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Determining the threat of mountain pine beetle range expansion in new habitats:
The impact of phenology and survival variation on spread

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Study participants and their roles and contributions

Kathy Bleiker, Research Scientist, CFS (Pacific)	Lead for field element.
Barry Cooke, Research Scientist, CFS (Northern)	Lead for modeling work.
Greg Smith, Forestry Officer, CFS (Pacific)	Support for study.
Forest Health Technical Pool, CFS (Pacific)	A number of technicians will assist with field work.
Jim Weber, Technician, CFS (Northern)	Support for some aspects of field study.
Les Safranyik, Emeritus Scientist, CFS (Pacific)	Retired scientist providing valuable advice.
Dan Lux, Forest Health Manager, AB SRD; Ken White, Entomologist, BC MFR; Rory McIntosh, Prov. Forest Entomologist, SK MoE; Irene Pines, Forest Health Biologist, MB CON	Participants and clients that will provide substantial in-kind contributions by assisting with site selection, field work at certain sites or climate station data.
SERG-I	Funding partner and members are potential clients.
Foothills Research Institute (FRI Contact: Don Pudlubny)	Funding partner, in-kind contributor and client.
Forest Companies in AB and BC	Anticipated clients and in-kind supporters. Aid with site location and approval.

Abstract

The key to determining the risk of spread of mountain pine beetle (MPB) in Canada's boreal and northern forests lies in understanding the biological and environmental processes driving population size in the new, expanded range where the insect is subject to different weather, organisms and host trees than in its historic range. Most of our current knowledge on MPB population dynamics comes from south-eastern BC; however, recent findings suggest key geographic differences may exist between populations that could affect their eruptive potential and spread rate. In the summer of 2010, we established a total of 18 research sites in 3 geographic regions (southern BC, north-western BC, and north-eastern BC/northern AB) as part of a 3-year study to assess the effects of under-canopy and under-bark temperatures on MPB development, mortality and attack behaviour. ***Here, we report on the study design and progress to date as we enter the first winter of the field study.*** In addition to assessing geographic variation in MPB development and survival, this work will generate data that can be used to: develop guidelines to effectively sample mortality for population trends in areas with complex phenology and high variation in mortality; update population models (phenology and survival); and support susceptibility and connectivity analysis. *Our overall objective* is to provide the biological knowledge and an effective decision-making tool that can be used to develop management practices and strategies to slow the spread of MPB in Canada.

Background

MPB is exposed to dramatically different weather, topographies and even host tree species in its expanded range east of the Rocky Mountains in northern AB. Overwintering survival and development (phenology) appear to be highly variable in the newly-invaded region compared to the beetle's historic range west of the Divide in BC. The seminal work on MPB by L. Safranyik, R. Reid and others, which forms our current understanding of MPB biology and population dynamics, comes mainly from populations in south-eastern BC (e.g., Invermere, Canal Flats). This area has a distinct regional climate, pine hosts that have co-evolved with the MPB and biotic communities specific to the region. The following findings suggest that key differences could exist between MPB populations in the traditional and expanded ranges:

- Faster development in northern vs. southern populations within traditional range in the United States and BC; larger beetles in southern populations (Bentz & others, USDA)
- Greater pupal chamber production in northern vs. southern populations in BC (Cudmore & Lindgren, UNBC)

- Multiple cohorts, asynchronous development, high variation in survival and phenology in trees in the same stand or between proximate stands in northern AB and northern BC (observations by Bleiker, CFS; Hundsdoerfer, AB SRD; White, BC MNRO)
- Qualitative and quantitative differences in the defensive chemistry of lodgepole vs. jack pine as well as between populations of lodgepole pine that have co-evolved (within traditional range) vs. not co-evolved (north of traditional range) with the MPB (Clarke and Huber, UNBC)
- Potential impact of insulating properties of hosts as jack pine has thicker bark than lodgepole pine

Complex phenology may affect the MPB's ability to survive, aggregate and reproduce – this will ultimately determine its eruptive and spread potential in the boreal forest. Variation in development and survival can not be predicted using the coarse spatial scale of available weather station data. Therefore, in the summer of 2010 we initiated a study that quantifies variation in MPB development and survival and relates it to under-canopy and under-bark temperatures in three geographic areas.

Specific Objectives

i) Quantify geographic variation in MPB phenology (development) and overwintering survival and relate to under-canopy and under-bark temperatures; and

ii) Provide data necessary to validate and re-parameterize the Powell-Régnierè process-based climatic suitability model for MPB (an integrated ecophysiological model, which couples phenology and overwintering survival) using the necessary, relevant field data for calibration and practical application in AB and BC.

Progress to Date

Site selection. In May 2010, we selected a total of 18 research sites in 3 geographic regions (southern BC, north-western BC, north-eastern BC/northern AB) (Figure 1, Table 1). Sites were located in both the historical range and the recently-invaded range of the MPB and cover a range of climates as well as elevations within a region. All sites had surviving MPB populations in May 2010 (i.e., living brood found in 2009 attacks) with susceptible pine still in the stand. Suitable, multi-year sites were difficult to locate in northern AB due to aggressive beetle control activities and mature (susceptible) pine being targeted for harvesting in the region. The sites selected in May were subsequently re-visited with field crews 4 times prior to the onset of winter. Ambient temperature stations were established at 3 sites in the Lesser Slave area, as well as at 3 sites putatively in advance of the beetle in Saskatchewan in September 2010 (Figure 1, Table 1).

Visit 1 (pre-2010 flight). In June and July 2010, we surveyed 1 to 3 ha at all sites (except for Smithers and Terrace) prior to 2010 beetle emergence and marked all trees attacked in 2009 or earlier. We also sampled brood development in trees attacked in 2009 to estimate when peak emergence in each region would occur, and thus, estimate when new 2010 attacks would likely first appear. Three pheromone-baited funnel traps were also hung in a cluster adjacent to study sites to help monitor the flight throughout the summer.

Visit 2. Sites were re-surveyed at the onset of the main 2010 flight in the area to identify new attacks (Figure 2). Six to nine of these new 2010 attacks, hereafter called "early-attacked" trees, were located and selected for intensive sampling at most sites. The length of several parent galleries around 0.5 to 0.75 m high on the bole of sample trees were measured to help estimate the time of initial mass attack. Likewise, notes were made on the extent of fungal colonization around the galleries and the presence of attacking beetles on the outer bark or working in and out of fresh pitch tubes. The diameter at 1.4 m and the location of each sample tree was recorded. Under-bark temperature probes were located on the north and south aspects of all sample trees at 1.4 m (Figure 3). Under-bark temperature probes were similarly located at 0.25 m on two trees per site to measure the potential insulating effect of snow in the winter. At most sites, temperature probes were also inserted at 3.5 m on one tree. The number of attack starts in a 30 x 30 cm square around each temperature probe was recorded to calculate attack density. A 14 mm diameter arch punch was used to take phloem and outer sapwood samples from the east and west aspects at the height of each temperature probe. Samples were refrigerated until processed in the laboratory. Phloem thickness was measured and phloem moisture and sapwood moisture (outer 3 mm) was measured using the oven dry weight method.

Ambient temperature stations with temperature probes at 1.4 m and 0.25 m above the ground were located adjacent to three sample trees at each site (Figure 3). The ambient stations were tied to distant sample trees where possible (i.e., dispersed in the stand). An azimuth was randomly selected and the station was established on the nearest tree to that azimuth that was less than 10 cm in diameter and within 8 m of the sample tree. The ambient stations were established on small diameter trees to avoid any potential thermal effects associated with objects of large mass.

Visit 3. Sites were re-visited 4-5 weeks after temperature probes were established in early-attacked trees; this sample time coincided with when early-instar larvae were expected. The number of attack starts in a 30 x 30 cm square around each probe was recorded. The closest approximately 15 attack starts around each temperature probe were located on the outer bark. Locating attack starts on trees that produced pitch tubes was straight-forward; however, attacks on many trees at some sites were quite cryptic with boring dust in bark crevasses as the only sign of attack. We put push pins in the bark to help keep track of attack starts. Three galleries were then randomly selected for sampling; however, galleries immediately adjacent to the probe or just below it were excluded from sampling at this time to maintain the integrity of the bark around the probe.

Using a chisel, the bark was carefully removed starting at the base of each selected gallery until 5 live brood larvae or healthy eggs, the top of the parent gallery appeared, or 30 cm of gallery had been excavated (Figure 4). If the gallery was unsuccessful or yielded no live larvae or healthy-looking eggs within 30 cm of the gallery start, a note was made and another gallery was selected for sampling. Female beetles can lay eggs over an extended period of time and we wanted to relate brood development time to thermal measurements, therefore we sampled the oldest brood in each gallery because it could be aged most accurately based on the time of tree attack than brood further up the gallery. In some galleries many of the young larvae perished, apparently due to natural enemies or pathogens, making it surprisingly difficult to find 5 live larvae in some cases. While dissecting a gallery, larvae from adjacent galleries were often discovered, but these larvae were not sampled unless their parent gallery was traced back to its start to ensure that the oldest larvae in the gallery were being sampled. Due to low attack densities around a few probes at some sites, it was not possible to sample three galleries without jeopardizing future samples. Such rare cases were noted and only two galleries were sampled. The azimuth of the exposed egg gallery was recorded. Five larvae were collected from each gallery where larvae were present and stored in 70% ethanol in the fridge until head capsule width and total length were measured using a ocular micrometer on a dissecting microscope. The exposed surface of the sapwood was covered in pruning seal to prevent excessive drying (Figure 3).

Sites were re-surveyed at this time to identify any trees that were recently mass attacked by the MPB. Anecdotal reports had raised the possibility of multiple cohorts, two flight periods or late season mass immigration events in some areas resulting in trees attacked late in the season, hereafter referred to as "late-attacked trees". We wanted to quantify the development and reproductive ability of beetles in late attacks if possible. Any brood developing in late attacks could enter the winter in a different larval instar or life stage than brood developing in early attacks. The age of the attack was estimated by examining galleries on the bole as described above. Temperature probes were inserted at 1.4 m on the north and south aspects and measurements taken as described above.

Visit 4. All sites were re-visited between 20 September and 9 October 2010. An additional 3 galleries were randomly selected around each probe on early-attacked trees and sampled as described above. Brood development was sampled for the first time on late-attacked trees following the methods outlined previously for early-attacked trees. Chicken wire was wrapped around tree boles near temperature probes to deter woodpeckers and preserve future samples (Figure 3). All temperature loggers were downloaded at this time.

As of mid-October, we completed sampling on a total of 129 trees attacked in 2010 – 99 early-attacked trees and 30 late-attacked trees (Table 1). Measurement of over 5,200 larvae collected in 2010 was just completed in the middle of January and the database is currently being cleaned prior to analysis. Short field trips to measure (anticipated) peak snow pack depth will occur in late February or early March 2011. Temperature and brood development through emergence will be sampled on trees attacked in 2010 in 2011 to capture the complete life cycle. To maximize the amount of variation we capture in terms of temperature and insect development and survival, trees attacked in 2011 will also be sampled as described above. Capturing sufficient variability is key to calibrating predictive models.

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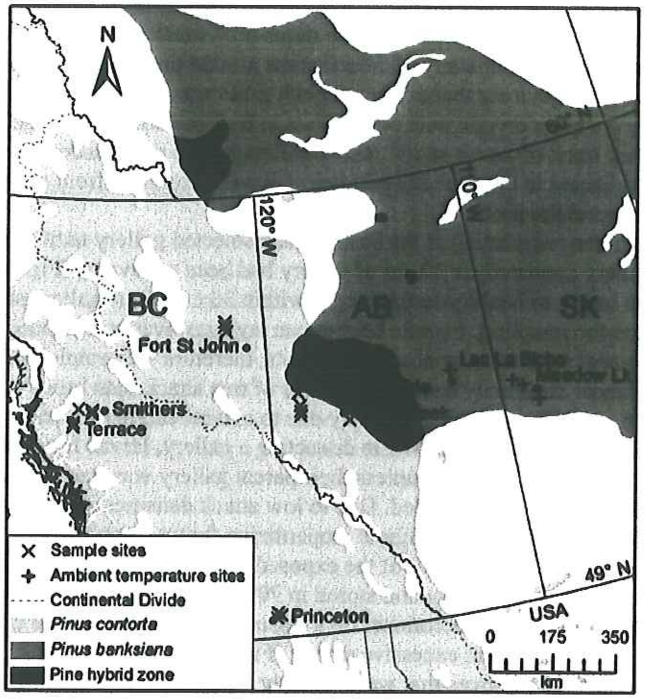

Figure 1. Location of research sites established in British Columbia, Alberta and Saskatchewan in 2010.

Table 1. General location of field sites and the number of early- and late-attacked trees sampled by area.

General Location	# of Sites	# of 2010 Early-Attacked Trees	# of 2010 Late-Attacked Trees
Terrace (historic range)	3	19	3
Smithers (historic range)	2	16	0
Princeton (historic range)	3	18	9
Fort St. John (expanded range)	3	15	4
Grande Prairie (expanded range)	4	12	10
Fox Creek (expanded range)	3	19	4
Total, sampling MPB brood and temperature	**18**	**99**	**30**
Lesser Slave (ambient temperature only)	3	--	--
Saskatchewan (ambient temperature only)	3	--	--

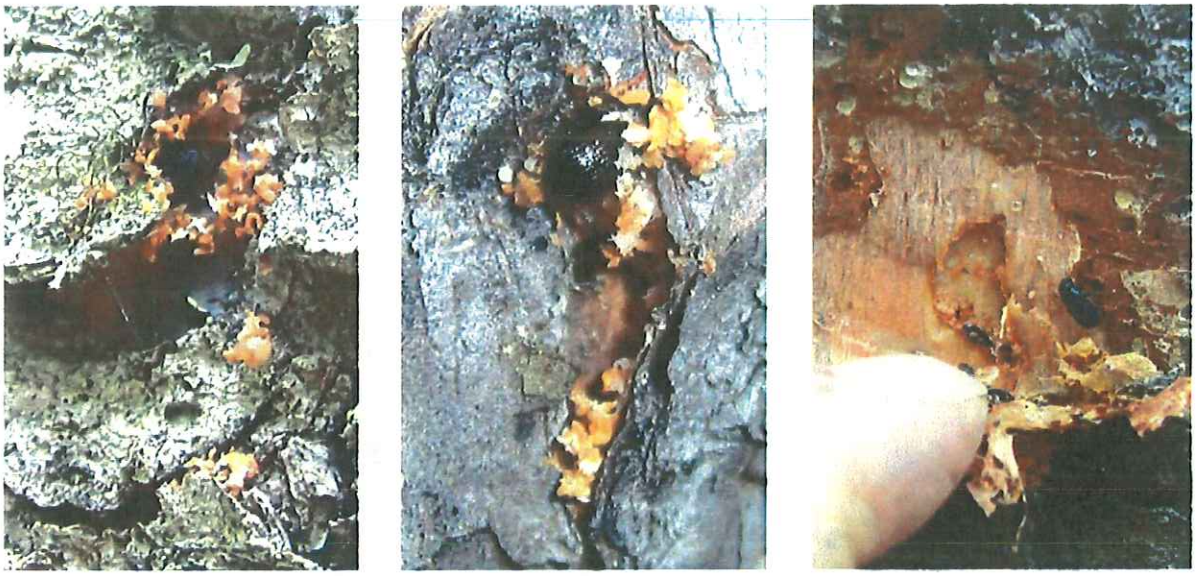

Figure 2. Mountain pine beetles in the process of attacking pine trees. Sites were visited at the onset of 2010 beetle emergence to facilitate an accurate estimate of time of attack in 2010 and total brood development time.

Figure 3. Pine tree attacked by the mountain pine beetle prior to sampling with temperature probes inserted under the bark at 0.25 m and 1.4 m and an ambient temperature station in the background (left panel); and a sample tree wrapped in chicken wire to deter woodpeckers with past sample locations blackened with pruning seal (right panel).

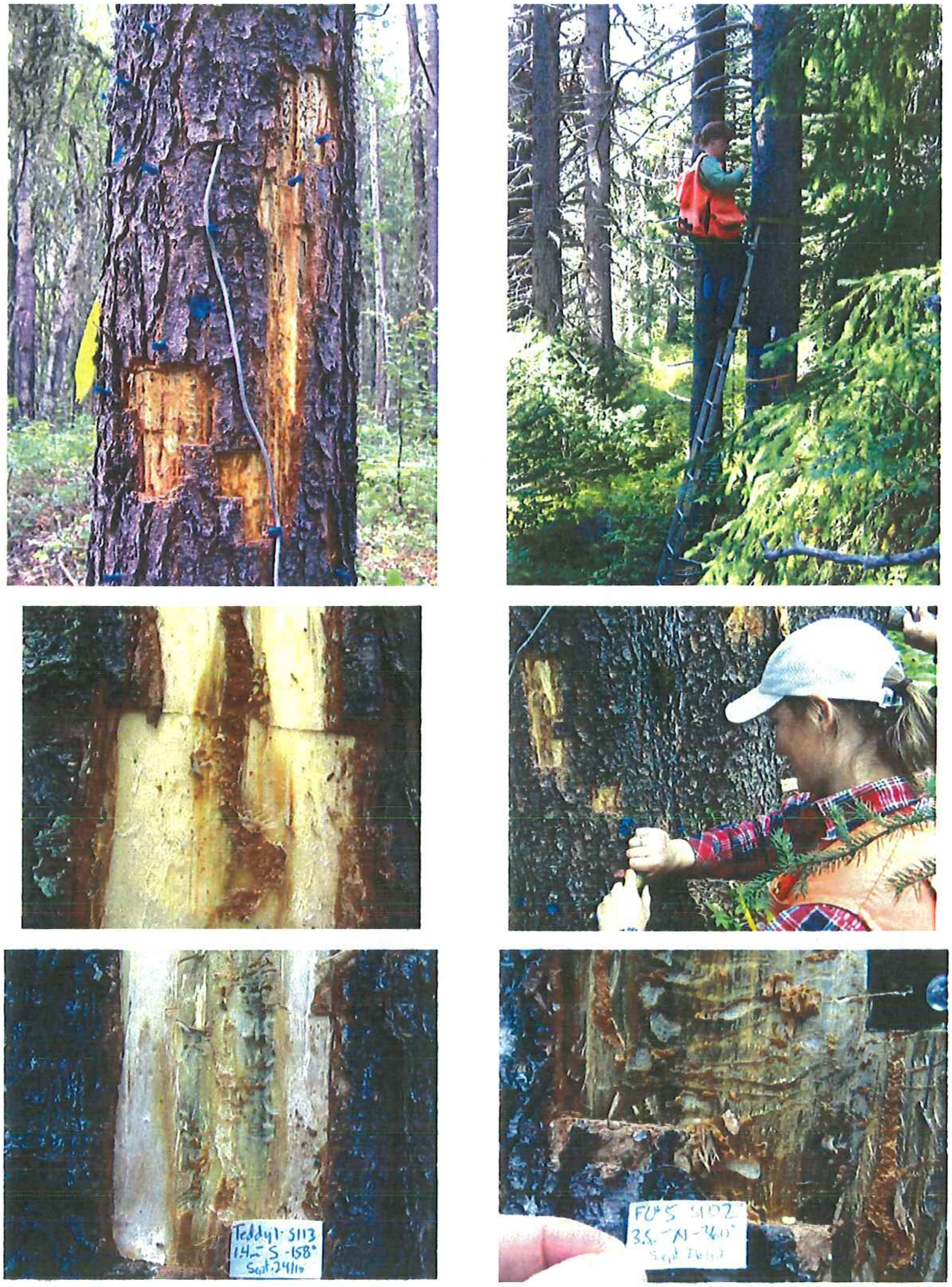

Figure 4. Sampling mountain pine beetle development in trees attacked in the summer of 2010.