Part 3: Food-Web Robustness

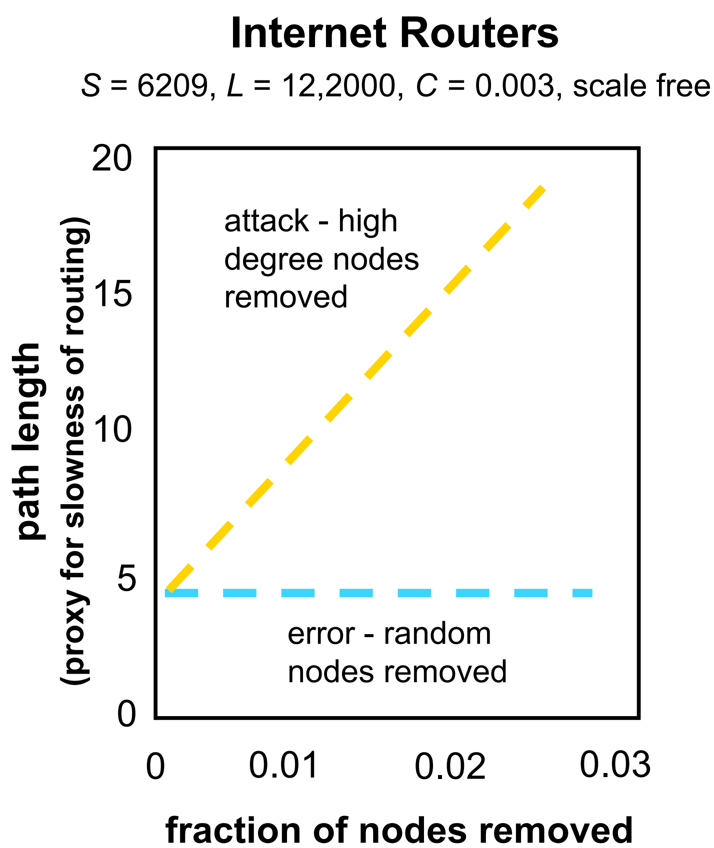
Why might ecological network structure matter?

"Devious Strategies" for Ecosystem Stability, Robustness, Persistence

In short, there is no comfortable theorem assuring that increasing diversity and complexity beget enhanced community stability; rather, as a mathematical generality the opposite is true. The task, therefore, is to elucidate the devious strategies which make for stability in enduring natural systems.

Bob May (1973) Stability and Complexity in Model Ecosystems

Robustness of small world, scale free networks



- Small-world, scale-free networks:
  - -are tolerant of errors (random node losses)
  - -are vulnerable to attacks (removal of hubs)
- Demonstrated for
  - -WWW
  - -Internet routers
  - -yeast protein network
  - -metabolic networks
- What about networks that lack small-world, scale-free topology? (like food webs!)

Albert, R., Jeong, H., and Barabási, A.-L. 2000. Error and attack tolerance of complex networks. Nature 406:378-382.

An ecological perspective

What is the potential for biodiversity loss to trigger cascading extinctions in food webs?

- Loss of prey items can lead to secondary extinctions
  - → Other dynamics can mitigate or exacerbate trophic effects
- Species richness/ecosystem function
  - → Average effects of species loss vs. loss of particular types of species

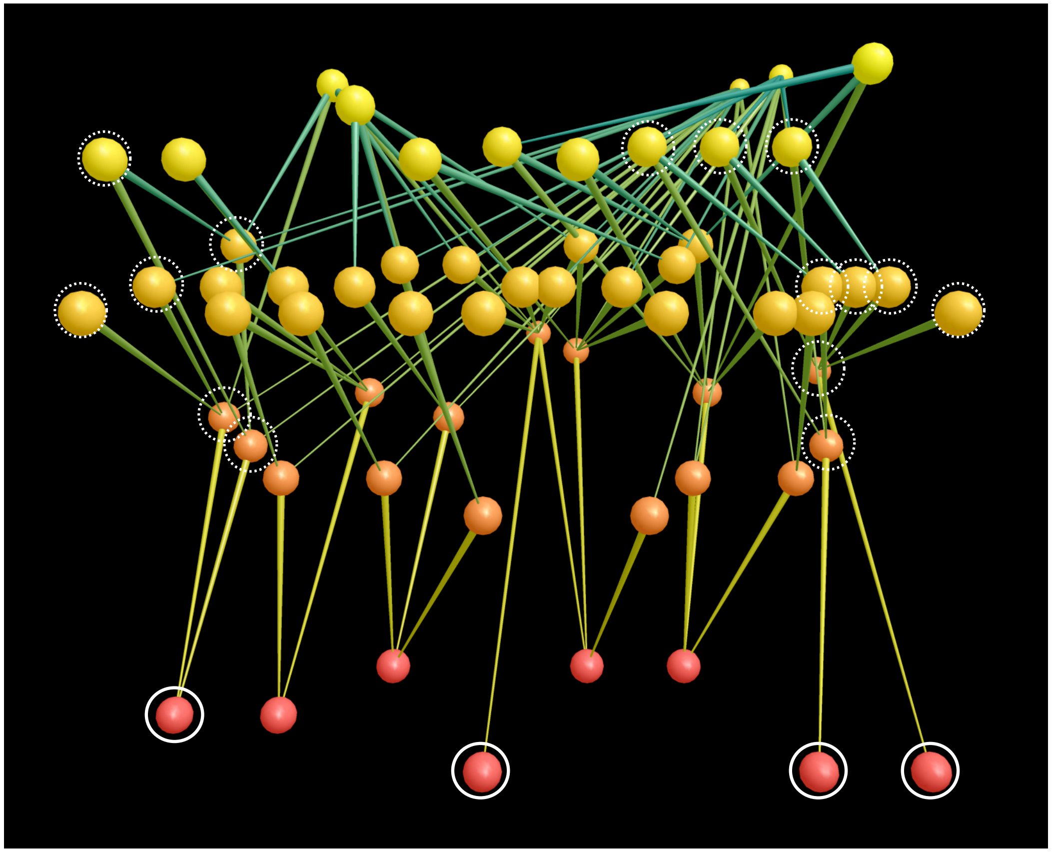
Does complexity confer robustness to perturbation?

- Dynamical Stability of Communities – MacArthur, May, and beyond
- Structural Stability of Communities – a complementary approach

UK Endophytic Grassland Web

Remove 4 Grasses → 15 Secondary Extinctions

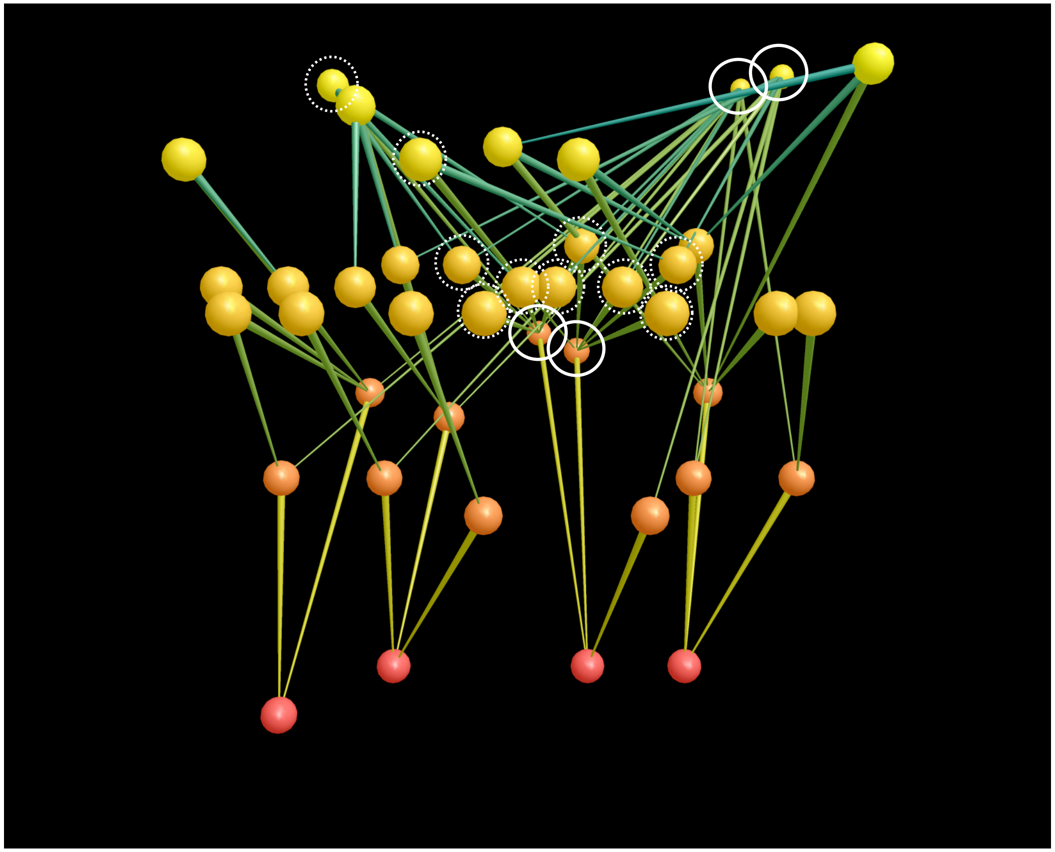
S = 61, C = 0.03



UK Endophytic Grassland Web

Remove 4 Insects → 10 Secondary Extinctions

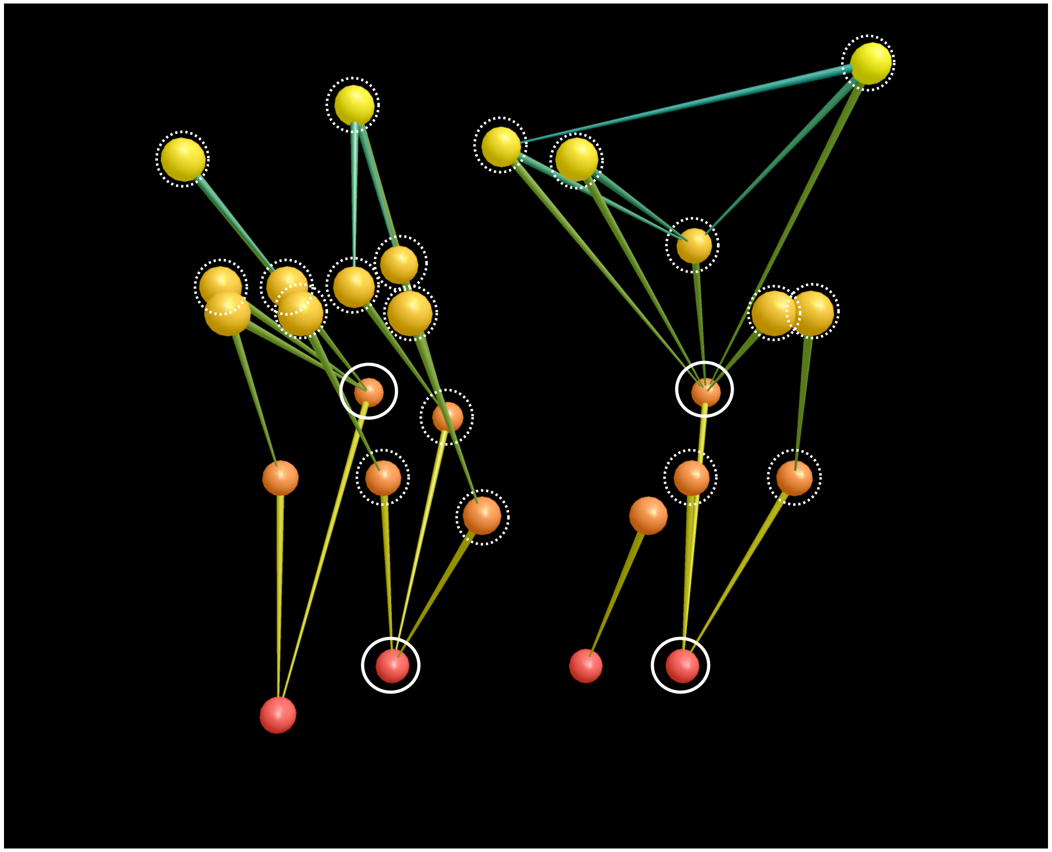
S = 42, *C* = 0.04



UK Endophytic Grassland Web

Remove 2 Grasses, 2 Insects → 19 Secondary Extinctions

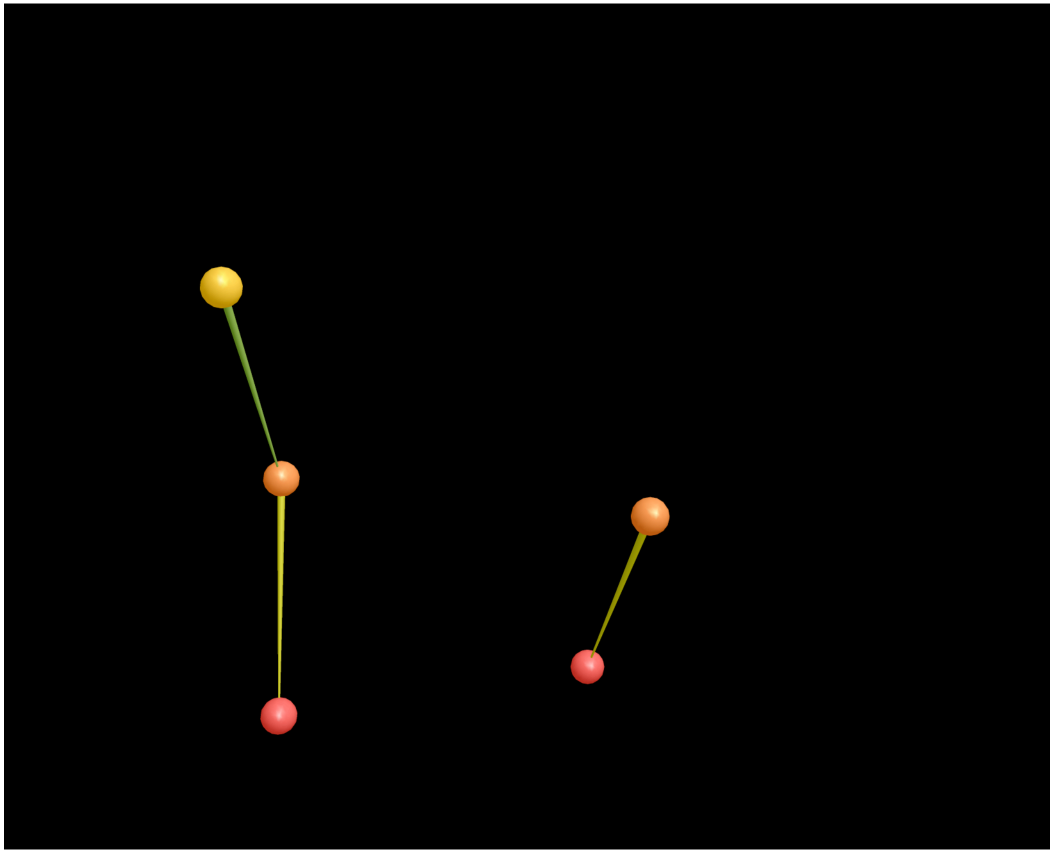
S = 28, 4 sub-webs



UK Endophytic Grassland Web

Total: 12 Primary Removals → 44 Secondary Extinctions

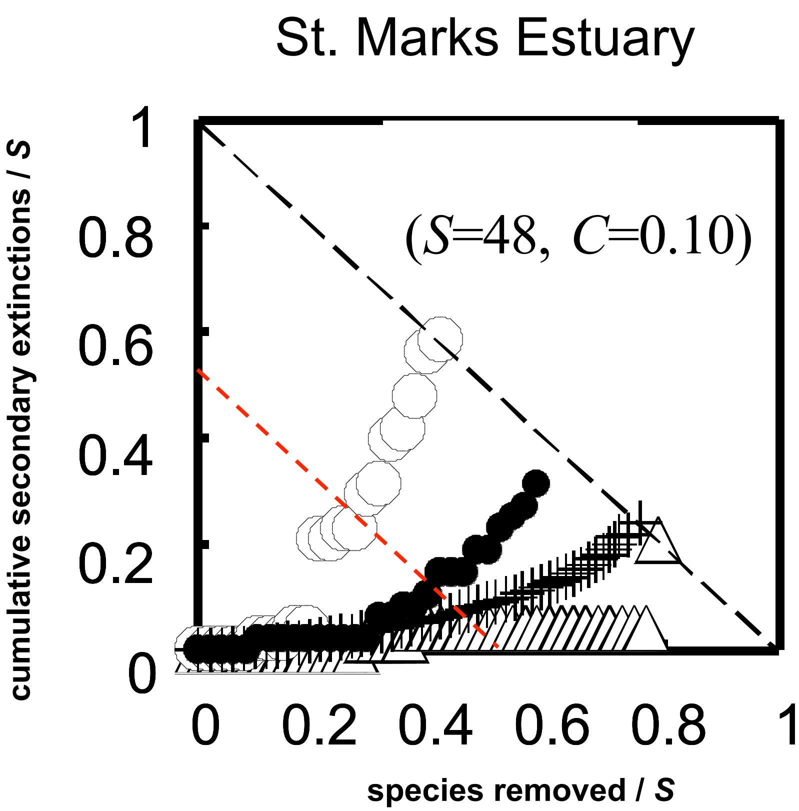
S = 5, 2 food chains



Simulated species loss & secondary extinctions

- Systematically remove taxa from food webs
- 4 criteria for species removal sequences (based on degree centrality)
  1) Most-connected species
  2) Most-connected species, but protect basal taxa
  3) Random species
  4) Least-connected species
- If a taxon loses all prey items, it goes extinct
- Quantify secondary extinctions
- "Robustness" = proportion of species removed that results in 50% total species loss (primary removals + 2° extinctions)

2° extinctions in empirical food webs



Dark dashed line:
100% total species loss line

Red dashed line:
50% total species loss line

Robustness: Proportion of primary species loss to reach ≥ 50% total species loss for a particular food web and type of loss

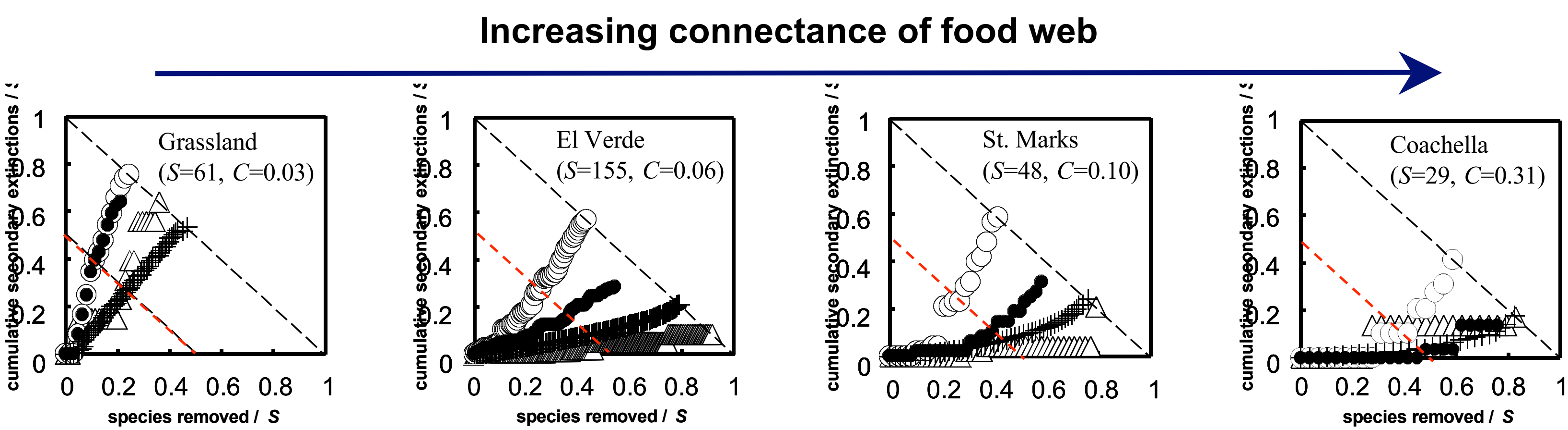
Species Deletion Sequences:

Most connected ◯; Most connected, no basal deletions ●; Random +; Least connected △

What types of food webs tend to be robust?

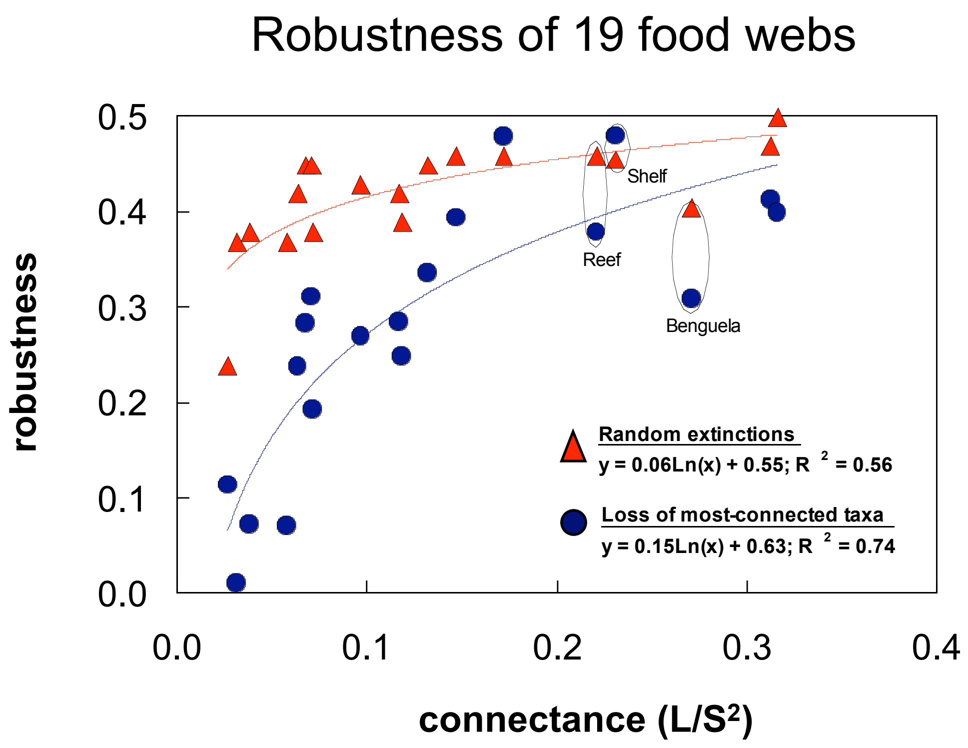
Species Deletion Sequences:

Most connected ◯ Most connected, no basal deletions ; R ● andom ┼; Least connected △



Structural robustness increases with connectance

Robustness: Proportion of primary removals that results in ≥ 50% total species loss



Robustness Summary

- Different types of biodiversity loss lead to different levels of potential 2° extinctions in food webs.
  - Loss of highly connected species (high 2° extinctions, threshold effects)
  - Loss of random species (lower 2° extinctions)
  - Loss of minimally connected species (usually few 2° extinctions)
  - Protecting basal species generally mitigates 2° extinctions

- Food web structure (empirical and model) displays increasing robustness to species loss with increasing connectance. Higher *C* (and less skewed degree distributions) results in:
  - Lower sensitivity to species loss
  - Delayed thresholds of increased sensitivity
  - Differences among different types of species loss

- Structural robustness doesn't vary with *S* or omnivory in empirical webs; in model webs structural robustness increases slowly with *S*.