Ecological stability despite environmental disruption – searching for ecological rules governing Carboniferous brachiopod assemblages from the North American Mid-continent

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A key topic in paleoecology and macroevolution is whether assemblages of species show patterns of persistence over millions of years; a phenomenon that has been variously referred to as ‘Turnover Pulse’ or ‘Coordinated Stasis’. It has generally been presumed that any abrupt environmental changes discernible in the geological record will often lead to community turnover and the establishing of a new community that is discrete from the previous iteration, even if environmental conditions return to those that existed prior to the disruptive event. A related topic is, if patterns of stability can and do prevail despite disruption, what are the processes that allow for this. Potential options include the degree of change in the physical environment, which may not be great enough to exceed the threshold required for community collapse, or due to ‘Ecological Locking’, where directional selection is constrained by ecological processes.

Our touchstone to consider these topics is the detailed fossil record of Carboniferous brachiopod communities from the Mid-continent of North America. These were highly diverse communities that persisted in a very dynamic environmental setting. In particular, these communities were subjected to frequent and geologically rapid phases of marine transgression and regression associated with climate change over approximately a 20-million-year period. These changes likely resulted in repeated community destruction and renewal as suitable habitat was lost and then subsequently re-established.

Using a suite of statistical techniques, we characterized the nature and scope of changes in these fossil communities over time. We found that, at one scale, fossil communities were not stable throughout this interval, both in terms of taxonomic composition and the associated abundance of those taxa. Thus, there is no evidence of obdurate ecological stasis, as new discrete communities, statistically dissimilar from previous and subsequent iterations, form following each environmental disruption. However, at a higher scale, stability is manifest, as diversity patterns are stable across time and despite episodes of environmental change. In particular, we identify a form of qualified ecological stasis for both the different environments present during this interval and for the larger region as a whole. Ultimately, whilst the individual taxa that comprise each community differ, there is a consistent number of species that can exist in any given community, such that communities remain functionally similar. This indicates that whilst the individual taxa
that come to form communities arrive via the exigencies of recruitment, the overall diversity of the communities is set by some higher-level ecological rules. Specifically, the rules for taxon packing are seemingly constant in distinct environments, likely due to energetic controls that limit how many taxa can be maintained in an environmental setting and/or perhaps because the amount of space needed for any individual to develop into an adult is invariant across different taxa within the same clade. Further, these ecological rules lead to stability even in the face of constant disequilibrium, which matches patterns identified in the recovery of marine invertebrate communities from disruptive events in modern systems.