

Ocean fertilization: time to move on

Adding iron to the ocean is not an effective way to fight climate change, and we don't need further research to establish that, say **Aaron Strong, Sallie Chisholm, Charles Miller and John Cullen.**

In the face of seemingly accelerating climate change, some have proposed tackling the problem with geoengineering: intentionally altering the planet's physical or biological systems to counteract global warming. One such strategy — fertilizing the oceans with iron to stimulate phytoplankton blooms, absorb carbon dioxide from the atmosphere and export carbon to the deep sea — should be abandoned.

It is already commonly accepted that ocean iron fertilization should not be rushed into as a mitigation strategy. The Intergovernmental Panel on Climate Change regards it as supported by neither appropriate assessment of environmental side effects nor a clear institutional framework for implementation. Similarly, last year, two United Nations conventions passed resolutions restricting large-scale ocean iron fertilization activities, citing concerns about the environmental risks and lack of a scientific basis on which to justify such activities — concerns that have been recognized for some time. A Royal Society report released this month emphasized that the technique has a relatively small capacity to absorb carbon, and comes with “probably deleterious ecological consequences”.

Yet concerns about the profound consequences of global climate change have led to calls (see, for example, K. O. Buesseler *et al. Science* **319**, 162; 2008) for field studies of iron fertilization on larger and longer scales. Although we agree that the kinds of experiments being promoted have more to teach us about ocean processes, we argue that they will not resolve any remaining debate about the risks of iron fertilization for geoengineering. Engaging in experiments with the explicit purpose of assessing iron fertilization for geoengineering is both unnecessary and potentially counterproductive, because it diverts scientific resources and encourages what we see as inappropriate commercial interest in the scheme.

Global impact

The intended effect of ocean iron fertilization for geoengineering is to significantly disrupt marine ecosystems. The explicit goal is to stimulate blooms of relatively large phytoplankton that are usually not abundant, because carbon produced by such species is more likely to sink eventually to the deep ocean. This shift at the base of the food web would propagate



Modern commercial interests in ocean fertilization should not be confused with hypothesis-driven science such as the first IronEx experiment (shown).

throughout the ocean ecosystem in unpredictable ways. Moreover, nutrients such as nitrogen and phosphorus would sink along with the carbon, altering biogeochemical and ecological relationships throughout the system. Some models predict that ocean fertilization on a global scale would result in large regions of the ocean being starved of oxygen, dramatically affecting marine organisms from microbes to fish. Ecological disruption is the very mechanism by which iron fertilization would sequester carbon.

The specific effects of global-scale ocean fertilization are hard to predict, because the ocean's response is dependant on the scale at which such fertilization is done. Small-scale experiments are inherently inadequate to verify model predictions of the long-term side effects of global fertilization. Large-scale alteration of

the ocean would be needed to resolve fundamental uncertainties about environmental risks.

Ocean fertilization for climate mitigation would have to be widespread and cumulative over decades. Thus, properly field testing its geoengineering potential would entail fertilizing and sampling an enormous swath of ocean. Assessment would be needed for between decades and a century or so to demonstrate sequestration, and to document the downstream effects on ecosystem productivity — “nutrient robbing” as described in the Royal Society report — and oxygen depletion. Such a test would have to be implemented against the background of a dynamic ocean that would remain exposed to unprecedented climate change, making the impacts of iron fertilization difficult to extract from other ongoing

effects. In such a global experiment, there could be no 'control patch'.

Given that the efficacy and indirect effects of ocean fertilization for geoengineering cannot be tested directly without altering the ocean on unprecedented scales, we must resort to using global-ecosystem models to predict its promise and pitfalls. Many modelling analyses have shown that iron fertilization cannot reduce atmospheric CO₂ enough to significantly alter the course of climate change. A model published in 2008 (K. Zahariev *et al. Prog. Oceanogr.* 77, 56–82; 2008), which is as convincing as any available, found that even if the entire Southern Ocean were fertilized forever with iron sufficient to eliminate its limitation of phytoplankton production, less than 1 gigatonne of carbon a year of CO₂ of probable future emissions (currently about 8 gigatonnes a year) would be sequestered, and that amount for only a few years at best. This level of effort is simply not going to happen.

We think the idea of geoengineering by iron fertilization persists because of the blurry line between it and small-scale ocean fertilization experiments that address specific hypotheses.

The original goal of iron fertilization experiments was to answer fundamental questions about how iron and carbon are used and cycled in marine ecosystems. They began with a project called IronEx I in 1993. Since then, 11 experiments have been conducted in regions of the equatorial Pacific, subarctic Pacific, and Southern Ocean that have high levels of most nutrients but a relatively low phytoplankton biomass. The experiments confirmed the testable hypothesis that iron is the crucial limiting nutrient in these regions, and they provided insights into plankton community dynamics. They were conducted on a relatively small scale (less than 300 square kilometres) and over relatively short periods of time (less than 40 days), and had ephemeral effects on surface ocean ecosystems. These experiments fuelled the idea that iron fertilization, scaled up, might be used for geoengineering — even though they were not designed to investigate that possibility. This in turn prompted commercial interest in fertilizing the ocean to sell 'carbon credits'.

Setting rules

In response to concerns about the ecological impact of large-scale commercial iron fertilization, the UN Convention on Biological Diversity issued a decision in May 2008 requesting member states to restrict ocean iron fertilization activities, with the exception of small-scale studies. Several months later, the London

Convention on Marine Pollution issued a resolution stating that, given the present state of knowledge, ocean fertilization activities other than "legitimate scientific research" should not be allowed. These recommendations are a good start, but they are subject to interpretation. They do not resolve the blurred line between scientific hypothesis testing, and experiments focused on demonstrating geoengineering potential.

In January this year, for example, an experiment called LOHAFEX, which was designed to fertilize a small patch of the Southern Ocean with iron sulphate, was delayed for two weeks by the German government while it dealt with accusations from various environmental groups. The charge was that LOHAFEX was a dangerous 'geoengineering project' that violated the recent UN restrictions. It was allowed to proceed, after the scientists submitted environmental impact statements and the German government determined that it fell within UN regulations. But the episode illustrates the persistent ambiguity that surrounds these types of experiments.

It is time to disentangle the science of small-scale ocean fertilization from geoengineering. In our view, small-scale projects addressing testable hypotheses should proceed unimpeded by unnecessary controversy or regulation, whereas larger projects aimed at exploring the geoengineering potential of ocean fertilization should not be allowed, as they cannot resolve crucial issues about this mitigation strategy. Differentiating between these two types of experiments requires regulatory clarity.

Working groups from the London convention met in February 2009 to develop an assessment framework for ocean fertilization that will define what constitutes "legitimate scientific research" under their rules. The framework drafted at that meeting requested rigorous environmental risk assessments and mandated that all legitimate research must be driven by predefined hypotheses. The scientific group of the London convention has also started the process of defining the parameters for assessing the environmental impact of small-scale iron fertilization. Although the details, scope and enforcement mechanisms of these provisions are yet to be developed, this type of structured framework could help to avoid the kind of controversy that surrounded LOHAFEX.

Such exacting regulation is particularly important given the continuing interest in commercial iron fertilization for the sale of carbon offset credits. CLIMOS, a company based in San Francisco, California, has plans to

conduct its first moderate-scale (40,000 square kilometres) 'demonstration experiment' in the Southern Ocean. Although it remains unclear where, when or if actual commercial iron fertilization might eventually take place, CLIMOS has attracted substantial initial investment on the prospect of selling carbon offsets from activities such as iron fertilization activities. CLIMOS has publicly agreed that all ocean iron fertilization activities should proceed only where there is an adequate scientific basis to justify them, and has promised to obtain any necessary permits. But there remains a lack of clarity over what might constitute an adequate scientific basis for such activities, given the scale-dependency of the ecosystem response to fertilization.

As for producing 'carbon credits' from experimental studies at any scale, the Kyoto Protocol's Clean Development Mechanism does not recognize ocean fertilization as a way to create carbon credits for regulated international trade. Thus, carbon credits generated from such activities, however they might be quantified, would presumably have to be sold on the voluntary carbon market. The London convention process cannot regulate the generation of carbon credits, but it could determine that experiments that are used to generate credits would not be considered 'legitimate scientific experiments'. The London convention has not yet addressed this issue. Given continued commercial interest in conducting moderate-scale demonstration experiments, which may or may not be considered 'legitimate scientific experiments', it seems essential to answer this question explicitly.

We already know enough about how ocean systems function to say that iron fertilization on large scales will be disruptive to ocean ecosystems and is unlikely to be effective for climate mitigation. Continuing to justify small-scale iron fertilization experiments in the context of global-scale geoengineering distorts the focus of oceanographic science, and encourages for-profit companies to continue pursuit of this strategy. It is time to move on. ■

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