Correlation between environment and Late Mesozoic ray-finned fish evolution

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In order to better understand the parameters that drove evolution of actinopterygian fishes from the Late Jurassic to the Late Cretaceous, we compare the actinopterygian diversity and evolutionary pattern with environmental indicators. The actinopterygian database we use is a compilation from primary literature about worldwide Late Jurassic–Palaeocene actinopterygians, including the literature concerned with dating fish assemblages and palaeoecology. We define three environmental indicators, which are detectable as concordant patterns in the geological and fossil records. These are:

1) Freshwater radiations. In our database, we define a freshwater radiation when two or more genera occurring in freshwater environment are considered to be their closest relatives, or when one or more genera are known with several well-defined species in the same formation. In some cases, the freshwater radiation recorded in the fossil record may represent species flocks.

2) Vicariant events. In our database, we define a vicariant event when two occurrences from two different formations are sister-genera, or situated in a pectinated position in the phylogenetic tree. The later situation is not a vicariant case *sensu stricto* as the vicariance actually occurred between the genus in the lowermost pectinated position and its complete sister-clade. But the approximation made here is justified, as the phylogeny we used cannot pretend to get the same resolution as modern phylogeny.

3) Sea temperature. For all fully or mostly marine higher taxa, mainly clades, we tested the correlation between diversity and the upper ocean temperature. The curve of upper ocean temperatures from the Late Jurassic to the end of the Cretaceous Tethyan domain was drawn up from the oxygen isotope data of fish tooth enamel.

We mapped the indicators onto a phylogeny of the Late Jurassic–Palaeocene actinopterygian taxa, and plotted the variations against time for each of the indicators. Our results show that for several of the marine clades, diversity is positively correlated with the sea temperature and for one clade negatively correlated with sea temperature. The marine radiation is very important in the mid-Cretaceous, especially in the Tethys, which may have been a centre of origin for some clades. Vicariant events occurred in both marine and freshwater groups, and are abundant during the opening of the south Atlantic in the Early Cretaceous. Freshwater radiations, forming in some cases species flocks, are especially evident in the basal Cretaceous in Asia.

Although these results are affected by biases related to the fossil record and to its study, we propose that these global patterns are genuine and reflect the strong impact of the Earth system on the evolution of fishes in the Late Mesozoic.