up activity includes regular monitoring and establishment of additional areas for replication if the techniques yield promising results.

Project Status:

Operational Control Trial — Method rated possible to fair chance of suitability for operational use; need data to precisely determine effectiveness and/or response to treatment.

White Pine Weevil: Pest Control Project PB-19

Title: Assess Permanent Sampling Plots in the Kitimat Valley for White Pine Weevil Incidence.

Area Treated/Surveyed: 18 plots surveyed (9 ha).

Contractor: K.D.M. Forestry Services, Ltd., Terrace.

B.C.F.S. Contact: T. Ebata, Prince Rupert Forest Region

Region: Prince Rupert Forest Region.

Date: February to March, 1987.

Cost: \$8,100

Objective:

1. Locate and remeasure Sitka spruce permanent sample plots (PSPs). Sample all trees for date of attack, damage code, tree vigour, damage by other agents, and leader length. Plot the location of all weevil attacks and summarize the number of trees attacked by year.

Description: All Sitka spruce plots were located and remeasured in order to assess the pattern of white pine weevil attack and rate of intensification in the Kitimat Valley, Kalum Forest District. A total of 12 plots were located on four sites. These plots were originally established in 1975 to obtain long-term information on growth and yield for four species. The data also formed part of a long-term impact evaluation study. Aerial photographs were taken of the plots in 35mm format in order to conduct stem mapping. Sites were located on different soil types throughout the valley. A total of 2728 Sitka spruce were remeasured in 12 plots (3 plots

per site over 4 sites). Buffer trees (mixed species) could not be mapped. Instead, buffer trees were tagged. Weevil attack per year was summarized and plotted by plot.

An increase in weevil attack over the previous four years was noted in all plots. Attack intensity was most severe at Site 2. Other damaging agents recorded were snow, wind and chlorosis. The latter may have been caused by suppression or other stress factors. Many old attacks had resulted in multiple leaders. Data indicated an intensification of attack which was verified during other survey work conducted throughout the valley. Weevil attack data from 1982-86 indicated low populations (approximately 3%) in a clumped distribution. Attacks then increased and became more uniform in this district.

Contractor Recommendations: None.

Project Report: Ebata, T., ed. 1990. Summary Report of a Spruce Weevil Survey in Permanent Sample Plots in the Kitimat Valley, E.P. 712: FRDA Projects PB-19 (1986-87), 28 (1987- 88), JM-099 (1989-90). Contractor's Reports. 100 pp approx.

Evaluation: All objectives were met in this project with the exception of stem mapping of buffer trees, which was later performed as part of Project 28. Suitable follow-up activities include regular assessment of plots in the Kitimat Valley for long-term damage appraisal.

Project Status: Damage Appraisal Operational Trial — Data base enhancement and appraisal of incidence and impact.

White Pine Weevil: Pest Control Project PB-20

Title: White Pine Weevil Surveys in the Kitimat Valley, Prince Rupert Forest Region.

Area Treated/Surveyed: 13 plantations.

Contractor: Silvicon Services Inc., Smithers.

B.C.F.S. Contact: T. Ebata, Prince Rupert Forest Region.

Region: Prince Rupert Forest Region.

Date: February to March, 1987.

Cost: \$9,600

Objective:

1. Survey 13 selected Sitka spruce plantations in the Kitimat Valley to determine the incidence of current and past weevil attacks. Summarize and submit all survey data.

Description: This survey was one of two bi-annual strip surveys conducted in the Kitimat Valley be-

tween 1986 and 1989. Thirteen plantations, which had been previously sampled annually from 1982 during Project PR-1 were surveyed using a modified 5m width strip method. Strips were of sufficient length to examine 25 Sitka spruce within 2.5m of either side of the transect. A minimum of 20 evenly spaced strips per plantation were positioned to give optimum site coverage. Current and past attacks were recorded and summarized. Attack codes were used to describe damage for each tree. Each strip had one 3.99m radius standard silviculture plot for determining stocking. All transect and plot data were summarized per strip and by plantation.

Results indicated that the "low hazard zones" reported in Project PR-1 did not remain lightly attacked. Instead, as attack intensity increased incidence became more uniform and damage levels approximated those in the "high hazard zones." Weevil populations had grown rapidly between

1982 and 1988 from less than 6% to an average of 16%. As might be expected, the impact was most pronounced in areas subjected to longer periods of high weevil infestation levels since multiple leaders and stunted growth have led to suppression. Impact will probably be more severe in the lower valley since virtually all Sitka spruce in this area have had at least one attack incident.

Contractor Recommendations: None.

Project Report: Ebata, T., ed. 1990. Summary Report of Two Spruce Weevil Surveys in Twelve Plantations in the Kitimat Valley: FRDA Projects PB-20 and JM-080. Contractors' Reports. 100 pp approx.

Evaluation: The survey method gave a good indication of damage levels but did not give systematic coverage of the entire plantation. Further trials of this method should be done to assess its effectiveness when weevil populations have a more clumped distribution. Other suitable follow-up activities include:

- monitoring additional Sitka spruce plantations as these become susceptible.
- resurveying plantations sampled in this project after spacing has been conducted.

Project Status: Operational Detection Trial — Method rated moderately to highly practicable; need data to substantiate operational use, then should be fully practicable.

White Pine Weevil: Pest Control Project 28

Title: Remeasurement of Sitka Spruce Plots for White Pine Weevil Damage in the Kitimat Valley.

Area Treated/Surveyed: 9 plots surveyed (6.8 ha).

Contractors: KDM Forestry Services, Terrace.

B.C.F.S. Contact: T. Ebata, Prince Rupert Forest Region.

Region: Prince Rupert Forest Region.

Date: November, 1987 to January, 1988.

Cost: \$3,500

Objective:

1. Locate and remeasure plots at three sites in the Kitimat Valley. Measure and record all trees in plot centres, tag and stem map all buffer trees, and summarize data.

Description: This project was basically a continuation of work commenced under PB-19. A total of 2,499 Sitka spruce were reassessed in nine plots on three sites, and 1923 plot buffer trees were stem-mapped and tagged. Data were summarized. Attack intensification trends, noted in the previous

year, continued in 1987-88. Attack levels increased in all three plots. The attack pattern noted in this project and in PB-19 was confirmed during other field work conducted within the area from 1982 to 1990. Data will be used in a long-term weevil impact assessment for the Kitimat Valley.

Contractor Recommendations: None.

Project Report: Ebata, T., ed. 1990. Summary Report of a Spruce Weevil Survey in Permanent Sample Plots in the Kitimat Valley, E.P. 712: FRDA Projects PB-19 (1986-87), 28 (1987-88), JM-099 (1989-90). Contractors' Reports. 100 pp approx.

Evaluation: This project continued plot remeasurements initiated under PB-19. Suitable follow-up activity includes regular monitoring of Sitka spruce plots in the Kitimat Valley to assess the long-term impact of white pine weevil attack and attack patterns.

Project Status: Damage Appraisal Operational Trials — Data base enhancement and appraisal of pest incidence and impact.

White Pine Weevil: Pest Control Project 43

Title: Remeasurement of White Pine Weevil Silviculture Control Trial.

Area Treated/Surveyed: 5.2 ha.

Contractor: Integrated Silviculture Services Ltd., Prince George.

B.C.F.S. Contact: R. Cozens, Timber Harvesting Branch, Victoria.

Region: Prince George Forest Region.

Date: April to May, 1988.

Cost: \$4,550.

Objective:

1. Remeasure white spruce trees in a silviculture control trial established under Project PB-10.

Description: A total of 5,383 trees were remeasured in three white pine weevil control plots established under Project PB-10. Total tree heights and 1987 and 1988 height increments were measured and recorded. A preliminary analysis of these measurements is still under way. To date, there is no noticeable difference in white spruce growth between shaded and open conditions. Initial indications, based on field observations, are that the weevil densities are less under shade than in the open.

White Pine Weevil (IWS) Projects

Contractor Recommendations: None.

Project Report: None.

Evaluation: Remeasurements were part of an ongoing assessment of silviculture control methods. Thus, results are inconclusive. Suitable follow-up consists of additional monitoring and analysis, and

additional treatment replications if results appear promising.

Project Status:

Operational Control Trial — Method rated possible to fair chance of suitability for operational use; need data to determine effectiveness and/or response to treatment.

White Pine Weevil: Pest Control Project JM-080

Title: White Pine Weevil Surveys in the Kitimat Valley, Prince Rupert Forest Region.

Area Treated/Surveyed: 291 ha (12 plantations).

Contractor: KDM Forest Services Ltd., Terrace.

B.C.F.S. Contact: T. Ebata, Prince Rupert Forest Region.

Region: Prince Rupert Forest Region.

Date: April to June, 1989.

Cost: \$5,760.

Objective:

1. Survey 12 selected plantations in the Kitimat Valley to determine the incidence of current and past weevil attacks.

Description: This survey was the second of two surveys performed in the Kitimat Valley between 1986 and 1989. Twelve plantations, sampled under PB-20, were resurveyed during this project. One plantation was dropped from the sampling because Sitka spruce was no longer the leading species.

A modified 5m wide strip method was employed as in PB-20. Strips were of sufficient length to examine 25 Sitka spruce within 2.5m of either side of the line. A minimum of 20 evenly spaced strips per plantation were placed to give optimum site average. Attack codes were employed to describe damage for each tree. In addition, each strip had one 3.99m radius plot for determination of stocking. All

transect and plot data were summarized per strip and by plantation.

Results substantiated trends seen in Project PB-20. Attack intensity increased exponentially. Damage levels appeared to be evenly distributed in the valley. In 1990, attacks intensified to approximately 30%. Impact is expected to be more severe in the lower Kitimat Valley.

Contractor Recommendations:

- Improve future assessments by using systematic sampling.

Project Report: Ebata, T., ed. 1990. Summary Report of Two Spruce Weevil Surveys in Twelve Plantations in the Kitimat Valley: FRDA Projects PB-20 and JM-080. Contractors' Reports. 100 pp approx.

Evaluation: Trends seen in PB-20 were substantiated by results of this project. The survey method is applicable to uniformly attacked stands, but may not give sufficient coverage where the weevil population is clumped in some areas. Thus, further trials of this technique should be done to evaluate its effectiveness with a clumped weevil population.

Other follow-up activities include:

- monitoring other susceptible Sitka spruce plantations.
- resurveying the plantations sampled in this project after spacing has been conducted.

Project Status: Operational Detection Trial — Method rated moderately to highly practicable. Need data to substantiate operational use.

White Pine Weevil: Pest Control Project JM-082

Title: White Pine Weevil in Spruce Plantations in the Prince George Forest Region.

Area Treated/Surveyed: 43 sites.

Contractor: Industrial Forestry Services, Prince George.

B.C.F.S. Contacts: J. Muir, Silviculture Branch, Victoria; S. Taylor, Prince George Forest Region.

Region: Prince George Forest Region.

Date: June to August, 1989.

Cost: \$21,800

Objective:

1. Survey 43 spruce plantations to determine the levels of white pine weevil damage and incidence.

Description: Forty-three stands were randomly selected within the subboreal spruce (SBS) biogeoclimatic zone in the Prince George Forest District.

Strips were variably spaced to give even coverage per plantation. No more than five strips were run per plantation since this number was considered to give reasonable accuracy. All spruce within 5m of either side of the line were examined and tallied.

Damage was recorded as the number of whorls destroyed and these data were then totalled by strip and plantation. The following site factors were also recorded: topography, slope, aspect, site class, age, stand composition, presence of deciduous overstory and previous white pine weevil damage. An analysis of variance was performed to test the effects of moisture, site class and age. An additional 15 stands, surveyed by the B.C.F.S., were included in this analysis.

The majority of sites (41) had low weevil intensities. Four stands had medium attack intensity. Only one stand had a heavy attack intensity. Twelve stands contained no evidence of weevil activity.

A trend toward increased attack with increasing moisture was observed. Stands 16 to 20 years of age exhibited the highest mean attack proportion. However, an analysis of variance indicated no significance for moisture, site or age class. This may have been due to the relatively small sample sizes within each category. The trend toward attack of 16-20 year old stands supported the hypothesis that spruce trees taller than 9m are less susceptible to attack. The effects of deciduous shading (overstory) or stand density on weevil attack incidence could

not be quantified. This survey method was found to be fairly productive and accurate.

Contractor Recommendations: None.

Project Report: Lewis, K. 1989. Distribution and Incidence of White Pine Weevil in the Prince George TSA. B.C.F.S. Internal Report PM-PB-43. 42 pp.

Evaluation: All project objectives were met. Weevil incidence and damage levels were determined for the areas surveyed and data were analyzed for additional sites and examined by B.C.F.S. personnel. Unfortunately, firm correlations could not be made between attack intensity and site moisture, nutrient regime or age class. Suitable follow-up activity includes surveys of additional susceptible spruce plantations, especially in the Bowron area. An attempt should be made to quantify the effects of deciduous overstory as well as other site factors. In addition, long-term impact on volume should be assessed.

Project Status: Damage Appraisal Operational Trials and Modelling — Data base enhancement and appraisal.

White Pine Weevil: Pest Control Project JM-099

Title: Remeasurement of White Pine Weevil Damage and Impact in the Kitimat Valley.

Area Treated/Surveyed: 6 plots (4.5 ha).

Contractors: KDM Forest Services Ltd., Terrace.

B.C.F.S. Contact: T. Ebata, Prince Rupert Forest Region.

Region: Prince Rupert Forest Region.

Date: February to March, 1990.

Cost: \$4,950

Objectives:

1. Locate and measure all Sitka spruce in six permanent sample plots at Sites 1 and 2 in the Kitimat Valley. Measure the leader length of 100 unattacked trees, classify and record attacked trees, replace tags and summarize data per plot and per site by number of stems attacked annually and by total number and percentage of stems with attacks affecting more than two years of growth.

Description: This project was the final FRDA-funded assessment of weevil attack in Sitka spruce permanent sample plots in the Kitimat Valley.

A total of 384 core trees were measured and recorded. A total of 1,495 buffer trees were assessed and re-tagged. A large increase in attack was noted from 1986 to 1990 for both sites. The attack pattern became more uniform rather than clumped, as indi-

cated by other survey projects. Many trees exhibited multiple tops.

Weevil damage was lower in Site 1 than in Site 2 despite the presence of a supposedly protective deciduous overstory at the latter site. Buffer trees were attacked at approximately the same rate as trees in the plot centre.

The leader lengths of 100 unattacked trees and 332 attacked trees were measured. However, there was no significant difference in leader lengths between attacked and unattacked trees at either site. In addition, these data could not be used to calibrate the Spruce Weevil Attack Trial (SWAT) model of Forestry Canada since the total tree height was not measured.

Contractor Recommendations: None.

Project Report: Ebata, T., ed. 1990. Summary Report of a Spruce Weevil Survey in Permanent Sample Plots in the Kitimat Valley, E.P. 721: FRDA Projects PB-19 (1986-87), 28 (1987-88), JM-099 (1989-90). Contractors' Reports. 100 pp approx.

Evaluation: This project concluded remeasurement of permanent sample plots initiated in projects PB-19 and 28. An assessment of attack was made over a five-year period. In addition, information obtained from these projects will be applied to an assessment of long-term impacts caused by white pine weevil attack. Suitable follow-up activities include regular monitoring of plots at sites 1 and 2 for long-term damage appraisal.

Project Status: Damage Appraisal Operational Trials — Data base enhancement and appraisal of pest incidence and impact.

White Pine Weevil: Pest Control Project JM-105

Title: White Pine Weevil Surveys at Fair Harbour.

Area Treated/Surveyed: 1.3 ha.

Contractor: Ronald J. Frank Ltd., Merville, B.C.

B.C.F.S. Contacts: J. Muir, Silviculture Branch, Victoria; D. Heppner, Vancouver Forest Region.

Region: Vancouver Forest Region.

Date: March, 1990.

Cost: \$1,770

Objectives:

1. Survey three Sitka spruce plantations at Fair Harbour to determine the incidence of white pine weevil.

Description: Three untreated Sitka spruce plantations near Fair Harbour, Campbell River Forest District were surveyed to determine white pine weevil incidence and damage. These plantations had been previously surveyed circa 1978 and maintained as control areas for comparison with clipping trials.

Strips 5m wide were run at 100m intervals to sample 5% of each plantation. All spruce trees greater than 2m height were examined for 1989 and 1988 attacks by white pine weevil. The number of spruce attacked were tallied every 50m. For each plantation the following was summarized: total number of spruce stems, total incidence of 1988 attack, total incidence of 1989 attack, total trees attacked prior to 1988, and 50m strip tallies. A total of 2505m of strip was run.

At Block 1 the proportions of 1989, 1988 and pre-1988 attacked trees were 12.1%, 20.0% and 51.1% and at Block 2 they were 14.0%, 29.8% and 25.6%, respectively. At Block 3, 14.3%, 34.7% and 57.1%. Sporadic damage by gall aphid was also noted. Understory trees were less frequently attacked than dominant or open grown trees. Survey accuracy was hampered on Block 1 by dense brush and Sitka spruce.

Contractor Recommendations:

- Differentiate between overstory and understory Sitka spruce to improve the data base.
- Conduct future surveys before the brush has leafed out in order to improve survey accuracy.

Project Report: Frank, R.J. 1990. Comments on the Fair Harbour (Kaouk River) Sitka Spruce Weevil Survey, Blocks 1, 2 and 3. 8 pp.

Evaluation: These areas will be resurveyed to determine long-term volume reductions. The survey technique has been previously used and is considered operational. Data from this survey were used to determine the effectiveness of clipping in reducing the level of white pine weevil damage. In general, clipping probably was effective but was discontinued because of cost and operational difficulty. This treatment must be exceptionally thorough in order to be effective. Future control efforts include establishing trials of resistant Sitka spruce cultivars on the coast and in the interior.

Project Status: Damage Appraisal Operational Trial — Establish pest incidence and severity.

Vole (AV) Projects

Vole: Pest Control Project 41

Title: Vole Repellant Purchase.

Area Treated/Surveyed: 35 ha.

Contractor: Semiochemicals International Ltd., Calgary, Alberta.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Prince Rupert Forest Region.

Date: April, 1988 to March, 1989.

Cost: \$2,400.

Objective:

1. Purchase vole repellant devices for a control trial.

Description: Two thousand encapsulated vole repellant devices at \$1.20 each were purchased to protect 35 ha of cottonwood on one of the Skeena Islands in the North Coast Forest District. Of approximately 40,000 trees planted, the encapsulated repellant was attached to 14,000 to discourage vole feeding for up to two years. Sample plots were proposed for control and treatment areas to monitor the efficacy of the repellant.

Contractor Recommendations: None.

Project Reports: None.

Evaluation: Funds were strictly for repellant devices to support a study which was not funded.

Project Status: Complete — all work completed on operational control trial.

Multiple Pest: Disease, Insect, Abiotic & Animal Projects

Multiple Pest: Disease, Insect, Abiotic & Animal: Backlog Research Project 1.9

Title: Literature Review and Problem Analysis of Survey Methods for Insect Pests and Diseases in Young Stands.

Area Treated/Surveyed: None.

Contractor: Industrial Forestry Service Ltd., Prince George.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Regions: All.

Date: December, 1985 to March, 1986.

Cost: \$10,000.

Objective:

1. Review available pest survey methods and the means by which pest damage information might be accommodated within surveys of young stands, particularly for northern areas.

Description: A review was conducted of all survey methods currently used (1985) by government and industry. B.C.F.S. organizations covered included Silviculture, Inventory, Protection, Timber, 14 forest companies and Forestry Canada. The review found that some 25 types of general forest and silviculture surveys were employed by these organizations throughout the province. Industry generally utilized methods initially developed by government agencies. Surveys were most frequently conducted in mature stands prior to harvest, on newly regenerated areas, and on selected young stands before spacing and included the following types: timber cruise, classification, forest sampling, growth and yield, decay, PHSP, planting quality, survival, stocking and specific pest surveys. These surveys usually employed strips and/or plots for data collection.

Data on damage were collected on a regular basis during surveys of mature stands but relatively little or no information was obtained for younger trees, depending on the survey type. During surveys of

younger stands tree mortality was sometimes noted but the damaging agent(s) was not recorded. Usually, only representative healthy trees were sampled. In addition, data on acceptable regeneration were collected but no information on the cause(s) of unacceptable regeneration was gathered. Once an area was assessed as free-to-grow it was not re-examined for many years, creating the potential for serious problems to develop. Universal codes were not used in any surveys.

Several specific survey methods were employed, such as leader weevil and root disease assessments in coastal stands, but these methods were general enough to be applicable in younger northern stands which exhibit damage.

Contractor Recommendations: A more general damage survey was recommended for use with PHSP's, regeneration and spacing surveys. Other recommendations included:

- Develop and implement standard damage codes
- Develop a general damage survey for young stands to be performed after free-growing surveys
- Develop a general procedure to identify areas that require specific surveys
- Develop specific surveys for damage, such as animal damage and stem rusts/cankers, if these are found to be economically significant
- Create a field reference guide.

Project Report: Einfeldt, F. and J.D. Beardsley. 1986. A Review of Pest-Damage Survey Methods for Young Trees and Backlog Reforestation Areas in British Columbia. B.C.F.S. Int. Rep. PM-PB-32. 24 pp.

Einfeldt, F., J.D. Beardsley and J.A. Muir. 1987. A Review of Pest-Damage Survey Methods for Young Trees and Backlog Reforestation Areas in British Columbia. F.R.D.A. Rep. No. 013. 21 pp.

Evaluation: Results from this project formed a useful basis for the development of surveys for young stands in the Prince George and Prince Rupert forest regions. Many of the recommendations from this project were implemented between 1985 and 1987. Standard coding is now employed, several modifications to operational surveys have been made, other specific surveys are being developed,

and a field guide has been completed and distributed (1).

Project Status: Complete.

1. Finck, K., P. Humphreys and G.V. Hawkins. 1989. Field Guide to Pests of Managed Forests in British Columbia. F.R.D.A. Joint Rep. No. 16. 181 pp.

Multiple Pest: Disease, Insect, Abiotic & Animal: Pest Control Project PB-3a

Title: Subalpine Fir Assessment.

Area Treated/Surveyed: 42,000 ha.

Contractor: A. J. Stock Forest Management Services, Smithers.

B.C.F.S. Contact: T. Ebata, Prince Rupert Forest Region.

Region: Prince Rupert Forest Region.

Date: January to March, 1986.

Cost: \$13,000.

Objectives:

1. Locate and estimate the severity and extent of damage to subalpine fir stands using recent records and aerial sketch mapping.
2. Develop methods for the establishment of permanent sample plots (PSP's) to determine cause(s), future rates of mortality and stand susceptibility.
3. Make recommendations for specific stands and for larger units such as ecosystems or biogeoclimatic subzones to prevent or ameliorate damage and avoid potential understocked areas.

Description: The project was implemented in the Bulkley T.S.A. where subalpine fir accounts for a significant portion (41 %) of the local timber supply. The subalpine fir stands were suspected of having serious damage levels due to insects and diseases but additional data were required because previous surveys had not been intensive enough. Work consisted of sketch mapping from aerial photos and intensive aerial surveying followed by establishment of ground plots and transects but all flight reconnaissance had to be cancelled because of continuous poor weather.

Stands were assessed for intensity and extent of damage using large-scale maps and recent air photos. Affected area was determined using a dot grid and four classifications of damage were employed, based on percent of red foliage observed in the crowns. For unphotographed areas, the location and limits of infestations were established from aerial sketch maps produced from previous surveys. Affected areas on these maps were labelled as susceptible. Prism plots and transects were established in six representative stands in order to verify dam-

age estimates obtained from the photos. The transect method was more accurate for a clumped distribution of "red attack" while prism plots more accurately assessed "green or grey attack".

Results of the ground survey indicated that an average of 38% of the total volume was damaged for all tree classes in all stands, 60% of the damage being attributable to standing dead within the older age classes 8 and 9. The most common damaging agent was western balsam bark beetle. Diseases were present but an accurate assessment of their incidence could not be determined during winter. A tentative trend toward verification of damage levels obtained by aerial photos was derived from the ground surveys, however aerial estimates were probably too low. P.S.P.'s were not established during this project but methods for establishing these were proposed after close liaison with B.C.F.S. staff. The proposed plan for determining the causes, rates and associated characteristics of subalpine fir mortality included the following:

- Conduct a variable plot cruise to provide data on age of attacked trees; stand height, density, composition, basal area and volume and mean annual increment; and ecosystem association.
- Label and classify all trees by damage and record damaging agent.
- Establish five 15 ha blocks in representative areas with sampling at one plot per hectare. — monitor plots annually for five years or at two year intervals for ten years.

Contractor Recommendations:

- Conduct a more intensive aerial survey. Re-evaluate volume expectations in overmature subalpine fir stands since losses to bark beetle and decay may be higher than current projections. Determine how long standing dead trees remain merchantable. Consider any age class of 8 or 9 as being at risk; damage and risk in younger stands requires further study. Find an estimator of "green attack" success in order to better predict losses.
- Recommendations for specific stands were not made because results from this project were preliminary. It was considered that such recommendations would best be made after further survey work and/or measurements of plots have been completed.

Multiple Pest: Disease, Insect, Abiotic & Animal Projects

Project Report: Stock, A. J. 1986. Assessment of Pest Damage to Subalpine fir Stands in the Bulkley T.S.A. Contractor's Report. 16 pp.

Evaluation: To date, the proposal for establishing plots has not been implemented and there has been little follow-up on recommendations resulting from this project. Losses in overmature subalpine fir stands, as determined in this project, are greater than those allowed in the calculation of the Bulkley T.S.A. annual allowable cut, despite a generous allowance (50%) for decay and mortality. Further work on the cause(s) and rate of subalpine fir mortality is essential since 66.4% of the stands in this area are in the age classes most frequently dam-

aged, greatly increasing potential N.S.R. Thus, the following items need to be accomplished. Sufficient plots should be established and monitored as proposed. Besides obtaining data on cause(s), rate and associated stand characteristics, an estimator of green attack success might be obtained by thorough monitoring of these plots. A more intensive aerial survey should also be performed. Subalpine fir stands of all ages could then be rated for risk.

Project Status: Operational Detection Trial — method rated moderately to highly practicable; need data to substantiate operational use then should be fully practicable.

Multiple Pest: Disease, Insect, Abiotic & Animal: Pest Control Project PB-3b

Title: Subalpine fir Assessment.

Area Treated/Surveyed: 12 Sites.

Contractor: Pathocon Consulting, Prince George.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Prince Rupert Forest Region.

Date: October, 1986 to February, 1987.

Cost: \$10,900.

Objective:

1. Assess the damage from insects, diseases and abiotic factors in subalpine fir stands by means of survey strips and sample plots in order to determine the cause(s) of subalpine fir decline and mortality.

Description: This project was implemented to determine courses of subalpine fir decline and mortality in the Bulkley and Morice Timber Supply Areas. Substantial losses had been recorded in previous surveys of these areas but the causal agent(s) were unknown.

Twelve stands were surveyed, nine of which had been identified as having significant damage in project PB-3a. Intensive survey strips, 100 m long and 10 m wide, were placed through areas of high damage incidence. This method, which was non-random, was selected in order to determine all of the causal agents in damaged areas rather than to record pest incidence per se. Along each transect all declining and dead subalpine fir were examined and the associated insects or disease recorded. If necessary, specimens were sent to Forestry Canada for confirmation. Trees were mapped, numbered, and tagged for future remeasurement and crown and tree class were recorded. In addition, an ecological assessment of each area was performed.

Several insects and fungi were associated with 85 % of the affected trees while 15 % exhibited no known causal agents. Western balsam bark beetle, the most common, was found alone or associated

with several pathogens, notably *Inonotus tomentosus* and *armillaria* spp. The beetle was recorded in 55.8 % of afflicted trees. Root feeding beetles (*Hylurgops* spp.) were also noted. Root and butt rots were associated with 52.5 %, decays 5 to 8 %, needle diseases 1.2 % and abiotic factors 1.7 %. A high proportion (31.9 %) of trees attacked by western balsam bark beetle were affected by other damaging agents. Root disease was associated with decline and mortality alone or in combination with bark beetle attack, but the exact causal relationship could not be determined in this survey. Root disease was present on approximately 50 % of the sites investigated and was severe on three of these.

The study was not intended to formulate management strategies for specific stands. In addition, the incidence of blue stain fungi with respect to western balsam bark beetle infestation was not quantified.

Contractor Recommendations:

- Surveys should be conducted to adequately determine the extent of subalpine fir dieback and mortality outside of bark beetle attacked areas to determine the impact of the other damaging agents identified in this project.
- Stands examined in this survey should be closely monitored in future.

Project Report: Schulting, J. and M. Schulting. 1987. Causes of Decline and Mortality of Subalpine fir in the Bulkley and Morice Timber Supply Areas of the Prince Rupert Forest Region. Contractor Report. 24 pp.

Evaluation: All of the sites surveyed should be monitored for further decline and possible spread of any of the causal agents. Decline and mortality rates in subalpine fir could be determined if data on growth and infestation/infection rates were obtained from these sites on a regular basis. In turn, better information could supplement yield protection and analysis for subalpine fir stands and thus augment management plans for affected TSA's in the Prince Rupert Region.

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Project Status: Operational Detection Trial — method rated moderately to highly practicable;

need data to substantiate operational use then should be fully practicable.

Multiple Pest: Disease, Insect, Abiotic & Animal: Pest Control Project PB-IIa

Title: Damage Survey of Plantations in the Prince George Forest Region.

Area Treated/Surveyed: 3214 ha (41 plantations).

Contractor: Integrated Silviculture Services Ltd., Prince George.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria; S. Taylor (R. Cozens to 1988), Prince George Forest Region.

Region: Prince George Forest Region.

Date: October, 1986 to March, 1987.

Cost: \$18,300

Objectives:

1. Determine the incidence, type of damage and identity of causal agents in 41 plantations by means of transect lines to assess the impact of current and previous attacks.
2. Submit a final report with maps and floppy disk containing all data.

Description: A survey of 41 young (14-23 years old) plantations was conducted in the Prince George West, Prince George East, Vanderhoof and Fort St. James Forest Districts over five subzones of the SBS biogeoclimatic zone. Transects were established at 200m spacing with standard 3.99m radius silviculture plots every 100m for each plantation. Plot location was biased toward satisfactorily stocked portions of the sites surveyed in order to analyze any relationship between healthy and damaged trees. Damaged trees were recorded for 5m on either side of the line and all residuals were recorded within 20m. All damaging agents were recorded. Samples of damage caused by "unknown" agents, or suspected damage, were submitted for identification if a high incidence of these was found. Damaging agents included insects, disease, abiotic factors and animals.

Stands consisted of Douglas-fir, lodgepole pine and white spruce with a minor component of subalpine fir and black spruce. The SBS₂ biogeoclimatic subzone variant contained the highest percentage of damaged trees (42.5%), while the SBS₁ had the lowest (24.5%). Overall damage incidence was 31.3%, based on plot data. The Prince George East Forest District had the highest damage incidence at 39.2%, while the Vanderhoof Forest District had the lowest level at 21.7%. Lodgepole pine terminal weevil and western gall rust were the most serious, with 3.95 and 3.6% of the trees attacked, respectively. Leader die-back of Douglas-fir and northern pitch twig moth damage were also significant. Abi-

otic factors such as snow, wind or frost damage accounted for 9.6% of the damage.

Both current and older attacks caused a significant amount of deformity and potential volume loss in lodgepole pine. No significant correlation could be found between damaged trees, in terms of total tree density based on data from 20 of the areas surveyed. Data from the strip surveys indicated lower percentage attack values than from plots. This may have been due to inconsistent (patchy) stocking in most plantations and to biased plot locations. The ratio of attacked to healthy trees was considered to be accurate. Survey production varied, depending on stocking and damage levels. Production was 21.7 ha per person-day in the field, including access time, map review and summaries. A young tree pest survey card was produced for recording data in the field.

Contractor Recommendations:

- Conduct further studies on northern pitch twig moth and die-back of Douglas-fir to determine their significance.
- Conduct regular monitoring of plantations and stands to obtain a data base for improving forest management.
- Conduct spacing to reduce wind damage, reduce competition.
- Improve site prescriptions for some plantations, based on these results.

Project Report: Adamson, M.E. 1987. Young Tree Pest Survey for the Prince George Region. 9 pp.

Evaluation: All objectives were attained. This project provided a useful indication of damage incidence in young stands. However, an accurate assessment of plantations per district or biogeoclimatic subzone and variant requires a much larger survey. The relative ease with which pests could be incorporated into regular silviculture surveys indicated that this method is operational for the purpose of obtaining damage estimates. Future work should include regular monitoring of young plantations, reassessment of impact of northern pitch twig moth, and training silviculture survey crews in the identification of insects, disease, animal and abiotic signs and symptoms.

Studies on die-back have already been completed. Spacing should not be implemented as a control for wind damage until a significant correlation can be observed between decreased stand density and decreased damage.

Project Status: Detection Method Fully Practicable — Implement method on an operational basis.

Multiple Pest: Disease, Insect, Abiotic & Animal: Pest Control Project PB-IIb

Title: Pest Survey of Plantations and Young Stands in the Prince Rupert Forest Region.

Area Treated/Surveyed: 520 ha (104 units of 5 ha each).

Contractor: Laing and McCulloch Forest Management Services, Smithers.

B.C.F.S. Contact: S. Zeglen, Prince Rupert Forest Region (W. Martin to 1989).

Region: Prince Rupert Forest Region.

Date: July, 1986 to March, 1987.

Cost: \$25,000

Objectives:

1. Determine the incidence of damaging agents in stands less than 70 years of age in the Prince Rupert Forest Region.
2. Submit a final report with maps and a floppy disk containing all data.

Description: Basic survey procedures and standards defined by B.C.F.S. staff were assessed and modified during field trials on the first five sites. Maps and aerial photographs were examined for each selected stand. One or two 5 ha units were delineated in each area based on stand and site characteristics. Natural and artificially established stands were sampled as well as managed and unmanaged sites.

Transects 200m to 1000m long were established for each unit and were placed at 100m intervals if more than one line per unit was required. Each 100m of line represented one plot. Data on damage and damaging agents were collected within 5m of either side of the line. A sample card designed specifically for this project was used for this purpose. Stand information was tallied per 100m to derive totals per plot for density, composition and damage levels by causal agent. All residual trees were checked within 20m of each side of the line. Location was recorded on grid sheets. Samples were collected and submitted for verification by B.C.F.S. and Forestry Canada staff. Data were compiled by damaging agent, location of damage, tree species, age class, stand type, site class, subzone, and year of occurrence for each TSA.

A total of 84 stands was surveyed across the Prince Rupert Forest Region using 104 five ha sampling units. Stand age varied from 10 to 70 years and lodgepole pine, spruce, western hemlock, true fir and western red cedar in varying mixtures were examined.

A number of observations and apparent trends were noted. Significant levels of incidence were observed in localized areas for Warren's root collar weevil (lodgepole pine, occasionally on spruce), stem rusts (lodgepole pine), atropellis canker (lodge-

pole pine), *Pinneus* aphids (spruce), white pine weevil (spruce). Agents causing bud and/or foliage damage were also observed to be significant in some stands. Incidence of lodgepole pine terminal weevil, western hemlock dwarf mistletoe, *Inonotus tomentosus*, *Fomes annosus* and armillaria root disease was low and may have been stress-related. Northern pitch twig moth was low except in two localized areas where levels were 60.6% and 50%. Porcupine damage was noted in 82% of plots containing western hemlock in the Kalum Forest District.

At least some level of Warren's root collar weevil was recorded in 94% of all stands in which lodgepole pine was a component, affecting 6.5% to 12.6% of lodgepole pine and 4.1% to 4.8% of hybrid spruce, except in the North Coast to Kalum Districts. Stem rusts were present in 93% of pine stands 20 to 60 years of age. Rust incidence was frequently high in stands which had already been spaced. Atropellis canker incidence was higher in pine stands greater than 40 years of age, but mortality was rare. Frost damage was common in spruce in all six districts. Bud mortality appeared to be higher in planted stands than in natural stands. Ungulate damage was noted in 47% of all plots containing subalpine fir. Damage to foliage and buds due to disease occurred in 43% of the subalpine fir sampled. Frost damage affected 9.1% to 42.3% of the cedar in two areas and foliage flagging was noted in 33% of the cedar examined.

Overall, pest incidence was generally higher in the interior than on the coast. Brush competition was observed to be significant only on the coast. Production was less than anticipated at 4.22 100m plots per person-day. This figure included all related preparation and access time.

Contractor Recommendations:

- Summarize pest incidence and potential impact per tree species per TSA and Region in an easily communicated form.
- Improve production by reducing the range of stand and age classes sampled, reducing strip width, using 3.99m radius plots every 100m for silviculture characteristics, not recording residuals, not mapping disease location, measuring only potential free-growing trees, and not surveying known NSR areas.
- Analyze the role of pests with respect to the creation of NSR areas.

Project Report: McCulloch, L.D. and K.S. Laing. 1987. Pest Survey in Young Stands — Prince Rupert Forest Region. Contractor's Report. 20 pp.

Evaluation: Trends were noted but data were not analyzed because of excessive variability. The survey method was inefficient and awkward. It is

therefore not recommended. Instead, evaluate the survey technique used for young stands in the Prince George Forest Region (Project PB-11a). This method, utilizing narrow strips spaced at 100-200m intervals and standard 3.99m silviculture plots

every 100m, was much more productive and would be easier to implement.

Project Status: Detection Method Not Suitable for Operations — Do not implement on an operational basis.

Multiple Pest: Disease, Insect, Abiotic & Animal: Pest Control Project PB-23

Title: Editorial Assistance in Preparing F.R.D.A. Reports.

Area Treated/Surveyed: None.

Contractor: J.D. Beardsley and Associates Ltd., Victoria.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Regions: All.

Date: February to March, 1987.

Cost: \$6,400.

Objective:

1. Provide editorial assistance for preparing reports and establish report formats and standards.

Description: Editorial reviews were conducted and content completed for 13 F.R.D.A. reports. The report for Backlog Research Project 1.9 was revised in detail for publication as a F.R.D.A. Report. Standard formats were established for contractors' re-

ports and these were incorporated in the Protection Manual, Vol. II, in July, 1989.

Contractor Recommendations: As outlined in the Protection Manual, Vol. II, Chap. 16, Section 16.5.1.

Project Report: Addition to B.C.F.S. Protection Manual, Vol. II, Chap. 16: Writing Reports and Publications — Guidelines for Contractors Writing Reports and Publications. 16.5.1.

Evaluation: Standard formats were established for contractors' reports, as outlined in the B.C.F.S. Protection Manual, Vol. II. Thus, this project is complete. However, other project reports have not followed these standards. Future contracts should specify the requirement for adherence to report writing procedures and formats as outlined in the Protection Manual. Floppy disks (electronic copies) containing reports and/or data should also be forwarded to the B.C.F.S. contract supervisor upon project completion.

Project Status: Complete.

Multiple Pest: Disease, Insect, Abiotic & Animal: Pest Control Project 40

Title: Support Development of a Whole Forest Model Technique to Predict Pest Effects.

Area Treated/Surveyed: Modelling of 1 TSA.

Contractor: None.

B.C.F.S. Contacts: J. Muir, Silviculture Branch, Victoria; D. Errico, Research Branch, Victoria.

Region: Prince George Forest Region.

Date: October, 1987 to February, 1988.

Cost: \$2,000

Objective:

1. Support development of software and apply appraisal techniques to estimate impacts from several pests in a TSA in the Prince Rupert Forest Region and to help managers understand the general effects of catastrophic pest infestations.

Description: Funding was provided for travel to strategy and presentation meetings. Stand-level and forest-level models were developed which accounted for pest infestation and wild fire, with

probability of occurrence dependent upon stand age. The stand-level model consisted of formulae for long-run average yield and stumpage based on risk, with decreased volume occurring for increased risk and stand age. The forest-level model consisted of a harvest scheduling procedure, allowing for losses from pests and fire. The model was run with data for lodgepole pine from the Quesnel TSA, Prince George Forest Region. A variety of patterns of mountain pine beetle infestation was assumed.

Mountain pine beetle infestation intensities and attack periods were simulated, using an average annual rate. Based on current mountain pine beetle infestation data, short-term impacts with respect to timber supplies for a mill were considered to be significant for a period of 5-10 years. The long-run trend was not felt to be significantly affected. According to the scenario which was run, infected areas should be immediately harvested and replanted, regardless of the cost of rehabilitation. However, the model was not considered to provide a definitive analysis of pest problems in the Quesnel TSA, since this example was used for initial

model development. Other variables would have to be considered for input and additional trials implemented before greater accuracy can be attained.

Contractor Recommendations: None.

Project Report: Reed, W.J. and D. Errico. 1987. Techniques for Assessing the Effects of Pest Hazards on Long-run Timber Supply. Can. J. For. Res. 17: 1455-1465.

Evaluation: This project provided a general framework suitable for consideration of a variety of pests besides mountain pine beetle. However, long-term impacts on forest yield can only be adequately as-

sessed if rates of damage, infestation intervals and stand recovery rates are quantitatively understood. Other environmental variables also need to be considered. In addition, the model would have to be easy to run. Thus, the stand- and forest-level models are far from operational and any additional development and assessment should be conducted as research.

Project Status: Damage Appraisal Research Trials and Modelling — Development and evaluation of new modelling methods require research and replications before application in the field.

Air Pollution (NK) Projects

Air Pollution: Pest Control Project 46

Title: Evaluation of Remote Sensing Methods for Detecting Pollution Damage in Stands Affected by Sulphur Dioxide.

Area Treated/Surveyed: 10 plots.

Contractor: Innotech Aviation Enterprises Ltd., Ottawa; Ontario.

B.C.F.S. Contact: J. Beale, Vancouver Forest Region; P. Murtha, Department of Forest Resource Management, Faculty of Forestry, UBC.

Region: Vancouver Forest Region.

Date: August to September, 1988.

Cost: \$23,300

Objective:

1. Determine if pollution damage is identifiable using three remote sensing techniques and can be correlated to ground estimates of damage.

Description: This was a collaborative project, involving organizations in the U.S.A. as well as Forestry Canada, U.B.C., B.C. Ministry of Environment, Western Forest Products and the B.C.F.S. The study was located in the Port Alice area in western hemlock stands which had been severely, moderately or lightly damaged by sulphur dioxide (SO₂) emission from an adjacent mill which had been operating for 70 years. Approximately 200 ha of mortality had resulted.

Ground estimates in ten plots included visible assessment of crown damage, chemical analysis of foliage, and measurement of radial growth increment through tree-ring analysis. (The latter activity was completed during Project 50.) Ground verification plots were 30m x 30m in each damage class and were marked for the remote sensing overflights. Three control plots (undamaged) were also included.

Plots were chosen to be as similar as possible with respect to site index, stand composition and age to reduce variability. Trees were classified as to damage level, and DBH, height, and site index were recorded. Foliage samples were taken for

spectroradiometer analysis. Tree cores were taken for subsequent tree-ring analysis (Project 50).

Three remote sensing sampling methods were evaluated. Unfortunately, an evaluation of the (Portable Intelligent Display and Analysis Spectrometer) technique was not completed due to budgetary constraints. The PIDAS spectral reflectance measurement, an indicator of stress, was to be used as a ground reference for the two aerial remote sensing systems. The MEIS-II (Multi-Detector, Electro-optical Imaging Scanner) scanner obtained digital data in eight wavelengths at 1m and 5m resolutions. During data processing, pixels covering each plot were masked and exported for analysis in order to remove the extraneous effects of adjacent deciduous vegetation at both resolutions. NDVI (Normalized Difference Vegetation Index) and chlorophyll stress ratios were used to compare sample plots. NDVI has been commonly used to evaluate LANDSAT data for biomass estimates and was applied to both LANDSAT and MEIS-II data sets.

At 1m resolution, MEIS-II clearly showed greater NDVI values with increasing distance from the mill, indicating that SO₂ effects diminished with distance. NDVI values were negative in plots ground-assessed as severely damaged. Individual crowns on a single plot could be grouped into several stress categories. This discrimination was lost when pixel resolution dropped from 1m to 5m. This result may have been due to shading. LANDSAT TM-based NDVI could not differentiate between live and dead vegetation, but did rank the damage categories according to the ground damage assessments. The LANDSAT data resolution was too coarse to determine the extent of pollution damage. Thus, site specific analyses of SO₂ stress requires the resolution provided by the 1m MEIS-II data. Measurement would be further improved at finer resolution.

Contractor Recommendations:

- Collect data over time to detect changes in stress.

Air Pollution (NK) Projects

- Remeasure plots at the 1m resolution where plots were missed.
- Further analyze NDVI for classifying damage.
- Test fine resolution data on ecologically similar sites.
- Develop techniques to relate information derived at different scales.

Project Report: Murtha, P.A. 1990. Final Report on the Analysis of the Thematic Mapper Data and the MEIS-II Airborne Scanner Data for the Port Alice Sulfur Dioxide Forest Damage Appraisal Study. Contractor's Report. 28 pp, illus.

Evaluation: The project objectives were attained with the exception of an evaluation of PIDAS. Four problems arose which might have affected the results of this study. An important part of the electro-

magnetic spectrum (in the region of 633nm) with respect to assessing stress was not imaged in the study. Several plots were not measured at 1m resolution with MEISII. Data were collected only for one time. Finally, plots were not all ecologically similar. Despite these problems, this initial work established the usefulness of MEIS-II remote sensing in determining Sulfur dioxide-related damage. Suitable follow-up activities include all of the contractor recommendations. Further work should also include surveys of other affected areas and evaluation of the 633nm region of reflectance.

Project Status: Operational Detection Trial — method rated moderately to highly practicable; need data to substantiate operational use then should be fully practicable.

Air Pollution: Pest Control Project 50

Title: Tree Growth-Ring Measurement and Analysis from Trees in Stands Affected by Sulfur Dioxide.

Area Treated/Surveyed: Samples from 7 sites.

Contractors: Pacific Coast Forest Biology, Victoria.

B.C.F.S. Contact: J. Muir, Silviculture Branch, Victoria.

Region: Vancouver Forest Region.

Date: October, 1988 to March, 1989.

Cost: \$7,200

Objectives:

1. Measure increment core samples from approximately 300 trees in the Port Alice Pollution Damage Survey Project.
2. Conduct tree-ring cross-dating, run cross-dates data and provide average tree-ring chronologies for each plot.

Description: This project was part of the larger remote sensing Project 46. Tree cores from ground truthing plots were analyzed. Two cores were collected per tree from plots assessed as severely or moderately damaged or control (healthy), based on visible crown symptoms. Lightly damaged trees were assessed by other sensing means since this damage category was defined as consisting of trees without visible stress symptoms. Thus, control plots probably contained some affected trees. Each plot contained 25 to 30 sample trees. A total of 155 western hemlock core pairs from three control, two moderately, and two severely damaged plots were measured and analyzed.

Tree-ring measurements of the core samples were performed on a Digi-Mic digital micrometer which was linked to a VAX mainframe. Analysis of growth patterns was performed using the TREERING, INDEX and SAS programs. Core pair data were averaged where little or no discrepancy existed between core pairs. Unfortunately, 44 sample

trees had to be removed from the data due to unresolvable age discrepancies between pairs and very high variability during the cross-dating procedure. Variance was reduced by means of a cubic-spline function and the data set was truncated at 1940 due to excessive variance before this date. Data were sorted by plot and SAS MEANS, GLM and GPLOT procedures were performed. An analysis of variance was used to test for significant effects of damage levels on the last ten years of growth.

There was a significant decrease in growth over the last 10 years in core samples from moderate to severe damage plots relative to samples from control plots. There was no significant difference in the last 10 years' growth between the moderate and severe categories. For these categories, despite a very visible difference in the appearance of trees in these plots, confidence intervals overlapped or were extremely close over a 35-year period. This was probably the result of the ring growth characteristics of western hemlock under a prevailing mild and relatively steady climate. Other species, notably lodgepole pine and Douglas-fir, have much more distinct growth rings, but these species did not grow in the area under investigation. It is interesting to note that MEIS-II and PIDAS remote sensing data showed more differences between damage categories than results of the tree-ring analysis. In any case, radial increment is only one indication of tree health.

Contractor Recommendations: None.

Project Report: Hawkins, G.V. 1989. Port Alice Sulfur Dioxide Forest Damage Appraisal Methods Evaluation Study. Contractor's Report. 8 pp.

Evaluation: Tree-ring analysis did not provide an entirely satisfactory method of differentiation between damage categories compared to either visual estimates or remote sensing techniques (MEIS-II and PIDAS). Damage could be differentiated at a

coarse level only with this technique. This project can be considered as part of a larger study completed under Project 46. As a technique for verifying pollution damage, tree-ring analysis is not

recommended for further follow-up in an operational mode.

Project Status: Complete.

Bark Beetles (IB) Projects

Bark Beetles: Pest Control Project PB-18

Title: Establishment of Plots to Evaluate the Effectiveness of Fall and Burn Treatment.

Area Treated/Surveyed: 54 ha surveyed, 26 ha treated.

Contractor: Ron Klassen, Telkwa.

B.C.F.S. Contact: T. Ebata, Prince Rupert Forest Region.

Region: Prince Rupert Forest Region.

Date: February to March, 1987.

Cost: \$3,850.

Objective:

1. Determine the effectiveness of the fall and burn program for controlling mountain pine beetle by monitoring the rate of spread in conjunction with mortality surveys in untreated areas.

Description: Six plots, each nine hectares in size, were established in three infested, overmature lodgepole pine stands in the Bulkley Forest District. Study blocks were pairs of one control and one treatment (fall and burn) plot. Plots of each pair were separated by at least 200 m in order to reduce the effect of beetles from the control units affecting treated areas. Falling and burning followed stand-

ard procedures. Blocks were flagged in a 25 m by 25 m grid for simplified recording of infested trees. Reassessment occurred three times in the autumn after the plots were established. The first remeasurement took place under Project 35 and the other reassessments were conducted with district funds.

Contractor Recommendations: None.

Project Reports: Ebata, T. 1989. F.R.D.A.-B.C.F.S. Direct Delivery Funds Pest Control Project Report: Fall and Burn Efficacy Trial. 3 pp plus plot maps.

Evaluation: Subsequent reassessments revealed that only one site showed the expected result of a decrease in attacks after treatment. This occurred because the fall and burn treatment was incorrectly carried out in two of the blocks. Thus, results were inconclusive, a quantitative evaluation was not possible, and this project remains incomplete to date. Continuation of the trial for two or three more years may provide more conclusive information. Other suitable follow-up activities include a replication of this trial and an analysis of four consecutive years of beetle probe data.

Project Status: Incomplete — control trial not complete due to inconsistent treatment and results.

Bark Beetles: Pest Control Project 35

Title: Remeasurement of a Fall and Burn Treatment for Mountain Pine Beetle Control.

Area Treated/Surveyed: 54 ha.

Contractor: R.P. Rowsell Contracting Ltd., Smithers.

B.C.F.S. Contact: T. Ebata, Prince Rupert Forest Region.

Region: Prince Rupert Forest Region.

Date: December, 1987 to January, 1988.

Cost: \$2,800.

Objective:

1. Remeasure the treatment and control blocks established under Project PB-18 in order to assess the efficacy of fall and burn treatment in controlling mountain pine beetle infestations, and perform plot maintenance.

Description: A fall and burn efficacy trial, established under Project PB-18, was remeasured. All six blocks were resurveyed using the established 25 m

grid system. Current attacks were marked and mapped to update infestation data. Plots were re-flagged where required and maps and plot summaries were submitted. Unfortunately, the district did not burn all of the infested and felled trees in the winter of 1986-87 on some of the treatment blocks. To compound this problem, paired blocks were not situated in stands with the same density of susceptible pine and pheromone traps were inadvertently placed in the area. Thus, beetle attack patterns varied widely. Only one site, Gramophone Creek, exhibited results consistent with the treatment. Consequently, data from the first three years cannot be used for an analysis of efficacy.

Contractor Recommendations:

- Monitor the plots for one to three more years.

- Review and analyze four consecutive years of beetle probe data to determine fall and burn efficacy.

Project Report: Ebata, T. 1989. F.R.D.A.-B.C.F.S. Direct Delivery Funds Peet Control Project Report: Fall And Burn Efficacy Trial. 3 pp plus maps.

Evaluation: Unfortunately, results for the first three years are inconclusive and the project remains incomplete. More conclusive results may be provided if this trial is continued for two or more years. Other suitable follow-up activities include a replication of this trial, and an analysis of four consecutive years of beetle probe data.

Project Status: Incomplete — control trial incomplete due to inconsistent treatment results.

Appendix 1

Project Number	Title	Damaging Agent
PB-1	<i>Stump and Root Removal Trial for Root Disease Treatment.</i>	Laminated Root Rot
PR-1	<i>White Pine Weevil Survey and Control in Southern Plantations in the Kitimat Valley.</i>	White Pine Weevil
1.9	<i>Literature Review and Problem Analysis of Survey Methods for Insect Pests and Disease</i>	Multiple Pest
NE-2	<i>Establishment of Ingersoll Creek (Whatshan Lake) White Pine Demonstration Area.</i>	White Pine Blister Rust
PB-2	<i>Lodgepole Pine Dwarf Mistletoe in the Prince George Forest Region.</i>	Lodgepole Pine Dwarf Mistletoe
2.28	<i>Root Disease Assessment in Coastal Rehabilitation Areas.</i>	Laminated Root Rot
2.28	<i>Root Disease Assessment in Coastal Rehabilitation Areas.</i>	Laminated Root Rot
2.53	<i>Extension and Demonstration Activities for Rehabilitation Site Assessment Procedure.</i>	Laminated Root Rot
PB-2a	<i>Analysis of Plot Data From a Lodgepole Pine Dwarf Mistletoe Survey in the Prince George Forest Region</i>	Lodgepole Pine Dwarf Mistletoe
3.7	<i>Remeasurement of Lodgepole Pine Stem Rust and Canker Permanent Sample Plots.</i>	Stem Rusts and Cankers
3.8	<i>Development of Root Disease Survey Methods for Southern Interior Stands and Plantations.</i>	Multiple Root Disease
3.8	<i>Survey of Root Disease on Backlog Non-satisfactorily Restocked Areas.</i>	Multiple Root Disease
PB-3a	<i>Subalpine Fir Assessment.</i>	Multiple Pest
PB-3b	<i>Subalpine fir Assessment.</i>	Multiple Pest
PB-4	<i>Root Residue Surveys.</i>	Laminated Root Rot
PB-5a.	<i>Review of Root Disease Sampling Methods.</i>	Multiple Root Disease
PB-5b	<i>Evaluation of Three Root Disease Survey Methods for Interior Douglas-Fir Stands.</i>	Multiple Root Disease
27	<i>Laminated Root Rot Hazard and Yield Reduction in Coastal Douglas-fir Ecosystems.</i>	Laminated Root Rot
PB-11a	<i>Damage Survey of Plantations in the Prince George Forest Region.</i>	Multiple Pest
PB-11b	<i>Pest Survey of Plantations and Young Stands in the Prince George Forest Region</i>	Multiple Pest
PB-10	<i>White Pine Weevil Silvicultural Control Trial Establishment.</i>	White Pine Weevil
PB-12	<i>Tomentosus Root Rot PSP Establishment.</i>	Tomentosus Root Rot

Project Number	Title	Damaging Agent
PB-14	<i>Tomentosus Root Rot Survey for Permanent Sample Plots (PSP's) and Demonstration Area.</i>	Tomentosus Root Rot
PB-15a	<i>Porcupine Survey in the Kalum Forest District.</i>	Porcupine
PB-16	<i>Tomentosus Root Rot Control Trial Area Survey and Lay-out.</i>	Tomentosus Root Rot
PB-17	<i>Root Disease Silvicultural Assessment.</i>	Multiple Root Disease
PB-18	<i>Establishment of Plots to Evaluate the Effectiveness of Fall and Burn Treatment.</i>	Bark Beetles
PB-19	<i>Assess Permanent Sampling Plots in the Kitimat Valley for White Pine Weevil Incidence.</i>	White Pine Weevil
PB-20	<i>White Pine Weevil Surveys in the Kitimat Valley, Prince Rupert Forest Region.</i>	White Pine Weevil
PB-21	<i>Morictown Spruce Root Rot Survey for Stumping Trial.</i>	Tomentosus Root Rot
PB-22	<i>Stem Analysis to Determine the Impact of Lodgepole Pine Dwarf Mistletoe.</i>	Lodgepole Pine Dwarf Mistletoe
PB-23	<i>Editorial Assistance in Preparing F.R.D.A. Reports.</i>	Multiple Pest
23	<i>Porcupine Problem Analysis.</i>	Porcupine
PB-24	<i>Investigation of Black Army Cutworm Infestations.</i>	Black Army Cutworm
24a	<i>Porcupine Control Trials.</i>	Porcupine
24b	<i>Supply Information on Porcupine Damage and Control Requirements to the Public.</i>	Porcupine
25	<i>Tomentosus Root Rot Survey for Data on Occurrence and Infection.</i>	Tomentosus Root Rot
26	<i>Branch and Leader Dieback of Young Douglas-fir in the Central Interior.</i>	Stem Rusts and Cankers
28	<i>Remeasurement of Sitka Spruce Plots for White Pine Weevil Damage in the Kitimat Valley.</i>	White Pine Weevil
029	<i>Root Disease Spacing Trial.</i>	Armillaria Root Disease
30	<i>Morictown Tomentosus Root Rot Stumping Trial.</i>	Tomentosus Root Rot
31	<i>Detailed And Intensive Management of Possible Blister Rust Resistant White Pine at The Ingersoll Creek Demonstration Area.</i>	White Pine Blister Rust
32	<i>Halfway White Pine Pruning And Spacing Trial — July 1987 Remeasurement.</i>	White Pine Blister Rust
33	<i>Larch Mistletoe Spacing Trial.</i>	Larch Dwarf Mistletoe
034	<i>Trial of a Regeneration Survey Modified to Assess Armillaria Root Disease.</i>	Armillaria Root Disease
35	<i>Remeasurement of a Fall and Burn Treatment for Mountain Pine Beetle Control.</i>	Bark Beetles
38	<i>Evaluation of a Root Disease Model.</i>	Multiple Root Disease
40	<i>Support Development of a Whole Forest Model Technique to Predict Pest Effects.</i>	Multiple Pest
41	<i>Vole Repellant Purchase.</i>	Vole
PB-42	<i>Stem Analysis to Determine Tree Volume Correction Factors.</i>	Lodgepole Pine Dwarf Mistletoe
43	<i>Remeasurement of White Pine Weevil Silviculture Control Trial.</i>	White Pine Weevil
44	<i>Demonstration of a Root Disease Model in B.C.</i>	Multiple Root Disease
45	<i>Tomentosus Root Rot Survey: Data on Infection of Young Trees and Tests for Disease Responses to Infection.</i>	Tomentosus Root Rot

Appendix 1

Project Number	Title	Damaging Agent
46	<i>Evaluation of Remote Sensing Methods for Detecting Pollution Damage in Stands Affected by Sulphur Dioxide.</i>	Air Pollution
47	<i>Evaluate, Mark and Reserve White Pine Trees With Potential Genetic Resistance to White Pine Blister Rust.</i>	White Pine Blister Rust
PB-48	<i>Remeasurement of Lodgepole Pine Dwarf Mistletoe Sample Plots.</i>	Lodgepole Pine Dwarf Mistletoe
49	<i>Data Summary and Analysis From Tomentosus Root Rot Permanent Sample Plots.</i>	Tomentosus Root Rot
50	<i>Tree Growth-Ring Measurement and Analysis from Trees in Stands Affected by Sulfur Dioxide.</i>	Air Pollution
51	<i>Site Assessment for the Arrow TSA.</i>	Multiple Root Disease
52	<i>Trial Porcupine Hunting Program.</i>	Porcupine
053	<i>Knappen Creek Armillaria Control Trial: Area Survey and Layout.</i>	Armillaria Root Disease
54	<i>Rhizina Root Disease Surveys.</i>	Rhizina Root Disease
055	<i>Quartz Creek Armillaria Root Disease Survey.</i>	Armillaria Root Disease
056	<i>Survey For an Armillaria Root Disease Control Trials.</i>	Armillaria Root Disease
057	<i>Costs for Travel to Columbia West Stumping Trial.</i>	Armillaria Root Disease
58	<i>Salmon Arm Root Disease Survey.</i>	Multiple Root Disease
59	<i>Knockholt Root Disease Control Trial.</i>	Tomentosus Root Rot
JM-060	<i>Remeasurement of Forestry Canada Rust Spacing Trial at Ootsa Lake.</i>	Stem Rusts and Cankers
061	<i>Columbia West Road Stumping Trial for Control of Armillaria Root Disease.</i>	Armillaria Root Disease
PB-62	<i>Dwarf Mistletoe Growth Effects.</i>	Lodgepole Pine Dwarf Mistletoe
PB-63	<i>Dwarf Mistletoe Survey Procedure.</i>	Lodgepole Pine Dwarf Mistletoe
JM-064	<i>Cariboo Root Disease Survey — Phase I.</i>	Multiple Root Disease
JM-065	<i>Soil Analysis of Plots Established to Determine Rhizina Root Disease Guidelines.</i>	Rhizina Root Disease
JM-066	<i>Establishment of Texada Island Seed Production Area (S.P.A.).</i>	White Pine Blister Rust
JM-070	<i>Cariboo Root Disease Survey — Second Phase.</i>	Multiple Root Disease
JM-072	<i>Blackstain Root Disease Survey.</i>	Blackstain Root Disease
JM-073	<i>Root Collar Weevil Survey.</i>	1989-90 Project Number
JM-076	<i>Completion of Tomentosus Root Rot Survey: Data on Infection of Young Trees, Inoculations, Clonal Analysis and Infection Biology.</i>	Tomentosus Root Rot
JM-078	<i>Porcupine Hunting Program.</i>	Porcupine
JM-079	<i>Knockholt Tomentosus Root Rot Spacing Trial.</i>	Tomentosus Root Rot
JM-080	<i>White Pine Weevil Surveys in the Kitimat Valley, Prince Rupert Forest Region.</i>	White Pine Weevil
JM-082	<i>White Pine Weevil in Spruce Plantations in the Prince George Forest Region.</i>	White Pine Weevil
JM-083	<i>Texada Island (Pocahontas) White Pine Workshop.</i>	White Pine Blister Rust
JM-084	<i>Satellite Imagery for Forest Disease Surveying.</i>	Multiple Root Disease
JM-086	<i>Management of White Pine Demonstration Area, Whatshan Lake.</i>	White Pine Blister Rust
JM-087	<i>Salmon Arm Root Disease Survey.</i>	Multiple Root Disease

Project Number	Title	Damaging Agent
JM-088	<i>Soil Sampling for Rhizina Root Disease.</i>	Rhizina Root Disease
JM-089	<i>Determination of Growth Reduction in Lodgepole Pine Due to Dwarf Mistletoe Infection.</i>	Lodgepole Pine Dwarf Mistletoe
JM-090	<i>Root Disease Survey of Spaced Stands in the Port Alberni Forest District.</i>	Laminated Root Rot
JM-091	<i>Satellite Imagery for Forest Disease Interpretation.</i>	Multiple Root Disease
JM-092	<i>Rhizina Root Disease Pathology.</i>	Rhizina Root Disease
JM-093	<i>Hemlock-Dwarf Mistletoe Damage Assessment.</i>	Hemlock Dwarf Mistletoe
JM-094	<i>White Pine Cone Bagging at the Texada Island Seed Production Area (S.P.A.).</i>	White Pine Blister Rust
JM-095	<i>Soil Analysis for Laminated Root Rot Hazard and Yield Reduction Survey.</i>	Laminated Root Rot
JM-096	<i>Ecological Assessments for a Laminated Root Rot Survey.</i>	Laminated Root Rot
JM-097	<i>Satellite Imagery for Forest Disease Surveys.</i>	Multiple Root Disease
JM-099	<i>Remeasurement of White Pine Weevil Damage and Impact in the Kitimat Valley.</i>	White Pine Weevil
JM-100	<i>Blackstain Root Disease Survey on Southern Vancouver Island.</i>	1989-90 Project Number
JM-101	<i>Wickman Creek Armillaria Survey Assessment.</i>	Armillaria Root Disease
JM-102	<i>Compilation of Lodgepole Pine Dwarf Mistletoe Survey Data Compilation (Project PB-2).</i>	Lodgepole Pine Dwarf Mistletoe
JM-103	<i>Ecological Description of Blackstain Root Disease Monitoring Plots.</i>	1989-90 Project Number
JM-104	<i>Laminated Root Rot survey of the Stamp Falls Demonstration Area.</i>	Laminated Root Rot
JM-105	<i>White Pine Weevil Surveys at Fair Harbour.</i>	White Pine Weevil
JM-106	<i>Soil Analysis for Laminated Root Rot Survey.</i>	Laminated Root Rot

