# Early life physiological and energetic responses of Atlantic silversides (*Menidia menidia*) to ocean acidification, warming, and hypoxia

A Dissertation Presented by

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to

The Graduate School

in Partial Fulfillment of the Requirements

for the Degree of **Doctor of Philosophy** in

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Abstract of the Dissertation

# Early life physiological and energetic responses of Atlantic silversides (*Menidia menidia*) to ocean acidification, warming, and hypoxia

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Global environmental change caused by human actions is making the oceans warmer, deoxygenating coastal waters, and causing acidification through dissolution of atmospheric carbon dioxide (CO2). Understanding physiological mechanisms of fish responses to multiple co-occurring stressors is critical to conservation of marine ecosystems and the fish populations they support. In this dissertation I quantified physiological impacts of near-future levels of multiple stressors in the early life stages of the Atlantic silverside, Menidia menidia. In Chapter 1, I measured routine metabolic rates of embryos and larvae reared in combinations of temperature, CO2, and oxygen levels. An interactive effect of acidification and hypoxia in embryos prompted closer examination in Chapter 2, in which I characterized the relationship between metabolism and acute hypoxia in M. menidia offspring reared in different CO2 levels. In Chapter 3 I examined the density of skin surface ionocytes, cells used for acid-base balance, as an early life mechanism of high CO2 tolerance. The first three chapters highlighted how different CO2 effects could be depending on temperature, oxygen levels, and life stage. They also showed variable, but often high, tolerance of CO2 with stronger effects of temperature and hypoxia on physiology. Finally, in Chapter 4 I used a Dynamic Energy Budget model to identify the processes of energetic allocation responsible for previously observed experimental hypoxia effects on M. menidia hatching, growth, and survival. Energy budget modeling can enhance knowledge about stressor responses by providing the information to link organismal traits to life history and populations, making it more readily applicable to conservation and management. The findings presented here provide a foundation for a more comprehensive understanding of the highly variable effects of global change on M. menidia and should be applied to quantifying impacts on fitness and population growth in this ecologically important species.

This dissertation is dedicated to my partner and best friend, Max Grabinski. He has been by my side and supported me in more ways than I could have imagined througho

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