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

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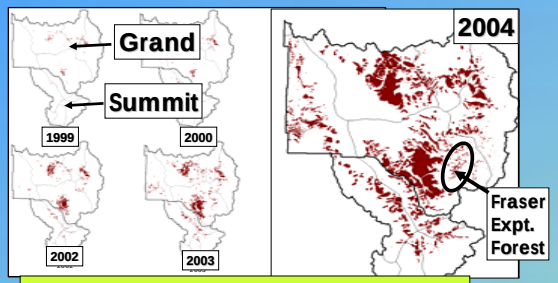
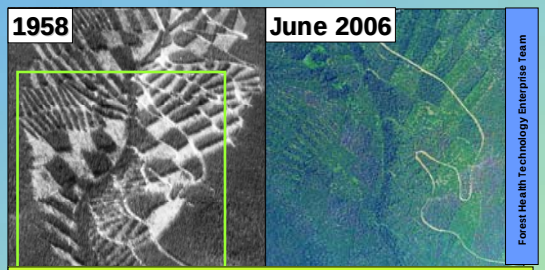
Lodgepole pine mortality near Tabernash, Colorado (8/05)

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 by 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 overstory 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.



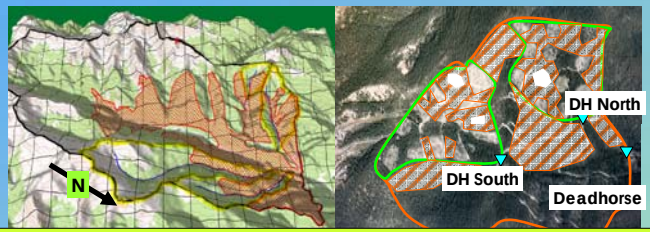
Expanding Mountain Pine Beetle Outbreak in Colorado's central Front Range ('99 to '04).



Fool Creek Watershed, Fraser Experimental Forest
Half the basal area was removed leaving alternating clear-cut and leave strips. Openings ranged from 20 to 100 m by about 150 m.

Study Site – Fraser Experimental Forest

- FEF is located on the western edge of the Front Range of the Colorado Rockies and contains 9,300 ha of subalpine and alpine ecosystems.
- Average annual precipitation is ~ 600mm/ yr (~2/3 as snow), MAT is 0.5°C. The subalpine forest overstory consists of Englemann spruce (*Picea englemannii*), 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.



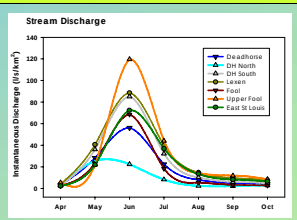
Lodgepole pine forest within the Fraser Experimental Forest. Lodgepole predominates on south aspects and lower elevations, but co-occurs in spruce-fir forests to treeline. Infested pine-dominated stands occupy 20 to 50% of the forested area in lower basins. Un-infested regenerating pine stands occupy half to a third of managed basins.

Streamwater Monitoring

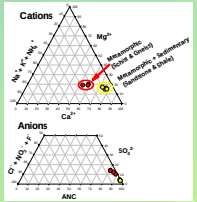
Long-Term Records
Watershed hydrologic measures began at FEF in 1940. Continuous streamflow and weekly chemical samples have been collected from 7 basins since 1990. Chemical analysis of 6 additional uncut streams begin in 2004.

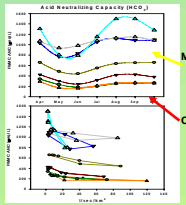
Watershed	Land Use	Old Growth Cover	Watershed Area	Forest Area	Total Pine Forest Cover	Old Pine Wshd Cover
		%	ha	ha	%	%
East St. Louis	Uncut	100	803	537	67	12
Fool	Cut in '50s	50	289	248	86	36
Upper Fool	Cut in '50s	50	66	66	100	0
Lexen	Uncut	100	124	115	93	41
Deadhorse	Cut in '80s	70	270	254	94	50
DH North	Cut in '80s	70	43	43	100	95
DH South	Cut in '80s	70	78	60	77	39
Iron	Uncut	100	791	389	49	36
Range	Uncut	100	774	366	47	16
Byers	Uncut	100	346	286	83	34
Lunch	Uncut	100	301	161	54	21
Gordon	Uncut	100	271	94	35	6
Mine	Uncut	100	247	122	49	0

* Old forests are 100 to 500 yrs old



Snow-dominated Hydrograph
Peak streamflow occurs during the first half of June. Aspect and harvesting influence timing and amount of discharge.





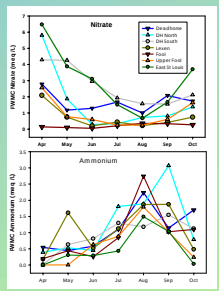
Mixed Bedrock Basins
EC = 70-135 µS/cm
pH = 7.5 – 8.0

Crystalline Bedrock Basins
EC = 30-60 µS/cm
pH = 7.2 – 7.4

Baseline Streamwater Chemistry
Calcium & ANC are the dominate constituents of Fraser streamwater. Geology regulates differences in basin water chemistry. Snow-melt discharge dilutes concentrations of most chemical constituents.

Nitrogen Dynamics

Streamwater N Responds to Biological Processes
- Spring snowmelt delivers nitrate from soil to streamwater.
- Nitrate production and release are higher 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.

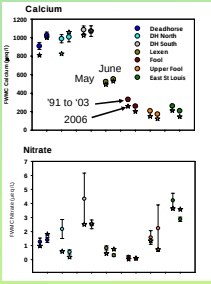


Current Status & Expected Change

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.
- Removal of >25% 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 cation leaching.
- Slow growth of the subalpine forest prolongs hydrologic and biogeochemical recovery (20 - 50 yrs).

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 overstory lodgepole pine. Some basins will lose > 30% forest cover.
- Pine mortality will decrease water and nutrient uptake and should increase their export.
- 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.



May & June 2006 flow-weighted calcium and nitrate concentrations compared to long-term means.

Relevant Literature

Elder, K.J., and L.S. Porth. 2005. The effect of timber harvest on the Fool Creek watershed, 49 years later. AGU Proceedings, Ft Collins, CO.

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