Introduction

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Interactions between organisms underpin the persistence of almost all life forms on Earth (Lawton, 1999). Furthermore, large body of work has shown that biotic interactions determine emergent properties of natural systems, such as stability (May, 1972; Wootton & Stouffer, 2016; Song & Saavedra, 2018), resilience (Capdevila *et al.*, 2021), ecosystem functioning (Turnbull *et al.*, 2013; Godoy *et al.*, 2020), and the coexistence of multiple species (Chesson, 2000; Saavedra *et al.*, 2017). Unsurprisingly, numerous ecological and evolutionary concepts revolve around the reciprocal forces that organisms exert on each other (Gause, 1934; MacArthur & Levins, 1967; Thompson, 1999; HilleRisLambers *et al.*, 2012; Chase & Leibold, 2009).

The study of biotic interactions often requires the use of mathematical models to represent them (Maynard-Smith, 1978). Mathematical descriptions of interactions are "useful fictions" (Box *et al.*, 2011) in a twofold manner. First, they create a description of how organisms that coincide in space and time reciprocally affect each other. Almost all known types of interactions can be described in the form of mathematical expressions that reproduce the observed data faithfully (Volterra, 1926; Holling, 1959; Holt, 1977; Adler *et al.*, 2018; Wood & Thomas, 1999; Holland *et al.*, 2002; Vázquez *et al.*, 2005; Stouffer & Novak,

2021) . For example, the effect neighboring plants have on each other can be accurately described in various natural systems with functions that only include the densities of the interacting species as well as a form of negative density dependence (Adler *et al.*, 2018; Hart *et al.*, 2018). Second, models that describe the effect of biotic interactions are pactical tools with which to make predictions beyond the phenomena they describe. For instance, models that describe competitive interactions between plants can be used to make predictions such as changes of biomass in the system (Fox, 2003; Godoy *et al.*, 2020), or whether or not species can coexist (Levine & HilleRisLambers, 2009; Godoy *et al.*, 2014).

However useful, models that capture the effect of biotic interactions are abstractions of reality. It is rare that we know the exact equations governing a system or the full set of biotic and abiotic factors (song). Our abstractions always reflect choices. A common assumption in ecological en evolutionary models, is that in order to achieve general insight, we should favour simple models. Indeed there is a general belief in ecology and evolution that a good model should include as little as possible.

The simplifying assumptions made to represent biotic interactions necessarily imply the omission of important heterogenities at various levels. These omissions

Despite the proven ability of models of biotic interactions to accurately fit data and to provide general insights into various ecological phenomna

Thus, When is relaxing the simplifying assumptions in models of of biotic interactions necessary? Theoretical studies typically make two critical assumptions that do not hold in real communities, thus limiting their applicability.

One of the impediments in comparing more complex models to simpler ones comes from the fact that there is no mathematical framework to incude complexity.

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Concluding remarks

The individual chapters of this thesis are thematically broad but all address in a different way the consequences of increasing complexity in models of biotic interactions. With the exception of I explore the consequences in terms of the coexistence of organisms. Through out this thesis I explored different ecological systems, with different types of interactions and species in them. However, the fundamental questions remains : what happens when add biological, environmental and mathematical complexity to the study of species interactions? Do they change our predictions?

As scientists, narrative reasoning allows us to explore, at a high level, the possible trajectories that evolution may take.

References

Adler, P.B., Smull, D., Beard, K.H., Choi, R.T., Furniss, T., Kulmatiski, A., Meiners, J.M., Tredennick, A.T. & Veblen, K.E. (2018). Competition and coexistence in plant communities: intraspecific competition is stronger than interspecific competition. *Ecology letters*, 21, 1319–1329.

Box, G.E., Luceño, A. & del Carmen Paniagua-Quinones, M. (2011). *Statistical control by monitoring and adjustment*. vol. 700. John Wiley & Sons.

Capdevila, P., Stott, I., Oliveras Menor, I., Stouffer, D.B., Raimundo, R.L., White, H., Barbour, M. & Salguero-Gómez, R. (2021). Reconciling resilience across ecological systems, species and subdisciplines.

Chase, J.M. & Leibold, M.A. (2009). *Ecological niches*. University of Chicago Press.

Chesson, P. (2000). Mechanisms of maintenance of species diversity. *Annual review of Ecology and Systematics*, 31, 343–366.

Fox, J.W. (2003). The long-term relationship between plant diversity and total plant biomass depends on the mechanism maintaining diversity. *Oikos*, 102, 630–640.

Gause, G.F. (1934). Experimental analysis of vito volterra's mathematical theory of the struggle for existence. 79, 16–17.

Godoy, O., Gómez-Aparicio, L., Matías, L., Pérez-Ramos, I.M. & Allan, E. (2020). An excess of niche differences maximizes ecosystem functioning. *Nature communications*, 11, 1–10.

Godoy, O., Kraft, N.J.B. & Levine, J.M. (2014). Phylogenetic relatedness and the determinants of competitive outcomes. *Ecology Letters*, 17, 836–844.

Hart, S.P., Freckleton, R.P. & Levine, J.M. (2018). How to quantify competitive ability. *Journal of Ecology*, 106, 1902–1909.

HilleRisLambers, J., Adler, P.B., Harpole, W.S., Levine, J.M. & Mayfield, M.M. (2012). Rethinking community assembly through the lens of coexistence theory. *Annual review of ecology, evolution, and systematics*, 43, 227–248.

Holland, J.N., DeAngelis, D.L. & Bronstein, J.L. (2002). Population dynamics and mutualism: functional responses of benefits and costs. *The American Naturalist*, 159, 231–244.

Holling, C.S. (1959). Some characteristics of simple types of predation and parasitism1. *The Canadian Entomologist*, 91, 385–398.

Holt, R.D. (1977). Predation, apparent competition, and the structure of prey communities. *Theoretical population biology*, 12, 197–229.

Lawton, J.H. (1999). Are there general laws in ecology? *Oikos*, pp. 177–192.

Levine, J.M. & HilleRisLambers, J. (2009). The importance of niches for the maintenance of species diversity. *Nature*, 461, 254–257.

MacArthur, R. & Levins, R. (1967). The limiting similarity, convergence, and divergence of coexisting species. *The american naturalist*, 101, 377–385.

May, R.M. (1972). Will a large complex system be stable? *Nature*, 238, 413–414.

Maynard-Smith, J. (1978). *Models in ecology*. CUP Archive.

Saavedra, S., Rohr, R.P., Bascompte, J., Godoy, O., Kraft, N.J. & Levine, J.M. (2017). A structural approach for understanding multispecies coexistence. *Ecological Monographs*, 87, 470–486.

Song, C. & Saavedra, S. (2018). Will a small randomly assembled community be feasible and stable? *Ecology*, 99, 743–751.

Stouffer, D.B. & Novak, M. (2021). Hidden layers of density dependence in consumer feeding rates. *Ecology Letters*, 24, 520–532.

Thompson, J.N. (1999). The evolution of species interactions. *Science*, 284, 2116–2118.

Turnbull, L.A., Levine, J.M., Loreau, M. & Hector, A. (2013). Coexistence, niches and biodiversity effects on ecosystem functioning. *Ecology letters*, 16, 116–127.

Vázquez, D.P., Morris, W.F. & Jordano, P. (2005). Interaction frequency as a surrogate for the total effect of animal mutualists on plants. *Ecology letters*, 8, 1088–1094.

Volterra, V. (1926). Fluctuations in the abundance of a species considered mathematically. *Nature*, 118, 558–560.

Wood, S.N. & Thomas, M.B. (1999). Super–sensitivity to structure in biological models. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 266, 565–570.

Wootton, K. & Stouffer, D. (2016). Many weak interactions and few strong; food-web feasibility depends on the combination of the strength of species' interactions and their correct arrangement. *Theoretical Ecology*, 9, 185–195.