Feeding-induced variations in ichthyocarbonate production and composition by the Gulf toadfish

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Introduction

Marine fish have a significant impact on the global carbon cycle but are often overlooked. One example of this contribution is their production of ichthyocarbonates (Oehlert et al., 2024). Ichthyocarbonates are Mg-rich calcium carbonate pellets produced by marine bony fish as a byproduct of osmoregulation. Having only been discovered in 1991 (Walsh et al., 1991), much is still unknown about their morphology, geochemical characteristics, and behavior in the natural environment.

Problem Statement

Previous studies of ichthyocarbonate production rate have been conducted using unfed fish. Consequently, while prior results provide an important foundation for understanding the role of marine fish in the carbon cycle, datasets produced from fed fish are lacking. Here, we investigate the influence of feeding state on production and composition of ichthyocarbonate.

Methods

The experimental tanks were stocked with Gulf toadfish (Opsanus beta) weighing 40 - 100 g. Ichthyocarbonate was collected daily from tank bottoms using disposable pipettes. Days since last feeding were recorded, and samples were divided into two treatments based on prior measurements of Specific Dynamic Action (SDA) for toadfish which indicates toadfish experience elevated metabolic rate from days 0-3 after feeding (“Fed”), with a return to baseline conditions after four days (“Fasted”). All experimental protocols were completed in accordance with University of Miami Institutional Animal Care and Use Committee (IACUC) approved practices. After collection, four analyses were performed:

1. Measurements of wet weight to calculate production rate
2. Particle morphology analysis using Imaris (FIJI) and MATLAB
3. Agilent 8900 ICP-QQQ mass spectrometry for assessment of mol%MgCO3 and phosphorus concentration in mineral fraction using MS/MS mode with O2 gas in the collision-reaction cell (CRC)
4. Zeiss Ultra Plus Field Emission SEM & Apollo 10 EDAX for crystallite morphology and mol%MgCO3

Results

No significant difference was observed in mol%MgCO3 (p = 0.05) between ichthyocarbonate produced by fed and fasted Gulf toadfish.

Phosphorus was significantly higher (p < 0.05) in ichthyocarbonate produced by fed fish.

Average concentrations:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Phosphorus (g/kg)</th>
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<tbody>
<tr>
<td>Fasted</td>
<td>8.59 ± 22.06 g/kg</td>
</tr>
<tr>
<td>Fed</td>
<td>18.88 ± 26.10 g/kg</td>
</tr>
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Fed Gulf toadfish produce ~ 70 % more ichthyocarbonate per day than fasted fish (p < 0.05).

Ichthyocarbonate produced by fed Gulf toadfish is characterized by higher eccentricity (11 %), and length/width ratios (18 %) compared to ichthyocarbonate produced by fasted fish (p < 0.05).

Discussion

As the climate warms, resources such as food may become limited to global fish populations. It is crucial to determine how this will affect ichthyocarbonate production and fate (Grosell and Oehlert, 2023; Oehlert et al., 2024). The results of this investigation showed the following:

1. Production rate by fed toadfish is ~ 70 % higher than fasted fish.
2. Fed fish ichthyocarbonate is more ellipsoidal than fasted fish.
3. Ichthyocarbonate bulk mol%MgCO3 does not change with fasting, but phosphorus content does.
4. Crystallite morphology, size, and mol%MgCO3, were impacted by fasting. EDS measurements suggest lower mol%MgCO3 in crystals produced by fasted fish, but more replication is needed.

A major finding of this study is that ichthyocarbonate production rate decreased significantly when fasted. Thus, prior estimates of global ichthyocarbonate production rate (Wilson et al., 2009; Oehlert et al., 2024) are likely underestimates. Compositional and morphometric changes were also shown to occur with fasting, which has implications for the fate of ichthyocarbonate in the oceans. Ichthyocarbonate fate is thought to be a fundamental determinant of the role of marine fish in the global carbon cycle.

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References


