Assessing biogeochemical & hydrologic change during incipient bark beetle outbreak in managed and unmanaged subalpine watersheds

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Background
- More than 30 million ha of pine forest are at risk of bark beetle attack in the United States. Mountain pine beetle (Dendroctonus ponderosae; MPB) killed nearly 1 million trees on national and private forestland in the Rocky Mountain region between 1995 and 1999.
- The USFS Fraser Experimental Forest (FEF) is located near the epicenter of the current outbreak in the central Rockies of Colorado. Extensive logging in the region followed wildfires in the early 1900s established lodgepole pine forests that have now reached an age and stand structure that put them at risk for bark beetle attack. MPB mortality was first observed at FEF in 2003 following several years of below average precipitation. MPB mortality now exceeds 90% of the inventory in several large areas of the Arapaho-Roosevelt National Forests that adjoin FEF.
- Long-term hydrologic and biogeochemical records at FEF provide a unique opportunity to evaluate the extent to which bark beetles alter watershed functions.

Study Site - Fraser Experimental Forest
- FEF is located on the western edge of the Front Range of the Colorado Rockies and contains 9300 ha of subalpine and alpine ecosystems.
- Average annual precipitation is ~600 mm yr⁻¹ (~2/3 as snow). MAT is 5.9°C. The subalpine forest consists of Engelmann spruce (Picea engelmannii), subalpine fir (Abies lasiocarpa) and lodgepole pine (Pinus contorta).
- As part of separate paired watershed studies aimed at assessing forest harvesting effects on watershed hydrology, portions of the Fool Creek (50%) and Deadhorse Creek (~33%) watersheds were clear-felled in the mid-1950s and 1980s.

Nitrogen Dynamics

Streamwater N Responds to Biological Processes
- Spring snowmelt delivers pulses from soil to streamwater.
- Nitrate production and release are highest in basins with greater alpine cover.
- Harvesting augments soil nitrate turnover and leaching.
- Subsurface N export remains 4-fold higher in clear cut areas after 20 years.
- Ammonium increases during summer months when soil and in-stream microbial processes peak.

Current Status & Expected Change

No Change in Streamwater Chemistry
- Stream chemistry has not responded to initial pine mortality.
- Watershed studies at FEF (Fool Ck and Deadhorse) show that forest structure regulates the water balance and nutrient budgets of subalpine watersheds.
- Pumping of 40% of forest cover significantly increases water yield and advances peak discharge.
- Responses relate to lower canopy interception losses and reduced plant water use.
- These factors increase snow accumulation and speed soil water recharge.
- Harvesting increases flow through shallow soil layers and greater ANC, nitrate and carbon leaching.
- Snow growth of the subalpine forest prolongs hydrologic and biogeochemical recovery (20 - 50 y).

Similar processes will regulate responses to MPB outbreak. However, we expect effects to be delayed and muted.
- Increased water yield will relate to loss of canopy interception and reduced plant water use.
- Unlike clear cut forests, dead pine crowns will intercept snow, delaying the gain in snow accumulation until branches or trees fall.
- Nitrate leaching lagged several years behind clear cutting and probably longer following canopy mortality.
- MPB-resistant conifer regeneration below pine canopies and in clear cuts will mask responses to overstory mortality.

Relevant Literature