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Bivalve shell formation in a naturally CO_2-enriched habitat: Unraveling the resilience mechanisms from elemental signatures

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HIGHLIGHTS

- *Mya arenaria* juveniles from Kiel Fjord can partially alleviate the impact of high pCO_2.
- Changes in the calcifying fluid chemistry can be inferred from shell elemental signatures.
- Cl/Ca_{shell} reflects the import of HCO_3^- in the calcifying fluid.
- U/Ca_{shell} indicates the pH in the calcifying fluid.
- Our work provides new evidence of how marine bivalves respond to high pCO_2.

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ABSTRACT

Marine bivalves inhabiting naturally pCO_2-enriched habitats can likely tolerate high levels of acidification. Consequently, elucidating the mechanisms behind such resilience can help to predict the fate of this economically and ecologically important group under near-future scenarios of CO_2-driven ocean acidification. Here, we assess the effects of four environmentally realistic pCO_2 levels (900, 1500, 2900 and 6600 μatm) on the shell production rate of *Mya arenaria* juveniles originating from a periodically pCO_2-enriched habitat (Kiel Fjord, Western Baltic Sea). We find a significant decline in the rate of shell growth as pCO_2 increases, but also observe unchanged shell formation rates at moderate pCO_2 levels of 1500 and 2900 μatm, the latter illustrating the capacity of the juveniles to partially mitigate the impact of high pCO_2. Using recently developed geochemical tracers we show that *M. arenaria* exposed to a natural pCO_2 gradient from 900 to 2900 μatm can likely concentrate HCO_3^- in the calcifying fluid through the exchange of HCO_3^-/Cl^- and simultaneously maintain the pH homeostasis through active removal of protons, thereby being able to sustain the rate of shell formation to a certain extent. However, with increasing pCO_2 beyond natural maximum the bivalves may have limited capacity to compensate for changes in the calcifying fluid chemistry, showing significant shell growth reduction. Findings of the present study may pave the way for elucidating the underlying mechanisms by which marine bivalves acclimate and adapt to high seawater pCO_2.

1. Introduction

Rapid uptake of anthropogenic carbon dioxide (CO_2) by the ocean is decreasing seawater pH, depressing the abundance of carbonate ion (CO_3^{2-}) and increasing aqueous CO_2 and bicarbonate ion (HCO_3^-) concentrations (IPCC, 2014), a process known as ocean acidification (OA). These alternations in ocean chemistry can have severe consequences for marine calcifying organisms by impairing their capacity to build $CaCO_3$ skeletons (Kroeker et al., 2013). Bivalves are amongst the taxonomic groups most vulnerable to OA (Gazeau et al., 2013). In particular, the formation and integrity of larval and juvenile shells have been shown to be dramatically affected (Talmage and Gobler, 2010; Waldbusser et al., 2014; Fitzer et al., 2015, 2016; Thomsen et al., 2015; Milano et al., 2016), resulting in large delays in metamorphosis and declines of survival (Wittmann and Pörtner, 2013) and eventually affecting the

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