Biological mechanism for enhanced carbon consumption in the ocean

Throughout Earth's history, the ocean has played a crucial role in modulating atmospheric carbon dioxide through a variety of physical, chemical and biological processes. The same processes are involved in the ocean's response to anthropogenic perturbations of the global carbon cycle. A key process responsible for about three quarters of the surface to deep-ocean gradient in dissolved inorganic carbon (DIC) is the biological carbon pump. This transports carbon bound by photosynthesis from the sunlit surface layer to the deep ocean. Integrated over the global ocean, the biotically-driven surface to deep-ocean DIC gradient corresponds to a carbon pool 3.5 times larger than the total amount of atmospheric carbon dioxide. Hence, small changes in this pool, for example, caused by biological responses to ocean change, would have a strong affect on atmospheric CO_2.

At present, one of the most far-reaching global perturbations of the marine environment is caused by the massive invasion of fossil fuel CO_2 into the ocean, making it the second largest sink for anthropogenic carbon dioxide after the atmosphere itself. CO_2 entering the ocean alters the seawater carbonate equilibrium, increasing seawater acidity and shifting dissolved inorganic carbon away from carbonate towards more bicarbonate and CO_2. For a 'business-as-usual' emission scenario, the CO_2 concentration will rise by about a factor of two relative to the present value (380 µatm) by 2100, and could increase by a factor of three by the middle of the next century. Changes in seawater chemistry of this magnitude in laboratory experiments are found to have adverse effects on calcifying organisms and to stimulate carbon and nitrogen fixation in some groups of photosynthetic organisms. Presently, little is known about the responses of natural marine ecosystems to CO_2 enrichment.

To investigate the effects of rising CO_2 on a natural plankton community, a mesocosm CO_2 perturbation study was conducted in the Raunefjord in southern Norway (Riebesell et al., 2007).

Fig. 1: Mescosm facility in the Raune Fjord, Norway.

Nine enclosures, each containing 27m^3 of ambient water, were aerated with CO_2-enriched air to achieve concentrations of 350 µatm (1xCO_2), 700 µatm (2xCO_2) and 1,050 µatm (3xCO_2). After nutrient addition, the development and decline of a plankton bloom was monitored over 24 days.

The enclosed plankton community responded quickly to the CO_2 enrichment by increasing photosynthetic CO_2 uptake. The community consumed up to 39% more dissolved inorganic carbon at increased CO_2 partial pressures compared to present levels, whereas nutrient uptake remained the same. The stoichiometry of carbon to nitrogen drawdown thereby increased from 6.0 at low CO_2 to 8.0 at high CO_2, thus exceeding the Redfield carbon:nitrogen ratio of 6.6 in today's ocean. This excess carbon consumption was associated with higher loss of organic carbon from the upper layer of the stratified mesocosms.

The CO_2 fertilization of marine plankton can have a positive effect on climate change in the future. The greenhouse gas consumed by plankton and removed from the surface ocean when the dying cells sink to depth makes way for the uptake of more CO_2. In a way, the tiny organisms act as a biological conveyer

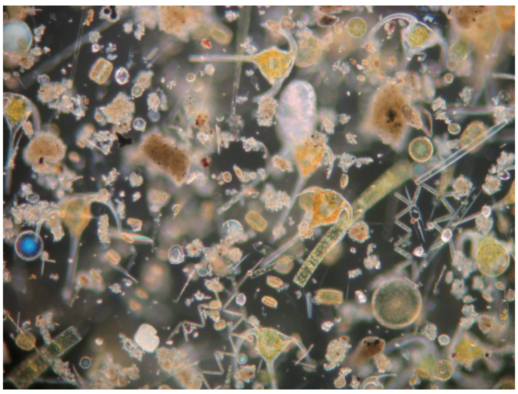

Fig. 2: Micoalgae under the microscope: CO_2 consuming plankton. Photo: A. Stuhr, IFM-GEOMAR.

belt for the transport of carbon dioxide out of the surface and into the deep ocean. However, what appears to be a blessing for the atmospheric greenhouse effect may prove to be a curse for deep ocean ecosystems. Decomposition of the increased biomass will consume more oxygen, a major problem for marine animals that occupy deep habitats. Another consequence of the biological conveyer belt is the accelerated rate of ocean acidification in the deep ocean due to more rapid transport of CO_2 to depth. Increasing carbon-to-nutrient ratios would also lower the nutritional value of primary-produced organic matter, which may affect the efficiency of bacterial degradation and zooplankton reproduction, thus having further implications for marine ecosystem dynamics.

The results of this study probably represent only the tip of the iceberg of climate-sensitive biogeochemical processes. Other biotically-driven feedback mechanisms responsive to ocean change are bound to emerge as studies continue. It is essential not only to identify and to understand these mechanisms, but also to quantify their effect on the global climate system, now and in the future.

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Reference

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