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

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CLIMTREE

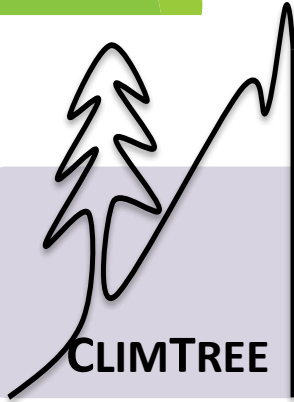
Ecological and socioeconomic
impacts of climate-induced tree
diebacks in highland forests
WP1 Impacts on biodiversity



Bouget, C. & Larrieu, L.



2nd 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

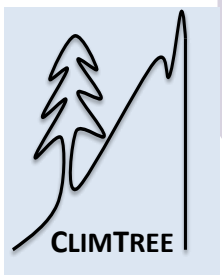
T2.1
Qualitative survey

T2.2
Quantitative survey

T2.3
Cost/Benefit study

Synthesis

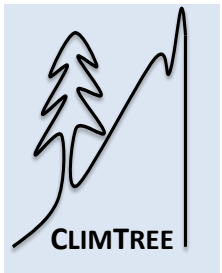
New Forest Management Policies
Integrating Biodiversity and Economical Stakes



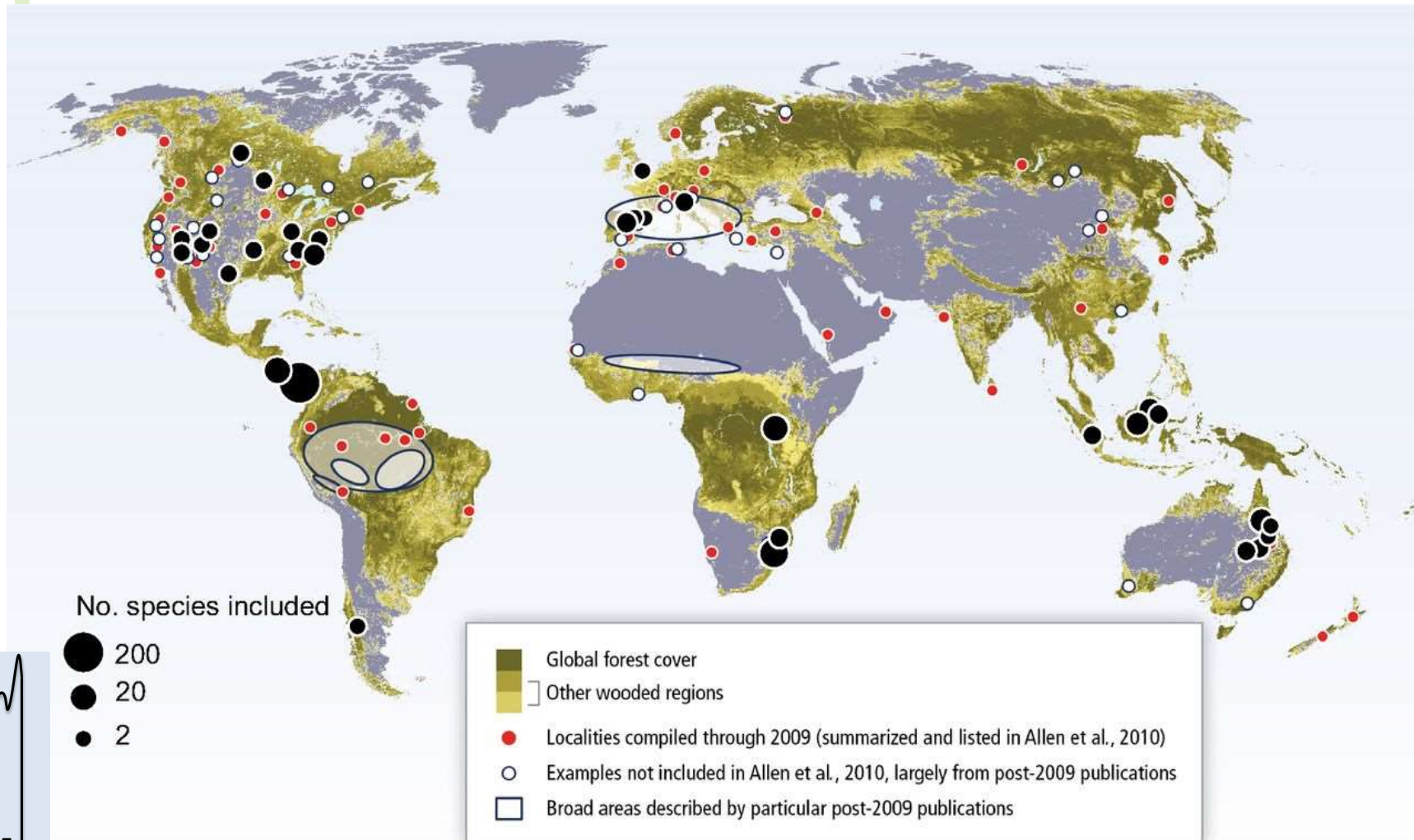
CLIMTREE



Context, questions and study design

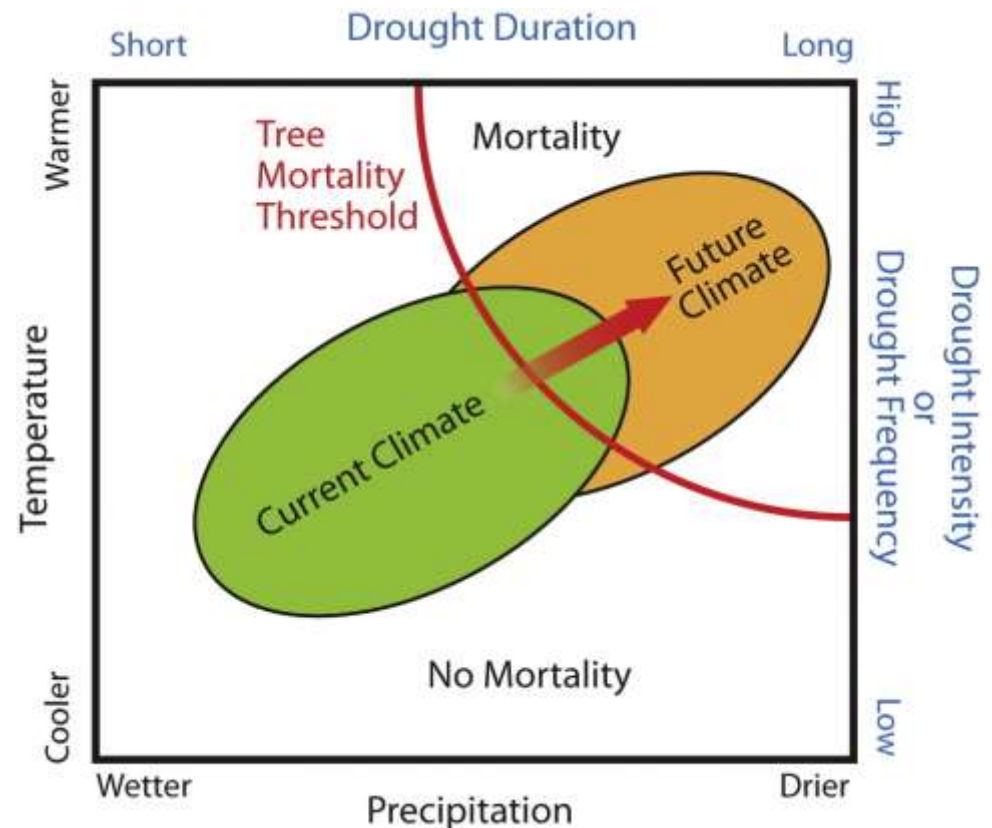


Drought- and heat-induced regional tree mortality events around the world

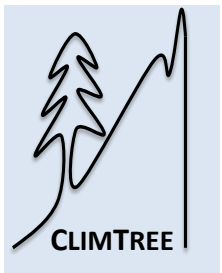


Climate change and tree mortality

"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.



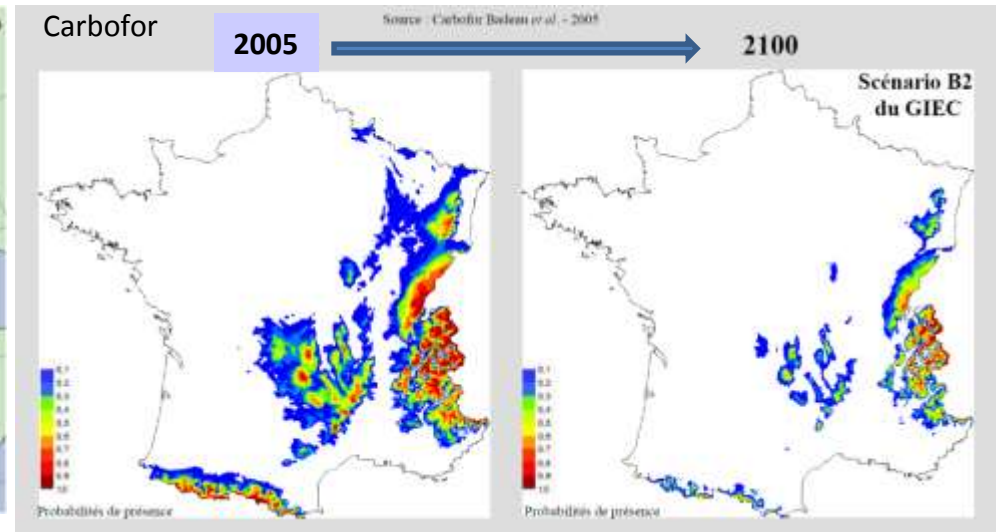
Breshears et al. Rangelands 2016



Silver fir in southern France



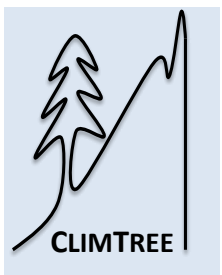
Expected climate-induced changes in silver fir distribution



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*)

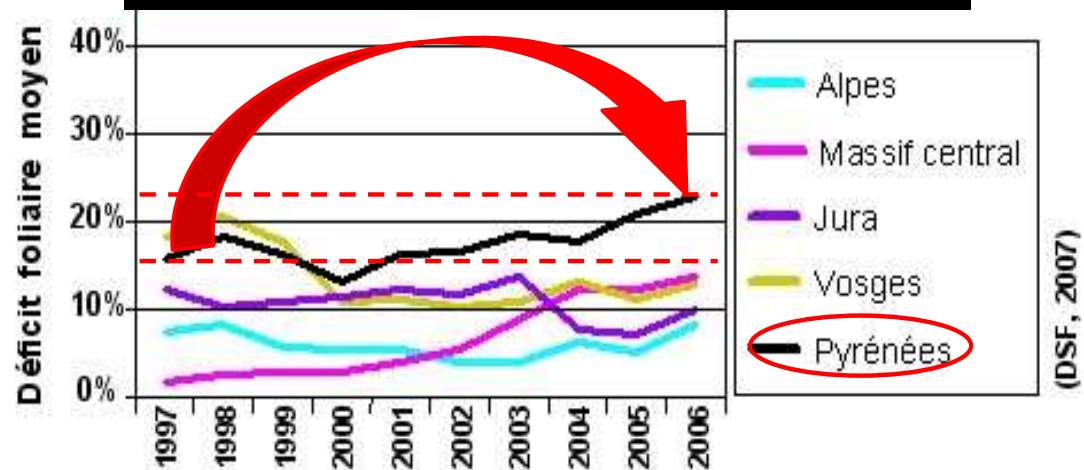
François Lebourgeois, Cyrille B.K. Rathgeber & Erwin Ulrich

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 :

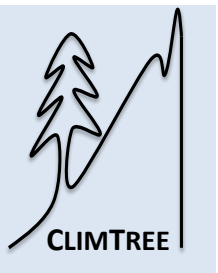
- 1980s (1983-1990)
- 1991-1993
- 2003-2007 (severe in the French Mediterranean region especially at altitudes lower than 1000 m, on south facing slopes or crests)

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



Forest Ecology and Management 217 (2005) 219–228

Forest Ecology
and
Management

www.elsevier.com/locate/foreco



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

Patricia Heuze^{a,*}, Annik Schnitzler^a, François Klein^{b,1}



Contents lists available at ScienceDirect

Forest Ecology and Management

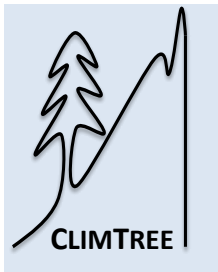
journal homepage: www.elsevier.com/locate/foreco



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



Marianne Bernard^{a,b}, Vincent Boulanger^c, Jean-Luc Dupouey^{e,*}, Lisa Laurent^f, Pierre Montpied^e, Xavier Morin^b, Jean-François Picard^e, Sonia Saïd^d



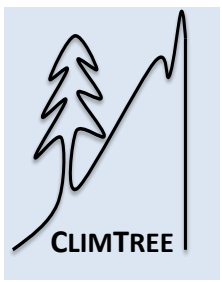
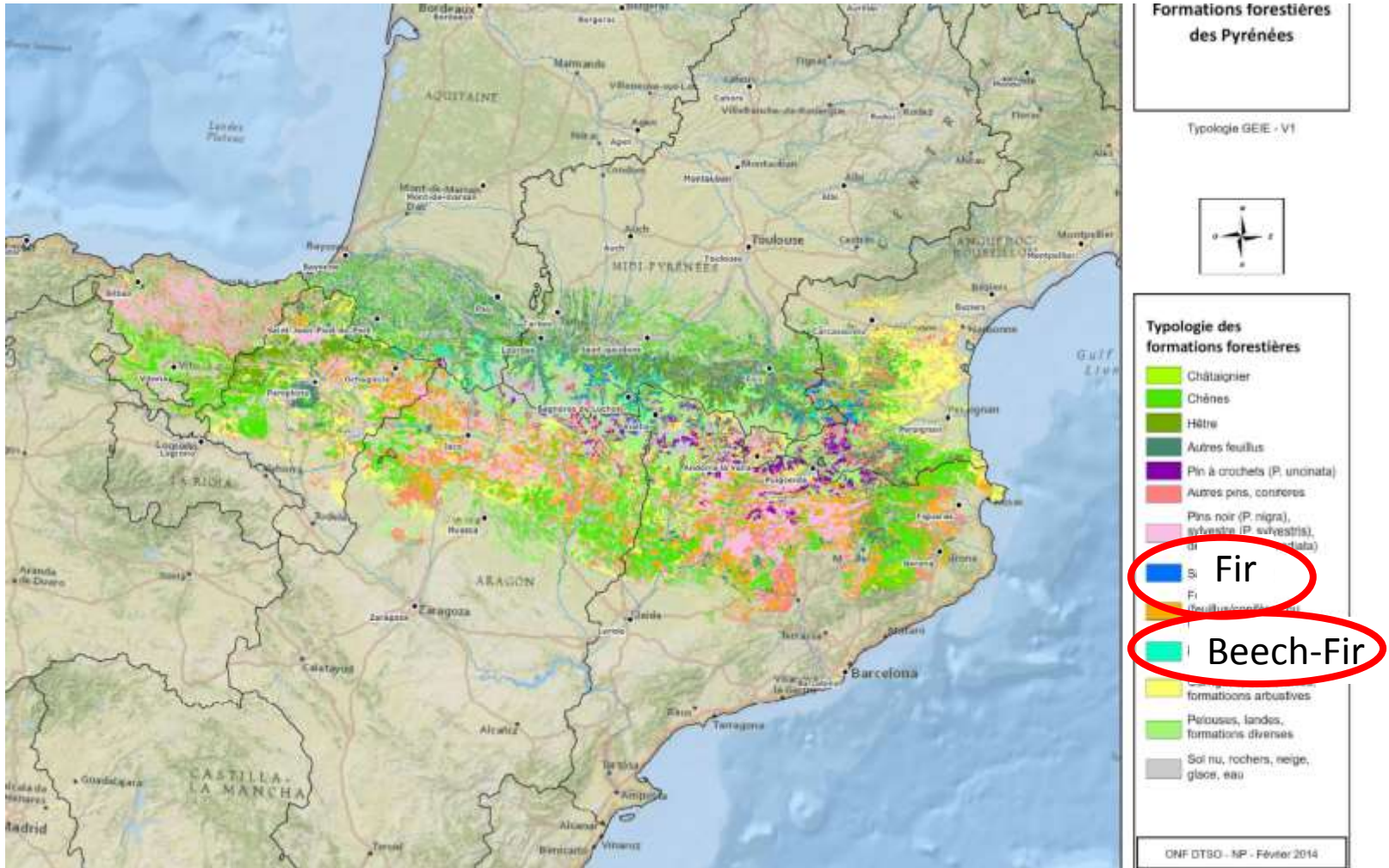
Silver fir dieback symptoms



- 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

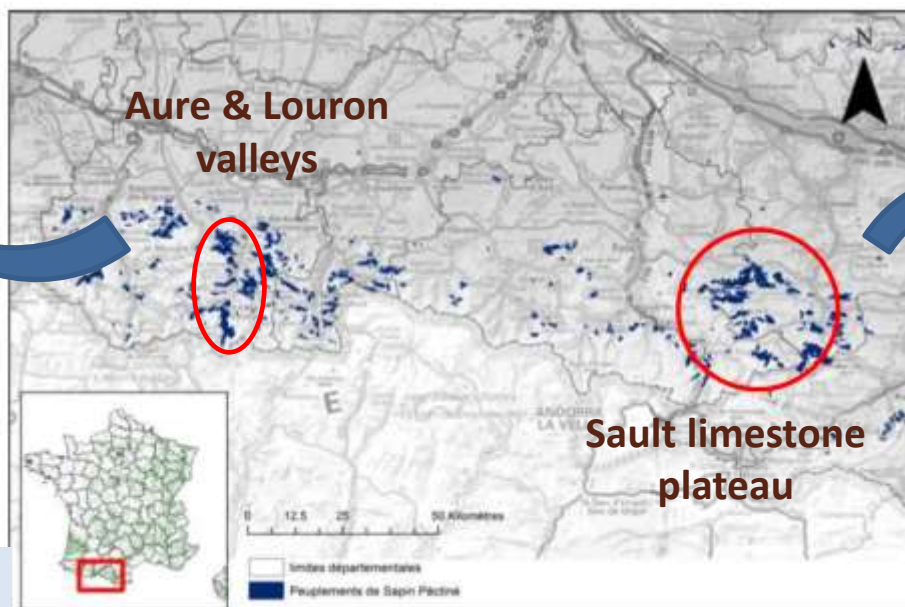
		Stand scale			
		Healthy	Declining		
			Low dieback level	High dieback level	
		No harvesting	No harvesting	Salvage logging	
Landscape scale	Low dieback level	10 plots	3	2	-
	High dieback level	0	3	4	6

Objectives of the French sampling design

Stratifying factors

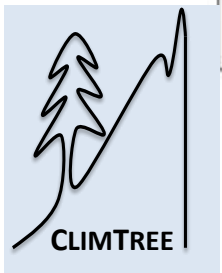
1. Local dieback intensity (- → +)
2. Salvage logging (0/1)
3. Dieback intensity at the landscape scale (- → +)

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



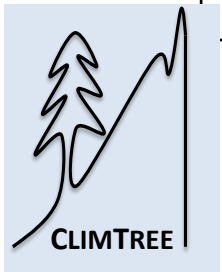
Objectives of the French sampling design

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





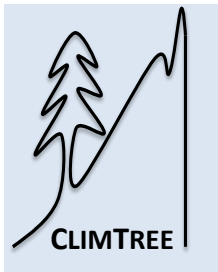
Which proxy for forest decline intensity?

Local dieback assessment using the ARCHI method

(Drenou et al., 2013)

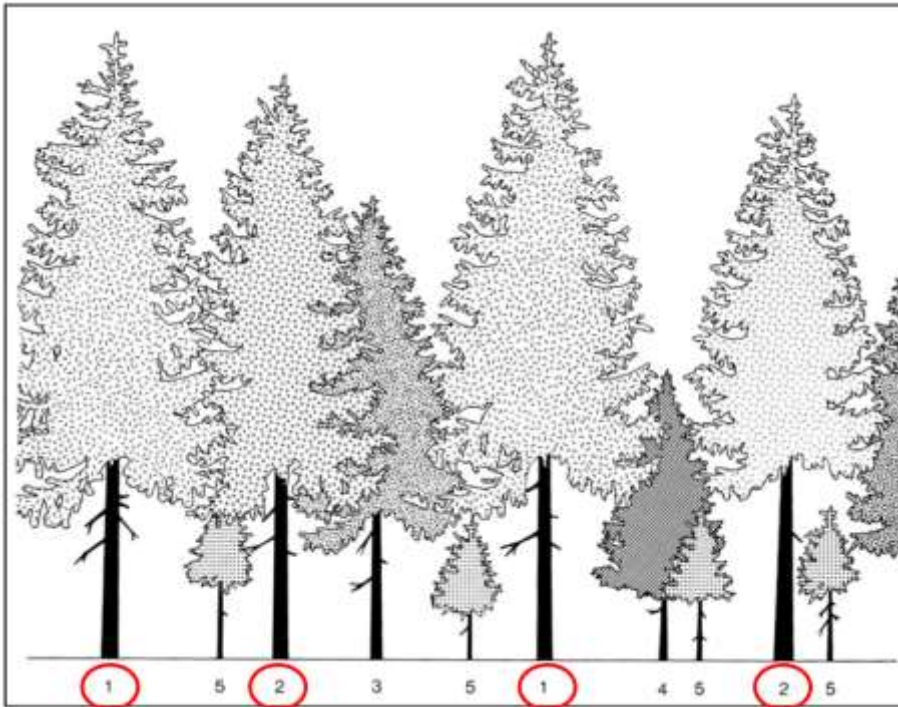
The ARCHI method analyses tree architecture (whole tree, crown, axes and branches) to establish a diagnosis of tree vitality status

A set of ergonomic keys to perform diagnoses in the field

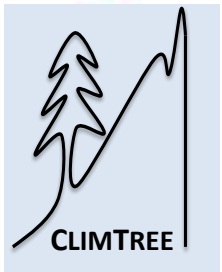
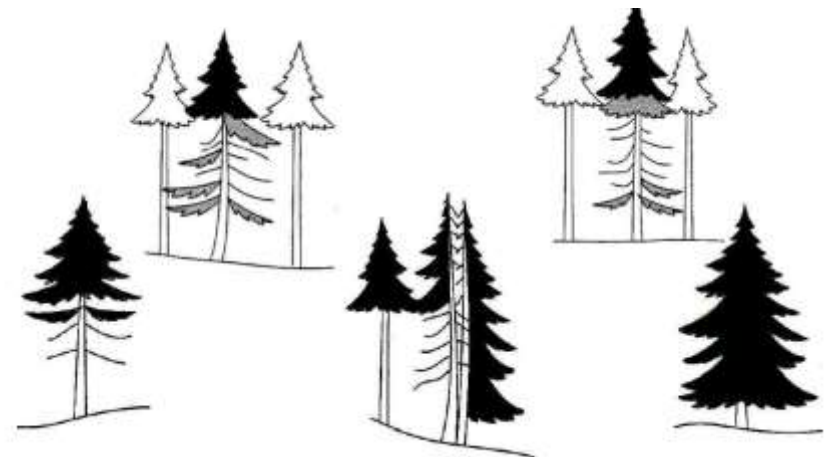


Local dieback assessment using the ARCHI method

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

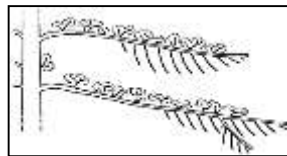
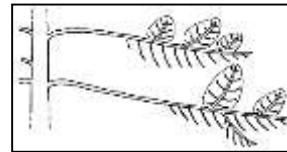
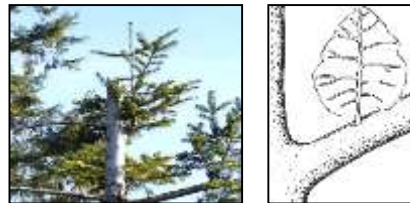
Defoliation
Crown decline
symptoms

+

Crown
restoration
process

=

ARCHI diagnosis
5 tree types

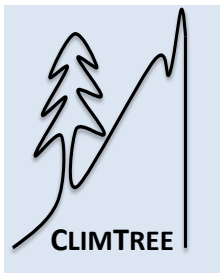


- **healthy**
- **stressed**
- **resilient**
- **dying**
- **crown dieback**

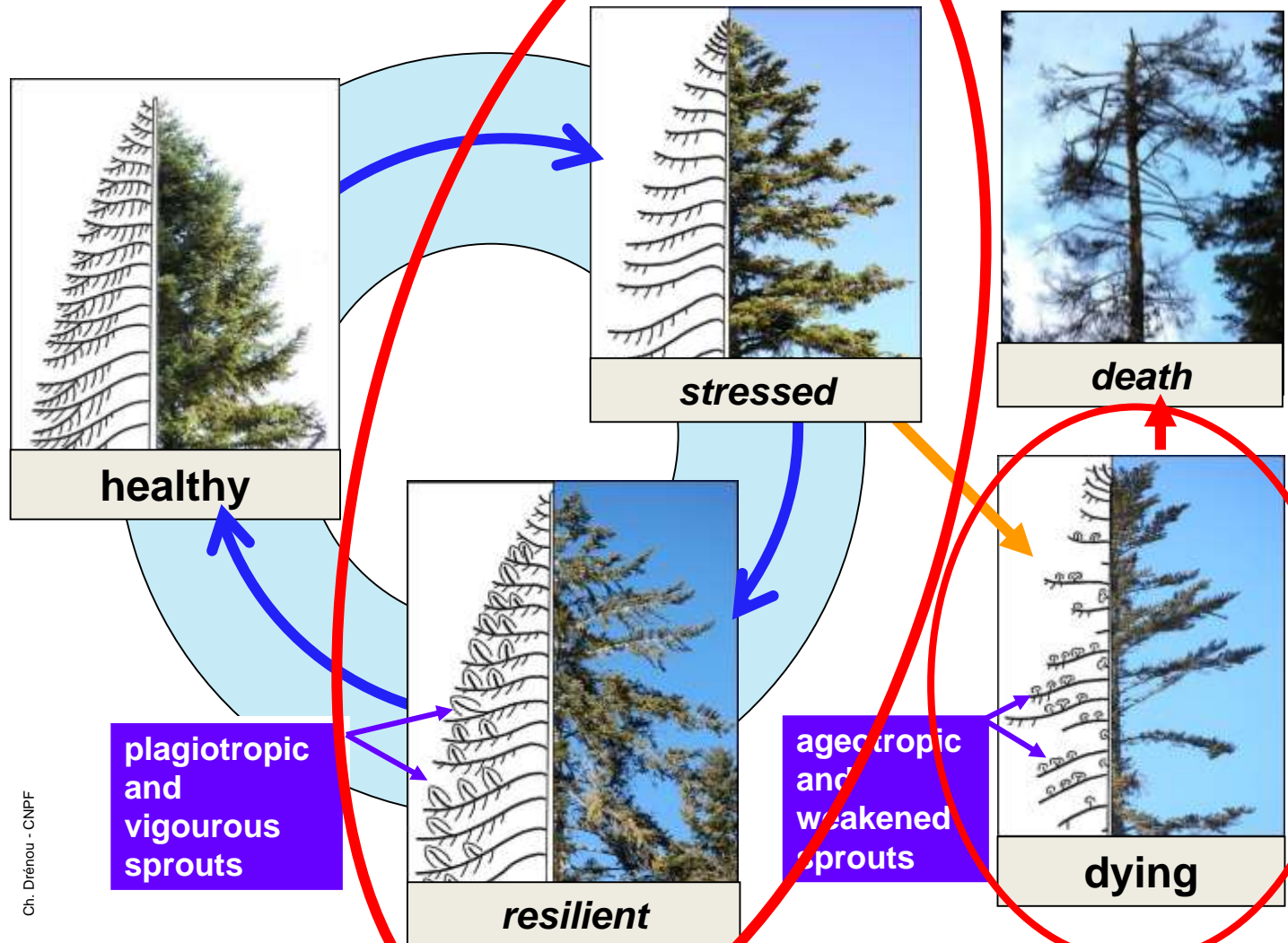
- +

+ Greenness level

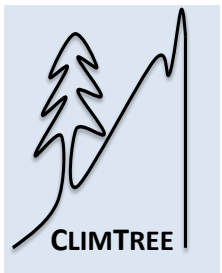
Type and vigor of sprouts



Local dieback assessment using the ARCHI method

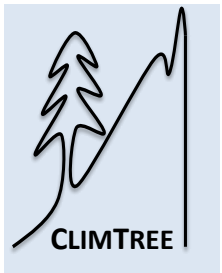
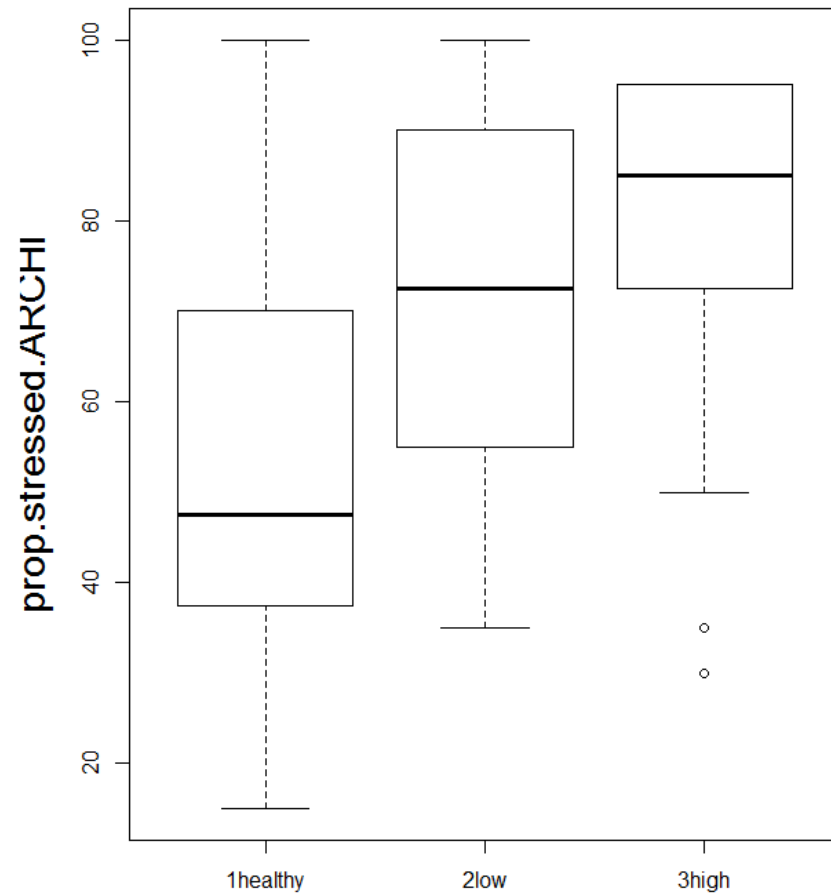
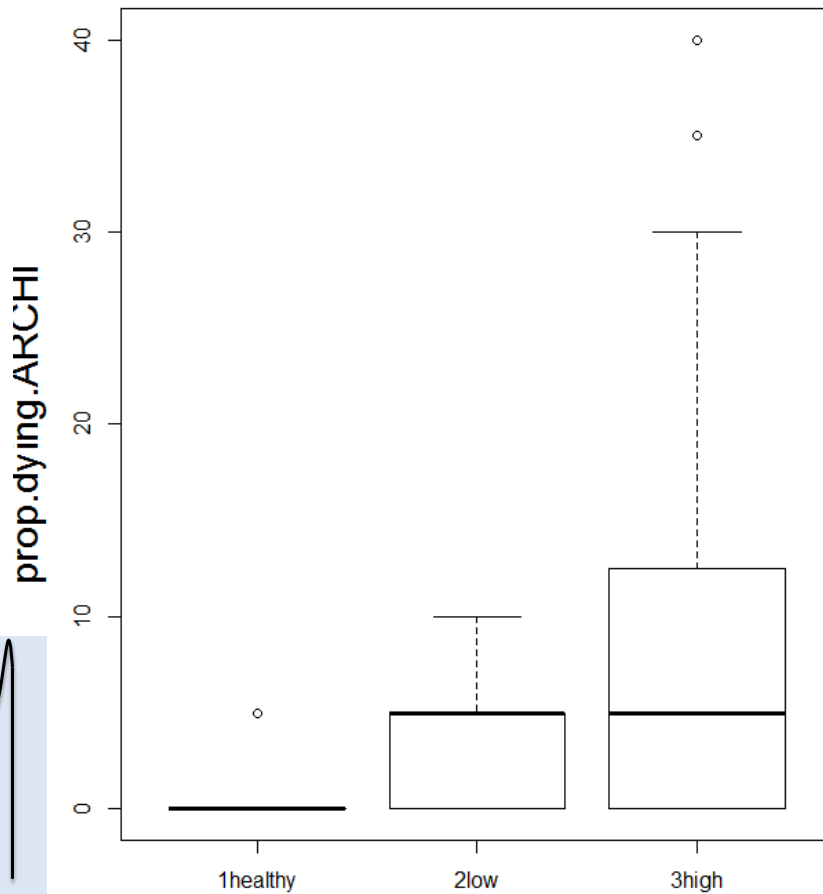


Ch. Drénou - CNPF



Post-hoc assessment of the sampling design

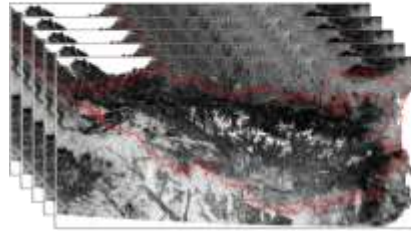
At the stand scale



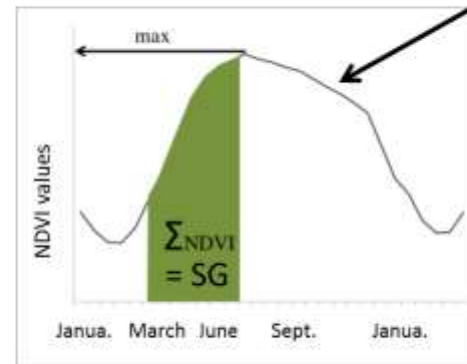
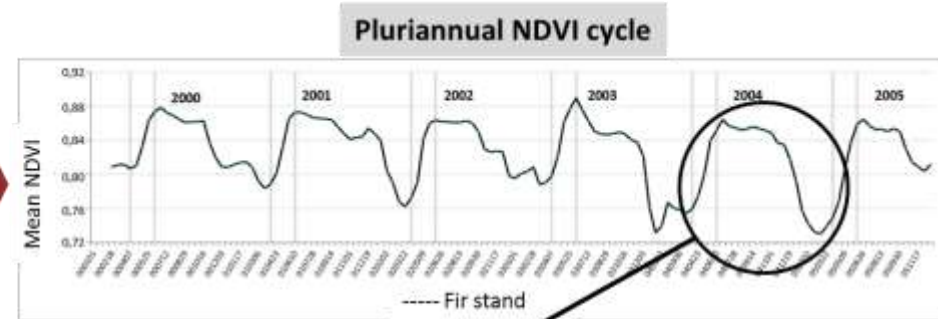
Dieback level at the landscape scale

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

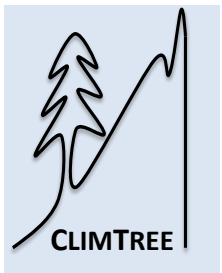


Vegetation index
NDVI
(Normalized Difference
Vegetation Index)
 $NDVI = (PIR-R)/(PIR+R)$

Spring Greenness (SG)

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

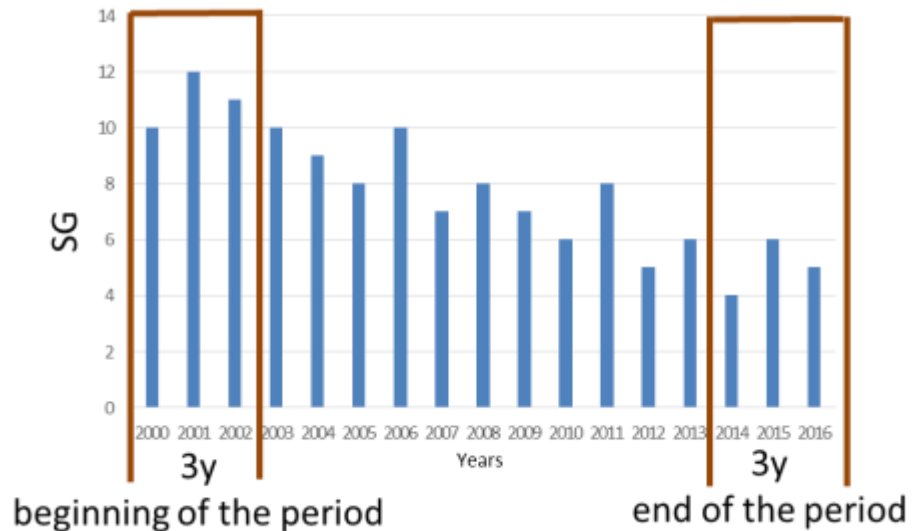
= sum of NDVI calculated over a fixed period of MODIS images from the onset of SG (end of April) to the maximum NDVI (in end of June) before the dry season (Reed 2006)¹⁸



Dieback level at the landscape scale

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

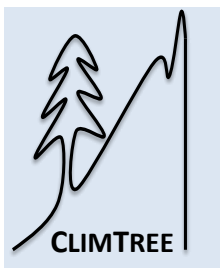
Measurement of variations of photosynthesis activity within the period 2000 – 2016 = **index of vitality trend**



for 1 pixel = 6ha

Index of vitality trend

$$D_{nor_SG} = \frac{\begin{matrix} 2014 \\ \text{max } SG \\ 2016 \end{matrix} - \begin{matrix} 2000 \\ \text{max } SG \\ 2002 \end{matrix}}{\begin{matrix} 2000 \\ \text{max } SG \\ 2002 \end{matrix}}$$



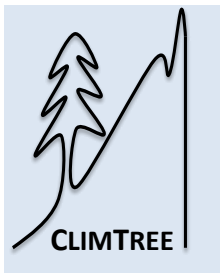
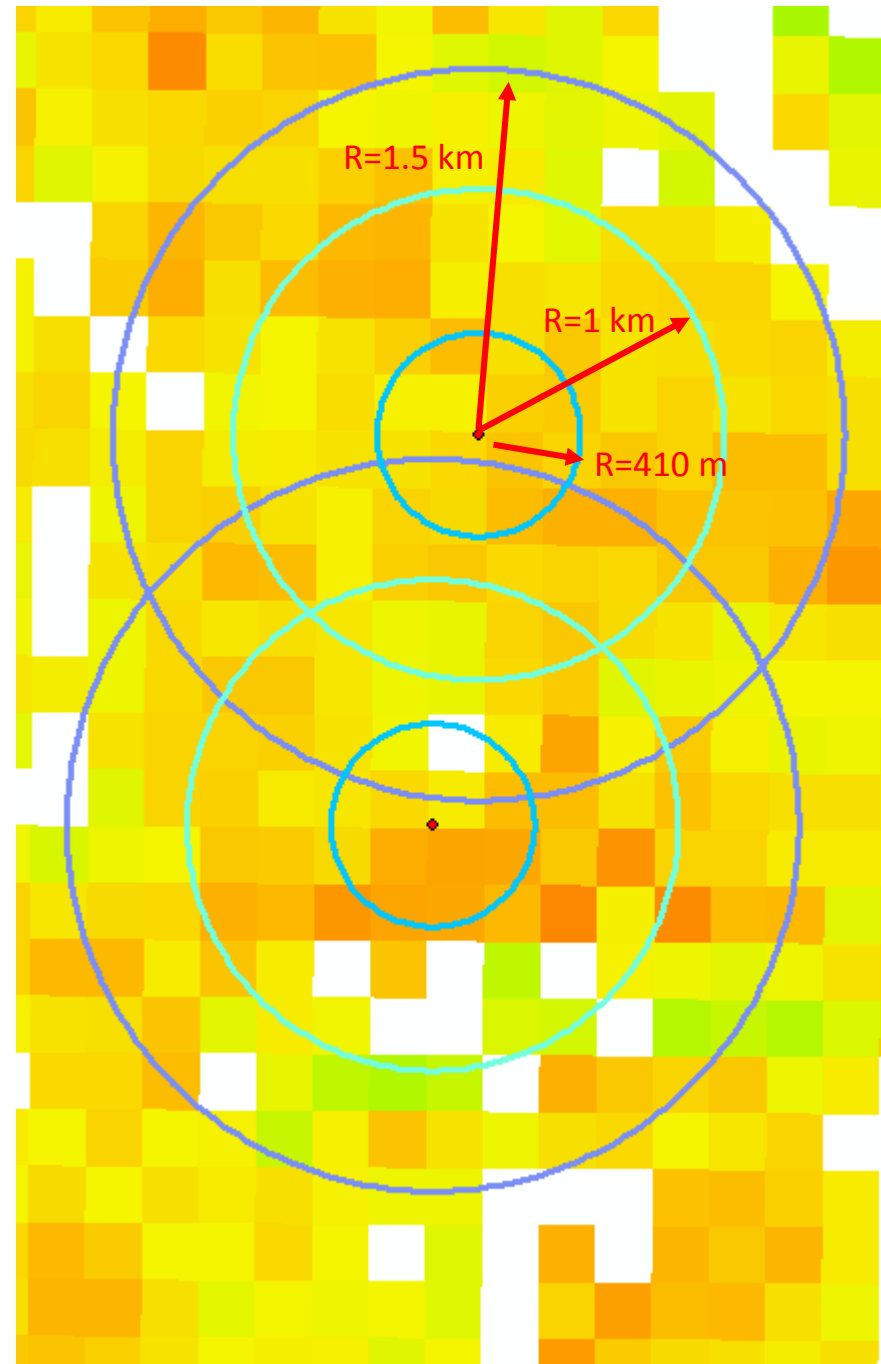
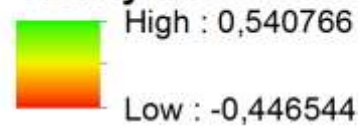
Dieback level at the landscape scale

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

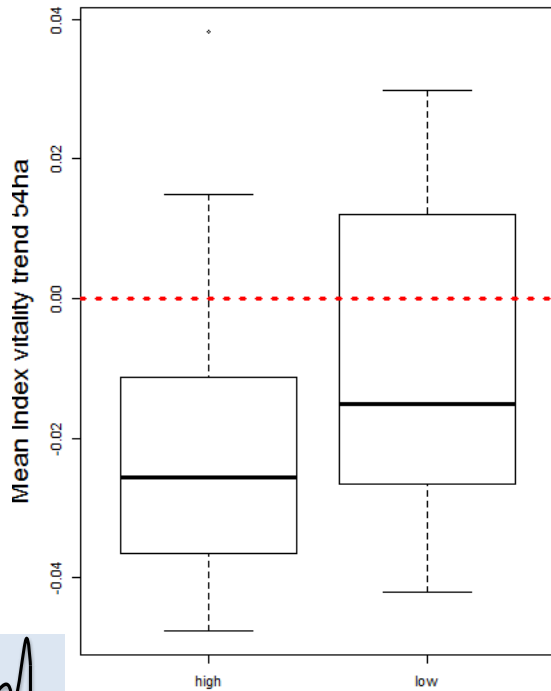


Post-hoc assessment of the sampling design

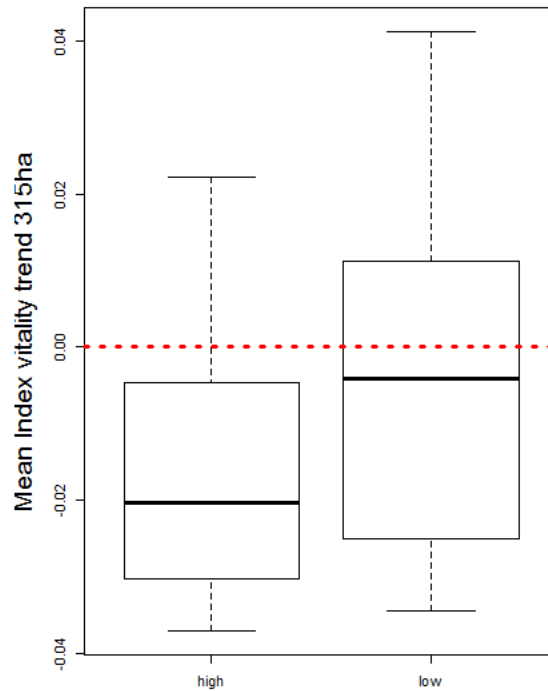
At the landscape scale

Dieback level at the landscape scale

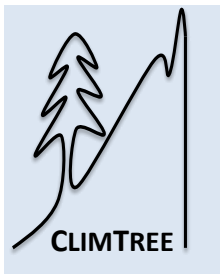
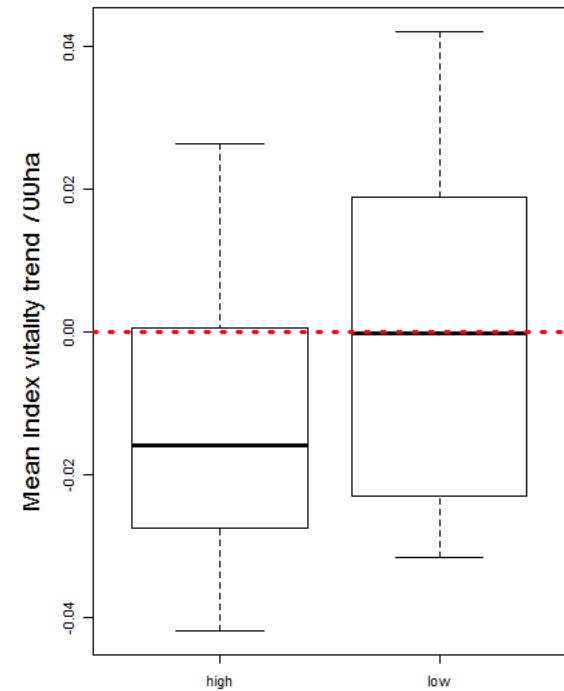
54 ha



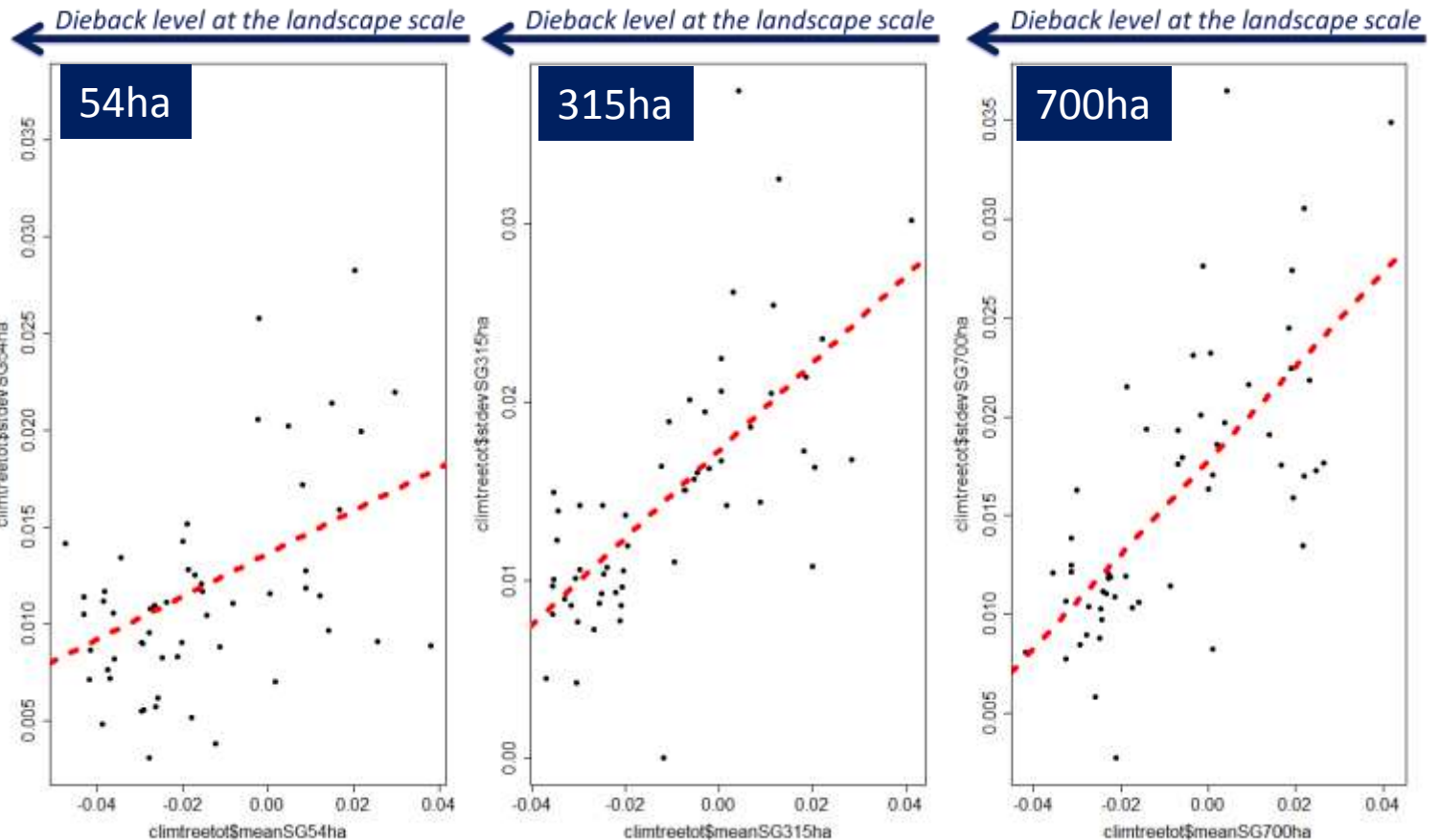
315 ha



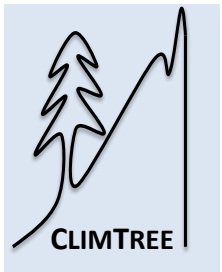
700 ha



Post-hoc assessment of the sampling design

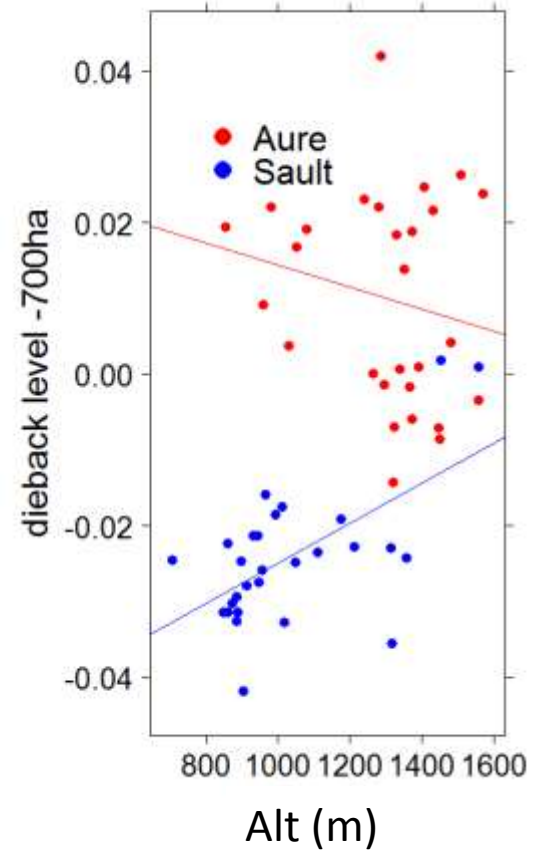
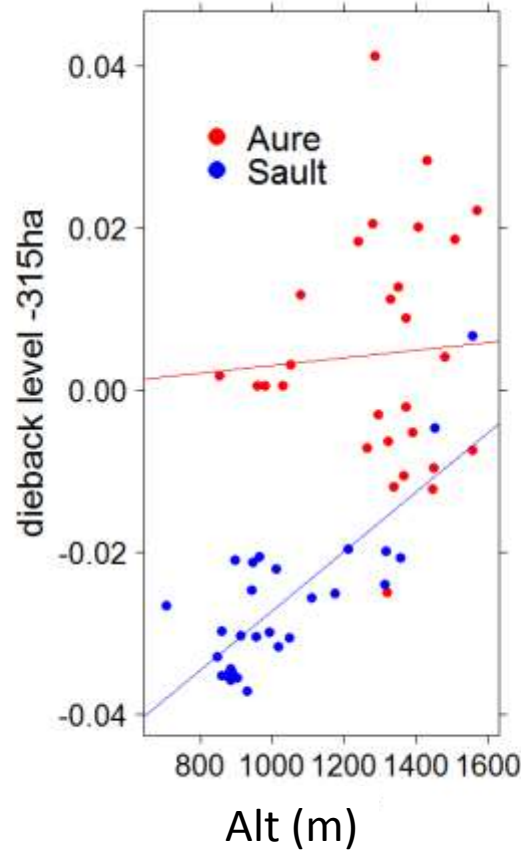
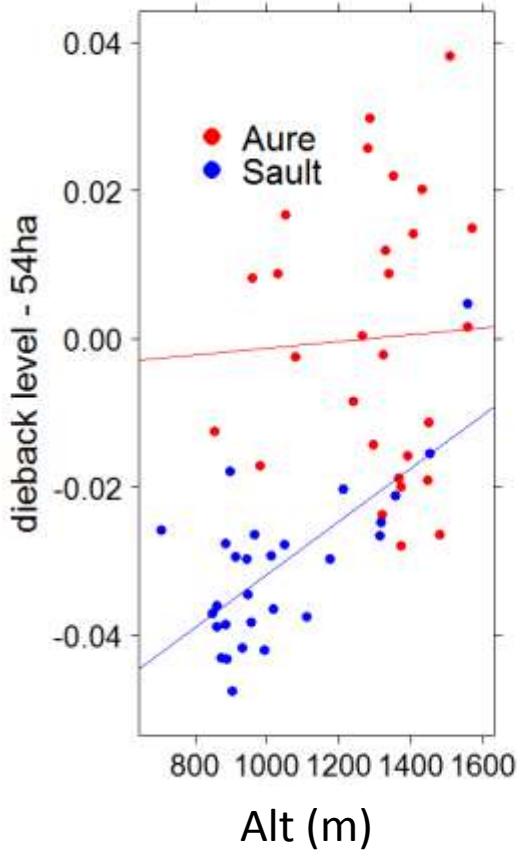


The higher the dieback level at the landscape scale, the less heterogeneous the landscape in terms of dieback level

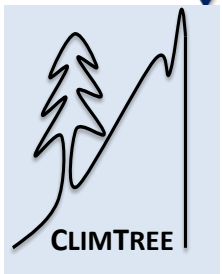


Post-hoc assessment of the sampling design

Dieback level at the landscape scale

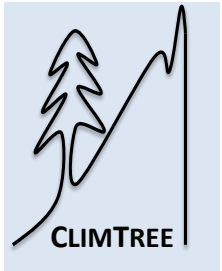


Dieback level at the landscape scale increases in lower altitudes (Sault region)





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

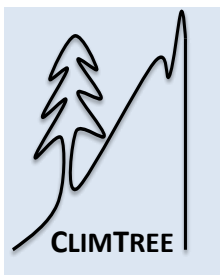
More available resources for phytophagous insects

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)

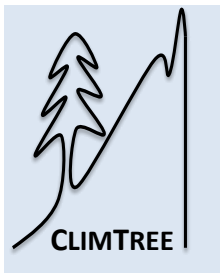


Tree-related microhabitats inventory on living trees

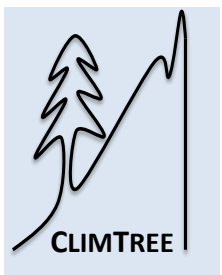
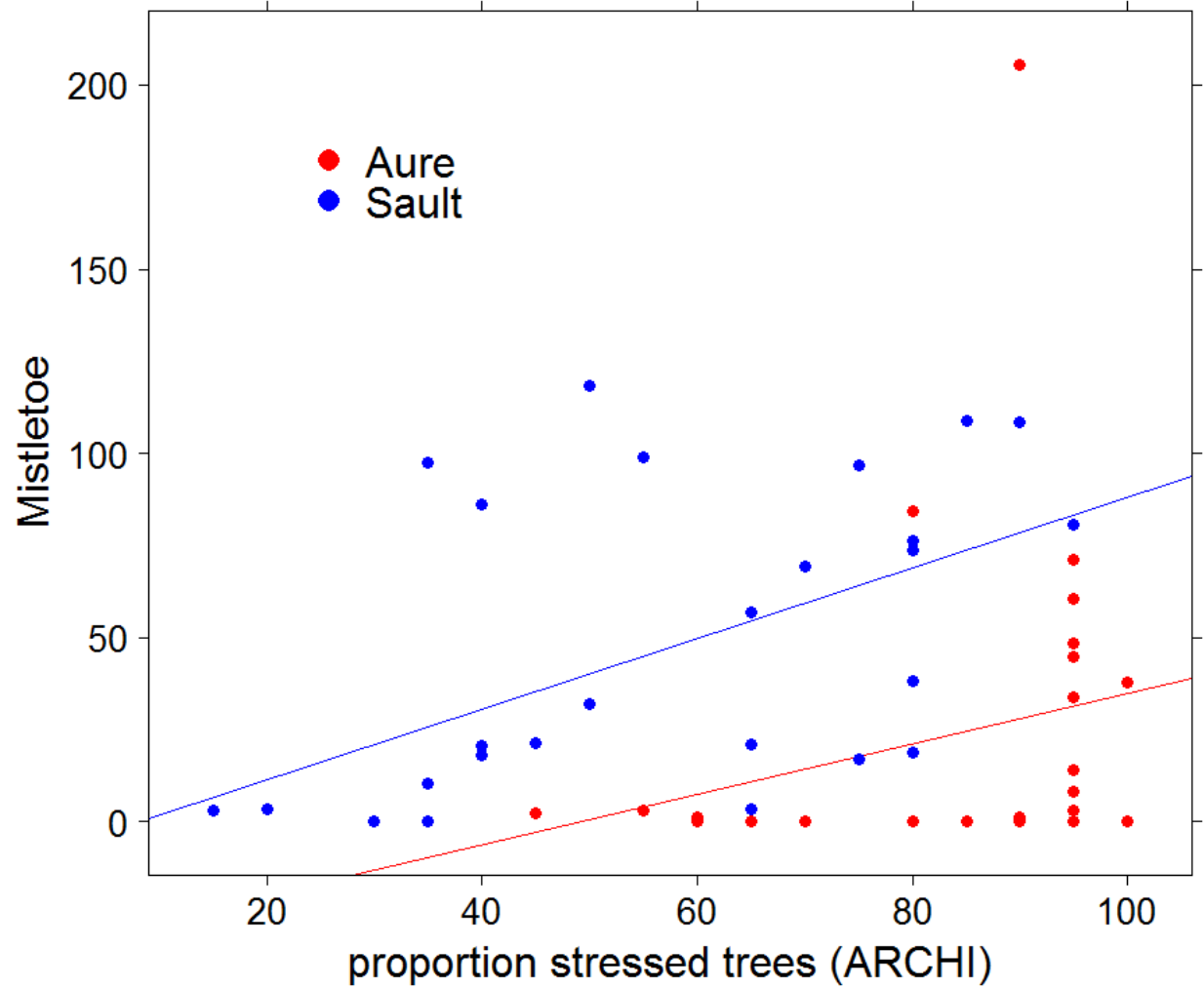
missing bark and mould cavities, woodpecker breeding cavities, sporophores of saproxylic fungi, sap runs, cracks and bark shelter/pockets, mistletoe

Canopy opening (spherical crown densiometer)

IBP 10 criteria (1ha)



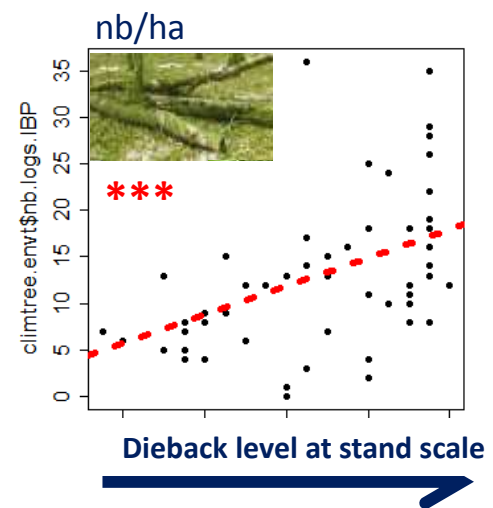
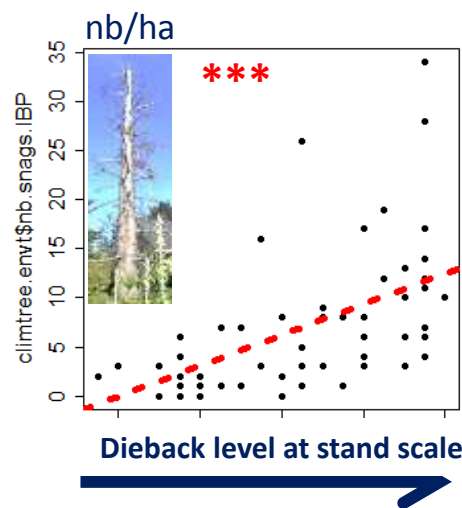
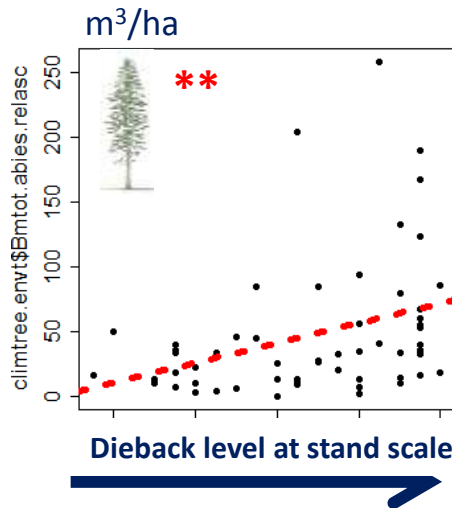
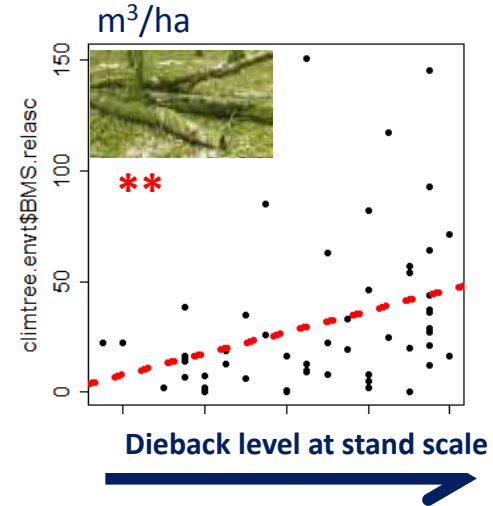
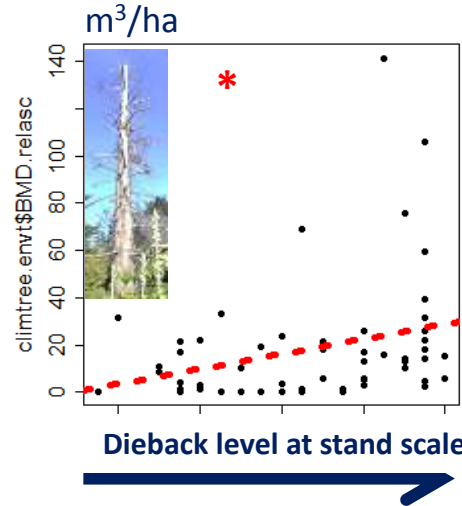
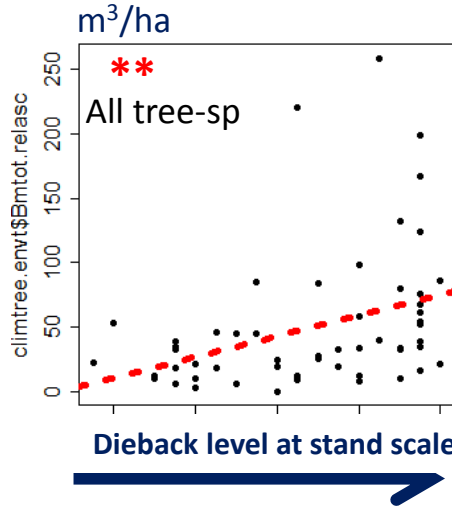
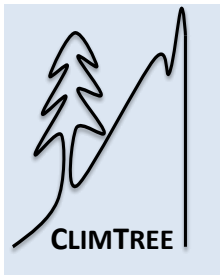
Stand dieback level and density of mistletoe-bearing trees



Effects of dieback level on forest structure

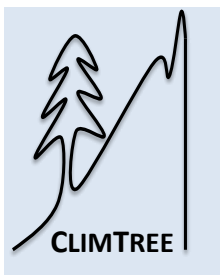
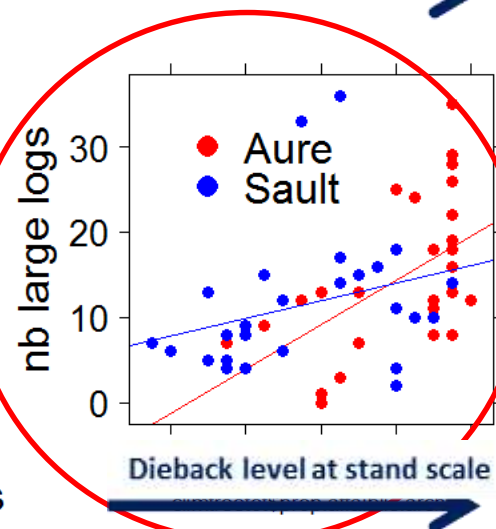
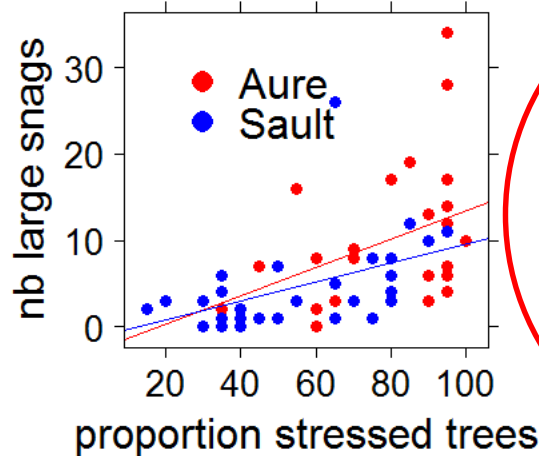
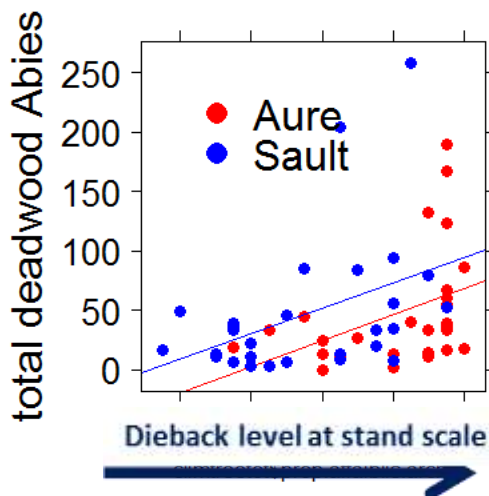
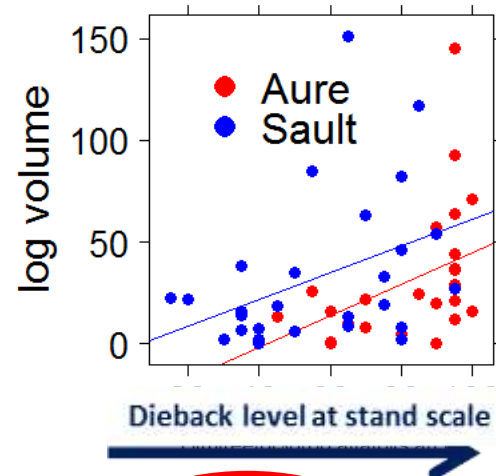
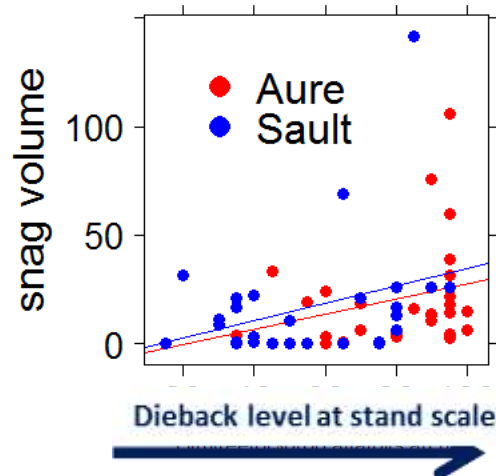
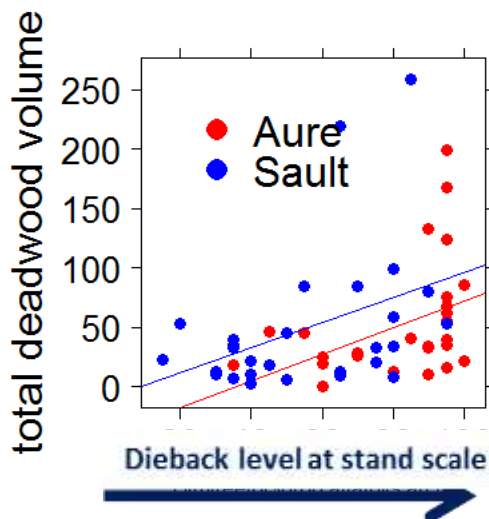
An overall increase in deadwood, mainly fir deadwood

Mixed models (« region » as a random variable)



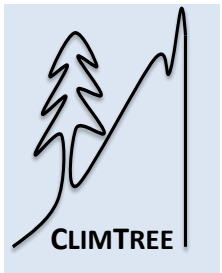
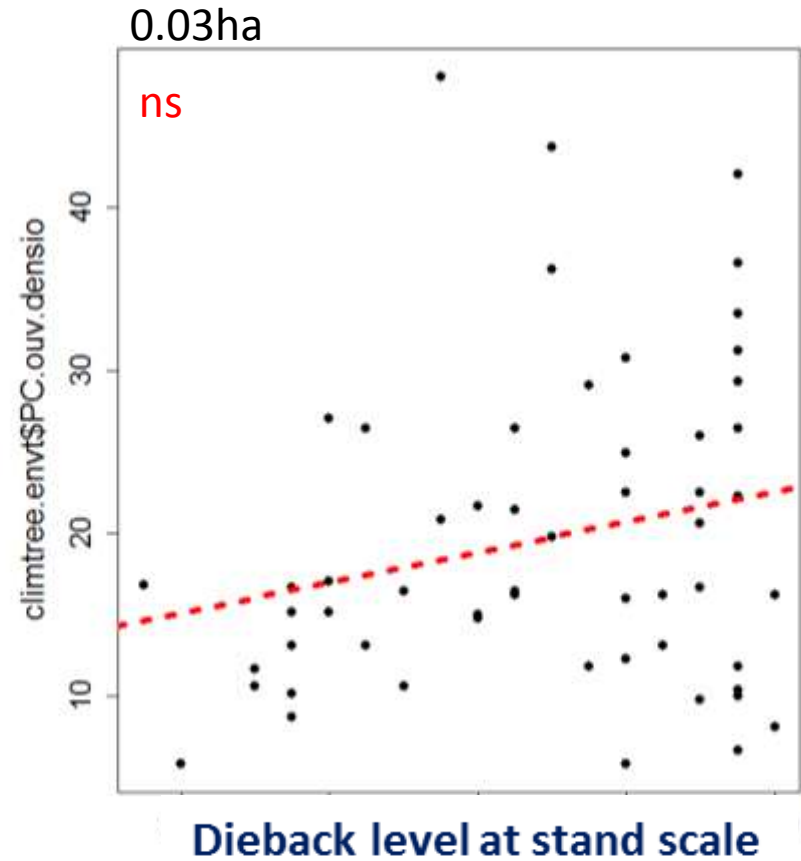
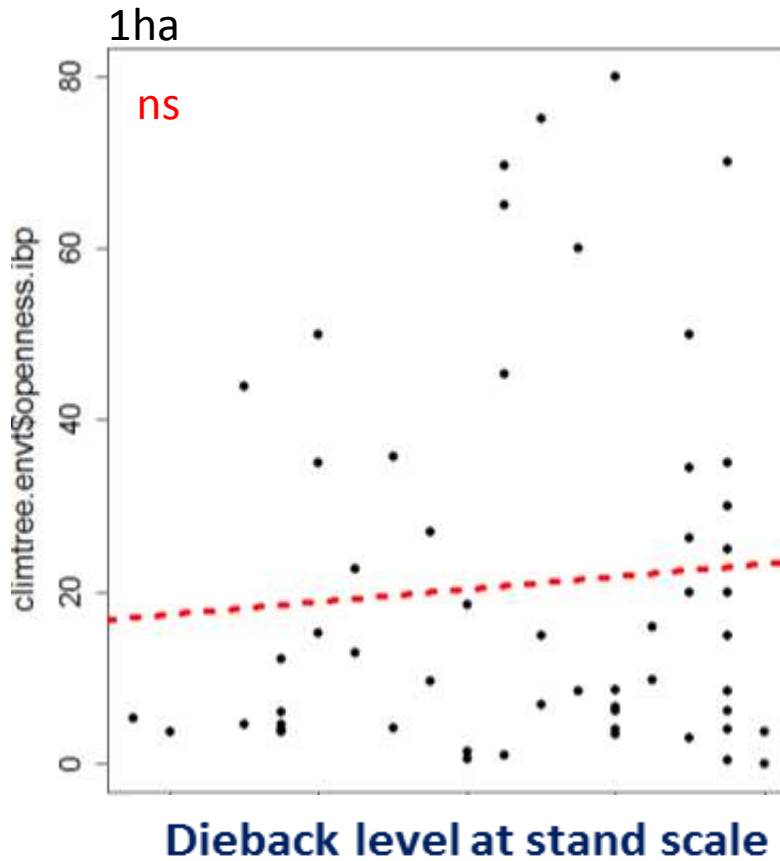
Effects of dieback level on forest structure

xy plots by region



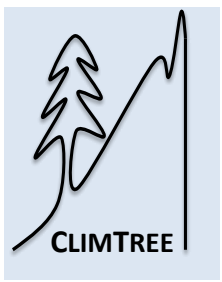
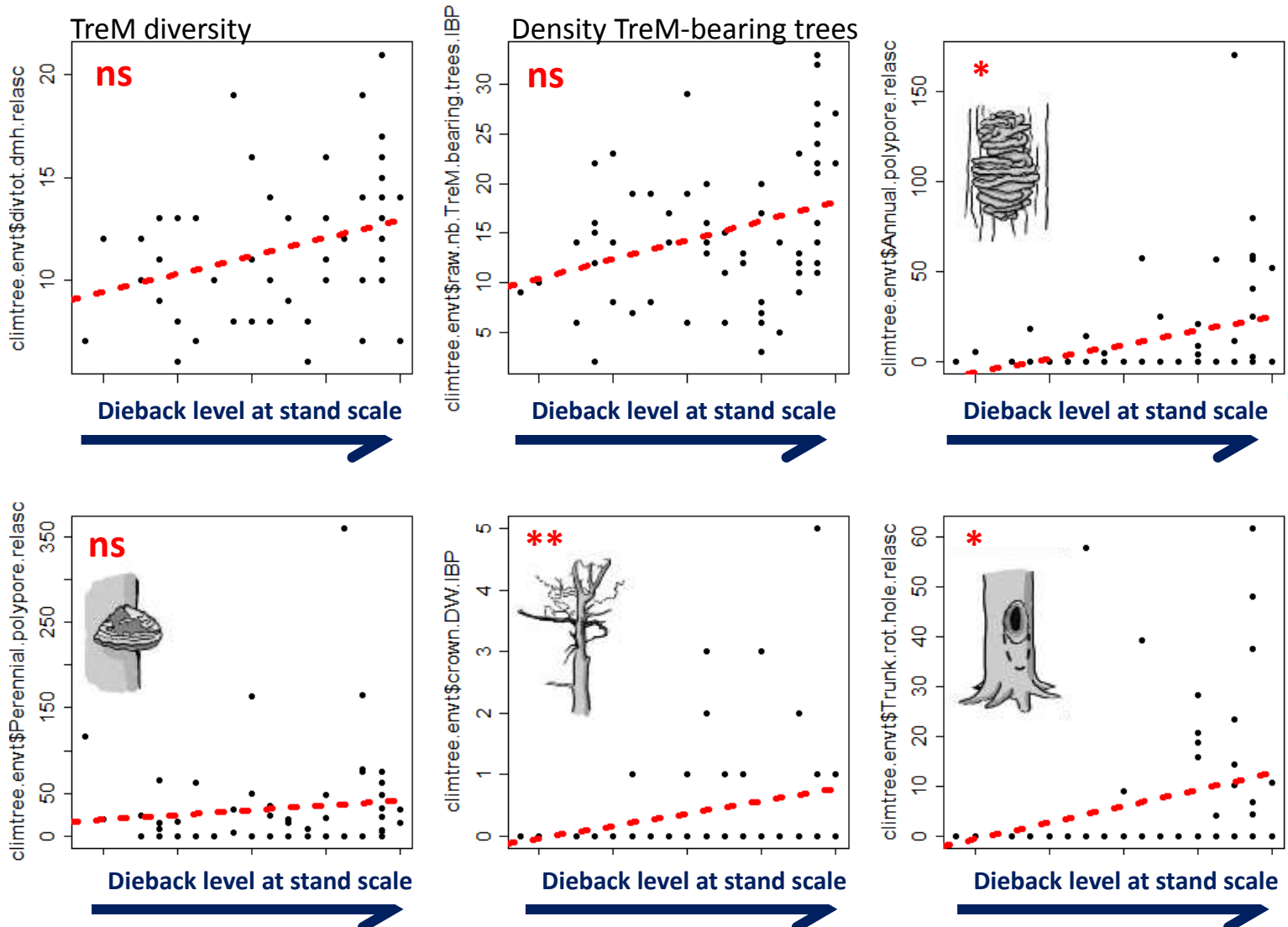
Effects of dieback level on forest structure

A non-significant increase in open-canopy conditions



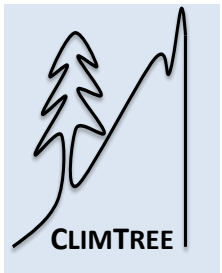
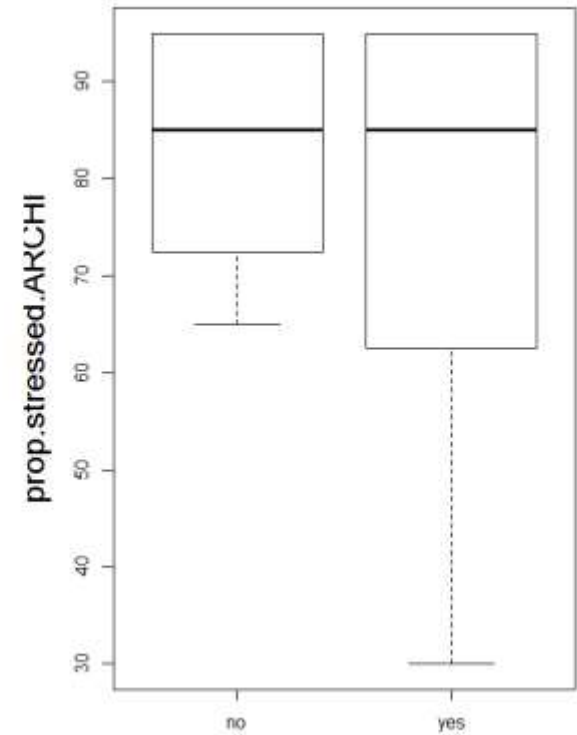
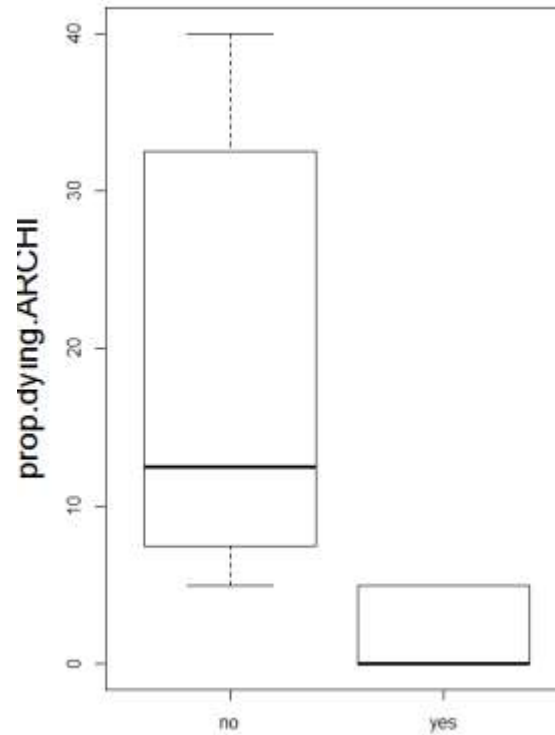
Effects of dieback level on forest structure

A slight increase in tree-related microhabitat density



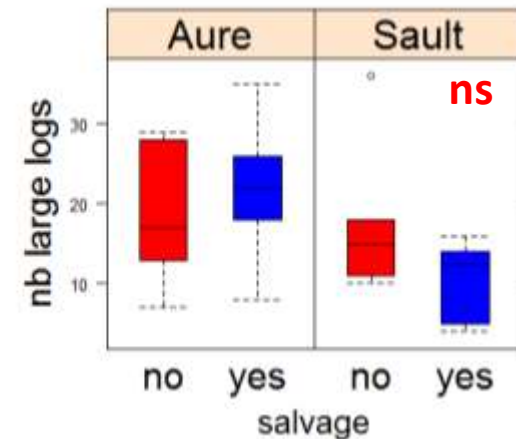
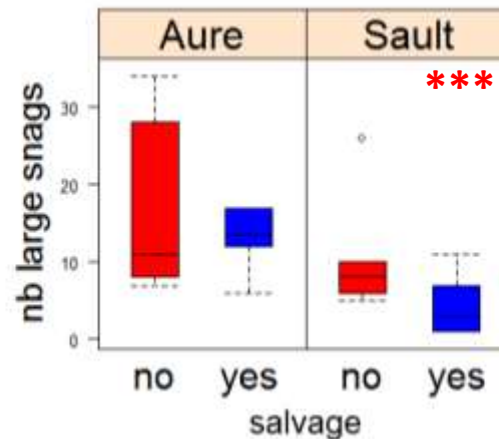
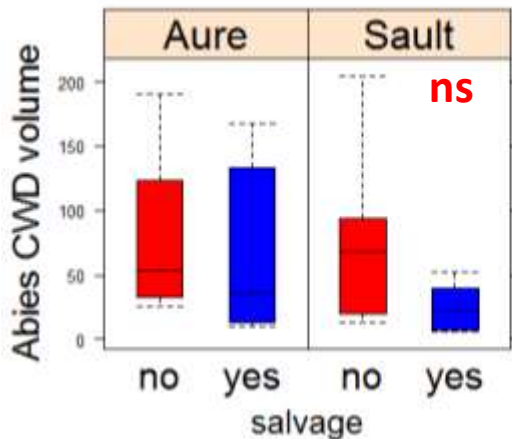
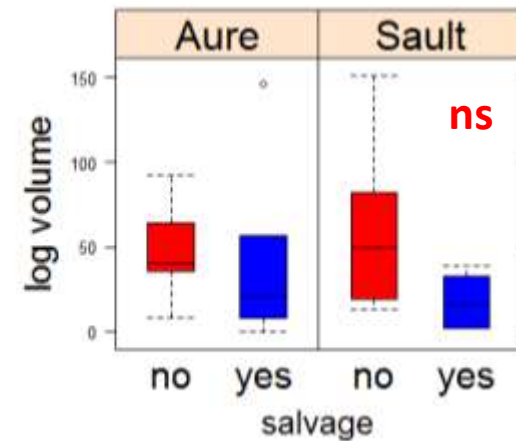
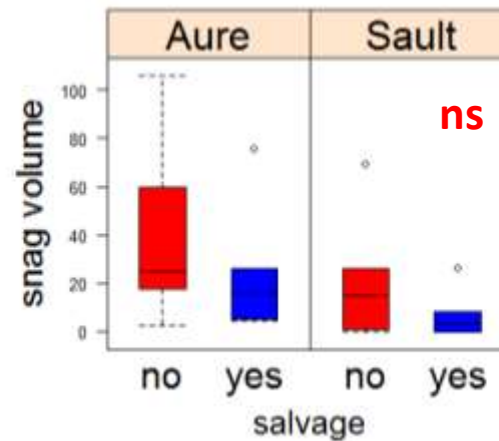
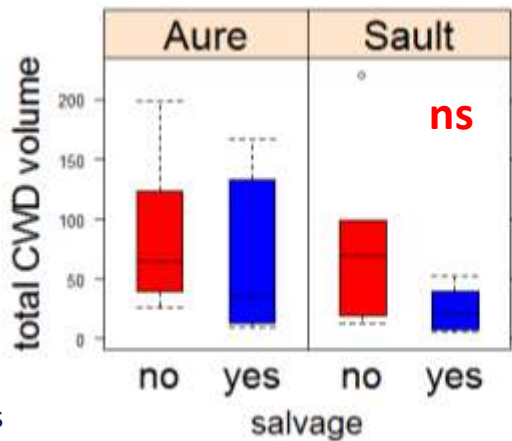
Effects of salvage logging on forest structure in declining stands

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

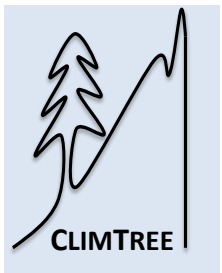


Effects of salvage logging on forest structure

Overall but slight decrease in deadwood...

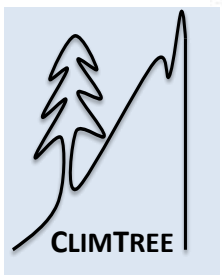
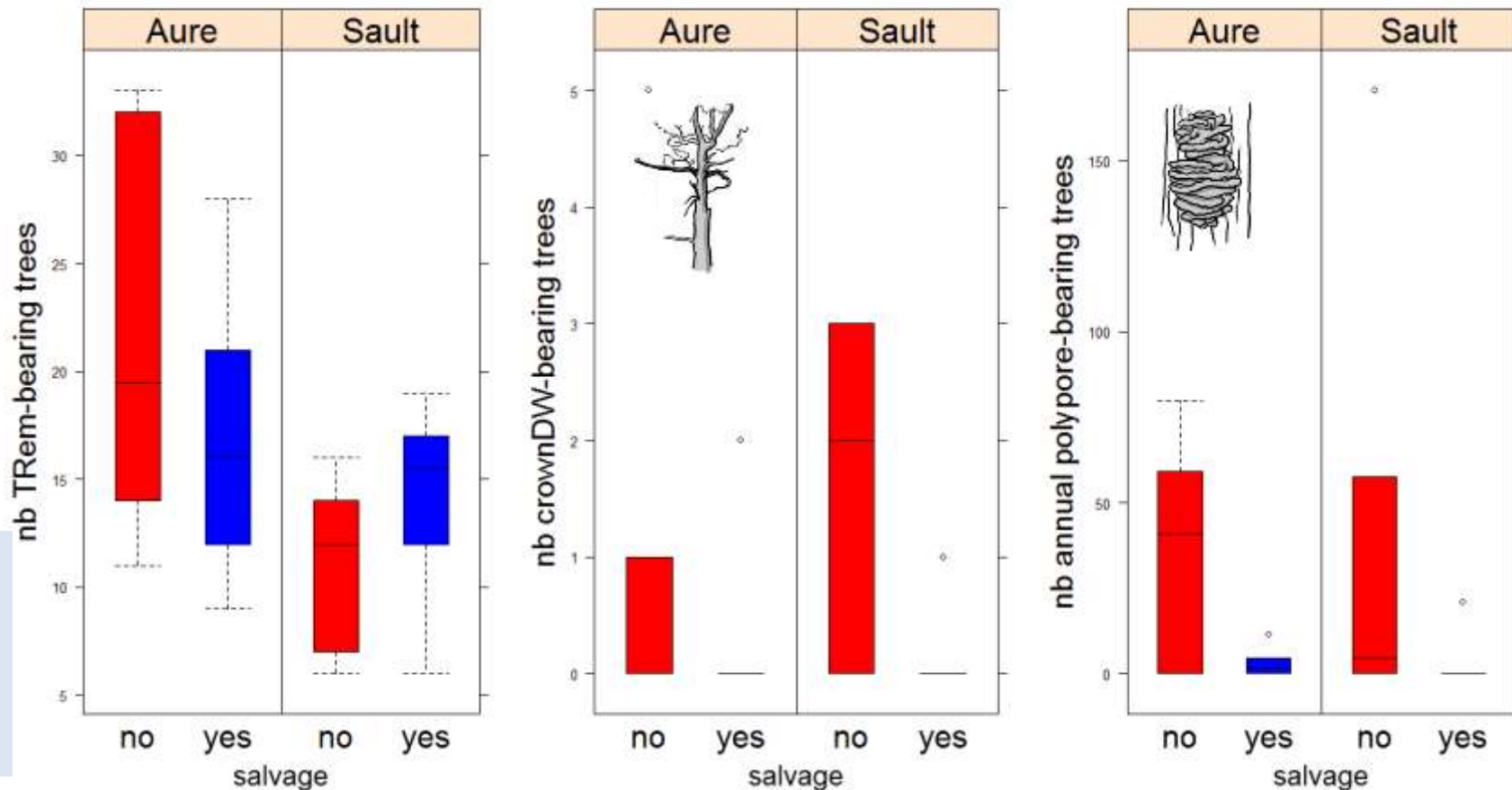


Mixed models
(« region » as a random
variable)



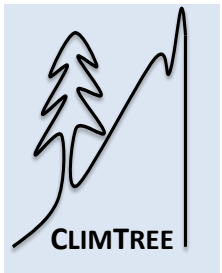
Effects of salvage logging on forest structure

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



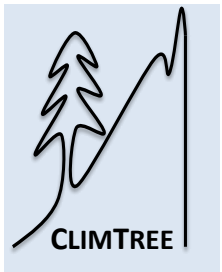


Response of insect communities to forest dieback



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

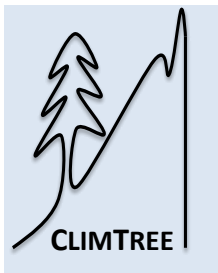


n = 56 traps

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



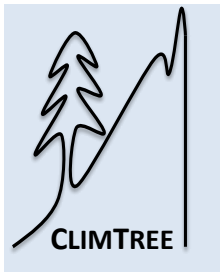


Insect datasets

	Nb individuals	Nb species
Malaise traps		Cf L. Sire
Fight-interception traps	40013	284

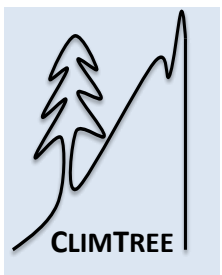
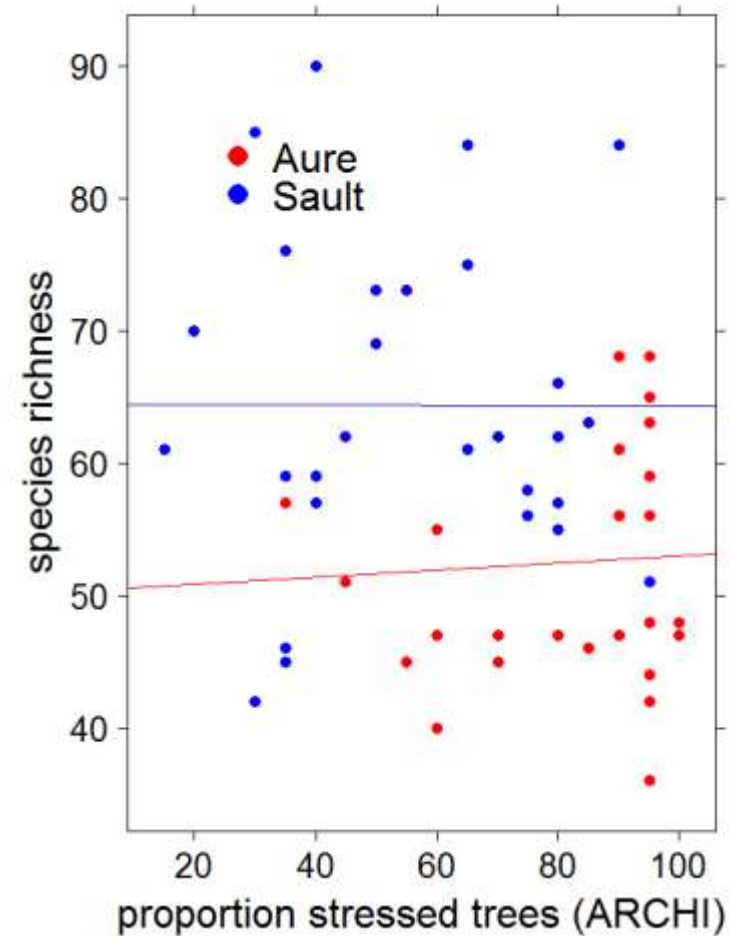
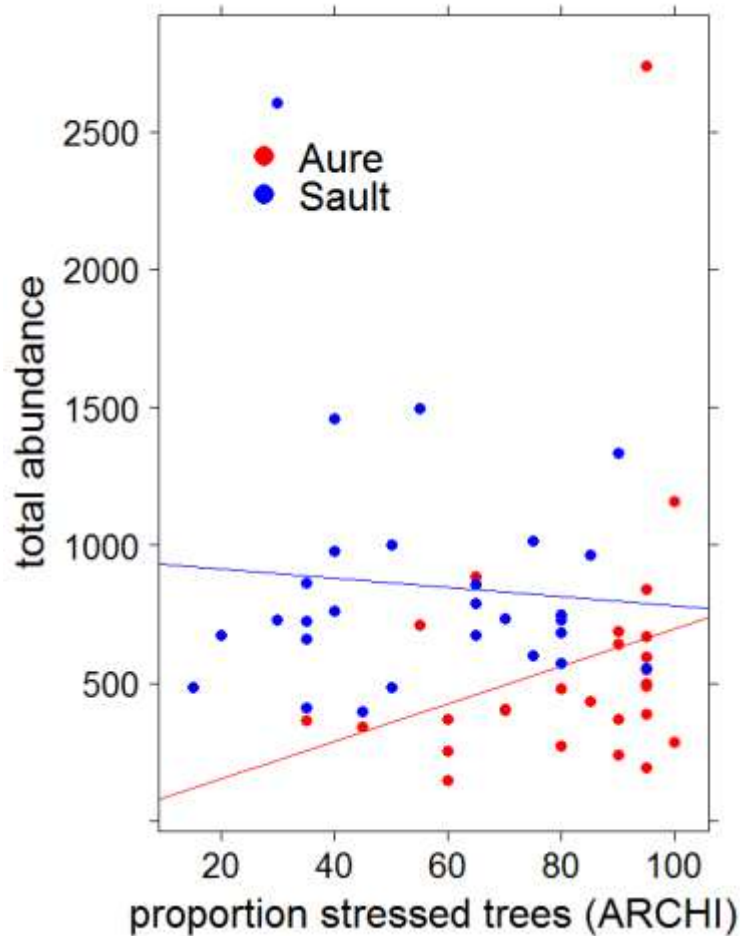


Families still at work (Staphylinids,
Mordellids, Scaptiids...)



Preliminary results about beetle response to dieback intensity and management

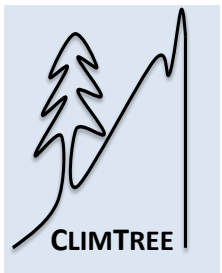
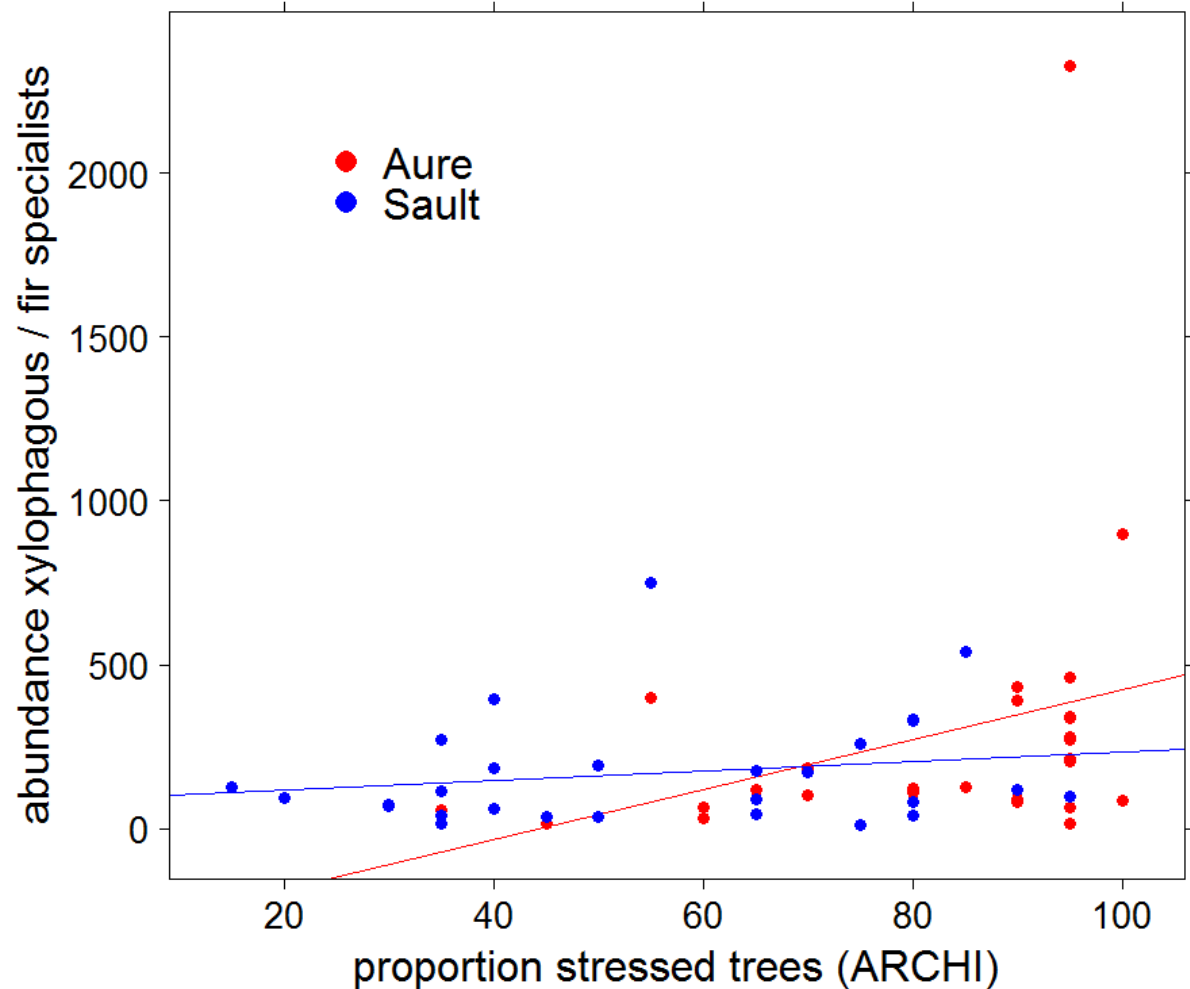
No overall increase in local abundance or species richness with local dieback level





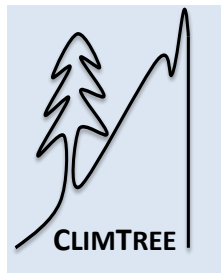
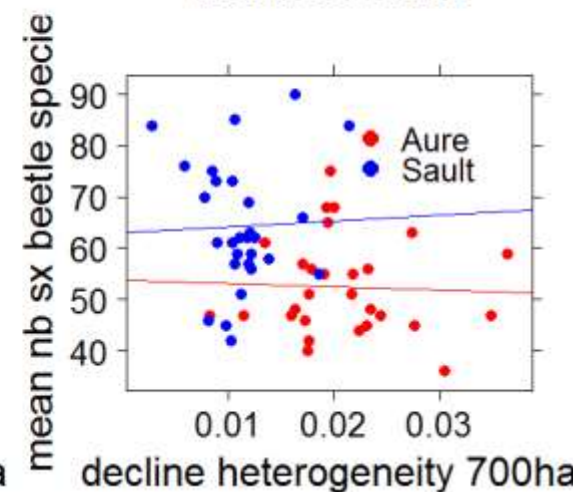
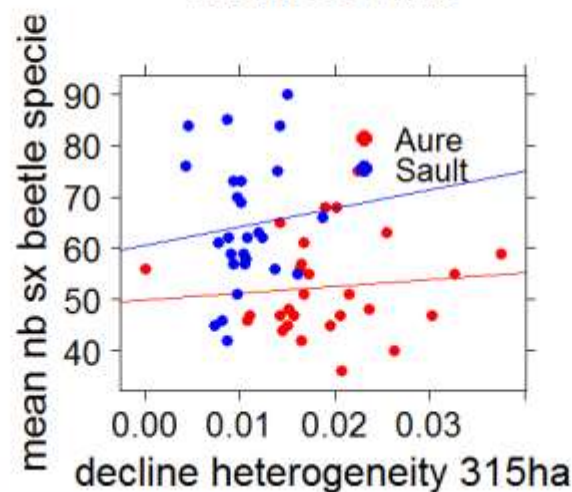
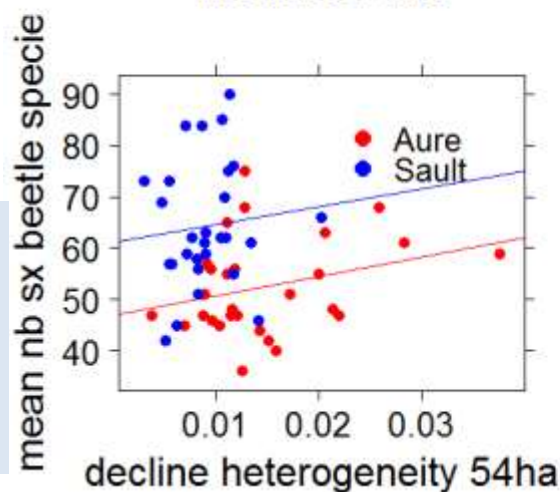
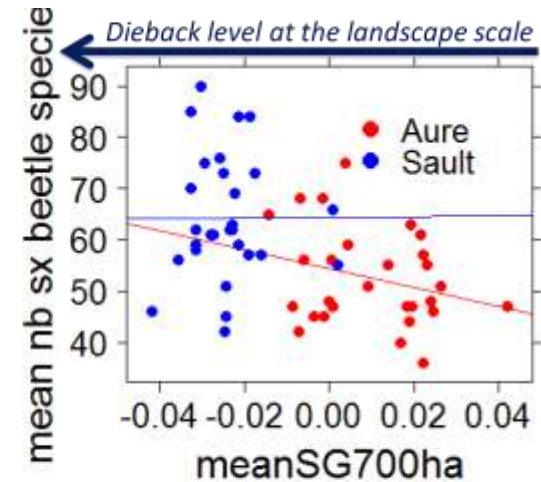
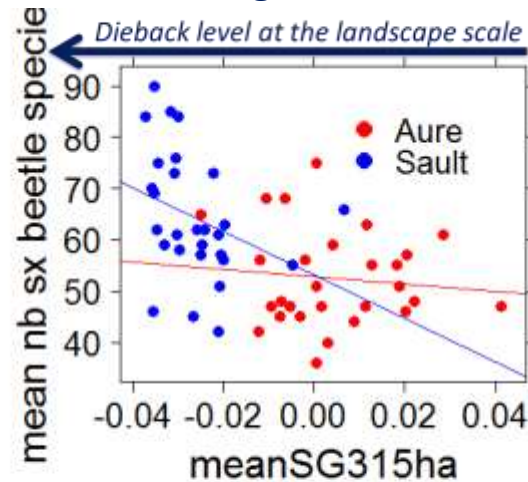
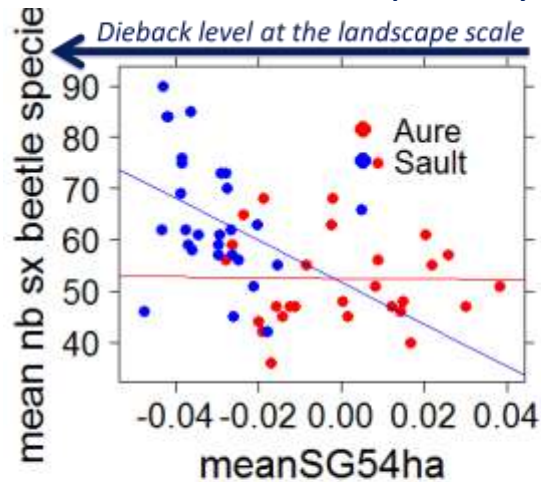
Response to dieback level at the local scale

Slight increase in local abundance of xylophagous fir specialists with local dieback level (Aure site)



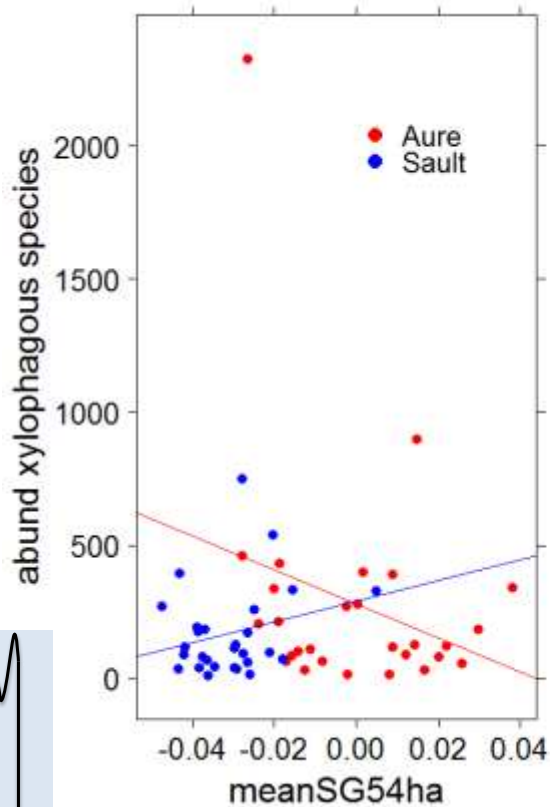
Response to dieback level at the landscape scale

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

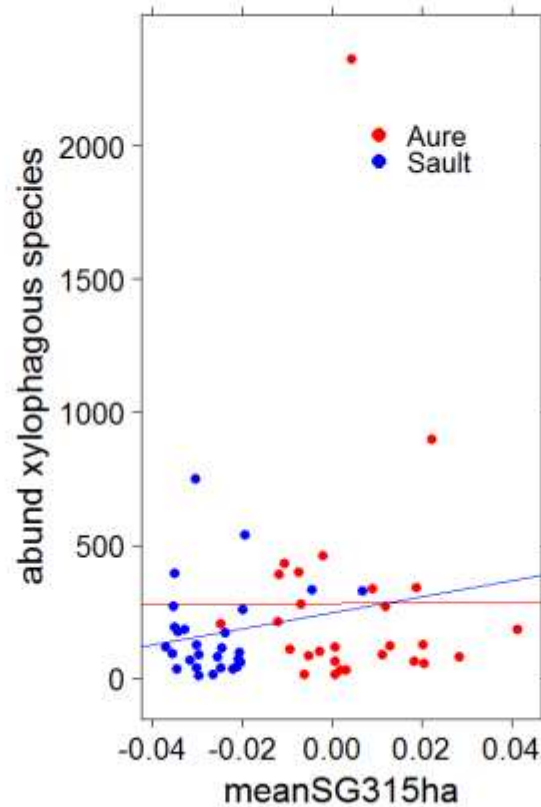


Response to dieback level at the landscape scale

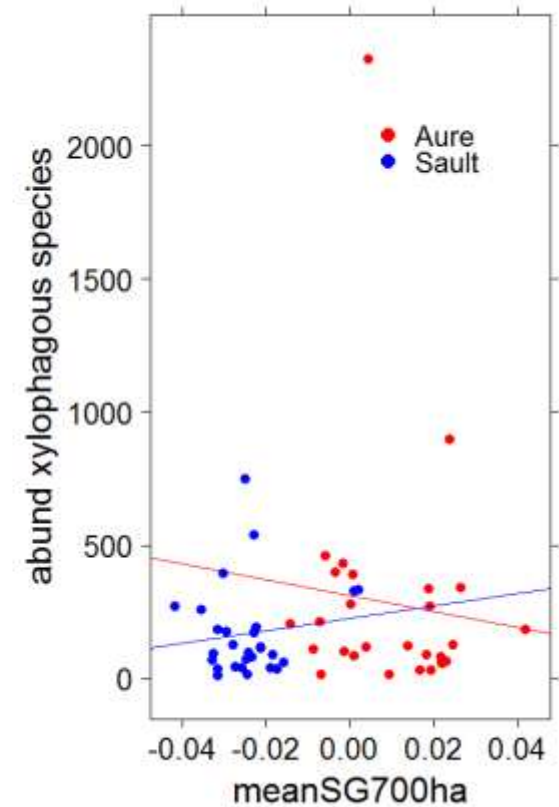
No increase in local abundance of xylophagous fir specialists with landscape dieback level



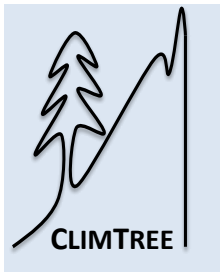
Dieback level at the landscape scale



Dieback level at the landscape scale

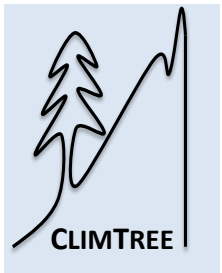
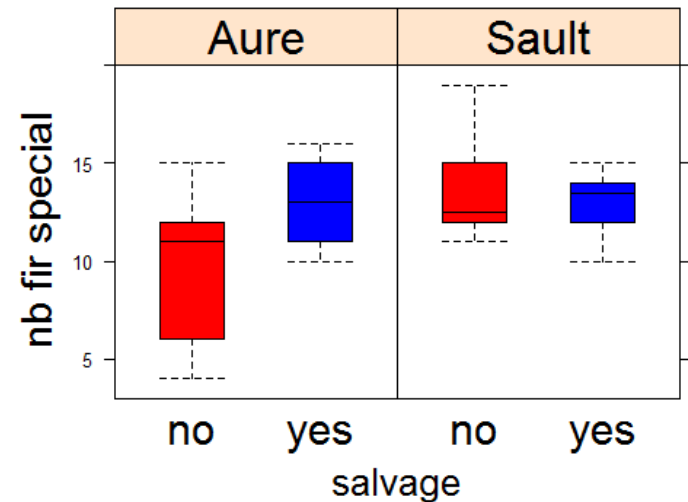
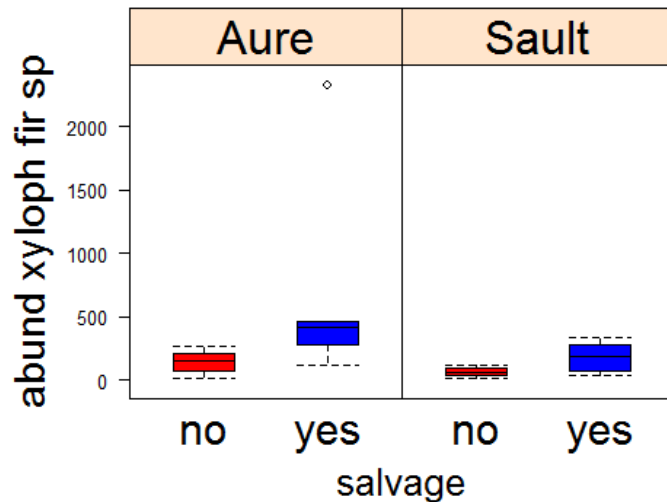
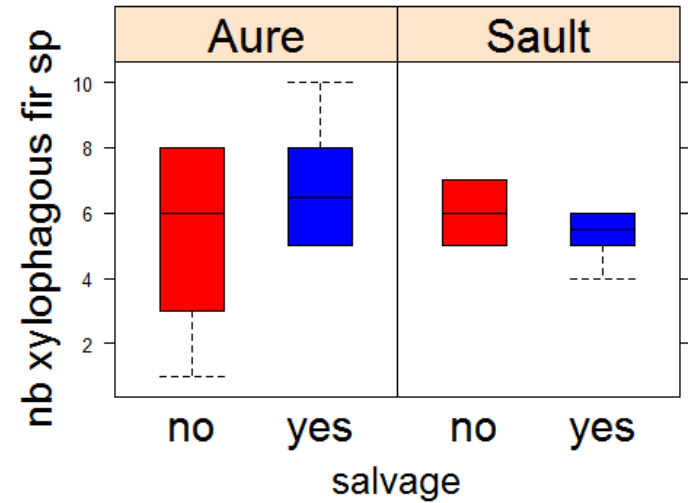
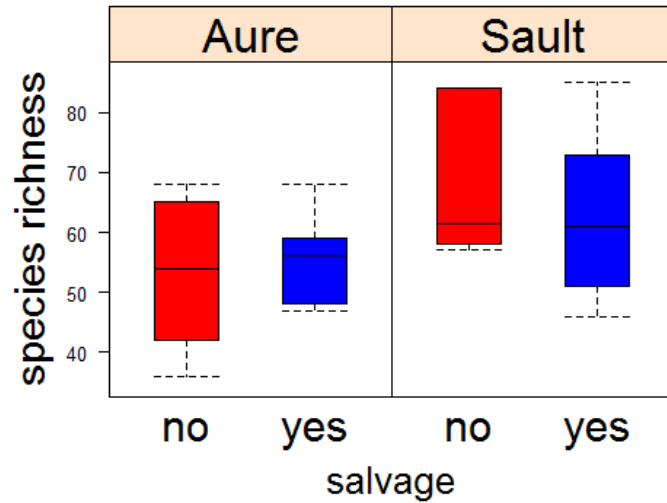


Dieback level at the landscape scale



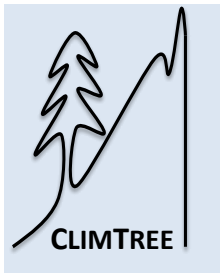
Response to salvage logging

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

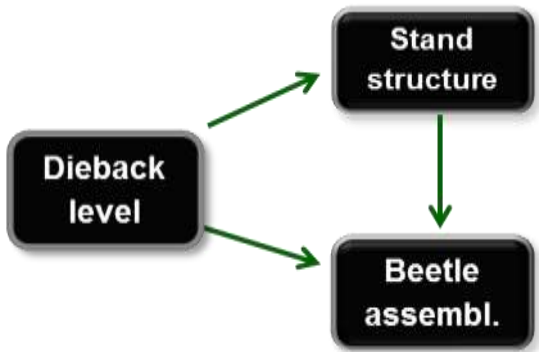




Perspectives



Further analyses after dataset completion



Analyses of response in :

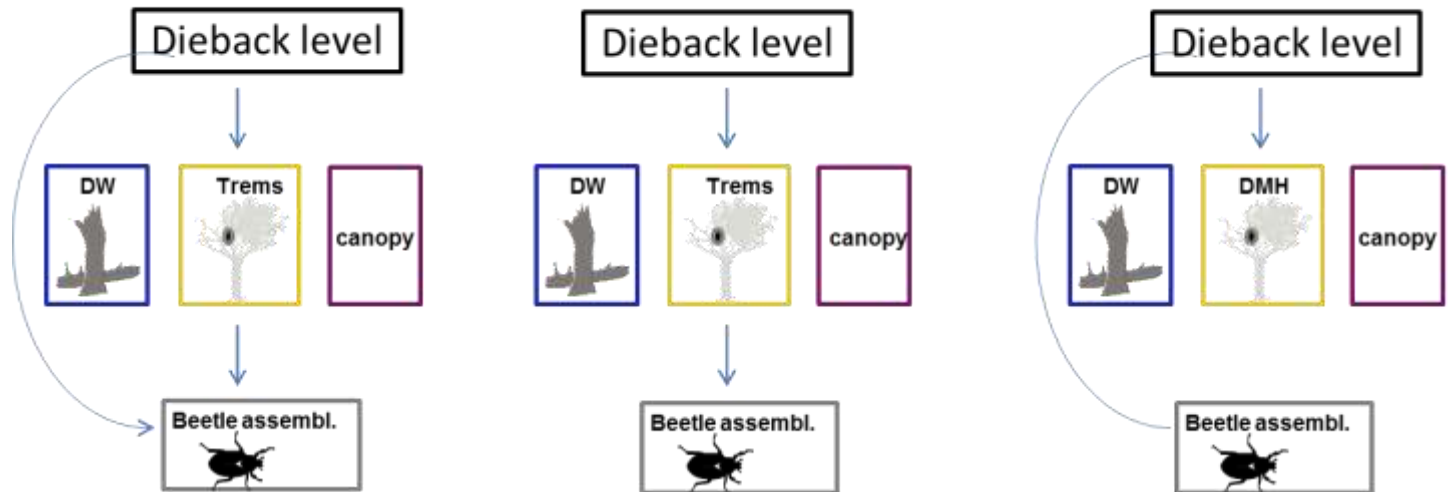
- sp composition
- niche traits CWM/Fdis
- ...

Model 1

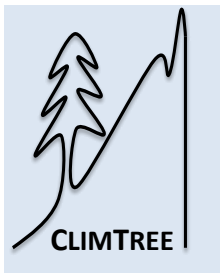
Model 2

Model 3

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
TOTAL	40013	284

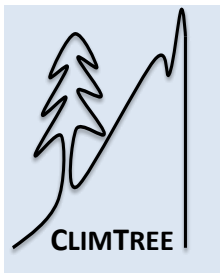


Germany
2016
Spruce

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

Incl. non-sx families

Several sx families at work...



Further analyses inside the Climtree project

Cf Lucas

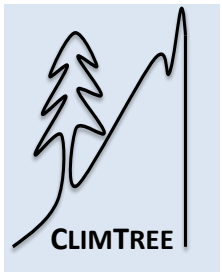


Option 1: morphol. indiv. sorting.



→ ... zzzzzZZZZZ

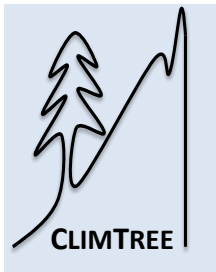
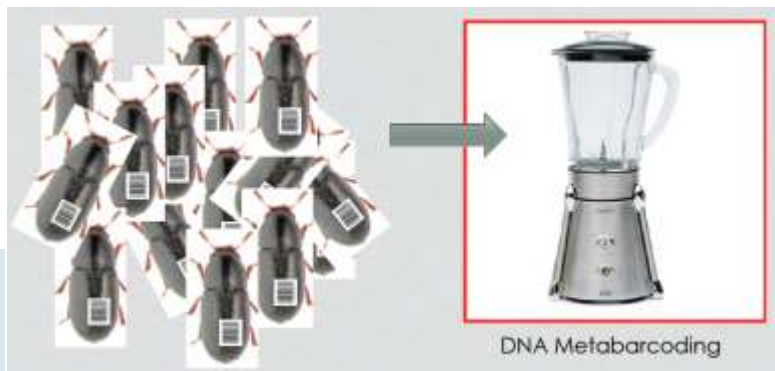
Option 2: eDNA storing EtOH



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 Markkula^{1*}, Bruno Carolina de Araujo², Athena Wei Lam¹, Axel Hassenmann^{1,2}, Michael Rabel^{1,2}, Stefan Schwaiblmair¹, Lars Hendrich¹, Dieter Döckel¹, Barbara Fahrenholz¹, Benoit Arnaud¹, Gerhard Hagenauer^{1,3}

Open Access Editor: David B. Clark, University of California, Berkeley, UNITED STATES



RESEARCH ARTICLE Open Access

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

Melissa J. Casati¹, Vincent J. Pettigrew¹, Leon Metcalfe¹ and Amy A. Hoffmann^{1,2*}

ECOLOGICAL LETTERS
Volume 15, Issue 10, October 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 the application of NGS to the rapid identification of macroinvertebrate bioindicator 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^{1,2†}, Yinqiu Ji^{1†}, Brent C. Emerson^{3†}, Xiaoyang Wang¹, Chengxi Ye¹, Chuntian Yang¹ and Zhaoli Ding¹

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†

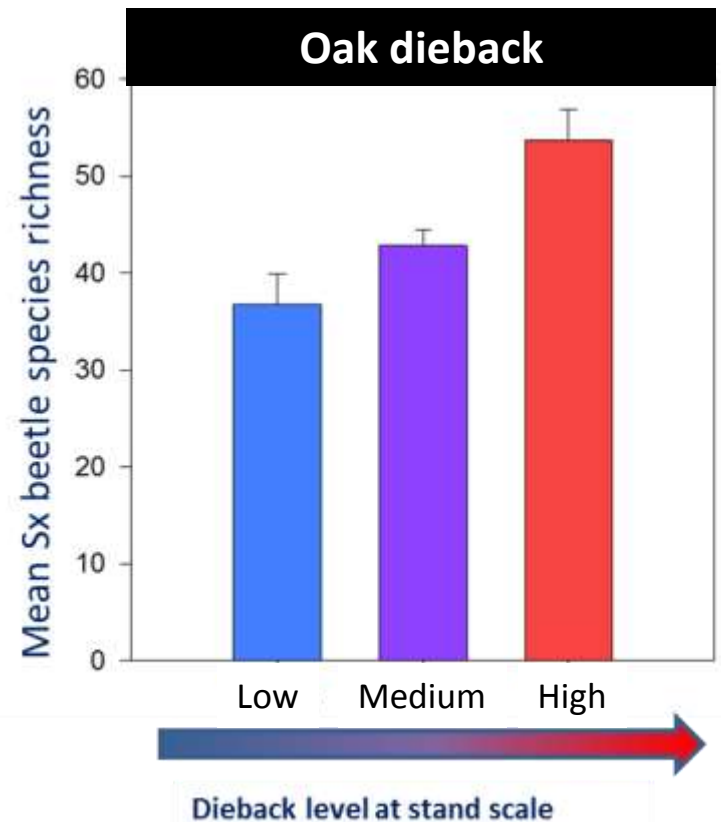
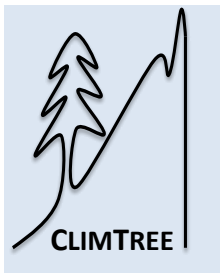
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Further analyses inside/outside the Climtree project

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

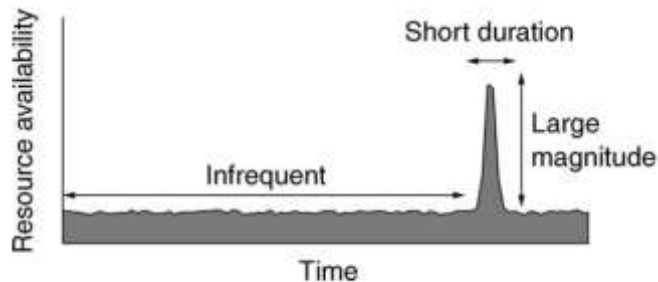


Conceptual framework of resource pulses

**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).

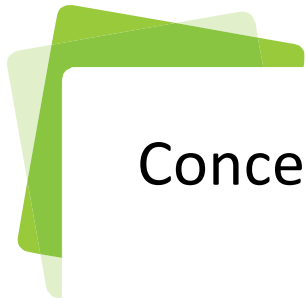


Ecology, 89(3), 2008, pp. 621–634
© 2008 by the Ecological Society of America

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

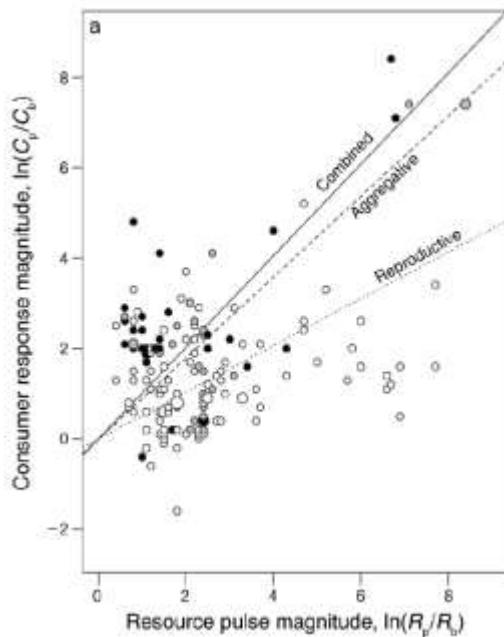
WHAT CAN WE LEARN FROM RESOURCE PULSES?

LOUIE H. YANG,^{1,3} JUSTIN L. BASTOW,¹ KENNETH O. SPENCE,² AND AMBER N. WRIGHT¹



Conceptual underpinnings

Relationship between numerical response of primary consumers and resource pulse magnitude

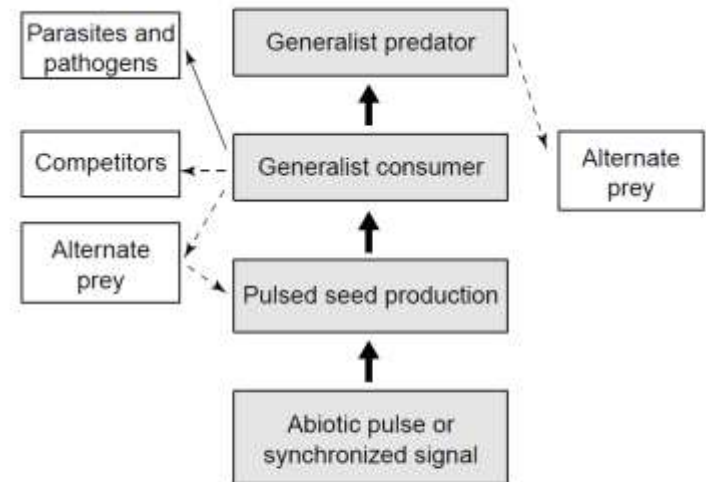


Ecological Monographs, 80(1), 2010, pp. 125–151
© 2010 by the Ecological Society of America

A meta-analysis of resource pulse–consumer interactions

LOUIE H. YANG,^{1,2,3,6} KYLE F. EDWARDS,³ JARRETT E. BYRNE,^{2,3} JUSTIN L. BASTOW,^{3,4} AMBER N. WRIGHT,³
AND KENNETH O. SPENCE³

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



Many thanks to:



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

