Ocean Acidification Research at UMass Boston's School for the Environment

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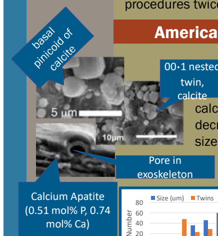
Biomineralogy – Structure and Function

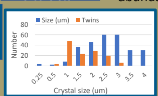
Fully replicated CO_2-dosed pH experiments (n=5 for OA only, n= 3 for multi-stressor; Wilcox-Freeburg et al., 2013). No pseudo-replication in any experiments. Animals fed native diets *ad litem* for duration of experiments (8 days to 2 months depending on animal). Water chemistry measured using standard procedures twice daily (Riesbell et al. 2010 and references therein).

American Lobster

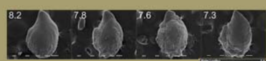


OA increases the occurrence of calcite twins and decreases the overall size of calcites.

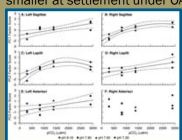
OA decreases the abundance of CAP and impacts structural integrity.



Reef Fish



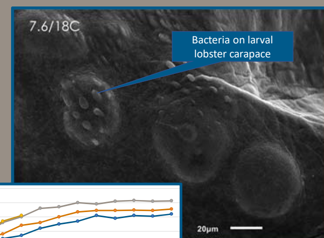
Larvae are also significantly smaller at settlement under OA.

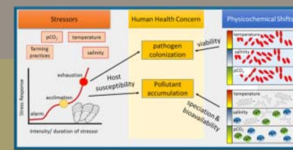


Otoliths (aragonite on a protein matrix) are used for hearing and gravisense in teleosts. OA significantly impacts 2-d and 3-D morphometry.

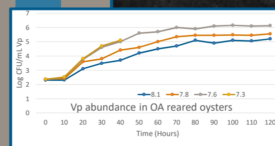
Crystal habit is significantly altered under OA leading to changes in function.

Animal Health and Disease



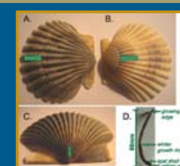


Research on animal disease like epizootic shell disease in lobsters or climate change induced stress on animals reveals differential responses of bacteria and other pathogens to ocean acidification.



Vibrios such as *V. parahaemolyticus* increase in abundance under OA. Temperature increase associated with climate change increases other diseases in shellfish such as *Perkinsus* sp., leukemia, and grey tissue disease. OA also impacts animal health through increased stress. Exacerbating these impacts are farming practices which can increase pathogen load in shellfish.

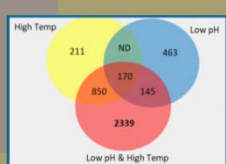
Ubiquitous bacteria associated with Epizootic Shell Disease also increase in abundance. While not directly impacting animal health the incidence of lesions in the poorly structured shell of OA-reared lobsters significantly impacts survival during molting.



Physiology and Genetics

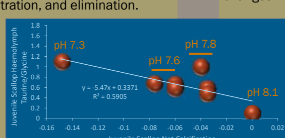
	pH 8.0		pH 7.7		pH 7.4	
Species	Conc. (M)	% Total	Conc. (M)	% Total	Conc. (M)	% Total
Pb^{2+}	$6.64e^{-8}$	6.5%	$7.70e^{-3}$ (16%↑)	7.5%	$8.10e^{-8}$ (22%↑)	7.9%
Cu^{2+}	$1.16e^{-7}$	16.1%	$2.51e^{-7}$ (60%)↑	25.2%	$3.53e^{-7}$ (119%)↑	35.3%
Ca^{2+}	$7.97e^{-3}$	84.8%	$7.98e^{-3}$ (0.1%)↑	85.0%	$7.99e^{-3}$ (0.2%)↑	85.0%

Lower pH due to OA and lower salinities lead to increases in free metal ion activity of some important metal contaminants. Changes in metal speciation affects bioavailability and uptake as well as circulatory transport, metabolism, sequestration, and elimination.

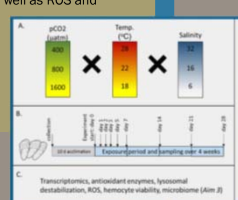


Differentially expressed genes in juvenile American Lobster reared under OA and increased temperature include those associated with calcification and cuticle production which were upregulated under low pH/high temperature.

Molecular biomarkers of stress in Eastern Oysters reveal integrative impacts of elevated pCO_2, temperature, and salinity fluctuations. Frequent sampling in the first week of exposure enabled us to follow the stress response of oysters across the three stages of the GAS (i.e. alarm, acclimation, exhaustion), while sampling at 2, 3, and 4 weeks monitors longer term biomarker responses. Stress response endpoints include transcriptomics as well as ROS and changes in the oyster microbiome.

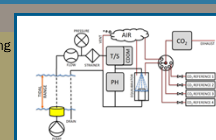


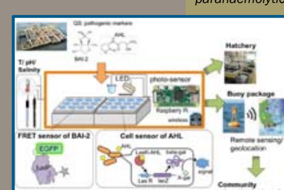
Net calcification is negatively impacted in some species with associated increases in taurine relative to glycine in the haemolymph. Glycine is critical for calcification as it provides a nucleation site for $CaCO_3$ deposition. Taurine promotes calcification under redox associated metabolic stress. Increases in Taurine relative to glycine accompanying decreased net calcification suggests animals are under oxidative stress and are shifting effort into maintaining calcification using the sulfur pathway.



Field and Lab-based Sensors

Leveraging the quorum chemical communication among bacterial paper-based and Fluorescence Resonance Energy Transfer (FRET) allow for rapid real-time detection of pathogenic bacteria including *V. parahaemolyticus*.



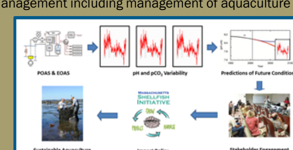


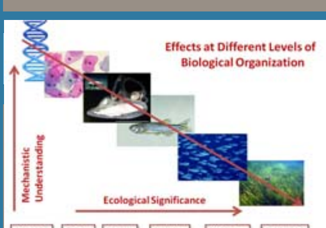
Paper-based sensors use plasmids to sense target and non-target quorum sensing molecules such as N-acyl homoserine lactones (AHLs) with detection by a shift from gray to blue on the paper and read-out by LED and photoresistors.

A FRET sensor is used to detect BAI-2, secreted by pathogenic vibrios.

Dockside ocean acidification sensor measures pH and pCO_2 every 10 minutes. Pumps surface seawater through a Sunburst AFT-pH sensor that uses a colorimetric indicator for accurate pH measurements and a Sunburst SuperCO_2 equilibrator system with equilibrated air measured with a LiCOR CO_2 sensor. Telemetry allows remote real-time data collection and display.

The dockside system, integrated with pathogen sensors, provides essential data for coastal zone management including management of aquaculture sites.

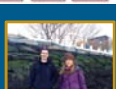


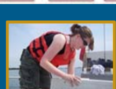


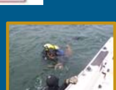
Future Work

Ultimately the goal of the OA research at UMass Boston is to understand the impact of OA along the biological continuum through fundamental research. Linking understanding of genetic and biochemical responses to climate change induced stress to mechanistic understanding of these effects on structural and function of organismal systems to impacts on commercially relevant marine populations will enable a holistic exploration of ecosystem-level impacts that are informed by real-time monitoring of both environmental conditions and animal health outcomes.

The work is embedded in a central focus of working collaboratively with recreation and commercial harvesters as well as coastal zone managers to ensure translation of the science into informed and actionable policy and regulations that protect and conserve essential habitats and populations while enhancing economic development.







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