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Synergistic effects of ocean acidification and feeding history on energy demand in an Antarctic pteropod, Limacina helicina

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High internal PCO2 may affect numerous physiological processes, but a common response is the suppression of total energy consumption (i.e. metabolic suppression). The extent to which elevated PCO2 affects animal physiology is species- and condition-specific. Many species studied to date show no detectable effect on metabolism of the increases in CO2 expected under climate-change scenarios. However, CO2 is not changing in isolation and animal metabolism is strongly dependent on a variety of environmental variables and on the animal's own nutritional state. Climate change alters temperature and oxygen levels as well as CO2 and may influence feeding dynamics via effects on primary productivity and ecological interactions with less tolerant species. Here I present the metabolic effects of ocean acidification, detectable only under specific experimental conditions. Importantly, these conditions do occur in nature but are rarely mimicked in the lab. Recent evidence suggests that energy limitation also plays a large role in the response of animals to elevated CO2 and that enhanced nutrition can ameliorate the effects in some cases. The shelled pteropod, Limacina helicina, is an ecologically important grazer, widely viewed as an indicator of ecosystem health in polar oceans. We examined the metabolic rate of L. helicina antarctica, over 6 seasons, and determined the effect of feeding history, body size, temperature and carbon dioxide. In seasons with low regional productivity, metabolism was suppressed and CO2 had no further effect. However, during seasons with elevated productivity, metabolism was high but strongly and negatively ($\sim$30%) impacted by elevated CO2 (790 ppm) relative to controls (380 ppm). The CO2-induced metabolic suppression is equivalent to that caused food deprivation, which has been linked to delayed spawning and local extinction. Thus, food deprivation and CO2 act independently, not additively, to limit metabolism with likely fitness consequences for the species and its predators. Without the context provided by our long-term observations, the effects of ocean acidification would have been overlooked or confounded by feeding effects. The reported inconsistency in the short-term response of marine organisms to CO2 alone is, thus, not surprising. We emphasize the need for long-term physiological monitoring and the inclusion of multiple stressors into analyses for accurate assessment of the impacts of ocean acidification.