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

# Update of the infestation projection based on the 2008 Provincial Aerial Overview of Forest Health and revisions to the "Model" (BCMPB.v6)

**by:**
Adrian Walton, Research Branch, BC Forest Service

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# 1 Introduction

For each of the past five years, a team led by the BC Ministry of Forests and Range, Research Branch has released an updated version of 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 2008 Provincial Aerial Overview of Forest Health and revisions to "the model" (BCMPB.v6)[5]. This year's results are different than what was anticipated from last year[6], and were complicated by an incomplete 2008 overview survey for the Northern Interior Forest Region (NIFR) because of poor weather conditions and contractor availability. However, the model results continue to provide insight into how the infestation may progress in the future.

It is important to note that the results of the projection of the infestation described in this document do not include any effects of forest 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/overview.htm
[4] http://www.pfc.forestry.ca/entomology/mpb/tools/modeling/mpbsim_e.html
[5] http://www.for.gov.bc.ca/hre/bcmpb/BCMPB.v6.ModelDocumentation.Update.pdf
[6] http://www.for.gov.bc.ca/hre/bcmpb/BCMPB.v5.BeetleProjection.Update.pdf

# 2 Factors Affecting the Results

As initially discussed in Appendix 3 of the Year-1 report on the Provincial Level Projection of the Current Mountain Pine Beetle Outbreak[7], 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 killed by beetles at that location in previous years of the outbreak, the age, percentage of pine, and climatic conditions of the stand, and the amount of beetle pressure from nearby infestations.

The successive years of data collected through the Provincial Aerial Overview of Forest Health (aerial overview) since 1999 are pivotal to BCMPB. Specifically, the aerial overview influences the beetle state at a location in the previous year, the cumulative amount 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 variations in aerial overview survey techniques and timing. Although BCMPB attempts to compensate for some inter-year variations due to inconsistencies in aerial overview mapping (see Year 3 model documentation[8]), 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 smooth them.

Usually the inter-year inconsistencies are fairly minor. In the 2008 aerial overview, however, the inconsistencies were substantial. These were in part due to weather conditions and contractor availability that resulted in completion of the 2008 aerial overview survey for portions of the Northern Interior Forest Region (NIFR) much later than is optimal[9]. The forest management units most negatively affected were the Lakes, Mackenzie and Dawson Creek Timber Supply Areas, and the Vanderhoof, Fort St. James and Prince George Forest Districts (Figure 1).

As a result, the Lakes, Mackenzie and Dawson Creek Timber Supply Areas and the Vanderhoof, Fort St. James and Prince George Forest Districts all showed a drop in overall infestation levels in 2008 according the aerial overview surveys. However, it is unknown how much of the drop in infestation levels in these management units is a result of inconsistencies in the 2008 aerial overview mapping and how much is real. A partial answer to this question may be obtained when the aerial overview is conducted in 2009. The management units adjacent, but outside, the area of inconsistent aerial overview mapping also experienced lower than projected levels of

[7] http://www.for.gov.bc.ca/hre/bcmpb/year1/ReportAppendices/BCMPB_Appendix3_MPBProjectionModel.pdf

[8] http://www.for.gov.bc.ca/hre/bcmpb/BCMPB.v3.ModelDocumentation.Update.pdf

[9] 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

infestation. So it is likely that part of the drop in infestation levels within the area of inconsistent aerial overview mapping is real.

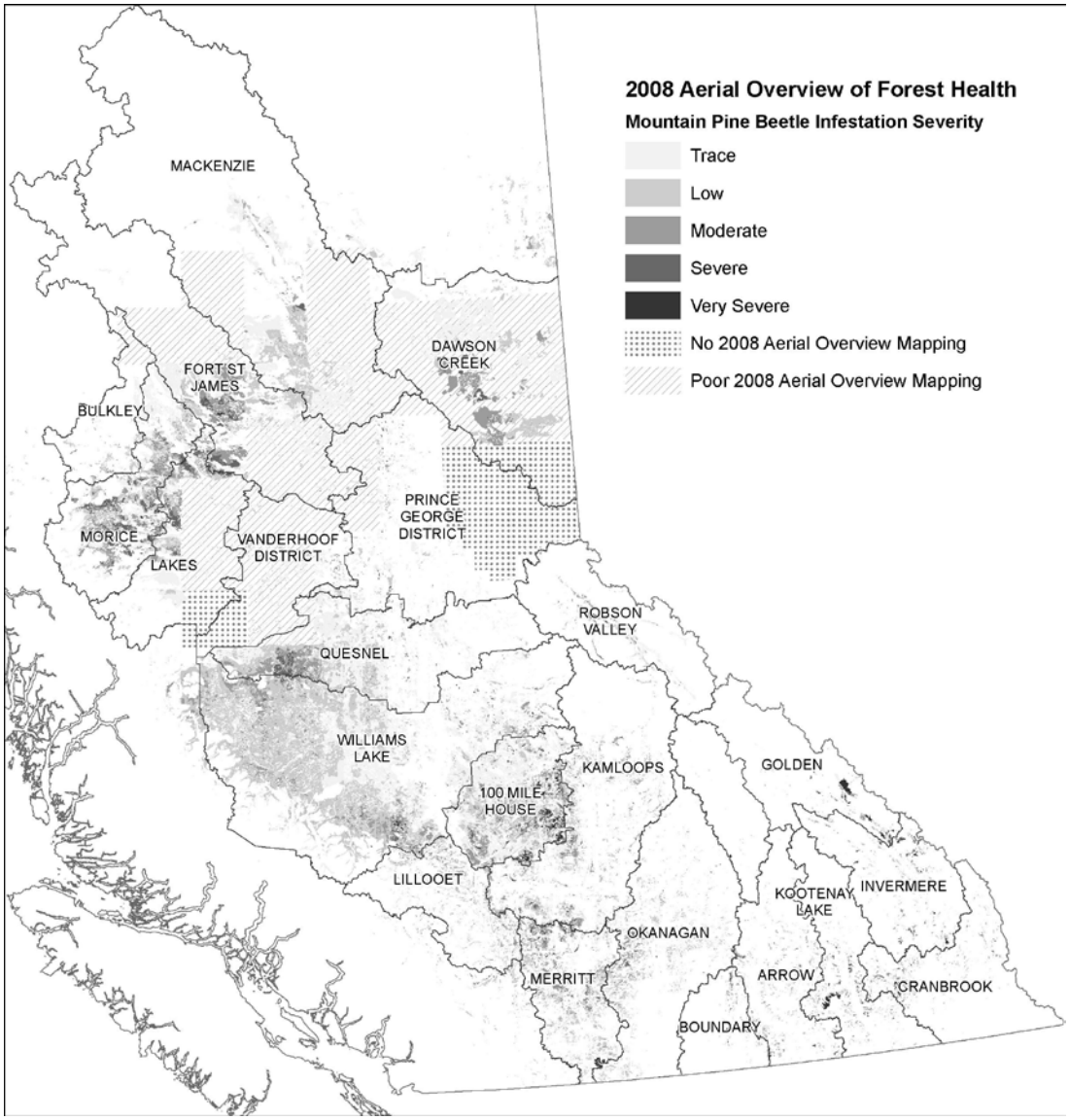


**Figure 1**. 2008 mountain pine beetle infestation severity as mapped by the Provincial Aerial Overview Survey of Forest Health. Note areas which received no or inconsistent (poor) aerial overview surveys.

# 3 Summary of Results

## 3.1 Annual Mortality

### 3.1.1 Observed Annual Mortality

It is now estimated that the provincial peak in annual kill of pine volume for this outbreak occurred during the summer of 2004 and was seen during the summer of

2005[10]. At the peak, there was an annual mortality of approximately 141 million $m^3$ of merchantable (>12.5 cm dbh) pine on the Timber Harvesting Land Base (THLB)[11]. Mortality has declined since then, and it is now estimated that approximately 36 to 43[12] million $m^3$ of merchantable pine on the THLB were observed killed during the summer of 2008 (killed during the summer of 2007) (Figure 2).

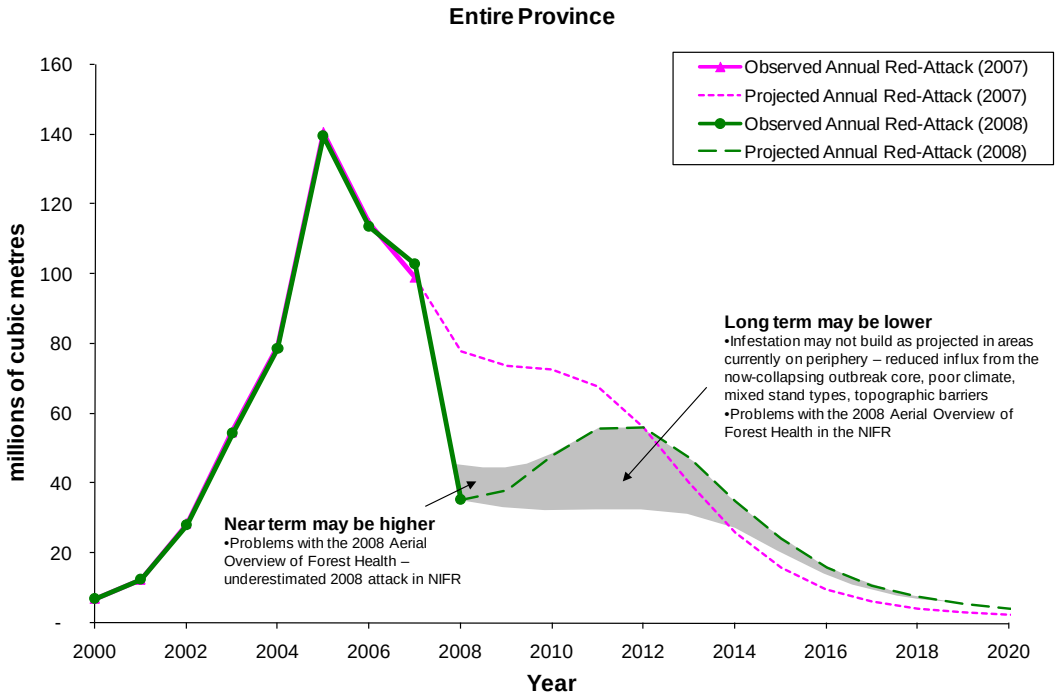


**Figure 2**. Observed and projected annual pine volume killed (red-attack) on the Timber Harvesting Land Base of the entire province. Also a comparison between results produced last year, which were based on the 1999 to 2007 aerial overviews, and current results, which include the 2008 aerial overview. The grey area highlights the uncertainty surrounding both the current and long term estimates of volume loss. The near term estimates may be underestimated by up to 7 million $m^3$ partially due to problems with the Aerial Overview in the Northern Interior Forest Region. The long term estimates may be considerably lower if the beetle does not proceed as projected within those units at the periphery of the current infestation that have large volumes of pine but may not be suitable for mass infestation either due to marginal climate, mixed forest types or topographic barriers to dispersal.

[10] 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) reports on and projects the overview, and therefore "observed mortality" is presented in graphs and tables unless otherwise specifically noted.

[11] All volume figures reported are for the Timber Harvesting Land Base only.

[12] 36 million $m^3$ of pine killed in 2008 on the THLB is what BCMPB is reporting given the 2008 aerial overview. However, the amount killed may be approximately 7 million $m^3$ higher if some compensation is made for inconsistencies in mapping the 2008 aerial overview within Lakes, Mackenzie and Dawson Creek Timber Supply Areas, and Vanderhoof, Fort St. James and Prince George Forest Districts.

The 22 "pine units"[13] can roughly be divided into five categories based on relative changes in pine volume in red-attack phase since the 2007 aerial overview: 1) large relative decrease (>30% drop), 2) small relative decrease (30%-10% drop), 3) essentially unchanged (+/- 9%), 4) small relative increase (10%-30% increase), and 5) large relative increase (>30% increase). The progression from large relative *decrease* through to large relative *increase* generally occurs as one moves south-east and north-west away from the "heart" of the outbreak (Lakes TSA, Vanderhoof Forest District, and west Quesnel TSA) (Figure 3). This is consistent with results from the previous two years, which indicated that the infestation is subsiding in areas both within and adjacent to the heart of the outbreak, and is growing on the periphery.

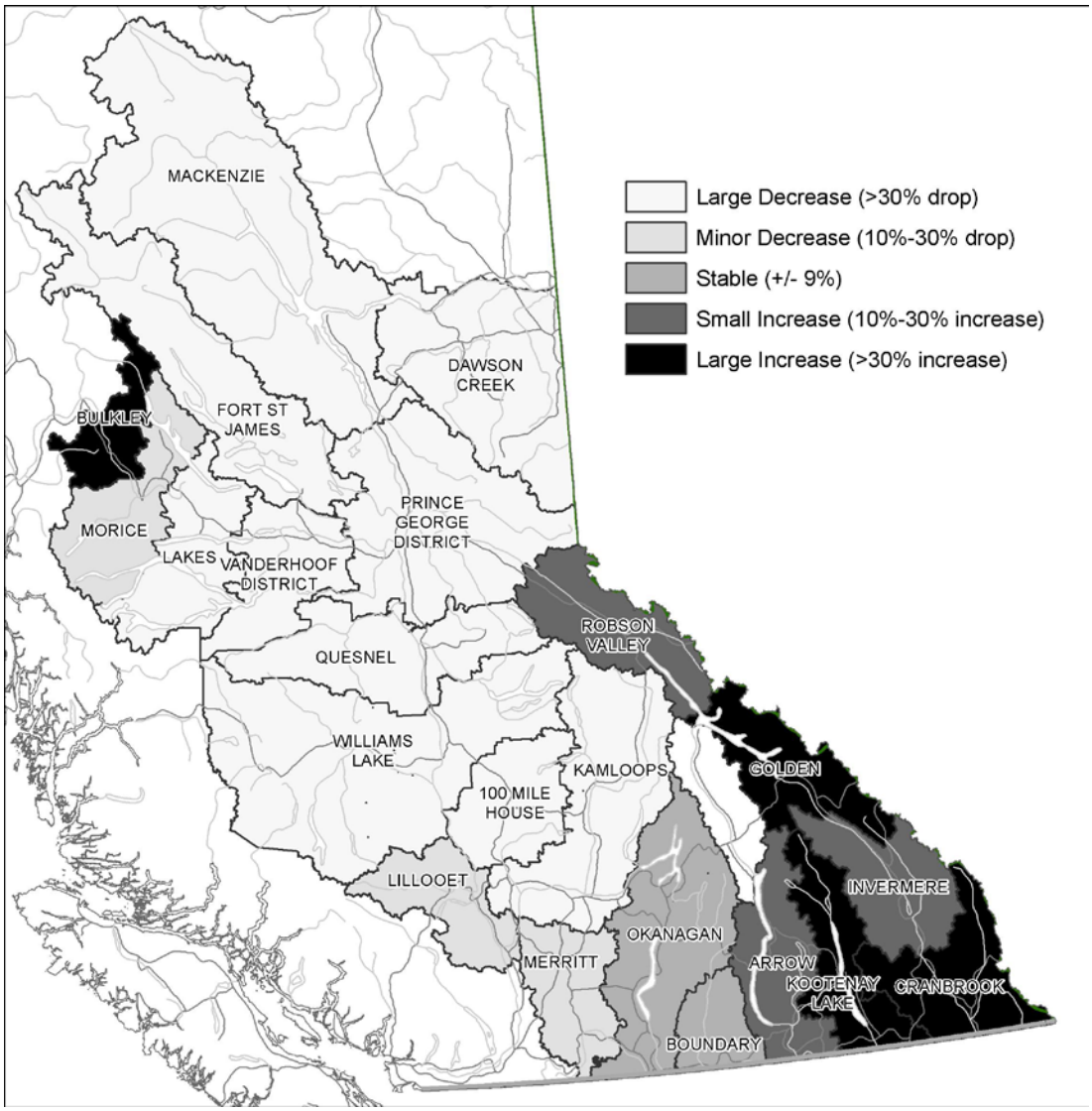


**Figure 3**. Relative changes in observed red-attack volume from 2007 to 2008 for the 22 pine units.

[13] 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.

Table 1 shows that there are 4 "pine units" where the peak in annual volume killed (green-attack) probably occurred in 2004: Vanderhoof Forest District, Quesnel, Lakes and Prince George Forest District. The peak in annual kill probably occurred in the summer of 2005 in Williams Lake, 100 Mile House and Kamloops, and summer 2006 in Fort St. James and Morice. The remaining pine units, near the periphery of the current outbreak, are projected to peak between 2009 and 2012.

**Table 1.** Observed (2004 – 2007) and projected (2008 – 2012) annual **green-attack** volume (millions $m^3$) for the 22 "pine units" (peak year of kill is highlighted by an outlined box). 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).

| | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| **Pine Unit** | **Observed** | | | | **Projected** | | | | |
| Vanderhoof | 24.5 | 7.1 | 3.9 | 0.1 | 0.1 | 0.0 | 0.1 | 0.1 | 0.1 |
| Quesnel | 23.7 | 11.8 | 5.1 | 0.9 | 3.0 | 2.4 | 2.0 | 1.5 | 1.1 |
| Lakes | 15.0 | 9.8 | 6.4 | 1.3 | 0.5 | 0.3 | 0.2 | 0.2 | 0.1 |
| Prince George District | 12.7 | 8.2 | 8.0 | 0.3 | 0.2 | 0.3 | 0.3 | 0.4 | 0.4 |
| Williams Lake | 19.3 | 20.5 | 17.7 | 4.5 | 3.0 | 2.4 | 2.0 | 1.5 | 1.1 |
| 100 Mile House | 8.7 | 17.8 | 7.5 | 1.9 | 0.8 | 0.4 | 0.3 | 0.2 | 0.2 |
| Kamloops | 6.1 | 9.1 | 7.1 | 2.0 | 2.0 | 1.9 | 1.8 | 1.5 | 1.2 |
| Ft St James District | 10.7 | 8.9 | 15.0 | 3.9 | 4.5 | 5.1 | 5.2 | 4.9 | 4.3 |
| Morice | 3.7 | 6.3 | 7.1 | 6.2 | 4.8 | 3.4 | 2.2 | 1.3 | 0.8 |
| Merritt | 1.3 | 2.5 | 4.1 | 3.5 | 4.8 | 5.4 | 5.4 | 4.6 | 3.4 |
| Lillooet | 0.4 | 0.9 | 1.3 | 1.0 | 1.6 | 2.0 | 1.9 | 1.5 | 1.1 |
| Robson Valley | 0.1 | 0.2 | 0.3 | 0.4 | 0.4 | 0.5 | 0.5 | 0.4 | 0.3 |
| Dawson Creek | 0.0 | 0.1 | 2.7 | 1.0 | 1.9 | 3.2 | 4.0 | 3.4 | 2.5 |
| Bulkley | 0.1 | 0.1 | 0.2 | 0.4 | 0.8 | 1.4 | 1.9 | 1.8 | 1.3 |
| Arrow | 0.5 | 0.5 | 0.2 | 0.2 | 0.4 | 0.6 | 0.7 | 0.6 | 0.5 |
| Mackenzie | 0.7 | 2.2 | 5.1 | 2.2 | 4.8 | 8.7 | 11.8 | 13.1 | 10.7 |
| Okanagan | 1.0 | 1.3 | 1.7 | 1.6 | 2.4 | 3.9 | 4.8 | 4.9 | 4.2 |
| Boundary | 0.1 | 0.2 | 0.1 | 0.1 | 0.3 | 0.7 | 1.4 | 1.8 | 1.7 |
| Invermere | 0.2 | 0.3 | 0.2 | 0.3 | 0.3 | 0.7 | 0.9 | 1.0 | 0.9 |
| Golden | 0.2 | 0.3 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.4 | 0.4 |
| Cranbrook | 0.6 | 0.5 | 0.3 | 0.6 | 0.7 | 1.3 | 1.9 | 2.4 | 2.5 |
| Kootenay Lake | 0.3 | 0.4 | 0.3 | 0.5 | 0.5 | 0.7 | 0.9 | 1.1 | 1.1 |
| Grand Total | 130.0 | 109.0 | 94.4 | 32.8 | 37.9 | 45.6 | 50.6 | 48.4 | 39.7 |

### 3.1.2 Projected Annual Mortality

It is now projected that the infestation will build again to approximately 56 million $m^3$ provincially by 2012 as it moves into those areas on the periphery of the current outbreak that contain significant amounts of pine (Mackenzie, Merritt, Okanagan) (see Figure 1). After that time, the infestation will continue to subside rapidly, and within 8 years it is projected that less than 5 million $m^3$ will be killed annually.

However, there is substantial uncertainty surrounding the rate of progress of the provincial annual kill and whether the infestation will in fact build again (see Figure 2). This uncertainty arises, in part, from the uncertainty around when and how intensely the infestation will peak in areas on the periphery of the current outbreak, and the degree to which these areas are driven by influx from the now-collapsing core of the outbreak. Although BCMPB projections include a "dispersal pressure" component to capture some effect of beetle movement between regions, the true

extent and importance of dispersal remains unknown, and BCMPB does not completely account for observed spatial structure in the infestation data. 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[14].

In particular, there are four pine units on the periphery of the current outbreak with significant amounts of live pine (i.e. Mackenzie, Merritt, Okanagan, and Dawson Creek). The timing and intensity of the outbreak in these areas will influence the provincial rate of infestation over the next few years (Figure 4). It is possible that these periphery units will not experience their projected peak annual mortality, and as a result the provincial projection of annual mortality will not build to the 56 million $m^3$ estimated for 2012.

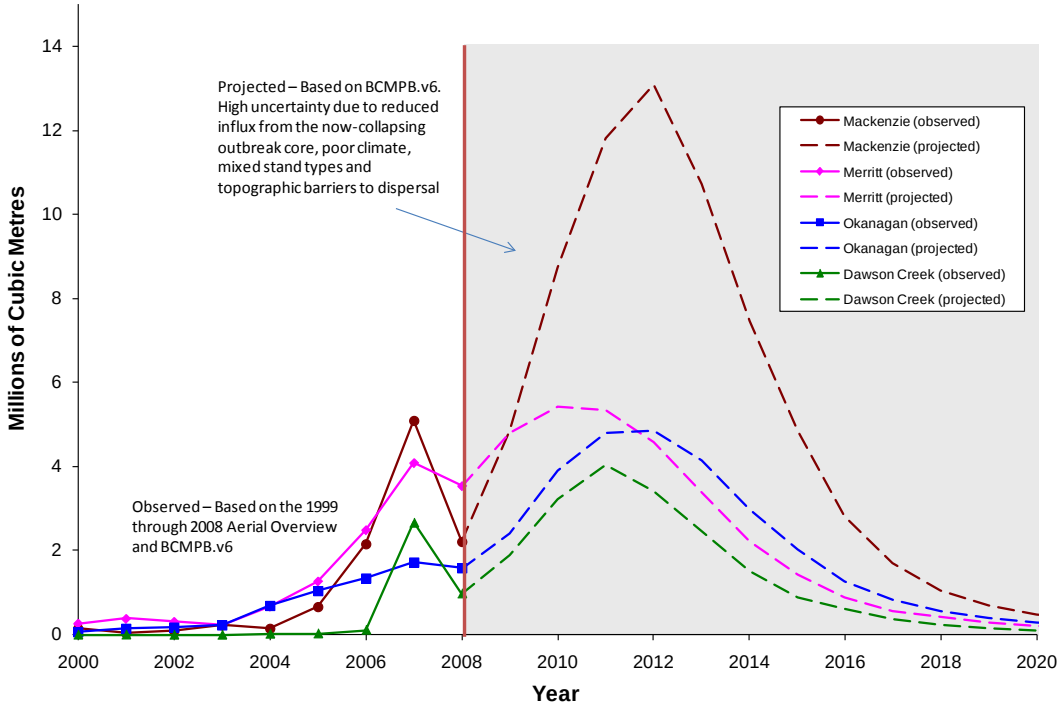


**Figure 4**. Observed and projected annual kill (red-attack) on the Timber Harvesting Land Base for Mackenzie, Merritt, Okanagan, and Dawson Creek Timber Supply Areas. The infestation may not proceed as projected within those units at the periphery of the current infestation.

Other pine units near the periphery of the current outbreak also have not yet experienced their peak in annual kill, but these units contain less pine and, therefore, will have less impact on the provincial rate of infestation subsidence.

[14] Recent detailed MPB population studies in Dawson Creek TSA and west-central Alberta show that external immigration is a key driver of population dynamics in these regions.

### 3.1.3 Comparing Annual Mortality from Last Year's Results to This Year's Results

The annual mortality observed (red-attack) during the summer of 2008 was significantly lower than projected last year by BCMPB.v5 (see Figure 2). Last year, it was projected that approximately 78 million $m^3$ of merchantable pine on the THLB would be observed killed during the summer of 2008. It is now estimated that approximately 36 to 43 million $m^3$ of merchantable pine on the THLB were observed killed during the summer of 2008.

Lower than anticipated annual kill was observed in most of the pine units. The largest relative difference between projected and observed mortality occurred in pine units that have already experienced peak annual mortality; specifically, Fort St. James, Kamloops, Lakes, Prince George, Vanderhoof and Williams Lake. This is consistent with our previous observation that BCMPB underestimates the rate of decline in infestation severity once peak annual mortality has occurred[15]. However, Fort St. James, Lakes, Prince George and Vanderhoof did not receive adequate aerial overview surveys and so it is difficult to tell if, or how much of, the drop is real in these improperly surveyed units.

The pine units that experienced higher than expected amounts of observed kill on the THLB were Cranbrook, Golden and Kootenay Lake. However, this difference between expected and observed kill was relatively small (320,000 $m^3$ higher), and was less than 1% of the provincial difference between expected and observed for 2008.

In the past, there was little information about how infestations might subside. There is now a significant amount of data from central areas where the infestation has mostly subsided, which allows better estimates of infestation-subsidence parameters in the model. However, projections at the outbreak periphery remain relatively uncertain due to uncertainty about the role of dispersal from central regions, effects of weather, topography, the mix of tree species and ages within forest stands, and the lack of standard aerial overview surveys conducted in the Northern Interior Forest Region in 2008.

## 3.2 Cumulative Impact

### 3.2.1 Observed Cumulative Mortality

It was estimated that the cumulative pine mortality from 1998 to 2007 (red- and grey-attack from 1999 to 2008) was between approximately 578 and 585 million $m^3$ (see footnote 12). Based on the model projection, it is estimated that an additional 38 million $m^3$ was killed (green-attack) during the summer of 2008, bringing the cumulative volume killed (green-, red-, and grey-attack) to approximately 616 to 623 million $m^3$. This represents approximately 46% of the total merchantable pine volume on the THLB at the start of the current outbreak (1.35 billion $m^3$). The majority of that mortality (574 to 581 million $m^3$) has occurred in the "pine units" and represents 49% of the pine volume in those units (Table 2).

[15] http://www.for.gov.bc.ca/hre/bcmpb/BCMPB.v4.BeetleProjection.Update.pdf

### 3.2.2 Projected Cumulative Mortality

In the "pine units", it is projected that 69% of the total merchantable pine volume on the THLB at the start of the current outbreak will be killed by 2015 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 2019. There is substantial variability in the cumulative percentage of pine killed in 2008, ranging from 81% in Quesnel to 6% in Boundary. However, it is projected there will be much less variability by the time the infestation subsides (81% to 62% in 2019).

**Table 2.** Cumulative percentage of pine projected to be killed (green-, red- and grey-attack) in each "pine unit" during selected years.

| | Year | | | |
|---|---|---|---|---|
| **Pine Unit** | **2008** | **2011** | **2015** | **2019** |
| Quesnel | 81% | 81% | 81% | 81% |
| Lakes | 74% | 75% | 75% | 76% |
| 100 Mile House | 73% | 75% | 76% | 77% |
| Vanderhoof District | 72% | 72% | 72% | 73% |
| Williams Lake | 61% | 65% | 67% | 68% |
| Prince George District | 60% | 61% | 63% | 64% |
| Morice | 54% | 67% | 70% | 70% |
| Kamloops | 52% | 61% | 67% | 69% |
| Ft St James District | 49% | 63% | 73% | 75% |
| Arrow | 33% | 57% | 72% | 75% |
| Robson Valley | 29% | 51% | 64% | 67% |
| Lillooet | 28% | 55% | 68% | 72% |
| Merritt | 28% | 51% | 63% | 65% |
| Golden | 22% | 41% | 61% | 66% |
| Dawson Creek | 19% | 53% | 71% | 74% |
| Kootenay Lake | 18% | 38% | 63% | 68% |
| Okanagan | 16% | 40% | 58% | 62% |
| Invermere | 15% | 37% | 57% | 61% |
| Bulkley | 14% | 53% | 73% | 76% |
| Mackenzie | 13% | 42% | 64% | 68% |
| Cranbrook | 12% | 29% | 55% | 63% |
| Boundary | 6% | 32% | 61% | 66% |
| **Grand Total** | **49%** | **61%** | **69%** | **71%** |

However similar to the annual mortality, there is substantial uncertainty surrounding the long-term projections of cumulative pine volume mortality (Figure 5). Again, this uncertainty arises, in part, from the uncertainty around when and how intensely the infestation will peak in areas on the periphery of the current outbreak, and the degree to which these areas are driven by influx from the 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.

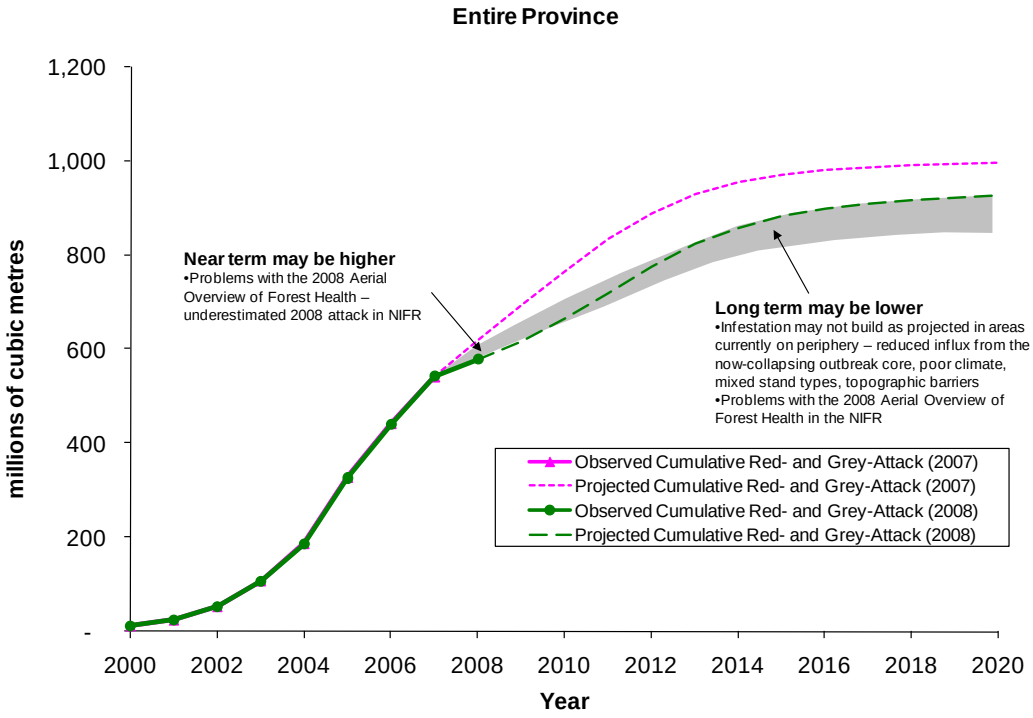


**Figure 5.** The observed and projected cumulative kill (red- and grey-attack) in the province. The grey area highlights the uncertainty surrounding both the current and long term estimates of volume loss. Also a comparison between results produced last year, which were based on the 1999 to 2007 aerial overviews, and current results, which include the 2008 aerial overview.

### 3.2.3 Comparing Cumulative Mortality from Last Year's Results to This Year's Results

Last year, it was projected that the infestation would kill 76% of the provincial pine volume by 2016, and that mortality would then slow substantially and the infestation would essentially be over by 2019 with 77% of the pine volume killed (see Figure 5). It is now projected that 71% of the merchantable pine volume will be killed once the infestation is essentially over in 2019. The 6% difference between what was projected for 2019 in last year's results and this year's results is significant, and highlights the large uncertainty surrounding the estimation of cumulative pine volume kill, which arises from a couple of factors. One is the model's consistent underestimation of how fast the infestation subsides after it has peaked within a management unit. The second, and possibly more important, is underestimation or overestimation of the red-attack by the aerial overview.

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. In particular, the estimation of current and future cumulative pine loss has been impacted by the large underestimation of red-attack in the Northern Interior Forest Region aerial overview surveys in 2008.

For example, the Prince George Forest District shows almost no new red-attack in 2008, most likely due to problems with the 2008 aerial overview survey in the NIFR (Figure 6). This, in addition to the fact that peak infestation had already occurred in 2005 and adjacent areas showed very low long distance dispersal pressure (partially caused by the underestimation of new red-attack by the aerial overview within adjacent areas), resulted in a projection that the infestation is essentially over in the Prince George Forest District. The impact on the projected cumulative pine volume kill is a fairly significant drop compared to the estimate provided last year (Figure 7).

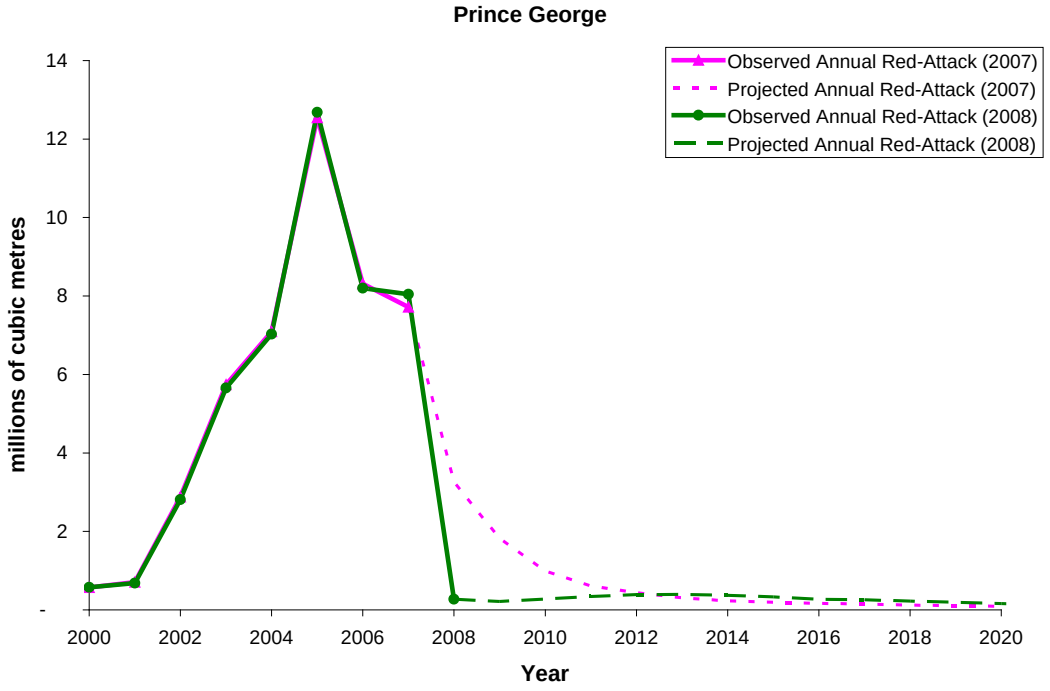


**Figure 6.** The observed and projected annual pine volume kill (red-attack) in the Prince George Forest District. Also a comparison between results produced last year, which were based on the 1999 to 2007 aerial overviews, and current results, which include the 2008 aerial overview.

Although the results of the 2008 aerial overview are exceptional in their underestimation of red-attack, they highlight the impact that underestimation and overestimation of the amount of red-attack by the aerial overview surveys has on projected cumulative pine loss. 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 estimated by BCMPB will vary significantly from those actually experienced. For example, BCMPB currently estimates that the Prince George Forest District has lost approximately 60% 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%. This is a significant difference.

It is for this reason that it is imperative to collect accurate estimates of cumulative pine loss due to MPB within those management units nearing the end of their

infestation (e.g. 100 Mile House, Lakes, Quesnel, Vanderhoof) using either field sampling or aerial photograph interpretation techniques.

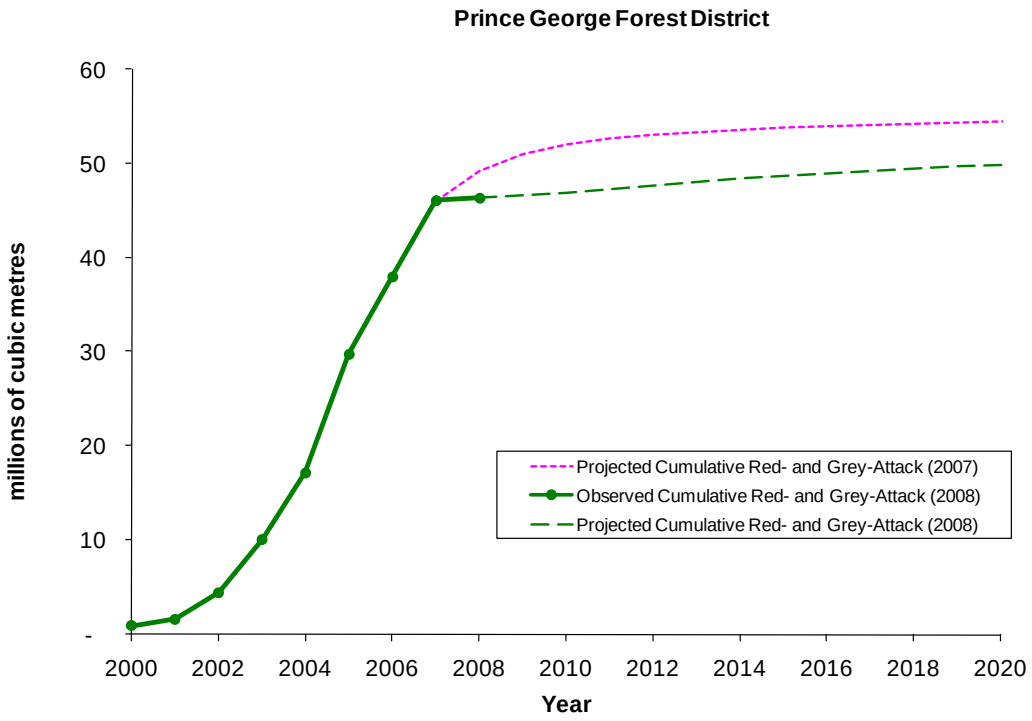


**Figure 7.** The observed and projected cumulative pine volume kill (red- and grey-attack) in the Prince George Forest District. Also a comparison between results produced last year, which were based on the 1999 to 2007 aerial overviews, and current results, which include the 2008 aerial overview.

# 4 Conclusions and Caveats

The principal conclusions about the infestation are:

- Approximately 46% of the merchantable pine volume in the province has likely already been killed.
- The worst year of the infestation, at a provincial scale, was 2004.
- The volume of pine killed by the infestation has declined rapidly, at a provincial scale, since 2004.
- The infestation is projected to build again to approximately 56 million $m^3$ provincially by 2012 as it moves into those areas on the periphery of the current outbreak that contain significant amounts of pine (Mackenzie, Merritt, Okanagan). However, there is substantial uncertainty around this aspect of the projection, in part due to the inconsistencies in mapping the 2008 aerial overview within Lakes, Mackenzie and Dawson Creek Timber Supply Areas, and Vanderhoof, Fort St. James and Prince George Forest Districts.
- After 2012, the infestation will begin to subside rapidly again, and within 8 years it is projected that less than 5 million $m^3$ will be killed annually.
- Approximately 70% of the pine volume in the "pine units" will be killed by 2017. The infestation will have largely subsided by that time and only an additional 1% may be killed after 2019. This is significantly less than the

80% mortality initially projected by Version 1 of the model released in 2004. However, there is also substantial uncertainty around this aspect of the projection.

- For those management units nearing the end of their current infestation, it is imperative to collect accurate estimates of cumulative pine loss due to MPB using either field sampling or aerial photograph interpretation techniques.
- There is substantial variability in the timing of the peak in the infestation in different areas of the province.

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.
- 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 account for 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.

# 5 Acknowledgements

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- Terry Shore, Pacific Forestry Centre, Canadian Forest Service
- Bill Riel, Pacific Forestry Centre, Canadian Forest Service
- Peter Hall, Forest Practices Branch, BC Forest Service

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