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

Herve Jactel, Johanna Boberg, Damien Bonal, Bastien Castagneyrol, Barry Gardiner, José-Ramon Gonzalez, Julia Koricheva, Nicolas Meurisse, Eckehard Brockerhoff

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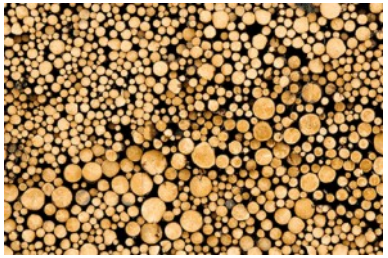
An urgent need for new, planted forests

to meet the social demand for wood products including energy wood



to contribute to climate change mitigation through carbon sequestration

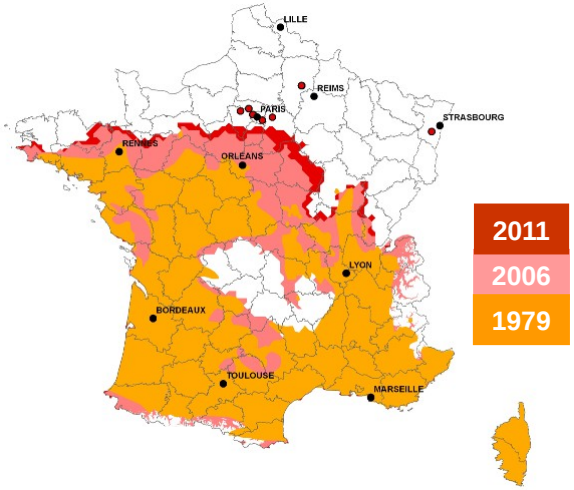
to alleviate the logging pressure on natural forests and preserve biodiversity

Rising threats due to global change

1. **Climate change**

↗ temperatures trigger pest outbreaks and range expansion

Mountain pine beetle



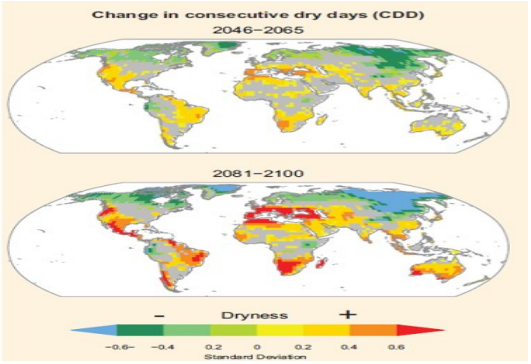
Pine processionary moth

Rising threats due to global change

1. **Climate change**

↗ droughts increase the risk of forest fires

↗ 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

1. ## Climate change

↗ wind damage

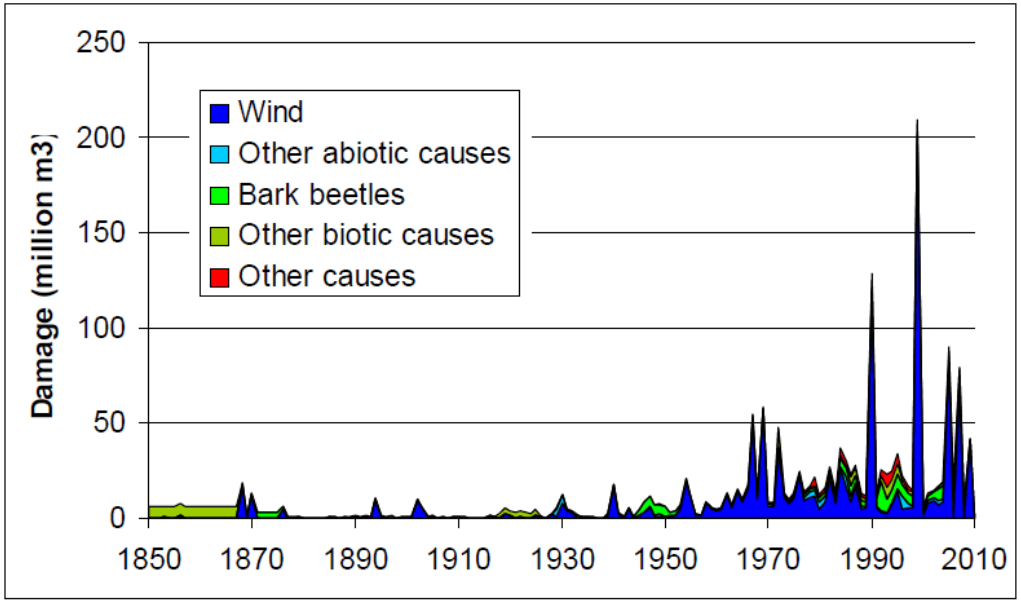
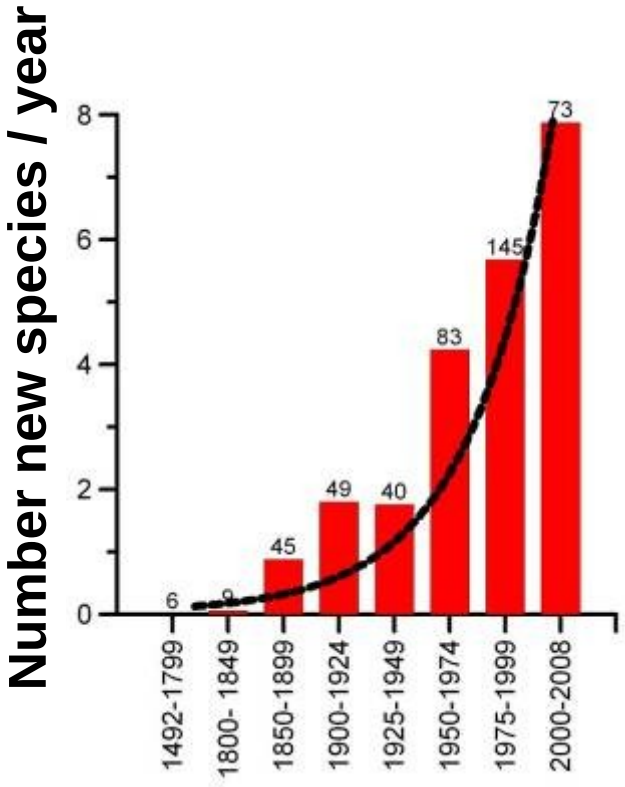


Figure 1a: Total damage due to disturbances in Europe (Schelhaas 2008a).

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

- Forests 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[24,25], Christiane Roscher[2,26], Eric W. Seabloom[1], Melinda D. Smith[27], Madhav P. Thakur[2,3], David Tilman[1,28], Benjamin F. Tracy[29], Wim H. van der Putten[8,30], Jasper van Ruijven[31], Alexandra Weigelt[2,3], Wolfgang W. Weisser[20], Brian Wilsey[32] & Nico Eisenhauer[2,3]

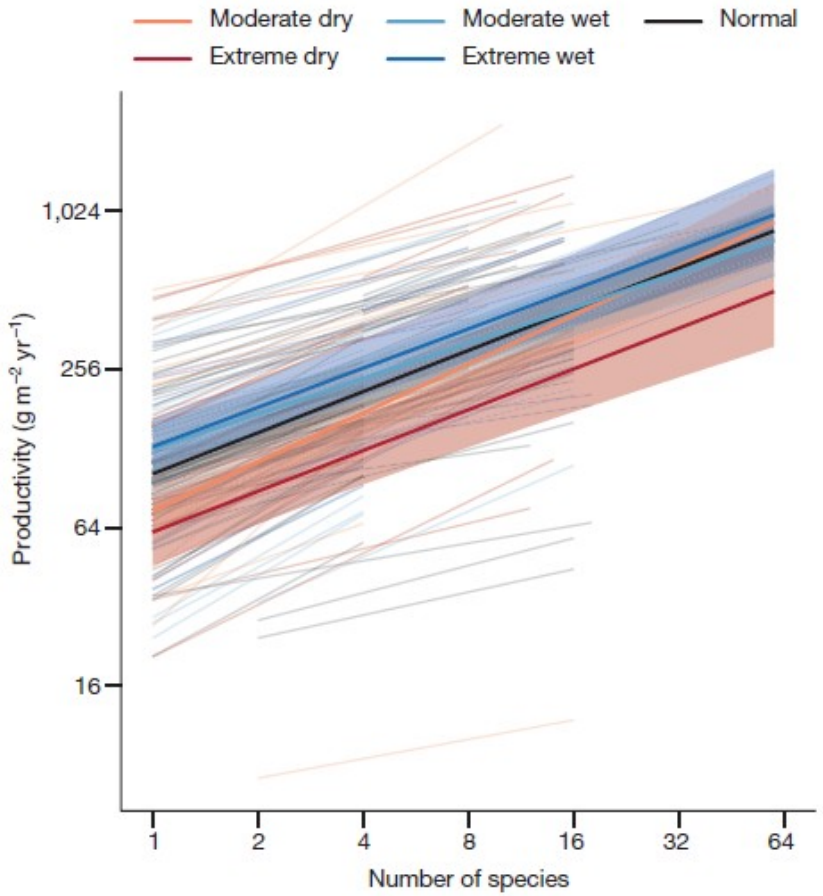


Figure 3 | Biodiversity effects on productivity during climate events or normal years. Lines are mixed-effects model fits for each year within each

Resistance of mixed forests to 7 natural disturbances

1. Drought
2. Fire
3. Windstorm
4. Mammal herbivores
5. Pest insects
6. Fungal pathogens
7. Invasive species

William M. Ciesla, Forest Health Management International, Bugwood.org

http://www.redbubble.com/people/bberwyn

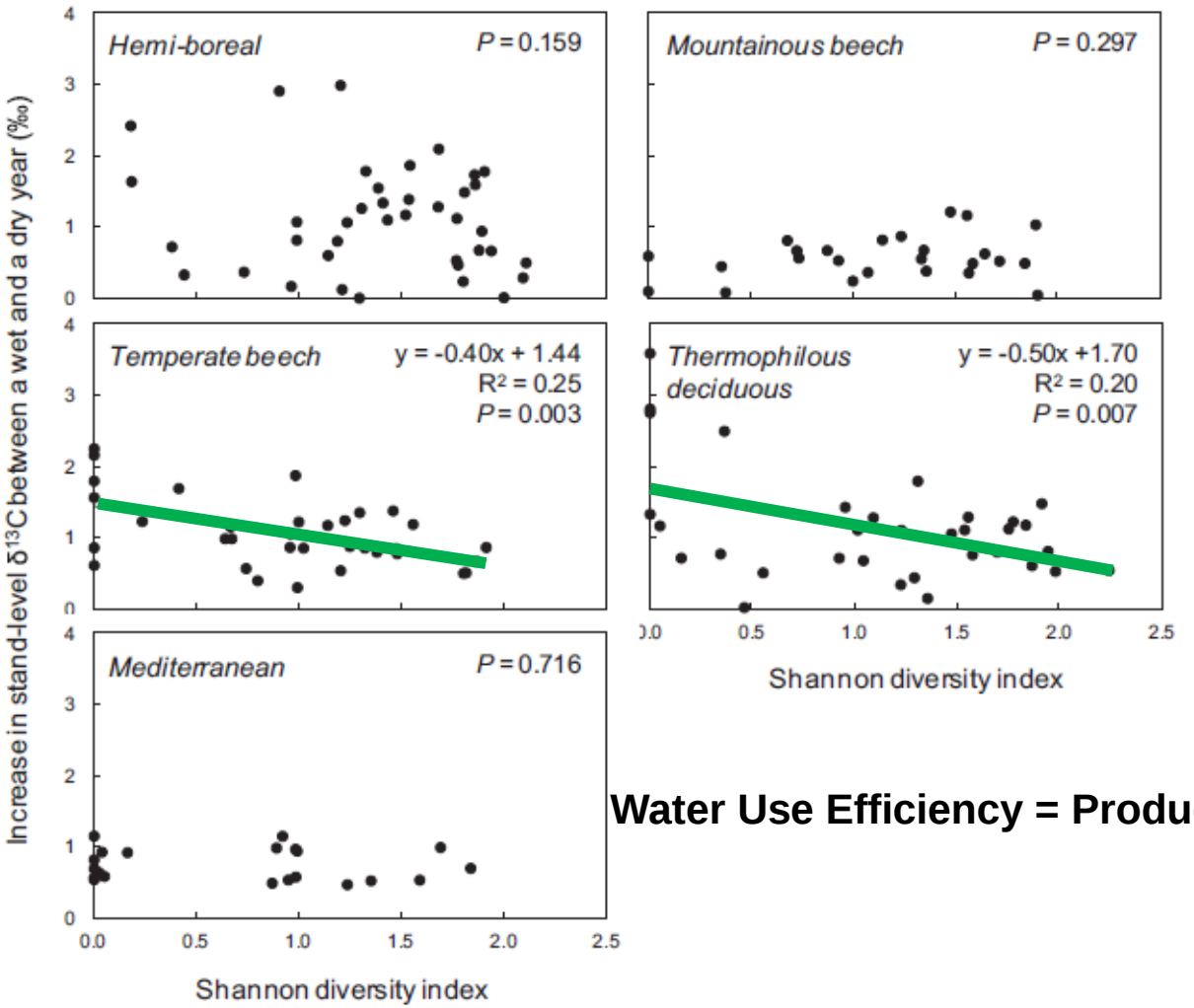
Patterns of response to tree diversit
Underlying ecological mechanisms

Resistance of mixed forests to drought

PNAS

Tree diversity does not always improve resistance of forest ecosystems to drought

Charlotte Grossiord[a], André Granier[a], Sophia Ratcliffe[b], Olivier Bouriaud[c], Helge Bruelheide[d,e], Ewa Chećko[f], David Ian Forrester[g], Seid Muhie Dawud[h], Leena Finér[i], Martina Pollastrini[j], Michael Scherer-Lorenzen[k], Fernando Valladares[l], Damien Bonal[a,1,2], and Arthur Gessler[m,n,2]



Water Use Efficiency = Productivity / Transpiration

Resistance of mixed forests to fires

Fire severity in relation to canopy composition within burned boreal mixedwood stands

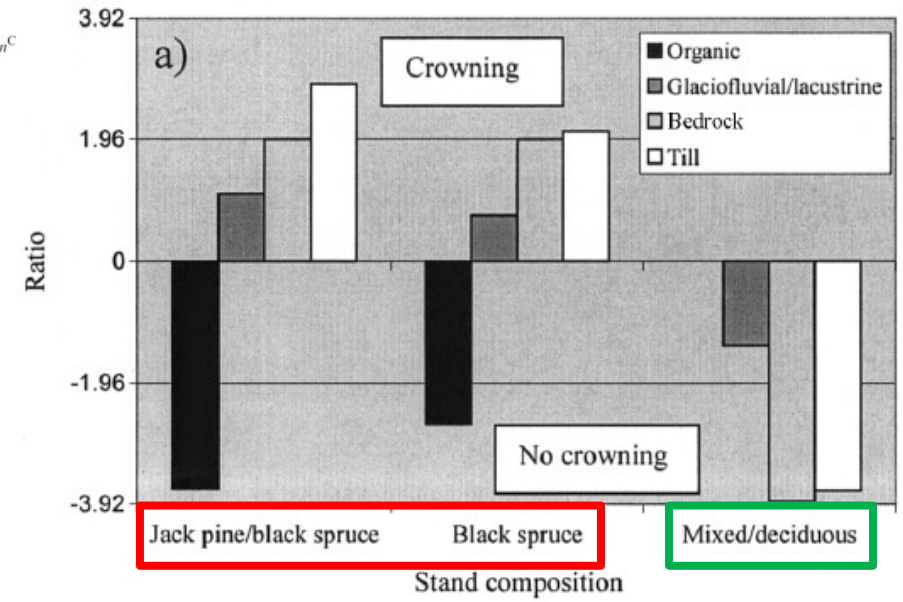
G.G. Wang*

Forest Ecology and Management 163 (2002) 85–92

Species composition	Fire severity class	
	Light	**Severe**
Softwood	6	16
Softwood–hardwood	15	4
Hardwood–softwood or hardwood	19	0

Fire impacts and crowning in the boreal forest: study of a large wildfire in western Quebec

Victor Kafka[A], *Sylvie Gauthier*[B], *and Yves Bergeron*[C]

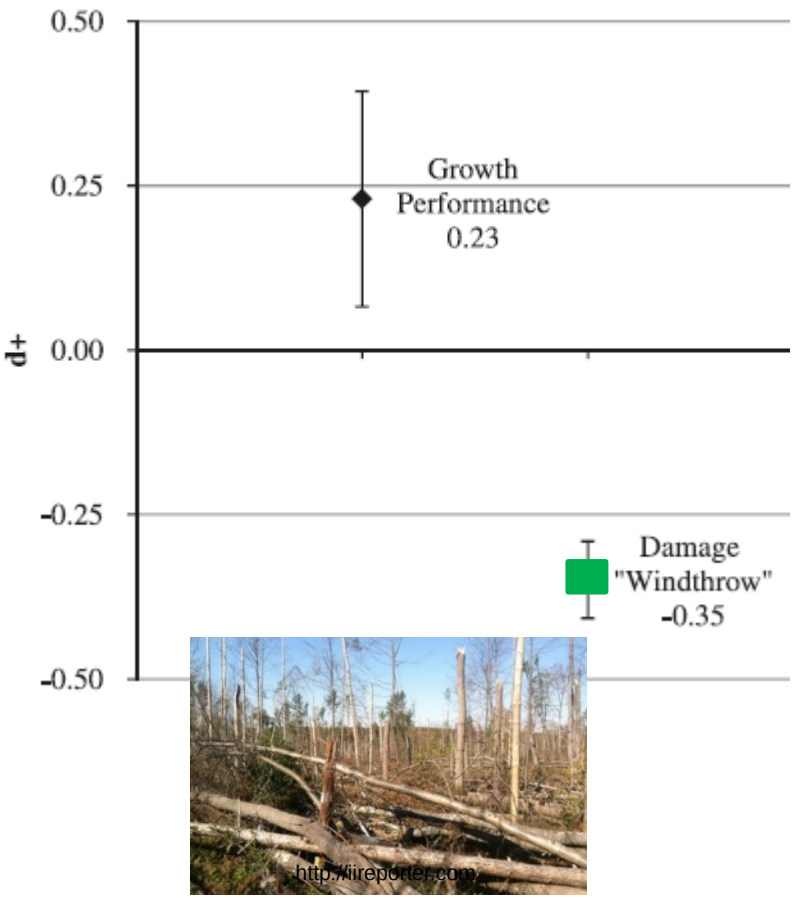


Resistance of mixed forests to windstorms

REVIEW / SYNTHÈSE

Growth performance, windthrow, and insects: meta-analyses of parameters influencing performance of mixed-species stands in boreal and northern temperate biomes

Verena C. Griess and Thomas Knoke



Jean-Philippe Schütz · Michael Götz
Willi Schmid · Daniel Mandallaz

Vulnerability of spruce (*Picea abies*) and beech (*Fagus sylvatica*) forest stands to storms and consequences for silviculture

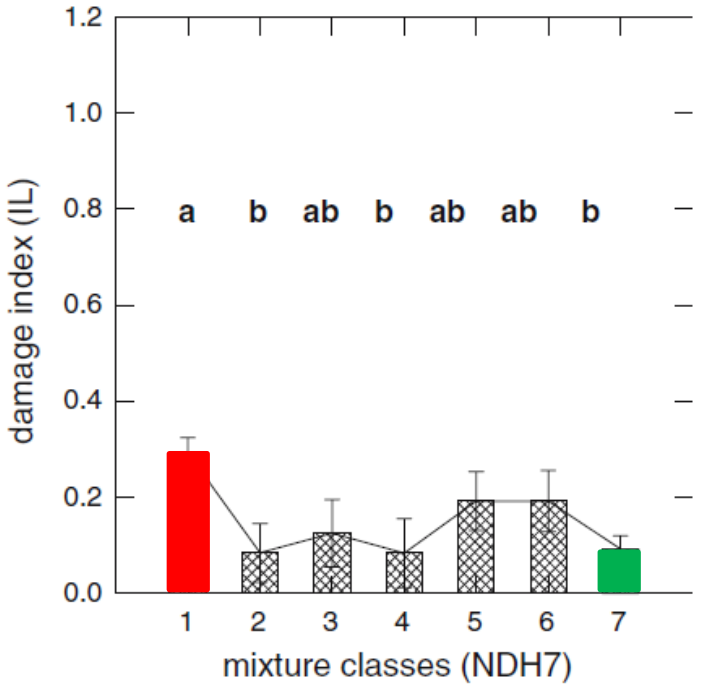


Fig. 10 Effect of tree mixtures on damage index: ANOVA with different mixed species and proportions. Mixtures classes with different letters were significantly different at $P=0.10$. *1* Pure spruce/fir (≥ 90%) *2* rich spruce/fir (80–89%), *3* dominant spruce/fir (70–79%), *4* admixture douglas fir (≥5%), *5* admixture larch (≥5%), *6* admixture pine (>10%) and *7* broad leaved (≥80%)

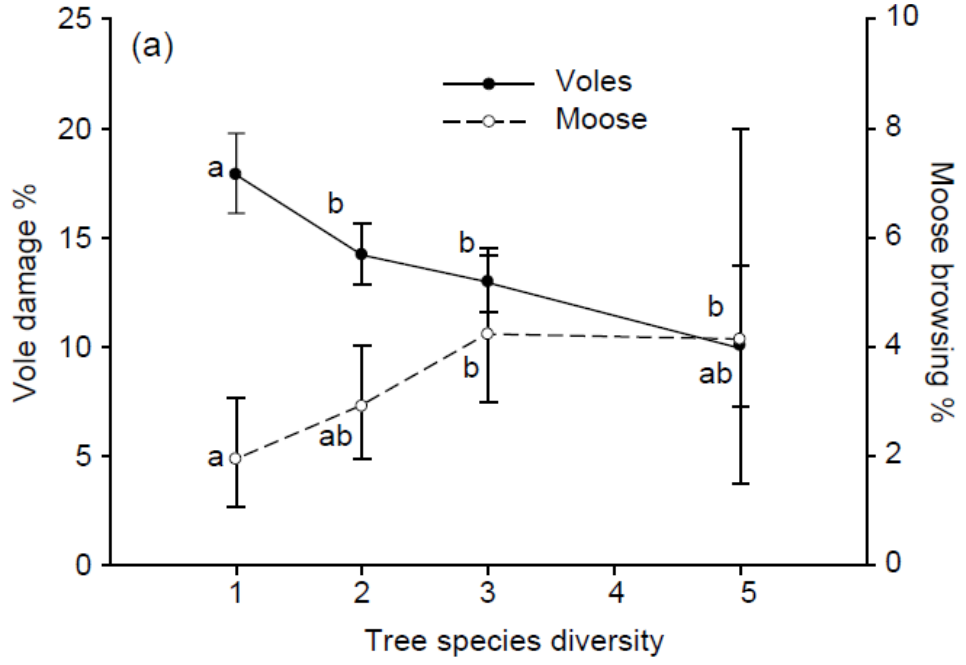
Resistance of mixed forest to mammal herbivor

Contrasting effects on mammal herbivores

ECOGRAPHY 29: 497–506, 2006

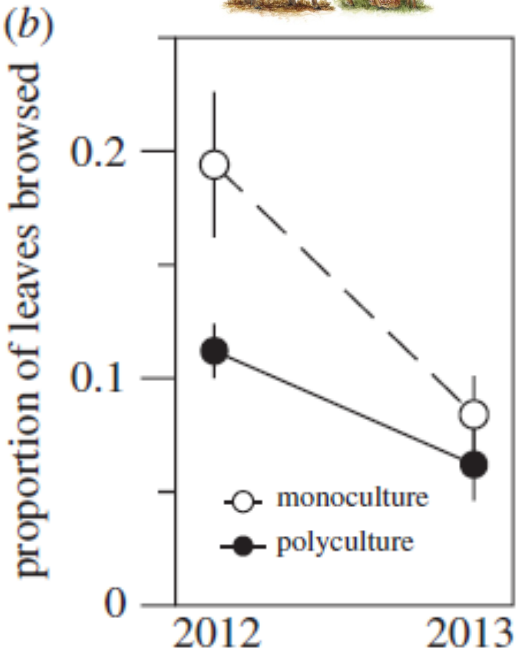
Moose and vole browsing patterns in experimentally assembled pure and mixed forest stands

Harri Vehviläinen and Julia Koricheva



Positive interactions between herbivores and plant diversity shape forest regeneration

Susan C. Cook-Patton, Marina LaForgia and John D. Parker



Resistance of mixed forest to pest insects

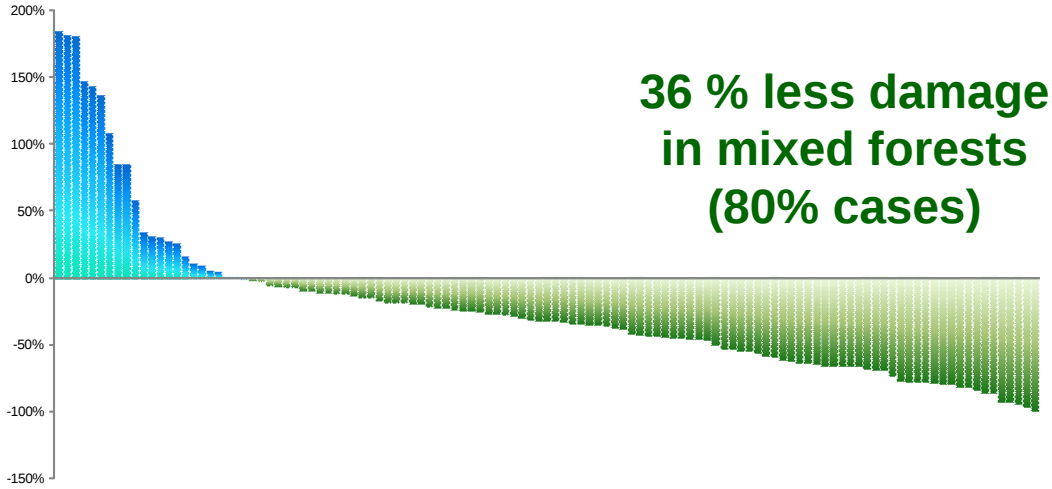
Ecology Letters, (2007) **10**: 835–848 doi: 10.1111/j.1461-0248.2007.01073.x

LETTER

Tree diversity reduces herbivory by forest insects

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

119 case studies, 33 tree species

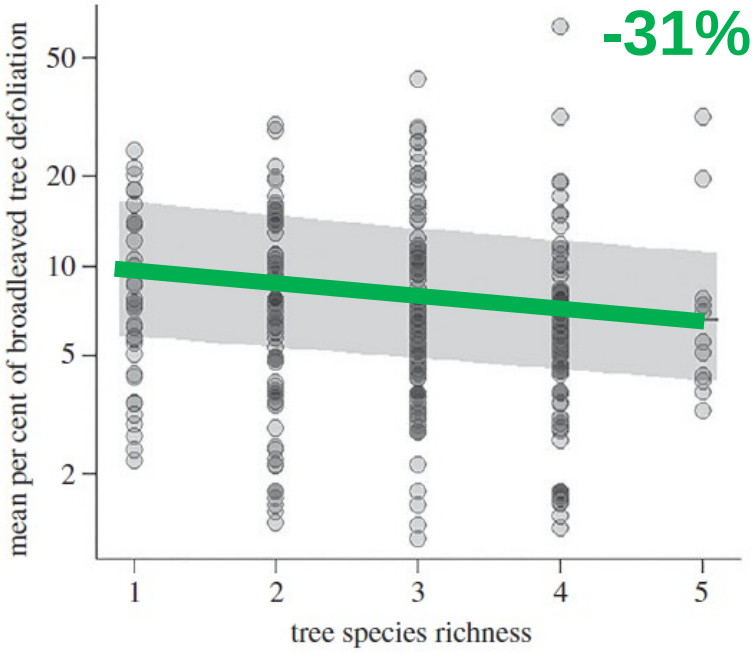


36 % less damage in mixed forests (80% cases)

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]

-31%

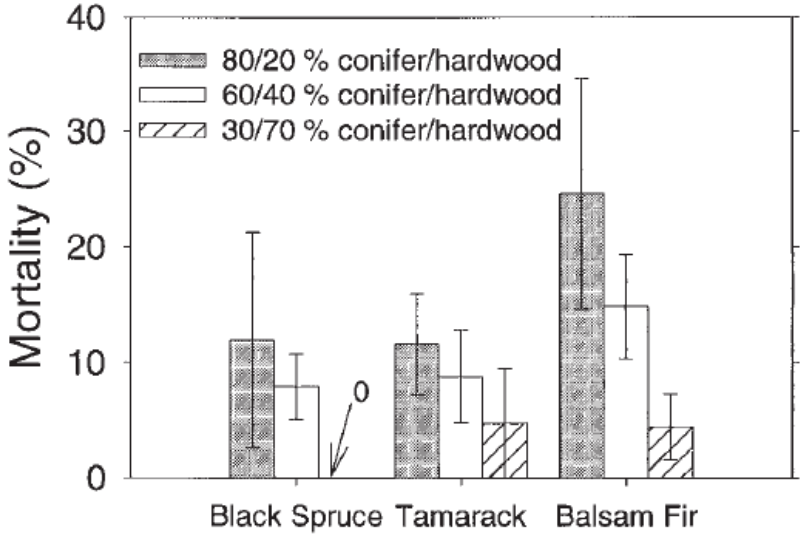


Resistance of mixed forest to fungal pathogens

Overall better resistance of mixed forests to root rot fungi

Species, diversity, and density affect tree seedling mortality from *Armillaria* root rot

J.P. Gerlach, P.B. Reich, K. Puettmann, and T. Baker



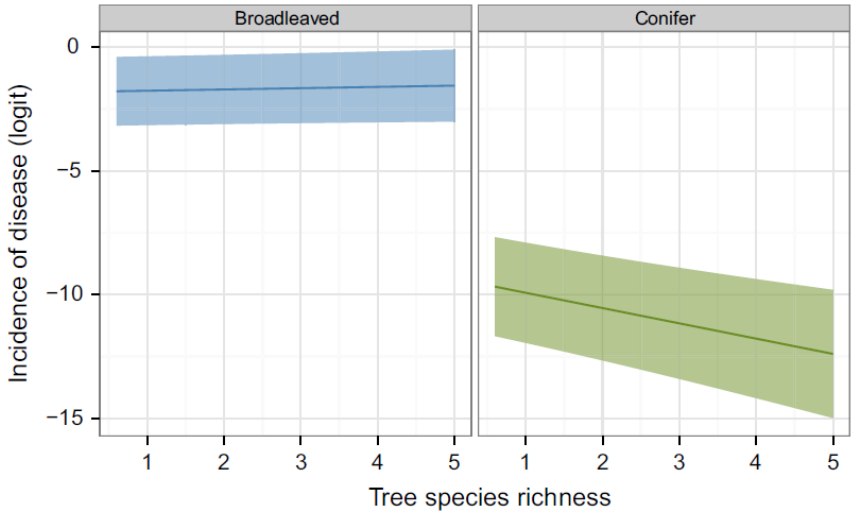
Resistance or neutral effects for foliar pathogens

Ecology and Evolution

Open Access

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

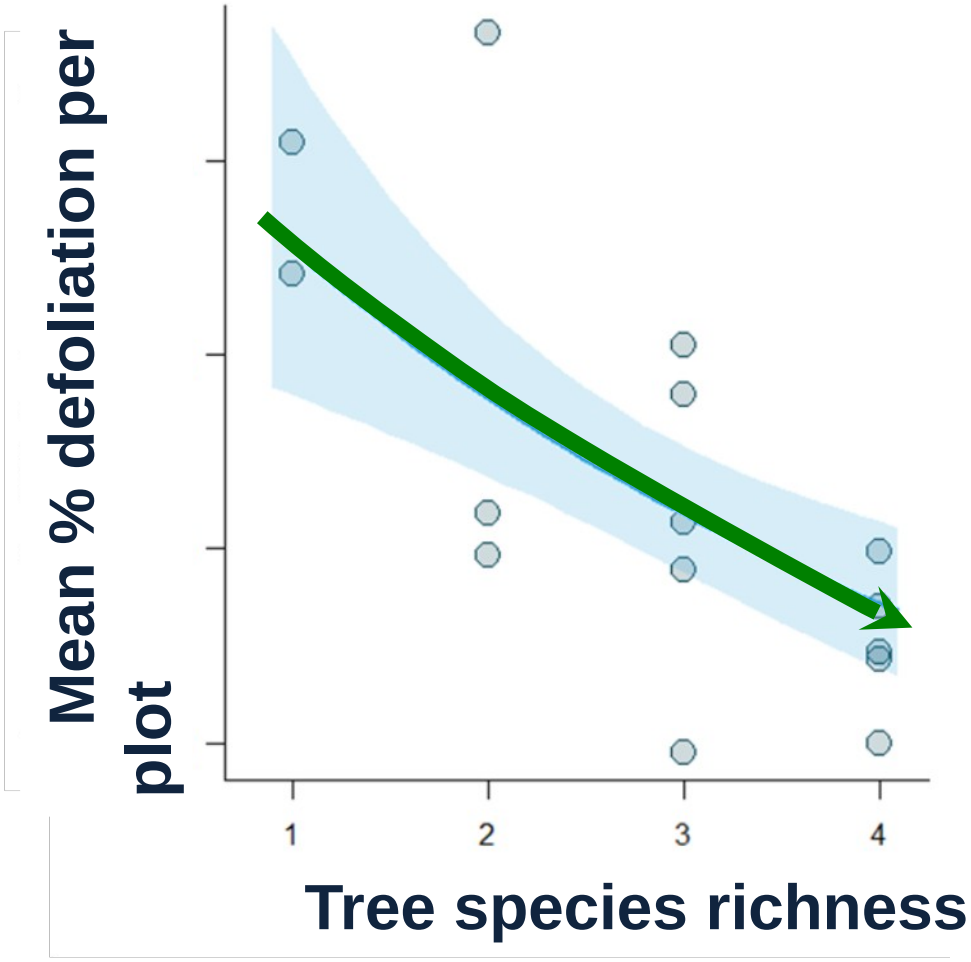
Diem Nguyen[1], Bastien Castagneyrol[2,3], Helge Bruelheide[4,5], Filippo Bussotti[6], Virginie Guyot[3,7], Hervé Jactel[2,3], Bogdan Jaroszewicz[8], Fernando Valladares[9], Jan Stenlid[1] & Johanna Boberg[1]



Resistance of mixed forests to invasive species

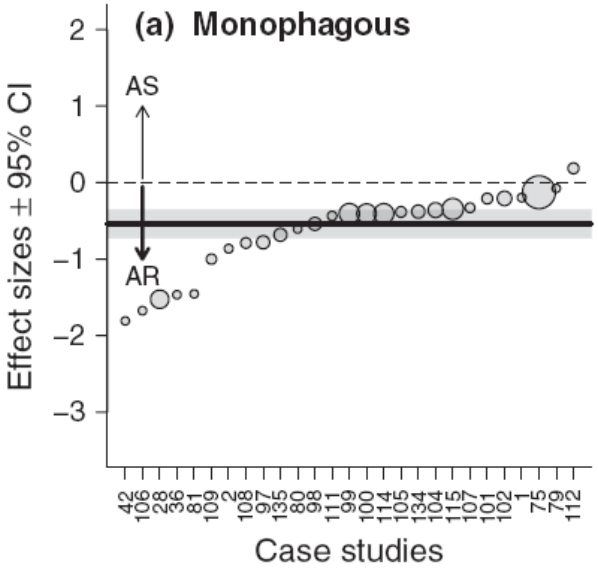
Tree Diversity Limits the Impact of an Invasive Forest Pest

Virginie Guyot[1,4]*, Bastien Castagneyrol[3,4], Aude Vialatte[1,2], Marc Deconchat[1], Federico Selvi[5], Filippo Bussotti[5], Hervé Jactel[3,4]

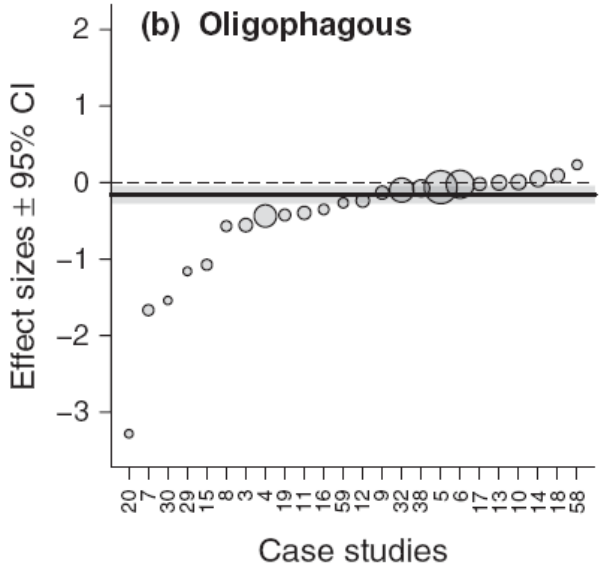


esistance of mixed forests: common features

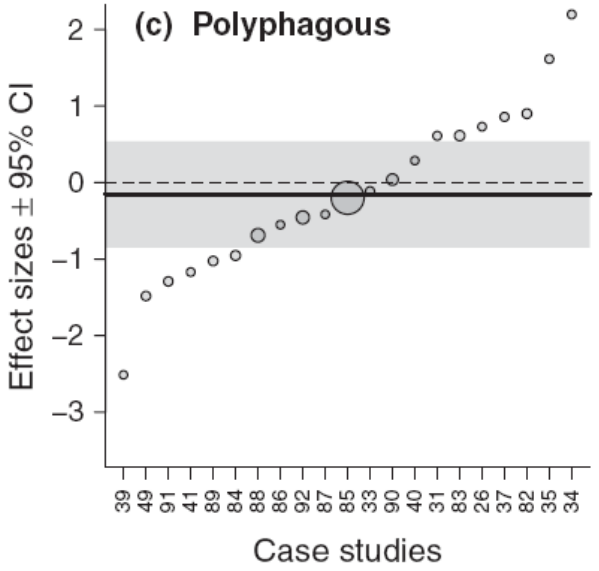
Direction and magnitude of effects depend on pest specializati



- 42%



- 15%



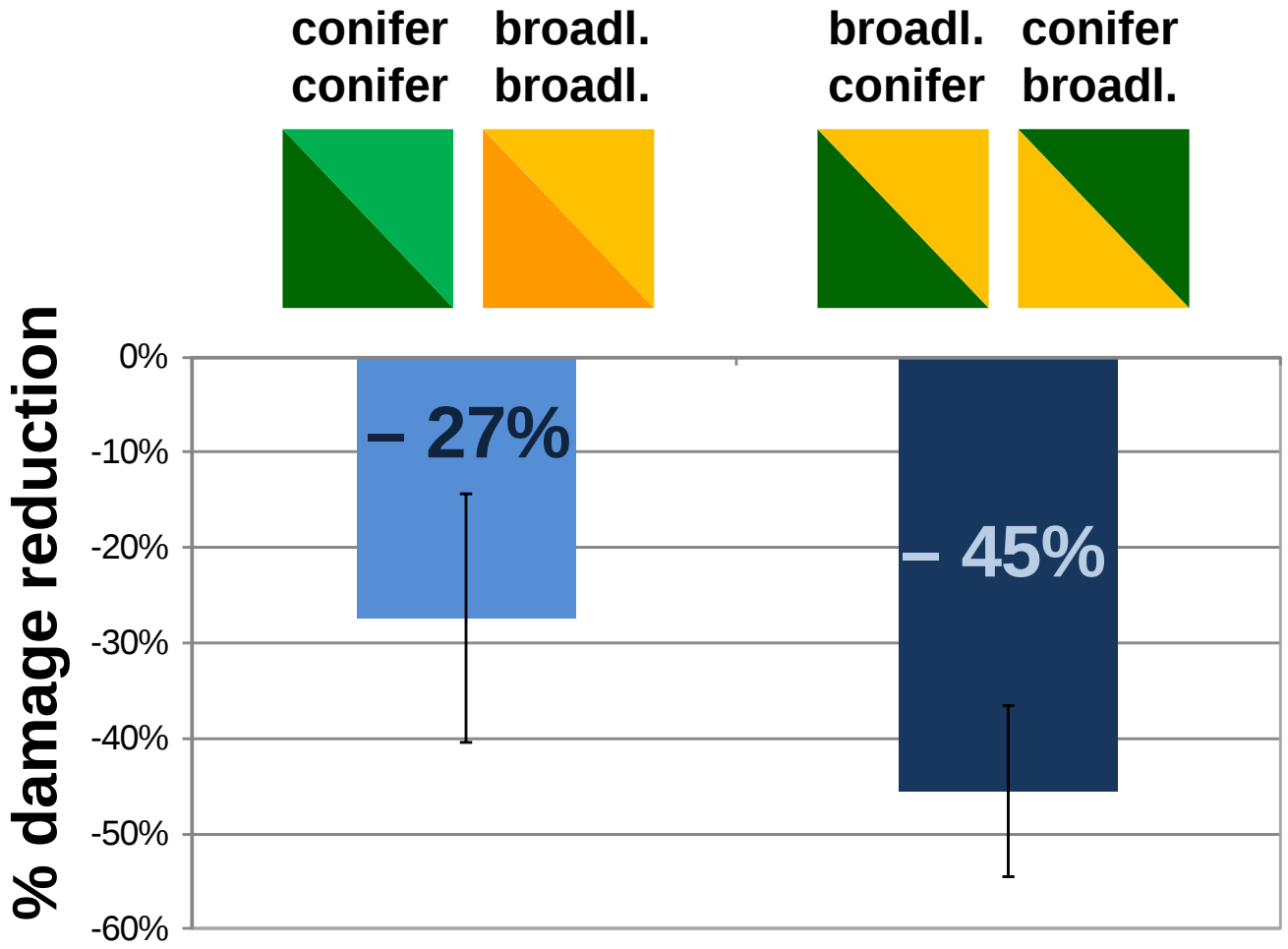
0%

Castagneyrol et al. 2014

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

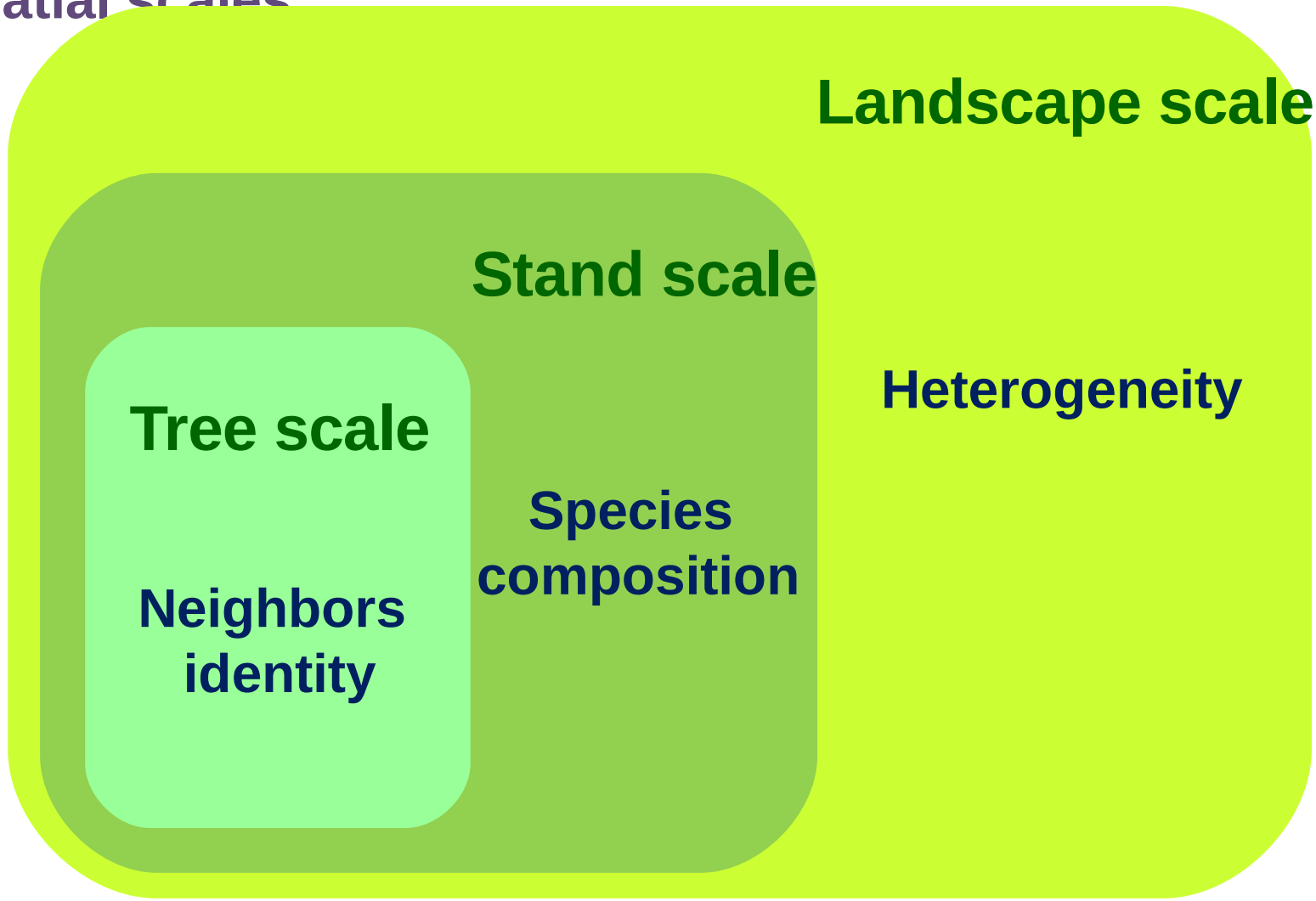
esistance of mixed forests: common features

Forest composition more important than tree species richnes



esistance of mixed forests: common features

3. **“Associational resistance” operate at several, nested spatial scales**



Mechanisms underlying diversity – resistance relationships

The insurance hypothesis

Proc. Natl. Acad. Sci. USA
Vol. 96, pp. 1463–1468, February 1999
Ecology

Biodiversity and ecosystem productivity in a fluctuating environment: The insurance hypothesis

(stochastic dynamic model/species richness/ecosystem processes/temporal variability/ecosystem stability)

SHIGEO YACHI AND MICHEL LOREAU*

Being composed of **several species** with **different functional traits**,

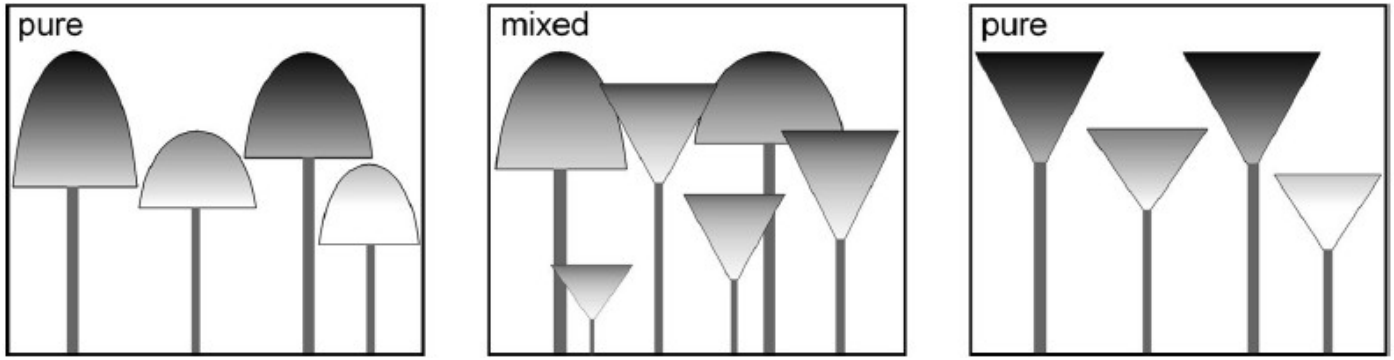
mixed forests have a **higher likelihood** of containing **resistant trees**,

thus providing **more opportunities** to **maintain a forest cover**

Mechanisms underlying diversity – resistance relationships

1. **Traits complementarity**

- Root depth / drought
- Bark anatomy / fire
- Crown architecture / wind



Eur J Forest Res (2015) 134:927–947

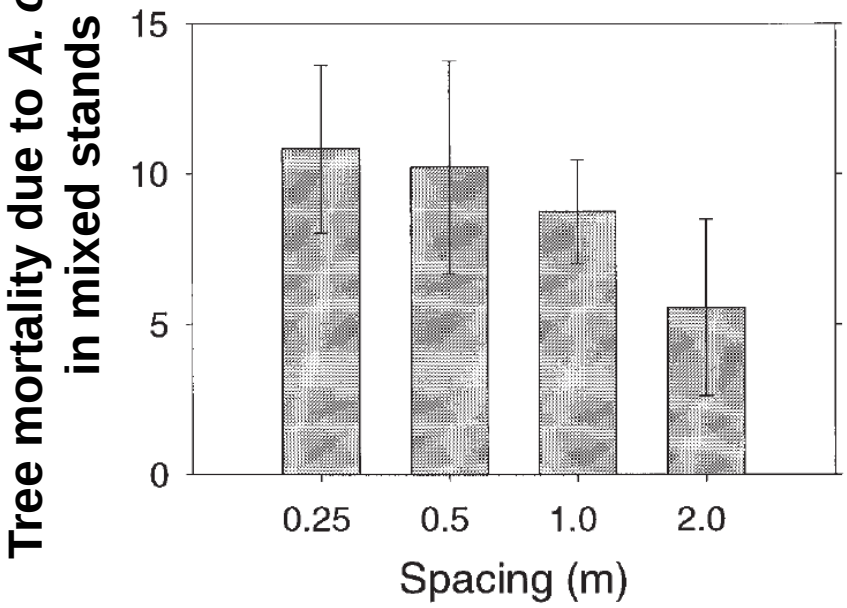
- Leaf quality / herbivores
- Niche occupancy / invasive species

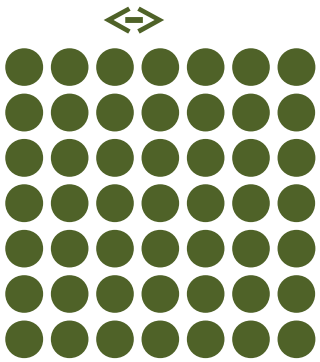
Mechanisms underlying diversity – resistance relationships

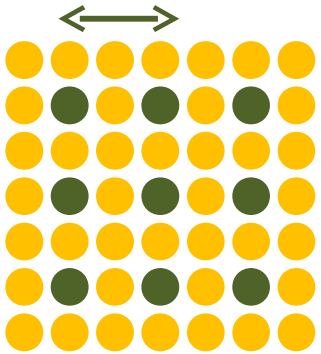
Reduced density (amount) of susceptible trees

- herbivores less likely to enter the pl
- lower amount of resources/fuel
- longer distance between host trees

Gerlach et al. 1997







Mechanisms underlying diversity – resistance relationships

Reduced probability of susceptible trees being hit

- physical protection by neighbors
- diversion (decoy) processes

Saplings planted under Eglantine

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]

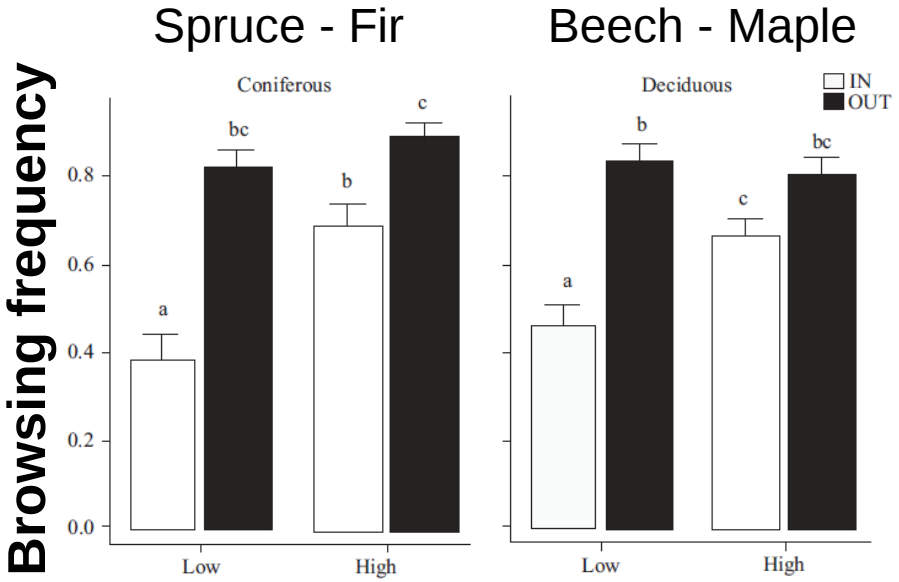


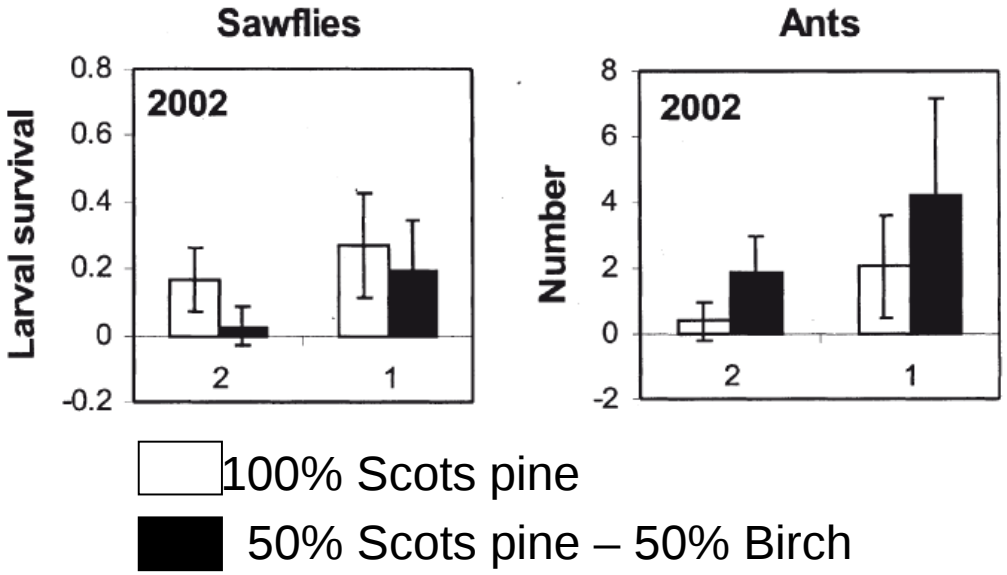
Fig. 2. The effects of grazing intensity (low and high) and position (in and out) on the browsing frequency (mean proportion ±1 SE, $n = 30$) of coniferous and deciduous saplings, after the fourth grazing period. Different letters indicate significantly different means (Tukey post hoc comparisons within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

Mechanisms underlying diversity – resistance relationships

Reinforced multitrophic interactions

- decomposers and mycorrhiza
- natural enemies

Neodiprion sertifer



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.

Conclusions

1. Mixed forests : **associational resistance** > susceptibility
2. Tree composition > species richness
3. Several scales, many processes involved
4. Tradeoffs for resistance to different disturbances?
5. Recommendations to forest managers:
   - 2 species mixtures might be enough
   - beyond the conifer – broadleaved mixtures

Thank you for your attention

http://mixedwoodecozone.weebly.com/natural-vegetation.html