Water Quality Impacts: Nutrient Cycling & Stream Chemistry

San Juan Bark Bark Beetles and Watersheds Workshop
Durango, CO
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Chuck Rhoades, Rob Hubbard & Kelly Elder
USFS Rocky Mountain Research Station
Fort Collins, CO
Jeff Lukas, Western Water Assessment
Water Quality issues common after forest disturbances

- Nitrogen (N) export and increased stream nitrate (NO$_3$) levels
- Increased Dissolved Organic Carbon (DOC) in streams
- Sedimentation (from erosion associated with initial disturbance, or post-fire)
Beetle Effects on Water Quality

Abiotic changes alter nutrient cycling
Tree mortality reduces nutrient uptake

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

Residual understory will dampen nitrate losses
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 Nitrate

Peaks in 7 yrs
Delayed Recovery
Subsurface Flows + Nitrate Production

Leachate Nitrate (kg NO₃ ha⁻¹)

Reuss et al. 1997
Starr 2003

Clear Cut

Years Since Harvest

18 Years
Harvesting Effects

**Prolonged Effect on Nitrate**

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Rhoades unpublished data
Outbreaks outside Colorado

Cankerworm in Appalachian 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 ; NO\(_3\)-N 0.09 mg /L (90 ug/L)

Outbreaks outside Colorado

*Ips beetle* in *Bavarian Spruce Forests*

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

(Huber 2005. *J Env Qual*)
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
2000s MPB Outbreak

Soil Changes under dead trees

Clow et al. (2011), Applied Geochemistry

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 Geochemistry
2000s MPB Outbreak

**Change in Foliar Nutrition**

<table>
<thead>
<tr>
<th></th>
<th>Beetle- Killed Lodgepole</th>
<th>Live Lodgepole</th>
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<tbody>
<tr>
<td>Yr 1 June</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Yr 1 Oct</td>
<td>0.8</td>
<td>1.0</td>
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<tr>
<td>Yr 2 June</td>
<td>1.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Yr 2 Oct</td>
<td>1.2</td>
<td>1.4</td>
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Foliar N concentrations decrease as trees die.

In residual live trees, foliar N more than doubled following loss of neighboring trees.
2000s MPB Outbreak

Stream Nitrate

MPB Effects
Small relative to seasonal change

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

Vary among basins

Old Growth
(Mixed Young & Old)

(Rhoades et al. 2008; AGU)
Streamwater NO$_3$ concentrations were strongly correlated to: aspect, elevation, forest cover, precipitation and discharge.

Correlations to % of basin affected by MPB were weak.

Rhoades et al. (2013), PNAS, *Explaining a weak nitrate response*
2000s MPB Outbreak

Stream nitrate vs. other Disturbances

Rhoades et al. (2013), PNAS, *Explaining a weak nitrate response*
Red-phase trees shed a lot of litter - this has affected water color ("tea") and odor in some CO watersheds

Humic forms of DOC react with chlorine to form disinfectant byproducts (i.e., trihalomethane)

DOC in streams is also increasing globally, due to climate and precipitation chemistry
Mikkelson et al (2013) found that treated water from MPB-affected watersheds had somewhat higher DOC and much higher (~3x) disinfectant byproducts (mainly trihalomethanes) than from control watersheds.

However – small sample size, and there’s a lot of variability in DOC between MPB-affected watersheds.
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:
2.0º C increase in some stream segments
Greatest effects where lodgepole was dominant riparian species (J. Stednick, CSU)
Forest harvest and sedimentation

Some compaction/disturbance of soils by harvesting equipment is unavoidable.

Erosion/sedimentation will depend on practices and on soils and slope steepness.

In general, greater sedimentation risk than from the beetle infestation alone.
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)

Do dead riparian buffers protect water quality?

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

Are current BMPs effective for ROW clearing?
Take Home Messages

- MPB infestation not causing changes in stream nitrate that would present problems for either human water use or aquatic ecosystems.

- MPB infestation may be causing DOC/disinfectant byproduct increases that are WQ issues.

- Changes in nutrient use and export depend on extent of mortality, species composition, understory response, and management action.

- SJ Spruce beetle infestation: prudent to monitor nitrate, DOC, and disinfectant byproduct levels.