Tree diversity - forest resistance relationships

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

Tree diversity - forest resistance relationships

EUMIXFOR
Cost Action

IUFRO

TF Contribution of Biodiversity to Ecosystem Services in Managed Forests

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

INRA SCIENCE & IMPACT

SLU Swedish University of Agricultural Sciences

E F I

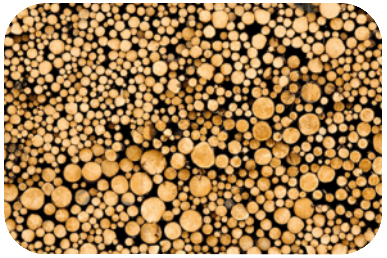
CEMFOR

ROYAL HOLLOWAY UNIVERSITY OF LONDON

scion forests · products · innovation

An urgent need for more productive 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

Mixed forests are likely more productive

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

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. Matović[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]

100 YEARS Journal of Ecology British Ecological Society

Journal of Ecology 2012, **100**, 742–749 doi: 10.1111/j.1365-2745.2011.01944.x

Forest productivity increases with evenness, species richness and trait variation: a global meta-analysis

Yu Zhang[1], Han Y. H. Chen[1]* and Peter B. Reich[2,3]

Ecology Letters, (2007) **10**: 241–250 doi: 10.1111/j.1461-0248.2007.01016.x

LETTER

Species richness and wood production: a positive association in Mediterranean forests

Montserrat Vilà[1]*, Jordi Vayreda[2], Lluís Comas[2], Joan Josep Ibáñez[2], Teresa Mata[2] and Berta Obón[2]

Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2010)

RESEARCH PAPER

The effect of biodiversity on tree productivity: from temperate to boreal forests

Alain Paquette* and Christian Messier

ECOLOGY LETTERS

Ecology Letters, (2014) **17**: 1560–1569 doi: 10.1111/ele.12382

LETTER

Stabilizing effects of diversity on aboveground wood production in forest ecosystems: linking patterns and processes

Tommaso Jucker,[1]* Olivier Bouriaud,[2] Daniel Avacaritei[2] and David A. Coomes[1]

ELSEVIER

Available online at www.sciencedirect.com
ScienceDirect

Forest Ecology and Management xxx (2007) xxx–xxx

Forest Ecology and Management
www.elsevier.com/locate/foreco

A meta-analysis comparing tree growth in monocultures and mixed plantations

Daniel Piotto

Curr Forestry Rep
DOI 10.1007/s40725-016-0031-2

ECOLOGICAL FUNCTION (K VERHEYEN, SECTION EDITOR)

A Review of Processes Behind Diversity—Productivity Relationships in Forests

David I. Forrester[1] · Jürgen Bauhus[1]

Received 7 Jun 2012 | Accepted 26 Nov 2012 | Published 8 Jan 2013 DOI: 10.1038/ncomms2328 OPEN

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]

100 YEARS Journal of Ecology British Ecological Society

Journal of Ecology 2015, **103**, 502–512 doi: 10.1111/1365-2745.12353

Overyielding in mixed forests decreases with site productivity

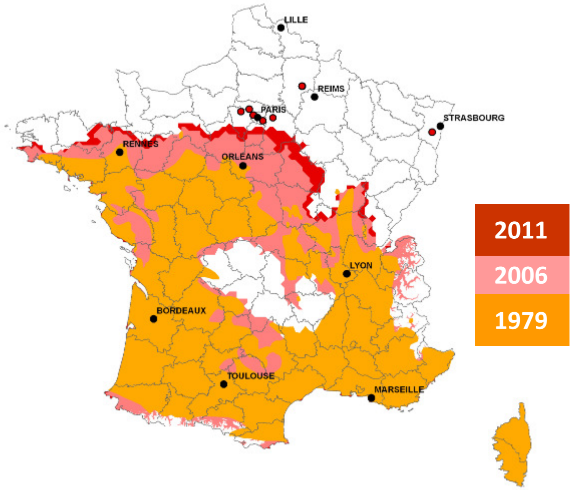
Maude Toïgo[1], Patrick Vallet[1]*, Thomas Perot[1], Jean-Daniel Bontemps[2,3], Christian Piedallu[2,3] and Benoit Courbaud[4]

But are mixed forests more prone to damage ?

1. Rising threats due to climate change

↗ temperatures trigger pest outbreaks and range expansion

Mountain pine beetle

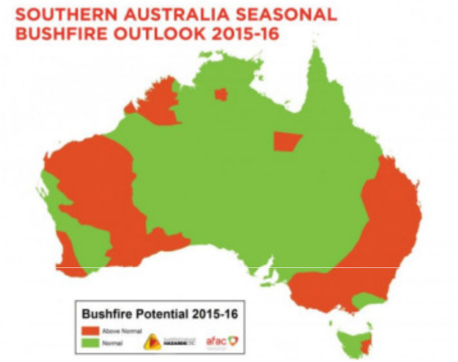


Pine processionary moth

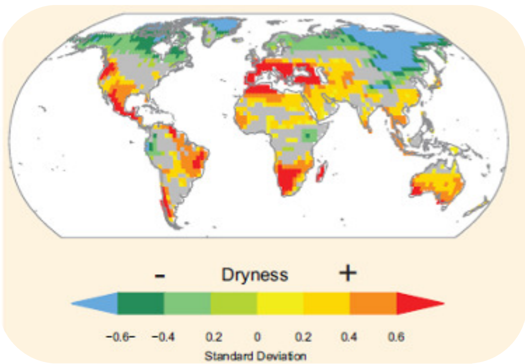
But are mixed forests more prone to damage ?

1. Rising threats due to 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¶

But are mixed forests more prone to damage ?

1. Rising threats due to climate change

↗ wind damage

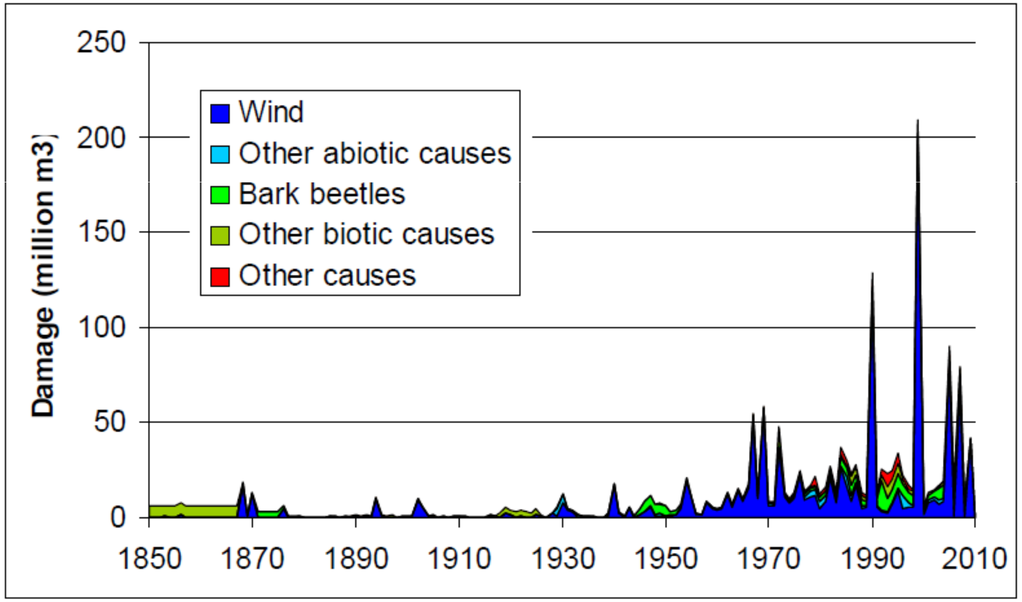
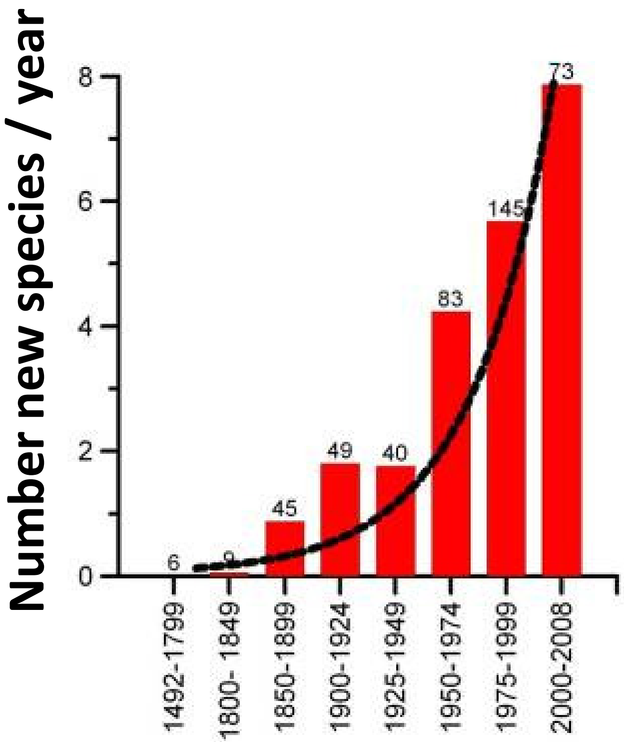


Figure 1a: Total damage due to disturbances in Europe (Schelhaas 2008a).

But are mixed forests more prone to damage ?

2. Rising threats due to global change

↗ globalization results in more biological invasions



Exotic arthropods

Dryocosmus kuriphilus
Origine: China

But are mixed forests more prone to damage ?

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]

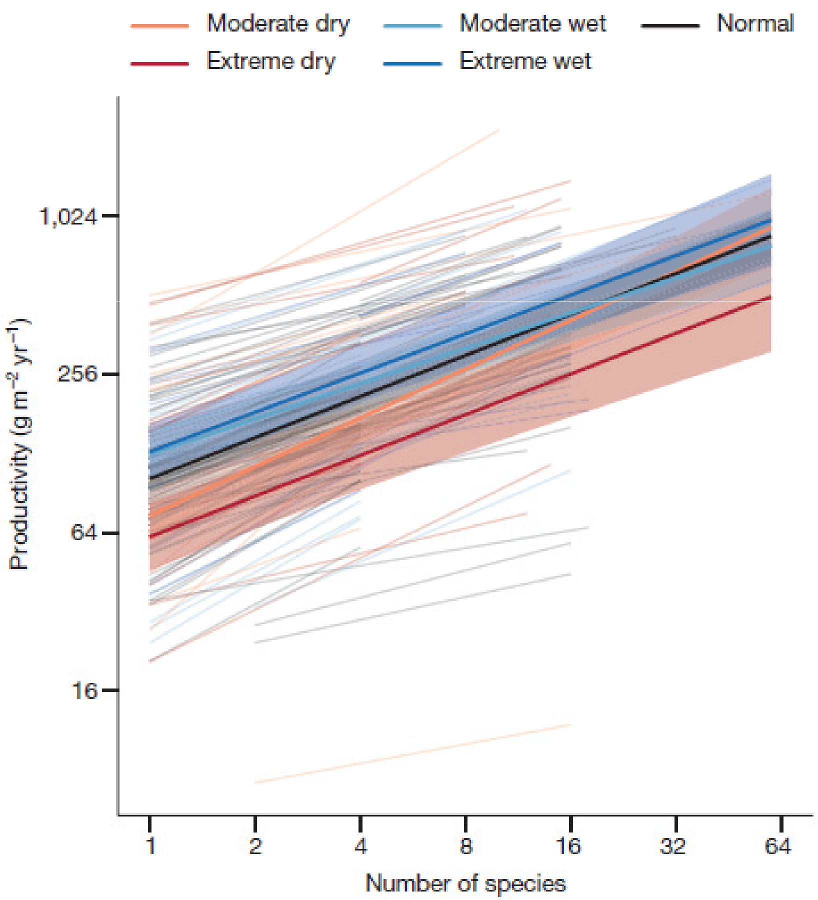


Figure 3 | Biodiversity effects on productivity during climate events or normal years. Lines are mixed-effects model fits for each year within each

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

1. Patterns of response to tree diversity
2. Underlying ecological mechanisms

Concept of Associational Resistance

Associational Resistance and Associational Susceptibility: Having Right or Wrong Neighbors

Pedro Barbosa,[1,2] Jessica Hines,[1] Ian Kaplan,[3] Holly Martinson,[1] Adrianna Szczepaniec,[4] and Zsofia Szendrei[5]

Annu. Rev. Ecol. Evol. Syst. 2009. 40:1–20

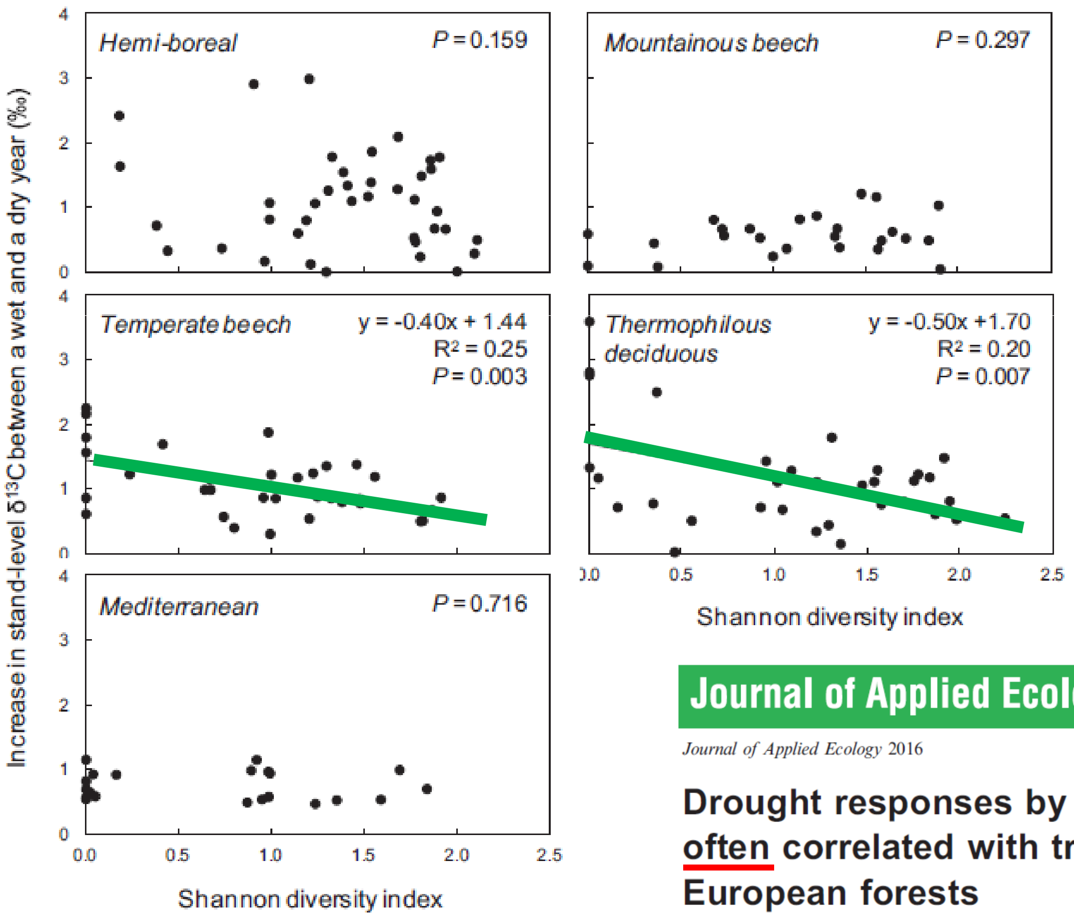
AR = greater resistance of plants against herbivores when surrounded by heterospecific neighbors as compared to plants growing among conspecifics
The opposite pattern is associational susceptibility (AS)

Associational resistance = emergent property of assemblages of different tree (plant) species resulting in lesser damage by natural disturbances at the stand level

1. Associational resistance to drought

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]



Idiosyncratic responses

Limiting factors (temperature, fertility)

Journal of Applied Ecology
British Ecological Society
Journal of Applied Ecology 2016
doi: 10.1111/1365-2664.12745

Drought responses by individual tree species are not often correlated with tree species diversity in European forests

David I. Forrester[1]*, Damien Bonal[2], Seid Dawud[3], Arthur Gessler[4,5], André Granier[2], Martina Pollastrini[6] and Charlotte Grossiord[7]

2. Associational resistance to fires

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

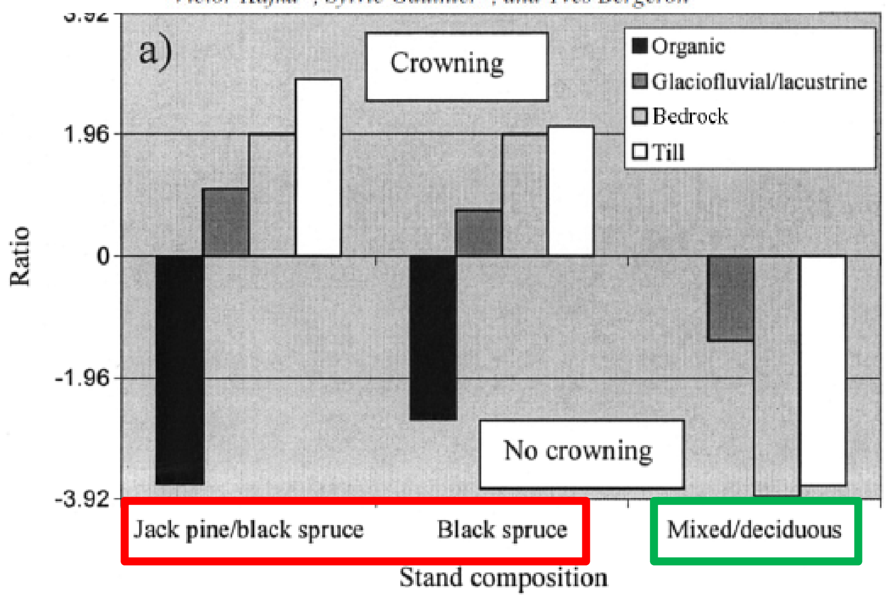
G.G. Wang*

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]



Several cases of AR

Mainly in boreal forests

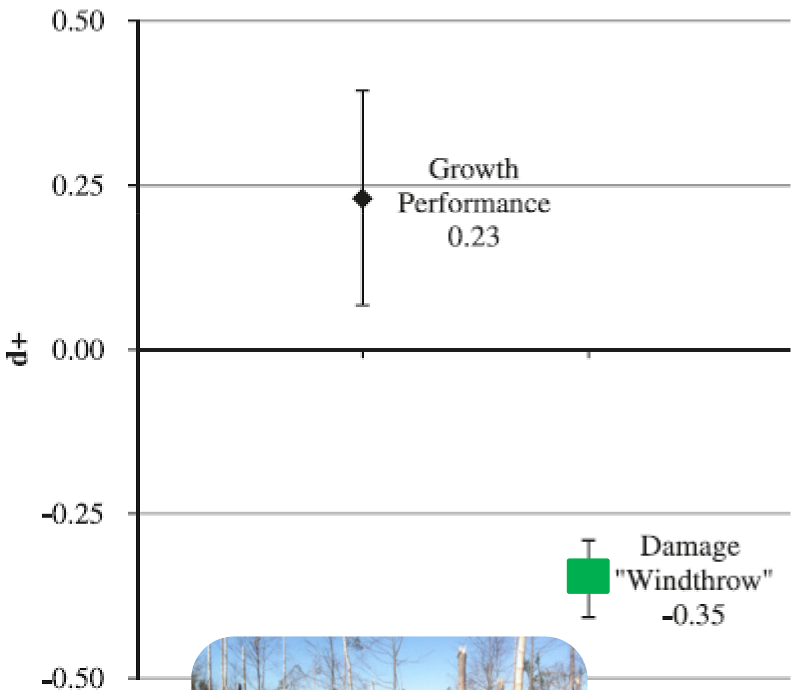
3. Associational resistance to windstorms

Consistent AR

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

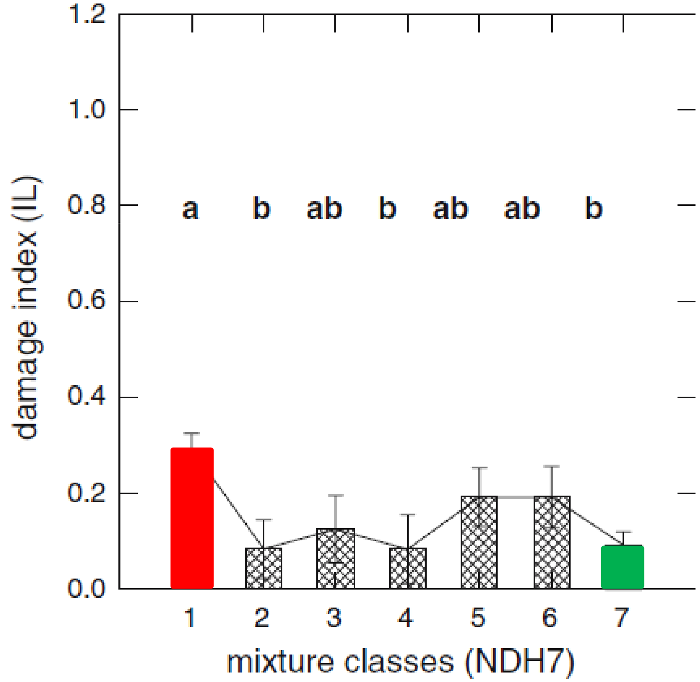


Fig. 10 Effect of tree mixtures on damage index: ANOVA with different mixed species and proportions. Mixtures classes with different letters were significantly different at $P=0.10$. *1* Pure spruce/fir (≥ 90%) *2* rich spruce/fir (80–89%), *3* dominant spruce/fir (70–79%), *4* admixture douglas fir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

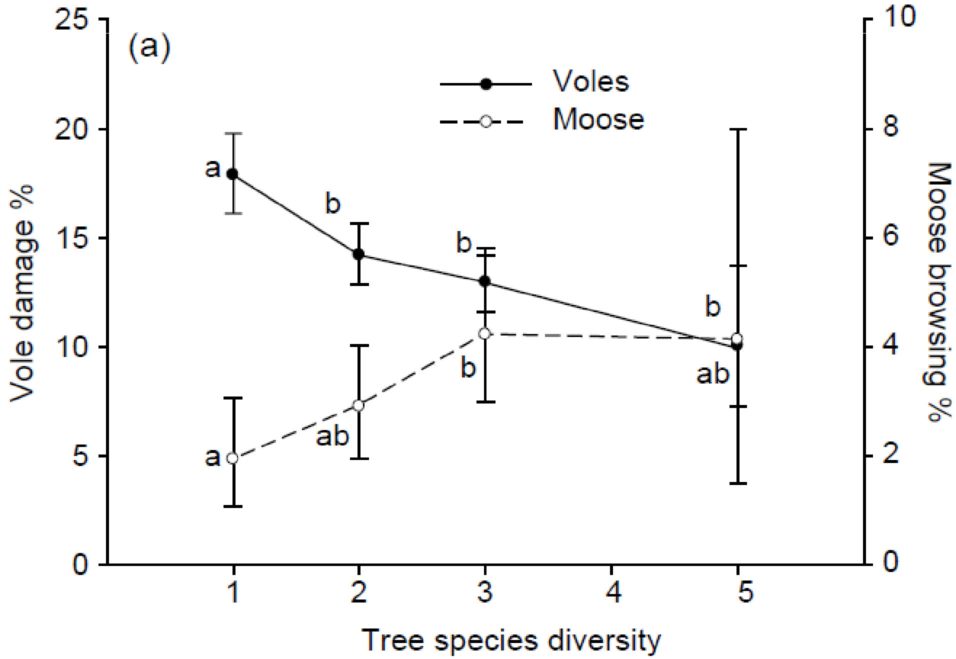
4. Associational resistance to mammal herbivores

Contrasting effects on mammal herbivores

ECOGRAPHY 29: 497–506, 2006

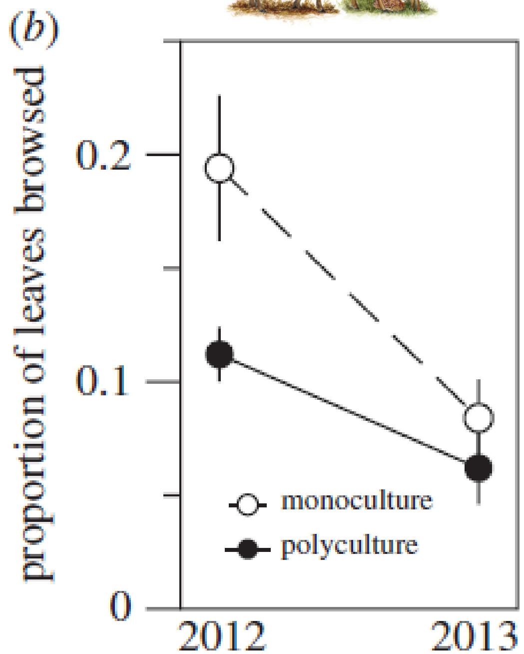
Moose and vole browsing patterns in experimentally assembled pure and mixed forest stands

Harri Vehviläinen and Julia Koricheva



Positive interactions between herbivores and plant diversity shape forest regeneration

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



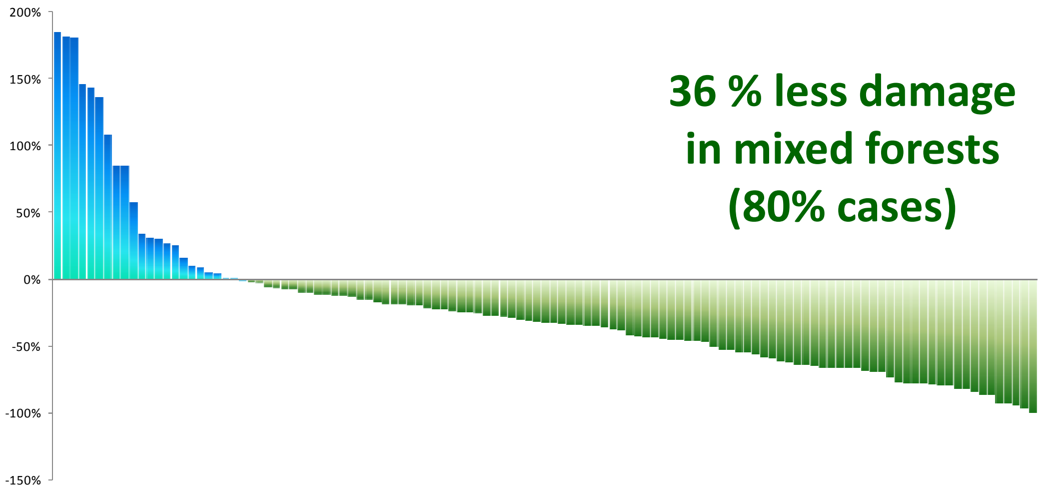
5. Associational resistance to pest insects

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

Tree diversity reduces herbivory by forest insects

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

119 case studies, 33 tree species

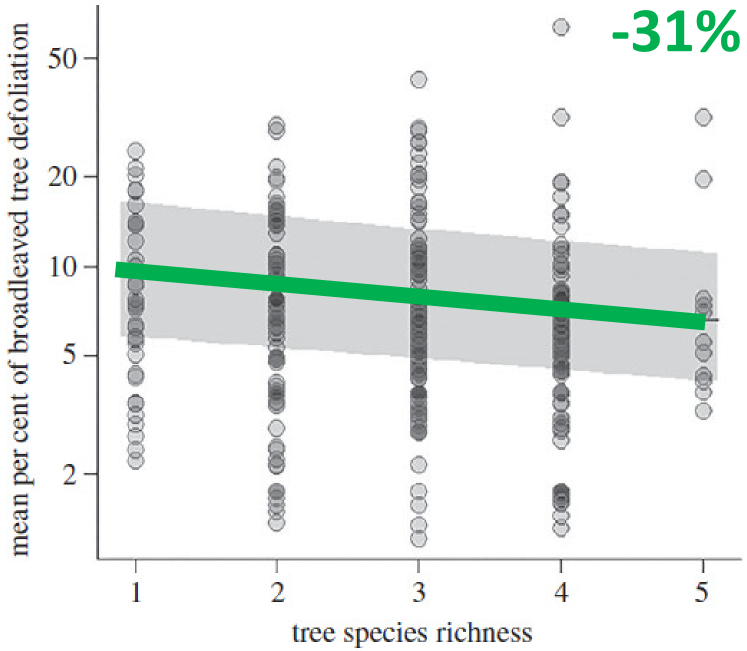


36 % less damage in mixed forests (80% cases)

Significant AR

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]

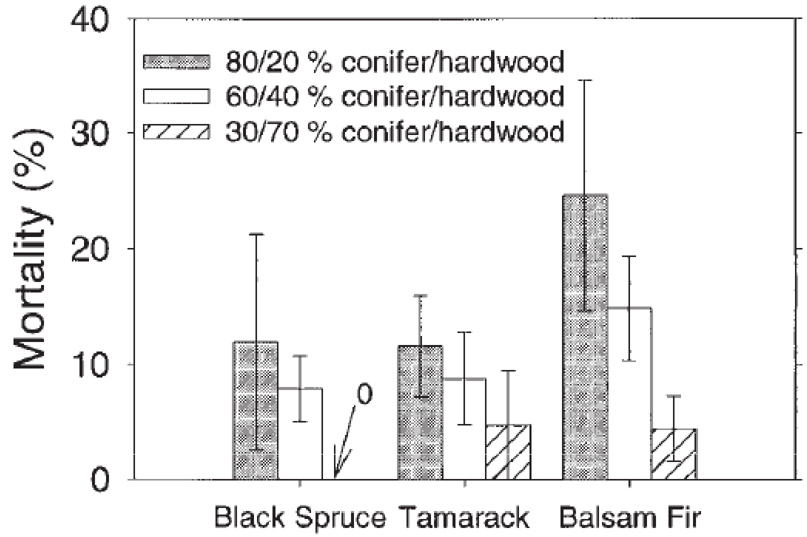


6. Associational resistance to fungal pathogens

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



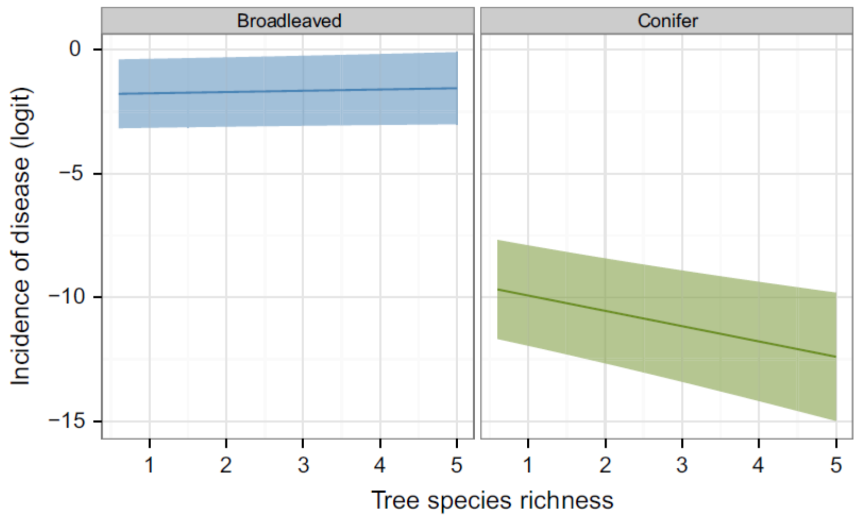
Resistance or neutral effects for foliar pathogens

Ecology and Evolution

Open Access

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

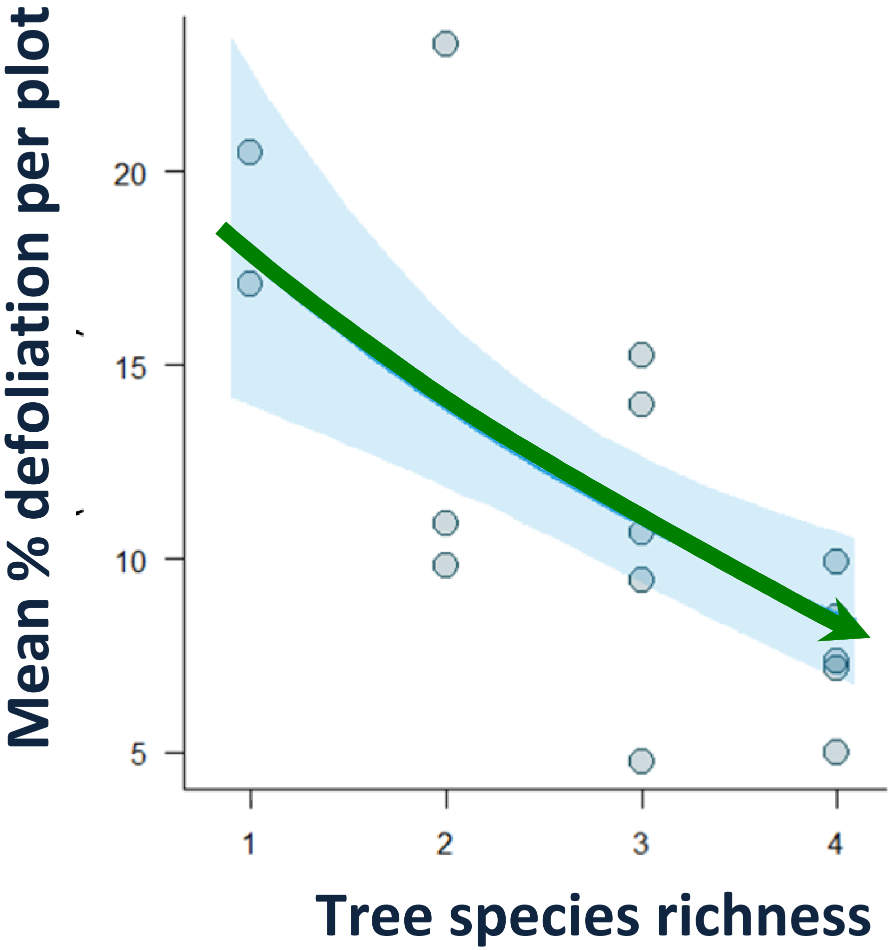
Diem Nguyen[1], Bastien Castagneyrol[2,3], Helge Bruelheide[4,5], Filippo Bussotti[6], Virginie Guyot[3,7], Hervé Jactel[2,3], Bogdan Jaroszewicz[8], Fernando Valladares[9], Jan Stenlid[1] & Johanna Boberg[1]



7. Associational resistance 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]

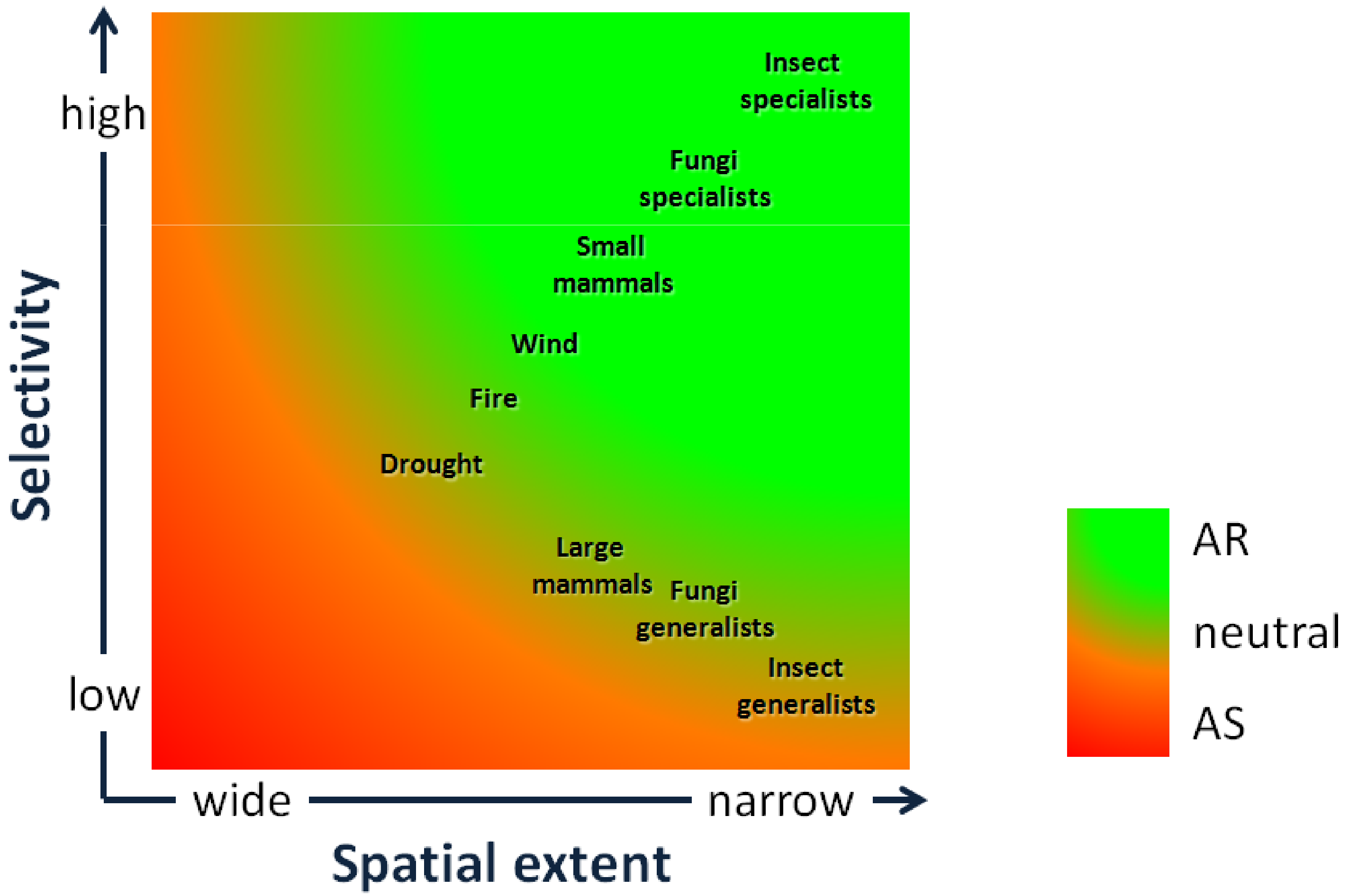


Theoretical

Rarely studied

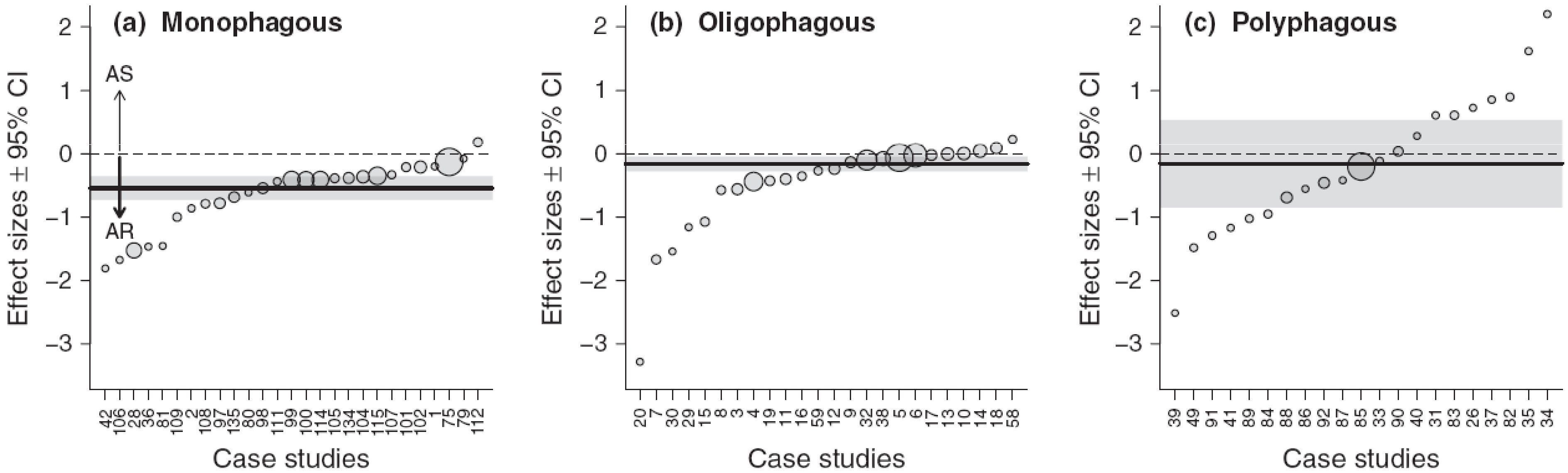
Associational resistance in mixed forests: common features

1. **Direction and magnitude of AR depend on spatial extent and/or selectivity of natural disturbances**



Associational resistance in mixed forests: common features

1. Direction and magnitude of AR depend on spatial extent and/or selectivity of natural disturbances



- 42%

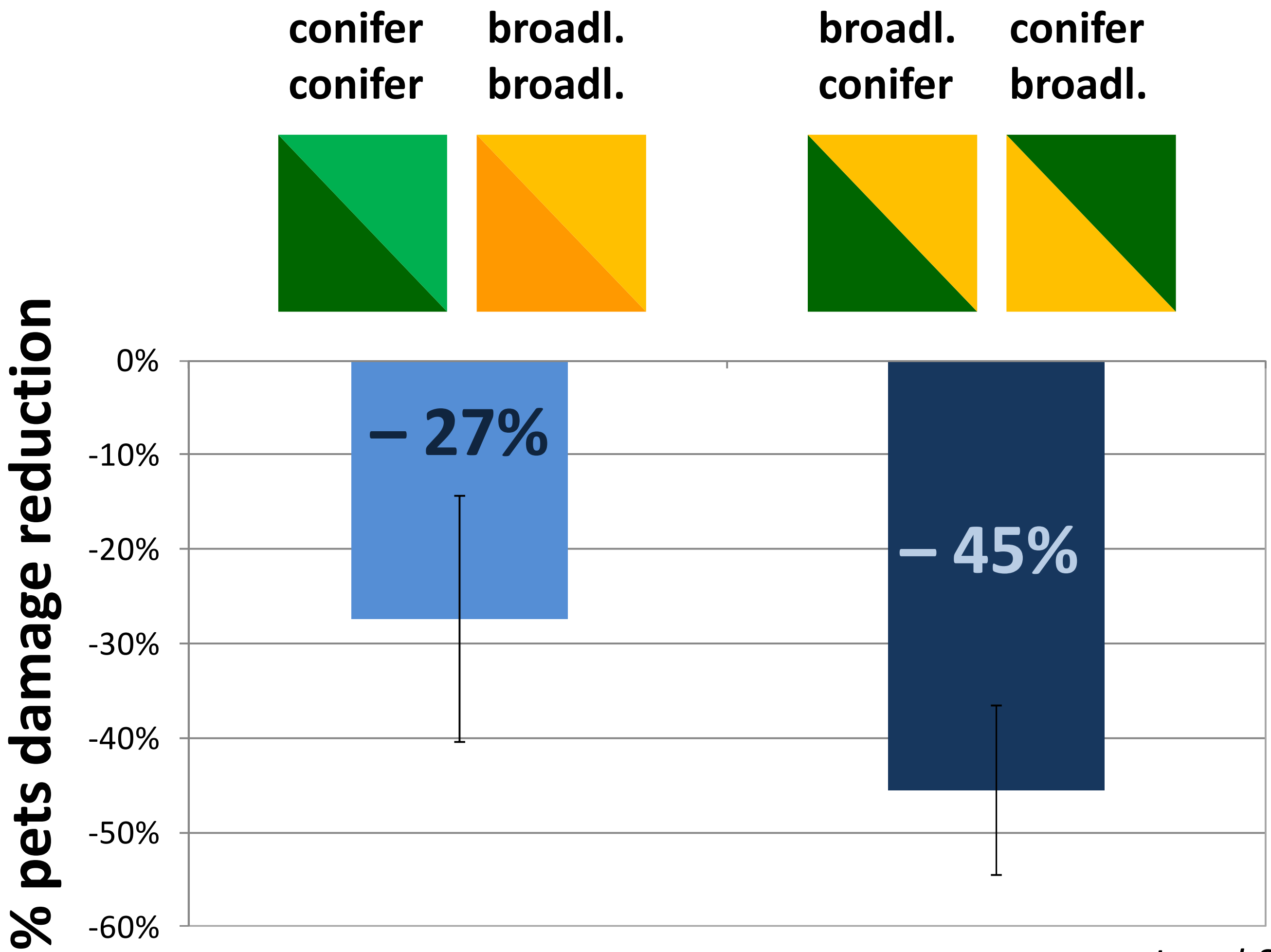
- 15%

0%

Castagneyrol et al. 2014

Associational resistance in mixed forests: common features

2. Forest composition more important than tree species richness



Jactel & Brockerhoff 2007

Mechanisms underlying diversity – resistance relationships

0. 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)

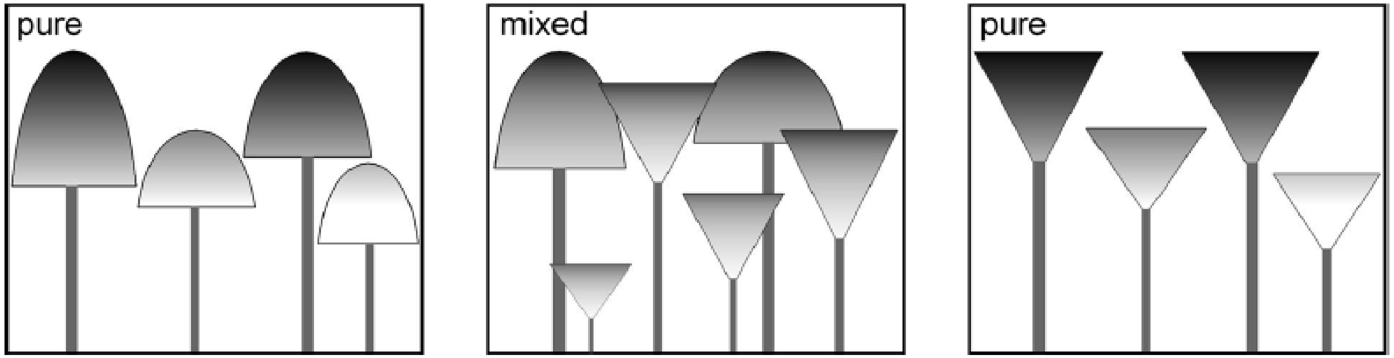
SHIGEO YACHI AND MICHEL LOREAU*

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** and **sustain basic ecosystem functions** on the long term
= risk spreading

Mechanisms underlying diversity – resistance relationships

1. Complementarity of resistance traits

- Root depth / drought
- Bark anatomy, branching pattern / fire
- Crown architecture / wind



Eur J Forest Res (2015) 134:927–947

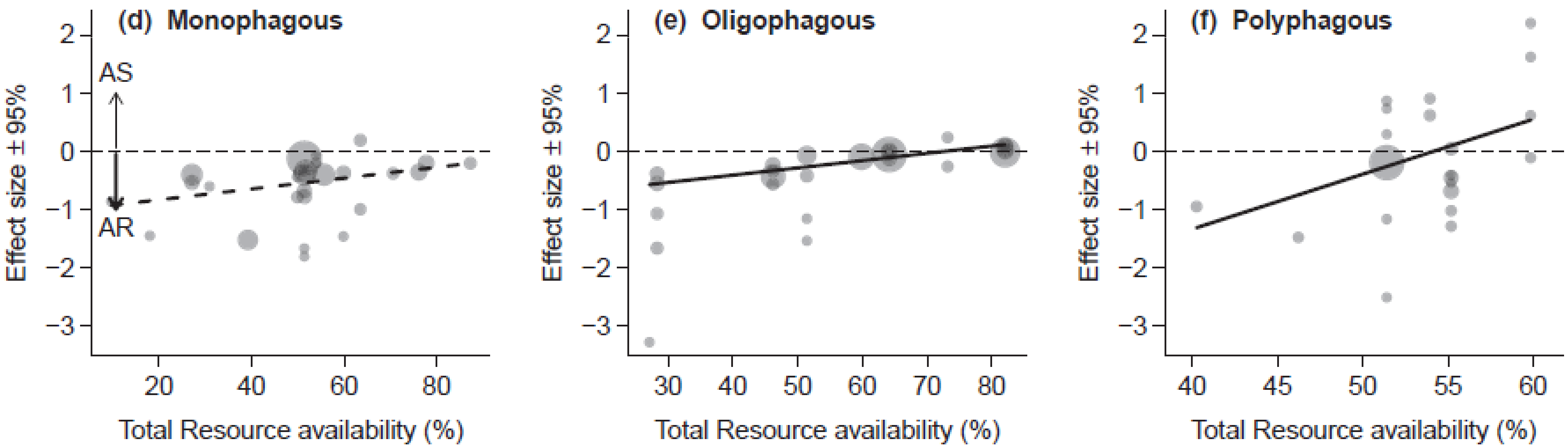
- Leaf quality / herbivores
- Niche occupancy / invasive species

Mechanisms underlying diversity – resistance relationships

2. Depletion of resources to feed or fuel

- lower amount of resources to fuel fire or contribute to windthrow

- lower amount of resource to feed mammals or insect herbivores



Journal of Applied Ecology
Journal of Applied Ecology 2014, 51, 134–141 doi: 10.1111/1365-2664.12175

Effects of plant phylogenetic diversity on herbivory depend on herbivore specialization

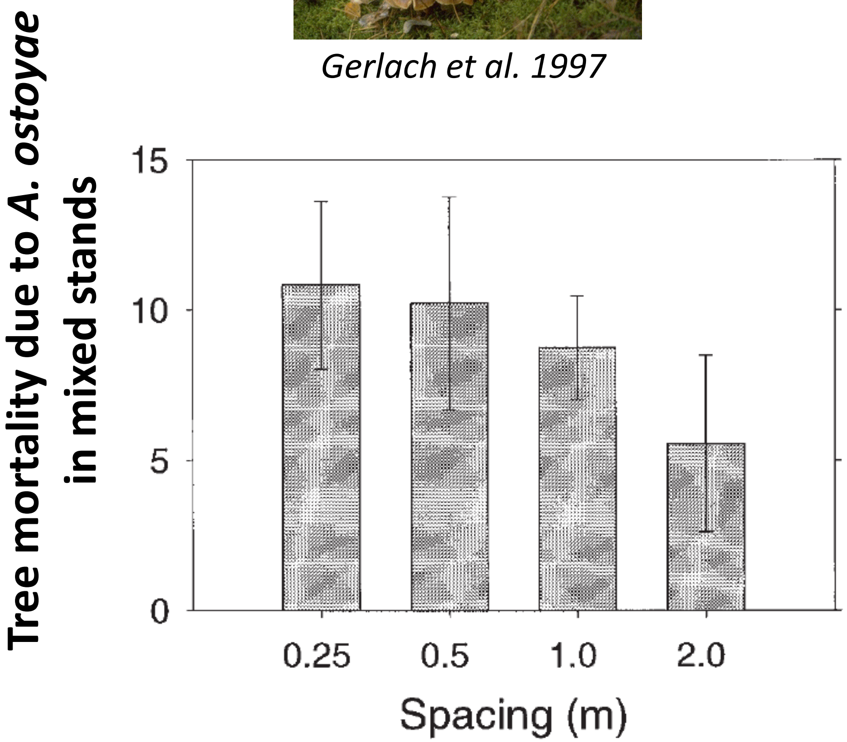
Bastien Castagneyrol[1,2,3*], Hervé Jactel[1,2], Corinne Vacher[1,2], Eckehard G. Brockerhoff[4] and Julia Koricheva[3]

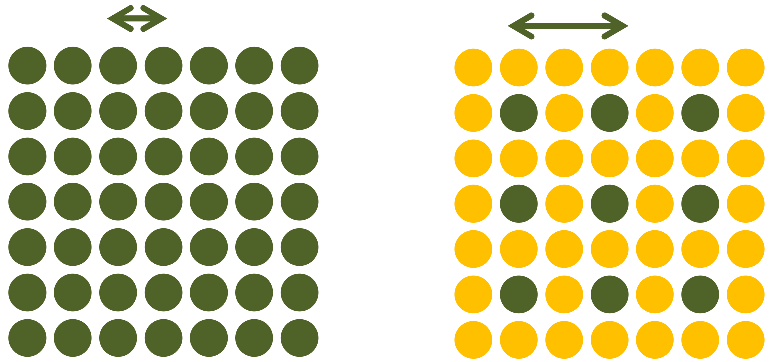
Mechanisms underlying diversity – resistance relationships

2. Disruption / diversion of host finding

- increasing spacing between target trees

Gerlach et al. 1997





Mechanisms underlying diversity – resistance relationships

3. Disruption / diversion of host finding

- 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]

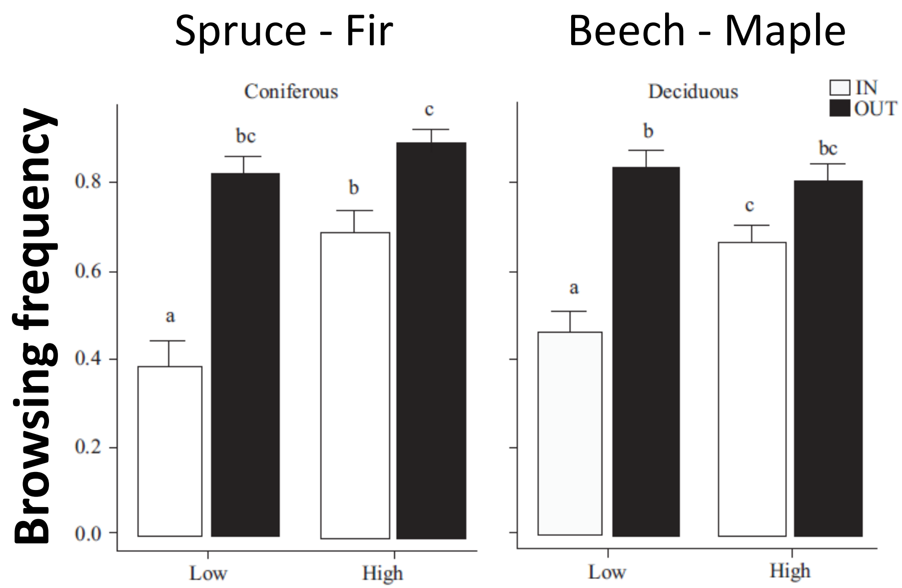


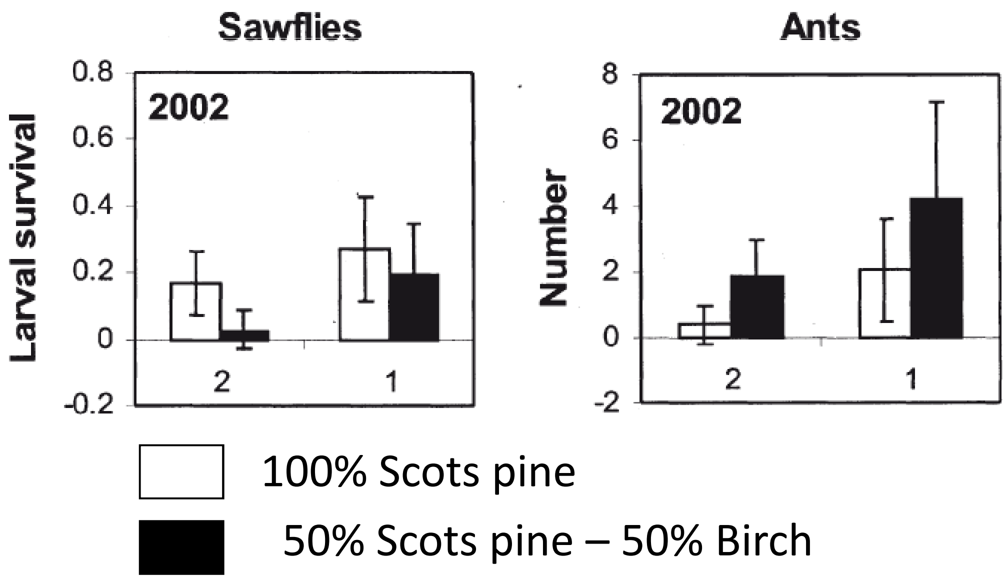
Fig. 2. The effects of grazing intensity (low and high) and position (in and out) on the browsing frequency (mean proportion ±1 SE, $n = 30$) of coniferous and deciduous saplings, after the fourth grazing period. Different letters indicate significantly different means (Tukey post hoc comparisons within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

Mechanisms underlying diversity – resistance relationships

4. Reinforced biotic interactions: symbiosis, predation

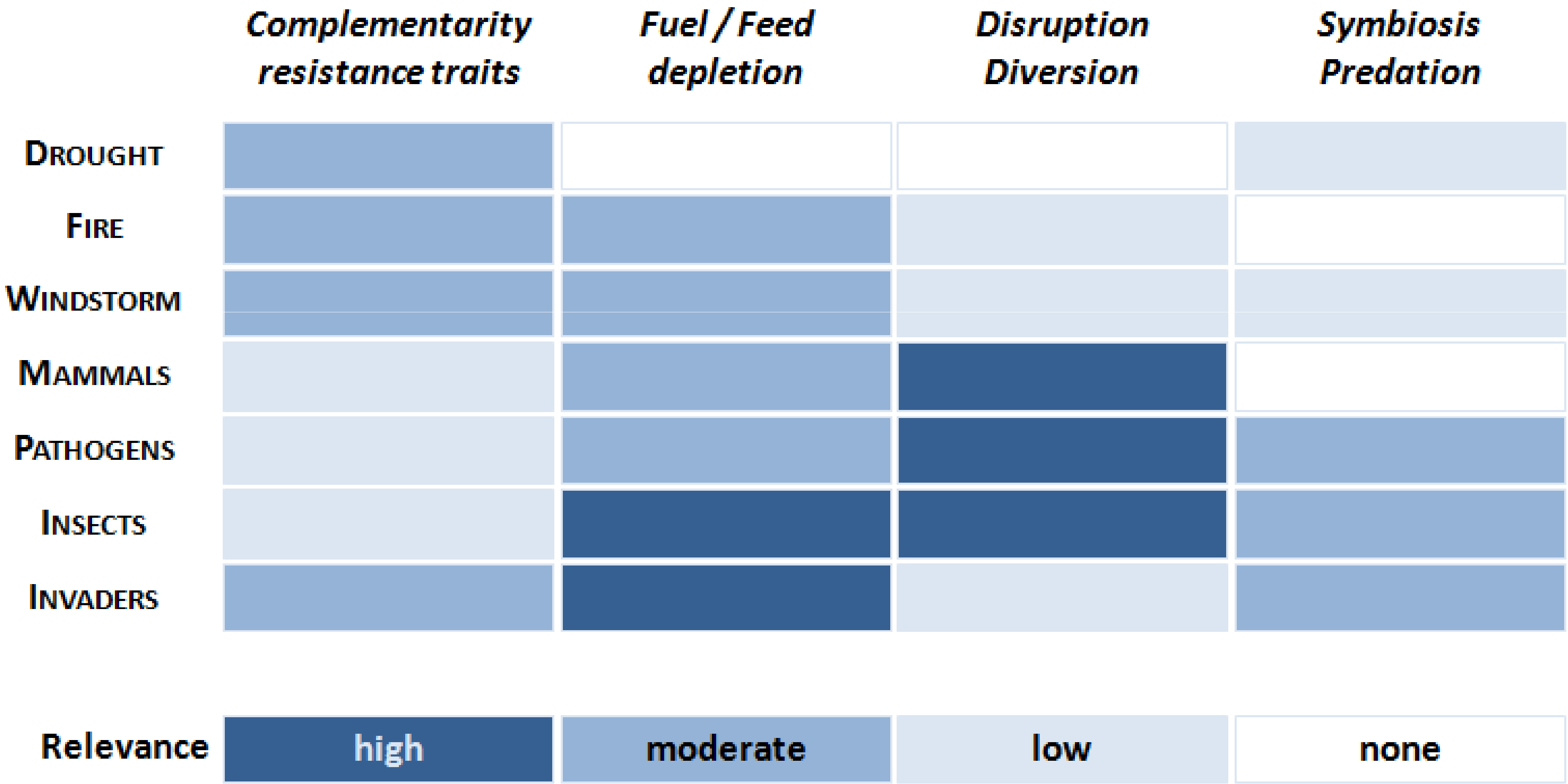
- decomposers and mycorrhiza (drought, wind)
- natural enemies (pest insects, pathogens)

Neodiprion sertifer

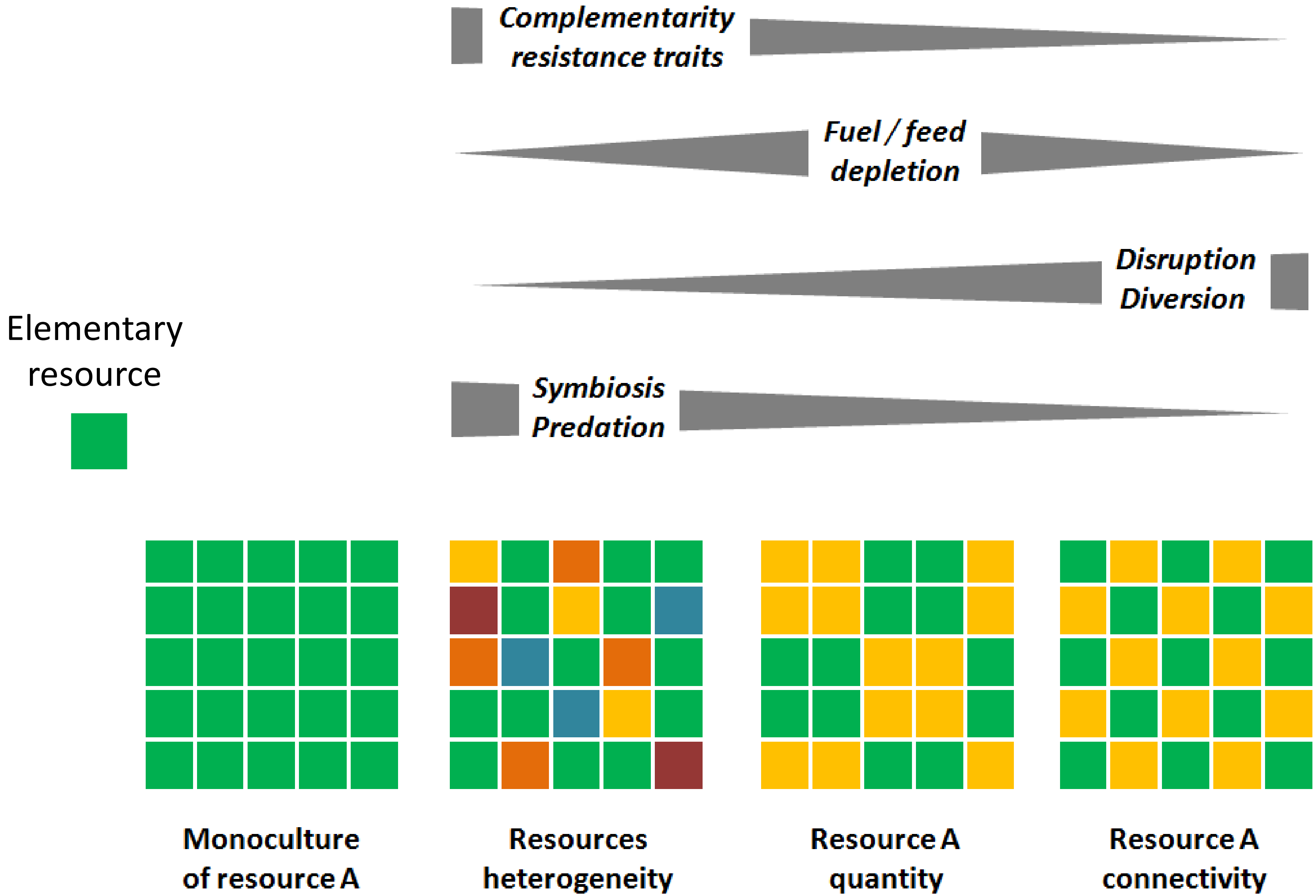


Kaitaniemi, P., Riihimäki, J., Koricheva, J. & Vehviläinen, H. 2007. Experimental evidence for associational resistance against the European pine sawfly in mixed tree stands. Silva Fennica 41(2): 259–268.

Mechanisms underlying diversity – resistance relationships



Mechanisms underlying diversity – resistance relationships



Conclusions

- Mixed forests : **associational resistance** > susceptibility
- Tree **composition** > species richness
- **3 biodiversity dimensions**:

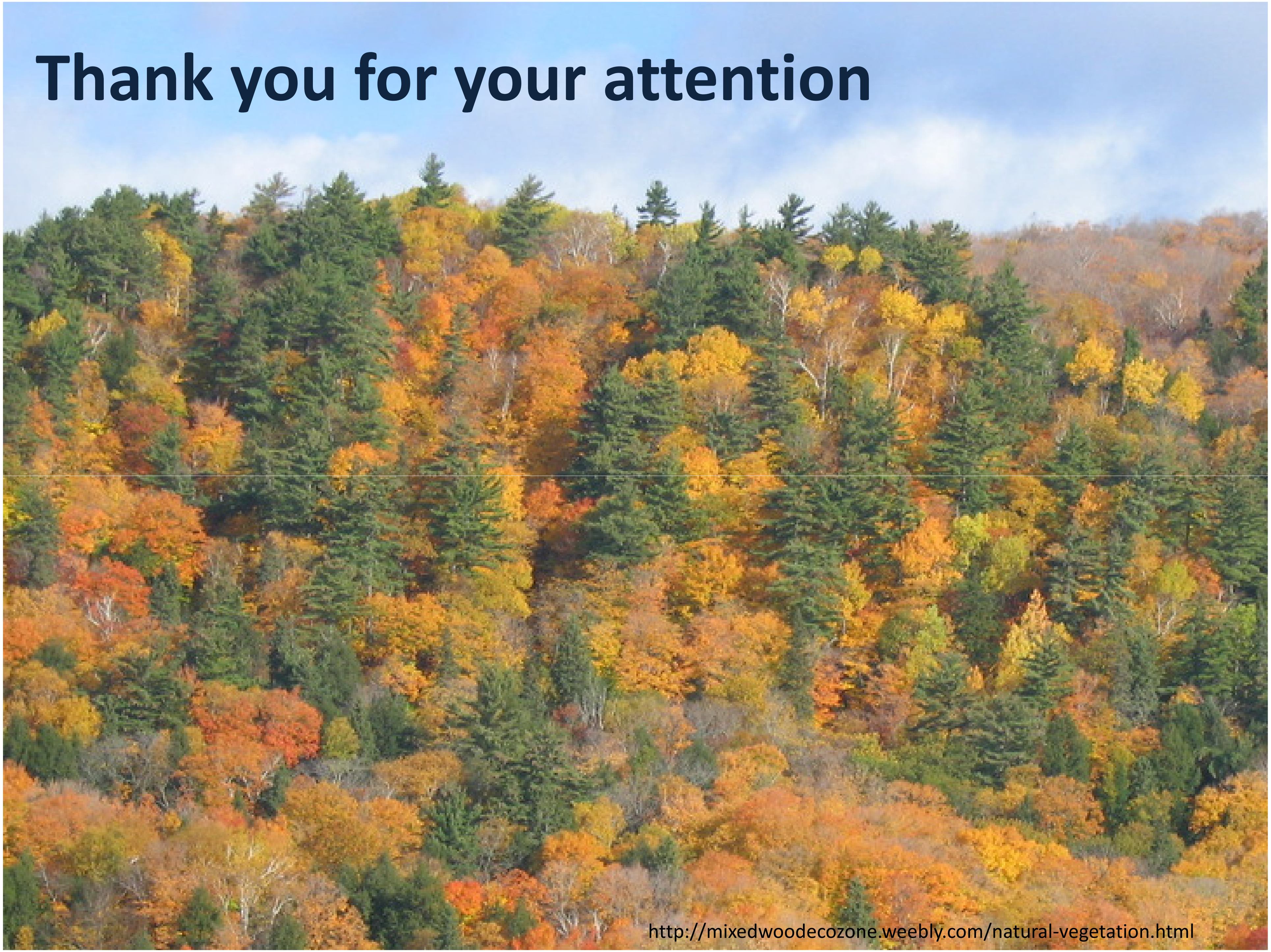
  "resource" heterogeneity, amount, connectivity
- **4 main processes** involved:

  complementarity, depletion, disruption, biotic interactions
- **Tradeoffs** for resistance to different disturbances?
- Compromises with mixed forest **productivity**

  Composition

  Spatial pattern

Thank you for your attention



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