Provincial-Level Projection of the Current Mountain Pine Beetle Outbreak:

Update of the infestation projection based on the 2010 Provincial Aerial Overview of Forest Health and the BCMPB model (year 8)

by:
Adrian Walton, BC Forest Service

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Introduction

For each of the past seven years, a team led by the BC Ministry of Forests and Range, Research and Knowledge Management Branch has released an update to the provincial-level projection of the current mountain pine beetle outbreak based upon new information produced by the Provincial-Level Mountain Pine Beetle Model (BCMPB)[1]. The model uses forest cover maps[2], the Provincial Aerial Overview of Forest Health[3] and information from a stand level mountain pine beetle (MPB) population model[4] to estimate the current extent of pine mortality and to project a possible course of the infestation into the future.

A revised estimate of current and potential future impact of the MPB infestation is now complete based on the 1999 through 2010 Provincial Aerial Overviews of Forest Health and the BCMPB model (aka "the model"). This year's result of observed annual kill is only slightly different than what was anticipated from last year[5]. However, the estimates of past and future infestation impacts have changed more significantly than what was estimated last year, largely as a result of changes in the BCMPB model and modeling methodology, which has changed the observed and projected cumulative impact of the MPB infestation.

It is important to note that the results of the projection of the infestation described in this document do not include any effects of future forest or beetle management. Only the infestation itself is discussed in this report.

[1] http://www.for.gov.bc.ca/hre/bcmpb
[2] http://www.for.gov.bc.ca/hts/vri/
[3] http://www.for.gov.bc.ca/hfp/health/overview
[4] http://cfs.nrcan.gc.ca/subsite/mpb/stand-mpbsim
[5] http://www.for.gov.bc.ca/hre/bcmpb/BCMPB.v7.BeetleProjection.Update.pdf

1 Model Background and Factors Affecting the Current Results

The Provincial-Level Mountain Pine Beetle Model (BCMPB) is a discrete probability transition model that runs on an annual time-step. The probability that a location will be in a given state (No Beetle, Endemic, Low, Moderate, Severe or Very Severe) depends on the beetle state at that location in the previous year, the estimate of the cumulative amount of pine killed by beetles at that location in previous years of the outbreak, the location's stand age and percentage of pine, the amount of beetle pressure from nearby infestations, the location's biogeoclimatic subzone, and the general climatic conditions of the location.

The successive years of data collected through the Provincial Aerial Overview of Forest Health (aerial overview survey) since 1999 are pivotal to BCMPB. Specifically, the aerial overview survey influences the beetle state at a location in the previous year, the cumulative amount of pine killed by beetles at a location in all previous years, and the amount of beetle pressure from nearby infestations.

As a result, BCMPB output is highly sensitive to both variations in aerial overview survey techniques and timing, and missing aerial overview survey mapping. Although BCMPB attempts to compensate for some inter-year variations due to either inconsistencies in aerial overview survey mapping (see Year 3 model documentation[6]) or missing aerial overview survey mapping, it cannot compensate for all inconsistencies. In particular, BCMPB cannot smooth out sudden increases or decreases when they occur in the most recent year of the aerial overview. It is only in the subsequent year when new data shows these sudden changes to be "bumps" or "troughs" can the model, in certain situations, smooth them. Similarly, BCMPB cannot correct or compensate for multiple years of either irregular or missing aerial overview survey mapping.

Usually the inter-year inconsistencies are fairly minor. In the northern part of the province, however, there have been multiple years where poor weather conditions have resulted in either inconsistencies or missing aerial overview survey mapping. This was most notable in 2008 when a large portion of the aerial overview survey in the Northern Interior Forest Region (NIFR) was hampered by poor weather conditions and contractor availability that resulted in either no aerial overview survey mapping or completion of the survey much later than was optimal[7] (Figure 1).

1.1 Changes to the Modeling Process

In an effort to compensate for missing or inconsistently gather aerial overview survey mapping, the BCMPB data preparation process was altered this year. The decision was made to replace the aerial overview survey mapping with infestation

[6] http://www.for.gov.bc.ca/hre/bcmpb/BCMPB.v3.ModelDocumentation.Update.pdf
[7] The optimal period for aerial surveys of mountain pine beetles is listed in Table 1 of http://ilmbwww.gov.bc.ca/risc/pubs/teveg/foresthealth/aerial-04.htm#p162_17805

severity estimates projected by BCMPB in those areas of the province with missing or inconsistently gathered aerial overview survey mapping.

Model results this year have also been impacted by a change to BCMPB, specifically, the addition of a general climate variable. This province-wide spatially-defined variable uses the provincial ecoprovinces to divide the province into 5 general climate classes. The goal of adding this general climate variable was to improve how BCMPB projects the MPB infestation impacts in those parts of the province dominated by mixed-stand types and topographic barriers to dispersal.

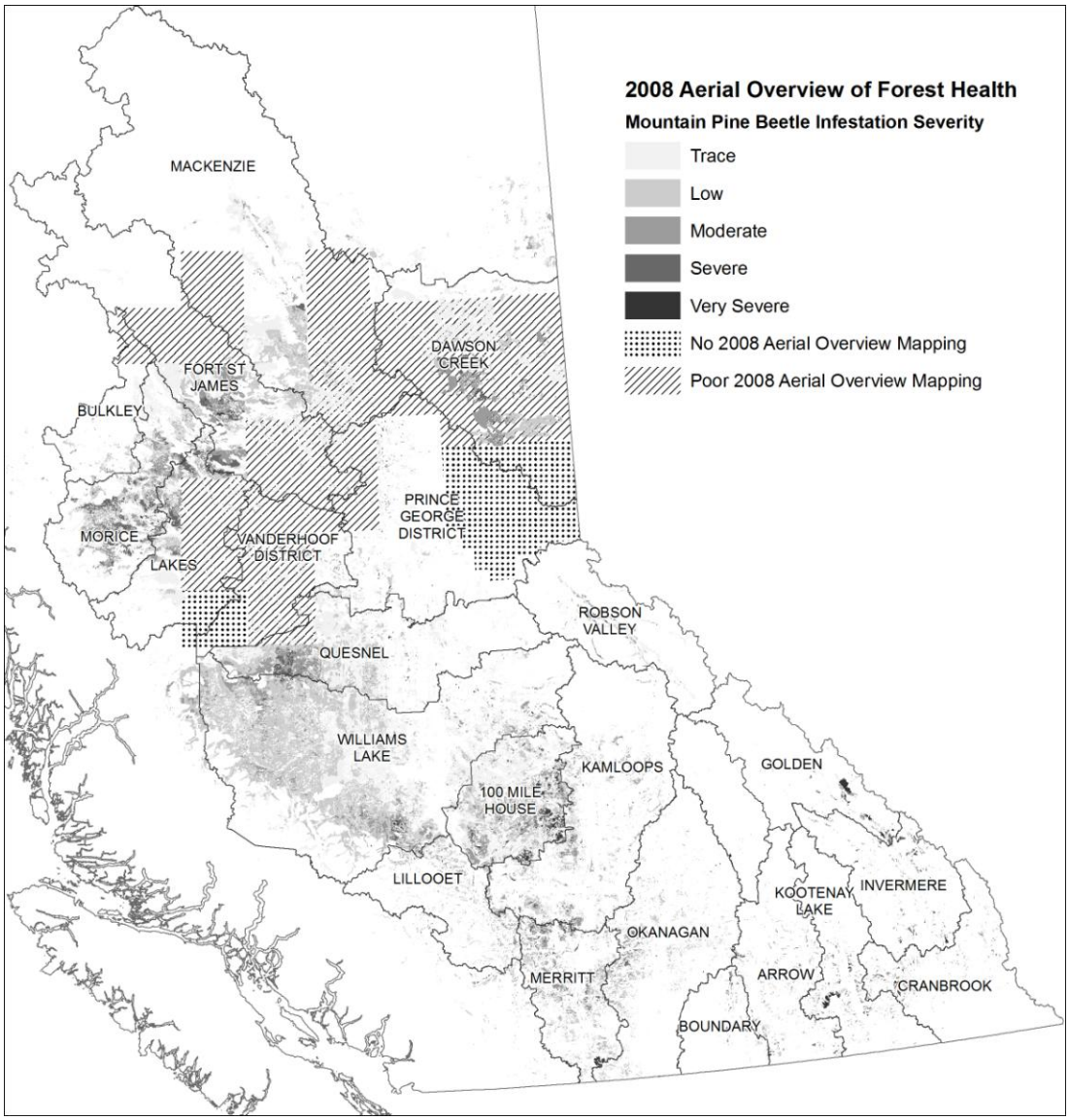

Figure 1. 2008 mountain pine beetle infestation severity as mapped by the Provincial Aerial Overview Survey of Forest Health. Note areas which received no or inconsistent (poor) aerial overview surveys.

2 Summary of Results

2.1 Annual Mortality

2.1.1 Observed Annual Mortality

As reported in prior BCMPB update reports, it is estimated that the provincial peak in annual kill of pine volume for this outbreak occurred during the summer of 2004 and was observed by the Provincial Aerial Overview of Forest Health during the summer of 2005[8]. At the peak, there was an annual mortality of approximately 140 million m^3 of mature (>60 years old) merchantable (>12.5 cm dbh) pine on the Timber Harvesting Land Base (THLB)[9]. It is now estimated that approximately 39 million m^3 of mature merchantable pine on the THLB were observed newly killed (red-attack phase) during the summer of 2010 (green-attack phase during the summer of 2009) (Figure 2).

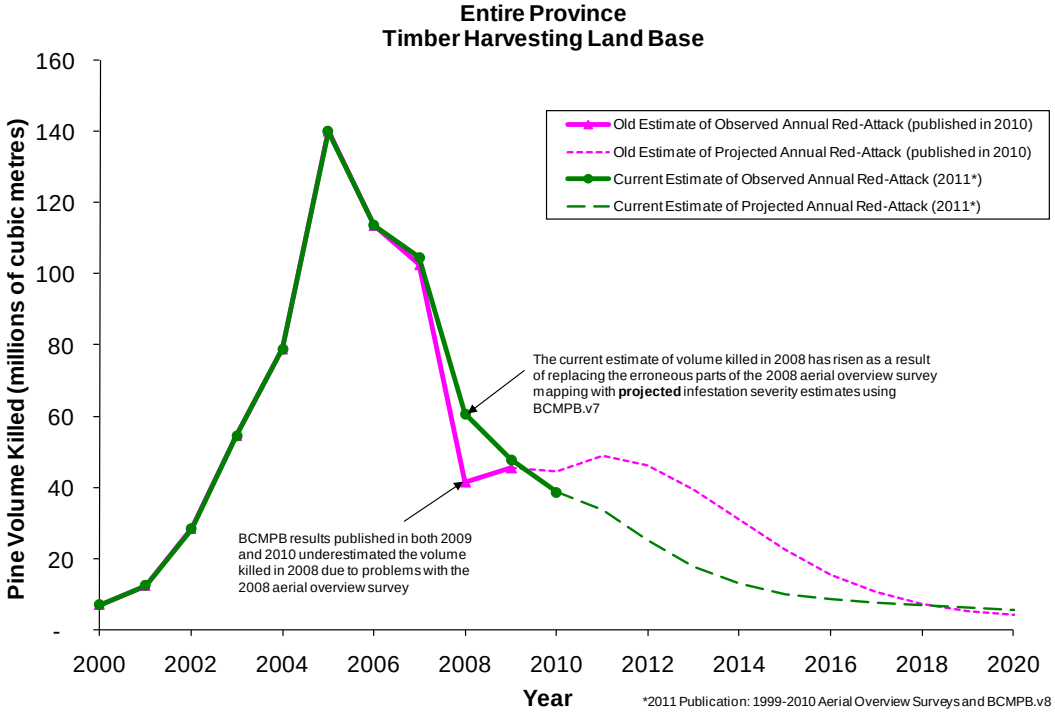

Figure 2. Observed and projected annual mature pine volume killed (red-attack) on the Timber Harvesting Land Base of the entire province. Also a comparison between results produced last year, which were based on the 1999 to 2009 aerial overviews, and current results, which include the 2010 aerial overview. The current estimate of volume killed in 2008 has risen as a result of replacing the erroneous parts of the 2008 aerial overview survey mapping with infestation severity estimates projected using BCMPB.v7

With the addition of the 2010 aerial overview survey mapping and the replacement of the erroneous parts of the past aerial overview survey mapping, the volume of red-

[8] Note that the mortality caused by MPB (green-attack) occurs in the year prior to that in which it is observed by the Provincial Aerial Overview of Forest Health (observed as red-attack). The model (BCMPB) results and projections are based on the Provincial Aerial Overview of Forest Health, and therefore "observed mortality" is presented in graphs and tables unless otherwise specifically noted.
[9] All volume figures reported are for the Timber Harvesting Land Base only.

attack pine has decreased every year since 2005. This is in contrast to the results published last year that showed an increase in red-attack between 2008 and 2009. I am now confident that the increase published last year was incorrect and solely resulting from the underestimation of the 2008 red-attack caused by the problems with the 2008 aerial overview survey.

2.1.1.1 Variations across the "Pine Units"

The 22 "pine units"[10] can roughly be divided into four categories based on their relative changes in mature pine volume in red-attack phase since the 2009: 1) large relative decrease (>30% drop); 2) small relative decrease (30%-11% drop); 3) essentially unchanged (+/- 10%); and 4) relative increase (>10% increase) (Figure 3). In general, most of the pine units experienced a decrease in pine mortality. The exceptions were Invermere and Robson Valley, which remained essentially unchanged, and Bulkley and Dawson Creek, which experienced a relative increase.

Similar to what was reported in last year's BCMPB update report, Table 1 shows that there were 4 "pine units" where the peak in annual volume of mature pine killed (red-attack) probably occurred in 2005 (green-attack in 2004): Vanderhoof and Prince George Forest Districts, and Quesnel and Lakes TSAs. Most of the remaining units peaked sometime since 2005. The exceptions being Bulkley, Cranbrook, Invermere, and Boundary TSAs, which are projected to experience peak annual pine volume loss sometime in the future (discussed further in the following section).

2.1.2 Projected Annual Mortality

It is now projected that over the next 4 years (until 2014) the annual volume of mature merchantable red-attack pine on the THLB will decrease steadily at roughly the current rate of decrease (from 39 million m^3 of red-attack pine in 2010 to 13 million m^3 in 2014). After 2014, the rate of decrease will subside slightly, and by 2021 it is estimated that less than 5 million m^3 will be killed annually.

Current BCMPB projections estimate that annual volume of mature merchantable red-attack pine on the THLB in the Cranbrook, Invermere and Boundary TSAs will rise gradually over the next 4 to 10 years before gradually subsiding (according to BCMPB.v8 peak kill is projected to occur in years 2014, 2018, 2020 for Invermere, Cranbrook, and Boundary TSAs, respectively). However, it is my opinion that BCMPB.v8 is still overestimating the epidemic growth in these three units, and that instead peak kill has **already** occurred and will continue to subside or remain stable.

I base this conclusion on the fact that over the past five years the infestation in these units has decreased on average. Additionally, as reported in earlier BCMPB update reports, there is considerable uncertainty on the degree to which the areas at the periphery (such as the south east of the province) are driven by influx from the

[10] Pine units are defined as those Timber Supply Areas (TSA) where more than 10% of the merchantable volume is pine. Note that the individual forest districts in the Prince George TSA are reported on separately.

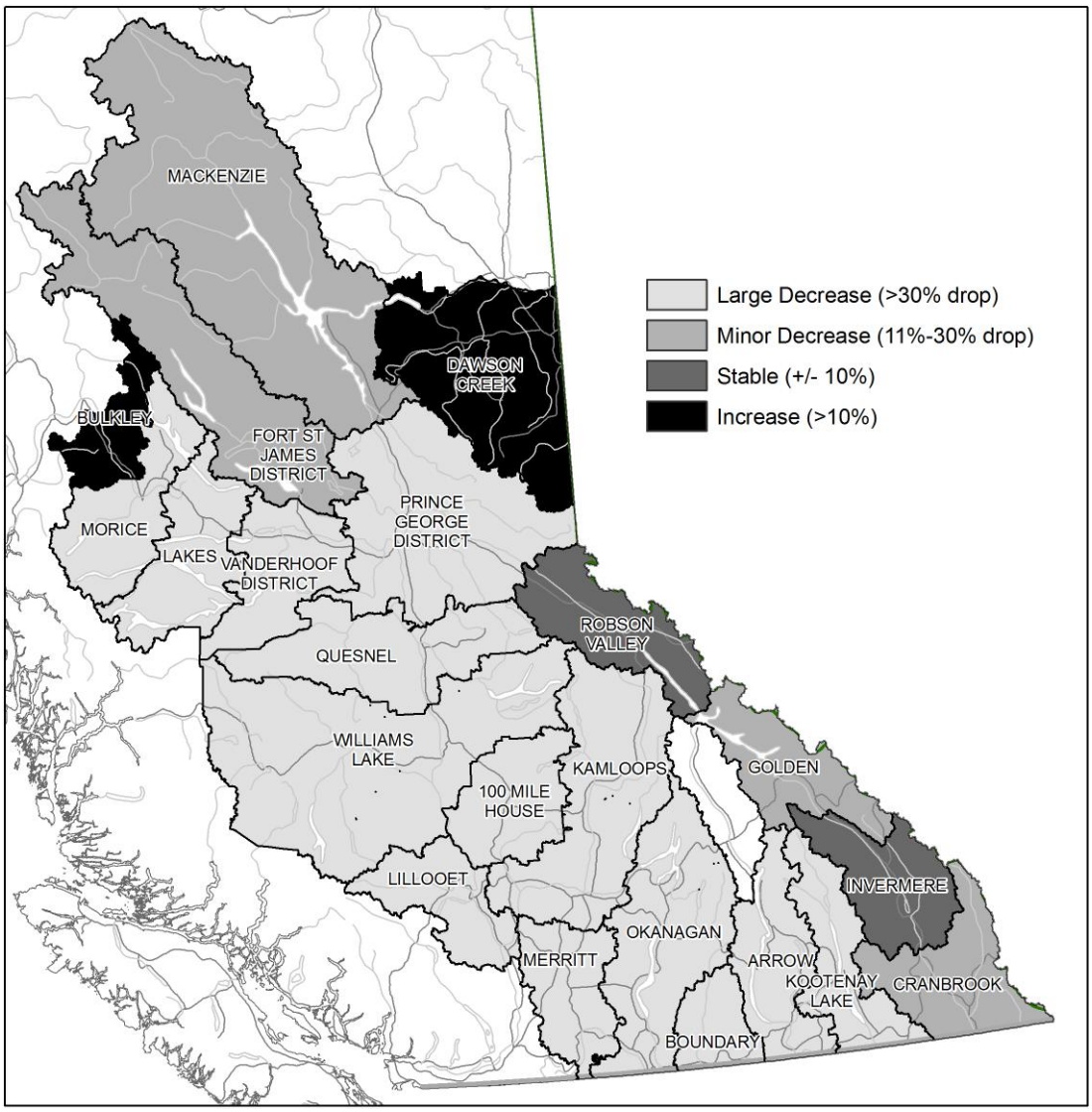

Figure 3. Relative changes in observed red-attack volume from 2009 to 2010 for the 22 pine units.

now-collapsing core of the outbreak. Outbreaks in peripheral landscapes with marginal climatic suitability, mixed tree types, and larger topographic barriers may either subside faster than expected, or not experience the projected peak annual mortality projected by BCMPB once the central outbreak subsides.

2.1.3 Notable Differences between the Current Estimates of Observed/Projected Annual Mortality and the Estimates Reported Last Year

As noted above, the estimate of observed annual volume of mature merchantable red-attack pine on the THLB in 2008 has increased to 61 million m^3 from the 41 million m^3 reported for 2008 last year. There have also been some minor increases in the estimated volume of red-attack pine for years 2007 (current estimate: 105 million m^3; previous estimate: 103 million m^3) and 2009 (current estimate: 48 million m^3; previous estimate: 45 million m^3).

Table 1. Observed (2005 – 2010) and projected (2011 – 2014) annual volume (in millions m^3) of mature merchantable red-attack pine for the THLB portion of the 22 "pine units" (peak year of red-attack is highlighted by an outlined box). Note that the mortality caused by the MPB (green-attack) occurs in the year prior to that in which it is observed by the Provincial Aerial Overview of Forest Health (observed as red-attack).

	Year									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Pine Unit	Observed						Projected			
Vanderhoof District	24.6	7.1	4.0	1.1	0.2	0.0	0.0	0.0	0.0	0.0
Quesnel TSA	23.7	11.8	5.1	0.9	0.1	0.0	0.0	0.0	0.0	0.0
Lakes TSA	15.0	9.8	6.5	2.8	0.6	0.1	0.0	0.1	0.0	0.0
Prince George District	12.8	8.3	8.2	2.4	0.2	0.1	0.1	0.1	0.1	0.0
Williams Lake TSA	19.4	20.6	17.7	4.8	2.0	0.2	0.1	0.1	0.1	0.1
100 Mile House TSA	8.7	18.0	7.5	1.8	0.1	0.0	0.0	0.0	0.0	0.0
Kamloops TSA	6.1	8.8	6.9	2.1	0.4	0.1	0.1	0.1	0.1	0.2
Arrow TSA	0.5	0.6	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.2
Golden TSA	0.2	0.3	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1
Ft. St. James District	10.7	8.9	15.4	9.6	6.2	4.8	5.3	3.7	2.2	1.1
Morice TSA	3.7	6.3	7.1	6.9	2.3	1.3	1.6	1.4	1.0	0.7
Merritt TSA	1.3	2.4	3.9	3.7	3.4	0.8	1.0	1.1	1.3	1.3
Okanagan TSA	1.1	1.3	1.7	1.6	1.3	0.8	0.9	1.1	1.2	1.3
Lillooet TSA	0.4	0.9	1.3	1.1	0.8	0.3	0.3	0.4	0.4	0.4
Dawson Creek TSA	0.0	0.1	2.7	3.3	1.9	3.2	2.8	2.3	1.7	1.1
Kootenay Lake TSA	0.3	0.4	0.3	0.5	0.2	0.2	0.2	0.2	0.1	0.2
Robson Valley TSA	0.1	0.2	0.3	0.4	0.4	0.4	0.2	0.2	0.1	0.1
Mackenzie TSA	0.6	2.1	6.4	9.0	21.2	17.4	12.7	7.9	4.2	2.1
Bulkley TSA	0.1	0.1	0.2	0.6	0.6	0.9	1.6	1.5	1.2	0.8
Cranbrook TSA	0.5	0.5	0.3	0.6	0.3	0.3	0.3	0.5	0.6	0.6
Invermere TSA	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.3	0.3	0.4
Boundary TSA	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3
Pine Units Total	130.1	108.9	96.0	54.0	42.7	31.3	27.7	21.1	15.0	11.0
Provincial Total	140.0	113.6	104.6	60.7	47.7	38.6	33.7	25.1	17.6	12.9

The increases for these three years (2007 through 2009) were almost exclusively the result of replacing the aerial overview survey mapping with infestation severity estimates projected by BCMPB in those areas of the province with missing or inconsistently gathered aerial overview survey mapping, which occurred exclusively in the Northern Interior Forest Region. Although this does mean I am now using BCMPB to fabricate the input data in places (sometimes in the same location over multiple years), I feel this is the only efficient method to correct the problems encountered with the aerial overview survey mapping.

Although most of the pine units in the Northern Interior Forest Region experienced an increase in estimated observed annual volume of mature merchantable red-attack pine on the THLB in years 2007, 2008 and 2009, Mackenzie Forest District experienced the largest increase (Figure 4). Most notably, the estimate of red-attack pine volume observed in Mackenzie increased by 6 million m^3 for the year 2008 (current estimate: 9 million m^3; previous estimate: 3 million m^3), but there was also a 1 million m^3 for the year 2007 (current estimate: 6 million m^3; previous estimate: 5 million m^3).

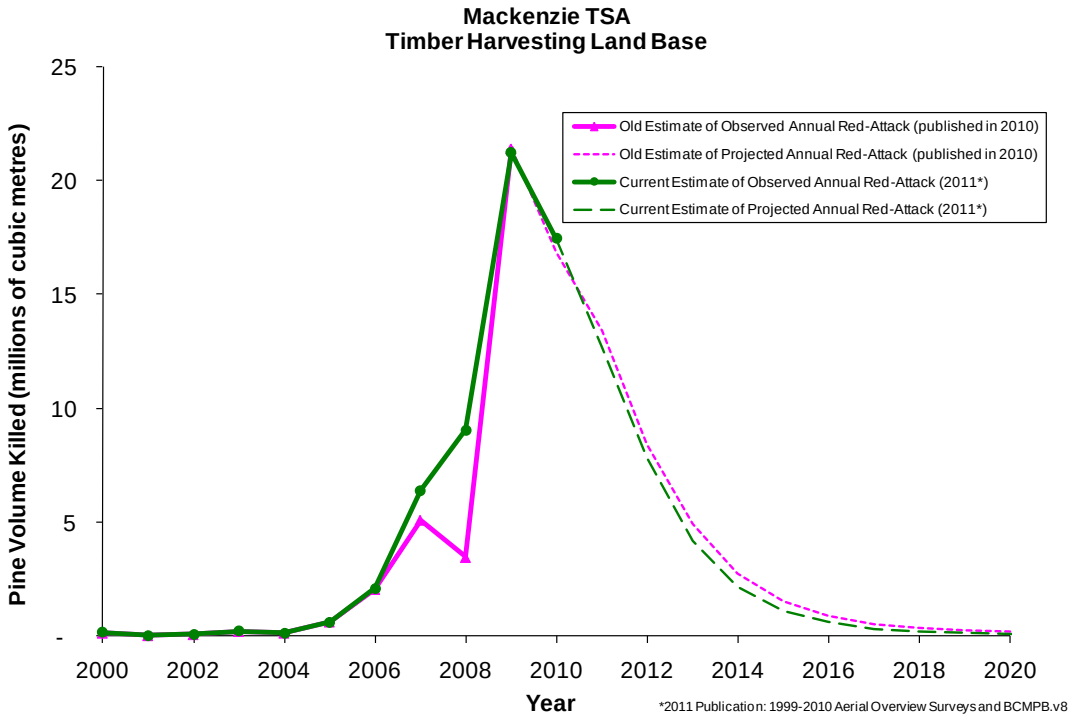

Figure 4. Observed and projected annual mature pine volume killed (red-attack) on the Timber Harvesting Land Base of the Mackenzie Forest District. Also a comparison between results produced last year, which were based on the 1999 to 2009 aerial overviews, and current results, which include the 2010 aerial overview. The current estimate of volume killed in 2007 and 2008 have risen as a result of replacing the erroneous parts of the 2007 and 2008 aerial overview survey mapping with infestation severity estimates projected using BCMPB.v7.

Another notable change to the projected future progression of the provincial infestation is that it no longer remains stable until 2012 as published previously (see Figure 2). Instead the infestation will continue to subside over time at a decreasing rate. This change in projected progression of the infestation is most likely due to two factors: 1) replacing the aerial overview survey mapping with infestation severity estimates projected by BCMPB within those areas of the province with missing or inconsistently gathered aerial overview survey mapping; and 2) adding the climate variable to BCMPB, which uses the provincial ecoprovinces to divide the province into 5 general climate classes.

The largest impact of adding the climate variable to BCMPB has been on the projected future progression of the infestation in those parts of the province dominated by mixed stand types and topographic barriers to dispersal. Most notably, the pine units in the south east of the province are no longer projected to experience a large increase in red-attack pine (see Figure 5 for an example). Although the current version of BCMPB does still project a minor/moderate increase in red-attack pine in the management units in the south east of the province, it is my opinion that BCMPB.v8 is still overestimating the epidemic levels in these units (as discussed earlier in the Projected Annual Mortality section above).

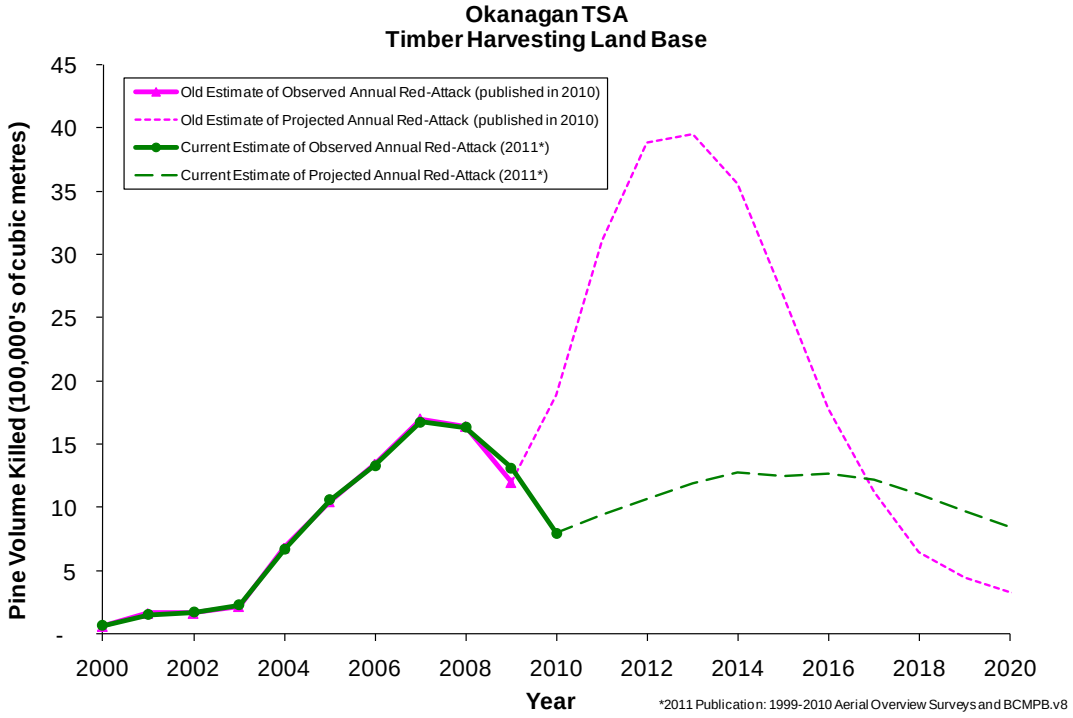

Figure 5. Observed and projected annual mature pine volume killed (red-attack) on the Timber Harvesting Land Base of the Okanagan Timber Supply Area. Also a comparison between results produced last year, which were based on the 1999 to 2009 aerial overviews, and current results, which include the 2010 aerial overview. With the addition of a new climate variable to BCMPB, pine units in the south east of the province are no longer projected to experience a large increase in red-attack pine. Although the current version of BCMPB does still project a minor/moderate increase in red-attack pine in these units, it is my opinion that BCMPB.v8 is still overestimating the epidemic levels in these units. Okanagan TSA is shown here as an example.

2.2 Cumulative Impact

2.2.1 Observed Cumulative Mortality

It is now estimated that the provincial cumulative volume of mature merchantable pine mortality (red- and grey-attack) from 1999 to 2010 is approximately 692 million m^3 (Figure 6). This represents approximately 51% of the total provincial mature merchantable pine volume on the THLB at the start of the current outbreak (1.35 billion m^3 in year 1999). The majority of that mortality (636 million m^3) has occurred in the "pine units" and represents 54% of the mature merchantable pine volume in those units (Table 2).

2.2.2 Projected Cumulative Mortality

Provincially, it is projected that 59% of the total merchantable pine volume on the THLB at the start of the current outbreak will be killed by 2016 if the infestation continues to behave as projected by the model (Table 2). The infestation will have largely subsided by that time and only an additional 2% may be killed by 2021(Figure 6).

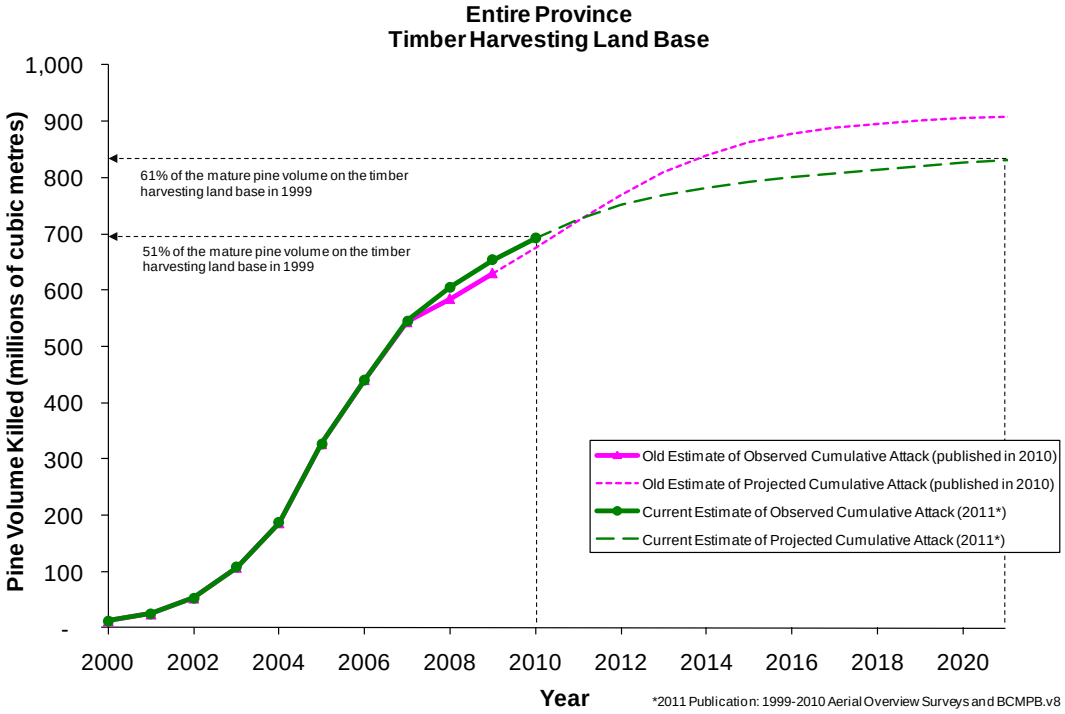

Figure 6. The observed and projected cumulative kill (red- and grey-attack) in the province. Also a comparison between results produced last year, which were based on the 1999 to 2009 aerial overviews, and current results, which include the 2010 aerial overview. It is currently estimated that the provincial cumulative volume of mature merchantable pine mortality (red- and grey-attack) from 1999 to 2010 is approximately 692 million m3, which represents approximately 51% of the total provincial mature merchantable pine volume on the THLB at the start of the current outbreak. It is projected that 61% of the total merchantable pine volume on the THLB at the start of the current outbreak will be killed by 2021 if the infestation continues to behave as projected.

In the "pine units", it is projected that 62% of the total merchantable pine volume on the THLB at the start of the current outbreak will be killed by 2016 if the infestation continues to behave as projected by the model (Table 2). By 2021, it is projected that 64% of total merchantable pine volume on the THLB in the pine units will be killed.

However, not all management units will experience the same percentage of pine loss. Currently it is estimated that, within the "pine units", the cumulative percentage of pine killed ranges from 81% in Quesnel TSA to 5% in Boundary TSA. As the infestation progresses, it is projected by BCMPB that the range between most impacted and least impact pine units will shrink, with 81% in Quesnel TSA and 34% in Cranbrook TSA. However, the current range between most impacted and least impacted TSA may remain mostly unchanged in the future if the infestation does not grow as projected in those pine units on the periphery of the outbreak (especially in those pine units in the south east of the province).

Table 2. Cumulative volume (millions of m^3) and percentage of mature pine on the THLB in 1999 projected to be killed (red- and grey-attack) in each "pine unit" during selected years.

Percent of Pine Volume Killed (red- and grey-attack)

	Year			
Pine Unit	**2010**	**2011**	**2016**	**2021**
Quesnel TSA	89.7 (81%)	89.7 (81%)	89.8 (81%)	89.8 (81%)
Lakes TSA	54.2 (76%)	54.3 (76%)	54.5 (77%)	54.5 (77%)
Vanderhoof Forest District	71.6 (73%)	71.6 (73%)	71.6 (73%)	71.6 (73%)
100 Mile House TSA	41.6 (72%)	41.6 (72%)	41.7 (72%)	41.9 (73%)
Prince George Forest District	49.2 (63%)	49.2 (63%)	49.5 (63%)	49.6 (64%)
Ft. St. James Forest District	66.2 (60%)	71.6 (65%)	79.5 (73%)	80.1 (73%)
Williams Lake TSA	86.8 (60%)	86.8 (60%)	87.3 (61%)	88.1 (61%)
Morice TSA	30.5 (53%)	32.0 (56%)	35.9 (63%)	36.4 (64%)
Mackenzie TSA	57.4 (49%)	70.1 (60%)	85.9 (74%)	86.7 (74%)
Kamloops TSA	28.9 (49%)	29.0 (49%)	29.9 (51%)	31.5 (53%)
Dawson Creek TSA	11.2 (36%)	14.1 (45%)	20.3 (66%)	20.9 (68%)
Robson Valley TSA	2.1 (34%)	2.4 (38%)	2.9 (46%)	3.0 (49%)
Arrow TSA	2.5 (31%)	2.5 (32%)	3.3 (42%)	4.0 (50%)
Merritt TSA	17.6 (27%)	18.6 (28%)	24.6 (37%)	28.3 (43%)
Lillooet TSA	4.9 (25%)	5.3 (27%)	7.3 (37%)	8.5 (44%)
Golden TSA	1.1 (21%)	1.1 (22%)	1.5 (30%)	2.0 (39%)
Bulkley TSA	2.7 (21%)	4.3 (33%)	8.5 (64%)	8.9 (68%)
Kootenay Lake TSA	2.3 (18%)	2.4 (19%)	3.4 (26%)	4.4 (34%)
Okanagan TSA	9.2 (16%)	10.1 (18%)	16.2 (28%)	21.1 (37%)
Invermere TSA	1.8 (16%)	2.1 (17%)	3.8 (32%)	5.0 (43%)
Cranbrook TSA	3.4 (11%)	3.8 (12%)	6.8 (22%)	10.7 (34%)
Boundary TSA	0.8 (5%)	0.9 (6%)	2.4 (16%)	5.2 (35%)
Pine Units Total	**635.8 (54%)**	**663.6 (56%)**	**726.3 (62%)**	**752.1 (64%)**
Provincial Total	**691.9 (51%)**	**725.7 (54%)**	**799.8 (59%)**	**831.2 (61%)**

2.2.3 Notable Differences between the Current Estimate of Projected Cumulative Mortality and the Estimates Reported in Previous Years

It is now projected that by the time the current infestation is essentially over the MPB will have killed approximately 61% of the merchantable pine volume on the THLB at the start current MPB infestation outbreak. Last year, it was projected that 67% of the provincial merchantable pine volume may be killed once the infestation was essentially over (see Figure 6). In 2006, when this project was in only its 3rd year, it was projected that 80% of the provincial merchantable pine volume may be killed by the time the infestation was over.

This difference (80% projected in Year 3 of the project, to 67% in Year 7, to 61% in current results) highlights the uncertainty surrounding the estimation of cumulative pine volume kill, which arises from a few factors. One is the model's consistent underestimation of how fast the infestation subsides after it has peaked within a management unit, which results in more pine remaining on the landscape than originally projected. Second is the model's overestimation of the amount of pine projected to be killed in the periphery units in the south-east of the province. Current estimates are that considerably less pine will be killed in these periphery units than initially projected. The third factor affecting the drop in projected kill is the impact of underestimation or overestimation by the Aerial Overview of Forest Health.

It is likely that underestimation or overestimation of the amount of red-attack by the aerial overview surveys has impacted the estimated cumulative percentage of pine volume killed, both provincially and within certain management units. Consistent over or underestimation of red-attack contributes to considerable uncertainty around the estimates of current and future cumulative pine loss. It is possible that the pine losses actually experienced will vary significantly from those estimated by BCMPB. For example, BCMPB currently estimates that the Prince George Forest District has lost approximately 63% of its mature merchantable pine to the mountain pine beetle. However, Ministry staff in the Prince George District estimate the current losses to be between 85% and 90%[11].

It is for this reason that I strongly recommend not relying on BCMPB for accurate spatial or management-unit level estimates of pine loss due to the MPB. Detailed surveys should be conducted for accurate estimates of cumulative pine loss within those management units nearing the end of their infestation.

3 Conclusions

The principal conclusions about the infestation are:

- The worst year of observed red-attack, at a provincial scale, was 2005.
- The volume of red-attack pine has declined rapidly, at a provincial scale, since 2005.
- Approximately 692 million m^3 (51%) of the merchantable pine volume in the province has likely already been killed (red- and grey-attack), which includes approximately 39 million m^3 observed as red-attack in the summer 2010.
- The annual volume of mature merchantable red-attack pine on the THLB will decrease steadily over the next 4 years at roughly the current rate of decrease. After 2014, the rate of decrease will subside slightly, and by 2021 it is estimated that less than 5 million m^3 will be killed annually.
- Approximately 59% of the pine volume in the province will be killed by 2016. The infestation will have largely subsided by that time and only an additional 2% may be killed by 2021. This is significantly less than the 80% projected mortality published in 2006.
- **Do not rely on BCMPB for accurate spatial or management-unit level estimates of pine loss due to the MPB. Detailed surveying techniques should be used to collect accurate estimates of cumulative pine loss within those management units nearing the end of their infestation.**

[11] John Pousette, pers. comm., April 2009

4 Caveats

The main caveats about these conclusions are:

- Current mortality estimates are based entirely on an analysis of the Provincial Aerial Overview of Forest Health. These estimates are essentially unverified. While there is no dispute that the infestation is causing extensive pine mortality provincially, the precise magnitude of the impact is not known. The model undoubtedly both overestimates and underestimates mortality in some areas. As mentioned above, do not rely these results for accurate spatial or management-unit level estimates of pine loss due to the MPB.
- The results presented assume that the future will resemble the past, and that differences in habitat suitability between regions are captured by factors included in BCMPB. The model produces a projection of what will occur if the infestation continues to progress as it has over the last eight years. It is important to realize that this is not a prediction of what will occur. There is substantial uncertainty about when and how the infestation will subside and eventually end.
- BCMPB does not include past weather effects or try to simulate future weather effects. As a result, the observed annual kill for a given year may vary considerably from the predicted annual kill. This was apparent in the red-attack observed during the summer of 2007 in the Dawson Creek area. In summer 2006, the Dawson Creek pine-unit experienced an unpredicted immigration of mountain pine beetles from the infestation in the central interior. This led to an unpredicted increase in the 2007 observed red-attack. As the outbreak subsides, it may be expected an increased effect of specific weather events on variability in projected outcomes.
- There is now a significant amount of data from central areas where the infestation is subsiding, but there is still minimal information about subsidence in the peripheral areas. The BCMPB model allows some difference between outbreak dynamics in peripheral areas by considering the effect of "long-distance dispersal pressure", which can reach higher levels in areas with abundant, extensive pine. However, the "dispersal pressure" component may not adequately capture all the differences between central and peripheral areas. In general, it is suspected that many of the differences between projected and observed behaviour arise because the dispersal component of BCMPB does not adequately model the observed spatial structure of the infestation data. BCMPB projections are generally less clumped than observed infestations, causing the model to under-project intensely infested areas, and over-project light infestations. Adequately understanding and accounting for the infestation's spatial structure is a challenging and rapidly developing area of research. Future modeling effort could likely benefit from insights and analysis techniques currently being developed, but incorporating this research is beyond the scope of the current BCMPB project.

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