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# **Ecological and socioeconomic impacts of climate-induced tree diebacks in highland forests WP1 Impacts on biodiversity**

Christophe Bouget, Laurent Larrieu

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# CLIMTREE

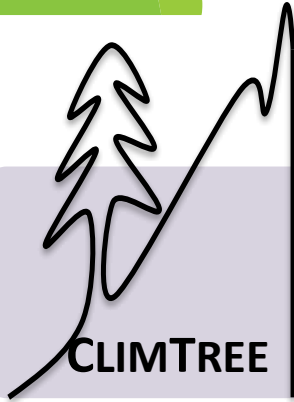
Ecological and socioeconomic  
impacts of climate-induced tree  
diebacks in highland forests  
WP1 Impacts on biodiversity



Bouget, C. & Larrieu, L.



*2<sup>nd</sup> meeting. Berlin 10-12/12/2018*



CLIMTREE

# Impact of Climate Change on Mountain Forest

*French Pyrenees*  
*Italian Alps*  
*Bohemian Forest*  
*Yunnan Forest*

WP1  
Impacts on Biodiversity

WP2  
Socio-Economic Impacts

Biological and Social Surveys

T1.1  
Field Sampling

T1.2  
DNA Bio-monitoring

T1.3  
Community Changes

T2.1  
Qualitative survey

T2.2  
Quantitative survey

T2.3  
Cost/Benefit study

Synthesis

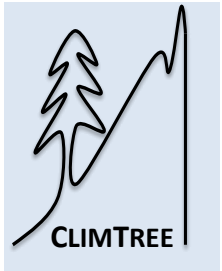
New Forest Management Policies  
Integrating Biodiversity and Economical Stakes



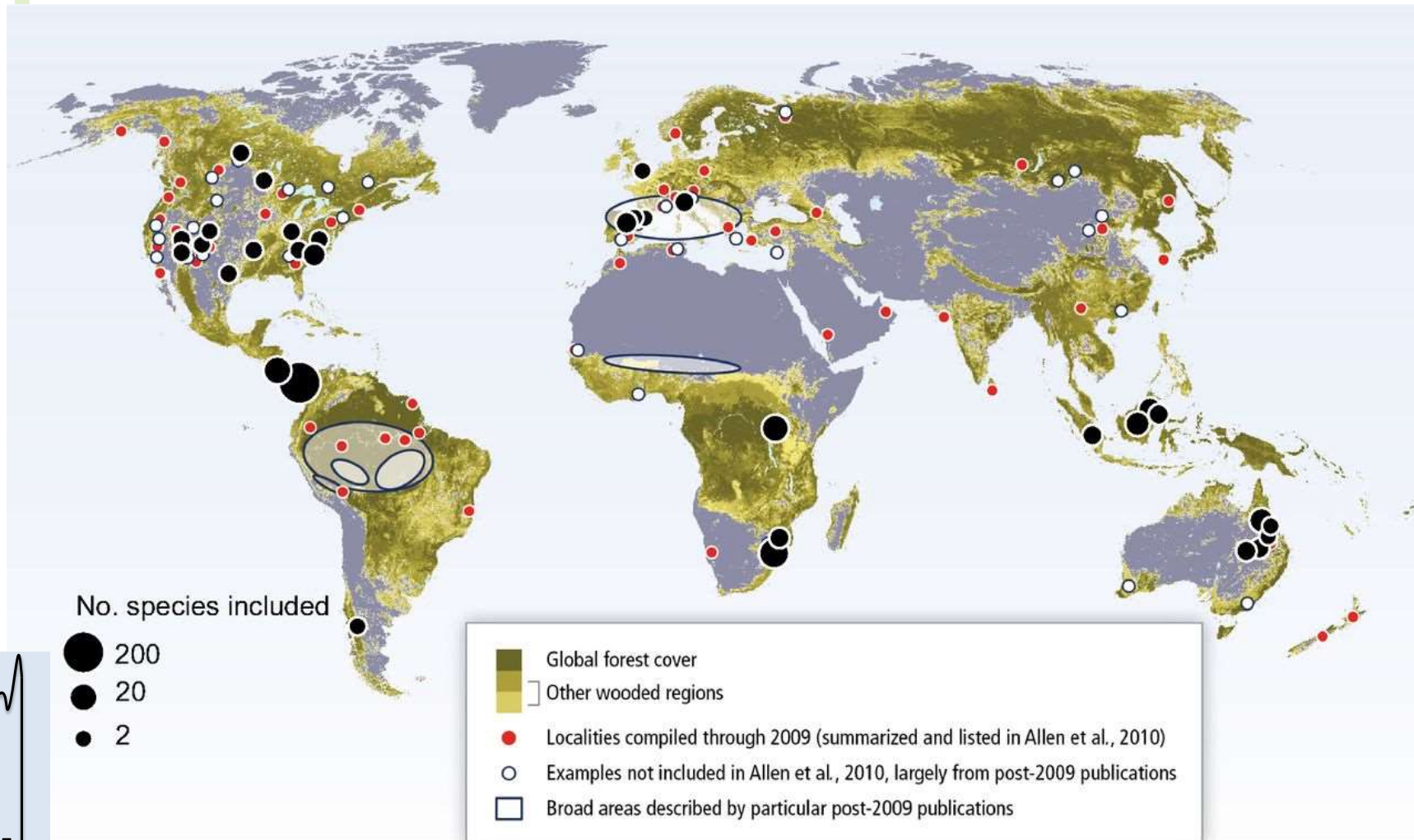
CLIMTREE



# Context, questions and study design

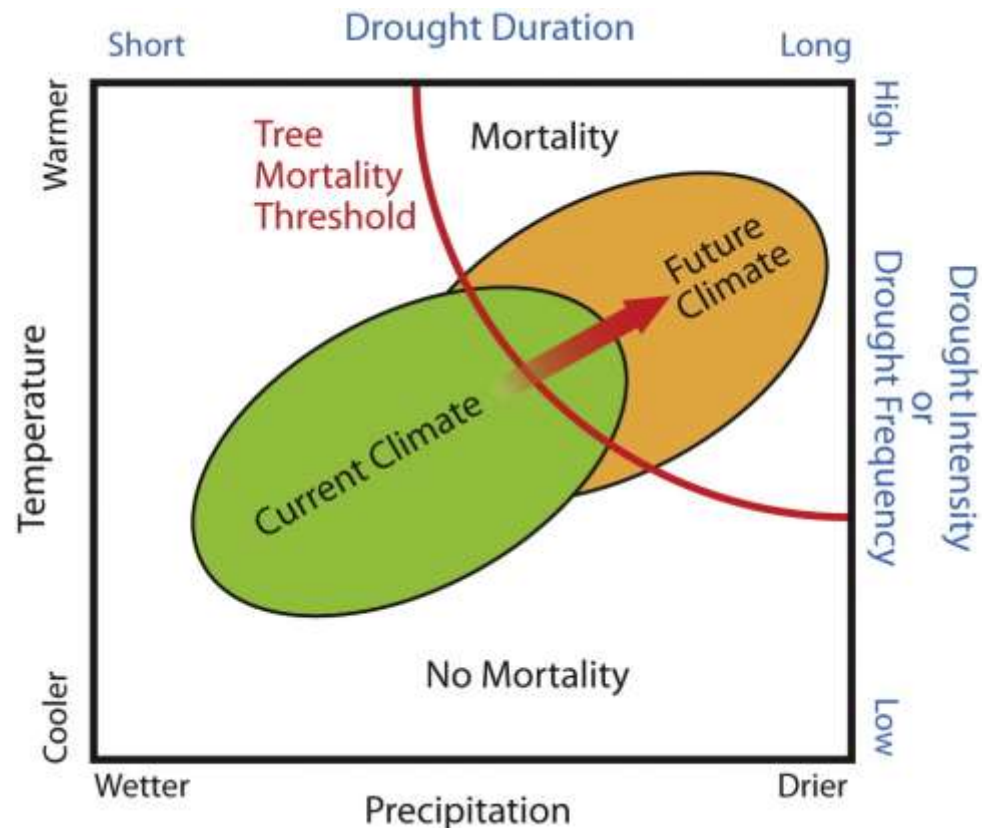


# Drought- and heat-induced regional tree mortality events around the world

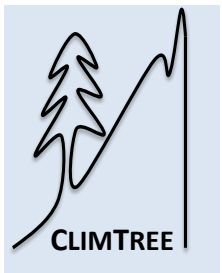


# Climate change and tree mortality

"Future Climate" shows increases in extreme drought and temperature events associated with projected global climate change, indicating heightened risks for drought-induced die off for current tree populations.



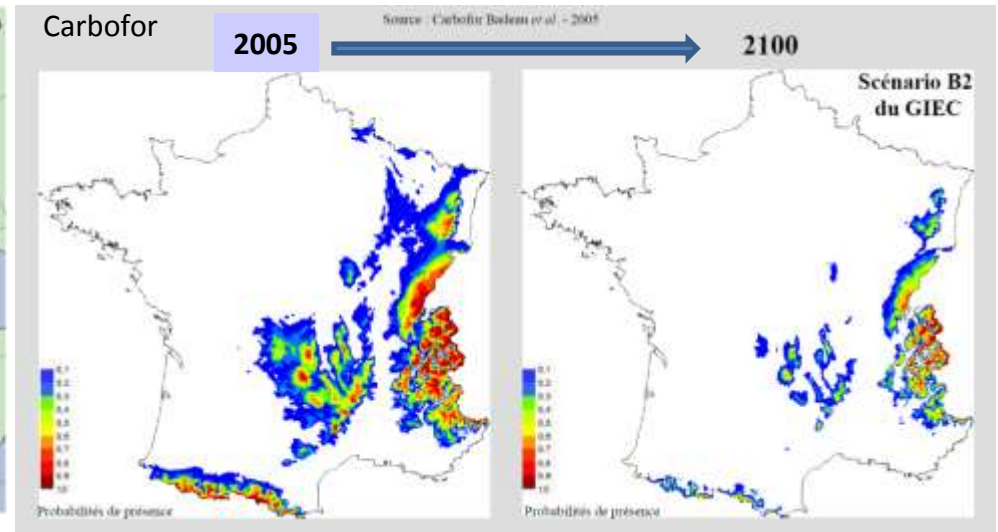
Breshears et al. Rangelands 2016



## Silver fir in southern France



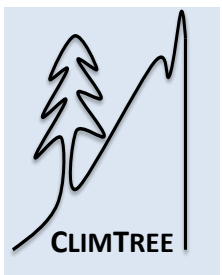
### Expected climate-induced changes in silver fir distribution



Silver fir, a **drought-sensitive** tree species (high moisture requirements)  
Silver fir at its southern limit in Mediterranean region (climate change hotspot)

#### Climate change

- Increase in the summer water deficit
- increase in vapour pressure deficit





# Silver fir dieback in France

*Journal of Vegetation Science* 21: 364–376, 2010  
DOI: 10.1111/j.1654-1103.2009.01148.x  
© 2009 International Association for Vegetation Science

## Sensitivity of French temperate coniferous forests to climate variability and extreme events (*Abies alba*, *Picea abies* and *Pinus sylvestris*)

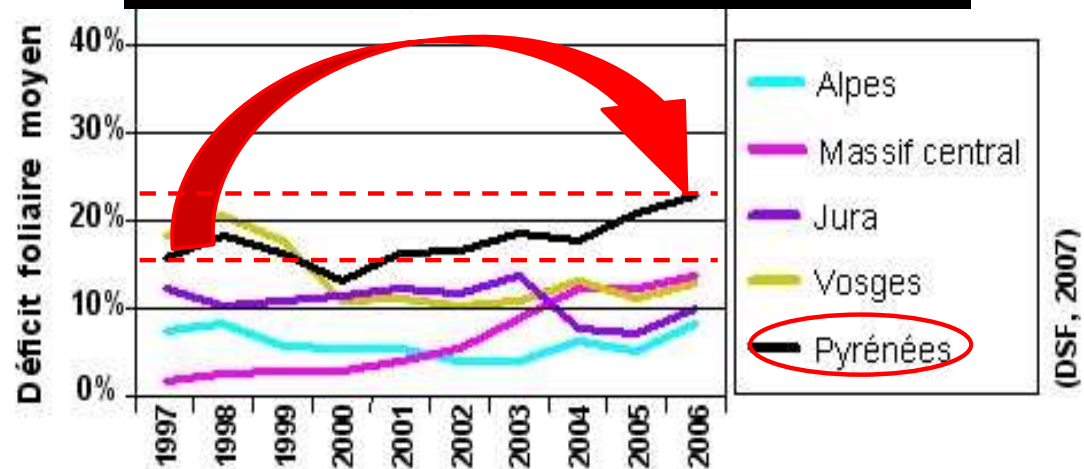
François Lebourgeois, Cyrille B.K. Rathgeber & Erwin Ulrich

Recurrent diebacks since 1973: 2794 reports of dying *Abies* in the north of France (Vosges) and in the south (Pyrenees, south Alps and Montagne noire) (Renecofor monitoring network)

### 3 major recent crises :

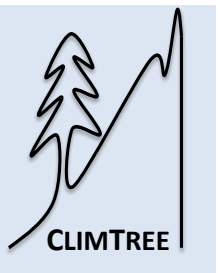
- 1980s (1983-1990)
- 1991-1993
- 2003-2007 (severe in the French Mediterranean region especially at altitudes lower than 1000 m, on south facing slopes or crests)

### Silver fir tree defoliation index in France



### Drivers

frost, drought, pollution, acid rains, biotic stresses  
(Chéret et al., 1987; Bigler et al., 2004)



# Silver fir dynamics is also affected by other biotic drivers in French forests



Available online at [www.sciencedirect.com](http://www.sciencedirect.com)



Forest Ecology and Management 217 (2005) 219–228

Forest Ecology  
and  
Management

[www.elsevier.com/locate/foreco](http://www.elsevier.com/locate/foreco)



## Is browsing the major factor of silver fir decline in the Vosges Mountains of France?

Patricia Heuze<sup>a,\*</sup>, Annik Schnitzler<sup>a</sup>, François Klein<sup>b,1</sup>



Contents lists available at [ScienceDirect](http://ScienceDirect)

Forest Ecology and Management

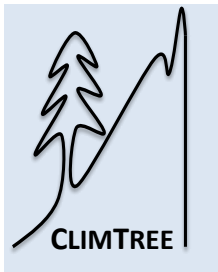
journal homepage: [www.elsevier.com/locate/foreco](http://www.elsevier.com/locate/foreco)



## Deer browsing promotes Norway spruce at the expense of silver fir in the forest regeneration phase



Marianne Bernard<sup>a,b</sup>, Vincent Boulanger<sup>c</sup>, Jean-Luc Dupouey<sup>e,\*</sup>, Lisa Laurent<sup>f</sup>, Pierre Montpied<sup>e</sup>, Xavier Morin<sup>b</sup>, Jean-François Picard<sup>e</sup>, Sonia Saïd<sup>d</sup>



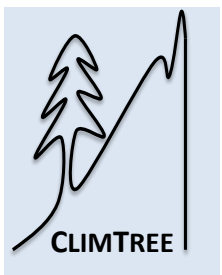
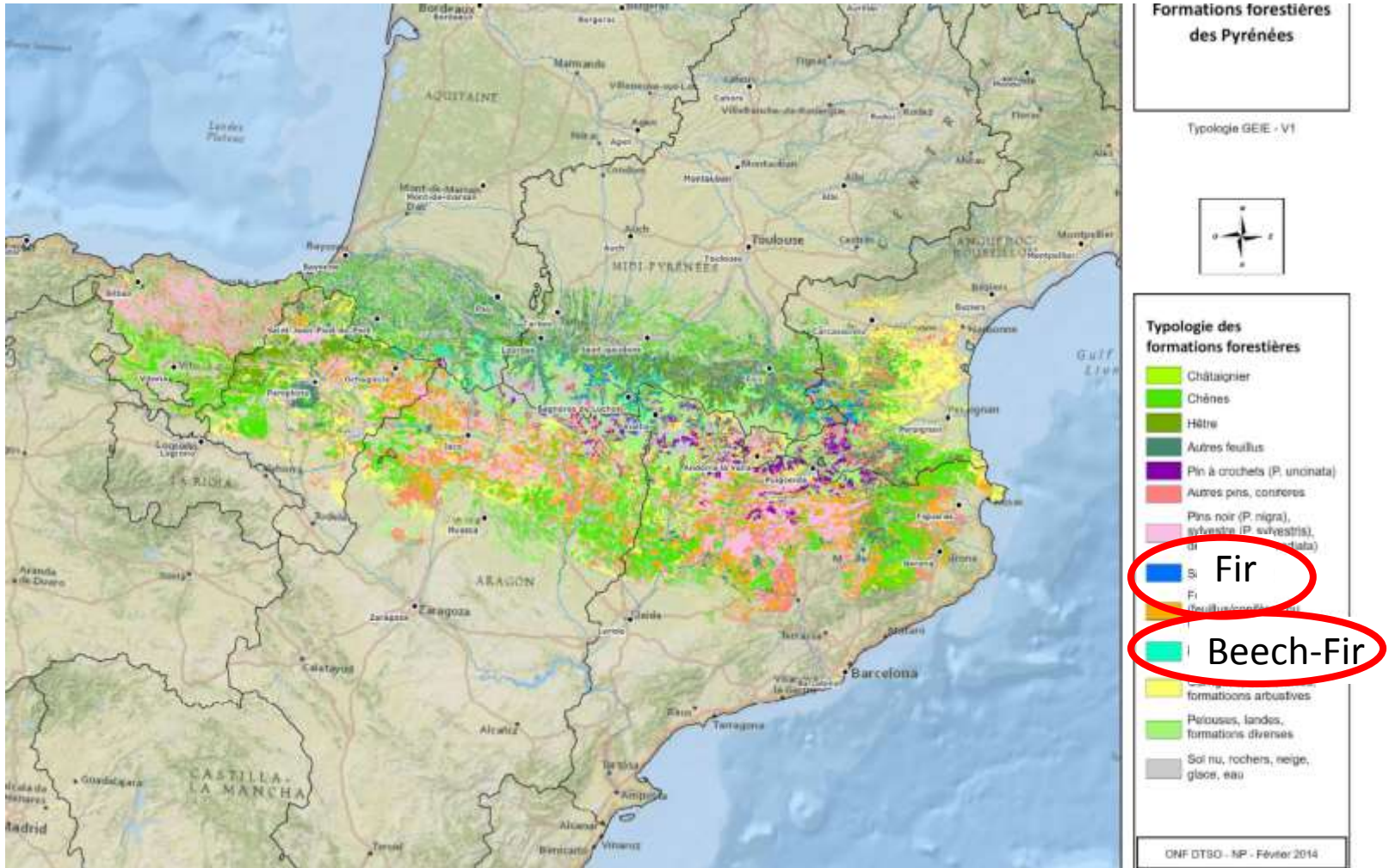
# Silver fir dieback symptoms



- Decline of the crown
- Regression of increment in the high crown
- Change of colour and fall of needles
- Increase in secondary parasites



# French sampling design



# Aure

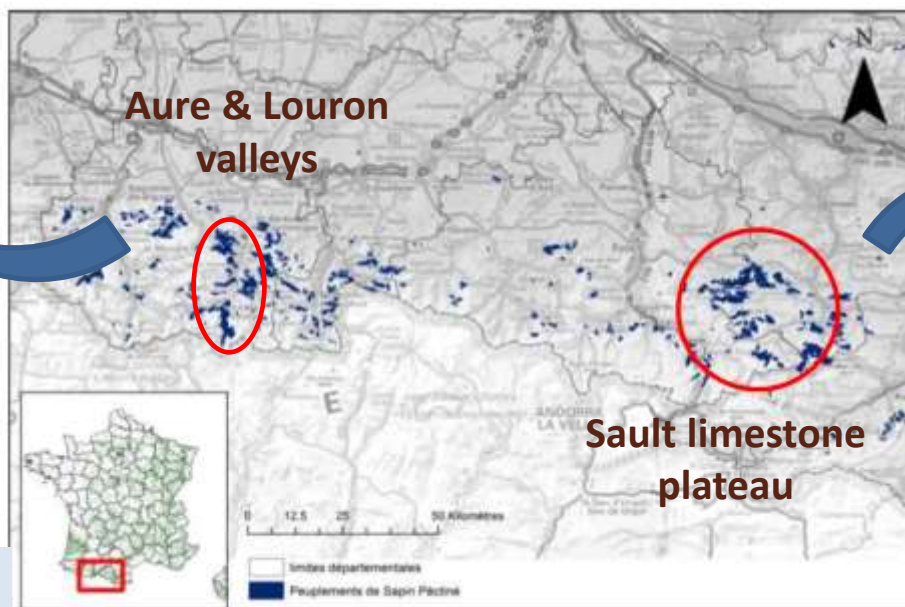
		Stand scale			
		Healthy	Declining		
			Low dieback level	High dieback level	
		No harvesting	No harvesting	Salvage logging	
Landscape scale	Low dieback level	10 plots	3	2	-
	High dieback level	0	3	4	6

## Objectives of the French sampling design

### Stratifying factors

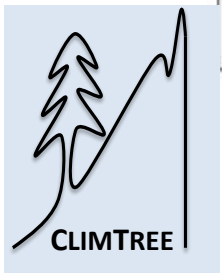
1. Local dieback intensity (- → +)
2. Salvage logging (0/1)
3. Dieback intensity at the landscape scale (- → +)

Design replicated in 2 regions



# Sault

		Stand scale			
		Healthy	Declining		
			Low dieback level	High dieback level	
		No harvesting	No harvesting	Salvage logging	
Landscape scale	Low dieback level	5	3	3	-
	High dieback level	5	3	3	6



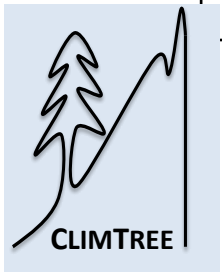
# Objectives of the French sampling design

3 crossed gradients to tackle several questions

Local decline intensity		Stand scale			
		Healthy	Declining		
			Low dieback level	High dieback level	
Landscape scale (R=200m)		No harvesting	No harvesting	Salvage logging	
Low dieback level	15	6	5	-	
High dieback level	5	6	7	12	

Decline intensity at the landscape scale

Salvage logging





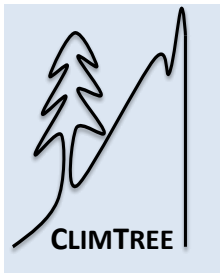
# Which proxy for forest decline intensity?

Local dieback assessment using the ARCHI method

(Drenou et al., 2013)

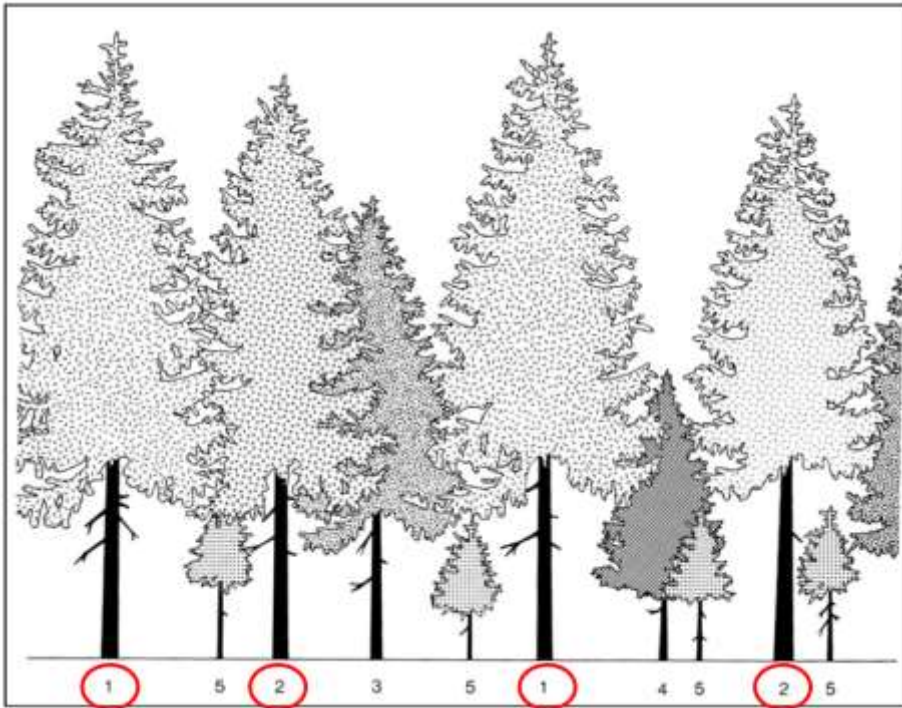
The ARCHI method analyses tree architecture (whole tree, crown, axes and branches) to establish a diagnosis of tree vitality status

A set of ergonomic keys to perform diagnoses in the field

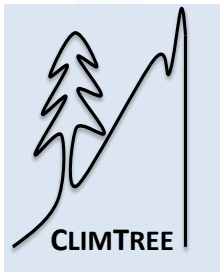
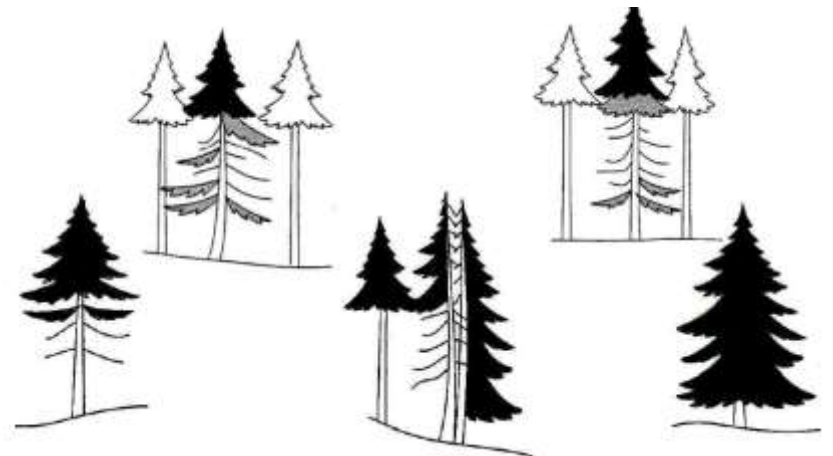


# Local dieback assessment using the ARCHI method

Health status of 20 (co)dominant trees at the plot center



Focus only on conspicuous tree crowns (in black below)



# Local dieback assessment using the ARCHI method

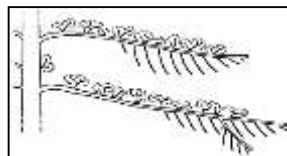
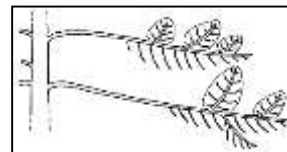
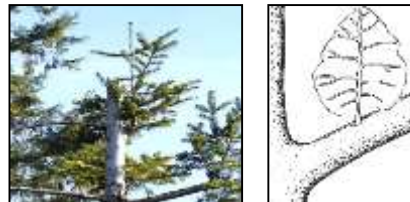
Defoliation  
Crown decline  
symptoms

+

Crown  
restoration  
process

=

ARCHI diagnosis  
5 tree types

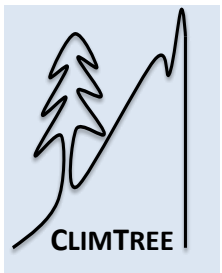


Type and vigor of sprouts

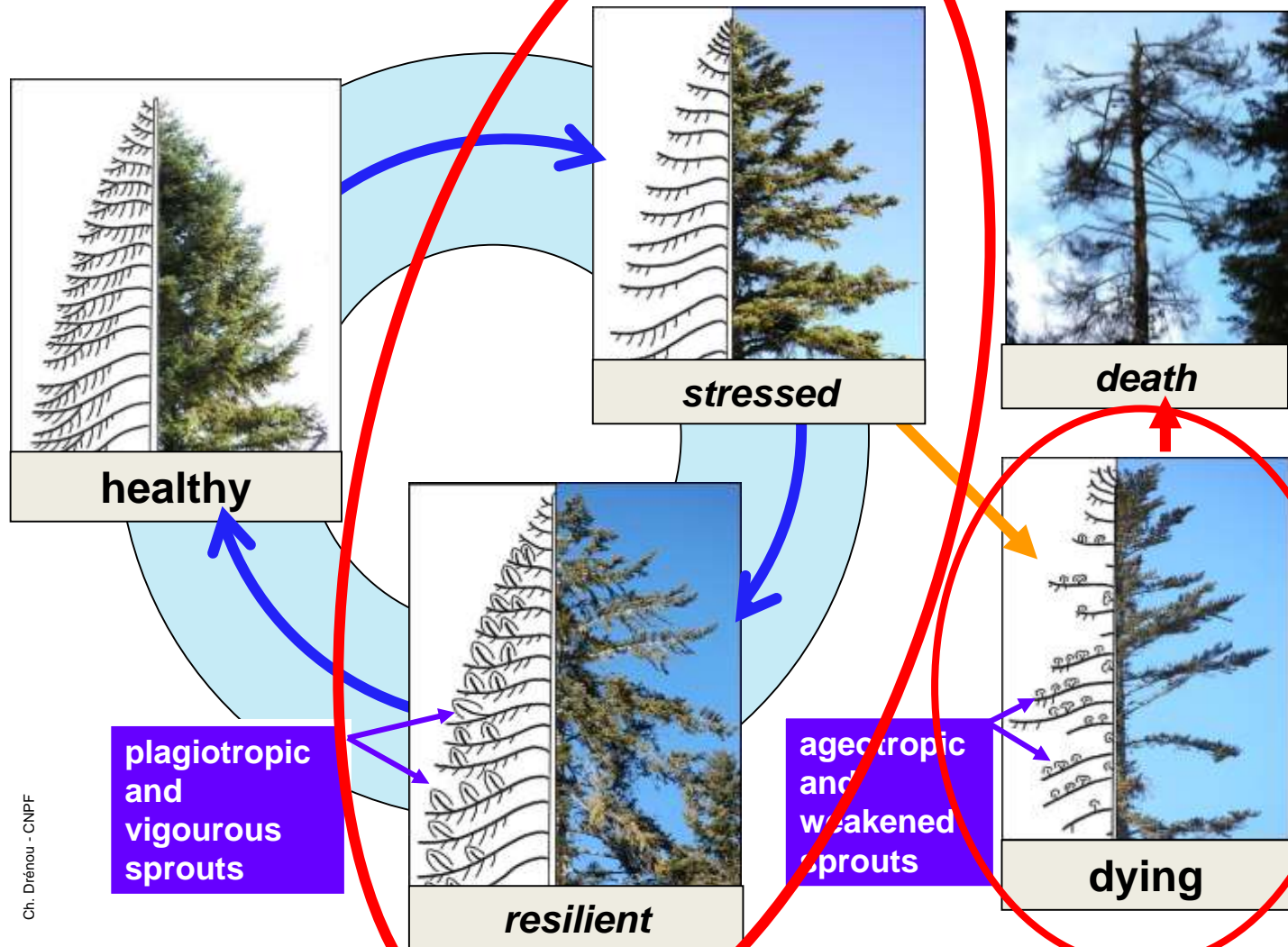
- **healthy**
- **stressed**
- **resilient**
- **dying**
- **crown dieback**

- +

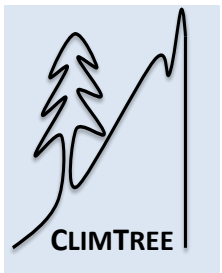
+ Greenness level



# Local dieback assessment using the ARCHI method

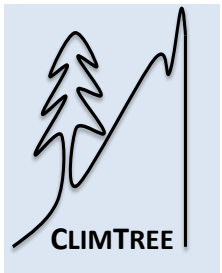
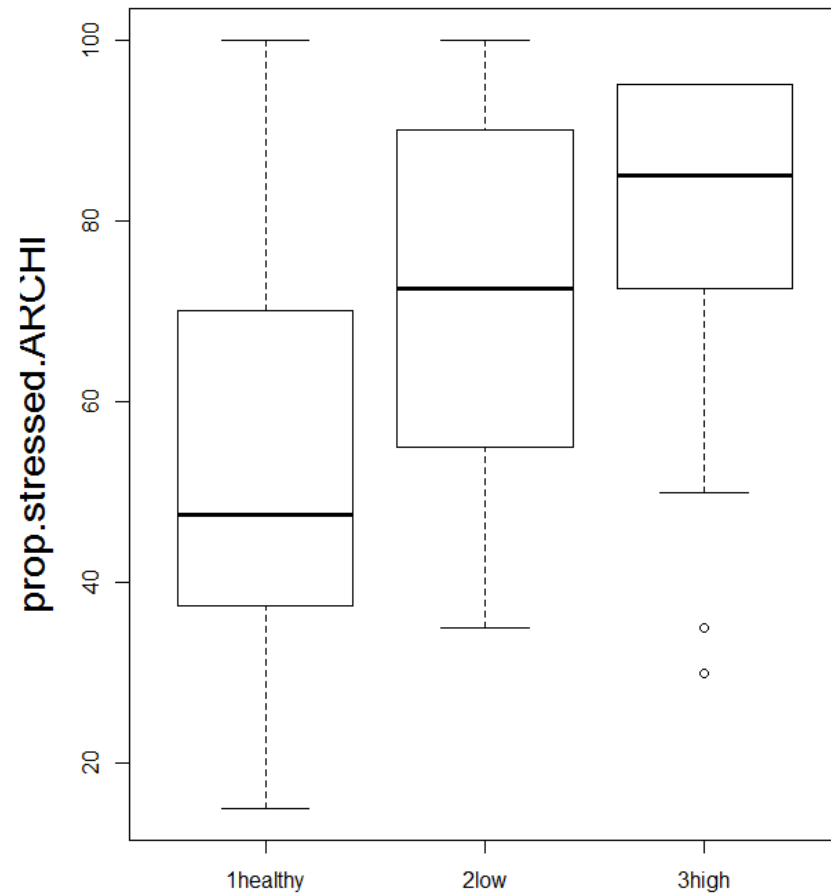
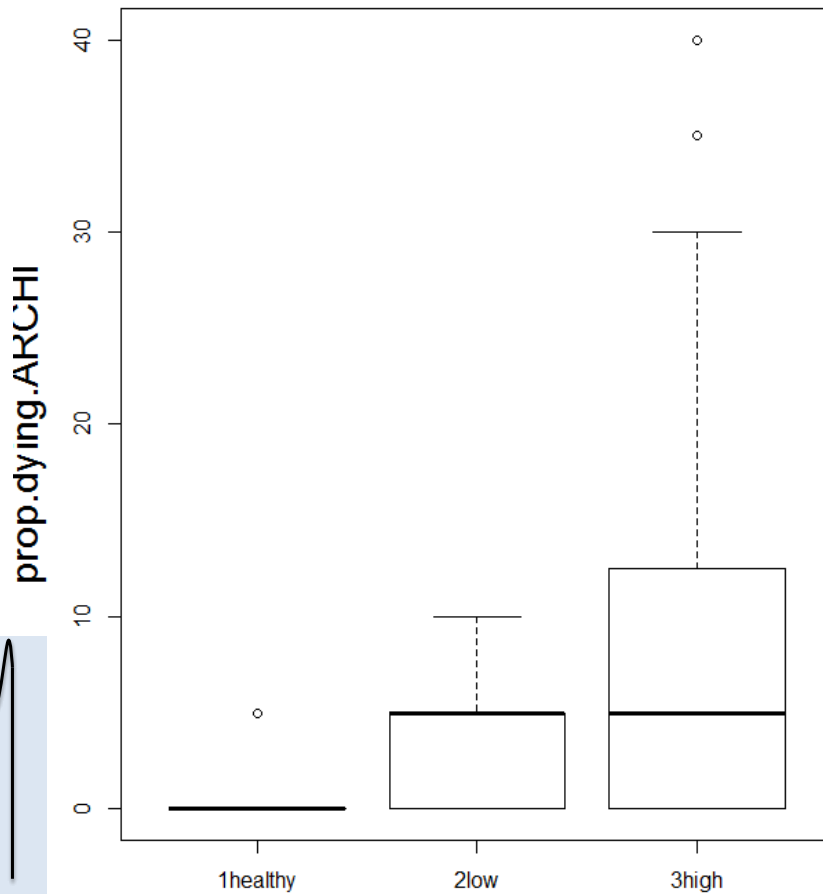


Ch. Drénou - CNPF



# Post-hoc assessment of the sampling design

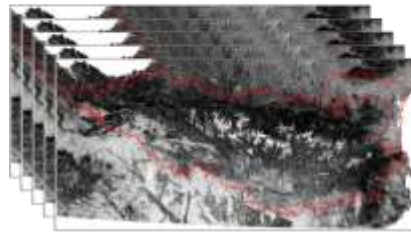
At the stand scale



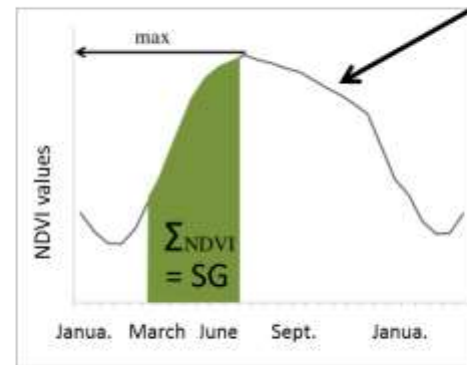
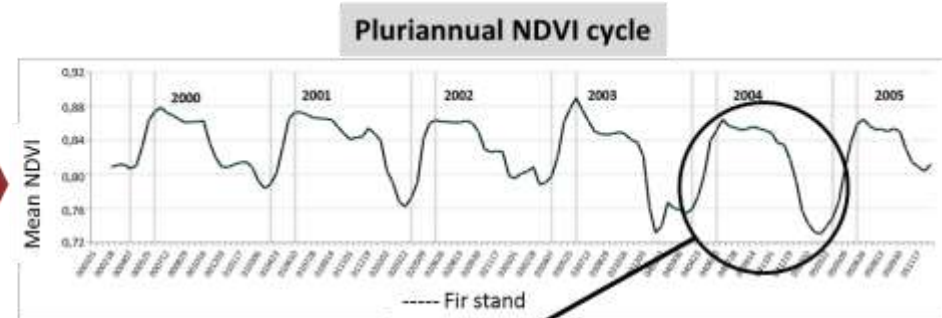
# Dieback level at the landscape scale

## Remote sensing data = MODIS Terra NDVI Time Series (2000- 2016)

- Moderate Resolution Imagery Spectroradiometer (MODIS)
- free data
- spatial resolution 250m (pixel=6.5 ha)
- Every 8 or 16-days



## Analysis of trends in MODIS NDVI time series

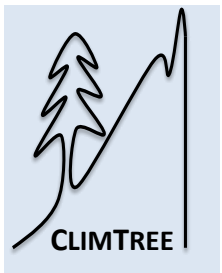


Vegetation index  
**NDVI**  
(Normalized Difference  
Vegetation Index)  
 $NDVI = (PIR-R)/(PIR+R)$

## Spring Greenness (SG)

SG= phenological indicator linked to **spring vegetation activity**

= sum of NDVI calculated over a fixed period of MODIS images from the onset of SG (end of April) to the maximum NDVI (in end of June) before the dry season (Reed 2006)<sup>18</sup>

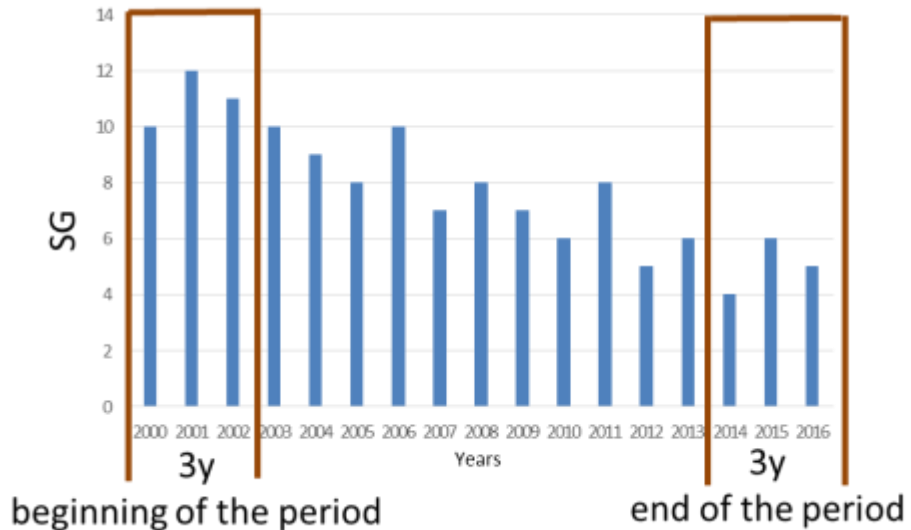




# Dieback level at the landscape scale

Detection and monitoring of gradual or sudden changes in forest health  
(Lambert et al., 2013)

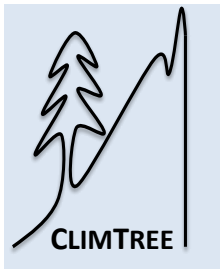
Measurement of variations of photosynthesis activity within the period 2000 – 2016 = **index of vitality trend**



for 1 pixel = 6ha

Index of vitality trend

$$\rightarrow D_{nor\_SG} = \frac{\begin{matrix} 2014 \\ \text{max } SG \\ 2016 \end{matrix} - \begin{matrix} 2000 \\ \text{max } SG \\ 2002 \end{matrix}}{\begin{matrix} 2000 \\ \text{max } SG \\ 2002 \end{matrix}}$$



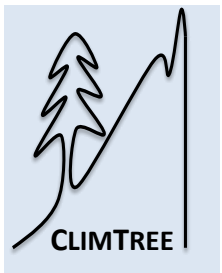
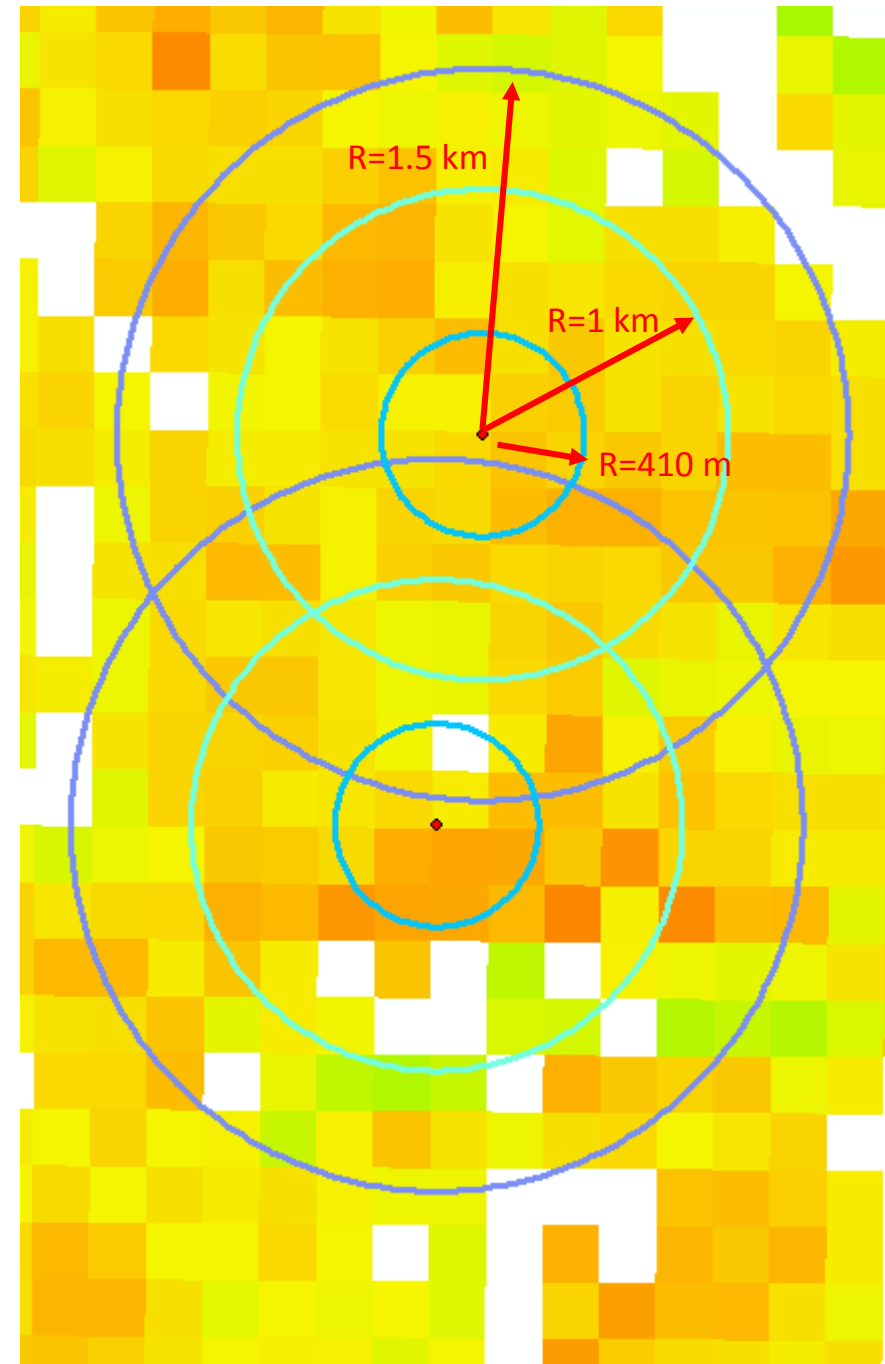
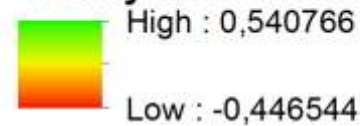
# Dieback level at the landscape scale

Dieback scores at 3 spatial scales centered on each sampling plot

## Legend

- ClimTree plots
- 54 ha buffer zone
- 315 ha buffer zone
- 700 ha buffer zone

## Vitality trend index

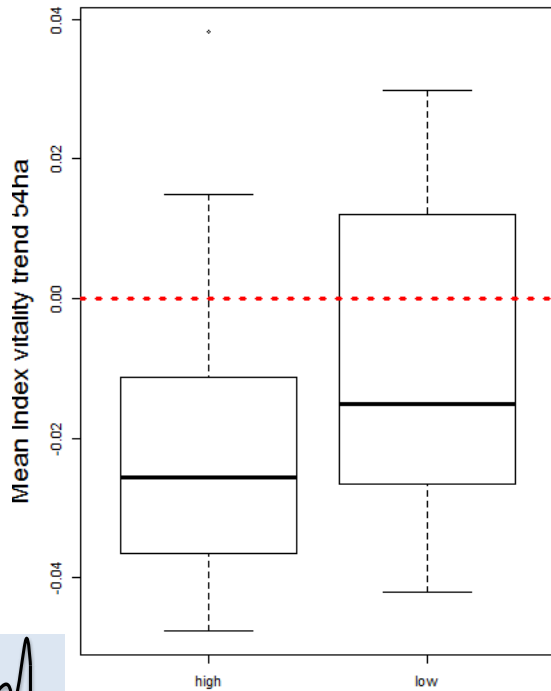


# Post-hoc assessment of the sampling design

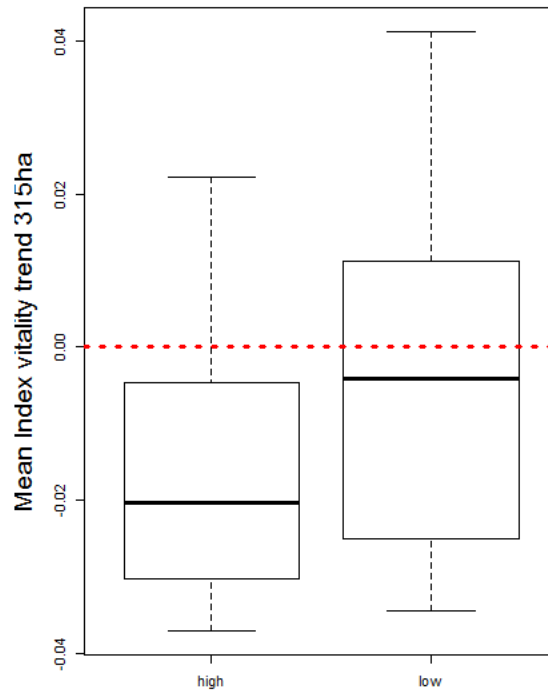
At the landscape scale

Dieback level at the landscape scale

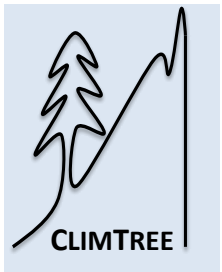
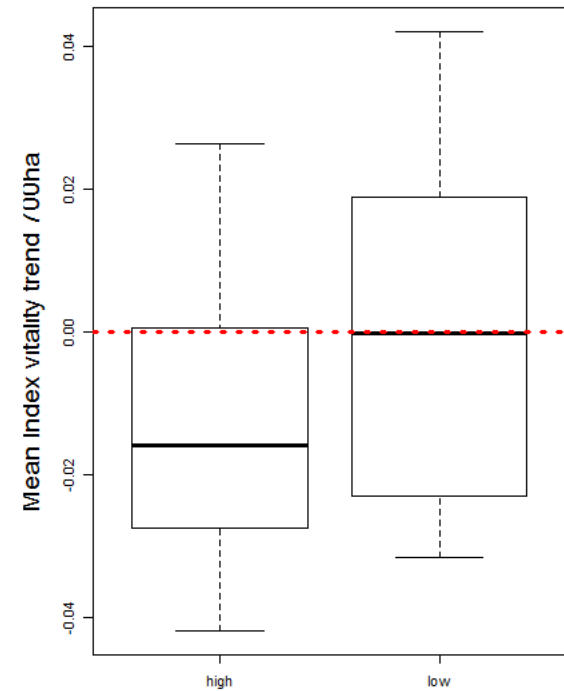
54 ha



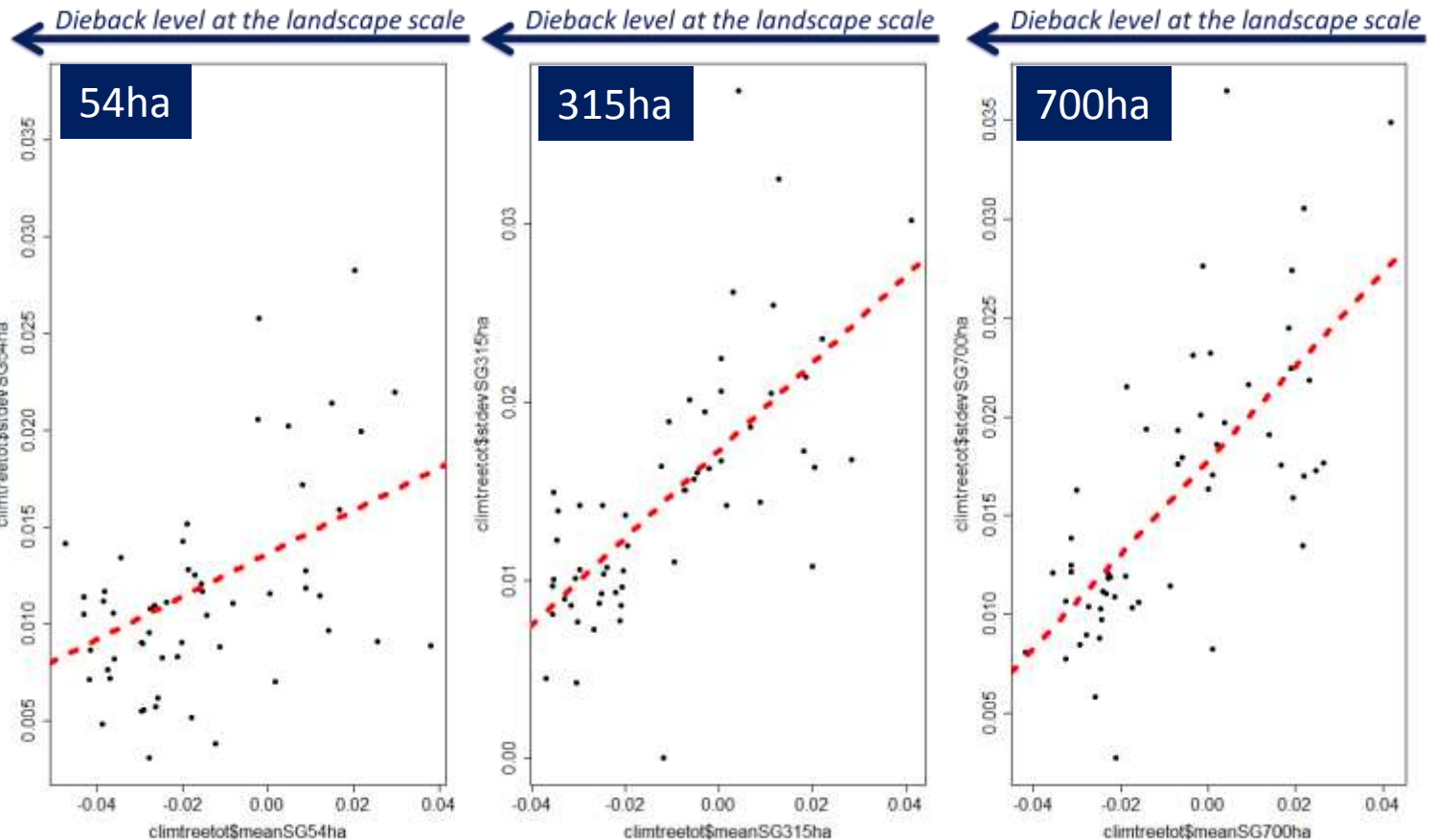
315 ha



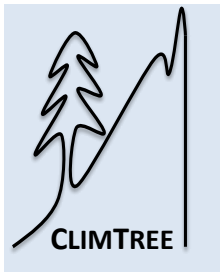
700 ha



# Post-hoc assessment of the sampling design

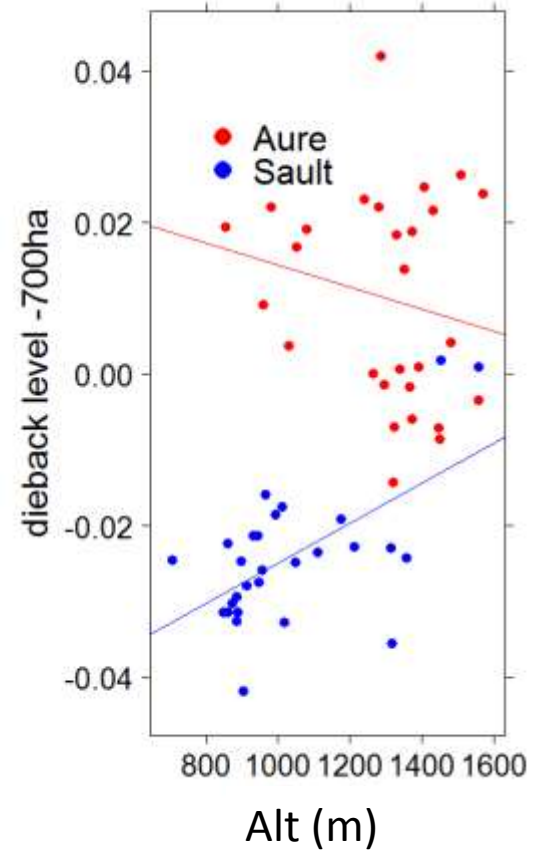
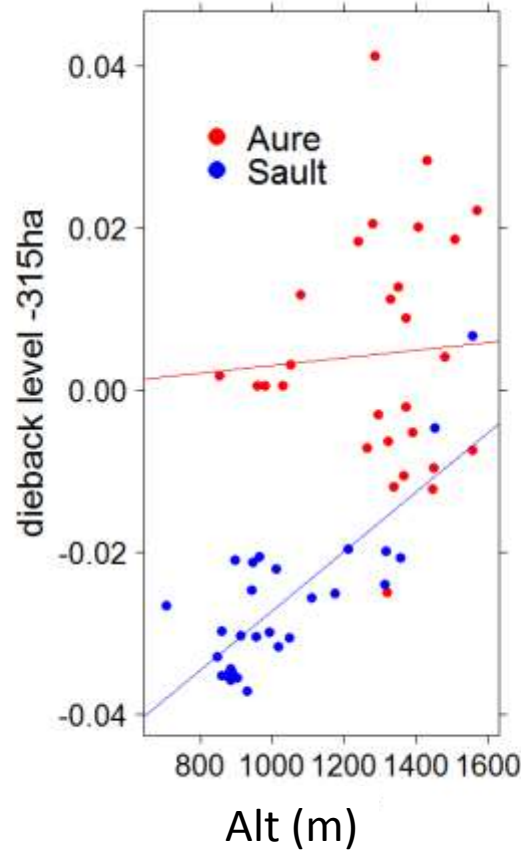
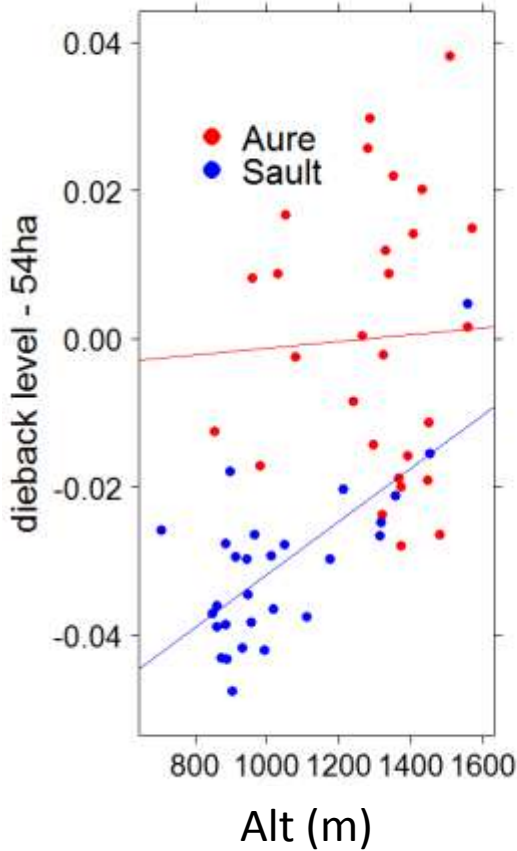


The higher the dieback level at the landscape scale, the less heterogeneous the landscape in terms of dieback level

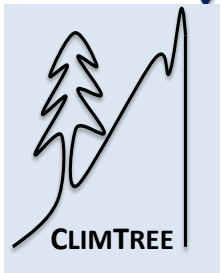


# Post-hoc assessment of the sampling design

Dieback level at the landscape scale

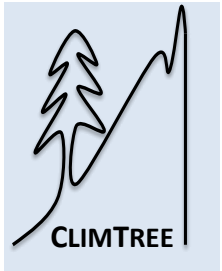


Dieback level at the landscape scale increases in lower altitudes (Sault region)





# Response of environmental conditions to forest dieback





# Ecological effects of dieback on forest conditions for insect communities

## Weakened, declining and dead trees

- Deadwood and tree-related microhabitats (TreMs)  
More resources for deadwood-dwelling insects
- Needles/shoots on vulnerable trees  
More available resources for phytophagous insects

## Openings

- Microclimate
- Herbaceous layer



Insect pests as aggravating factors on adult trees: *Pissodes piceae*, *Pityokteines curvidens*, *Cryphalus piceae*...



# Stand structure, deadwood and tree-related microhabitats

## Dendrometric measurements

September - October 2017

- Fixed-angle relascope sampling  
standing living, declining and dead trees  
coarse woody debris (tree species, length, decay stage)

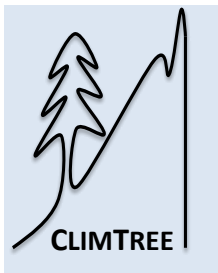


## Tree-related microhabitats inventory on living trees

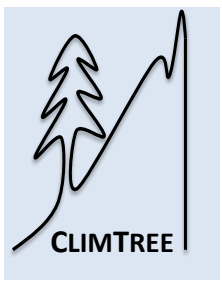
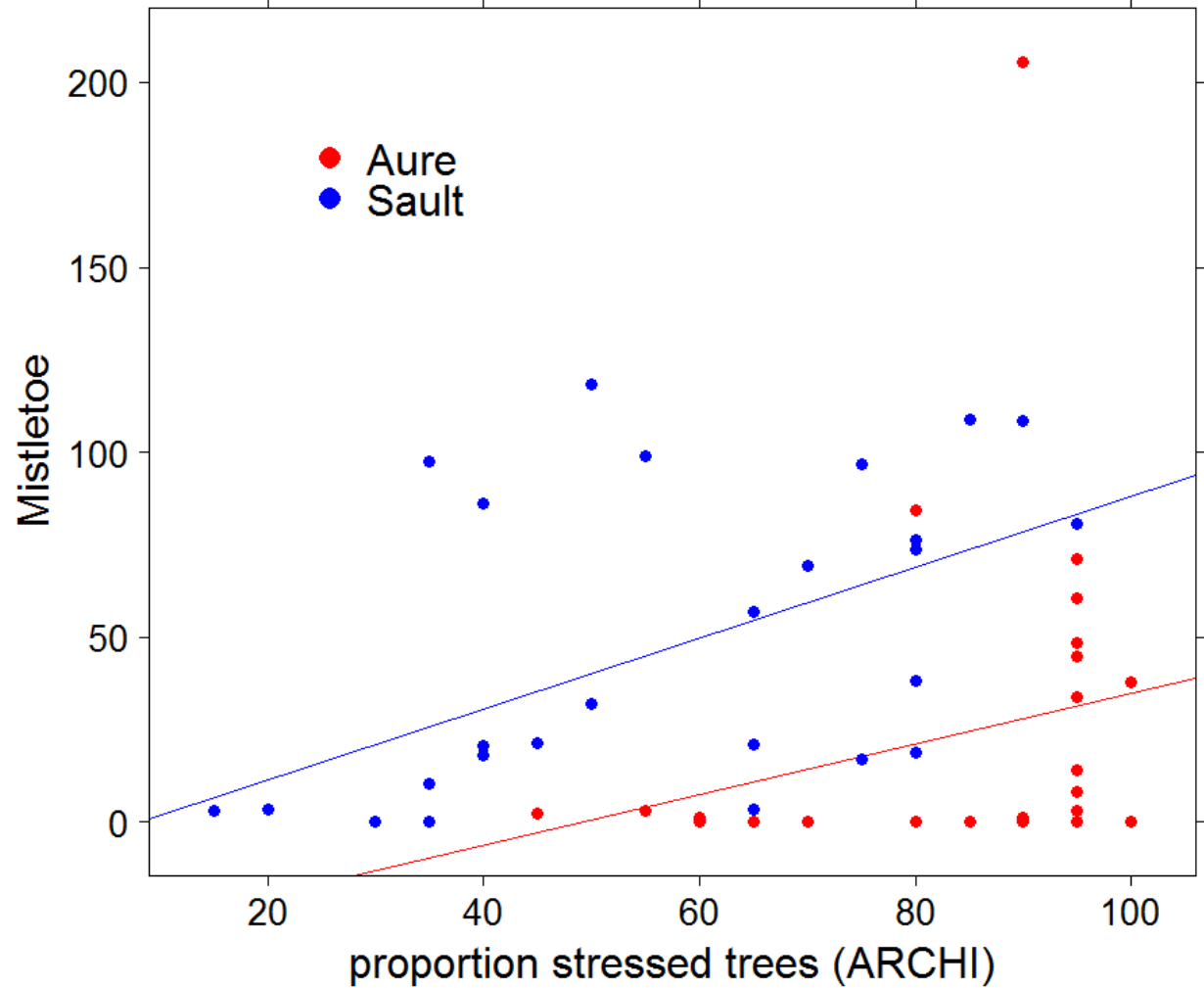
missing bark and mould cavities, woodpecker breeding cavities, sporophores of saproxylic fungi, sap runs, cracks and bark shelter/pockets, mistletoe

## Canopy opening (spherical crown densiometer)

IBP 10 criteria (1ha)



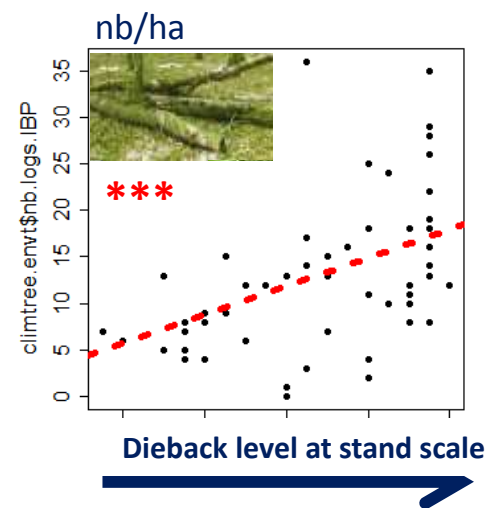
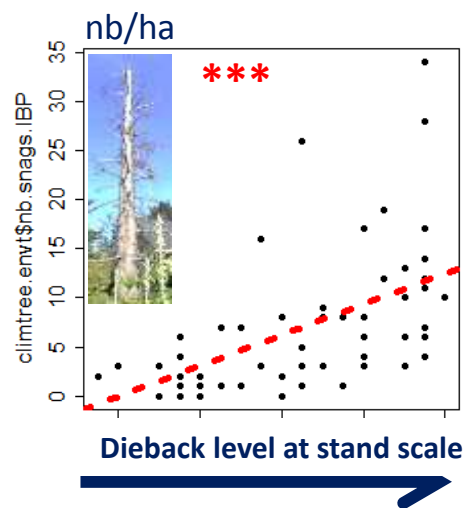
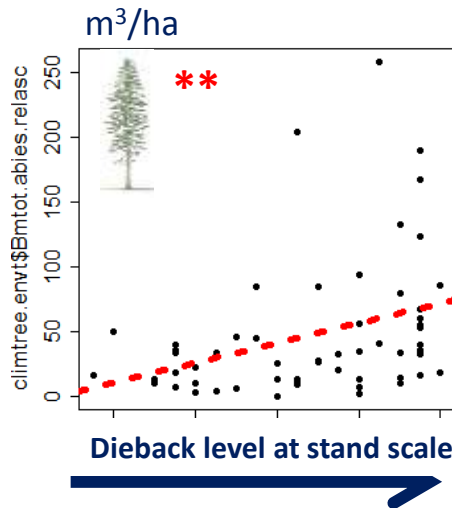
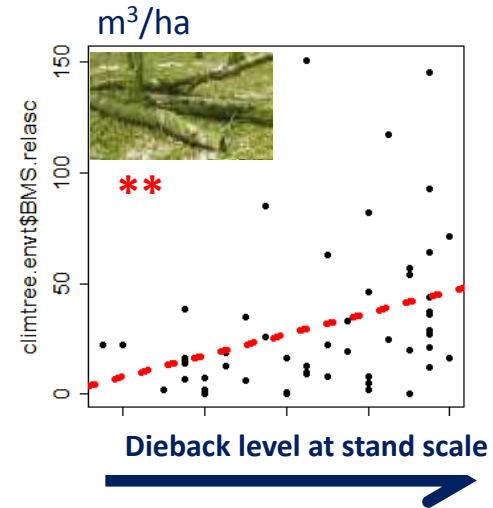
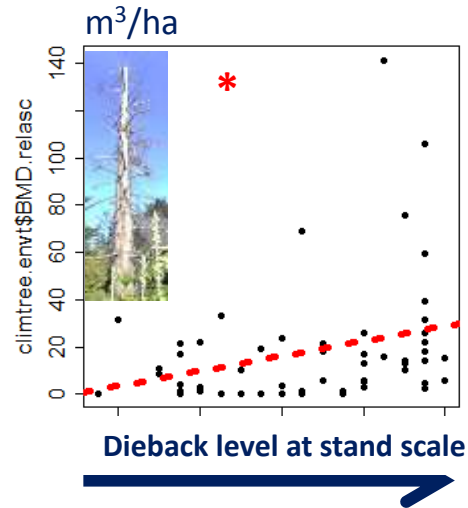
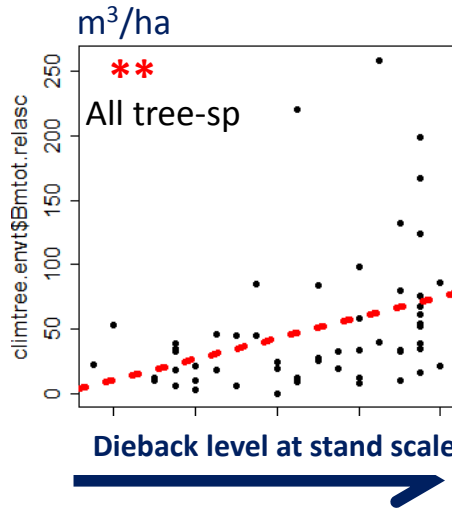
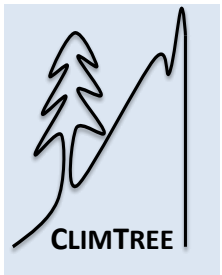
# Stand dieback level and density of mistletoe-bearing trees



# Effects of dieback level on forest structure

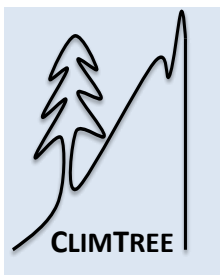
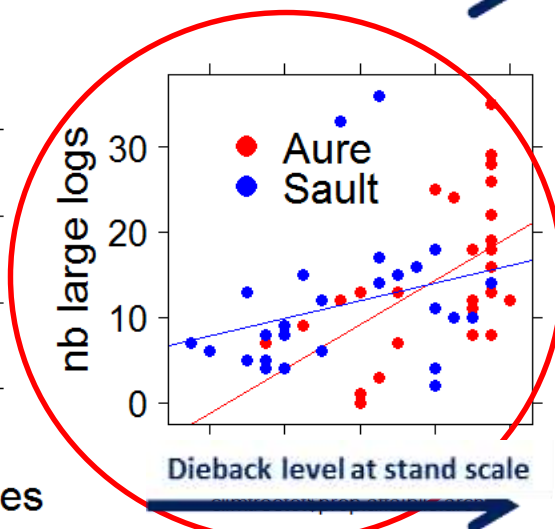
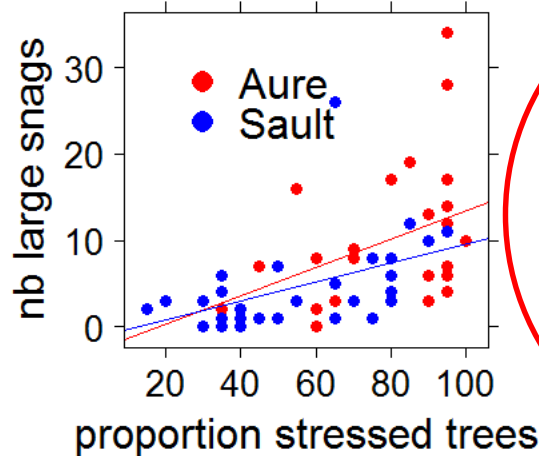
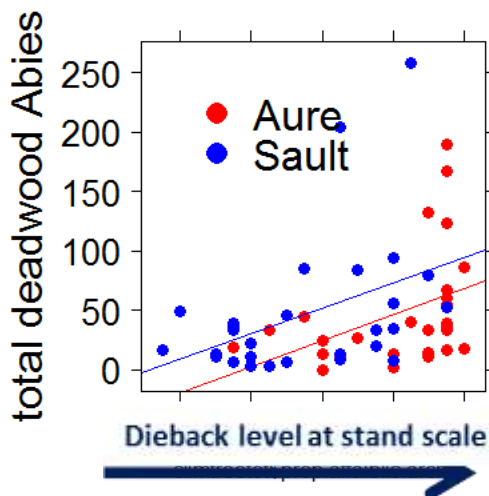
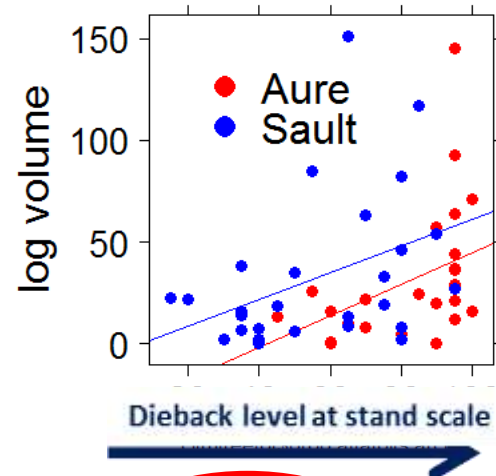
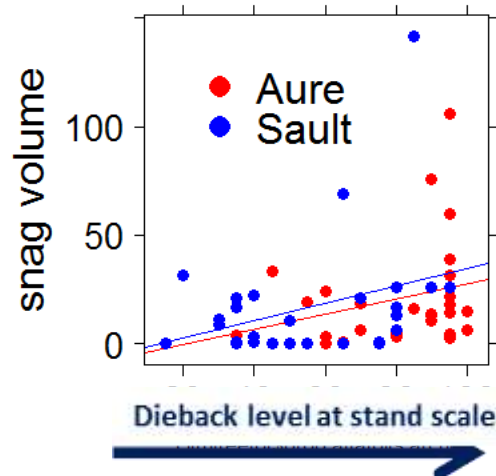
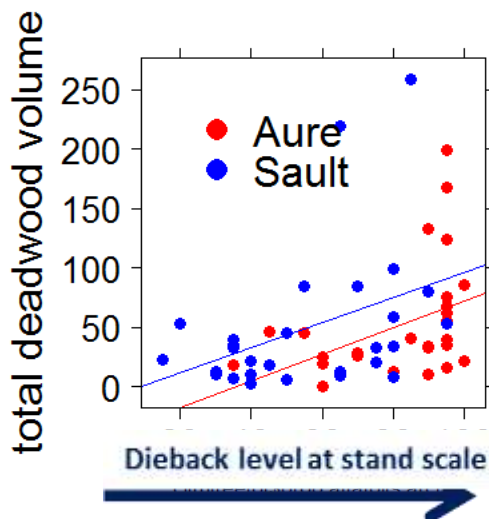
An overall increase in deadwood, mainly fir deadwood

Mixed models (« region » as a random variable)



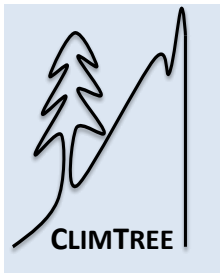
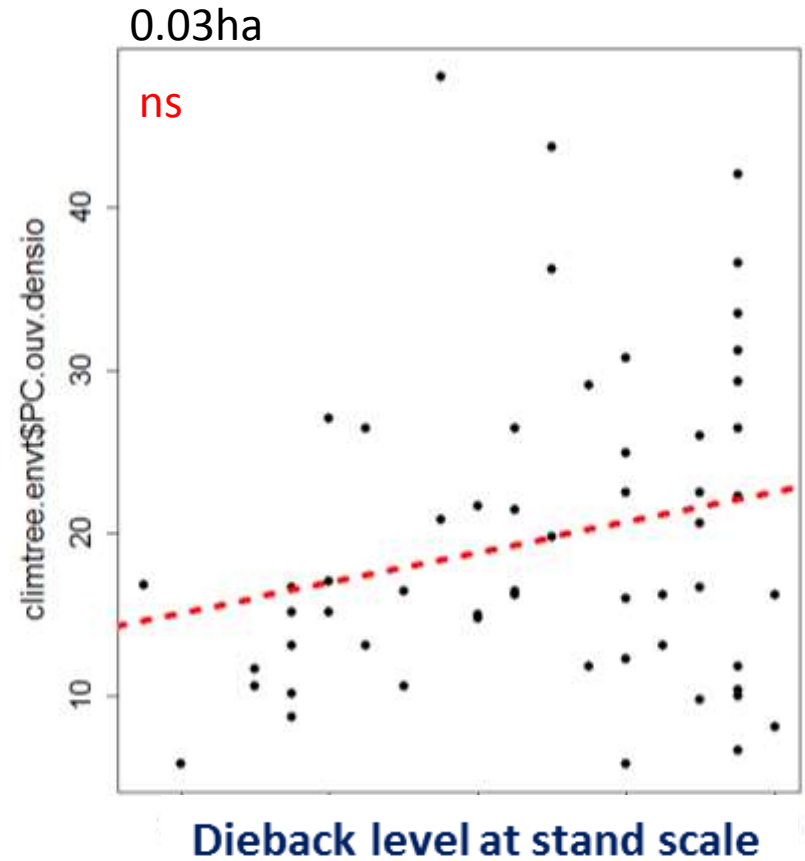
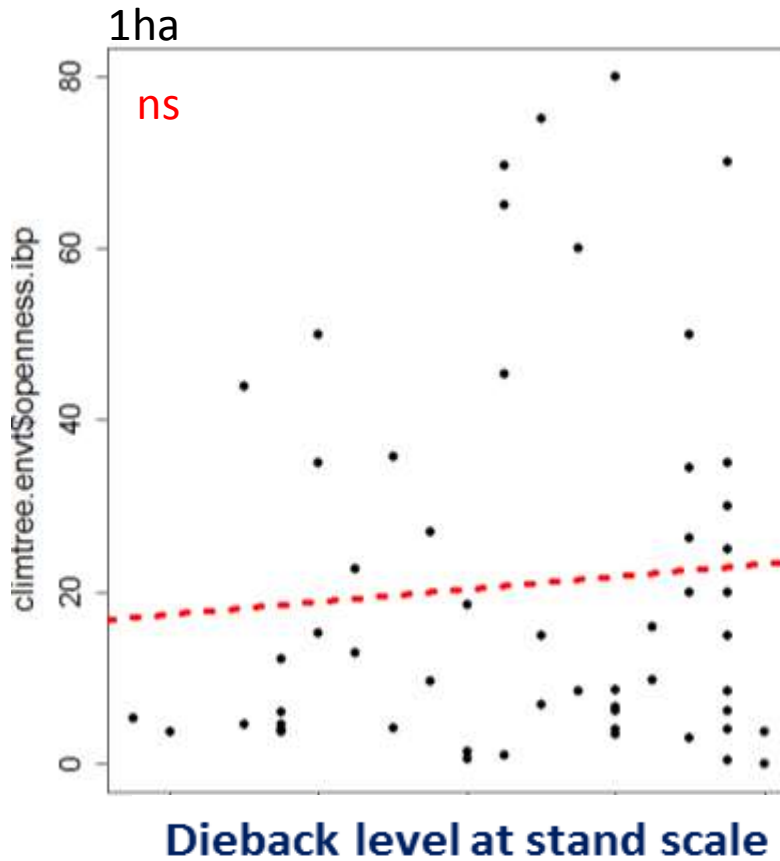
# Effects of dieback level on forest structure

xy plots by region



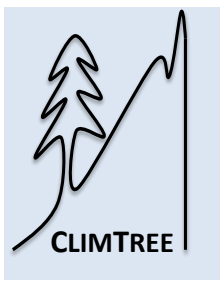
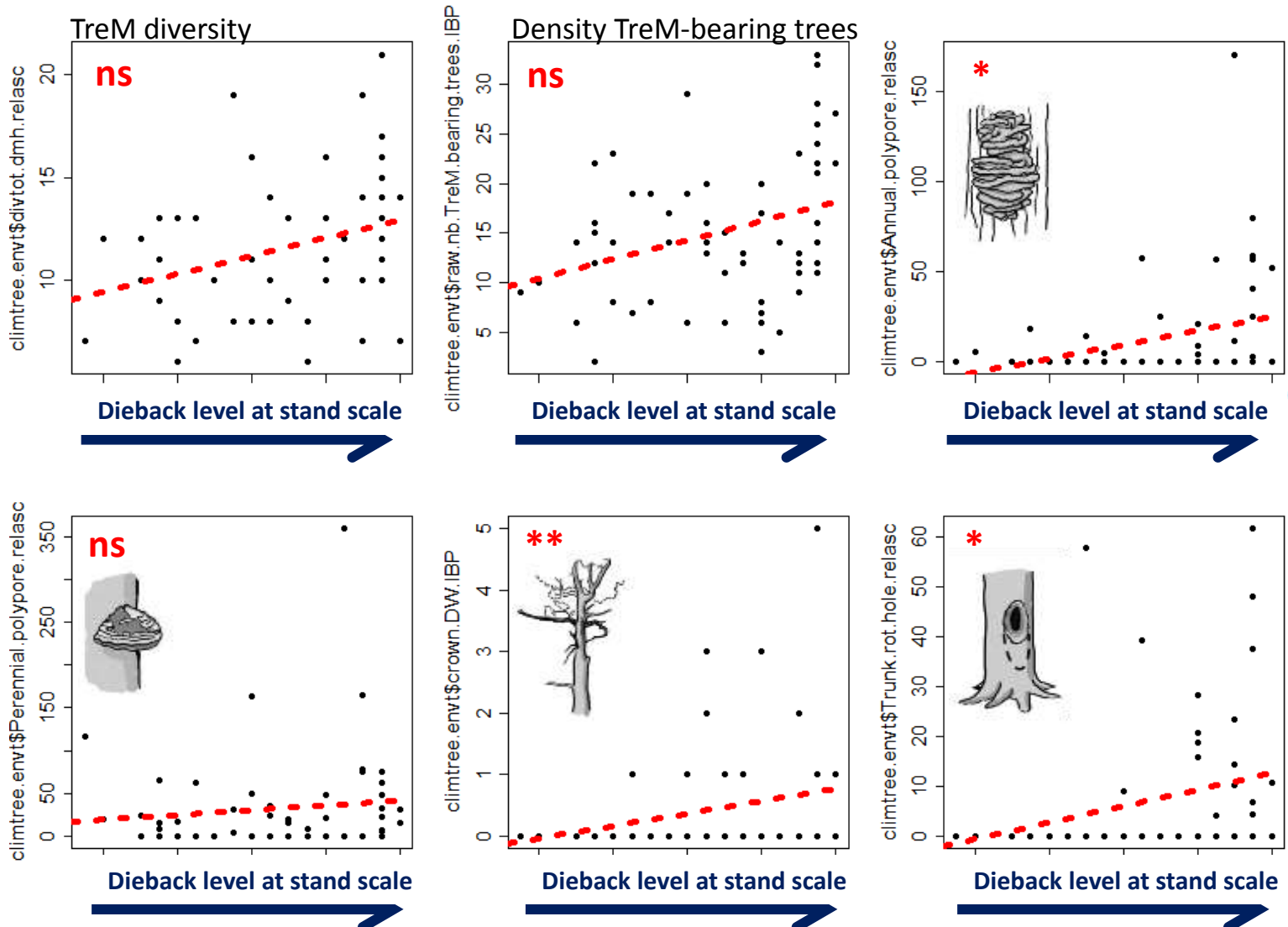
# Effects of dieback level on forest structure

A non-significant increase in open-canopy conditions



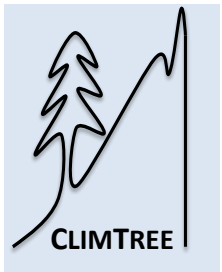
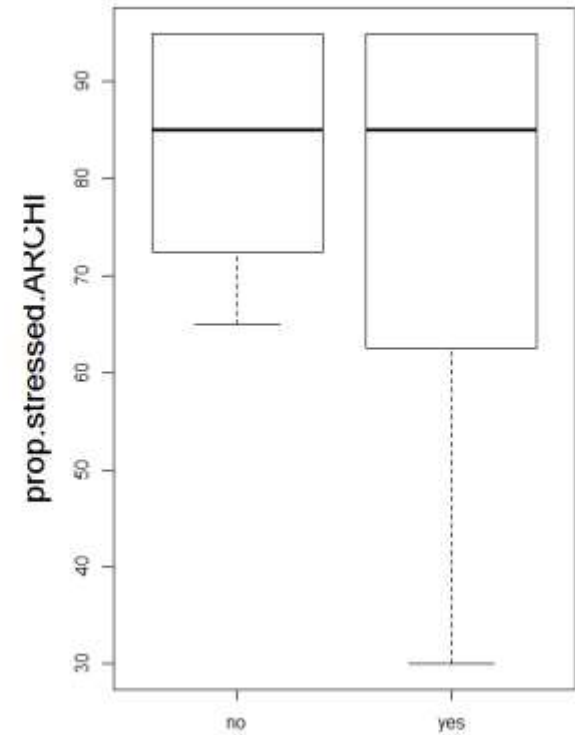
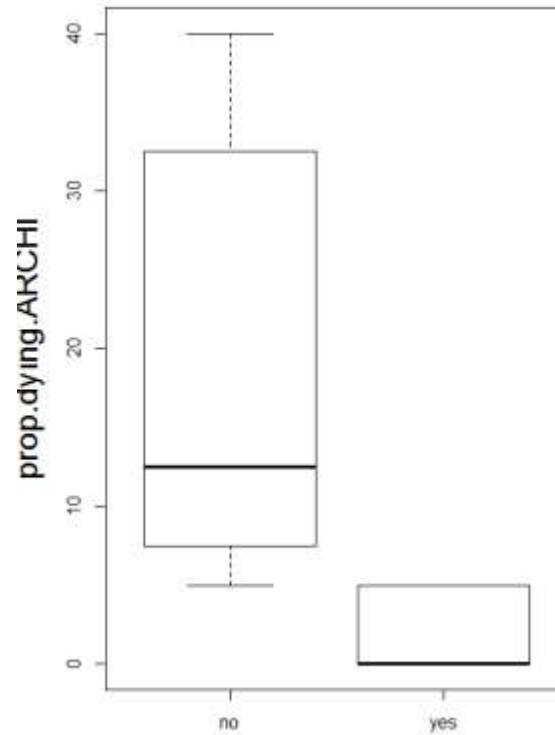
# Effects of dieback level on forest structure

A slight increase in tree-related microhabitat density



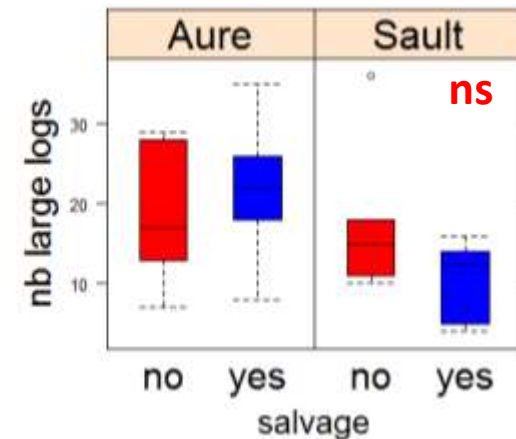
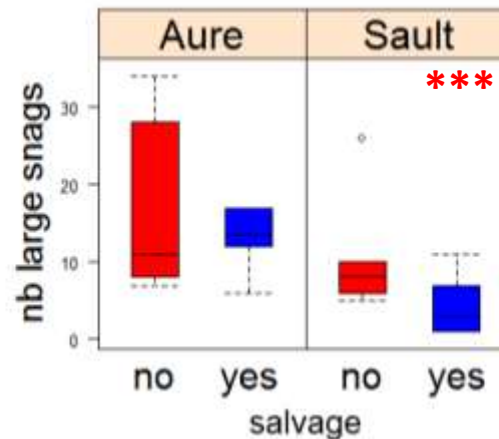
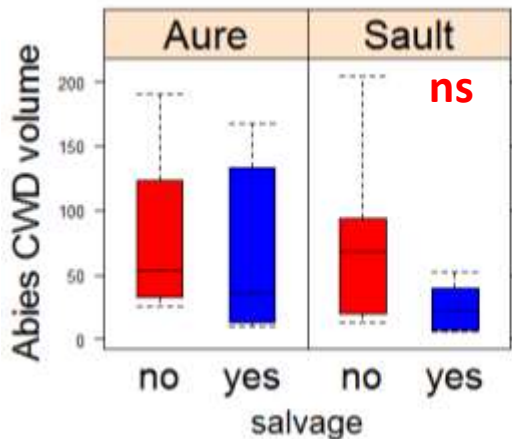
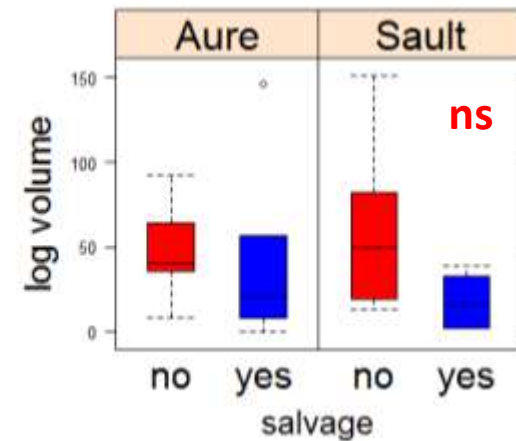
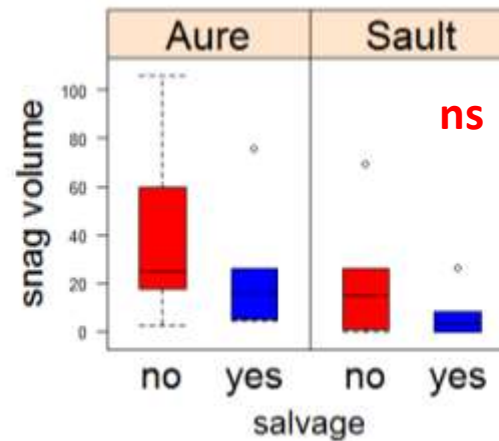
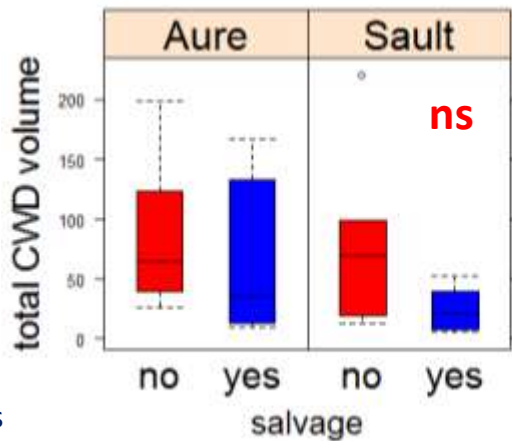
# Effects of salvage logging on forest structure in declining stands

Selection felling of  
dying fir trees...  
But not of all  
stressed trees

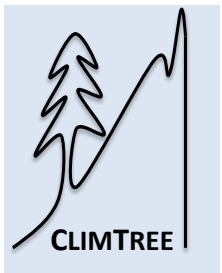


# Effects of salvage logging on forest structure

Overall but slight decrease in deadwood...

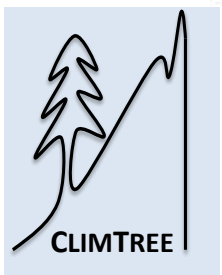
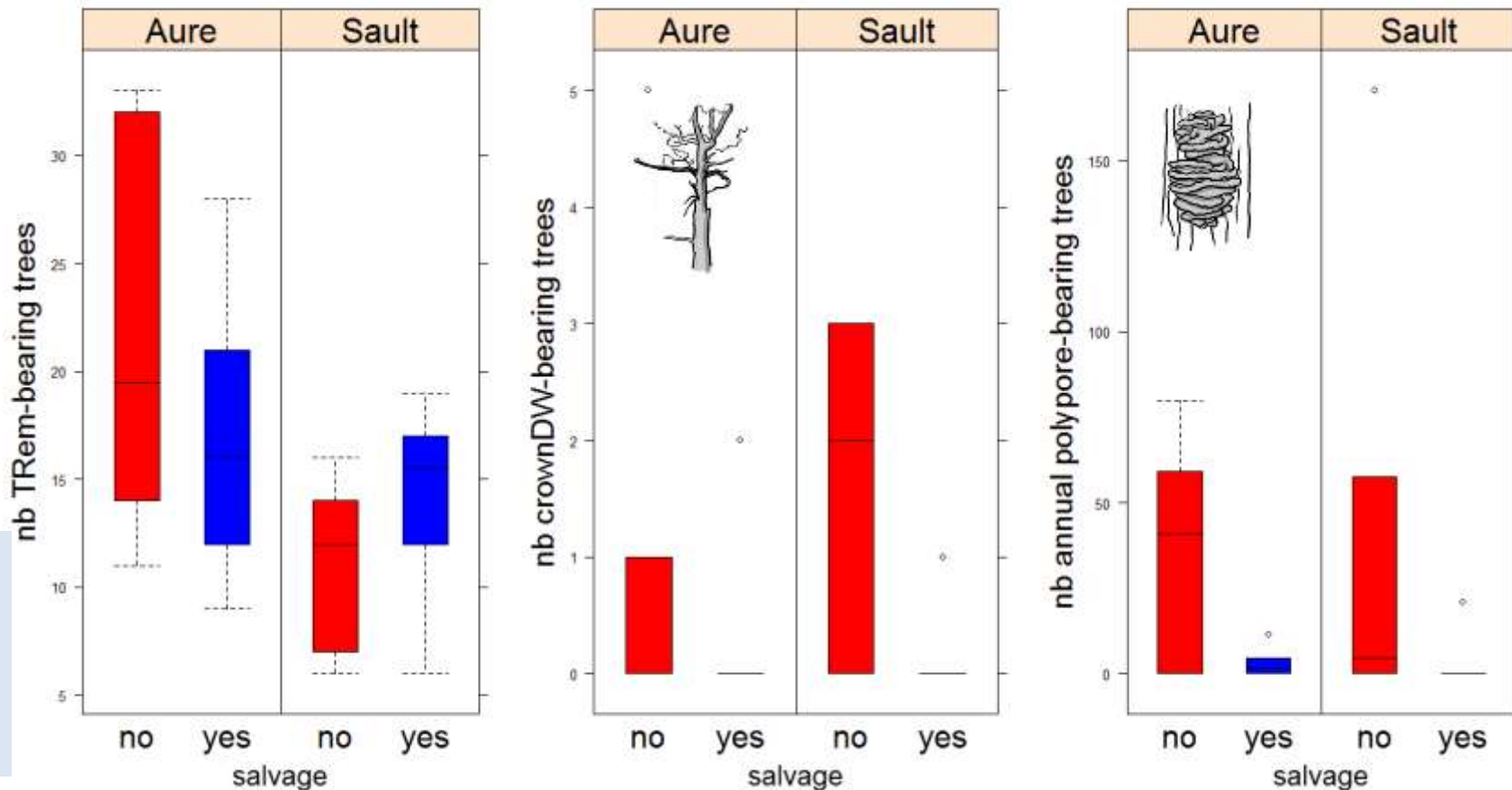


Mixed models  
(« region » as a random variable)



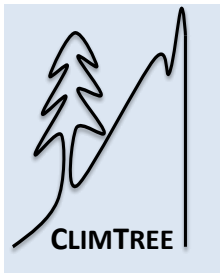
# Effects of salvage logging on forest structure

**Slight decrease in some TreM-bearing trees (crown deadwood, annual polypores)** (crown deadwood, annual polypores)



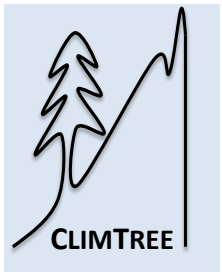


# Response of insect communities to forest dieback



# Potential response of saproxylic beetle diversity

		Stand scale			
		Healthy	Declining		
			Low level dieback	High level dieback	
			No harvesting	No harvesting	Salvage logging
Landscape scale (neighbouring stands R=200m)	Low level dieback	--	+/-	+	
	High level dieback	-	(+)	++	(+)





# Insect sampling

Insect trapping - May-August 2017

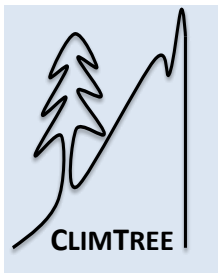


n = 56 traps

Standardized protocol	Nb per plot	Target	Sample processing
Alcohol-baited Malaise trap	1	Flying insects	DNA metabarcoding
Cross-vane unbaited flight-interception traps	2	Flying saproxylic beetles	Traditional sorting + eDNA metabarcoding



n = 112 traps



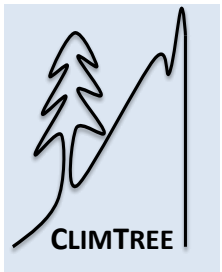


## Insect datasets

	<b>Nb individuals</b>	<b>Nb species</b>
Malaise traps		Cf L. Sire
Fight-interception traps	40013	284

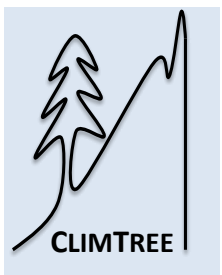
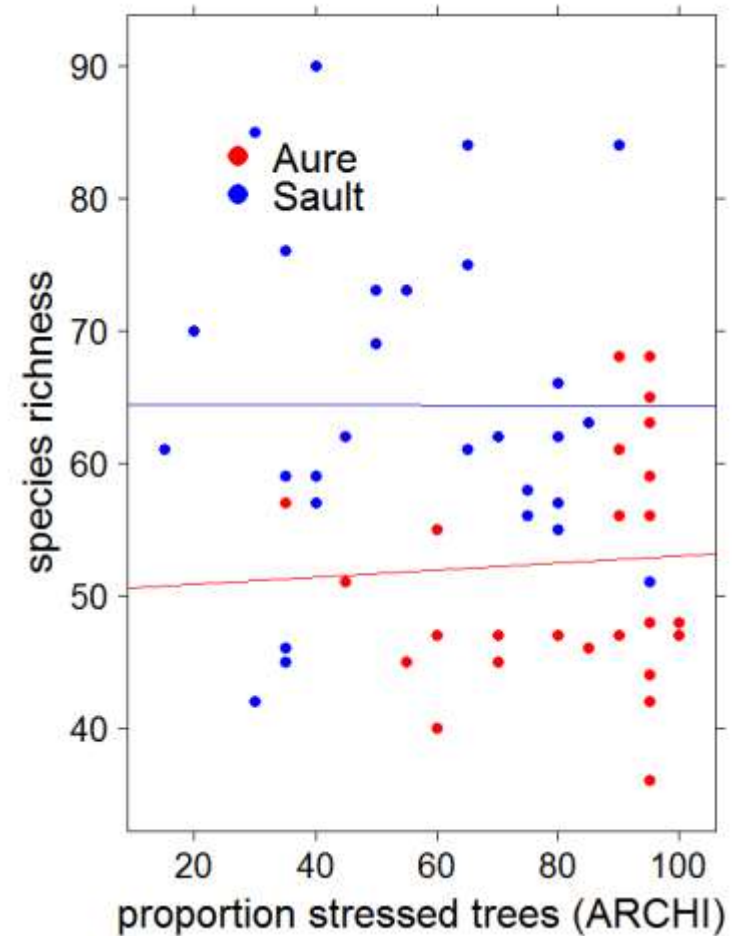
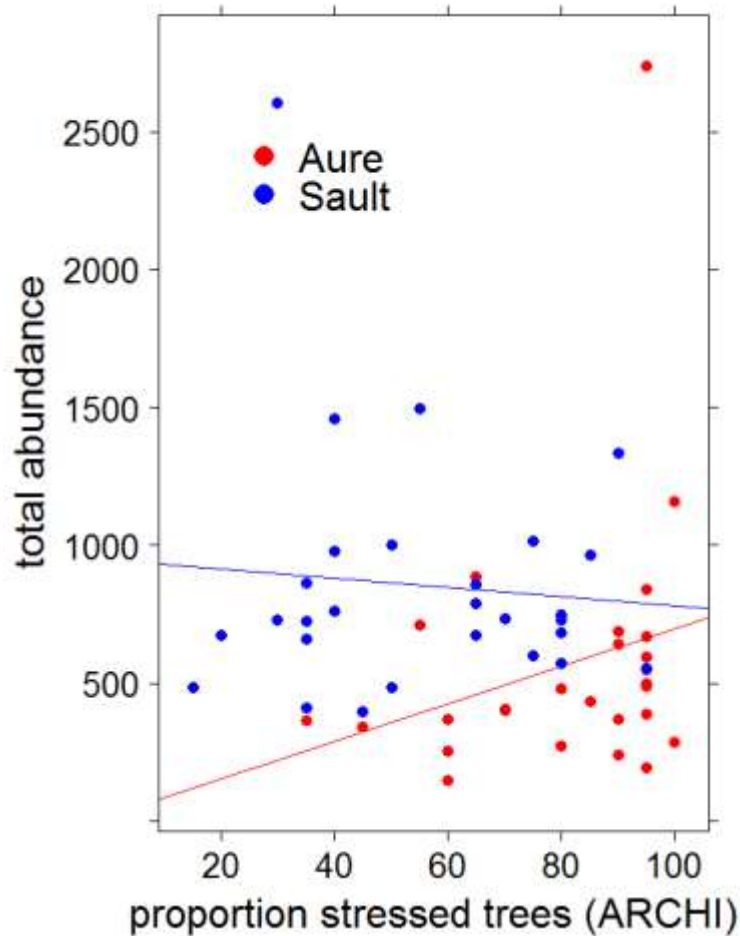


Families still at work (Staphylinids,  
Mordellids, Scaptiids...)



# Preliminary results about beetle response to dieback intensity and management

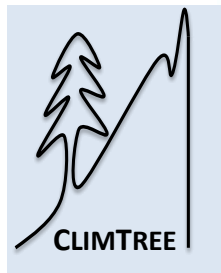
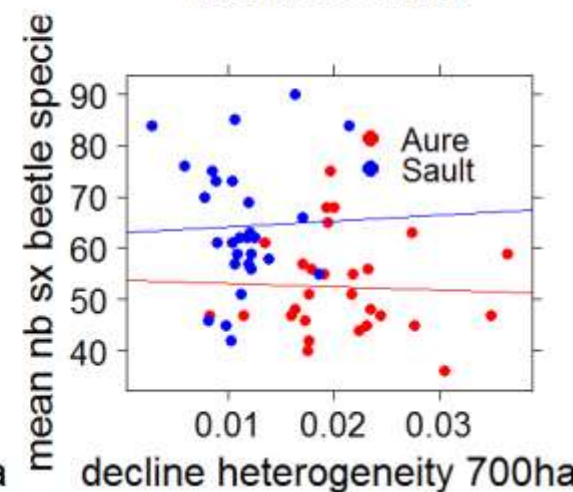
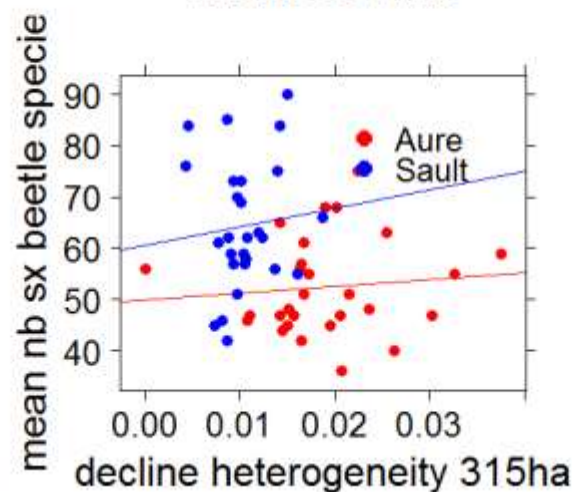
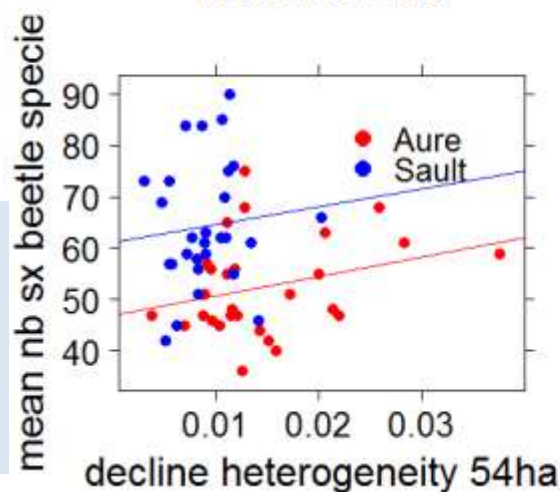
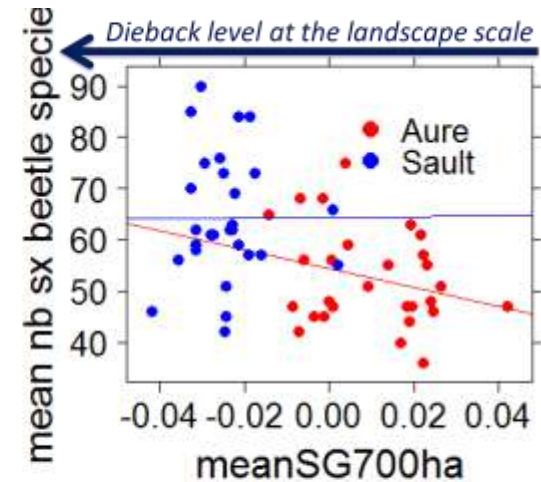
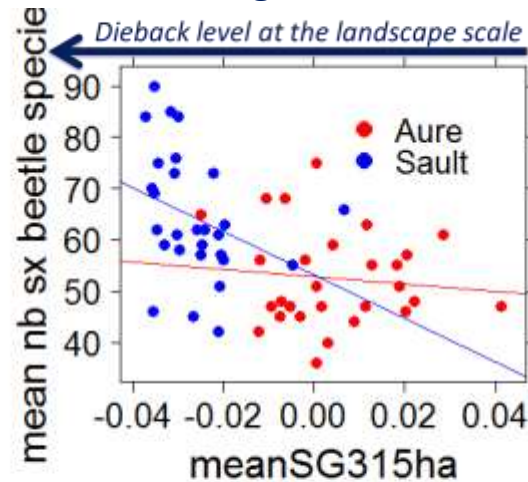
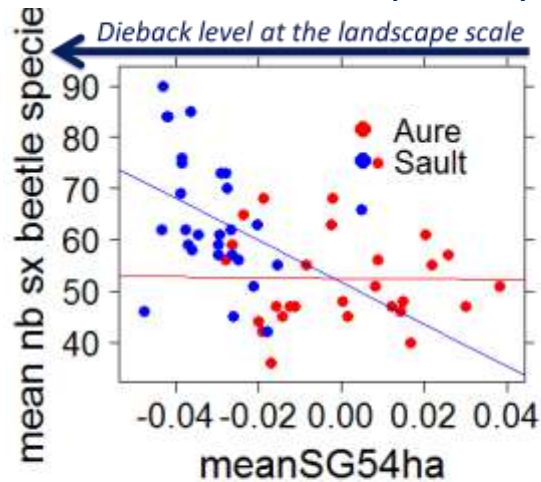
No overall increase in local abundance or species richness with local dieback level





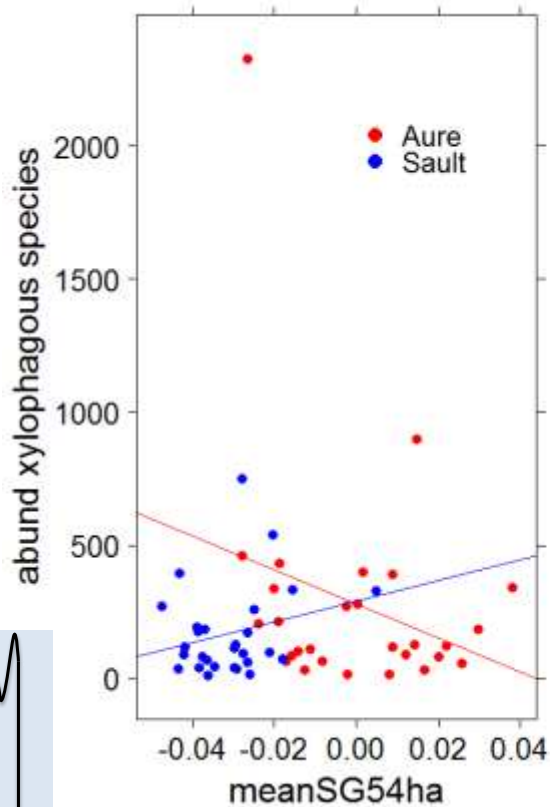
# Response to dieback level at the landscape scale

Increase in local species richness with landscape dieback level at the 54 and 315ha scales, especially in the Sault region

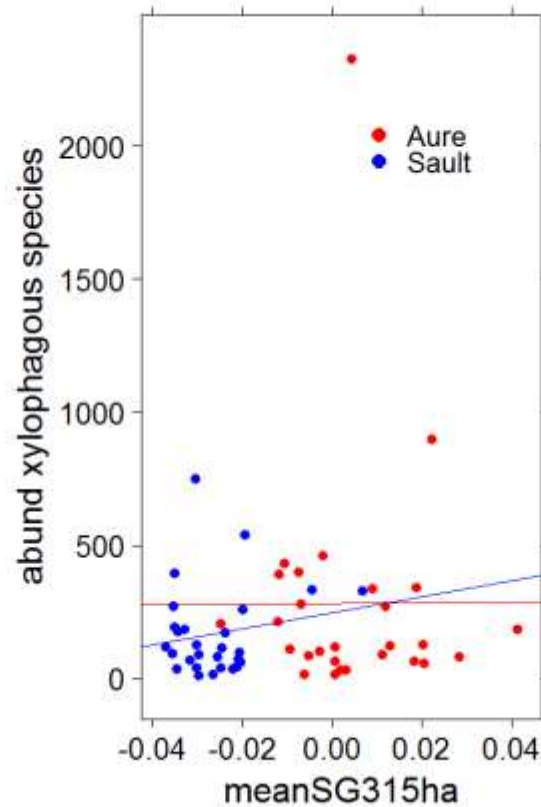


# Response to dieback level at the landscape scale

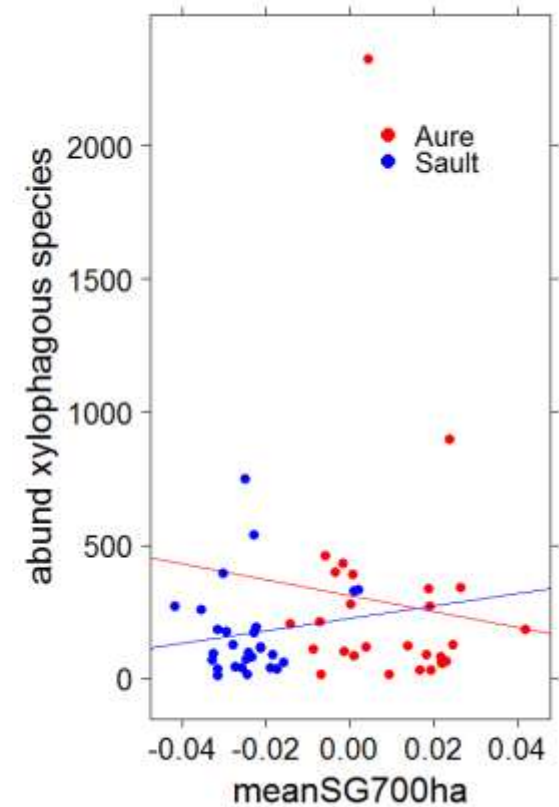
No increase in local abundance of xylophagous fir specialists with landscape dieback level



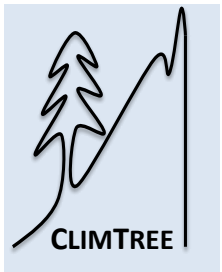
Dieback level at the landscape scale



Dieback level at the landscape scale

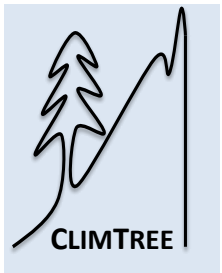
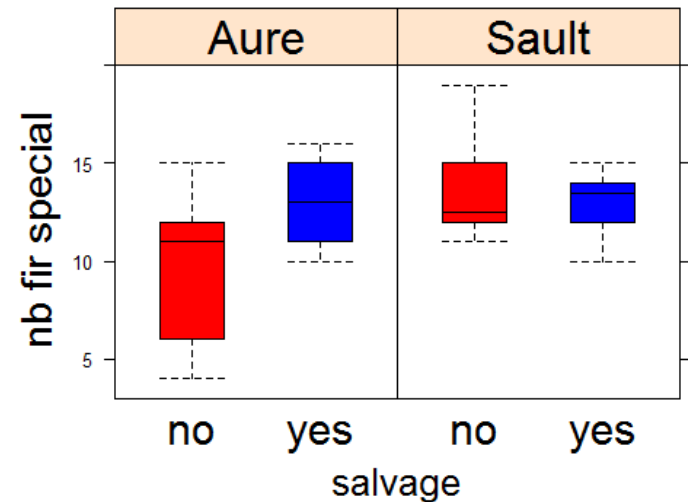
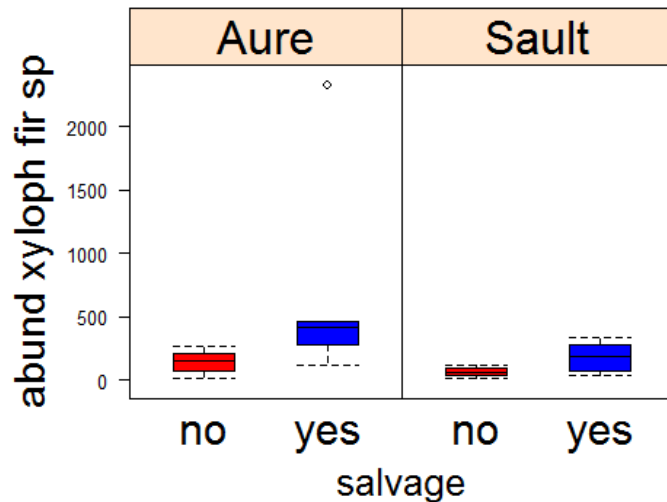
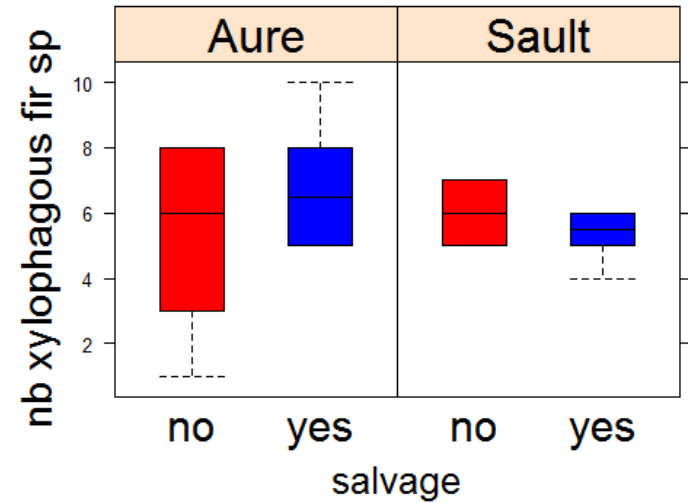
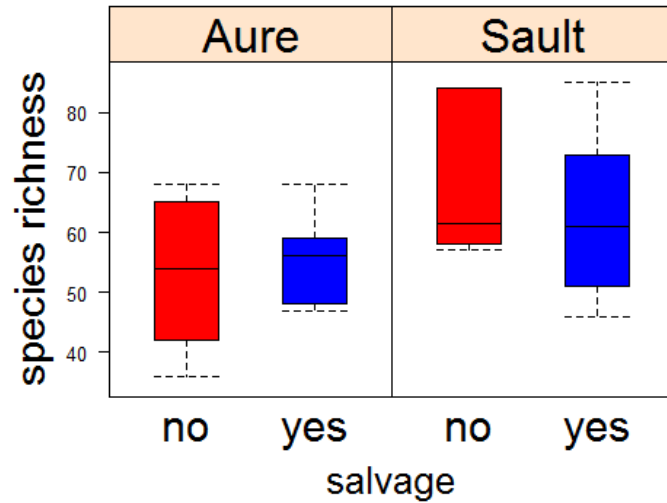


Dieback level at the landscape scale



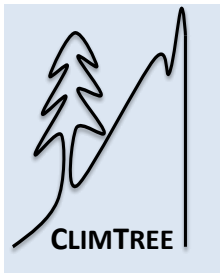
# Response to salvage logging

No overall increase of sx beetles in unsalvaged stands...

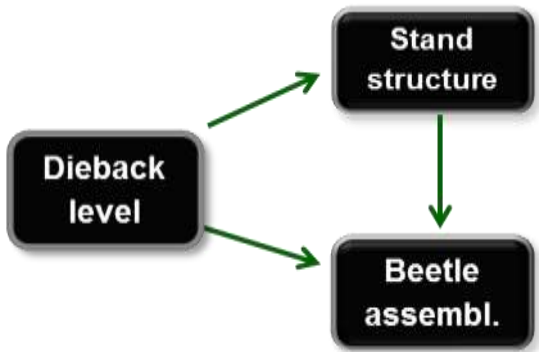




# Perspectives

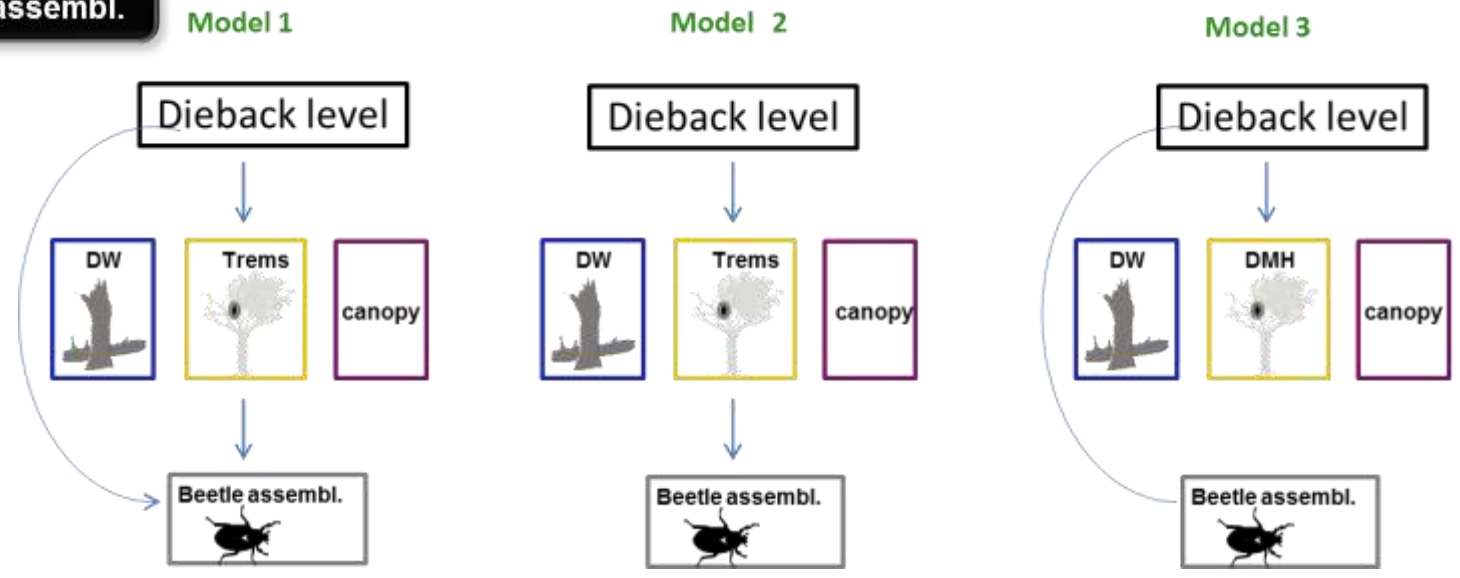


# Further analyses after dataset completion

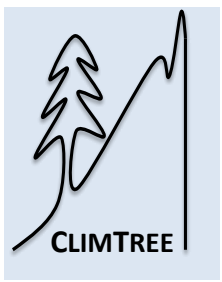


- Analyses of response in :
- sp composition
  - niche traits CWM/Fdis
  - ...

**piecewiseSEM**  
(Shipley 2009, 2013 ;  
Lefcheck 2015)



**SEM conceptual model**



# Further analyses inside the Climtree project

WFT analyses : merging  
French and German datasets ?

Co-analysis of French silver fir and  
German spruce data in forests  
affected by diebacks : an  
opportunity?



France  
2017  
Silver fir

Treatment	abtot	rs
declining stands (n=24 plots)	17095	227
salvage (n=12 plots)	11395	192
vital fir forest (n=20 plots)	11523	210
<b>TOTAL</b>	<b>40013</b>	<b>284</b>

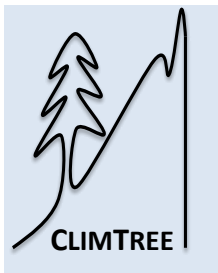


Germany  
2016  
Spruce

Treatment	abtot	rs
lps forest (n=10 plots)	1954	247
salvage (n=10 plots)	3259	232
vital spruce forest (n=10 plots)	1552	208
<b>TOTAL</b>	<b>6765</b>	<b>412</b>

Incl. non-sx families

Several sx families at work...



# Further analyses inside the Climtree project

**Cf Lucas**

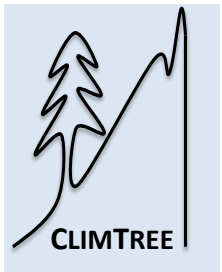


Option 1: morphol. indiv. sorting.



→ ... zzzzzZZZZZ

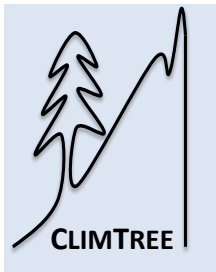
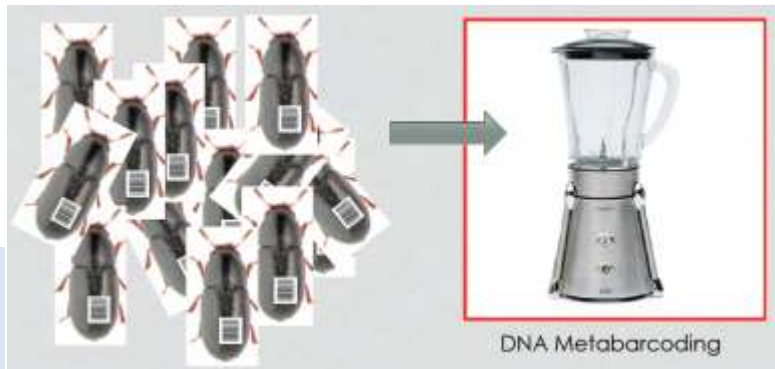
Option 2: eDNA storing EtOH



# Further analyses inside the Climtree project

Response of Malaise trapped insect assemblages to silver fir forest dieback

**Cf Lucas**



RESEARCH ARTICLE

## Species Identification in Malaise Trap Samples by DNA Barcoding Based on NGS Technologies and a Scoring Matrix

Johanna Markelin<sup>1\*</sup>, Bruno Carmona de Araujo<sup>2</sup>, Athena Wei Lam<sup>1</sup>, Axel Hassenmann<sup>1,2</sup>, Michael Rabe<sup>1,2</sup>, Stefan Schwaiblmair<sup>1</sup>, Lars Hendrich<sup>1</sup>, Dieter Dostal<sup>1</sup>, Barbara Farkner<sup>1</sup>, Benoit Arnaud<sup>1</sup>, Gerhard Hagenauer<sup>1,2</sup>

PLoS ONE 7(12): e42112, 2012. DOI: 10.1371/journal.pone.0042112



RESEARCH ARTICLE Open Access

## Environmental monitoring using next generation sequencing: rapid identification of macroinvertebrate bioindicator species

Melissa J. Casati<sup>1</sup>, Vincent J. Pettigrew<sup>1</sup>, Leon Metcalfe<sup>1</sup> and Amy A. Hoffmann<sup>1,2\*</sup>

ECOLOGICAL LETTERS  
Volume 15, 2012

IDEA AND PERSPECTIVE  
**Reliable, verifiable and efficient monitoring of biodiversity via metabarcoding**

**Abstract**  
To manage and restore biodiversity, we need tools that are fast, cheap, efficient, and able to work in the field. Next-generation sequencing (NGS) offers a promising solution to these challenges. We demonstrate a metabarcoding approach to identify and quantify macroinvertebrate species in environmental samples.

Methods in Ecology and Evolution  
doi: 10.1111/j.2041-210X.2012.00190.x

## Biodiversity soup: metabarcoding of arthropods for rapid biodiversity assessment and biomonitoring

Douglas W. Yu<sup>1,2†</sup>, Yinqiu Ji<sup>1†</sup>, Brent C. Emerson<sup>3†</sup>, Xiaoyang Wang<sup>1</sup>, Chengxi Ye<sup>1</sup>, Chuntian Yang<sup>1</sup> and Zhaoli Ding<sup>1</sup>

MOLECULAR ECOLOGY

Molecular Ecology (2012)

NEWS AND VIEWS

OPINION

## Biomonitoring 2.0: a new paradigm in ecosystem assessment made possible by next-generation DNA sequencing

DONALD J. BAIRD\* and MEHRDAD HAJIBABAEI†

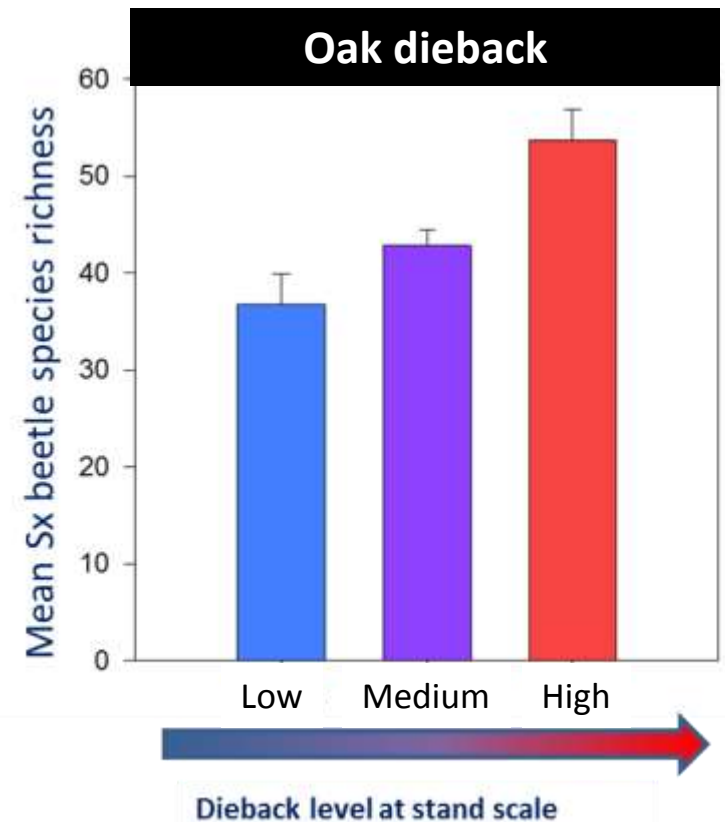
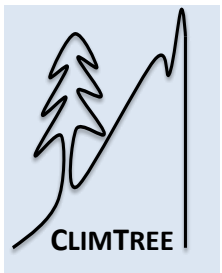
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## Further analyses inside/outside the Climtree project

### Response of sx beetle assemblages to forest diebacks

- Irstea projects :
  - Oak dieback (BUCHE, CANOPEE)
  - Ash dieback (YGGDRASIL)
- PhD student 2019-2022
  - Lowland and highland forest diebacks (oaks, ash, silver fir) and biodiversity supervisor = C. Bouget

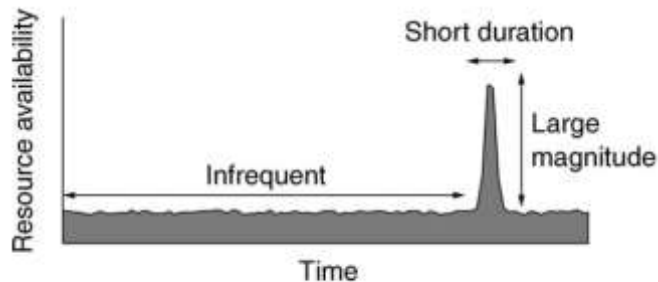


# Conceptual framework of resource pulses

**Do forest diebacks induce resource pulses for dead-wood associated beetles?  
Community dynamics associated to resource pulse: a synchronic approach**

## Resource pulses

- “the temporary availability of dramatically higher than normal levels of resources, which then become depleted with time” (Ostfeld and Keasing 2000)
- “intermittent production of abundant resources for consumers” (Schmidt 2003)
- “uncommon events of ephemeral resource superabundance” (Yang 2006),
- “brief, infrequent event[s] of high resource availability” (Yang 2004).



*Ecology*, 89(3), 2008, pp. 621–634  
© 2008 by the Ecological Society of America

FIG. 1. Resource pulses are events of increased resource availability over time that combine low frequency, short duration, and large magnitude.

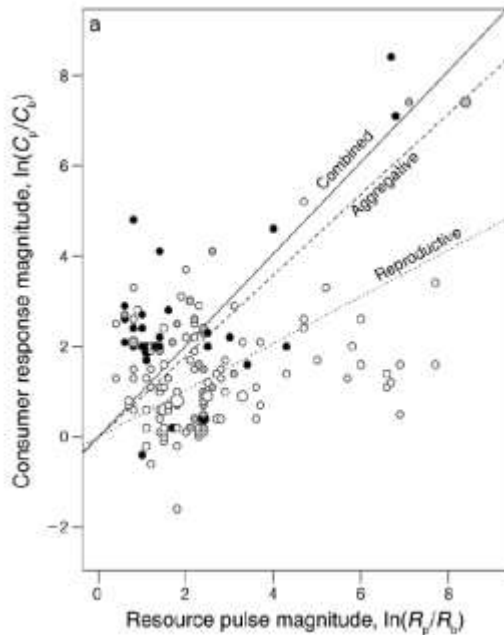
WHAT CAN WE LEARN FROM RESOURCE PULSES?

LOUIE H. YANG,<sup>1,3</sup> JUSTIN L. BASTOW,<sup>1</sup> KENNETH O. SPENCE,<sup>2</sup> AND AMBER N. WRIGHT<sup>1</sup>



# Conceptual underpinnings

## Relationship between numerical response of primary consumers and resource pulse magnitude

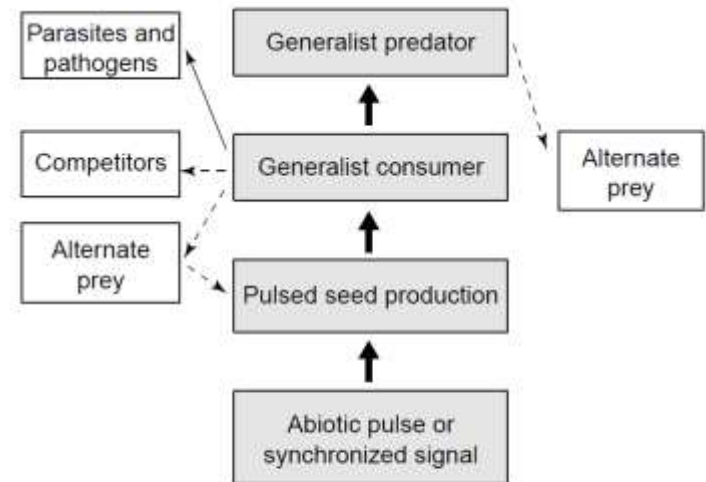


*Ecological Monographs*, 80(1), 2010, pp. 125–151  
© 2010 by the Ecological Society of America

## A meta-analysis of resource pulse–consumer interactions

LOUIE H. YANG,<sup>1,2,3,6</sup> KYLE F. EDWARDS,<sup>3</sup> JARRETT E. BYRNE,<sup>2,3</sup> JUSTIN L. BASTOW,<sup>3,4</sup> AMBER N. WRIGHT,<sup>3</sup>  
AND KENNETH O. SPENCE<sup>3</sup>

## Community dynamics through food webs after resource pulse 'top-down' and 'bottom-up'



*Trends in Ecology & Evolution*

**Fig. 1.** Conceptual model of the effects of pulsed resources permeating through a food web. The direction of arrows represents the direction of causal change in abundance or biomass. Solid lines indicate a positive effect and broken lines indicate a negative effect of one trophic group on another.

## Pulsed resources and community dynamics of consumers in terrestrial ecosystems

Richard S. Ostfeld and Felicia Keesing


*TREE* vol. 15, no. 6 June 2000



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Sylvie Ladet, Véronique Cheret,  
Guillem Parmain, Carl Moliard, Benoit Nusillard  
Laurent Burnel, Jerome Molina, Jerome Wilm,  
Wilfried Heintz, Grégory Sajdak



Olivier Rose, Gianfranco Liberti, Fabien Soldati,  
Thomas Barnouin, Thierry Noblecourt, Yves Gomy,  
Olivier Courtin, Benedikt Feldmann, Pierre Zagatti

...for **field**, **lab** and **GIS** work

