Insect adaptation to individual trees in a forest as a function of isolation from neighbouring trees: field experiments on oaks

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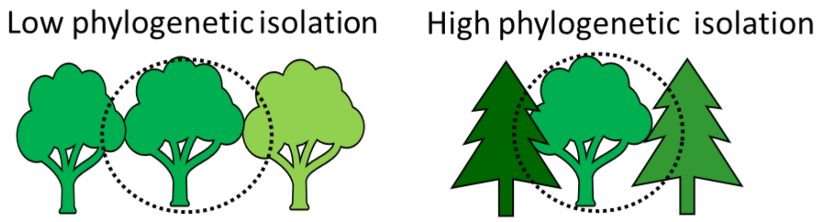
Phylogenetic isolation of individual trees

Since most herbivorous insects can feed only on a subset of plant species, from their point of view, individual trees in a mixed forest can be like islands that are isolated from other trees by a sea of trees that they cannot feed on. The proportion of neighboring trees on which an insect can feed is then like distance to the mainland for oceanic islands. Because insects tend to feed on sets of closely related species, this distance can be expressed as phylogenetic isolation expressed in millions of years of evolution.

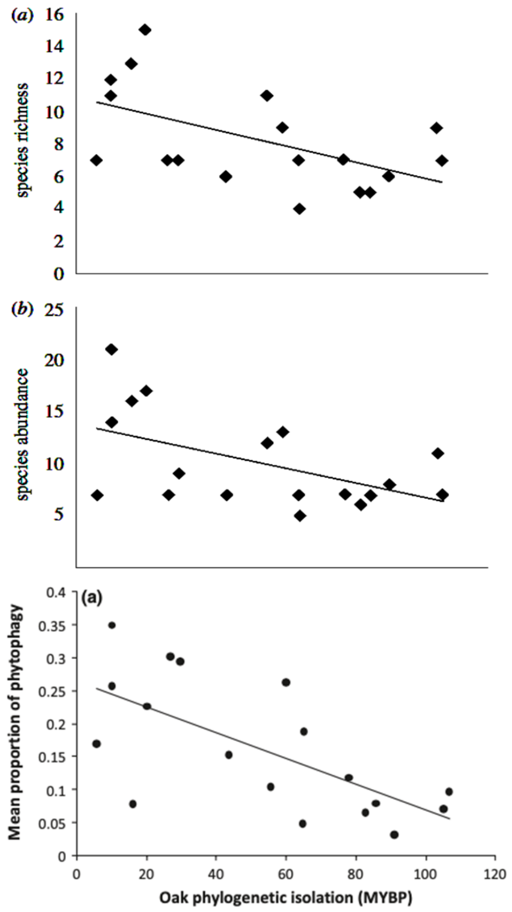


Focal trees (circled) with neighbors that are either closely related (low phylogenetic isolation) or distantly related (high phylogenetic isolation).

An oak tree surrounded by pines and beech trees in Puszcza Zielonka forest

Potential effects of phylogenetic isolation on insect diversity and abundance

Species richness and abundance*:* Isolation of habitat patches generally causes reduced movements between these patches, and thus more isolated trees are colonized by fewer insect species and this causes lower species richness. More isolated trees have also been shown to suffer less leaf damage.



Results of studies on effects of phylogenetic isolation of small oak trees in France.

1) Species richness lower on more phylogenetically isolated trees
2) Abundance lower on more phylogenetically isolated trees

Vialatte, A. Bailey, R.I., Vasseur, C., Matocq, A., Gossner, M.M., Everhart, D., Vitrac, X., Belhadj, A., Ernoult, A. & Prinzing, A. 2010. Phylogenetic isolation of host trees affects assembly of local Heteroptera communities. Proceedings of the Royal Society B 277: 2227-2236.

3) Leaf damage lower on more phylogenetically isolated trees

Yguel, B. Bailey, R., Tosh, N.D., Vialatte, A., Vasseur, C., Vitrac, X., Jean, F. & Prinzing, A. 2011. Phytophagy on phylogenetically isolated trees: why hosts should escape their relatives. Ecology Letters 14: 1117-1124.

Question: Can we discover similar effects for mature trees in Poland?

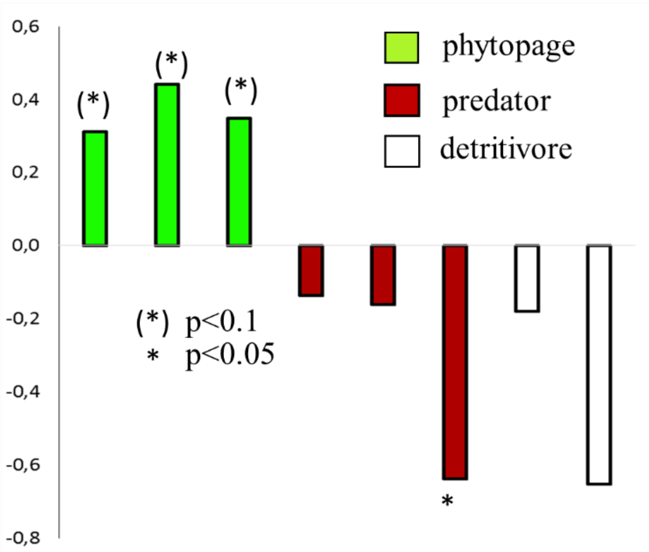
Result: We found the opposite result for caterpillar abundance. See What Drives Caterpillar Guilds on a Tree: Enemy Pressure, Leaf or Tree Growth, Genetic traits, or Phylogenetic Neighbourhood?
https://www.researchgate.net/publication/359660698_What_Drives_Caterpillar_Guilds_on_a_Tree_Enemy_Pressure_Leaf_or_Tree_Growth_Genetic_traits_or_Phylogenetic_Neighbourhood

Species traits

On more isolated trees, we may expect to find species that are better at moving and finding isolated trees, or that are less specialized on the particular tree species. For example, larger bodied insects may be able to fly further and colonize isolated trees. Alternatively, smaller bodied species may disperse in larger numbers on the wind and thus dominate isolated trees.

Adaptation to individual trees

Isolation of individual trees may affect local adaptation in the insects. These may be adaptations to the particular genetic background of the tree, as well as to different levels of competition or natural enemy pressure. The traits of a tree to which insects adapt may include, for example, concentrations of defensive chemicals, the timing of budburst in spring, and leaf size. Isolation can affect local adaptation on individual trees in at least two ways. Firstly, reduced exchange of genes between insect populations may permit local adaptations to persist. Secondly, less competition among insects or natural enemy pressure on more isolated trees alters the environment that exerts selection pressure on insects. While both adaptation to individual trees and large effects of isolation of trees on the insect community have been recorded, local adaptation has not been linked to the degree of isolation of trees in a forest, except in one study on click beetles. In that study, we found that on more isolated trees, beetle species with larvae that feed on the tree itself tended to become larger, while predators were smaller. This could be because the tree-feeders had less competition and the predators less prey on more isolated trees.



Variation in body size within species among click beetle body size for the 8 most common species. An overall test using 15 species shows that the effect of phylogenetic isolation on within-species shifts in body size depends on larval diet (p=0.06). This may be caused by local adaptation to competition for food for herbivores and prey availability in predators.

***Molleman**, F., Depoilly, A., Vernon. P., Müller, J., Bailey, R., Jarzabek-Müller, A. and **Prinzing**, A. 2016. The island rule of body size demonstrated on individual hosts: phytophagous click beetle species grow larger and predators smaller on phylogenetically isolated trees. Journal of Biogeography43: 1388-1399.*

Data collection

In the Puszcza Zielonka forest near Poznan, we select 34 oak trees that vary in the extent of isolation. Some are surrounded by other oaks, some mainly by other broad-leaved species, and some are surrounded by pine trees. For these focal trees we collect data on tree traits, their insect communities, and traits of particular insect species. We plan to perform reciprocal transplant experiments to measure local adaptation. We also work on cloning the focal trees so that we can perform field experiments. Our focus is on moths, leaf miners, and leaf gallers.

Interception-malaise cross traps are suspended high in the canopy of focal trees. Flying insects hit the transparent fabric and either climb to the top part or drop into the bottom below where they are preserved in glycol.

Winter moths can be captured after sundown when they mate on the trunk of trees. In this species, females are wingless and climb up trees to lay eggs on winter buds. The fitness of the eggs depends on egg hatching being synchronized with budburst. The degree of synchronization is therefore a measure of local adaptation. Photo: Urszula Walczak

Practical work

Sampling trees, estimating leaf damage, measuring leaf morphology (July & September).

Rearing moth larvae, measuring growth rate and body size (May-June).

Sorting and setting insects from traps, starting with moths.

Measuring budburst phenology (April).

Collecting winter moths (November).

Publication

Molleman, F.; Walczak, U.; Melosik, I.; Baraniak, E.; Piosik, Ł.; Prinzing, A. What Drives Caterpillar Guilds on a Tree: Enemy Pressure, Leaf or Tree Growth, Genetic Traits, or Phylogenetic Neighbourhood? Insects 2022, 13, 367. https://doi.org/10.3390/insects13040367