

The evolution of ecological networks

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Introduction

Interaction strengths are defined There is a lack of evolution in multi-dimensional trait space

The role of evolution on network structure

Coevolution's impact on interaction strength

I argue that the interaction strength between two species is at least partially determined by the evolutionary history of the species interacting. In mutualistic networks, species that have a common history of coevolution and co-speciation might have had a long time to optimise their common benefits. Interacting species that have been interdependent for evolutionary times should show a larger “potential” interaction strength than interacting species that have only interacted in recent evolutionary times.

Another wording for the same hypothesis is that species are more likely to respond to the evolutionary changes occurring in the interacting partners they depend the most.

Several factors are also known to affect species' interaction strength: in particular species abundances and environmental factors. I propose to employ a combination of modelling and empirical data to determine if evolutionary history provides the backbone of species interdependency or not. Evolutionary history might constrain the space of potential interactions and their relative importance, while contemporary ecological

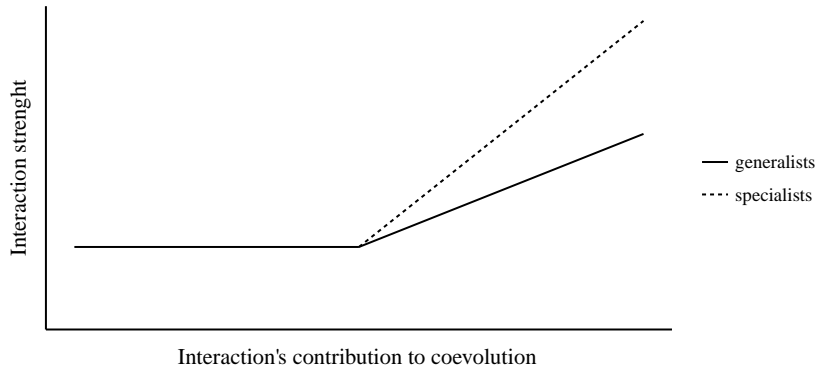


Figure 2.1: Interaction strength is related to the coevolutionary signal of an interaction.

conditions modulate the relationships.

We will measure the impact of evolution as the contribution of each interaction to the overall congruence of each guild's phylogenies (Balbuena, Míguez-Lozano, and Blasco-Costa 2013). This is an adequate measure because an interaction with high contribution to coevolution reflects that the species have been interacting over long evolutionary times.

For example, in the figure, the ancestors of A, B and C likely interacted with the ancestors of A', B' and C'. On the other hand, the interactions between A' and D and D' and B might be a consequence of ecological factors or the recent evolution of species' traits that enable these interactions to occur.

There is a second hypothesis that arises from this reasoning: the relative importance of contemporary ecological factors and the evolutionary dynamics in the interaction strength depends on the degree of ecosystem modification. Arguably species use physiological and behavioural adaptations to cope with ecosystem change. Adjustments on interaction strength caused by those changes (local extinctions or abundance changes of interacting species, arrival of invasive competitors or novel resources, etc.) might blur the evolutionary signature on interaction strength.

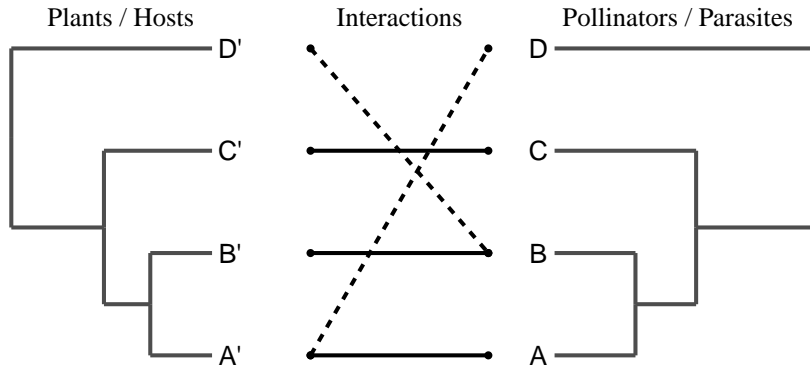


Figure 2.2: In a bipartite network, interactions that support the congruence of the phylogenies – solid lines – are high contributors to coevolution. Opposite, the interactions that contribute little to coevolution – dashed lines – are those that ‘distort’ the congruence between phylogenies.

Network structure arises from evolutionary dynamics

Which processes generate modularity and which processes originate nestedness?

Coevolution in multidimensional trait space

Dataset: analytical and individual based models

Coevolution has been shown to generate anti-nested patterns. But all those models have used one mechanism for generating and only one trait at a time. Since interaction probabilities can affect a lot the network structure we expect it to change when using multiple traits.

Also,

It has been previously shown that network structure has direct consequences on community persistence and stability and might also play an

Network structure heavily affects community stability. Here we aim how network structure can arise from evolutionary dynamics.

Do modular communities evolve towards nested by minimising niche overlap. Do nested communities evolve towards modular patterns in the absence of disturbances?

There is evidence that shows

How is nestedness reconciled with coe

The contribution of evolution and spatiotemporal patterns to network structure

Hypothesis modularity comes from phylogenetic history and ecological traits. Nestedness come from spatiotemporal patterns (recent immigration, spatial and temporal overlap). Though nestedness can also arise from weak coevolution and phenotype differences (which they argue is the one acting on species rich communities)

Phylogenetic history of modularity

Modules should show higher agreement to phylogenies than random modules

Dataset: all kind of networks we can get hands on

Nestedness

Specialists are more likely to be recent immigrants

Dataset: Wasps for spatial/ecological patterns Dataset: Temporal pollina

Some evidence shows that most specialist species can be actually recent immigrants and haven't had the time to adapt and either evolve large impacts on hosts or to become generalists (Nuismer, Thompson, and Gomulkiewicz 2003).

If that is true, then one should be able a) to see that the patterns of generalism/specialism for a species species changes in spatial scales; b) to see that individuals behaving as generalists in their communities

should have greater performance (fitness, impact?) than the individuals from the same species behaving as generalists in their communities. And that c) species should show be more specialists towards the fringes of their spatial distribution. Can we test that with the wasp-parasite UWA dataset?

Also in terms of phase shifts, if there is a sudden change in abiotic-conditions/community structure, then specialists would have a harder time adapting than generalists. Right? Is change in niche overlap what creates alternate stable states? Or if a specialist is still there will their performance decrease after/along with the shift?

3

How community structure affects stability

Functional redundancy and stability

Species that share similar interactions in an ecological network can be grouped in modules. In food webs for example, modules can successfully encapsulate trophic groups that resemble energetic pathways (Gauzens et al. 2014). In host/parasite networks, a parasite is more likely to share hosts with other parasites within than outside its module (Weitz et al. 2013). Similarly in mutualistic networks, pollinators within a module function as a group with preferences for some particular plants.

Because the species's functional role in the community is, at least to a great extent, defined by its interactions (Dehling et al. 2014), modules should implicitly group species with similar functional roles (Dupont and Olesen 2009).

Functional redundancy has been proposed as an important factor in determining the ecosystem's response to disturbances (Brandl and Bellwood 2014). Particularly when the

In pollination networks can be the similarity of In ecological networks, Functional redundancy Paradoxically high functional redundancy represents

Hypothesis: Functional redundant systems are more stable and resilient

Hypothesis: Systems with loss of functional groups are more vulnerable

Dead ends in fitness landscapes

Hypothesis: very efficient performers in a fitness landscape are more vulnerable because the loss capacity of adaptation

What is stability

Coexistence and stability

Niche changes over time. Trophic plasticity Consequences for stability

Niche overlap

4

Temporal dynamics in ecological networks

Reconstructing historical networks

Measuring network fitness

Measuring impact of hosts/infectivity

How is related to niche overlap and coexistence theory - Niche change over time

Perturbing networks

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**Ecosystem feedbacks are
indirect interactions**

References

- Balbuena, Juan Antonio, Raúl Míguez-Lozano, and Isabel Blasco-Costa. 2013. “PACo: A Novel Procrustes Application to Cophylogenetic Analysis.” *PLoS ONE* 8 (4). doi:[10.1371/journal.pone.0061048](https://doi.org/10.1371/journal.pone.0061048).
- Brandl, Simon J., and David R. Bellwood. 2014. “Individual-based analyses reveal limited functional overlap in a coral reef fish community.” *Journal of Animal Ecology*. doi:[10.1111/1365-2656.12171](https://doi.org/10.1111/1365-2656.12171).
- Dehling, D. Matthias, Till Töpfer, H. Martin Schaefer, Pedro Jordano, Katrin Böhning-Gaese, and Matthias Schleuning. 2014. “Functional relationships beyond species richness patterns: trait matching in plant–bird mutualisms across scales.” *Global Ecology and Biogeography* 23: 1085–93. doi:[10.1111/geb.12193](https://doi.org/10.1111/geb.12193).
- Dupont, Yoko L., and Jens M. Olesen. 2009. “Ecological modules and roles of species in heathland plant-insect flower visitor networks.” *Journal of Animal Ecology* 78 (2): 346–53. doi:[10.1111/j.1365-2656.2008.01501.x](https://doi.org/10.1111/j.1365-2656.2008.01501.x).
- Gauzens, Benoit, Elisa Thébault, Gérard Lacroix, and Stéphane Legendre. 2014. “Trophic groups and modules: two levels of group detection in food webs.” *Journal of The Royal Society Interface*, 1–29. doi:[10.1098/rsif.2014.1176](https://doi.org/10.1098/rsif.2014.1176).
- Nuismer, S. L., J. N. Thompson, and R. Gomulkiewicz. 2003. “Coevolution between hosts and parasites with partially overlapping geographic ranges.” *Journal of Evolutionary Biology* 16 (6): 1337–45. doi:[10.1046/j.1420-9101.2003.00609.x](https://doi.org/10.1046/j.1420-9101.2003.00609.x).
- Weitz, Joshua S., Timothée Poisot, Justin R. Meyer, Cesar O. Flores, Sergi Valverde, Matthew B. Sullivan, and Michael E. Hochberg. 2013. “Phage-bacteria infection networks.” *Trends in Microbiology* 21 (2): 82–91. doi:[10.1016/j.tim.2012.11.003](https://doi.org/10.1016/j.tim.2012.11.003).