Boron isotope data from bivalves from 2022 tank experiment in the Gulf of Maine, USA

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Abstract
The boron isotopic composition (δ11Bc) of many marine carbonates provides insight into the pH at the site of calcification within biocalcifiers and, by extension, the pH of ambient seawater when the carbonate formed. A 20.5-week flowthrough tank experiment was conducted in which four species of commercially important bivalves from the northwest Atlantic Ocean were grown in tanks with controlled pHT (pH 7.4 to 8.0) and temperature conditions (6 to 12 °C). A total of 106 shell samples from 99 individuals of adult and juvenile Arctica islandica (ocean quahog), juvenile Mercenaria mercenaria (northern quahog or hard clam), juvenile Mya arenaria (soft-shell clam), and juvenile Placopecten magellanicus (Atlantic sea scallop) were analyzed from this controlled experiment to assess the seawater pH, temperature, and growth rate controls on shell δ11Bc. Juvenile P. magellanicus and juvenile M. mercenaria demonstrated significant relationships (R≥0.60; p-value <0.006) between tank pHT and δ11Bc, suggesting potential utility as proxies for past ambient seawater pH. Conversely, the δ11Bc of juvenile A. islandica and juvenile M. arenaria did not yield a strong relationship with seawater pHT but instead yielded significant relationships with shell growth rate (linear extension), with a positive relationship for M. arenaria and a negative relationship for juvenile A. islandica. The δ11B results from the few (n=9) adult A. islandica shells measured show the most variability across the range of pH and temperatures (range of 16‰), and no significant relationship was found with seawater pH or growth rate. Despite rigorous oxidative cleaning of samples, the data suggest that adult A. islandica shells contain boron-rich organic phases resistant to traditional cleaning techniques. The data on this site (summary file) include the average temperature, pH, and salinity used for the boron isotope analysis, in addition to the δ11B of the borate in water calculations, δ11B measured in the shells, the B/Ca ratio measured in the shells, and the delta pH values calculated using the above values. Additional data include (temperature file) all temperature measurements from the tank experiment (every minute measurements) and daily averages. pH (pH file) and salinity (salinity file) data from weekly measurements are included. Data needed to perform the delta pH calculations are included (delta pH file). The specimens grown in each tank that were used for boron isotope measurements are also included (boron specimens by tank file). This file specifies the number and species that were grown under the various tank conditions.

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Coverage

Location: Schiller Coastal Studies Center at Bowdoin College, Orr's Island, ME, USA
Temporal Extent: 2022-01-14 - 2022-06-08

Methods & Sampling

Experimental setup:

These four species were grown in four pH treatments (~7.4, 7.6, 7.8, and ambient conditions with a pH=8.0) at three temperature treatments (~6, 9, 12° C). There was one tank at each pH for T=6 and 12° C and two tanks at each pH for T=9° C.

Specimens were randomly assigned to tank conditions with roughly equal numbers of each specimen in each tank condition.

Specimens were in the tank conditions for 20.5 weeks before removed with the following exception. Half of the *P. magellanicus* were removed in April 2022.

Environmental Conditions:

pH and salinity were measured weekly with a YSI probe. pH was controlled within each tank condition by the Apex control system. Tanks with lower pH conditions than ambient were obtained by bubbling CO2 from compressed cylinders into the water of a mixing chamber before leading to each of the three sets of controlled pH tanks.

Temperature was measured with two Hobo Tidbit devices in each tank throughout the experiment. Temperatures were measured every minute throughout the 20.5 weeks. Temperatures were maintained within the tanks using Inkbird controllers and two (500W/800W) heaters per tank.

All pH measurements are on the total pH scale (pHT).

The reported measurements for temperature, salinity, and pHT are measured tank averages.

Specimen measurements:

All study specimens were measured for maximum height, dry (live) weight, and buoyant weight at the start and end of the experiment. For the *P. magellanicus* removed in April 2022, height, dry (live) weight, buoyant were measured after removal from the tanks. Photos were taken of each specimen at the conclusion of the experiment.

After the conclusion of the experiment, all specimens were dissected, shells were rinsed with DI water and allowed to air dry prior to sampling for boron isotopes.

Shell sampling:

Organic matter was removed with burring bit (Brasseler #835.11.010) and hand milling with a Dremel tool prior to sampling of the shell. 8 mg of shell was sampled (3-4 mg for P. magellanicus) for boron isotopes with the same bit and Dremel tool.

Boron samples were collected on the shells from the portion of the shell that grew from approximately week 2 to week 10 of the experiment (prior to the spring freshening and second calcein stain line in April 2022) for all species except the adult *A. islandica*. Due to much slower growth in the adult *A islandica*, the portion of the shell that grew during the entire tank experiment was sampled.

For most shells, one sample was collected from each shell. There were two exceptions: a comparison was done between the two halves of the shell for three juvenile *A. islandica* (g5, g32, g48) and a comparison of the outer shell layer (both inner and outer layers of the outer shell) and the inner shell layer on two juvenile *A. islandica* (g40 and g52). The samples selected for these comparisons were randomly chosen.

Sample preparation:

All powdered shell samples were subject to two 15-minute leaches in warm 10% (by volume) H2O2 (80 °C; buffered in NH4OH) and a weak acid leach (0.0005 M HNO3) before powders were dissolved in distilled 0.5 M HNO3. Dissolved samples were centrifuged (1 min at 13k rpm), and if there was any visible undissolved non-carbonate material at the bottom of the microcentrifuge tube the dissolved sample was transferred to a clean vial, rejecting the small undissolved fraction.

The burring bit was used to remove all visible organic matter from the outside of the shells. The leaching in H2O2 was performed to remove the remaining organic matter.

Chemical Processing:

All trace element and boron isotope analyses were performed at the University of Bristol. An aliquot of the dissolved sample was analyzed by Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) using well-characterized, matrix-matched, synthetic standard solutions to give B/Ca and U/Ca ratios. Samples and standards were introduced in 0.5 M HNO3 and an acid wash solution of 0.5 M HNO3 matrix and 0.3 M HF was utilized between samples/standards to aid B wash out.

The remaining sample containing between 4 and 40 ng of B was separated from the carbonate matrix using 20 µl micro-columns containing Amberlite IRA 743 boron-specific anionic exchange resin. The boron separation from the matrix was performed only on the day preceding Multi Collector-ICP-MS (MC-ICP-MS) analysis. All samples, blanks, and standard solutions were introduced to the instrument in a 0.5 M HNO3 and 0.3 M HF acid matrix again to ensure optimal B wash out.

A total of 108 samples were prepared for boron isotope analysis. There were two samples that did not produce useful results due to blocked columns (one adult *A. islandica* and one juvenile *P. magellanicus*).

See Thatcher et al., (2026; GCA) and McMahon et al. (2024; PLOS Climate) for full details on the methods.

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Related Publications

McMahon, T., Thatcher, D., Williams, B., Wanamaker, A., Jellison, B., Franklin, H., Guay, K., Whitney, N. M., Stewart, J. A., & LaVigne, M. (2024). Contrasting responses of commercially important Northwest Atlantic bivalve species to ocean acidification and temperature conditions. PLOS Climate, 3(11), e0000509. https://doi.org/10.1371/journal.pclm.0000509
Results

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Parameters

Parameters for this dataset have not yet been identified

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