Water Quality Impacts
Nutrient Cycling & Stream Chemistry

Western Water Assessment Beetle-Water Workshop
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Watershed Change

Responses Regulated by Change in Canopy interception & Snowpack accumulation
Water uptake & Soil nutrient use

Complicating Factors
Responses may lag, difficult to detect, prolonged
Complex spatial & temporal patterns
Harvesting Effects

Prolonged Effect on N Loss

Peaks in 7 yrs
Delayed Recovery
Subsurface Flows + Nitrate Production

Reuss et al. 1997
Starr 2003
Harvesting Effects

Prolonged Effect on N Loss

Soil Nitrogen
Effects after 25 & 50 yrs
Nitrate > 2X higher in cuts

Nitrate is a greater part of IER soil N

Production of N
Higher in cuts
(net mineralization, nitrification)

Magnitude of Increase
= Atmospheric Deposition
(2-3 kg N ha\(^{-1}\) yr\(^{-1}\))

Rhoades unpublished data
Beetle Effects on Water Quality

Tree mortality reduces nutrient uptake

Decreased plant N demand increases leaching of water soluble N (i.e., nitrate)

Residual understory will dampen nitrate losses
Beetle Effects on Water Quality

Abiotic changes alter nutrient cycling

Litterfall → Temperature → Moisture → Nutrient Production → Soil Nutrients → Nutrient Leaching
Nutrient Turnover

Nitrification was low in small gaps, but was stimulated by moist, warmer soil in larger gaps

Plant Uptake
Small gaps exploited by surrounding trees

Nitrate leaching was higher in large gaps

Previous ‘Simulated’ Outbreak
MPB vs. Wyoming lodgepole

Parsons et al. 1994
Previous Outbreaks
*Defoliator vs. Hardwoods*

Coweeta Hydrologic Lab, Western NC

Stream nitrate after 33% loss of leaf mass

Peak Nitrate concentrations
- PreBug: 20-30 mg N L\(^{-1}\)
- Bug: 60-70 mg N L\(^{-1}\)

Increase in Export
- 0.25 kg /ha/yr
  - (<10% of N dep.)

Central & Eastern Forested Uplands (XI)
- TN 0.31 mg /L; NO3-N 0.09 mg /L (90 ug/L)


Fall Cankerworm
Previous Outbreaks

*Ips* vs. *Bavarian Spruce Forests*

- 85% tree mortality
- Nitrate Export
  - 10X higher post-outbreak
  - Peak: 5 yrs
  - Recovery: 15 yrs
- Decrease attributed to uptake by understory
- Longer recovery than from harvest or windthrow

(Huber 2005. J Env Qual)
25 yr post outbreak

- Thinner forest floor (~50% less)
- Reduced litter C stock (>30% less)
- Higher N concentration and C:N ratio
- Lower litter inputs
- Higher organic matter turnover

Current Outbreak

Tree Water Use Declines Fast

Transpiration drops ~50% within 3 weeks of MPB

Water status of girdled trees unchanged – continued growing for 1 year after attack

Hubbard et al. in review
Current Outbreak

Soil Changes under Fading Trees

**Soil Moisture**
Highest under red, gray

**Soil N Availability**
Lowest under live trees
Highest under gray

**Factors Responsible**
Lack of plant uptake
Soil N turnover
Litter inputs

11 sites – Grand Cty, CO
Green: Healthy
Red: 1-3 yr post-attack
Gray: ≥4 yr post attack

(Clow et al. 2011 Applied Geochem)
Current Outbreak

*Change in Foliar Nutrition*

Foliar N concentrations decrease as trees die.

In residual live trees, foliar N more than doubled following loss of neighboring trees.
Current Outbreak

Changes in Streamwater N

Comparison
5 yrs Post-Infestation vs. 20 yrs Pre-Outbreak

Spring Nitrate Pulse
1.4 & 2.0 fold increase

Magnitude of Change
20 g N ha\(^{-1}\) yr\(^{-1}\)
~1% of N deposition

*Non-MPB N Retention
~ 95% of N deposition
MPB-Related Changes

**Stream Nitrate**

MPB Effects
Small relative to seasonal change

Minor relative to atmospheric inputs (~1% of N deposition)

Vary among basins

(Rhoades et al. 2008; AGU)
Level of Forest Mortality

*Depends on Species Composition & Structure*

**Old Growth**

Basal Area Loss
- Old Growth: 73-83% LPP loss
- Mixed Age/Managed: 50-70% of LPP

**Mixed Young/Old**

Basal Area Loss
- Old Growth: 39 - 41% total loss
- Mixed Age/Managed: 20-25% of total

[Graphs showing mean basal area (m²/ha) for different species in East St Louis, Fool Creek, Lexen, and Deadhorse.]
Streamwater NO$_3$ concentrations were strongly correlated to: aspect, elevation, forest cover, precipitation and discharge.

Correlations to % of basin affected by MPB were weak.

(Cooper et al. unpublished)
MPB-Related Changes?

Compared to other Disturbance

(McCutchen et al. under revision)
Dissolved Organic Carbon

Global/Local Patterns

Increasing globally
Climate
Precip chemistry

Export from forests, peatland soils, litter decay

Humic forms of DOM react with chlorine to form DBP’s
(i.e., the carcinogen, trihalomethane)

Possible links to MPB

(Monteith et al., 2007, Nature)

(Beggs and Summers 2011, EST; McCray et al. in prep)
Stream Temperature

Reduced shading tends to increase stream temperatures

Higher temps affect some aquatic spp. directly, and WQ by increasing rates of chemical reactions and metabolism

Western Colorado:

- 2.0°C increase in some stream segments
- Greatest effects where lodgepole was dominant riparian species (J. Stednick, CSU)
Take Home Messages

In general, Colorado studies do not show initial changes in stream N of the magnitude that would present problems for either human water use or aquatic ecosystems.

Decline in stand transpiration and nutrient use depends on extent of mortality, species composition, understory response

Magnitude and timing of changes in water differ from harvest response
Carbaryl was found in the Silverthorne (CO) water treatment plant effluent in 2007 (>3 ppb) and 2008; source undetermined
Carbaryl found in Boulder (CO) drinking water (0.5 ppb) in 2007
WWA-funded sampling in Rocky Mtn NP down-stream of application area in 2010 found no carbaryl above detection limit (~0.1 ppb)

Carbamate (carbaryl) and pyrethroid (permethrin) pesticides are widely used on private and public lands in infestation areas
Both are neurotoxins and have some toxicity to humans and aquatic organisms
New EPA guidelines recommend carbaryl levels <2.1 ppb to protect aquatics
MPB-Related Management Issues

Soil responses to Management Options

Soil N was highest in slash retention treatment

Ammonium ($NH_4^+$)
- 35% to 2.5X > uncut
- 20 - 30% > Whole Tree

Nitrate ($NO_3^-$)
- 1.3 to 5.2 fold > uncut

*Extractable Soil N (0-15 cm mineral soil)
MPB-Related Management Issues

Rethinking Riparian Management

Riparian Fuel Management - Fuels reduction underway in riparian zones on > ½ of western USFS districts. (Stone et al. 2010)

Corridor clearing to protect power transmission lines, roads, trails, etc.

Do dead riparian buffers protect water quality?

Are current BMPs effective for ROW clearing?
There are > 100,000 unburned piles in R2’s MPB forests
(J. Krugman USFS R2, pers comm)

Lasting effects on forest stocking, soil & stand productivity
Pathways for spread of invasives
Influence soil and runoff nutrients

Peak concentrations exceeded EPA drinking water quality standards
(Johnson et al. 2011)
Rehabilitating Burn Piles

Pile burns are known problems, but they will likely remain a management option for the foreseeable future.

However, rehabilitation may be fairly simple.

Mulching piles reduces the pulse of soil N reduces soil N.

Hand scarifying increases native plant cover. Seeded piles respond to both treatments.