The consequences of ocean acidification for organisms

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Background:

As most ecosystems are wont to do, the ocean has a series of checks and balances governing the various environments that organisms find themselves in. One such system is called the **carbonate buffering system**. There are many elements and compounds dissolved in the world's oceans, chief among them, carbon dioxide (CO_2). When CO_2 dissolves in seawater, it reacts to form carbonic acid (H_2CO_3) (1). Carbonic acid can disassociate to form bicarbonate (HCO_3^-) (2) and bicarbonate can then disassociate to form carbonate ions (CO_3^{2-}) (3).

Organisms use bicarbonate to form the compound calcium carbonate ($CaCO_3$) (4), which they utilize in building skeletons as in coral reefs, or protective shells as in snails. For that reason alone, bicarbonate is an extremely important component of the dissolved materials in the ocean.

However, carbonate ions are also very important, for they are chiefly responsible for buffering the ocean against changes in pH. If an acid is added to seawater, the carbonate ion ties up the excess H^+, which results in the production of carbonic acid (5). If a base is added, carbonic acid will donate hydrogen ions, which neutralize the excess OH^-. In this way, carbonate ions regulate the pH of seawater.

However, all of these reactions are reversible, meaning if any one of these compounds is increased, it will shift the reaction in the opposite direction. If more CO_2 were added to the right side of equation 4, it would shift the reaction to the left. This results in decalcification (6), which is not ideal for organisms that use calcium carbonate for skeletal support or protection.

$$CO_2 + H_2O \rightarrow H_2CO_3 \tag{1}$$

$$H_2CO_3 \rightarrow H^+ + HCO_3^- \tag{2}$$

$$HCO_3^- \rightarrow H^+ + CO_3^{2-} \tag{3}$$

$$2HCO_3^- + Ca^{2+} \rightarrow CaCO_3 + CO_2 + H_2O \tag{4}$$

$$CO_3^{2-} + H_2SO_4 \text{ (sulfuric acid, for example) } \rightarrow H_2CO_3 + SO_4^{2-} \tag{5}$$

$$CaCO_3 + CO_2 + H_2O \rightarrow 2HCO_3^- + Ca^{2+} \tag{6}$$