Selection – Mutualistic Networks

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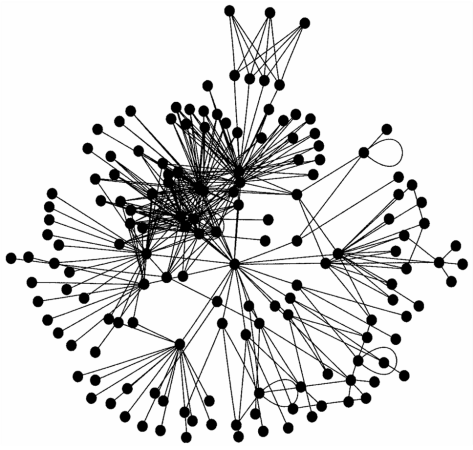
OUTLINE

- Introduction
- Overview of Mutualistic Networks
- Structure and Stability
- Summary, Questions, and Readings

RECALL: ECOLOGICAL NETWORKS

The Silwood Park Food web



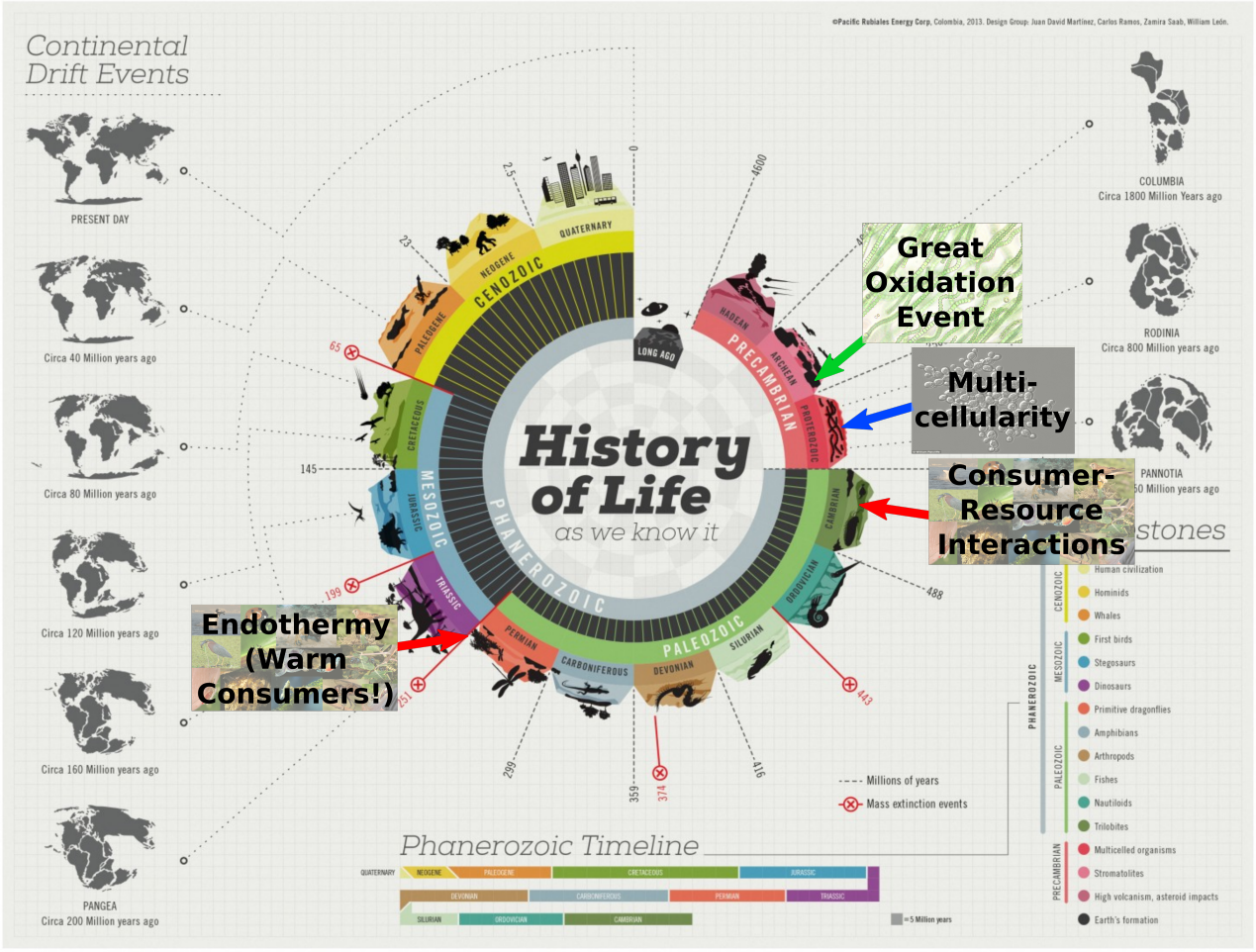
- **Ecological Network**: Network of interactions where *nodes* (·) are individuals or (usually, species') populations, and *links* (—) the interactions between pairs of nodes

- Types:
  - Trophic networks (+/−) (e.g., food webs)
  - **Mutualistic networks (+/+) (e.g., plant-pollinator networks)**
  - Competitive networks (−/−) (e.g., plant-plant or microbe-microbe)
  - Behavioural networks (+/−, +/+,+/−) (e.g., social networks)

MUTUALISTIC NETWORKS

- **Mutualistic Networks**: Network of interactions made of pairs of individuals or (usually species') populations *mutually benefiting* each other
- The benefit can be through direct exchange of matter/energy/metabolites/nutrients
  - Plant-fungal (especially, Mycorrhizal) soil interaction networks
  - Bacterial interaction networks—mutualisms can develop by exchange of organic substrates/metabolites between populations (e.g., Yogurt and Cheese!)
- Or through combination of direct and indirect benefits
  - Plant-Pollinator Networks: Pollination is an indirect benefit to the plant, nectar is a direct (energy) to the pollinator
  - Plant-Animal seed dispersal Networks: Also an indirect-direct benefit combination
  - Ant-Plant association networks: Plant gets protection (direct, but non-energy benefit), Ants get nectar (energy)

ORIGIN OF MUTUALISTIC NETWORKS

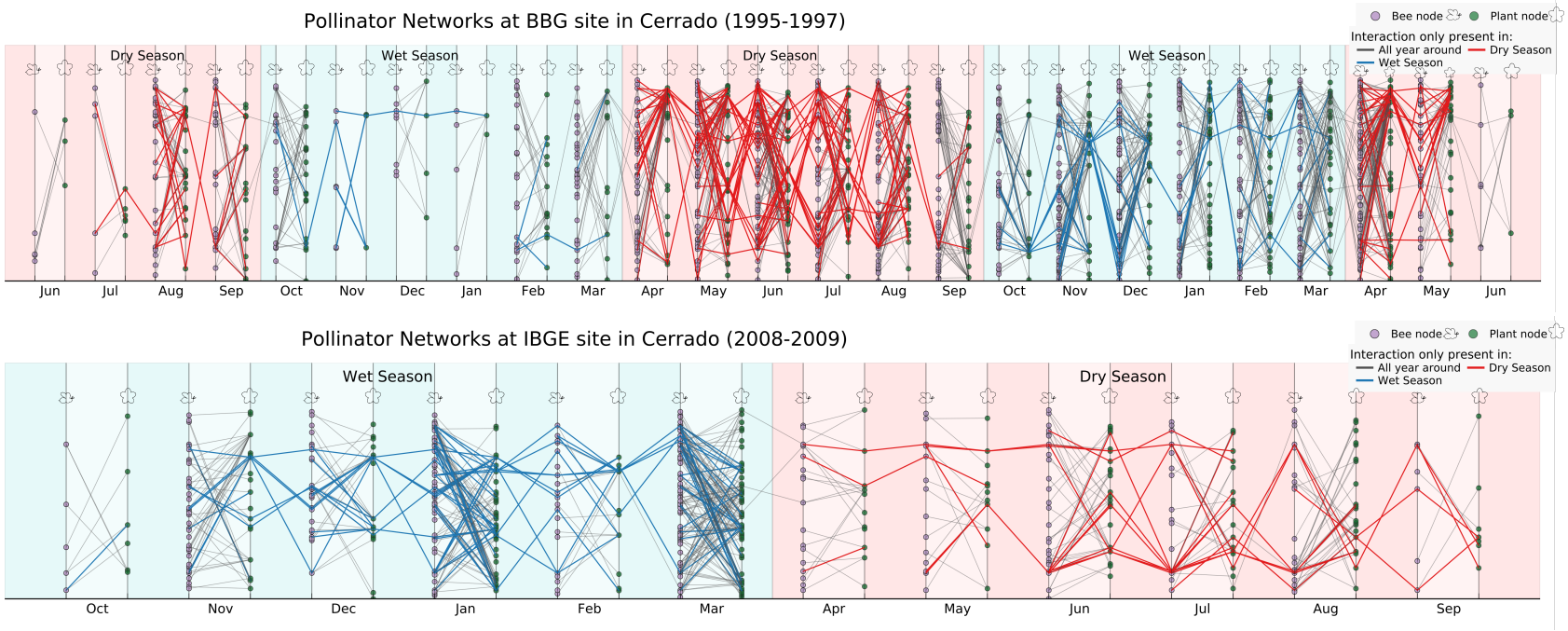


- Mutualistic networks are almost as old as life itself
  - *Multi-cellularity possibly arose from a mutualism*

WHY STUDY MUTUALISTIC NETWORKS?

- Pollination services
- Ecosystem functioning
- Biodiversity loss

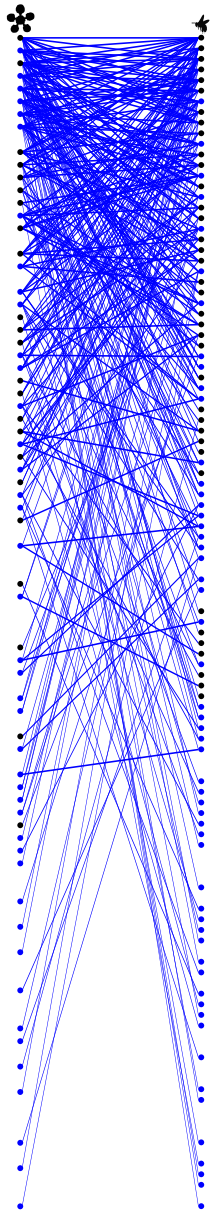
Source: `https://morningchores.com/pollination`



Rabeling et al PLoS One 2019

https://commons.wikimedia.org/w/index.php?curid=763031

STRUCTURE AND STABILITY

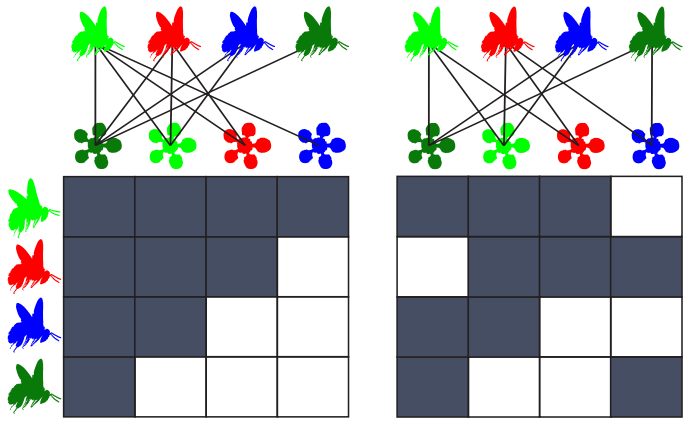


- Most work has been done on Plant-Pollinator networks
  - These are called "bipartite" networks because the nodes are at only two levels: Plants and Pollinators
- *Nestedness* is considered to be an important feature for the system's *stability* and *resilience* (coming up)
- Interaction *generalization* vs *specialization* is also considered important (coming up)
- Mutualistic networks have *Modules*[1]
  - But modules in these systems are less easy to identify and are poorly understood

[1] Like other ecological networks: Review lecture on Ecological Interaction Networks

THE ROLE OF NESTEDNESS

- **Nestedness of a network**: a network structural pattern where specialist pollinators species visit plant species that are subsets of those visited by more generalist pollinators
- Means that the network has a "strong" core of highly connected generalists
  - A generalist pollinator visits and pollinates many different plant species (same criteria can be applied to plants)

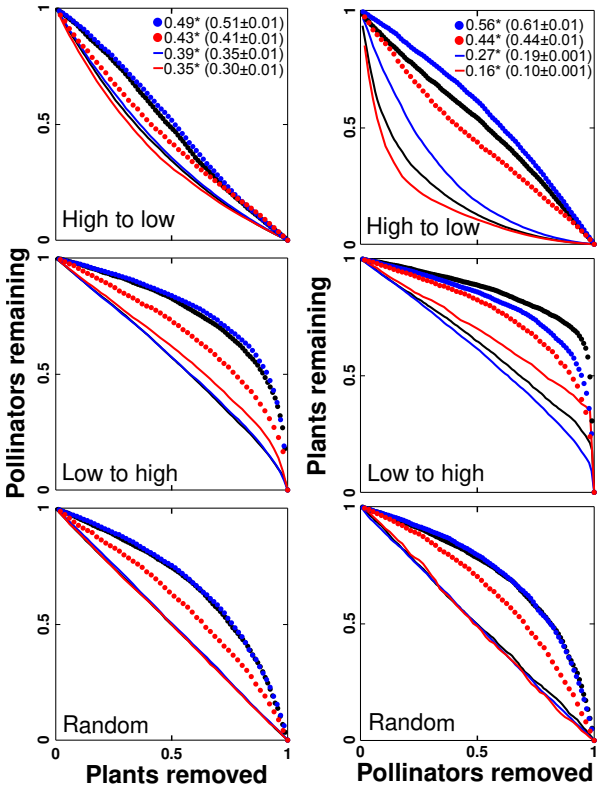


Pawar, Science 2015

- Nestedness Illustrated: The network on the left is perfectly nested, while the one on the right is not

THE ROLE OF NESTEDNESS

- Nestedness also means asymmetry in specialization: Specialist plants are pollinated by generalist animals, but generalist plants are pollinated by both specialist and generalist pollinators[2]
- All these properties have been linked to *robustness* of pollination networks to species loss:
  - If you remove a random species in a more nested network, it is less likely to collapse
- *But role of nestedness remains debated...*

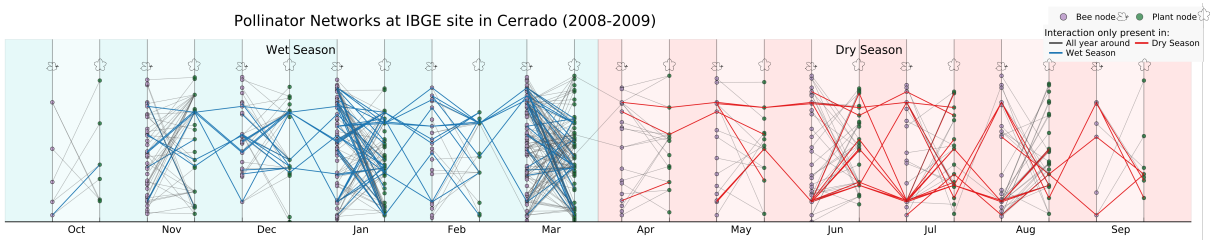


Rabeling et al, PlOS One 2019

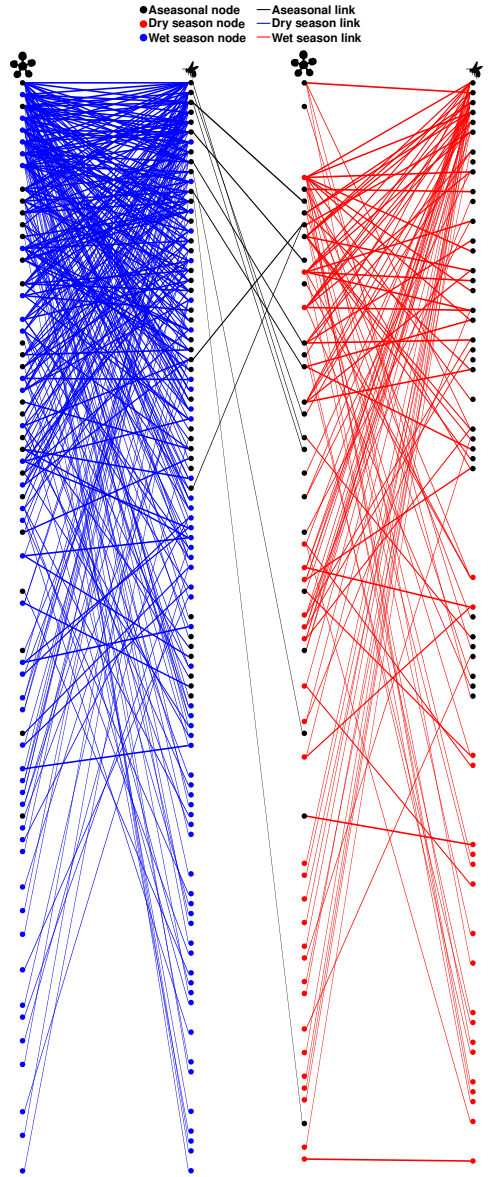
[2] In contrast to *reciprocal specialization* where specialist pollinators interact with specialist plants

TEMPORAL VARIATION IN MUTUALISTIC NETWORKS

- The structure of Mutualistic networks can change rapidly over time
- This issues is poorly understood, but very important
- These changes in network structure are linked to climate (and temperature)
- Climate change can disrupt such temporally changing networks (e.g., though *Phenological mismatches* between plants and pollinators)



Rabeling et al PLoS One 2019



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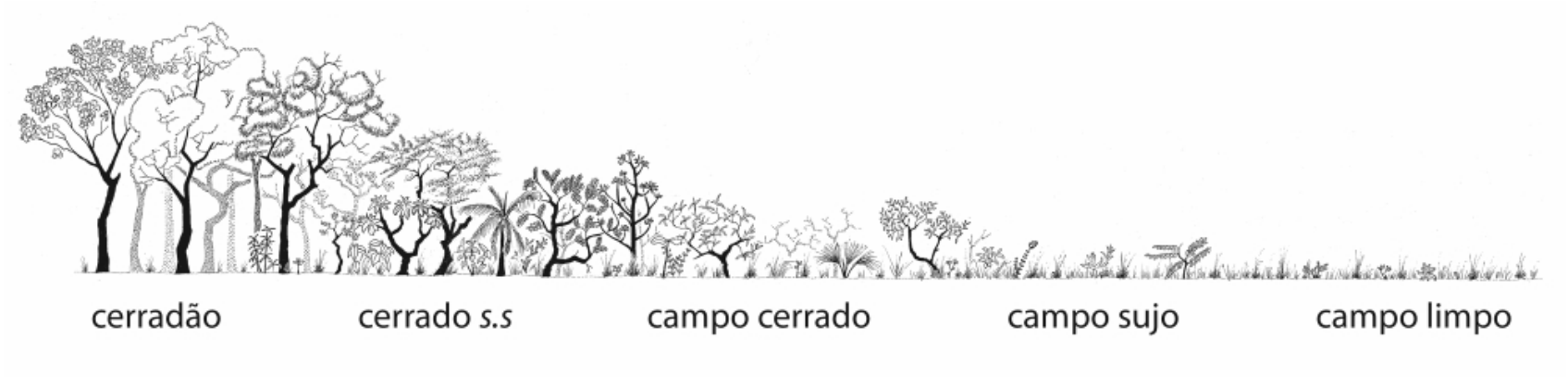
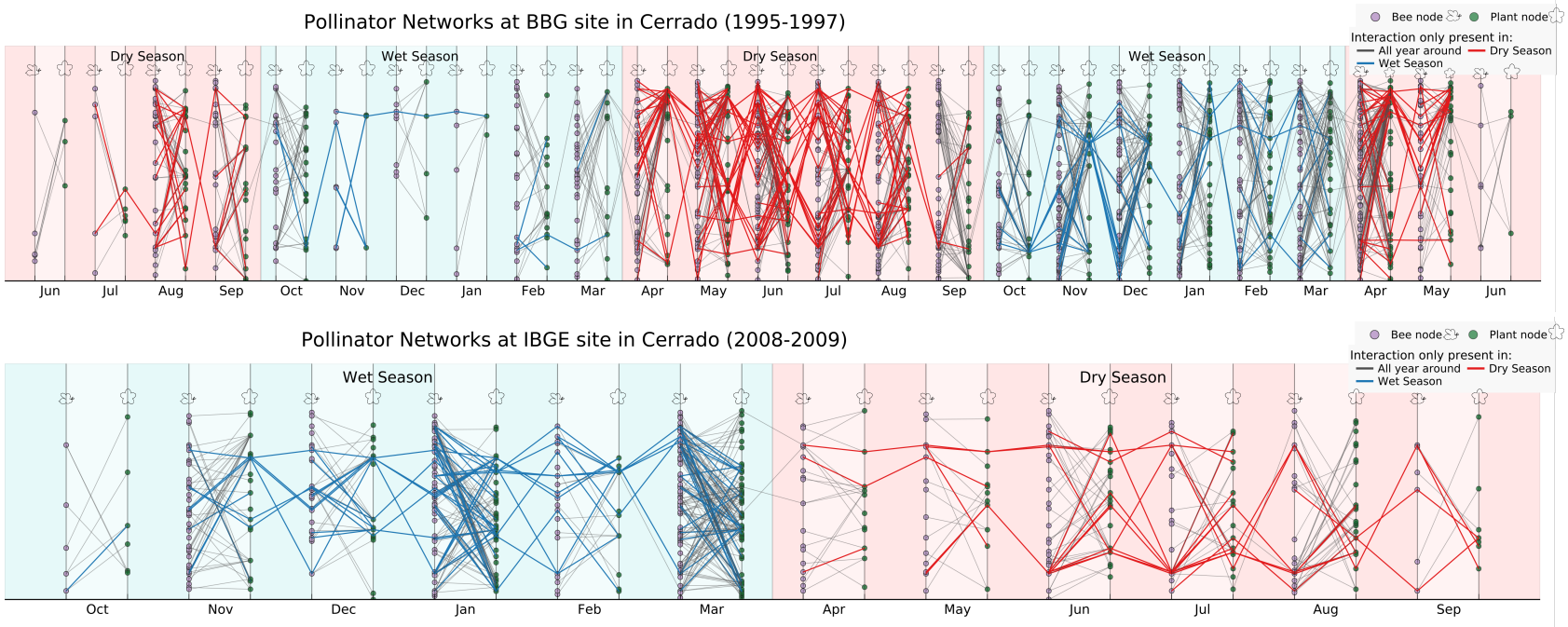


Gottsberger & Silberbauer-Gottsberger, Acta Bot. Brasilica 2018



Rabeling et al PLoS One 2019

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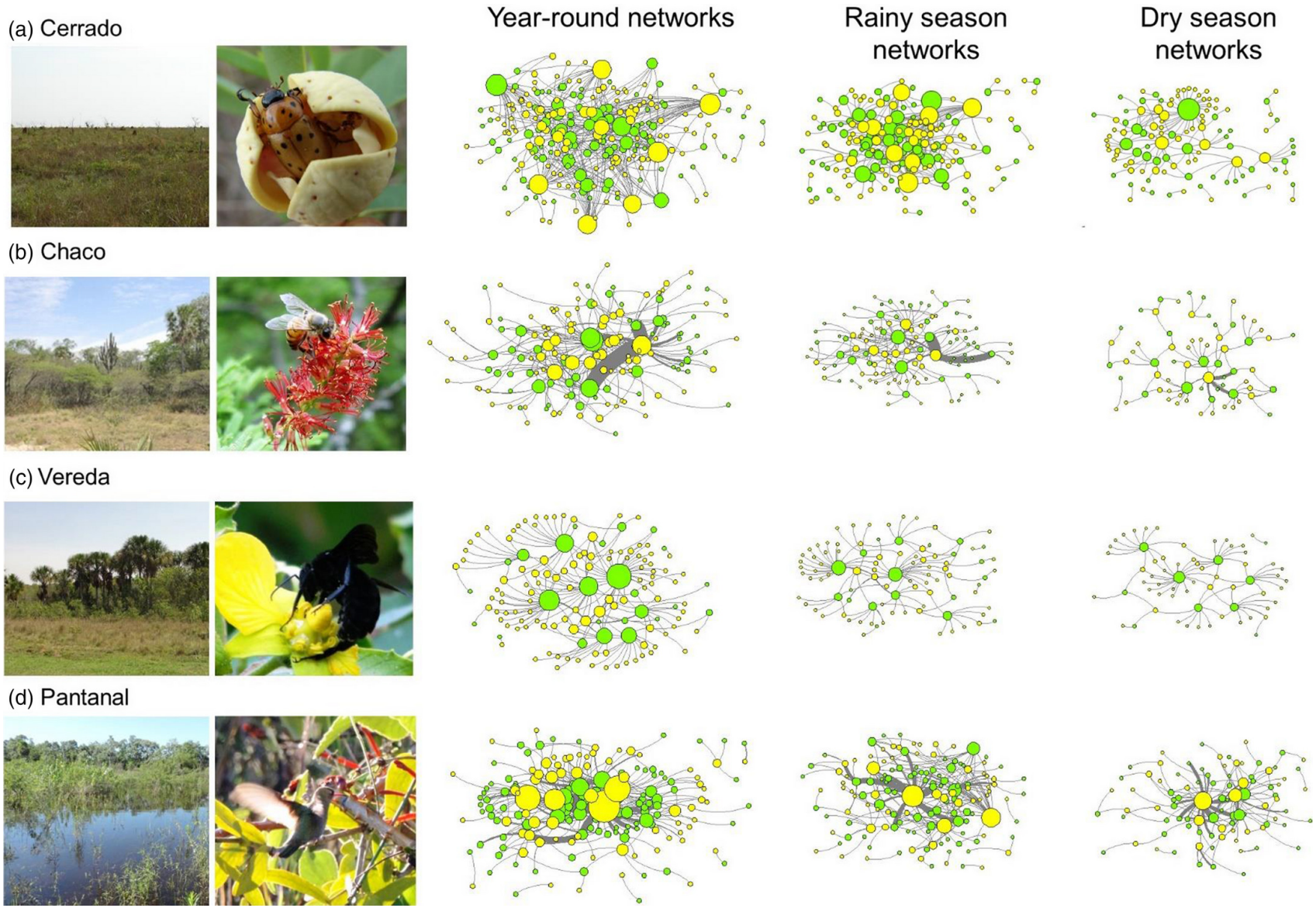
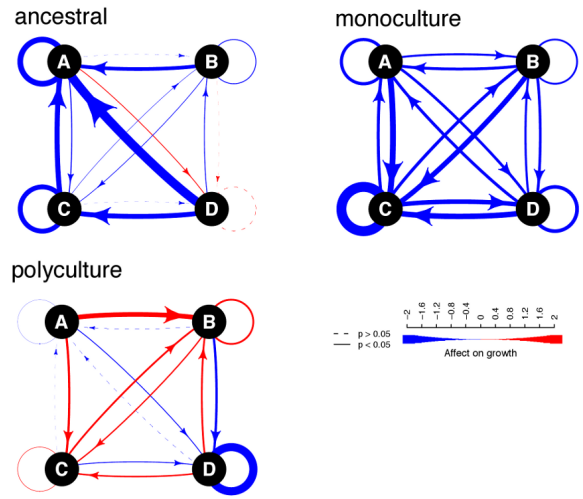


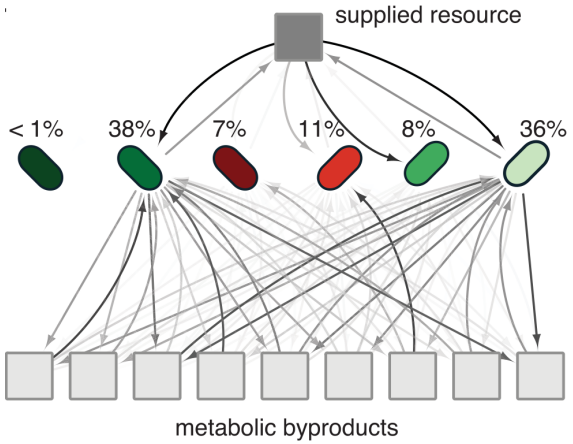
Souza et al. J. Ecol. 2018

MICROBIAL MUTUALISTIC NETWORKS

- Microbial networks are important model systems for understanding mutualism vs competition
- In fact, the interaction network in microbial communities can go from being competitive to mutualistic in a matter of days and months!
- Increasing mutualism increases the rate of microbial community functioning (e.g., decomposition of leaf litter)
- Temperature can accelerate this effect[3]



Lawrence et al PLoS Biology 2012



Goldford et al Science 2018

[3] Review lectures on Energy and Metabolism as well as Consumer-Resource Interactions

Summary

- Mutualistic networks are important for many ecosystem "services" (e.g., pollination)
- The structure of mutualistic networks affects their stability, resilience, and robustness
- Nestedness is believed to enhance the robustness (and stability) of mutualistic networks (but this is still debated)
- Plant-Pollinator networks can change over time (but this is poorly understood)
- Microbial networks can rapidly switch from being competitive to cooperative (mutualistic) over time

Discussion Questions

1. What are the differences between trophic (e.g., food web) and mutualistic networks?
2. Can we truly study Mutualistic and Trophic networks separately?
3. What role might body size play in Mutualistic (e.g., plant-pollinator) networks?
4. How do you thing global climate change might affect plant-pollinator networks and pollination services?
5. How do you think increasing mutualism increases the rate of microbial community functioning (e.g., decomposition of leaf litter)? What role can temperature play in this? How does this relate to the global carbon cycle? (Hint: Leaf litter decomposition releases CO_2)

Readings

1. Bascompte, J. & Jordano, P. Plant-animal mutualistic networks: The architecture of biodiversity. Annual Review of Ecology Evolution and Systematics 38, 567–593 (2007).
2. Thébault, E. & Fontaine, C. Stability of ecological communities and the architecture of mutualistic and trophic networks. Science. 329, 853–856 (2010).
3. Rabeling, S. C. et al. Seasonal variation of a plant-pollinator network in the Brazilian Cerrado: Implications for community structure and robustness. PLoS One 14, (2019).
4. Tylianakis, J. M., et al. Conservation of species interaction networks. Biological Conservation 143, 2270–2279 (2010).
5. Lawrence, D. et al. Species interactions alter evolutionary responses to a novel environment. PLoS Biol. 10, e1001330 (2012).