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Diffusion-reaction modelling to predict the boron isotope composition of photosymbiont species *O. universa* from observed physiological fluxes

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The boron isotope composition ($\delta^{11}B$) of planktic foraminifera tests is primarily controlled by ambient seawater pH and is therefore a well-established proxy for reconstructing surface ocean carbonate chemistry in the geological past. Reconstructions of past seawater pH from planktic foraminifera underpin estimates of atmospheric pCO_2 over geological time and have driven recent advances in using past climate states to improve projections of Earth's future climate. However, biological "vital effects" necessitate empirical, species-specific, $\delta^{11}B$-pH proxy calibrations for accurate pH (and pCO_2) palaeo-reconstructions. Specifically, physiological processes including respiration, photosynthesis and calcification alter the pH of the diffusive boundary layer (DBL) surrounding living foraminifera. Given it is this pH that is thought to be recorded by foraminferal calcite $\delta^{11}B$, shell composition typically deviates from what is predicted based upon equilibrium seawater borate $\delta^{11}B$. This can be mechanically understood using diffusion-reaction modelling, which predicts pH and associated boron systematics within the DBL, and thus the expected $\delta^{11}B$ at the shell surface, if respiration, photsynthesis and calcification fluxes are known. Here we report modelled pH and $\delta^{11}B$ of individual *O. universa* specimens using respiration and photosynthesis rates calculated from direct observations using light-dark microelectrode and respiration chamber measurements of $[O_2]$ within the DBL. Together with modelled DBL pH/$\delta^{11}B$, these provide valuable insight into the drivers of species-specific and inter-specimen offsets between $\delta^{11}B$ of foraminiferal calcite $\delta^{11}B$ and seawater borate, addressing a critical limitation in reconstructing past seawater pH, particularly during greenhouse high-CO_2 intervals, when vital effects and metabolic behaviour may have differed from the present. Ultimately, this work opens avenues to reconstruct past changes in seawater pH using single shell $\delta^{11}B$ analysis, providing a methodology to significantly improve the temporal resolution of palaeo-pH and CO_2 records relative to traditional, monospecific, bulk population analyses.