INCREASING REALISM IN MODELS OF BIOTIC INTERACTIONS:

ecological and evolutionary consequences

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Different abstractions from the same wholes capture different aspects of the reality but also leave us with different blindnesses. Therefore it is always necessary to recognize that our abstractions are intellectual constructs, that an "object" kicks and screams when it is abstracted from its context and may take its revenge in leading us astray.

– Richard Levins

1 INTRODUCTION

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; Song and Saavedra, 2018; Wootton and Stouffer, 2016), resilience (Capdevila et al., 2021), ecosystem functioning (Godoy et al., 2020; Turnbull et al., 2013), 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 (Chase and Leibold, 2009; Gause, 1934; HilleRisLambers et al., 2012; MacArthur and Levins, 1967; Thompson, 1999).

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, Luceño, and Carmen Paniagua-Quinones, 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 somewhat accurately described in the form of mathematical expressions; mutualistic interactions, competition, parasitism, commensalism, and even the co-evolution of species. Second, they are practical tools with which to make predictions beyond the phenomena they describe. For instance.

However, 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 can dramatically impact model-based predictions. For instance, the elementary pair-wise interactions between species have been studied extensively.

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.

In this thesis, I add another criteria to that, when it fundamentallyl.

INTRODUCING BIOTIC DRIVERS

I investigate precisely this and explore how

EXPLORING UNCERTAINTY

NON-CONSTANT ENVIRONMENTS

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 Chapter 2 I explore the consequences in terms of the coexistence of species.

changes our understanding of the system. 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.

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2 THE CONTEXT-DEPENDENCY OF POLLINATOR INTERFERENCE

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3

THE INTERPLAY OF ENVIRONMENTAL CONDITIONS, PARAMETER SENSITIVITY AND STRUCTURAL SENSITIVITY IN PREDICTIONS OF SPECIES COEXISTENCE

This is your bayesian competition manauscript

4

COEXISTENCE OF ALLELES

This is your coexistence of alleles manauscript

5 CONCLUSION

Where is the rest of the world?
That is the question we must always ask about any model:
where is the rest of the world?

— Levins (2006)

In this thesis, I show how to incorporate biotic and abiotic complexity in models of biotic interactions to increase model realism. Furthermore, I provide direct evidence that many models used to describe biotic interactions are oversimplistic since they fail to capture dynamics accurately by *a priori* ignoring biotic and biotic factors. Throughout this thesis, I also show that increasing realism in models of biotic interactions has important repercussions on our understanding and predictions about the maintenance of diversity at ecological and evolutionary scales.

SUMMARY OF RESULTS

In Chapter 2 I found that the abundance of co-foragers can substantially change the number of visits pollinators make. These results imply that it is necessary to account for the density of species other than the focal pair to characterize plant-pollinator interactions accurately. However, results from this chapter also show that the environmental context pollinators experience mediates density-dependent responses to co-foraging species. Thus, abiotic drivers can modify the number of visits made by pollinators through both density-independent and density-dependent responses. These two types of responses can cause the same environmental context to have opposite effects on floral visits. Such is the case of high resource abundance in our foraging experiment. Additionally, in this chapter I show that pollinators do not respond equally to all co-foraging species. Therefore the effects of biotic and abiotic drivers depend on the identity of the interacting species. Results from this chapter clearly show that including these levels of complexity in a model of floral visits is justified, despite the increasing number of parameters necessary to parameterize it. Since floral visitation is a good predictor of the strength of plant-pollinator interactions my results demonstrate that failing to account for biotic and abiotic complexity

GENERAL IMPLICATIONS

Model realism

Diversity maintenance

Models of mutualistic interactions are generally used to understand the number of species that can be maintainted in a community.

FUTURE DIRECTIONS

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