Fossil Food Webs: Quantifying Changes in Marine Ecosystems During Times of Escalating Predator-Prey Interactions

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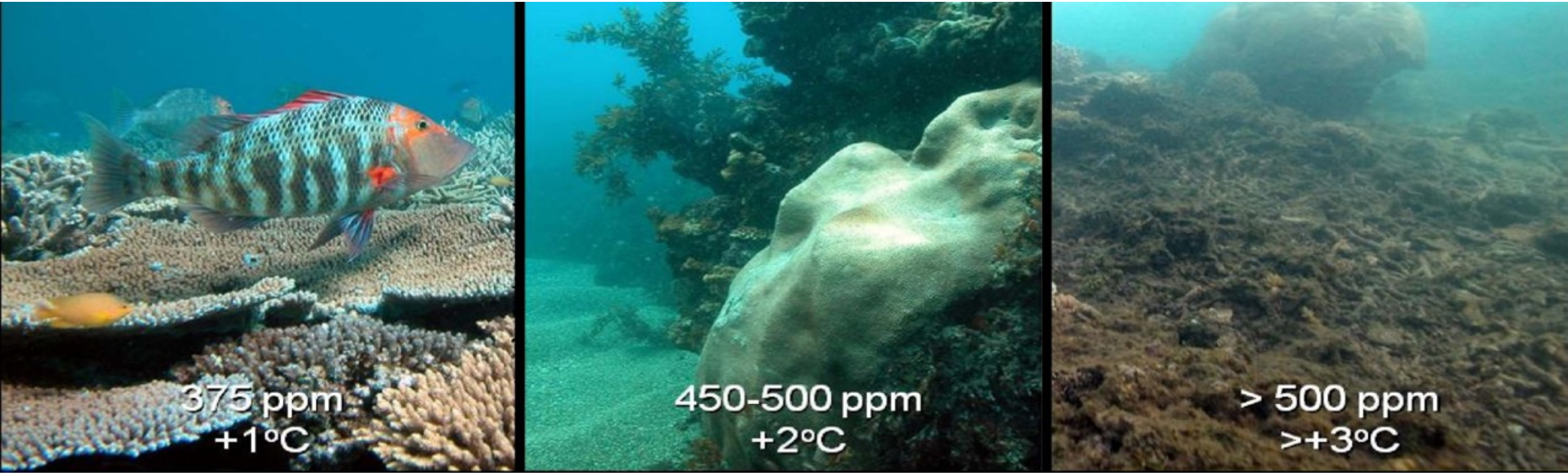
Ecosystems in Crisis

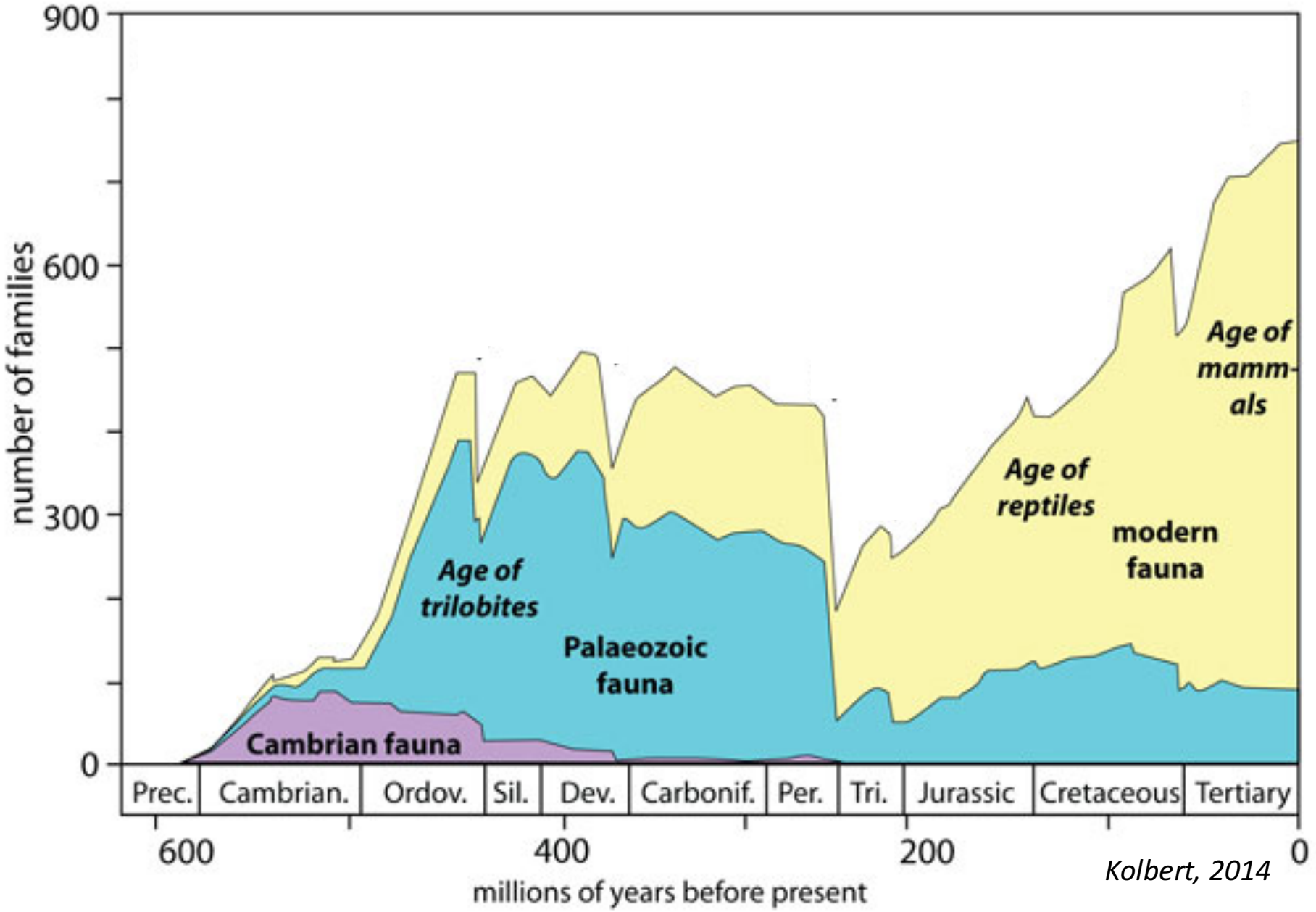
Does diversity matter?

Ecosystem responses to changes in diversity and abundance are poorly understood…

Does greater complexity lead to increased stability, or do periods of stability promote complexity?

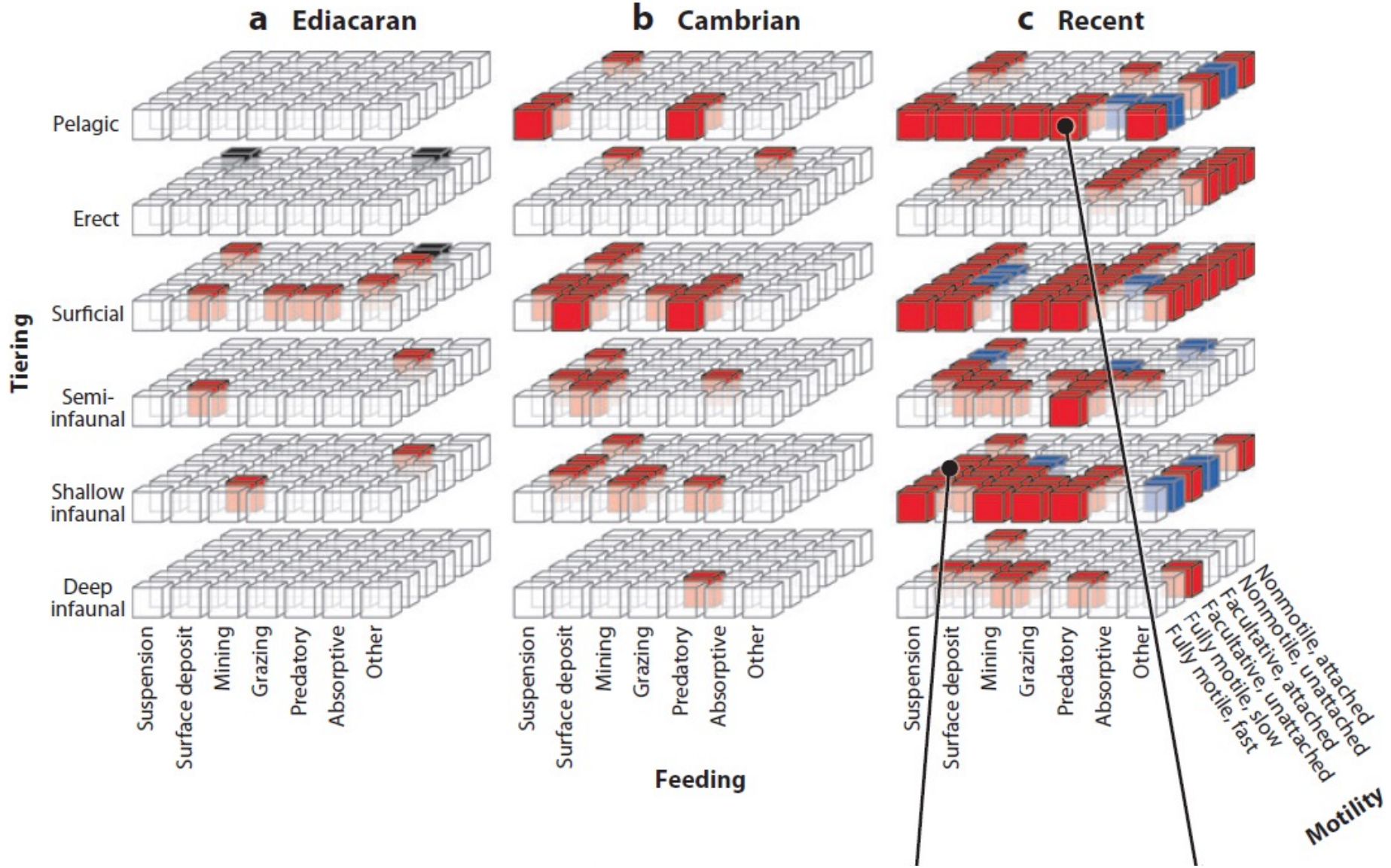


Shifts in Faunal Dominance

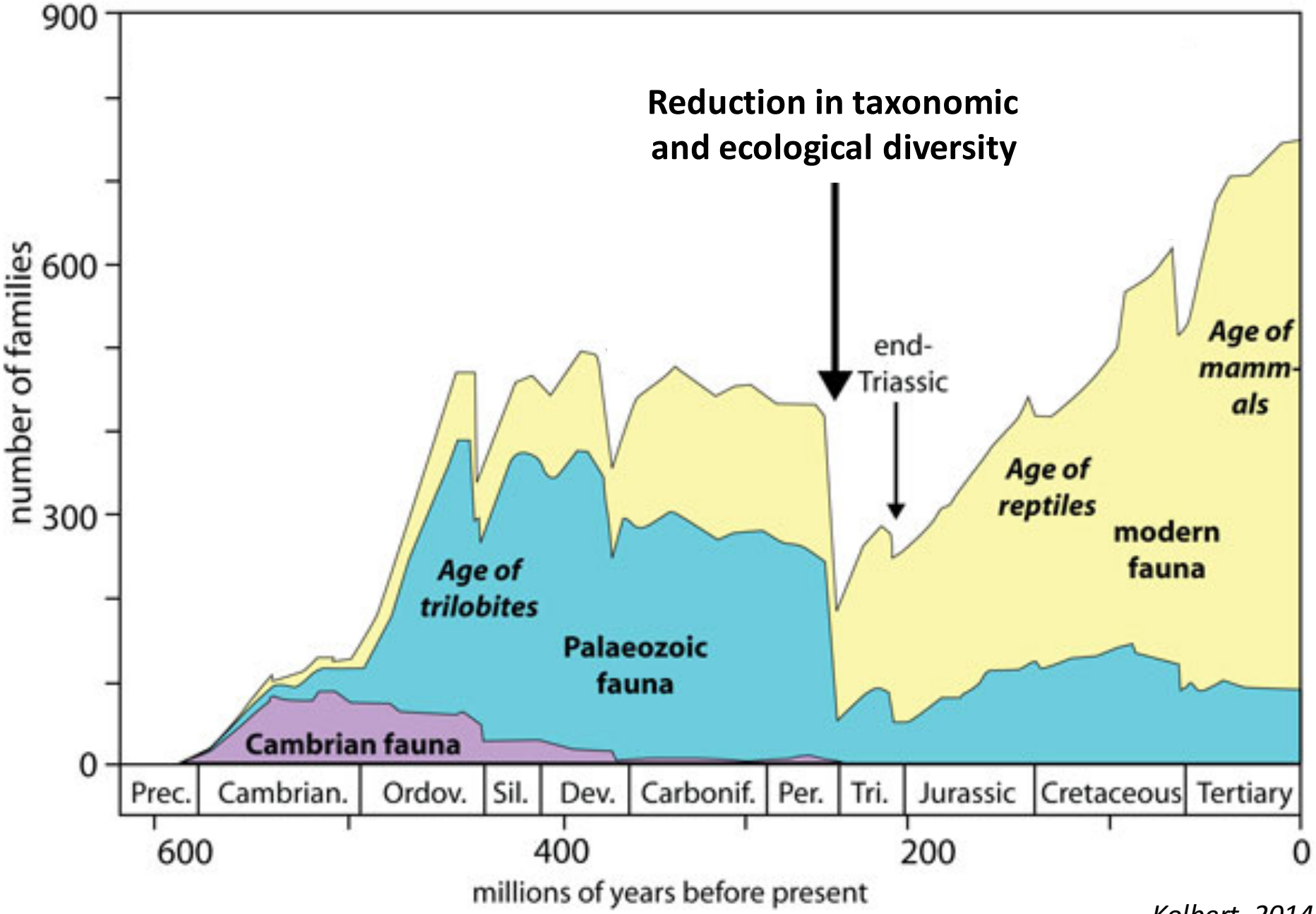


Kolbert, 2014

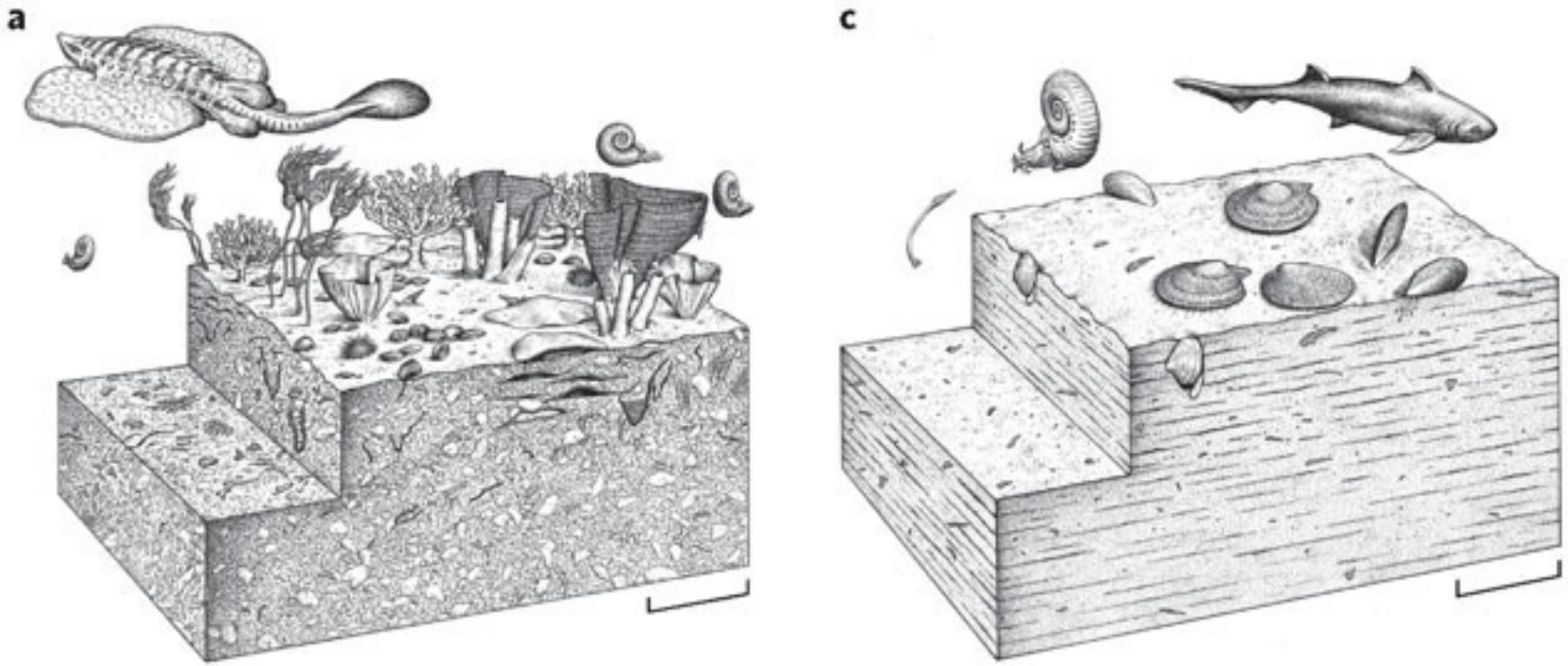
Increasing Ecospace Utilization



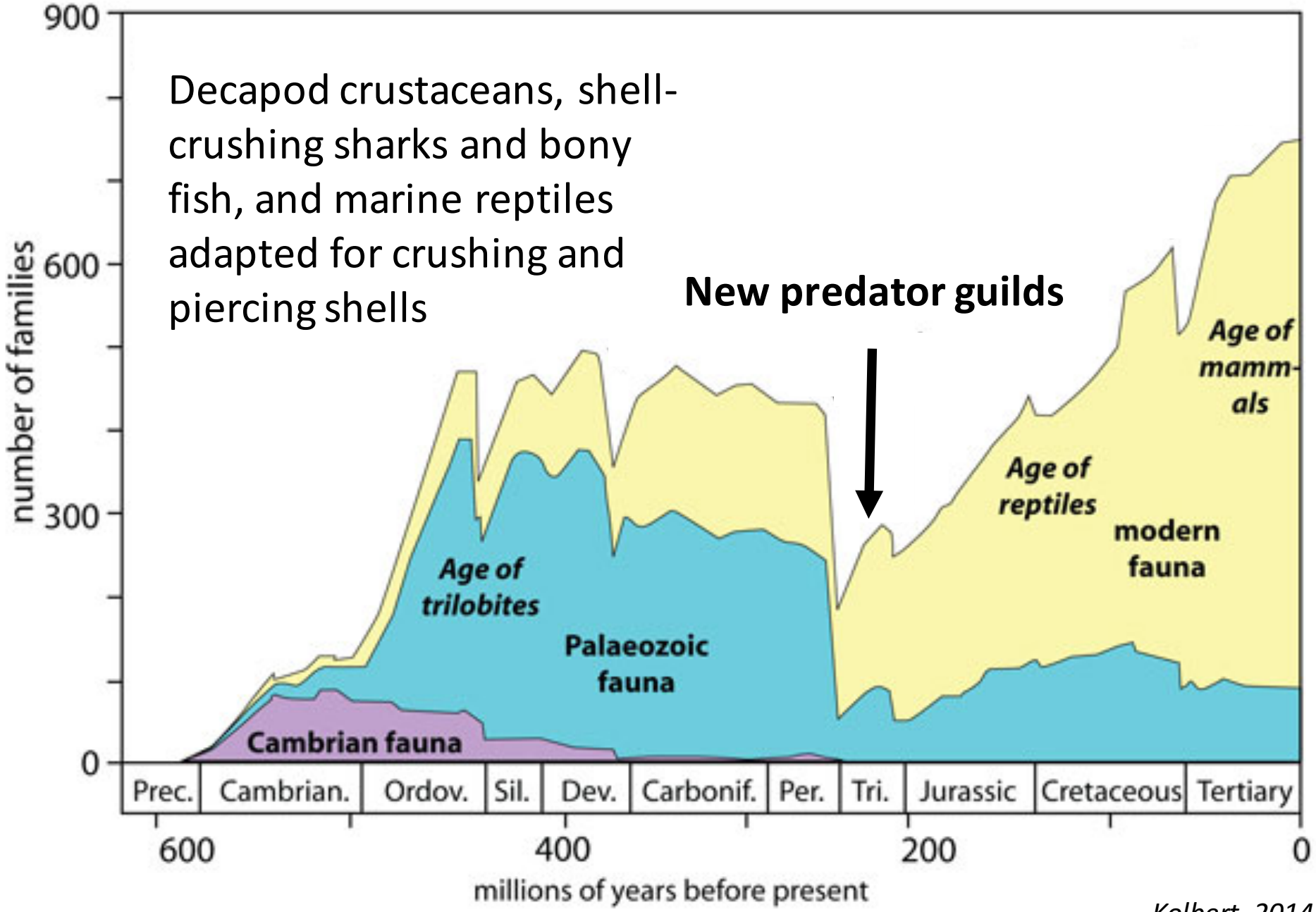
Bush & Bambach Ann Rev Earth & Plan Sci, 2011



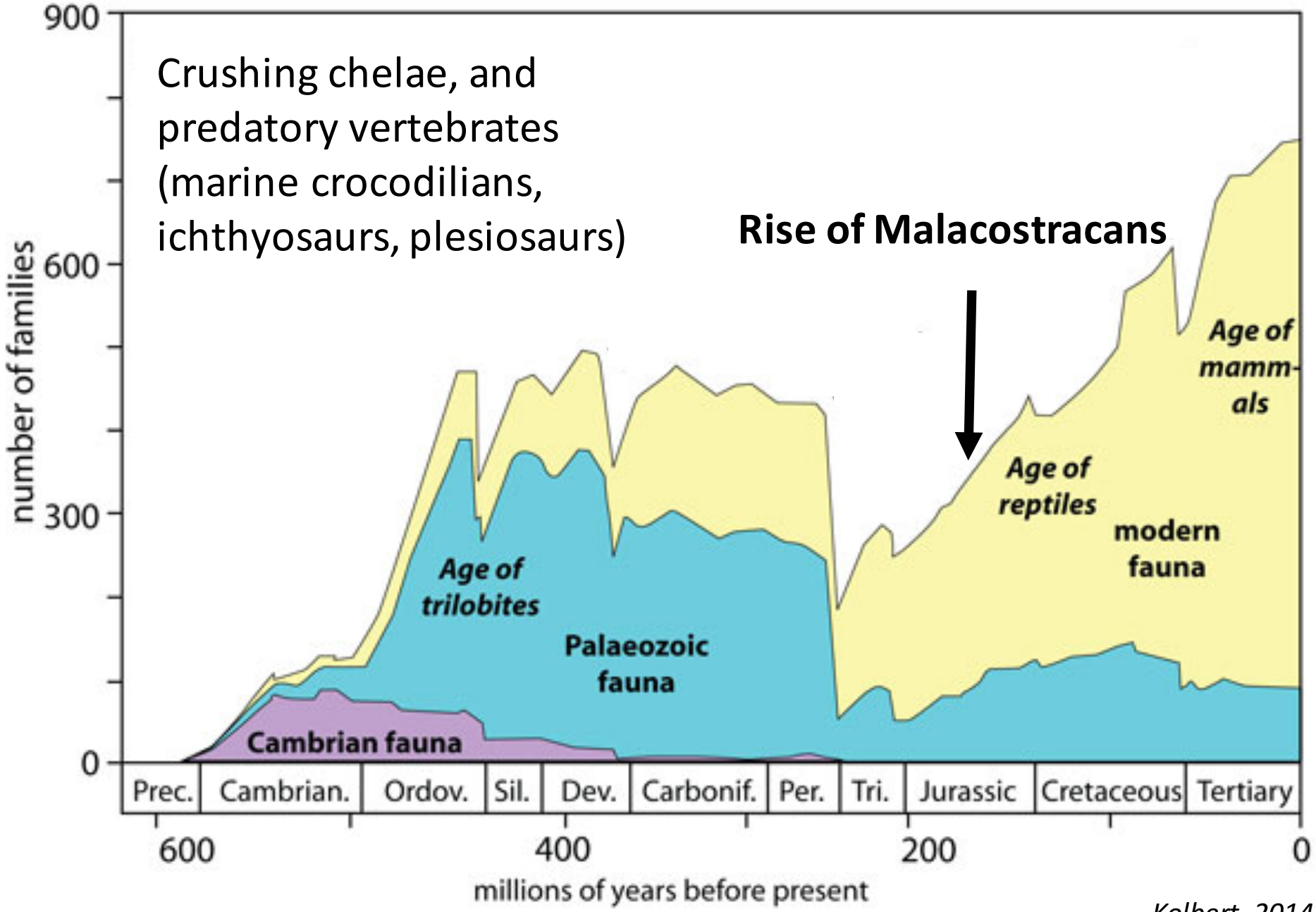
Kolbert, 2014



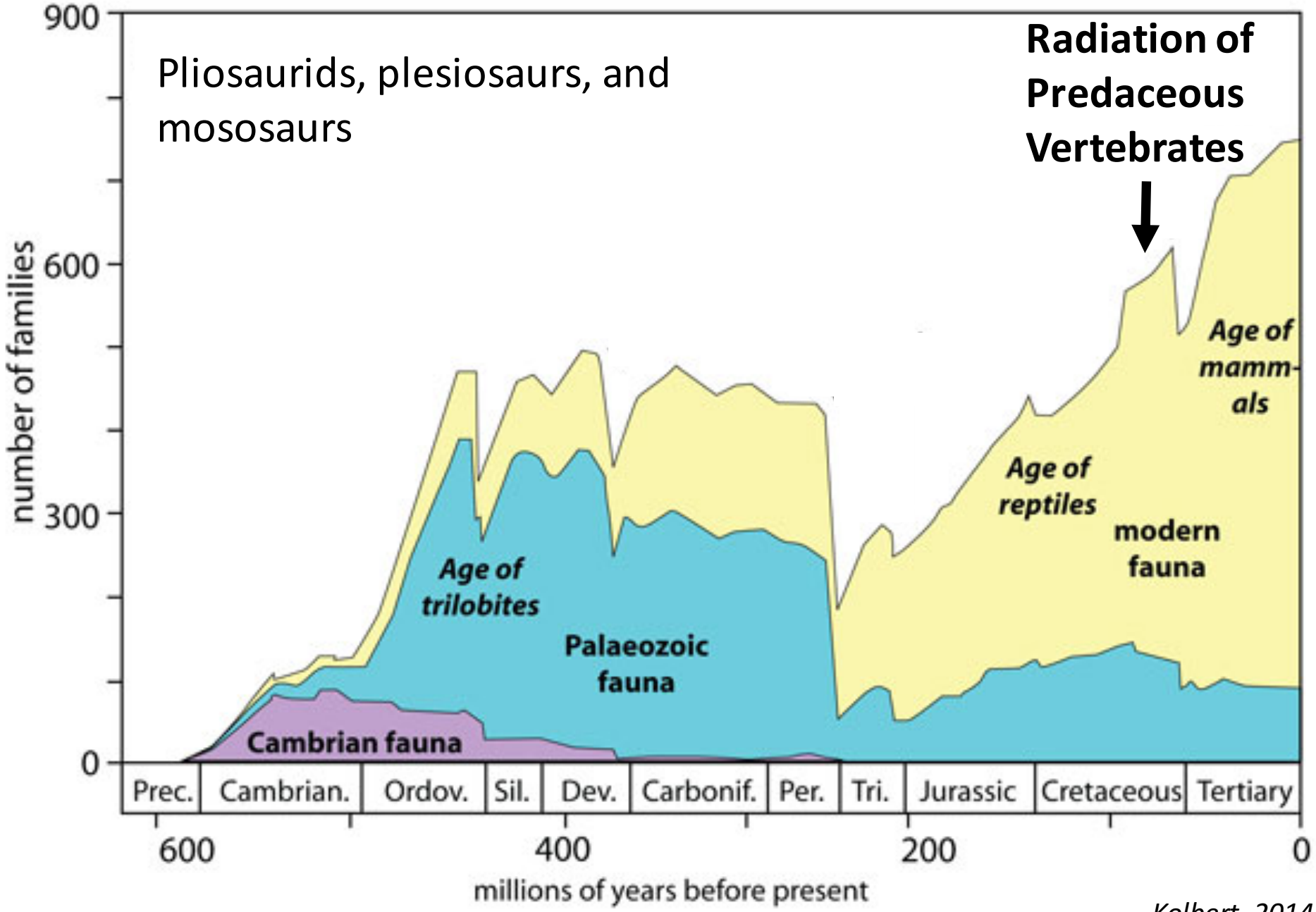
Chen & Benton Nature Geoscience, 2012



Kolbert, 2014



Kolbert, 2014



Kolbert, 2014

Changing Community Structure?

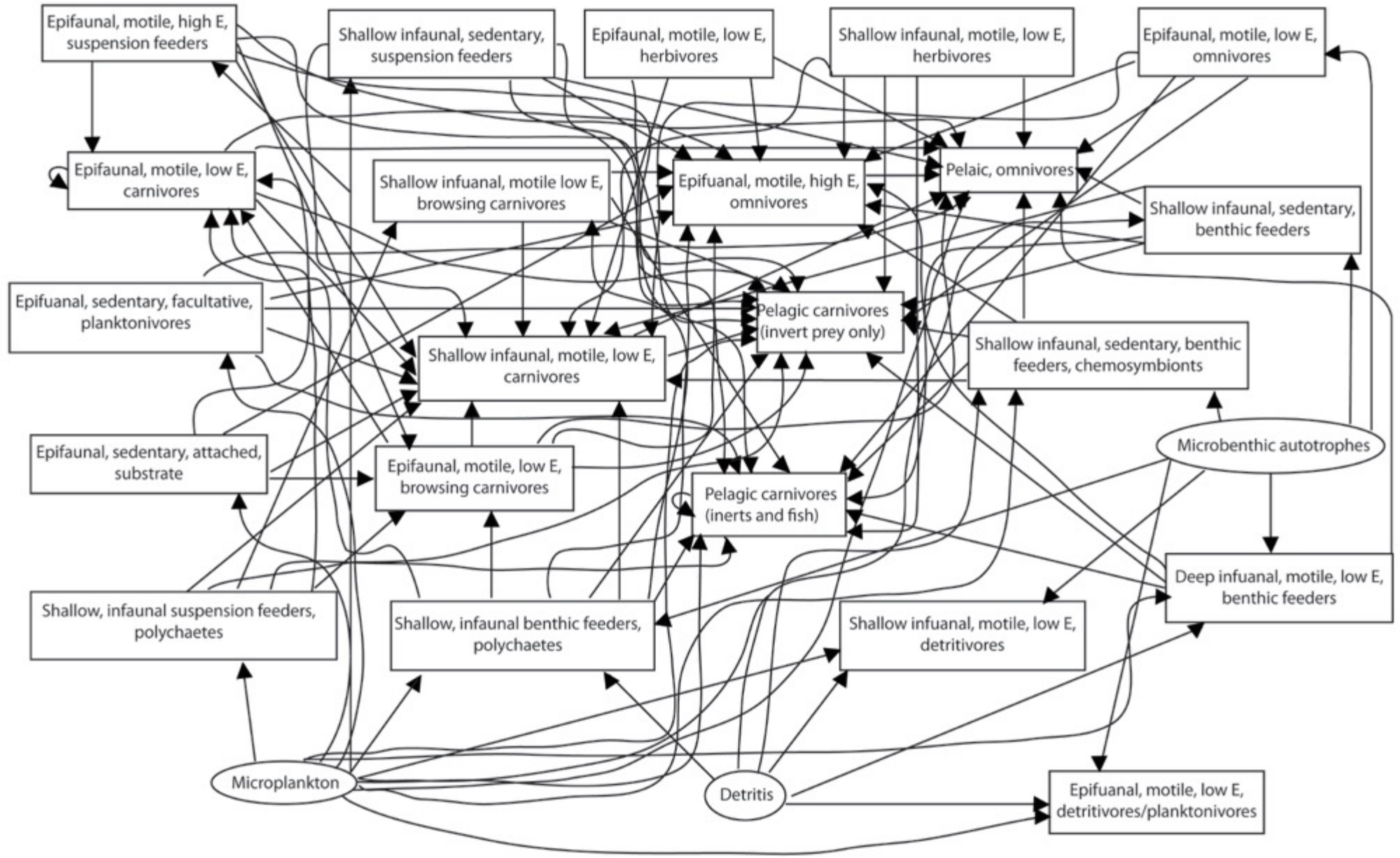
- Shifts in faunal dominance and increasing diversity
- Increasing ecospace utilization
- Increasing predation intensity through time (Escalation) - Radiations of important predator groups and increasing antipredatory adaptations
- Mesozoic is a period of taxonomic and ecological diversification
- Abrupt reorganization during and after Late Permian and Late Triassic mass extinctions
- Mesozoic thus serves as an ideal candidate to find changes in ecosystem structure and function

- **Does increasing predation intensity and corresponding changes in biodiversity correspond with changes in:**
  - **Community structure**
  - **Trophic organization**
  - **Ecosystem stability**

Food Webs

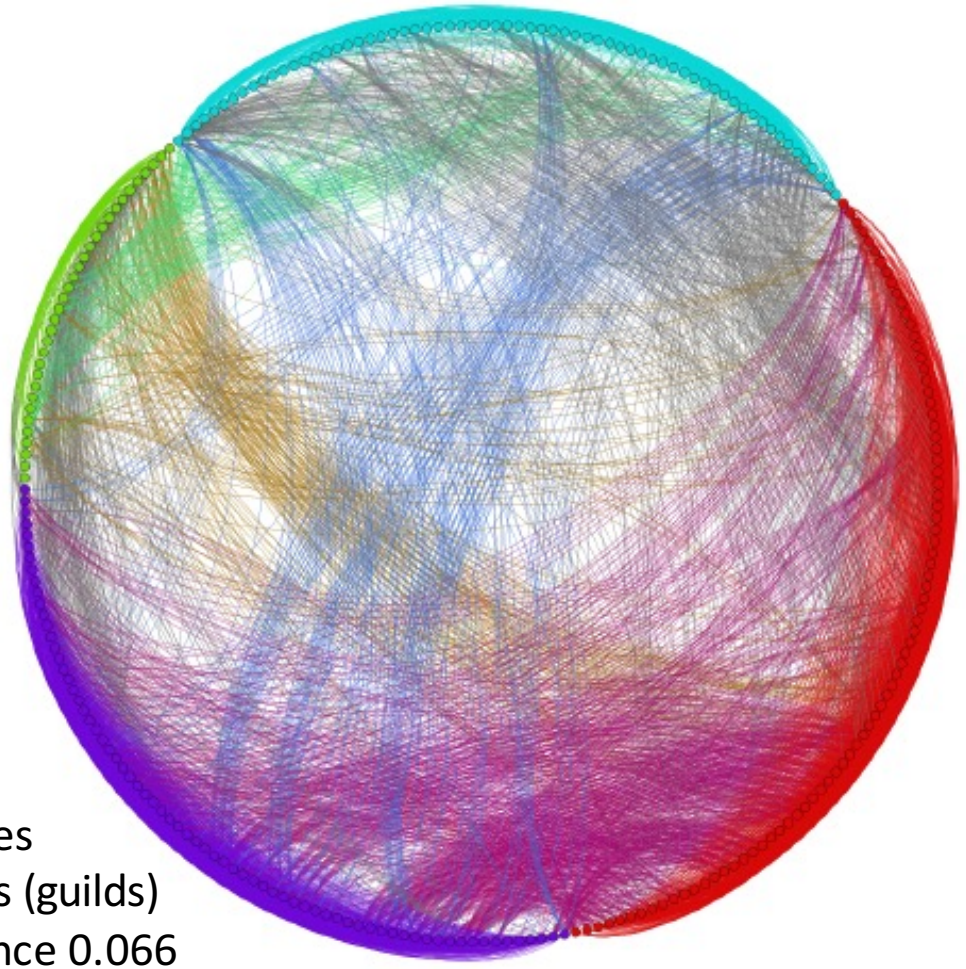
- Cambrian and modern food webs may, in fact, be remarkably similar (Dunne et al. 2008)
- Trophic organization may not have undergone any significant changes since the Cambrian!
- Has increasing diversity, ecological complexity, and intensity of biotic interactions resulted in increasing ecosystem complexity?

Guild Metanetwork: Energy Transfer and Interactions



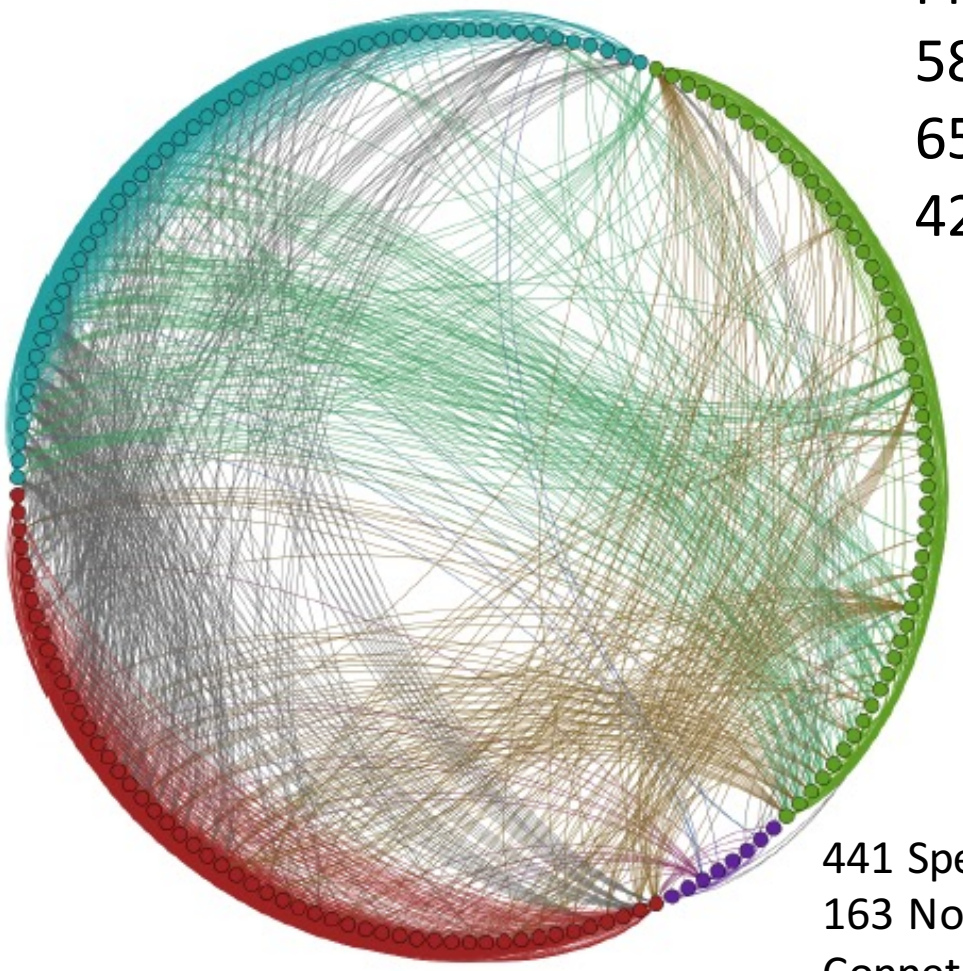
Maintaining Paleo-community Structure

Modern Caribbean Reef



756 Species
249 Nodes (guilds)
Connectance 0.066

Predicted “Fossil” Reef

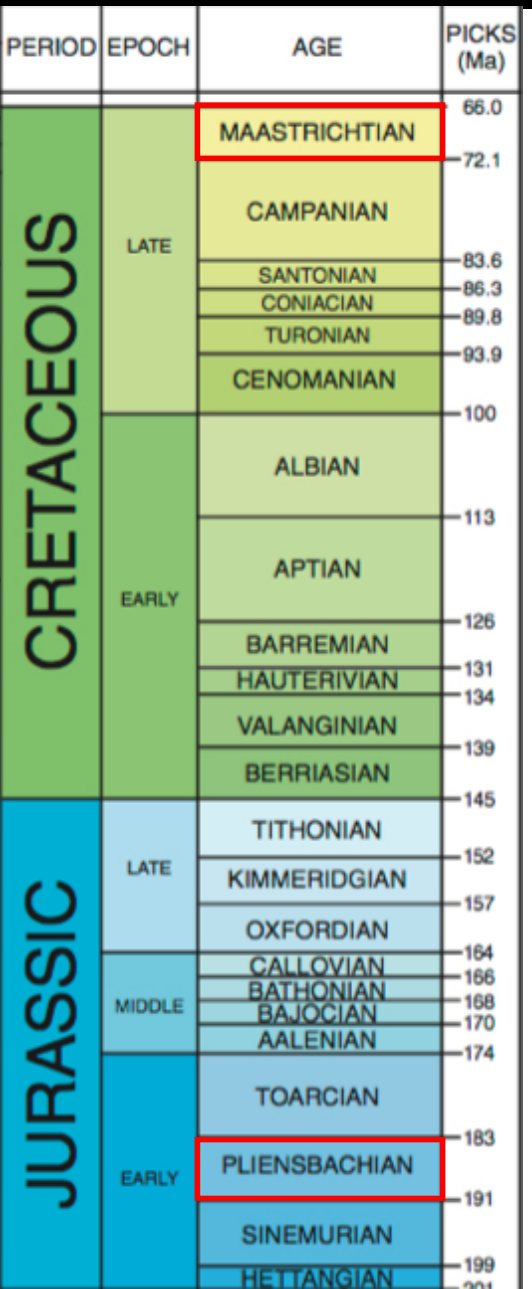


441 Species
163 Nodes (guilds)
Connetance 0.065

Preserves:
58% of species
65% of genera
42% of guilds

Roopnarine, 2014

Mesozoic Changes in Ecosystem Structure???



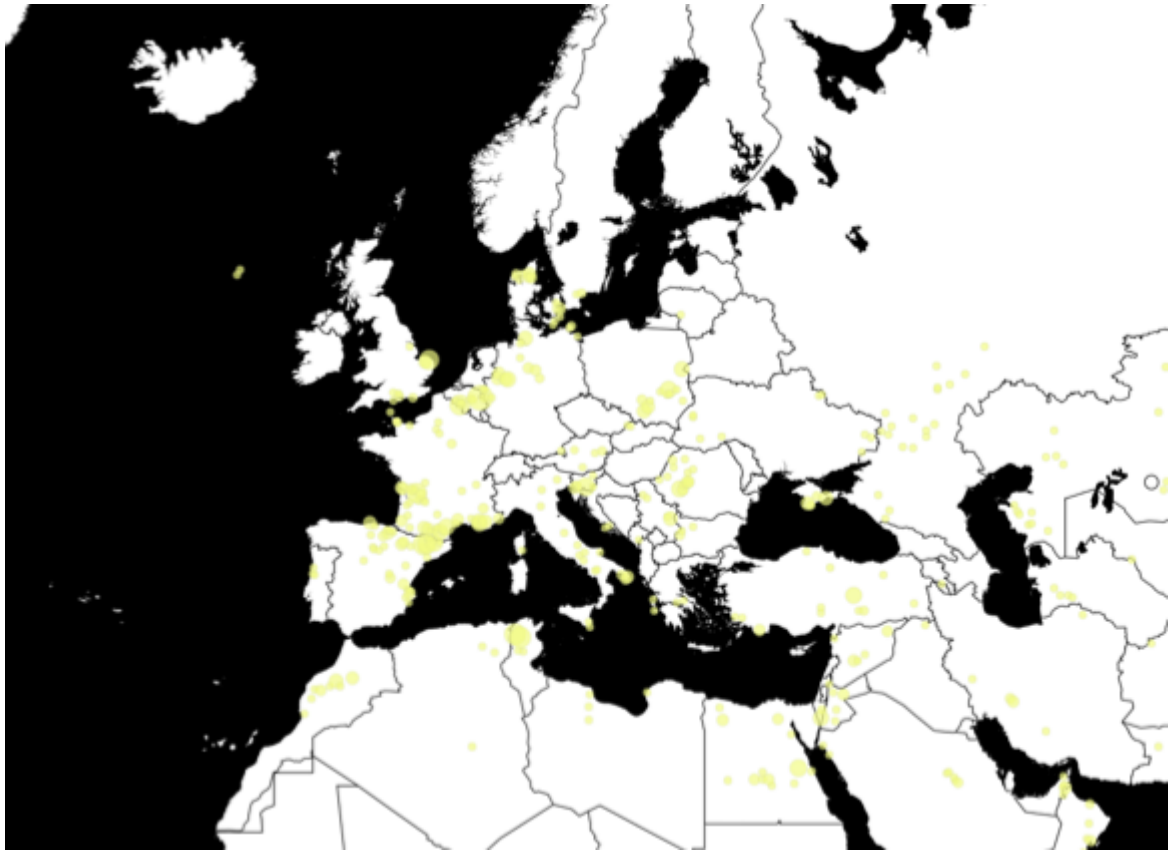
- **Does increasing predation intensity and corresponding changes in biodiversity correspond with changes in:**
  - **Community structure**
  - **Trophic organization**
  - **Ecosystem stability**

- Examine trophic interactions in marine communities from the Jurassic and Cretaceous
- Construct Guild Metanetworks
- Data downloaded from the Paleobiology Database:
  - Restricted to 2 stages in Europe – Early Jurassic & Late Cretaceous
- Trophic interactions inferred from predation traces, gut contents, functional morphology, habitat, and extant analogs

Geographic Distribution of Collections

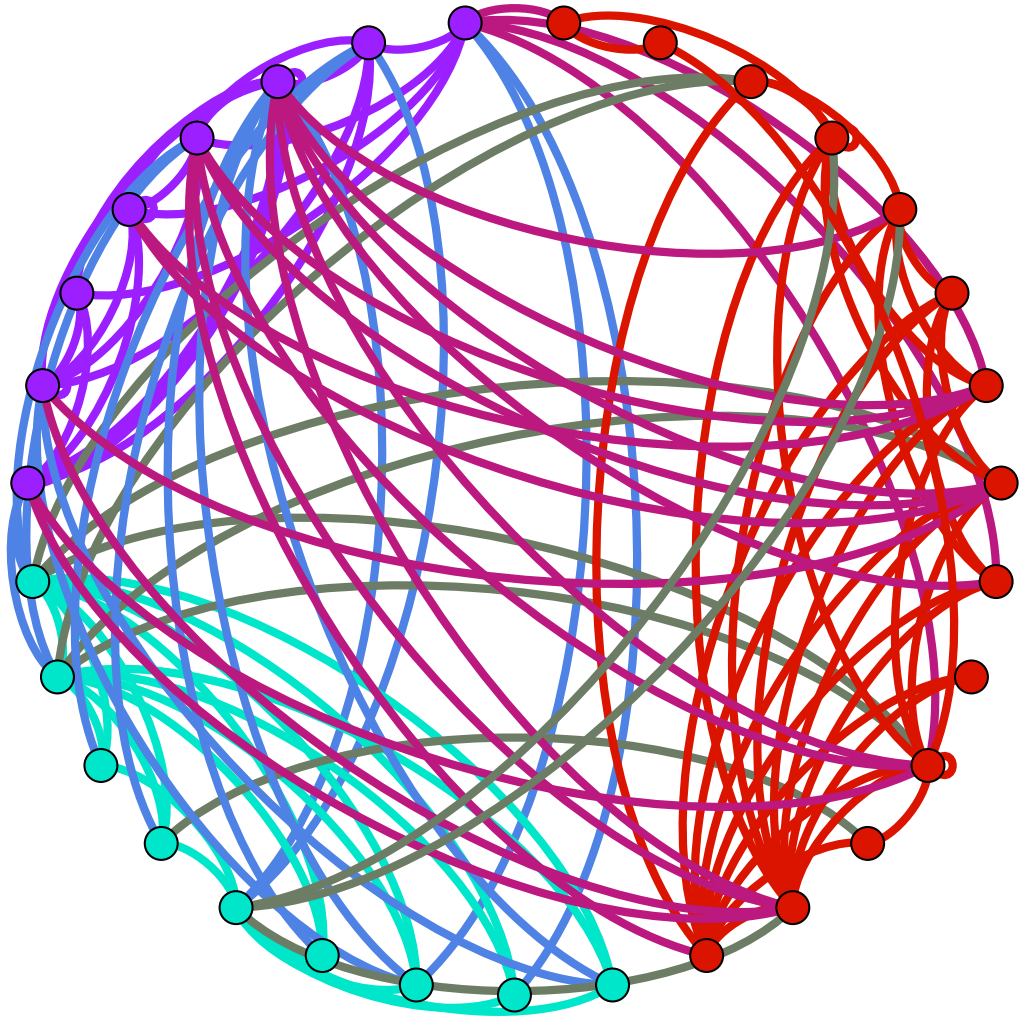
Early Jurassic of Europe
(Pliensbachian)
1,807 species

Late Cretaceous of Europe
(Maastrichtian)
1,906 species



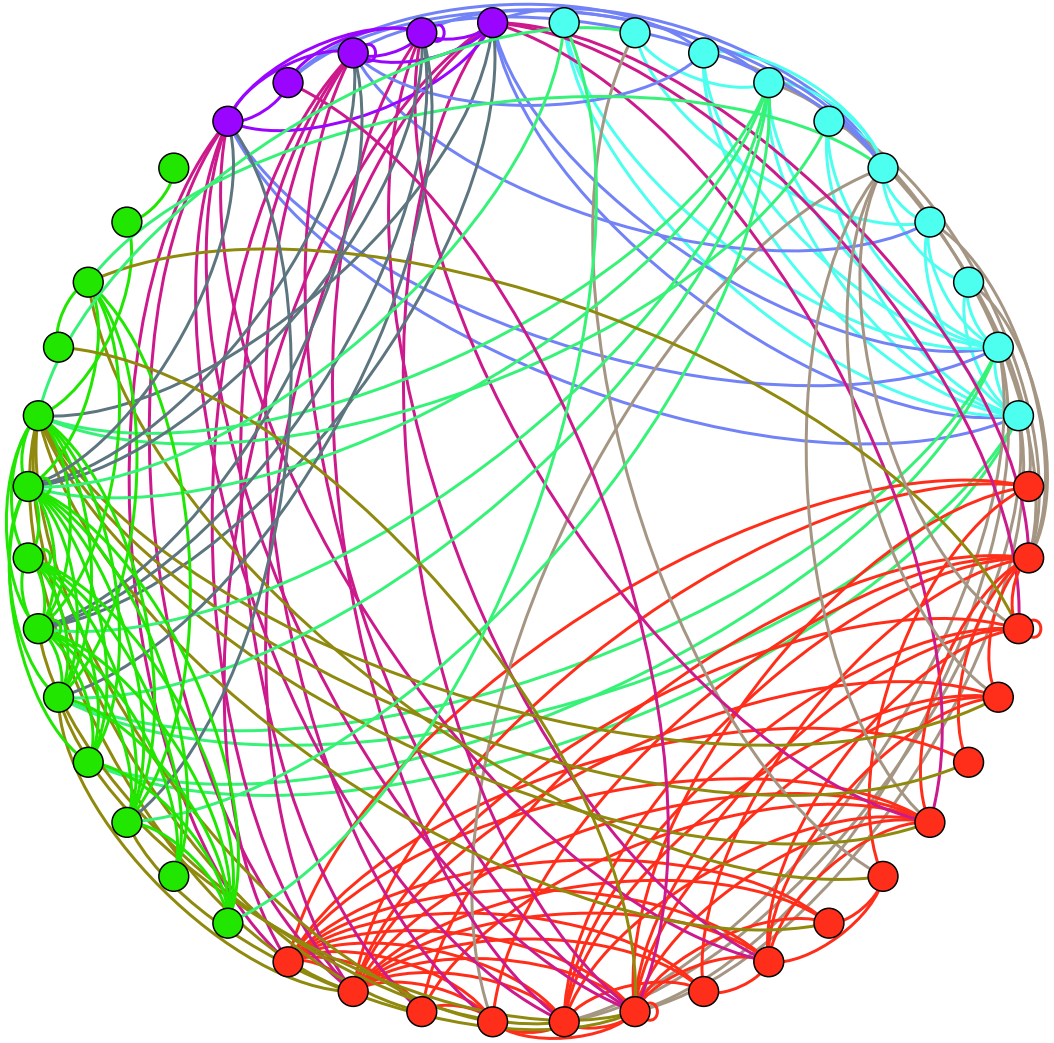
Early Jurassic Network Visualization

- 31 Nodes (Guilds)
- 122 Interactions
- Average path length is 1.478 (shortest possible path between all nodes in the network)
- Most influential node (Betweeness Centrality) is semi-infuanal omnivores followed by carnivorous crustacea
- Connectance 0.13 (13% of nodes are connected with one another)



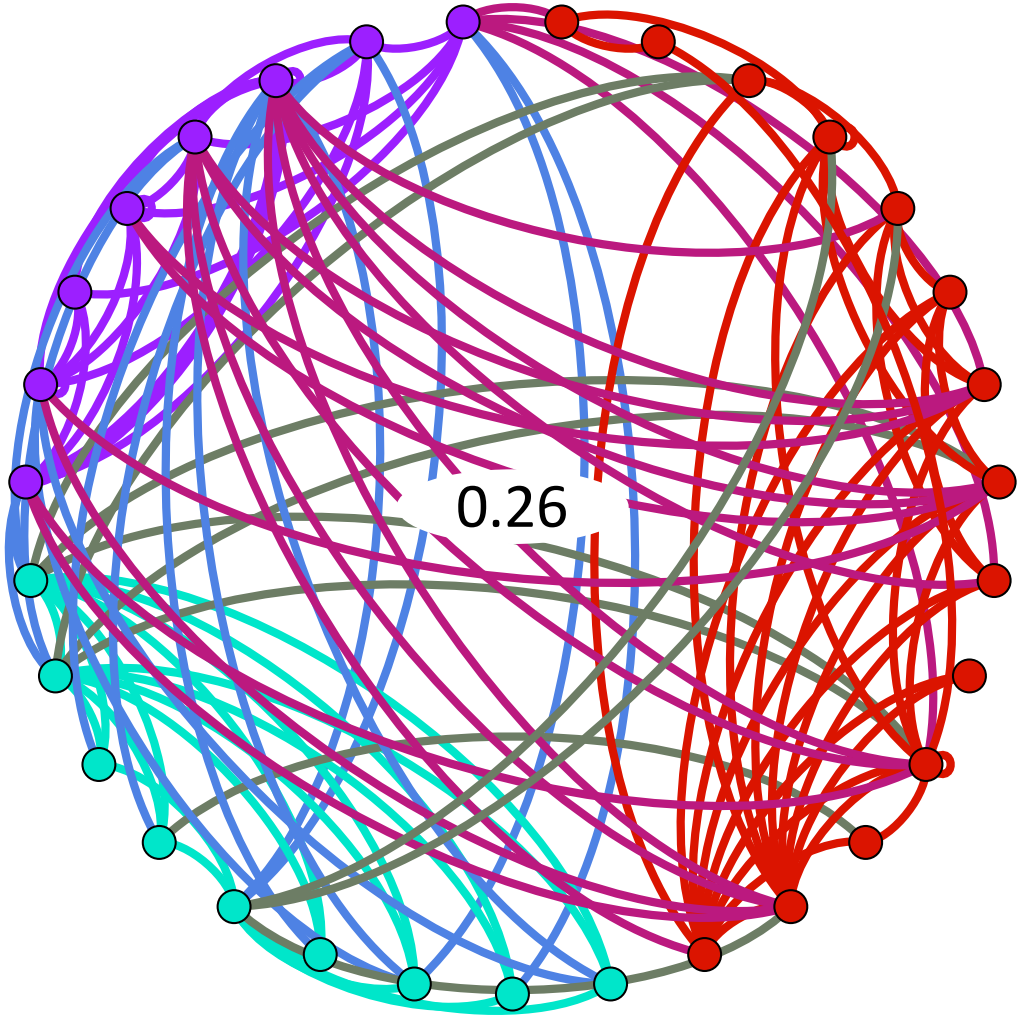
Late Cretaceous Network Visualization

- 44 Nodes
- 205 Edges
- Average path length is 1.83 (shortest possible path between all nodes in the network)
- Most influential node (Betweeness centrality) is carnivorous crustacea followed by ray-finned fish
- Connectance 0.10 (10% of nodes are connected with one another)

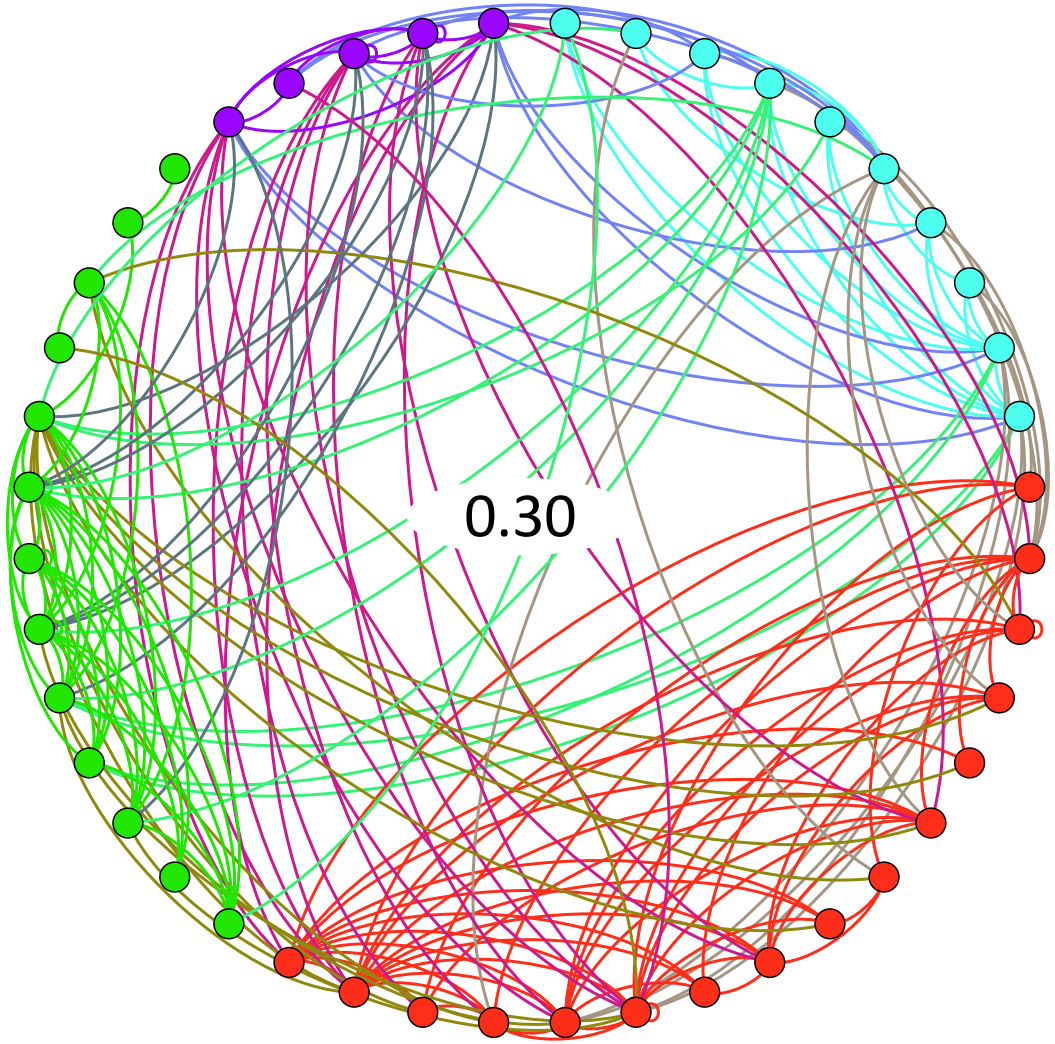


Community Structure: Modularity

Early Jurassic



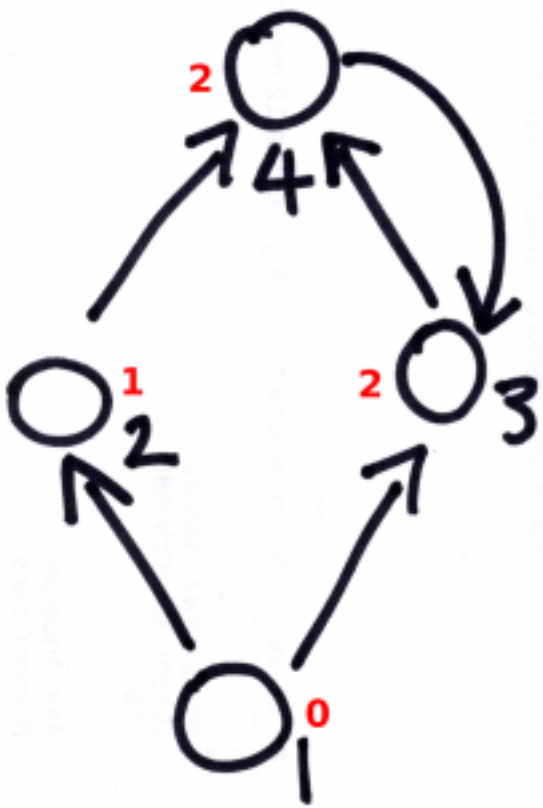
Late Cretaceous



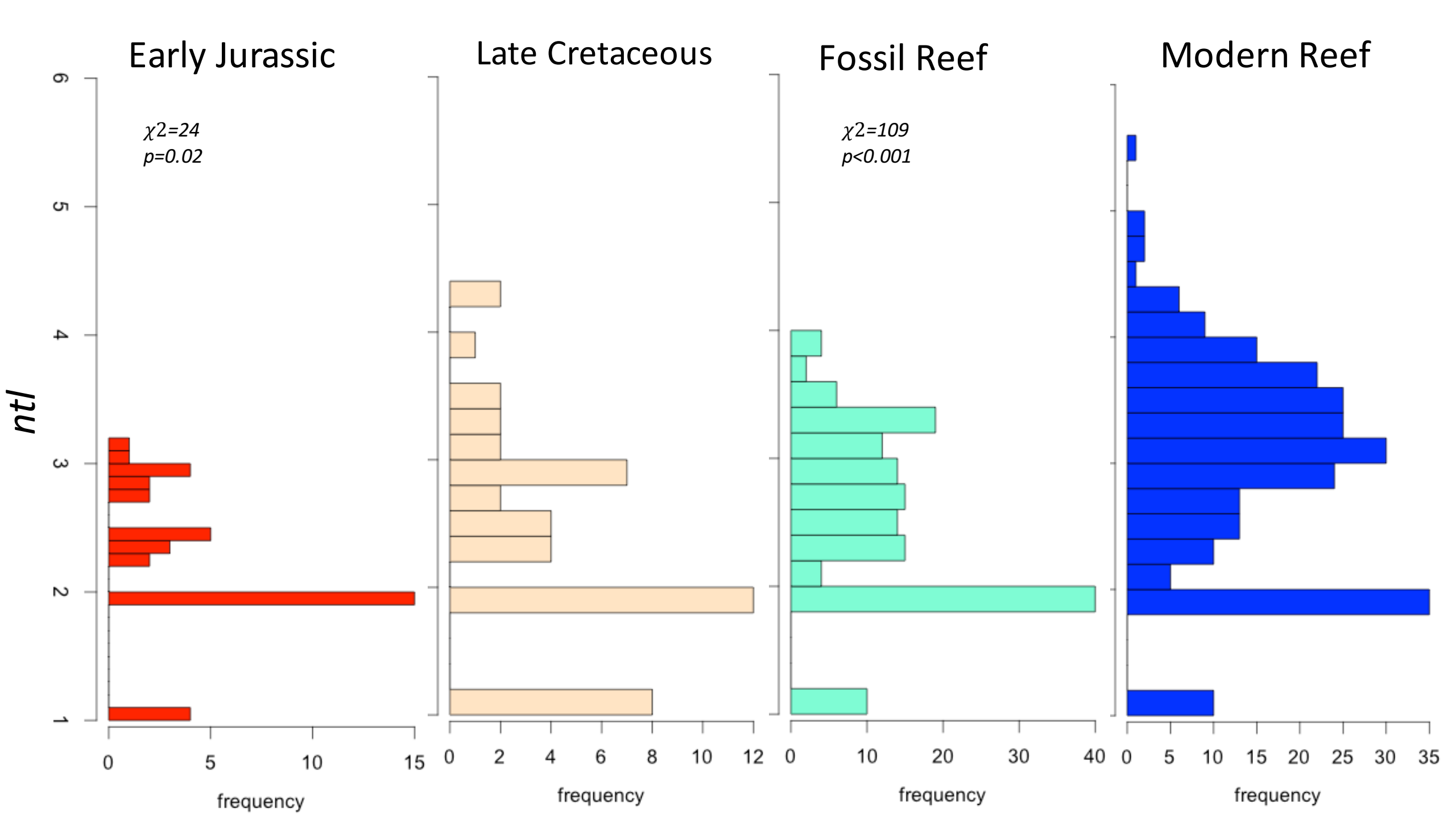
Network Trophic Level

- The Network Trophic Level (*ntl*) is the average shortest path length of a species' prey to primary production.
- First assign trophic level to nodes
- Trophic level is mean shortest path length from a nodes prey to a primary producer
- Describes the number of intermediaries between basal species and predators

$$ntl = 1 + \frac{1}{r}\sum_{i}^{S} a_{ij}\, l_j$$

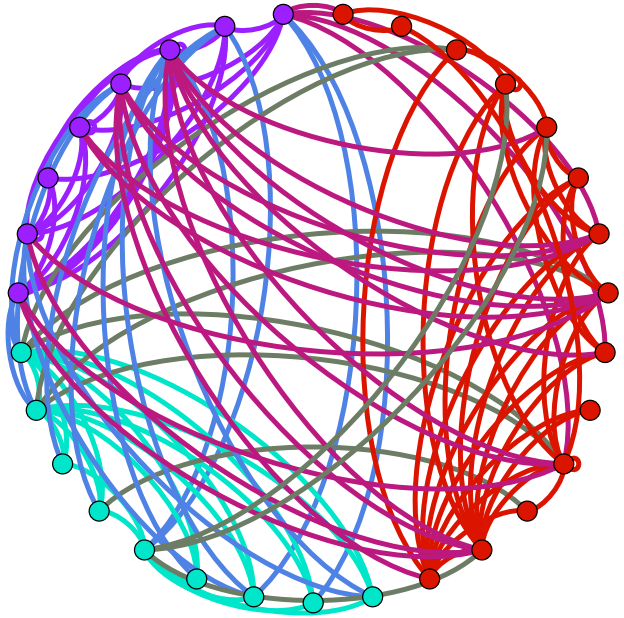


Roopnarine, 2014


Early Jurassic
Late Cretaceous
Fossil Reef
Modern Reef
χ2=24
p=0.02
χ2=109
p<0.001
ntl
frequency
frequency
frequency
frequency

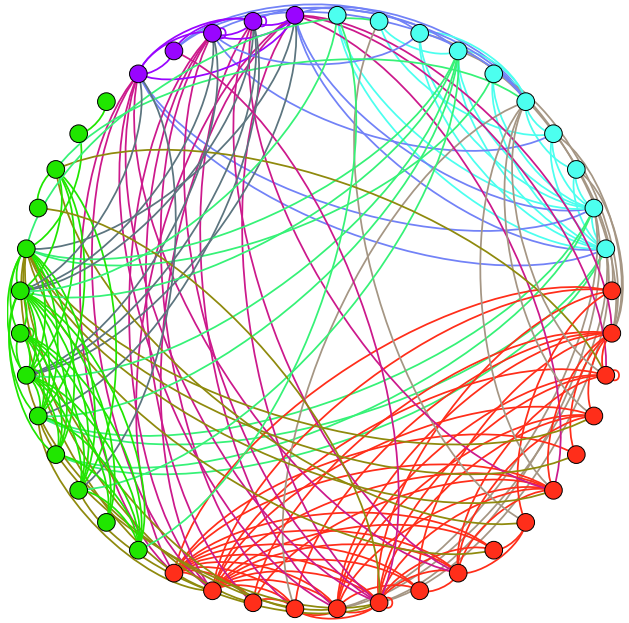
Community Structure

Early Jurassic



1,807 Species
31 Nodes (guilds)
122 Interactions
Connectance 0.13

Late Cretaceous



1,906 Species
44 Nodes (guilds)
205 Interactions
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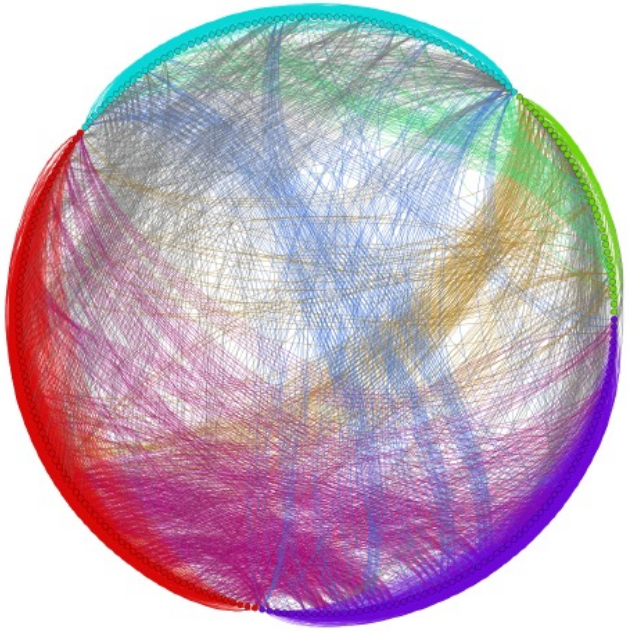
“Fossil” Reef

441 Species
163 Nodes (guilds)
1,737 Interactions
Connectance 0.065

Modern Reef



756 Species
249 Nodes (guilds)
4,105 Interactions
Connectance 0.066

Ongoing Work

- **Were Cretaceous ecosystems more complex and/or more stable than Jurassic ecosystems?**
- **Were Cretaceous ecosystems less robust than Jurassic ecosystems?**
- Changes in community structure and stability will be quantified using Cascading Extinctions on Graphs – CEG (Roopnarine 2006)
- Changes in community structure measured as stability after minor perturbation, robustness, or resistance to the propagation of secondary extinctions
- Differences in community dynamics during the Mesozoic will therefore be reflected by differences in stability and robustness (model response to simulated perturbations)

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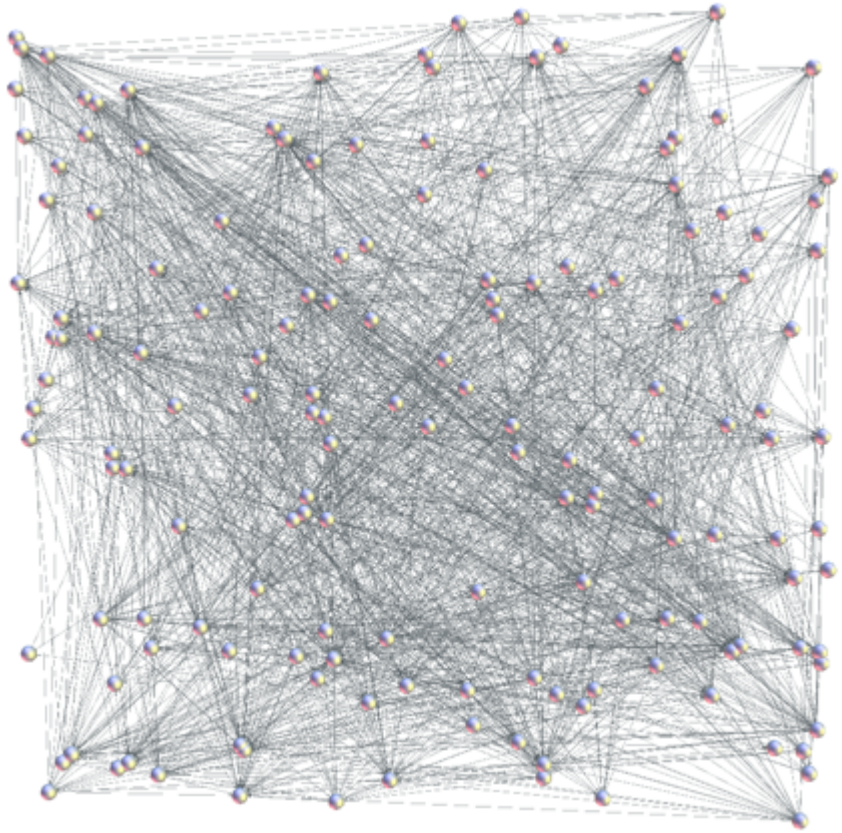
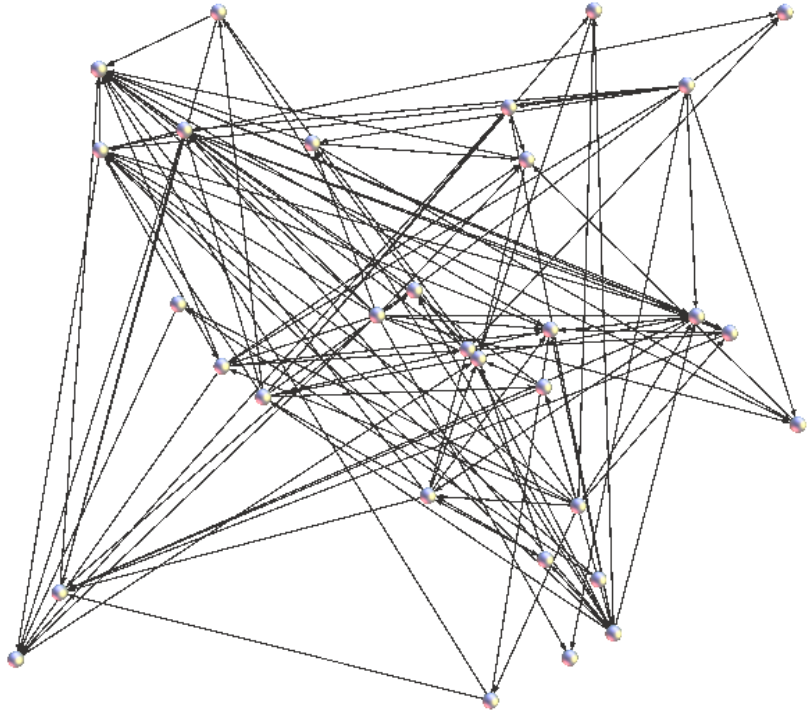
Modern



Jurassic



Cretaceous