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MANAGING THE ECONOMIC IMPACTS OF MOUNTAIN PINE BEETLE OUTBREAKS IN ALBERTA

FOOTHILLS MODEL FOREST CASE STUDY

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Preface

The recent outbreaks of Mountain Pine Beetle in Western Canada are having a dramatic impact on the forest environment and on those who live and work within these forestlands. The British Columbia Interior has already experienced a devastating infestation and the Mountain Pine Beetle has now quickly spread westward beyond the Rockies and into Alberta.

While the Alberta government and private sector interests are reacting swiftly to limit the impact of the infestation, the economic impact of the Alberta outbreak has not been clearly established. This case study represents an early attempt to examine and measure the economic, social and environmental impacts of the Mountain Pine Beetle infestation within Alberta, utilizing the Foothills Model Forest which encompasses the Hinton Wood Products Forest Management Area.

The Western Centre for Economic Research at the University of Alberta's School of Business assembled an excellent team of forestry experts to explore this timely topic: Blake Phillips, James Beck and Trevor Nickel have helped quantify this emerging and dramatic regional issue, with modeling help provided by Mike Patriquin and Bill White of the Canadian Forestry Service. West Fraser Mills Ltd. provided critical feedback on early report findings.

I believe this study will be useful as first efforts to deal with the Alberta Mountain Pine Beetle infestation get underway.

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Abstract

Output from the SELES MPB Landscape Scale Mountain Pine Beetle Model (Fall et al., 2004) was utilized to estimate potential mountain pine beetle spread rates within the Hinton Wood Products Forest Management Area (HFMA) of the Foothills Model Forest. From the SELES model output three spread rate scenarios were hypothesized. Scenario 1 hypothesized a Mountain Pine Beetle (MPB) spread rate slower than the rate estimated by the SELES MPB Model. Within Scenario 1, current Annual Allowable Cut (AAC) levels were hypothesized to be adequate to harvest MPB damaged lodgepole pine stands. Scenario 2 hypothesized that spread rates would be consistent with the recommended run from the SELES MPB Model, resulting in attack of the majority of the stands within the HFMA within 29 years. Scenario 3 hypothesized that spread rates would be higher than estimated by the SELES MPB Model, resulting in attack of the majority of lodgepole pine stand in the HFMA in 20 years (Scenario 3.1) or 10 years (Scenario 3.2).

The even flow harvest rates required to utilize commercially viable stands attacked by MPB were determined (Surge Period). The modeling program Forest Muncher was utilized to estimate the decrease in AAC which could result from succession / salvage harvest of the majority of lodgepole pine stands within the HFMA within each scenario (Post Surge Period). Based on these AAC estimates, the potential economic impact of MPB attack influenced AAC changes was examined utilizing output from the Computable General Equilibrium Framework (CGE) Model developed by Mike Patriquin and Bill White of the Canadian Forest Service (Patriquin et al., 2005). Scenario 1 had a nearly inappreciable impact on the economic indicators for the forest industry or the total economy in the Foothills Model Forest Area. Within Scenario 2, forest industry revenue, royalties, labour income, and employment were estimated to increase by 40 – 50% during the Surge Period and decrease by 4.7– 6.0% in the Post Surge Period. Within Scenarios 3.1 and 3.2 forestry revenue, royalties, labour income and employment increases ranged from 70 – 90% for Scenario 3.1 and ranged from 160 – 210% for Scenario 3.2 during the Surge Period. Revenue, royalties, labour income and employment in the forest industry were estimated to decrease by 6 – 9% within the Post Surge Periods of Scenarios 3.1 and 3.2.

Economic, forest industry capacity, social and environmental factors which may limit the feasibility of large scale salvage of mountain pine beetle damaged stands are discussed within the report.

The authors would like to acknowledge the support and contribution of West Fraser Mills Ltd. whose staff provided feedback regarding the implications of the report findings during informal discussions. We would also like to acknowledge the contribution of Mike Patriquin and Bill White who completed the Computable General Equilibrium Framework Model runs discussed within this report. All errors and/or omissions remain solely the responsibility of the authors.

Contents

Abbreviations used within this report

AAC:	Annual Allowable Cut
CGE Model:	Computable General Equilibrium Framework Model
FMF:	Foothills Model Forest
HFMA:	Hinton Wood Products Forest Management Area
HWP:	Hinton Wood Products
MPB:	Mountain Pine Beetle
SELES:	Spatially Explicit Landscape Event Simulator
SELES MPB Model:	SELES MPB Landscape Scale Mountain Pine Beetle Model
SRD:	Alberta Sustainable Resource Development
WFM:	West Fraser Mills Ltd.

Introduction

The mountain pine beetle (*Dendroctonus ponderosae*) (MPB) is a small insect endemic to forests in Western North America and historically has been the most destructive western bark beetle species (Coulson and Witter, 1984). The MPB and its primary host, the lodgepole pine tree (*Pinus contorta*), have always co-existed as a natural part of the forest ecosystem. Young, robust pine trees have typically been able to ward off the attacks of the pine beetle, utilizing natural defense mechanisms. Traditionally the MPB only successfully attacked large, over mature and stressed lodgepole pine trees contributing to the natural process of succession in forested landscapes. Winter temperatures below negative 35 - 40° Celsius act as one of the primary natural population controls for the MPB. The process of global warming has reduced the regularity of these extreme cold climatic events, resulting in an explosion in the population of the MPB within the interior of British Columbia. The intensity of the attacks resulting from this population explosion has rendered the lodgepole pine's natural defense mechanisms ineffective. The majority of pine stands within British Columbia, and beyond, have become susceptible to attack.

2005 aerial overview surveys estimate the current area of MPB red attack (areas attacked in the previous year) to encompass 8.7 million hectares in British Columbia, an increase of over 1.5 million hectares from the previous year. Within the attacked area, it is estimated that 400 million cubic metres of timber is affected, up from 283 million cubic metres the previous year (Gov. of B.C., 2006).

The rapid deforestation caused by MPB attacks has forced forest managers in B.C. to develop methods to utilize beetle killed wood and manage the economic and environmental effects of the loss of mature lodgepole pine stands. The rate of spread of the MPB has not been significantly slowed by natural barriers or human interventions and continues largely unabated. Outbreaks of beetle attack are appearing across the Alberta border and the contiguous nature of the boreal forest between British Columbia and Alberta renders the risk of significant spread of the MPB into Alberta extremely high and almost inevitable. Similar to their colleagues to the west, forest managers within Alberta will likely soon need to address the effects of MPB induced, large scale lodgepole pine deforestation.

The objective of this report is to examine the economic, social and environmental impacts of a MPB infestation within Alberta, utilizing the Foothills Model Forest (FMF) as a case study. First, the report will examine rates of MPB spread within the Foothills Model Forest area. Second, we will examine management issues related to utilization of MPB attacked wood. Potential economic impacts which may result from deviations from current annual allowable cut levels influenced by the beetle attack will also be examined. Last, we will briefly identify and discuss some of the key environmental and social issues which need to be considered and balanced when developing policies for management of beetle attacked forest landscapes.

Background

The Mountain Pine Beetle (*Dendroctonus ponderosae)*

The mountain pine beetle (*Dendroctonus ponderosae*) (MPB) is a small, relatively innocuous looking beetle. At just a few millimeters in length, the MPB is about the size of a grain of rice, dark brown in color and lives its entire life, from egg to larva to adult normally in a singe year.[1] In cooler, northern latitudes the progression from larva to adult beetle may take two years.

Figure 1: Adult Mountain Pine Beetle (left) and larva (right)[2]

In midsummer, the adult beetle emerges from its pine tree host to find a new host tree. Dispersal is achieved via wind currents which the beetle access by flying to altitudes high above the forest canopy. Females initiate the attack by boring through the bark into the phloem of the tree. The pine tree can defend against attack by expelling the boring female with sap. Females which identify susceptible pine trees emit pheromones to attract other females, resulting in multiple, simultaneous attacks on the same tree. Attacks of adequate intensity overcome the natural defenses of the tree (Coulson and Witter, 1984).

Once the female penetrates the phloem of the tree it bores an egg gallery, where she is joined by a male beetle and mates. The fertilized eggs are laid in bored niches along the vertical egg gallery. Larvae emerge from the eggs and mine horizontally around the tree, feeding on the phloem. This cuts off the flow of nutrients within the tree, eventually causing death of the tree. Additionally, during mating the adult beetles inoculate the tree with blue staining fungi. The fungi aids in killing the host tree by causing dehydration and limiting the ability of the tree to defend against further attack (Coulson and Witter, 1984). The larva

[1] http://mpb.cfs.nrcan.gc.ca/biology/biology_e.html
[2] Images from mpb.cfs.nrcan.gc.ca/biology/images/

matures over winter within the bark of the host tree, emerging in midsummer as a mature beetle to complete the life cycle.

In the first year of attack the foliage of the pine tree remains green (green attack) but attack is easily identifiable. The abundant penetration holes by the adult beetle and the pitch emitting from bore holes where the tree has attempted to ward off attack are easily visible along the stem. In the second year, the foliage of the pine tree turns red (red attack) and the stem begins to dry and is susceptible to entry by secondary boring insects and birds. Within the various entry points into the pine tree, decay sets in. Gradually over the third to fifth year the red foliage is lost. Once the structural integrity of the root system is compromised by rot, the tree falls over.

Figure 2: A stand of lodgepole pine killed by Mountain Pine Beetle[3]

The maturing beetle is protected from the cold, winter climate by the insulating nature of the bark of the tree and the snow pack surrounding the tree stem. Only pine stems with adequately thick bark (typically greater than 80 years of age) offer adequate protection from the winter elements. Temperature events below negative 35-40° Celsius can overcome the insulating nature of the beetle's winter habitat resulting in death. Global warming has resulted in a significant reduction in the abundance of extreme cold temperature events which historically have maintained beetle populations at endemic levels. Additionally, warmer winter temperatures reduce the thickness of bark necessary for winter survival, making smaller pine stems suitable for sustaining maturing beetles through the winter.

[3] Image from mpb.cfs.nrcan.gc.ca/biology/images/

The availability of suitable host tree species appears to have been augmented by current fire control policies, although the efficacy of fire prevention techniques is questioned within the fire frequency literature (Armstrong, 1999). Utilizing the variance in age-class distribution characteristics between protected and unprotected landscapes and fire scarring to determine the timing of fire events within boreal forests, stand renewing fire events appear to occur approximately every 40-90 years (Murphy, 1985; Larson, 1997). Within individual stands the actual timing of the renewing fire cycle is likely highly variable (Armstrong, 1999). Regardless of the source, there is an abundance of 80+ year old pine stands within the boreal forest which are highly susceptible to MPB attack.

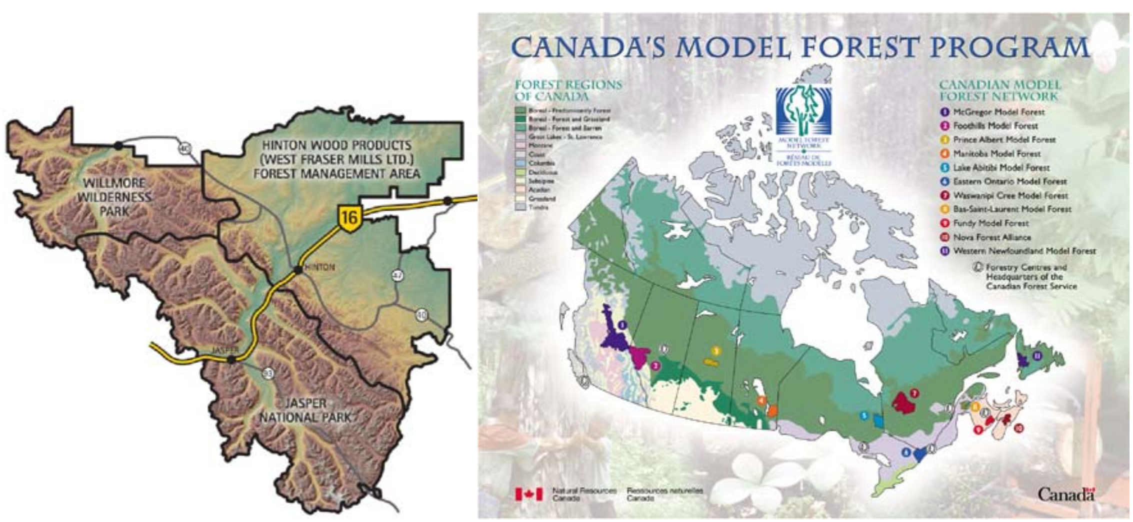
Beyond the primary MPB population controls of winter climate and host availability, the feeding activities of birds and other insects on mature beetles and larvae is one other natural MPB population limiting factor.

The Foothills Model Forest Region

Canada's Model Forest Network is a series of forest partnerships that have devoted the management of their land bases towards education, research, and demonstration purposes. The second largest in the network (27,500km^2), the Foothills Model Forest (FMF) comprises three major land management groups, Jasper National Park, Wilmore Wilderness Park, and the West Fraser Mills Ltd. (Hinton Wood Products) Forest Management Area.

The FMF is located on the western border of Alberta between Latitude 53^o and 54^{o}N, in the transition zone between prairie, parkland and montane ecosystems. The dominant vegetation in the region is lodgepole pine forest, with spruce, fir and aspen forests of secondary importance (Llarena, 1987).

Figure 3: The Foothills Model Forest[4]



[4] Image from www.fmf.ca

This report focuses on the potential economic, social and environmental impacts of a bark beetle attack within the Hinton Wood Products Forest Management Area (HFMA), leaving the analysis of impacts within the park system to other projects.

Geographic and Ecological Information

The HFMA is located west of Edmonton, along Highway 16 (Yellowhead Highway) throughout Yellowhead County. Latitudinally it lies between 53° and 54° North, and longitudinally between 116° and 118° W occupying an area of approximately 1,000,000 hectares (Llarena, 1987). Elevation ranges significantly over the HFMA, from 853m on the eastern boundary to 2,621m in the southwestern corner.

The climate is described as "continental," traditionally having long, cold winters and shorter, cool summers. Average monthly temperatures range from negative 2-9° Celsius during the winter months (November to March) and between 9-15° Celsius during the summer months (May to August)[5] .

Average annual precipitation is 462mm, with approximately 70% falling between May and September (Llarena, 1987). In 2005, environment Canada indicates that precipitation in the area amounted to 620.2mm, with 73% of precipitation received as rain.[5]

Above 1,150m in elevation, lodgepole pine (*Pinus contorta*) is the dominant tree, while below that elevation, there is considerable co-domination of lodgepole pine with trembling aspen (*Populus tremuloides*), white spruce (*Picea glauca*), balsam poplar (*Populus balsamifera*) (Bonar, 2001). Other species of tree present in smaller numbers are black spruce (*Picea mariana*), tamarack (*Larix laricina*) and fir (*Abies lasiocarpa*).

The productive forest land base under management by Hinton Wood Products encompasses approximately 799,000 ha which is divided into an Active Land Base of approximately 715,000 ha and a Passive Land Base of approximately 84,000 ha. The Passive Land Base includes environmentally and socially sensitive areas which are excluded from harvesting.

The species composition of the Active and Passive Land Bases, as provided by Sustainable Resource Development (SRD) on March 24, 2006, are shown in Tables 1 and 2 below. The total area of the Active and Passive Land Bases as provided by SRD have been configured with MPB susceptibility rankings and have therefore been adapted to the objectives of this report. The total SRD area of the Active Land Base is approximately 709,000 ha and the Passive Land Base is approximately 111,000 ha. The SRD provided areas are not consistent with Hinton Wood Products 1999 Forest Development Plan. The variance in total area is not considered significant to the findings of this report

[5] http://www.climate.weatheroffice.ec.gc.ca/climate_normals/results_e.html?Province=ALTA&StationName=&SearchType=&LocateBy=Province&Proximity=25&ProximityFrom=City&StationNumber=&IDType=MSC&CityName=&ParkName=&LatitudeDegrees=&LatitudeMinutes=&LongitudeDegrees=&LongitudeMinutes=&NormalsClass=A&SelNormals=&StnId=2542&start=1&end=13&autofwd=0

Table 1: Species composition of the HFMA Active Land Base by area (ha), displayed by age class.

	Leading Species							
Stand Mean Age	**Lodgepole Pine**	**White Spruce**	**Black Spruce**	**Tamarack**	**Mixedwood Conifer Leading**	**Mixedwood Deciduous Leading**	**Deciduous**	**Total**
5	33,982	1,766	7	0	206	69	986	37,016
15	20,586	3,280	221	0	752	501	1,677	27,017
25	22,423	5,372	1,237	64	2,208	1,740	5,429	38,472
35	21,611	7,247	1,895	46	2,138	1,279	4,158	38,374
45	12,933	1,616	839	122	458	307	876	17,151
55	4,075	2,258	700	188	249	238	616	8,324
65	13,997	3,443	1,095	69	484	755	1,618	21,461
75	17,960	4,473	2,625	327	990	1,203	3,508	31,086
85	19,735	3,973	1,425	27	761	1,016	3,714	30,650
95	53,485	4,100	6,008	31	2,207	2,957	8,524	77,311
105	110,802	13,804	12,842	233	6,429	6,669	22,026	172,805
115	53,407	8,466	11,211	100	2,913	2,467	7,273	85,837
125	16,445	7,435	4,943	13	2,006	729	2,186	33,757
135	13,683	12,097	4,501	35	1,474	1,015	2,343	35,148
145	2,163	2,307	890	6	71	14	36	5,486
155	3,025	1,869	881	2	112	41	18	5,947
165	6,198	6,278	1,048	0	605	256	447	14,833
175	611	1,267	116	0	16	3	0	2,014
185	3,149	2,461	335	0	94	5	2	6,046
195	6,487	8,439	605	1	168	27	8	15,734
200+	1,531	2,699	49	0	36	0	0	4,315
Total Area	438,287	104,649	53,472	1,264	24,378	21,289	65,445	708,785
% Active Base	61.8%	14.8%	7.5%	0.2%	3.4%	3.0%	9.2%	

Approximately 62% of the Active Land Base is occupied by lodgepole pine stands, of which over 70% are over 80 years of age and at high risk of mountain pine beetle attack. Stands which are white spruce leading or mixedwood likely also contain significant lodgepole pine components at risk to MPB attack. Approximately 25% of stands within the Active Land Base are at high risk to MPB attack (susceptibility score of 40 or higher) (Shore et al., 2000). Approximately 30% of stands in the Active Land Base are at moderate risk to MPB attack (susceptibility score of 20 – 30).

Large portions of the Passive Land Base are located within riparian reserves, along major river corridors or are located on other lower slope, moisture receiving ecotypes. The variance in average ecological conditions has resulted in a lower component of lodgepole pine stands and a higher component of spruce and deciduous type stands in the Passive Land Base, relative to the Active Land Base. Approximately 35% of the Passive Land Base is occupied by lodgepole pine stands, of which over 60% are over 80 years of age and at high risk of MPB attack. 14% of stands within the Passive Land Base are estimated to have a high risk of MPB attack and 19% are estimated to have a moderate risk of MPB attack.

Table 2: Species composition of the HFMA Passive Land Base by area (ha), displayed by age class.

	Leading Species							
Stand Mean Age	Lodgepole Pine	White Spruce	Black Spruce	Tamarack	Mixedwood Conifer Leading	Mixedwood Deciduous Leading	Deciduous	Total
5	2,276	106	4	0	11	1	90	2,489
15	1,269	216	14	0	61	38	178	1,776
25	1,457	390	152	4	222	231	605	3,061
35	1,694	585	349	21	184	170	542	3,544
45	1,728	657	222	32	58	106	227	3,029
55	1,684	876	231	59	107	292	659	3,908
65	2,950	4,514	316	150	303	588	1,143	9,964
75	1,815	1,461	816	332	257	190	866	5,736
85	1,769	931	520	55	135	311	685	4,405
95	6,400	1,371	1,688	96	437	607	1,582	12,181
105	8,412	5,609	7,508	342	1,017	696	2,437	26,021
115	4,404	2,604	3,500	68	390	542	826	12,333
125	1,184	3,294	2,743	45	435	68	149	7,917
135	1,035	2,955	2,625	1	191	79	204	7,089
145	83	821	728	11	16	0	3	1,662
155	95	749	289	1	20	0	1	1,153
165	416	1,299	771	0	99	6	16	2,607
175	25	201	36	0	3	1	0	266
185	15	295	84	0	13	0	0	406
195	285	596	56	0	24	0	0	962
200+	11	134	1	0	2	0	0	147
Tot Area	39,006	29,662	22,651	1,217	3,985	3,923	10,212	110,655
% Passive Base	35.2%	26.8%	20.5%	1.1%	3.6%	3.5%	9.2%	

Economic Information

In 1995, forestry (dimension milling and pulp milling, excluding harvesting) accounted for 28.5% of all economic activity in the HFMA area, well above the average provincial level of 1% (Alavalapati et al., 1998). Other industries of importance in the HFMA area are mining, tourism and, increasingly, oil and gas exploration and extraction. In 1995, mining made up 27.9% of economic activity; oil and gas made up 11.9% and tourism made up 16.5%. Anecdotal evidence would suggest that oil and gas generates a greater proportion of the economic activity in the region in 2006[6]. The Town of Hinton is experiencing a population and economic boom with increased petroleum exploration and drilling in the area (Alberta Labour Market News, 2005).

[6] Personal communication, John Parkins, Ph.D., Senior Sociologist, Canadian Forest Service

Social Information

The communities of Hinton, Marlboro, Robb and Cadomin are contained within the HFMA, while the town of Edson is nearby.

Hinton

The Town of Hinton had a population of 9,961 in 1996, and 9,405 in 2001[7], and has a population of approximately 10,500 in 2006[8]. This represents a negative growth rate of 5.9% between 1996 and 2001, and positive growth of 11.6% between 2001 and 2006. This is consistent with the current oil and gas activity boom in the area.

In 1996, the median age of the population of Hinton was 33.3[9], with the largest portion of the population in the 25-44 year old age group. The population was 51% male, and 49% female. Approximately 70% of the population of Hinton has finished at least secondary education, and there appears to be a trend for younger people to complete higher levels of education[10].

The main employment industry in Hinton is manufacturing, followed closely by wholesale and retail trade and natural resource based industry. 860 people (86% male) work in natural resource related industries; this represents 16% of the labour force in Hinton[11].

Yellowhead County (Surrounding communities and rural area, excluding the Town of Hinton)

Yellowhead County had a population of 10,092 in 1996, and 9,881 in 2001. This represents a slight decline of 2.1% over the five years between census takings[12]. In 1996, the median age of the population of Yellowhead County was 38.2. The majority of the population was in the 25-44 year-old age group, including 53% male and 47% female occupants[13]. Approximately 69% of the population had completed at least a secondary level of education in 1996.

Within Yellowhead County, the main employment area is natural resource related industries, where 1,490 people are employed (75% male) representing 27% of the employed labour force in the county[14]. The next most important section of the labour market is manufacturing, with services and retail trade following at a distance.

[7] http://www12.statcan.ca/english/profil01/CP01/Details/Page.cfm?Lang=E&Geo1=CSD&Code1=4814019&Geo2=PR&Code2=48&Data=Count&SearchText=hinton&SearchType=Begins&SearchPR=01&B1=All&Custom=

[8] http://www.town.hinton.ab.ca/siteengine/ActivePage.asp?PageID=110

[9] http://www12.statcan.ca/english/profil01/CP01/Details/Page.cfm?Lang=E&Geo1=CSD&Code1=4814019&Geo2=PR&Code2=48&Data=Count&SearchText=hinton&SearchType=Begins&SearchPR=01&B1=All&Custom=

[10] Ibid.

[11] Ibid.

[12] http://www12.statcan.ca/english/profil01/CP01/Details/Page.cfm?Lang=E&Geo1=CSD&Code1=4814003&Geo2=PR&Code2=48&Data=Count&SearchText=Robb&SearchType=Begins&SearchPR=01&B1=All&Custom=

[13] Ibid.

[14] Ibid.

Edson

The population of the Town of Edson was 7,399 in 1996, and 7,585 in 2001. This represents a slight population increase of 2.5%. A municipal census completed in 2005 shows a current population of 8,365, which is a 7% increase over the four years since the 2001 census[15]. The recently competed municipal census in Edson shows that there is a 51% male, 49% female distribution, and that the majority of the population falls in the 25-44 year-old age group[16]. The municipal census generally agrees with the Statistics Canada 2001 census that shows a median age for Edson in 1996 of 33.9[17].

Edson's labour market is employed in natural resource related industries, wholesale and retail trade, and manufacturing, respectively. 785 people were employed in 2001 in the resource area (89% male), which represents approximately 18% of the employed labour force in Edson.

Methodology

Mountain Pine Beetle Spread Rate Estimation

The report "Application of the SELES MPB Landscape Scale Mountain Pine Beetle Model in the Foothills Model Forest" (Fall et al., 2004) was used as the foundation for the estimation of MPB spread rates within the HFMA. The Spatially Explicit Landscape Event Simulator (SELES) is a tool for building spatially explicit simulations to model the role of disturbance in creating and maintaining landscape structure (Fall & Fall, 2006). Within the SELES framework, the modeler defines landscape events (such as disturbance and succession) which determine landscape dynamics. Each event is governed by a series of expressions which dictate how the cell is affected by the event and how the event spreads from cell to cell (Fall & Fall, 2006). Starting with a simple model that operates on a neutral landscape, the modeler adds levels of complexity incrementally and incorporates parameters from real landscapes to refine hypothesizes about landscape dynamics (Fall & Fall, 2006). The end result is a probabilistic model, which governs a series of interacting landscape altering events. Modeled events collectively operate in a spatial manner upon a base landscape defined by multiple raster layers such as vegetation cover, elevation and climate.

Specifically within the SELES MPB Landscape Scale Mountain Pine Beetle Model (SELES MPB Model), the likelihood of MPB spread from cell to cell is based on the following set of factors, as described in Fall et al. (2004):

[15] http://www.townofedson.ca/municipal/edson/edson-website.nsf/AllDoc/11D70532A84FF09387257007005CD266?OpenDocument
[16] Ibid.
[17] http://www12.statcan.ca/english/profil01/CP01/Details/Page.cfm?Lang=E&Geo1=CSD&Code1=4814003&Geo2=PR&Code2=48&Data=Count&SearchText=Robb&SearchType=Begins&SearchPR=01&B1=All&Custom=

Stand Susceptibility (Shore et al., 2000)

Stand susceptibility is generally defined by the underlying landscape characteristics.

Stand Age

Older trees are less robust and are less able to produce resin to expel beetles as they bore into the phloem. Older trees are generally larger and therefore are easier for beetles to locate.

Stand Density

Stands of low density tend to produce more vigorous trees better suited to ward off beetle attack. Additionally, low density stands have less favorable microclimate during the over wintering stage of the beetle within the tree. High density stands tend to produce small diameter trees with thin phloem and bark which are less suitable for over wintering due to the limited insulation provided by thin bark. Medium density stands tend to provide the most favorable habitat for MPB, due to controlled microclimate and availability of moderate to large diameter stems.

Percentage of Susceptible Pine within the Stand

The proportion of the stand, as measured by relative basal area, which is a suitable host for attack by MPB.

Location

The influence of latitude, longitude and elevation on climatic conditions throughout the life cycle of the MPB.

Internal MPB Pressure (existent population levels)

Internal MPB pressure was hypothesized to exist at one of two levels:

1. No MPBs were present within the cell
2. A MPB population existed at 10 times the level estimated using spot treatment data from the interior of BC.

External MPB Pressure (beetle migration into the FMF)

External MPB pressure was hypothesized to exist at one of four levels: 0%, 25%, 50% or 100% expressed as a percentage of cells in each pass that emit beetles with long dispersion range. Dispersal range was held constant and was based on dispersal range data from the British Columbia Lakes District.

Climatic Temperature

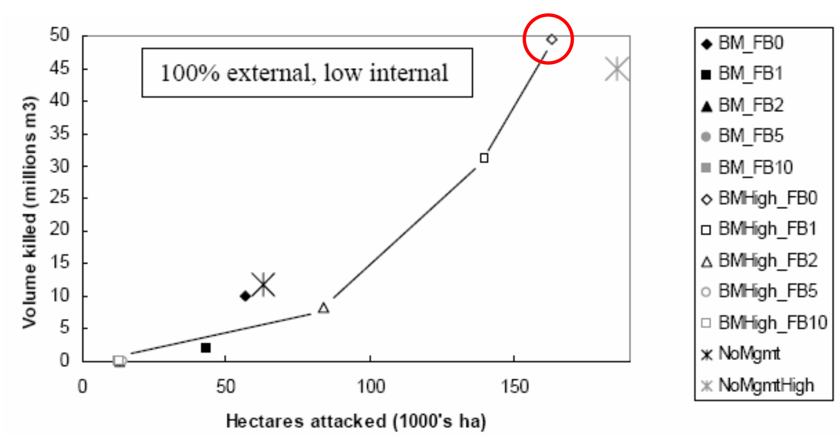
Over winter climatic temperatures were hypothesized as either normal (consistent with historic averages) or as high (above historic averages).

Influence of Human Interventions

Potential human intervention levels were hypothesized as either no management or harvesting with fall and burn at 0x, 1x, 2x, 5x and 10x current levels.

The overall objective of the model was not to predict the most likely spread pattern, but to examine how MPB spread rates may vary based on changes in the hypothesized levels of each of the influencing factors. The SELES MPB Model has been utilized to estimate MPB spread rates over a range of landscapes within British Columbia and Alberta and has proven to be conservative. The model has generally projected lower MPB spread rate estimations than have been later observed. The Canadian Forest Service is in the process of completing new SELES runs based on higher external MPB pressure from British Columbia. Via email communication, Terry Shore, a Forest Entomologist with the Canadian Forest Service and one of the primary authors of the SELES pine beetle spread rate model used here, indicated the most accurate prediction scenario in the current set of SELES runs would likely be the least conservative scenario set which includes an existent internal beetle population, high external beetle pressure and high winter climatic temperatures (Figure 4). He also indicated that this scenario likely understates the rate of MPB spread based on model experience in the interior of BC. Currently there is little evidence that human interventions have a significant effect in regard to slowing the rate of MPB spread or the amount of live pine retained on the landscape (Eng et al., 2005). Eng et al. do note the potential for human interventions to be effective on the "leading edge" of the attack. Considering the interior BC evidence indicating limited efficacy of human interventions, we selected the harvest with no fall and burn scenario as likely being the best predictor of MPB spread within the FMF from the SELES MPB Model.

Figure 4: Volume and area of MPB attacked wood over a 20 year period predicted by the SELES MPB Landscape Scale Mountain Pine Beetle Model under the scenario of harvesting attacked wood but no fall and burn, warmer than average winter climatic temperatures, 100% external MPB pressure and low internal beetle population levels (red circle) (Fall et al., 2004)



The selected SELES MPB Model scenario estimated 50 million cubic metres of lodgepole pine wood would be attacked within the FMF over a 20 year period, affecting an area over 150,000 hectares. This estimation is based on the best available current information, but is recognized as being bound by a large margin of error. Refinements in the SELES MPB Model and the incorporation of the influence of higher external beetle pressure currently underway will aid in reducing the margin of error in the future.

Mount Pine Beetle Infestation Influence on Annual Allowable Cut

To model the potential influences of a MPB infestation on the annual allowable cut (AAC) within the HFMA we utilized the cut grow timber supply model Forest Muncher (Beck and Beck, 1995). Forest Muncher utilizes the initial age and volume of each stand within the landscape and annually grows each stand based on growth and yield curves for each species or species mix. Through repetitive iteration, Forest Muncher estimates a potential AAC level which is the maximum even flow harvest level for a fixed planning period. By having long planning periods (200 years in this case) and frequent re-planning (5 – 10 years in Alberta) a sustainable harvest rate is estimated. The initial forest state, including individual stand age, area, species mix, and a susceptibility code, was included in the forest data base. The Alberta provincial average growth and yield tables were used to annually grow each stand within the landscape. Based on the initial forest state, with no beetle influence, Forest Muncher estimated a max even flow AAC separately for the Active Land Base and Active and Passive Land Bases combined, termed base AAC levels. Forest Muncher was further utilized for each scenario to estimate the necessary surge cut of pine to achieve the harvest appropriate for the scenario to allow utilization of MPB infested timber. Following the surge, pine only harvest, the maximum AAC for the remaining time in the planning horizon was determined using the remaining uncut forest and the cut over pine areas. The total planning horizon was 200 years and a minimum merchantable volume of 50 cubic metres per ha was utilized.

The potential influence of a MPB infestation on AAC within the HFMA was estimated using three scenarios:

Scenario 1: Low Spread Rate

Scenario 1 hypothesized a MPB spread rate slower than the rate estimated by the SELES MPB Model. Under this scenario it is assumed that the current AAC is adequate to allow utilization of the majority of commercially viable timber within the MPB attacked stands. The AAC is utilized to target attacked or high risk stands resulting in focused harvesting of older age class, lodgepole pine stands. For the first 20 years of the 200 year simulation, only lodgepole pine stands were harvested, prioritizing oldest stands first for harvest. For years 21-200 of the simulation, the new resultant AAC for the entire forest is re-determined with a large proportion of the lodgepole pine stock removed.

Scenario 2: Moderate Spread Rate

Within Scenario 2 it is assumed the rate of MPB spread within the HFMA is consistent with the rate estimated by the selected SELES MPB Model run. Under this scenario, 50 million cubic meters of lodgepole pine wood is attacked in the first 20 years of the model resulting in a harvest rate 2.13 times greater than the base AAC level. At this harvest rate, all commercially viable lodgepole pine stands would be harvested in a 29 year period. In years 30-200 of the simulation, the new resultant AAC for the entire forest is re-determined with the majority of the lodgepole pine stock removed.

Scenario 3: High Spread Rate

Scenario 3 is included as a sensitivity analysis of Scenario 2. Within Scenario 3 it is assumed that the rate of MPB spread within the HFMA is faster than predicted by the selected SELES MPB Model run. Scenario 3.1 assumes that all susceptible lodgepole pine stands are attacked within a 20 year period and Scenario 3.2 assumes that all susceptible lodgepole pine stands are attacked within a 10 year period. The surge cuts in Scenario 3.1 and 3.2 represent a 2.99 and 5.63 times increase in AAC, relative to the Active Land Base baseline AAC. Although both Scenario 3.1 and 3.2 represent a significantly higher rate of spread than estimated by the SELES MPB Model, these rates of spread are not inconsistent with spread rates witnessed within British Columbia. Following full removal of commercially viable lodgepole pine stock in 20 and 10 years respectively, within each scenario the resultant AAC for the altered landscape is determined over years 21-200 and 11-200 respectively.

Significant Assumptions of the Forest Muncher Model

Even Flow Harvest Rates

The Forest Muncher Model assumes an even flow AAC resulting in equal annual harvest volumes within each segment of the model. The rate of MPB population growth would not be linear but would occur in an exponential manner as each beetle's multiple offspring successively mates and produces its own offspring. The even flow harvest rate assumption would theoretically result in non-attacked wood being harvested at the start of the model period. At the end of the model period, even flow harvesting would result in harvesting wood which had been attacked a number of growing seasons prior.

The critical event from the modeling perspective is stand death. Whether this event is the result of MPB attack or harvesting activity is irrelevant from the perspective of growth and yield modeling at the accuracy level of this report.

Stand Regeneration

The Forest Muncher Model assumes the stand regenerates in the year following the harvest. The actual timing of seedling or germinant establishment will vary depending on a number of factors:

- Disturbance levels to the forest floor potentially caused by harvesting and the removal of seed sources also potentially due to harvesting techniques
- Summer temperatures and fire occurrence which influence the serotenous reproduction process of lodgepole pine cones
- Planting and other silviculture activity timing
- Vegetation type which pioneers each stand following disturbance

Growth and Yield Tables

Provincial average growth and yield tables where utilized as these were the only tables available to the authors. Growth and yield tables specific to the HFMA would increase the accuracy of the estimates. Mixed species conifer stands dominated by one species were treated as pure, one species stands. Within each stand a unique mixture of species likely exists, resulting in a unique average growth and yield rate for each stand. Yield table growth rates were applied to each stand based on the dominant conifer species. Mixedwood stands (conifer and deciduous mixes) were classified as either CD (conifer dominated mixedwoods) or DC (deciduous dominated mixedwoods) and the provincial yield table for these two mixes was used. Only conifer volumes were considered merchantable for this analysis.

Commercial Viability of Harvested Stands

Forest Muncher does not have a spatial component and does not consider proximity of stands when optimizing AAC levels. It is assumed that all stands in excess of a merchantable volume of 50 m^3 per ha are commercially viable for harvesting. Geographic limitations may exist which limit accessibility to the stand or limit commercial viability from a cost-benefit perspective. It is expected that AAC estimates would decrease if spatial constraints were also considered utilizing a different modeling technique.

Given the coarse accuracy level of the estimation process and the general objectives of this report, the assumptions related to Forest Muncher are considered acceptable but should be noted by the reader.

Economic Impact of MPB Influenced Variations in AAC

To model the potential impacts of MPB attack influenced AAC variations a Computable General Equilibrium Framework (CGE) Model developed and operated by Mike Patriquin and Bill White of the Canadian Forest Service was utilized. The CGE Model operates under the recognition that the economy is a single system of interconnected components (Patriquin and White, 2006). Shocks to one sector of the economy impact upon the other sectors and institutions of the economy (Patriquin and White, 2006). The strength of the CGE Model in the application of modeling AAC shocks is the model allowance of resource shifts from one sector to another. Workers laid off from one sector of the economy, due to work shortages, do not necessarily disappear from the economy, but likely seek work in another sector. Booms in one sector are able to influence the wage rates of other sectors, allowing the various components of the economy to interact and respond to ebbs and flows in the other segments of the economy. A detailed summary of the endogenous and exogenous variables and their interactions are provided within Appendix A.

Baseline economic data for the FMF region was collected for the 1998 paper "An Economic Impact Model of the Foothills Model Forest" (Alavalapati et al., 1998). Data sources included major firms operating within the region and a visitor study conducted by the CFS Socioeconomic Research Group. Information about household activity was obtained from a 1996 FMF household expenditure survey also conducted by the CFS Socioeconomic Research Group (Jagger et al., 1998). Where regionally specific data was not available or could not be collected, provincial averages were used as proxies for regional levels. Central to this report, baseline forest industry data was obtained from Weldwood of Canada Limited (now West Fraser Mills Ltd.).

The AAC estimates generated by the Forest Muncher Model were the primary inputs into the CGE Model. The CGE Model output included estimates of the affect of variation of the AAC level on the various components of the HFMA regional economy.

Significant Assumptions of the Computable General Equilibrium Framework Model

Linear Response of the Model to Reductions in AAC

Within the CGE Model it is assumed a linear relationship exists between harvest volume and employment in the forest industry. The relationship between harvest volume and employment is likely more staggered. Milling operations require shifts of people to operate the range of machinery required for wood processing. Small increases in volume can be accommodated within the current shift structure, but large volume increases will require the addition of an additional shift of workers. The result is large one time changes in employment as shifts are added or removed as opposed to small incremental linear increases or decreases. The shift structure at the mill has a trickle down effect throughout all forestry activities. To maximize profitability, forest operation managers attempt to optimize but not exceed the volume of wood necessary to keep the current shift workers active.

It is difficult to estimate the biasing effect of the linear harvest volume to employment relationship. Small increases in harvest volume could result in overtime for current workers while small decreases are likely reflected in the profitability of the firm due to inefficiency and have little effect on employment levels. Moderate changes in harvest levels are inefficient for the firm and likely rarely occur. Large increases in harvest levels are subject to available capacity within the mill if additional shift workers can be added.

Constant Commodity Prices

Commodity prices are influenced by a host of global, national and regional macroeconomic factors which collectively generate the supply – demand relationship for chips and lumber. Significant increases in the supply of wood products, caused by wide spread salvage of MPB infested lodgepole pine stands, would likely apply downward pressure on wood commodity prices. A decrease in lumber prices due to increased supply could be offset or augmented by changes in new home starts in the United States or changes in interest rates to name a few of many factors. The interactions of the various macroeconomic factors are extremely complex and difficult, if not impossible to predict. Within the context of this report and the CGE Model it is not possible to predict changes in commodity prices, therefore commodity prices are held constant, as the current price is a reasonable proxy for future prices.

Commodity prices significantly influence the viability of harvesting activities. If lumber or chip prices were negatively shocked, it could become economically unviable to utilize beetle damaged wood, significantly altering the estimations of this report.

Royalty Calculation

The royalties paid by HWP within the CGE Model are estimated based on rates in 1998 and may not be reflective of rates paid in the event of a MPB attack. The stumpage system is complex and the CGE Model can not possibly reflect the multitude of factors which drive royalty rates. For the purposes of this report, the 1998 royalty rates are deemed appropriate.

Results

Mount Pine Beetle Infestation Influence on Annual Allowable Cut

To evaluate the estimated influences of a MPB infestation on AAC within the HFMA, three time periods were established. During the Pre Attack Period AAC levels are established at the sustainable level estimated by Forest Muncher based on the current age class distribution of the forest within the HFMA. The Pre Attack Period acts as the baseline for comparison of the estimated effects of a MPB infestation on AAC within the other periods.

During the Surge Period, AAC is elevated to allow utilization of attacked lodgepole pine stands for production of chips and dimension lumber. Within each scenario, AAC is established at the necessary level to allow even flow harvesting of all commercially viable attacked stands based on the minimum merchantable volume of 50 m^3 per ha. Within the Post Surge Period AAC levels are recalibrated and the effect of the loss of attacked lodgepole pine stands within the Surge Period is realized. Table 3, below, shows duration of Surge and Post Surge Periods.

Table 3: Duration of the Surge and Post Surge periods within each scenario

	Scenario 1 (years)	Scenario 2 (years)	Scenario 3.1 (years)	Scenario 3.2 (years)
Surge	20	29	20	10
Post Surge	180	171	180	190

Currently, only stands within the Active Land Base of the HFMA are being harvested. In the event of a significant MPB infestation, we assume that salvage/sanitation harvesting of pine stands would also occur within the Passive Land Base. Thus for all scenarios, harvesting within the Active Land Base only or within both the Active and Passive Land Base combined are considered. For scenarios which consider harvesting within the Passive Land Base, the baseline AAC level is determined including the Passive Land Base in the harvestable area. For each scenario, in the Surge Period, only pine is harvested from the appropriate land base and both the Active and Passive Land Bases are harvested.

Following the Surge Period, where it is assumed in each scenario that the MPB attack has run its course, the post surge AAC of the HFMA is calculated using either the Active Land Base or the combined Active and Passive Land Base as described in each scenario. During the Surge Period older, larger diameter pine stands are harvested before younger, small diameter pine stands which follows the priority codes for stand susceptibility attack.

The estimated magnitude of the Surge Period AAC increases which allow full timber utilization are displayed within Figure 5 and the associated percentage increase in harvest volume is reported within Table 4, below.

Figure 5: Estimated percentage change in AAC levels based on the assumptions of each scenario. For surge cuts only lodgepole pine is harvested.

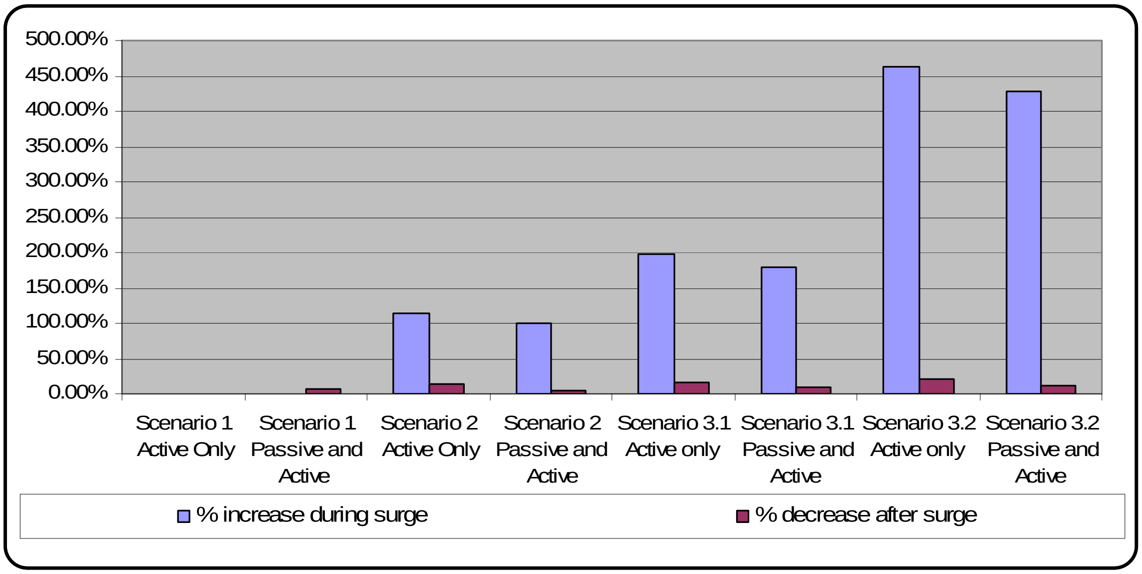


Table 4: Percent increase in AAC during the Surge Period and percent decrease in AAC in the Post Surge period for each scenario as estimated by the Forest Muncher Model

	Scenario 1 Active Only	Scenario 1 Passive and Active	Scenario 2 Active Only	Scenario 2 Passive and Active	Scenario 3.1 Active only After Surge	Scenario 3.1 Passive and Active After Surge	Scenario 3.2 Active only After Surge	Scenario 3.2 Passive and Active After Surge
% increase during surge	0.00%	0.00%	113.31%	100.16%	198.63%	180.22%	463.14%	428.42%
% decrease after surge	0.17%	6.24%	13.23%	4.88%	16.98%	8.41%	20.56%	12.01%

The duration and the magnitude of the AAC increases within the Surge Period are driven entirely by the rate of MPB ingress into the HFMA and the desire to utilize all of the attacked lodgepole pine stands of commercial size. As is addressed within the Discussion portion of this report, utilization of all or even a majority of the lodgepole pine stands may be significantly limited by human and physical resource availability, the economic viability of extraction and utilization, and the environmental effects of stand removal.

The greater the estimated AAC increase during the Surge Period, the more significant is the estimated AAC decrease within the Post Surge Period, relative to the Pre Attack Period. Although the AAC level was not increased during the Surge Period within Scenario 1, a resultant decrease in AAC in the Post Surge

Period was still realized. Within Scenario 1, the targeted harvesting of lodgepole pine stands during the Surge Period results in harvesting of young age class pine stands before they reached maximum growth potential. Additionally, the targeted harvesting of pine results in stands of other species entering the over-mature portion of the growth curve, when annual growth rates significantly decrease. The cumulative effect of targeted pine harvesting is lower overall proportional annual growth in the HFMA leading to a decrease in AAC in the Post Surge period.

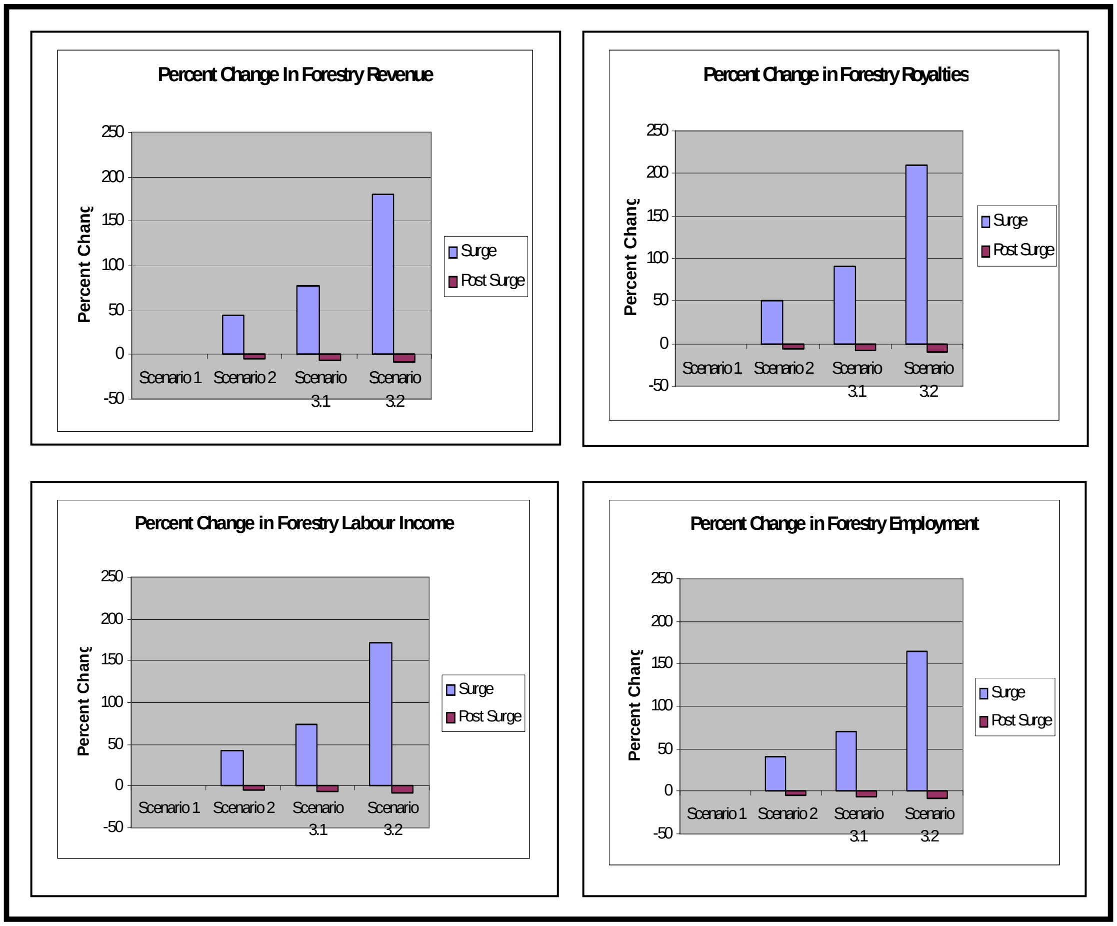
It is difficult to estimate if harvesting would be considered within the Passive Land Base in the event of a MPB attack within the HFMA. One potential scenario is attacked lodgepole pine stands are harvested as salvage, sanitation or preventative measures and stands dominated by non MPB host species are retained as much as possible. It is likely that disturbances within the Passive Land Base will be minimized as much as possible; therefore the estimates which include only the Active Land Base within the harvestable area are the further focus of this report. Accelerating the rate of MPB infestation to require harvesting of all lodgepole pine stands in 29, 20 or 10 results in decreases in estimated AAC of 13.23%, 16.98% and 20.56% respectively in the Post Surge Period if only the Active Land Base is considered.

Economic Impact of MPB Influenced Variations in AAC

A detailed summary of the estimated economic effects of varying AAC within the HFMA in a manner consistent with the Forest Muncher Model output for the three described scenarios appears in Appendices B and C. Appendix B includes data specific to the Surge Period of the Forest Muncher Model and Appendix C includes data specific to the Post Surge Period.

Figure 6, below, displays the percent change in revenue, royalties, employment and labour income generate by the forest industry during the Surge and Post Surge Periods. Correspondingly, Figure 7, below, displays the same variables for the total economy for the Surge and Post Surge Periods.

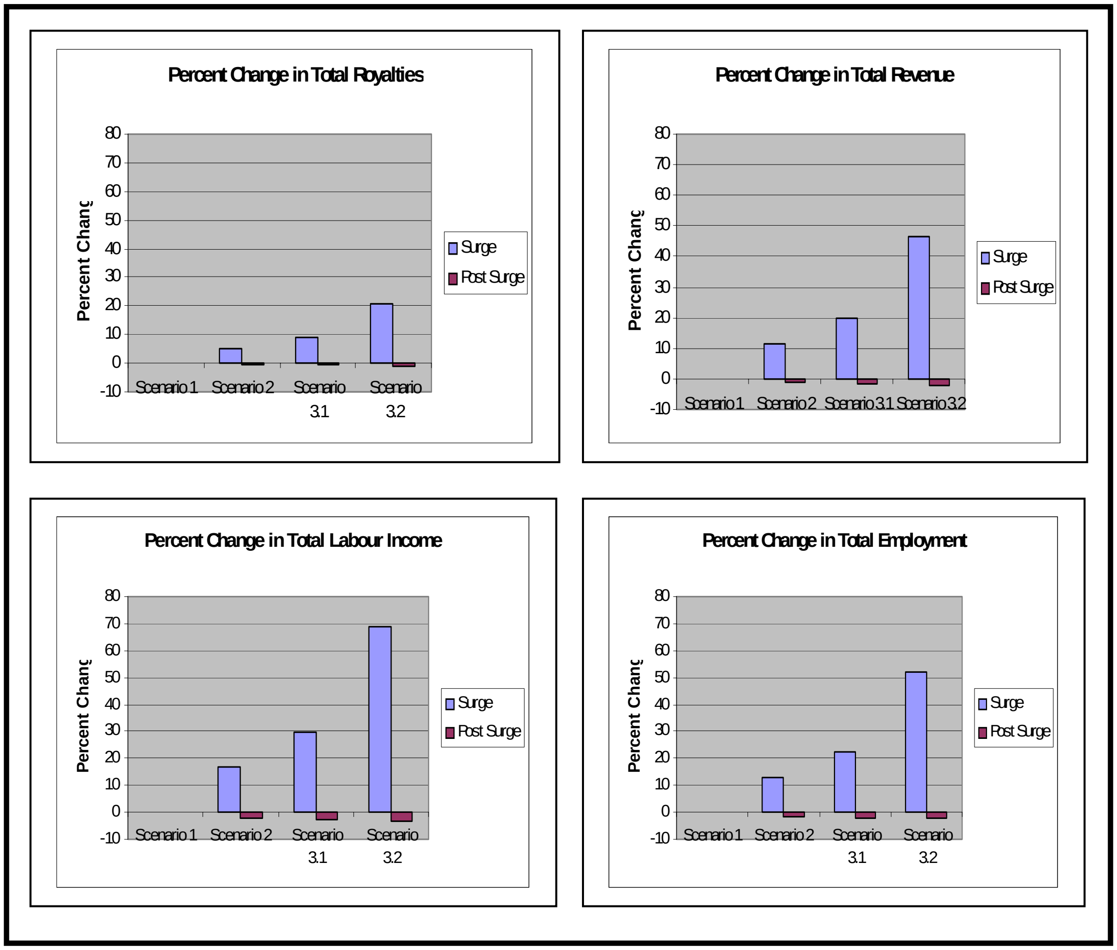
Figure 6: Estimated economic effect of MPB infestation influenced AAC variation on the forest industry within the HFMA



Referring to Figure 6, the small estimated decrease in AAC in the Post Surge Period of Scenario 1 had a nearly inappreciable impact on the economic indicators for the forest industry or the total economy. Within Scenario 2 forest industry revenue, royalties, labour income and employment were estimated to increase by 40 – 50% during the Surge Period and decrease by 4.7 – 6.0% in the Post Surge Period. The estimated effects on economic characteristics were far more dramatic for Scenarios 3.1 and 3.2. Forestry industry revenue, royalties, labour income and employment increases during the Surge Period ranged from 70 – 90% for Scenario 3.1 and ranged from 160 – 210% for Scenario 3.2. Despite extremely large estimated percentage increases in the economy during the Surge Period of the model, estimated percentage decreases in the Post Surge Period remained relative low. Decreases in forest industry revenue, royalties, labour income and employment were estimated to decrease by 6 – 9% within the Post Surge Periods of Scenarios 3.1 and 3.2.

Referring to Figure 7, the effect of AAC variations on the relative output of the total economy was less marked, reflecting the relatively small proportional contribution of forestry to total economic output within the region. Based on 1995 values, the forest industry contributes approximately 20% of total revenue within the region and that value has likely decreased in the last decade as oil and gas exploration and extraction has expanded. Changes in the total output of the economy reflect the changes directly realized within the forest industry and also account for changes in support industries dependent on the forest industry.

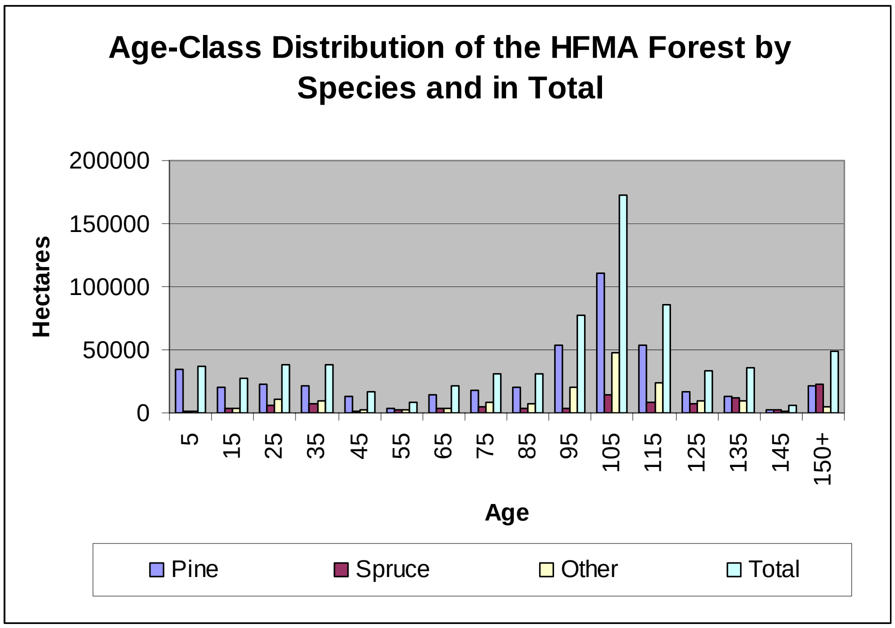
Figure 7: Estimated economic effect of a MPB infestation influenced AAC variation on the total economy within the HFMA



The large disparity between the increases in economic output of the forest industry during the Surge Period relative to the resultant decreases in economic output during the Post Surge Period can be attributed to the age-class distribution of the forest within the HFMA. From the perspective of optimization of even flow harvest volume, the proportion of each stand within each age class should be equal and each species should be harvested at the peak of its growth curve at which time contribution to the total volume output of the stand has been optimized. The result is commonly referred to as a regulated stand age-class distribution.

Forest operations were initiated in 1951 by North Western Pulp & Power and Weldwood acquired the FMA in 1988. The HI-ATHA Sawmill opened in 1993 to produce 220 million board feet/year[18]. In spite of harvesting for over 50 years, the age-class distribution within the HFMA still has a larger proportion of older age class stands than would be present within a regulated stand. Figure 8, below, displays the current age class distribution of the Active Land Base of the HFMA. One potential effect of a MPB infestation would be the acceleration of succession / utilization of the older age class lodgepole pine stands which are growing at a rate less than younger stands. Replacement of the older age class stands with younger stands with higher proportional annual growth rates, cushions the impact of the loss of lodgepole pine stands within the forest.

Figure 8: Age-class distribution of the HFMA forest Active Land Bace by species and in total



The overall impact of the loss to lodgepole pine stands within the HFMA is further reduced by the relative abundance of non-MPB host tree species which occupy approximately 40% of the Active Land Base.

[18] http://www.weldwood.com/hinfr01/internet/hinnet.nsf

Limitations to Utilization of MPB Damaged Wood

Forest Operations Capacity

Milling Capacity

As briefly discussed within the Methods section, small increases in AAC can often be accommodated within the current shift structure of the mill, but increases of the magnitude discussed within this report would require the acquisition of additional capacity at the West Fraser Mills Ltd. (WFM) milling facility. The feasibility of expanding the current milling infrastructure would be dependent on the sustainability of the additional volume, construction worker availability and capital availability. Likely a time frame of two or more years would be needed to significantly expand the current milling facility.

Forest Workers and Equipment

Demand for natural resource workers, and workers in general, is currently extremely high within Alberta due to high oil prices driving booms in oil exploration and extraction. Contractors and licensees within the forest industry are finding it increasingly difficult to employ staff to meet current operating requirements. A boom in harvesting activity to utilize MPB damaged timber would further aggravate this situation. During discussions with WFM representatives, it was indicated that historically they have been able to acquire adequate fallers and harvesting equipment operators and felt adequate capacity existed to meet an increase in AAC. WFM representatives speculated that the most likely limiting factor in accommodating a signification increase in AAC would be obtaining additional hauling workers and equipment.

MPB spread into Alberta will likely not be limited to the Foothills Region and simultaneous attacks in several different regions are likely, resulting in simultaneous booms in harvesting activity. Simultaneous booms in harvesting activity could create significant shortages of forest workers and equipment, limiting the utilization potential of MPB damaged wood. If forest workers and equipment are available, they will likely be able to demand a price premium resulting in an increase in production costs for the licensee.

MPB Damaged Wood Utilization Economic Viability

The immediate economic viability of utilization of timber on any landscape is related to the simple requirement of the sale value of the processed wood product exceeding the total cost of rent, harvesting, hauling and processing. Additional, less tangible costs, such as environmental and social costs, also need also be considered when making resource management decisions. For simplicity sake we will consider only the immediate economic viability of MPB damaged timber and leave environmental and social considerations for following sections. Some of the factors which effect either the sale value of, or the processing cost of, MPB damaged timber are discussed in the following sections.

__Sale Value of Wood Products Created from MPB Damaged Timber__

MPB attacked lodgepole pine stems undergo three significant morphological changes which have the potential to effect the sale value of the end wood product.

Blue Stain

The blue stain fungus introduced into the stem by the boring adult beetle discolors the wood a light blue tinge.

Pin Holes

The entry of the pine beetle and secondary boring insects introduces pin holes into the wood compromising the integrity of portions of the stem

Advanced Dehydration

The compromised bark of the stem and the introduction of the blue stain fungus cause rapid dehydration of the wood. The rapid dehydration process introduces checks and cracks into the stem.

Current research indicates that blue stained wood has similar strength and utilization properties as clean, uncoloured wood, as long as it is harvested recently after attack. Lum (2003) and Chow (2005) found strength and elasticity properties were generally consistent between blue stained and non-blue stained wood. Blue stained wood was found to have a weaker Modulus of Rupture (MOR, or the amount of bending a piece of lumber can withstand) in both studies. Overall, research indicates that blue stained wood can be utilized for structural, furniture and preservative treated end uses without compromising performance (Lum, 2003; McFarling & Byrne, 2003; Williams and Mucha, 2003; Chow, 2005).

The checks and cracks which develop as the stem dries reduces the optimization of lengths and widths of boards and reduces overall lumber grades obtained from each stem. Research by Plank (1979) on live and dead lodgepole pine found that of the total volume of live trees within the sample, 47% was graded standard and better, 17% was graded utility and 8% was graded economy. For dead trees in the sample, 24% were graded standard and better, 37% were graded utility and 13% were graded economy.

In summary, green attacked lodgepole pine wood can be utilized in a similar manner to clear wood. Dimensional lumber products produced from green attacked wood may be less desirable to some customers due to the blue discoloration. Dead attacked wood deteriorates due to rapid dehydration and the lumber grade quality and board width and length potential decrease as checks and cracks form during drying. The longer the period since death, the more significant checks, cracks and stem deformities become. Research on the usable lifespan of beetle attacked wood is currently inconclusive and is ongoing, But general consensus within the current research is a period of 2 – 4 years after death (Eng et al., 2005).

Beyond reductions in wood quality resulting from MPB attack, a potentially far more significant factor impacting potential end wood product sale value is overall wood supply in Western Canada. MPB spread will likely result in harvesting booms within numerous regions within B.C. and Alberta. Significant increases in AAC levels have already been witnessed within a number of forest districts within British Columbia. The increase in harvesting activity will likely result in oversupply of MPB attack lodgepole pine wood products, exerting considerable downward pressure on lumber commodity prices. This downward price pressure could be exasperated or mitigated by numerous macroeconomic factors making overall price impact assessments complicated and difficult.

Processing MPB Attacked Lodgepole Pine

The dehydrated state of beetle killed wood complicates and increases the costs of harvesting and processing. The dryness of MPB killed wood increases the likelihood of breakage during harvesting and processing (Bryne et al., 2005). Due to its unique moisture content, dead MPB attacked lodgepole pine must be kiln dried separately from green attacked or non-attacked live lodgepole pine wood (Nielson et al., 1986). Separated, kiln drying of blue stained wood results in clustering of blue stained wood in batches, increasing the likelihood of reduced prices from customers (Nielson et al., 1986).

In respect to utilization of blue stained lodgepole pine wood for pulp production, additional bleaching is required to remove the blue coloration during production (Gee, 2003). Dead attacked trees had significantly higher fine and pin chip content resulting from mechanical damage during the chipping process due to the dry, brittle nature of the wood (Gee, 2003). Gee (2003) found that 2 year beetle infested lodgepole pine can be utilized for pulp production without any significant effect on mechanical or optical quality of the end product.

Collectively, reductions in sale value due to oversupply within the market and reductions in lumber quality and yield due to MPB attack damage could render a large number of attacked stands economically unviable for timber harvest. The Government of Alberta may be able to induce utilization of these stands by reducing other licensee realized costs, such as reducing stumpage paid on dead lodgepole pine stands, a practice which has become common in British Columbia.

Other Considerations

Full consideration of the numerous and complex social and environmental issues which surround large scale utilization of MPB attacked stands is beyond the scope of this report. Research in this field is relatively new and ongoing. Kimmins et al. (2005) address the myriad of social issues surrounding large scale management of the MPB epidemic. The Canadian Forest Service is currently funding active research by Fred Bunnell titled "Integrating silvicultural control of mountain pine beetle with wildlife and sustainable forest management objectives" which will seek to address the challenges of integrating wildlife habitat concerns with the economic motivations to salvage MPB damaged stands. The interested reader is directed to these papers for greater detail in regard to the topics we briefly discuss within this section.

Fire Hazard within MPB Damaged Stands

It is clear that the mortality induced within lodgepole pine stands by MPB attack should influence fire behavior. Lodgepole pine stem mortality within MPB attacked stands alters the type, structure and abundance of fire fuels potentially contributing to higher fire hazard risk. Research by Turner et al. (1999) found that severe MPB attacks, which caused greater than 50% stand mortality, resulted in an increase in crown fire probability. Mitchell and Preisler (1998) found that after 5 years, beetle killed trees started to fall over, 50% of beetle killed trees had fallen over after 9 years, and 90% had fallen over after 14 years. Based on this timeline, there is a continuous contribution of coarse and fine woody fire fuel to the forest floor within MPB attacked stands over years 5 – 15 following death. Hawkes et al. (2003) examined fuel loading in a series of MPB attacked stands within British Columbia and Southern Alberta. Table 5, below, presents their findings.

Table 5: Fine and course wood fuel volume and loading by study area (Hawkes et al. 2003)

Study Area	No. of Stands	Fine Woody Fuel < 7 cm (m^3/ha)	Coarse Woody Fuel > 7 cm (m3/ha)	Fine Woody Fuel < 7 cm (t/ha)	Coarse Woody Fuel > 7 cm (t/ha)
Kamloops	4	16.8 (4.5)	222 (71)	6.9 (1.8)	91 (29)
Nelson	1	16.4 (–)	70 (–)	6.7 (–)	31 (–)
Chilcotin	15	12.9 (1.3)	66.9 (7.7)	5.3 (0.5)	27.4 (3.2)
Manning	5	10.3 (3.0)	117 (24)	4.3 (1.2)	45 (8.7)
Entiako	10	13.2 (2.1)	57 (14.3)	5.6 (0.9)	23.4 (5.8)
Waterton	4	16.1 (2.0)	103 (37)	6.8 (0.8)	42 (15.0)

( ) Standard error of the estimate.

Page et al. (2006) found that greater than 80% of MPB attacked stands produced significant increases in woody fire fuels. Small fuels decayed after 20 years and returned to background levels. Post epidemic stands had significantly lower available canopy fuels. Utilizing the Rothermel fire spread model, Page et al. (2006) estimated that post MPB epidemic stands had increased rates of surface fire spread, fire line intensity and total heat release.

In general, MPB attacked stands have the potential for greater ground level fine and coarse woody fuel volumes which can significantly alter forest fire behavior and increase the fire hazard within the stand. Harvesting MPB damaged stands reduces fire fuel contribution and creates breaks in the continuity of fire fuels.

Environmental Impacts of MPB Attacked Stand Salvage Logging

Currently there is little literature which address the potential impacts of MPB damaged wood salvage at the scale and magnitude currently underway in B.C. and estimated within this report. MPB attack can result in a variety of stand structures, each which can fulfill the habitat needs of a variety of species. Some species, termed generalists, are able to utilize a variety of types of habitats, MPB damaged lodgepole pine stands being one of those habitats. Other species, termed specialists, require the unique habitat condition which is present only within disturbed, mature stands for survival.

Currently, the two primary disturbance agents within HFMA are wildfire and human activities such as harvesting and landscape alteration to accommodate oil and gas industry related activities. A proportion of fire damaged stands are currently salvage harvested within Alberta, already limiting availability of the unique habitat niche of disturbed, mature forest.

MPB attack results in the loss of canopy cover within the stand, allowing an increase in light penetration to the forest floor or understory vegetation. The magnitude of the increase in light penetration is proportional to the magnitude of attack within the stand and the abundance of lodgepole pine in the stand. Attack of small patches of lodgepole within larger intact forest tracts creates a mosaic of age classes and habitat types within the same geographic space, encouraging increases in biodiversity and fulfilling the habitat requirements of many specialist species. As sunlight penetrates to the forest floor, pioneering vegetation species begin to establish and repopulate the site. Depending on the magnitude of canopy alteration, unique vegetation types will dominate the pioneering process.

The beetles and secondary boring insects present within the MPB attacked wood attract a wide variety of bird species including woodpeckers. Other insects are attracted as the wood decays creating a boom in insect populations which further attracts large populations of bird species. As the stem further decays, the stem becomes suitable for excavation by cavity dwelling species. Bunnell et al. (2004) estimated that 47 species within the interior of B.C. utilized MPB killed stands for nesting or denning. As the lodgepole pine stems fall over, it contributes to considerable increases in coarse woody debris on the forest floor.

As this wood decays, nutrients are recycled back into the soil. Harvesting activities have the potential to significantly alter nutrient cycling regimes and the overall nutrient availability within the soil.

Pioneering shrub species are utilized by birds for nesting and foraging cover. Rodents utilize the shrub species similarly for cover and forage, and ungulates forage within the new shrub cover, particularly adjacent mature timber edges (Bunnell et al., 2004).

To try to provide guidance to forest managers when developing management plans for MPB damaged stands Bunnell et al. (2004) provide a series of recommendations which are highlighted here. The list is not exhaustive and the interested reader is referred to the complete text of the report.

Retain species other than lodgepole pine during logging. This practice increases the structural and species diversity of the site and creates a wider range of habitat types within the stand. Live stems retained within MPB damaged stands have been noted to have increased growth rates, likely due to greater sunlight and nutrient availability (Hawkes et al., 2003).

Provide small buffers of dead lodgepole pine around retained inclusions of other tree species. This practice also increases the structural and species diversity of the site and creates a wider range of habitat types within the stand.

Avoid small patch-wise approaches. Plan to harvest larger areas (e.g. up to 1000 ha) quickly and deactivate roads when finished. Small patch-wise harvesting acts to fragment the landscape, reducing habitat availability for species that require large areas of undisturbed forest. Quick harvest and road deactivation reduces the period of disturbance and reduces potential negative effects experienced by some species due to increased human access.

Plan both areas to be harvested and areas to be reserves as large blocks.

Retain slash >15cm where it lies. Large diameter slash is utilized by a variety of species. Large diameter coarse woody debris is persistent on the landscape for a greater timeframe and contributes greater amounts to nutrient cycling. The decay process attracts insects and the species which feed upon them.

Reserve riparian areas and upland hardwoods from harvest.

Leaving tall stumps or stubs can act as cavity sites and reduce the overall impact of salvage practices.

Avoid salvage in selected areas where intermixed pine represents <40% of the species mix.

In summary, stand disturbance by MPB accelerates the succession process of the stand, resulting in a unique early seral stage habitat type utilized by a range of species. The resultant stand structure and habitat type varies from stand to stand depending on the intensity of MPB attack and the density and proportion of lodgepole pine within the original stand. Large scale salvage of MPB damaged wood has the potential to have significant and long term negative environmental impacts, affecting a variety of species which utilize the unique habitat niche. Economic, fire hazard and environmental factors must be jointly considered and balanced when developing MPB management plans. Further research is needed and is ongoing but a variety of management techniques have already been identified which can mitigate the environmental impact of large scale salvaging operations.

Extension of the findings of this report to other regions within Alberta

The objective of this report was to examine the economic, social and environmental impacts of a MPB infestation within Alberta, utilizing the Foothills Model Forest as a case study. The estimations and assumptions within this report are specific to the unique economic, social and physical characteristics of the Foothills Model Forest area. Extrapolation of results to the province as a whole or to other specific areas of the Boreal Forest is difficult. Depending on geographic, climatic and external pressure, MPB spread rates within the Boreal Forest of Canada will likely vary significantly. Variability in spread rates and the availability of susceptible stands will likely significantly alter the economic and social implications of a MPB attack. Research is ongoing in regard to the susceptibility of Jack Pine to MPB attack which will be a major driver of spread rates within a large portion of the Canadian Boreal Forest including large areas of Alberta.

This report has estimated a relatively small decrease in allowable cut following utilization of MPB damaged timber. The small decrease is primarily a result of the large surplus of older age class non-susceptible timber types. The MPB attack within the Foothills Model Forest area acts to liquidate the surplus of older age class pine stands. These older stands are hypothesized to be replaced by more rapidly growing juvenile pine stands, which are not attacked by beetles. The increased in growth rate of the juvenile pine stands and relative abundance of older age class, non-susceptible stands acts to buffer AAC levels from a significant decrease. This buffer may not exist or may be more significant in other regions of the province.

Although the specific estimates regarding AAC and economic indicator changes can not be extended to other regions, the basic economic, management and policy challenges apply to all regions with abundant lodgepole pine stands. Regardless of the magnitude of AAC changes in the Surge and Post Surge Periods within each region, all forest managers will need to address the myriad of challenges associated with large scale loss of mature lodgepole pine stands due to MPB attack. The effect of harvesting surges in MPB attacked stands on forest worker and equipment availability and cost and on lumber and chip prices have the potential to impact regions geographically far removed from areas of MPB attack.

Conclusion

The objective of this report was to examine the economic, social and environmental impacts of a MPB infestation within Alberta, using the Foothills Model Forest as a case study.

To estimate the potential rate of spread within the HFMA we utilized the SELES MPB Landscape Scale Mountain Pine Beetle Model runs completed by Fall et al. in 2004. Based on the predictions of the SELES MPB Model and evidence from British Columbia, three potential scenarios regarding MPB spread rates within the HFMA were hypothesized. Scenario 1 hypothesized that the rate of MPB spread within the HFMA would be slower than the rate estimated by the SELES MPB Model and current AAC levels would be adequate to harvest the MPB damaged lodgepole pine stands. Scenario 2 hypothesized that spread rates would be consistent with the recommended run from the SELES MPB Model, resulting in attack of the majority of the stands within the HFMA within 29 years. Scenario 3 hypothesized that spread rates would be higher than estimated by the SELES MPB Model, resulting in attack of the majority of lodgepole pine stand in the HFMA in 20 years (Scenario 3.1) or 10 years (Scenario 3.2).

The even flow harvest rates required to utilize commercially viable stands attacked by MPB were determined. The modeling program Forest Muncher was utilized to estimate the decrease in AAC which could result from succession / salvage harvest of the majority of lodgepole pine stands within the HFMA. Based on these AAC estimates, the economic impact of MPB attack influenced AAC changes was examined utilizing output from the Computable General Equilibrium Framework (CGE) Model developed and operated by Mike Patriquin and Bill White of the Canadian Forest Service (Patriquin et al., 2005).

Scenario 1 had a nearly inappreciable impact on the economic indicators for the forest industry or the total economy. Within Scenario 2 forest industry revenue, royalties, labour income and employment were estimated to increase by 40 – 50% during the Surge Period and decrease by 4.7 – 6.0% in the Post Surge Period. Within Scenarios 3.1 and 3.2 forestry industry revenue, royalties, labour income and employment increases ranged from 70 – 90% for Scenario 3.1 and ranged from 160 – 210% for Scenario 3.2 during the Surge Period. Decreases in revenue, royalties, labour income and employment in the forest industry were estimated to decrease by 6 – 9% within the Post Surge Periods of Scenarios 3.1 and 3.2.

The viability of large scale salvage of MPB damaged stands to the scale and magnitude modeled by this report is significantly constrained by a number of factors. In the event of a harvesting boom triggered by large scale salvage activities, milling capacity and forestry equipment and worker availability could potentially restrict the ability of licensees to harvest and process timber. The economic viability of damaged MPB stands could also be limited by downward pressure on wood product commodity prices resulting from oversupply in the market. If wood is not utilized quickly after attack, additional losses in wood value may occur as a result of rapid drying, further reducing the economic viability of MPB damaged stands.

Beyond economic and forest industry capacity considerations regarding MPB damaged wood utilization, there are a myriad of social and environmental issues which need to be balanced when developing MPB management plans. Potential fire hazard, environmental implications and visual impact are but a few of many issues which need to be cohesively integrated into MPB landscape level planning and strategy.

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Appendix A

Endogenous and Exogenous Variable and their Interaction within the Computable General Equilibrium Framework Model (Patriquin et al., 2005)

The generalized equations that form the theoretical structure of the regional CGE models.

1. $L_j = X_j - (W - (\alpha_w W + \alpha_{Kr} R_j^K + \alpha_{Dr} R_j^D))$	j = 1,2,…,6
2. $ELF = \sum_{j=1}^{6} \beta_j L_j$	j = 1,2,…,6
3. $K_j = X_j - (R_j^K - (\alpha_w W + \alpha_{Kr} R_j^K + \alpha_{Dr} R_j^D))$	j = 1,2,…,6
4. $D_j = X_j - (R_j^D - (\alpha_w W + \alpha_{Kr} R_j^K + \alpha_{Dr} R_j^D))$	j = 1,2,…,6
5. $X_{ij} = X_j$	i,j = 1,2,…,6
6. $X_{jc} = Y - P_j$	j = 1,2,…,6
7. $X_i = \sum_{j=1}^{6} \varphi_{ij} X_{ij} + \eta_i X_{ic} + \theta_i E_i + \eta_g G_j$	i = 1,2,…,5 j = 1,2,…,6
8. $E_i = -\phi(P_i - Wp_i + er)$	i = 1,2,…,5
9. $P_j = \sum_{n=1}^{6} \delta_{nj} P_n + (\delta W_j + \delta_{Krj} R_j^K + \delta_{Drj} R_j^D + \delta_m PM_j + \delta_T GT_j)$	j = 1,2,…,6
10. $Y = \alpha_i ELF_i + \alpha_i W + \varsigma_i K_i + \varsigma_i R_i^K + \lambda_j D_j + \lambda_j R_j^D + \lambda_g G$	i,j = 1,2,…,6

The endogenous variables contained within the regional CGE models. Note that depending on the scenario in question, various endogenous variables can be switched with exogenous variables. This allows for a greater degree of flexibility in the range of scenarios and solution techniques possible.

L_i i=1,…,6	Labour employed in sector i
X_i i=1,…,6	Output of sector i
R^k_i i=1,…,6	Rental rate of capital in sector i
R^D_i i=1,…,6	Rental rate of land in sector i
D_i i=1,…,6	Land employed in sector i
X_{ic} i=1,…,6	Final demand for output from sector i
Y	Household income
P_i i=1,…,6	Domestic price of output from sector i
E_i i=1,…,5	Exports from sector i
ELF*	Employed Labour Force
W*	Wage rate

* If W is endogenous ELF is exogenous and vice versa

The exogenous variables contained within the regional CGE models. Again, depending on the scenario in question various variables can be switched between endogenous and exogenous.

K_i i=1,…,6	Capital employed in sector i
D_i i=1,…,6	Land employed in sector i
X_{ic} i=1,…,6	Final demand for output from sector i
WP_i i=1,…,6	World price of output from sector i
Er	Foreign exchange rate
G_i i=1,…,6	Government expenditure in sector i
PM_i i=1,…,6	Price of imports in sector i
GTi i=1,…,6	Indirect taxes in sector i
WLE	World labour export
GTF	Government transfers to households

Appendix B

Computable General Equilibrium Framework Model Output: Estimated Economic Effect of AAC Variation within the HFMA during the Surge Period of the Forest Muncher Model

Simulated indicator level	Baseline	Scenario 2	Scenario 3.1	Scenario 3.2
Total revenue ($M)	2575.3	2869.6	3091.2	3778.2
Forestry	566.4	815.0	1002.3	1582.6
Mining	384.3	386.6	388.3	393.6
Crude petroleum and natural gas	1058.7	1061.2	1063.1	1069.1
Visitor	261.5	266.7	270.7	282.9
Rest of the economy	304.4	340.0	366.8	450.0
Total net regional product ($M)	951.3	1082.4	1181.1	1487.1
Forestry	230.9	336.6	416.3	663.3
Mining	103.4	104.1	104.6	106.2
Crude petroleum and natural gas	340.1	341.2	342.0	344.5
Visitor	91.3	93.1	94.5	98.7
Rest of the economy	185.6	207.3	223.7	274.4
Total royalties ($M)	151.0	158.7	164.5	182.4
Forestry	13.0	19.7	24.8	40.4
Mining	15.0	15.0	15.1	15.4
Crude petroleum and natural gas	115.5	115.8	116.1	116.9
Visitor	3.8	3.9	4.0	4.1
Rest of the economy	3.7	4.2	4.5	5.5
Total labor income ($M)	445.0	519.8	576.1	750.8
Forestry	132.6	188.1	230.0	359.7
Mining	49.4	49.8	50.0	50.8
Crude petroleum and natural gas	50.7	50.8	51.0	51.3
Visitor	62.7	63.9	64.9	67.8
Rest of the economy	149.6	167.1	180.3	221.2
Total employment (#)	13380.0	15077.4	16355.6	20318.0
Forestry	1845.0	2588.9	3149.0	4885.5
Mining	590	594	597	606
Crude petroleum and natural gas	590	592	593	598
Visitor	2,725	2,779	2,820	2,947
Rest of the economy	7,630	8,523	9,196	11,282

Appendix C

Computable General Equilibrium Framework Model Output: Estimated Economic Effect of AAC Variation within the HFMA during the Post Surge Period of the Forest Muncher Model

Simulated indicator level	Baseline	Scenario 1	Scenario 2	Scenario 3.1	Scenario 3.2
Total revenue ($M)	2575.3	2574.8	2540.9	2531.2	2521.8
Forestry	566.4	566.0	537.4	529.1	521.3
Mining	384.3	384.3	384.0	383.9	383.9
Crude petroleum and natural gas	1058.7	1058.7	1058.4	1058.3	1058.2
Visitor	261.5	261.5	260.9	260.7	260.6
Rest of the economy	304.4	304.3	300.2	299.0	297.9
Total net regional product ($M)	951.3	951.1	936.0	931.6	927.5
Forestry	230.9	230.7	218.5	215.0	211.7
Mining	103.4	103.4	103.3	103.3	103.3
Crude petroleum and natural gas	340.1	340.1	340.0	340.0	340.0
Visitor	91.3	91.3	91.1	91.0	91.0
Rest of the economy	185.6	185.5	183.0	182.3	181.6
Total royalties ($M)	151.0	151.0	150.1	149.8	149.6
Forestry	13.0	13.0	12.2	12.0	11.8
Mining	15.0	15.0	14.9	14.9	14.9
Crude petroleum and natural gas	115.5	115.5	115.4	115.4	115.4
Visitor	3.8	3.8	3.8	3.8	3.8
Rest of the economy	3.7	3.7	3.7	3.7	3.7
Total labor income ($M)	445.0	444.9	436.2	433.8	431.4
Forestry	132.6	132.5	126.1	124.2	122.5
Mining	49.4	49.4	49.4	49.4	49.4
Crude petroleum and natural gas	50.7	50.7	50.7	50.7	50.7
Visitor	62.7	62.7	62.5	62.5	62.4
Rest of the economy	149.6	149.6	147.6	147.0	146.4
Total employment (#)	13380.0	13377.4	13181.9	13125.6	13072.0
Forestry	1845.0	1843.9	1758.2	1733.5	1710.0
Mining	590	590	590	589	589
Crude petroleum and natural gas	590	590	590	590	590
Visitor	2,725	2,725	2,719	2,717	2,715
Rest of the economy	7,630	7,629	7,526	7,496	7,468