Measuring Stable Isotopes in Giant Clams (*Tridacninae*) to Reconstruct Past Ocean Conditions in Malakal Harbor, Palau

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Introduction

- An increase in anthropogenic carbon dioxide (CO_2) in the earth's atmosphere over the past several centuries has caused an increase in ocean acidity, harming calcareous marine species like giant clams (*Tridacninae*) by accelerating the dissolution of calcium carbonate and reducing aragonite concentration in the surrounding seawater (Coral Reef Research Foundation et al., 2018).
- For decades, the giant clam has served as a critical resource for the islands of Palau serving as a food source for locals, and an important source of income for many Palauans (Guibert et al., 2020).
- **Analyzing stable oxygen ($\delta^{18}O$, $\delta^{16}O$) isotopes in sub-fossil *Tridacna* shells can reveal important, high-resolution records of the past including changing sea surface temperatures and freshwater influence on the marine environment by precipitation and ENSO events (Aharon and Chappell, 1983; Conroy et al., 2017; Duprey et al., 2015; Romanek and Grossman, 1989; Grossman and Ku, 1986).**

Objective: Determine the best sea surface temperature (SST) reconstruction equation using $\delta^{18}O_{aragonite}$ measurements from each specimen along with local $\delta^{18}O_{seawater}$ records from Palau and examine possible species differentiation between *H. hippopus (#199152)* and *T. derasa (#199151)* (see Figure 1).

Methods

- Two sub-fossil *Tridacna* shells were sampled, one *H. hippopus* (previously sampled by Dr. Michelle Gannon) and one *T. derasa* shell. Both specimens were collected in 1955 from a shallow reef environment in Malakal Harbor, Palau (see Figure 1).
- Samples were milled using a Dremel in the inner layer of the shell to reduce spatial and temporal variability to yield a total of 35 samples or isotopic signatures for the *T. derasa* shell and 96 samples for the *H. hippopus* shell (see Figure 2; Gannon et al. 2017).

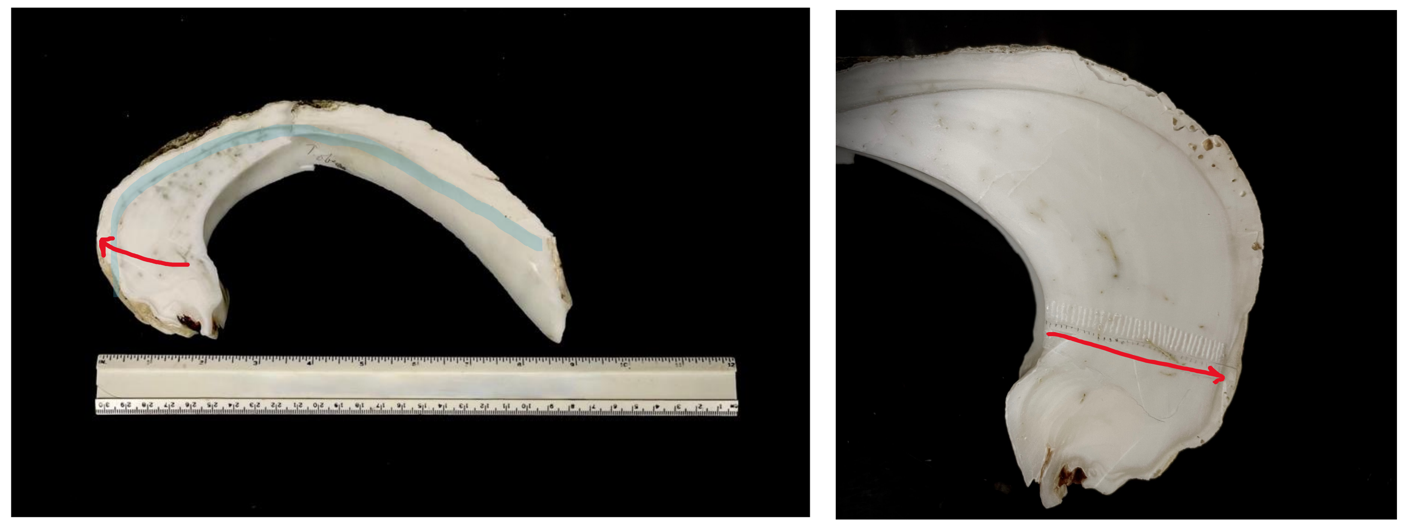

Figure 2 – *T. derasa* shell profiles used for isotope sampling; sampling track show in red, line separating inner and outer layer of the shell shown in blue. Close up of aliquots and sampling track shown on the right.

- The aliquots of powdered carbonate from *Tridacna* specimens were analyzed with an Elementar Isoprime100 Isotope Ratio Mass Spectrometer interfaced with a Multiflow Prep system to obtain stable carbon and oxygen isotope values for each aliquot.
- Various equations used to reconstruct the ocean temperature during each specimen's growth period were tested (e.g., Aubert et al., 2009; Romanek and Grossman, 1989; Aharon and Chappell, 1983; Watanabe and Oba, 1999; Duprey et al., 2015; Grossman and Ku, 1986) using $\delta^{18}O_{aragonite}$ values from modern shells obtained by Dr. Gannon (see Figure 1) and unpublished $\delta^{18}O_{seawater}$ data from Dr. Jessica Conroy, and compared to several actual SST records from Palau (Alpert et al., 2017; CRRF; Conroy et al., 2017; see Figure 4).
- Ultimately, an empirical analysis of the data was done using the equation shown below, originally developed by Grossman and Ku (Grossman and Ku, 1986) defined for aragonitic species of mollusks:

$$T\ (^{o}C) = 21.8 - 4.69\ (\delta^{18}O_{aragonite} - \delta^{18}O_{seawater})$$

Sample Locations

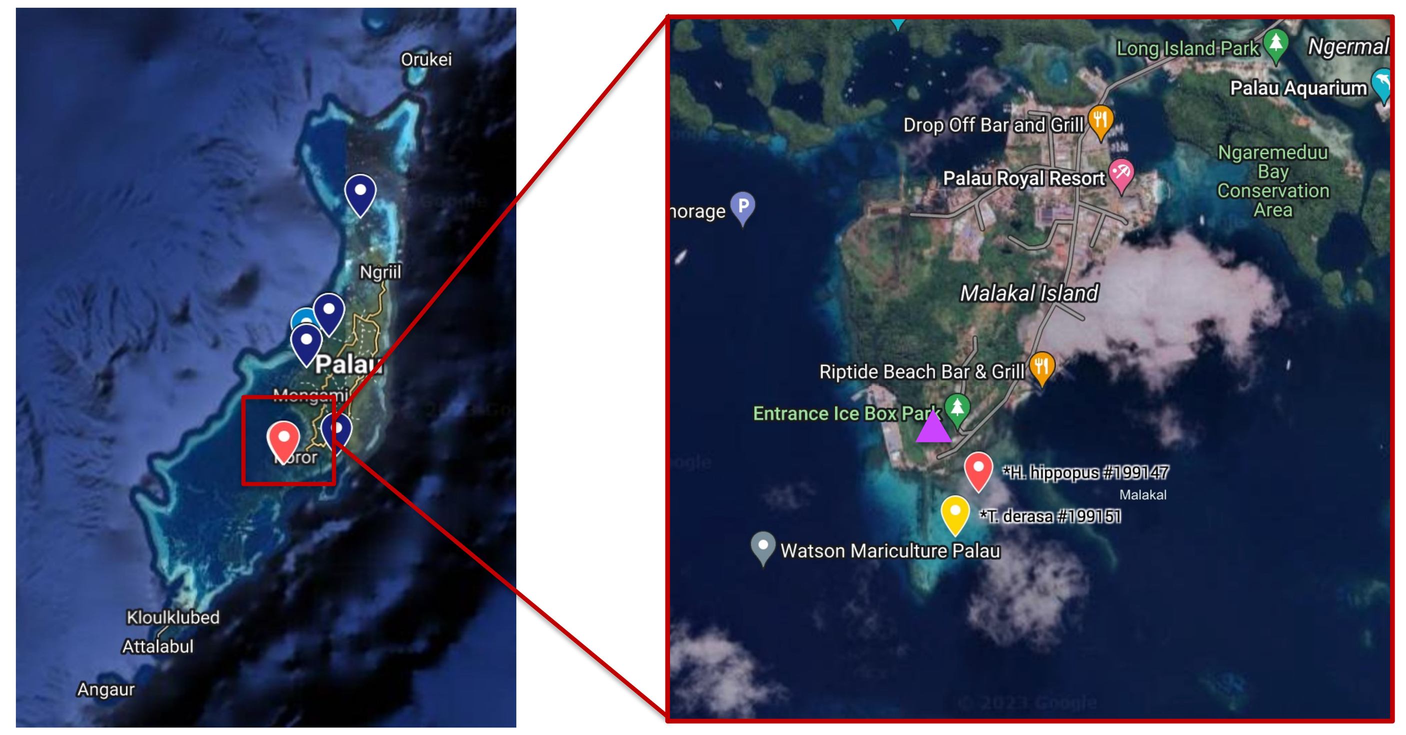

Figure 1 – The main island of Palau (left) and Malakal Harbor (right). Approximate shell locations shown by points on map. *H. hippopus #199147* (red) and *T. derasa #199151* (yellow) were both collected in Malakal Harbor in 1955 on an expedition led by A.J. Ostheimer III and R. Tucker Abbott. All points shown in dark blue are modern *T. derasa* and *T. squamosa* shells collected in 2016 and 2017 by Dr. Lincoln Rehm and sampled by Dr. Michelle Gannon. The Koror-Airai Sewage Treatment Plant is shown as a purple triangle.

Results

- Comparing the newly measured *T. derasa* isotope data with the previously collected *H. hippopus* isotope data, similar environmental conditions seem to be recorded by both shells (see Figure 3).
- However, the $\delta^{18}O_{aragonite}$ values measured from the *T. derasa* specimen record significantly more negative $\delta^{18}O$ values compared to the *H. hippopus* specimen that lived in similar conditions (see Figure 3).

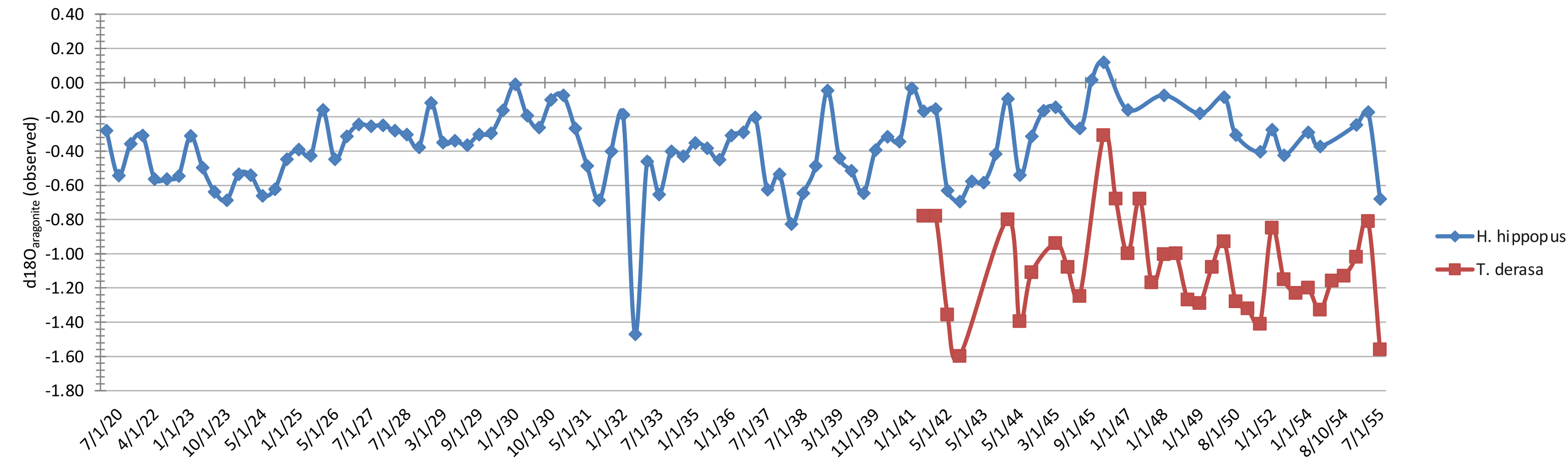

Figure 3 – Comparison of recorded $\delta^{18}O_{aragonite}$ isotope values between *H. hippopus* (top) and *T. derasa* (bottom) specimen collected at the same location at the same time. Note that time ranges from 1920-1955.

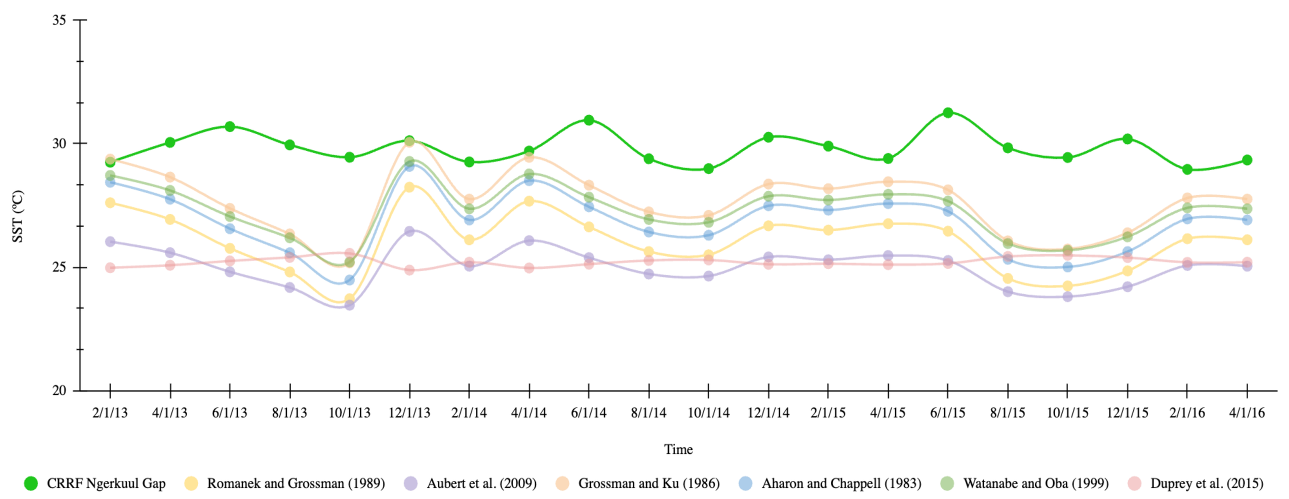

Figure 4a – Comparison of SST reconstruction equations for aragonite species conducted using Coral Reef Research Foundation SST record.

- When multiple locations in Palau with varying environments (i.e. estuary, lagoon, barrier reef) and multiple species (i.e. *T. squamosa*, *T. derasa*) were tested, the equation developed by Grossman and Ku in 1986 was the most successful at reconstructing SST according to multiple SST records (Grossman and Ku, 1986; see Figures 4a and 4b).

Results

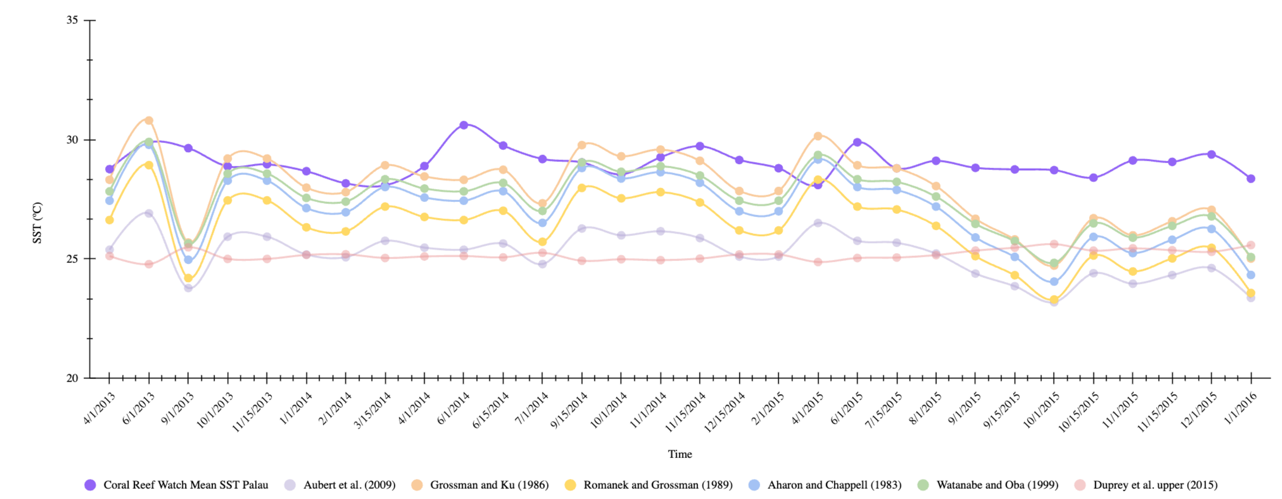

Figure 4b – Comparison of SST reconstruction equations for aragonite species conducted using NOAA Coral Reef Watch SST record.

Discussion and Conclusion

- Similar environmental conditions were recorded by both specimens during their overlapping lives (see Figure 3), though the *T. derasa* specimen records much lower $\delta^{18}O$ values than the *H. hippopus*.
- To explain this difference, the faster growth rate of *T. derasa* clams (3-6cm/yr) compared to *H. hippopus* (3-5cm/yr) could generate differences in the uptake of stable oxygen isotopes (Beckvar, 1981). Alternatively, these specimens could have been collected from slightly different depths on the reef (i.e. 3ft vs. 12ft) which could impact the uptake of oxygen isotopes in each shell (Gannon et al. 2017).
- The possibility of freshwater input into parts of Malakal Harbor from the Koror-Airai Sewage Treatment (see Figure 1) could contribute heavily to the isotopic signature of each shell. Freshwater exhibits relatively lower $\delta^{18}O/\delta^{16}O$ ratios when compared to seawater due to its higher concentration of the isotopically lighter $\delta^{16}O$. Essentially, more freshwater influence could help explain more negative $\delta^{18}O$ values.

Further Work:

- Measuring trace metals with ICP-MS such as Sr, Ca, B, and Mg to deduct alternative SST reconstructions as well as trends in ocean acidity over time.
- Conducting an inter-species comparison of shells collected at different locations in the same year to examine differences in isotopic uptake between regions in Palau.
- Using *Tridacna* as paleoclimate proxies to examine ENSO patterns and signatures.

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