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The combined effects of acidification and hypoxia on pH and aragonite saturation in the coastal waters of the California current ecosystem and the northern Gulf of Mexico

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ABSTRACT

Inorganic carbon chemistry data from the surface and subsurface waters of the West Coast of North America have been compared with similar data from the northern Gulf of Mexico to demonstrate how future changes in CO_2 emissions will affect chemical changes in coastal waters affected by respiration-induced hypoxia ($[O2] \leq \sim 60$ µmol kg^{-1}). In surface waters, the percentage change in the carbon parameters due to increasing CO_2 emissions are very similar for both regions even though the absolute decrease in aragonite saturation is much higher in the warmer waters of the Gulf of Mexico. However, in subsurface waters the changes are enhanced due to differences in the initial oxygen concentration and the changes in the buffer capacity (i.e., increasing Revelle Factor) with increasing respiration from the oxidation of organic matter, with the largest impacts on pH and CO_2 partial pressure (pCO_2) occurring in the colder West Coast waters. As anthropogenic CO_2 concentrations begin to build up in subsurface waters, increased atmospheric CO_2 will expose organisms to hypercapnic conditions (pCO_2 > 1000 µatm) within subsurface depths. Since the maintenance of the extracellular pH appears as the first line of defense against external stresses, many biological response studies have been focused on pCO_2-induced hypercapnia. The extent of subsurface exposure will occur sooner and be more widespread in colder waters due to their capacity to hold more dissolved oxygen and the accompanying weaker acid-base buffer capacity. Under present conditions, organisms in the West Coast are exposed to hypercapnic conditions when oxygen con-centrations are near 100 µmol kg^{-1} but will experience hypercapnia at oxygen concentrations of 260 µmol kg^{-1} by year 2100 under the highest elevated-CO_2 conditions. Hypercapnia does not occur at present in the Gulf of Mexico but will occur at oxygen concentrations of 170 µmol kg^{-1} by the end of the century under similar conditions. The aragonite saturation horizon is currently above the hypoxic zone in the West Coast. With in-creasing atmospheric CO_2, it is expected to shoal up close to surface waters under the IPCC Representative Concentration Pathway (RCP) 8.5 in West Coast waters, while aragonite saturation state will exhibit steeper gradients in the Gulf of Mexico. This study demonstrates how different biological thresholds (e.g., hypoxia, CaCO3 undersaturation, hypercapnia) will vary asymmetrically because of local initial conditions that are af-fected differently with increasing atmospheric CO_2. The direction of change in amplitude of hypercapnia will be similar in both ecosystems, exposing both biological communities from the West Coast and Gulf of Mexico to intensification of stressful conditions. However, the region of lower Revelle factors (i.e., the Gulf of

Mexico), currently provides an adequate refuge habitat that might no longer be the case under the most severe RCP scenarios.

Full Text

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