

MOUNTAIN PINE BEETLE AND CLIMATE CHANGE

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ABSTRACT

The mountain pine beetle (MPB) (*Dendroctonus ponderosae*) is a native insect of pine forests in western North America. While it has a broad geographical distribution, it has been historically confined to the western side of the continent, in the U.S. by the distribution of its pine hosts and in the northern half of British Columbia in western Canada by the geoclimatic barrier of the Rockies. Since the early to mid-1990s, an outbreak of MPB has reached unprecedented levels in terms of acreages and numbers of pine trees, in particular lodgepole pine, killed throughout its range, most notably in Colorado and British Columbia. The MPB is also causing very high mortality among whitebark and limber pines at high elevations. Historical records from the past 100 years suggest these ecosystems have had pulses of MPB-caused mortality but not at levels currently being observed. Since 2006, MPB has extended its range into the Peace River area of north-central Alberta. Climate change may well be involved in this recent northeastward and upward range expansion. There is ample and mounting evidence of similar latitudinal and altitudinal shifts in insect distributions throughout the world, many convincingly linked to climate change. The main concern at this time is the likelihood that this insect will continue spreading east into the pines of Canada's boreal forest, eventually reaching the eastern provinces and threatening the pines growing on the Atlantic side of the continent all the way into the Southern U.S. Because of this recent incursion at the gates of the Canadian boreal forest, MPB is being viewed as a potential invading species in eastern pine ecosystems. It could be viewed as an invader into the high-elevation whitebark pine ecosystems as well.

There are three well-understood links between climate and MPB that form the basis for our belief that changing climate (temperature and precipitation) has had (and

will have) a role to play in the recent outbreaks and range expansion of this insect. A well-synchronized adult emergence pattern is a prerequisite for successful mass attack of healthy pine trees by MPB. Such highly synchronized emergence is most likely to occur where (and when) the insect has a strictly univoltine life cycle. For more than 20 years, process-based models describing MPB responses to temperature have been under development and analysis (Bentz et al. 1991, Bentz and Mullins 1999, Logan and Bentz 1999, Powell and Logan 2005). In addition to the synchrony issue, a hemivoltine life cycle (one generation every 2 years) leads to lower population performance mainly because it implies that the MPB is exposed to two winters. We know that cold winter temperature is the major mortality factor in MPB ecology (Amman and Cole 1983). A third weather factor is drought, because it affects the ability of pine trees to defend themselves against MPB attack (Safranyik et al 1975). We thus have three model components available to study the impact of weather on MPB populations. A phenology model predicts life stage-specific developmental timing (Gilbert et al. 2004). A cold tolerance model predicts probability of MPB larval mortality due to cold temperature (Régnière and Bentz 2007). And a drought-stress model can be extracted from the climatic suitability index of Safranyik et al (1975) and predicts fluctuations of tree susceptibility. All three models have been implemented within BioSim (Régnière and St. Amant 2007) to make landscape-scale predictions of MPB performance under climate change scenarios.

The phenology model is very good at predicting the portions of the continent where the insect has a high likelihood of being univoltine. This model predicts the northward and upward shift of MPB. Under a conservative climate change scenario, it also predicts that by the end of the 21st century, the area at risk of univoltine MPB will

shift considerably north, to a point that the insect may be misadapted over much of its current distributional range. The cold tolerance model suggests that winter survival is very low and will remain so in the foreseeable future throughout the boreal pine forests of the Canadian central provinces from Alberta to Ontario. While drought stress is and will be more common in that same area, there is not a very large change in this risk factor predicted in the near future. Thus, with our current understanding of the insect's physiology and host plant interactions, the risk of seeing the MPB roll across the northern forests of Canada into the eastern pine forests seems rather low. This, of course, is contingent upon the insect not adapting (evolving) to change its thermal responses and upon the distribution of pines not changing appreciably over the time range under consideration.

These models currently must be run separately, and it will be difficult to really integrate the development and survival processes until the two models are truly integrated. Temperature regimes that are favorable for adaptive developmental timing may not necessarily be favorable for survival and vice versa. Predicting outbreak risk also depends on an understanding and incorporation of population growth rates through time. Thus, one of our main objectives is to integrate these models, a task that will require a different modeling approach, probably using an individual-based framework, coupled with a distributed-computing system, to deal with the very high CPU demands of such a model.

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