Tree-related microhabitats (TReMs) in European temperate forests
New insights for biodiversity conservation

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WSL, Birmensdorf, 2015, April 1st
TReMs: tree singular features hosting a wide range of life forms

(Temporary definition)

- Singular morphological features borne by a tree, dead or living, and strongly dependant on it
- Encompassing decaying wood (=saproxylic) or not (=epixylic)
- Habitats for species with preferentially-associated biodiversity
- Small-size habitats (cm/cm³ → m/m³)
All the tree parts can bear a TReM

Crown deadwood

Broken main branch

Mould filled trunk cavity

Woodpecker cavity

Crack

Creeper

Saproxylic fungi

Active sap run

Dendrothelm

Missing bark

Mould filled base cavity

Bark lined base cavity

Emberger et al. 2013
TReMs are observed daily and are a key issue for forest management

Managers

- silvicultural items
- flaw depreciating wood

Naturalists

**Conservation biologists**

- ecological items
- singular features hosting life

Conflict

Compromise = negotiated standards (e.g. PEFC, FSC)

ecological relevance?

Do scientists have the answers?
Talk plan

I-TReMs in theoretical frameworks

II-Why and how I studied TReMs?
   • History of TReM research
   • Contexts and methods

III-Selection of results with practical implications for management
   • Are TReMs drivers for biodiversity at stand level?
   • Role of the largest trees in unharvested forests
   • Effects of harvesting on TReM “communities”
   • Conservation of TReM diversity

IV-Towards future research
I-TReMs as ecological items
Proposal of theoretical frameworks

1-Nested system

2- « Ephemeral Resource Patches »

3- Landscape Ecology concepts

Crucial, discrete and ephemeral resource

Complementation and supplementation resources, metapopulation, connectivity, matrix
TReM and its TReM-bearing tree show a nested pattern

TReM
• genesis
• associated community
• dynamic and lifespan

TREE
• species life-traits
• age/diameter
• management
• close environment
• stochastic events

Background
Unharvested forest
Harvested forest
Conclusion & future
TReMs as «ephemeral resource patches »? (Finn 2001)

Resource:

- high quality → Dependence gradient
- spatially limited → Small size and limited by the tree size
- temporary → TReM of type X

Disappearance evolution

- type Y (=lifespan)
- operational or not (=“useful” period)
What is the “matrix” for the species associated with TReMs?

Matrix
• inhospitable habitat
• brake or obstacle to dispersion
Ilia-Some elements of history

From...

Limoniscus violaceus
Ischnodes sanguinicollis
...

...to

Roughly 15,000 y.
Until 2003, studies focused on biodiversity at TReM level

- **Cavities**
  - filled by mould
    (e.g. Ranius 2000)
  - drilled by woodpeckers
    (e.g. Martin & Eadie 1999; Penicaud 2000)
  - dendrothelms
    (e.g. Kitching 1971; Vaillant 1978; Sota 1998)

- **Sporophores of saprophytic fungi**
  (e.g. Bader et al. 1995)
In 2008, TReMs were identified as a relevant tool for biodiversity monitoring at stand level.
In 2011, knowledge of TReMs was still fragmentary and more studies were required.

**Requirements**

- A definition of a TReM
- A typology of TReMs
- Quantitative data for practical recommendations

Research approach focusing on data collection
Finalized research to take biodiversity associated with TReMs better into account in forest management

1-Unharvested forests (reference)
- Practical recommendations
- Tools

2-Harvested stands
- Differences?

3-Taxonomic biodiversity
- TReMs (stand level)
- Practical recommendations
- Tools

Introduction  Background  Protocols  Results  Biodiversity  Unharvested forest  Harvested forest  Conclusion & future
Ilb-Methodology: an overview
Sampling has been done mainly in two forest types

- Mixed mountain forest
- Hilly beech-oak forest

- Roughly 35% of French forest dedicated to timber production
- Huge economic value
TReMs have been sampled using two procedures

1-TReMs / tree level-management

“exhaustive” recording of TReMs on all the trees of the plot

2-TReM / stand level-biodiversity

rapid habitat assessment protocols centered on available taxonomic data
Only the trunk TReMs have been sampled

- time saving
- reduction of observer effect

Sampling area
“Direct” biodiversity sampling used a diversified set of 9 potential taxa “bio-INDICATORS”

- Available data

- Standardized protocols
  - Corticolous bryophytes
  - Diptera Syrphidae
  - Vascular flora
  - Saproxylic beetles
  - Coleoptera Carabidae
  - Saproxylic fungi
  - Bats
  - Corticolous lichens
  - Birds

Pluritaxonomic approach
Results have been mainly expressed at the spatial scales used by forest managers.
An “elementary” TReM is sometimes difficult to define

Outside: a “simple” woodpecker hole...
...inside: a set of habitats

**Tough plug**
- Procaerus tibialis
- Rhynocorus ater / Phloeophagus lignarius

**Brown rot**
- Ampedus cardinalis
- Pentaphylus testaceus / Tenebrio opacus

**Young mould**
- Elater ferrugineus
- Osmoderma eremita / Gnorimus variabilis

**Evolved mould**
- Ischnodes sanguinicollis
- Ctenophora ornata / Pseudocistela ceramboidea

Commitment: the whole singular feature is the “elementary” TReM

*From Stokland et al. 2012 and Brustel pers. com.*
III: Results

a-TReMs as key factors in biodiversity at stand level

b-Role of the largest trees in unharvested forests

c-Effects of harvesting on TReM “communities”
Illa: TReMs as key factors in biodiversity at stand level
TReMs contributed significantly to biodiversity at stand level

(Larrieu et al. in prep.)

- **Density of TReM-bearing trees**

  → **Assemblage composition** of:
  - Saproxylic beetles
  - Ground beetles
  - Lichens
  - Birds
  - Vascular plants
  - Polypores

  → **Species richness** of polypores

102 forests, harvested or not, France
For saproxylic beetles, TReM contribution depends on forest type and taxon status (Bouget et al. BC 2013)

**Contribution of TReM-bearing tree density to species richness**

<table>
<thead>
<tr>
<th>Forest Type</th>
<th>Common species</th>
<th>Rare species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oak forest</td>
<td>5th rank</td>
<td>ns</td>
</tr>
<tr>
<td>Beech forest</td>
<td>ns</td>
<td>1st rank</td>
</tr>
</tbody>
</table>
Positive relationships between TReM density and species richness of saproxylic beetles were sometimes thresholded (Bouget et al. El 2014)

Local biodiversity was, on average, higher above the threshold of:

1 cavity-bearing tree/ha
in pine stands

21 cavity-bearing trees/ha
in beech stands

- Number of cavity-bearing trees/ha
- Species richness

46 forests, harvested or not, France
Relationship between TReM density and diversity of saproxylic beetles depended on stand openness (Bouget et al. El 2014)

Significant interaction effect (lme)

16 mountain forests, harvested or not, France
IIIb: TReM sampling in unharvested forests
Very large trees play a crucial role for TReM availability
(Larrieu et al. EJFR 2014)
A thresholded relationship between tree girth and TReMs (Larrieu et al. EJFR 2012; Larrieu & Cabanettes CJFR 2012)

recursive partitioning method (Hothorn et al. 2006)
Statistical thresholds matched with management girth thresholds (Larrieu et al. EJFR 2012)

Management threshold = 70 cm (CBH 220 cm)

Statistical threshold = 73 cm (CBH 225 cm)

Confidence interval at 80% (CBH 205-239 cm)

We suggest a new girth category: “Largest Trees”

• European Beech: dbh > 90cm
• Silver fir: dbh > 100cm
Only the largest trees bore all TReM types

(Larrieu et al. EJFR 2012; Larrieu et al. EJFR 2014)
IIIc: TReM sampling in harvested stands
TReM distribution patterns were quite different in harvested vs unharvested stands (Larrieu et al. EJFR 2012)

- **TReMs**
  - wide range of total density
  - number of bearing-trees
  - diversity
  - patterns of relative proportions quite different

Harvested stands

"favoured" by harvesting

Dendrothelm
Missing bark

vs

“unfavoured” by harvesting

Cracks
Cavities
Sporophores

2 harvested & 1 unharvested forests, Pyrénées
The decrease of density of TReM-bearing trees in harvested stands resulted mainly from selection during tree-marking for beech but from large-tree harvesting for fir (Larrieu et al. EJFR 2014)

<table>
<thead>
<tr>
<th>Cutting dbh = 70 cm</th>
<th>Selection during tree-marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>-16% (ns)</td>
<td>-39%***</td>
</tr>
<tr>
<td>-30% (ns)</td>
<td>0%</td>
</tr>
</tbody>
</table>

Effect on density of TReM-bearing trees (TReM “unfavored” by harvesting)
What about TReM knowledge now?

• Almost accomplished and stable definition and typology, shared by the European TReM team → towards standardized protocols

• Database of TReM-associated taxa at the TReM level

• Quantitative relationships and thresholds inspiring practical recommendations

• Influence of tree-species on harvesting effects

• TReM-bearing trees drive biodiversity at stand level

• Current negotiated standards are not enough demanding
From results to practical recommendations
From results to tools

Samsara2 (Irstea)

10 factors of PBI

Factor F: TReM
IV: Towards future research
Data about spatio-temporal distribution of TReMs might open new research fields

- Distribution patterns in unharvested forests
  - Relationships between TReMs and associated biodiversity
    - relevant study scale
    - study of species dispersion capacity
    - matrix permeability
    - redundancy/complementarity between saproxylic TReMs and deadwood

  - What are the key factors for TReM genesis and co-occurrence?
  - TReM “lifespans”

- Distribution patterns in harvested forests
  - Effects of TReM density vs effects of TReM spatial distribution?
  - Better conservation of associated biodiversity
This work required a lot of funding organizations and scientific collaborations

**Forest owners**
- Forest access

**WSL/Univ. Dresde/IDF**
- Dendrometrical data

**Irstea Nogent**
- Taxonomic data
- Papers
- Statistics
- Ecological theories

**Irstea Grenoble**
- Modelling

**Bavarian NP**
- Papers

**INRA**
- UMR-Dynafor
- Geomatic/Remote sensing
- Logistics
- Sampling
- Papers
- Statistics/Modelling
- Ecological theories

**GEVFP/ONF/RNF/PNM**
- Taxonomic data

**CRPF CA, MP**
- Sampling
I’d like to bear TReMs like you...

Thanks for your attention
TReMs support a wide range of biological functions which determine species dependence

- Nutrition/hydration
- Roosting site only
- Regulation of temperature/humidity
- Hibernation
- Several functions?
- All the vital functions

Foraging place
Roosting place
Breeding place
Whole life cycle
Large set-aside patches are necessary to conserve the largest TReM diversity (Larrieu et al. 2014)
TReMs are naturally abundant and diversified throughout all silvigenetic cycle (Larrieu et al. FEM 2014)
Silvigenetic phase vs eco-unit vs forest stand

- Mature forest stand
- Matrix
- Eco-unit
- Disintegration FDP
- Growing FDP
- Regeneration FDP

Young forest stand