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

# Update of the infestation projection based on the Provincial Aerial Overview Surveys of Forest Health conducted from 1999 through 2011 and the BCMPB model (year 9)

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February 28, 2012

# Summary

For each of the past eight years, a team led by the BC Ministry of Forests, Lands and Natural Resource Operations 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 Surveys 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 2011 Provincial Aerial Overview Surveys of Forest Health and the BCMPB model. This year's result of observed annual kill is lower than what was anticipated from the previously published results[5] (aka "last year's update report"). The estimate of future infestation impacts are also lower than what was published previously.

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 710 million $m^3$ (53%) of the merchantable pine volume in the province has likely already been killed (red- and grey-attack), which includes approximately 20 million $m^3$ observed as red-attack in the summer 2011.
- The annual volume of mature merchantable red-attack pine on the THLB may remain above 10 million $m^3$ for the next couple of years, and by 2017 it is estimated that less than 5 million $m^3$ will be killed annually.
- Approximately 57% of the pine volume in the province will be killed by 2017. The infestation will have largely subsided by that time and only an additional 1% may be killed by 2021. This is significantly less than the 80% projected mortality published in 2006.

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] Riel W.G, A. Fall, T. L. Shore and L. Safranyik. 2004. A Spatio-temporal Simulation of Mountain Pine Beetle Impacts on the Landscape. Canadian Forest Service. Victoria, BC
[5] http://www.for.gov.bc.ca/ftp/hre/external/!publish/web/bcmpb/year8/BCMPB.v8.BeetleProjection.Update.pdf

# 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].

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

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[6] http://www.for.gov.bc.ca/ftp/hre/external/!publish/web/bcmpb/year3/BCMPB.v3.ModelDocumentation.Update.pdf

[7] The optimal period for aerial surveys of mountain pine beetles is listed in Table 1 of http://ilmb.gov.bc.ca/risc/pubs/teveg/foresthealth

# Summary of Results

## Annual Mortality

### Observed Annual Mortality

As reported in prior reports of the Provincial-Level Projection of the Current Mountain Pine Beetle Outbreak, 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 20 million $m^3$ of mature merchantable pine on the THLB were observed newly killed (red-attack phase) during the summer of 2011 (green-attack phase during the summer of 2010) (Figure 1). With the addition of the 2011 aerial overview survey mapping and the replacement of the erroneous parts of the past aerial overview survey mapping, the volume of red-attack pine has decreased every year since 2005.

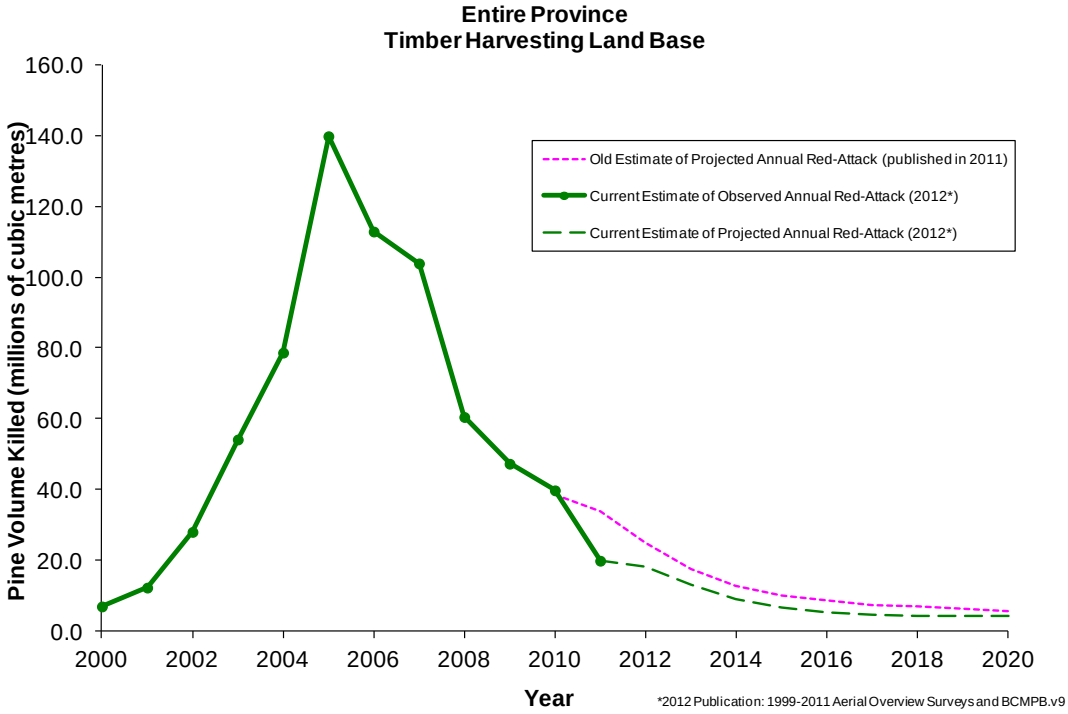


**Figure 1**. Observed and projected annual mature pine volume killed (red-attack) on the Timber Harvesting Land Base of the entire province. Also a comparison between results produced last year, which were based on the 1999 to 2010 aerial overviews, and current results, which include the 2011 aerial overview.

[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.

*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 2). In general, most of the pine units experienced a decrease in pine mortality – primarily a *large* relative decrease. The exceptions were Robson Valley and Boundary, which remained essentially unchanged, and Bulkley, which continued to experience a increase in observed red-attack.

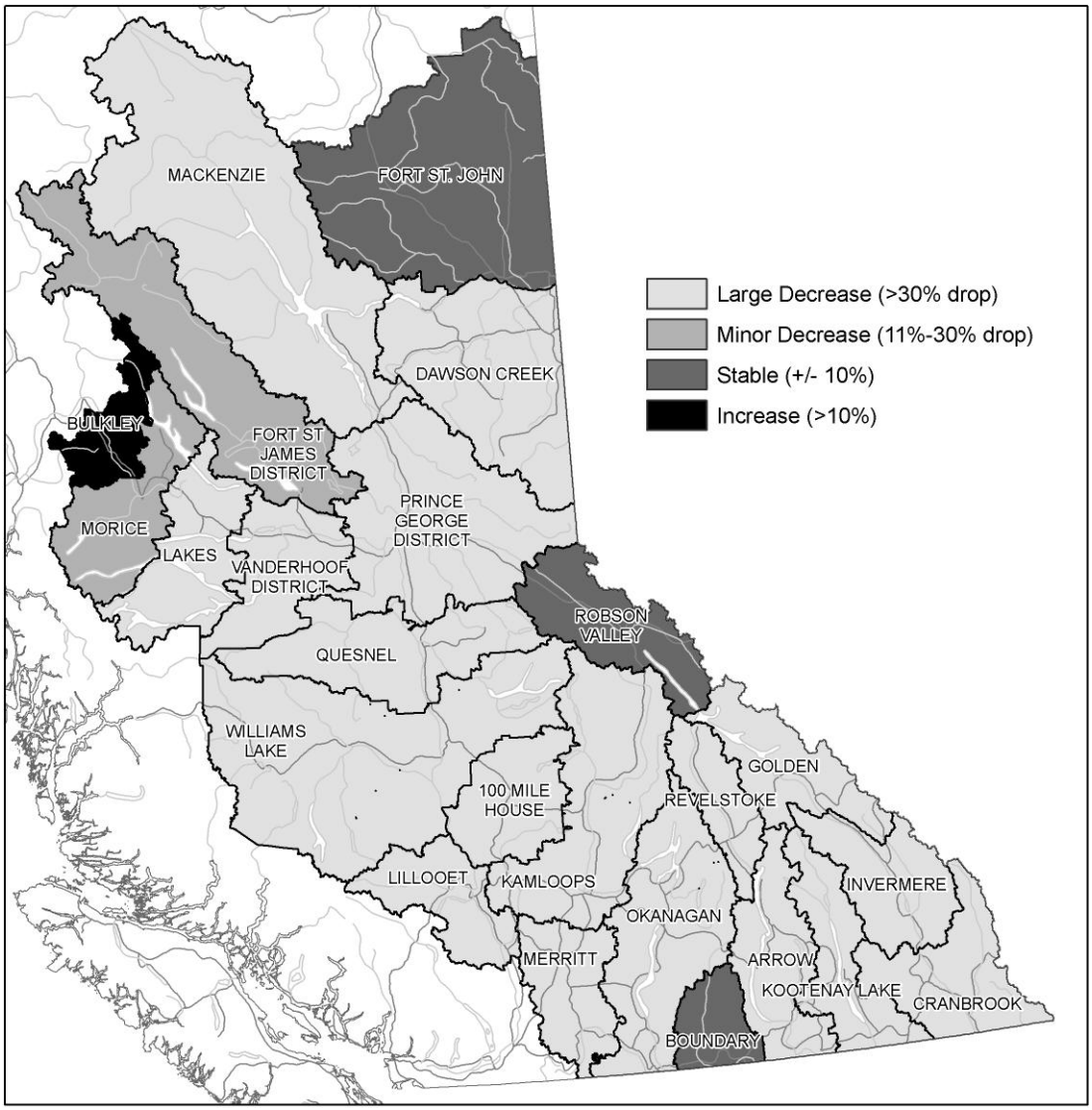


**Figure 2**. Relative changes in observed red-attack volume from 2009 to 2011 for the 22 pine units, Fort St John and Revelstoke TSAs.

[10] Pine units are defined as those Timber Supply Areas (TSA) where more than 10% of the merchantable volume is pine. Although not considered a "pine unit" in past publications due to initial speculation that it was climatically unsuitable to support an MPB infestation, Fort St John did have more than 10% of the merchantable pine volume at the beginning of the current MPB infestation. Note that the individual forest districts in the Prince George TSA are reported on separately.

Similar to what was reported in last year's update report, Table 1 and Figure 3 show 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 exception being Bulkley TSA, which is projected to experience peak annual pine volume loss sometime in the future.

**Table 1.** Observed (2005 – 2011) and projected (2012 – 2014) annual volume (in millions $m^3$) of mature merchantable red-attack pine for the THLB portion of the 22 "pine units" and Fort St John TSA (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 | 3.9 | 1.1 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Quesnel TSA | 23.8 | 11.8 | 5.1 | 0.9 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lakes TSA | 15.0 | 9.8 | 6.4 | 2.7 | 0.6 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Prince George District | 12.7 | 8.2 | 8.2 | 2.4 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Williams Lake TSA | 19.3 | 20.4 | 17.6 | 4.8 | 2.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| 100 Mile House TSA | 8.7 | 17.8 | 7.5 | 1.8 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Kamloops TSA | 6.2 | 8.8 | 6.8 | 2.0 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Arrow TSA | 0.5 | 0.6 | 0.2 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 |
| Golden TSA | 0.1 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Boundary TSA | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Ft. St. James District | 10.8 | 8.9 | 15.2 | 9.7 | 6.2 | 5.1 | 4.1 | 3.6 | 2.2 | 1.1 |
| Morice TSA | 3.7 | 6.3 | 7.1 | 6.9 | 2.2 | 1.4 | 1.0 | 1.3 | 1.0 | 0.6 |
| Merritt TSA | 1.3 | 2.4 | 3.8 | 3.6 | 3.4 | 0.9 | 0.2 | 0.2 | 0.1 | 0.1 |
| Okanagan TSA | 1.0 | 1.3 | 1.6 | 1.6 | 1.3 | 0.8 | 0.5 | 0.4 | 0.4 | 0.4 |
| Lillooet TSA | 0.4 | 0.9 | 1.3 | 1.1 | 0.8 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 |
| Dawson Creek TSA | 0.0 | 0.1 | 2.7 | 3.3 | 1.9 | 3.2 | 1.1 | 1.2 | 1.0 | 0.8 |
| Cranbrook TSA | 0.6 | 0.5 | 0.3 | 0.6 | 0.3 | 0.3 | 0.1 | 0.1 | 0.2 | 0.2 |
| Kootenay Lake TSA | 0.3 | 0.5 | 0.3 | 0.5 | 0.2 | 0.2 | 0.0 | 0.1 | 0.1 | 0.1 |
| Invermere TSA | 0.2 | 0.3 | 0.2 | 0.3 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 |
| Mackenzie TSA | 0.6 | 2.1 | 6.4 | 9.1 | 21.2 | 17.9 | 6.8 | 5.5 | 3.5 | 2.0 |
| Ft. St. John TSA * | 0.0 | 0.0 | 0.0 | 0.4 | 1.2 | 3.9 | 3.5 | 3.0 | 2.2 | 1.4 |
| Robson Valley TSA | 0.1 | 0.2 | 0.3 | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.2 | 0.1 |
| Bulkley TSA | 0.1 | 0.1 | 0.2 | 0.6 | 0.6 | 1.0 | 1.2 | 1.4 | 1.1 | 0.8 |
| **Pine Units Total** | **130.2** | **108.2** | **95.4** | **53.9** | **42.4** | **32.4** | **15.8** | **14.5** | **10.3** | **7.0** |
| **Provincial Total** | **139.8** | **112.9** | **103.9** | **60.5** | **47.3** | **39.8** | **19.9** | **18.2** | **13.2** | **9.2** |

* Ft. St. John TSA is not one of the historic Pine Units so it has been ommitted from the Pine Units Total

Although not considered a "pine unit" in past publications due to initial speculation that it was climatically unsuitable to support a multi-year MPB infestation, Fort St John has been experiencing continued MPB infestations over the past four years. Initial infestation growth was observed in 2008 and continued rapidly until 2010. The amount of red-attack observed in 2011 remains relatively high for this TSA at approximately 3.5 million $m^3$.

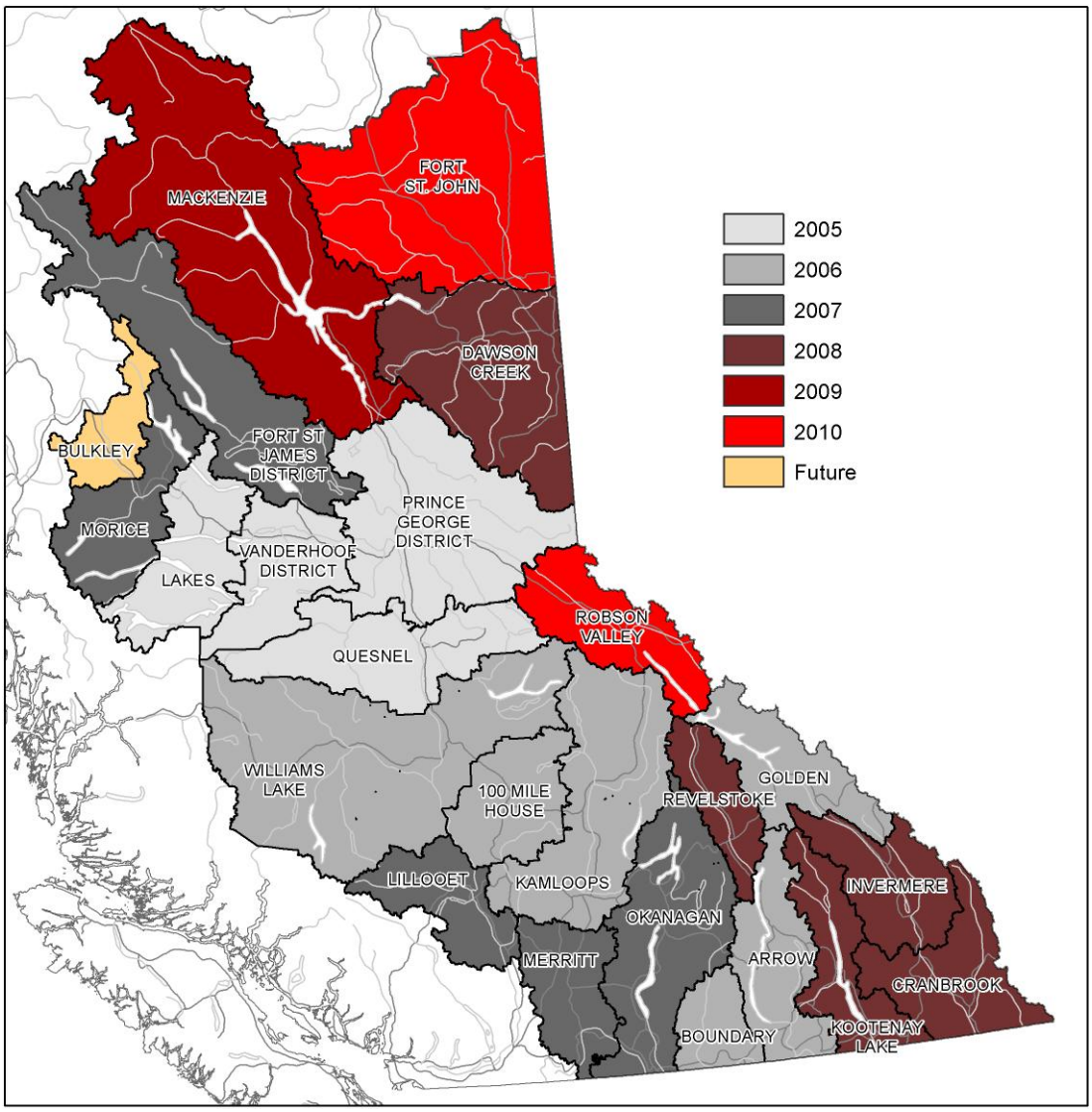


**Figure 3**. Peak year of observed red-attack volume for the 22 pine units, Fort St John and Revelstoke TSAs.

## Projected Annual Mortality

It is now projected that the provincial infestation will continue to kill pine at a rate considerably lower than was observed just a few years prior. Losses over 10 million $m^3$ may still be observed over the next couple of years, but by 2017 it is estimated that less than 5 million $m^3$ will be killed annually (See Figure 1).

As noted in last year's update report, BCMPB projections estimate that annual volume of mature merchantable red-attack pine on the THLB will continue to increase in the southeast of the province –most notably Boundary TSA– even though most of this area of the province experienced peak infestation either in 2005 or 2008. It is my opinion that BCMPB.v9 is overestimating the epidemic growth in the southeast of the province, and that instead the kill will continue to subside or remain stable.

I base this conclusion on the fact that over the past three to six years the infestation in southeast of the province 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 now-collapsing core of the outbreak. Outbreaks in peripheral landscapes with marginal climatic suitability, mixed tree types, and larger topographic barriers may not experience the projected peak annual mortality projected by BCMPB once the central outbreak subsides.

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

As noted above, the current estimate of observed annual volume of mature merchantable red-attack pine on the THLB in 2011 is approximately 20 million $m^3$. This is lower than the 34 million $m^3$ projected to be red-attack in 2011 using the 1999 through 2010 aerial overview surveys and BCMPB.v8. This discrepancy between the newly observed red-attack and previously projected red-attack for the same time period is a continuation of what has been reported since peak red-attack in 2005; and that is that since its peak in 2005, the provincial infestation is subsiding faster than projected.

## Cumulative Impact

### Observed Cumulative Mortality

It is now estimated that the provincial cumulative volume of mature merchantable pine mortality (red- and grey-attack) from 1999 to 2011 is approximately 710 million $m^3$ (Figure 4). This represents approximately 53% 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 (651 million $m^3$) has occurred in the "pine units" and represents 55% of the mature merchantable pine volume in those units (Table 2).

### Projected Cumulative Mortality

Provincially, it is projected that 57% of the total merchantable pine volume on the THLB at the start of the current outbreak will be killed by 2017 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 1% may be killed by 2021 (see Figure 4).

In the "pine units", 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 2017 if the infestation continues to behave as projected by the model (Table 2). By 2021, it is projected that 60% of total merchantable pine volume on the THLB in the pine units will be killed.

**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.

| | Year | | | |
|---|---|---|---|---|
| **Pine Unit** | **2011** | **2012** | **2017** | **2022** |
| Quesnel TSA | 89.7 (81%) | 89.7 (81%) | 89.7 (81%) | 89.7 (81%) |
| Lakes TSA | 54.0 (76%) | 54.0 (76%) | 54.1 (76%) | 54.1 (76%) |
| Vanderhoof Forest District | 71.3 (73%) | 71.3 (73%) | 71.3 (73%) | 71.4 (73%) |
| 100 Mile House TSA | 41.5 (72%) | 41.5 (72%) | 41.6 (72%) | 41.6 (72%) |
| Ft. St. James Forest District | 70.5 (64%) | 74.1 (68%) | 78.7 (72%) | 79.0 (72%) |
| Prince George Forest District | 49.1 (63%) | 49.1 (63%) | 49.2 (63%) | 49.2 (63%) |
| Williams Lake TSA | 86.4 (60%) | 86.4 (60%) | 86.6 (60%) | 87.4 (61%) |
| Mackenzie TSA | 64.9 (56%) | 70.4 (60%) | 78.1 (67%) | 78.9 (68%) |
| Morice TSA | 31.5 (55%) | 32.8 (57%) | 35.3 (62%) | 35.6 (62%) |
| Kamloops TSA | 28.8 (49%) | 28.9 (49%) | 29.1 (49%) | 29.8 (51%) |
| Robson Valley TSA | 2.5 (41%) | 2.8 (45%) | 3.2 (51%) | 3.2 (52%) |
| Dawson Creek TSA | 12.3 (40%) | 13.5 (44%) | 16.8 (54%) | 17.7 (57%) |
| Arrow TSA | 2.4 (31%) | 2.4 (31%) | 2.9 (36%) | 3.4 (43%) |
| Bulkley TSA | 3.9 (30%) | 5.3 (41%) | 8.0 (61%) | 8.4 (64%) |
| Merritt TSA | 17.7 (27%) | 17.9 (27%) | 18.6 (28%) | 19.7 (30%) |
| Lillooet TSA | 5.0 (26%) | 5.1 (26%) | 5.6 (29%) | 6.2 (32%) |
| Ft. St. John TSA * | 9.1 (23%) | 12.0 (30%) | 17.9 (45%) | 19.3 (48%) |
| Golden TSA | 1.0 (21%) | 1.1 (21%) | 1.3 (25%) | 1.6 (31%) |
| Kootenay Lake TSA | 2.3 (18%) | 2.4 (18%) | 2.9 (22%) | 3.6 (28%) |
| Okanagan TSA | 9.4 (16%) | 9.9 (17%) | 12.1 (21%) | 14.9 (26%) |
| Invermere TSA | 1.9 (16%) | 2.0 (17%) | 2.8 (24%) | 3.6 (31%) |
| Cranbrook TSA | 3.6 (12%) | 3.8 (12%) | 5.2 (17%) | 7.3 (24%) |
| Boundary TSA | 0.8 (6%) | 0.9 (6%) | 1.8 (12%) | 3.6 (24%) |
| **Pine Units Total** | **650.8 (55%)** | **665.3 (56%)** | **694.8 (59%)** | **709.9 (60%)** |
| **Provincial Total** | **710.0 (53%)** | **728.2 (54%)** | **767.4 (57%)** | **787.8 (58%)** |

* Ft. St. John TSA is not one of the historic Pine Units so it has been ommitted from the Pine Units Total

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 6% in Boundary TSA. As the infestation continues to subside, it is projected that the range between most impacted and least impact pine units will shrink slightly, with 81% in Quesnel TSA and 24% in Boundary 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 (as discussed in the Projected Annual Mortality section above).

### 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 58% of the merchantable pine volume on the THLB at the start current MPB infestation outbreak. 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 (see Figure 4).

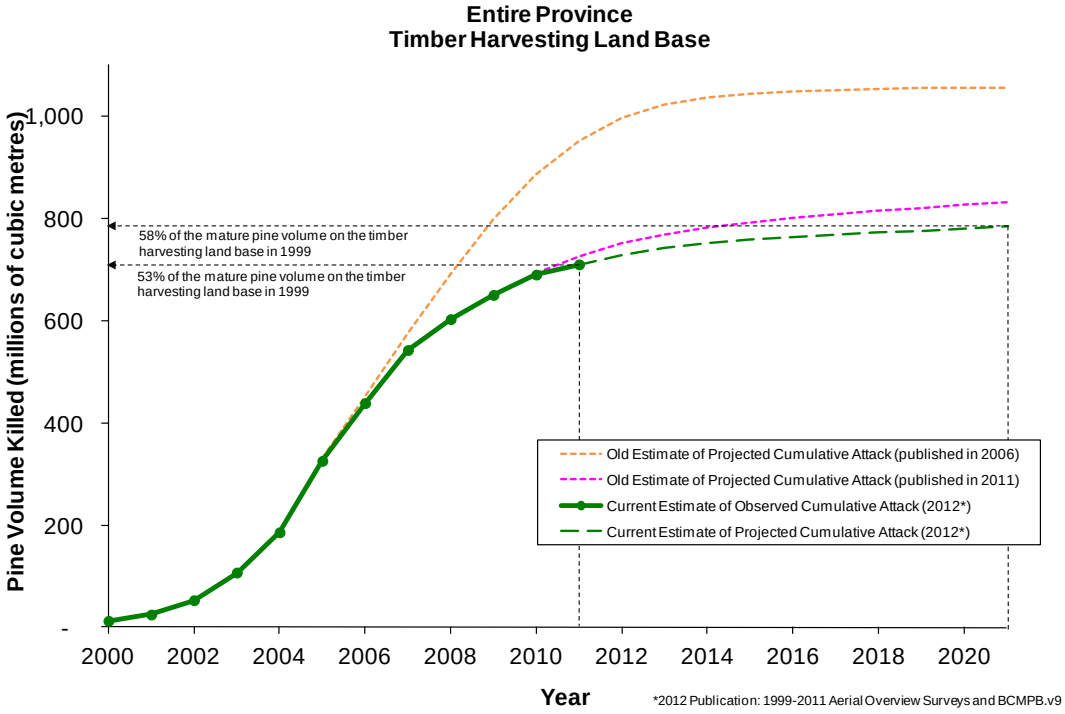


**Figure 4.** The observed and projected cumulative kill (red- and grey-attack) in the province. Also a comparison between: 1) results produced in 2006, which were based on BCMPB version 3 and the 1999 to 2005 aerial overview surveys; 2) results produced last year, which were based on BCMPB version 8 and the 1999 to 2010 aerial overviews; and 3) current results, which include the 2011 aerial overview.

This difference (80% projected in Year 3 of the project to 58% in current results) highlights the uncertainty surrounding the projection 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].

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

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.

# 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 710 million $m^3$ (53%) of the merchantable pine volume in the province has likely already been killed (red- and grey-attack), which includes approximately 20 million $m^3$ observed as red-attack in the summer 2011.
- The annual volume of mature merchantable red-attack pine on the THLB may remain above 10 million $m^3$ for the next couple of years, but by 2017 it is estimated that less than 5 million $m^3$ will be killed annually.
- Approximately 57% of the pine volume in the province will be killed by 2017. The infestation will have largely subsided by that time and only an additional 1% may be killed by 2021. This is significantly less than the 80% projected mortality published in 2006.

# Caveats

The main caveats about these conclusions are:

- Current mortality estimates are based on an analysis of the Provincial Aerial Overview of Forest Health and in some places annual mortality projected by BCMPB. 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 on 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.

# Acknowledgements

This report is a continuation of the work originally conducted by the following people:

- Marvin Eng, Forest Practices Board
- Josie Hughes, Research Consultant
- Andrew Fall, Gowlland Technologies Ltd.
- Terry Shore, formerly with Pacific Forestry Centre, Canadian Forest Service
- Bill Riel, Pacific Forestry Centre, Canadian Forest Service
- Peter Hall, formerly with Forest Practices Branch, BC Forest Service

Each of their individual contributions to this project has been immensely important in advancing the model to where it is currently.

Thanks also to Albert Nussbaum for reviewing this document and providing feedback.