Environmental biases in the study of ecological networks at the planetary scale

Introduction

Ecological networks are a useful way to think about ecological systems in which species or organism interact (Poisot et al. 2016c; Delmas et al. 2018), and recently there has been an explosion of interest in their dynamics across large temporal scales (Tylianakis & Morris 2017; Baiser et al. 2019), especially alongside environmental gradients (Trøjelsgaard & Olesen 2016; Pellissier et al. 2017). As ecosystems and climates are changing rapidly, ecologists realized that networks are at risk or unravelling, being invaded by exotic species that can destabilize them (Strong & Leroux 2014; Magrach et al. 2017), or adopt entirely novel configurations (Guiden et al. 2019; Hui & Richardson 2019). Simulation studies seem to suggest that knowing the shape of the extant network is not sufficient (Thompson & Gonzalez 2017), and that it needs to be supplemented by additional data on species properties, climate, and climate projection.

This renewed interest in ecological networks has prompted several methodological efforts. First, an expansion of the analytical tools to study ecological networks and their variation in space (Poisot et al. 2012, 2015, 2017). Second, improvements in large-scale data-collection, through increased adoption of molecular biology tools (Evans et al. 2016; Eitzinger et al. 2019) and crowd-sourcing of data collection (Pocock et al. 2015; Bahlai & Landis 2016; Roy et al. 2016). Finally, a surge in the development of tools that allow to *infer* species interaction (Morales-Castilla et al. 2015) based on limited but complementary data on existing network properties (Stock et al. 2017), species traits (Gravel et al. 2013; Desjardins-Proulx et al. 2017; Brousseau et al. 2017; Bartomeus et al. 2016), and environmental conditions (Gravel et al. 2018). These approaches tend to perform well in data-poor environments (Beauchesne et al. 2016), and can be combined through ensemble modeling or model averaging to generate possibly more robust predictions (Pomeranz et al. 2018).

The common goal to these efforts is to facilitate the prediction of network structure, both extant [Poisot et al. (2016b); **MARINE FOODWEB**] and future (Albouy et al. 2014), and to appraise its possible variation in response to changes. All of these developments also share the need to be supported by state

of the art data management: novel quantitative tools demand a higher volume of network data; novel collection techniques demand powerful data repositories; novel inference tools demand easier integration between different types of data, including but not limited to interactions, species traits, taxonomy, occurrences, and local bioclimatic conditions.

Poisot et al. (2016a) – overview of original DB + updates, **TODO** map of networks + networks over time

- New data
- number and amount of new information
- web API for better data access, and two packages (one in Julia, the other in R) for accessing these data.
- Mangal in its current form offers open network data that is ready to support synthesis at many scales.

Borrett et al. (2014) identified network ecology as one of the fastest growing sub-field in the ecological sciences.

Synthesizing ecological data presents important challenges and also some exciting opportunities. Mangal is well suited to offer such opportunities in the study of ecological networks.

- A major challenge to ecological synthesis is generalizing from samples to the behaviour of ecological systems
- two obstacles to such generalizing in ecological systems: data coverage and data quality
  - data coverage: are data collected from every relevant system?
  - data quality: are data fit-for-purpose? Two particular aspects of quality
    * taxonomic resolution
    * sampling effort

Main question, is the data fit for purpose, what can we do and cannot do with it?

Global trends in ecological networks description

Network coverage is accelerating

Different interaction types have been studied at different places

Although the volume of available networks has increased over time, the sampling of these networks in space has been uneven. In fig. 2, we show that globally,
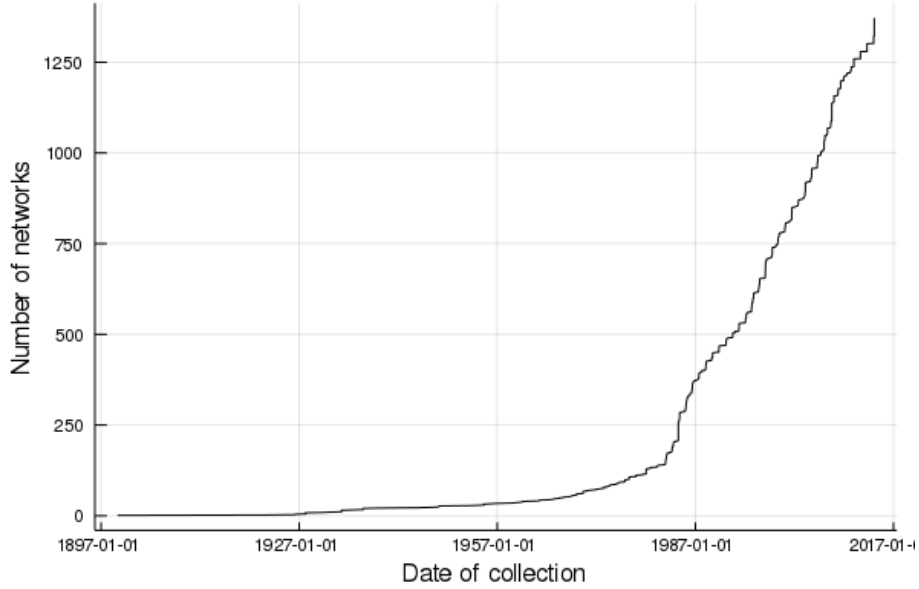
Figure 1: fig1

network collection is biased towards the Northern hemisphere, and than different types of interactions have been sampled in different places. As such, it is very difficult to find a spatial area of sufficiently large size in which we have networks of predation, parasitism, and mutualism. The inter-tropical zone is particularly data-poor, either because data producers from the global South correctly perceive massive re-use of their data by Western scientists as a form of scientific neo-colonialism (as advanced by Mauthner & Parry 2013), thereby providing a powerful incentive *against* their publication, or because ecological networks are subject to the same data deficit that is affecting all fields on ecology in the tropics (Collen et al. 2008). As Bruna (2010) identified almost ten years ago, improved data deposition requires an infrastructure to ensure they can be repurposed for future research, which we argue is provided by `mangal.io` for ecological interactions.

Different interaction types have been studied in different biomes

Whittaker (1962) suggested that natural communities can be partitioned across biomes, largely defined as a function of their relative precipitation and temperature; in fig. 3, we show that even though networks, overall, capture the diversity of the precipitation/temperature climate well, types of networks have been studied in sub-spaces only. Specifically, parasitism networks have been
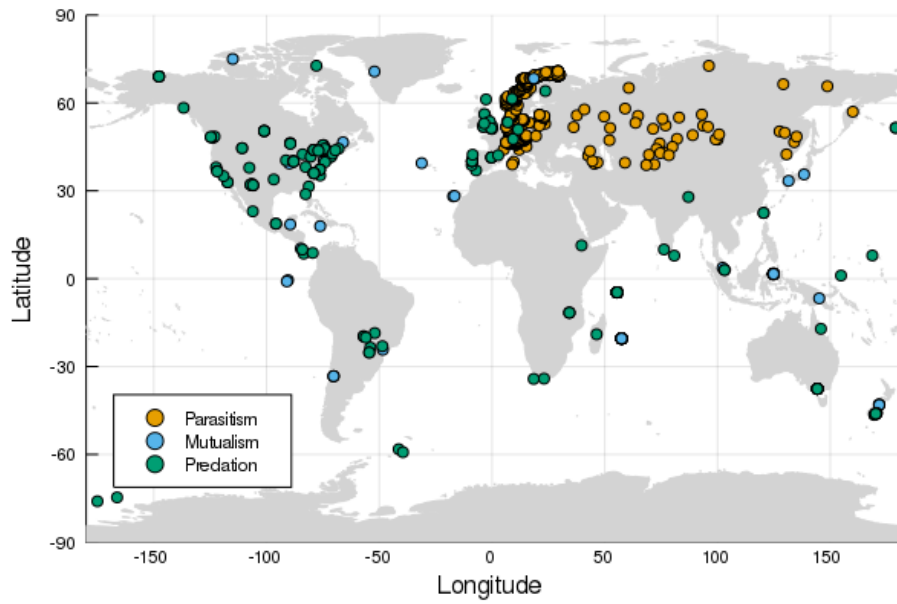
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Figure 2: Each point on the map corresponds to a network with parasitic, mutualistic, and predatory interactions. It is noteworty that the spatial coverage of these types of interactions is uneven; the Americas have almost no parasitic network, for example. Some places have barely been studied at all, including Africa and Eastern Asia. This concentration of networks around rich countries speaks to an inadequate coverage of the diversity of landscapes on Earth.

studied in colder and drier climates; mutualism networks in wetter climates; predation networks display less of a bias.
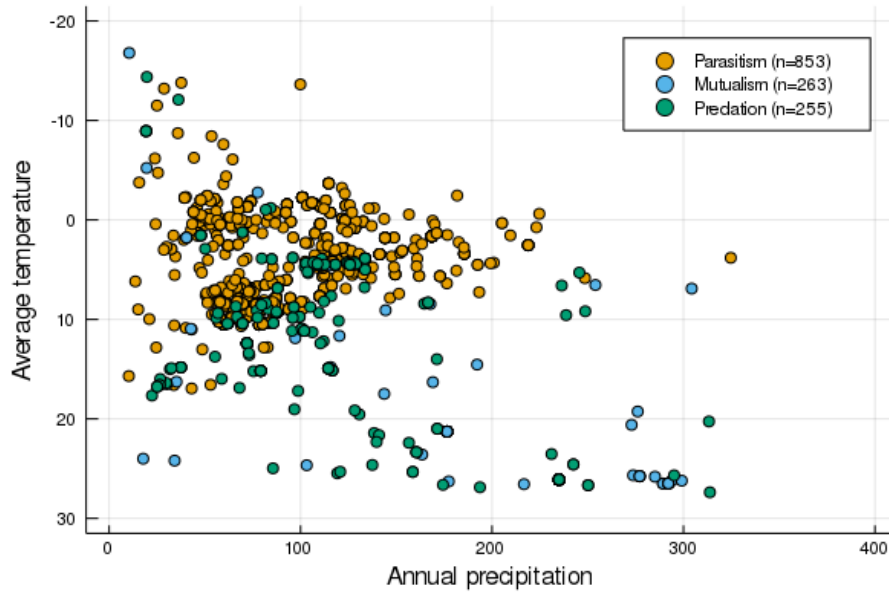

Figure 3: List of networks across biomes

Some locations on Earth have no climate analogue

Climate analogue

Mutualistic networks are biased towards more unique environments

Conclusions

reducing uncertainty through 'analogues'

When we lack direct observation of a community, often we must resort to the use of 'analog' communities – that is, communities which are similar in space or environment which have been sampled.

- Communities may be similar in at least two ways – close in space, or close in climate
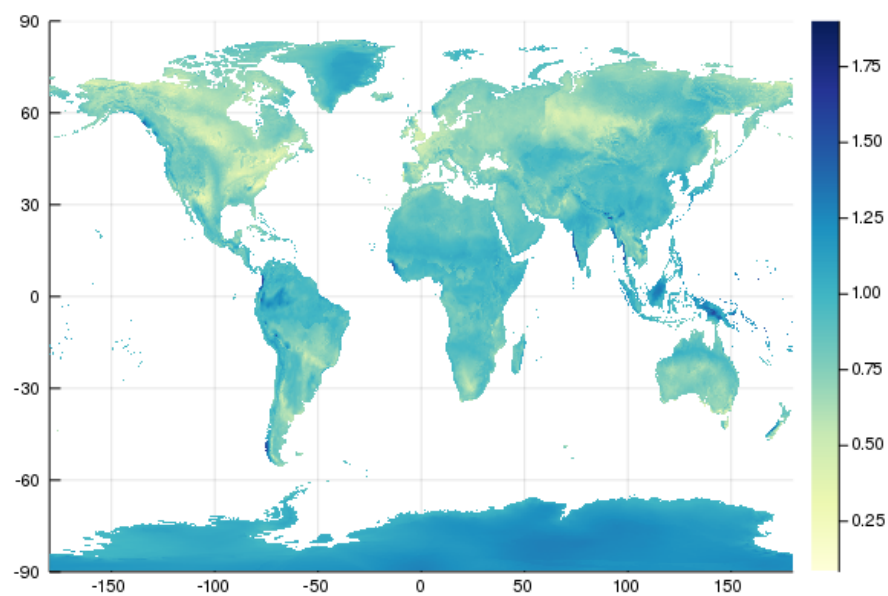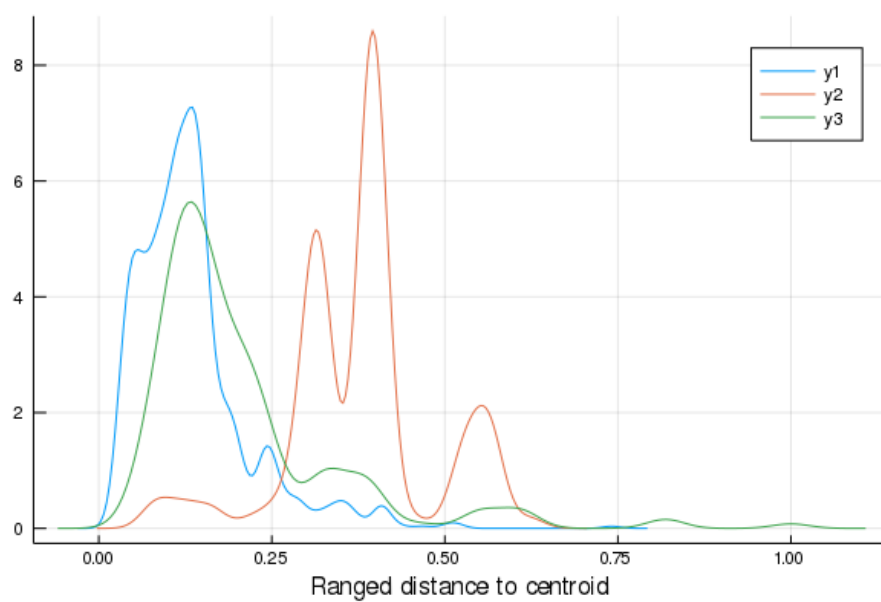
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Figure 4: tk

Figure 5: tk

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- similarity may result in some (?) similarity in network structure, even if species different.
- Always some uncertainty in such comparisons
- reflects the need for more data gathering, can be used to target efforts

Future of network ecology

Use this spatial gaps for sampling recommendations

more complete analyses

We have only shown some high-level summaries of the data here; many possibilities remain.

more data collection

We have demonstrated the considerable coverage of Mangal; however, our summary also highlights important data-collection needs. In particular, we need better information about (mutualists, desert food webs?)

Active development and data contribution

This is an open-source project: all data and all code supporting this are available on the Mangal project GitHub organization. Our hope is that the success of this project will encourage similar efforts within other parts of the ecological community. In addition, we hope that this project will encourage the recognition of the contribution that software creators make to ecological research.

Data quality: sampling effort and taxonomy

Sampling effort and taxonomic detail are two very challenging but important part of any ecological dataset. The datasets in Mangal represent some of the most detailed studies of ecological networks available. * measures of network structure may be particularly sensitive to the amount of sampling effort * repeat sampling may be necessary to capture a "saturation" of interactions. * we present some visualization of the sampling coverage of Mangal [tk] * High taxonomic resolution is difficult to achieve in ecology, especially depending on the sampling method used (e.g. gut contents vs observations). We present a breakdown of the taxonomic resolution of Mangal. * Ecological networks occur in various kinds, but they are not all equally well sampled. We present a breakdown of the number of parasitic, mutualistic and predator-prey networks sampled in Mangal

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