Mass Extinctions Increase Evenness of Genus Diversity Across Ecological Modes

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Introduction

In the big five mass extinctions, diversity is preferentially lost in ecological modes with greater diversity preceding these events,[1] but little is known about how diversity rebounds. Bambach et al. (2007) created the scheme of ecological modes[2] and Knope et al. (2015) used these modes as proxies for functional diversification in marine animals across time.[1] Using the Knope et al. (2015) data set, I explore the following question: **When diversity rebounds, does it recover to a similar distribution of genus diversity across ecological modes or to a more even distribution spanning different ecological modes?**

Background

The Knope et al. (2015) data set consists of the assignment of modes to 18,621 marine animal genera using Bambach's scheme, categories constructed by combinations of habitat tiering levels, motility levels, and feeding modes. Using that data, they created a heatmap (Figure 1).
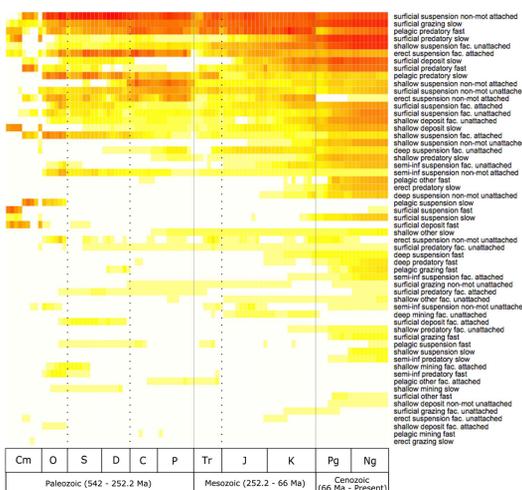

Figure 1. Heatmap of Marine Animal Genus Diversity in Ecological Modes across Time. Vertical lines represent the big five mass extinctions. Columns represent the number of genera within ecological modes at each point in time. Color intensity represents the number of genera, with yellow depicting one genus and red depicting 521 genera.
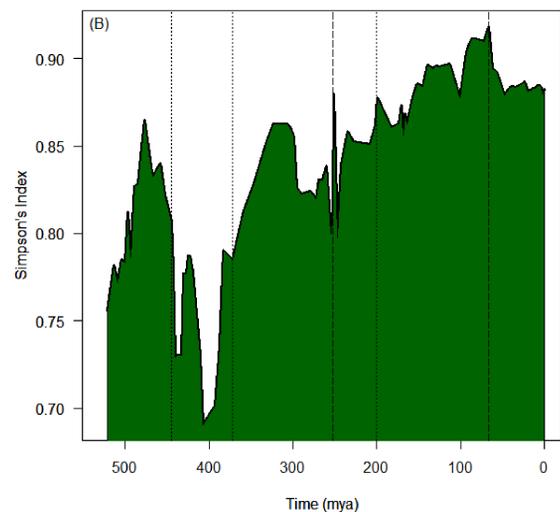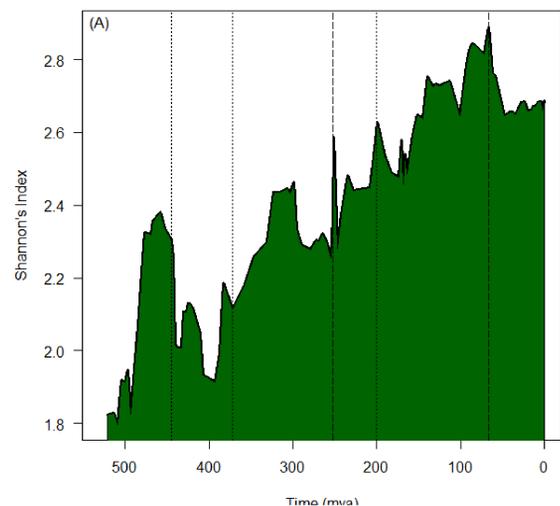
Results

Figure 2. Evenness of Ecological Modes Steadily Increases over Time. Indices, Shannon's (A) and Simpson's (B), were plotted against time, in millions of years ago or mya, for 18,621 marine animal genera. **The indices, which represent the evenness of ecological modes, increase over time, significantly jumping after mass extinctions, depicted by the vertical lines.** While Shannon's (A) shows the increasing trend, Simpson's (B) reaffirms that evidence while showing more prominent peaks and valleys in evenness.

Methods

Whereas diversity index equations combine species richness and species evenness to quantify the diversity within a community, I substituted ecological modes and number of genera respectively to quantify the evenness of ecological modes for each geologic stage (~5 million year intervals) from the Cambrian Explosion (542 mya) to the present day. (Equations 1 and 2).

The Shannon index and the Simpson index were calculated for each column so that the trend could be graphed with evenness of ecological modes against time. Statistical analyses were performed in the R computer programming environment   .

Equation 1. The Shannon Index

$$H = -\sum_{i=1}^{s} p_i \ln(p_i)$$

Equation 2. The Simpson Index

$$D = \sum_{i=1}^{s} (p_i)^2$$

Then, $1 - D$ is performed.

s = the number of ecological modes at a point in time

p_i = the proportion of genera in the ith ecological mode

Discussion

The Shannon index quantifies evenness of ecological modes, accounting for both number of modes and proportion of genera in each. The Simpson index looks at an aspect of evenness by measuring the probability that two genera randomly selected at a point in time belong to different modes. While it follows the same trend as the Shannon index, the peaks and valleys in evenness are more pronounced.

During mass extinctions, there is a spike in evenness, with the most genera being lost from modes with higher genus diversity and the least being lost from those with fewer genera, decreasing the disparity in diversity among the modes. In the recovery interval, there is a rapid decline, then this increased evenness is not only maintained but continues to increase. With each subsequent mass extinction, this pattern repeats and as the disparity is continuously lessened, evenness increases over time. **When diversity rebounds, it recovers to a more even distribution spanning different ecological modes.**

Future Directions

Since this study is a first step into understanding *how* diversity rebounds, future studies should address the mechanism of *why* it tends to recover more evenly across ecological modes.

- Following each mass extinction, there is a rapid decline in evenness before evenness continues to increase. A future study would be to investigate what is causing it.
- Another study would be to examine how the functional diversification of species after mass extinctions change the trajectory of species' interactions, such as competition or predation, also causing diversification in those unaffected by the mass extinctions.

References

(1) Knope, M.L., N.A. Heim, L.O. Frishkoff, and J.L. Payne. "Limited role of functional differentiation in early diversification of animals." Nature Communications (2015): 1-6.
(2) Bambach, Richard K., Andrew M. Bush, and Douglas H. Erwin. "Autecology and the Filling of Ecospace: Key Metazoan Radiations." Paleontology 50.1 (2007): 1-22.