Introduction

- definition
- domains + questions

Invariants in ecological networks

One striking particularity of ecological networks is their consistency: even though the depict interactions between different organisms across all sorts of ecosystems, they all tend to look the same (Jordano, Bascompte, and Olesen 2003). Remarkably, even when interactions among species themselves vary (see section **x**), the overall network structure tends to remain unchanged (Kemp et al. 2017). Most ecological networks have a very specific degree distribution (Williams 2011), whereby most species have a small number of interactions, and a small proportions of species have a large number of interactions. In food webs, which represent interactions between preys and their predators, there is a well-described relationship between the number of species and the number of interactions: the number of interactions (L) increases proportionally to the number of species (L) raised to some exponent, or $L \propto S^k$. Martinez (1992) suggested that this exponent is approximately equal to 2, *i.e.* the number of interactions is proportional to the squared number of species. Brose et al. (2004) show that this general relationship holds even across space: it is possible to estimate how many interactions a species will establish across its entire range. In some other instances, networks may differ on some aspect of their structure, despite obeying to a shared underlying principle. For example, Fortuna et al. (2010) show that in networks with a low connectance, nestedness (the degree to which the diet of specialists and generalists overlaps) and modularity (the tendency of species to form densely aggregated clusters) are positively correlated. In networks with higher connectance, this became the opposite: networks with a large number of interactions were either nested (and not modular) or modular (and not nested). In the recent years, it emerged that many aspects of network structure covary with connectance (Chagnon 2015; Poisot and Gravel 2014): this suggests that simply knowing how many species there are, and how many interactions they establish, is already very informative about the network structure.

- motifs **ED**
- evo/phylogenetic structure **MB**
  - Eklöf et al. (2012) => network structure effect on evolutionary history

From structure to properties

- perturbations/extinctions **MB**
- BEF **ED**

- stability **MB**
  - Jacquet et al. (2016)

Linking interactions to ecological mechanisms

It is worth remembering that ecological interactions are the direct expression of ecological mechanisms. A pollinator is able to effectively reach the nectar in a plant because the traits of the two organisms match, because they have compatible phenologies, and because they occur in the same environment. A virus can infect its host because it is able to attach to the cell surface, effectively penetrate it, and hijack the cellular machinery to its benefit. Interactions that are not allowed because trait values do not match have been called "forbidden links" (Olesen et al. 2011). This prompted a search for "linkage rules" (Bartomeus 2013) in ecological networks, *i.e.* the relationships that must exist between traits borne by two organisms in order for an interaction between them to exist. These can be identified from existing data on traits and interactions (Bartomeus et al. 2016), and then used to generate realistic ecological networks (Crea, Ali, and Rader 2015). González-Varo and Traveset (2016) point out that interactions are happening between individuals: this requires to consider how the traits are distributed at the individual scale, but also how different behaviors may allow organisms to overcome some of the forbidden links. Although traits are an important part of what makes interactions happen, they are only relevant insofar as the organisms are able to encounter one another. The importance of neutral dynamics (*i.e.* how abundances of different species can determine the probability that they can interact, based on how often they would bump into one another by chance) is, somewhat counter-intuitively, great. E. Canard et al. (2012) reveals that simulating food web dynamics by using only population abundances to predict interactions yields realistic food webs. In a host-parasite system, local abundances has also been identified as a key predictor of species interactions (E. F. Canard et al. 2014). Speaking more broadly, because interactions emerge from all of these ecological mechanisms, there is a need to develop a deeper understanding of them (Poisot, Stouffer, and Gravel 2015). Beyond the fundamental advance that this represents, this would allow to predict interactions based on external information (Morales-Castilla et al. 2015).

- interactions => populations and biomass dynamics **ED**
- spatial and temporal variation **TP**

Other uses of networks in ecology

- epidemiology **TP**
- animal societies
- landscape connectivity **TP**

Conclusion

References

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