Evidence for disruptive and stabilizing selection and bet-hedging in pre-extinction populations of planktonic Foraminifera

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Natural populations, when exposed to environmental change, may experience either stabilizing or disruptive selection. The relationship between the type of selection and the severity of environmental stress, however, is difficult to study in nature, because the severity of the stress measured as the outcome of the exposure is difficult to predict. Here we take advantage of the fossil record, where the ecological outcome of stress exposure is discernible from the species abundance pattern. Specifically, we analyse shell morphology of planktonic Foraminifera in sediment samples from a Mediterranean sapropel, during an interval where their populations were exposed to different levels of stress over natural time scales. In the two species \textit{Orbulina universa} and \textit{Globorotalia scitula}, representing different plankton habitats, we observe shifts in trait state and decrease in variance in association with non-terminal stress, indicating stabilizing selection. At terminal stress levels, we observe increasing growth asymmetry and trait variance, indicating disruptive selection. In both species, immediately before extinction the populations reached a unique state of variability consistent with the concept of bet-hedging. This phenomenon is distinct from the stabilizing and disruptive selection pattern and its existence suggests that terminal levels of stress may leave a discernible morphological fingerprint in the community.