Fertilizing the Ocean with Iron

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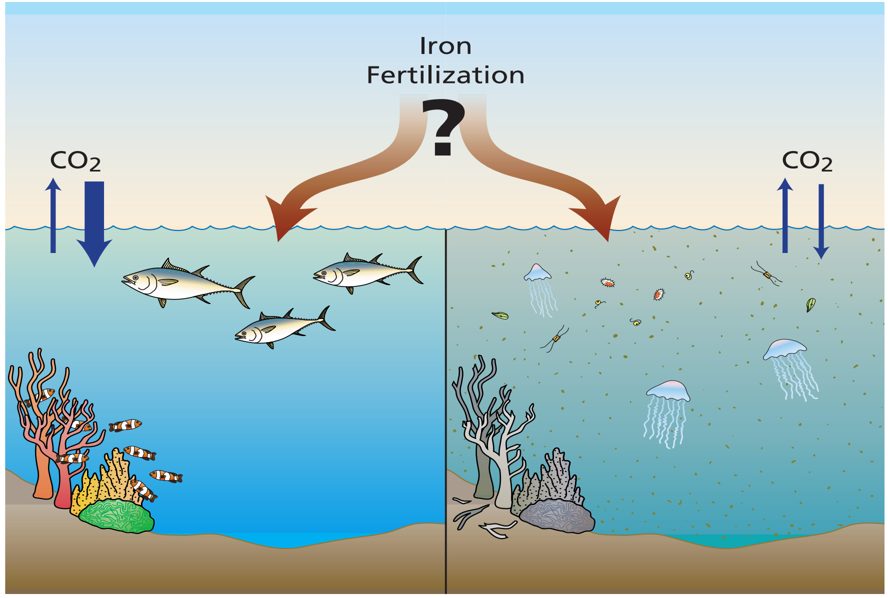
Iron fertilization of the ocean is a hot topic not only within the ocean research community but also among ocean entrepreneurs and venture capitalists who see the potential for enhancing fisheries through large-scale ocean manipulations. In the 1980s, the late John Martin (Moss Landing Marine Laboratory) advanced the idea that carbon uptake during plankton photosynthesis in many regions of the world's surface ocean was limited not by light or the major nutrients nitrogen or phosphorus but rather by a lack of the trace metal iron, which is typically added to the open ocean as a component of dust particles. Laboratory experiments and correlations between dust and atmospheric carbon dioxide levels in ancient ice core records suggested that the ocean would respond to natural changes in iron inputs by increasing carbon uptake and hence decreasing atmospheric carbon dioxide, thus altering the greenhouse gas balance and climate of the earth. Martin once dramatically said: "Give me half a tanker full of iron and I'll give you an ice age."

In two 1990s experiments, US investigators led by Ken Coale (Moss Landing Marine Laboratory) purposely "fertilized" a large patch of water near the equatorial Pacific with iron. The results showed a strong biological response and a chemical drawdown of carbon dioxide in the water column.

But what was the fate of this carbon? We know that plant uptake of carbon in the ocean is generally followed by a zooplankton bloom as grazers respond to the increased food supply. These populations then produce a blizzard of marine snow, as fecal pellets and other particles descend through the water column, carrying or "exporting" their carbon load to the deep sea in



Jack Cook

Potential long-term outcomes for iron fertilization of the ocean are unknown, and could include newly productive fisheries and reduced atmospheric carbon dioxide (left) or a polluted ocean, unenhanced fisheries, and little effect on atmospheric carbon dioxide (right).

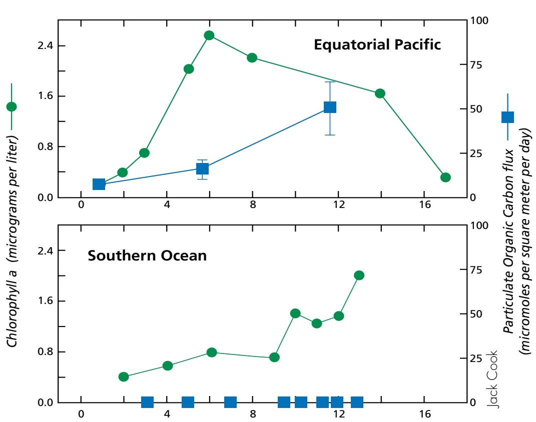
a process known as the "biological pump." Drawing on many years' experience working with thorium in seawater, my laboratory colleagues and I are studying the decrease in surface water thorium following iron fertilization as a proxy for carbon export from the surface to the deep sea. Thorium is a naturally occurring element that by its chemical nature is "sticky," and, due to its natural radioactive properties, relatively easy to measure.

Analysis of a series of seven surface water samples, collected during a 1995 experiment called FeExII, told us that, indeed, as iron was added and plant biomass (measured as chlorophyll) increased, there was a corresponding decrease in total thorium levels. We used the measured thorium decrease to quantify the increase in particulate organic carbon export as particles sank out of the surface layer (upper graph below), noting an interesting delay between the uptake of carbon by the plants and its export as sinking particulate organic carbon. We also noted that the relationship between uptake and export was not 1:1, but rather the iron-stimulated biological community showed very high ratios of export relative to carbon uptake. Thus by the end of the experiment, the efficiency of the biological pump had increased dramatically.

However, results of a similar iron fertilization experiment led by Phil Boyd (University of Otago, New Zealand) during the 1999 summer season in waters south of Australia were very different. The biological response was much slower and less dramatic, and total thorium levels never responded, indicating that the biological pump was not activated (lower graph). We speculate that the difference is due to the colder waters and the resulting slowness of the biological community's response to stimulation. Whether the biological pump turned on after we left the site is a more complicated question, but for now we cannot say that simply adding iron to these waters will result in enhanced removal of atmospheric carbon dioxide to the deep ocean.

The delays in export after an iron-stimulated bloom fits with some of our recent thorium studies in natural systems in the Arabian Sea and in waters around Antarctica. Further work on the effects of iron fertilization in Antarctic waters is scheduled for early 2002. This time we hope to follow the response for 20 to 30 days with a large team of US scientists. In the meantime, the pressure to try something on an industrial scale is mounting and likely to take place with or without scientific input as entrepreneurs gather permits and patent processes for fertilizing the ocean with iron on a large scale.

For example, the territorial waters of the Marshall Islands have been leased to conduct an iron fertilization experiment. The new businesses involved suggest that the iron fertilization process will reduce atmospheric carbon dioxide levels, allowing the Marshall Islands (and other island countries) to profit by trading carbon credits with more industrialized nations. They also point to increased fisheries as a consequence of enhanced iron levels. Prior to these large scale manipulations, more dialogue is needed between these commercial interests, economists, national governments with a marine interest, climate modelers, fisheries biologists, and ocean scientists. While dumping iron may not produce an ice age, it is likely to alter the ocean in unforeseen ways. Whether we end up with productive fisheries and lower carbon dioxide levels, or a polluted ocean with new opportunistic species that do not support enhanced fisheries, is unknown.



Chlorophyll (green) and carbon flux (blue) response to iron fertilization in the Equatorial Pacific and Southern Ocean.