Tree-ring analysis of aspen forest responses to climate variation and insect defoliation in western Canada.

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Introduction

Trembling aspen (*Populus tremuloides* Michx.) is the most abundant deciduous tree species in the North American boreal forest, and is also the predominant tree in the aspen parkland zone along the northern edge of the Canadian prairies. Since the early 1990s, dieback and reduced growth of aspen forests has been noted in some areas of western Canada . Previous studies (Hogg & Schwarz, 1999; Hogg, Brandt & Kochtubajda, 2002) indicate that the aspen decline in these areas was caused by a combination of climatic factors (drought and early spring thaw-freeze events) and multiple-year defoliation by the forest tent caterpillar (*Malacosoma disstria* Hbn.) During the period 1998-2001, conditions were exceptionally warm across most parts of Canada, and severe drought has affected large areas of the western Canadian interior. This has posed concerns about the current status of western Canadian aspen forests, and how the productivity and health of these forests might be affected by the warmer and drier conditions predicted for this region under climate change.

To address these concerns, we established a large-scale study entitled "Climate Change Impacts on Productivity and Health of Aspen" (CIPHA). CIPHA consists of a network of long-term research plots in 72 aspen stands across western Canada, where annual monitoring of forest health and dieback was initiated in the year 2000. A major component of this study is the use of tree-ring analysis to examine how climate and insects have affected interannual variation in the radial growth of aspen forests over the past 50 years. Specifically, we examined the hypothesis that cycles of drought and insect defoliation have caused major reductions in aspen radial growth at the regional scale (1800 x 500 km area) encompassed by this study.

Materials and Methods

The study area includes 24 study sites in the southern boreal forest and adjacent aspen parklands of western Canada, extending from the southwestern Northwest

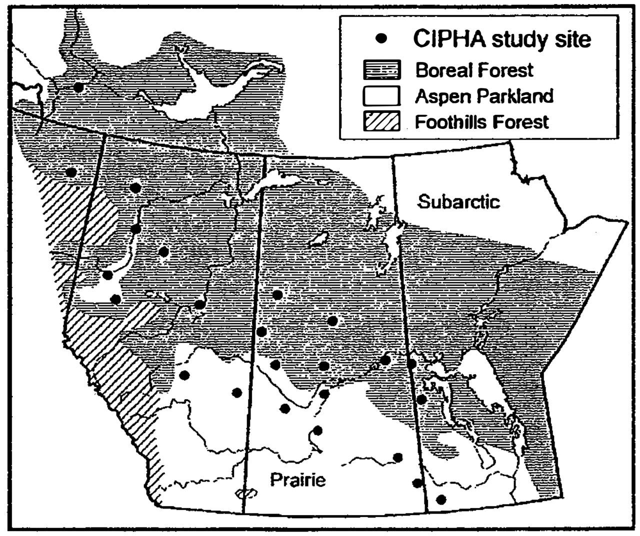

FIGURE 1. Map showing the location of the 24 CIPHA study sites in the western Canadian interior.

Territories to southwestern Manitoba (Figure 1). At each site, three pure, undisturbed aspen stands (40-80 years old) were selected within a distance of 25 km (total of 72 stands). During 2000, two long-term research plots were established 50-100 m apart within each stand. The plots were rectangular, with a width of 10 m and sufficient length (typically 15-35 m) to include at least 25 living aspen trees. In 2000, heights and diameters (1.3-m height) of all aspen in the plots were measured and annual forest health assessments were initiated. The live basal area (m^2 ha^{-1}) of aspen in each plot was calculated from the tally of stem diameters and plot area. In the early autumn of 2000, 3 aspen trees located adjacent to, but outside each plot were felled for tree-ring analysis (total of 432 trees). Disks were collected at stump height (for age determination only), 1.3-m height, and at 1/3 and 2/3 of total tree height; this analysis focuses on tree-rings of disks from the 1.3-m height. The disks were dried (50° C), sanded and polished, and ring widths along two radii per disk were measured manually under 25X magnification. Ring widths from the two radii were averaged, and used to calculate tree growth

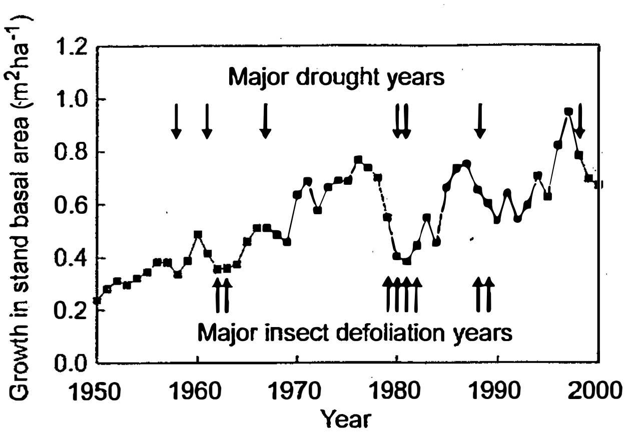

FIGURE 2. Trends in mean growth of 72 aspen stands from tree-ring analysis, based on the estimated stand basal area increment contributed by trees living in the year 2000. Major drought years are defined as having a mean Climate Moisture Index < -10 and major defoliation years are defined as those having >10% frequency of white tree rings among the 432 aspen sampled.

as annual increment in stem cross-sectional area (Hogg, Brandt & Kochtubajda, 2002). Increment in stand growth (m^2 ha^{-1} yr^{-1}) was estimated by using stand basal area to "scale up" the tree-based growth increments. The history of severe insect defoliation was determined from the presence of abnormally pale-coloured "white" tree-rings (Hogg & Schwarz, 1999) and from the insect survey records of the Canadian Forest Service. The incidence of past droughts was assessed by calculating annual values of a Climate Moisture Index (Hogg, Brandt & Kochtubajda, 2002) from the historical daily records of maximum and minimum temperature and precipitation at one or two Environment Canada climate stations adjacent to each of the 24 study sites.

Results and Discussion

The tree-ring analysis of disks from the 1.3-m height (Figure 2) shows that aspen forests in western Canada have undergone several cycles of collapses in growth followed by recovery since 1950. Growth was greatly reduced during 1961-1964, 1979-1984, and 1988-1995, corresponding to periods with regional drought and large-scale outbreaks by forest tent caterpillar. The greatest oscillation in regional-scale growth included a 50% growth reduction between 1976 and 1981, followed by a doubling of growth between 1981 and 1986. The last peak in aspen growth was in 1997, following a cool, moist period with little defoliation. Regional aspen growth started to decline during the unusually warm, dry year of 1998, and decreased by a total of 30% between 1997 and 2000.

The results show that during the period 1950-2000, western Canadian aspen forests have undergone major oscillations in growth, even at the regional scale encompassed by this study. Preliminary analyses (not shown) suggest that forest tent caterpillar defoliation and drought are important factors driving interannual variation in aspen growth, as noted in two previous tree-ring studies of aspen in western Saskatchewan (Hogg & Schwarz, 1999) and northwestern Alberta (Hogg, Brandt & Kochtubajda, 2002). Repeated defoliation by forest tent caterpillar has also been implicated as a factor in causing recent mortality affecting more than 300 000 ha of aspen forest in the Kapuskasing area of northern Ontario. (G. Howse, Canadian Forsest Service, pers. comm., 2002). However, there are several other factors that may impact aspen growth and ultimately lead to crown dieback and decline of aspen forests in these regions. These include the influence of thaw-freeze events in late winter or spring (Hogg, Brandt & Kochtubajda, 2002) and potential influences of air pollutants such as ozone. Also, insect defoliation and climatic stressors may predispose aspen to chronic subsequent damage by fungal pathogens and wood-boring insects (Churchill et al., 1964; Hogg, Brandt & Kochtubajda, 2002). Continued monitoring and a future update of tree-ring analysis within the CIPHA study will determine how the growth and health of western Canadian aspen forests are responding to the drought that affected much of this region between 1998 and 2001. Future directions include the "scaling up" of tree-ring analyses for annual estimates of net primary production and the validation of models for projecting future impacts of climate change on the aspen forests of western Canada.

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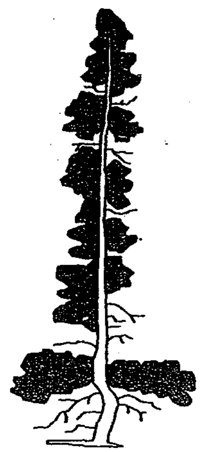

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