

Evaluating the robustness of *Mytilus californianus* skeletal chemistry as a paleoenvironmental archive: Effects of microenvironment and ontogeny

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INTRODUCTION

Mg/Ca ratios and $\delta^{18}\text{O}$ of metazoan carbonate may provide a useful archive of decadal and seasonal parameters (e.g. mean annual temperature, annual temperature range), but the reliability of this proxy remains questionable given potential ontogenetic and microenvironmental effects. We investigated these potential effects in the intertidal mussel *Mytilus californianus* by directly comparing instrumental environmental data to *in situ* mussel shell chemistry to evaluate the influence of intertidal position (microenvironment) and growth rate (ontogeny).

ENVIRONMENT

Mussels (*Mytilus californianus*) from a range of ontogenetic stages (24-72 mm in length) were outplanted from 30 Aug 2004 - 16 Sept 2005 at lower intertidal position (LIP: -0.2 m MLLW) and upper intertidal positions (UIP; +1.1 m MLLW) within Cabrillo National Monument, San Diego, CA (Figure 1). Temperature was recorded every five minutes via loggers and seawater samples were collected approximately every 3 weeks for $\delta^{18}\text{O}$ and salinity. $\delta^{18}\text{O}$ varied from -0.36 to -0.67 ‰ with an average of -0.51 ‰ (± 0.05 ‰ precision), while salinity varied from 36.7 to 35.8 with an average of 36.4 (± 0.27 precision). Seawater $\delta^{18}\text{O}$ and salinity show a significant positive correlation ($r^2 = 0.60$, $p = 0.001$, $\delta^{18}\text{O} = 0.276 \cdot \text{Salinity} - 10.569$). Water temperatures for submersion intervals of the UIP were averaged to produce a daily mean submersion temperature. This record was then fit with cubic spline and smoother functions, and 100 evenly-spaced interpolated values were extracted from each record.

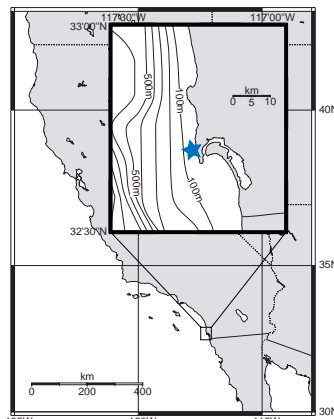


Figure 1. Study location

GROWTH DYNAMICS

Mussels at the UIP and LIP experienced significantly different percent submersions (24-46% versus 91-100% per half-lunar cycle; Figure 2). A General Linear Model indicates that the amount of shell accretion significantly depends on both tidal position (F-ratio = 16.245, $p = 0.001$) and starting length (F-ratio = 47.496, $p = 0.001$). Though the average accretions over the outplant year are significantly different (i.e., UIP = 17.8 ± 8.0 mm vs. LIP = 22.7 ± 8.1 mm), the UIP and LIP regression slopes are not significantly different, indicating similarly decreasing growth rates through ontogeny with larger specimens accreting less shell material.

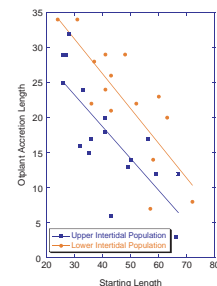


Figure 2. Outplant growth

MICROSAMPLING AND ANALYSIS

To evaluate interspecimen variability in Mg/Ca and $\delta^{18}\text{O}$, six specimens each from the UIP and LIP were selected to cover the observed range of accretion rates. These specimens were sectioned along their maximum growth axis and contiguously microsampled ($n = 22$ to 45) on a New Wave Micromill (Figure 3). Carbonate splits were analyzed for Mg/Ca by ICP-OES (± 0.027 mmol/mol precision) and for $\delta^{18}\text{O}$ by dual-inlet mass-spectrometry (< 0.07 ‰ precision).

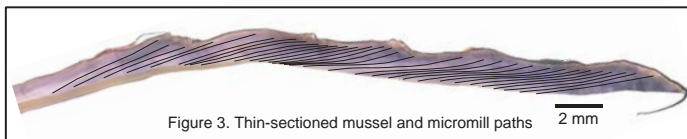


Figure 3. Thin-sectioned mussel and micromill paths

Mg/CA RATIO RESULTS

In Figure 5 below, Mg/Ca values are plotted against observed upper intertidal temperature curves derived from cubic spline (grey) and smooth (black) fitting. Small specimens are shown in green, medium specimens in orange, and large specimens in blue. Mg/Ca values are plotted by their relative drilling position with no correction for seasonal growth variations. If Mg/Ca faithfully records ambient sea surface temperatures then specimen values should trace the sea surface temperature reconstructions for the outplant year. However there is noticeable downward trend in the Mg/Ca in medium and large specimens. Values during the later part of the outplant year fail to record a clear seasonal pattern and do not match values recorded during the initial outplant. This observation suggests there are clear ontogenetic effects in the Mg/Ca ratio for *M. californianus*.

Figure 4 is a box plot of Mg/Ca variation within each specimen ($n = 12$), within each intertidal position, and for the total population. Small specimens are shown in green, medium specimens in orange, and large specimens in blue. Results support a strong positive relationship between high accretion rates (i.e., small specimens) and average Mg/Ca (GLM: F-ratio = 4.580, $p = 0.047$). Tidal position appears to be a weaker contributing factor, with slightly higher average Mg/Ca in individuals from the UIP (GLM: F-ratio = 2.539, $p = 0.150$).

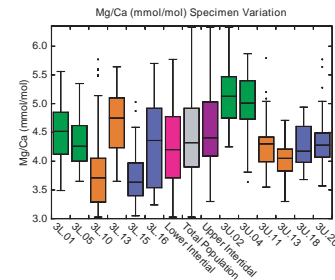


Figure 4. Box plot of Mg/Ca variation

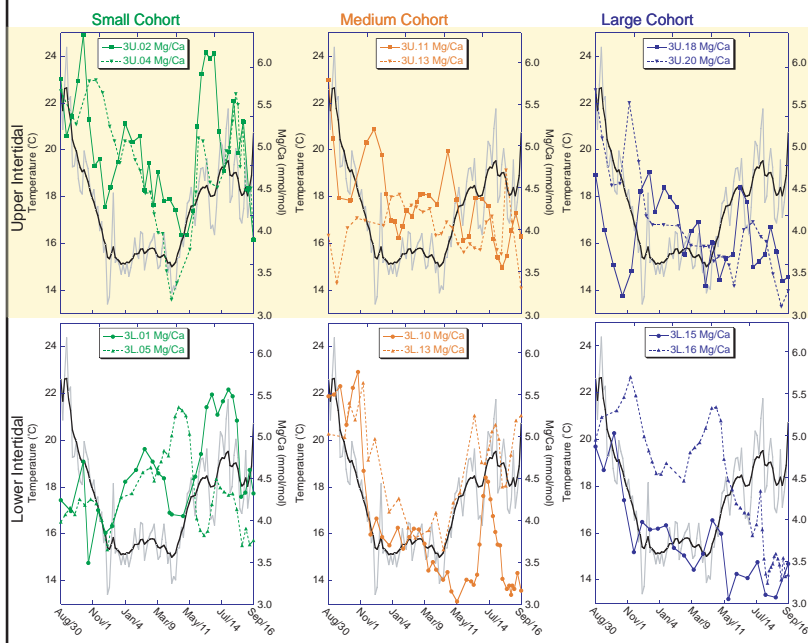


Figure 5. Mg/Ca (mmol/mol) variation throughout the outplant year plotted against cubic spline and smooth fit temperature records

CARBONATE RESULTS

The low-resolution seawater $\delta^{18}\text{O}$ record was treated with a cubic spline to produce 100 evenly-spaced interpolated seawater $\delta^{18}\text{O}$ values. These values were coupled with the previously discussed interpolated temperatures records to produce synthetic carbonate $\delta^{18}\text{O}$ records via the paleotemperature equation of Epstein et al. (1953). Figure 7 shows the $\delta^{18}\text{O}$ plotted against the synthetic carbonate record using upper intertidal temperature curves derived from spline (grey) and smooth (black) fitting. Small specimens are shown in green, medium specimens in orange, and large specimens in blue. $\delta^{18}\text{O}$ values are plotted by their relative sampling position with no correction for seasonal growth variations. Though $\delta^{18}\text{O}$ values is enriched by 0.8 ‰ when compared to the synthetic carbonate record, each mussel captures the seasonal variability of the outplant year.

Figure 6 is a box plot of the total combined $\delta^{18}\text{O}$ analytical variation each specimen ($n=12$), specimens combined for each intertidal position, and total site population. Small specimens are shown in green, medium specimens in orange and large specimens in blue. Contrary to the results found in the Mg/Ca ratios, neither cohort size (GLM: F-ratio=0.729, $p=0.512$) or tidal position (GLM: F-ratio=0.417, $p=0.536$) seem to have an effect on the $\delta^{18}\text{O}$.

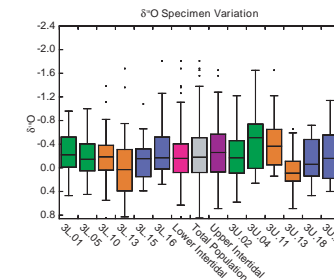


Figure 6. Box plot of $\delta^{18}\text{O}$ variation

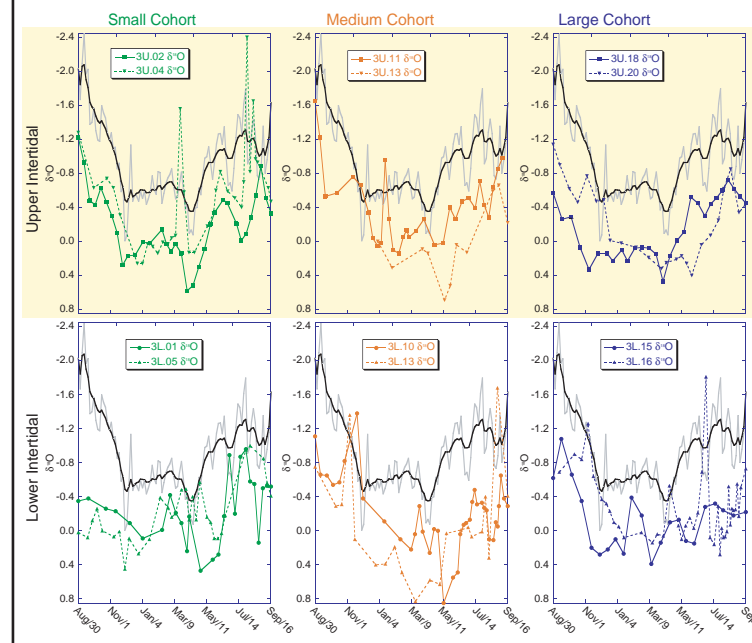


Figure 7. $\delta^{18}\text{O}$ carbonate variation throughout the outplant year for synthetic and mussel records



Figure 8. An intertidal mussel community, San Diego, CA

CONCLUSIONS

- Average accretion between the two intertidal populations is significantly different, though they retain a similar decrease in growth rate through ontogeny (Figure 2).
- Observed Mg/Ca ratios seem to significantly decrease in medium and large cohort specimens through a single growth year (Figure 5).
- Average Mg/Ca ratios for a given specimen are strongly affected by ontogeny and mildly affected by intertidal microenvironmental (Figure 4).
- Though enriched by ~ 0.8 ‰ relative to the predicted synthetic record, the mussel carbonate $\delta^{18}\text{O}$ captures most of the observed seasonal variation (Figure 7).

IMPLICATIONS AND FUTURE WORK

Important parameters for paleoclimate research include seasonal to decadal variation in sea surface temperature and salinity. A source for such data has been the coupling of Mg/Ca and $\delta^{18}\text{O}$ records from molluscan shell growth by assuming that Mg/Ca is largely a function of temperature. However, our results from modern *M. californianus* populations indicate that ontogeny significantly affects observed Mg/Ca values, with intertidal position playing an additional, though minor, role.

Future research includes consideration of seasonal growth rate changes to better correlate the instrumental and carbonate records in the time-domain. Correlating these records will allow further assessment of Mg/Ca as a paleotemperature proxy, and whether ontogenetic and microenvironment affects can be constrained. Additional outplants and collections from the intertidal of Santa Cruz, CA, will also be analyzed for their Mg/Ca and $\delta^{18}\text{O}$ values. Santa Cruz has a more variable seawater temperature and $\delta^{18}\text{O}$, which will allow further assessment of the potentials and pitfalls for combining Mg/Ca and $\delta^{18}\text{O}$ values for environmental reconstructions.

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