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Impact of ocean warming and ocean acidification on marine invertebrate life history stages: vulnerabilities and potential for persistence in a changing ocean

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Global warming and increased atmospheric CO_2 are causing the oceans to warm, decrease in pH and become hypercapnic. These stressors have deleterious impacts on marine invertebrates. Marine invertebrate propagules live in a multistressor world and climate change stressors are adding to the mix. Ocean pH, pCO_2 and $CaCO_3$ covary and will change simultaneously with temperature, challenging our ability to predict future outcomes for marine life histories. Available data show that invertebrate embryos are highly sensitive to warming while later stage calcifying larvae are sensitive to acidification. Embryos that develop through the bottleneck of mortality due to warming may succumb as larvae to acidification. Early juveniles may be vulnerable to skeletal dissolution, although warming may diminish the negative impact of acidification on calcification. Multistressor experiments show if thermal thresholds are breached, embryos may not reach the calcifying stage. Thus, if the bottleneck for species persistence is embryonic thermotolerance than the question of compromised calcification due to acidification is less relevant. The effects of climate change stressors and their interaction differs among life history stages and species. This has implications for species persistence and community function in a changing ocean.