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Fish responses to ocean acidification comes with a cost

Ocean acidification is currently recognized as a major threat to marine ecosystems and has become one of the fastest growing research fields in marine sciences. The excessive amount of anthropogenic carbon dioxide is making our oceans warmer and more acidic, by changing its basic chemistry. Since the industrial revolution era, ocean water has become 30% more acidic – faster than any known change in ocean chemistry for the last 300 million years. Present predictions indicate that with the current carbon dioxide emissions, this acidity values may double until the end of this century, comparing to pre-industrial times. This profound and abrupt change in ocean chemistry can lead to a multitude of cascading effects in different ecosystems. Many of the physiological changes expected to occur may affect particular key functional groups of species such as phytoplankton (the base of marine food webs) and ecosystem engineers (responsible to create and modify habitats) like corals. These are good examples of calcifying marine groups, which are known to be particularly susceptible to ocean acidification due to their dependence on calcium carbonate (an element that is scarce under acidified conditions) to build their exoskeleton. Nonetheless, the tolerance and sensitivity of other marine organisms to changes imposed by ocean acidification is becoming increasingly evident.

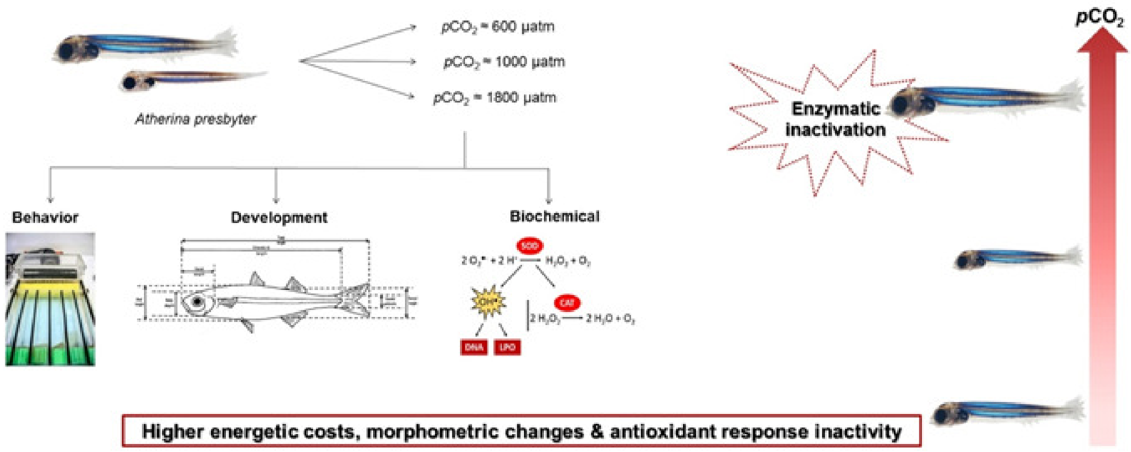

Fig. 1. The exposure to higher pCO2 levels may lead to changes in morphometric sizes associated with activation/disruption of antioxidant response mechanisms, impairing the internal balance of sand smelt larvae.

Coastal ecosystems species, including fish, are exposed to environmental stress caused by natural factors (e.g., upwelling, biological activity), but also anthropogenic pressures (e.g., organic and nutrient input, toxic and metal compounds, overfishing). Thus, acting synergistically with other stressors, impacts on organisms may increase under acidification scenarios. Due to the particular sensitivity of early life stages to environmental changes, recent studies have been reporting dramatic impacts of ocean acidification on larval and juvenile stages, including reduced growth, impaired social interactions and neurological functions, and increased mortality. These disturbances may have substantial impacts on settlement, recruitment, connectivity and population replenishment, leading to changes at higher levels of biological and ecological relevance.

This study aimed to evaluate impacts of exposure to simulated ocean acidification scenarios on swimming behavior, development and biochemical responses on larval stages of sand smelt (*Atherina presbyter*), a temperate fish species with economic and ecological interest. Wild larvae were caught and maintained in laboratory controlled conditions under three treatment conditions – Control: ~ 600 µatm, pH=8.03; Medium: ~ 1000 µatm, pH=7.85; High: ~ 1800 µatm, pH=7.64 – for a maximum exposure period of 15 days, after which swimming behavior was tested and morphological and biochemical analysis performed (oxidative stress and energy metabolism related parameters).

Swimming was unaffected by exposure to these treatments, but exposure to increasing levels of acidification suggests the impairment of internal balance capacity of sand smelt larvae. Organisms of medium treatment presented smaller sizes, but an efficient antioxidant response capacity (protection mechanisms for cellular integrity) and an increase in energetic metabolism, in contrast with larvae of higher treatment, which presented larger sizes but no antioxidant response capacity. Our results indicate that larvae in medium treatment may be allocating more energy to cellular defense strategies in order to compensate and adjust to the imposed variations, leaving less energy available to allocate to other important functions like growth. The opposite happened with larvae exposed to higher levels of acidity: the stress imposed might have overpassed larvae capacity to restore their internal balance. Antioxidant enzymes became inactivated and so, higher levels of energy allocated for a growth strategy.

In future ocean acidification scenarios, marine organisms may be subjected to an increasing demand of energy to ensure maintenance of physiological homeostasis. This energetic demand may come with a cost, likely affecting other processes such as growth, reproduction and ultimately, survival.

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