Complex biotic interactions in a natural multitrophic community

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# Feedback

Below, I briefly explain the motivation behind the first chapter of my PhD (the global title of my PhD is “How prevalent is facilitation in annual plant communities?”). The methodology is too long to be explained in detail, but I tried to explain it in “Challenges and solution” shortly. I am looking for feedback on how to present my results concisely. I am also open to suggestions on telling this story (e.g., focus on facilitation, complex biotic interactions in general, or how to capture natural complexity). Thank you for your help!!

# Motivation

Facilitative interactions between species are a prominent avenue to understanding the dynamics of natural ecosystems. While facilitation's relevance in explaining species co-persistence is recognised, its consistent exclusion from the study of species coexistence remains traditional. The main theoretical framework of coexistence, Modern Coexistence Theory (MCT), investigates species coexistence in light of competitive interactions between species pairs. Yet, natural ecosystems with multispecies and multi-trophic levels include many diverse biotic interactions besides competition. Here, we investigate how the dynamic of an annual plant community can be described by multispecies interactions with other plants and higher trophic levels (floral visitors and herbivores) over four years.

# Challenges and solutions

Investigating an annual plant dynamic embedded in a multitrophic network is challenging empirically and theoretically. Empirically, one needs to capture the effect of each plant's neighbours, floral visitors, and herbivores on the fecundity of the focal species. Theoretically, capturing the ecologically relevant biotic processes requires balancing simplicity and natural complexity. The mathematical model describing the fecundity distribution must include complex interactions, such as facilitative and higher-trophic interactions1, while staying generalisable.

First, we meet the former challenge by combining three observational protocols, one per trophic level, in an annual grassland system in Doñana NP, southwest Spain, from 2018 to 2021. The observations allow the thorough investigation of the persistence of the annual plant species in the community. They involve fecundity assessment in relation to plant neighbourhood density and identity, floral visitation rate and herbivore abundance. Additionally, we include three potential grouping factors for species in each trophic level: function group, family and species. For instance, the plant neighbours of the focal species can be divided following a less to more restraint grouping factor with first the functional group (forbes vs grasses), second the family level (e.g., Asteraceae), and last the species level (e.g., *Hordeum marinum*), depending on what fits best the model.

Second, we tackle the latter challenge by using an extended Bayesian-Sparse modelling approach to the non-linear model of individual fecundity, allowing the consideration of numerous parameters while maintaining plausible fitting (please see Weiss-Lehman et al. (2021) for a detailed explanation). In brief, the fecundity distribution of a focal species is explained by an intrinsic growth rate, direct interactions – the intraspecific plant interaction, generic interaction coefficients(effect of the presence of one individual, regardless of its identity; specific for each trophic level), the relevant species-specific interaction(s) (divergence from the generic effect; specific to a relevant species)- and the relevant species-specific HOIs (see conceptual figure below). This non-linear model gives equal opportunity to species interactions to be negative or competitive.

1 Higher-order interactions (HOIs) are interaction modifications initiated by the presence of a third species (the initiator) which changes the per capita effect (or pairwise interactions) of a competing species (the transmitter) on a focal species (the receiver/focal).

# Figures

Conceptual figure.

Caption: The fecundity distribution of a focal species is the number of seeds produced per individual. The fecundity distribution is described according to the intrinsic fecundity (i.e., fecundity without neighbours), direct interactions and higher-order interactions (HOIs). There are three types of direct interactions: (i) plant-plant, (ii) plant-floral visitor (Fv), and (iii) plant-herbivore (H). Plant-plant interactions include intraspecific interactions (effect of focal individuals on the fecundity) and interspecific interactions. Each type of direct interaction is defined by a generic effect (i.e., the effect of the presence of one individual, regardless of its identity) and a species-specific effect (i.e., divergence from the generic effect specific to a relevant species; identified by the Sparsity approach). Plant interactions are evaluated by the identity and abundance of plant neighbours (around a 7.5 cm diameter). The average floral visitation rates for the focal species per plot are the floral visitors' effect. The herbivores effect is the average number of herbivores on the focal species per plot. The HOIs are any three-species interactions where at least two are plants, and the focal is a plant species - “X” can be a plant, a floral visitor, or a herbivore. HOIs have a generic effect equal to zero, allowing only relevant species-specific HOIs to be considered. An interactor is coloured in grey when its effect on the focal species’ fecundity is defined by a generic effect proper for each trophic level. And inversely, when coloured in natural colours, it diverges from the generic effect is significant. We collected the data for 4 consecutive years.

Results – 1. We focus on two focal species: *Leontodon marocanus* (species code: LEMA),Asteraceae, Forb and Centaurium *tenuiflorum* (species code: CETE),Gentianaceae, Forb. Note that in the future, we will add two other focal species.



Caption:

Direct species interactions for each year, each focal. The density distributions show the generic effect for one type of direct interaction. Boxplots are present when a species-specific interaction has been identified by the Sparse approach to be relevant and has an effect significantly different from the generic effect. Here, only LEMA has a species-specific interaction highlighting the increased competition from Poaceae individuals on the generic plant-plant interaction. Noted that species are grouped according to “family” – different grouping levels had similar estimated distributions.

Main messages:

1. Facilitation is as common as competition.
2. Facilitation is more present in plant-Fv and plant-H rather than in plant-plant interactions.
3. Intraspecific interactions included more frequent facilitation than interspecific plant interactions.
4. Species-specific interactions are rarely present but tend to increase competition.
5. HOIs are not relevant for these two species.