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Repeat Exposure to Hypercapnic Seawater Modifies Performance and Oxidative Status in Tolerant Burrowing Clam

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Abstract:

Moderate oxidative stress is a hypothesized driver of enhanced stress tolerance and lifespan. Whereas thermal stress, irradiance, and dietary restriction show evidence of dose-dependent benefits for many taxa, stress acclimation remains understudied in marine invertebrates, despite being threatened by climate change stressors such as ocean acidification. To test for life-stage and stress-intensity dependence in eliciting enhanced tolerance under subsequent stress encounters, we initially conditioned pediveliger Pacific geoduck (Panopea generosa) larvae to (i) ambient and moderately elevated pCO2 (920 µatm and 2800 µatm, respectively) for 110 days, (ii) secondarily applied a 7-day exposure to ambient, moderate, and severely elevated pCO2 (750 µatm, 2800 µatm, and 4900 µatm, respectively), followed by 7 days in ambient conditions, and (iii) implemented a modified-reciprocal 7-day tertiary exposure to ambient (970 µatm) and moderate pCO2 (3000 µatm). Initial conditioning to moderate pCO2 stress followed by secondary and tertiary exposure to severe and moderate pCO2 stress increased respiration rate, organic biomass, and shell size suggesting a stress-intensity-dependent effect on energetics. Additionally, stress-acclimated clams had lower antioxidant capacity compared to clams under initial ambient conditions, supporting the hypothesis that stress over postlarval-to-juvenile development affects oxidative status later in life. We posit two subcellular mechanisms underpinning stress-intensity-dependent effects on mitochondrial pathways and energy partitioning: i) stress-induced attenuation of mitochondrial function and ii) adaptive mitochondrial shift under moderate stress. Time series and stress intensity-specific approaches can reveal life-stages and magnitudes of exposure, respectively, that may elicit beneficial phenotypic variation.

Keywords: hormesis, ocean acidification, oxidative stress, phenotypic variation, stress acclimation, geoduck