Ecological and socioeconomic impacts of climate-induced tree diebacks in highland forests

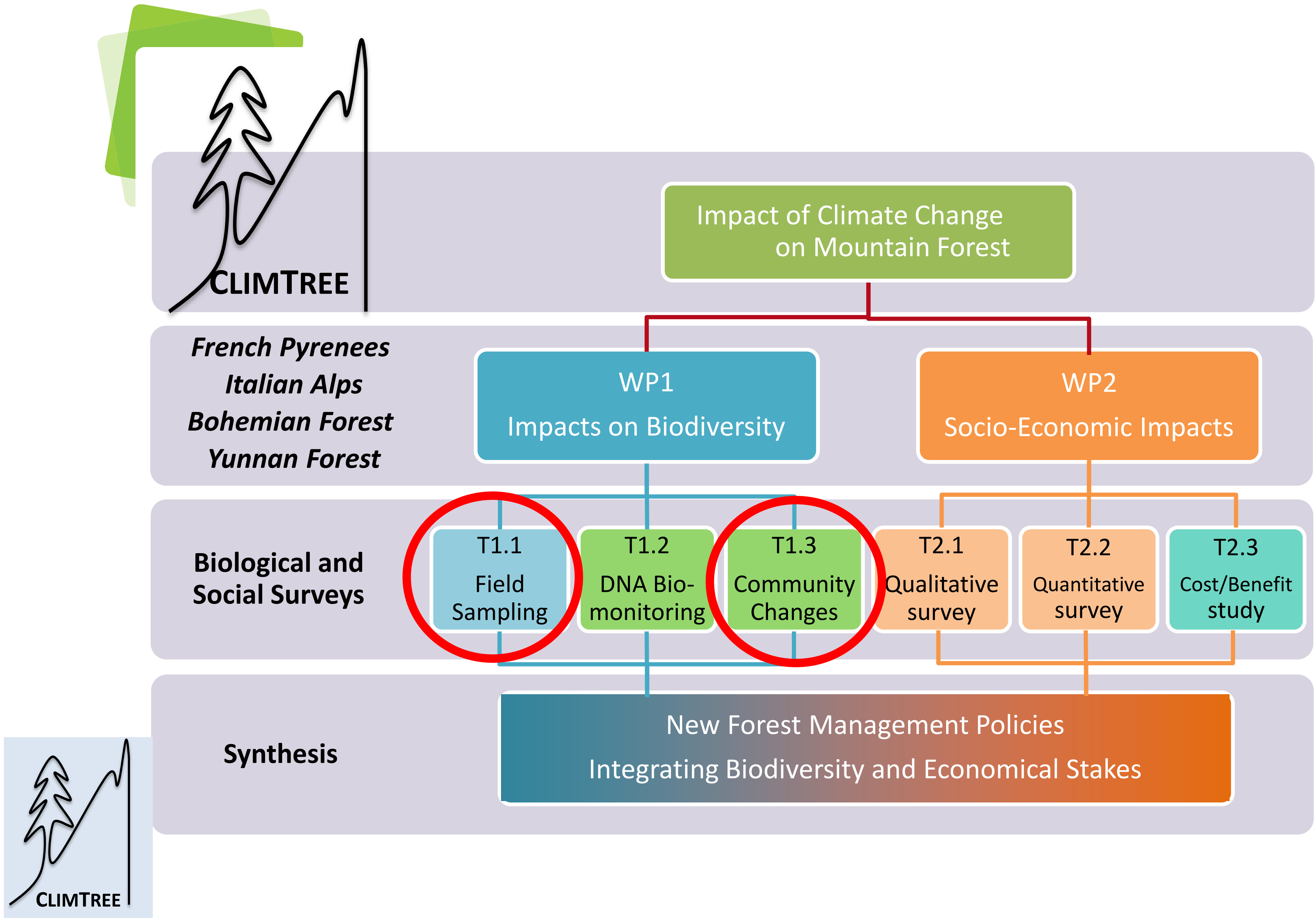
Christophe Bouget, Laurent Larrieu

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

Belmont Forum Collaborative Research Action / Call for Proposals on Mountains as Sentinels of Change

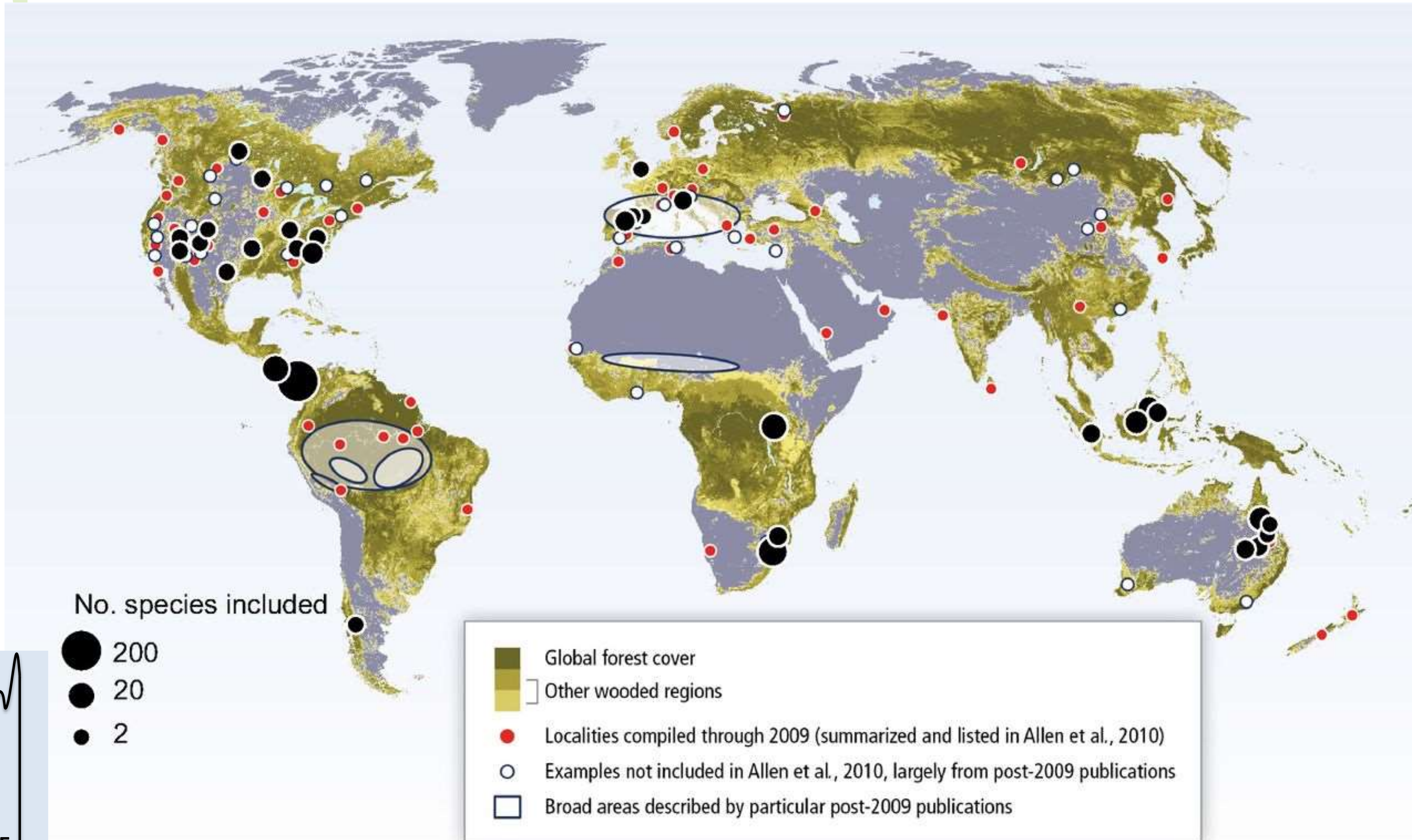


CLIMTREE
Impact of Climate Change on Mountain Forest
French Pyrenees
Italian Alps
Bohemian Forest
Yunnan Forest
WP1
Impacts on Biodiversity
WP2
Socio-Economic Impacts
Biological and Social Surveys
T1.1 Field Sampling
T1.2 DNA Bio-monitoring
T1.3 Community Changes
T2.1 Qualitative survey
T2.2 Quantitative survey
T2.3 Cost/Benefit study
Synthesis
New Forest Management Policies
Integrating Biodiversity and Economical Stakes
CLIMTREE

Context, questions and study design

CLIMTREE

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

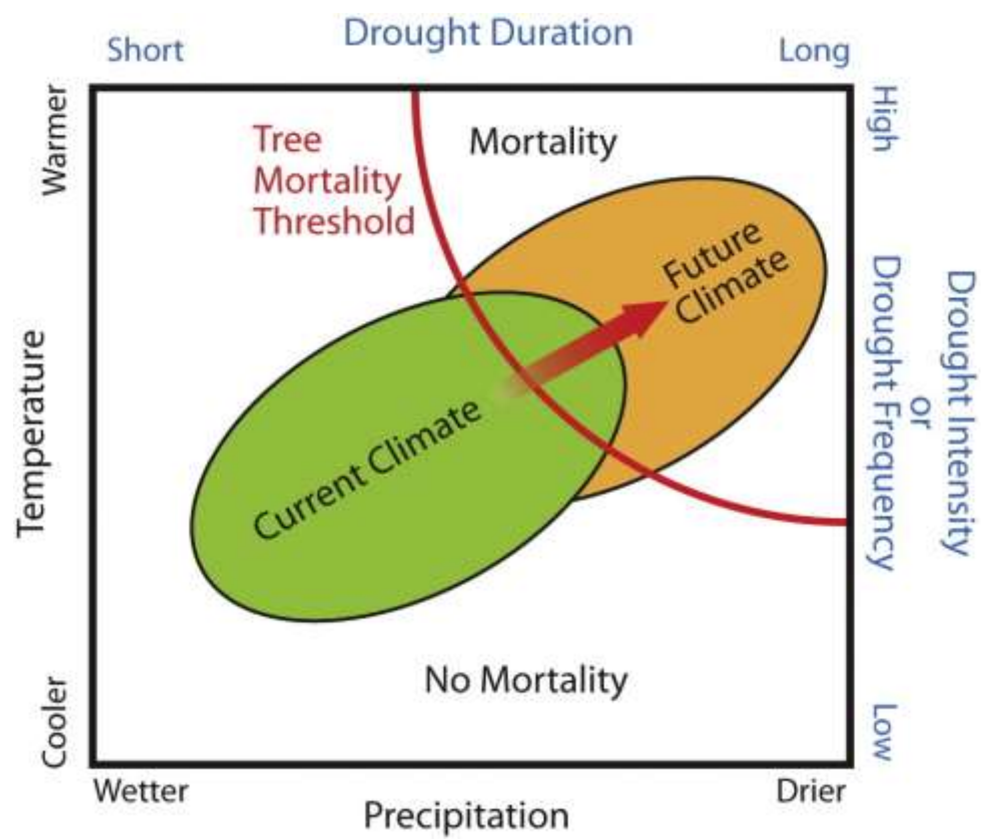


Anderegg et al. PNAS 2016

CLIMTREE

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.

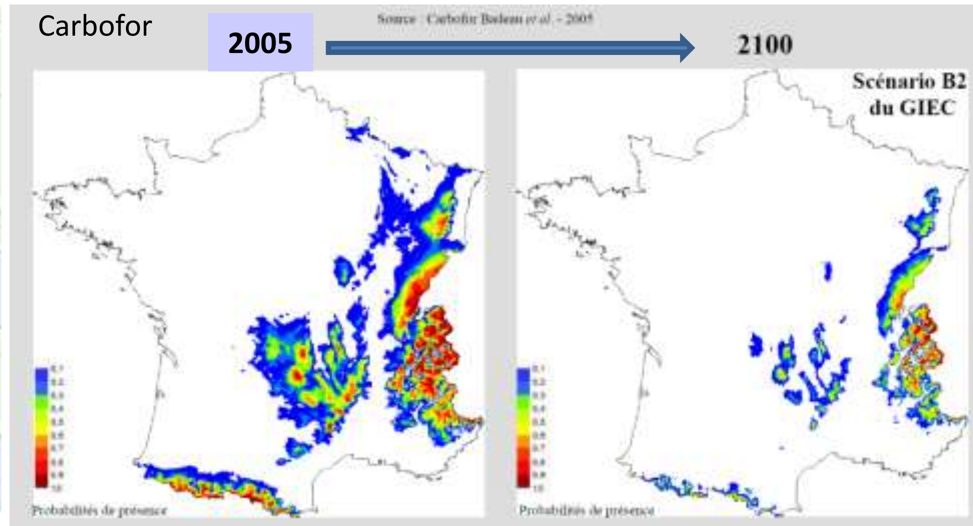


Breshears et al. Rangelands 2016

CLIMTREE

Silver fir in southern France

Expected climate-induced changes in silver fir distribution



CLIMTREE

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

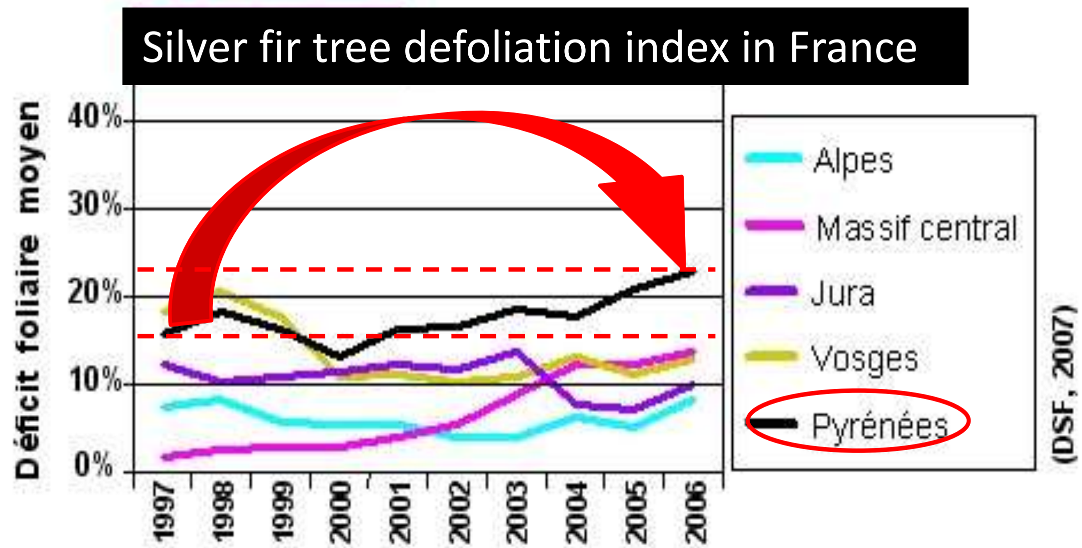
Sensitivity of French temperate coniferous forests to climate variability and extreme events (*Abies alba*, *Picea abies* and *Pinus sylvestris*)

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)



Drivers

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

CLIMTREE

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

ELSEVIER
Available online at www.sciencedirect.com
SCIENCE DIRECT
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]

ELSEVIER
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

CrossMark

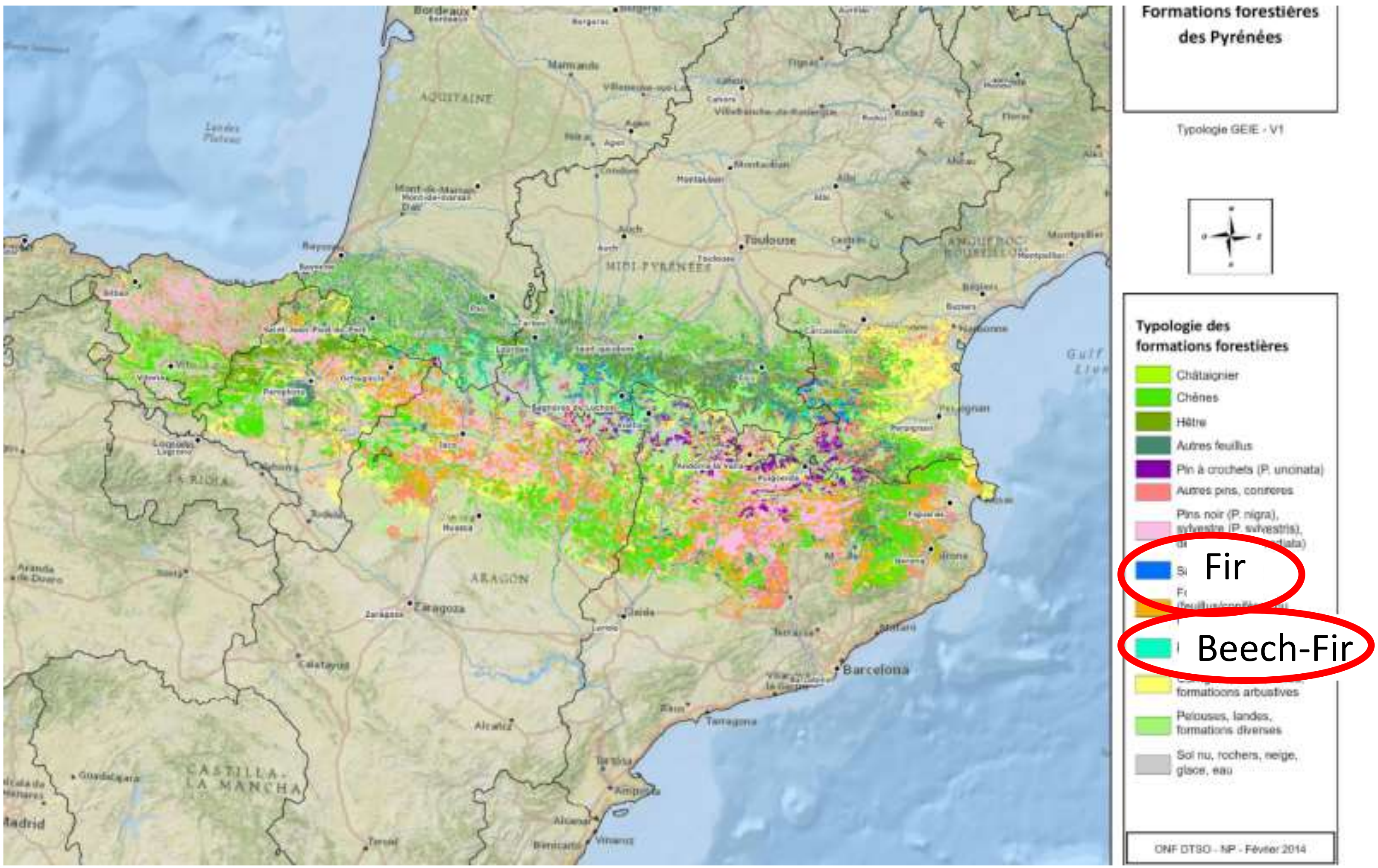
Marianne Bernard[a,b], Vincent Boulanger[c], Jean-Luc Dupouey[e,*], Lisa Laurent[f], Pierre Montpied[e], Xavier Morin[b], Jean-François Picard[e], Sonia Saïd[d]

CLIMTREE

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



Objectives of the French sampling design

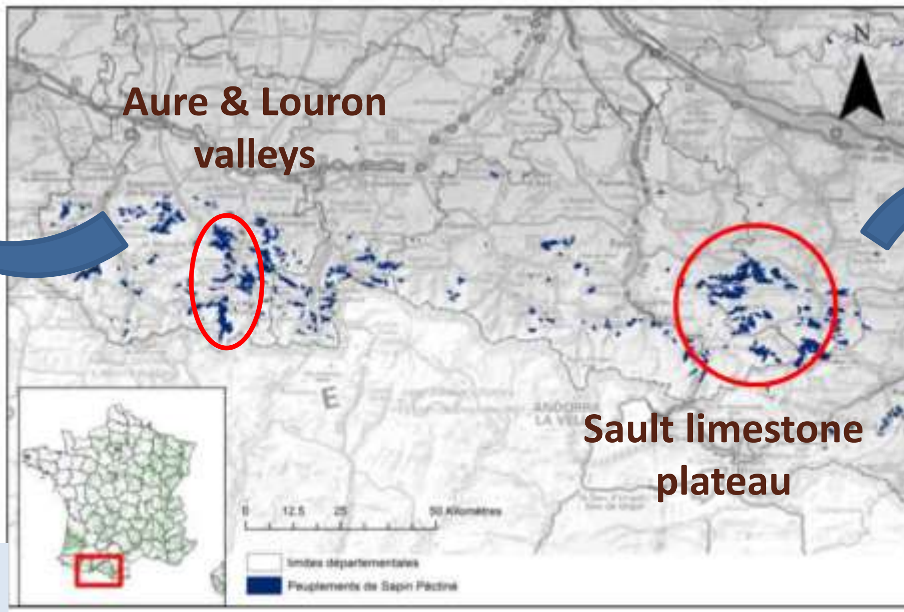
Stratifying factors

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

Design replicated in 2 regions

Aure

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



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

CLIMTREE

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	
			No harvesting	No harvesting	Salvage logging
Landscape scale (R=200m)	Low dieback level	15	6	5	-
	High dieback level	5	6	7	12

Decline intensity at the landscape scale

Salvage logging

CLIMTREE

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

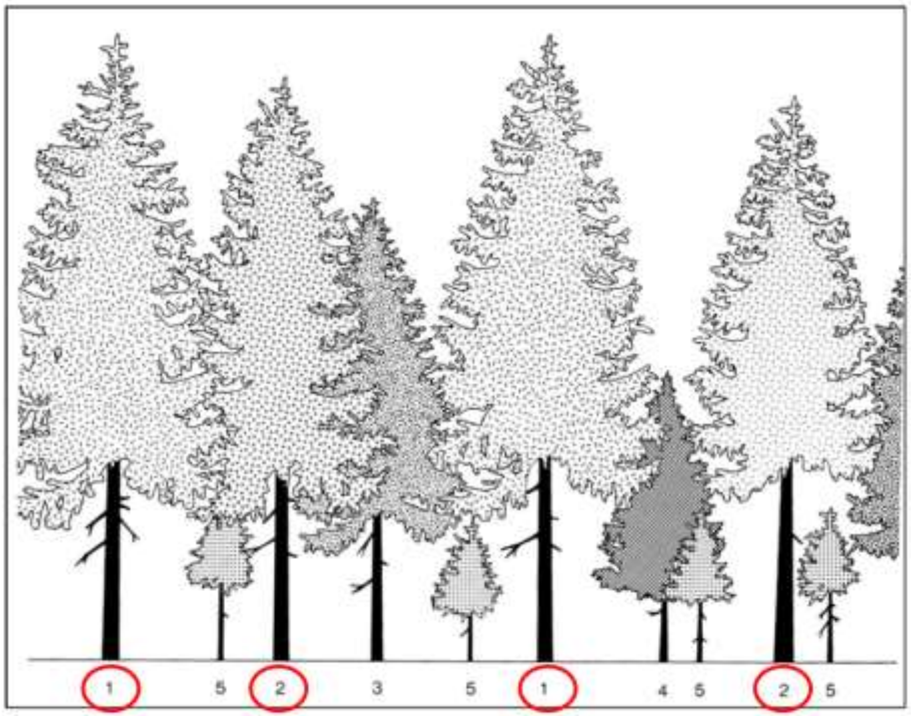
CLIMTREE

VITALITÉ DES ARBRES ARCHI CENTRE NATIONAL de la PROPRIÉTÉ FORESTIÈRE

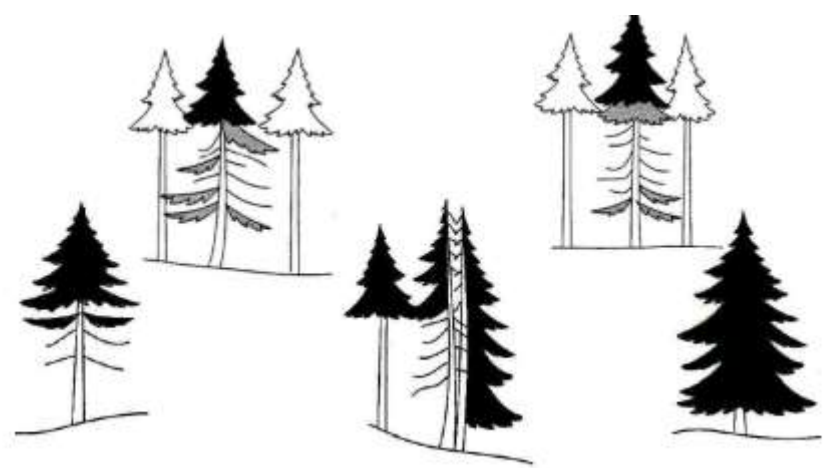
Forêt Privée Française CNPF IDF

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)



CLIMTREE

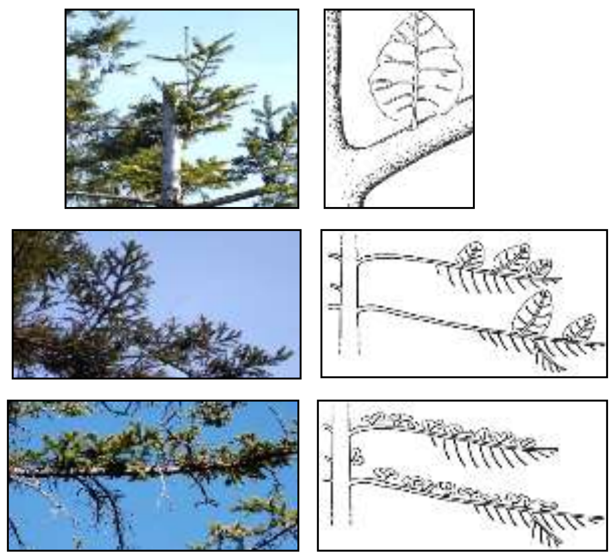
Local dieback assessment using the ARCHI method

Defoliation
Crown decline
symptoms

+ Greenness level

+

Crown
restoration
process



Type and vigor of sprouts

=

ARCHI diagnosis
5 tree types

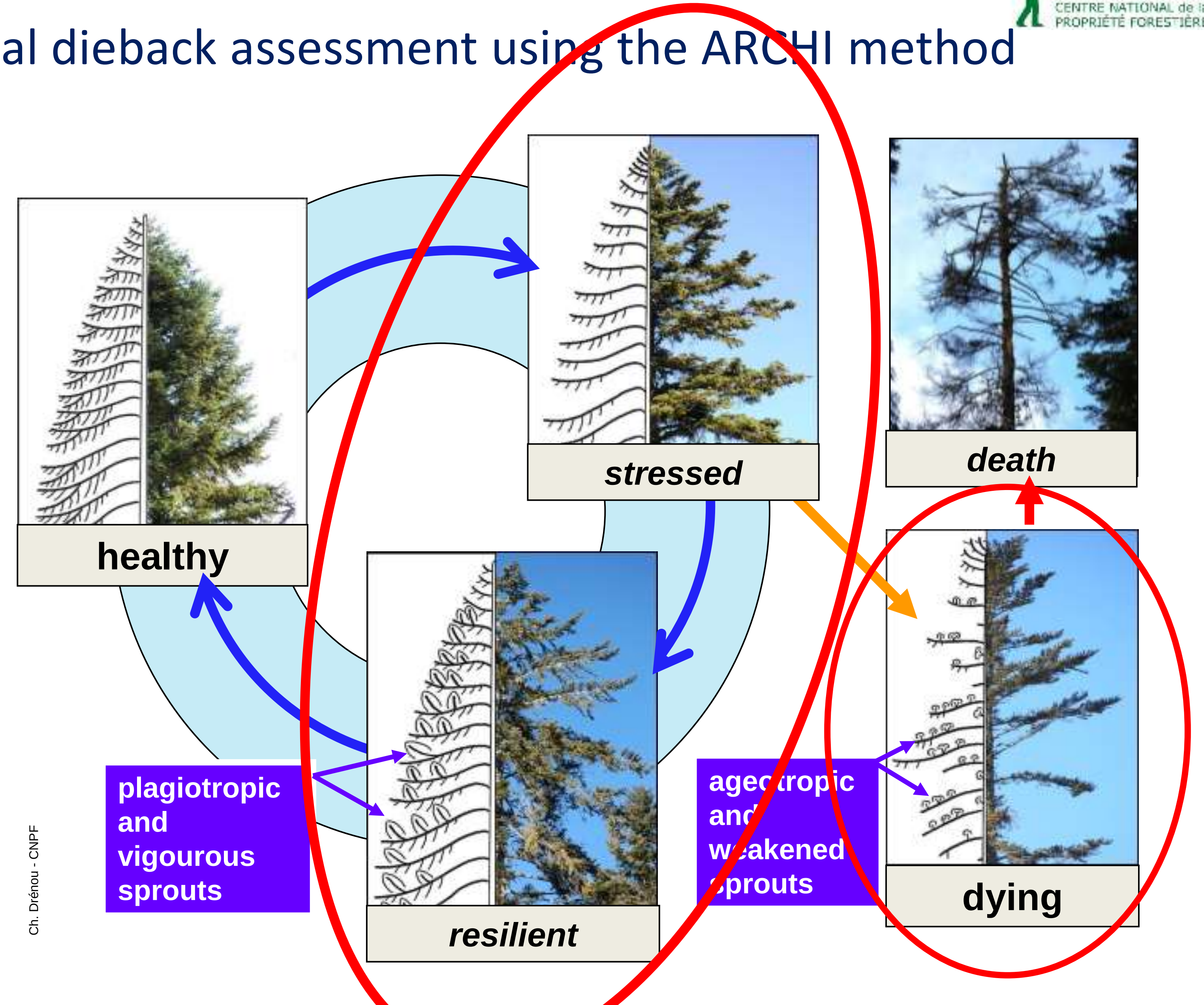
- **healthy**
- **stressed**
- **resilient**
- **dying**
- **crown dieback**

CLIMTREE

ARCHI
CENTRE NATIONAL de la PROPRIÉTÉ FORESTIÈRE

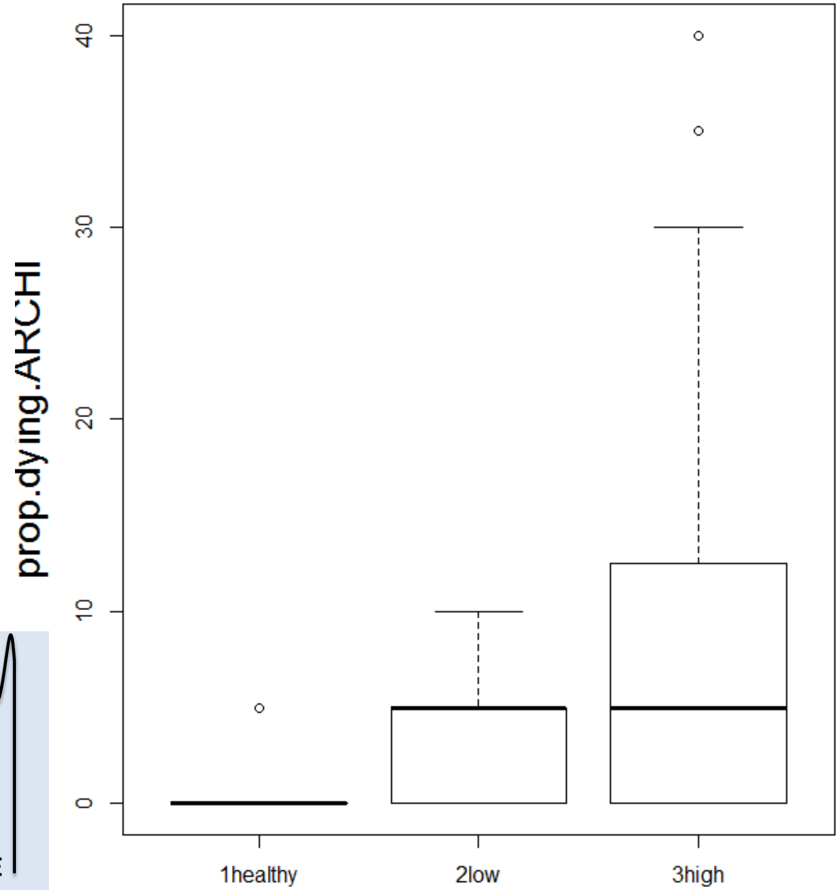
Drénou, C. 2012 - La méthode ARCHI. Forêt entreprise, n°203, 29-31.

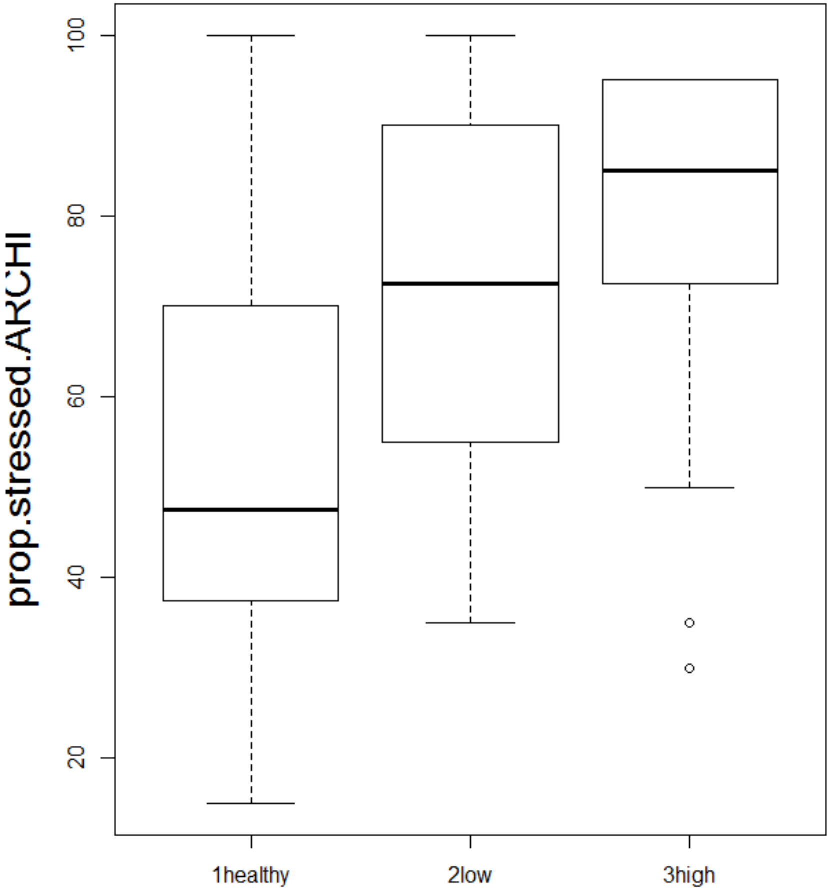
Local dieback assessment using the ARCHI method



Post-hoc assessment of the sampling design

At the stand scale





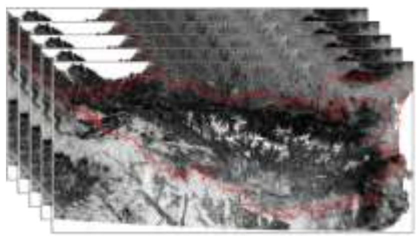
CLIMTREE

Dieback level at the landscape scale

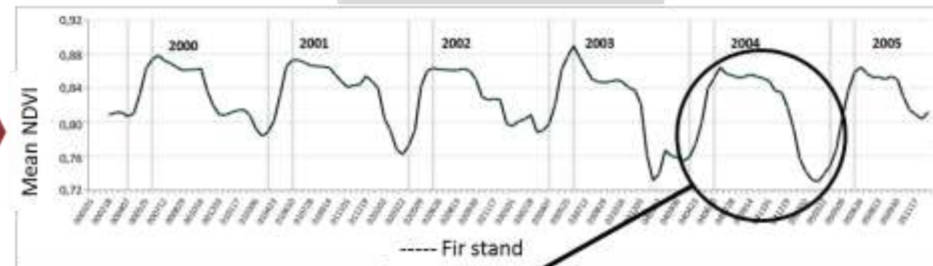
Remote sensing data = MODIS Terra NDVI Time Series (2000-2016)

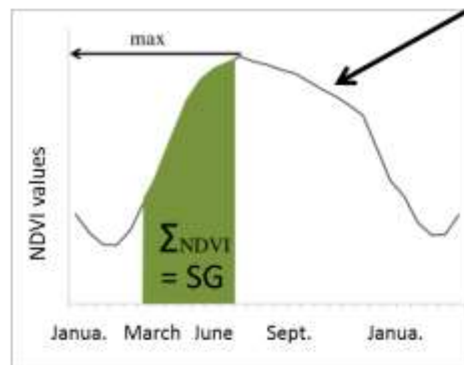
- Moderate Resolution Imagery Spectroradiometer (MODIS)
- free data
- spatial resolution 250m (pixel=6.5 ha)
- Every 8 or 16-days

Analysis of trends in MODIS NDVI time series



Pluriannual NDVI cycle





Spring Greenness (SG)

Vegetation index **NDVI**
(Normalized Difference Vegetation Index)

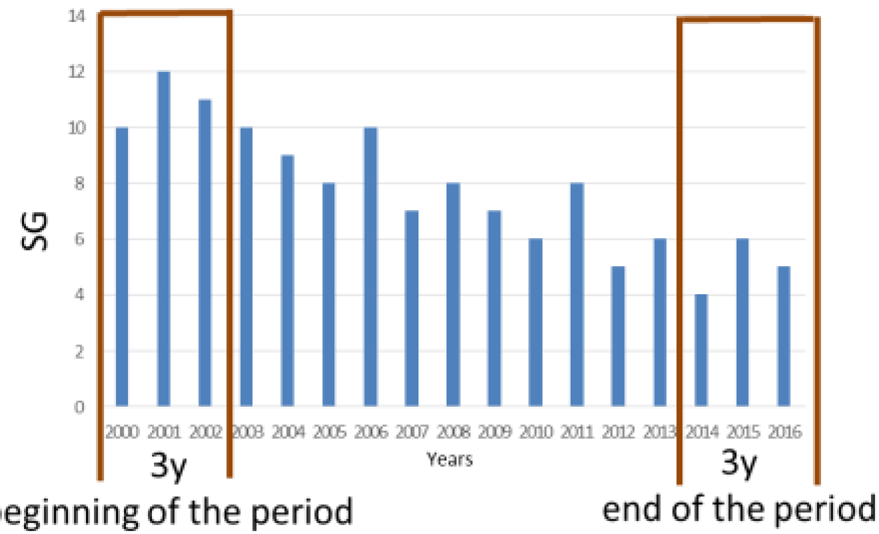
NDVI = (PIR-R)/(PIR+R)

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)

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

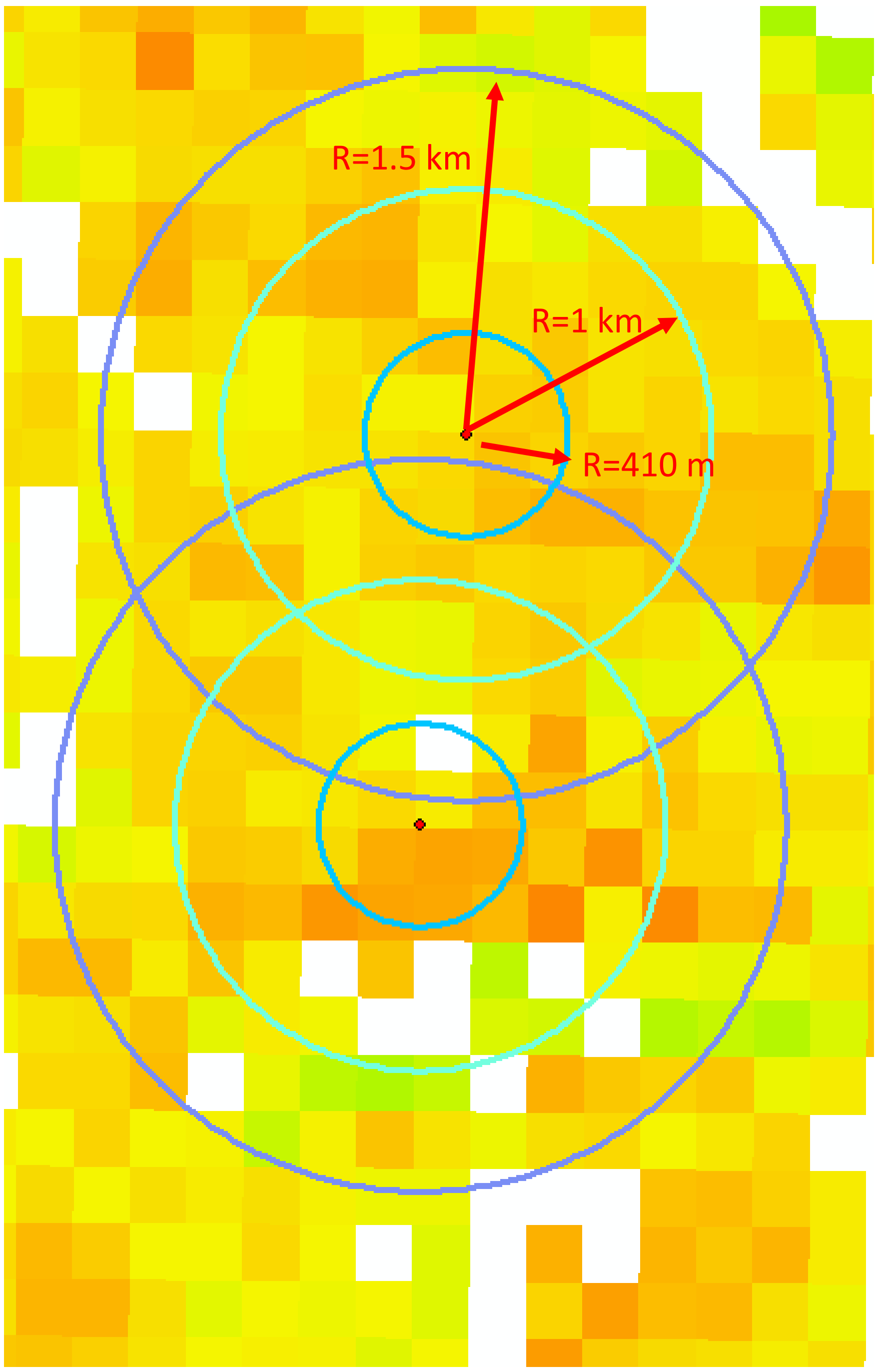
Index of vitality trend

$$Dnor\_SG = \frac{\max_{2014}^{2016} SG - \max_{2000}^{2002} SG}{\max_{2000}^{2002} SG}$$

Lambert J. et al. (2013) Monitoring forest decline through remote sensing time series analysis. GIScience & Remote Sensing 50 (4): 437-457

Dieback level at the landscape scale

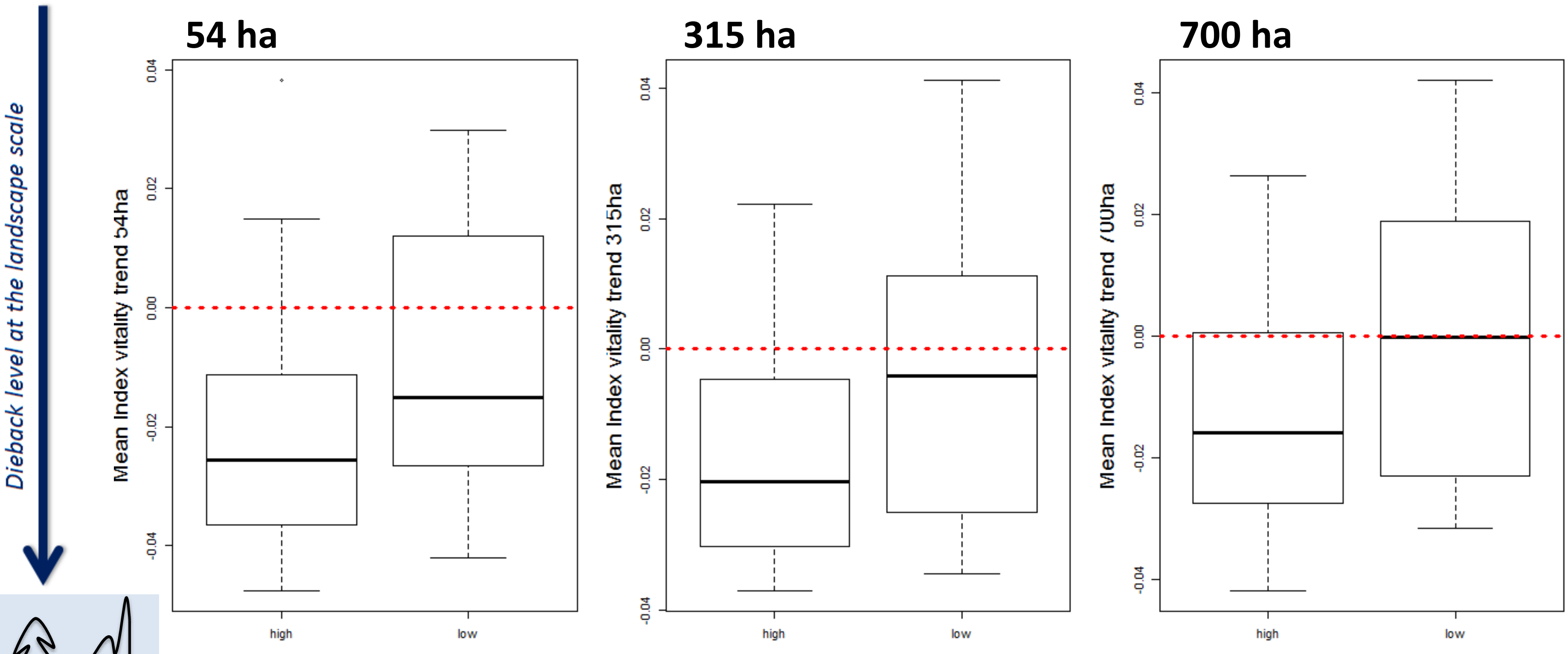
Dieback scores at 3 spatial scales centered on each sampling plot



CLIMTREE

Post-hoc assessment of the sampling design

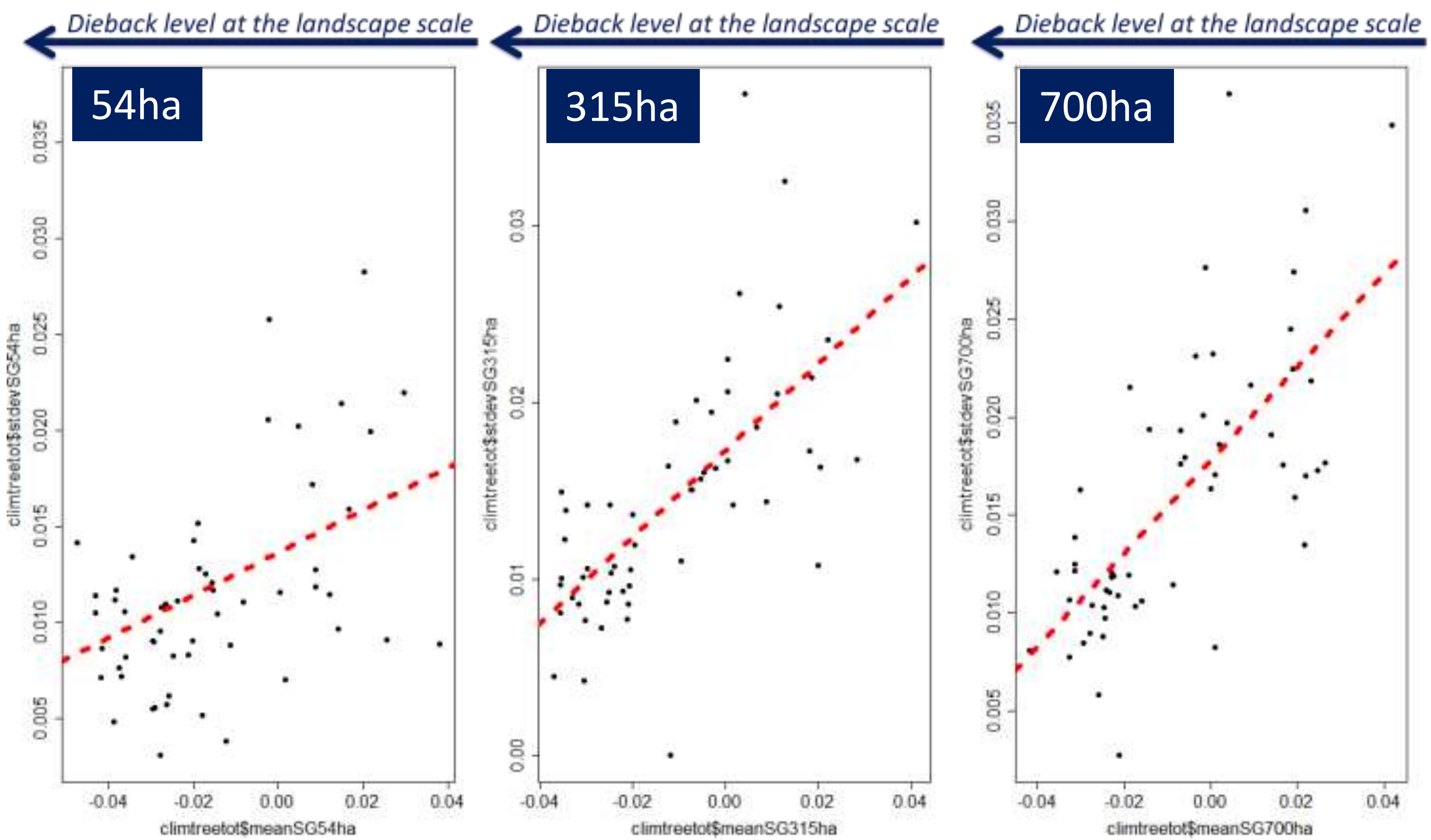
At the landscape scale



CLIMTREE

Post-hoc assessment of the sampling design

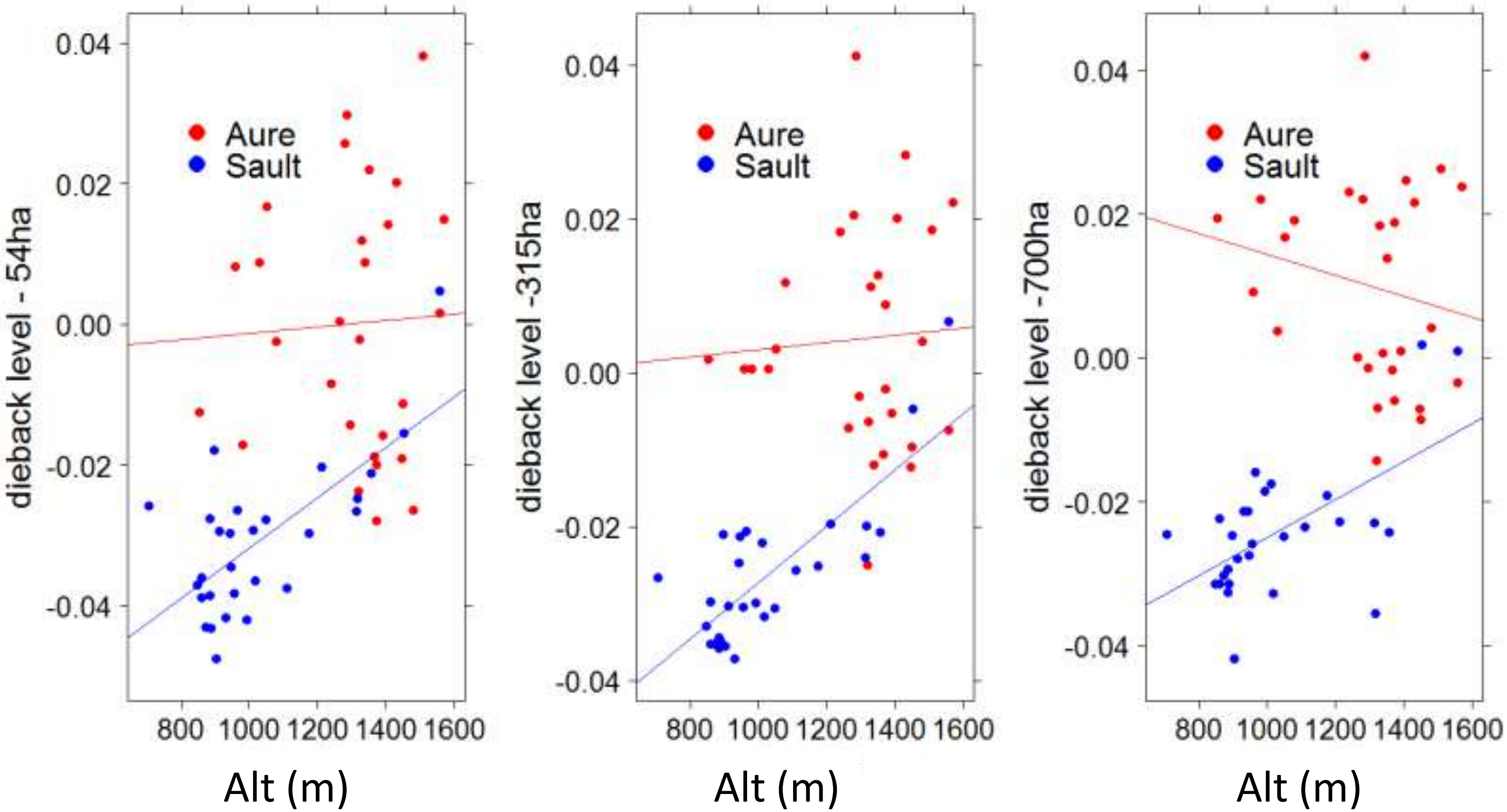
The higher the dieback level at the landscape scale, the less heterogeneous the landscape in terms of dieback level



CLIMTREE

Post-hoc assessment of the sampling design

Dieback level at the landscape scale



CLIMTREE

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

CLIMTREE

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)

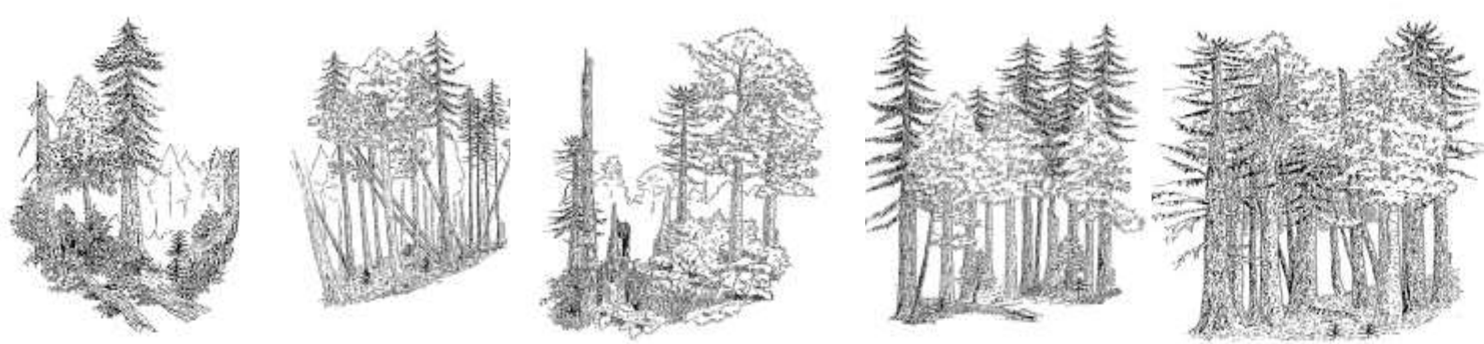
Tree-related microhabitats inventory on living trees

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

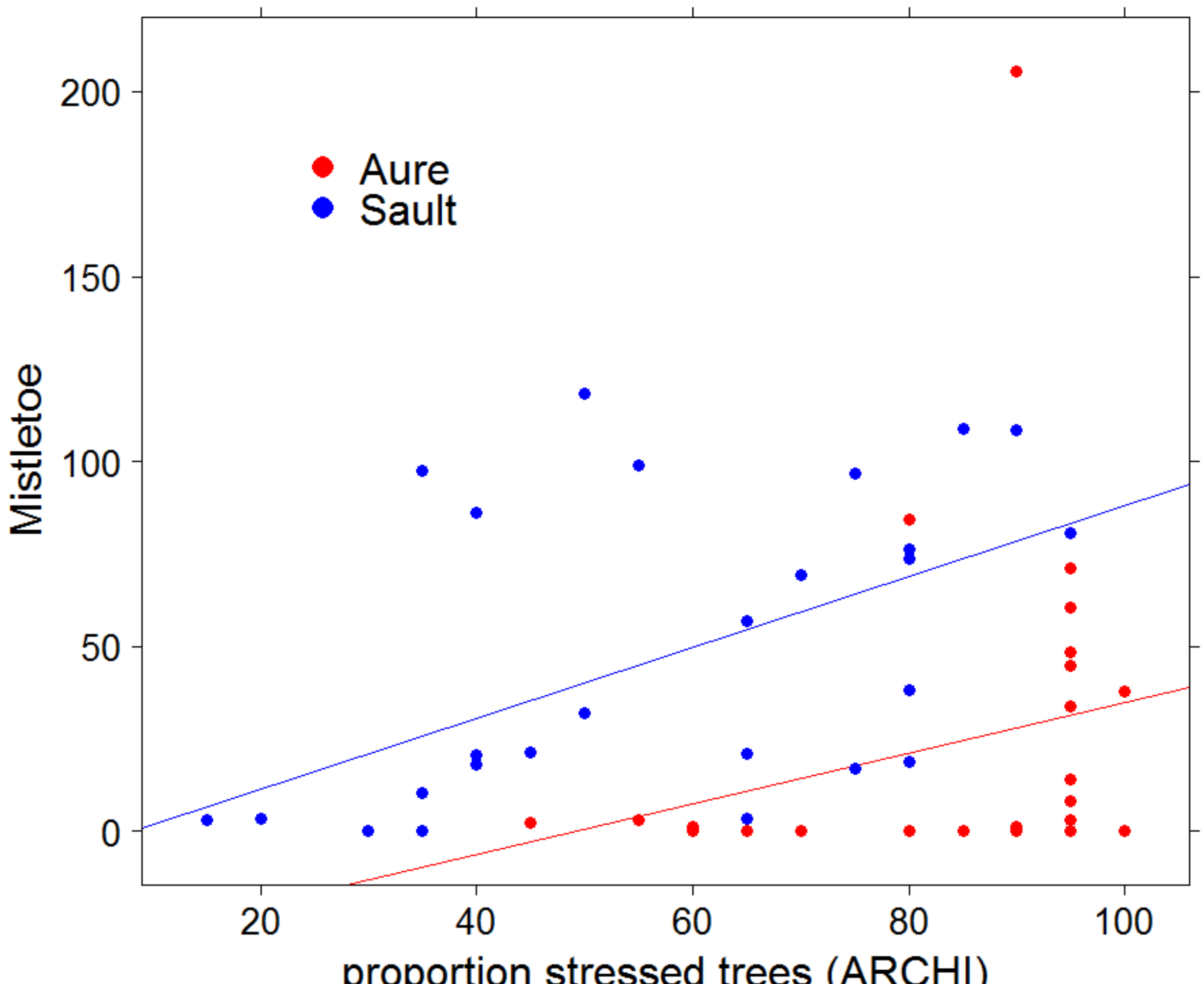
Canopy opening (spherical crown densiometer)

IBP 10 criteria (1ha)

CLIMTREE



Stand dieback level and density of mistletoe-bearing trees

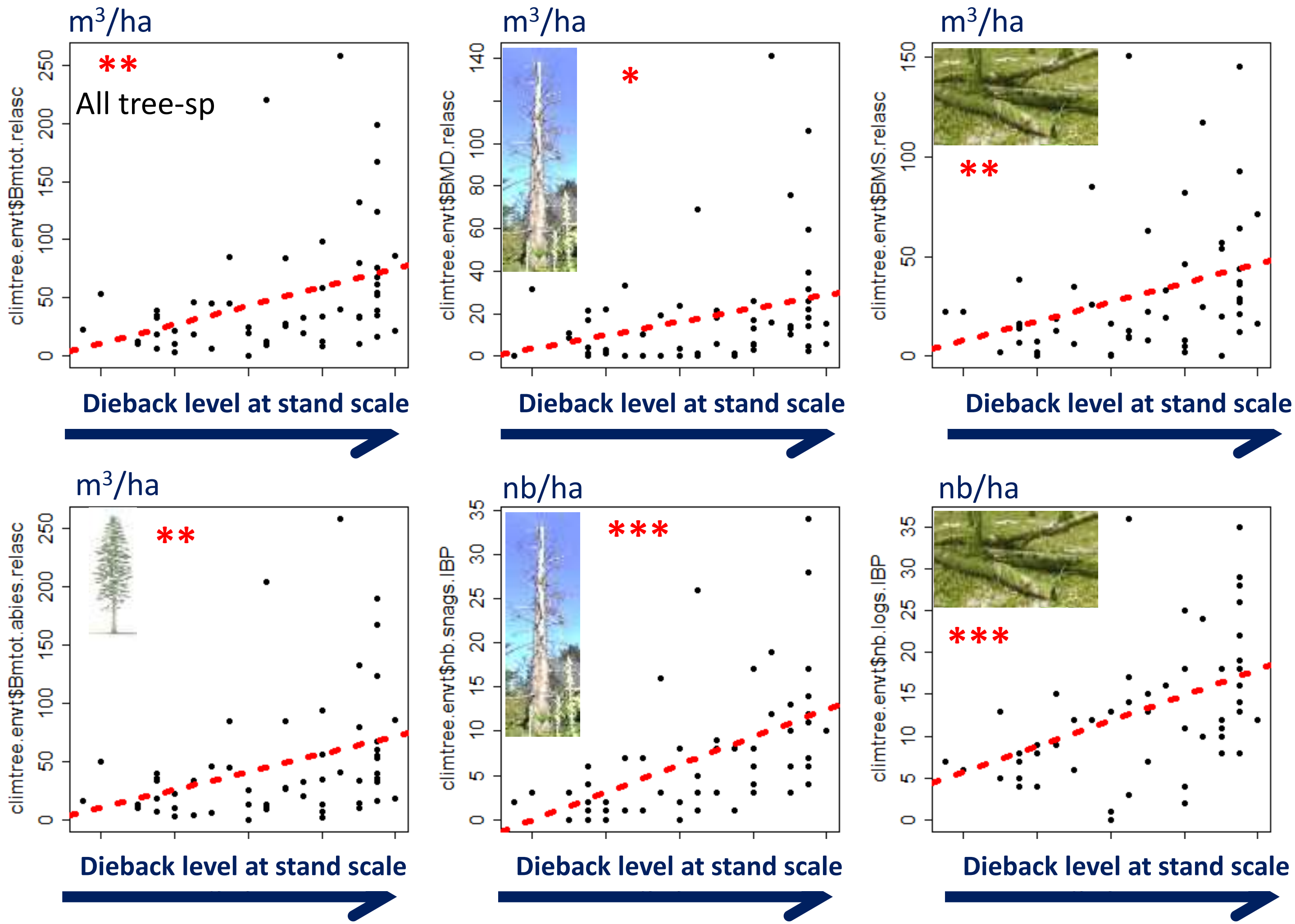


CLIMTREE

Effects of dieback level on forest structure

An overall increase in deadwood, mainly fir deadwood

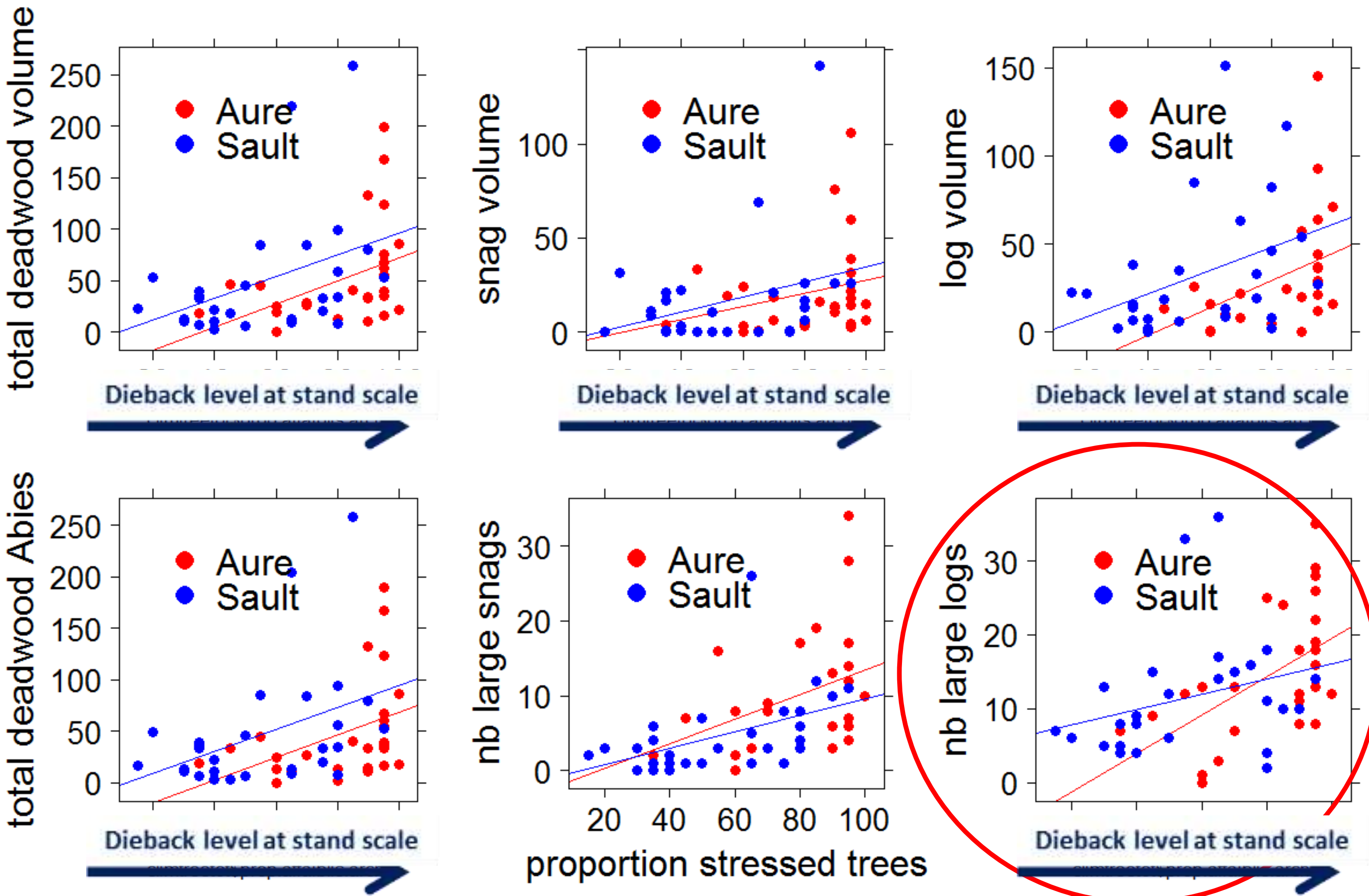
Mixed models (« region » as a random variable)



CLIMTREE

Effects of dieback level on forest structure

xy plots by region

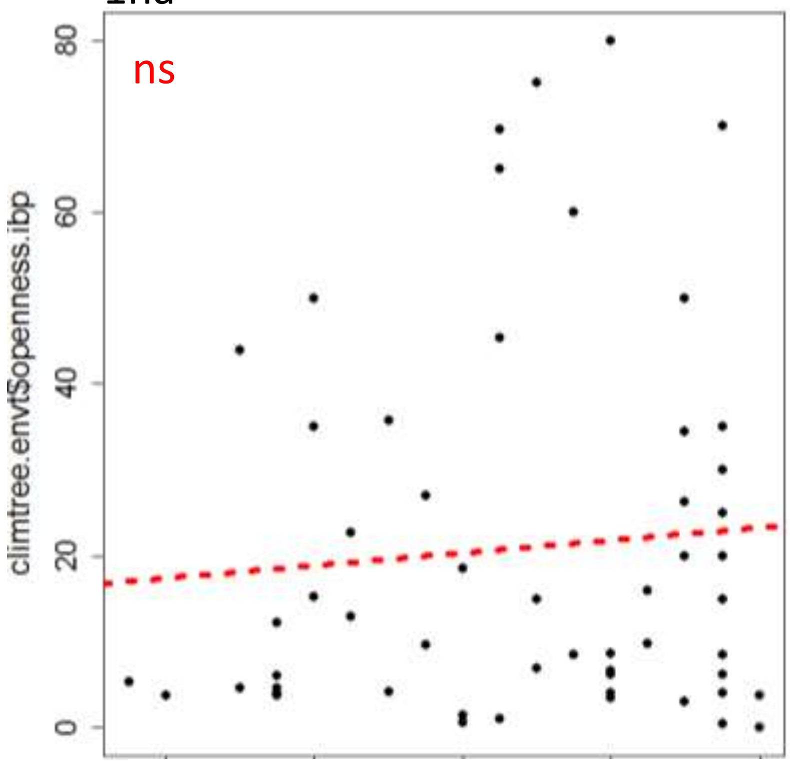


CLIMTREE

Effects of dieback level on forest structure

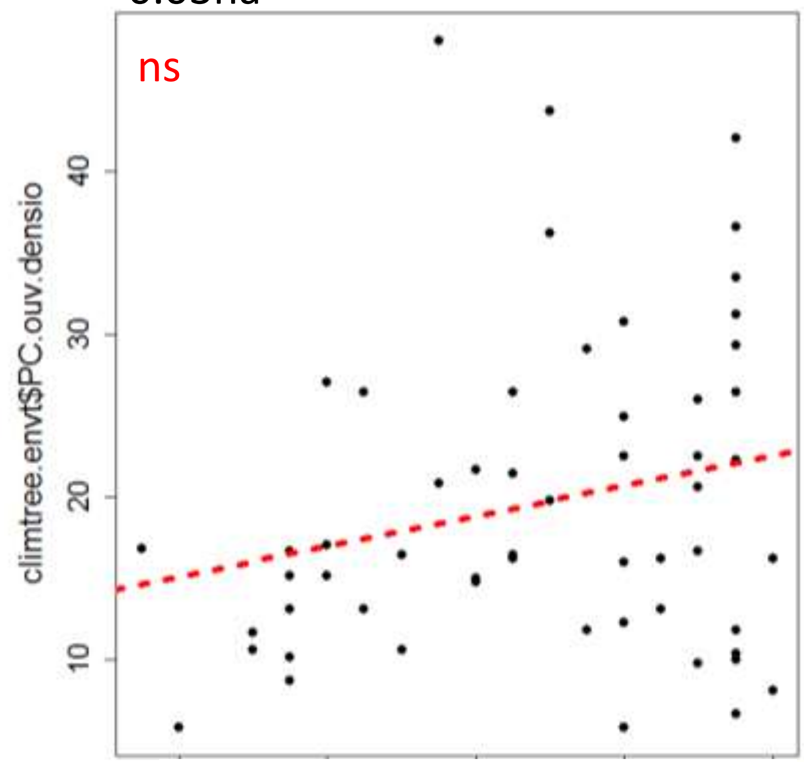
A non-significant increase in open-canopy conditions

1ha



Dieback level at stand scale

0.03ha

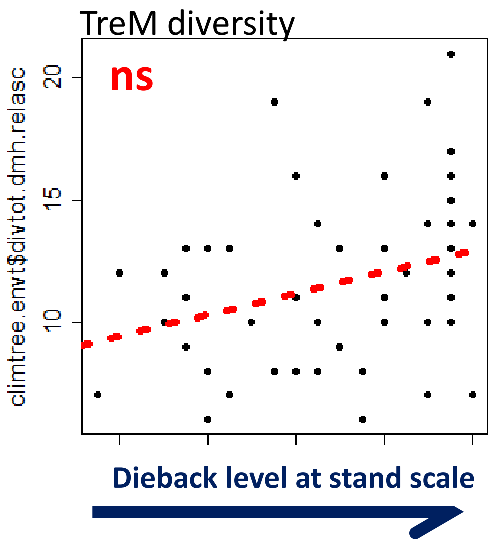


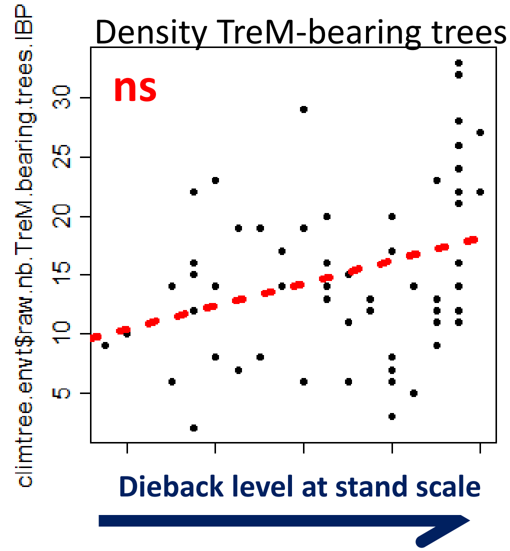
Dieback level at stand scale

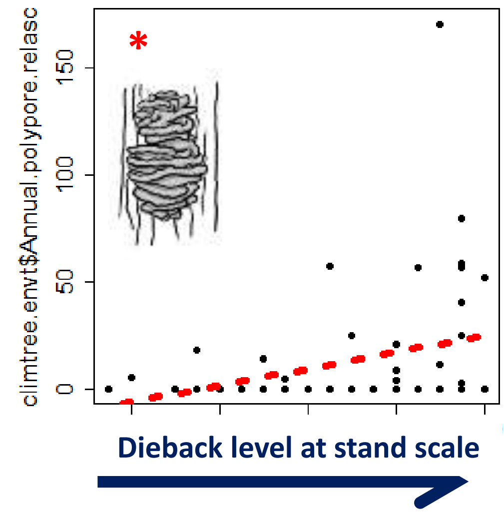
CLIMTREE

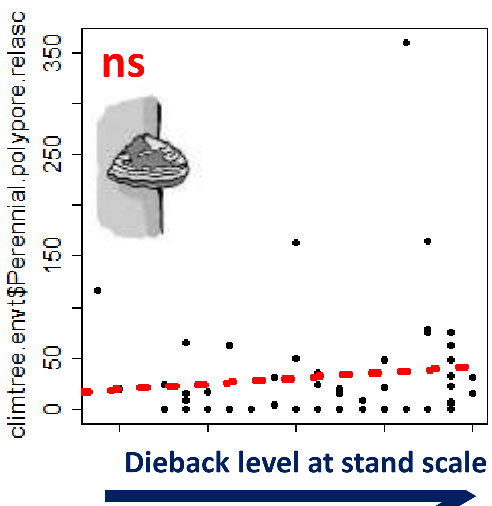
Effects of dieback level on forest structure

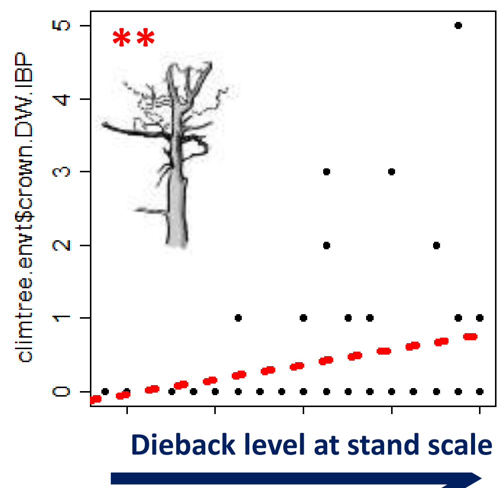
A slight increase in tree-related microhabitat density

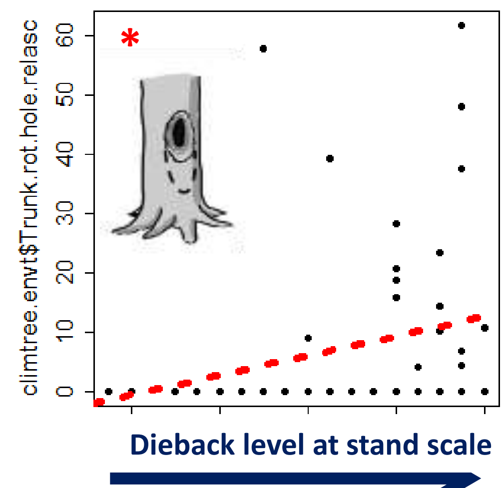










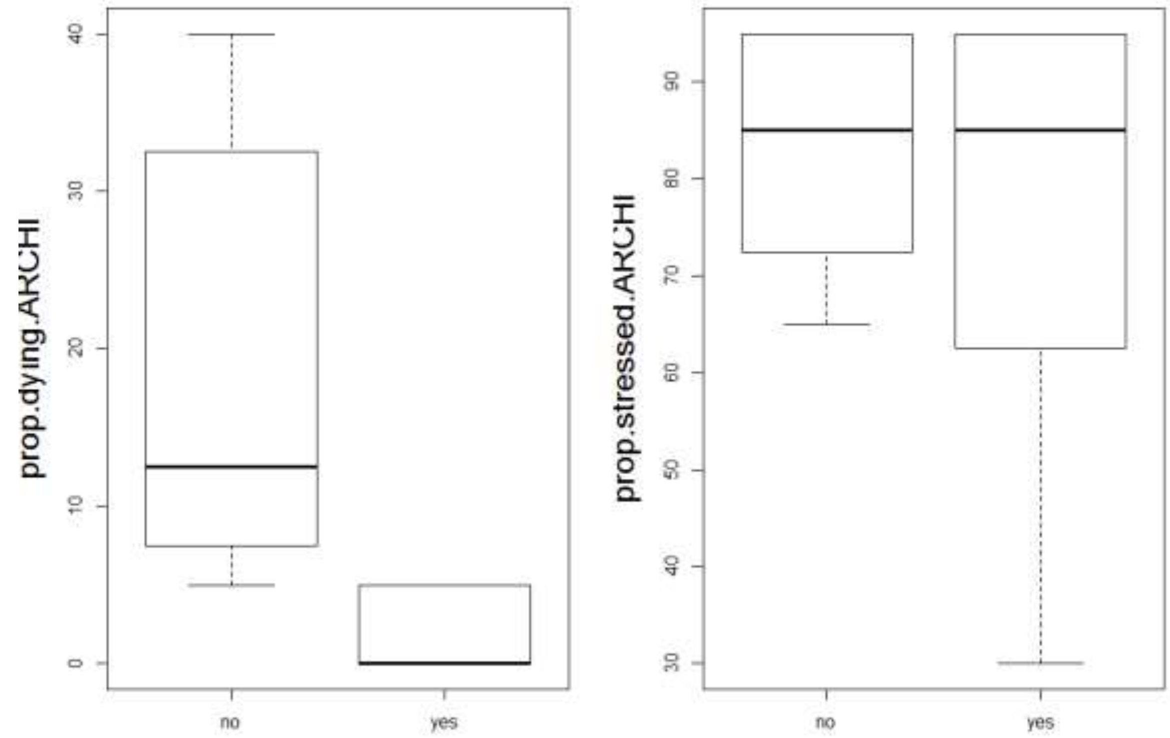


CLIMTREE

Effects of salvage logging on forest structure in declining stands

Selection felling of dying fir trees…

But not of all stressed trees

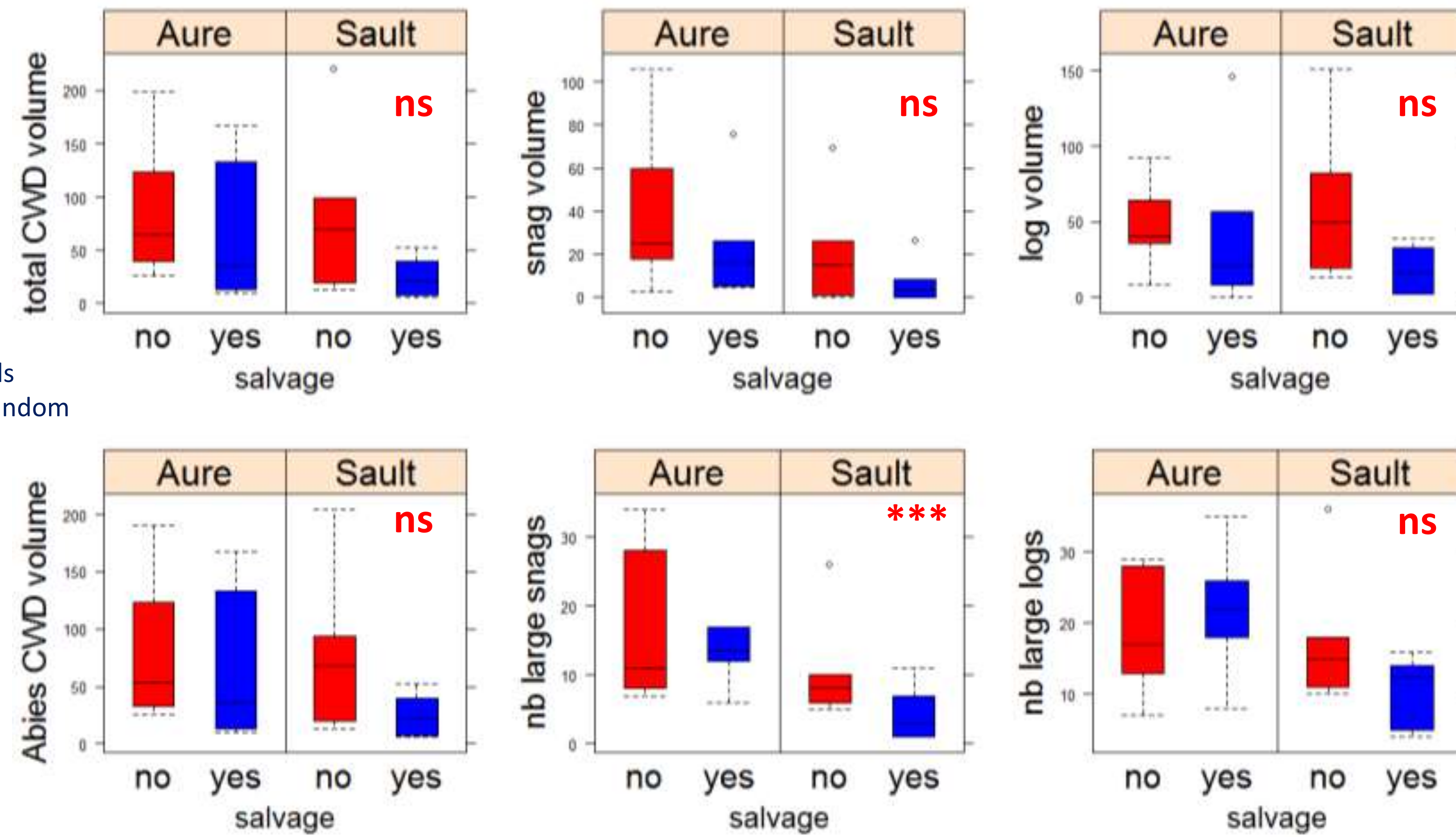


CLIMTREE

Effects of salvage logging on forest structure

Overall but slight decrease in deadwood…

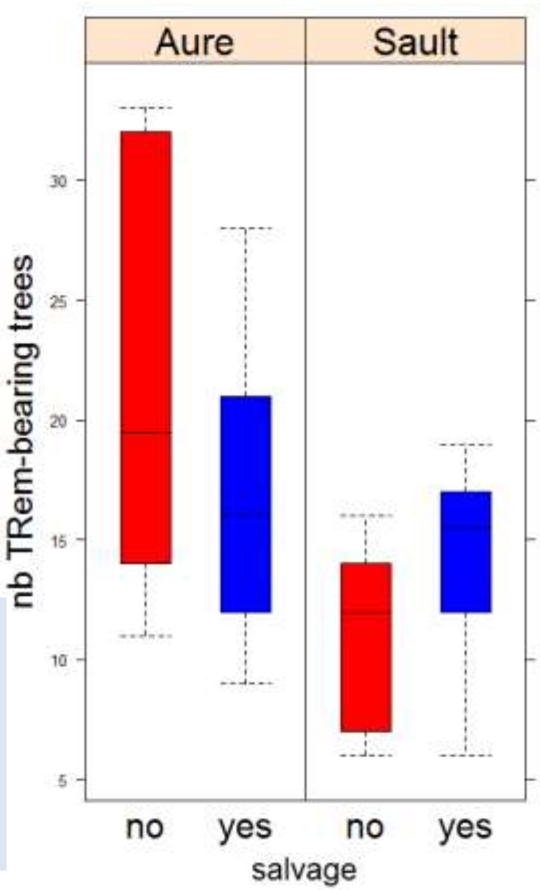
Mixed models
(« region » as a random variable)

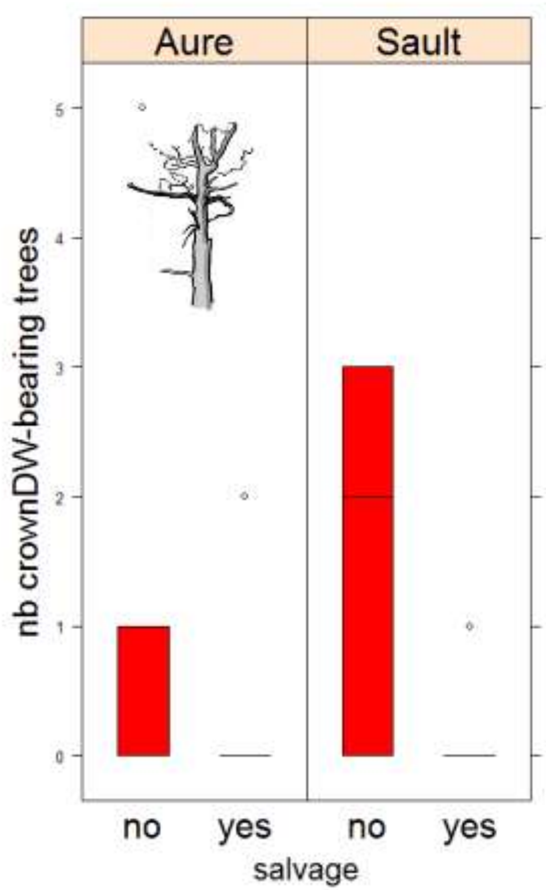


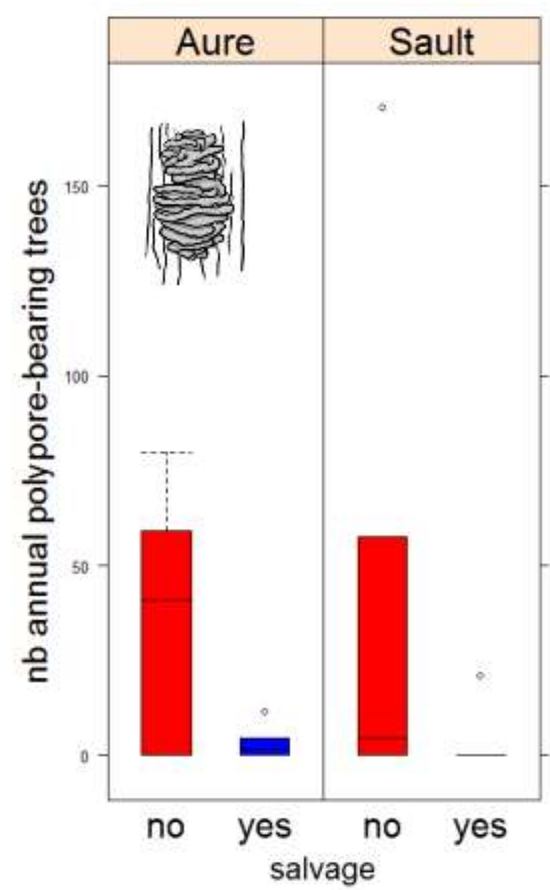
CLIMTREE

Effects of salvage logging on forest structure

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







CLIMTREE

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	-	(+)	++	(+)

CLIMTREE

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

CLIMTREE

Insect datasets

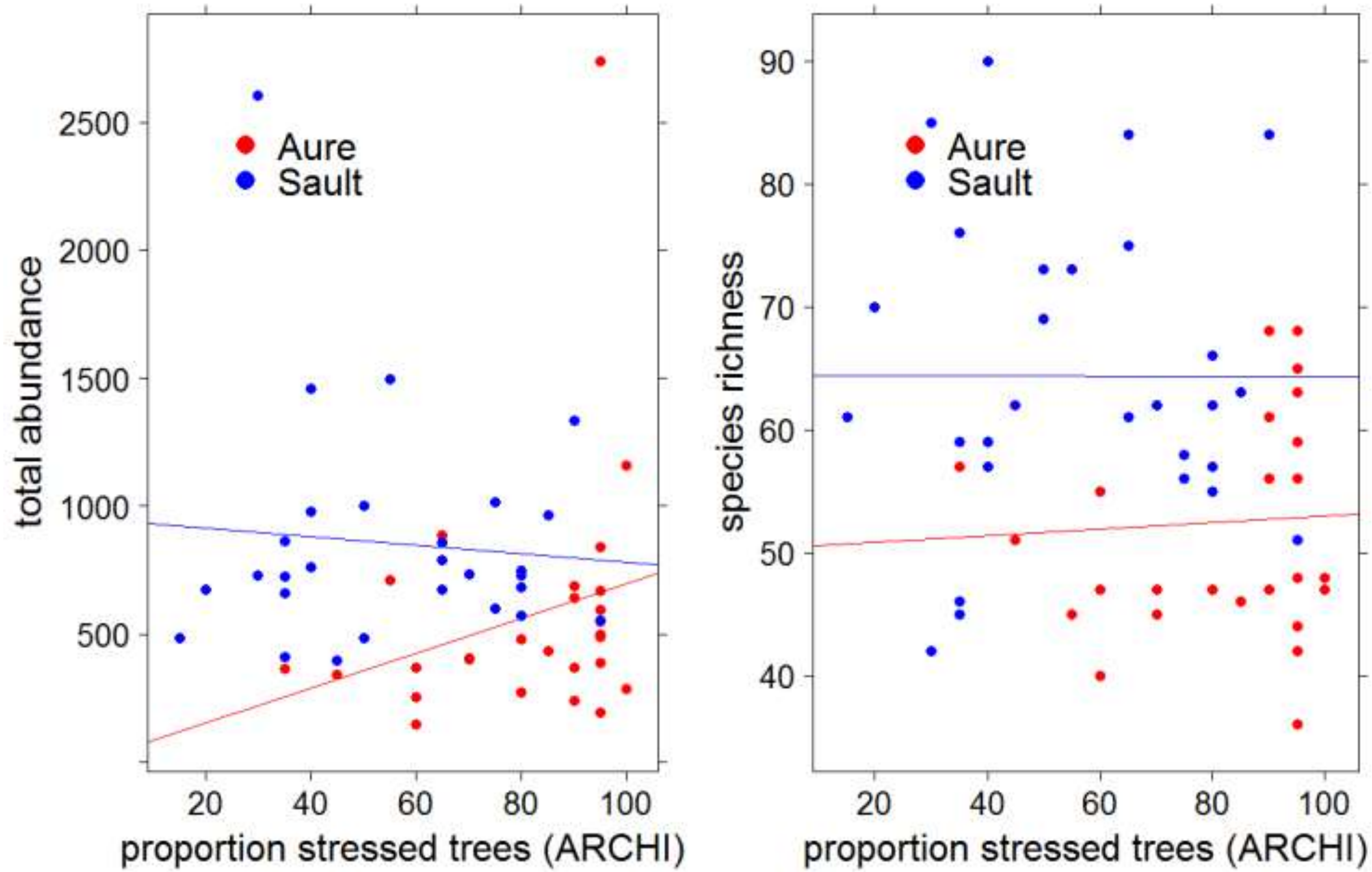
	Nb individuals	Nb species
Malaise traps	Cf L. Sire	
Fight-interception traps	40013	284

Families still at work (Staphylinids, Mordellids, Scraptiids…)

CLIMTREE

Preliminary results about beetle response to dieback intensity and management

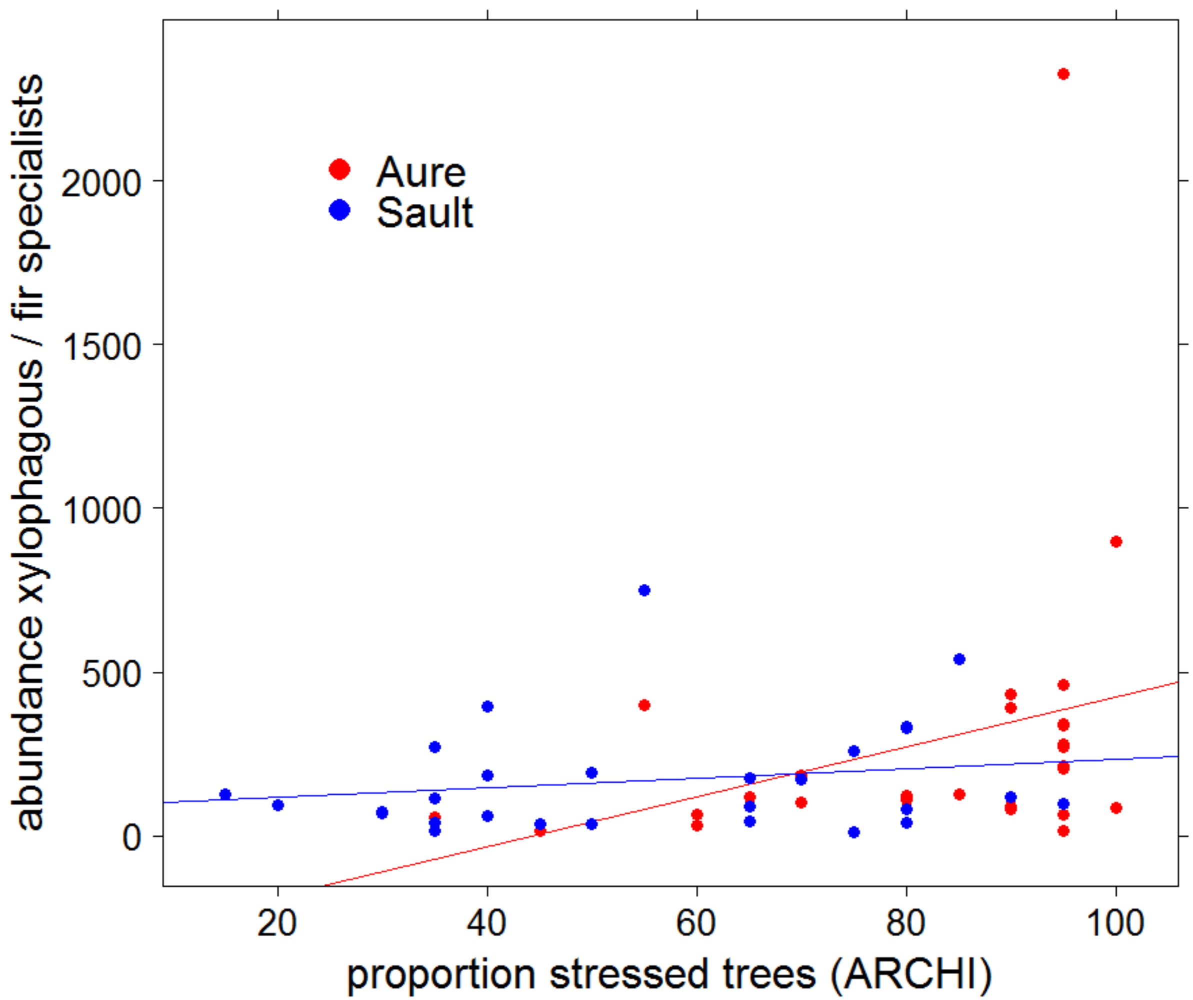
No overall increase in local abundance or species richness with local dieback level



CLIMTREE

Response to dieback level at the local scale

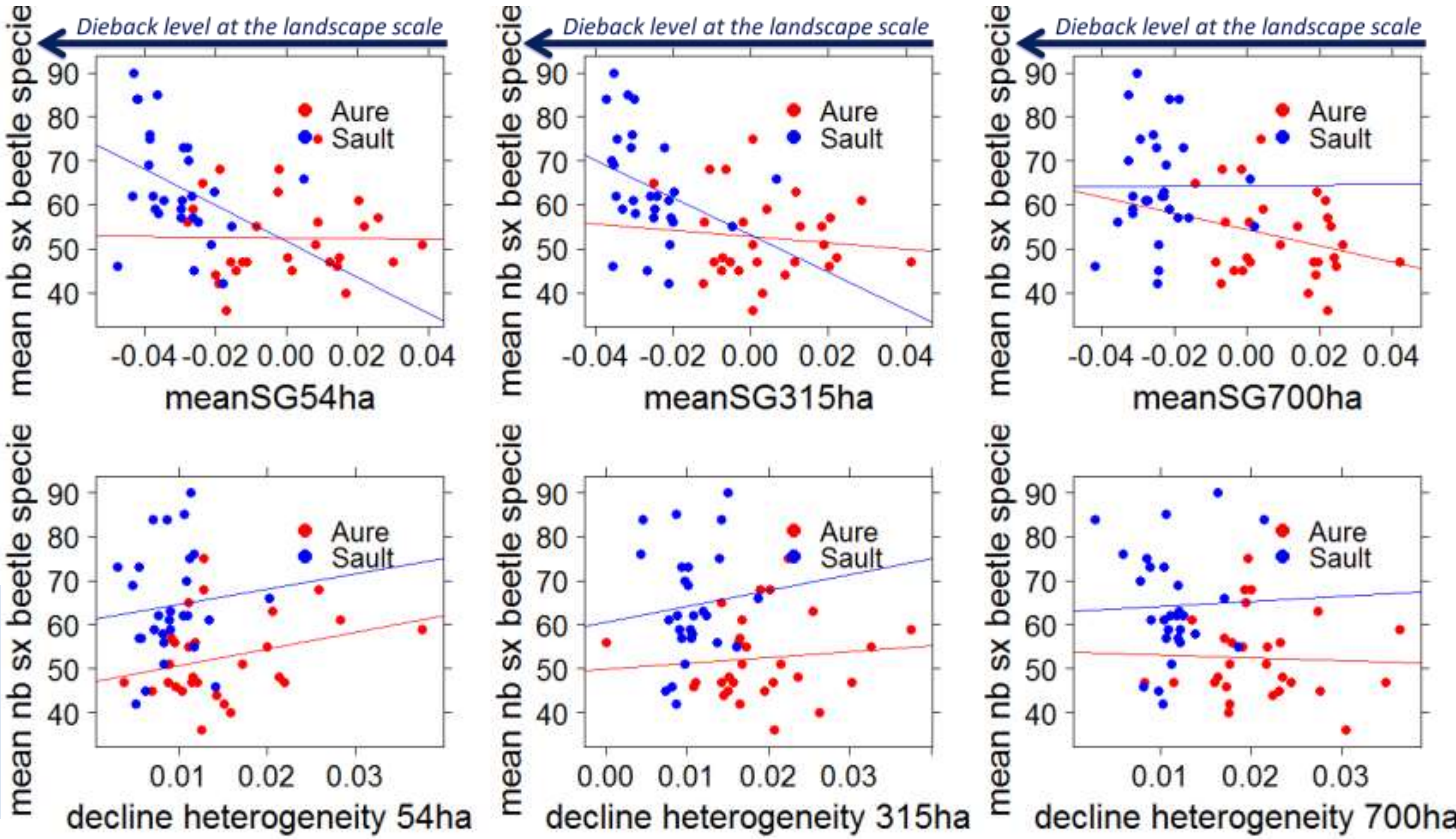
Slight increase in local abundance of xylophagous fir specialists with local dieback level (Aure site)



CLIMTREE

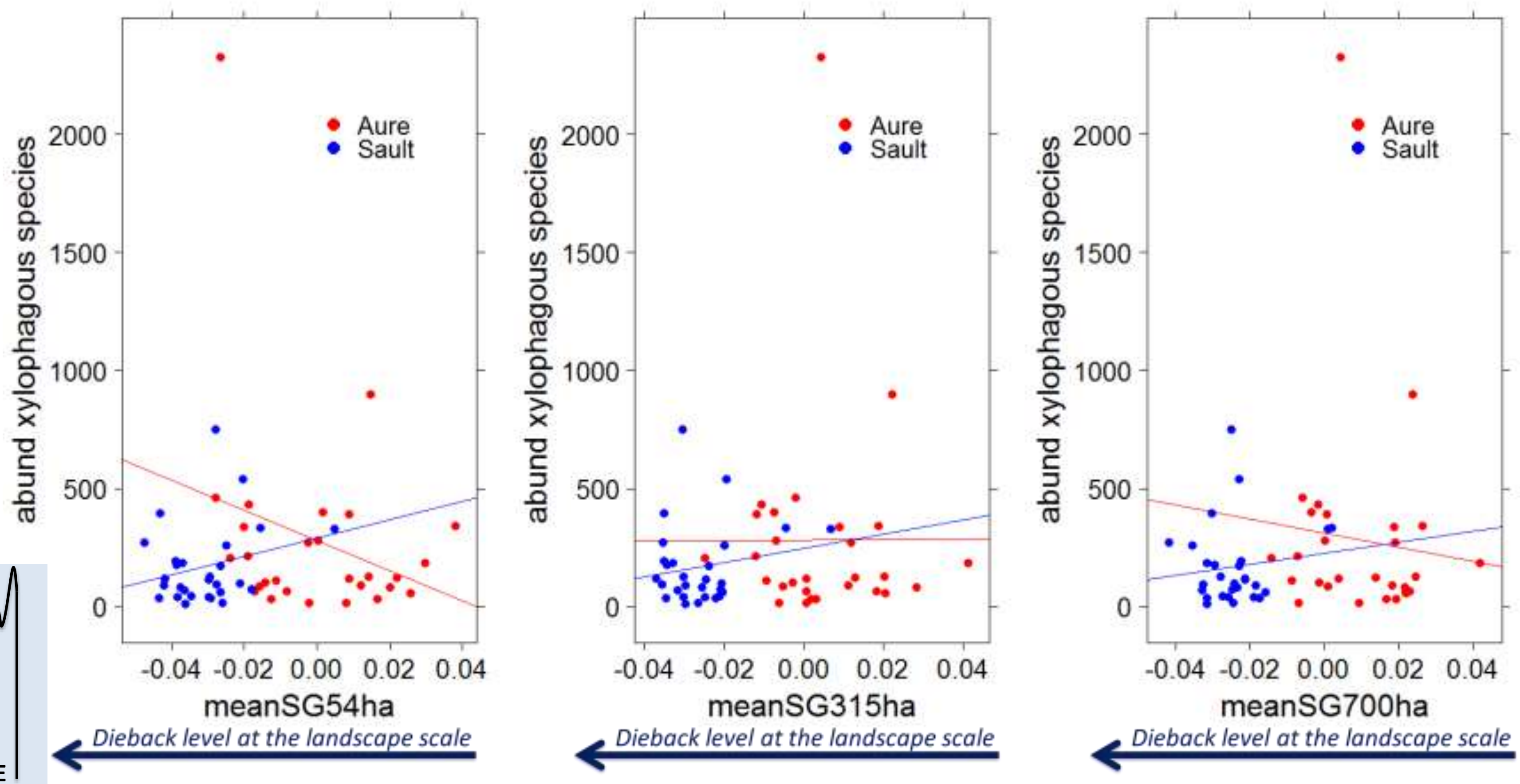
Response to dieback level at the landscape scale

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

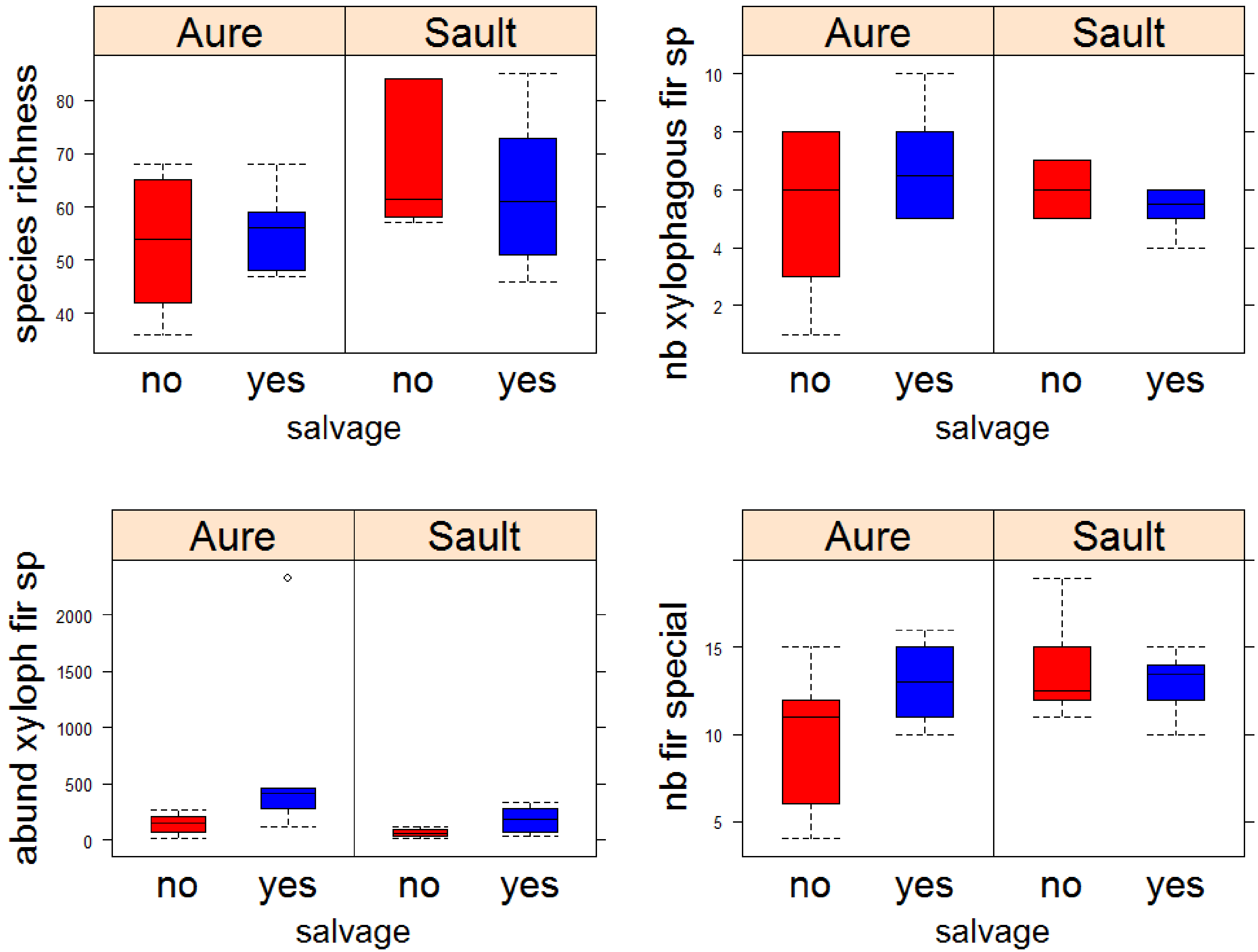
No increase in local abundance of xylophagous fir specialists with landscape dieback level



CLIMTREE

Response to salvage logging

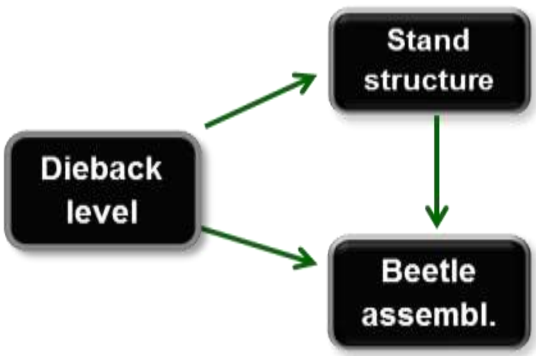
No overall increase of sx beetles in unsalvaged stands…



CLIMTREE

Perspectives

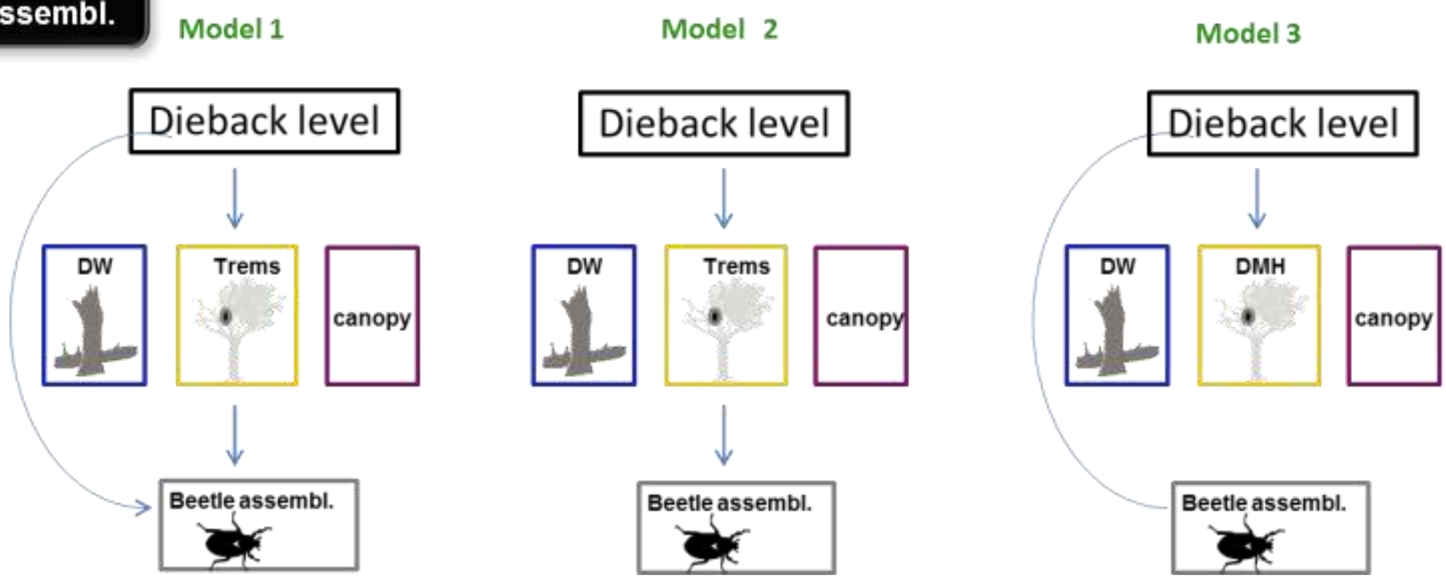
Further analyses after dataset completion



Analyses of response in :

- sp composition
- niche traits CWM/Fdis
- …

piecewiseSEM
(Shipley 2009, 2013 ; Lefcheck 2015)



SEM conceptual model

CLIMTREE

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?

Germany
2016
Spruce

Treatment	abtot	rs
Ips 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

France
2017
Silver fir

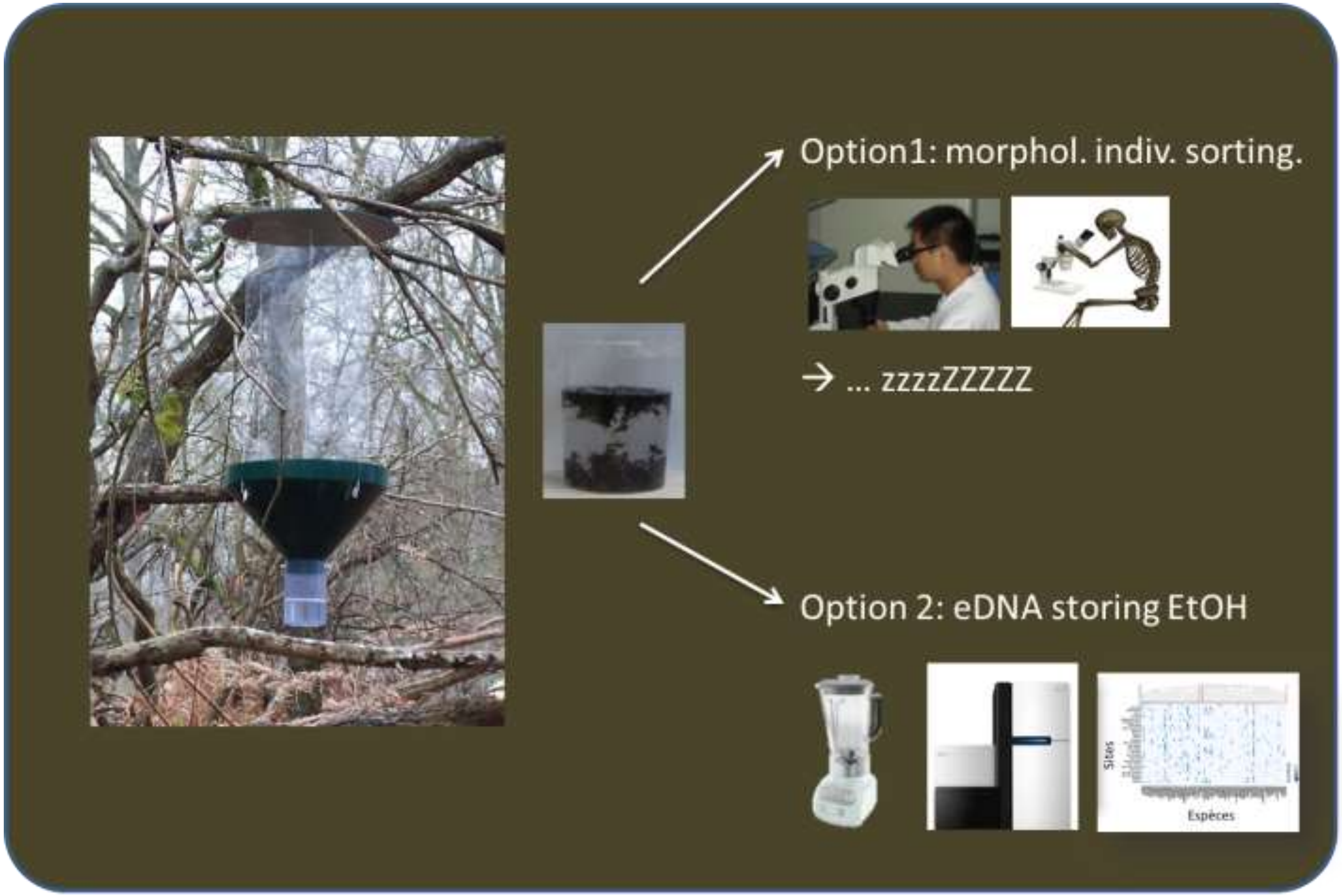
Treatment	abtot	rs
declining stands (n=24 plots)	17095	227
salvage (n=12 plots)	11395	192
vital fir forest (n=20 plots)	11523	210
TOTAL	40013	284

Several sx families at work…

CLIMTREE

Further analyses inside the Climtree project

Cf Lucas

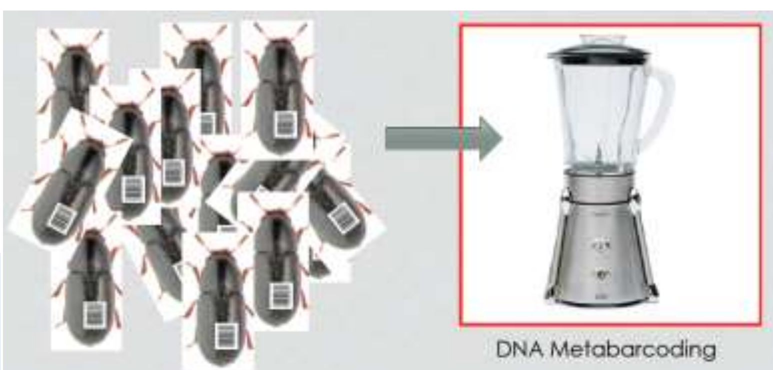


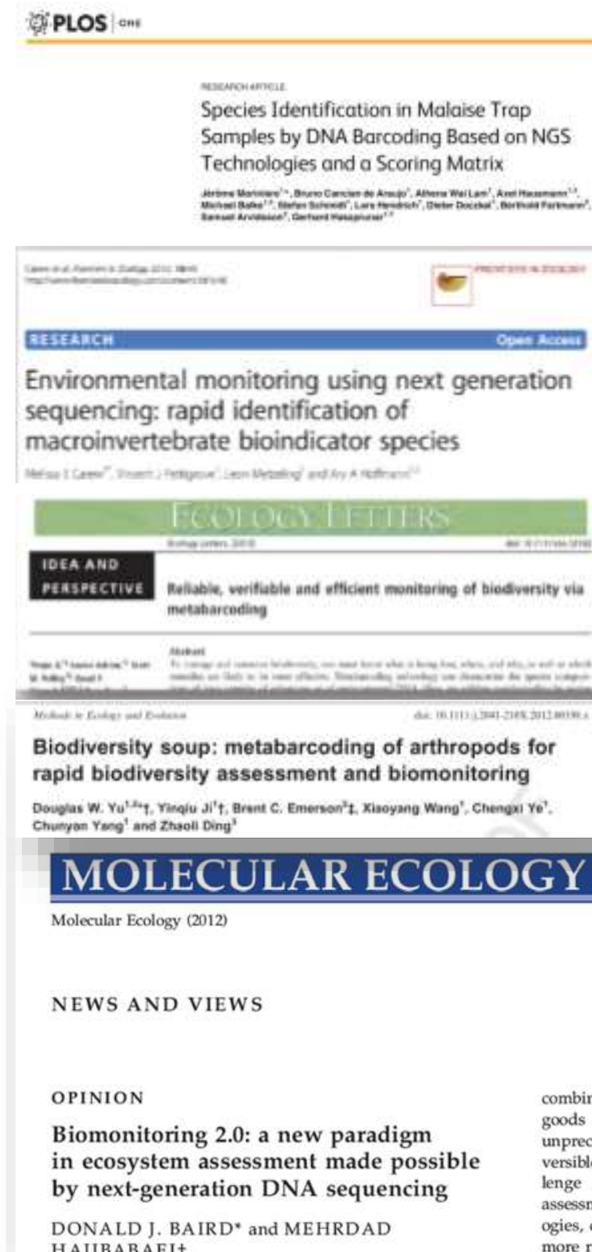
CLIMTREE

Further analyses inside the Climtree project

Response of Malaise trapped insect assemblages to silver fir forest dieback

Cf Lucas




PLOS ONE

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

RESEARCH Open Access

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

ECOLOGY LETTERS

IDEA AND PERSPECTIVE

Reliable, verifiable and efficient monitoring of biodiversity via metabarcoding

Methods in Ecology and Evolution

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

Douglas W. Yu, Yinqiu Ji, Brent C. Emerson, Xiaoyang Wang, Chengxi Ye, Chunyan Yang and Zhaoli Ding

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†

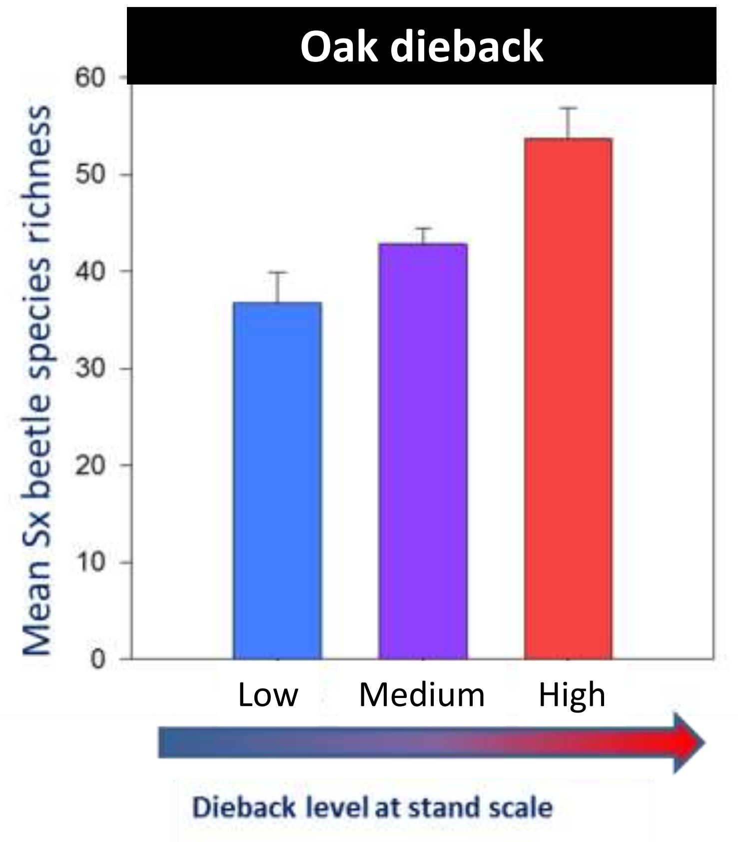
CLIMTREE

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



CLIMTREE

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
- Keesing 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).

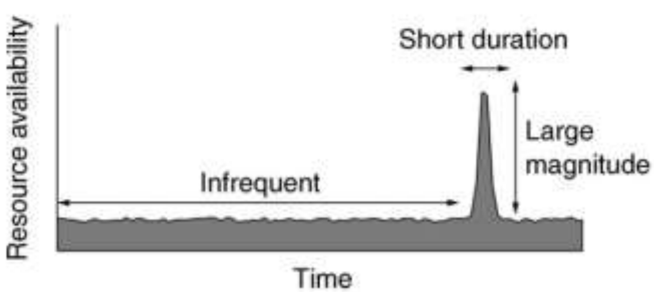


Fig. 1. Resource pulses are events of increased resource availability over time that combine low frequency, short duration, and large magnitude.

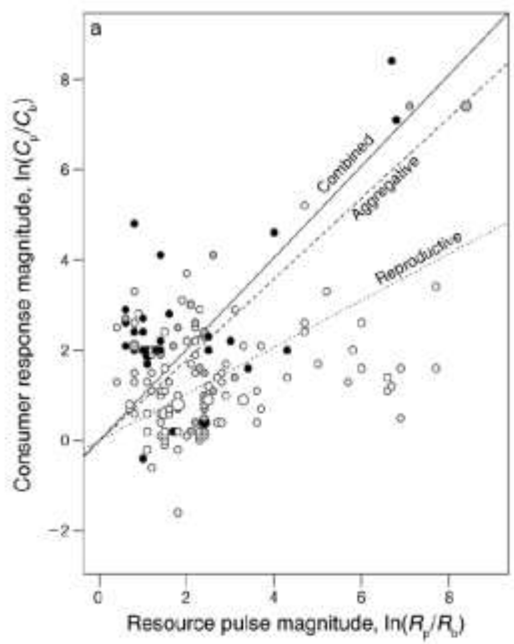
Ecology, 89(3), 2008, pp. 621–634

WHAT CAN WE LEARN FROM RESOURCE PULSES?

Louie H. Yang,[1,3] Justin L. Bastow,[1] Kenneth O. Spence,[2] and Amber N. Wright[1]

Conceptual underpinnings

Relationship between numerical response of primary consumers and resource pulse magnitude



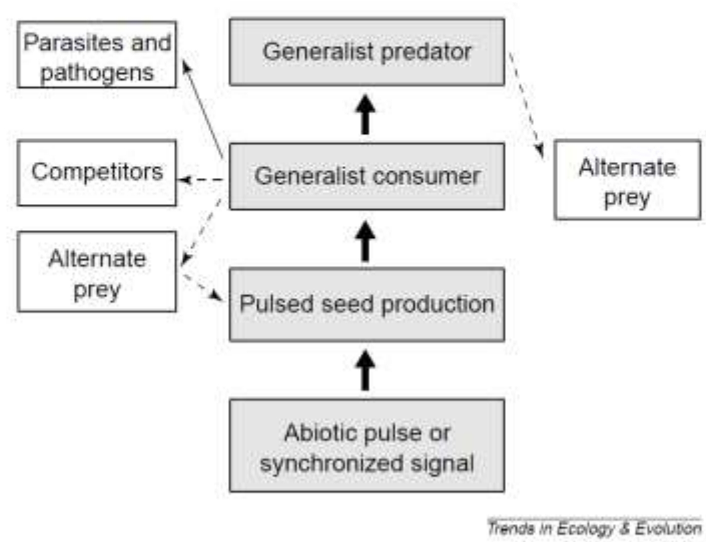
Ecological Monographs, 80(1), 2010, pp. 125–151

A meta-analysis of resource pulse–consumer interactions

Louie H. Yang,[1,2,3,6] Kyle F. Edwards,[3] Jarrett E. Byrnes,[2,3] Justin L. Bastow,[3,4] Amber N. Wright,[3] and Kenneth O. Spence[5]

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