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High P_{CO2} does not alter the thermal plasticity of developing Pacific herring embryos during a marine heatwave

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Abstract:

Forage fish tend to respond strongly to environmental variability and therefore may be particularly sensitive to marine climate stressors. We used controlled laboratory experiments to assess the vulnerability of Pacific herring (*Clupea pallasii*) embryos to the combined effects of high partial pressure of carbon dioxide (P_{CO2}) and a simulated marine heatwave. The two P_{CO2} treatments reflected current conditions (~550 µatm) and a future extreme level (~2300 µatm). The dynamics of the heatwave (i.e. rate of onset: ~0.85°C day^{-1}; maximum intensity: +4.4°C) were modeled from the most extreme events detected by a long-term regional temperature dataset. Simultaneous exposure to these potential stressors did not affect embryo survival. However, the heatwave did elicit significant metabolic effects that included higher rates of routine metabolism (Q_{10}=1.15–1.72), growth (Q_{10}=1.87), rate of development to hatch (Q_{10}=3.01) and yolk consumption (Q_{10}=3.21), as well as a significant reduction in production efficiency (−10.8%) and a three-fold increase in the rate of developmental anomalies. By contrast, high P_{CO2} conditions produced comparatively small effects on vital rates, including a significant increase in time to hatch (+0.88 days) and a reduction in routine metabolic rate (−6.3%) under the ambient temperature regime only. We found no evidence that high P_{CO2} increased routine metabolic rate at either temperature. These results indicate that Pacific herring embryos possess sufficient physiological plasticity to cope with extreme seawater acidification under optimal and heatwave temperature conditions, although lingering metabolic inefficiencies induced by the heatwave may lead to important carryover effects in later life stages.

Keywords: ocean acidification, extreme climatic events, Clupea pallasii, early life history, metabolic rates, embryogenesis, survival