*Extended Abstract**

BC Journal of Ecosystems and Management

Hydrologic effects of mountain pine beetle in the interior pine forests of British Columbia: Key questions and current knowledge

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Abstract

The mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopkins) could have a large effect on hydrologic regimes in British Columbia watersheds. Given the recent increase in size of the beetle infestation, many questions around forest management, particularly salvage harvesting, have emerged. Unfortunately, information to address these questions is limited to a handful of research studies. Although local initiatives to address knowledge gaps are under way, it is important to use the best available science to guide current management decisions related to MPB. This article highlights some of the key hydrologic questions associated with the MPB epidemic, identifies current knowledge on the effects of MPB on watershed hydrology, shows where research information is lacking, and comments on future directions for research. The effects of MPB on stream channel stability, water quality, hillslope processes, riparian function, and fisheries are not discussed. We hope this brief article will stimulate further discussion amongst hydrologists and foresters in British Columbia.

KEYWORDS: *annual water yield, forest operations, groundwater, hydrologic recovery, low flow, modelling, peak flow, salvage harvesting, soil moisture, regeneration, water quality.*

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* Editor's Note

This extended abstract is included as part of *JEM*'s special series of articles on mountain pine beetle-related issues. The article originally appeared in *Streamline Watershed Management Bulletin* 9(2):1–6; the full article, including literature cited, is available at: ***http://www.forrex.org/publications/streamline/ISS31/streamline_vol9_no2.pdf***

Uunila, L., B. Guy, and R. Pike. 2006. Hydrologic effects of mountain pine beetle in the interior pine forests of British Columbia: Key questions and current knowledge. Extended Abstract. *BC Journal of Ecosystems and Management* 7(2):37–39. URL: ***http://www.forrex.org/publications/jem/ISS35/vol7_no2_art4.pdf***

Key Questions

With an underlying concern for water quality, fisheries resources, and (or) constraints to forest operations, hydrologists and foresters are commonly asked what impact the mountain pine beetle (MPB) will have on annual water yield, peak flows, low flows, soil moisture, and groundwater levels. Answers to these questions are urgently needed as British Columbia moves toward a large-scale timber salvage strategy (Snetsinger 2005).

Uncertainty about the effects of beetle-kill leads to the following management questions.

- Is there a threshold at which the hydrologic effects of MPB will be measurable?
- How do small group infestations compare in their hydrologic impact with larger infestations?
- How do location, elevation, aspect, physiography, and weather control the hydrologic impacts of MPB?
- How do the density, type, and extent of the forest understorey affect hydrologic response and subsequent forest management?
- How do the hydrologic impacts of MPB vary with time?
- What is the impact of standing dead timber on key hydrologic processes? How does this compare with salvage logging?
- How long will it take for unsalvaged beetle-killed stands to regenerate and hydrologically recover? Is regeneration faster or slower if salvage logging occurs in beetle-killed stands?
- Should forest managers approach salvage harvesting in the same manner as conventional harvesting?
- Will alternative silvicultural systems be required in unsalvaged MPB-affected stands to minimize impacts?

What We Know

We identified relatively few studies that examined the hydrologic effects of insect infestation; even fewer are relevant to British Columbia. The following text and Table 1 highlight the major findings of these studies.

Most watershed-scale investigations [described in the original article] simply assume that infested forests are dead or alive; however, a stand-scale investigation in the Rocky Mountains of Colorado by Schmid *et al.* (1991) found that infested forests are more complex than initially assumed. That the presence of a multi-storeyed stand may mitigate the hydrologic effects of beetle-kill (Schmid *et al.* 1991) supports the recent recommendation of British Columbia's Chief Forester to increase retention levels when salvaging beetle-killed stands (Snetsinger 2005). Retaining structure, such as live trees (including understorey) and standing and fallen dead trees, may reduce the risks of large-scale salvage, particularly until watersheds have reached hydrologic recovery (Snetsinger 2005). On this basis, Snetsinger (2005) recommends that licensees balance retention both at the landscape and stand levels. During harvest planning, this will involve identifying areas with significant (live) understorey for retention and ensuring these areas are well distributed spatially within all harvested areas (Snetsinger 2005).

Recent research has used hydrologic models that are refined as watershed- and stand-scale information becomes available. Overall, the research summarized in Table 1 suggests that the effects of MPB on forest hydrology may be similar to those experienced after forest harvesting. Within even-aged stands without significant understorey, these effects include:

1. increases in annual water yield,
2. increases in late summer and fall low flows,
3. variable responses (no change or increases) in peak flow size, and
4. possibly earlier timing of peak flows.

Furthermore, these effects may last up to 60–70 years. The presence of uneven-aged, multi-storeyed stands will likely reduce these effects (Schmid *et al.* 1991).

Challenges and Future Research

Although the research is limited, it does shed some light on key MPB management questions and knowledge gaps in British Columbia, which present significant opportunities for research. In the short term, Hélie *et al.* (2005) recommend hydrologic modelling and a thorough analysis of available hydroclimatic data within a before, after, control, impact (BACI) study framework. Hydrologic modelling likely provides the best means to obtain short-term answers to many long-term issues.

In the mid to long terms, Hélie *et al.* (2005) suggest a comprehensive monitoring program that follows a priority list of research questions. This will require a substantial commitment of time and money and prove challenging before results become available several years in the future—possibly after salvage harvesting is complete. Therefore, it may be advantageous to focus research on approaches to accelerate hydrologic recovery, rehabilitation of salvaged areas, and water use by

TABLE 1. Summary of research on the hydrologic effects of beetle infestation

Location	Drainage area (km)	Dominant forest cover	% of watershed infested	Average change in annual water yield	Change in monthly low flow (late summer–fall)	Change in monthly high flow (spring)	Change in instant, peak flow	Expected time for hydrologic recovery to pre-disturbance condition	References
White River, Colorado	1974	Engelmann spruce	80% of trees covering 30% of watershed	+50 mm (19%)	—	—	—	—	Love (1955)
				+40–48 mm (15–18%)	—	—	—	—	Mitchell and Love (1973)
				+31.8 mm (12%)	—	—	—	—	Bethlahmy (1974)
				+37.9 mm (15%)	+1.6 mm (31.4%)	+14.9 mm (22%)	+20.2 m^3/s (27%)	> 25 years	Bethlahmy (1975)
Yampa River Colorado	1564	Engelmann spruce	80% of trees covering 30% of watershed	+23.6 mm (11%)	—	—	—	> 25 years	Bethlahmy (1974)
				+35.2 mm (16%)	+1.2 mm (9.6%)	+12.0 mm (14%)	no significant change	> 25 years	Bethlahmy (1975)
Jack Creek, Montana	133	Lodgepole pine	35% trees (50–60% of trees > 18 cm DBH)	+45 mm (15%)	+2 mm (10%)	+26 mm (52%)	no sig. change to magnitude; peak 2 weeks earlier	> 5 years	Potts (1984)
North Platte River, Wyoming and Colorado	1978	Engelmann spruce	Assumed 30–50% tree mortality	+56 mm	—	—	—	60–70 years	Troendle and Nankervis (2000)
Interior British Columbia	Varying	Lodgepole pine	In progress						Alila (2005)

young stands and understorey vegetation. Although beyond the scope of this article, the predicted effects of climate change in the British Columbia interior (e.g., Leith and Whitfield 1998; Whitfield and Cannon 2000) should also be considered when evaluating the hydrologic responses to MPB. In the interim, professionals must use the knowledge gained from applicable case studies [such as those presented in the original article], and consider local research on the effects of timber harvesting to help guide forest operations in beetle-infested areas.

Test Your Knowledge . . .

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How well can you recall some of the main messages in the preceding extended abstract? Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. According to the available literature, mountain pine beetle effects on forest hydrology include the following:
   A) Increased peak flow magnitude
   B) Decreased peak flow magnitude
   C) No change in peak flow magnitude
   D) Both A and C
   E) Both B and C

2. All things being equal, the hydrologic effects of mountain pine beetle are likely reduced in:
   A) Multi-storeyed stands of various ages
   B) Even-aged mature stands
   C) Effects are similar in both A and B

3. Most of the available research to date on hydrologic impacts of mountain pine beetle has been conducted in British Columbia.
   A) True
   B) False

Answers

1. D 2. A 3. B