DETERMINING THE IMPORTANCE OF ICHTHYOCARBONATE IN GREENHOUSE WORLDS

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PROJECT OBJECTIVES

- Determine whether changing seawater chemistry influences ichthyocarbonate production rates
- Assess composition of ichthyocarbonate produced by fish acclimated to Cretaceous seawater chemistry
- Predict how ichthyocarbonate fate may have changed through geological time

PROJECT RATIONALE

Marine bony fish produce significant quantities of magnesium-rich carbonate (ichthyocarbonate; Grosell and Oehlert, 2023). With an annual production magnitude estimated to rival that of foraminifera or coccolithophores, marine fish are one of the top carbonate producers in the oceans today (Oehlert et al., 2024). The only marine vertebrates who consistently drink seawater to stay hydrated, marine fish precipitate ichthyocarbonate to maintain internal salt and water balance and continuously excrete these precipitates to the environment (Grosell and Oehlert, 2023).

In the modern oceans, ichthyocarbonate is typically comprised of carbonate polymorphs such as (very) high magnesium calcite (HMC) and amorphous calcium magnesium carbonate (ACMC) with high dissolution rates, potentially limiting significant accumulations of ichthyocarbonate to shallow and tropical sedimentary environments (Wilson et al., 2009). Throughout the Phanerozoic, environmental conditions have varied substantially, with significant changes in temperature, pCO_2, and seawater chemistry occurring over time (Fig. 1). Factors like temperature, salinity, and pCO_2 are known to increase ichthyocarbonate production rates (Wilson et al., 2009; Genz et al., 2011; Heuer et al., 2012, 2016). Similarly, increased pCO_2 was shown to increase base excretion by > 34% (Heuer et al., 2012). However, little is known about how

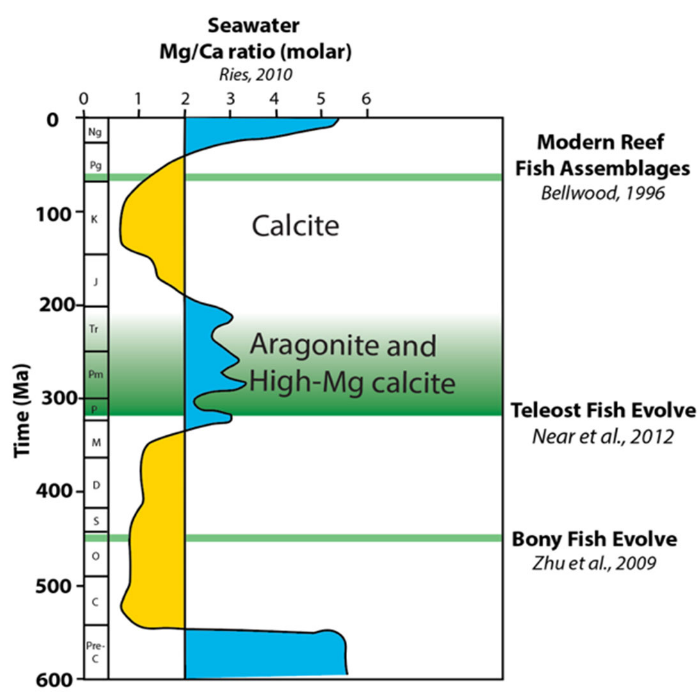

Figure 1. Changing seawater chemistry (Mg/Ca ratio) and evolutionary milestones of marine bony fish.

seawater chemistry impacts the production and preservation potential of ichthyocarbonate. Secular changes in the ionic composition of Phanerozoic seawater have resulted in mineralogical shifts in inorganic carbonate precipitates (Fig. 1). Transitions between Calcite and Aragonite Seas occurred as many as 3 times since the rise of bony fish, suggesting marine fish have had to adapt to changes in seawater chemistry.

APPROACH

We acclimated triplicated tanks holding Gulf toadfish (*Opsanus beta*) in modern seawater and synthetic seawater with ionic composition similar to Cretaceous oceans, (Mg/Ca ~1; sulfate ~9 mM; alkalinity ~2 mM). Production rate was assessed daily by collecting wet masses of ichthyocarbonate normalized to fish biomass in the tanks. Differences in ichthyocarbonate size were determined using a Python-based morphological analysis, and mol%$MgCO_3$ of the ichthyocarbonate were measured using ICP-QQQ. pH stat approaches were used to determine dissolution rates.

SIGNIFICANCE

Results suggest that marine fish acclimated to Cretaceous seawater produce ichthyocarbonate 3.6x faster and with 2.5x lower mol%$MgCO_3$. The dissolution rate of ichthyocarbonate produced by toadfish acclimated to Cretaceous seawater was ~3x slower than modern controls, suggesting ichthyocarbonate was more likely to reach sediments. We conclude that marine fish likely played an even more prominent role in Mesozoic carbon cycling than today.

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