`mangal` – making ecological network analysis simple

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This is a *working document* describing `mangal`, a set of `JSON` objects templates to encode ecological networks of virtually any complexity. There are plans to host a pilot database.

Introduction

Ecological networks enable ecologists to accommodate the complexity of natural communities, and to discover mechanisms contributing to their persistence, stability, resilience, and functioning [1, 2]. Yet, meta-analyses of a large number of ecological networks are still extremely rare, and most of the studies comparing several networks {ref} do so within the limit of particular systems. Networks, as they encode the structure of complex ecological interactions, have been time and again presented as useful tools to understand ecosystem properties and dynamics {ref}. Coming up with a clear conceptual and mechanistic understanding of the relationships between the structure of ecological networks and ecosystem properties require to pool a large quantity of data.

On the other hand, the recent years saw the development of the idea that network structure is itself a dynamical object, which will change as a function of environmental conditions and as a result of meta-community processes {ref}. Although the *existence* of this variation has been demonstrated, the reasons for which it happens are much less clearly understood, and will require a change in focus, from species to populations {ref}. Because the variability of interactions involve a host of ecological mechanisms, it is likely that important data mining efforts will be required to fully understand it. Notably, new approaches based on the replication of networks over temporal, spatial, and environmental gradients are promising, but require to have a data structure ready to accomodate the results they will produce. Beyond just describing the structure of interactions, these data will need to include informations about environmental context, population characteristics, and other relevant additional explanatory variables.

In this paper, we (i) establish the need of a data specification serving as a *lingua franca* among network ecologists, (ii) describe this data specification. Finally, we (iii) describe `mangal`, a `R` package and compagnon database, relying on this data specification. We provide some use cases showing how this new approach makes complex analyzes simpler, and allows for the integration of new tools to manipulate biodiversity resources.

Why do we need a data specification?

Ecological networks are (often) stored as their *adjacency matrix* (or as the quantitative link matrix), that is a series of `0` and `1` indicating, respectively, the absence and presence of an interaction. This format is extremely convenient for *use* (as most network analysis packages, *e.g.* `bipartite`, `betalink`, `foodweb`) require data to be presented this way, but is extremely inefficient at storing *meta-data*. In most cases, an adjacency matrix will inform on the identity of species (in cases where rows and columns headers are present), and the presence or absence of interactions. If other data about the environment (*e.g.* where the network was sampled) or the species (*e.g.* the population size, trait distribution, or other observations) are available, they are most either given in other files, or as accompanying text. In both cases, making a programmatic link between interaction data and relevant meta-data is difficult and error-prone.

By contrast, a data specification provides a common language for network ecologists to interact, and ensure that, regardless of their source, data can be used in a shared workflow.

Elements of the data specification

{complete}The data specification is built around the idea that (ecological) networks are collections of relationships between ecological objects, each element having particular meta-data associated.

Node informations

Taxa

Population

Item

Network informations

Interaction

Network

Dataset

Meta-data

Trait value

Environmental condition

User

paternity {ref}

References

Use cases

Network centroid

Network beta-diversity

Connectance and richness relationships

References

1. Dunne JA: **The Network Structure of Food Webs**. In *Ecological networks: Linking structure and dynamics*. edited by Dunne JA, Pascual M Oxford University Press; 2006:27–86.

2. Blüthgen N, Fründ J, Vázquez DP, Menzel F: **What do interaction network metrics tell us about specialization and biological traits?** *Ecology* 2008, **89**:3387–99.