Functional responses of soil Collembola communities to woody debris harvesting in the boreal forest

Laurent ROUSSEAU
Tanya HANDA (UQÀM) & Lisa VENIER (SCF - NRCan)
3 May 2014
Context:

- Ecological & socioeconomic importance of Canadian boreal forest (e.g. timber)
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- Strong forestry pressure & energy demand increasing have impacts on ecological functioning & biotic communities of forests
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- Strong forestry pressure & energy demand increasing have impacts on ecological functioning & biotic communities of forests

- Sustainable management for certification (e.g. Forest Stewardship Council)
Context:

• Potential use of residual biomass for bioenergy
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• Residual biomass = branches, stumps & smaller woody debris left on the ground after clear-cutting
Context:

- Potential use of residual biomass for bioenergy
- Residual biomass = branches, stumps & smaller woody debris left on the ground after clear-cutting
- Different treatments of residual biomass harvesting with associated disturbances
Context:

• Potential use of residual biomass for bioenergy

• Residual biomass = branches, stumps & smaller woody debris left on the ground after clear-cutting

• Different treatments of residual biomass harvesting with associated disturbances

• Impacts on soil fauna communities via the residual biomass loss?
Context:

Soil Collembola communities:
Soil Collembola communities:
• More than 500 species in Canada
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Soil Collembola communities:
• More than 500 species in Canada

• 50-100,000 ind. & 20-40 species by m² of boreal forest soil with moss layers
Soil Collembola communities:

- More than 500 species in Canada
- 50-100,000 ind. & 20-40 species by $m^2$ of boreal forest soil with moss layers
- Significantly influenced by soil environmental conditions (e.g. humidity)
Soil Collembola communities:

- More than 500 species in Canada
- 50,000-100,000 ind. & 20-40 species by m² of boreal forest soil with moss layers
- Significantly influenced by soil environmental conditions (e.g. humidity)
- Essential for soil ecological processes (e.g. litter decomposition)
Soil Collembola communities:

- More than 500 species in Canada
- 50-100,000 ind. & 20-40 species by m² of boreal forest soil with moss layers
- Significantly influenced by soil environmental conditions (e.g. humidity)
- Essential for soil ecological processes (e.g. litter decomposition)
- Residual biomass as soil cover provides a high diversity of ecological niches
Functional approach using response traits:
Functional approach using response traits:
Functional approach using response traits:

Local community
Functional approach using response traits:

Local community
Functional approach using response traits:

Local community
Functional approach using response traits:

Local community

Modified community
Functional approach using response traits:

Local community

Environmental filter (biotic & abiotic)

Modified community
Functional approach using response traits:

Local community

- Body size
- Pigmentation
- Trait i

Environmental filter (biotic & abiotic)

Modified community

Community mean value of traits
Functional approach using response traits:

- Local community
  - Body size
  - Pigmentation
  - Trait i

Community mean value of traits

- Environmental filter (biotic & abiotic)

- Modified community
  - Changes in mean trait values?

- Body size
- Pigmentation
- Trait i

- Trait i
Objectives:
Objectives:

Different treatments of the residual biomass harvesting
Objectives:

Different treatments of the residual biomass harvesting

Modifications of environmental conditions
Objectives:

Different treatments of the residual biomass harvesting

Modifications of environmental conditions

Functional responses of soil Collembola communities?
Experimental design & methods:

- Experimental site of Island Lake
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- 45 years old stand of Jack pine (*Pinus banksiana*) harvested in 2011
Experimental design & methods:

• Experimental site of Island Lake

• 45 years old stand of Jack pine (*Pinus banksiana*) harvested in 2011

• Implementation of several harvesting treatments
Gradient of biomass harvesting & disturbance with 5 treatments
Gradient of biomass harvesting & disturbance with 5 treatments
Gradient of biomass harvesting & disturbance with 5 treatments

Clear cutting

Control (CTL)
Gradient of biomass harvesting & disturbance with 5 treatments
Gradient of biomass harvesting & disturbance with 5 treatments

Control (CTL)

Clear cutting

Woody debris = 84 m³ ha⁻¹

Tree-length (T)
Gradient of biomass harvesting & disturbance with 5 treatments

Woody debris = 84 m³ ha⁻¹

Tree-length (T)

29 m³ ha⁻¹

Control (CTL)

Clear cutting
Gradient of biomass harvesting & disturbance with 5 treatments

Control (CTL)

Clear cutting

Tree-length (T)

Woody debris = 84 m$^3$ ha$^{-1}$

Full-tree (F)

29 m$^3$ ha$^{-1}$

Traditional
Gradient of biomass harvesting & disturbance with 5 treatments:

- Control (CTL)
- Clear cutting
- Woody debris = 84 m$^3$ ha$^{-1}$
- Full-tree (F) 29 m$^3$ ha$^{-1}$
- Traditional
- Stumped (S) 24 m$^3$ ha$^{-1}$
Gradient of biomass harvesting & disturbance with 5 treatments:

- Control (CTL)
- Clear cutting
- Woody debris = 84 m³ ha⁻¹
- Full-tree (F)
- Traditional
- Bladed (B)
- Stumped (S)
- 0 m³ ha⁻¹
- 29 m³ ha⁻¹
- 24 m³ ha⁻¹
5 blocks as replicates
Sampling:
Sampling:

One sampling campaign: May 2014
Sampling:

One sampling campaign: May 2014

- 2 soil cores per plot
Sampling:

One sampling campaign: May 2014
- 2 soil cores per plot
- + 2 moss samples per CTL plot
Sampling:

One sampling campaign: **May 2014**
- 2 soil cores per plot
- + 2 moss samples per CTL plot
**Sampling:**

One sampling campaign: **May 2014**

- 2 soil cores per plot
- + 2 moss samples per CTL plot
- N = 25 sampling points
  (samples grouped)

**Extraction & ID**
Measure of environmental factors:
Measure of environmental factors:

- Soil & mosses relative humidity
- Soil temperature
Measure of environmental factors:

• Soil & mosses relative humidity
• Soil temperature
• Soil profile & density (compaction)
• Soil chemical fertility
Measure of environmental factors:

- Soil & mosses relative humidity
- Soil temperature
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- Soil chemical fertility
- Soil herbaceous vegetation cover & diversity
Measure of environmental factors:

- Soil & mosses relative humidity
- Soil temperature
- Soil profile & density (compaction)
- Soil chemical fertility
- Soil herbaceous vegetation cover & diversity
- Fine/coarse woody debris volume
Measure of Collembola functional traits:
Measure of Collembola functional traits:
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Body length
Measure of Collembola functional traits:

- Body length
- Body width
Measure of Collembola functional traits:

- Body length
- Body shape ratio
- Body width
Measure of Collembola functional traits:

- Body length
- Body width
- Body shape ratio
- Bothriotricha
Measure of Collembola functional traits:

- Body length
- Body width
- Relative furcula length
- Body shape ratio
- Bothriotricha
Measure of Collembola functional traits:

- Body length
- Body shape ratio
- Body width
- Bothriotricha
- Scales
- Relative furcula length
Measure of Collembola functional traits:

- Body length
- Body shape ratio
- Body width
- Bothriotricha
- Relative leg length
- Scales
- Relative furcula length
Measure of Collembola functional traits:

- Body length
- Body shape ratio
- Body width
- Bothriotricha
- Body pigmentation
- Relative leg length
- Scales
- Relative furcula length
Measure of Collembola functional traits:

- Body length
- Body width
- Relative furcula length
- Relative leg length
- Body pigmentation
- PAO
- Scales
- Bothriotricha
- Body shape ratio
Measure of Collembola functional traits:

- Body length
- Body shape ratio
- Body width
- Bothriotricha
- Relative antenna length
- PAO
- Body pigmentation
- Relative leg length
- Scales
- Relative furcula length
Measure of Collembola functional traits:

- Body length
- Body width
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- Relative furcula length
- Relative leg length
- Body pigmentation
- Mouthpart structure
- Body shape ratio
- Bothriotricha
- PAO
- Scales
Measure of Collembola functional traits:

- Body length
- Body shape ratio
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- Body shape ratio
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- Bothriotricha

+ Reproduction mode

Scales
Determination of ecological preferences:
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- **Microhabitat**: euedaphic (soil-dwelling) / hemiedaphic / epiedaphic (surface-dwelling) taxa (life-form) via body length, ocelli number, pigmentation level & PAO
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- **Dispersal capacity**: low / high
  
  via relative antenna & leg length & ocelli number
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Hypotheses:
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<td>+ + + sexual partners</td>
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**Due to:**

- +++ food resources supply & complexity
- +++ predation
- +++ soil humidity & cover
- +++ complex microhabitats
- +++ sexual partners
- - - soil temperature
- - - predation
- - - soil humidity & cover
- - - complex microhabitats
- - - sexual partners
- +++ soil temperature
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**Microhabitat**

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| Diversity                  | Soil ecological processes                     |                                 |                              |
Data analyses:
Data analyses:

1) **RLQ analysis**: coinertia between R matrix (treatments / environmental factors) & Q matrix (functional traits / preferences) weighted by L matrix (taxa abundances)
Data analyses:

1) RLQ analysis: coinertia between R matrix (treatments / environmental factors) & Q matrix (functional traits / preferences) weighted by L matrix (taxa abundances)

2) **Fourth-corner analysis**: tests the associations between traits & treatments / environmental factors
Data analyses:

1) RLQ analysis: coinertia between R matrix (treatments / environmental factors) & Q matrix (functional traits / preferences) weighted by L matrix (taxa abundances)

2) Fourth-corner analysis: tests the associations between traits & treatments / environmental factors

3) Functional diversity (Rao quadratic entropy ~ taxa relative abundances & dissimilarity between taxa by traits) according to the harvesting treatments
Results:
Results:

• 2555 specimens identified
• 37 species found
• 557 specimens used to measure functional traits & preferences
Functional response according to the harvesting treatments:
Functional response according to the harvesting treatments:

**RLQ Traits**

Matrix correlation coefficient (RV) = 0.41***

- **BL** = Body length
- **BSR** = Body shape ratio
- **RAL** = Relative antenna length
- **ON** = Number of ocelli
- **BOP** = Bothriotricha present
- **SP** = Scales present
- **PAO** = PAO present
- **MPS** = Mouthpart structure
- **SRS** = Sexual reproduction strategy

Axis 1 = 78.37 %
Axe 2 = 17.34 %
Control treatment:
+ sexual reproduction & hemiedaphic taxa (PAO & BOP)
- “slender” body shape

Axis 1 = 78.37%
Axe 2 = 17.34%

Fourth-corner:
Positive significant relation
Negative significant relation
Stumped treatment:
+ complex mouthparts

Fourth-corner:
Positive significant relation
Negative significant relation

BL = Body length
BSR = Body shape ratio
RAL = Relative antenna length
ON = Number of ocelli
BOP = Bothriotricha present
SP = Scales present
PAO = PAO present
MPS = Mouthpart structure
SRS = Sexual reproduction strategy
Bladed treatment:
+ “slender” body shape
- sexual reproduction, antenna length & complex mouthparts

Axis 1 = 78.37%
Axe 2 = 17.34%

Fourth-corner:
Positive significant relation
Negative significant relation

BL = Body length
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PAO = PAO present
MPS = Mouthpart structure
SRS = Sexual reproduction strategy
RLQ Preferences
RV = 0.22**

Dispersal capacity

Euedaphic

Control

Full-tree

Tree-length

Stumped

Hemiedaphic

Epiedaphic

Bladed

Axis 1 = 83.04 %

Axis 2 = 11.84 %
Control treatment:
+ dispersal capacity & hemiedaphic taxa

- Dispersal capacity
- Euedaphic
- Hemiedaphic
- Epiedaphic

Bladed
Full-tree
Tree-length
Stumped

Axis 1 = 83.04%
Axis 2 = 11.84%

Fourth-corner:
Positive significant relation
Negative significant relation
Bladed treatment:
+ euedaphic taxa / - dispersal capacity & hemiedaphic taxa

Axis 1 = 83.04 %
Axis 2 = 11.84 %

Fourth-corner:
Positive significant relation
Negative significant relation
Lowest functional diversity in the Bladed (B)

Functional diversity

** **
Relations to modifications of environmental factors:
**RLQ Traits**

**RV** = 0.63*

Veg_cover = Herbaceous vegetation soil cover  
Plant_H = Herbaceous vegetation diversity  
CWD_volume = Coarse woody debris volume  
FWD_volume = Fine woody debris volume  
OLP = Organic soil depth  
BD = Soil bulk density

Axis 1 = 80.57 %

Axis 2 = 15.69 %

BL = Body length  
BSR = Body shape ratio  
RAL = Relative antenna length  
ON = Number of ocelli  
BOP = Bothriotricha present  
SP = Scales present  
PAO = PAO present  
MPS = Mouthpart structure  
SRS = Sexual reproduction strategy
**Bulk density (soil compaction):**

+ “slender” body shape / - complex mouthparts

**Fourth-corner:**

Positive significant relation
Negative significant relation

**Variables:**
- **Veg_cover** = Herbaceous vegetation soil cover
- **Plant_H** = Herbaceous vegetation diversity
- **CWD_volume** = Coarse woody debris volume
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**Axes:**
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**Labels:**
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- **MPS** = Mouthpart structure
- **SRS** = Sexual reproduction strategy
- **CWD_Volume**
- **FWD_Volume**
- **OLP**
- **Plant_H**
- **Soil_chemical_fertility**
Organic layer depth: + complex mouthparts

\[
\begin{align*}
\text{Veg\_cover} &= \text{Herbaceous vegetation soil cover} \\
\text{Plant\_H} &= \text{Herbaceous vegetation diversity} \\
\text{CWD\_volume} &= \text{Coarse woody debris volume} \\
\text{FWD\_volume} &= \text{Fine woody debris volume} \\
\text{OLP} &= \text{Organic soil depth} \\
\text{BD} &= \text{Soil bulk density}
\end{align*}
\]

Axis 1 = 80.57 %

Axis 2 = 15.69 %

Fourth-corner:
Positive significant relation
Negative significant relation

\[
\begin{align*}
\text{BL} &= \text{Body length} \\
\text{BSR} &= \text{Body shape ratio} \\
\text{RAL} &= \text{Relative antenna length} \\
\text{ON} &= \text{Number of ocelli} \\
\text{BOP} &= \text{Bothriotricha present} \\
\text{SP} &= \text{Scales present} \\
\text{PAO} &= \text{PAO present} \\
\text{MPS} &= \text{Mouthpart structure} \\
\text{SRS} &= \text{Sexual reproduction strategy}
\end{align*}
\]
Vegetation cover: 
+ body length, sexual reproduction & complex mouthparts

**Axis 1 = 80.57 %**

**Axis 2 = 15.69 %**

**Veg_cover** = Herbaceous vegetation soil cover
**Plant_H** = Herbcaeous vegetation diversity
**CWD_volume** = Coarse woody debris volume
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**Fourth-corner:**
Positive significant relation
Negative significant relation
Fine woody debris volume:
+ complex mouthparts

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RLQ Preferences

RV = 0.33*

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Axis 1 = 88.36 %
Axis 2 = 8.36 %

Dispersal capacity
Euedaphic
Hemiedaphic
Epiedaphic
Bulk density (soil compaction):

+ euedaphic taxa / - dispersal capacity & hemiedaphic taxa

Veg_cover = Herbaceous vegetation soil cover
Plant_H = Herbaceous vegetation diversity
BD = Soil bulk density
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Axis 1 = 88.36 %
Axis 2 = 8.36 %

Fourth-corner:
Positive significant relation
Negative significant relation
**Organic layer depth:**
+ hemiedaphic taxa

Dispersal capacity

Euedaphic

Epiedaphic

**Veg_cover** = Herbaceous vegetation soil cover
**Plant_H** = Herbaceous vegetation diversity
**BD** = Soil bulk density
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Axis 1 = 88.36 %

Axis 2 = 8.36 %
Vegetation cover:
+ dispersal capacity & hemiedaphic taxa
- euedaphic taxa

**Axes**
- Axis 1: 88.36%
- Axis 2: 8.36%

**Variables**
- Veg_cover: Herbaceous vegetation soil cover
- Plant_H: Herbaceous vegetation diversity
- Soil_chemical_fertility
- BD: Soil bulk density
- CWD_Volume: Coarse woody debris volume
- OLP: Organic soil depth
- FWD_Volume: Fine woody debris volume
- Axis 1 = 88.36 %

**Legend**
- Dispersal capacity
- Hemiedaphic
- Euedaphic

**Definitions**
- Veg_cover: Herbaceous vegetation soil cover
- Plant_H: Herbaceous vegetation diversity
- BD: Soil bulk density
- CWD_volume: Coarse woody debris volume
- FWD_volume: Fine woody debris volume
- OLP: Organic soil depth
- BD: Soil bulk density
Conclusion:
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• Significant short term effect of residual biomass harvesting & associated disturbances on functional structure of soil Collembola communities
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Conclusion:

• Significant short term effect of residual biomass harvesting & associated disturbances on functional structure of soil Collembola communities

• No biomass harvesting (CTL) maintained epi-hemiedaphic communities (higher vegetation & org. soil depth)

• The T, F & S treatments showed intermediate functional responses while conserving a high diversity of communities

• Strong negative effect of B treatment on functional structure especially diversity with only euedaphic taxa (higher soil compaction & forest floor loss)
Conclusion:

• Our study showed the relevance of the functional approach in the context of the impact assessment of the boreal forest management
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• Our study showed the relevance of the functional approach in the context of the impact assessment of the boreal forest management

• These results should help to the sustainable management of the boreal forest
Thanks to all the collaborators of the project...


D. Morris & M. Kwiaton - Ontario Ministry of Natural Resources and Forestry (OMNRF)

Sandrine Salmon - Muséum National d'Histoire Naturelle (France)

Marco Moretti - Institut fédéral de recherches sur la forêt, la neige et le paysage (Suisse)

T. Work & C. Messier - Université du Québec à Montreal & Centre for Forest Research

Tembec & Ontario Power Generation

Laurence Codebecq & Adriana Ramos Diaz for their contribution in identification and functional measures!

... and of your attention!
Results:

• 2555 specimens identified
• 37 species found
• 557 specimens used to measure functional traits & preferences
<table>
<thead>
<tr>
<th>Functional attributes</th>
<th>CTL treatment</th>
<th>S treatment</th>
<th>B treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body length</td>
<td>[Vegetation cover]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body shape ratio</td>
<td></td>
<td></td>
<td>[soil compaction]</td>
</tr>
<tr>
<td>Rel. antenna length</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bothriotricha</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAO</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sexual reproduction</td>
<td>+ [Vegetation cover]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complex mouthpart structure</td>
<td>[Organic soil depth Vegetation cover]</td>
<td>+ [FWD volume]</td>
<td>[soil compaction]</td>
</tr>
<tr>
<td>Microhabitat</td>
<td>Hemiedaphic [Organic soil depth Vegetation cover]</td>
<td></td>
<td>Euedaphic [soil compaction]</td>
</tr>
<tr>
<td>Dispersal capacity</td>
<td>+ [Vegetation cover]</td>
<td></td>
<td>[soil compaction]</td>
</tr>
<tr>
<td>Functional diversity</td>
<td>+</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>