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The response of planktic foraminifera *Globigerina bulloides* to changing environmental parameters through extensive culturing experiments

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Planktic foraminifera are calcifying marine protists living in the upper water column of the world's oceans. As they grow, the composition of their calcite shells is influenced by their local environment. Thus, by analysing the geochemical signature of their fossil shells, a record of past changes in temperature, pH and salinity of the seawater can be reconstructed. *Globigerina bulloides* is a spinose planktonic foraminifera species that tolerates sub-tropical to sub-polar conditions and is present in high concentrations in the southern Norwegian Sea. It is of ecological interest as it encroaches into previously 'cold water' territories due to climate warming and Nordic Seas "Atlantification". The relative abundance and shell geochemistry of fossil specimens of *G. bulloides* are also widely used for palaeoceanographic reconstructions in the region. Despite the widespread use of *G. bulloides* for these reconstructions, biological, metabolic, and behavioural observations are scarce, leaving large knowledge gaps regarding the impacts of these 'vital effects' on its calcification and preserved geochemical signature. One way to fill this gap is via the study of the species in controlled culture conditions, however to date, all reported culturing studies have been carried out in a temperate to warm water setting (>14^{o}C), and using sub-tropical specimens. This reduces the applicability of these studies to *G. bulloides* inhabiting the high latitudes.

We cultivated over 250 individual specimens of *G. bulloides* from the Norwegian Sea across a range of temperatures (6 - 13^{o} C), salinities (30.4 – 37.8), pHs (7.7 - 8.3) and carbonate ion concentrations (70 – 230 µmol/kg). Experimental conditions were chosen relative to ambient seawater at the collection site(s) and were intended to reflect a plausible range of past and future scenarios.

After several weeks in culture, we observed that *G. bulloides* was tolerant of environmental conditions well outside their natural range, with no significant difference in mortality or final size. This was corroborated by a high percentage of spine regrowth and/or maintenance (~65% for

most treatments) after the first week. Many individuals thrived in culture, with some surviving up to three months. Two alternative strategies appeared to be employed; specimens opted either for rapid growth shortly followed by death, or for a prolonged lifespan with minimal size increase. Longer living specimens developed ectoplasmic structures on multiple occasions. Our observations suggest *G. bulloides* can exhibit considerable adaptability to shifting environmental conditions with implications to its tolerance to ongoing ocean changes.