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Extremely heat tolerant photosymbiosis in a shallow marine benthic foraminifera

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Thermal stress leads to the loss of algal symbionts (bleaching) in many shallow marine calcifiers including foraminifera. The bleaching threshold often occurs at water temperatures, which are likely to be exceeded in the near future due to global warming. Preadaptation represents one mechanism allowing photosymbiotic organisms to persist under warmer conditions, providing the tolerance can be carried to new habitats. Here we provide evidence for the existence of such adaptation in the benthic foraminifera *Pararotalia calcariformata* recently discovered in the eastern Mediterranean. We identify its symbionts as a consortium of diatom species dominated by *Minutocellus polymorphus*. We show that in the field, the foraminifera retains its pigments at a thermally polluted site, where peak water temperatures reach 36°C. To test whether this tolerance represents a widespread adaptation, we conducted manipulative experiments exposing populations from an unpolluted site to elevated temperatures for up to three weeks. The populations were kept in co-culture with the more thermally sensitive diatom-bearing foraminifera *Amphistegina lobifera*. Reduced photosynthetic activity in *A. lobifera* occurred at 32°C whereas photochemical stress in *P. calcariformata* was first observed during exposure to 36°C and chronic photoinhibition (but not mortality) first occurred at 42°C. Survivorship was high in all treatments, and growth was observed under thermal conditions similar to summer maxima at the thermally polluted site (35-36°C). The photosymbiosis in *P. calcariformata* is unusually thermally tolerant for a photosymbiont-bearing eukaryote. The thermal tolerance of this photosymbiosis is present in a natural environment where its thermal threshold is never realized. These observations imply that photosymbiosis in marine protists can respond to elevated temperatures by drawing on a pool of naturally occurring pre-adaptations. It also provides a perspective on the massive occurrence of symbiont-bearing foraminifera in the early Cenozoic hothouse climate.