Buried wood – or the role of bryophytes in the deadwood cycle of humid boreal forests

Ulrike Hagemann, Martin T. Moroni, Johanna Gleißner, and David W. Beilman
Deadwood Cycle

1st order disturbances → de novo
2nd order disturbances - on heritage dead wood

Decay via: - Respiration
- Fragmentation
- Leaching

Aboveground dead wood

J. Gleißner
Study Region and Sites

Study region: Labrador

- High-boreal forest
  - Cold (MAT < -1.0°C)
  - Perhumid (MAP ~1000 mm)
  - Fire-driven (interval 300-500 yrs)
  - Black spruce (*Picea mariana*)

Study sites

- Old-growth (n = 3)
- Clearcut harvested (1, 17, 34-36 years) (n = 3)
- Middle-aged burned (21 years) (n = 3)
Deadwood Stocks

Deadwood types

- (Downed) Woody debris
  \[ \phi \text{ BW C stocks} \]
- Snags
  \[ 5.8 \pm 2.8 \text{ to } 37.3 \pm 6.6 \text{ Mg C ha}^{-1} \]
- Stumps
  \[ \phi \text{ BW volume} \]
- Buried wood
  \[ 57 \pm 28 \text{ to } 389 \pm 67 \text{ m}^3 \text{ ha}^{-1} \]

Deadwood Cycle

CO₂

1st order disturbances → de novo

2nd order disturbances - on heritage dead wood

Decay via: - Respiration - Fragmentation - Leaching

Aboveground dead wood

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Buried wood

• Process of WD burial
  • WD is gradually overgrown by moss and incorporated into organic layer
  • Expected:
    • ↓ temperature
    • ↑ moisture
    • ↓ decomposition
  • Required conditions: cool and wet climate, vital moss layer, high groundwater table, long fire return interval, WD for burial, ...?
Burial Experiment

- Burial of
  - 36 standardized spruce logs
  - 4 placement positions
  - Ends sealed

- DWD respiration
  - Closed dynamic chamber – IRGA
  - Bi-weekly measurements (12/07–01/09, 2008)

- Environmental variables
  - Temperatures
    - Air
    - Soil (2 and 10 cm depth)
    - DWD (surface, top sap, heartwood, bottom sap)
  - Relative humidity
  - DWD and soil moisture content
Temperature

- Temperature of moss-covered logs significantly lower than of uncovered logs
- Differences most pronounced on warm days

Mosses influence buried wood (& organic layer/mineral soil) through
- Insulation

Hagemann et al. (2010) Ecosystems
Moisture

- Moisture content increases with burial depth
- High variability due to variability in wood density

Mosses influence buried wood (& organic layer/mineral soil) through
  - Insulation
  - Water retention

Hagemann et al. (2010) Ecosystems
Results III

Respiration

- High variability
- 68% of variability due to temperature, moisture & density
- Decreasing trend with burial depth
- Decrease in respiration initiated by moss cover, not by burial depth

Mosses influence buried wood (& organic layer/mineral soil) through
  - Insulation
  - Water retention

→ Reduction of decomposition
→ Initiation of preservation

Hagemann et al. (2010) Ecosystems
Buried wood preservation

$^{14}$C Dating
- Age range 200-450 years
- Some samples likely preserved for 250-300 years after tree death
- Bias towards younger samples

Mosses influence buried wood (& organic layer/ mineral soil) through
  - Insulation
  - Water retention
→ Reduction of decomposition
→ Initiation of preservation
→ Buried wood is a (possibly very) long-lived ecosystem C pool

450-year-old wood, partly charred

Moroni et al. (2010) Ecosystems
WD burial requires a vital moss layer which can overgrow WD before it has completely decomposed.

WD burial is a 2-phase process: I) Initialization and II) Burial.

Moss influences buried wood (and organic layer/mineral soil) through insulation, water retention ... and chemistry?!

Decomposition rates of buried wood greatly reduced.

Bryophytes with disproportional effects on organic layer, buried wood & mineral soil C pools.

Bryophytes are a key driver of the deadwood and C cycle of humid boreal black spruce forests in Labrador.

Elsewhere?

- Mosses are an integral component of
  - Most boreal forests
  - Many coniferous forests outside the boreal biome
  - Micro-habitats of mixed forests

Buried wood likely occurs over a wide range of environmental conditions.
Effects of bryophytes on ecosystems processes increase with deteriorating soil drainage (paludification)

Buried wood occurrence linked to the ecological relevance of bryophytes

Moisture and bryophytes determine patterns of soil C storage at landscape and regional scales

Bryophyte-regulated forests may release large amounts of CO₂ from buried wood and soil C pools due to decreased bryophyte productivity and enhanced decomposition
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Thank you for your attention ...
WD respiration ... vs. mass loss rates

• Standardized sample log:
  – Diameter 13.9 cm and length 31 cm
  – Volume 0.0047 m³ and surface 0.135 m²
  – Weight 2 kg and density 425 kg/m³
  – C content 50%

• Respiration rate
  – Measured 0.2 g CO₂ m⁻² h⁻¹
  – Per day  4.8 g CO₂ m⁻² d⁻¹
  – Per year  0.864 kg CO₂ m⁻² yr⁻¹ (assuming 180d)
  – Equaling  0.236 kg C m⁻² yr⁻¹
  – Per log  0.032 kg C m⁻² yr⁻¹

• Life-time  31.3 years  (steady linear decay)
• For 300 years  ~0.02 g CO₂ m⁻² h⁻¹  (10%)
Wildfire combests most of the live moss and the organic layer, and the wood buried within it.

Forest stand matures and goes into gap dynamics; until the next stand-replacing wildfire, the accumulation of buried wood and successional paludification are the dominant processes.

>120 yrs

0—10 yrs

Case-hardening and collapse of snags

Snags
Woody debris
Shrubs
Buried wood
Live moss
Organic layer
Mineral soil

The collapse of most snags results in large amounts of woody debris; onset of tree regeneration.

10—20 yrs

20—40 yrs

Tree regeneration establishes; onset of feathermoss recolonization and likely the burial of fire-generated woody debris.

80—120 yrs

Forest canopy closure; feathermoss dominates ground vegetation layer; fire-generated woody debris either decomposed or buried; continuous organic layer accumulation.