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The Importance of Benthic Macroinvertebrates to Unravel Biotic Responses to Climate Change in Deep-Time

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Editorial

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Editorial

In current days, bioindicators of water quality consist of groups that suggest the proportion of environmental impacts in a given aquatic ecosystem [1], such as some benthic macroinvertebrates. There are several reasons for benthic macroinvertebrates to be considered suitable bioindicators. Apart from being obvious components of the food chain in aquatic settings [1], they have a sedentary lifestyle, and therefore, tend to be representative of the area in which they were collected; they also have relatively short life cycles in contrast with fish, and will consequently more quickly reflect changes in the environment through changes in the structure of populations and communities; and the communities of benthic macroinvertebrates have high biological diversity, which means a greater variability in responses to different types of environmental stress [2].

According to their tolerance, it is possible to classify benthic macroinvertebrates into three main groups: sensitive, tolerant, and resistant organisms. The first group includes mainly representatives of the aquatic insect orders Ephemeroptera, Trichoptera, and Plecoptera [3]. The second group is formed by a variety of aquatic insects and other invertebrates, including mollusks, bivalves, some Diptera families, and mainly by representatives of representatives of the insect orders Heteroptera, Odonata and Coleoptera, although some species inhabits unpolluted settings [3]. In the former, the need for high concentrations of dissolved oxygen is less, since part of its representatives, such as the Heteroptera, Coleoptera adults, and some Pulmonata (Gastropoda) use atmospheric oxygen [3]. The third group is made up of extremely tolerant organisms, formed predominantly by larvae of Chironomidae, other Diptera, and by the entire Oligochaeta class. These organisms are capable of living in total oxygen depletion (anoxia) for several hours [3]. These groups, therefore, can assist reconstructions of paleoenvironments when present in the fossil record, as well as in current days.

Several groups of fossils (especially microfossils) have been used as paleoclimatic indicators. Considering the macrofossils, the trilobites and brachiopods were extensively studied for this purpose in the Paleozoic; the large reptiles, conifers, and mollusks in the Mesozoic; as well as mammals and angiosperms in the Cenozoic [4]. Insects are extremely accurate as indicators of ecology, climate, and geographical conditions of their habitats, being very sensitive to their changes [5], although not frequently used for this purpose, at least not in paleontological studies. A more detailed analysis of fossil insects may reveal similar patterns of biotic crises and environmental stress that are currently seen in nature, producing useful data for paleoenvironmental, paleoclimate, and paleobiogeographic inferences. Insects preserved in carbonate are often of groups that rely on water (e.g. habitat, hunting, laying eggs) [6], and for that, are interesting in terms of reconstructing geological and climatic changes in past times, but mostly, those groups that are part of the benthic macroinvertebrates.

An example of biological responses in the fossil record is observed in mass mortality events, as they generally represent climatic stresses. Mass mortality events are useful when detecting past stresses, however, it is important to differentiate if a mass mortality is being observed, or just a mere accumulation that occurred by different taphonomic ways and/or time averaging. Well-defined mass mortality events of fish are recorded in the Crato Formation (Araripe Basin, Brazil) [7], and in the Yixian Formation (Jehol Group, China) [8]. Also, similar events were documented for the Green River Formation (USA), but are limited to few laminae [9], unlike the frequent events in the Crato and Yixian deposits.

However, more interesting for environmental reconstructions are the events that affect benthic macroinvertebrates, such as the mass mortality of mayfly's larvae (Ephemeroptera) observed in the Crato Formation, that was already attributed to possible high evaporation rates, caused by a weather tending to aridity [4], but so far, this mayflies' mortality events has not been studied extensively, including taphonomic and stratigraphical descriptions.

The problems that caused the death of terrestrial arthropods, may not be the same for aquatic ones, and events that affect terrestrial individuals are more challenging to uncover in the fossil record. For that, among the insects, the aquatic forms are the most promising in demonstrating stresses in the fossil record because they are more prone to be autochthonous [6], in other words, organisms that lived in the deposition site, and for that, are ideal for paleoenvironmental reconstructions. To identify either an individual is autochthonous or allochthonous it is crucial to interpret taphonomical signatures. The degree of transport of the fossils implies the recognition of autochtonous or allocthonous assemblages, the latter indicating that the elements found are not in their natural habitat [10]. Disarticulation and transport are two closely related parameters since disarticulation often occurs during transport events, as well as orientation [11].

Even with the difficulty of identifying past stresses in allochthonous fauna, there are some examples of success in such inferences, like the evidence of environmental stress in the grasshopper fauna (Orthoptera) of the Crato Formation reported by Martins-Neto [4]. All the specimens analyzed by Martins-Neto [4] were in a natural post-mortem position (overlapping wings); in excellent condition of preservation; and fully articulated three-dimensionally, which is perfectly compatible with a short transport. The mass mortality of these grasshoppers was conditioned by environmental stress, hypothesized as being an event of migration, that caused a multiplication of the population on a geometric scale, due to increase of the temperature [4].

After all, to unravel biotic responses in deep-time, first, it is necessary to evaluate the presence of a bioindicator group of environmental quality, such as the benthic macroinvertebrates mentioned above, if present, it is important to assess whether this group lived in the deposition site (autochthonous), or if it was transported (allochthonous). It is also essential to carry out controlled excavations to assess climatic stresses, since isolated records may be biased. Moreover, it is essential that in addition to stratigraphic and taphonomical data, geochemical data such as isotopic and diagenetic analyzes are combined.

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