A Preliminary Examination of White Pine Weevil Hazard Potential in the Mackenzie Basin Under Climate Change

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Introduction

The white pine weevil, *Pissodes strobi* (Peck), causes growth reductions in forest plantations of pine and spruce in western Canada. Tree leaders are killed by larvae mining and consuming phloem. Leader death does not kill the tree, but results in crooking and forking as laterals become dominant (Finck *et al.* 1989). These deformities adversely affect log quality and value. There is also reduced height growth and longer rotation times because slowed growth may enable other species to overtake attacked spruce in the stand (Wright 1960).

Temperature is an important environmental factor regulating white pine weevil development. Its effect can be quantified in terms of accumulated degree days. Degree days are equal to the mean daily temperature, (MAX+MIN)/2, minus a threshold temperature (Equation 1).

Equation 1 $\quad$ Daily Degree Day Accumulation = Mean Daily Temperature - 7.2° C

Previous studies have found that 785 degree days above a threshold of 7.2° C are required between May and September (Equation 2) for completion of the weevil's life cycle on white spruce, *Picea glauca*, leaders in the interior of British Columbia (McMullen 1976).

Equation 2

$$\text{Total Heat Sum} = \sum_{\text{May 1}}^{\text{Sept 30}} \text{Daily Degree Accumulation}$$

An increase in summer air temperatures as a result of climate change could increase weevil hazard, as the weevil would be able to survive in areas currently too cold for completion of its life cycle. This preliminary study assesses the potential white pine weevil hazard in the 1 787 000 km^2 Mackenzie River Drainage Basin (Figure 1) of western and northern Canada under the present climate and a 2.2° C climate warming scenario.

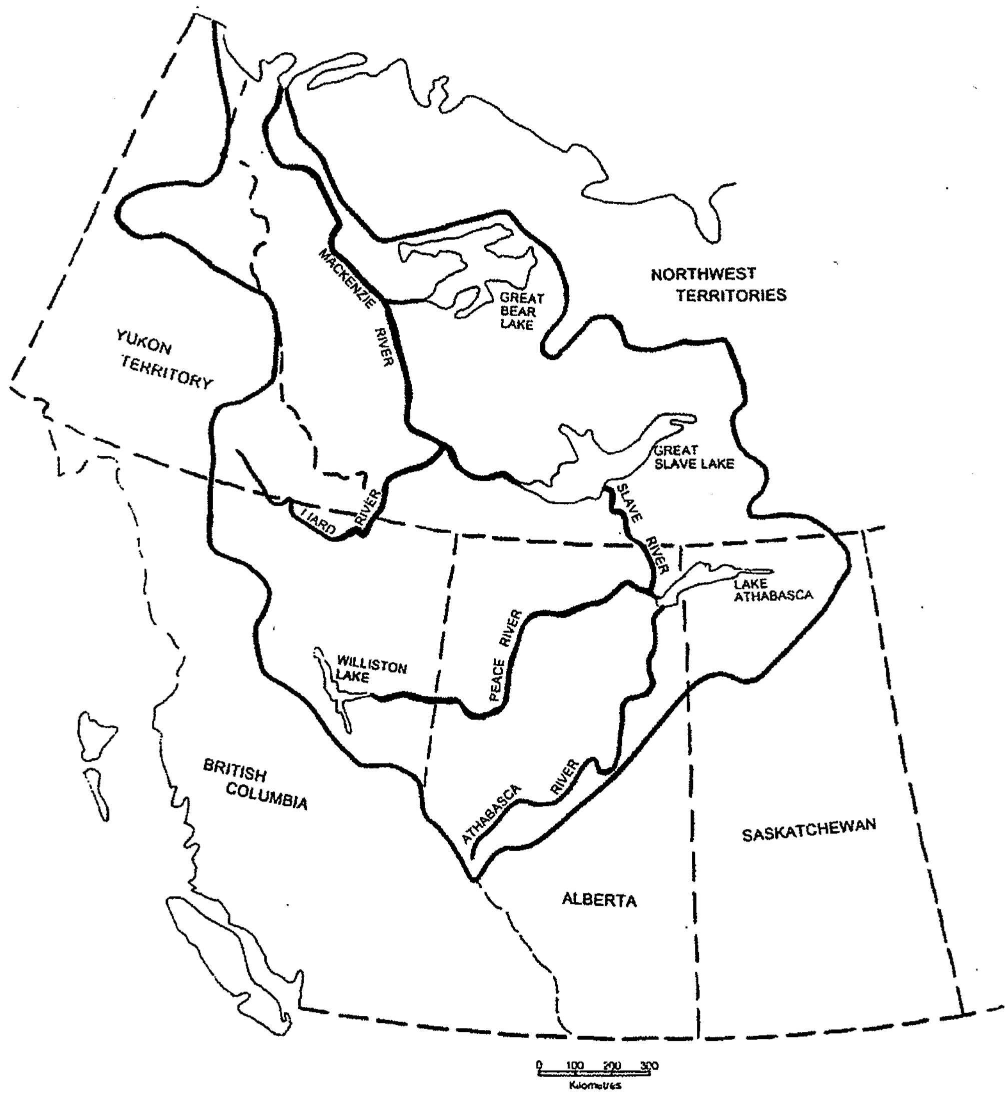

FIGURE 1. Location of the Mackenzie Basin study area.

Methods

Heat sums were calculated by interpolation using 1951–1980 Environment Canada monthly degree day normals (Atmospheric Environment Service, 1982). Heat sums for a 7.2° C base temperature were derived by interpolation between the 5 and 10° bases. This approach gives values that are about 3% higher than those calculated from daily data.

Monthly heat sum normals for the interpolated 7.2° C base were summed for May through September to calculate the total heat available. Three hazard classes were used to produce hazard rating maps: high (>800 degree days), medium (720–800 degree days), and low (<720 degree days).

A climate warming scenario of a 2.2° C increase in mean daily temperature was simulated by determining the hazard using the 5° C base degree day normals.

Degree day lapse rates depict the change in heat accumulation with elevation. Lapse rates were constructed from adjacent climate stations at different elevations. Lapse rates were used in conjunction with topographic maps to aid in the determination of elevational boundaries for each hazard class.

Results

Under the present climate, most low elevation sites in the three western provinces are at risk, as are sites along the Mackenzie River as far north as Fort Good Hope. With a 2.2° C warming, most sites in the western provinces will have sufficient heat for weevil development, as well as a significant portion of the basin north of 60° north latitude including low elevation sites up to Fort McPherson. The climate change scenario resulted in the area of the high hazard class increasing from 24 to 51% (Table 1).

TABLE 1. Relative proportion of the Mackenzie Basin in each hazard class under present and climate change scenarios

Hazard class	Present climate	Climate change
Low	55	28
Medium	21	21
High	24	51

Conclusions

The hazard rating system indicates where there is sufficient heat available for the white pine weevil to complete the summer component of its life cycle. The actual range of the weevil may be less than the potential range indicated by the hazard rating system because of factors including the insect's predators and parasites and the lack of a suitable host tree. The effect of overwinter conditions on adults is not assessed.

The hazard rating system indicates that a significant portion of the basin is at risk under present climate conditions. Although much of Alberta is warm enough for weevil development, there is currently little weevil damage. This could change when aspen now shading spruce is harvested, converting stands to pure spruce.

Leaders exposed to direct sunlight may be at an increased risk as these leaders have been found to be 2–3° C above air temperature, while shaded leaders remain close to air temperature. The climate warming scenario of 2.2° C represents approximately the same temperature increase associated with moving a leader from shade to full sunlight. Thus, the present and climate change scenarios depicted in this paper may also be viewed as a hazard rating system using shaded and unshaded leaders. The climate change scenario is equivalent to a hazard rating system for unshaded (warm) leaders, while the present climate scenario is equivalent to a hazard rating system for shaded (cool) leaders.

With climate change, the white pine weevil's range will expand upward in elevation and northward in latitude. If the assumed climate change occurs, almost all of the southern region will be susceptible to weevil attack, as well as a significant portion of the northern basin. Cohen (1991) states that with a 2 x CO_2 climate change scenario the average summer basin temperature will rise by 3.5° C. Thus, the weevil hazard may be even greater than depicted in this study.

Further studies will examine the difference between leader and air temperature, silvicultural control through shading, the time period for weevil development, and improved spatial distribution of temperature data.

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