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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

► To cite this version:

Herve Jactel, Johanna Boberg, Damien Bonal, Bastien Castagneyrol, Barry Gardiner, et al.. Effects of tree species diversity on resistance to natural disturbances in planted forests. 5. International EcoSummit. EcoSummit 2016. Ecological Sustainability: Engineering Change., Aug 2016, Montpellier, France. 26 p. hal-02793549

HAL Id: hal-02793549

<https://hal.inrae.fr/hal-02793549v1>

Submitted on 5 Jun 2020

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

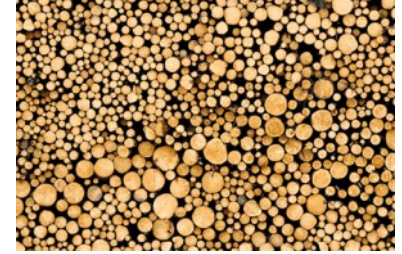


Hervé Jactel, Johanna Boberg, Damien Bonal, Bastien Castagneyrol, Barry Gardiner, José-Ramon Gonzalez, Julia Koricheva, Nicolas Meurisse, Eckehard Brockerhoff



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



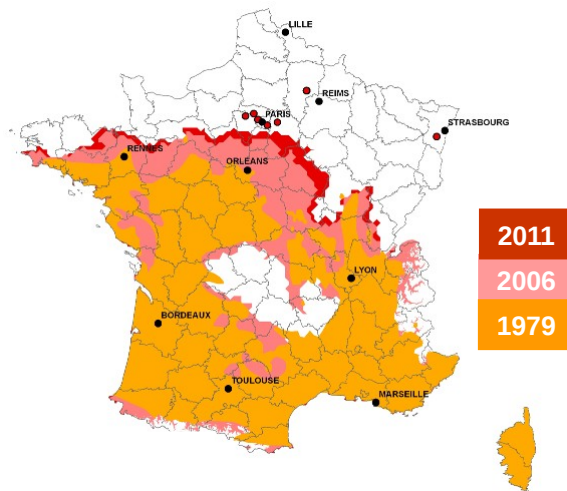
Rising threats due to global change

1. Climate change

↗ temperatures trigger pest outbreaks and range expansion



Mountain pine beetle



Pine processionary moth

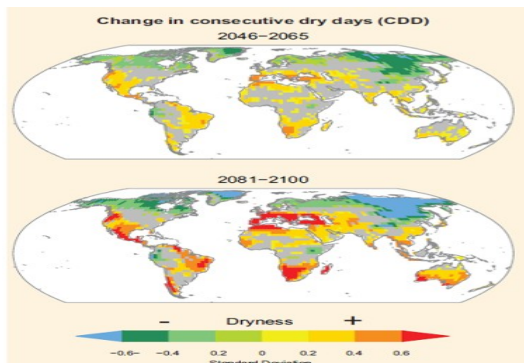
Rising threats due to global change

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 PIOUS‡, ANDREA BATTISTI§ and JULIA KORICHEVA¶

Rising threats due to global change

1. Climate change

↗ wind damage

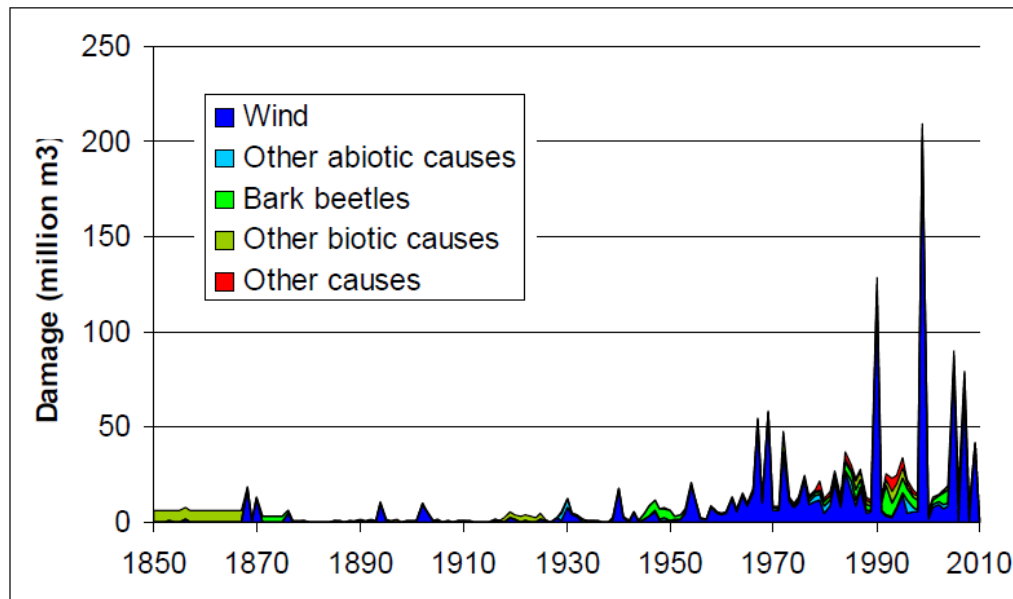
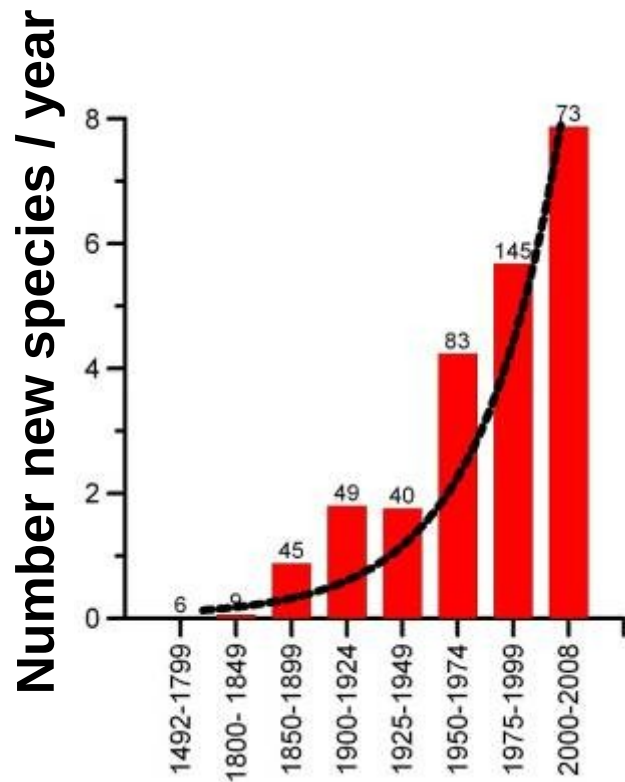


Figure 1a: Total damage due to disturbances in Europe (Schelhaas 2008a)

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 Isbell¹, Dylan Craven^{2,3}, John Connolly⁴, Michel Loreau⁵, Bernhard Schmid⁶, Carl Beierkuhnlein⁷, T. Martijn Bezemer⁸, Catherine Bonin⁹, Helge Bruelheide^{2,10}, Enrica de Luca⁶, Anne Ebeling¹¹, John N. Griffin¹², Qinfeng Guo¹³, Yann Hautier¹⁴, Andy Hector¹⁵, Anke Jentsch¹⁶, Jürgen Kreyling¹⁷, Vojtěch Lanta¹⁸, Pete Manning¹⁹, Sebastian T. Meyer²⁰, Akira S. Mori²¹, Shahid Naeem²², Pascal A. Niklaus⁶, H. Wayne Polley²³, Peter B. Reich^{24,25}, Christiane Roscher^{2,26}, Eric W. Seabloom¹, Melinda D. Smith²⁷, Madhav P. Thakur^{2,3}, David Tilman^{1,28}, Benjamin F. Tracy²⁹, Wim H. van der Putten^{8,30}, Jasper van Ruijven³¹, Alexandra Weigel^{2,3}, Wolfgang W. Weisser²⁰, Brian Wilsey³² & Nico Eisenhauer^{2,3}

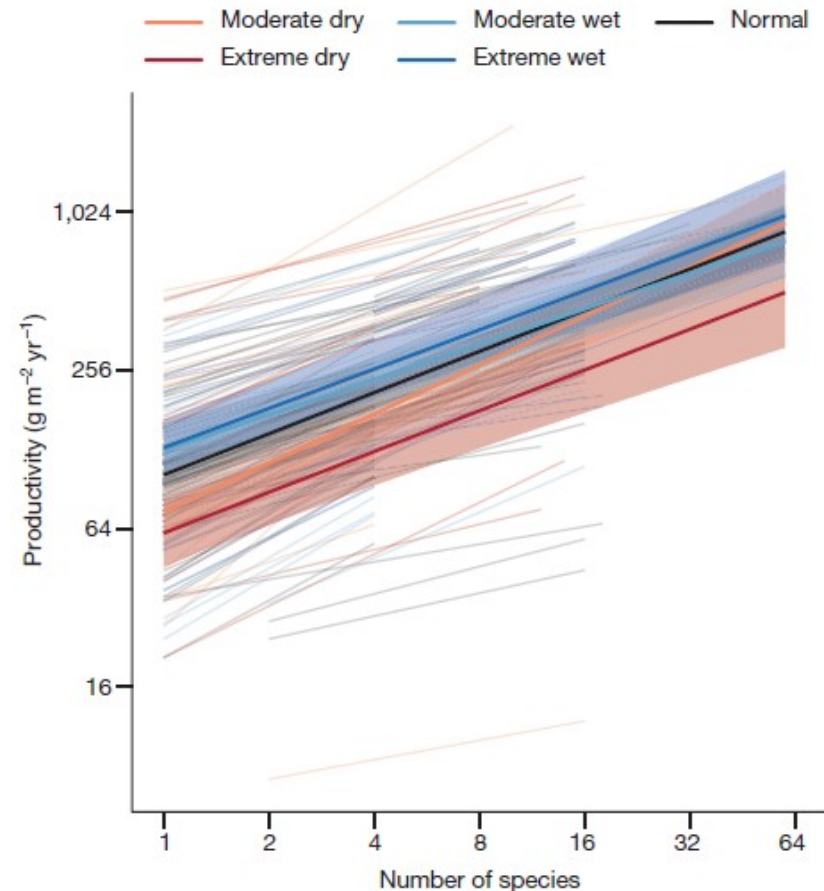


Figure 3 | Biodiversity effects on productivity during climate events or normal years. Lines are mixed-effects model fits for each year within each

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**



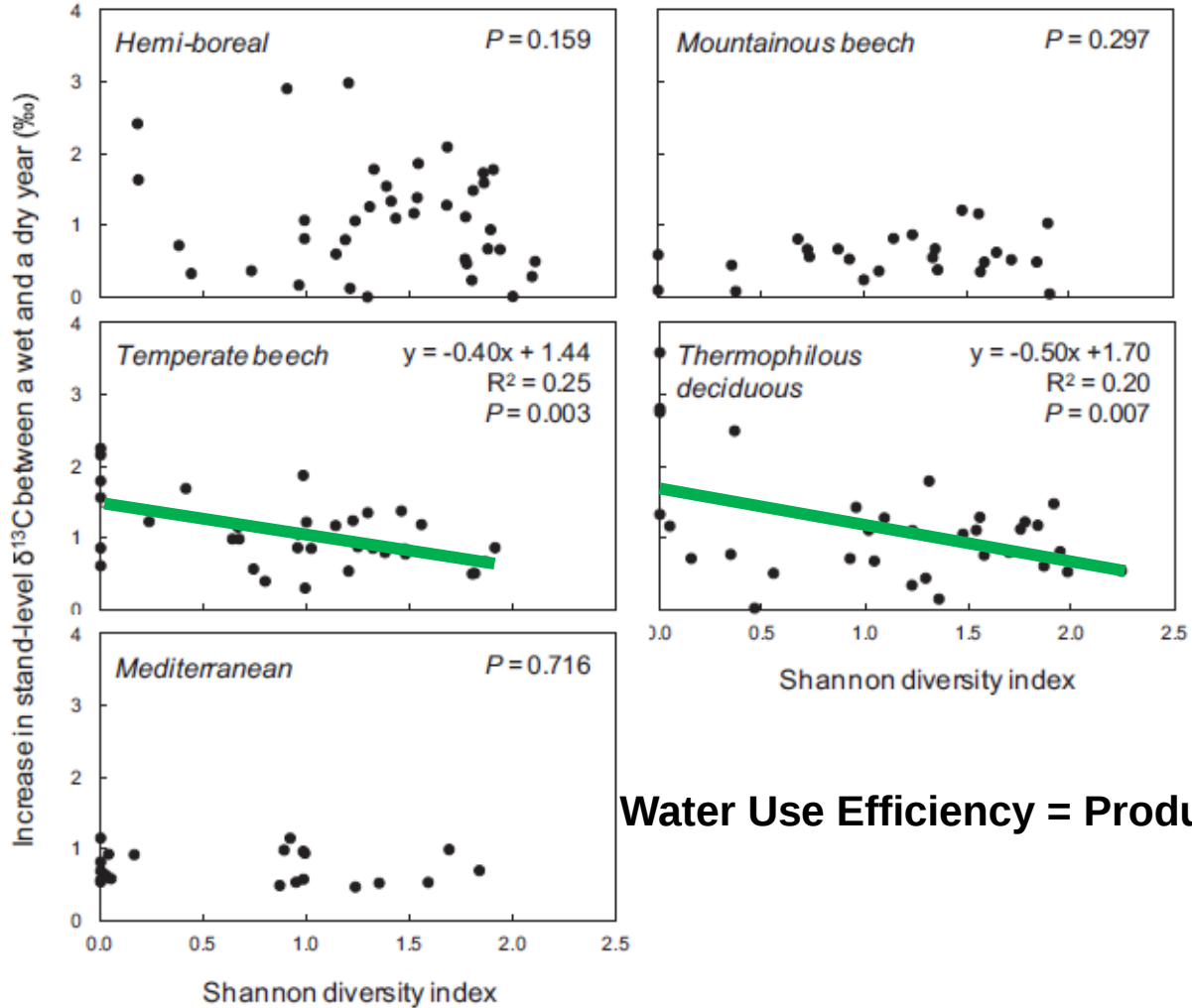
Patterns of response to tree diversity
Underlying ecological mechanisms

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 Chečko^f, David Ian Forrester^g, Seid Muhie Dawud^h, Leena Finérⁱ, 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

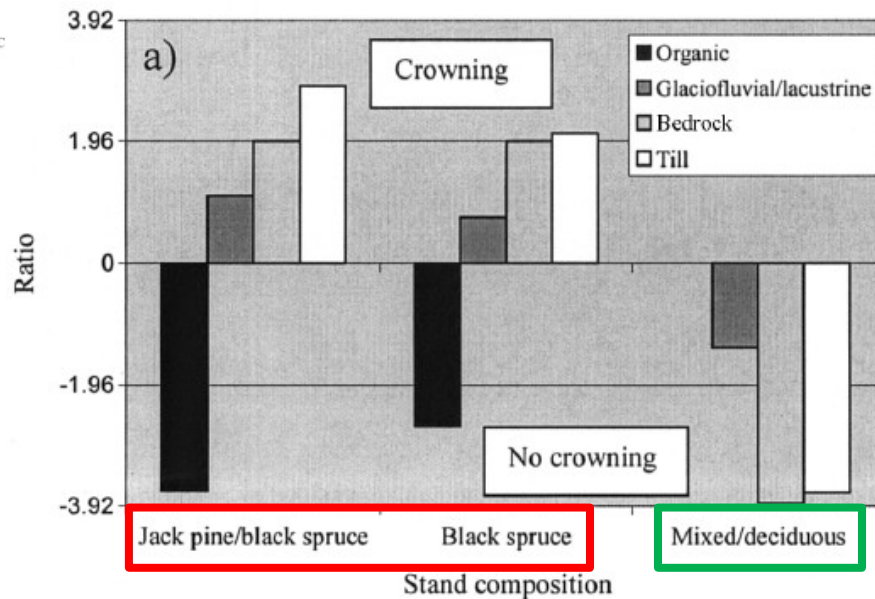
G.G. Wang*

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

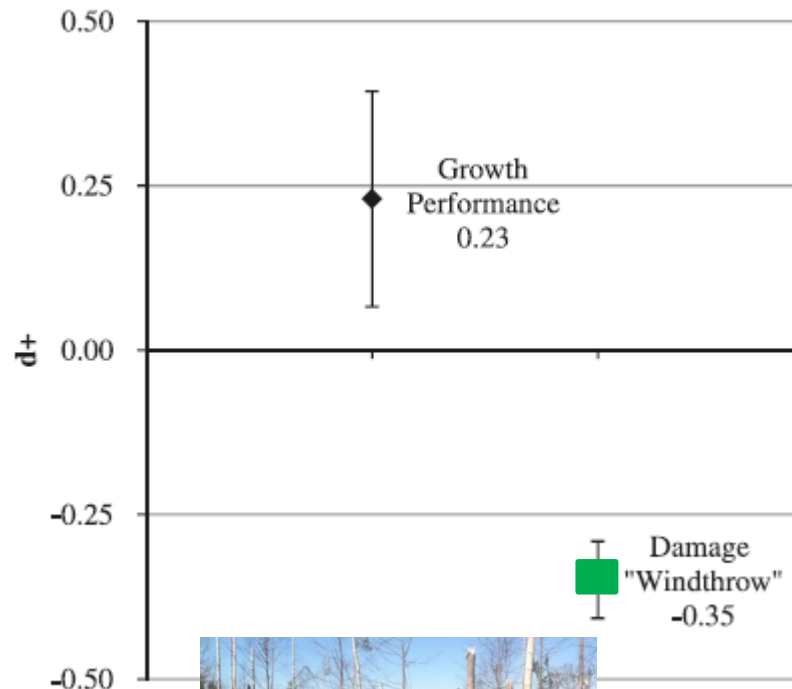


Resistance of mixed forests to windstorms

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



<http://iireporter.com>

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

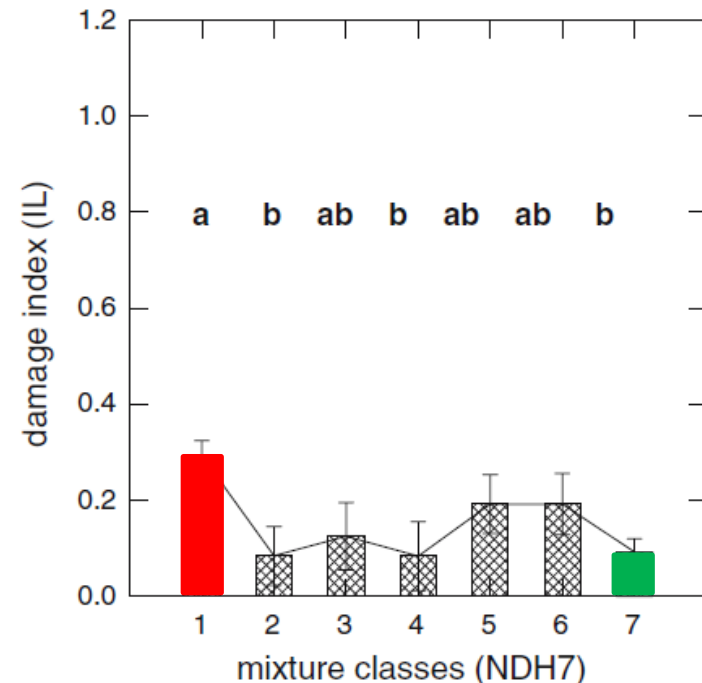


Fig. 10 Effect of tree mixtures on damage index: ANOVA with different mixed species and proportions. Mixtures classes with different letters were significantly different at $P=0.10$. 1 Pure spruce/fir ($\geq 90\%$) 2 rich spruce/fir (80–89%), 3 dominant spruce/fir (70–79%), 4 admixture douglas fir ($\geq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

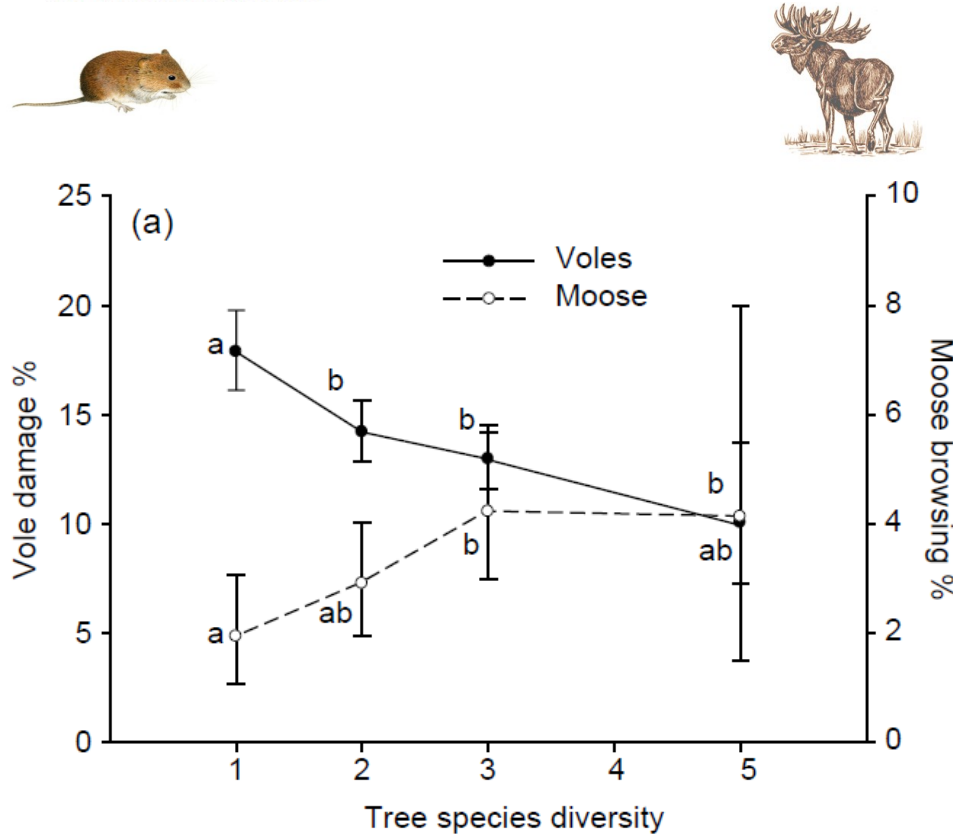
Resistance of mixed forest to mammal herbivory

Contrasting effects on mammal herbivores

ECOGRAPHY 29: 497–506, 2006

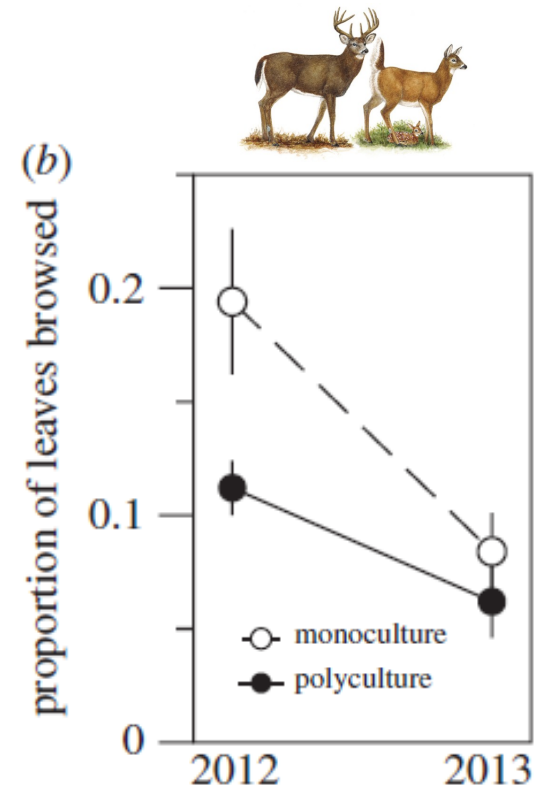
Moose and vole browsing patterns in experimentally assembled pure and mixed forest stands

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

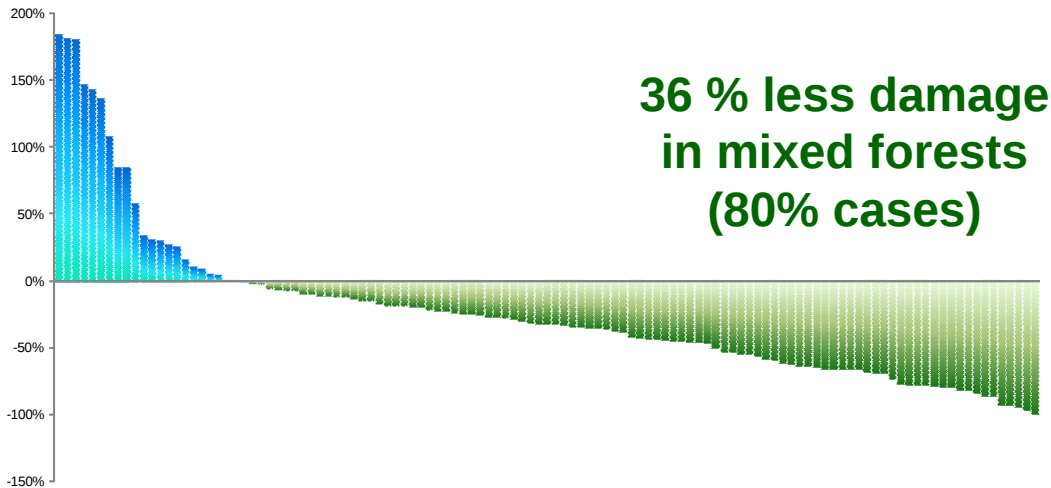
doi: 10.1111/j.1461-0248.2007.01073.x

LETTER

Tree diversity reduces herbivory by forest insects

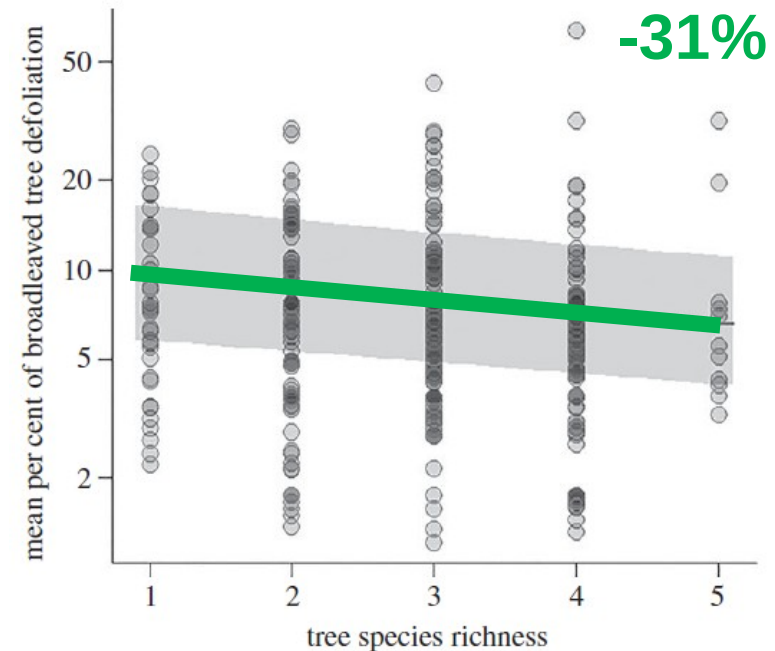
Hervé Jactel^{1*} and Eckehard G.
Brockerhoff²

119 case studies, 33 tree species



Tree diversity reduces pest damage
in mature forests across Europe

Virginie Guyot^{1,3}, Bastien Castagneyrol³, Aude Vialatte^{1,2}, Marc Deconchat¹
and Hervé Jactel³

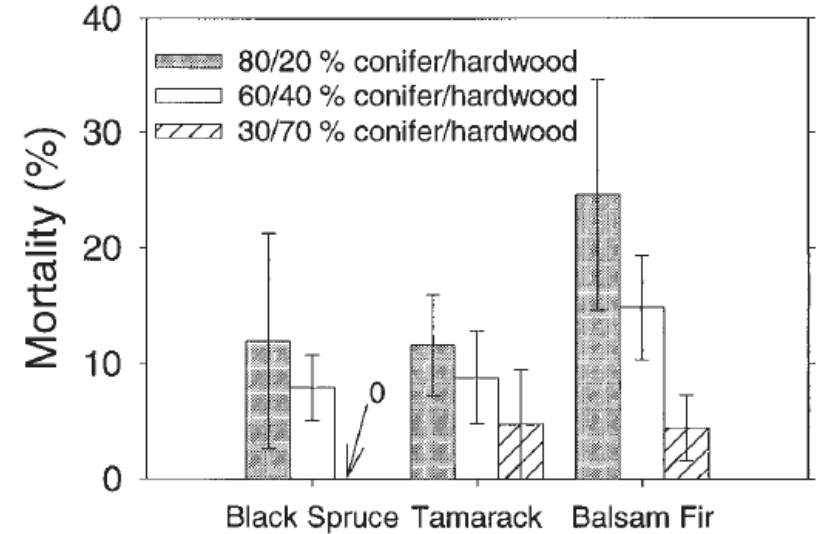


Resistance of mixed forest to fungal pathogens

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



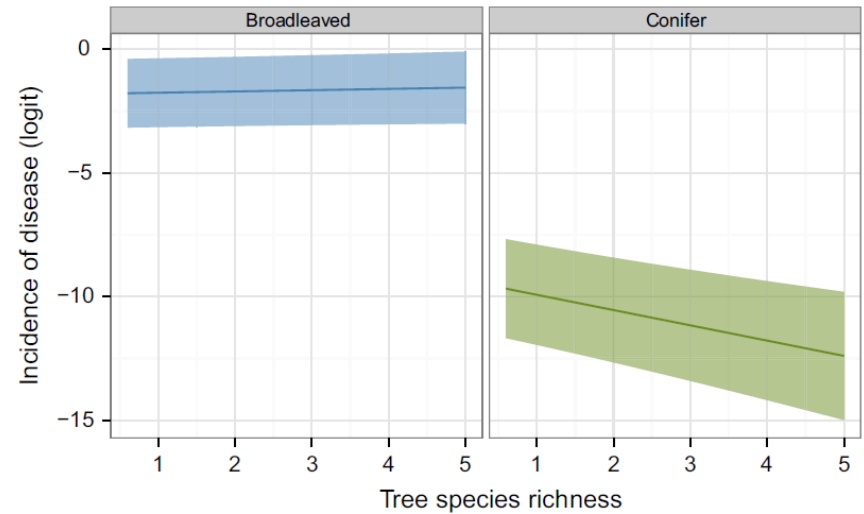
Resistance or neutral effects for foliar pathogens

Ecology and Evolution

Open Access

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

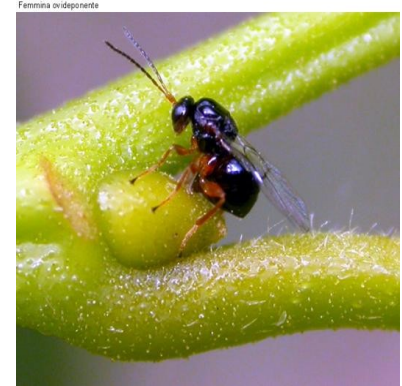
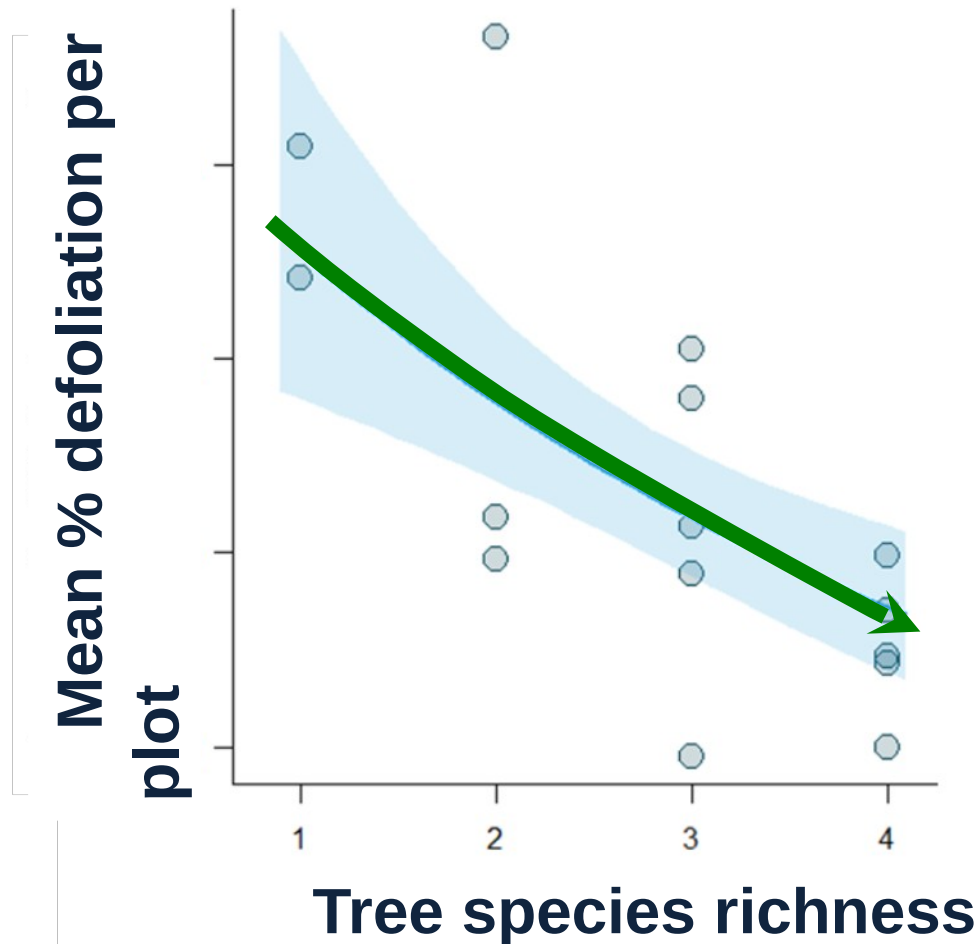
Diem Nguyen¹, Bastien Castagneyrol^{2,3}, Helge Bruelheide^{4,5}, Filippo Bussotti⁶, Virginie Guyot^{3,7}, Hervé Jactel^{2,3}, Bogdan Jaroszewicz⁸, Fernando Valladares⁹, Jan Stenlid¹ & Johanna Boberg¹



Resistance of mixed forests to invasive species

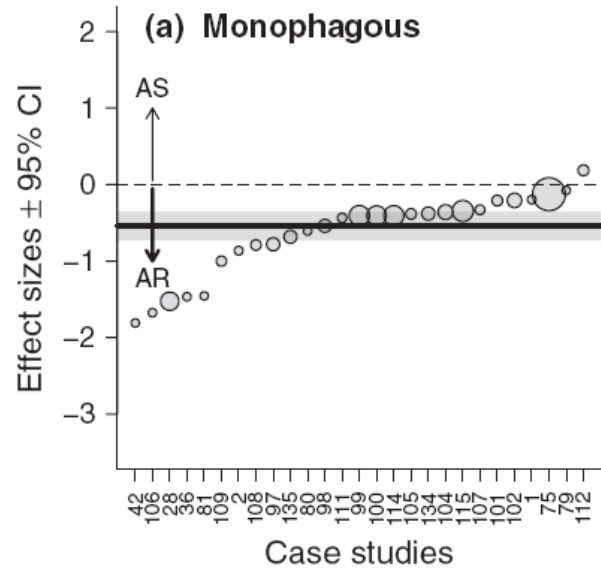
Tree Diversity Limits the Impact of an Invasive Forest Pest

Virginie Guyot^{1,4*}, Bastien Castagneyrol^{3,4}, Aude Vialatte^{1,2}, Marc Deconchat¹, Federico Selvi⁵, Filippo Bussotti⁵, Hervé Jactel^{3,4}

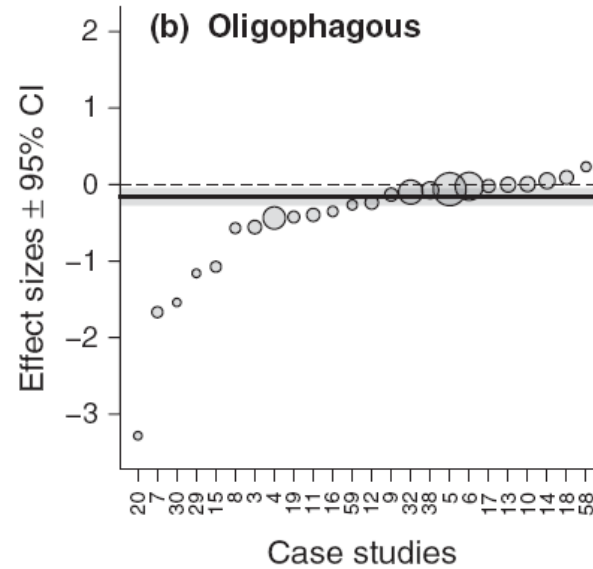


Resistance of mixed forests: common features

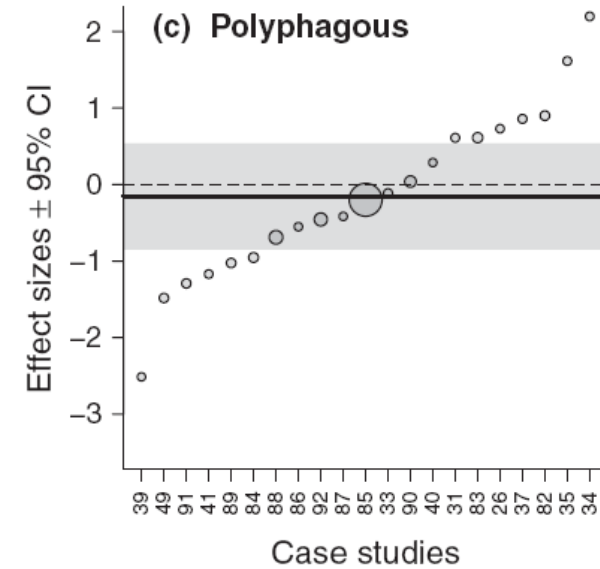
Direction and magnitude of effects depend on pest specialization



- 42%



- 15%



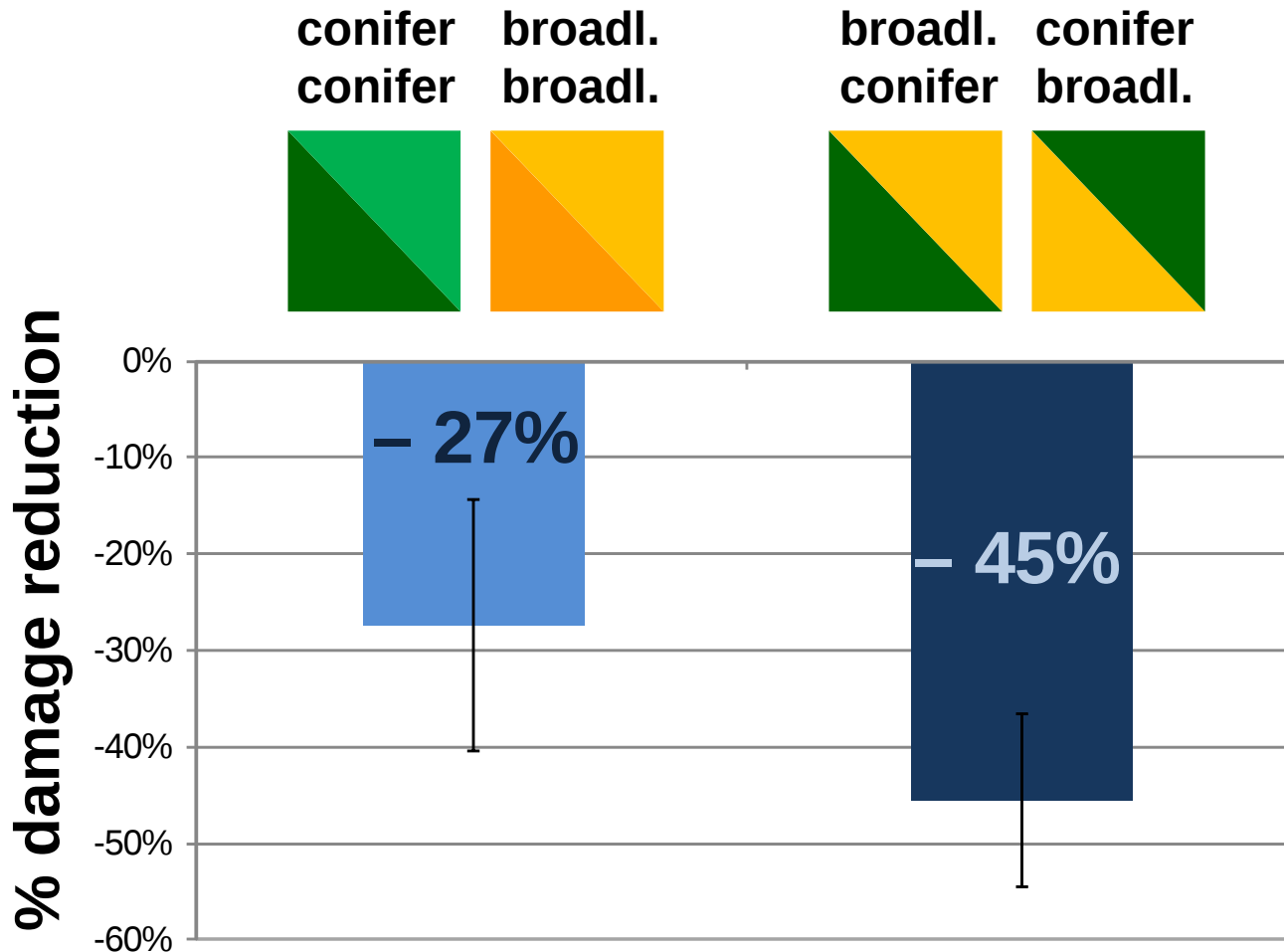
0%

Castagneyrol et al. 2014

- Spill over
- Mixing diet

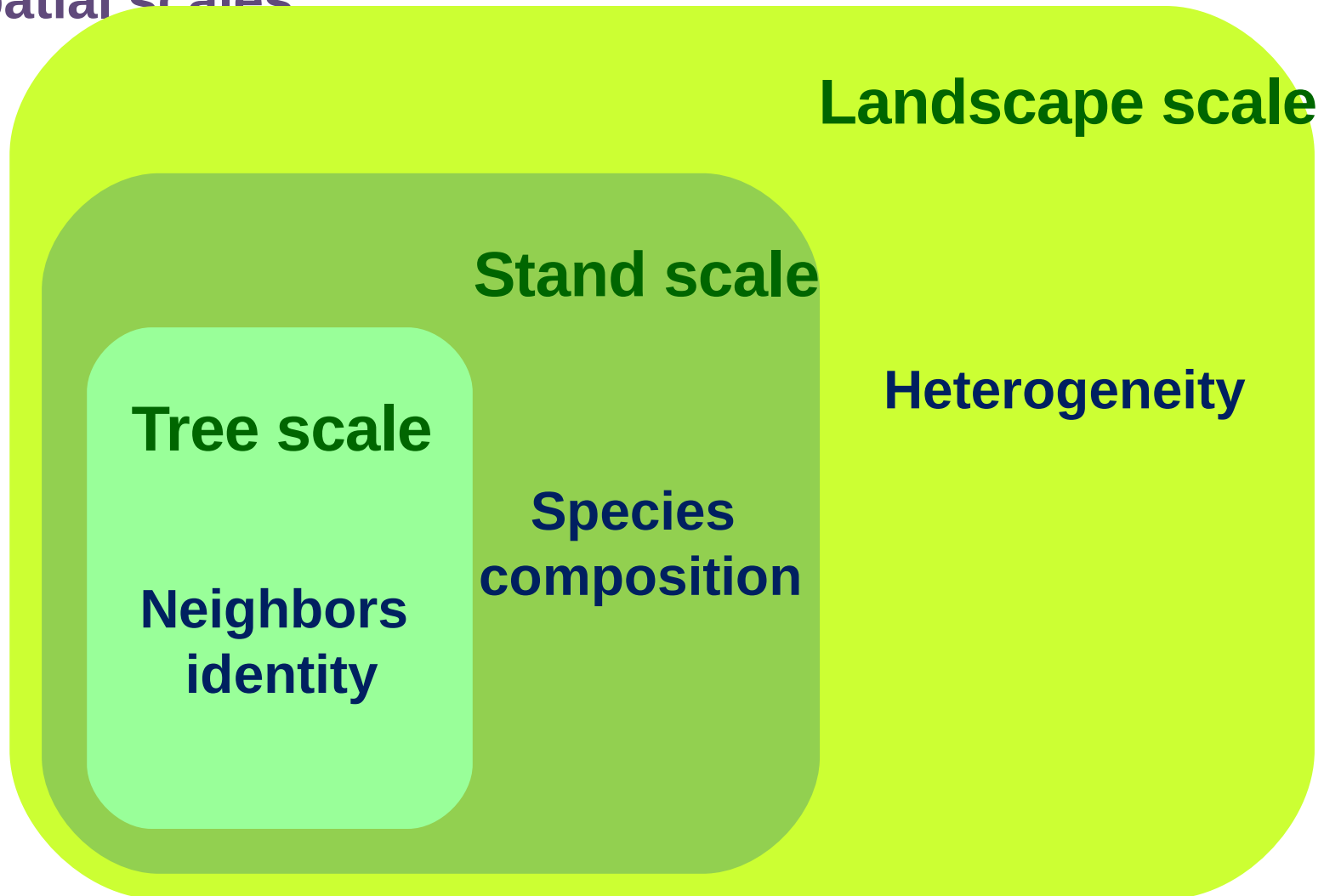
Resistance of mixed forests: common features

Forest composition more important than tree species richness



Resistance 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)

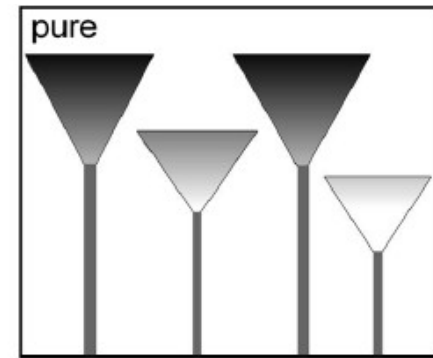
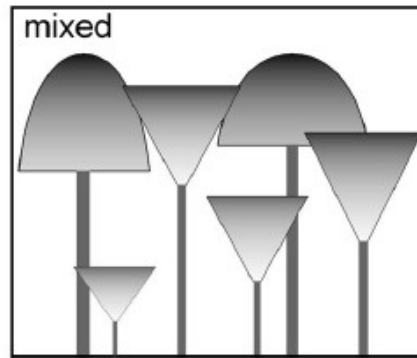
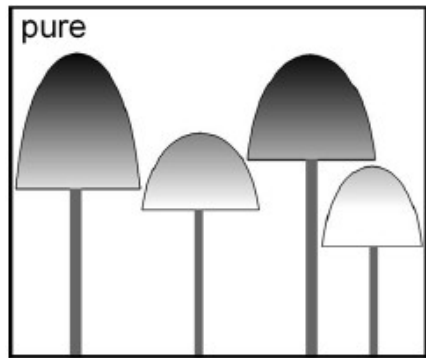
SHIGEO YACHI AND MICHEL LOREAU*

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

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

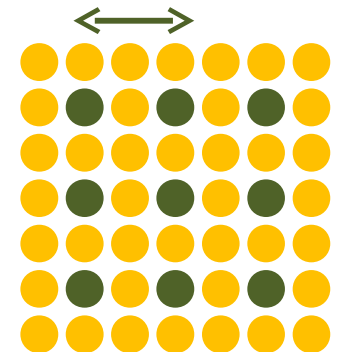
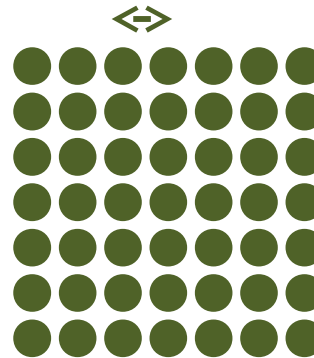
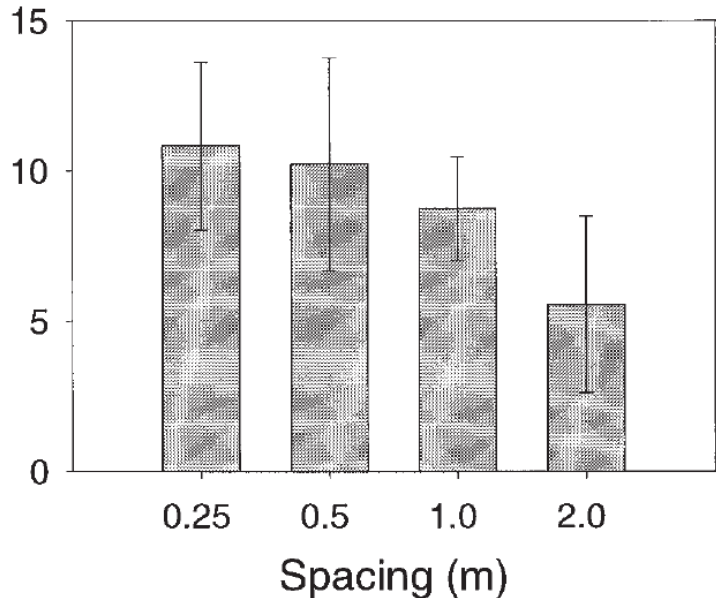
Reduced density (amount) of susceptible trees



Gerlach et al. 1997

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

Tree mortality due to *A. ostoyae*
in mixed stands



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}

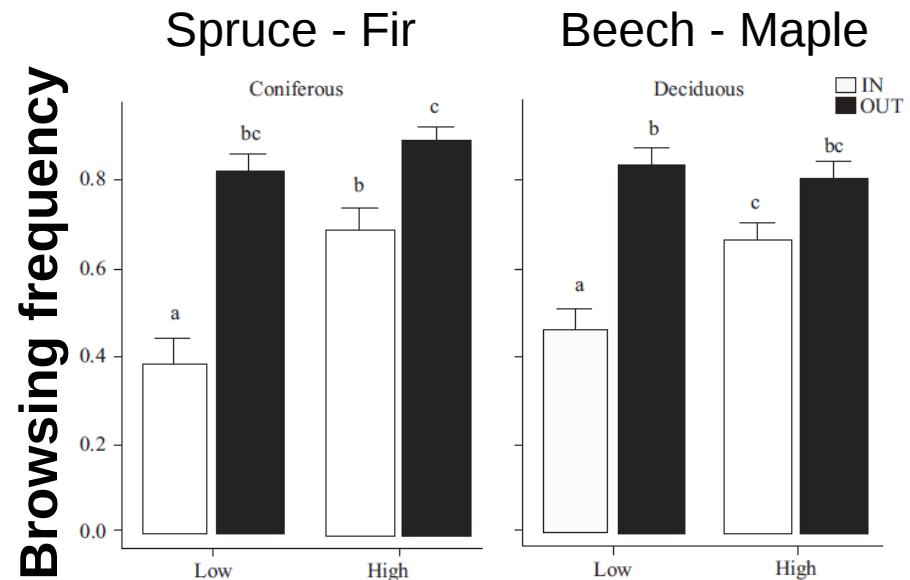


Fig. 2. The effects of grazing intensity (low and high) and position (in and out) on the browsing frequency (mean proportion \pm 1 SE, $n = 30$) of coniferous and deciduous saplings, after the fourth grazing period. Different letters indicate significantly different means (Tukey post hoc comparisons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

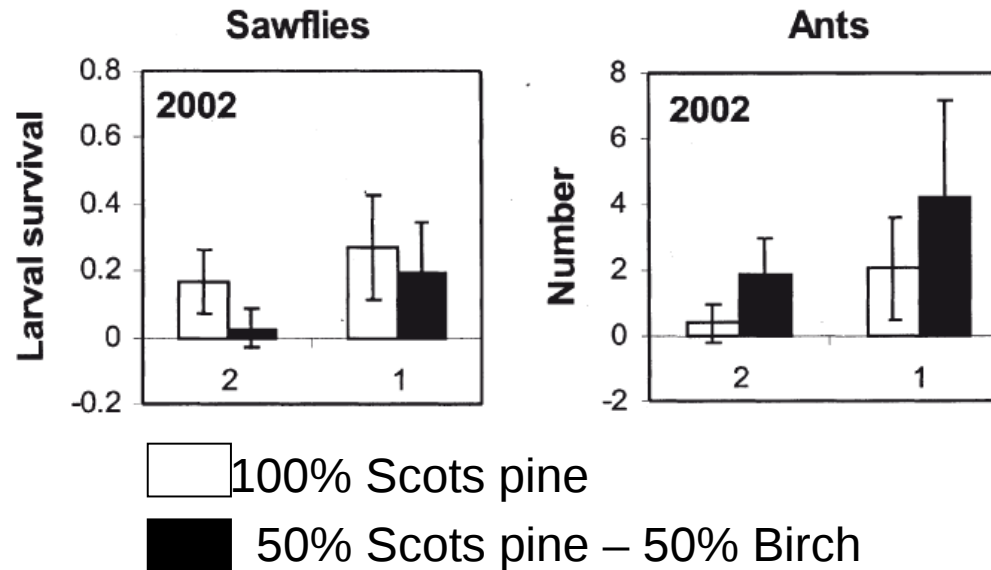
Mechanisms underlying diversity – resistance relationships

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

