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Assessment of Spruce Budworm Impacts In the Hawk Hills Management Area
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(Final Comprehensive Project Report)

by

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October 21, 1998

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DISCLAIMER

The study on which this report is based was funded by the Manning Diversified Forest Products Research Trust Fund which is a component of the Government of Alberta's Environmental Protection and Enhancement Fund. The views, statements and conclusions expressed and the recommendations made in this report are entirely those of the authors. And should not be constued as the statements, conclusions, or opinions of members of the Manning Diversified Forest Products Research Trust Fund Committee, the Government of Alberta, or the Alberta Forest Research Advisory Council.

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ABSTRACT

The behavior of the spruce budworm in white spruce stands in sprayed and unsprayed blocks was contrasted. Populations in blocks sprayed operationally with BTK were suppressed for 2 years. Where population suppression was used populations were suppressed up to and including the generation that fed in 1997. Cost benefit analyses evaluated on the impacts of the pest on tree growth alone suggest that all control strategies investigated were superior to simply letting the outbreak run its course. However, a preemptive strategy that prevents stands from becoming damaged is best. If tree mortality is considered the benefit cost analyses are even more persuasive. The impact of budworm feeding on the scenic beauty of forest stands was evaluated using survey instruments. It is concluded that the effects of chronic defoliation has a significant impact on the quality of the scenes perceived by the general public and Forest Protection officers

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Andu Yohannes supervised the spruce budworm collections and other field work. Bradley Tomm supervised the collection and processing the tree disks for radio-graphic analysis and processing of these images. Robert Lucas, John Brace and Charity Brière did much of the counting and processing of insects. In addition we thank the many summer students that assisted in field sample processing for the population estimates. Wolfgang Haider assisted in the assessment of images and Dieter Kuhnke made an effort at helping with the acquisition of visual impact data. Thierry Varem-Sanders assisted in the preparation of the test images. Several volunteers from the Manning area, the Northwest Boreal Region of Alberta Environmental Protection and the Northern Forestry Centre served as subjects for rating the visual impact scenes. We are grateful for all this assistance.

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PROLOGUE

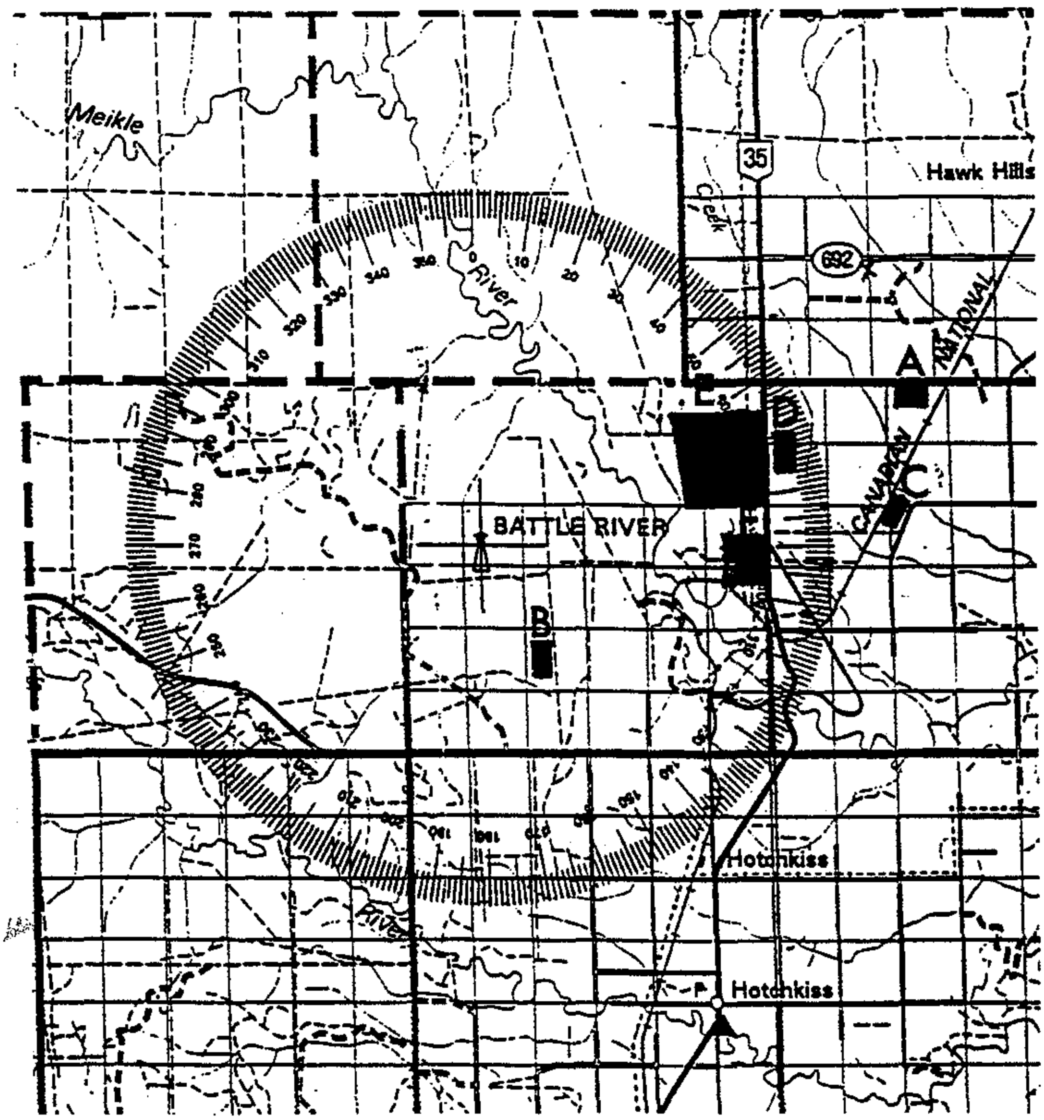
This is the final report on work conducted on a project entitled: **"Assessment of spruce budworm impacts in Hawk Hills Management Area"**. This work was funded, in part, by the **Manning Diversified Forest Products Research Trust Fund** and is based on the proposal attached in Appendix A. The report has three parts: 1) a discussion of budworm population behaviour in the Hawk Hills area as determined by annual population samples going back to 1990, 2) a description of the physical impact of the spruce budworm on trees that were and were not protected from budworm feeding together with an evaluation of the benefits and costs of controlling budworm, and 3) the final part incorporates the evaluation of budworm impacts on non-timber values concentrating on scenic values.

Background

The spruce budworm, *Choristoneura fumiferana* (Clem.) (Lepidoptera: Tortricidae), is a serious defoliator of Abietoid conifers found in the boreal forest of Canada. In the western boreal forest the principal host of the insect is white spruce (*Picea glauca* (Moench)). In Alberta, and adjacent jurisdictions, systematic records of outbreaks have been conducted annually for several decades. The picture that emerges from these records is that spruce budworm outbreaks last for several years, reduce tree growth, cause tree mortality in prolonged outbreaks, and outbreaks may be terminated by late spring frosts that destroy the current year's foliage before the insect completes its feeding (Cerezke and Volney 1995).

In 1989 an outbreak was detected in white spruce stands of two townships (Tp 95, R 22 & R 23 W 5th Principal Meridian) in the Hawk Hills Management Area. In 1990 two blocks were sprayed experimentally with a preparation of *Bacillus thuringiensis* var *kurstaki* (BTK). Block E (Fig. 1), west of Highway 35 was sprayed with FUTURA HP whereas Block D, east of the highway, was sprayed with FUTURA O. Both blocks were treated with 30 Billion International Units (BIU) per ha of BTK. A check block (F) was located 1 km south of the two spray blocks and received no treatment. In 1991 these blocks were treated again with BTK, this time the product used was DIPEL 132. Block D received 2 applications at 25 BIU/ha while block E received one application of 25 BIU/ha. In addition, two isolated blocks (A and B) were treated with two applications of 50 BIU/ha each. A second untreated block C was also established in an untreated isolated stand. Details of the results of these trials are provided in confidential file reports (Volney 1990 and 1992). In summary, the populations in the isolated blocks (A and B) were suppressed with a consequent recovery of the stands whereas the populations in blocks D and E were reduced to the point where defoliation was negligible for several years after spraying.

Figure 1. The general plot layout in the Hawk Hills Management Area.



PART I: POPULATION STUDIES & TREE GROWTH

by

W. Jan A. Volney and David O. Watson

INTRODUCTION

The overall objectives of the current study were to continue spruce budworm population assessments within the blocks so that their effects on defoliation, tree growth and tree mortality can be described.

The second objective is to assess the damage caused by the insects and describe the impacts of the insect on forest productivity. Thirdly the information impacts can be used to develop an understanding of the economic impacts of the budworm on both timber and non-timber values in the Hawk Hills Management Area. These objectives are more fully described in the original proposal (Appendix A).

The specific objectives for the population sampling were:
1. Re-sample the 24 plots in the 4 treated and 2 untreated spruce budworm populations and determine the spruce budworm densities at 3 life-stages and the budworm caused defoliation at the end of the feeding period.

2. Select and dissect 96 white spruce trees in the treated and untreated blocks and conduct stem analyses on these trees to assess the impacts on tree growth.

3. Conduct a literature review on the economic impacts of pests in forest stands.

METHODS

Population Studies

Population densities were determined on each of the sample plots at the late larval stage and the pupal stage of the spruce budworm generation feeding in the spring. In addition, egg mass densities were determined for the subsequent generation. Defoliation levels due to feeding in the current year were determined when egg mass densities were determined. Population densities and defoliation were determined by cutting two branches from the mid-crown of each of 4 trees in each plot. The 45 cm tip from each branch was removed and used as the standardized branch sample (Volney 1990). There are 4 plots in each block, thus 32 branch samples serve as the basis of population estimates in each block. The branch samples were examined for insects and the counts recorded. Defoliation was assessed by the Fettes method modified for white spruce foliage. This method requires that 10 current year shoots be examined and classified for the percentage defoliation. The mean defoliation class per branch is then used in calculating an average for the plot.

Stem Analyses

Four trees were selected in each of the 24 sample plots for stem analyses in the spring of 1995 (before the 1995 growth commenced). A mark 1 m from the base of the tree was painted on the trees and then the tree was felled by cutting the stem midway between the base of the tree and the mark. The total height of the felled tree was determined and cross section disks were cut from the stem at 1 m intervals starting with the base and ending with the disk within 1 m of the tree's apex. These disks were labelled, returned to the laboratory and kept refrigerated at -2^0 C until processed. Each disk was sanded and a longitudinal section 2 mm thick that included the pith and bark was removed. This section was mounted on a jig together with other sections from the same tree and an X-ray photograph was taken. The X-ray image of the section was then scanned electronically and the resulting image processed to obtain tree ring widths, remove false rings, and add missing rings. The array of tree-ring widths thus obtained were used to calculate the annual volume growth of the tree from the time of its germination to 1994.

The information derived from the trees thus obtained was further reduced to calculate a mean annual specific volume increment. This is the mean volume put on by a one square cm of the tree's cambium (and is also the average radial growth over the whole surface area of the whole stem). The year 1988 was chosen as the year against which all subsequent growth would be compared because the budworm had not yet started to visibly damage trees. In the analysis, the trees annual specific volume increment for 1988 was designated 100%. The mean growth of trees since 1988 was analysed using analysis of variance (ANOVA). Calculations were performed using the GLM procedure in SAS (SAS 1985).

Economic Studies

The literature was searched to identify papers that dealt with economic concerns associated with pest management. The literature data bases searched were: TREE-CD, AGRICOLA and CAB. In addition, the journals that carry such articles were scanned for citations. The literature database is current as of March 15, 1996. Summaries of the relevant citations are found in Appendix B.

RESULTS

Population Studies

The population estimates for the blocks that were sprayed in 1990 and again in 1991 as well as their check block (blocks E, D & F) are presented in Tables 1 to 3. Initially larval populations were highest in Block E and comparable in blocks D and the check F (Table 1). There was a substantial reduction in the two treated blocks while the population in the check remained high in 1991. This persisted for two years. By 1994, however, the populations were apparently comparable and in 1995 the populations in the treated blocks were as large as in the check. (However, see below.)

Table 1. Late larval spruce budworm population per 45-cm mid-crown branch tip

	Block		
Year	D	E	F
1990	80.3	214.3	100.9
1991	36.0	28.5	82.0
1992	16.2	29.2	50.4
1993	15.9	21.1	46.4
1994	4.0	6.8	5.9
1995	11.4	5.7	7.0
1996*	0.5	1.3	1.0
1997	4.4	5.4	2.2

* Note that the population estimate is based on larvae in the pupal sample.

Nevertheless, these population levels were low compared to the initial population densities.

Similar trend occurred with the pupal populations, but the reductions were even more dramatic after the 1991 sprays when there was a 100 fold reduction in block E relative to the population in the check block (Table 2). The apparent rebound in the population in 1994 and 1995 is also evident. The population in the treated blocks remained above that in the check blocks until 1997. In 1997 no pupae were found in the sample. Evidently the local population collapsed in the area although there was a catch of male moths in pheromone traps.

Table 2. Spruce budworm pupal population per 45-cm mid-crown branch tip

	Block		
Year	D	E	F
1990	43.4	47.0	100.9
1991	8.0	0.95	82.0
1992	1.0	29.2	45.5
1993	1.0	5.8	29.5
1994	2.9	5.4	1.8
1995	7.3	4.44	2.8
1996	4.9	4.9	3.5
1997	0.0	0.0	0.0

Egg mass population densities are a reflection of what occurs locally in the block and the influence of migration. They also represent the new generation for the year, thus the influx of moths in 1993 and 1994 probably laid the eggs (Table 3) that gave rise to the populations in 1994 and 1995. It is clear that in 1997 eggs were again laid in the stands and that this was the highest population recorded in block D and the second highest detected in Block E since the experiment began. The egg population in the check block, F, does not appear high, but the little foliage left on these trees indicated that the population pressure on this foliage is intense.

Whereas defoliation remained severe in the check block in all years since 1990, the foliage in the treated blocks were allowed to recover in 1992 through 1993 (Table 4). Thus the apparent similarity of densities in 1994 and 1995 resulted in a higher feeding intensity on the trees' remaining foliage complement in the un-treated block compared to those in the treated blocks. We can now see trees that are virtually without needles in the check block but this is rare in the treated blocks. One larva feeding on the severely damaged branch from the check block has a far greater impact on the trees resources than a larva feeding on a branch from the treated blocks.

Table 3. Spruce budworm egg mass population per 45-cm mid-crown branch tip

	Block		
Year	D	E	F
1990	2.50	3.08	6.83
1991	2.33	0.92	2.66
1992	0.19	0.13	4.06
1993	0.88	1.06	4.88
1994	0.03	0.00	0.03
1995	1.66	0.56	1.53
1996	1.98	2.03	1.24
1997	4.00	3.03	3.98

Table 4. Per cent spruce budworm caused defoliation evaluated on 45-cm mid-crown branch tips. (Cumulative annual defoliation in parentheses.)

	Block		
Year	D	E	F
1990	100 (100)	50 (50)	100 (100)
1991	76 (176)	69 (119)	99 (199)
1992	5 (181)	6 (125)	75 (274)
1993	13 (194)	19 (144)	63 (337)
1994	86 (280)	48 (192)	100 (437)
1995	89 (369)	93 (285)	71 (508)
1996	67 (436)	68 (353)	55(563)
1997	72 (508)	68 (421)	40 (603)

After the full effect of population reduction following spraying was achieved, the treated trees mature between 50 and 65% of the new foliage grown whereas trees in the check plot had matured 16% of the foliage by the end of 1993. The cumulative effect of the defoliation on the untreated trees indicated that most of the foliage that would have grown over the eight years of the experiment never matured. As a result the trees are virtually without foliage at the present. The initial complement of foliage possessed by these trees has fallen because of needle senescence and by 1997 only approximately 25% of the foliage produced since 1990 was unaffected by budworm feeding. In contrast, the treated blocks retained close to half the foliage produced over this time.

The picture is somewhat different in the small isolated blocks that were treated in 1991 with high doses of BTK (Tables 5-7). Block A was severely defoliated in 1990. By contrast blocks B and C were only lightly defoliated as determined by aerial surveys. Blocks A and B were thus chosen because they permitted a contrast as to what would happen to trees with different levels of damage. Late larval densities in block A were highest in 1991 but by 1992, the year after spraying, the population in the check were higher and remained so to the present (Table 5). By 1993 the populations in block B was extremely low and by 1994 the population in block A was also virtually undetectable. Since 1995 there has been a slow increase in the late larval populations in block A., although they are not close to damaging levels.

Table 5 Late-larval spruce budworm density per 45-cm mid-crown branch tip

	Block		
Year	A	B	C
1991	21.4	16.1	15.8
1992	9.11	1.70	27.6
1993	1.96	0.00	32.7
1994	0.00	0.00	6.00
1995	0.69	0.13	4.12
1996	0.83	0.10	0.38
1997	1.08	0.00	1.85

* Note that the population estimate is based on larvae in the pupal sample.

The pupal population showed a similar pattern (Table 6). Populations in blocks A and B remained low after 1992 while the populations in the check block remained fairly high.

Table 6. Spruce budworm pupal density per 45-cm mid-crown branch tip

	Block		
Year	A	B	C
1991	8.7	1.9	15.8
1992	0.00	1.5	8.38
1993	0.77	0.00	32.1
1994	0.00	0.00	4.97
1995	0.21	0.00	3.22
1996	0.80	0.03	2.40
1997	0.00	0.00	0.13

The egg mass samples show similar trends (Table 7.) After spraying in 1991 egg mass populations remained low in Blocks A and B but remained moderately high but declining in the check Block C.

Table 7. Spruce budworm egg mass density per 45-cm mid-crown branch tip

	Block		
Year	A	B	C
1991	0.75	0.00	0.50
1992	0.00	0.00	0.75
1993	0.00	0.00	2.44
1994	0.00	0.03	1.59
1995	0.53	0.03	1.81
1996	0.23	0.00	1.13
1997	0.93	0.00	1.98

The pattern of defoliation in the small isolated blocks differs among blocks (Table 8). Block A which was defoliated in 1990 and probably in 1989 as well received severe defoliation in 1991 before the effects of BTK took effect. However, by 1992 the defoliation was extremely low and reflects the effect of successfully suppressing the population. In block B, other than light defoliation in 1991 and probably the same damage in 1989 , defoliation remained low since the spraying. In block C, by contrast, no spraying was done and defoliating levels have risen to 100% by 1995 and have oscillated between light and moderate defoliation since.

Table 8. Spruce budworm caused defoliation evaluated on 45-cm mid-crown branch tips.

	Block		
Year	A	B	C
1991	73	25	28
1992	3	2	27
1993	1	2	11
1994	8	0	41
1995	10	3	100
1996	34	3	38
1997	23	2	50

Stem Analyses

The relative volume growth of trees in Blocks D, E and F, as indicated by specific volume growth, is presented in Figs. 2 to 4. After 1988, after which defoliation became common in the Hawk Hills blocks, tree growth was below the 1988 level. In block D the growth declined for 5 consecutive years, including 1993. It was not until 1994 that the respite (in 1992 and 1993, Table 4) from severe defoliation provided by spraying that the trees appear to be recover. In 1993 the growth in Block D was only 38% of what it was in 1988.

In block E, the growth pattern was somewhat similar, but the trees increased their growth in 1989 over that in 1988 (Fig. 2). The decline in growth in this block was not as severe as that in Block D reflecting the lower levels of defoliation sustained in block E than that which occurred in block D (Table 4). The minimum growth in block D was 54 % of the 1988 level and this occurred in 1993, as in block D.

In the check block, F, the pattern of growth was similar to that in Block E until 1990. After that the cumulative effects of defoliation depressed this growth below that of block D and to date the trees have not recovered. The Growth rate of the trees are now 20 % of what they were in 1988 in block F. The corresponding growth rates are 46 % and 68% in blocks D and E respectively.

The tree growth in the small isolated blocks and their check (Blocks A, B & C) also reflect the effects of defoliation. Block A went unprotected for an additional year when compared to blocks D and E. As a result, growth reduction was more severe and by 1993 the growth had declined to 20 % of the 1988 level before the recovery evidenced in the other treated plots (Figure 4). This occurred despite the absence of significant defoliation since 1991.

By way of contrast, Block B was never allowed to develop severe defoliation and the growth rates oscillated within a much narrower band (Figure 5). After increasing in 1989 there was a slight decline until 1993 and then an upswing in 1994. At no time did the growth rate decline below 80% of the 1988 rate after the beginning of the experiment.

In block C, growth increased to 120 % of the 1988 growth rate in 1990 but declined to 53% of that rate by 1993 following several years of defoliation.

Figure 2. Pattern of specific volume increment averaged for 16 trees from block D.

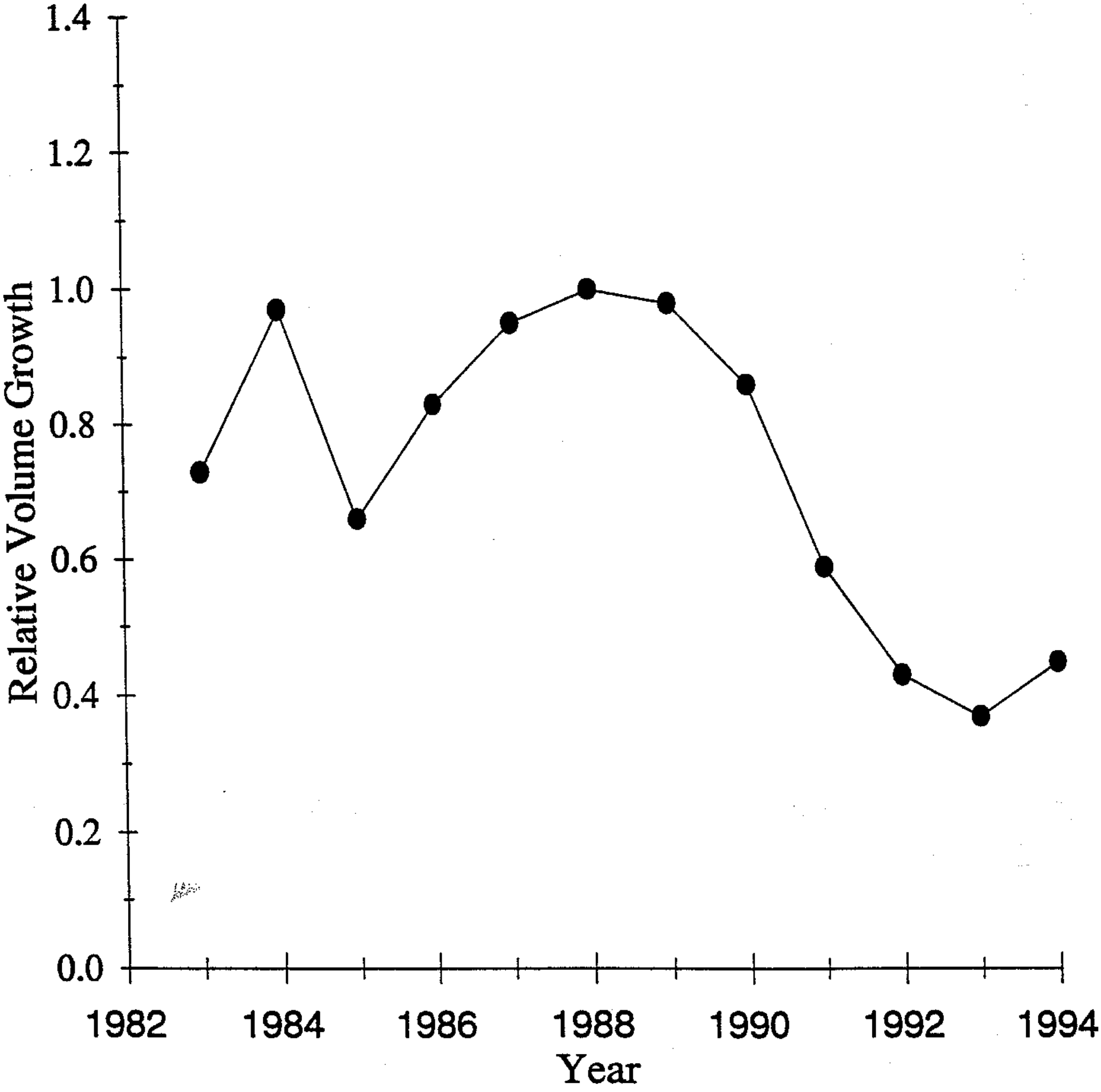


Figure 3. Pattern of specific volume increment averaged for 16 trees from block E.

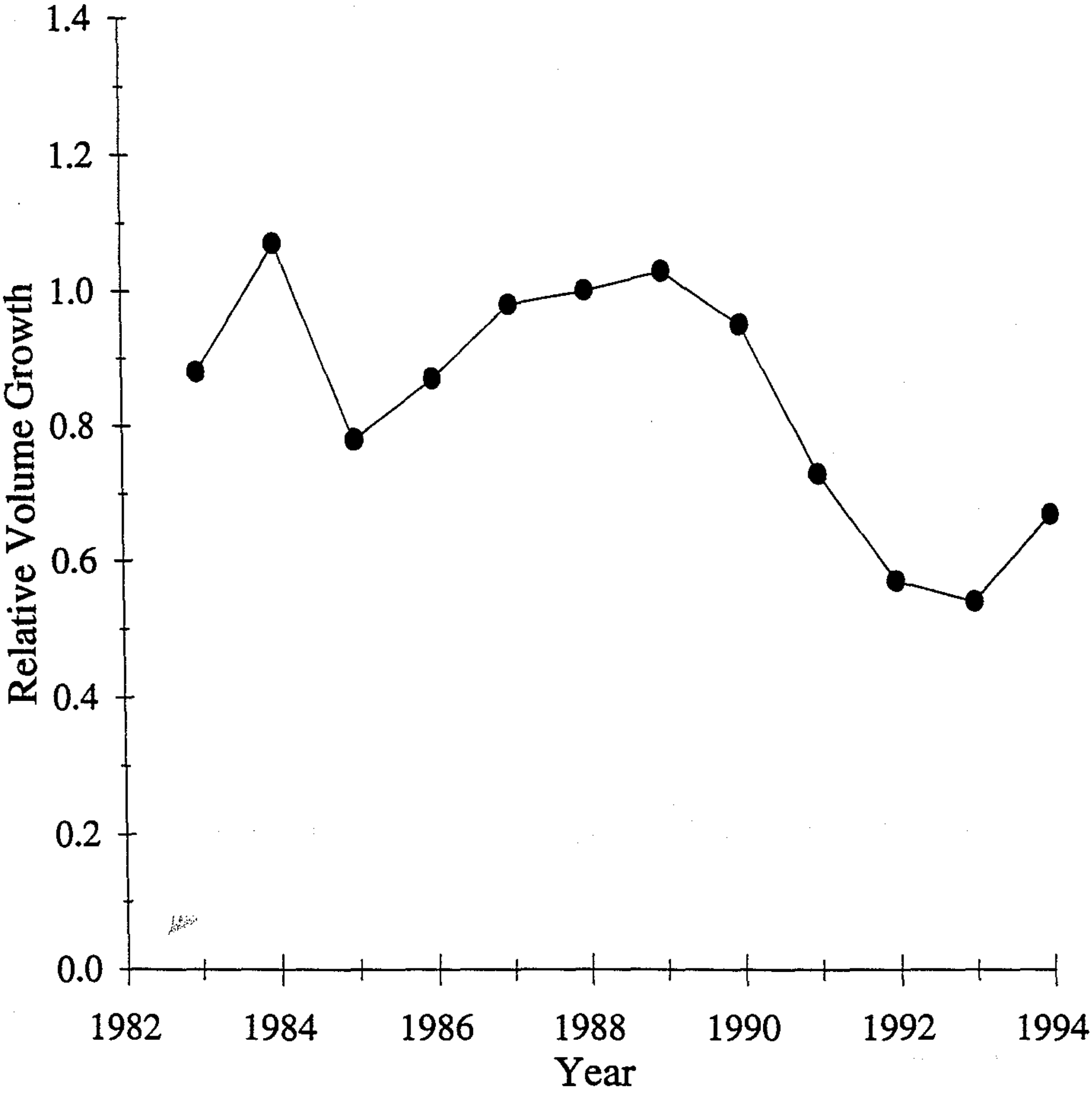


Figure 4. Pattern of specific volume increment averaged for 16 trees from block F.

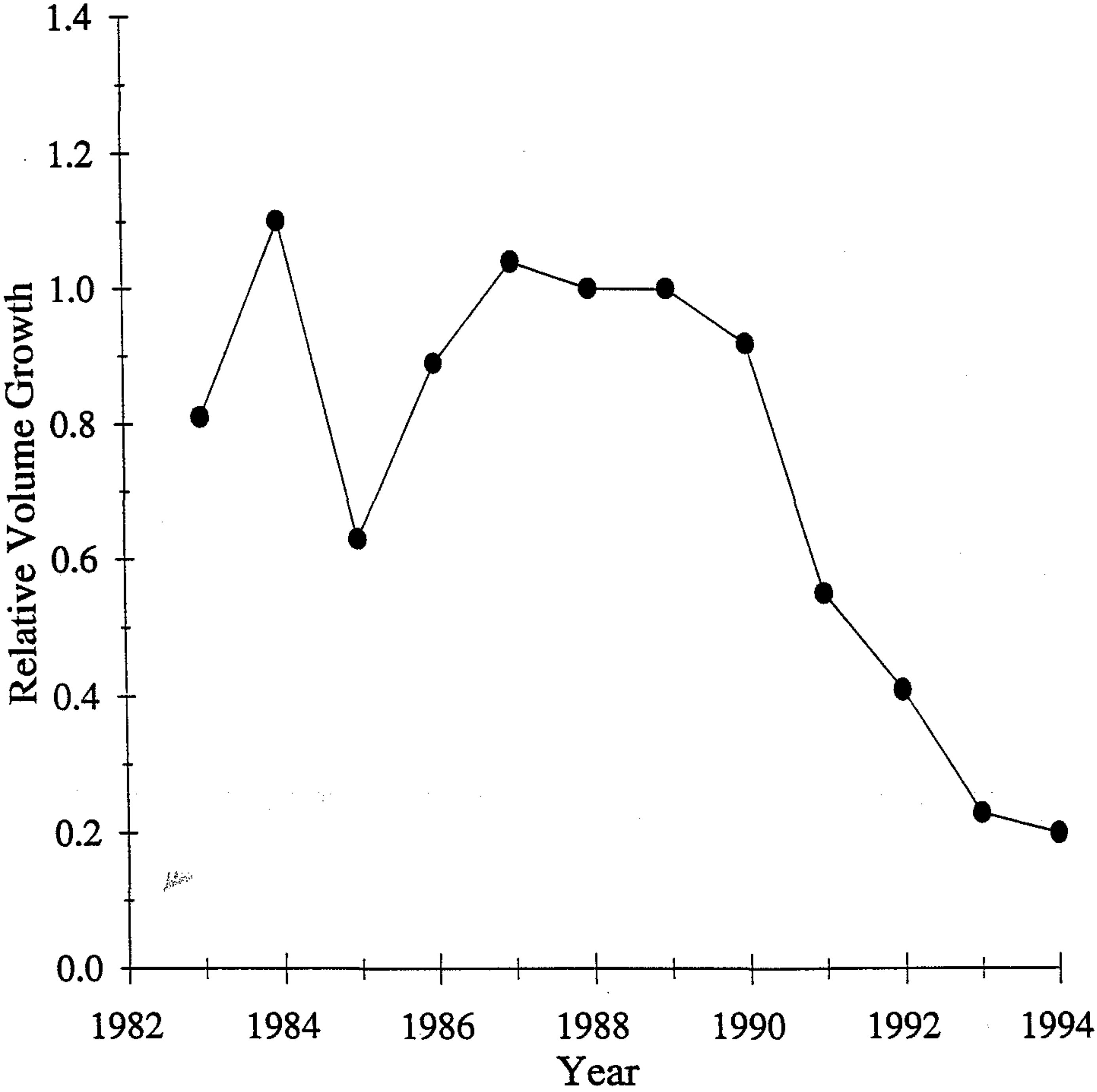


Figure 5. Pattern of specific volume increment averaged for 16 trees from block A.

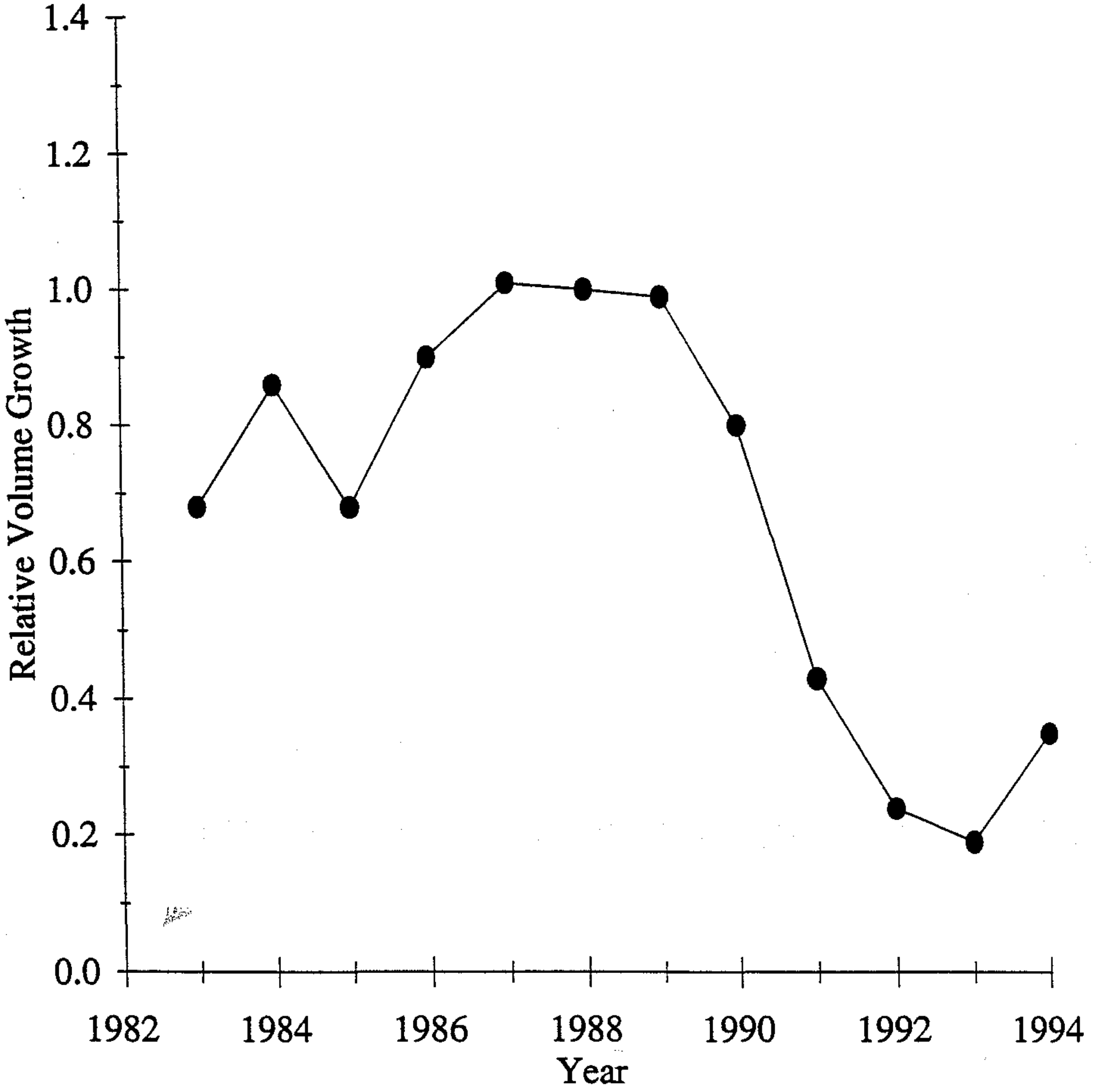


Figure 6. Pattern of specific volume increment averaged for 16 trees from block B.

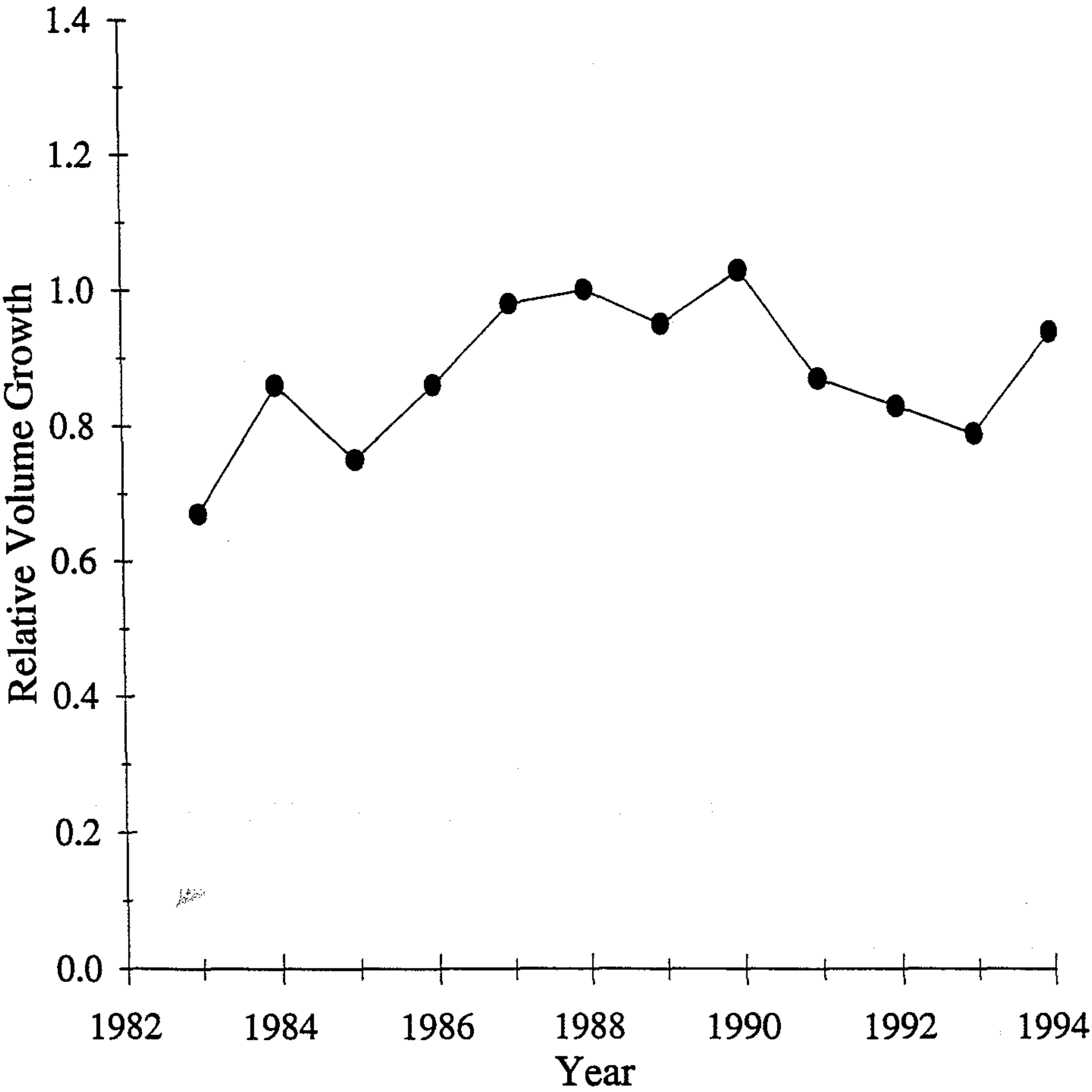
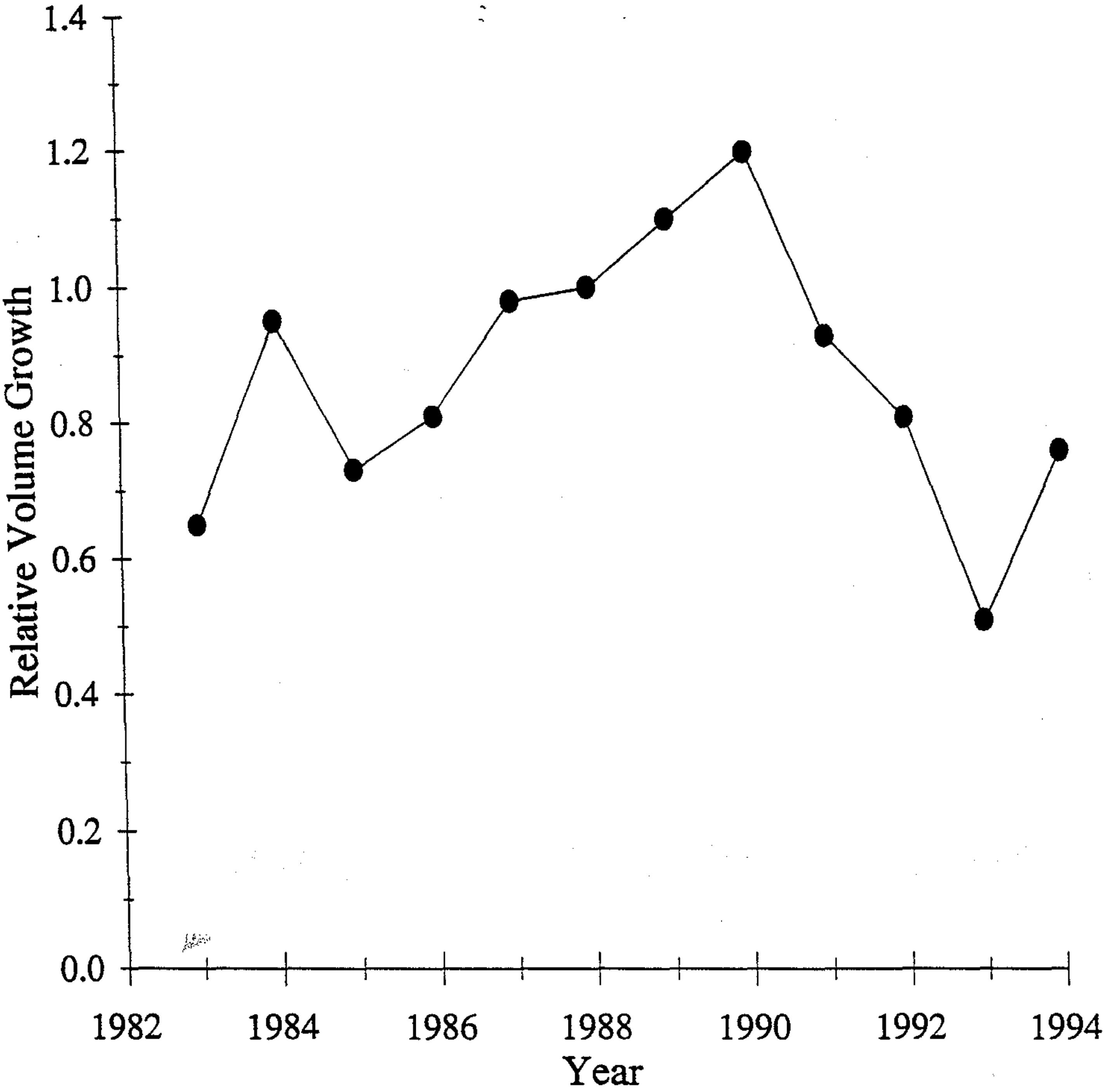


Figure 7. Pattern of specific volume increment averaged for 16 trees from block C.



Economic Studies

Valuation General

An emerging issue in the management of natural resources is the measurement of the benefits of services that resources provide. An important step in this measurement process is the estimation of demand for the various services. One resource that is typically not priced and is consequently under-valued in the decision-making process is recreation resources. Recreation has been a popular activity used in the resource economics literature to investigate various demand models with a point to developing valuation methodologies (for examples, see the review in Sorg and Lommis, 1984).

Valuation Methods

A review of the literature has discovered that there are three general themes used in valuation of the damage caused by insect infestations of forests, some but not all related to recreational camping. The first theme is to measure the cost of programs to control the insects, and to relate this to perceptions of lost value. This theme incorporates economic valuation, which may be either related to the insects, or to the use of insecticides. The usual form is a cost-benefit or financial analysis. The second theme is to rate the scenic value of forest vistas, normally without any economic value attached. The third theme is non-market valuation techniques that determine economic values for the loss of benefits associated with the environmental change.

Cost of Control Program Methods

In general, cost of control program methods attempt to evaluate (or justify) the expenditures on insect control in relation to the loss of benefits caused by the insect. For forestry, such studies relate strictly to the value of time lost in carrying out the control. No studies were found relating cost to the loss of recreational values. Some studies are reviewed that relate to general "quality of life". The pests involved are biting insects such as black fly or mosquitos.

Benefit Cost analysis is often used, as is financial present value criterion. Benefit cost is a well know method that relates the present value of costs to the program to the present value of expected benefit. A summation formula of benefits over costs is created, and if the ratio gives a value greater than one, the project is deemed worthwhile. The costs usually include the opportunity cost of alternatives. The general problem of non-market goods exists under this method. The benefits derived from non-market goods being immeasurable in dollar terms, they are not included in the formula. Thus their implicit value is zero.

Scenic Preference Rating Methods

Methods that attempt to measure the preference of individuals or groups for varying scenic views, or features contained, stem from work in the psychology literature. In this literature, attempts to measure preferences date back to the early part of the century (Thurstone, 1927 is the most often cited). In psychology, the method is called "comparative judgement test", or "Signal Detection Theory." The assumption, when related to the subject of interest here, is that campers would prefer to use a more beautiful setting, than one perceived as less attractive.

In simple terms, the method involves presenting photograph of different forest scenes to individuals, and asking them which scene they prefer. The photographic series typically contain a graduated scale of the variable of interest, such as insect damage. Regression analysis is then carried out on the results to obtain a preference scale. It can be used to estimate the preference for more than one feature. These methods allow quantification without monetarization, and those most interested in the results are landscape architects.

The methods in this group received a good deal of interest dating roughly from the publication by Daniel and Boster (1976) of a paper outlining the Scenic Beauty Estimation (SBE) method, until the early 1980's. Recent work includes papers (reviewed here) that attempt to combine, or correlate SBE with other, monetary, methods. SBE is primarily used for forestry issues by a small group of authors based at the Forest Experimental Station in Fort Collins, Colo, and at the University of Arizona.

Two typical and related, visual quality scaling methods are Scenic Beauty Estimation Method and the Law of Comparative Judgement Method The Scenic Beauty Estimation Method (SBE) was first outlined by Daniel and Boster (1976)[1]. They class it a method that provides measures of landscape beauty independent of observer judgemental criteria. Each value is assumed to result from the combined effects of a number of landscape properties.

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[1]Arthur and Boster (1976) is a bibliography of earlier, usually similar methods, that estimate scenic beauty in general.

In this procedure each subject is shown each scene for a short time period, and asked to assign a score between zero (low) and nine (hight quality). The surveyor must use multiple presentations (views) of each landscape to be compared. The SBE method is then used to convert these ordinal scores into interval scores using a mathematical procedure (related to Signal Detection Theory), that compares the Z-score of cumulative probability of a score for each landscape. Their difference between standard normal scores for each landscape as related to an arbitrary base case gives values call Scenic Beauty Estimates. The average SBE for each person gives a group SBE. It should be noted that individual's SBE's are not considered valid alone, the true values are derived from judgements made by a number of observers for a variety of landscapes. Observers ratings are adjusted (by using z-scores) to account for the effect of differing judgement criteria.

Law of Comparative Judgement (LCJ).

This method is related closely to the SBE, but does not involve the manipulation required in SBE to account for potential different use of the rating scale. Two sub-methods, as outlined by Buhyoff *et al.* (1982) are the Full Pair Comparison and Rank Order methods. This method also is adapted from the psychology literature, and creates interval measures from data on the ratio of times each stimulus is chosen on some given attribute over all the other alternative stimuli. The proportions can be derived from data collected by either presenting all possible pairs of stimuli (eg landscape slides) and having subjects select which of each pair they prefer most, or by having the subjects rank order the stimuli. The rank orders can then be used to calculate the proportion of times (ie the proportion of the total number of subjects) each landscape was preferred over every other one.

Both the SBE and LCJ produce a scale value of scenic quality for each landscape across a group of observers. They do not produce a value for each individual. The two provided significantly correlated metrics in Buhyoff *et al.* (1982).

There are a number of known problem areas associated with these methods. For the purposes of this study, one of the largest is that it does not provide monetary valuation. Much of the literature from 1976 to the present has been involved with outlining, and to some extent, overcoming these problems. In order to examine the method, insect infestation has often been used, which is why several articles are reviewed later in this report.

The problems can be broken down into several categories. The first would be the selection of sites, or views, and the presentation of the survey by the study team. The last category would be the interpretation of the results, and the assumptions regarding the behaviour of respondents in completing the questionnaire.

The selection of sites can be very important for the results obtained, as is the photographs used. Daniel and Boster (1976) suggest that the quality of photographs be carefully examined to ensure that respondents are reacting to the view, and not to one photo being better than another. They performed tests to verify that photos can be substitute for actual site visitation, and also relied on the work of Shafer *et al.* (1969). However, the assumption has recently been challenged by Brown *et al.* (1989), who performed comparative tests on photos and actual on-site valuation. In their tests, the photos gave lower values than the actual site, even when comparing the site with a photograph of the same site. This does not suggest that the comparison between photos is invalid, but rather that the values obtained may be too low overall (in general).There may be unknown "panorama" aspects that are not presently considered by the method.

The viewpoint of the photo can be important in the amount of variation accounted for by the regression. For example, a long view, with damage in the foreground or in the distance, versus in-stand photos. The presence or absence of other landscape features can mitigate the effect of any one variable on preference. How and where people would normally view a forest is thus important. Possible choices are scenic viewpoints and vistas, or the surrounding area when camping. In a way, this could reflect the type of use, tourism versus camping. Hiking could include both views.

Important dimensions in photo selection includes : topographic variation, vegetative variation, variation in the variable of interest (i.e. amount of insect damage), observer position with regard to the seen landscape, and quality of the photo.

A key component of these methods seems to be whether or not those shown the photographs are aware of the variable in question. This knowledge causes radical variation in the preference functions obtained. A further proof of this knowledge (or perception) factor is examined by Anderson (1981). In her study, labelling the photos with land use designation (varying from wilderness area to managed range area) affected the values given. Respondents gave lower scores for the same sites, depending on their perceptions of the designation used.

The method itself gives a preference list, but no relative preferences. It requires that only a small number of sites (choices) are given, and is time intensive in application. A typical application will have a group of experts decide in advance the features that are important, and the regressions are then run using these variables. It is rare that participants in the experiment are ever questioned regarding why one scene is preferred to another. Arthur (1977) evaluates several techniques for selecting feature to be used. The SBE is designed to factor out the possibility that respondents are not all using the rating scale in the same manner (for example one all high scores, one all low scores). The type of regression to be used has been examined, logarithmic seems to work best.

Non-market Valuation Methods

Direct Versus Indirect Methods

The main objective of non-market valuation is to derive a monetary assessment of the impact of changes in the quality or quantity of a good or service which is not typically priced in a market. The two main approaches to valuation are the direct (or survey) approach and the indirect (or inferential) approach. The indirect approach is the method which is most comfortable to economists because it is based on behaviour, rather than opinion. It comprises Travel Cost Methods and Hedonic Price Methods. Traditional economic analysis generally employs information on actual behaviour and attempts to construct models which represent this behaviour. Manipulation of these models can be used to estimate the monetary impact of changes in either quantity or quality. The direct approach involves talking (Smith 1990) with individuals in an attempt to reveal their "values" for the non-market good or service.

Contingent Valuation (CV) is the most commonly used of the direct techniques. The term contingent valuation arises from the fact that the valuation of the good is contingent on the assumption of a market for the good, the method does not evaluate actual behaviour. CV in its simplest form is a description of the situation (a camping day) and a question of the form "what would you be will to pay for a day of camping, over and above all other expenses you might incur." Problems encountered with the use of CV centre upon the existence of biases claimed to be inherent in the technique. This debate over bias is well documented in Mitchell and Carson (1989). Mitchell and Carson also outline the basic assumptions used in CV to produce the welfare measures, which require that the respondent have: a) an accurate description of current level of the good (camping available), b) and accurate understanding of the good being valued (a camping day), c) an understanding of the time dimension of the change in quality or quantity, and how payment would be made, and d) an understanding of what the payment amount represents.

Economists have trouble accepting surveys based on people's attitudes. As shown above with the SBE, others do not have the same reservations. It should be noted that the recent development of contingent behaviour models, that uses photos in place of a descriptive summary for changes, is similar to SBE, and seems somewhat to integrate the two methods.

The Travel Cost Method

The most popular approach to estimating recreation demand is the Travel Cost Method (TCM). This method was first proposed informally in 1947 by Harold Hotelling. Since that time extensive research has been conducted on this and other methods, and the TCM has emerged as one of the most robust approaches to modelling recreation demand (Smith 1988). The TCM uses the cost incurred by a recreationist in travelling to a particular site as a proxy for the market price of that recreation. The variation among respondents in distance to the site, and number of visits allows a demand curve to be created. In its earliest formulations (e.g. Clawson 1959), TCM involved establishing zones of origin relative to the recreation site, and the demand for site based recreation was derived by regressing the number of trips per capita in each zone against travel costs per trip. More sophisticated forms of this regional TCM involved the incorporation of variables describing zone characteristics, site characteristics, and a measure of the cost and quality of substitute sites (e.g. Donnelly *et al.* 1985).

Further investigation of the simpler TCM models highlighted a number of serious issues. These are: the question of consistency with an underlying utility function when estimating economic benefits, the opportunity cost of travel time, the role of substitute sites, and the effects of site quality changes and the deletion or addition of sites to the recreationist's choice set (Smith 1988). One of the major disadvantages of the standard TCM is that it cannot be used to value site quality changes, (Adamowicz 1991). Because of these issues, effort in the recent literature has been directed towards alternate forms of the standard TCM. The effect of substitutes and quality change in particular, have generated considerable interest due to heightened awareness of the general public to deterioration in the quality of the environment.

One proposed TCM model which attempts to incorporate site and quality variables is the Generalized TCM (Smith and Desvauges 1986). The first stage estimates separate travel cost functions for a number to sites. The second stage involves estimating a systematic quality parameter using the coefficients from the travel cost functions regressed on the established site quality measures. However, this model does not consider site substitution effects. This is the result of the model's assumption that recreationists will not reallocate their trips to other sites after a quality change at one site, but that they will simply change the number of trips taken to the affected site.

The Hedonic Travel Cost Method

Another form of the TCM which focuses on the characteristics of recreation sites rather than on the site itself is the hedonic TCM (Brown and Mendelsohn 1984). The hedonic TCM develops implicit prices of quality attributes related to site characteristics in a two stage regression procedure. The theory used here is that recreationists will travel farther for better quality attributes and hence will be willing to pay more to travel. However, although this method incorporates site substitution due to quality changes, negative prices can be observed (e.g. Smith and Kaoru 1986). This results from the assumed positive or increasing relationship between costs and quality attributes. It has also been noted that there is a problem in that the estimated demand functions are associated with attributes and not directly with the recreation sites themselves. Thus it is not clear how to assess changes in quality at any one specific site, and how this affects demand across available sites. Englin and Mendolsohn (1991) reviewed below, provide a good study of the use of this method for forest recreation valuation.

The Discrete Choice or Random Utility Model

Recently discrete choice modelling has been applied to behaviour related to recreation services provided by natural resources like fish and wildlife (e.g. Carson *et al.* 1989). Discrete choice models are based upon research reported in the transportation literature (Domencich and McFadden 1975; Ben-Akiva and Lerman 1987). These models, also called random utility models (RUM), are useful for investigating situations here consumers face a discrete rather than a continuous set of choices. Because of this property, the models have been used to investigate the choice of specific sites related to recreation, and have been incorporated into the broader category of travel cost models.

Random utility models have the advantage of being established within a utility maximizing framework. In this framework a recreationist selects a site that yields the highest utility based upon the characteristics of the choice of sites available. However, since RUM's focus on discrete sites they can explicitly model the substitution of alternate sites. In addition, these models can treat entry and exit from the recreational activity due to changes in site quality. These "corner solutions" (zero visits to some sites) cannot be handled easily in traditional TCM models. The most popular RUM used in modelling recreation choices is the multinominal logit model (Stynes and Peterson 1984).

Nested Discrete Choice Models

There is a known problem with the use of discrete choice models that relates to the distribution of the error terms, which are assumed by the model to be Weibull distributed. A test for this assumption, Independence from Irrelevant Alternatives, (IIA) is well documented. If IIA is a problem, one solution is the use of a nested model. In a nested model, the choice of a site is deemed to follow a sequential process. For example, the angler would first decide the type of fishing to undertake, or the species of fish sought, and then the actual site is chosen. The choice set for each level of the sequence of decisions is effectively smaller, and better differentiated. However, this also imposes a much stricter behavioural assumption on the respondents. Nested models can overcome the IIA assumption, but they are more complex and require and development of a hierarchial nesting scheme. These schemes can be difficult to derive and can involve significant knowledge of the choice set. It is a point of debate in the literature which is more problematic, the behavioural assumption of a nested model, or the breaking of the IIA assumption.

The major problem of all travel cost methods is that the behaviour of individuals is used to determine a model which is in fact still based upon attitude and perception. It is impossible to know if the assumed decision process that the model reflects is in fact carried out by the camper. As well, the "qualities" of a site may be perceived differently by all who visit the site.

The Hedonic Price Method

In this method, the valuation of environmental services is assumed to be imbedded in the property values in the surrounding area. The method has been used for water and air quality changes. It would be difficult to use for forest camping in Alberta, given the public ownership of the campgrounds, and the surrounding terrain.

CONCLUSIONS

The spruce budworm populations in the Hawk Hills Management Area seem to be behaving as other budworm populations in Alberta have behaved. They have persisted for a considerable time and have fluctuated in density causing defoliation annually unless they were controlled. In the check blocks the population seems to be uncontrolled eventually causing 100 % defoliation. The repeated annual defoliation has caused unprotected trees to lose much of the foliage. We have witnessed this development in one block (C) and seen the persistence of high populations in another (F). Unless controlled by natural events such as spring frosts, we have every expectations that the populations will persist and ultimately kill large numbers of trees. To date we have seen a gradual rebound in populations in the operationally treated blocks to damaging levels. In the blocks treated for population suppression, this has resulted in populations that have remained stable and low in one block and a slow rising population in one block. In neither block has the population and damage reverted to populations found when the experiment began. In contrast, the population in the untreated, check, block has risen so that, by 1995 it caused severe defoliation and now persists to cause light to moderate defoliation annually.

The experiment to control the spruce budworm that was undertaken, now provides and opportunity to assess the impacts of the damage by comparing the stands that were protected with those that were left un-protected. The tree ring studies indicate that a substantial amount of growth loss has already accrued in the un-protected stands. The results so far also point out the losses that might accrue if steps are not taken to immediately deal with on outbreak. The losses sustained (80% in 1993) in Block A, which sustained defoliation for one year longer than either block D or E, is to be contrasted to the growth loss sustained in blocks where control was taken a year earlier (54 and 32%). Contrast this further to the situation in block B where the outbreak conditions was not permitted to develop. The trees here never lost more than 20% of the annual growth during the period of observation.

The various blocks in the study provide the basis for making a benefit/cost comparison of the various treatment options that were selected in managing the budworm populations in the Hawk Hills Management Area. The information on growth loss and the relative rates of trees can be combined with stand data to determine the potential growth with and without budworm caused defoliation to make the comparisons necessary to conduct an effective benefit/cost analysis. This will supply the basic information relating to the losses of timer value associated with the different management options and is discussed in the next section.

The non-timber values can also be assessed. The condition in some of the check stands provide for graphic evidence of what budworm populations can do. Photographs of these conditions can be used in contrasting the conditions in undamaged stands (eg Block F vs Block E) to provide the basis for the Scenic Beauty Estimation procedure. Because of the variation in damage experienced in the different blocks, the Law of Comparative Judgement procedure can be applied in assessing losses of aesthetic value. It is proposed to continue with this approach using the contingent valuation method to assess the impacts of defoliation on the recreational amenities of the area. This is the subject of the third section of this report.

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PART II:
BENEFIT/ COST EVALUATION OF SPRUCE BUDWORM CONTROL

by
D.O. Watson, W. Jan A. Volney and Peter Boxall

INTRODUCTION

This part of the report describes an extension to work previously conducted and described in previous reports (Volney 1991, 1992) and Part I.

The purpose of the work reported here was to describe the economic impacts of spruce budworm defoliation to stands that were defoliated by the spruce budworm and protected with *Bacilus thuringiensis* var *kurstaki* (BTK) applied with various strategies in mind. Unprotected stands served as controls. Two treatment strategies were investigated: reactive spraying in stands that were damaged by severe budworm defoliation for at least two years prior to spraying and pro-active spraying in which stands were prevented from ever becoming severely defoliated. The net economic benefit of these strategies are estimated and discussed in the present report.

METHODS

In order to measure the effect of a spruce budworm outbreak on the value of wood fibre production of a stand, information on stand growth and yield, with and without budworm effects is required. A knowledge of the economic value of fibre and the cost associated with the control program used to reduce the effects of the insect are also required to estimate costs and benefits. MacLean and Erdle (1984) outline a similar procedure for a hypothetical fir forest, but do not describe economic measures. Because the benefits and costs of budworm control operations accrue at different times, the net economic benefits are calculated by discounting these values to a common year: 1990.

As described in Part I, two experiments were conducted on white spruce stands in the Hawk Hills Management Area. The first experiment involved three relatively young stands: designated E, D, and F that were about 60 years old. Here the outbreak was permitted to develop and severe defoliation occurred before spraying BTK on 2 of the 3 stands was undertaken. In this case the third stand was used as a control so that the effect of spraying could be assessed. This experiment was used to evaluate the merits of an operational control tactics where measures to influence the outbreak were enacted after the outbreak was well established.

The second experiment involved three older stands (roughly 100 years old). In this case, insect control measures were used on two of the stands (A, B), one in which the damage to foliage was permitted to become severe (A) before spraying and the other (B) in which protection was applied before severe defoliation developed. This experiment was designed to contrast the net present benefits from reactive and pre-emptive control policies. A third unsprayed stand (C) in this group was to be used as a control. However, it could not be used because its site index was too dissimilar from the other two. Projections based on yield tables were used where contrasts with the undamaged condition were required.

Each experiment involved two scenarios and two different time periods. One time period involved the measurement of growth in the six years following an infestation. The second time period involved a forecast of the growth in volume of the stand to the rotation period. In each case the analysis involved a comparison of volume growth that would have occurred without budworm damage with growth involving budworm effects. To extend the results of the study for the duration of the outbreak, the second of the time periods, two scenarios were developed; one involved assessing stand volume with extra mortality due to the effect of budworm and one without. This approach was necessary because we have not made observations for the duration of a full outbreak.

In the initial phases of this study, the test plots were established and the growth and yield of white spruce in these plots was evaluated. A review of existing literature was conducted on the effects of spruce budworm defoliation on growth and yield. Furthermore, literature relating to the economic effects of the budworm on forest yield was examined and discussions with Manning Diversified and Alberta Land and Forest Service (LFS) personnel were conducted to collect in formation on the costs of control measures and the gross revenues derived from harvesting white spruce stands in the study area.

Standardized growth and yield tables for the province published by AFS (1985) were used to model general growth and yield of white spruce in the Hawk Hills area. However, a number of the formulas in that report were unclear or incorrect. This caused some confusion and errors during attempts to re-create growth and yield tables. In discussions with LFS staff, the formulas were amended and an example table for a good site of white spruce was prepared. These are shown in Appendix C. These growth and yield tables require a knowledge of the Site Index (SI). We used information on height of trees at age 50 to determine the SI. This data was obtained from 96 trees felled within the 24 plots (Part I).

Three test blocks were established in the Hawk Hills area in 1990 that covered areas affected by an outbreak initiated in 1988. Each of these blocks contained four 0.04 hectare plots for a total of 12 test plots. At the same time, LFS Permanent Sample Plots were set up adjacent to the 12 plots. Another set of three test blocks (each containing 4 plots) was initiated in 1991. Here one of these blocks (B) did not show signs of the spruce budworm defoliation. Further information on the experimental design, and the entomological measurements is available in Volney (1992, 1993). The set up of the blocks, and spray regime is shown in Table 9.

Growth and Yield Estimation

Three methods to determine stand growth were compared. First, the height at age 50 for 16 felled trees within each block was used for an un-managed, even-aged, single species stands of white spruce to determine the block's SI and thus their volumes. Second, the same height measurements were used in computing the volumes for the white spruce component of un-managed mixed-wood stands. Third, height and diameter at breast height (DBH) measurements of all white spruce within each plot were used to calculate individual tree volumes and combined with stem densities to obtain volumes per hectare. In consultation with Huang (LFS), the resulting estimates were compared, corrected for plot conditions, and volumes obtained using the SI of single species white spruce. These volumes were selected as the most appropriate measure of stand volume. It is important to note that in all stands these procedures resulted in a lower SI than the height at age 50 would have given. Thus, the estimated stand volumes are conservative (underestimates).

Table 9. Experimental design and project plot numbers

Block	Plot numbers	Year plot initiated	Permanent Sample Plots	Spray regime
Experiment 2: Reactive versus pre-emptive spraying				
A	13 - 16	1991	none	50 BIU[1] twice in 1991
B	17 - 20	1991	none	50 BIU twice in 1991
C	21 - 24	1991	none	none
Experiment 1: Growth comparison with and without spraying				
D	5 - 8	1990	495, 496, 497, 498	30 BIU once in 1990 25 BIU twice in 1991
E	1 - 4	1990	466, 467, 468, 471	30 BIU once in 1990 25 BIU once in 1991
F	9 - 12	1990	472, 473, 474, 494	none

[1] BIU is Billion International Units of BTK. Normal operational spraying for northern Alberta is 25.4 BIU in two separate applications within the same year.

The rotation age of a stand is normally calculated by foresters as the age at which the Mean Annual Increment (MAI) and Periodic Annual Increment (PAI) are equal. MAI is the average annual increment over the life span of the stand or tree, calculated by dividing the volume by the age. PAI is the difference in volume during a specific period: in this case we chose 10 year divisions used in the growth and yield tables. The age at which the MAI and PAI graphs intersected was chosen as the rotation age. The pertinent productivity information for the six blocks is shown in Tables 10a and 10b.

Table 10a. Experiment 2: Basic data

	Combined	Average Block Features		
	A-B-C	A	B	C
Site Index (m @ 50 y)	13.3	16.1	13.4	10.5
Age (in 1990) (y)	99.5	101.8	90.1	107.4
Age at MAI maximum[1] (y)	110.0	100.0	110.0	130.0
MAI/PAI rotation age (y)	115.0	100.0	114.0	139.0
Volume at rotation age (m^3/ha)	309.7	330.0	309.3	294.5

[1] MAI max measured from tables with 10 year growth increments.

Table 10b. Experiment 1: Basic data

	Combined	Average Block Features		
	D-E-F	D	E	F
Site Index (m @ 50 y)	14.2	16.5	15	12
Age (in 1990) (y)	64.7	67.8	63.2	63.1
Age at MAI maximum[1] (y)	100	90	100	120
MAI/PAI rotation age (y)	109	96	104	125
Volume at rotation age (m^3/ha)	316.2	328.5	319	302.3

[1] MAI max measured from tables with 10 year growth increments

Discussions with LFS personnel in Peace River (Carl Peck, pers comm 1996) about white spruce rotations suggests that our calculated values are "about" right. The average rotation age for that general area is 105 years. They have always used the point of peak MAI for their rotations. They also set the rotation for a whole FMA at one time, and then establish the cutting plan within the FMA. There are also other factors taken into consideration, such as the market price of saw logs when involved. In practice, however, the age at which the stand is cut is generally older than the rotation age. Though rare, it has occasionally happened that salvage harvesting took place on infested areas near the rotation age. It depends as much as anything on the cutting plan, and the capacity of the receiving plant to process the wood.

Analysis of Reduced Tree Growth From Budworm

The history of defoliation in these plots is shown in Table 11. A basic assumption of this study, substantiated by the tree ring record, is that the budworm outbreaks became severe in 1988 for the 5 Blocks where their presence was detected in 1989. However, Block B did not show signs of defoliation at the time of setup. These observations allow the assessment of two different control treatments mentioned above (e.g. reactive and pre-emptive). In the first experiment Blocks D and E were sprayed after the outbreak was established and F was not. For Blocks A, B and C, A was sprayed after the budworm infestation began and trees were damaged, B was sprayed before the budworm caused severe defoliation, and C was unsprayed. Combing these results in theory should permit a comparison of the effects of spraying pre-emptively reactive spraying, and not spraying at all.

Table 11. Measured defoliation levels in test blocks

Block	1990	1991	1992	1993	1994	1995	1996
A	S	S	O	O	O	O	M
B	M	O	O	O	O	O	O
C	M	O	O	O	S	M	O
D	S	M	O	O	M	O	M
E	S	M	O	O	M	O	M
F	S	S	S	S	S	O	M

O = less than 35% defoliation; M = 35% to 70% defoliation; S = greater than 70% defoliation

The procedures outlined in above provide information on what the volume should be for a given SI. However, growth in the presence of budworm is likely to be different. In Part I the **actual** annual growth was obtained by stem analysis of 96 trees. Growth was compared relative to a base year, 1988, (which assigned a relative growth rate of 1.0). when the budworm infestation was assumed to have started in the area. Note that this procedure provides information on the **actual** annual growth during a portion of the budworm outbreak, 1988-1994.

Table 12 shows the average values for the blocks in the 6 years preceding and following the infestation year of 1988. The measures shown in Table 12 are called the relative annual volume increment. Thus, normal or expected growth levels in the trees in the absence of budworm involves the annual increment in volume growth relative to the base year of 1988. For example, the relative growth in 1990 would be: $(Vol_{90} - Vol_{89})/(Vol_{88} - Vol_{87})$.

One can see from these figures that the incremental change in volume relative growth is larger prior to the reference year (1988) than after it. This suggests that the budworm outbreak is affecting the rate of increase in volume (in addition to the increase in volume) in these stands. We took a conservative approach and did not account for this increase (acceleration) in growth rate after the outbreak began.

It is also evident that the growth rate in the unsprayed block F shows no sign of recovery and the growth in the stand badly damaged before spraying commenced (A) continued to deteriorate until 1994. Again a conservative approach was adopted: a value close to the mean for the years 1989 to 1994 was used in comparisons.

In order to calculate the total damage that would occur over the duration of the outbreak, the length of the infestation, and the assumed growth during the time following the measured period, must be hypothesized. The trees showed signs of previous infestations. In particular, nearly all of the 96 felled trees showed signs of an outbreak that started approximately in 1940, and lasted for 18 to 20 years. This outbreak was confirmed by studies in the Wabasca River area to the east (Stevenson, unpubl.). During the 1940-1960 outbreak the average incremental growth was 0.5 of the growth before the outbreak. While there was some annual variation, this average was consistent for all of the trees measured and approaches the value of 0.55 (Table 12) we observed for the earlier part of the current outbreak.

Based on these observations we postulated an 18 year outbreak which would take the present case from 1988 to 2006. Given that no action was taken in 1940, we also postulated that in the no-spray case, the relative incremental growth would be 0.5 in each of the years 1994 to 2006. The effect of spraying was postulated to raise this relative annual increment to 0.65 in each of the years to the end of the outbreak. The former estimate is based on the ratio of volume increase exhibited during the 1940-1960 outbreak. The latter was obtained from a comparison of the affected growth between the unsprayed and sprayed stands over the 6 measured years. Thus, for experiment 1 incremental growth of volume in Blocks D and E was projected at a relative growth rate (with the 1988 rate = 1.00) of 0.5 where unprotected and 0.65 with protection (Table 12). For experiment 2, the relative incremental growth of volume in Block B was projected at 0.65 and 0.8. These latter estimates were chosen to:

Table 12. Volume increment relative to 1988 growth

Year	*Actual Measures*					
	A	B	C	D	E	F
1983	0.68	0.67	0.65	0.73	0.88	0.81
1984	0.86	0.86	0.95	0.97	1.07	1.10
1985	0.68	0.75	0.73	0.66	0.78	0.63
1986	0.90	0.86	0.81	0.83	0.87	0.89
1987	1.01	0.98	0.98	0.95	.098	1.04
1988	1.00	1.00	1.00	1.00	1.00	1.00
1989	0.99	0.95	1.10	0.98	1.03	1.00
1990	0.80	1.03	1.20	0.86	0.95	0.92
1991	0.43	0.87	0.93	0.59	0.73	0.55
1992	0.24	0.83	0.81	0.43	0.57	0.41
1993	0.19	0.79	0.51	0.37	0.54	0.23
1994	0.35	0.94	0.76	0.45	0.67	0.20
'89-94 mean	0.51	0.90	0.80	0.61	0.75	0.55

Year	*Hypothetical Measures*					
	Control (C) or No Control (NC) Options					
	C	NC	C	NC	C	NC
1995 . . 2006	0.80	0.65	0.65	0.5	0.65	0.5

1) provide a comparison with the 0.65 relative annual increment in experiment 1; and 2) the 0.80 was chosen to represent an improvement in the volume change as a result of spraying. We will show that these estimates for both experiments are very conservative and will serve to make an analysis of the costs and benefits of spraying more moderate by underestimating the difference in growth between protected and unprotected stands.

Analysis of increased tree mortality from budworm

Increased mortality is also a known effect of outbreaks, and this is examined in the second scenario for each experiment beyond the observation period (i.e. to rotation age). To assess the effect of increased mortality caused by the insect, calculation of reduced numbers of stems was carried out separately for each experiment. The increased mortality was projected beginning in 1990. Mortality rates were calculated from a combination of literature reviews, and work by Volney on jack pine in Saskatchewan. The assumptions for the mortality function were: during a year of light infestation no increase in the background mortality was projected; for moderate infestation, the level is assumed to be double the normal rate; and for a severe infestation, mortality was assumed to be 5 times the normal rate. This corresponds reasonably well with levels reported previously in the literature (e.g. McClintock 1955, Pare 1981). Mortality rates previously reported are quite variable, and often dependent upon other factors of interest to the authors, but our assumptions fall well within an average level.

When mortality was assumed to occur, the growth during the infestation period, of surviving trees was assumed to be 0.65 (relative to 1988 rates) when stands were protected and declines to 0.40 in un-protected stands. For the projected outbreak, the level of infestation was assumed to be moderate for the 12 years of 1994 to 2006. This means we calculated mortality to be two times the background normal for each of these 12 years. This is true for our calculations of Block D and E, and scenario 1 of Block B. Block B was subjected to mortality rates evident when defoliation was light, in the case of pre-emptive spraying. The result of these projections is a total mortality rate over the infestation of 40% in the unsprayed comparison Block F, and Block D and E with mortality rates of approximately 30%. This is nearly twice as high as the normal mortality rates for these two blocks of 12-15%.

Once the infestation ends (year 2006), we return growth to normal and use the growth and yield tables to determine what the volume of the stand would be at rotation age. Thus, this procedure will show the effect of the reduced growth (and or increased mortality) during the outbreak on the final volume at rotation. For this, we calculated what the rotation volume would be with and without increased mortality in each experiment. This volume was then located in the growth and yield tables and the corresponding age was noted. This age was then subtracted from the age of the stand at the end of the outbreak, inserted into the breast height age equation at the age equal to the age at the outbreak, and all subsequent breast height age formulas to the end of the rotation. Volume was then estimated using the equations computed in the usual way. To illustrate, Block D would be 84 years old in 2006, and in the presence of an 18 year budworm outbreak with added mortality would have a stand volume of 179.93 m^3/ha. Locating this volume on the normal growth and yield tables, we note that this volume would have been achieved at age 60 in the absence of budworm. Thus during the 18 years of the outbreak, the stand lost 24 years of growth.

This method of calculation is somewhat arbitrary, but the resulting growth rates compare well to previous studies of growth rate following thinning of stands. The increased mortality would result in a stand with similar stems per hectare as achieved with thinning. Gal and Bella (1996) reported an annual increment nearly double following thinning. Our calculations show a very similar increase in growth after the budworm induced mortality thinning.

Cost Benefit Analyses

Based on a review of the literature we could find no cost benefit analyses of pest control measures in Canada at the stand level. Given that the outputs from the experiments described above will provide volume based measures of the success of control actions, it is possible to compare the economic value of the changes in volume with the costs of the control measures. A number of issues must be addressed in this comparison, however.

The first is that the costs will be incurred in the short term, but often the benefits achieved will not be gained for some time, specifically when the stand is harvested. Thus, it is necessary to bring all costs and benefits into the same time period (e.g. present values) in order to make a valid comparison. This procedure is called discounting and involves the selection of an interest rate. This is a controversial subject largely because most investments in forest pest control measures are made with public funds. We chose to discount costs and benefits back to the year that the control measures were enacted, 1990. Based on the work of Heaps and Pratt (1989) a discount rate of 4% was chosen. They recommend rates of 3-5% for silvicultural investments using public funds. Furthermore, cost benefit analysis of pest management methods in B.C. (Deloitte and Touche 1992), which was subject to "expert" review, also used 4%, and Canham (1986) report that the US Forest Service uses a similar rate..

A second issue is the value of timber harvested and the costs of harvesting timber at a site. Conversations with Manning Diversified personnel suggest a gross value of approximately $100.00 m^3 of standing timber. This value is assumed to be constant over time. However, this timber value does not include harvesting costs. These are highly variable and generally unknown at the stand level. However, the cost of harvesting will be incurred whether or not the outbreak occurs, and at the same rotation age, and so is not included in the economic analysis.

A third issue are the costs of the budworm control methods. These were estimated using the actual applications outlined in Table 9. In conversations with LFS personnel (S. Ranasinghe) the average cost of spraying was $12.0685 per hectare per application, with the normal procedure being two applications. In the experiments described in this report, the normal procedures were used with two applications of BTK in 1990 and in some cases additional applications in 1991 (Table 9).

We calculate net present benefits for two scenarios. First is a **short term** benefit cost ratio which involves only the changes in volume to 1994. The benefits of the spray were estimated using only the measured tree ring data multiplied by the $100.00 value of standing timber. The costs of the spraying was determined proportional to the application rates, and in the case of 1991 spraying, discounted at 4.0% back to 1990.

To compare the effect of spraying to not spraying, first the difference in relative volume growth between the sprayed blocks (D and E) and the control (block F) was obtained. Next, the measured volume growth in D and E was compared to what it would have been in the absence of spraying; in other words if the growth had been like F. For example, suppose the relative growth in the sprayed blocks was 90% of pre-outbreak levels, and in the unsprayed areas 85% of pre-outbreak growth rate. Comparing the 90% growth rate to the estimated 85% growth rate in the same block results in a 5% difference which would be the volume saved by the spraying operation. The benefit (in dollars) of this 5% difference in 1994 is then discounted back to the base year of 1990 when the costs of control were made. If the value of the benefit achieved is greater than the costs, then the operation is efficient in economic terms.

The second scenario involves a **long term** net present benefits. This involves an assessment of the efficiency of the program at the end of the rotation age, assuming no fires, further budworm outbreaks, no changes in fibre prices, and no further costs of management. In this scenario, the total block volume per hectare is estimated at the rotation age, the volume converted to economic values ($100/m^3), and the value is discounted back to the base year of 1990. The resulting economic benefits are then compared to the costs to see if the control operation is efficient.

RESULTS

The Short Term Scenario

Experiment 1: The Young Stands with Reactive Control

During the period 1988-1994 block volumes were assessed using the actual measures of relative incremental growth (Table 12) from felled trees. Resulting volumes are shown below in Table 13. The stand volume with and without budworm was calculated, along with the differences between the two. For the two blocks that were sprayed, Block D lost 17.96 m^3/ha, or 8% of normal volume, and block E lost 11.65, or 6% of normal volume. The unsprayed block F lost 14.96 m^3/ha or 11% of normal volume. To measure the effect of spray, we calculated what blocks D and E would have presumably lost without spraying (11% of their normal), and compared it with actual losses. Block D would have lost an extra 7.91 m^3/ha, and Block E would have lost an extra 9.62 m^3/ha if they had not been sprayed.

Table 13. Stand volume (m^3/ha) in Experiment 1 for the short term scenario; 1988 to 1994.

	Sprayed		Unsprayed
Block	D	E	F
Expected 1994 volume (without damage)	235.02	184.23	131.96
Observed 1994 volume (with budworm)	217.08	172.58	117.00
Volume loss [Expected minus observed]	17.96	11.65	14.96
Growth level as affected (% of expected)	92.00	94.00	89.00
Volume without spraying	209.17	163.96	117.00
Volume saved by treatment	7.91	9.62	0.00

Experiment 2: The Older Stands Comparing Reactive with Pre-emptive Control

Recall that in this experiment two stands were used to compare a reactive regime which involved spraying after the outbreak had been established (Block A) with a pre-emptive control regime in which spraying occurred before the budworm outbreak was firmly established (Block B). For the reactive regime the volume loss was 5.17% of normal, while in the pre-emptive regime the loss was 1.54% (Table 14). If the outbreak had allowed to become established we estimate that Block B would have lost an extra 9.08 m^3/ha. This additional volume represents the savings in timber benefits gained during the period 1988-1994 as a result of the pre-emptive control regime.

Table 14. Stand volume (m^3/ha) in Experiment 2 for the short term scenario; 1988 to 1994.

	Sprayed	
	Reactive	Pre-emptive
Block	A	B
Expected 1994 volume (without damage)	345.96	250.05
Observed 1994 volume (with budworm)	328.10	246.20
Volume loss [Expected minus observed]	17.86	3.85
Growth level as affected (% of expected)	94.83	98.46
Volume without pre-emptive spraying	n/a	237.12
Volume saved by pre-emptive spraying	n/a	9.08

Long Term Scenario

In order to capture the complete picture of the effect of budworm in the long term, changes in mortality must be considered in addition to the changes in growth of surviving trees. There are several studies on increased mortality in balsam fir and jack pine, but none for white spruce directly. We assumed that mortality rates in undamaged white spruce stands, based on an inspection of growth and yield tables, approach 0.1% annually. This value was incremented, as described above, depending on the level of defoliation.

The method of using the growth and yield tables must be altered when calculating the effect of added mortality. The usual procedure is to proceed in several steps from breast height age to stand volume. Stems per hectare is usually calculated from a basal area equation which is based on volume. We wish to show the change in volume caused by a combination of reduced growth, and a reduction in stem numbers per hectare and so the usual series of steps must be reversed.

To calculate the mortality effect we started with the number of stems that would be present in the absence of budworm.. This was then adjusted for each year based on the defoliation level mentioned above. Previously, we mentioned the values used for individual tree relative annual growth, which can be used to obtain the individual tree volumes. These individual tree volumes were multiplied by the adjusted stem count to obtain the stand volume as affected by increased mortality from 1994 to the end of the outbreak in 2006, and to the end of the rotation period.

Experiment 1: Volume Changes to the End of the Outbreak and at Rotation Age.

We project the growth in Blocks D and E into the future using the methods outlined above. In this analysis we do not estimate volume changes for the control stand, F because it provided an indication of the difference **between** a spray versus no spray situation for the period 1988 to 1994. Now we project this difference **within** the stands that had been sprayed.

Table 15 shows that there is still some volume loss due to budworm under the reactive spray regime in the young stands. However, it is less than it would have been if no spraying had occurred and the effect of considering additional mortality makes a difference. At rotation, the control measures in Block D saved about 8 m^3/ha in the case with no added mortality, and about 29 m^3/ha if increased mortality is considered. For Block E, the control measures resulted in volume savings of 10 m^3/ha with no additional mortality and 11 m^3/ha with additional mortality. Note that the volumes saved by spraying are lower at the end of the rotation than they were at the end of the outbreak (Table 15). The reason for this is that the stand has time to regrow some of the lost volume and the rate of growth will be higher in the affected stand than the normal since the rate is partially dependent on age (young stands grow faster than older stands). We also assumed that the damaged stands would recover at a rate corresponding to that of a young stand and that their growth rates had not been compromised by the outbreak. This can be seen in Figures 1 and 2 where the cumulative change in volume in these stands over time under the various scenarios are shown.

Table 15. Stand volumes (m^3/ha) at the end of the outbreak and at rotation age

	Normal	Without added mortality		With mortality	
		Spray	No spray	Spray	No Spray
Block D					
At end of outbreak	284.13	237.29	224.18	211.56	191.72
Volume saved by spraying		13.11 m^3/ha		19.84 m^3/ha	
At rotation age	328.02	284.20	276.20	242.84	229.72
Volume saved by spraying		8.00 m^3/ha		13.12 m^3/ha	
Block E					
At end of outbreak	236.13	192.45	180.10	166.34	152.60
Volume saved by spraying		12.35 m^3/ha		13.74 m^3/ha	
At rotation age	318.99	282.96	272.50	261.81	250.84
Volume saved by spraying		10.46 m^3/ha		10.97 m^3/ha	

Figure 8. Volumes in block D under different spray regimes.

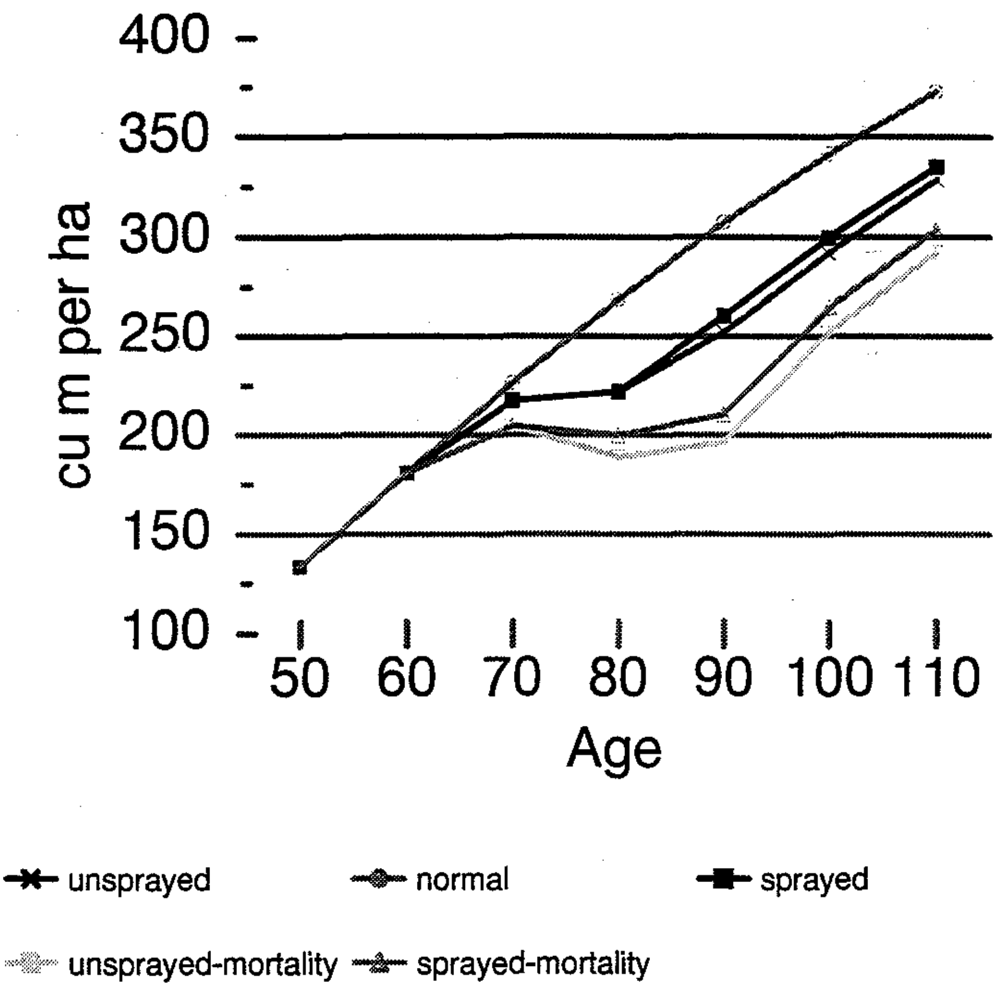
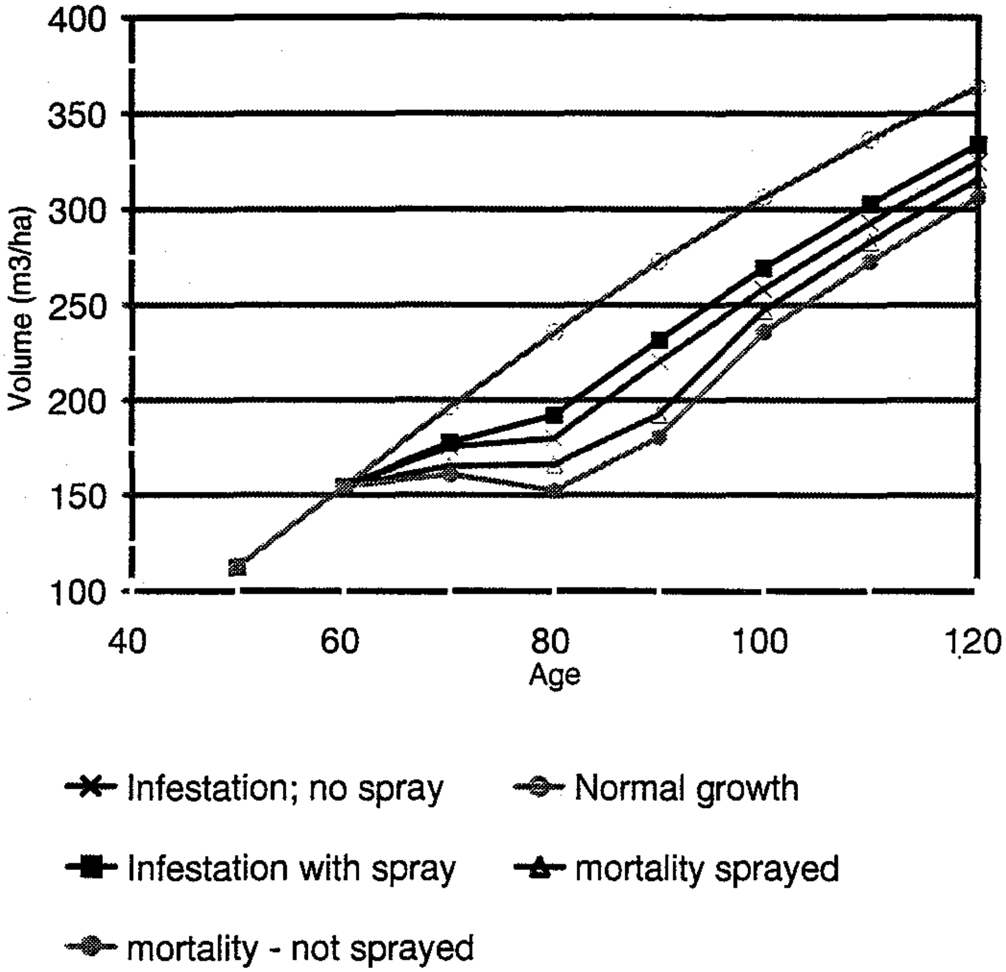


Figure 9. Volumes in block E under different spray regimes.



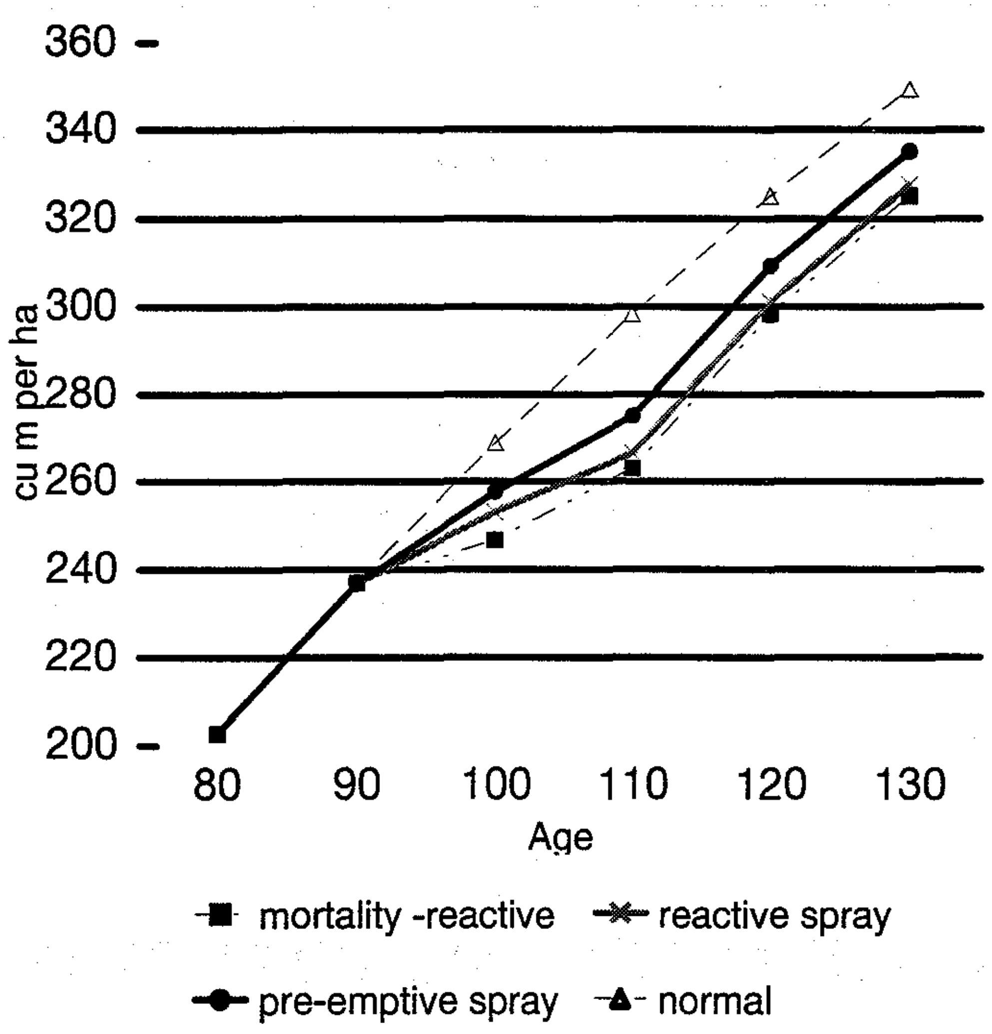
Experiment 2: Volume Changes to the End of the Outbreak and at Rotation Age

In this section the analysis will concentrate on Block B the pre-emptively sprayed plot. Here it is necessary to show what the stand volume would be in the future under both the reactive and pre-emptive regimes. Given that the pre-emptive regime successfully prevented the outbreak from becoming established (Table 14), we postulate that there would be no increase in mortality using this control regime. In Block B, the pre-emptive control regime would save about 7 m^3/ha by the time the 18 years of the outbreak had passed, and just under 5 m^3/ha by rotation (Table 16). These results also identify a volume saved at rotation that is lower than that at the end of the outbreak. As in experiment 1 the reason for this is the same, as we assume recovery rates following outbreaks that correspond to stands growing as though they were several years younger. This is shown in Figure 3 where the lines of total volume gradually converge after the outbreak period.

Table 16. Stand volumes (m^3/ha) at the end of the outbreak and at rotation age: block B.

Time Period	Normal	Spray regime		
		Without added mortality		With added mortality
		Pre-emptive	Reactive	Reactive
End of infestation	286.84	268.07	259.51	256.15
Volume saved by pre-emptive spraying		8.56		
Rotation age	309.32	285.00	280.35	277.10
Volume saved by pre-emptive spraying		4.65		7.90

Figure 10. Volumes in block B under different spray regimes.



Benefit Cost Analysis

Reactive Spraying on Young Stands

Recall from Table 13 that the amount of volume saved by reactive spraying was 7.91 m^3/ha in Block D and 9.62 m^3/ha in plot E. When these blocks reach rotation age, these volume savings will be affected by the assumptions of increased mortality. Without increased mortality, spraying saves an estimated 8.00 m^3/ha in Block D, and 10.5 m^3/ha in Block E. With added mortality, spraying saves 29.10 m^3/ha in Block D and 11.00 m^3/ha in Block E.

With knowledge of the costs and benefits as outlined in the methods these volumes were converted to economic values. Table 17 outlines the results of these conversions and shows the net present benefits provided by the control measures over the period 1988-1994 and also at rotation age. In all scenarios, the net present benefits are greater than 0, suggesting that the control measures are justified on economic grounds. Over the short term period (1988-1994) for which we have accurate measures of the volume losses, the net present benefits are large. At rotation, which is the time at which the forest manager harvests the stand and receives any benefits, these values are reduced. As expected, increased mortality could play a large role in assessing the net present benefits. However, even without increased mortality as a result of budworm outbreaks, the control measures are worthwhile.

Regarding the efficiency of reactive versus pre-emptive spraying, similar calculations was made for block B. Table 18 provides the results. Here the net present benefits are also positive but are considerably smaller than those for the younger stands. This is probably due to the older age of the stands in this experiment and is particularly evident at rotation.

Table 17. The Benefits and costs of reactive spraying on young stands.

Block	D	E
Volume saved by spraying	7.91 m^3/ha	9.62 m^3/ha
Value ($1994) of saved volume	$791	$962
Discounted benefit/ha ($1990) of reactive control	$650.14	$790.70
Costs/ha of control regime ($1990)	$74.51	$52.20
Present net benefit/ha ($1990) (benefits minus costs)	$575.64	$738.50

At estimated rotation				
	No increased mortality		Increased mortality	
Block	D	E	D	E
Volume saved by spraying (m^3/ha)	8.00	10.46	13.12	10.97
Net present benefit/ha of control ($1990)	$182.02	$149.23	$346.19	$159.06

Table 18. Net Present benefits of pre-emptive control regimes

	Without mortality increase
Block	B
Volume (m^3/ha) saved by spraying	9.08
Present benefit/ha ($1994) of pre-emptive control	$908.00
Discounted benefit/ha ($1990) of pre-emptive control	$749.88
Costs/ha of control regime ($1990)	$92.81
Present net benefit/ha ($1990) (s benefits minus costs)	$657.07

At estimated rotation		
	No increased mortality	Increased Mortality
Volume saved by spraying (m^3/ha)	4.65	7.90
Net present benefit/ha of control ($1990)	$85.19	$207.10

DISCUSSION

Our findings suggest that spruce budworm outbreaks have negative impacts on the growth of white spruce stands in the study area. These impacts on stand volumes were assessed with some very conservative assumptions on growth and yield. Budworm defoliation in the younger stands examined reduced volume growth by 11% of normal. However, the use of BTK had a significant effect in depressing these negative effects. In two replications of spraying BTK in young stands (Blocks D, E) where the outbreak was established, this volume reduction decreased to 6% and 8% of normal respectively. In an older stand (Block A) where a similar BTK application regime was used, a reduction of 5.17% of normal was observed. The success of these control measures, however, raises further questions about the use of different application regimes and the economic efficiency of the BTK control measures.

A second BTK application regime was examined in an additional experiment. In this case, BTK was applied to an older stand (Block B) before the budworm outbreak became established. This pre-emptive control strategy resulted in an even further reduction in the decrease of volume, in this case to 1.54% of normal. Thus, in older stands a reactive control strategy, while effective, would not achieve the same level of success as a pre-emptive strategy. However, whether pre-emptive control strategies work on younger stands remains an open question. Further research will be required to address this issue. Simulating the effects of a pre-emptive spray using the growth and yield formulas on Blocks D and E (by using the same relative annual increment of 0.8 as used in Block B) does show a very strong reduction in loss. Calculation shows that the stand volumes would be 303 and 296 m^3/ha respectively. Under the reactive spray regimes they would be 284 and 283 if we assume no elevated mortality, and 243 and 261 respectively, with mortality, (Table 15). This strategy, applied to young stands, can save a potential 30 to 60 m^3/ha under a worst case scenario.

We found that the costs of the BTK applications were less than the benefits in constant dollar terms. This difference was consistent over the short term period in which actual measurements where conducted (1988-1994), and over a longer term period to an estimated rotation age of the stands. A forest manager using current knowledge of the costs and timber values who decides to control a budworm outbreak in young or old stands would appear to making the correct decision. In older stands, of course, the benefits of the pre-emptive policy are larger than those for the reactive policy. These findings suggest that the use of BTK to control spruce budworm outbreaks in white spruce stands is economically efficient when only timber values are considered. Furthermore, we emphasize that all the assessments of volume changes and mortality are conservative.

The effect of spruce budworm outbreaks and their control on non-timber values remain an important issue. Examining linkages between budworms, BTK control measures, and non-timber goods and services is difficult. What is required is: 1) an inventory of non-timber goods and services provided by forest stands where outbreaks occur; 2) knowledge of the impacts of budworm outbreaks on these goods and services; 3) knowledge of the impacts of the budworm control measures on these goods and services; and 4) a process that collects information on these impacts that allows conversion to economic values so they can be incorporated into the benefit cost analysis.

First, any inventory of non-timber goods and services should include ecological services, marketed non-timber goods (e.g. mushrooms), and non-marketed goods and services such as aesthetic values, recreation, and passive use values[2]. Ecological services, while important, are exceedingly difficult to measure in economic terms and thus will be virtually impossible to assess. In many cases an inventory of non-timber goods and services will reveal few direct linkages between people and the stands due to remoteness, or these linkages will not involve enough individuals to have a significant impact on the benefits and costs. Thus, more indirect linkages which involve aesthetic and passive use values may have to be examined.

Second, in order to assess the impacts of forest pests and BTK on non-timber values considerable research remains to be done. A literature review reported in the previous year (Volney and Watson 1996) revealed few studies in this area. Furthermore, many of these studies were dated and have not used more recent developments in economic modeling. On the other hand, significant effort has been expended on the impacts of pests on aesthetic or scenic values of the forest. However, few, if any, of these have been conducted in Canada. The impacts of budworm on aesthetic values remains fertile ground for future research.

In the next section of this report we propose to examine some of the impacts of budworm on non-timber values. A preliminary inventory of some of the non-timber services provided by forest in the Hawk Hills area was completed (see Appendix D). This inventory suggests that it will be difficult to assess the impacts of budworm outbreaks on these values for the reasons stated above. Thus, we examine impacts of budworm on the visual and aesthetic features of the forests. This required continuing

[2] These latter values include such things as the values of the existence of various species, option values, and bequest values. See Adamowicz (1991) for a review of these concepts.

field work to collect photographs of damaged and undamaged stands as well as some additional plot measurements to calibrate the visual qualities. We propose to utilize the Scenic Beauty Method (Daniel and Boster 1976) in concert with econometric techniques. To assist with this endeavour, we have invited Dr Wolfgang Haider from the Centre for Northern Forest Ecosystem Research to join the research team. Dr. Haider is a national expert on scenic quality of forests in Canada agreed to assist us with this project.

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PART III:
IMPACTS OF BUDWORM OUTBREAKS ON SCENIC BEAUTY

by

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INTRODUCTION

The previous section showed measures of the economic loss of timber values caused by the budworm, and examined the economic effectiveness associated with various control measures. That analysis did not consider any non-timber values in the economic assessment of outbreaks and their control. This section describes attempts to assess some impacts of budworm outbreaks on non-timber forest values.

There are a number of potential non-timber values affected by the budworm. Forest-based recreation in the area was initially chosen for examination. The first step was to investigate the recreation resource potential and pattern of use in the region. This investigation combined an *ad hoc* inventory of parks of the area and discussions with Alberta Environmental Protection staff (principally parks and fish and wildlife personnel). This information (summarized in Appendix D) suggested that intensity of recreational use of forests in the area is relatively low, is widely dispersed, and involves mainly local residents. The spatial pattern of historical and current budworm outbreaks did not correspond with the spatial pattern of recreation. This incongruence would make examination of the role of budworm outbreaks on recreation user preferences difficult, if not impossible. We concluded that the impacts on forest-based recreation was minimal.

Nevertheless, some indications of the impacts budworm outbreaks might have on recreation user preferences may be obtained by assessing the effect of defoliation on scenic beauty. This approach assesses fundamental attributes of the resource that influences user preferences. It also has the appeal that it is more general in its application than the empirical approach originally contemplated because it examines basic principles. The results may therefore be applied to any of several non-timber values where scenic beauty is a component determining resource value and use, whether it be hunting, fishing, nature study or other activity where visual attributes of the forest environment is of major significance to the user.

Scenic beauty is an important feature of forests and in many jurisdictions it is mandated that visual aesthetics should be considered in forest management (e.g. Forestry, Lands and Wildlife, 1990). There are proven methods for determining the scenic beauty of forest features. Visual stimuli can be an important part of forest recreation experiences and variables affecting scenic beauty have been shown to be important in determining recreation site choice (Daniel et al. 1989; Boxall et al. 1996). There are numerous influences on the visual aesthetics of forests from both biogenic and anthropogenic sources. Insect outbreaks are a natural force and have been shown to affect scenic quality in US jurisdictions (e.g. Buyhoff and Leuschner 1978) but there has not been much research effort examining the influences of forest pests and recreation potential. Virtually no research on visual aesthetics has been conducted in the boreal forest. One study was undertaken in Quebec, that dealt with the aesthetics of cutblocks as seen in landscapes vistas overlooking boreal fir forests, but did not include insect damage (Paquet and Belanger 1997).

In this project we attempted to integrate these issues in the analysis of the scenic beauty of forests in northern Alberta. Along with the scenic beauty experiment, we wished to survey the forest use history of the respondents, and their attitudes to forest management options. This information often shows a strong correlation with the scenic beauty perceptions.

Scenic Preference Rating Methods

Several different methods for assessing the scenic beauty of landscapes in general, or forested landscapes in particular, have been developed over the past 30 years. Reviews have categorized the multitude of approaches into four different paradigms: the expert method, the phenomenological method, the psychological method and the psychophysical method (Zube et al., 1982). Among these approaches, only the last one satisfies all three scientific measurement criteria of reliability, validity and utility (Haider and Hetherington, 1998). Also, the psychophysical method bears the most relevance to issues of forest management, as it combines lay-person landscape evaluations with the rigor of forest inventory measures. It thus permits the development of statistical tests and models that determine which forest attributes contribute the most to forest landscape aesthetics. Therefore, the Scenic Beauty Estimation method, which arguably is the most widely applied psychophysical method, has been selected for this study.

The Scenic Beauty Estimation Method was first outlined by Daniel and Boster (1976)[3], who class it as a method that provides measures of landscape beauty independent of observer judgmental criteria. Each value is assumed to result from the combined effects of a number of landscape properties. Scenic Beauty Estimation has been used extensively in the United States. Since its' inception numerous researchers have worked on improving the method by focussing on the selection of

[3]Arthur and Boster (1976) is a bibliography of earlier, usually similar methods, that estimate scenic beauty in general.

sites or views, the best way to present photos to subjects, the interpretation of the scenic beauty estimators (SBEs), and the assumptions regarding the behaviour of respondents in conducting ratings of the scenes. Most of published studies have examined pine forests in the Rocky Mountain regions of Colorado and the southern USA. There has been only one study (Paquet and Belanger 1997) published on scenic beauty in the boreal forest. As well, the published studies have examined either "in-stand" forest scenes (i.e. the view of someone standing in the middle of the forest), or large scale forested landscape features. Given the nature of the boreal forest in the region, neither of these options is applicable. Users of the forest in the region generally follow roads or cut-lines, and the time spent "in-stand" is very limited. Thus for this study the choice was made to photograph the forest edge as seen from various access corridors. There have been only two studies that features road side scenic beauty (Schroeder and Daniel 1980, Ruddell et al 1989), neither of which involved recreation, or insect damage. The first set out to show that the scenic beauty method could be used to better plan the location of roads through a region, and the second was measuring how the amount of undergrowth, and visibility into the forest affected peoples sense of security.

The application of the SBE method involves the following steps: 1) representing landscapes in some form of stimuli; 2) presenting stimuli (slides) to observers; 3) evaluating / analysing observer judgements; 4) collecting a bio-physical forest inventory; 5) integrating (modelling) observer evaluation and biophysical inventory.

Past research has verified repeatedly that colour slides provide an accurate representation of landscapes for the purpose of landscape evaluation. Comparisons between slide evaluations and on-site judgements have not produced any significant differences (Buhyoff and Wellman, 1979; Daniel and Boster, 1976; Shelby and Harris, 1985). Crucial for the successful application of slides is a random selection of sites and a standardized photographic procedure for taking the slides.

In Scenic Beauty Estimation each subject is shown each scene for a short time period and asked to assign a score along a rating scale, such as between one (low) and ten (high quality). A viewing period of 5 seconds is generally sufficient to form an opinion. A "warm-up" group is generally given before the actual slide presentation. These slides consist of pictures that are considered to represent the range of features in the subsequent presentation of slides. It is also advisable that at regular intervals respondents are given a short rest accompanied by a slide which indicates the number of the next slide to be shown. This rest provided subjects with an opportunity to adjust their responses to match the slide sequence. There are conflicting results on the potential of the order of the slides to affect ratings (sequencing effect). A sequencing effect would occur if showing slide A before slide B results in a consistently different rating than showing slide B first. Daniel et al (1977) did not find an effect, but most later studies have randomized the presentations in case an effect exists.

The ordinal scores obtained from the ratings are then converted into interval scores using a mathematical procedure (related to Signal Detection Theory) that compares the normalized (z-) score of cumulative probability of a score for each landscape. The difference between standard normal scores for each landscape as related to an arbitrary base case gives values called Scenic Beauty Estimates (SBEs). The average of the SBEs for each person gives a group SBE. It should be noted that the SBEs from a single individual cannot be considered valid alone; the SBE values must be derived from judgements made by a number of observers for a variety of landscapes. Observers ratings are adjusted (by using z-scores) to account for the effect of differing judgement criteria. The calculation of the SBE for each slide involves: 1) finding the mean Z for the slide; 2) determining the mean of the mean Zs for the set of slides; and 3) adjusting the mean Z of each slide by subtracting from it the mean Z of the slide set. A detailed description of the calculations, and the need for these adjustments can be found in Brown and Daniel (1990).

Brown et al (1990) have developed a computer program called RMRATE that calculates the SBE. This Fortran based program also conducts a number of statistical tests on both the observers and the stimuli (in this case the photographs). For the observers, the most important series of statistics are: i) the correlation of an individual's ratings with the overall group ratings; ii) the range used by the observer (i.e. whether the whole 1-10 scale or only part of the range, for example only ratings within the range 2-6); and iii) and the standard deviation of the ratings. For the photographs, the measure most interesting is an analysis of the principal components contributing to scenic beauty. Using the individual component scores for each photograph it is possible to conduct cluster analyses and then group the photos into their respective clusters. This can be used to visually examine some of the features that may differentiate the clusters of photos.

The bio-physical forest inventory is important to have scientific measures of the forests shown in the slide set. In previous work, many different variables have been attempted, in part depending on the forest quality of interest to the researcher. The most common attributes collected correspond to easily obtainable standard silvicultural measures, such as diameter at breast height (dbh), and tree height.

Mapping of the trees encountered will give the stem density, the species mix in the stand, as well as the openness of the forest. Any or all of these can be used in further modelling, or adapted to easier to use measures.

The integration of the observer evaluations and the biophysical inventory is normally done with OLS linear regresssions. Schroeder and Brown (1983) examined various functional forms for the regression stage, and determined that the linear form gives very good results. The biophysical attributes to be used at this point are in part determined by other manipulation of the SBE calculation process. As mentioned above, the principal component analysis that is part of RMRATE separates the slides based on attributes found within them. By laying out the slides along the scattergrams created by comparing the principal components, it is possible to "eyeball" which features are involved.. As well, simply laying the slides out along the gradient of SBEs allows further insight into which features come into play in the ratings.

METHODS

Site Selection and Photography

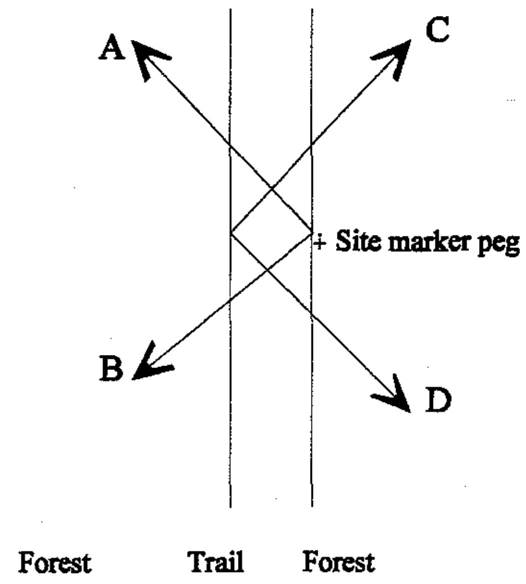
In order to study how spruce budworm damage may affect scenic beauty, photographs of forest scenes with varying levels of visible damage were necessary. It was decided that the preferred method would be to take the photos along forest access routes, including secondary highways, pipelines, seismic lines, haul roads, and trails, which provide the most common viewing points of the forest for the various users..Images for the SBE process were selected to show a variety of forest types, ages, and level of damage. There was some difficulty in locating enough sites with budworm damage so some scenes were included which had damage caused by other factors such as other insects or water damage. The visible damage from these other sources is similar in aspect to the damage from the spruce budworm.

Photo locations along a particular corridor were selected by a random start process. At the beginning of a corridor, where it branches off a main road, the centre of the first sampling plot (site) was selected by walking a random number of paces (between 20 and 50) from the roadside to the first photo location. Subsequently, photo locations were evenly spaced along the access corridor at a pre-determined distance, (normally 150m, but with some variation depending on the corridor). At each photo site, a total of 4 photo directions were possible; from each side of the corridor and in both directions. Furthermore, two types of framing are possible: horizontal and vertical (camera rotation). The plot center was marked with a metal peg and was given a site number for later inventory work. Each directional shot was given an alphanumeric site code which corresponded to the direction the photograph was taken (see Figure11). All pictures were taken between July 20 and August 1 1997 with a Nikon 601 35mm camera (50mm lens). To provide consistency in the photographs, the same person took all of the photographs.

The photographs were taken in the Hawk hills north of Manning along Highway 35, and adjacent to Highway 58 between High Level and Rainbow Lake. The locations are described more fully below:
A.) Hawk hills; The sites here correspond to the budworm damage assessment plots E and F described in an earlier section of this report. The photos were taken along the trails leading from the highway to the test plots.
B.) Highway 58; there are four lines here, between the turn-off at High Level, and the crossing of the Chinchaga River, 72 km west of High Level. The first two are marked by an oil company lease sign, which reads 280c0, and is to the north and the

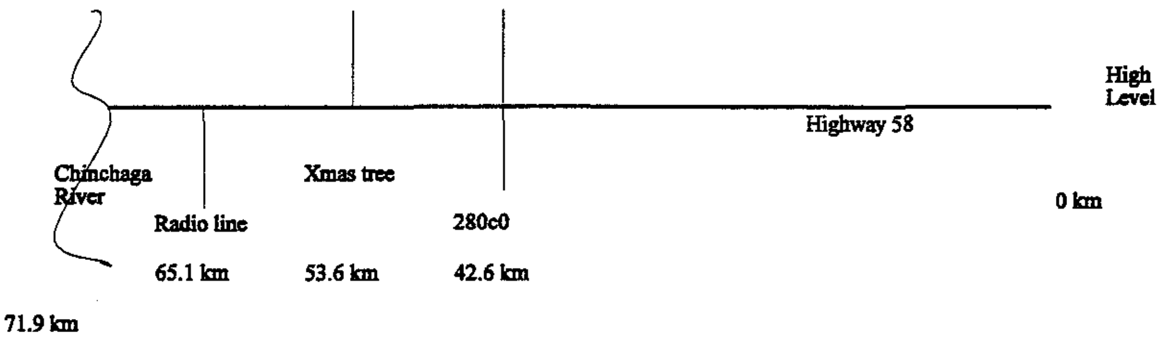
south of the highway. It is 42.6Km from the turnoff.

Figure 11. Position of photograph direction



The third, which we labelled the Xmas tree line, has no marking on the highway, but is an reasonably well established road to the north, at 53.6 km from High Level.. This road goes for about 200m beside a dugout, then shifts to the west. There is a large opening, with a capped well in the middle. The line runs north from this clearing. The fourth is just past a radio tower at 65.1 km (the tower is at 64.6 km). It is not marked on the highway. The line runs south from the road. Figure 12 is a schematic map of the location of these sites. Note that the distances marked are from the start of the highway at High Level.

Figure 12. Schematic map of Rainbow Lake sites



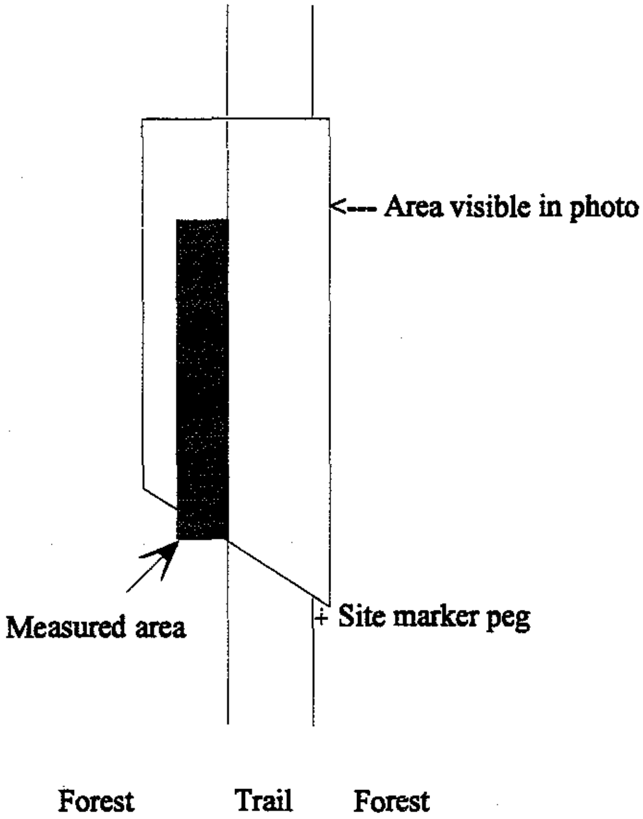
Physical Inventory at Photographic Sites

During the fall of 1997 and the spring of 1998 physical measurements of the photograph sites were conducted. The diameter at breast height, location, and species of each tree were noted in a strip 2 m wide and 50 m long from the metal pin placed where the photos were taken, as shown in Figure 13. The 2 m measure was thought to be sufficient depth to capture the amount of forest visible in the scenes, and 50 m measure was chosen as the maximum beyond which visual details may begin to get unclear. In addition, the height of the dominant tree at intervals of 7 and 10 m were taken (i.e. 7 and 10, then 17 and 20 etc). From these measures, summary inventory data such as percent of each species per hectare or stems per hectare could be calculated.

Collection of Ratings Data

In order to determine the number and the suitability of the photographs to be rated a pre-test was conducted. From an initial group of over 500 slides, 54 containing both vertical and horizontal views, were chosen for a pre-test. The selection of photos was based upon the presence or absence of damaged trees, an attempt to have a wide range of forest types and ages, and overall picture quality. As well, any photo with prominent and distracting features, such as a large rock, were not included.

Figure 13. Photograph site physical inventory measurement



The pre-test was conducted on a 3rd year natural resource economics class of about 25 students at the University of Alberta. The students were first provided with an initial group of 7 "warm-up" slides. Following the presentation of slides, a questionnaire was administered (see below) and a discussion of the slide presentation occurred.

The students found that the number of slides presented was acceptable, and that the time allotted for response was sufficient. They did however indicate that there was not a high variety of scenes. Of particular concern was the number who said they did not use the entire 1 to 10 scale, because they were "saving" the high and low numbers for "something" more spectacular. Many also seemed to be judging the overall picture rather than the forest beauty. There was no apparent difference in the ratings of vertical and horizontal views. This was tested by including vertical and horizontal shots of the same site in the presentation.

As a result of these findings, changes were made in the introduction to the slide show to place strong emphasis on the importance of rating the forest. The presenter avoided phrases like the "scenic beauty of the photo, or view", and instead used the word forest. These revisions were first used in a second pre-test involving a group of administrative and support staff at the Northern Forestry Centre. For this group, the number of slides was increased to 64, with only horizontal views, and a stronger attempt to include slides that were similar in all aspects except the level of forest insect damage. In The final ratings instrument is shown in Appendix E.

A second change was the wording of the introduction to the warm-up slides. It was stressed before and after the "warm up" slides were shown that the full range of forest scenes would be shown in this group of slides. Subjects were told directly that if a type of scene was not in the warm-up group, it would not be in the slides to be rated. A comparison of the ratings between the pre-test students and support staff showed that these changes resulted in more consistent rating of the forest beauty, the range of response was greater, and more consistent from the beginning to the end of the show.

For the actual SBE experiment, an attempt was made to get as many respondents as possible from the study region. To this end, schools, church groups, and public service organizations in Manning and Peace River were contacted. It was felt that using contacts with established groups would be more productive in achieving an acceptable response than a general call in the press or by telephone. This resulted in one class each of respondents from the Manning and Peace River High Schools, two church groups in Manning, the Manning Toastmasters, and the Manning Area Trappers Association. The slides were also presented to a general public group in Edmonton. The order of the slides was randomized, and changed for each presentation. This was done to prevent the possibility that the order of the presentation was affecting the ratings, (i.e. sequencing effects).

The slides were also shown and rated at the annual provincial government Forest Protection Officers' (FPO) meeting in Peace River in early March. For this meeting, the participants (FPOs) were broken into two groups and shown the slides in a different order to ensure there would not be a sequencing effect. A hypothesis was formulated that this group would show a different set of ratings than the other, non-professional groups. Several past studies have shown this effect, for example, McCool et al (1986), where the forestry professionals were less sensitive to forest thinning than the general public.

Table 19. Schedule of presentations to respondents

Group	Date	Location	Group Size
Pre-test	February 5	Edmonton	23
North. For. Cent. staff	February 19	Edmonton	12
General Public 1	February 25	Edmonton	12
High School	March 3	Manning	33
Trappers Association	March 3	Manning	8
Toastmasters	March 5	Manning	5
Forest Protection. Officers	March 5	Peace River	61
Churches 1	April 3	Manning	4
Churches 2	April 4	Manning	3
High School	April 7	Peace River	23
Total useable ratings			161

Forest Use and Values Survey

Following the collection of scenic beauty ratings, subjects were asked to complete a short written questionnaire designed to provide information on the level of use of the forest, knowledge of insects that damage trees, and knowledge of insect control measures. It also used components of a previous questionnaire developed by McFarlane and Boxall (1996) to gather information on attitudes regarding forest management and use. The questionnaire was used in the first pre-test and slight changes based upon discussion with the pre-test subjects were incorporated. The final questionnaire administered to subjects is shown in Appendix E.

RESULTS

Scenic Beauty Estimates (SBEs)

The ratings of all respondents (except the pre-test students who had a different photo set) were entered electronically and then were analyzed using RMRATE program to derive SBEs. The SBEs were calculated for each individual and sub-group in the data. The sub-groups examined were: i) FPOs; ii) the general public; and, iii) high school students. The general public and high school samples were also separated geographically and examined. However, the sample sizes for this combination of sub-group were too small to provide significant results. The ratings for each sub-group were examined to investigate the possibility of differences in ratings among the sub-groups. The SBE scores for the sub-groups are displayed in Table 20.

Correlation analyses can be constructed between individuals and sub-groups to examine the degree of consistency of their ratings. The Pearson method was used which generates a correlation coefficient, r, which can take a value between 1.00 and -1.00 An r of 1.00 indicates that the SBEs from two individuals or groups are perfectly positively correlated, while an r of -1.00 indicates a perfect negative correlation between the SBEs.

Table 20. SBE ratings by photograph for the major sub-groups of the sample.

Photo number	FPO	High School	General Public	Public plus high school	Total Sample
p1.10	48.91	24.92	48.34	38.91	48.6
p1.12	10.3	107.25	38.74	79.17	59.49
p1.20	36.81	30.43	26.58	31.39	33.08
p1.22	49.3	53.45	58.89	60.73	58.75
p1.24	41.87	64.3	84.14	74.35	65.63
p2.12	52.03	13.82	26.95	17.03	26.54
p2.15	58.09	-5.66	36.53	9.24	21.35
p2.33	50.96	67.97	70.86	74.29	68.82
p2.37	48.34	136.07	64.57	111.47	97.87
p3.02	35	106.71	72.74	98.29	84.58
p3.04	30.53	27.69	38.54	34.92	35.64
p3.06	8.46	84.54	44.98	72.44	49.45

p3.08	79.98	74.35	65.76	71.48	76.04
p3.21	-0.65	-11.6	-8.35	-11.59	-9.89
p4.17	-18.13	-32.52	-9.39	-26.26	-23.82
p4.32	1.17	0.56	-1.41	-1.56	-0.91
p5.26	-23.91	-21.67	9.02	-6.28	-14.75
p5.28	-17.66	-30.99	18.86	-9.98	-15.32
p6.22	-7.91	-29.27	-26.55	-27.4	-25.47
p6.33	-16.07	-41.3	3.7	-28.27	-24.74
p7.19	23.36	-19.98	14.52	-8.59	0.87
p7.26	-32.15	-56.99	-68.65	-68	-56.84
p7.30	-7.21	-51.59	-48.52	-51.56	-38.88
p8.05	36.84	18.91	5.22	15.1	23.49
p8.09	34.91	-1.63	11.62	4.04	16.37
p8.13	14.47	58.08	22.9	49.01	39.04
p8.15	-0.71	-38.1	-34.31	-42.4	-31.14
p8.17	-9.84	-20.48	-10.54	-20.23	-19.9
p8.19	-44.11	-49.79	2.6	-34.22	-41.61
p8.28	-72.71	-113.14	-90.22	-110.89	-104.64
p9.10	-49.17	-75.13	-16.49	-55.31	-50.98
p9.12	-50.29	7.84	-17.67	-0.66	-13.4
p9.14	0.81	8.98	12.7	10.03	7.29
p9.16	-27.07	-16.19	-48.74	-30.6	-30.37
p9.18	5.86	14.58	-12.93	3.73	4.38
p9.27	-3.49	28.75	18.92	27.67	20.18
p10.09	-4.73	-6.81	-27.49	-19.43	-11.79
p10.10	-8.9	-48.79	-14.91	-39.18	-29.11
p10.12	11.84	33.9	14.68	28.64	24.35
p10.14	20.08	29.6	-5.94	18.94	20.76
p10.16	-17.22	-54.83	-37.77	-50.85	-46.02
p10.20	54.28	39.87	55.01	46.92	51.47
p10.28	-19.53	42.04	30.31	40.39	24.8

p11.06	-37.75	20.9	-13.94	12.13	-5.84
p11.08	-45.73	2.95	-20.4	-4.95	-18.15
p11.16	-26.06	46.74	11.87	36.53	21.64
p11.18	-15.53	-12.63	-16.33	-14.65	-15.29
p11.20	6.75	50.01	16.75	43.47	36.2
p12.02	-0.36	45.95	9.35	30.31	23.07
p12.18	1.26	-27.77	-59.67	-44.94	-33.53
p12.20	-2.61	-10.15	-19.87	-15.5	-15.64
p15.06	-0.8	-23.77	-33.3	-30.34	-21.96
p15.08	-1.34	30.63	10.41	27.18	20.81
p15.11	5.68	-17.59	46.32	7.46	7.54
p15.13	-21.46	-26.67	25.2	-3.5	-6.42
p15.16	-34.12	-90.27	-66.93	-85.47	-72.07
p15.18	-34.19	-100.34	-59.17	-87.42	-73.97
p15.20	-3.77	-59.46	-50.03	-54.32	-40.81
p15.21	-39.37	-35.72	-51.49	-41.38	-43.12
p15.22	-31.52	-42.09	-57.49	-48.07	-44.79
p15.24	1.52	7.27	-10.49	2.43	5.35
p15.29	-19.46	-27.51	-30.29	-31.88	-31.51
p15.33	-17.46	-31.93	-3.65	-21.65	-21.58
p15.35	-6.44	-46.72	-44.61	-50.33	-39.16

RMRATE generates Pearson correlation coefficients among individuals within sub-groups of the ratings data. The program can be used to exclude an individual's ratings if they do not exhibit an acceptable degree of correlation with others in the sub-group. This exclusion is based on the chance that those with radically different ratings did not understand the scenic beauty experiment, or have preferences for scenic beauty that are significantly different than others in the sub-group. A correlation coefficient value of -0.700 was chosen as the point where subjects in a sub-group were excluded from further analysis.

In the sample gathered for this study 23 individuals were dropped from the analysis because their rating responses appeared to be significantly different that others in their sub-groups. Inspection of the characteristics of these 23 people showed that most of the people who were over 60 years of age were excluded. This suggests that age may play a significant role in scenic preferences, or that these older individuals did not understand the experiment. The role of age in scenic preference research warrants further study in the future.

Correlations were also examined between sub-groups. The high school and general public sub-groups were the most highly correlated, with an r of 0.82. The ratings of the FPOs were less correlated with both the general public and students with coefficients of 0.74 and 0.65 respectively. This information suggests that the general public and student groups could be combined and that the FPOs may exhibit significantly different scenic preferences. Thus, further statistical comparisons of the SBEs among the sub-groups should be between the FPOs and the other two groups combined.

Principal Component and Cluster Analysis

RMRATE also provides the opportunity to perform some multivariate statistical analysis on the slide ratings. The purpose of a principal components analysis (PCA) is to reduce the complex structure of a data set composed of many variables to a few components. PCA is considered successful if those few components account for a large proportion of the total variance in the data set, and at the same time these components can be interpreted in a meaningful way. In the case of RMRATE, the PCA uses the individual observer ratings by treating each observer as a variable and each stimulus (slide) as an observation. In a PCA the first component represents the best line of fit which maximizes the total variance that can possibly be explained by that line in the data set. The second component maximizes the remaining total variance of the residuals, and so on. In PCA, eigenvalues are used as a measure of explanatory power of each component. A component ought to carry an Eigenvalue of at least one in order to contribute more to explaining total variance than a regular variable would.

As in most scenic beauty studies, the number of components with Eigenvalues above 1 is rather large (33), but many of these Eigenvalues are less than 2, indicating that their contribution to explanatory power is marginal. However, the first three components contribute to a total of 60% of the total variance (Table 21), and also it is possible to attach meaningful explanations to these three components. Because the slides were used as observations in the PCA analysis, any analysis of the slides necessitates the calculation of their component scores. These scores can then be used for interpretation of patterns in the data, which can be accomplished efficiently by plotting two dimensions against each other at a time. Readers are reminded that these component scores are value neutral, i.e. a positive or negative number does not indicate like vs. dislike or preference, but should simply be interpreted as a polarization measure.

Table 21. Eigenvalues and explained variance for the first three principal components

	Eigenvalue	Variance
Component 1	34.12	24.73
Component 2	17.32	12.55
Component 3	7.72	5.60
TOTAL	60.16	42.88

Apparently Component 1 distinguishes scenes by the amount of lighting available in each scene, and also the width of the trail. Unfortunately slides of the most narrow trail system, corresponding to Hawk Hills experimental plot F, were taken under overcast conditions, and therefore one must suspect that collinearity exists between these two attributes.

Component 2 is associated with the amount of damage in the scenes. Because none of the hardwood stands contain any damage in the data set used, both mature aspen and slides with a large proportion of shrubs also concentrate on the undamaged end of the spectrum.

Component 3 separates the images by the amount of mature hardwood. Images on the positive end of the spectrum (high component scores) all include scenes of mature aspen forests. Scenes with a slightly lower but still positive loading show mixedwood forest, but several mature aspen stems show prominently in those. On the negative end of the spectrum one finds pure conifer scenes, as well as some scenes that are dominated by very young hardwood bushes with no or only a minor conifer component.

In one further step of analysis, we used the component scores of the first three components to perform a cluster analysis in order to identify meaningful groupings among the stimuli. Using Ward's method and squared Euclidian distance, the dendrogram (Figure 14) suggests a three cluster solution. Interpretation of these clusters can be assisted by calculating means on the variables (Table 21). These three clusters group the images along the following criteria:

The largest cluster (Cluster 1 N=32) contains the scenes with no or minimal damages, and also the scenes with major hardwood components. Images belonging to this cluster have the highest average component score on Component 2, confirming the absence of damage, while their average component scores for Components 1 and 2 are insignificant. These mean component scores by cluster confirm the earlier interpretation of the three components. Scenes of this cluster are located in the lower centre and lower right section of the scattergram.

Most of the scenes in Cluster 2 (N=19) contain damaged trees, mainly budworm damage but also some scenes with water damaged trees. These scenes have the lowest mean component scores for both Component 1 and Component 2. Low scores on Component 1 coincide with bright images, and low scores on Component 2 indicate heavy damaged stands. Consequently these images are located in the lower left section of the plot. In the scattergram, Clusters 1 and 2 are not clearly separated from each other.

Cluster 3 (N=13) is composed of a group of images that are clearly separated from the remaining images in the top of the plot. This group of 13 images obtained by far the highest average component score on Component 1, referring to the images with lush green vegetation along narrow trails / lines. Also, all these images were taken under overcast skies and therefore have a darker appearance.

The dendrogram clearly suggests a three cluster solution as most efficient. However, given the exploratory nature of the study it is worthwhile to point out that the eight cluster solution also produces results that are easily interpretable and make a lot of sense (Table 22). Of particular interest is the fact that with eight clusters Component 3, which remained insignificant as an indicator in the three cluster solution, now also contributes to the explanation. In the eight cluster solution, Cluster 1 splits into four sub-groups. Subgroup 1 (S1) consists of two scenes of fairly pure mature aspen stands, which coincides neatly with a high index of brightness (negative C1), absence of damage (positive C2) and a significant measure of birch stems (C3). Sub-group 2 also has a high aspen score, with the other two components being insignificant. The third sub-group combines a large number of scenes that are on the brighter side with minimum damage. Sub-group 4 differs from the previous group mostly by the complete lack of damage.

The two subgroups of Cluster 2 differ on both C1 and C2, with Subgroup 6 containing the brighter and more damaged scenes, when compared to Subgroup 5. The two subgroups of Cluster 3, the dark scenes, differ mostly on the damage component.

Figure 14. Hierarchal cluster analysis

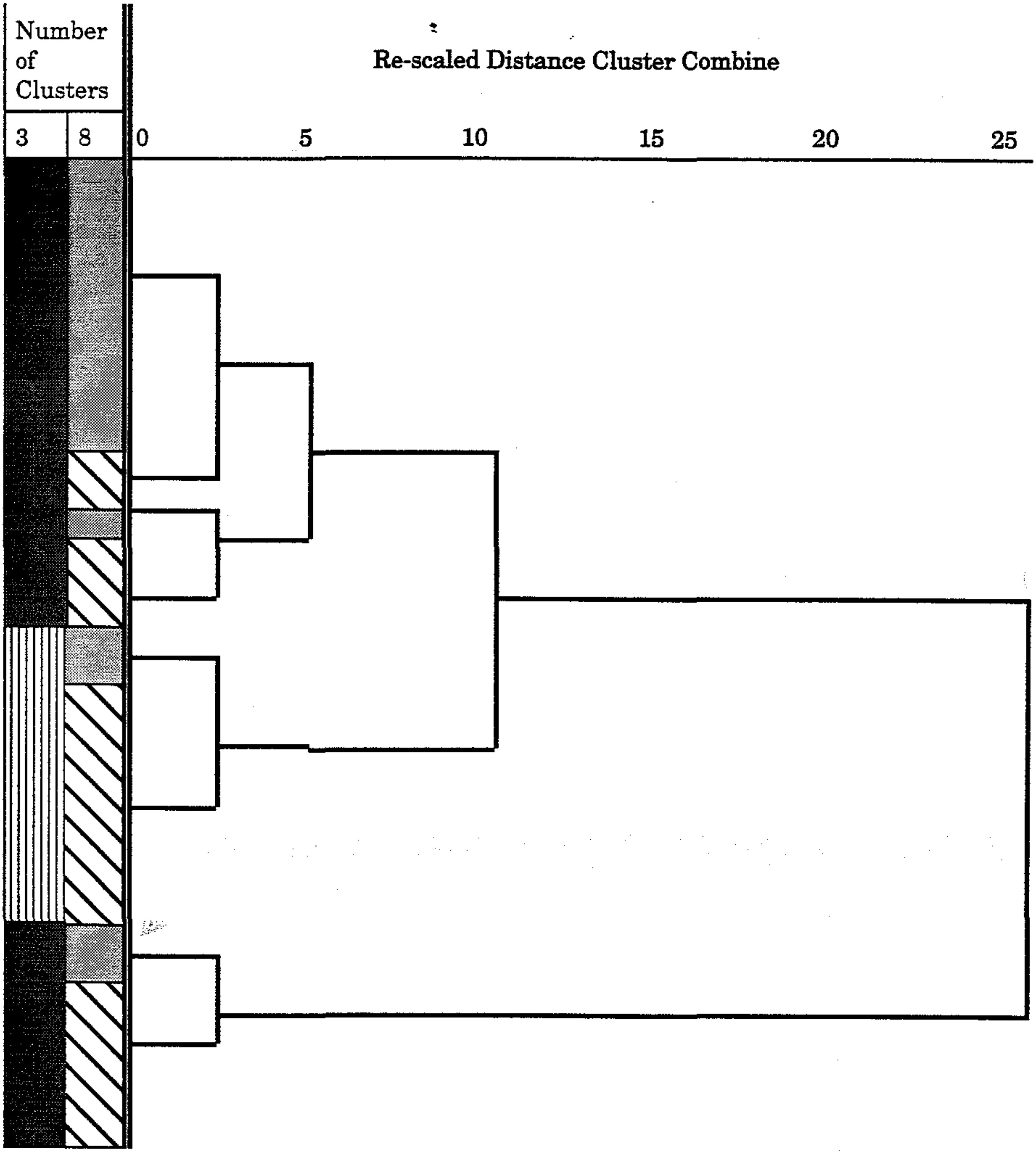


Table 22 Mean component scores by clusters[1]			
	PC1	PC2	PC3
CLUSTER 1	-.18 .35	.40 .33	.02 .42
CLUSTER 2	-.54 .41	-.47 .28	.03 .25
CLUSTER 3	1.23 .30	-.32 .40	-.08 .27

1. The first line reports the mean component score, the second line reports the associated standard deviation.

Table 22 Mean Component Scores by 8 Sub-Clusters			
SUB-CLUSTER	PC1	PC2	PC3
1	- .67 .25	.53 .08	.87 .15
2	.18 .23	.19 .19	.55 .20
3	- .32 .27	.32 .26	- 19 .21
4	.14 .07	.93 .10	- .18 .28
5	- .38 .27	- .37 .13	.09 .22
6	-1.15 .20	- .83 .40	- .20 .26
7	1.32 .27	- .13 .31	.01 .21
8	1.04 .28	- .74 .20	- .29 .31

Regression Analyses of the Scenic Beauty Estimates

The scenic beauty estimates derived above were hypothesized to be related to biophysical variables found in the individual photographs and the quality of the photographs. Determining these relationships is key in relating this research to on the ground management planning (e.g. Daniel et al. 1989; Brown 1987). In order to examine this hypothesis, scenic beauty estimates were regressed against a set of variables derived from plot measurements of the forest stands depicted in the slides, the estimates of damage, and indicators of photographic quality and other anthropogenic features, such as access corridor width, and newness. The full set of variables is described in Table 23.

Since the focus of this research is the impact of insect outbreaks on scenic beauty, we hypothesized that greater amounts of insect damage visible in the photographs would have a negative effect on scenic beauty ratings. The influence of other features can be ascertained to a degree from a preliminary cluster analysis (based on principle components derived during the scenic beauty estimation) which resulted in groups of photos. While the cluster analysis does not specifically detail which features cause these groupings, laying the photos out according to their corresponding clusters as shown in Figure 14 suggests that features such as the amount of understory, willow and alder, as well as the number, species, and size of trees may play a role in explaining scenic beauty. Thus, in most cases there was no *a priori* notion of the effects of forest variables on scenic beauty.

The SBEs for three configurations of the sample were used in the regression analysis. These included: 1) the General Public which consisted of adults from Edmonton and Manning, and high school students from Manning and Peace River; 2) Forest Protection Officers (FPO); and 3) the entire sample. The SBEs were regressed against the full set of variables in Table 23 using stepwise ordinary least squares regression utilizing forward elimination procedures. The software utilized for this purpose was SAS. The forward stepwise procedure starts with no independent variables in the model but adds them one-by-one through the calculation of F-statistics. A variable is added if the significance of the F-statistic exceeds a probability of 0.15. In essence what this means is that a variable is included in the model if it explains SBE at some minimum level of significance.

Table 23. Description, means and standard deviation of variables used to explain scenic beauty estimates.

Variables	Description	Mean	SD
Width of the trail	Subjective rating on a 1-5 scale	3.14	0.91
Shadow in photo	Subjective rating on a 1-5 scale	2.02	1.05
Amount of understory	Subjective rating on a 1-5 scale	2.50	0.84
Insect damage	Composite rating by forest protection scientists and technicians on a 1-10 scale	4.02	1.78
Basal area per ha.	Tree stem areas (breast height)	46.37	23.60
Average height of trees	Average height per hectare	14.84	5.02
Total stems	Number tree stems/ha	4529.38	3612.36
No. white spruce stems	Number white spruce stems/ha	2360.35	3057.45
No. black spruce stems	Number black spruce stems/ha	328.17	1101.36
No. of aspen stems	Number aspen stems/ha	564.17	566.64
No. willow , alder stems	Number willow, alder stems/ha.	11.01	14.56

** Physical inventory per hectare is based on measured plots 50m long by 2 m wide of the forest frontage seen in the photos. Basal area was calculated from Dbh measurements of all trees of greater than 10cm, and approximation for trees less than 10cm. Each tree of all species was counted and mapped in the plots, giving the stem counts for the given area. Heights of trees at 5m intervals for a length of 80m of frontage were measured, to give an average height for the area.*

The linear functional form is reported in this report. Schroeder and Brown (1983) have examined different functional forms in predicting forest scenic beauty and report that the linear form is appropriate for practical use. However, future research is planned to determine if this is the appropriate functional form. Multi-collinearity among the independent variables was explored by inspecting the matrix of correlation coefficients. The influence of unusual or aberrant observations (i.e. outliers) were examined by inspecting a series of statistics proposed by Belsey, Kuh and Welsch (1980). These are generated by SAS using the "influence option" and include studentized residuals, a covariance ratio statistic, and a number of other statistics that examine the effect of deleting observations on predicted values of the dependent variable (i.e. SBE).

The regression results are reported in Table 24. The adjusted R^2 are reasonably high and all three regression models were significant through the inspection of F statistics. For the general public and the entire sample 6 variables were determined to be explanators of scenic beauty. For the Forest Protection Officer's model 4 of these 6 and one additional variable were found to be influential.

Table 24. Results of ordinary least squares regression analyses explaining scenic beauty estimates for two subgroups of the sample, and the entire sample.

	Parameters (standard errors)		
	General public	For. Prot. Off.	Entire Sample
Intercept	139.865[a] (35.875)	80.357[a] (26.728)	120.884[a] (32.407)
Understory	11.777[a] (5.670)	7.434[b] (4.304)	11.195[a] (5.121)
Insect damage	-15.840[a] (2.507)	-6.032[a] (1.893)	-12.949[a] (2.264)
Width of trail	-31.100[a] (5.963)	-21.766[a] (4.362)	-28.579[a] (5.385)
Number of Black Spruce stems	-0.009[a] (0.004)	-0.008[a] (0.003)	-0.009[a] (0.003)
Amount of shadow in picture	-7.683[a] (3.646)		-5.649[b] (3.284)
Number of stems	0.002[b] (0.001)		0.002[c] (0.001)
Amount of willow and alder		-0.334[c] (0.201)	
R^2 (adj)	0.611	0.511	0.599

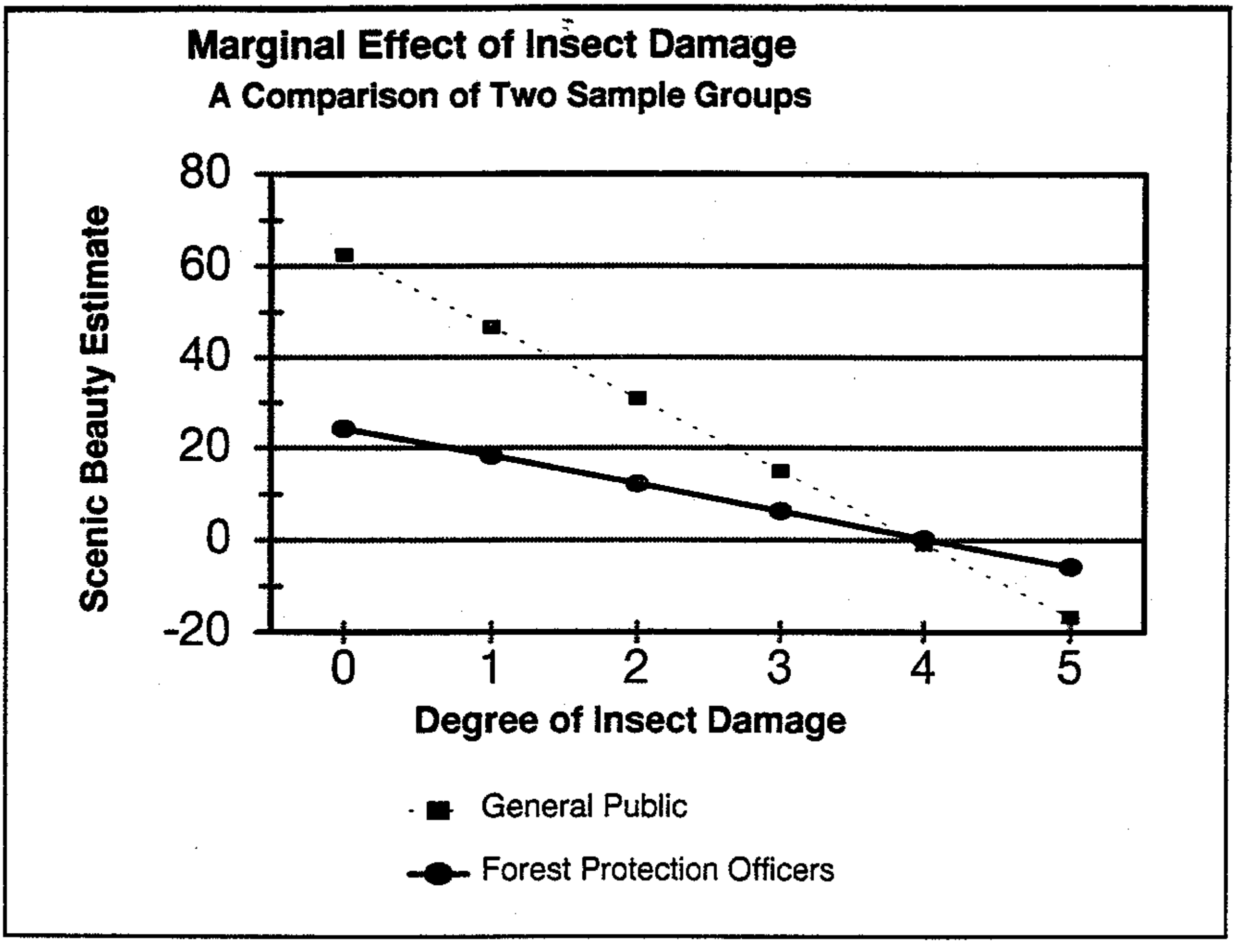
[a] Indicates estimate is significantly different than 0 at the 5% level or better
[b] Indicates estimate is significance at the 10% level
[c] Indicates parameter significance at the 15% level

In all three group models, the coefficient on damage was negative and highly significant, indicating that the more damage present in a photograph, the lower the scenic beauty rating. This result is consistent with our *a priori* hypothesis. The amount of understory had significant positive effects on scenic beauty. The coefficients on the number of stems was found to positive for two of the models (general public and combined sample), but not significance at the P=5% level. However, the number of black spruce stems was found to be negative and significant across the three models. This finding is consistent with other research in Canada on the influence of forest ecosystem type on recreation choice behaviour. In Manitoba canoeists were found to avoid wilderness areas with large amounts of black spruce forests (Boxall et al. 1996). Similarly, moose hunters in Newfoundland avoided black spruce trails (Akabua 1996). The wider the trails or access roads had a negative influence on scenic beauty in all three models and the larger amounts of shadow in the photographs had significant negative effects in two models.

Inspection of the regression models for the General Public and Forest Protection Officers suggests that they are different. For the latter, the shadow and number of stems variables did not load in the stepwise procedure, indicating these variables did not affect scenic beauty ratings. The willow/alder variable did load, but was only significant at the 15% level. To examine the differences between the groups a number of analyses were conducted including jointly estimating the regressions and using a dummy variable for the Forest Protection Officers. These analyses suggest that the models are not significantly different. However, while the *models* may be the same, the influence of *individual parameters* may not be.

An example of this difference are the parameters on damage. For the General Public and Forest Protection Officer models the means of each variable (Table 24) except damage were multiplied by their respective parameter values and summed. Then a simulation was performed on the damage variable. This involved calculating the "new" intercept (the model intercept plus the sums of the other variables times their parameters) and predicting scenic beauty estimates for different levels of damage. The results are plotted in Figure 15. This graph identifies the relative sensitivities of the two subgroups to forest damage levels. The General Public appears to be more sensitive to damage than the Forest protection Officers. This difference in sensitivity may relate to the background knowledge of forest/insect interactions, control methods, as well as the attitudes toward forest management.

Figure15. Comparison of response to insect damage by two groups.



Levels of Knowledge and Attitudes

It is probable that background knowledge of the forest in general and knowledge of damage-causing agents is a factor in explaining the different ratings for the groups. The responses to the questionnaire support this contention.

Knowledge about the role of insects in forests and insect control in managing forests in Alberta was highly different between the groups. For example, 79% of the FPO group had been to a public information session on forest management, versus 46% for the public. With regards to insects, 90% of the public had never been to a public information session on managing insects that feed on trees, while nearly half of the FPOs had.

When respondents were asked about their knowledge of methods used to control insects populations in the forest, 66% of the public answered spraying chemical insecticides, and 29% knew of no methods. For the FPO group, 53% said spraying and 18% said biological insect control. A number of different answers, such as burning and log traps had less than 5% each.

The public was also much less aware of the types of insects that feed on the trees in the regions forest. The two major pests mentioned were the spruce budworm, and the forest tent caterpillar (Table 25), though which was the most important was reversed. A large number of the public could not think of any local pests. When asked which did the most damage, the response difference was magnified. The general public was about evenly split between none, spruce budworm, and the tent caterpillar. The FPOs overwhelmingly decided on the spruce budworm (Table 25).

Table 25. Awareness of insect pests by sub-group (% response).

Species	Awareness		Which does most damage	
	Forest Protection Officers	General Public	Forest Protection Officers	General Public
Spruce budworm	55	21	69	27
Sawfly	3.3	0	0	0
tent caterpillar	20	35	12.7	29.1
pine beetles	10	0	3.6	0
spruce beetles	5	3	5.5	2
lady bugs	3	0	0	0
caterpillar (generic)	0	13.6	0	20
NONE	0	16.7	0	27

The respondents were further questioned regarding their feelings about insects, and managing the control of these insects. The separate responses to the actual questions are shown in Tables 26 and 27. There are some strong differences between the groups. In the FPO group, nearly 90% felt that insect control is needed in forest management, and 85% felt it was necessary for a stable wood supply. Less than half of the public saw the need in forest management, and just over half (57%) wanted it for a stable timber supply. Both groups were about equally opposed to controlling insect pests if it meant harm to beneficial insects. Finally, the public strongly felt that spraying to control insect can harm humans (75%), while less than 50% of the FPO group felt this way.

Table 26. General Public response to values statements (percent responses).

	strongly disagree	disagree	neither agree or disagree	agree	strongly agree
Insect control is needed in forest management	4.3	15.2	27.2	38	15.2
Spraying to control insects can pose a threat to human health	1.0	13	10.9	52.1	22.8
Scientists are able to make accurate estimates of the risks involved in controlling insects	2.1	19.6	38	34.8	5.4
Controlling insects is important for a stable supply of timber for the forest industry	3.3	17.4	21.7	47.8	9.8
It is alright to control insects even if it reduces the food supply of birds	20	46.7	14.4	16.7	2.2
Controlling insects helps maintain a healthy forest	7.7	22.0	20.8	47.2	2.2
The benefits of controlling insects outweigh any negatives	11	29.7	45	12.1	2.2
It is acceptable to control large outbreaks of insects in the forest	2.2	12.0	17.4	51.1	17.4
Forests should be logged rather than allow insects to damage them	13	22.8	32.6	23.9	7.6
We should control insects considered as pests even if this can result in the death of beneficial insects	18.5	45.7	25	9.8	1.1
Under no circumstances should we attempt to control any insects in the forest	22.8	45.7	20.7	9.8	1.1

Table 27. Forest Protection Officers' response to forest value statements.

	strongly disagree	disagree	neither agree or disagree	agree	strongly agree
Insect control is needed in forest management	0	3.1	9.5	60.3	27
Spraying to control insects can pose a threat to human health	3.1	30.1	20.6	36.5	9.5
Scientists are able to make accurate estimates of the risks involved in controlling insects	3.1	22.2	19	54	1.6
Controlling insects is important for a stable supply of timber for the forest industry	0	6.4	9.6	60.3	23.8
It is alright to control insects even if it reduces the food supply of birds	11.3	35.5	21	30.7	1.6
Controlling insects helps maintain a healthy forest	0	12.7	30.2	47.7	9.6
The benefits of controlling insects outweigh any negatives	3.2	33	31.8	28.6	3.2
It is acceptable to control large outbreaks of insects in the forest	0	1.6	1.6	74.6	22.2
Forests should be logged rather than allow insects to damage them	3.2	28.6	33.3	31.8	3.2
We should control insects considered as pests even if this can result in the death of beneficial insects	11.1	52.4	22.2	14.3	0
Under no circumstances should we attempt to control any insects in the forest	25.4	63.5	6.4	3.2	1.6

DISCUSSION

Given the preliminary nature of the study, which was characterized by a relatively small and rather diverse set of slides, the patterns that were detected and the explanations derived from the multivariate analysis are rather impressive The PCA resulted in three highly interpretable components, and these three components provide the basis for isolating meaningful clusters.

One major deficiency in the data set is the discrepancy in the illumination of the slides, which was noticed by respondents and reflected in the evaluation. With stricter standards for the photography of forest stands it would be possible to reduce this type of variation, which would then be available for observation of other trends. Also, the selection of stands in this study attempted to capture the wide range of forest conditions in the boreal mixedwood forest. The fact that Component 3 reflects mostly the presence / absence of mature hardwoods proves that respondents are sensitive to this variation and that the various stages of succession in the boreal mixed wood forest are perceived as aesthetically different. At the same time this finding also implies that by eliminating pure aspen stands from the study set, most of the variance observed in Component 3 would be controlled for.

Narrowing the data set might become more important, if a future study desires to model the effects of budworm damage on aesthetic evaluations more precisely. For that purpose it might be useful to eliminate pure aspen stands from the set of slides included in the study. This would focus more attention on the issue of spruce budworm, especially if at the same time more scenes replicate the variation of damages associated with the different stages of infestation during the life-cycle of a budworm infestation.

The most accurate measurements of the effects of spruce budworm damage on lay-person perceptions can be achieved by including digital photo imaging in the study. In that recent innovation one would digitize several of the landscape slides, and then use computer software such as Adobe Photoshop to simulate changes to one forest stand due to budworm infestation. By including the original and the altered scene in the set of study slides, a very precise measure of the difference caused by the effect under investigation would be obtained. By extending this idea to several slides it becomes possible to model an entire sequence of succession of a spruce budworm infestation.

Two types of non-timber values influenced by budworm and its control are the effects of outbreaks on visual aesthetics and the effects of budworm control measures on non-target insect species. Studying the effects of BT control measures on non-target insects should involve local and non-local people in the research. The values considered here would be related to concepts of existence value and biodiversity. Essentially the research would explore people's preferences for insects (principally Lepidoptera) and the role of various insect assemblages in the boreal forest ecosystem. This type of project would require knowledge of the effects of BT on non-target species and their role in the boreal forest ecosystem. The social science research methods used to examine these issues would be general population surveys and the application of the contingent valuation method (Mitchell and Carson 1989). However, the current level of knowledge about non-target species and the research resources available precluded examination of this area of non-timber valuation research. This issue remains a viable avenue for future research on budworm pest management and non-timber values.

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APPENDIX A

Proposal to the **Manning Diversified Forest Products Research Trust Fund**

MANNING DIVERSIFIED FOREST PRODUCTS TRUST FUND PROJECT PROPOSAL & APPLICATION FOR FUNDING

Project Title: **ASSESSMENT OF SPRUCE BUDWORM IMPACTS IN HAWK HILLS MANAGEMENT AREA**

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Project Status: New Project in Alberta

Locations For Proposed Work: Manning/Hawk Hills (Summer & Field Work); Edmonton (Lab & Winter Work)

Purpose of Project: The spruce budworm damages the most productive white spruce stands in northern boreal forests. It is thus a threat to the sustainability of any enterprise that relies on healthy, productive white spruce stands. This work is designed to better understand the biological, physical and economic impacts of spruce budworm defoliation of mature spruce stands so that populations can be managed more effectively. (See attached material)

Project objectives:

1) Assess the degree to which the spruce budworm has reduced the productivity of mature white spruce stands in Hawk Hills and contrast this with the productivity of stands protected by spraying.

2) Using the results of 1) develop a benefit/cost analysis of forest pest management activities which include both timber and non-timber (including recreation, visual and aesthetic) values in the assessment of benefits.

3) Continue the biological assessment of the Hawk Hills study plots to better understand the dynamics of the spruce budworm population.

Study Design:

Study plots were established in the Hawk Hills area in 1990 and 1991 when treatment blocks were sprayed. A series of 16 treated and 8 untreated 20 X 20 m plots have been monitored for insect populations and defoliation annually since plot establishment. In addition 12 100 X 100 m permanent sample plots were established adjacent to the entomological plots in which annual non-destructive assessments of tree condition have been conducted annually since 1990. This infra-structure will be used to determine tree growth and mortality to date in both the treated and untreated plots to arrive at an estimate of impacts on wood volume accretion. Stem analysis of 72 trees and a remeasurement of all trees in the permanent sample plots will be conducted.

Estimation of growth loss and losses to mortality will be used in the economic analysis to assess the impacts on timber and non-timber values in the defoliated area. A literature review of insect defoliation as it affects non-timber value will be conducted and incorporated in the analysis of non-timber impacts.

The entomological observations will be conducted annual to accumulate a data set on the treated and untreated plots which can be used to analyse the dynamics of the insect population. We currently have 4 complete years' data but require continued monitoring to improve monitoring and forecasting techniques to manage spruce budworm populations. It is proposed to monitor the insect population at 4 critical life stages and monitor the natural enemy population.

Projected Long-Term Benefits from Project: Direct Jobs Created: 4.5 p.yr.

Anticipated Benefits for Management and Uses of the Boreal Forest:

The spruce budworm is a native insect that, if left unchecked, can cause catastrophic losses in spruce stands. The Hawk Hills experiment, has demonstrated that controls using *Bacillus thuringiensis* var. *kurstaki* can suppress populations for several years. We do not at present know the benefits in terms of economic values from forest spraying. This project would provide the economic and scientific basis for making decisions to manage this pest in Alberta. The benefit/cost ratios developed could also indicate what the opportunity costs are for investments in competing forest management activities. The net result will be an opportunity to make rational decisions about allocations of forest management resources.

Other Anticipated Benefits: The information developed will provide improved monitoring and forecasting technologies to assist in spruce budworm management. A knowledge of the spruce budworm parasite and predator complex will be obtained and may provide opportunities to enhance the natural controls of the pest.

Proposed Starting Date: April 1, 1995, **Project Duration** 3 years
Estimated Completion Date: March 31, 1998.

Direct Funding Contributions From Other Sources

	1995/96	1996/97	1997/98
Secured By Proponents:			
Salaries (Prof. & Technical)	$56,000.00	$56,000.00	$56,000.00
In Kind Support :			
AL&FS (Accommodation)	$ 4,000.00	$ 4,000.00	$ 4,000.00

Budget Requested From MDFP Trust Fund:

Technologist (For. Entomol.)	$30,000.00	$30,000.00	$30,000.00
Economics Tech	$14,000.00		
Summer Student	$ 8,000.00	$ 8,000.00	$ 8,000.00
ATV rental	$ 1,000.00	$ 1,000.00	$ 1,000.00
Travel (mileage)	$ 2,000.00	$ 2,000.00	$ 2,000.00
Supplies	$ 1,000.00	$ 1,000.00	$ 1,000.00
Overhead	$10,000.00	$ 8,000.00	$ 8,000.00
Total	$66,000.00	$50,000.00	$50,000.00

Other Relevant Information:

The Hawk Hills study is unique in North America. Most information on the spruce budworm was developed on balsam fir. We have found that prescriptions and understanding developed on those systems do not apply to conditions in Alberta. The

Hawk Hills study is the longest running study on spruce budworm dynamics on spruce and has produced several innovations for the management of the spruce budworm in Alberta. These include improved spray timing recommendations, survey and sampling techniques for the budworm on spruce, and an understanding of appropriate spray tactics for managing the budworm in Alberta. The successful development of B.t. for use in forest protection in Alberta is largely derived from the cooperative studies undertaken by AL&FS and this group in the Hawk Hills area. A list of the Reports and Manuals produced by this study to date is attached. Earlier work on the Hawk Hills Project was funded in part by the Alberta Forest Service, Canada/Alberta Partnership Agreement in Forestry and Canada's Green Plan, Integrated Forest Pest Management Initiative.

Materials Attached

Cost benefit analysis (CBA) is an economic tool which can be used to examine the economic efficiency of a specific program or activity. It is useful in that not only does it assess some ratio of benefits to costs, but it also provides a framework for identifying where the benefits and costs are coming from. Regarding forest management, economists question whether many of the activities (silviculture, peatland drainage etc.) currently ongoing in Canada's forests have a cost benefit ratio greater than or equal to 1. The control of forest insect pests is one of these activities.

NONTIMBER VALUES

A complete CBA of forest insect spraying should include impacts in terms of incremental costs or gains on both timber and nontimber goods and services provided by the forest. The challenge with including these is knowledge of the full set of goods and services provided by the forest, as well as their relative economic values. Research is currently ongoing at the Canadian Forest Service to identify some of the nontimber values provided by Alberta forests. This task, when complete, will provide some information on these values. However, many of the other nontimber services will remain unknown.

Another more important challenge regarding insect control programs is the impact of the spraying on the flow of benefits (or costs) provided by nontimber outputs. In other words, simply knowing that forest recreation in an area provides benefits worth some amount of dollars is not going to assist in evaluating a spraying program. What is required is knowledge of how the forest insect pests change the benefit flow and how spraying affects this benefit flow and others associated with it. This is a complex task that has not been addressed in the literature to date and will require a major research effort to examine completely.

What can be done regarding the impacts of insects and insect control programs on nontimber values is a literature review of certain aspects of their effects on some nontimber values, principally recreation. This will help focus future CFS and AL&FS research efforts on areas that may allow a more complete picture of nontimber-insect pest relationships. Some work has already begun on this front at the Northern Forestry Centre and all that is required is some funding to complete the annotated bibliography and develop a conceptual model that can be used in future research.

TIMBER VALUES

Despite the impacts of pests on timber, few quantitative results exist which provide a complete picture of the effects of pests on timber growth and the effects that spraying has in reducing these impacts. However, Volney at the Northern Forestry Centre has established research plots in Alberta such that a research design incorporating spraying on insects, as an effect on timber growth, can be established. We propose to use this design in a quantitative examination of the specific effects of budworm infestations on the growth of white spruce. This can be coupled with data on spruce stands that have been sprayed or not sprayed in the AL&FS insect control program. These comparisons of the spraying were explicitly incorporated into the experimental design for this purpose.

Economic analysis of this data involves estimating the growth functions of trees in the various types of plots, and comparing timber volumes and projected revenues in both single and multiple rotation formats. This analysis will allow forest managers to understand the effects of the insect of timber volumes, and when cast in an economic framework, will allow economic comparisons of benefits and costs to be made.

In order to conduct these analyses, trees in the plots have to be measured and assessed for timber growth and volume. This can be done in one year with one summer student and a research assistant. Thus, funds are required for student salary, technician time, and field expenses. Once this data is collected, statistical analysis can be initiated along with the cost benefit analysis.

Products

1. Report on timber volumes lost to insect defoliation and saved by spraying.

2. Report on costs and benefits of protecting white spruce stands in northern Alberta.

3. An annotated bibliography of studies relating to insect defoliation and impacts on forest recreation and scenic values.

4. A report synthesizing the dynamics and physical impacts of the spruce

budworm on white spruce stands.

Manuals and reports relevant to the Hawk Hills Project to date:

Manuals

Volney, W.J.A. 1990. Hawk Hills spruce budworm project. Instructions and procedures. Unpublished manual, Forestry Canada, Northern Forestry Centre, Edmonton, Alberta.

Volney, W.J.A. 1991. Hawk Hills spruce budworm project. Instructions and procedures. Unpublished manual, Forestry Canada, Northern Forestry Centre, Edmonton, Alberta.

Reports

Volney, W.J.A. 1989. Biology and Dynamics of North American coniferophagus *Choristoneura* populations. Agricultural Zoology Reviews. 3:133-156.

Volney, W.J.A. 1990. Hawk Hills spruce budworm project report. Unpublished report. Forestry Canada, Northern Forestry Centre, Edmonton, Alberta.

Volney, W.J.A. 1992. Hawk Hills spruce budworm project 1991 report. Unpublished report, Forestry Canada, Northern Forestry Centre, Edmonton, Alberta.

Volney, W.J.A. 1993. The impact of the spruce budworm on tree growth in the Footner Forest, Alberta. Unpublished confidential report, Forestry Canada, Northern Forestry Centre, Edmonton, Alberta.

Volney, W.J.A. and Cerezke, H.F. 1992. The phenology of white spruce and the spruce budworm in northern Alberta. Can. J. For. Res. 22:198-205.

APPENDIX B

Annotated bibliography of relevant literature on economic impacts of forest pests.

AUTHOR: Arthur L.M.

YEAR: 1977

TITLE: PREDICTING SCENIC BEAUTY OF FOREST ENVIRONMENTS: SOME EMPIRICAL TEST

SOURCE: Forest Science 23:151-160

KEY POINTS: The study tests the usefulness of three landscape description techniques - scaling of physical features, inventories of visual (design) features, and timber cruises - for predicting scenic beauty of forested environments. The evaluation involved 6 sites, with varying times since some form of harvest operation was carried out. The evaluation involved two stages. In the first stage there were 3 groups; psychology students, landscape architects, and general public group. In this stage preferences were recorded. In the second stage, the groups were student and professional landscape architects. In the first stage, the landscape architects had the lowest and most homogeneous preference functions.

METHOD USED: Scenic Beauty Estimation initially was used. Then the value of three landscape description techniques was evaluated fro predictive ability corresponding to the initial estimation.

STRENGTH AND WEAKNESS: The technique relies on relating all of the sites to one base case, which can be any of the six sites. The Scenic Beauty Estimation allows users to identify scenes they prefer, without actually being present. There is no truncation problem often seen with on-site interviews. However, there is also no economic estimation, and no indication respondents would actually visit any of the sites. The second stage is important preference functions determined in the first stage. It is not certain that the features identified by the experts in the second stage are those actually used by the groups in the first stage. This is evidenced by the statistically different preference functions they had from the other two groups. The method is time consuming for respondents, and could be costly to undertake on a large scale.

APPLICABILITY TO ALBERTA: The method could be used to identify preferences in Alberta. It could be applied equally to insect damage, fire damage, or to preferences for mixed wood stands of varying composition.

INSECT: None

FOREST TYPE: Ponderosa Pine

AUTHOR: Buhyoff, G.J., W.A. Leuschner and L.K. Arndt

YEAR: 1980

TITLE: REPLICATION OF A SCENIC PREFERENCE FUNCTION

SOURCE: Forest Science; 26:227-230

KEY POINTS: A replication of a previous work(Buhyoff and Leushner, 1978) that shows the ability to measure people's visual landscape preference as a function of insect infestation intensity. The replication shows that the original model has predictive validity ant that landscape knowledge that damage might be present, and caused by southern pine beetle infestation. The previous paper also had control group, for which the method did not work as well. A second methodology (correlation tests between the two replications(was also used to test the validity of the preference measurement.

METHOD USED: A paired comparison methodology was used to scale landscapes preferences. Regression analysis was used to evaluate the resulting revealed preferences.

STRENGTH AND WEAKNESS: The paper shows further proof that visual preference, in general, can be validly measured. Absolute values of preference cannot be compared for a given forest scene between two replications of the method, though the differences between preferences can be compared.

Because of the time involved and the difficulty of comparing or ranking many landscapes, the number of stimuli which can be used is limited to fifteen or less.

The strengths and weaknesses outlined in Buhyoff and Leuschner (1978) also apply.

INSECT: Southern Pine Beetle

FOREST TYPE: Pine

AUTHOR: Buhyoff, Gregory J and William A Leuschner

YEAR: 1978

TITLE: Estimating Psychological Disutility From Damaged Forest Stands

SOURCE: Forest Science 24:424-432

KEY POINTS: The paper deals with insect damage to scenic beauty (aesthetic beauty), caused by the southern pine beetle. A paired comparison methodology was used to scale preferences for landscapes depicted in 35 mm colour slides. Several subject groups, varying in their familiarity with forestry, evaluated a series of photographically controlled forest scenes with various levels of insect damage. Some subjects were told that insect damage was present (experimental), others were not (control). Logarithmic regression models were used to predict preference from the amount of visible damage. Two regression models resulted: one for experimental subjects, one for control subjects. These predicted regression lines are interpreted as psychological disutility functions.

Psychological utility or visual preference drops rapidly as damage increases to approximately 10 percent of the forest area. Declines in preference are slight thereafter. It appears it is more important to prevent new insect outbreaks than it is to prevent additional spread from an aesthetic impact standpoint.

METHOD USED: A paired comparison methodology was used to scale landscapes preferences. Regression analysis as used to evaluate the resulting revealed preferences.

STRENGTH AND WEAKNESS: The method allows quantification of scenic preferences without prior knowledge of physical values people use in making perceptual judgements. It is a reliable method for measuring scenic preferences in general. However, this feature is shown to be less important as knowledge increases, for when one sub-sample was given information that the damage was caused by insects, this knowledge became the overriding choice factor. The experimental group had a statistically different preference curve than the control group. The regression for the control group was not as accurate in predicting the variability in preference (33% versus 85% for the experimental group). At the time of writhing, the paper results had to be judged cautiously, as it was a single experiment, in a unique physiographic region; general applicability to other regions was not shown.[4]

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[4]see also Buhyoff et al 1982, for a further application of the method.

This method is not useful for economic analysis, as it cannot measure economic utility functions.

APPLICABILITY TO ALBERTA: The method could be usefully applied to judge the preferences of Albertans for differing levels of damage, to scenic landscapes, from a variety of causes. Knowledge of these preferences could be applied in a policy choice, in determining the need for prevention of such things as forest fires, or insect infestations, from an aesthetic preference viewpoint. The type of damage evaluated is highly visible, and permanent, (within the parameters of the normal lifespan of the trees involved). Insect infestations that damage the scenic beauty temporarily, or that cause non-visual damage, are not as well assessed using this method. The method cannot be used to judge economic utility changes, and market value changes. There are better methods that can both judge economic factors, and scale people's preferences in relation to specific damage variables.

INSECT: Southern Pine Beetle

FOREST TYPE: Pine

AUTHOR: Buhyoff, G.J., J.D. Wellman, and T.C. Daniel

YEAR: 1982

TITLE: Predicting Scenic Quality for Mountain Pine Beetle and Western Spruce Budworm Damaged Forest Vistas

SOURCE: Forest Science 28:827-838

KEY POINTS: The scenic beauty of sixty-four forest vista landscapes from the Colorado Front Range was measured for a large group of subjects (observers) by the Scenic Beauty Estimation Method. some of the landscapes evidenced insect damaged trees and stands. One group of subjects were not told a priori of the presence of damage; another group was informed. Results indicated that the negative visual impact of insect damage for naive observers is mitigated by the presence of dense forests, long viewing distances, and mountainous terrain.

The study hoped to overcome the weakness of Buhyoff and Leushner which relied solely on insect damage to differentiate vistas.

The two methods used provided similar preference metrics.

STRENGTH AND WEAKNESS: The study hoped to overcome the weakness of Buhyoff and Leushner which relied solely on insect damage to differentiate vistas. It adds topographic variability, vegetative variability and viewer position. The features that could potentially affect choice were decided upon by an expert panel. There is no certain proof that these features were used by the respondents.

Informing respondents that they are looking at insect damaged vistas results in a lowering of preference values. This suggests that bias exists in the choices. As well, campaigns that inform the public about pest problems will lower overall utility.

APPLICABILITY TO ALBERTA: See other Buhyoff papers.

INSECT: Southern Pine Beetle, Spruce Budworm

FOREST TYPE: not mentioned, assumed pine, spruce

AUTHOR: Czerwinski, C. and M.B. Isman

YEAR: 1986

TITLE: Urban Pest Management: Decision Making and Social Conflict in the Control of the Gypsy Moth in West Coast Cities

SOURCE: Bulletin of the ESA 32:36-41

KEY POINTS: Examines the conflict often seen between opposing factions in the use of pesticide control of insects in a forest setting. Conflict is seen to exist because 1) the proponent agencies were unprepared and unwilling to consult with legitimate interests, 2) when legitimate interests requested clarification of the public health effects of the control materials, the agencies were not frank about this information, and 3) the agencies attempted to prevent the legitimate interests from participating in the decision making process. Recommendations for actions to be taken by agencies in future programs are outlined.

METHOD USED: None

STRENGTH AND WEAKNESS: Useful points to keep in mind regarding possible public opinions regarding insect infestations, especially near urban areas. No mention of recreation, or economics.

APPLICABILITY TO ALBERTA: Not applicable to this study, though the planning guidelines certainly apply to the province. This is evidenced by the controversy over recent forest developments, where groups felt they were not adequately consulted.

INSECT: Gypsy moth

FOREST TYPE: not mentioned

AUTHOR: Deloitte and Touche

YEAR: 1992

TITLE: An Assessment of the Economic Benefits of Pest Control in Forestry

SOURCES: Report prepared for the Forest Pest Management Council, Guelph

KEY POINTS: A very comprehensive report of the effects of three identified pests: competing vegetation, insects and diseases. Useful analysis of the value of the forest industry to the Canadian economy. It contains an overview and economic comparison of different pest control methods.
METHOD USED: Benefit Cost Analysis

STRENGTH AND WEAKNESS: The report provides a good analysis of the value of the forest industry in Canada. It also provides useful measures of the damages caused by forest pests. However, the "national" nature of the analysis, as well as the aggregation of damages caused by the three main pests identified makes it less useful for measuring costs of insects alone, for a single province. The measurement of non-timber values is weak.

APPLICABILITY TO ALBERTA: The report shows how benefit cost analysis can be used in the forest industry. For a more complete accounting, non-market benefit analysis would have to be carried out concurrently.

INSECT: Multiple.

FOREST TYPE: Multiple

AUTHOR: Holmes, T.P., Kramer, R.A., and M.A. Haefele.

YEAR: 1992

TITLE: Economic Valuation of Spruce Fir Decline in the Southern Appalachian Mountains: A Comparison of Value Elicitation Methods

SOURCE: Proc. of the Forestry and the Environment Conference, Jasper Canada Mar 9-12 1992, published by Forestry Canada, Northern Research Centre, Edmonton.

KEY POINT: This study measures the Willingness to pay to preserve high elevation spruce-fur forest from both the balsam woolly adelgid and ozone acid rain. Also compares discrete choice and payment card methods form the measurement of value. The insect measured causes high mortality to the trees in question. The respondents were limited to those living within 500 miles of the site, in order that they would have knowledge of the site. there was a measurable difference in valuation between the two methods chosen, though both showed significant demand for protection.

METHOD USED: Contingent Valuation; both dichotomous choice and payment card methods of value elicitation.

STRENGTH AND WEAKNESS: The study is basically well designed. It shows that the discrete choice method better mimics the trade-offs that exist in a real market; (shown by non-response and protest votes).

APPLICABILITY TO ALBERTA: The type of forest in question is similar to the sub-alpine forests of Alberta, where a great deal of recreation activities occur. The mail-out survey design could be easily copied, and provide adequate coverage of active users.

INSECT: balsam woolly adelgid

FOREST TYPE: Spruce fir

AUTHOR: John, K.H., J.R. Stoll, and J.K. Olson

YEAR: 1987

TITLE: An Assessment of the Benefits of Mosquito Abatement in an organized Mosquito Control District

SOURCE: Journal of the American Mosquito Control Association, 3:8-15

KEY POINTS: A case study application of contingent valuation to the measurement of mosquito program benefits is presented. The survey was carried out through a mail out, with two target populations; owner and renter. Knowledge of the presents costs, and efficiency of mosquito control was assumed. Annual program benefits in Jefferson County, TX are estimated to exceed cost by 1.8 times. Mean household benefits are $22.44 for owners and $18.96 for renters. Using ordinary least squares procedures these household benefits were found to be related to household socioeconomic characteristics, effectiveness of control efforts and environmental concerns.

METHOD USED: Contingent valuation of program benefits, followed by Ordinary Least Squares estimation of correlation to household socio-economic characteristics.

STRENGTH AND WEAKNESS: The use of Contingent Valuation by mailout allows for a wide selection among the target population. The division into sub-populations of owners and renters account for the differing present costs. That is, the present program is paid from county taxes, and so paid for by owners. The benefits estimation for owners is a summation of the estimated present cost, plus the willingness to pay for a tax increase. The willingness to pay by renters is entirely a new charge. This division would seem to be a weak link in the benefits estimation. No attempt was made to estimate the value of damages to other environmental factors caused by chemical application, which could mean the benefits are overestimated. The assumed knowledge of the sample is another area of weakness. Though the questionnaire did outline a means of determining the present cost to taxpayers, it is not certain that this was properly understood and applied.

APPLICABILITY TO ALBERTA: The general method can be useful in a cost/benefit ratio estimation for existing insect control measures. The specific values achieved are dependent on socio-economic variables for the study region, and cannot be extrapolated.

The contingent valuation method can be used for estimating the value of forests that are not infested, and to obtain the full range of utility loss caused by infestation.

In application to Alberta, it would not be necessary to use the dubious division of owners and renters, as the program for insects that cause forest damage are generally paid provincially, not by a county or municipality.

INSECT: Mosquito

FOREST TYPE: not applicable

AUTHOR: Leuschner, W.A., T.A. Max, G.D. Spittle and H.W. Wisdom

YEAR: 1978

TITLE: Estimating Southern Pine Beetle Timber Damages

SOURCE: Bulletin of the Entomological Society of America, 24:29-34

KEY POINTS: Measures the loss of timber value caused by insect damage. It also provides different methods of determining the amount of physical timber loss caused by insect damage. Present survey methods can allow for large errors in physical estimates, and thus in economic loss.

METHOD USED: Financial present net worth estimation based on forestry rotation and growth models. It introduces new models for estimation of damage loss.

STRENGTH AND WEAKNESS: The study does not measure the value of recreation, and so is not truly applicable to this report. Allows a justification of a control program (which would also effect recreation values) based on the loss of timber values.

APPLICABILITY TO ALBERTA: not applicable

INSECT: Southern Pine Beetle

FOREST TYPE:

AUTHOR: Leuschner, WA and CM Newton

YEAR: 1974

TITLE: Benefits of Forest Insect Control

SOURCE: Bulletin of the Entomological Society of America 20:223-227

KEY POINTS: This paper seeks to develop a framework of social benefits involved in forest insect management using the principles of benefit-cost analysis and to indicate the conceptual methods for measuring them. The hope is to provide better guidelines for policy decisions. Benefits from insect control listed are categorized as: timber, recreation, aesthetic, watershed, soils, wildlife and grazing. Loses identified with recreation are based on recreationist groups: continuing users, substituters, and those that stop using the area.

METHOD USED: Review of changes in general to the forest caused by insects. Estimation of change is based on the principles involved in benefit-cost analysis.

STRENGTH AND WEAKNESS: A strong overview of the many changes in benefit involved when insects damage a forest. The reliance on benefit-cost analysis is necessary for application to the many damages listed, but is not the most appropriate for recreation loss. The recreation loss could be integrated into the benefit-cost analysis.

APPLICABILITY TO ALBERTA: The damages listed are appropriate to the province. There is nothing in the study which can be used directly in analysing insect damage in Alberta.

INSECT: none in particular

FOREST TYPE:

AUTHOR: Leushner, W.A. and R.L. Young

YEAR: 1978

TITLE: Estimating the Southern Pine Beetles Impact on Reservoir Campsites

SOURCES: Forest Science 24:527-543

KEY POINTS: Applied the zonal travel cost to estimate the effect of southern pine beetle damage to ponderosa pine on demand for recreation at 19 campgrounds located on two reservoirs in Texas. A multiple regression analysis included participation in camping as a dependent variable and pine tree density, as shown by aerial photos, one of the independent variables. They statistically estimated the change in participation associated with southern pine beetle infestation. The effect of varying the proportion of the recreation sites covered by pine crowns was isolated from other site characteristics such as presence of hardwood trees, size of the campground, facilities available, quality of access, and number of substitute sites available. Change in participation was multiplied by a constant benefit per camping day estimated by the travel cost model of recreation demand.

They did not attempt to measure the recreational damages suffered by people who continue to use attacked sites in spite of the evidence of mountain pine beetle damage. Since people are observed to continue to use affected sites, inclusion of their losses are essential to an accurate accounting of the total impact of insect damage on recreational values.

METHOD USED: Zonal travel cost

STRENGTH AND WEAKNESS: Using a series of alternative sites showing varying levels of damage, it is possible to measure loss due to insects directly. However, the zonal travel cost method is one of the weaker models of this type. A similar study that used individuals would be more efficient.

INSECT: Southern pine beetle

FOREST TYPE: Pine Beetle

AUTHOR: Michaelson, E.L.

YEAR: 1975

TITLE: Economic Impact of Mountain Pine Beetle on Outdoor Recreation

SOURCE: Southern Journal of Agricultural Economics, 7:42-50

KEY POINTS: Applies the individual travel cost approach to estimate the effect of mountain beetle damage for recreation at six campgrounds in the Targhee National Forest in Idaho. The impact on demand was calculated as the difference in visitor days per trip to infested and non-infested campgrounds. Sites were selected solely on the basis of infestation. Recreation resources are directly impacted by the large number of dead trees observed in infested campgrounds. Consumer surplus was based on the Forest Service estimates of recreational use. The study projected losses by new infestation from the difference in value between infected and non-infected sites.

METHOD USED: Individual Travel Cost approach. Data was collected by questionnaire distributed on location, to be filled in overnight.

STRENGTH AND WEAKNESS: The study essentially used two Travel cost models which allowed comparison of infected versus non-infected sites to show the impact of MPB. This study attributes all of the difference in demand to beetle damage. While insect damage is an important determinant of demand, other characteristics of the sites would also affect recreational demand.

APPLICABILITY TO ALBERTA: This approach could be used to show how much money an agency is justified in spending on a control program. Alberta has campground supervisors in most locations. The questionnaire could be handed out as this study did, in the evening with return in the morning. It would provide general estimates of the economic loss caused by insects at specific sites. In order to show the loss for large areas, a large number of sites would need to be included.

INSECT: Mountain Pine Beetle

FOREST TYPE: Lodgepole Pine

AUTHOR: Moeller, G.H., Marker, McCoy and W.B. White

YEAR: 1977

TITLE: Economic Analysis of the Gypsy Moth Problem in the Northeast Part III: Impacts on Homeowners and Managers of Recreation Areas

SOURCE: Research Paper NE-360, Northeast Forest Experimental Station, Forest Service USDA, Upper Darby, Penn, 1077

KEY POINTS: Asking homeowners and recreation site managers to estimate the reduction in recreation days attributable to gypsy moth infestation. However, they did not estimate a demand function.

METHOD USED: Direct survey

STRENGTH AND WEAKNESS: A good method for a benefit cost analysis of the cost of control for an insect pest. The correlation with the importance of various cottage owning objectives is interesting in an anecdotal fashion. However, it does not directly relate the insect with the loss of recreation benefit.

APPLICABILITY TO ALBERTA: A similar study could be undertaken, but would not provide a great deal of useful information.

AUTHOR: Reiling, S.D., K.J. Boyle, H. Cheng and M.L. Phillips

YEAR: 1989

TITLE: Contingent Valuation of Public Program to Control Black Flies

SOURCE: Northeastern Journal of Agricultural and Resource Economics 18:126-134

KEY POINTS: The paper estimates the value of control program for a nuisance insect, the Black Fly. The authors believe that the method is not sufficiently well established for measuring the values from this sort program, so they also evaluate the method by means of examination of outliers, the timing of questioning, and the relation of damage perceptions to values stated.

The study assessed two groups of 374 homeowner residents, one group during the "nuisance season", and one group after. The response rate was 74%, Maximum willingness to pay, as a fee not a tax, was the payment vehicle chosen. The majority of respondents were not willing to pay at all for a control program. Those that gave a positive value for control increased their value (in an increasing fashion) as the control increased.

METHOD USED: Contingent Valuation, with TOBIT evaluation of the relation between selected variables and willingness to pay.

STRENGTH AND WEAKNESS: Does not mention recreation per se, though does relate to quality of life outside of the home. Relates to control, rather than damage. The study rests on control of late season black flies only. However, there are also early season flies. Therefore, the control would not affect the nuisance for a large part of the relevant period. Personal control also exists, which people consider adequate.

APPLICABILITY TO ALBERTA: While the study is not strictly related to the examination of insect damage to forests, the insect in question would certainly affect the recreation experience. The willingness to pay for a control program does relate to the possibility of controlling insects that damage trees. It is in effect, the "flip side of the coin", here measuring the benefit of control, versus other studies that measure the damage from the insect pest.

INSECT: Black Fly

FOREST TYPE: not applicable.

AUTHOR: Reiling, S.D.,K.J. Boyle, M.L. Phillips, V.A. Trefts and M.W. Anderson

YEAR: 1988

TITLE: The Economic Benefits of Late Season Black Fly Control

SOURCE: Maine Agricultural Experimental Station, University of Maine Bulletin # 822

KEY POINTS: See Reiling et al above

METHOD USED: Contingent Valuation

STRENGTH AND WEAKNESS: see Reiling et al above

APPLICABILITY TO ALBERTA:

AUTHOR: Walsh, R.G., Ward, F.A. and J.P. Olienyk

YEAR: 1989

TITLE: Recreational Demand for Trees in National Forests

SOURCE: Journal of Environmental Management, 28:255-268

KEY POINTS: The intention of this paper is to compare the applicability of the two methods used for measuring the recreational demand for trees. That is, how tree density affects benefits derived from a site. In particular, the authors seem to believe that the TCM is more valid, as it is based on actual behaviour. They compare TCM with the CVM to judge the usefulness of CVM. The results obtained show that the two methods result in statistically comparable values. They suggest the use of CVM in valuing existing forest recreation sites and to measure the effect of changes in forest quality on demands and benefits of recreation sites and to measure the effect of changes in forest quality on demands and benefits of recreational use. Tree density was the main site quality variable.

On site interviews were carried out with 435 respondents, at six sites in the study area.

Those interviewed were asked their actual travel costs to the site, and then their willingness to pay in extra travel cost to pay for a control program resulting in higher tree densities. Benefits of the experience was assumed to be equal to the extra willingness to pay. Pictures were used to hypothetical changes to the site.

METHOD USED: Contingent Valuation and the Travel Cost Method, with a comparison of the values obtained by the two methods.

STRENGTH AND WEAKNESS: The study wasn't actually measuring benefits, but rather evaluating the two methods. The use of on-site interviews means that they obtained a truncated sample, which was not corrected for, or mentioned. However, the use of on-site interviews meant that the respondents were more likely to be knowledgeable of the site, and similar sites.

Interviewees were asked to estimate tree density, of the site, actual densities were not measured. The values thus relate to perceptions and not to actual site qualities. However a quality negates the effects,and synergistic effects, of other variables.

The only choice available was to pay more travel costs to have a control program or to forgo any recreational experience. The lack of site substitution could be a serious fault in the study set-up.

APPLICABILITY TO ALBERTA: Tree density is assumed to be related to insect damage. Insects pests to Alberta do not necessarily cause a reduction in number of trees, as often as not there is damage without mortality.

INSECT: Mountain Pine Beetle

FOREST TYPE: Ponderosa Pine, mountain setting.

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Arthur, L.M. 1977. Predicting scenic beauty of forest environments: some empirical tests. For. Sci. 23: 151-160

Buhyoff, G.J., Leuschner, W.A., Arndt, L.K. 1980. Replication of a scenic preference function. For. Sci. 26: 227-230

Buhyoff, G.J., Leuschner, W.A. 1978. Estimating psychological disutility from damaged forest stands. For. Sci. 24: 424-432

Buhyoff, G.J., Wellman, J., Daniel, T.C. 1982. Predicting scenic quality for mountain pine beetle and western spruce budworm damaged forest vistas. For. Sci. 28: 827-838

Czerwinski, C., Isman, M.B. 1986. Urban pest management: decision making and social conflict in the control of the gypsy moth in west cost cities. Bull. Entom. Soc. Amer. 32: 36-41

Deloitte and Touche.1992. An assessment of the economic benefits of pest control in forestry prepared for the Forest Pest Management Council, Guelph

Holmes, T.P., Kramer, R.A., Haefele, M.A. 1992. Economic valuation of spruce fir decline in the southern appalachian mountains: A comparison of value elicitation methods. Proc. of the Forestry and the Environment Conference, Jasper, Canada. Mar 9-12 1992, published by Forestry Canada, Northern Research Center, Edmonton.

John, K.H., Stoll, J.R., Olson, J.K. 1987. An economic assessment of the benefits of mosquito abatement in an organized mosquito control district. J. Amer. Mosquito Control Assoc. 3: 8-15

Leuschner, W.A., Max, T.A., Spittle, G.D., Wisdom, H.W. 1978. Estimating southern pine beetle timber damages. Bull. Entom. Soc. Amer. 24: 29-34

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Walsh, R.G., Ward, F.A., Olienyk, J.P. 1989. Recreation demand for trees in national forests. J. Envi. Manage. 28: 255-268.

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APPENDIX C

Growth and yield techniques used in assessing site index, growth, and projecting stand volumes.

This appendix includes the equations used in the growth and yield tables to calculate the stand volumes in the various test blocks. The equations do not change between the blocks, though the site index they are based on will. These equations are taken from AFS (1985). However, it should be noted that due to typographical errors, several of these are incorrect in AFS (1985).

Site Index (SI)

To calculate the site index (normally done at age 50), the stand must be measured for dbH, and an average height calculated. This site specific height along with the stump age are used in the SI formula.

Height (HT) is: $$\ln HT = a + \frac{b}{(dbH+1)}$$

where a and b are region speciric coefficients for white spruce. This is used in the SI calculation as follows:

$$SI50 = 21.7888 + (0.5564\ X\ HT) - (0.9144\ X\ (\ln(HT))^2) - (4.1848\ X\ \ln(STAGE)) - (45.2407/STAGE) + (37.0182\ X\ (HT/STAGE))$$

where STAGE is the stump age, measured from felled trees 1.3 meters from ground level.

The equations to arrive at the required values of stand total volume, and number of stems per hectare follow a progression as follows; a series of 3 age equations, from actual age to stump age to breast height age; then two height equations, the site height and top height, and volume. Stems per hectare series starts with the volumes values, through a basal area equation and a diameter equation to arrive at the number of trees.

Total age: usually listed in steps of 10 years.

Y2STMP: the years of growth needed to reach stump height of 0.3 m.

Y2STMP = 6.0

YR2BH: the years of growth needed to reach breast height of 1.3 m.

YR2BH = Y2STMP + 2.16 + (110.76/SI)

SHT: Site height, which uses the SI and YR2BH

$$HT = 1.3 + \frac{(SI - 1.3)\ X\ (1 + \exp(9.6183 - (1.4627\ X\ \ln(50)) - (1.2240\ X\ \ln(SI - 1.3))}{(1 + \exp(9.6183 - (1.4627\ X\ \ln(YR2BH)) - (1.2240\ X\ \ln(SI - 1.3)))}$$

TOPH

T: top height, which progresses from the site height as follows

$$TOPHT = 1.3 + (1.65\ X\ (SHT - 1.3)^{0.865})$$

VOLUME: The calculation of total stand volume uses the top height value

$$VOLUME = 1100\ X\ \frac{1 - \exp(-.0675\ X\ (TOPHT - 1.3))}{1 + (8.8862\ X\ \exp(-.0675\ X\ (TOPHT - 1.3)))}$$

The number of stems (NTREE) is calculated by first using the volume values in a basal area equation (BA), and the TOPHT values in a diameter equation A(QDIA).

$$BA = -1 + (1.1356\ X\ (VOLUME + 1)^{0.8626})$$

$$QDIA = [-100.080 + \ln(1 - \frac{(TOPHT - 1.3)}{45)})]^{0.7115}$$

$$NTREE = \frac{BA}{0.00007854\ X\ QDIA^2}$$

APPENDIX D

Preliminary inventory of non-timber assets of the Hawk Hills Region.

This appendix contains a preliminary inventory of the non-timber assets of the forest in the Hawk Hills study region, and the results of interviews with members of the surrounding communities. In order to judge the attraction of the area for recreation, the inventory includes features that are contained in a larger geographical region than the budworm study area. The assets are broken down into parks and recreational areas, wildlife use (consumptive and non-consumptive), and other uses.

In overview, the park statistics, and interviews suggest that while the potential is strong, actual recreational use of the region is limited. The main recreational uses of the forest are hunting, both local and guided, and some camping in the parks. The hunting activities are mainly on the forest fringe, and along seismic cut lines. Fishing in the region is very limited, basically in the stocked lakes of parks, and along the Peace River. Random camping outside of the parks is either non-existent, or unmeasured. Winter use for snow-mobiling is not common. The other main non-timber use of the forest is fur-trapping.

Parks and Recreation areas

There are two provincial parks and one campground within 25 km of the study area, and several others within 100km.

Twin Lakes Provincial Park, located north of the study area along Highway 35. It is a short distance off the highway, and across from a lodge of the same name. There are two very small lakes, that have been stocked with trout. Motorboats are not allowed on these lakes. There are 49 camping sites, with self-registration (pay), and firewood provided.

Regional parks personnel suggest that the park is mostly used by locals, as a place to go fishing with the children. Only about 20% of use is by non-local, off the highway traffic. Total use for the period April 1994 to Mar 1995 (latest available statistics) was 551 occupied campsite nights, with average group size of 3.1. The Jul/Aug 1994 period shows an occupancy rate on average of 12%. For the same period, the day use figures show a total of 15,700 visits, with an average group size of 2.5. Historical statistics, dating back to 1987/89 show only small fluctuations within the camping nights, ranging from 482 to 591, but a steady and significant increase in day use, from 580 in 87/88 to 2,075 in 91/92, and 15,700 in 94/95. The 94/95 day use numbers are a 22% increase from the previous year.

Notikewan provincial park is a quite large, measuring nearly 20 km south to north, and 5 km east to west. Most of this area is not accessible by road, and the camping/picnic area has poor road access. The access is from Highway 35 near Hawk Hills, with first 20 km of gravel, then changing to dirt that seems to go through a farmers field. The park has a gate and office, but these are no longer manned. From the entry, the road goes down a long steep hill to the 19 sites in the campground, the picnic area, and the boat launch onto the Peace River. This park has very low use, with only 76 occupied campsite nights in 1994/95, and average group size of 3.6 The July/Aug occupancy rate was 3%. Day use for the same period was 800 total party visits, with average group size of 2.6. These numbers are about half the equivalent visits for the late 1980's, where the average annual occupied campsite nights was 125. Regional parks staff suggest the drop is due in large part to the road and hill having been intermittently washed out where a culvert diverted a small stream. Even though repairs, and a new bigger culvert is said to solve this, it is thought that people either no longer trust the road in the park, or are unaware of the repairs. The hill would probably still be slippery in rainy weather. There is no structured boat launch, just a track to the shore. [Parks staff say they can't afford the $800K necessary for a proper boat launch, and anything less just keeps washing away].

The use the park does get is mostly by local people, though it is listed in provincial parks guides and in the Alberta Wildlife viewing guide, with a mention of sandhill cranes, raptors and cavity nesting birds. The wildlife viewing guide also lists the presence of moose, black bear and grizzly bear.

The Hotchkiss campground is located where Highway 35 crosses the Hotchkiss River. There is no fee, and there are no designated camping sites. Use statistics are not keep for this area. Within the campground, there are cleared spots that appear to be used for camping, a central kitchen, and ball diamonds. Weekend and special tournaments would appear to be the main uses of this campground. It would not likely be attractive to traffic passing through the region.

There are other parks within 100km of the study area, that may also provide accommodation for visitors to the study area, such as Queen Elizabeth park close to Grimshaw, or the Sulfur River campground near Dixonville. Information on these is not yet available.

Wildlife use

Visits related to wildlife may be broken down into two categories, non-consumptive (such as birdwatching), and consumptive (hunting and fishing). Within the consumptive category, a further division can be made into commercial (guided hunting and trapping), and non-commercial (personal hunting).

There is very little information on non-consumptive use of the forest in this area. Interviews revealed no organized clubs or activities, though there was mention of "one fellow who may do some bird watching". There have been no previous large-scale surveys of visitors that included a section on reason for visiting the area. A limited distribution survey was conducted for Notikewan park, that included a section on activities of visitors while in the park. Summary statistics for this survey are not available to the public.

Both segments of consumptive use would appear to be the major use of the forest in this region. This would include fishing and personal hunting as non-commercial, along with the commercial activities of guided hunting, and fur-trapping. For future work, it may be possible to obtain the particulars of hunting permits issued for the region, and conduct a survey of users, and economic statistics of fur sales for that activity.

Fishing is not strong in the immediate area, and is not heavily engaged in. The best fishing is in the stocked lakes of Twin Lakes park, the confluence of the Notikewan and Peace Rivers in Notikewan park, and the Peace River in general. These areas would not be enough of an attraction to draw in non-local visitors.

Personal hunting is very strong among the local population. Interviews with various sources such as local fish and wildlife officers, parks staff, and town officials elicited comments such as "most of the males in town have a rifle and hunt". As well, due to recent restrictions placed on hunting seasons in other parts of the province that will not apply here, there may be a future influx of non-local Albertans to the region. The main species sought are bear, moose and geese, with the forest type not conducive to deer hunting. The hunting that is carried out only involves the forest fringe (roads and cut-lines), and the interface between forest and agricultural areas.

Guided hunting is well established in the area, with about 10 to 12 main operators, and perhaps others that operate from nearby (i.e. Peace River). As well, there are two commercial lodges within 50 km of the study area. Conversations with operators and clients suggest that the majority of clients are working class individuals or groups from the United States. One operator stated that he only advertises in one hunting magazine in the US, and that provides him with sufficient clients for his operation. This is probably an area where future growth is possible, given operators with the ambition to expand.

Trapping is well established in the area, with a strong local trappers associated. In general it is an activity for a secondary income, with another career (such as agriculture) providing the main income. Representatives of the association were unsure how a budworm infestation would affect their activities, but were willing to participate in further surveying or questioning of their opinions. They were more concerned about how the activities of the forest companies did affect their trapping.

Other non-timber forest uses

This category could include snowmobiling, collection of edible plants and berries, collection of materials for artistic creations, or hiking. There is no information on any of these activities, with the possible exception of limited knowledge of snowmobiling. The town of Manning does have a snowmobile club. Interviews with various local people suggested that snowmobiling, to their knowledge, was more likely to be pursued on agricultural land than on forested land.

APPENDIX E

Survey instruments used.

You and the Northern Forest

Thank you for taking the time to complete this questionnaire. Please try to answer all of the questions. Most of them can be answered by circling a number next to the answer you choose or writing in the blank space provided. If there are any questions you do not wish to answer, please omit them and move to the next question.

All information you provide is strictly confidential. Your name will never appear with your answers. Only a summary of the results will be publicized.

Canadian Forestry Service
Northern Forestry Centre
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

Part I. Your use of the northern forest

We are interested in learning more about what you do in the forest in this area. This will help us understand the way in which the forest contributes to your quality of life.

1. Which of the following activities have you pursued in the forest locally **during the last two years** (since 1996). Please place a checkmark (✔) under the heading that best describes how often you participated in each activity.

	Never	Sometimes	Often
Hunting	☐	☐	☐
Bird watching	☐	☐	☐
Snowmobiling on forest trails	☐	☐	☐
Quadding on forest trails	☐	☐	☐
Cutting firewood	☐	☐	☐
Hiking	☐	☐	☐
Berry or mushroom picking	☐	☐	☐
Snowshoeing	☐	☐	☐
Horseback riding on forest trails	☐	☐	☐
Camping	☐	☐	☐
Trapping	☐	☐	☐
Collecting materials for handicrafts	☐	☐	☐
Cutting a Christmas tree	☐	☐	☐

2. Have you travelled outside of the local region to pursue these activities in the last two years? If yes, write down which ones:

____

____

3. During your outings in the local forest, have you ever seen trees affected by insects?

No	Yes	If yes did this;	No	Yes
☐	☐	lower your enjoyment of the visit	☐	☐
		cause you to take a shorter visit	☐	☐

Part 2. Management of the northern forest

We would like to get an idea of your knowledge about the role of insects and insect control in forest management in Alberta. Please answer the following questions as completely as possible.

4. Have you ever been to a public information session on forest management?
   Yes No

5. Have you ever been to a public information session on managing insects that feed on trees?
   Yes No

6. Which methods do you know of that are used to control insect populations in the forest? Please list them all. If you do not know of any methods, write "**NONE**" in the space provided.

   ____
   ____
   ____

7. Are you aware of any insects that feed on trees in the forest in this area? If not, write "**NONE**" in the space provided, otherwise, please list those that you can think of:

   ____
   ____
   ____

8. Which one of these do you think has the largest effect on the forest:

   ____

9. Please indicate how you feel about the following by circling the number that best describes your agreement or disagreement with each statement. Note that when we refer to insects, we mean insects that feed on live trees.

	strongly disagree	disagree	neither agree or disagree	agree	strongly agree
Insect control is needed in forest management	1	2	3	4	5
Spraying to control insects can pose a threat to human health	1	2	3	4	5
Scientists are able to make accurate estimates of the risks involved in controlling insects	1	2	3	4	5
Controlling insects is important for a stable supply of timber for the forest industry	1	2	3	4	5
It is alright to control insects even if it reduces the food supply of birds	1	2	3	4	5
Controlling insects helps maintain a healthy forest	1	2	3	4	5
The benefits of controlling insects outweigh any negatives	1	2	3	4	5
It is acceptable to control large outbreaks of insects in the forest	1	2	3	4	5
Forests should be logged rather than allow insects to damage them	1	2	3	4	5
We should control insects considered as pests even if this can result in the death of beneficial insects	1	2	3	4	5
Under no circumstances should we attempt to control any insects in the forest	1	2	3	4	5

Part III. Forest Values

10. One aspect of our study is understanding how people feel about Alberta's forests. Please indicate how you feel about the following by circling the number that best describes your agreement or disagreement with each statement.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
It is important for me to know that forests exist in Alberta	1	2	3	4	5
Forests should be managed to meet as many human needs possible	1	2	3	4	5
Forests should have the right to exist for their own sake, regardless of human concerns and uses	1	2	3	4	5
Forests give us a sense of peace and well-being .	1	2	3	4	5
Forests should exist mainly to serve human needs	1	2	3	4	5
Forests are sacred places	1	2	3	4	5
It is important to maintain the forests for future generations	1	2	3	4	5
Forests that are not used by humans are a waste of our natural resources	1	2	3	4	5
Humans should have more respect and admiration for the forests	1	2	3	4	5
Forests let us feel close to nature	1	2	3	4	5
If forests are not threatened, we should use them to add to the quality of human life	1	2	3	4	5
Forests rejuvenate the human spirit	1	2	3	4	5
Forests can be improved through management by humans	1	2	3	4	5

11. Another important part of our study is understanding people's opinions on how **Alberta's public forests** should be managed. Please indicate how you feel about the following by circling the number that best reflects your agreement or disagreement with each statement.

	strongly disagree	disagree	neither disagree nor agree	agree	strongly agree
Typical examples of Alberta's forest regions (for example boreal and aspen parkland) should be excluded from all development such as forestry, oil and gas, and tourism	1	2	3	4	5
Our forests are being managed successfully to meet our future needs	1	2	3	4	5
Some forests should be set aside from timber harvesting even if it means lower wages or fewer jobs	1	2	3	4	5
Legislation should be established to protect endangered species in our forests	1	2	3	4	5
Providing jobs and economic development is more important than setting aside forests from logging	1	2	3	4	5
Forests should be managed mainly to provide a variety of plants and wildlife	1	2	3	4	5
Forests should be managed mainly for timber and lumber products	1	2	3	4	5
Forestry practices generally produce no long term negative impacts on the environment	1	2	3	4	5
The economic benefits from forestry practices usually outweigh any negative impacts	1	2	3	4	5
Some existing protected areas such as parks should be opened for logging	1	2	3	4	5
Enough harvested trees are being replaced by planting new ones or by natural seeding to meet our future timber needs	1	2	3	4	5
Logging forests is acceptable if the forest is not harmed	1	2	3	4	5
When making forest decisions, the concerns of people living in the forest should be given a higher priority than people in other communities	1	2	3	4	5
Clear-cut logging should be banned on public land	1	2	3	4	5
Economic stability of communities is more important than setting aside forests from logging	1	2	3	4	5

Part 4. Demographic Information

We would like to know some things about you and your family to determine if there are connections between people's backgrounds and their answers. Your name never appears with your answers, however, if for some reason there is a question you do not wish to answer, just leave it blank and move to the next question. Your answers will be **strictly confidential.**

12. Are you male or female? male ____ female ____

13. Including yourself, how many people live in your household? ____________

14. What is your age? ____ years

15. Do you belong to any of the following nature, environmental, or outdoor oriented clubs or associations?

Ducks Unlimited	Yes / No	Snowmobile club	Yes / No
Fish and Game Association	Yes / No	Friends of the North	Yes / No
Federation of Alberta Naturalists	Yes / No	Sierra Club	Yes / No
Alberta Wilderness Association	Yes / No	CPAWS	Yes / No

Other (Please list them)____

16. Which is the highest level of education that you have completed *(please circle one)*

1. Never attended school
2. Grade school (grades 1 to 9)
3. Some high school
4. High school graduate
5. Technical school
6. Some university
7. Undergraduate degree
8. Some graduate study
9. Postgraduate degree

17. What do you consider you main occupation to be:

____

Part 5. Managing the forest to control the effect of insects

18. There are insects that may feed on trees in the forest in this area. This feeding is part of nature, and natural cycles. Some people think that the result of the feeding may affect human use of the forest, and that the insect populations should be controlled.

From the following list, please indicate whether you have heard of any one of these insects, whether you believe that they are present locally, and whether you believe that they are a problem in the forests in this area.

	I have heard of it		It is present locally			It is a problem locally		
	No	Yes	No	Yes	Don't know	No	Yes	Don't know
Bark beetles	☐	☐	☐	☐	☐	☐	☐	☐
Spruce budworm	☐	☐	☐	☐	☐	☐	☐	☐
Jackpine budworm	☐	☐	☐	☐	☐	☐	☐	☐
Birch leaf miner	☐	☐	☐	☐	☐	☐	☐	☐
Deathwatch beetle	☐	☐	☐	☐	☐	☐	☐	☐
Gypsy moth	☐	☐	☐	☐	☐	☐	☐	☐
Spider mites	☐	☐	☐	☐	☐	☐	☐	☐
Whirlygig beetle	☐	☐	☐	☐	☐	☐	☐	☐
Forest tent caterpillar	☐	☐	☐	☐	☐	☐	☐	☐
Large aspen tortrix	☐	☐	☐	☐	☐	☐	☐	☐

Caterpillars are the larval stage of butterflies and moths. There are many species of caterpillars found in the northern forest. One of these is the spruce budworm which eats the developing needles of spruce trees. All of the caterpillars, including the spruce budworm, provide food for birds. When budworm populations become very high, they slow tree growth and in some cases may cause trees to die. Tree deaths begin after about 5 years of high budworm populations being present. These periods of high populations may last up to 20 years depending on environmental conditions; late spring frosts are the only known natural cause for the collapse of spruce budworm outbreaks.

Methods to control budworm include aerial spraying of chemicals or biological insecticides, selectively cutting down trees, or doing nothing at all. The province of Alberta sprays a biological insecticide, a bacterium called *Bacillus thuringensis* (or Bt) to control spruce budworm. It is not known how much Bt affects the populations of other moths and butterflies. Some of these may also be pests, such as the forest tent caterpillar. Others may be harmless or beneficial. Chemical insecticides are approved for use in Canada, but none are presently used in the province due to the possibility of unknown risks to other insects and wildlife generally. Other methods to control the budworm include cutting some of the infected trees, and thinning. Thinning means cutting healthy trees so that the remaining trees can outgrow the effects of budworm feeding. Cutting trees to control budworm is not commonly used in Alberta.

19. We would like to get your opinion about these control methods.
Please circle the number that best corresponds with how acceptable these are to you personally.

	very unacceptable	unacceptable	neither acceptable or unacceptable	acceptable	very acceptable
Aerial spraying of chemical insecticides	1	2	3	4	5
Aerial spraying of biological insecticides	1	2	3	4	5
Logging infested areas before heavy damage occurs	1	2	3	4	5
Leave it alone, let nature take its course	1	2	3	4	5
Thinning the forest stand	1	2	3	4	5
Other insects species may die because of budworm control methods	1	2	3	4	5

APPENDIX F

Representative photographs of the 8 scenic beauty clusters.

Two colour plates are included in the envelope.

APPENDIX G

Expenditures and proposed budget for 1996/1997.