A study of the ecomorphology of the shell of extant turtles using geometric morphometrics and its application to fossil turtles

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Turtles represent a successful reptile clade that originated in the Late Triassic. During evolution the group adapted to different types of environments, ranging from dry land to ponds, rivers, and the open ocean, and survived all Mesozoic and Cenozoic extinction events. The body of turtles is characterized by a shell. The shell has been hypothesized to have several functions, like protection, thermal and pH regulation, but also to be adapted in its shape to the ecology of the animal. However, only few correlations between shell shape and ecology have been investigated in a global context so far. To explicitly test for such a correlation, I assembled a three-dimensional dataset of 69 extant turtles and 3 fossils, in particular, the Late Triassic *Proganochelys quenstedtii* and *Proterochersis robusta* and the Late Jurassic *Plesiochelys bigleri*. 3D models were obtained using surface scanning and photogrammetry. I used geometric morphometrics to capture the general shape of the shells. The habitat ecology of extant turtles was classified using the webbing type of their forelimbs as a proxy. Principal component analysis (PCA) highlights much overlap between habitat groups, but phylogenetic flexible discriminant analysis (pFDA) suggests significant differences. However, while *Plesiochelys bigleri* tends to cluster with highly aquatic turtles, the two Triassic species group with intermediate morphologies hinting at an unspecialized continental shape at best. Although the shape of the shell of turtles indeed contains an ecological signal, it is overall too weak to allow using shell shape in paleoecological studies with the current methods.

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