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

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Natural Resources Canada
Canadian Forest Service
Ressources naturelles Canada
Service canadien des forêts

cef
Centre d'étude de la forêt

Context:

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

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- **Different treatments of residual biomass harvesting with associated disturbances**

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- 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:

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- 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:

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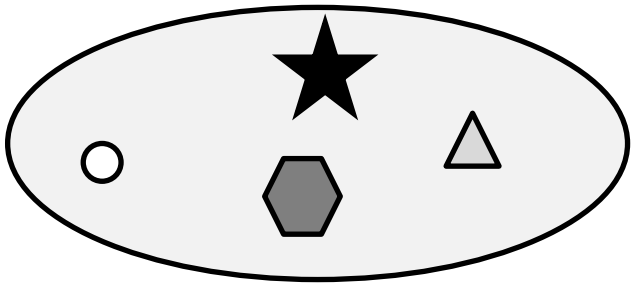
Local community



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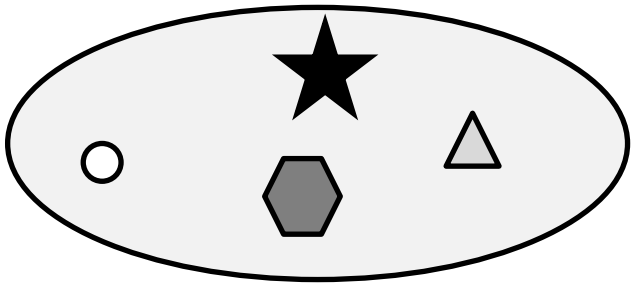

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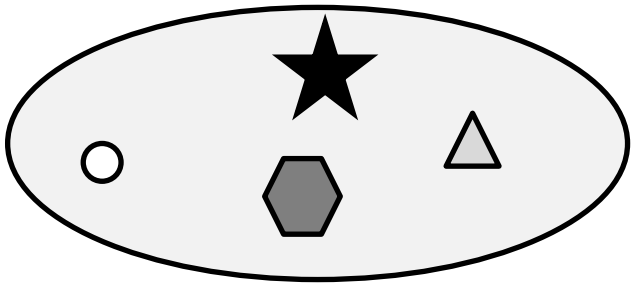

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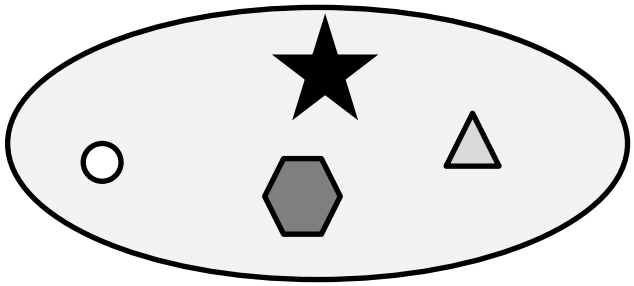

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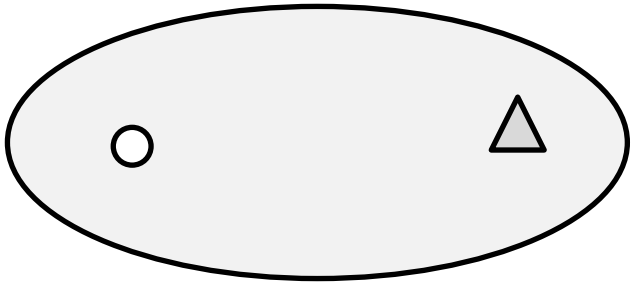
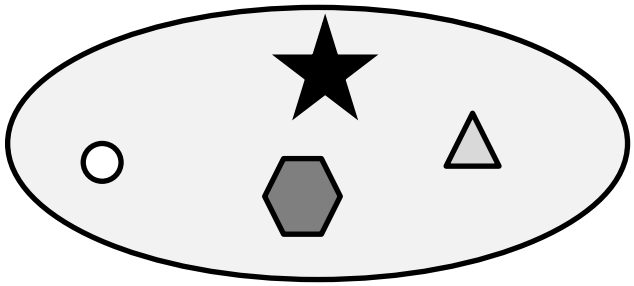


Functional approach using response traits:

Environmental filter (biotic & abiotic)

Local community



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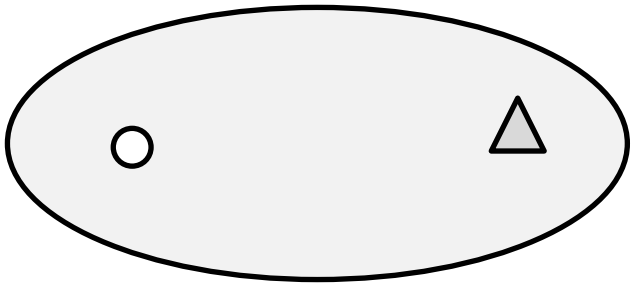

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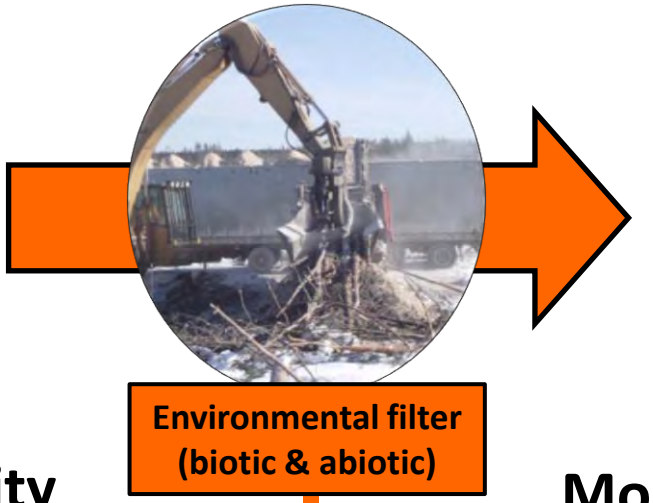

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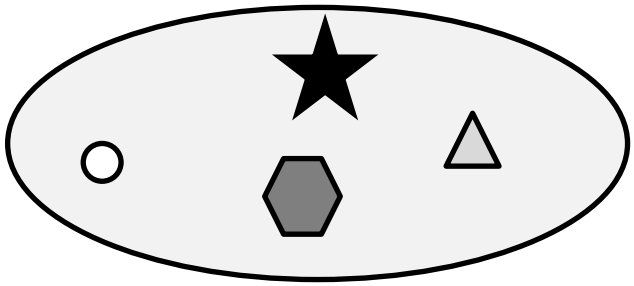

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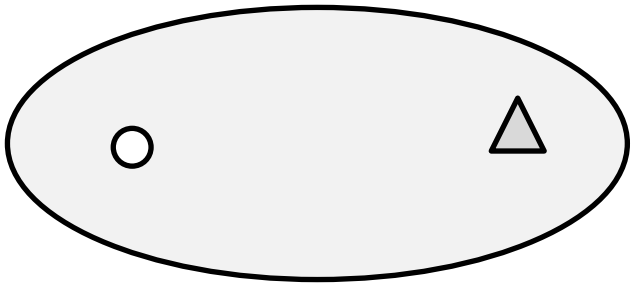
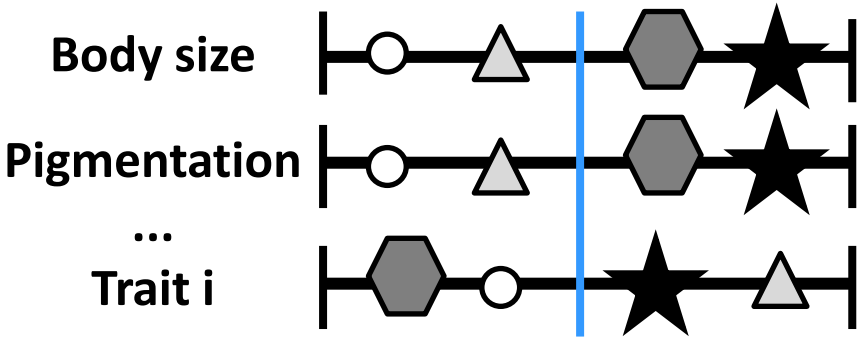


Community mean value of traits



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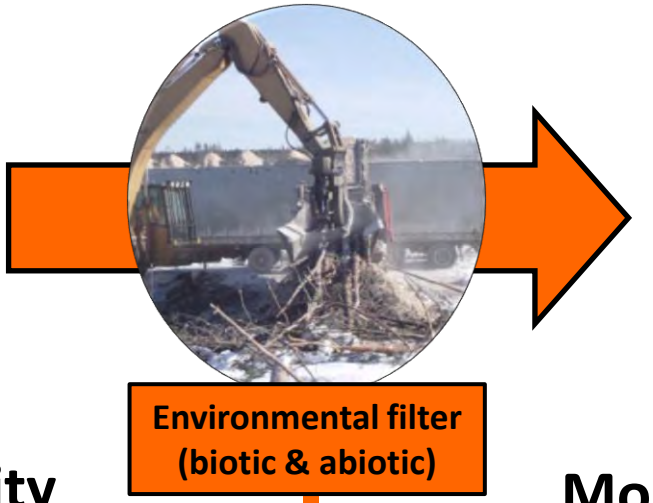

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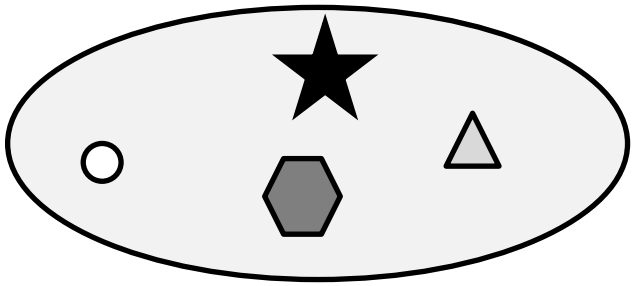

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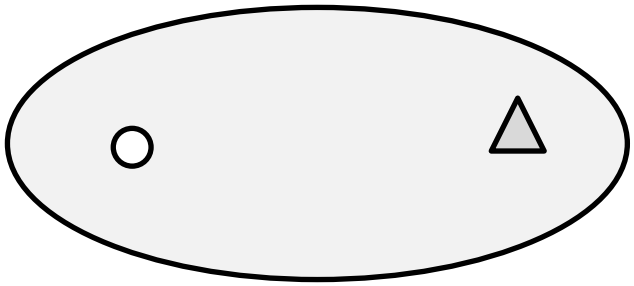

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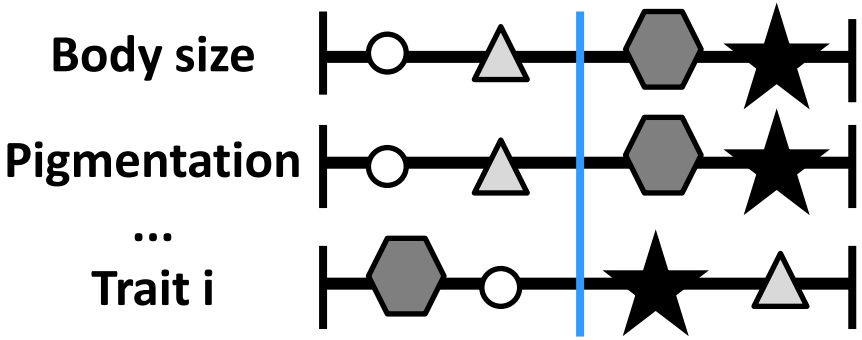
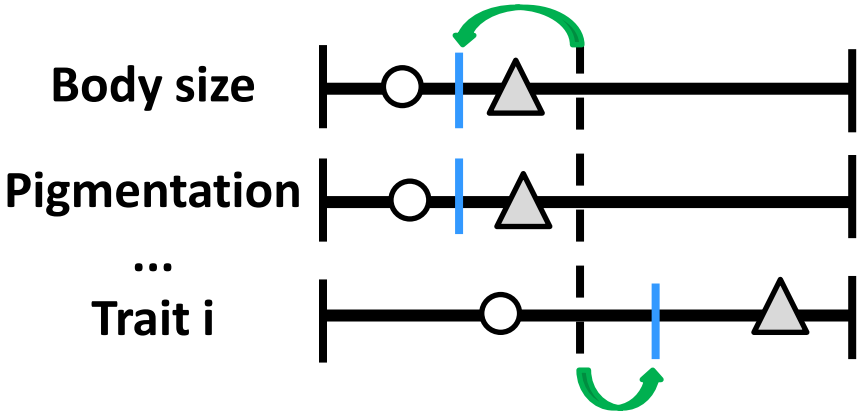


Changes in mean trait values?



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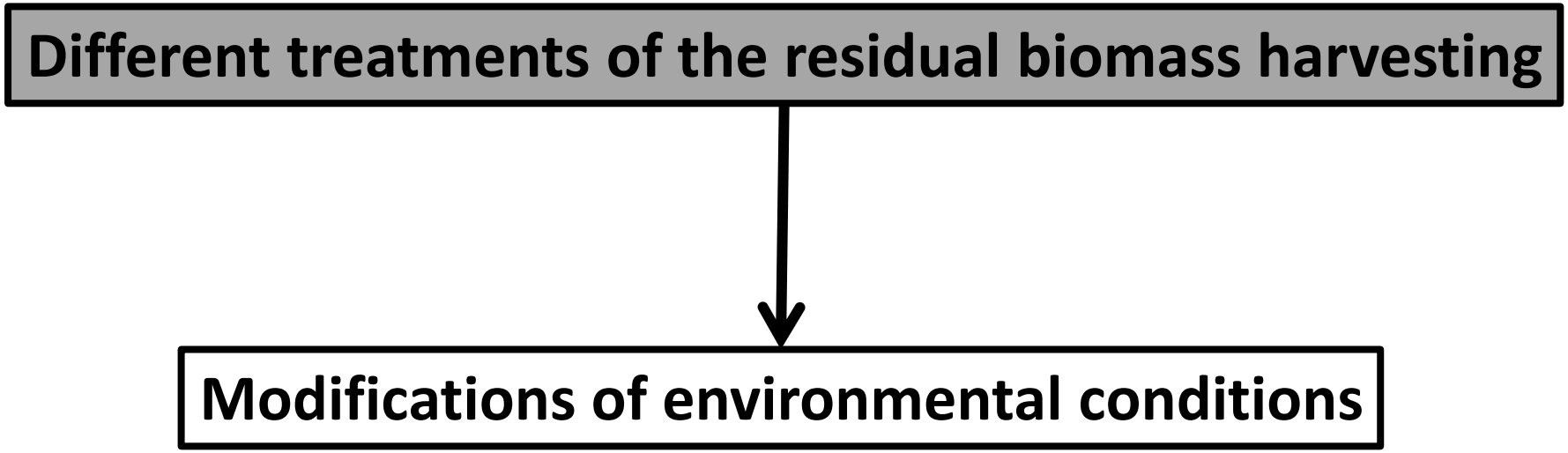
Different treatments of the residual biomass harvesting
Modifications of environmental conditions

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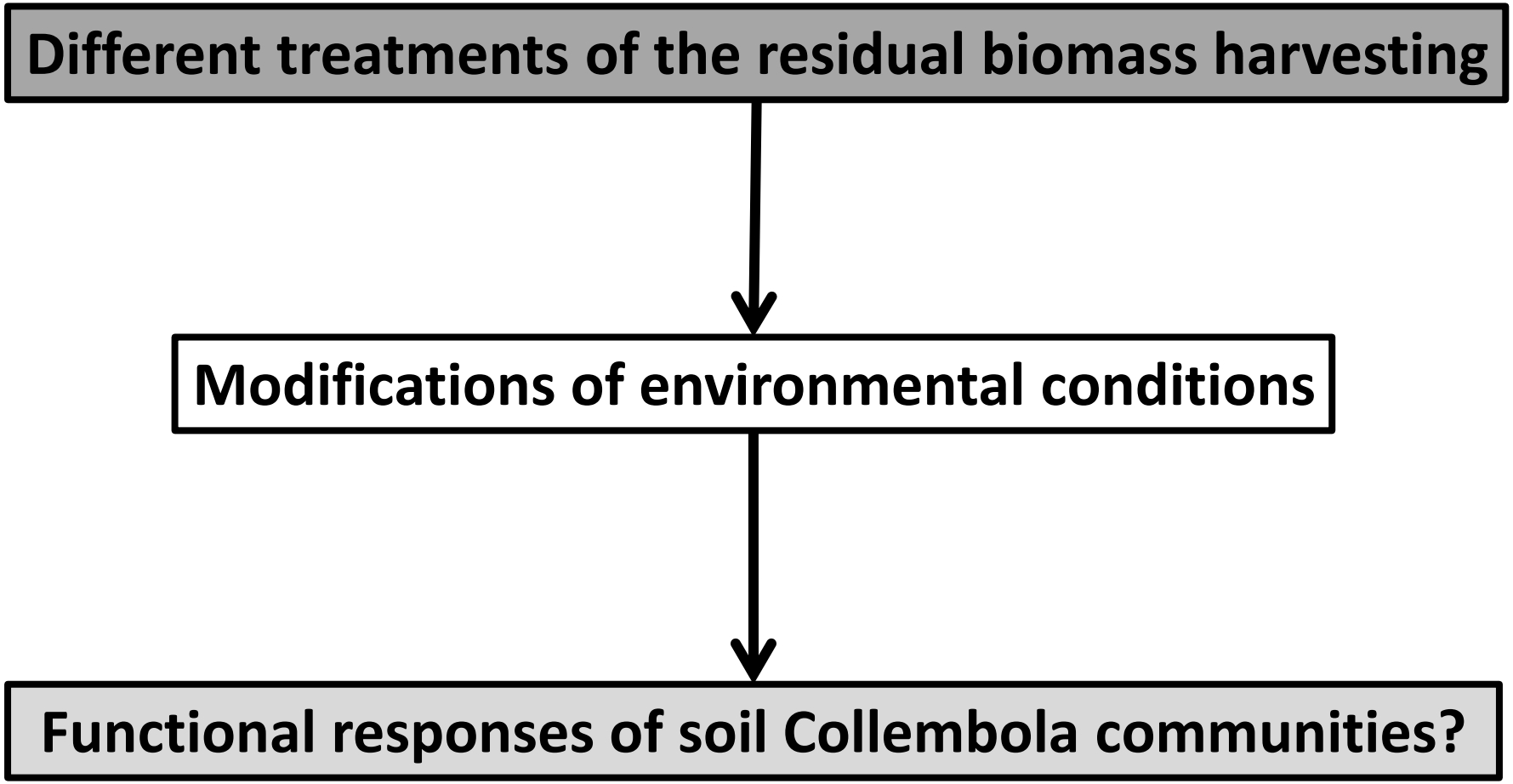
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Functional responses of soil Collembola communities?

Experimental design & methods:

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- 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

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Clear cutting

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

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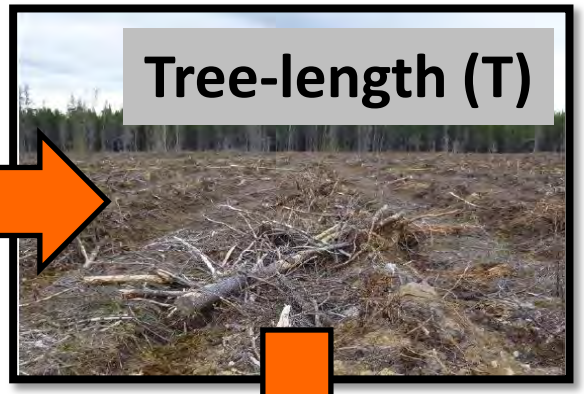
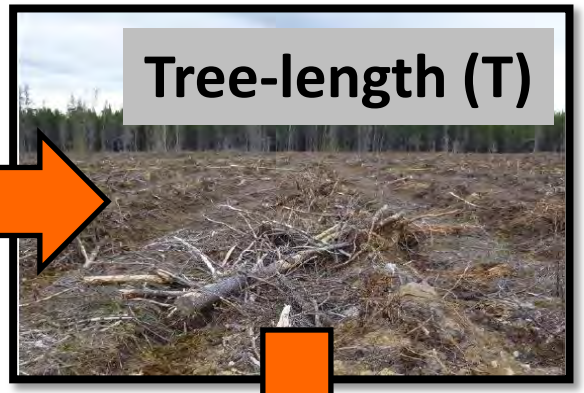


Gradient of biomass harvesting & disturbance with 5 treatments

29 m^3 ha^{-1}

Clear cutting

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



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Traditional

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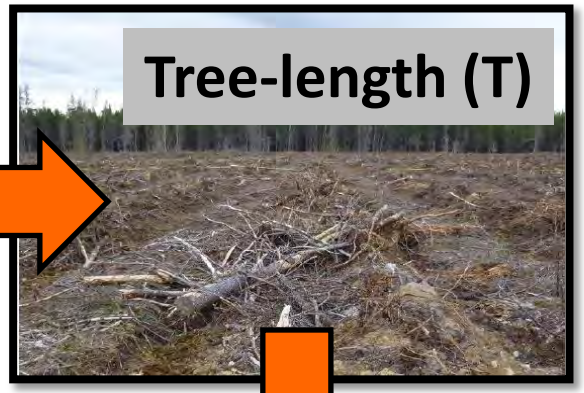

Gradient of biomass harvesting & disturbance with 5 treatments

29 m^3 ha^{-1}

Traditional

24 m^3 ha^{-1}

Clear cutting

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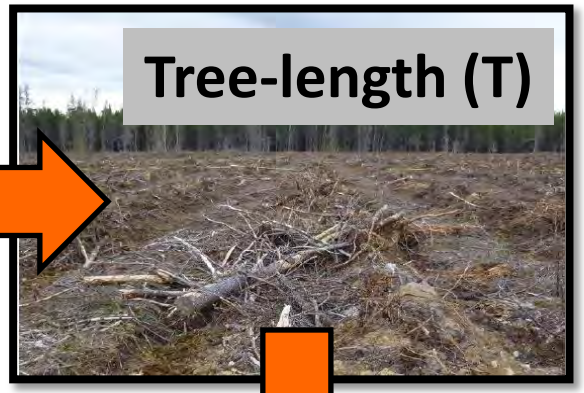


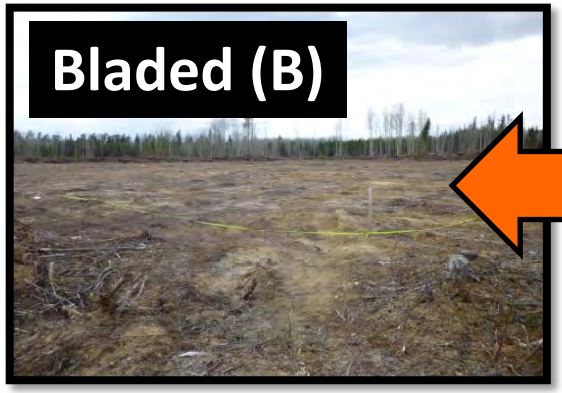
Gradient of biomass harvesting & disturbance with 5 treatments

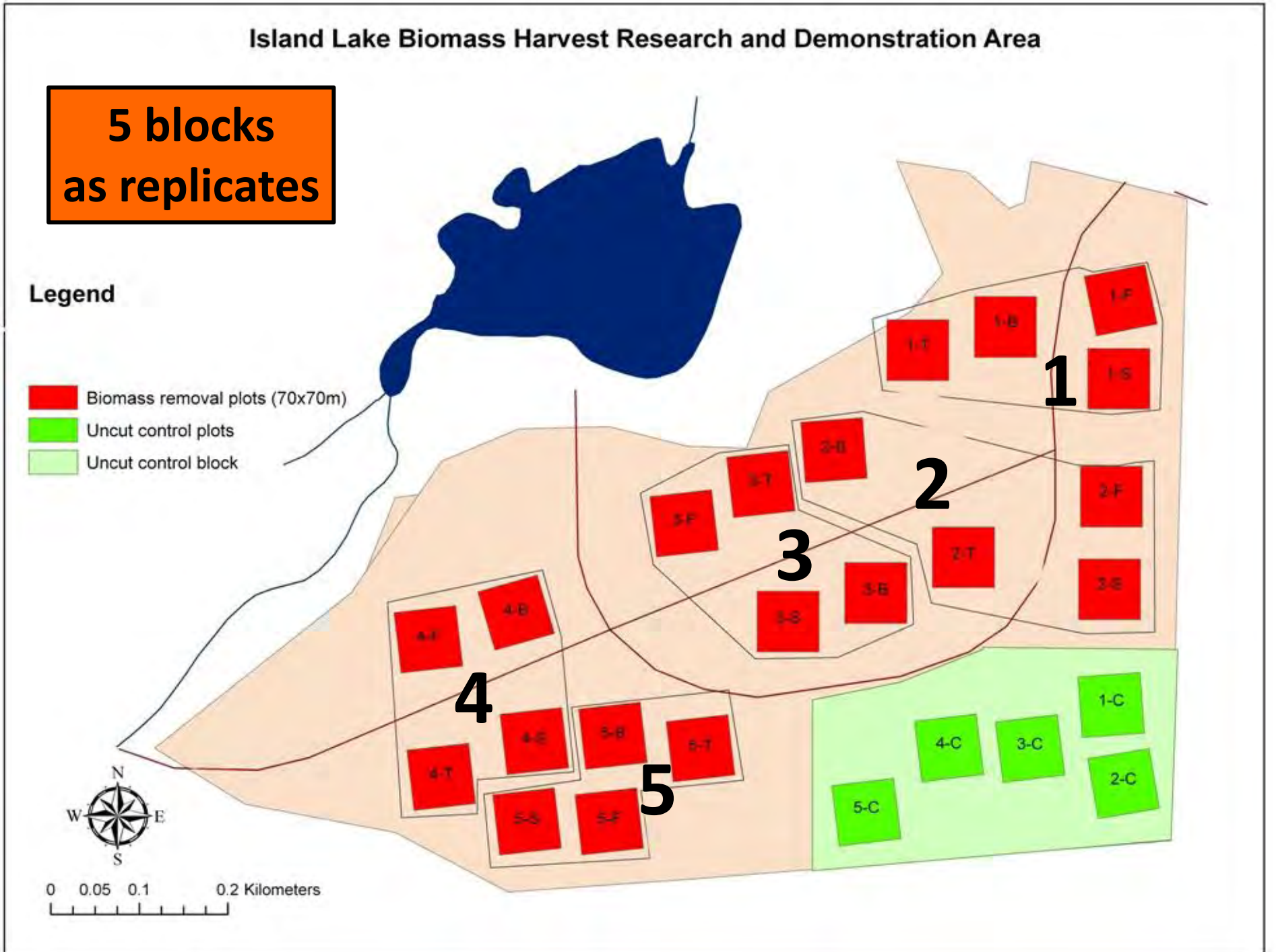
29 m^3 ha^{-1}

Traditional

24 m^3 ha^{-1}

0 m^3 ha^{-1}




Island Lake Biomass Harvest Research and Demonstration Area
5 blocks as replicates
Legend
Biomass removal plots (70x70m)
Uncut control plots
Uncut control block
1
2
3
4
5
1-T
1-B
1-F
1-S
2-B
2-T
2-F
3-F
3-T
3-B
2-T
3-B
3-S
3-E
4-T
4-B
4-E
5-B
5-T
5-S
5-F
1-C
4-C
3-C
2-C
5-C
N
W
E
S
0 0.05 0.1 0.2 Kilometers

Sampling:

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One sampling campaign: May 2014

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- **2 soil cores per plot**

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- **N = 25 sampling points (samples grouped)**

Measure of environmental factors:

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- Soil temperature

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- **Soil profile & density (compaction)**
- **Soil chemical fertility**

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- Soil temperature
- Soil profile & density (compaction)
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- **Soil herbaceous vegetation cover & diversity**

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- Soil & mosses relative humidity
- Soil temperature
- Soil profile & density (compaction)
- Soil chemical fertility
- Soil herbaceous vegetation cover & diversity
- **Fine/coarse woody debris volume**

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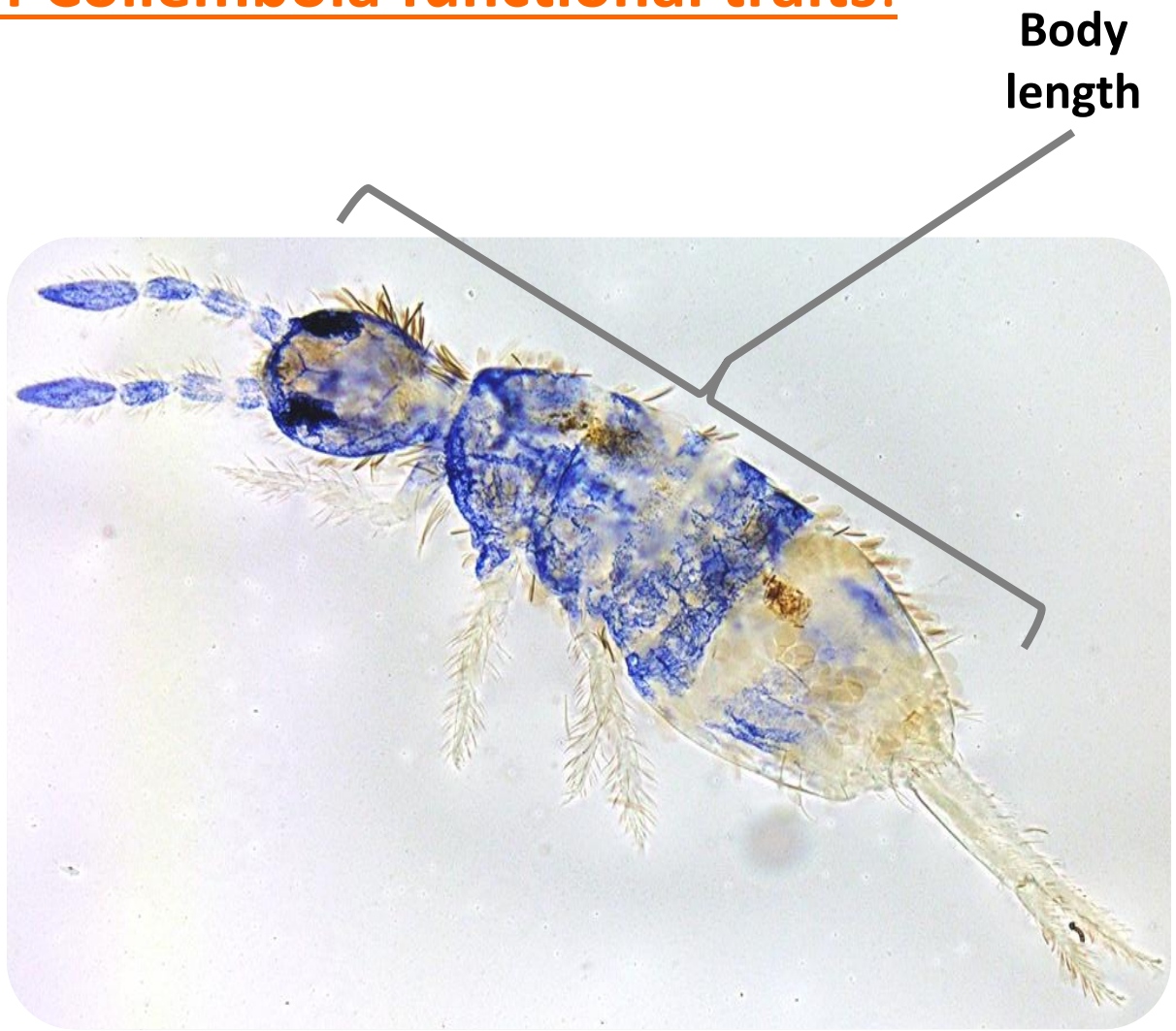

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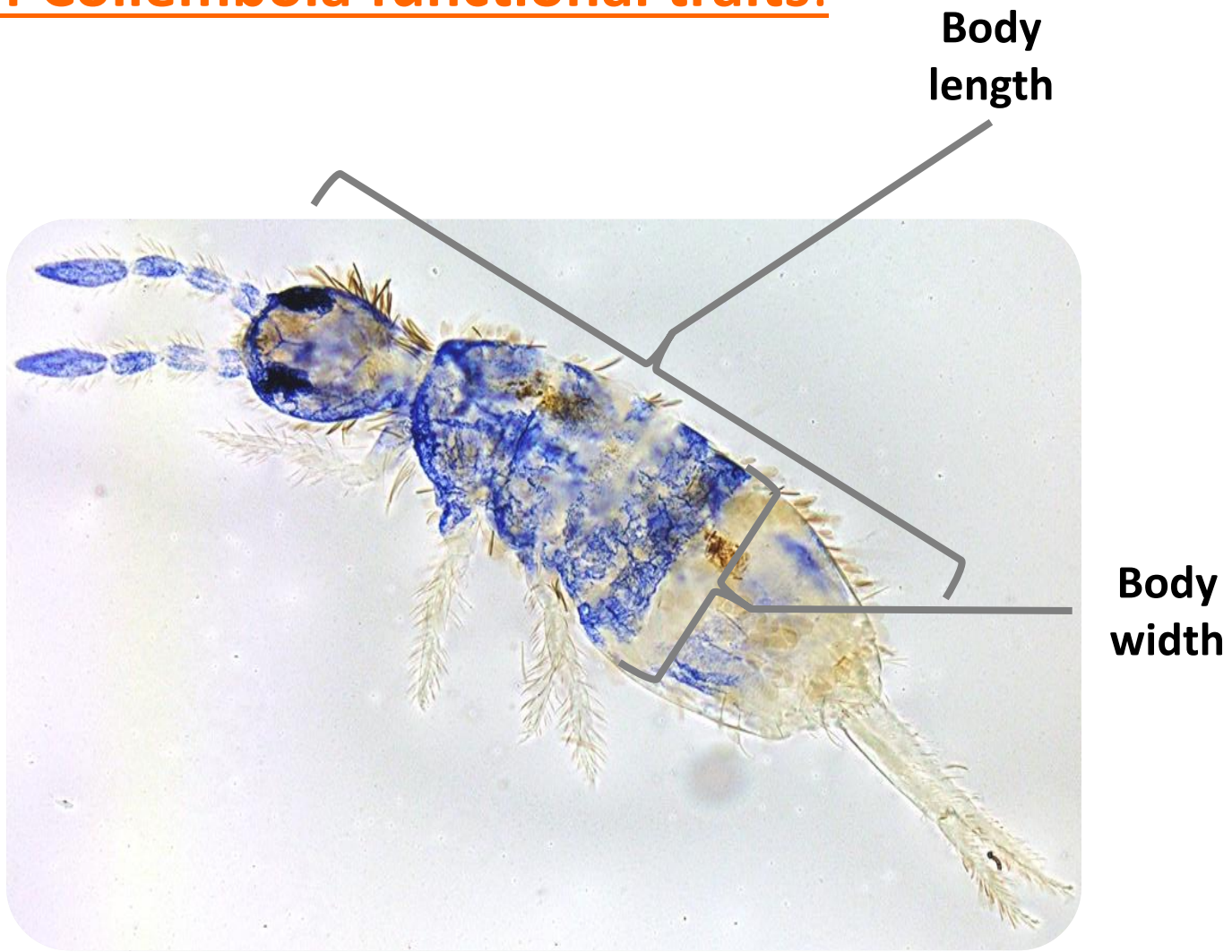

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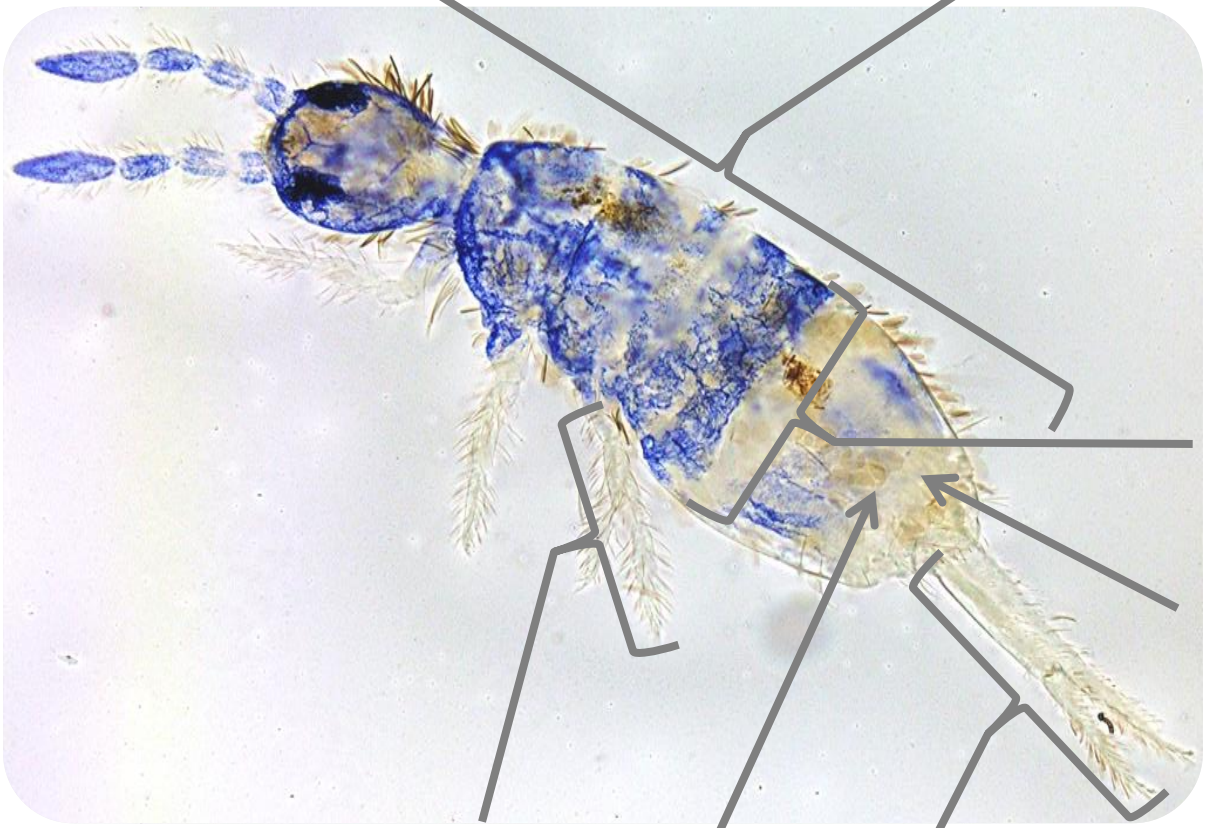

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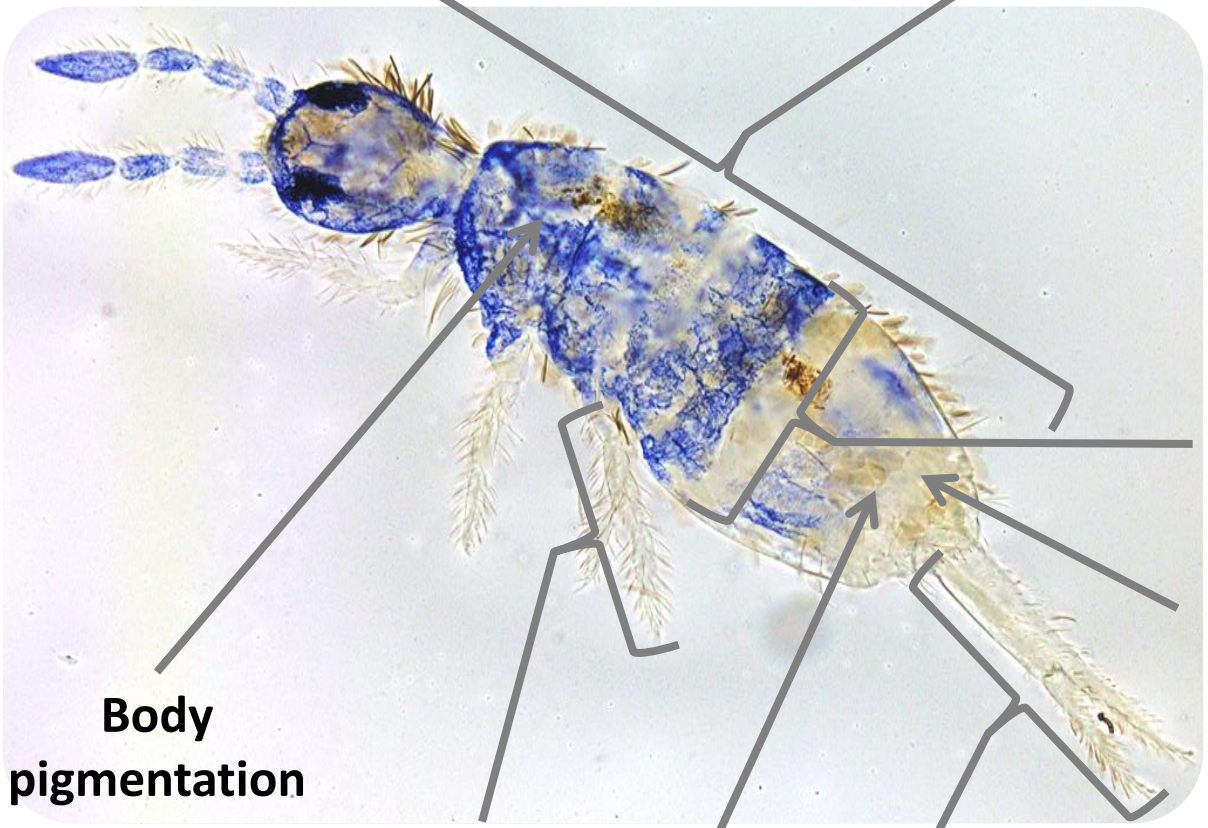

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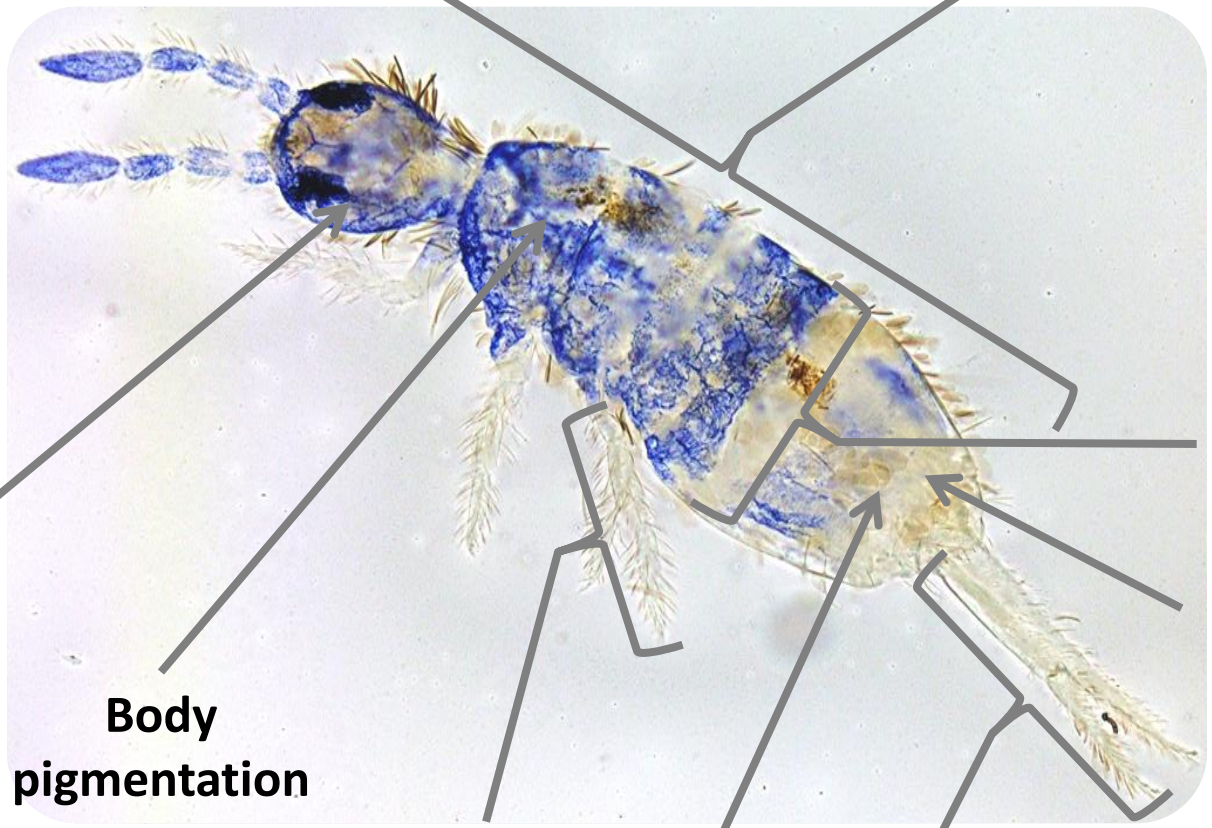

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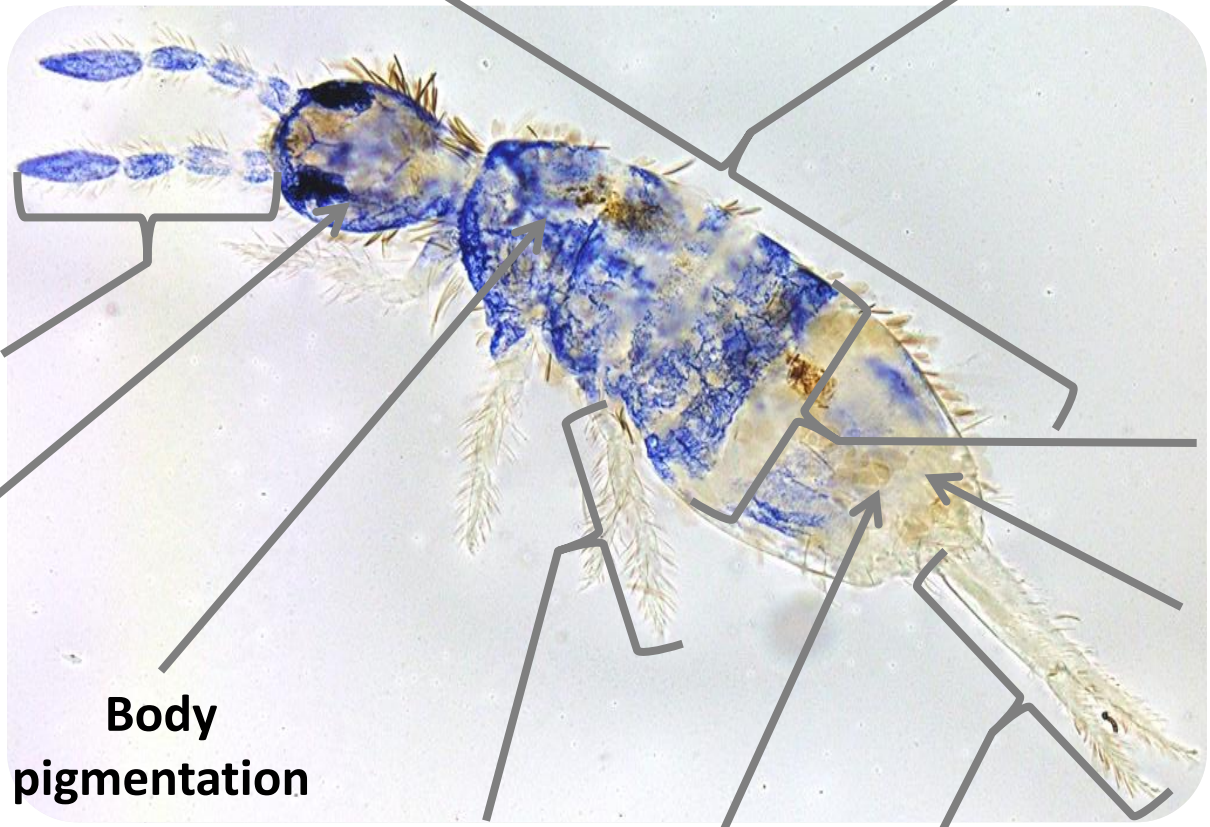

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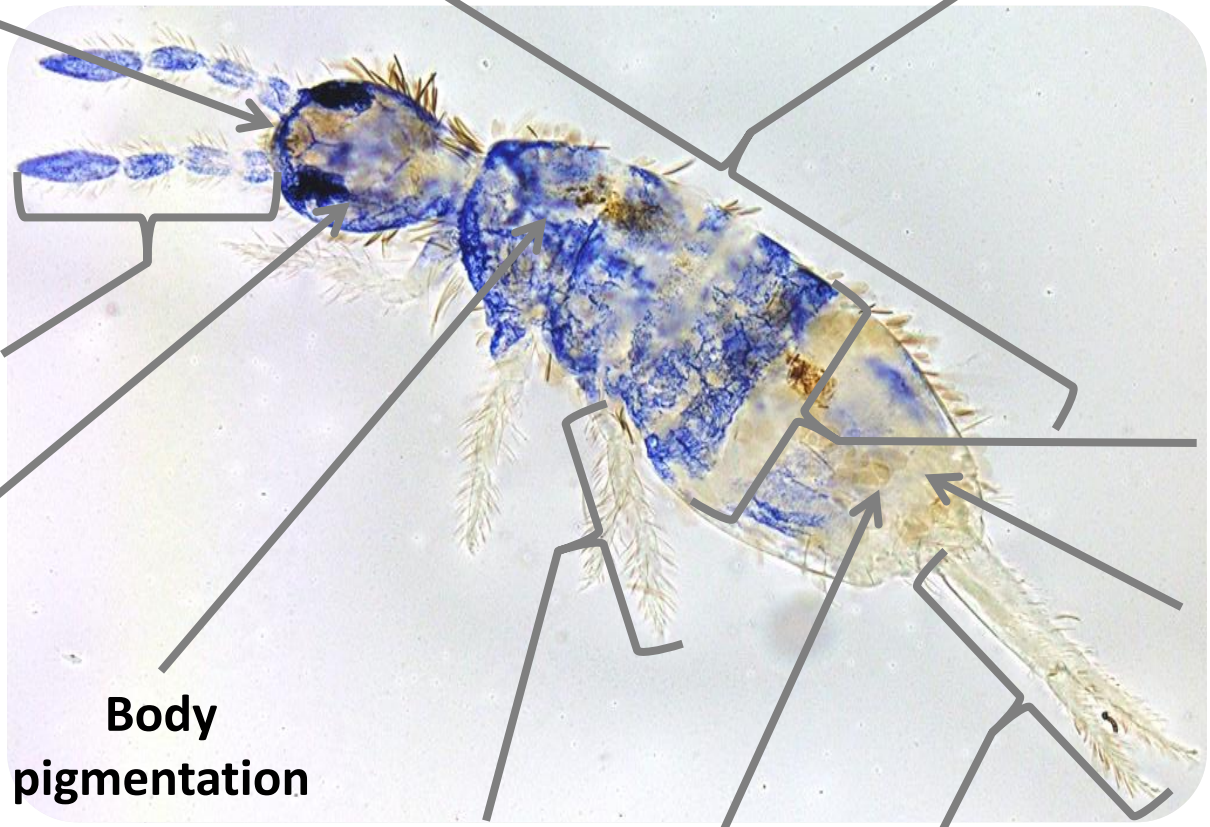

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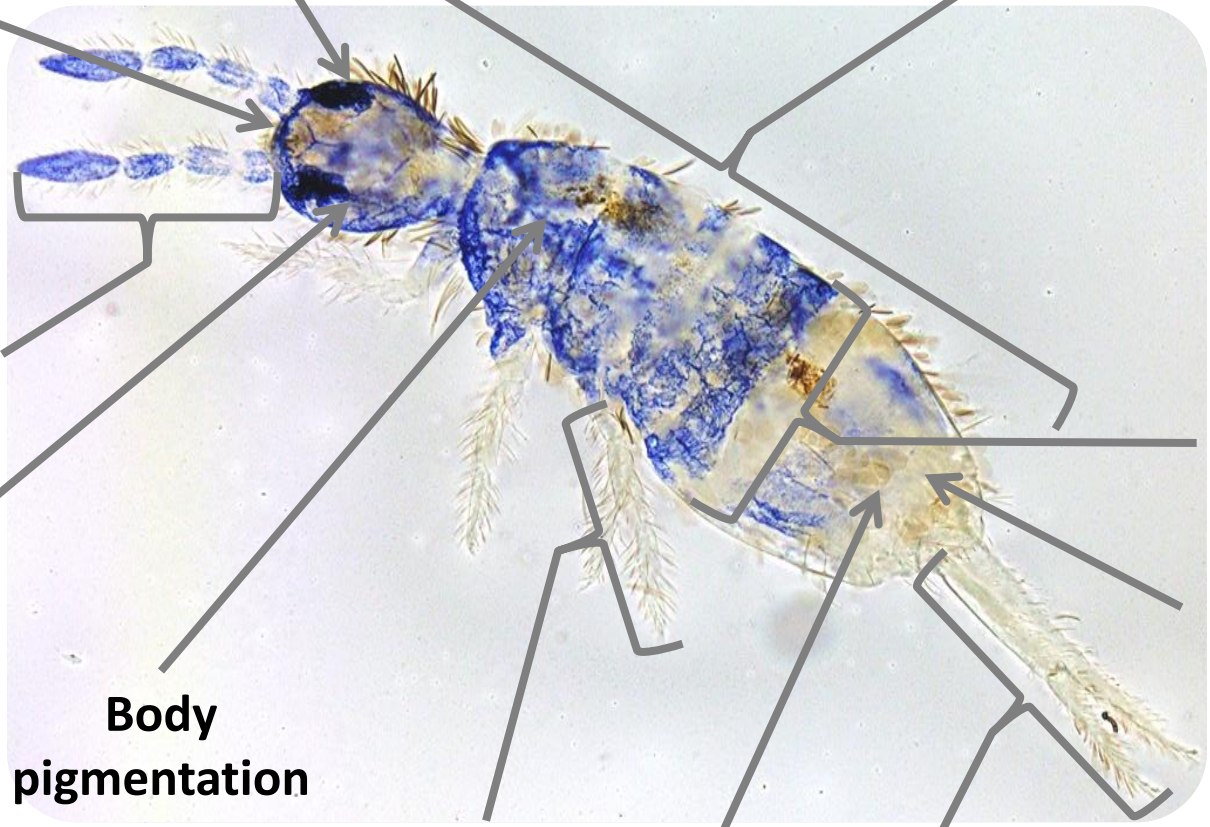

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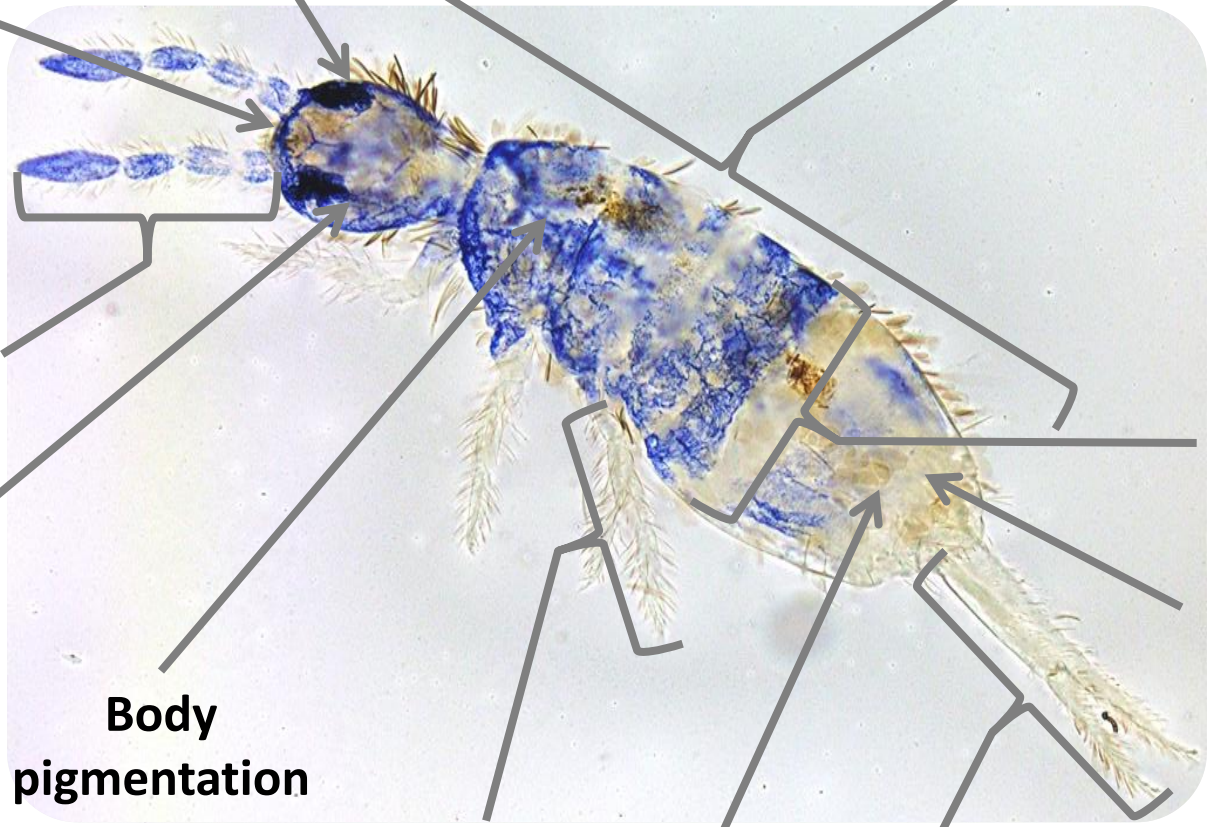

Ocelli number

Body length

Mouthpart structure

Body shape ratio

Relative antenna length

Body width

PAO

Bothriotricha

Body pigmentation

Relative leg length

Scales

Relative furcula length

+ Reproduction mode

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

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aggregated traits

Hypotheses:

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Functional attribute	Function
Body length	Use of food resources
Rel. furcula length	Predation avoidance
Scales	
Rel. antenna length	Detection of soil surface chemical & physical conditions
Bothriotricha	
Ocelli number	
Rel. leg length	Spatial displacement
Body pigmentation	Light protection & body temperature
Sexual reproduction	Colonization by dispersal
Mouthpart structure complexity	Food ressources complexity (quantity & diversity)

Hypotheses:

Functional attribute	Function	Values in no/low-intense harvest	Values in high-intense harvests
Body length	Use of food resources	 **Due to:** **+++ food resources supply & complexity** **+++ predation** **+++ soil humidity & cover** **+++ complex microhabitats** **+++ sexual partners** **- - - soil temperature**	 **Due to:** **- - - less food resources supply & complexity** **- - - predation** **- - - soil humidity & cover** **- - - complex microhabitats** **- - - sexual partners** **+++ soil temperature**
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Sexual reproduction	Colonization by dispersal		
Mouthpart structure complexity	Food ressources complexity (quantity & diversity)		
Body shape ratio	Soil spatial displacement	 **Due to: - - - soil compaction life-form equilibrium**	 **Due to: +++ soil compaction euedaphic taxa dominant**
PAO	Detection of soil-dwelling chemical & physical conditions		

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Microhabitat	Ecological processes by soil strata	More epi-hemiedaphic taxa	Only euedaphic taxa
Dispersal capacity	Colonization / recolonization		

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Diversity	Soil ecological processes	+	-

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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:

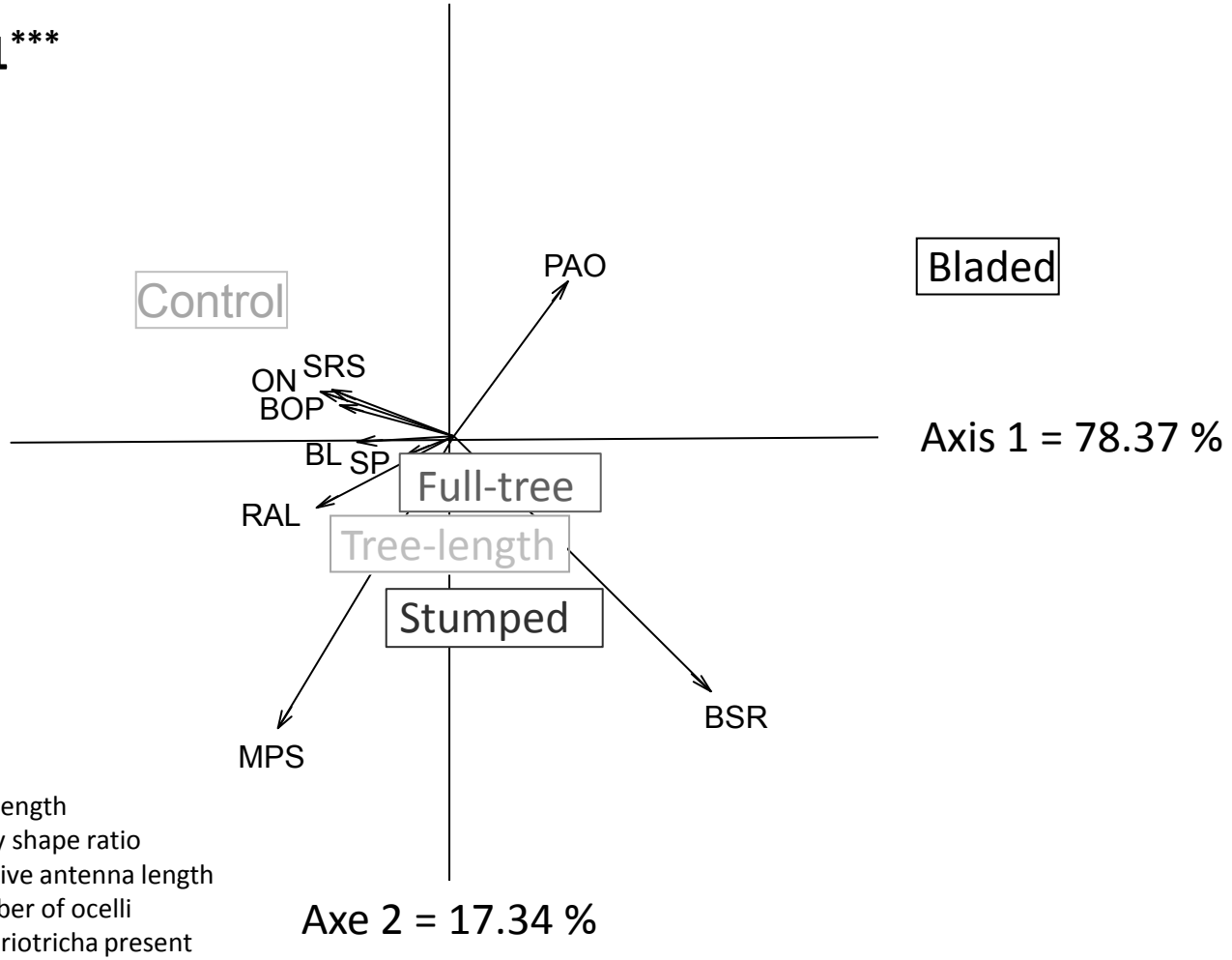
- **2555 specimens identified**
- **37 species found**
- **557 specimens used to measure functional traits & preferences**

Functional response according to the harvesting treatments:

Functional response according to the harvesting treatments:

RLQ Traits

Matrix correlation coefficient (RV) = 0.41***

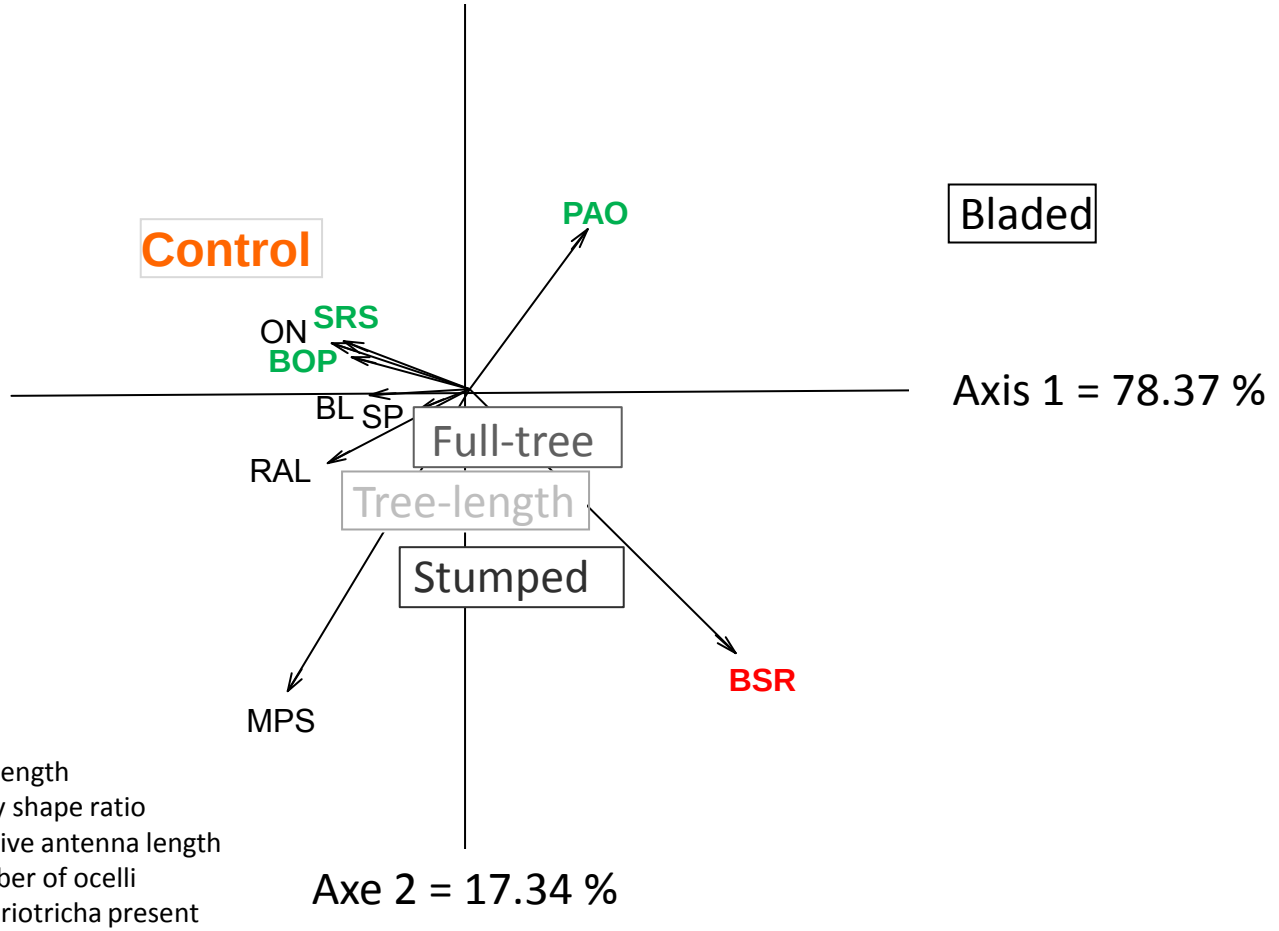


BL = Body length
BSR = Body shape ratio
RAL = Relative antenna length
ON = Number of ocelli
BOP = Bothriotricha present
SP = Scales present
PAO = PAO present
MPS = Mouthpart structure
SRS = Sexual reproduction strategy

Control treatment:

+ sexual reproduction & hemiedaphic taxa (PAO & BOP)

- “slender” body shape



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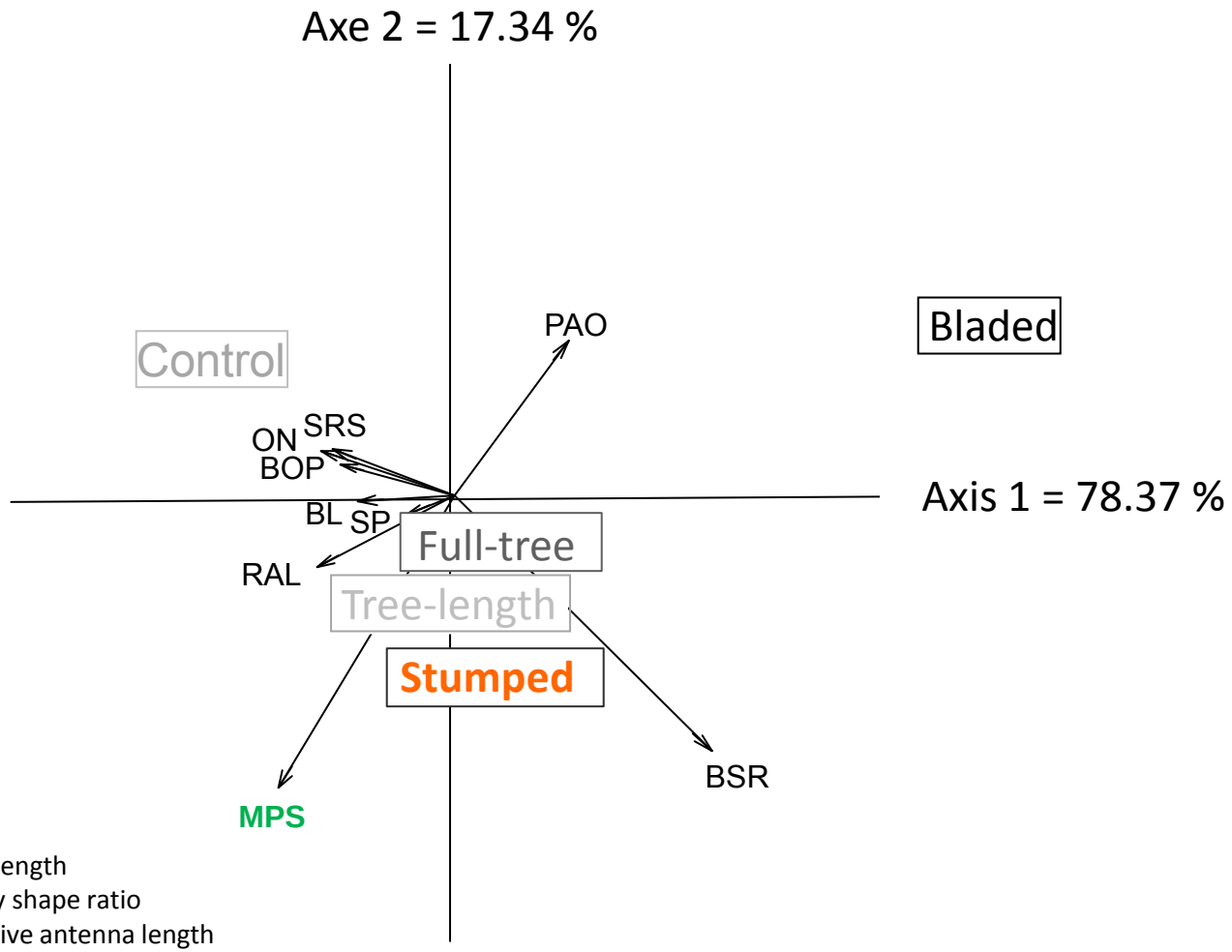
Fourth-corner:
Positive significant relation
Negative significant relation

Stumped treatment:

+ complex mouthparts



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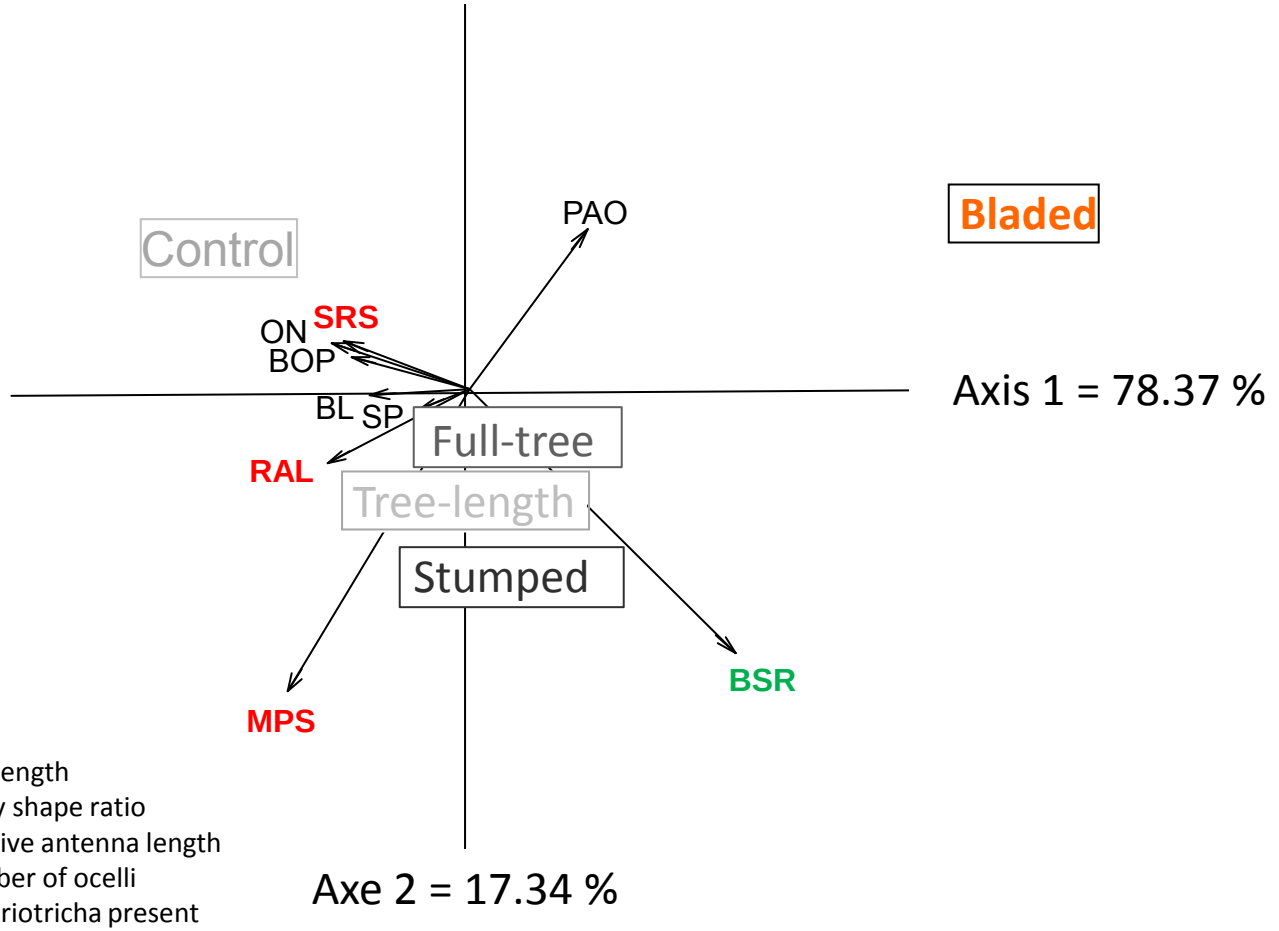
Fourth-corner:
Positive significant relation
Negative significant relation

Bladed treatment:

+ “slender” body shape

- sexual reproduction, antenna length & complex mouthparts



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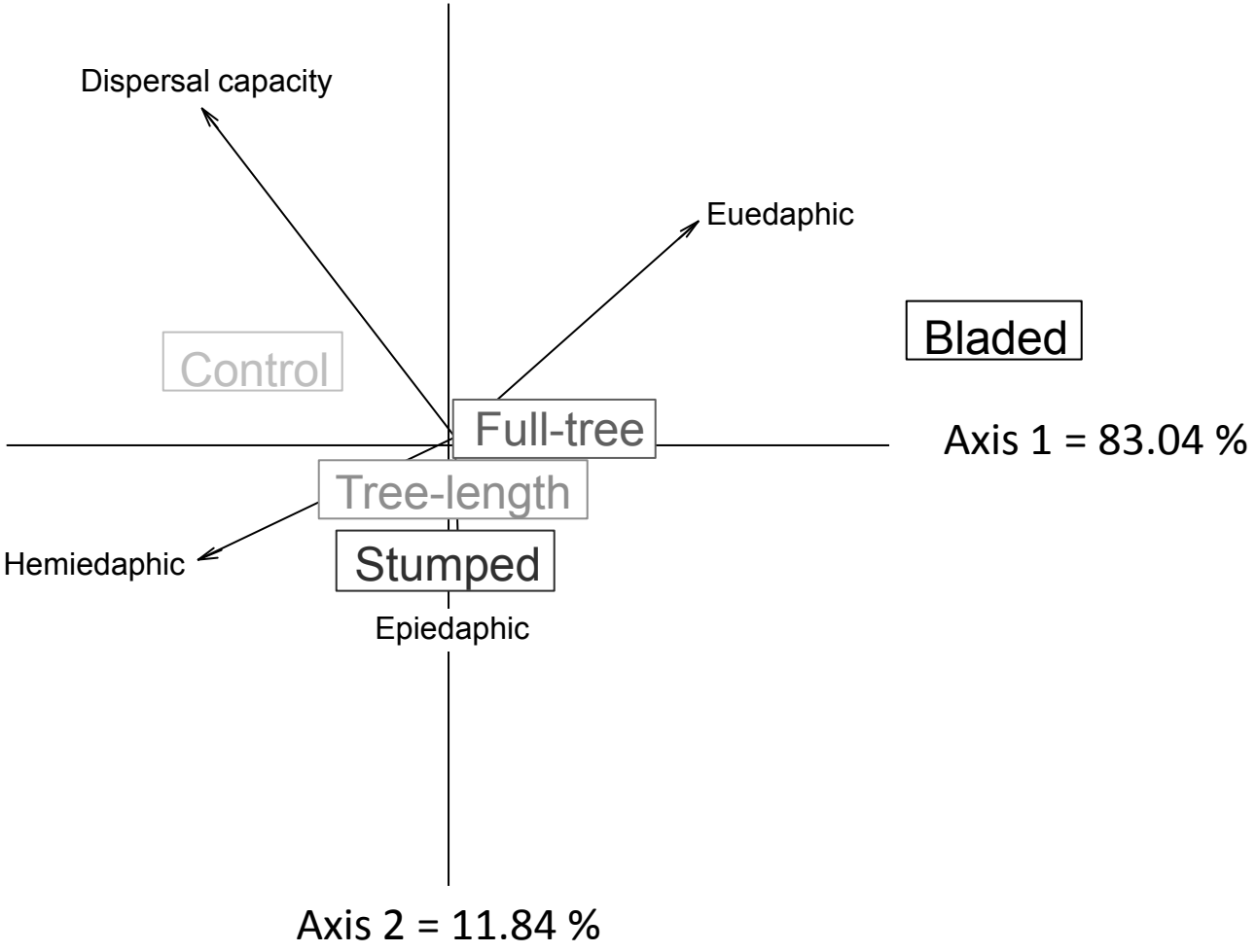
Fourth-corner:
Positive significant relation
Negative significant relation

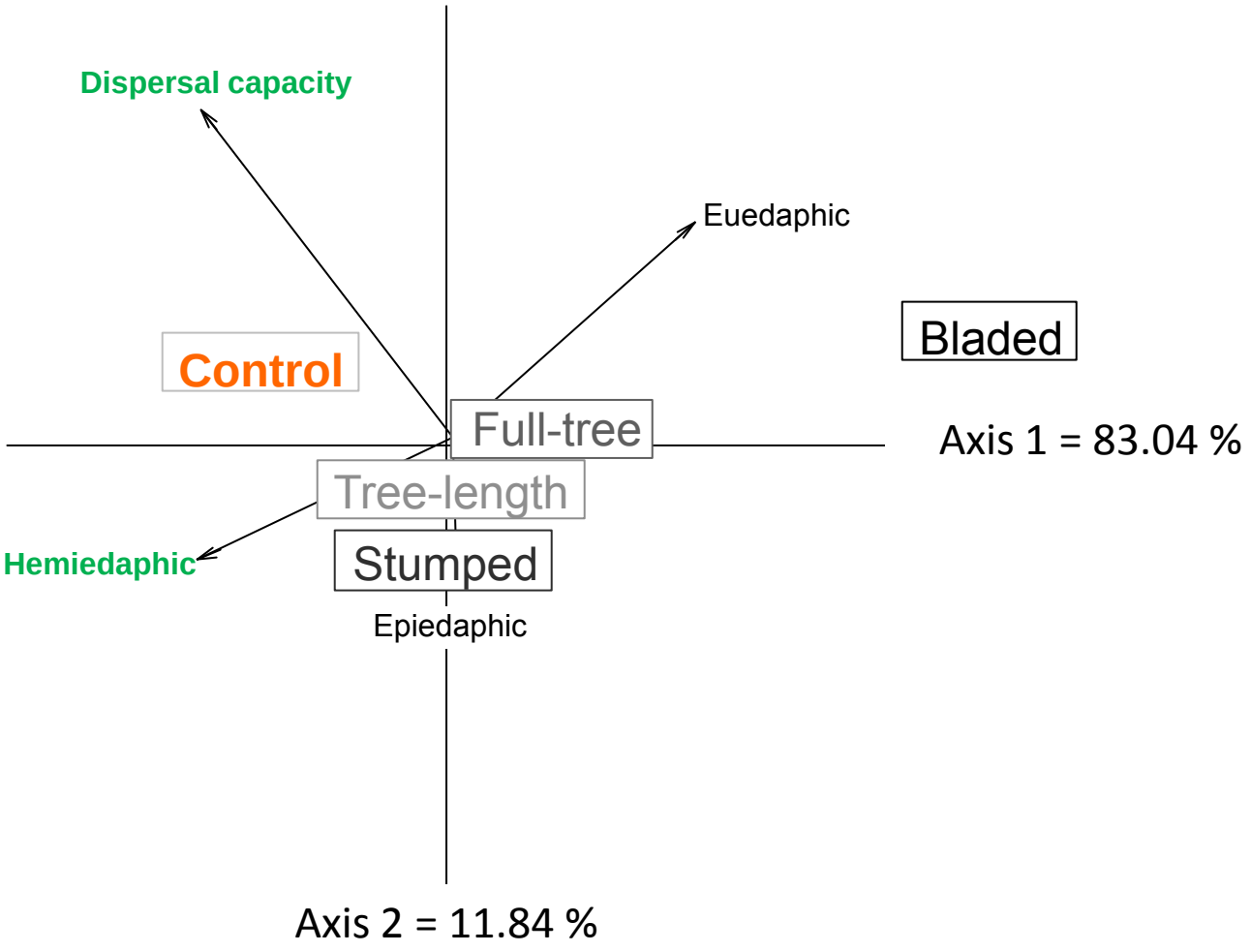
RLQ Preferences

RV = 0.22**



Control treatment:

+ dispersal capacity & hemiedaphic taxa



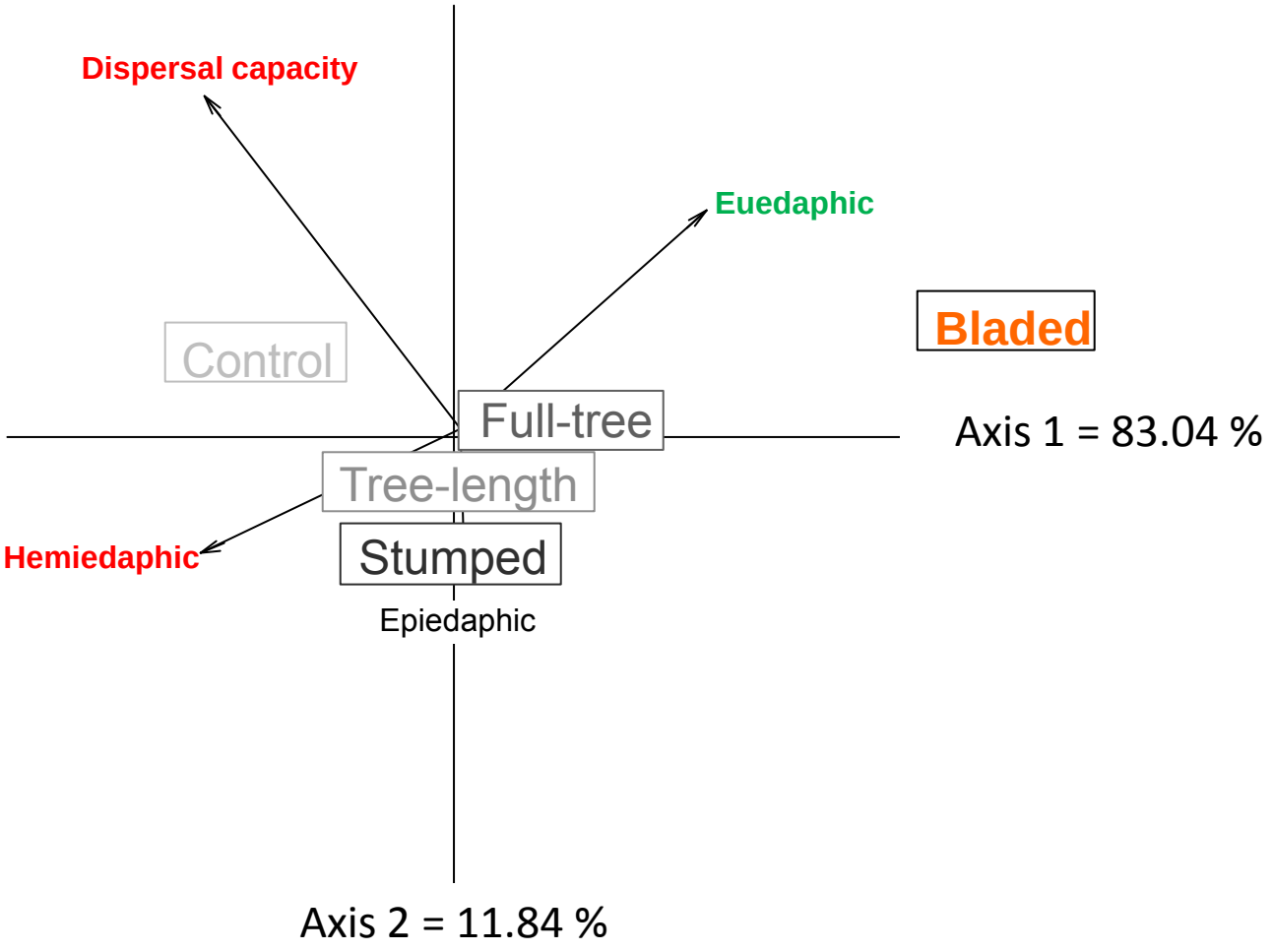
Fourth-corner:

Positive significant relation

Negative significant relation

Bladed treatment:

+ euedaphic taxa / - dispersal capacity & hemiedaphic taxa

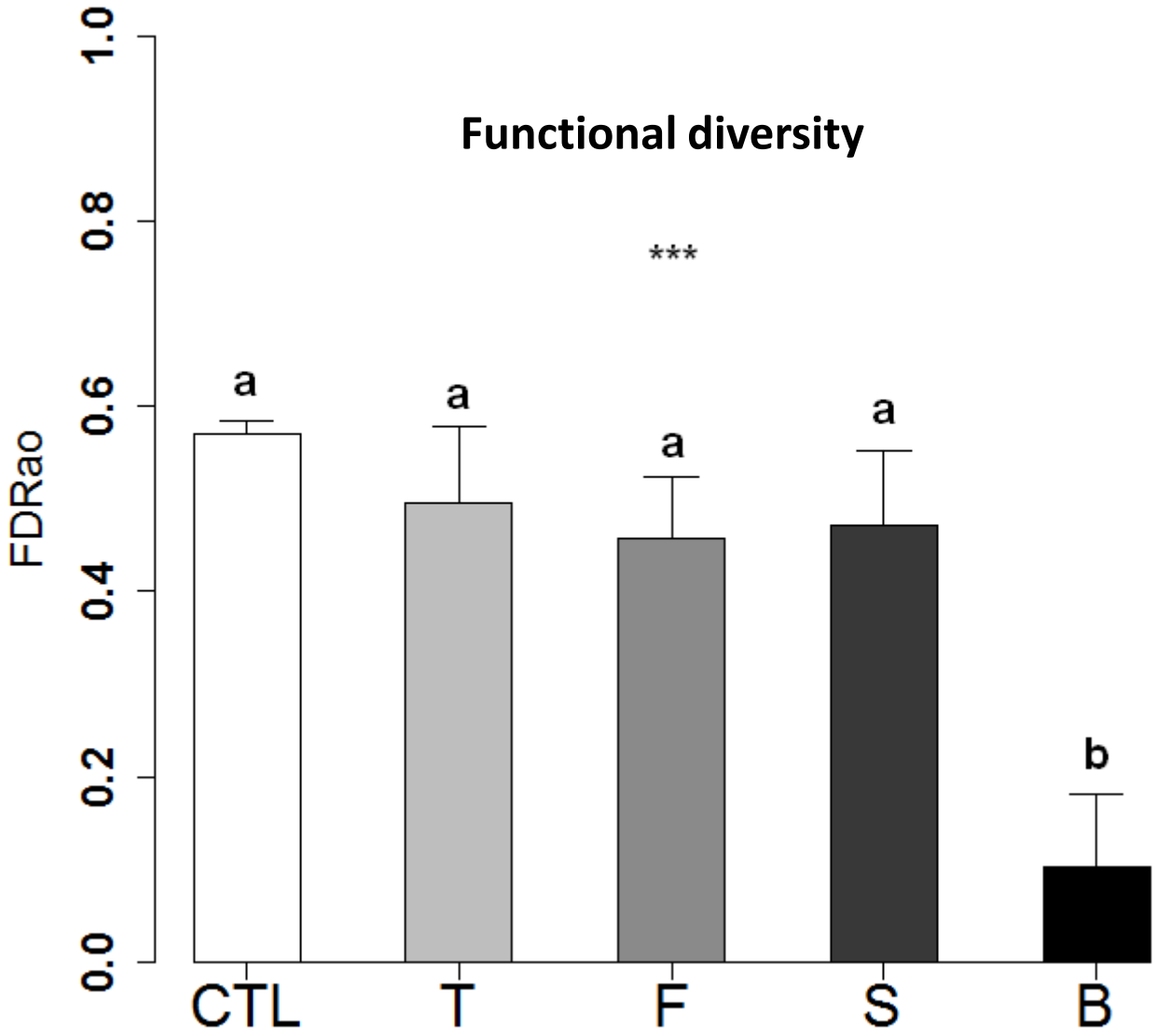


Fourth-corner:

Positive significant relation

Negative significant relation

Lowest functional diversity in the Bladed (B)

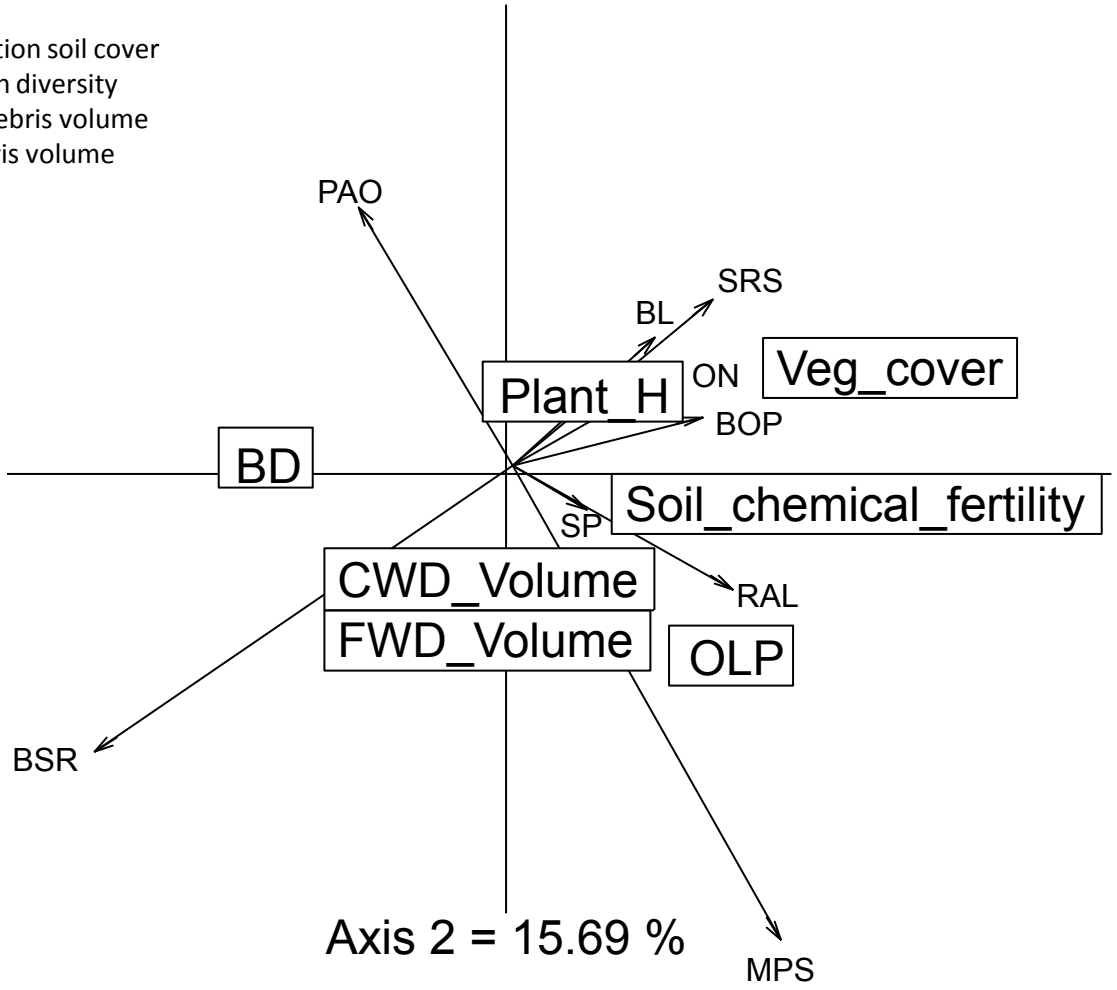


Relations to modifications of environmental factors:

RLQ Traits

RV = 0.63*

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



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Bulk density (soil compaction):

+ “slender” body shape / - complex mouthparts

Veg_cover = Herbaceous vegetation soil cover
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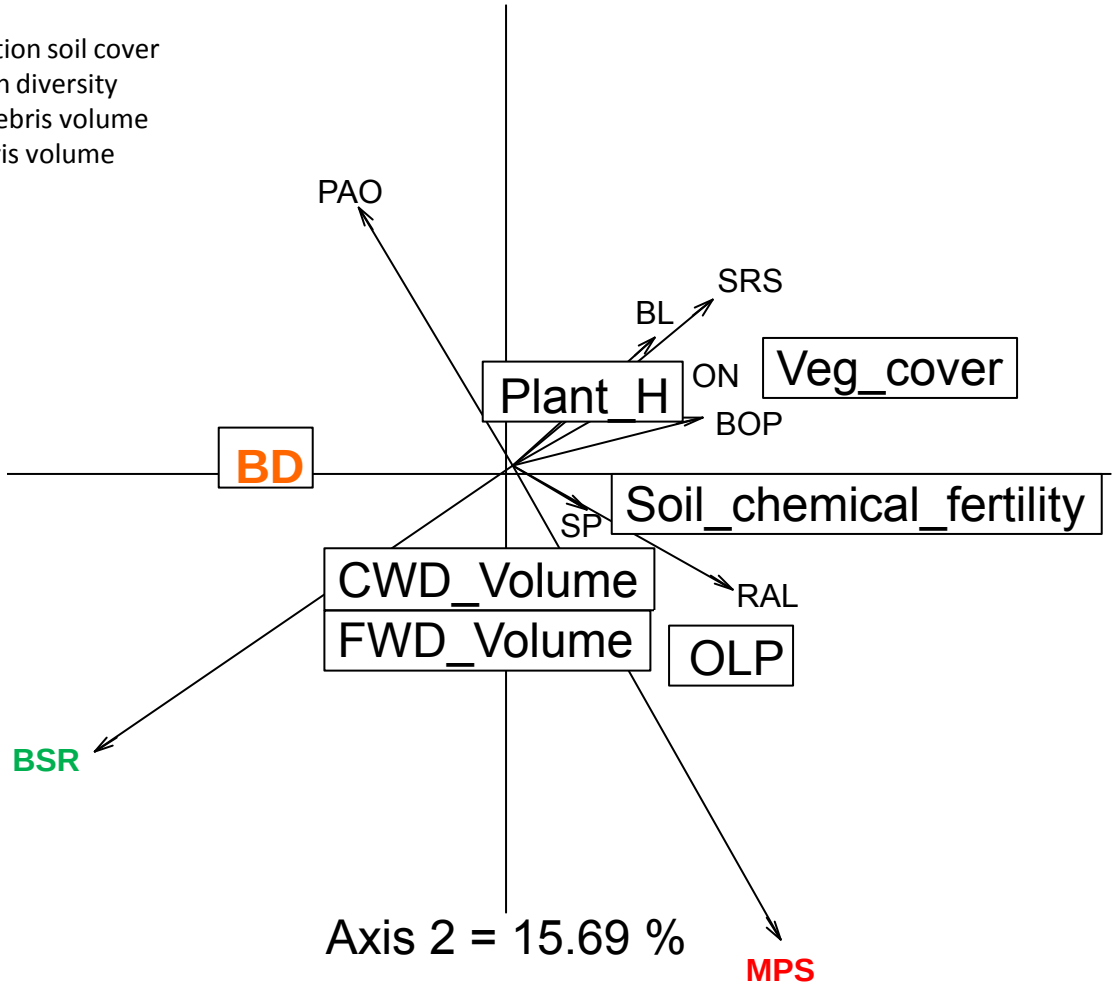

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Fourth-corner:
Positive significant relation
Negative significant relation

Organic layer depth:
+ complex mouthparts

Veg_cover = Herbaceous vegetation soil cover
Plant_H = Herbcaeous vegetation diversity
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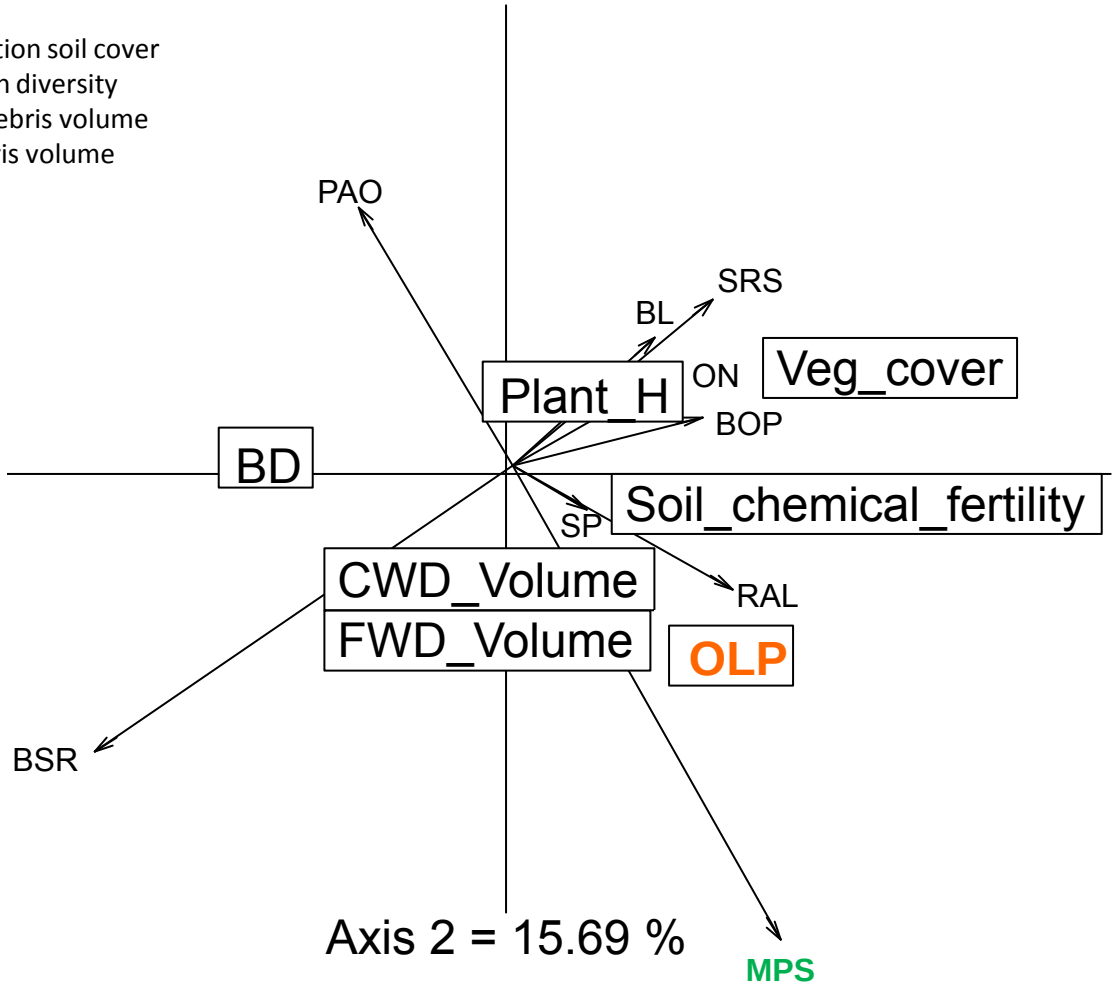

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SP = Scales present
PAO = PAO present
MPS = Mouthpart structure
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Fourth-corner:
Positive significant relation
Negative significant relation

Vegetation cover:

+ body length, sexual reproduction & complex mouthparts

Veg_cover = Herbaceous vegetation soil cover
Plant_H = Herbcaeous vegetation diversity
CWD_volume = Coarse woody debris volume
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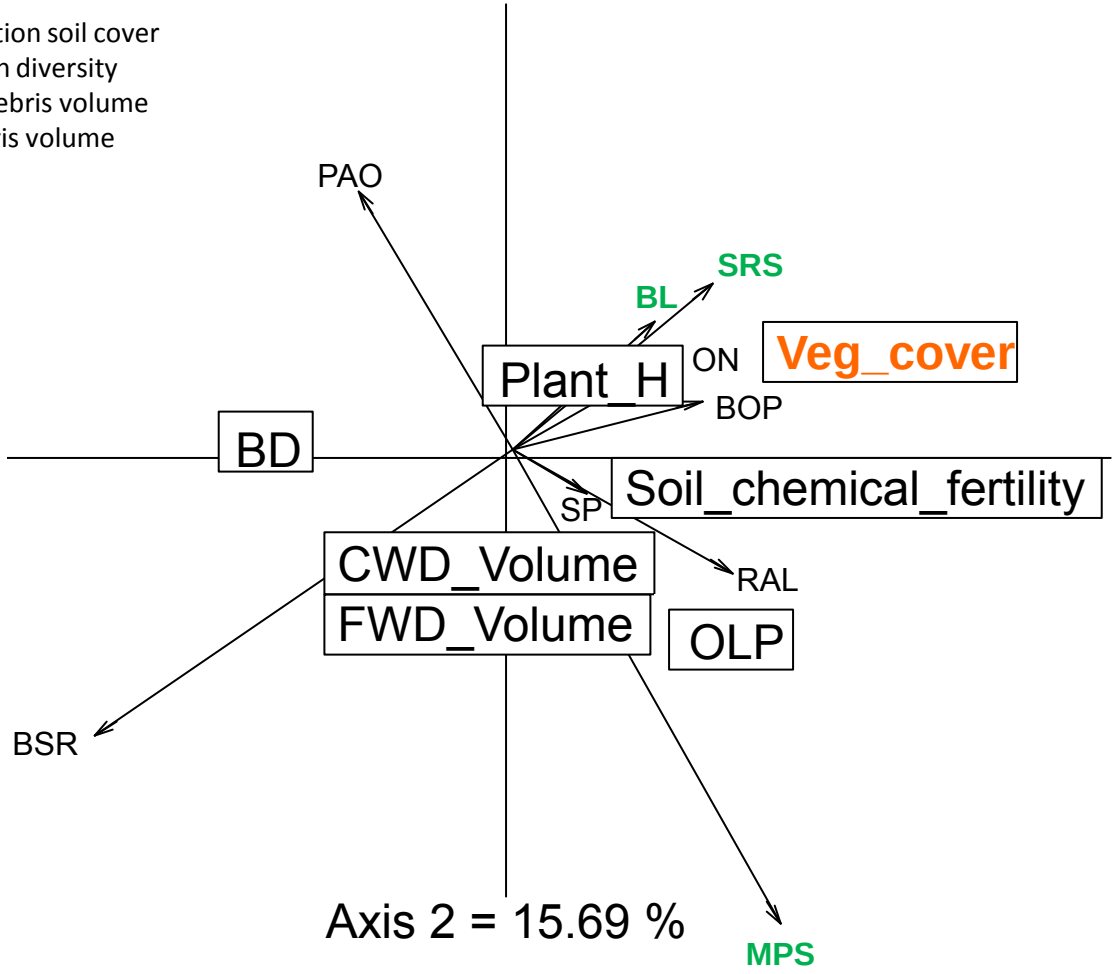

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MPS = Mouthpart structure
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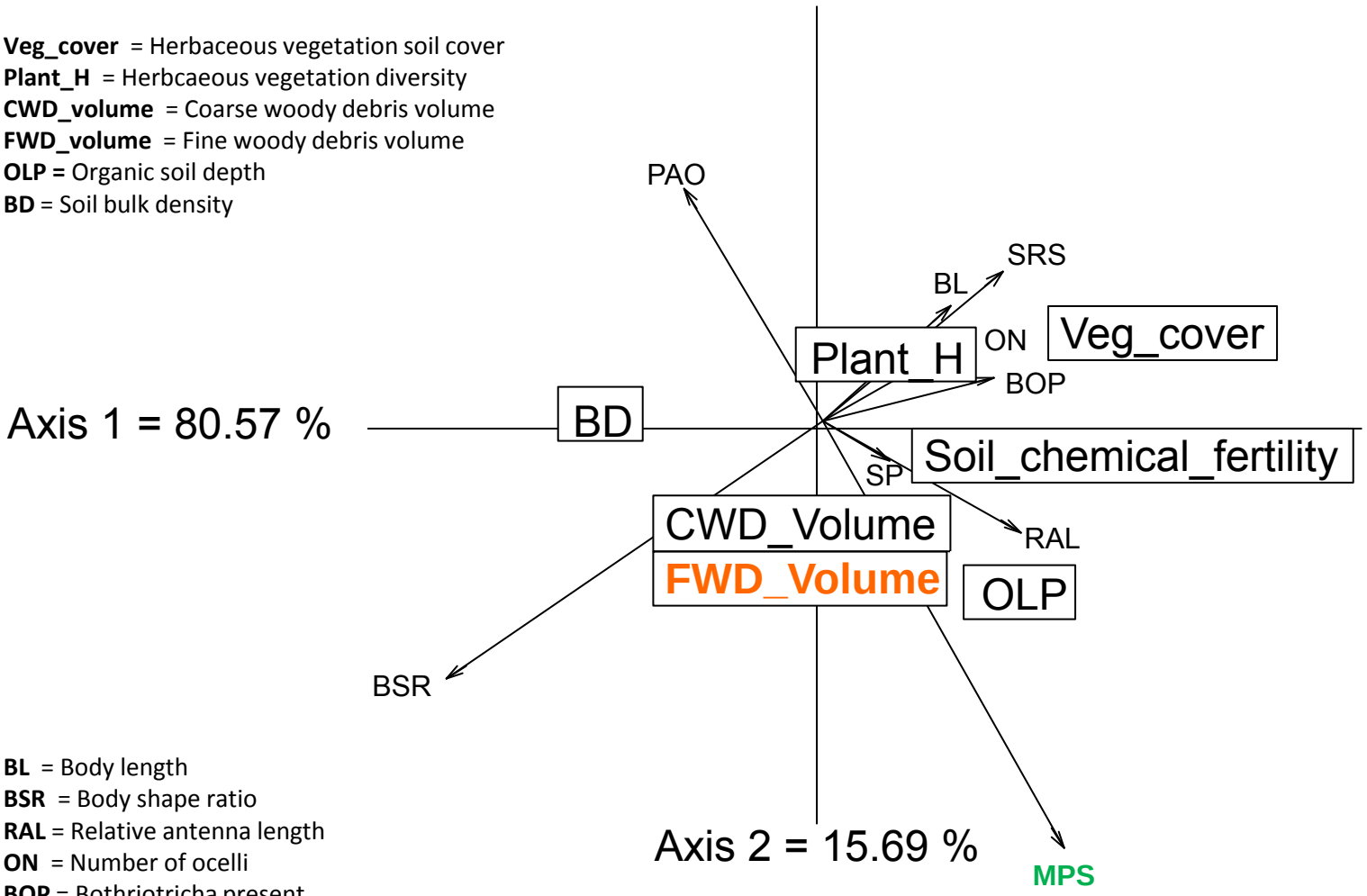
Fourth-corner:
Positive significant relation
Negative significant relation

Fine woody debris volume:
+ complex mouthparts

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



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Fourth-corner:
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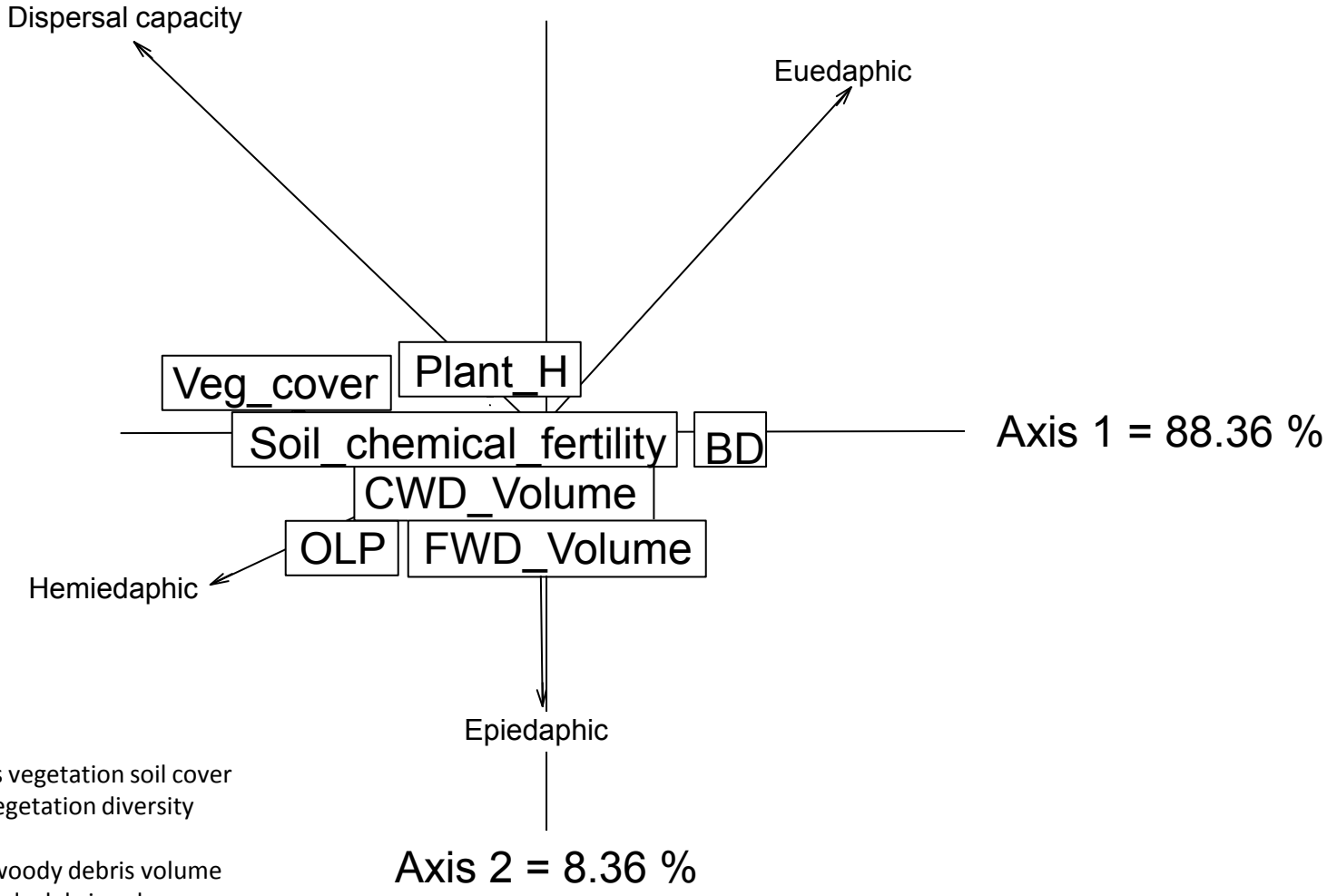
Negative significant relation

RLQ Preferences

RV = 0.33*



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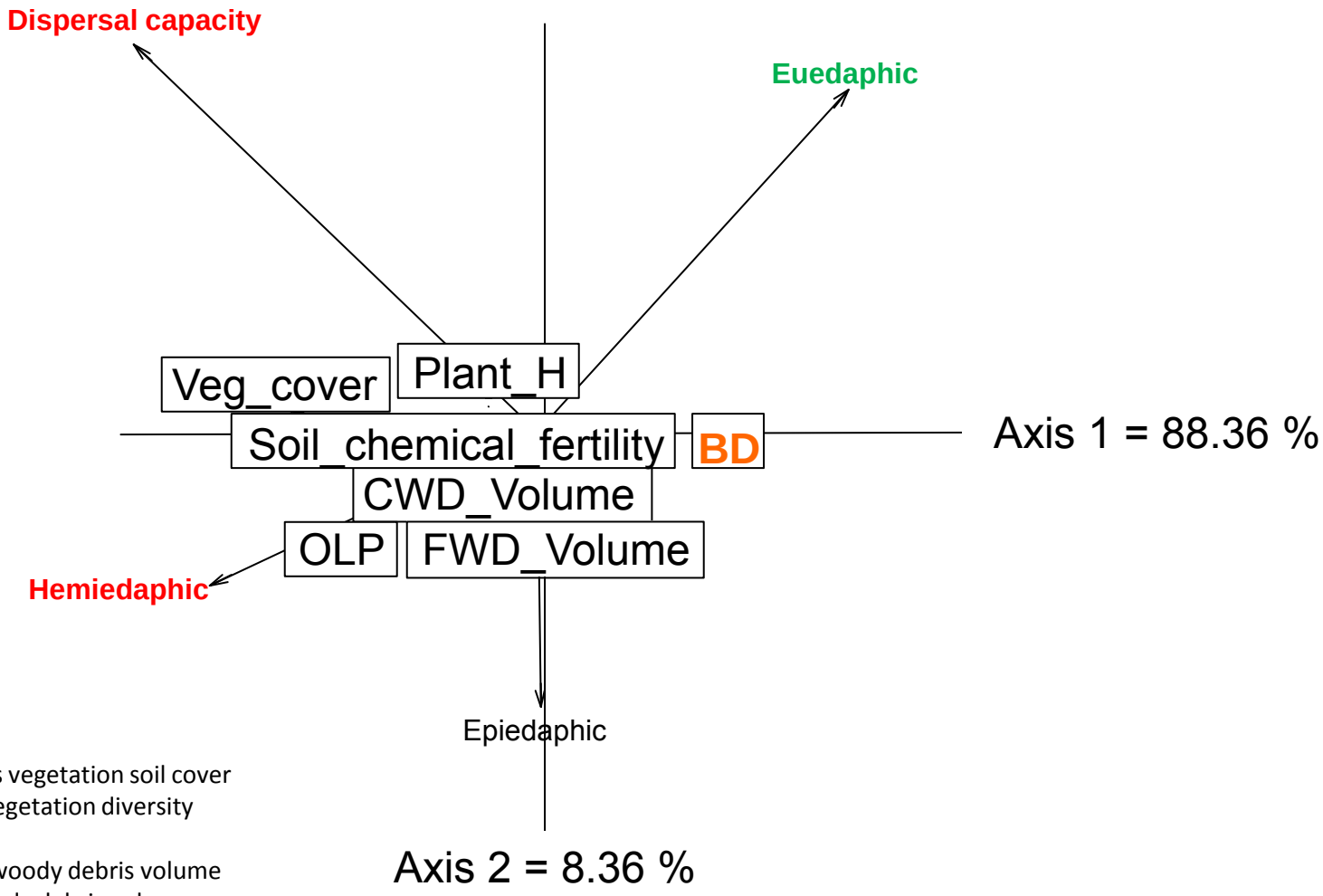
Bulk density (soil compaction):

+ euedaphic taxa / - dispersal capacity & hemiedaphic taxa



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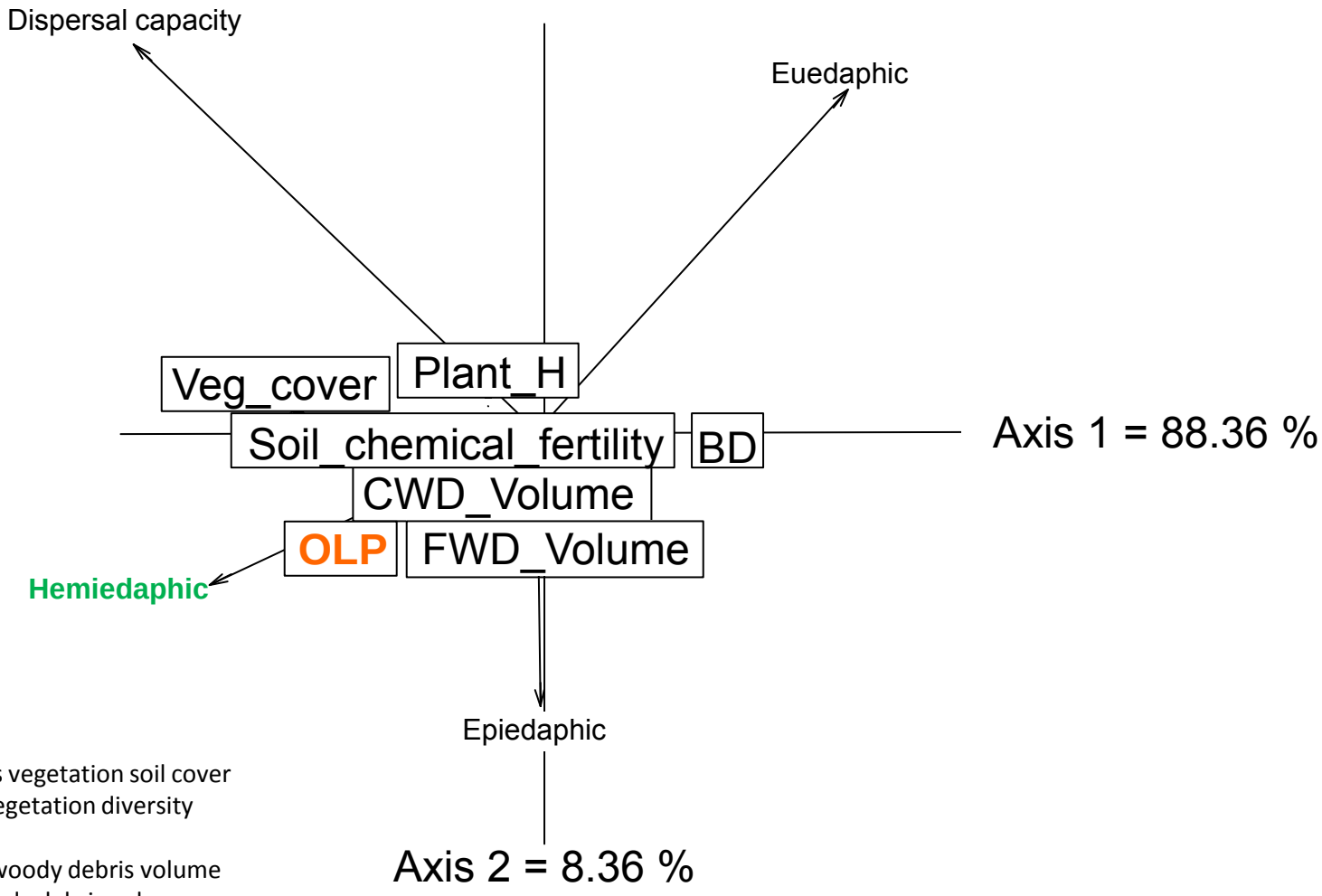
Fourth-corner:
Positive significant relation
Negative significant relation

Organic layer depth :
+ hemiedaphic taxa



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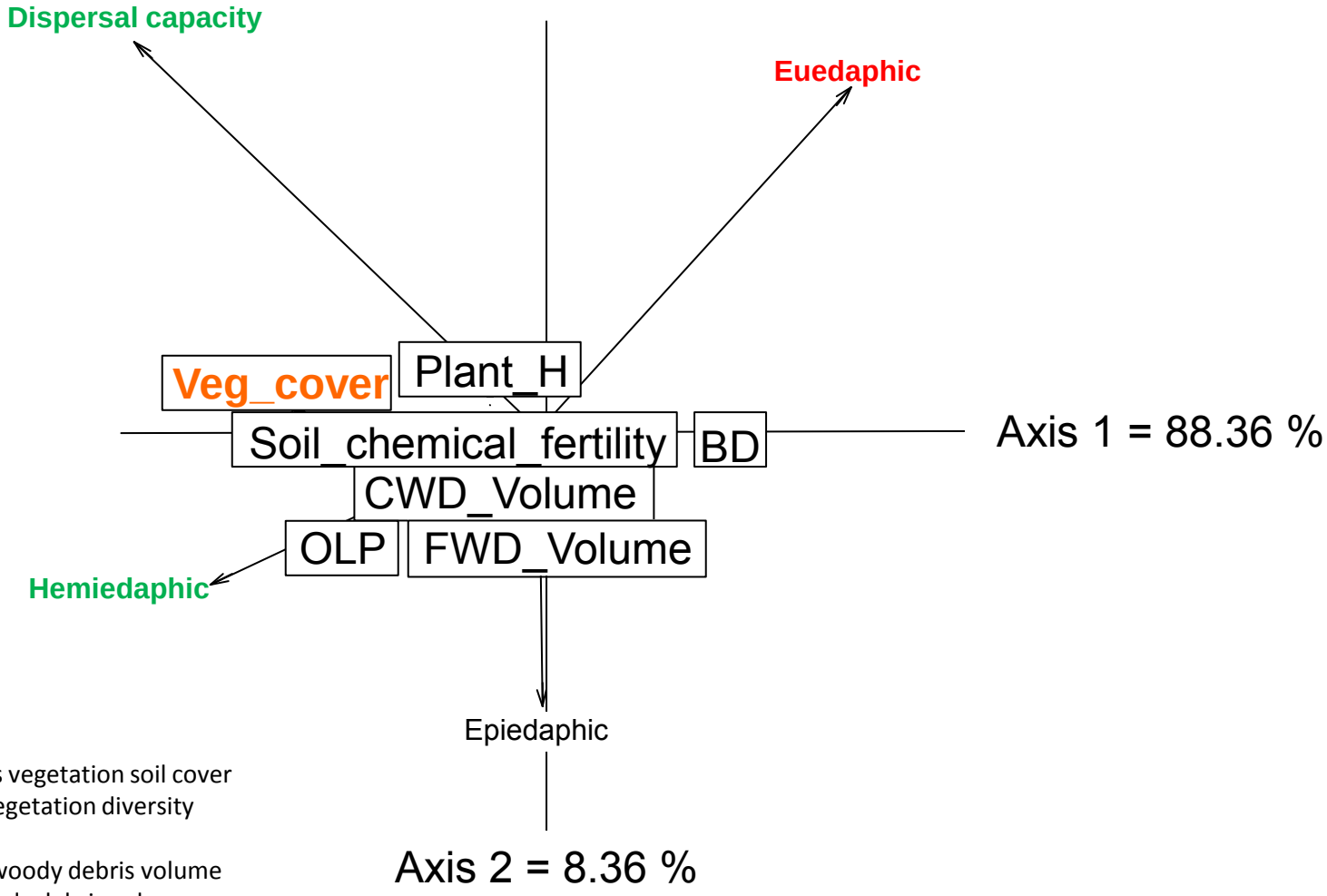
Vegetation cover:

+ dispersal capacity & hemiedaphic taxa / - euedaphic taxa



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Conclusion:

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Conclusion:

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- 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**

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**

Conclusion:

- 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...

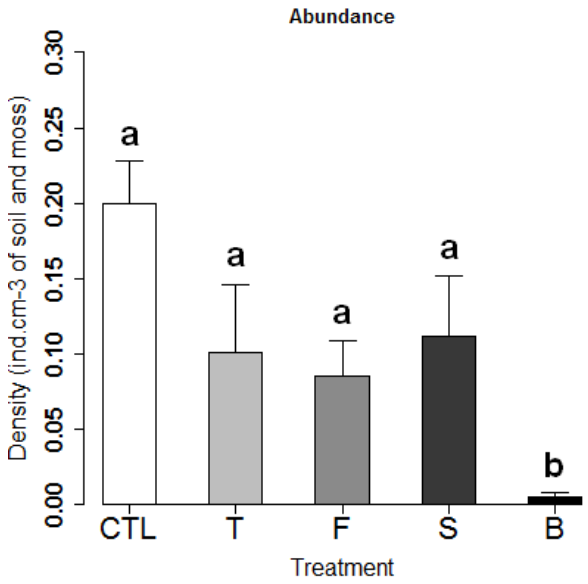
R. Fleming, P. Hazlett, K. Webster, I. Aubin, K. Wainio-Keizer, K. Good, L. Hawdon, T. Weldon, M. Primavera, S. Wilson & J. Curry – Canadian Forest Service
D. Morris & M. Kwiaton - Ontario Ministry of Natural Resources and Forestry (OMNRF)
Sandrine Salmon - Muséum National d'Histoire Naturelle (France)
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

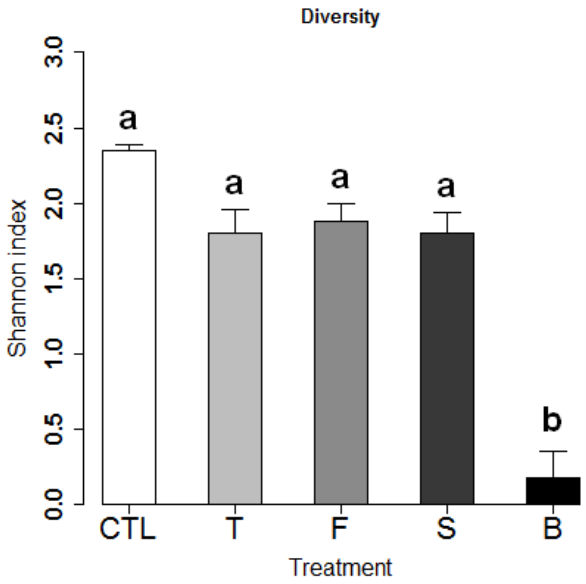
Laurence Codebecq & Adriana Ramos Diaz for their contribution in identification and functional measures!

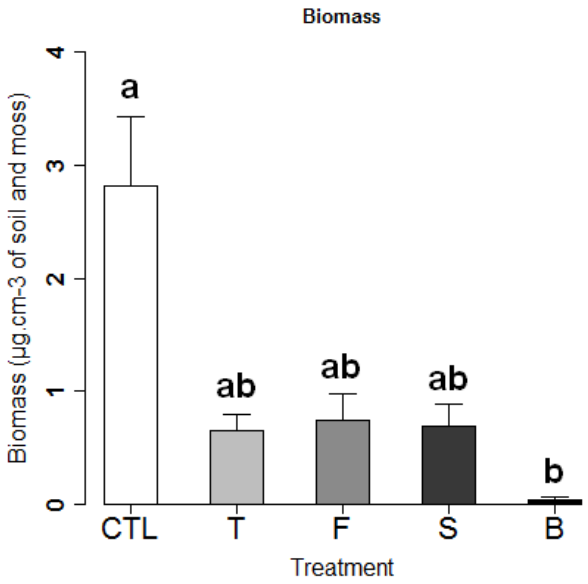
... and of your attention!

Results:

- 2555 specimens identified
- 37 species found
- 557 specimens used to measure functional traits & preferences







Functional attributes	CTL treatment	S treatment	B treatment
Body length	[Vegetation cover]		
Body shape ratio	−		+ [soil compaction]
Rel. antenna length			−
Bothriotricha	+		
PAO	+		
Sexual reproduction	+ [Vegetation cover]		−
Complex mouthpart structure	[Organic soil depth Vegetation cover]	+ [FWD volume]	− [soil compaction]
Microhabitat	Hemiedaphic [Organic soil depth Vegetation cover]		Euedaphic [soil compaction]
Dispersal capacity	+ [Vegetation cover]		− [soil compaction]
Functional diversity	+		−