Adaptive capacity of the sea urchin *Heliocidaris erythrogramma* to ocean change stressors: transgenerational responses from gamete performance to the juvenile

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Background

To predict impacts of ocean acidification (OA) and warming (OW) on the responses of marine populations, it is important to determine an organism's capacity for phenotypic plasticity and genetic adaptation.

The gametes of male and female sea urchins can be isolated for experimental matings, making it possible to compare the performance of offspring genotypes in different environments. The North Carolina II (NC II) (Fig. 1) where males and females are crossed in all combinations, allows variance in traits within a population to be partitioned into additive, maternal, interactive and environmental components.

We used the short development time of the sea urchin *H. erythrogramma,* as a model system to assess the response of genotypes to OW and OA to the benthic juvenile using the NC II design.

Methods

The effects of near-future OA and OW on *H. erythrogramma* from fertilisation to metamorphosis in the progeny of 16 sire-dam crosses was investigated. Sources of variation in tolerance to OW (+3ºC) and OA (-0.3-0.5 pH units) were investigated for fertilisation, larval success and metamorphosis. Spine number was used as a proxy for calcification across all genotypes and treatments.

Results

- For the 16 genotypes, fertilisation was affected by OW, but not OA. Larval development was affected by OA, but not OW. By metamorphosis, no impact of OW or OA was evident.
- Juveniles showed a similar ability to calcify across all treatments
- Reaction norms for pairs show a resilient subset of genotypes (Fig. 2), however the ranking of pair performance across life history stages (Fig. 3) showed that genotypes that had a high fertilisation success did not subsequently have the highest % of normal larvae.

Major Findings

★Maternal and parental pair effects have the strongest influence on *H. erythrogramma* development where maternal buffering and male-female pairs with high tolerance to stressors will allow for adaptation.
★The effects of environmental stressors and contributions of male and female change throughout the life cycle of a sea urchin, and transgenerational effects across life-history stages could be significant in reducing the impacts of stressors.

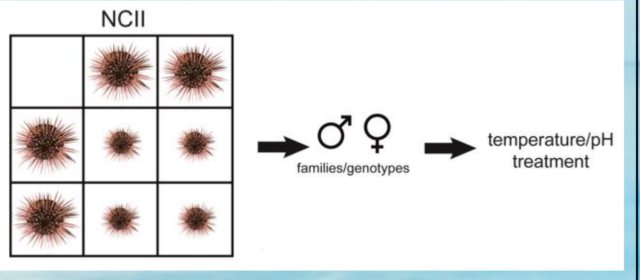

Figure 1. **The North Carolina II design.** The design involves mating N_M males with N_F females in all combinations giving M x F different genotypes. The example shows that fully crossing two females with two males results in four possible genotypes. For a tractable and robust design, this needs to be repeated in blocks to create large numbers of genotypes for analysis.

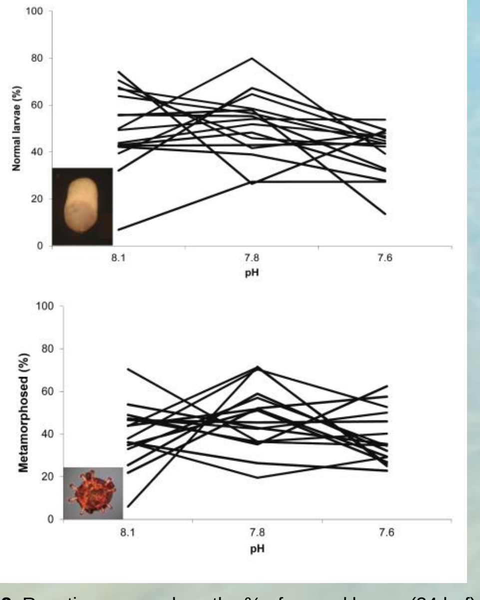

Figure 2. Reaction norms show the % of normal larvae (24 hpf) (top panel) and juveniles (96 hpf) (bottom panel) across *H. erythrogramma* offspring of the 16 male-female pairs in response to experimental pH levels pooled for temperature. Lines represent the mean percentage for each pair (n = 16).

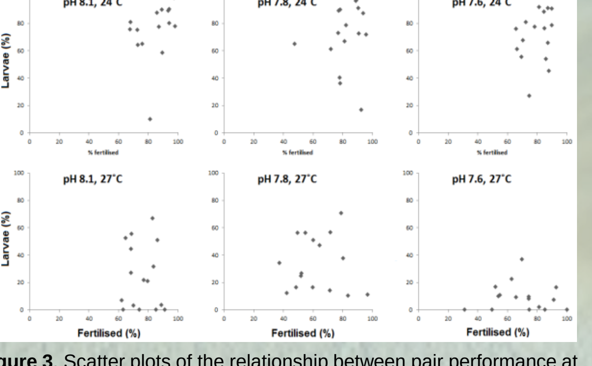

Figure 3. Scatter plots of the relationship between pair performance at fertilisation (y-axis) and larvae (x-axis) of *H. erythrogramma*. Each point represents the mean performance of an individual pair (16 in total) across both stages for each treatment. No relationships were evident for any of the six treatments.