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

Reduction in taxonomic and ecological diversity

Kolbert, 2014
Decapod crustaceans, shell-crushing sharks and bony fish, and marine reptiles adapted for crushing and piercing shells

New predator guilds
Crushing chelae, and predatory vertebrates (marine crocodilians, ichthyosaurs, plesiosaurs)
Pliosaurids, plesiosaurs, and mosasaurs

Radiation of Predaceous Vertebrates

Kolbert, 2014
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
• 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?
Maintaining Paleo-community Structure

Modern Caribbean Reef

- 756 Species
- 249 Nodes (guilds)
- Connectance 0.066

Predicted “Fossil” Reef

- 441 Species
- 163 Nodes (guilds)
- Connectance 0.065

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

Roopnarine, 2014
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
• 31 Nodes (Guilds)
• 122 Interactions
• Average path length is 1.478 (shortest possible path between all nodes in the network)
• Most influential node (Betweenness Centrality) is semi-infuanal omnivores followed by carnivorous crustacea
• Connectance 0.13 (13% of nodes are connected with one another)
• 44 Nodes
• 205 Edges
• Average path length is 1.83 (shortest possible path between all nodes in the network)
• Most influential node (Betweenness centrality) is carnivorous crustacea followed by ray-finned fish
• Connectance 0.10 (10% of nodes are connected with one another)
Early Jurassic

Late Cretaceous

Community Structure: Modularity
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 node's prey to a primary producer
- Describes the number of intermediaries between basal species and predators

$$ntl = 1 + \frac{1}{r} \sum_{i}^{S} a_{ij} l_{j}$$
Early Jurassic

\[ \chi^2 = 24 \\ p = 0.02 \]

Late Cretaceous

\[ \chi^2 = 109 \\ p < 0.001 \]

Fossil Reef

Modern Reef
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
- Connectance 0.10

“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)
Modern

Jurassic

Cretaceous