Impacts of future ocean acidification on the ecology of two sea urchin species

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Introduction

Ocean acidification (OA) is a process where carbonate chemistry is altered due to the increase in anthropogenic atmospheric CO_2. Calcifying organisms are generally negatively affected by OA, with sea urchins particularly sensitive to the altered conditions showing reduced growth and survival (Harvey et al. 2013). Sea urchins are key benthic macroherbivores in contemporary systems, playing an important role in the maintenance and control of habitat structure and composition (Baggini et. al., 2015). Despite their importance, the effects of OA on the ecological role of urchins are still not well-known. Here, we assess how OA affects the ecology of two locally important urchin species (*Echinometra* sp. and *Diadema setosum*) using a CO_2 seep in Shikine-jima (natural analogue for future OA).

Material & Methods

The effects of OA on urchins were considered under two temporal scales, acute exposure (1-month aquarium experiment under OA compared to control conditions) and chronic exposure (lifetime residing in CO_2 seep compared to adjacent bay under contemporary conditions). For acute exposure, urchins were individually held for one-month under control- (pH_T ~8.15), mid- (pH_T ~7.90), or high- (pH_T ~ 7.70) CO_2 conditions (n = 8 per treatment). Both urchin species were tested separately. For chronic exposure, individuals from the CO_2 seep site (pH_T ~7.80) and adjacent bay (pH_T ~8.15) were collected (n = 8 per site) and maintained under their respective conditions while measurements (described below) were taken. Only *Echinometra* sp. were tested for chronic exposure due to the extremely low abundance of *D. setosum* in the CO_2 seep area (0.02 individuals m^{-2}). At the end of all experiments, metabolism (O_2 consumption), feeding rate, and the gonadal somatic index (GSI) via dissection were measured, as well as size, and growth (changes in wet weight).

Results

Under acute exposure, both *Echinometra* sp. and *D. setosum* demonstrated similar metabolic rates, GSI and growth rates under all treatments (control-, mid-, and high-CO_2). Feeding rates, however, did differ; for *Echinometra* sp., there was a two-fold increase in mean feeding rates (albeit non-significantly, p = 0.274) under high-CO_2 conditions compared to control-CO_2 conditions (with mid-CO_2 similar to control). For *D. setosum*, however, feeding rates were significantly suppressed (p = 0.017) under high-CO_2 conditions compared to control conditions. When considering the longer-term (chronic) exposure to elevated CO_2 conditions, *Echinometra sp.* individuals showed a significant two-fold increase in their metabolic rate (p = 0.006) and 1.5-fold increase in their GSI (p = 0.003), but no differences between treatments for feeding rate or growth.

Discussion

Exposure to OA conditions resulted in different responses for the urchin *Echinometra* sp., with acute exposure leading to increased feeding rates while metabolic rates remained stable, and chronic exposure causing higher metabolic rates without a corresponding increase in feeding. These suggest that while greater feeding rates may compensate for increased energy demands under acute conditions, this was insufficient when exposed to OA for extended (chronic) periods (termed an energetic mismatch). *D. setosum* individuals also appeared to have their feeding rate altered by exposure to OA, with their feeding rate suppressed when they were exposed to short-term elevated CO_2 conditions. This would suggest that unlike *Echinometra* sp. they are unable to behaviorally compensate even on the short-term, which may contribute towards their particularly low abundance in the CO_2 seep area. Reductions in available energy (due to increased metabolism or decreased feeding rates) can reduce the ability of organisms to properly maintain bodily functions, requiring them to alter their energy allocations, with long-term implications for population survival. Here, urchins exposed to (chronic) high-CO_2 conditions were smaller but had a significantly greater GSI. While this may simply be a shift in reproductive timing between the sites, this may also represent a terminal investment, where reproduction is favoured over individual survival. Taken together, our results suggest that while some species-specific responses may exist, OA will generally cause energetic mismatches and altered energy allocations in urchins, leading to potential long-term impacts on population survival. Given that urchins play a crucial role in controlling habitat structure and composition, declines in their feeding rates and/or population survival will hinder their ability to perform this role, potentially having significant impacts on the future health of coastal ecosystems.

References

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