Effects of tree species diversity on resistance to biotic disturbances in planted forests

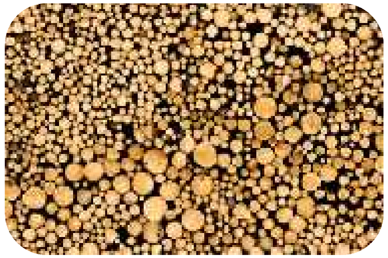
http://www.waldwissen.net

Hervé Jactel, Johana Boberg , Eckehard Brockerhoff, Bastien Castagneyrol, Julia Koricheva, Nicolas Meurisse

INRA SCIENCE & IMPACT
SLU Swedish University of Agricultural Sciences
SCION forests·products·innovation
ROYAL HOLLOWAY UNIVERSITY OF LONDON
IUFRO

An urgent need for new, planted forests

1. to meet the social demand for wood products including energy wood



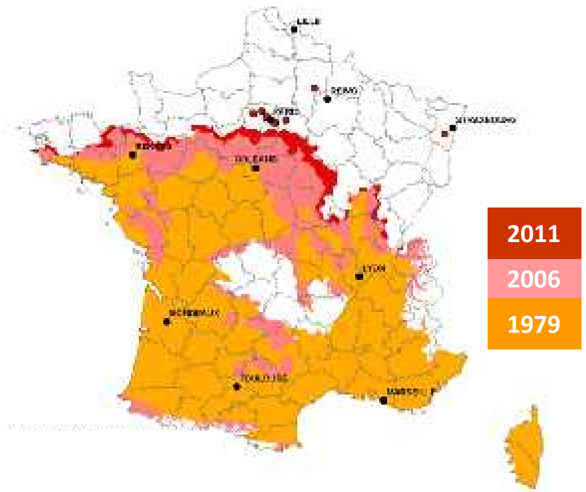
2. to contribute to climate change mitigation through carbon sequestration

3. to alleviate the logging pressure on natural forests and preserve biodiversity

Rising threats due to global change

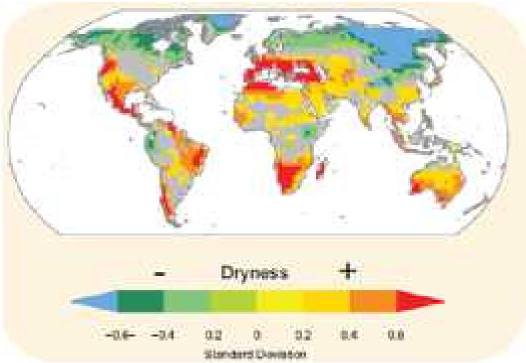
1. Climate change

↗ temperatures trigger pest outbreaks and range expansion



Pine processionary moth

↗ droughts increase tree susceptibility to infection



Global Change Biology

Global Change Biology (2012) 18, 267–276, doi: 10.1111/j.1365-2486.2011.02512.x

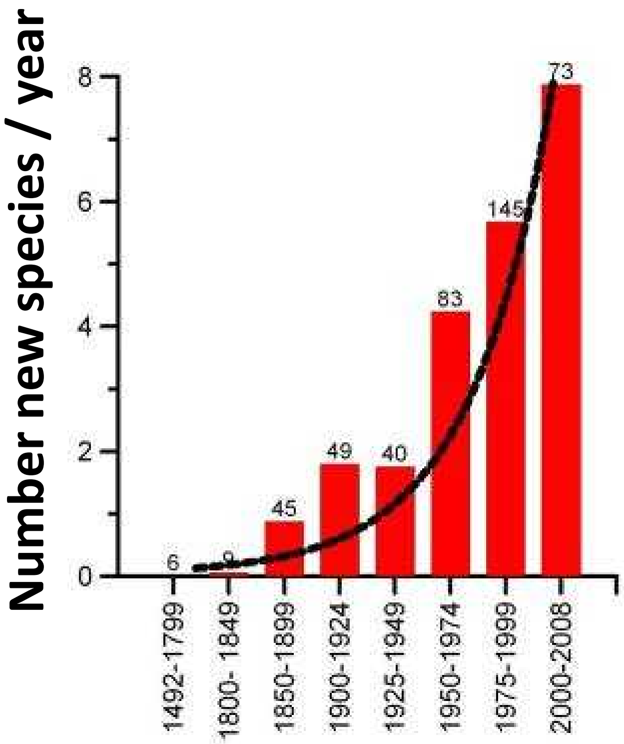
Drought effects on damage by forest insects and pathogens: a meta-analysis

HERVÉ JACTEL*, JÉRÔME PETIT†, MARIE-LAURE DESPREZ-LOUSTAU*, SYLVAIN DELZON*, DOMINIQUE PIOU‡, ANDREA BATTISTI§ and JULIA KORICHEVA¶

Rising threats due to global change

2. World trade

↗ globalization results in more biological invasions



Exotic arthropods

Dryocosmus kuriphilus
Origine: China

Challenge: design new planted forests less vulnerable on the long term

- Trees are being planted for decades or centuries
- Trees will experience disturbances never met before

Is mixing tree species in planted forest an option?

- **Diversity – resistance relationships in grasslands**

LETTER

doi:10.1038/nature15374

Biodiversity increases the resistance of ecosystem productivity to climate extremes

Forest Isbell[1], Dylan Craven[2,3], John Connolly[4], Michel Loreau[5], Bernhard Schmid[6], Carl Beierkuhnlein[7], T. Martijn Bezemer[8], Catherine Bonin[9], Helge Bruelheide[2,10], Enrica de Luca[6], Anne Ebeling[11], John N. Griffin[12], Qinfeng Guo[13], Yann Hautier[14], Andy Hector[15], Anke Jentsch[16], Jürgen Kreyling[17], Vojtěch Lanta[18], Pete Manning[19], Sebastian T. Meyer[20], Akira S. Mori[21], Shahid Naeem[22], Pascal A. Niklaus[6], H. Wayne Polley[23], Peter B. Reich, Christiane Roscher, Eric W. Seabloom[1], Melinda D. Smith[27], Madhav P. Thakur, David Tilman, Benjamin F. Tracy, Wim H. van der Putten, Jasper van Ruijven[31], Alexandra Weigelt, Wolfgang W. Weisser, Brian Wilsey & Nico Eisenhauer

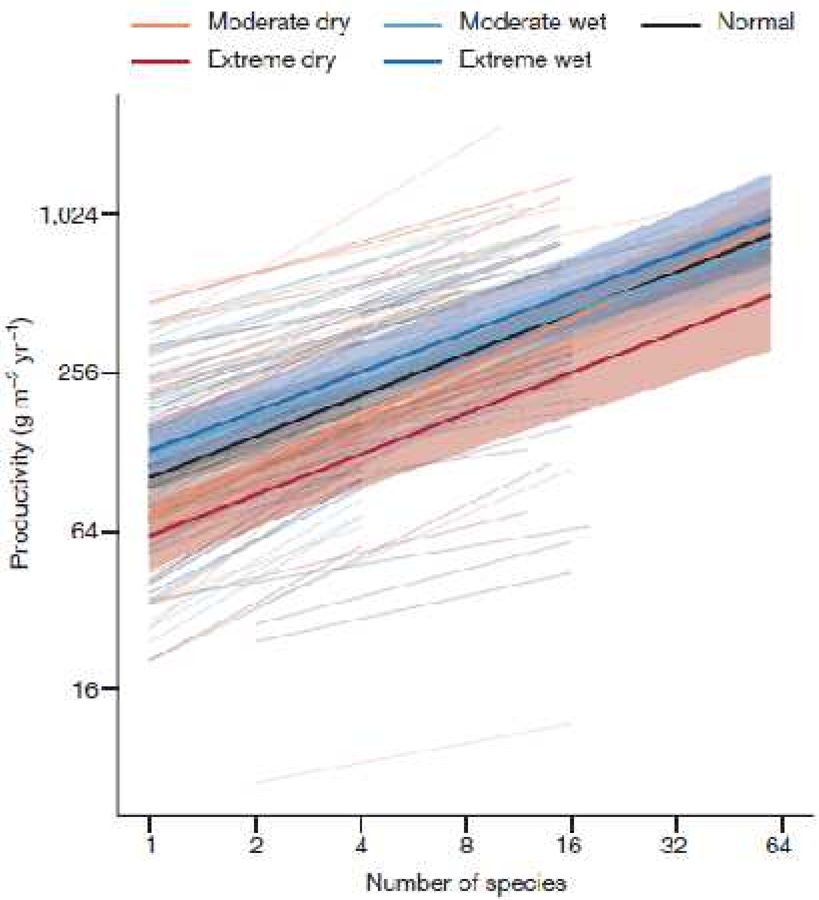


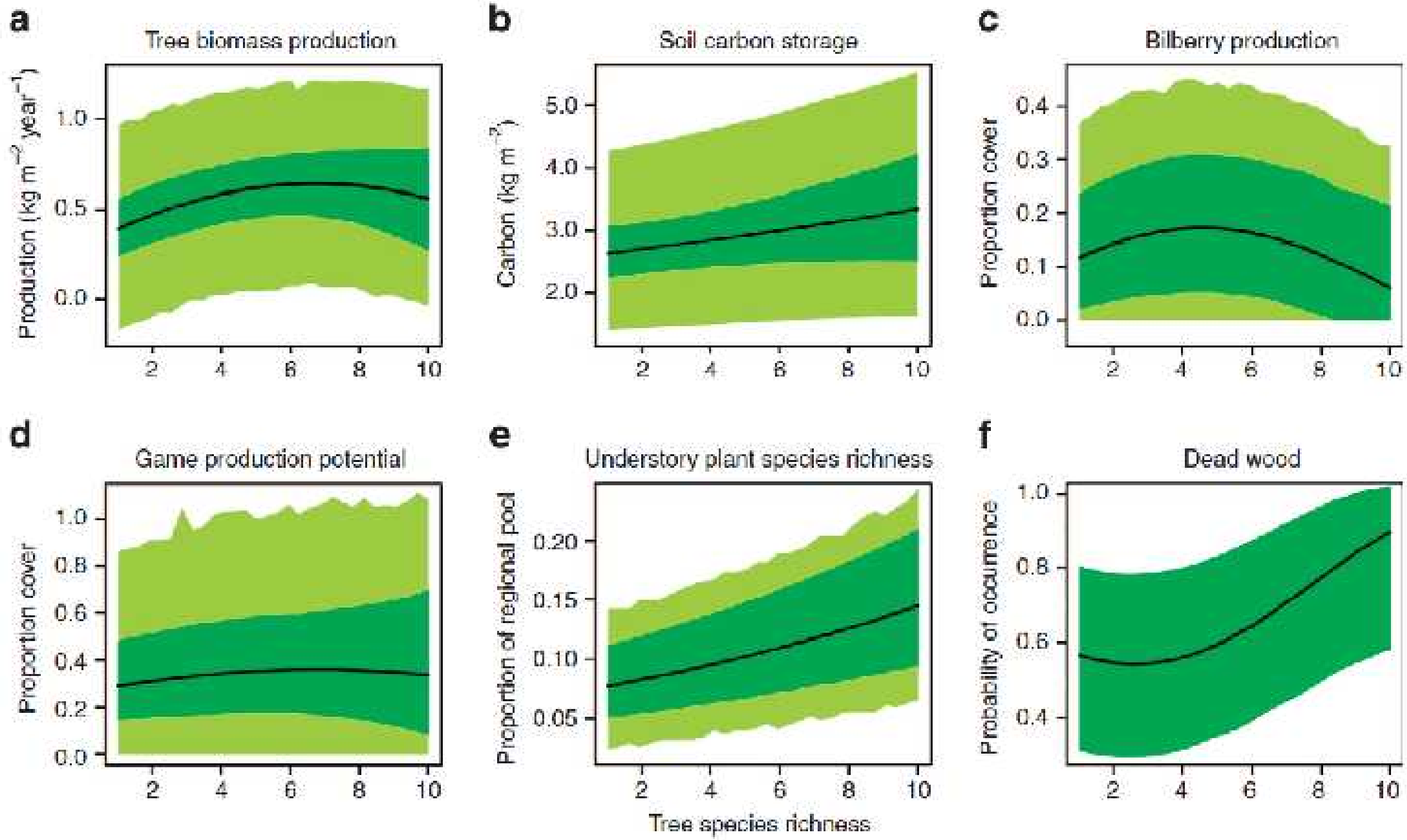
Figure 3 | Biodiversity effects on productivity during climate events or normal years. Lines are mixed-effects model fits for each year within each

Is mixing tree species in planted forest an option?

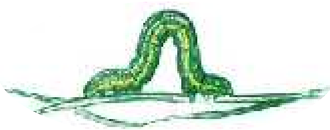
- **Evidence of multifunctionality in multiple species forests**

Higher levels of multiple ecosystem services are found in forests with more tree species

Lars Gamfeldt[1,2], Tord Snäll[1], Robert Bagchi[3], Micael Jonsson[4], Lena Gustafsson[1], Petter Kjellander[5], María C. Ruiz-Jaen[6], Mats Fröberg[7,8], Johan Stendahl[8], Christopher D. Philipson[9], Grzegorz Mikusiński[5], Erik Andersson[10,11], Bertil Westerlund[12], Henrik Andrén[5], Fredrik Moberg[11], Jon Moen[4] & Jan Bengtsson[1]



Resistance of mixed forest to biotic disturbances



- **Pest insects**

- **Fungal pathogens**

- **Mammal herbivores**

1. **Patterns of response to tree diversity**
2. **Underlying ecological mechanisms**
3. **Recommendations to managers**

Resistance of mixed forest to pest insects

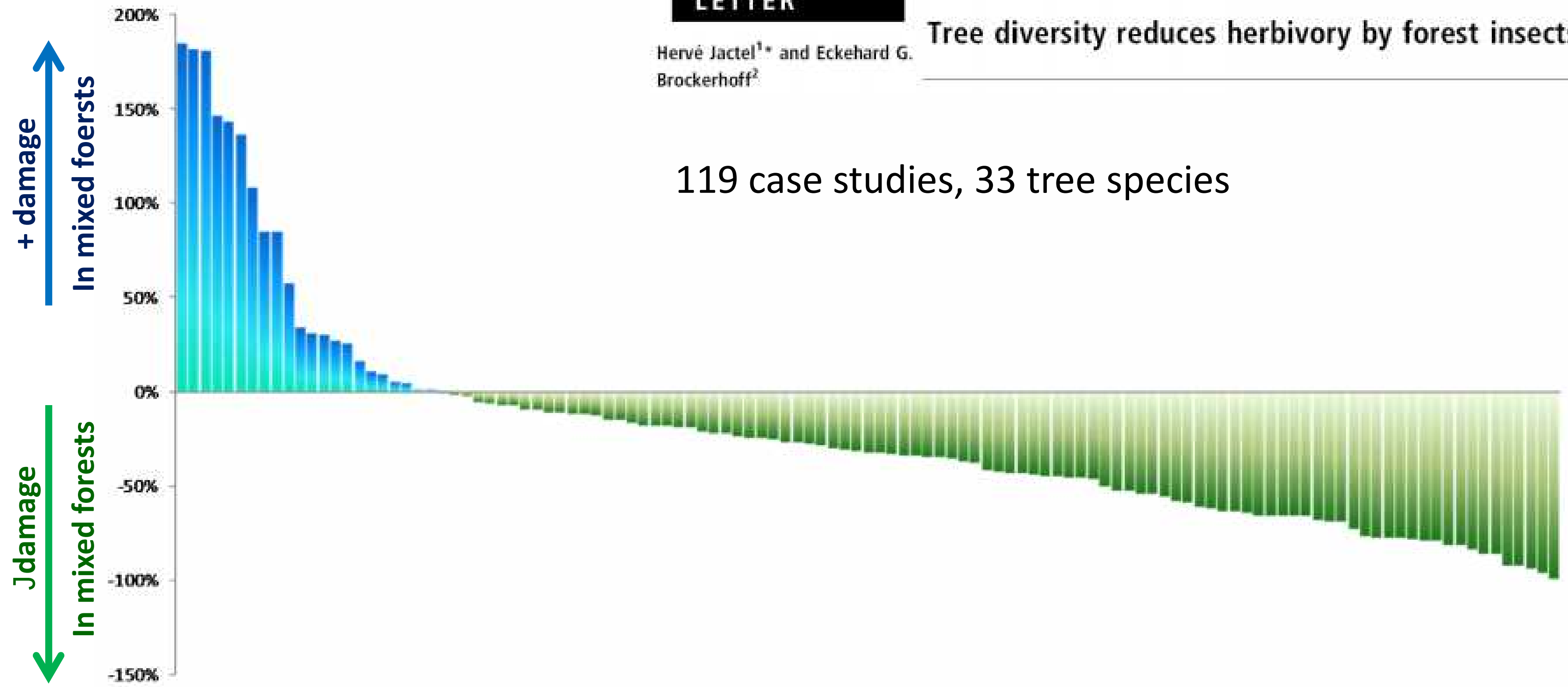
Ecology Letters, (2007) **10**: 835–848 doi: 10.1111/j.1461-0248.2007.01073.x

LETTER

Tree diversity reduces herbivory by forest insects

Hervé Jactel[1]* and Eckehard G. Brockerhoff[2]

119 case studies, 33 tree species



- **Lower damage in mixed forests in 80% of the cases**
- **36% decrease of damage for a tree species grown in mixed stands**

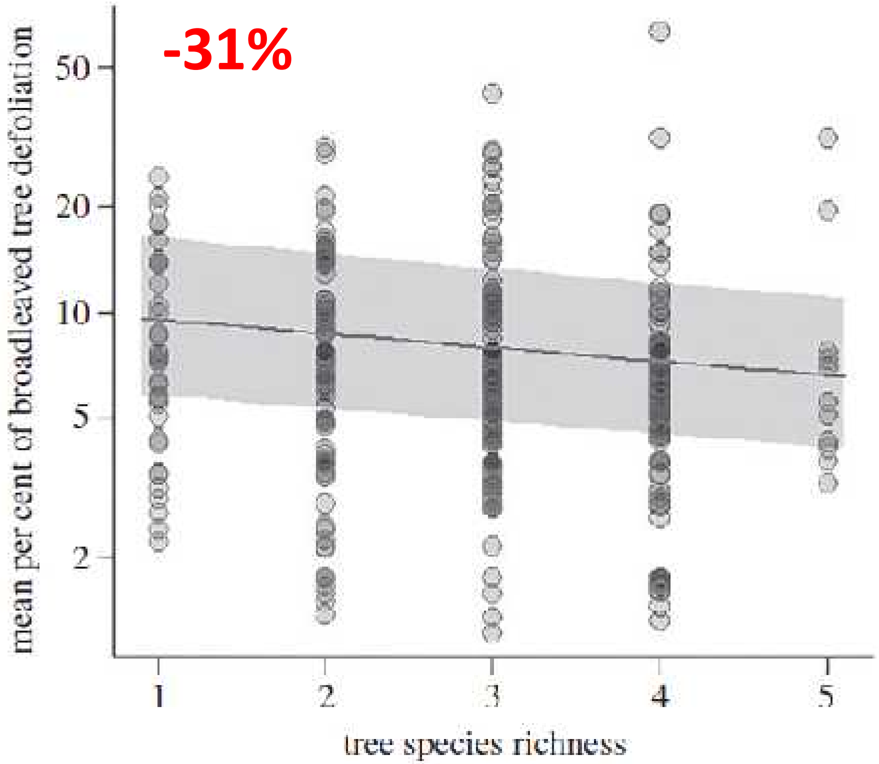
Resistance of mixed forest to pest insects

15 tree species in 209 forests

BIOLOGY LETTERS

Tree diversity reduces pest damage in mature forests across Europe

Virginie Guyot[1,3], Bastien Castagneyrol[3], Aude Vialatte[1,2], Marc Deconchat[1] and Hervé Jactel[3]

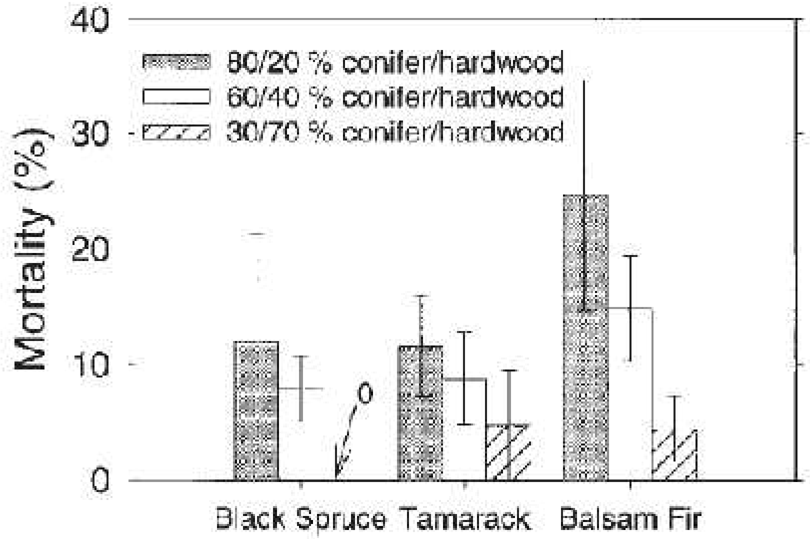


Resistance of mixed forest to fungal pathogens

Overall better resistance of mixed forests to root rot fungi

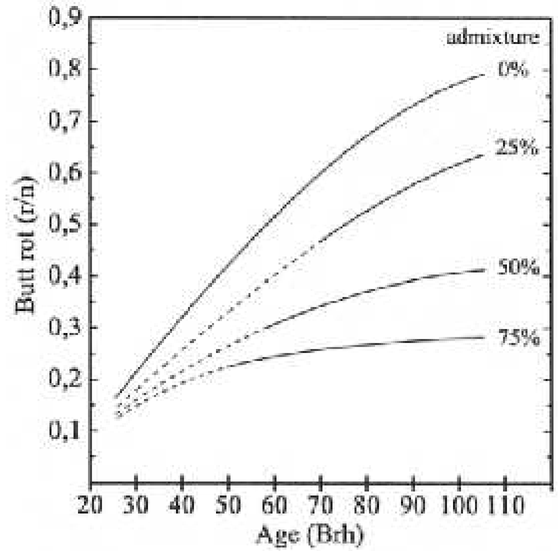
Armillaria

Gerlach et al. 1997



Heterobasidion

Linden & Vollbrecht 2002



Resistance of mixed forest to fungal pathogens

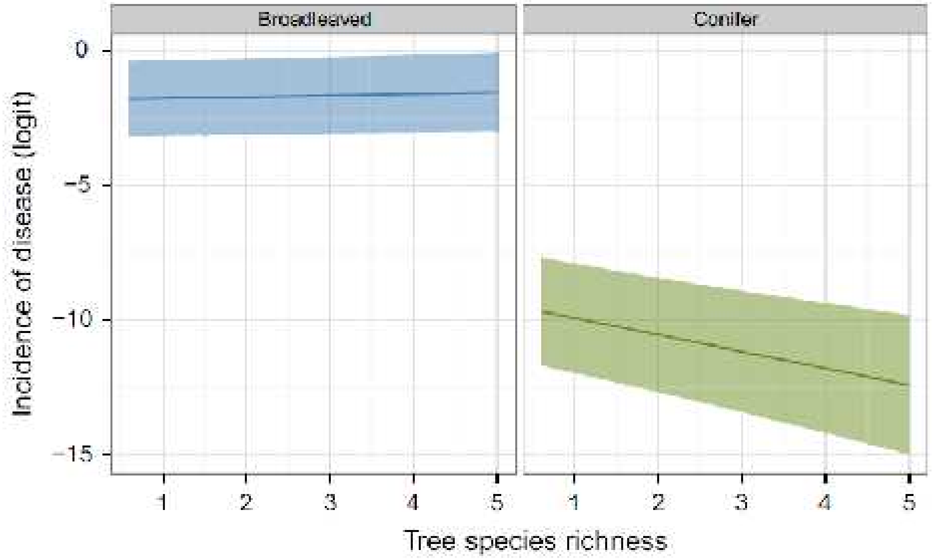
Resistance or neutral effects for foliar pathogens

Ecology and Evolution — Open Access

Fungal disease incidence along tree diversity gradients depends on latitude in European forests

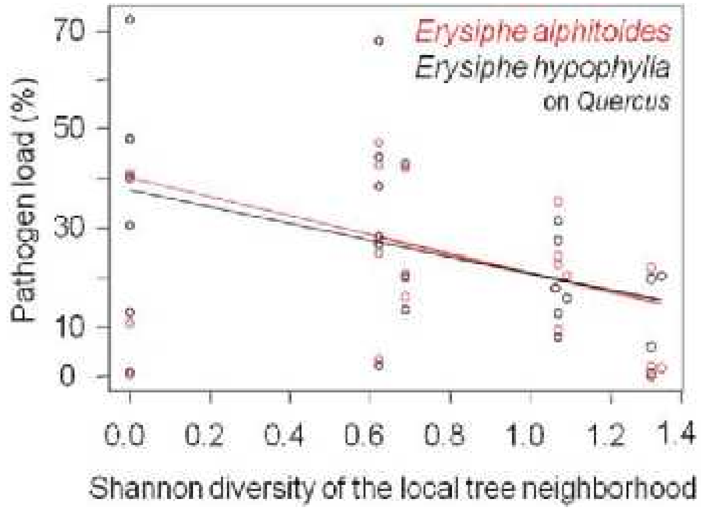
Diem Nguyen, Bastien Castagneyrol, Helge Bruelheide, Filippo Bussotti, Virginie Guyot, Hervé Jactel, Bogdan Jaroszewicz, Fernando Valladares, Jan Stenlid & Johanna Boberg

209 forests



Oïdium

Hantsch et al. 2013



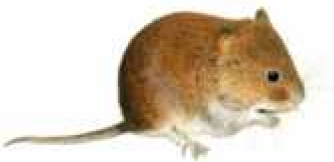
Resistance of mixed forest to mammal herbivores

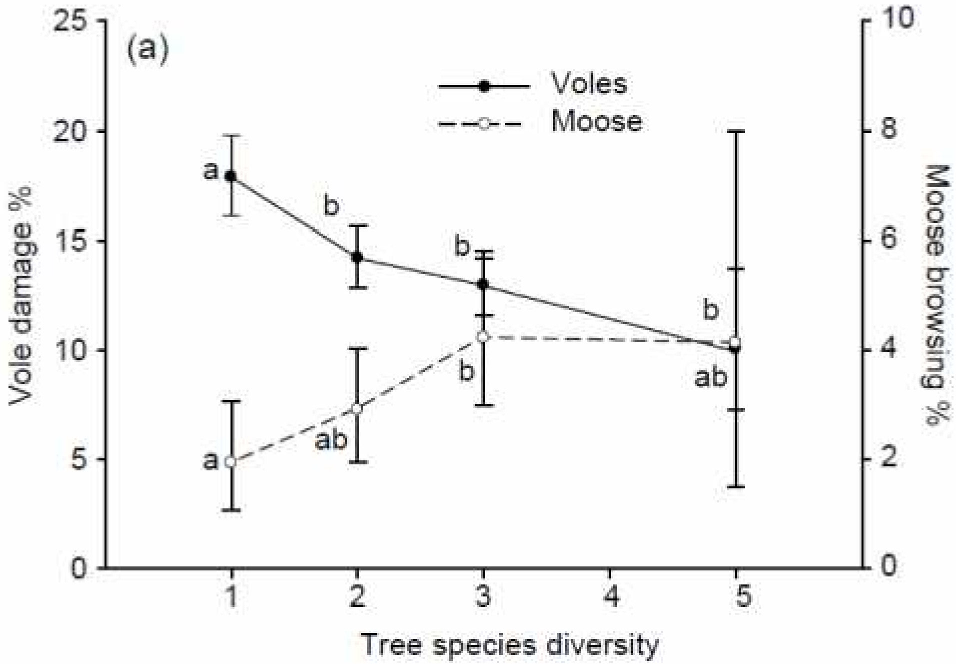
Contrasting effects on mammal herbivores

ECOGRAPHY 29: 497–506, 2006

Moose and vole browsing patterns in experimentally assembled pure and mixed forest stands

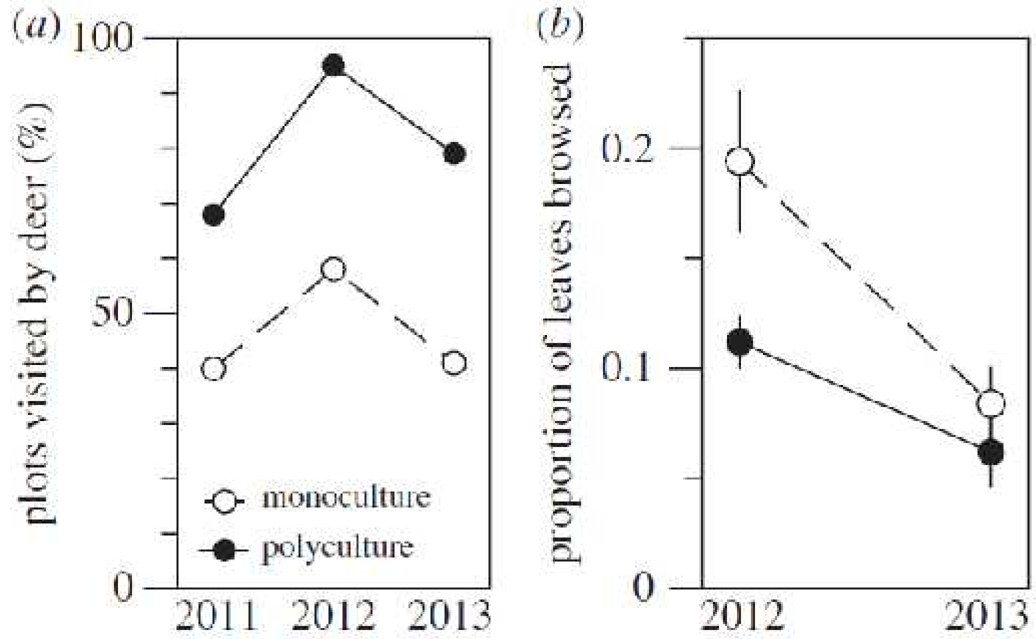
Harri Vehviläinen and Julia Koricheva





Resistance of mixed forest to mammal herbivores

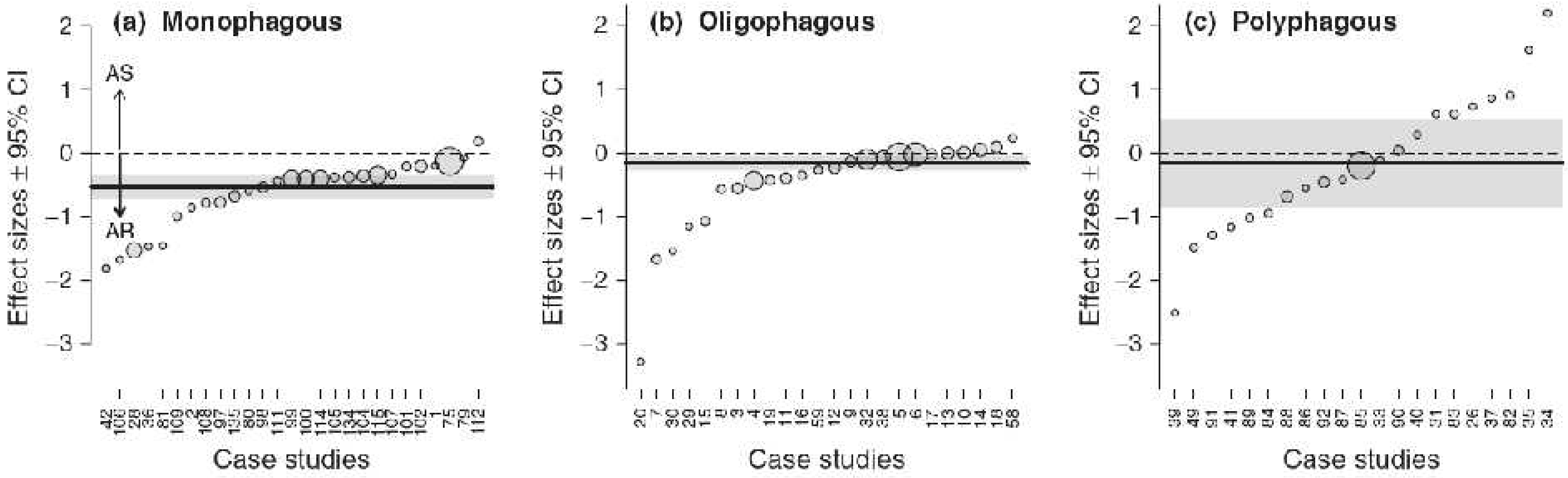
Contrasting effects on mammal herbivores



Cook-Patton et al. 2014

Resistance of mixed forest: common features

1. Direction and magnitude of effects depend on pest specialization



- 42%

- 15%

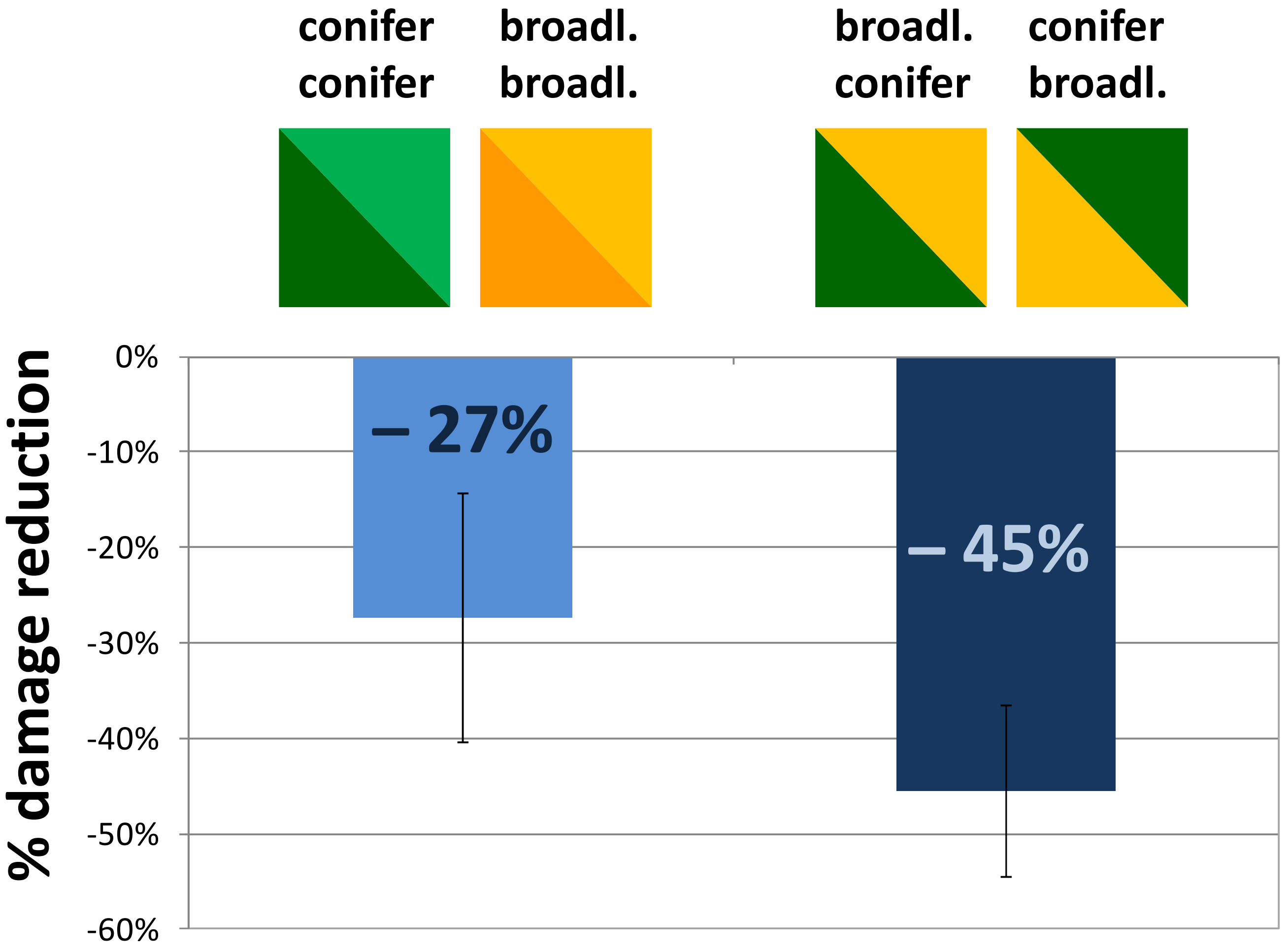
0%

Castagneyrol et al. 2014

- **Spill over**
- **Mixing diet**

Resistance of mixed forest: common features

2. Forest composition > tree species richness

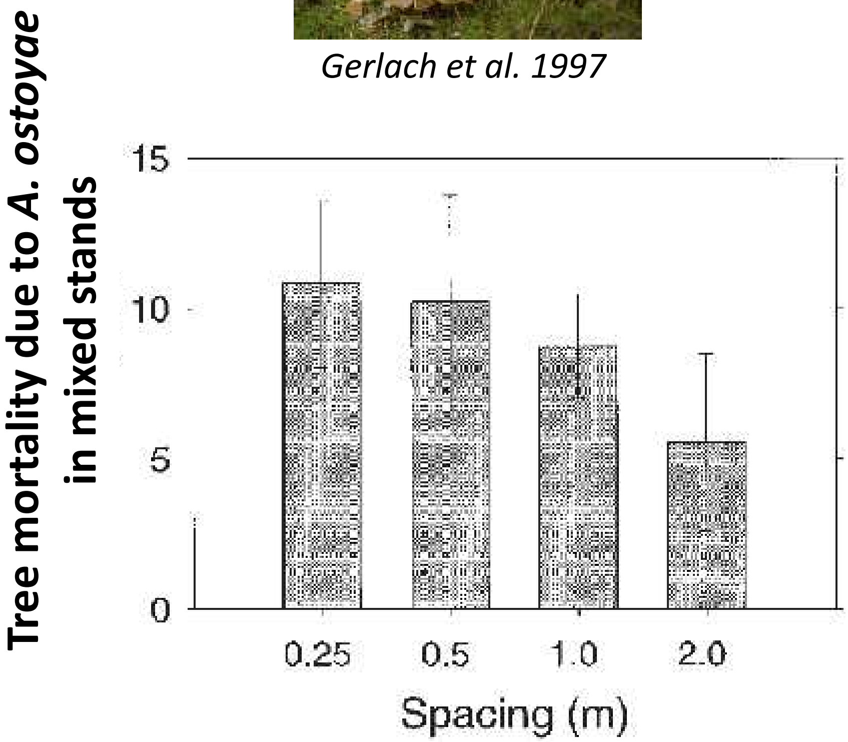


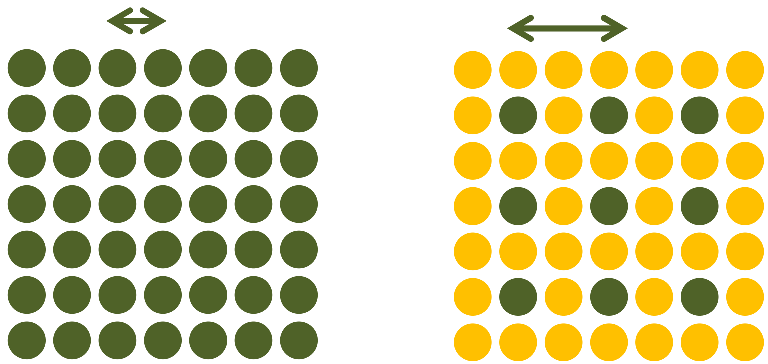
Mechanisms underlying diversity – resistance relationships

1. Reduced host tree density

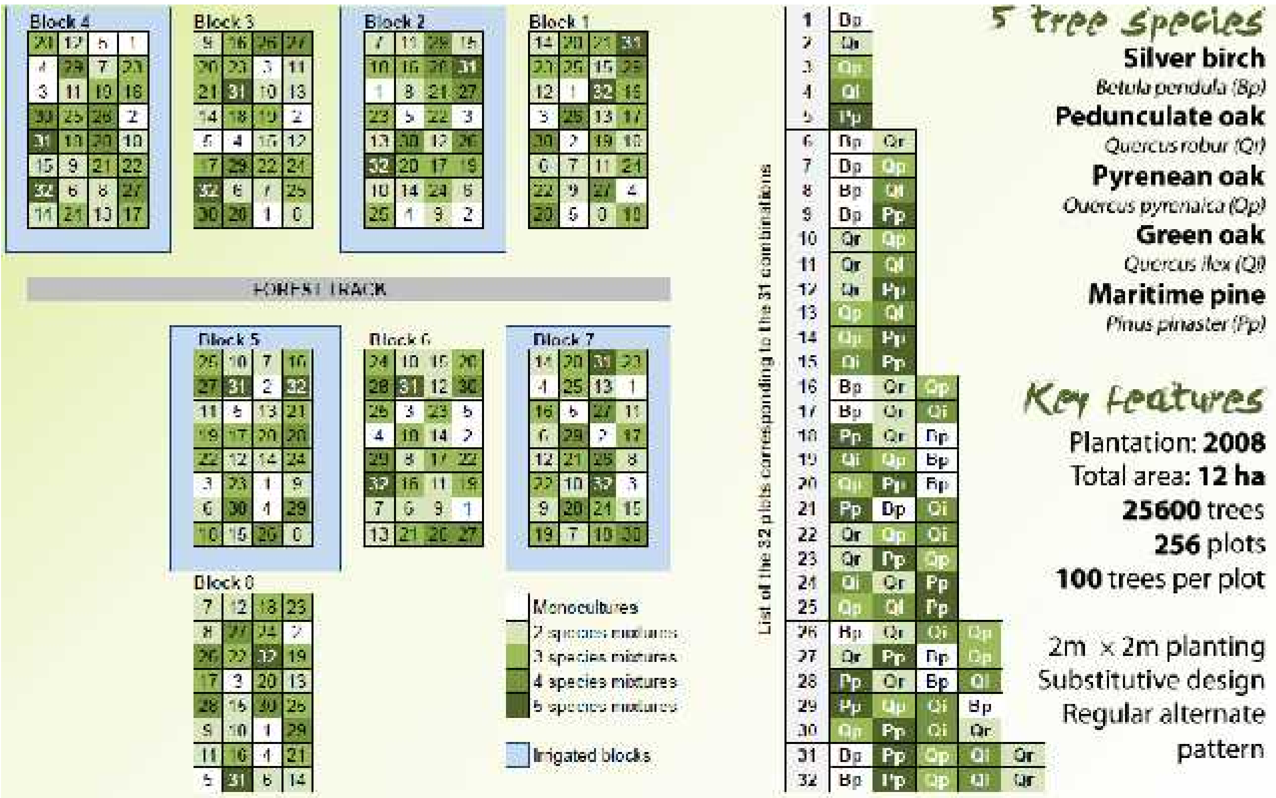
- less likely to enter the plot
- reduced residence time (OFT)
- lower amount of resources
- longer distance between host trees

Gerlach et al. 1997





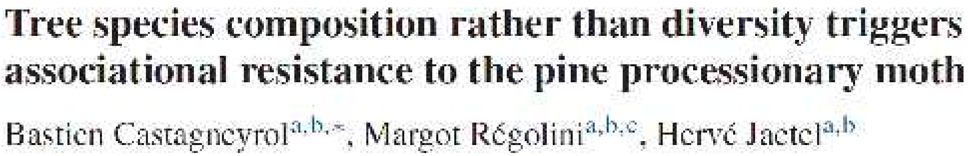
ORPHEE experiment

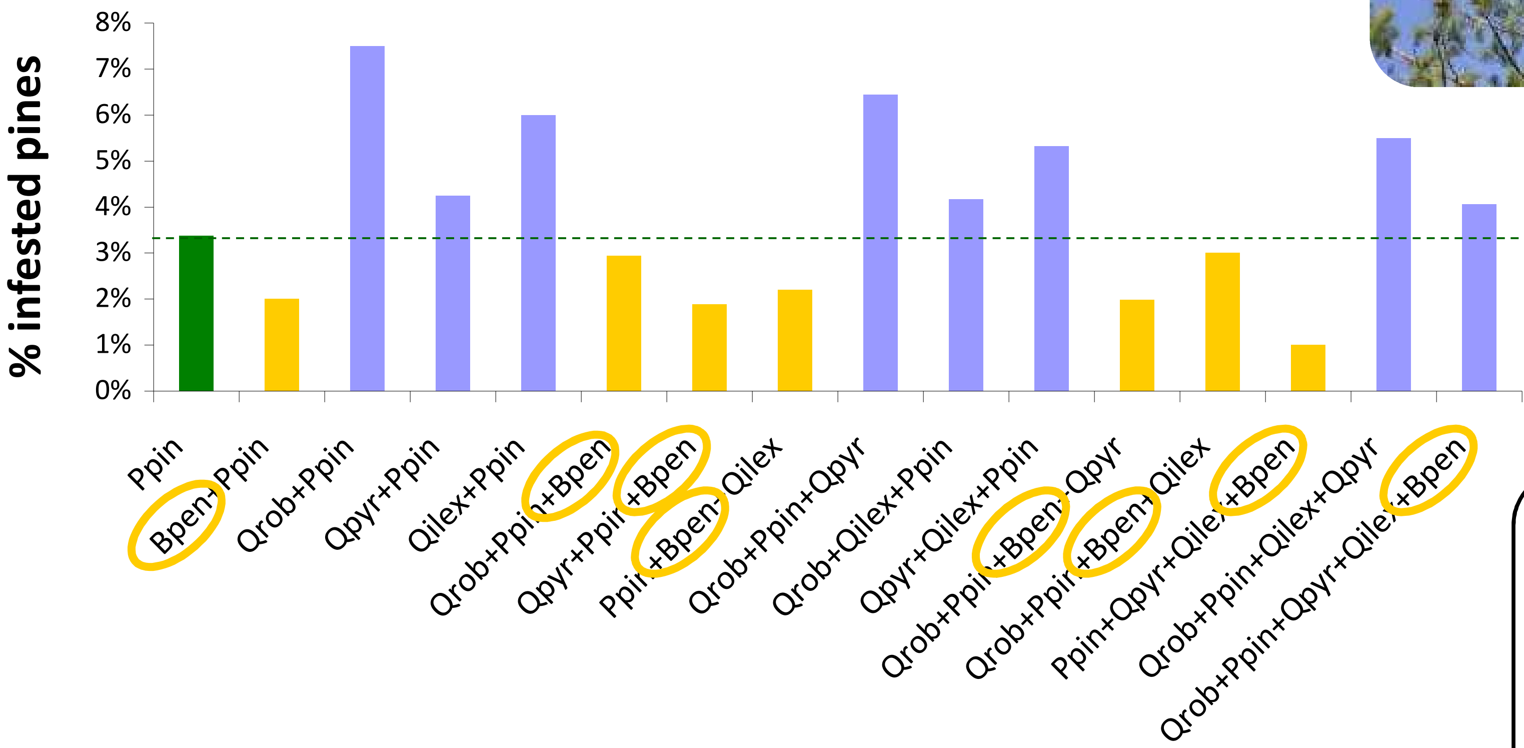


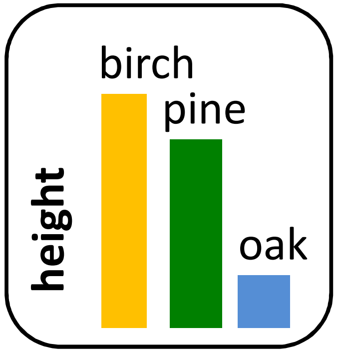
www.facebook.com/orpheeexperiment

Mechanisms underlying diversity – resistance relationships

2. Reduced probability of host tree being found







Mechanisms underlying diversity – resistance relationships

2. Reduced probability of host tree being consumed

Does the strength of facilitation by nurse shrubs depend on grazing resistance of tree saplings?

Charlotte Vandenberghe[a,b], Christian Smit[c,*], Mandy Pohl[a,1], Alexandre Buttler[a,b], François Freléchoux[a,b]

Saplings planted under Eglantine

Spruce - Fir

Beech - Maple

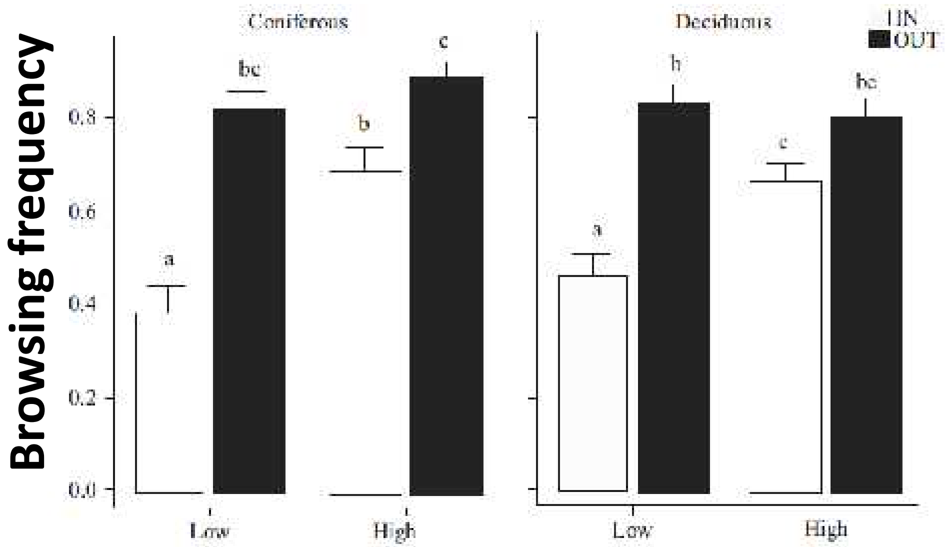
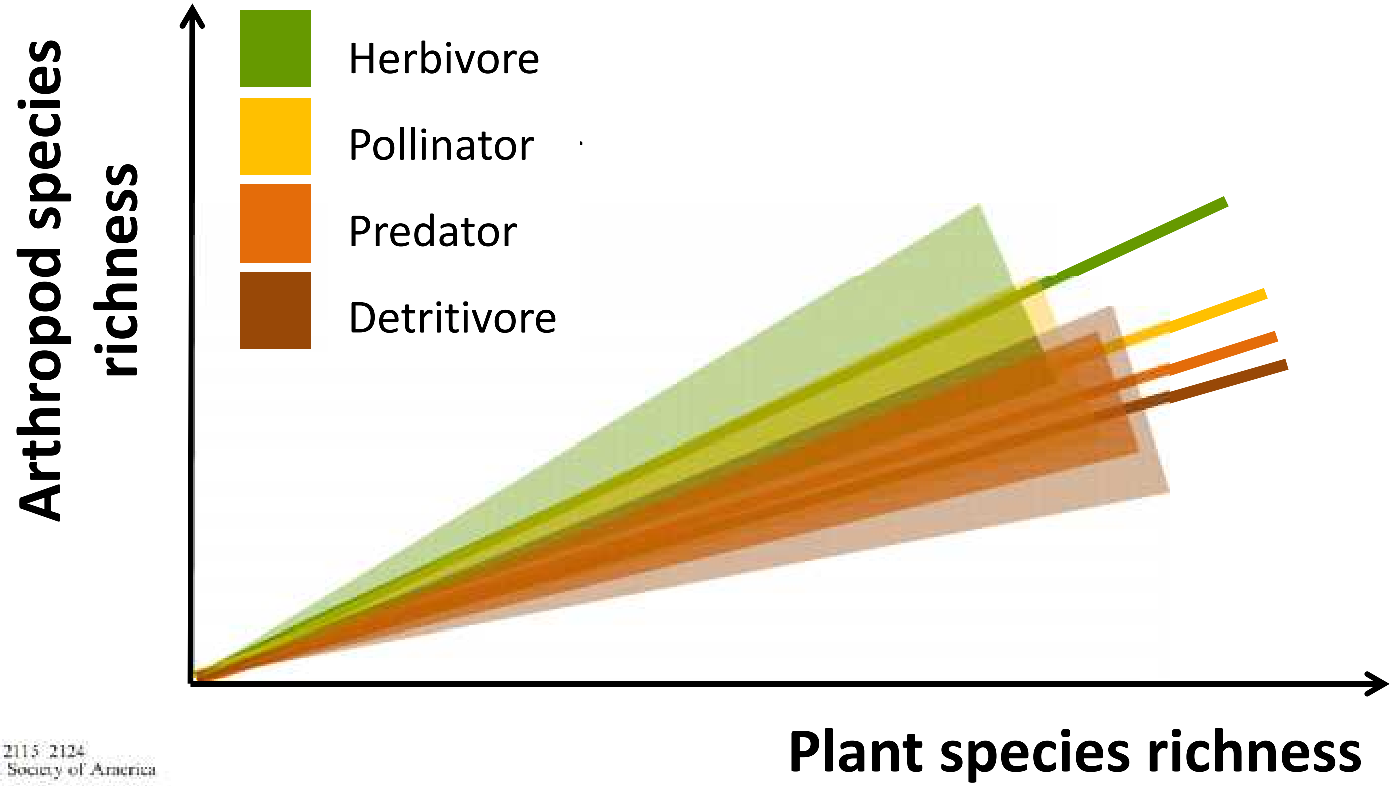


Fig. 2. The effects of grazing intensity (low and high) and position (in and out) on the browsing frequency (mean proportion ± 1 SE, $n = 30$) of coniferous and deciduous saplings, after the fourth grazing period. Different letters indicate significantly different means (Tukey post hoc comparisons within each species-group, $p < 0.05$).

Mechanisms underlying diversity – resistance relationships

3. Reinforced biological control by natural enemies



Ecology, 93(9), 2012, pp. 2115–2124

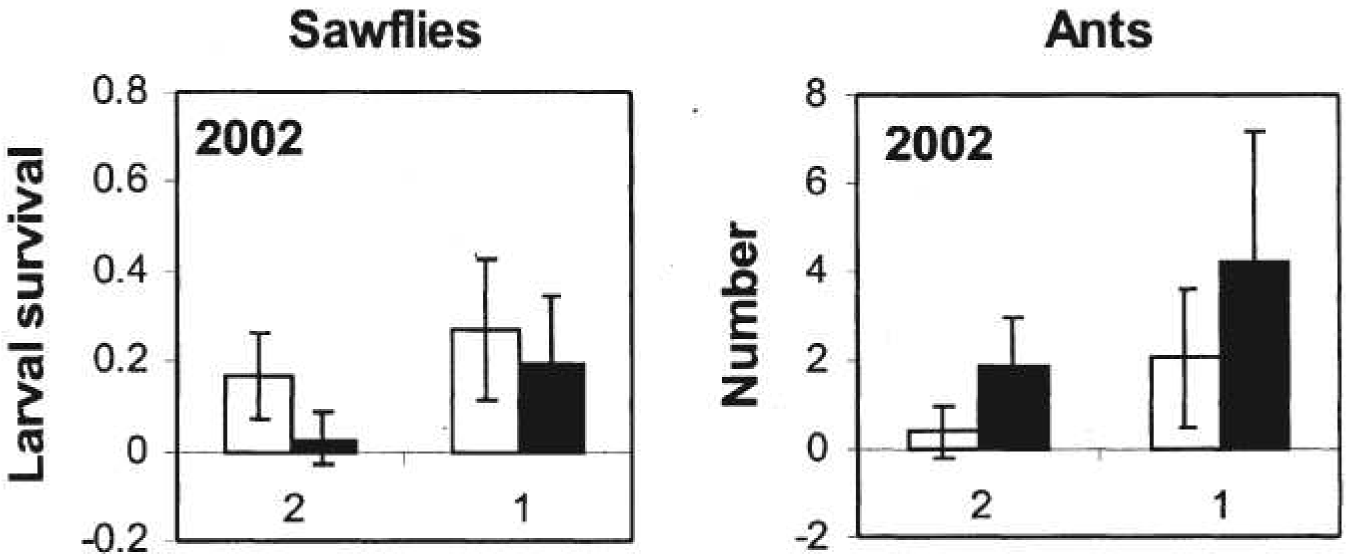
Unraveling plant–animal diversity relationships: a meta-regression analysis

Bastien Castagneyrol[1] and Hervé Jactel

Mechanisms underlying diversity – resistance relationships

3. Reinforced biological control by natural enemies

Neodiprion sertifer



100% Scots pine

50% Scots pine – 50% Birch

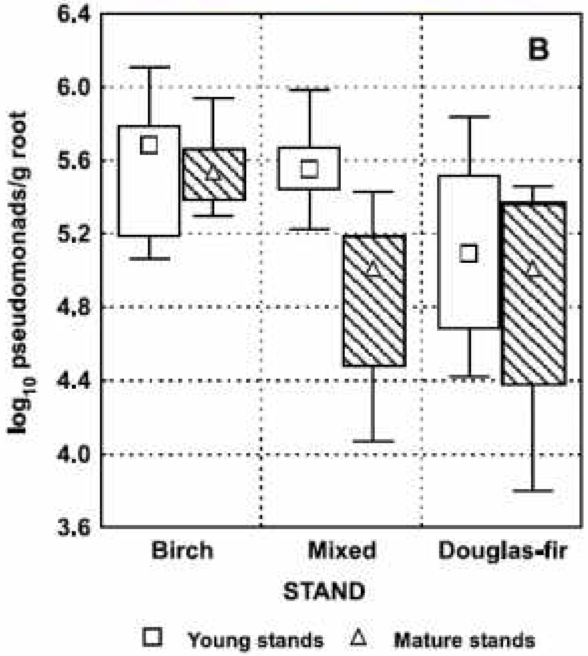
Kaitaniemi, P., Riihimäki, J., Koricheva, J. & Vehviläinen, H. 2007. Experimental evidence for associational resistance against the European pine sawfly in mixed tree stands. Silva Fennica 41(2): 259–268.

Mechanisms underlying diversity – resistance relationships

3. Reinforced biological control by antagonists

Fluorescent pseudomonad population sizes baited from soils under pure birch, pure Douglas-fir, and mixed forest stands and their antagonism toward *Armillaria ostoyae* in vitro

R.L. DeLong, Kathy J. Lewis, Suzanne W. Simard, and Susan Gibson



Recommendations to forest managers

1. Mixing 2 species can be enough
2. Providing that they have contrasting traits
3. Favour conifer – broadleaved mixtures

Eur J Forest Res (2015) 134:927–947
DOI 10.1007/s10342-015-0900-4

CrossMark

ORIGINAL PAPER

Growth and yield of mixed versus pure stands of Scots pine (*Pinus sylvestris* L.) and European beech (*Fagus sylvatica* L.) analysed along a productivity gradient through Europe

H. Pretzsch[1] · M. del Río[2] · Ch. Ammer[3] · A. Avdagic[4] · I. Barbeito[5] · K. Bielak[6] · G. Brazaitis[7] · L. Coll[8] · G. Dirnberger[9] · L. Drössler[10] · M. Fabrika[11] · D. I. Forrester[12] · K. Godvod[7] · M. Heym[1] · V. Hurt[13] · V. Kurylyak[14] · M. Löf[10] · F. Lombardi[15] · B. Matovic[16] · F. Mohren[17] · R. Motta[18] · J. den Ouden[17] · M. Pach[19] · Q. Ponette[20] · G. Schütze[1] · J. Schweig[1] · J. Skrzyszewski[19] · V. Sramek[21] · H. Sterba[9] · D. Stojanović[16] · M. Svoboda[22] · M. Vanhellemont[23] · K. Verheyen[23] · K. Wellhausen[1] · T. Zlatanov[24] · A. Bravo-Oviedo[2]

In mixture standing volume (+12 %), stand density (+20 %), basal area growth (+12 %), and stand volume growth (+8 %) were higher

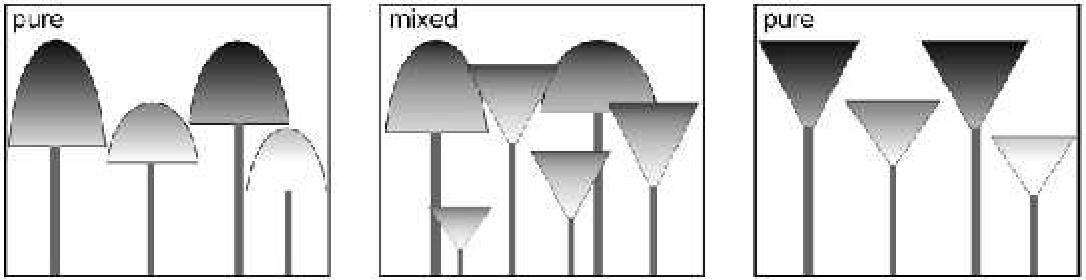


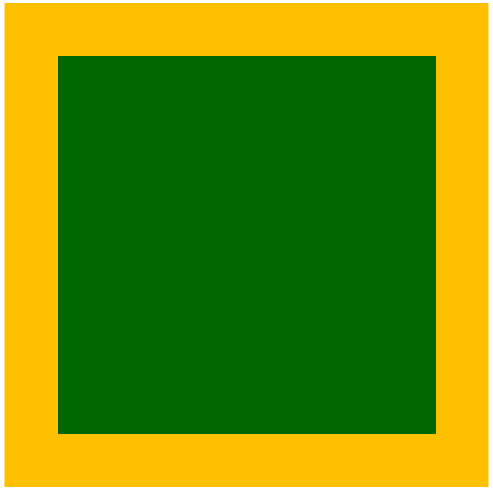
Fig. 9 Forest canopy can be denser in mixed stands b compare with pure stands, a, c due to wider tree crown extension, multi-layering, and higher stocking density. The more complete canopy space filling may increase the light interception in mixed stands. Replacement of inefficient organs or trees of one species by more efficient neighbours of the other species may increase the light-use efficiency. *Black hatching* means high efficiency of light use, *grey* and *white* indicates medium and low efficiency

Recommendations to forest managers

1. Mixing 2 species can be enough
2. Providing that they have contrasting traits
3. Favour conifer – broadleaved mixtures

4. Two possible spatial configurations

Strip pattern



Edge pattern

Dependent variable and effect	Diversification scheme							
	Inter-crop	In-other	In-trap	In-repel	Push–pull	Around-crop	In-flower	Around-flower
Herbivore abundance								
No. studies	100	43	23	<2	8	29	17	<2
Effect size	−1.42	−1.30	−2.43		−0.49	−0.86	0.01	
Crop damage								
No. studies	48	12	4	9	15	8		
Effect size	−2.39	−0.47	0.39	−1.49	−3.44	−3.05		

Letourneau et al. 2011


Thank you for your attention