HOT TOPICS IN MARINE BIOLOGY 19.1

Is Iron Really a Fix?

Phytoplankton grow if there are enough nutrients and light. In most situations, phytoplankton growth is nutrient limited, and nitrogen was believed to be the limiting nutrient of overall marine primary production. The late John Martin, who discovered an apparent relationship between primary production in the northeastern Pacific and the abundance of iron, challenged this orthodox view successfully.* Martin added iron to bottles of phytoplankton, and primary production increased greatly. This finding may prove crucial in our understanding of global climate change. Data from cores taken in Antarctic glacial ice show a relationship between aluminum and atmospheric carbon dioxide. When aluminum is up, carbon dioxide is down. Because aluminum is often correlated with iron, we may have found the smoking gun of global climate control. An iron increase may stimulate primary production, which would increase the import of carbon dioxide from the atmosphere, in order to fuel photosynthesis. In this scenario, as organic carbon particles sank into the ocean, carbon dioxide would decrease and the greenhouse effect would decline as well.

In the Antarctic Ocean, phytoplankton growth seems not to be limited by nitrogen or phosphorus. Surface waters downwell and carry much unused dissolved nitrogen below the depths at which photosynthesis is possible. Some other nutrient must be limiting phytoplankton growth. That appears to be iron, which is an essential, if more minor, element, required in the synthesis of a number of proteins. The Antarctic Ocean may be able to be far more productive.

This potential could prove the source of inspiration for a massive experiment in global ecology. Over the last century, the burning of fossil fuels has increased the earth's atmospheric carbon dioxide by about a quarter, and there is good evidence that the earth warmed over that period. Was this due to burning of fossil fuels? We can't be sure, but it is dangerous to take the risk of inaction. Global warming will turn formerly rich and moist agricultural zones into deserts and will help melt glacial ice and drown many of the lowlands and coastal cities of the world. Deforestation is also a major problem because trees absorb carbon dioxide, and they are being removed and even burned at a rapid rate throughout the tropics. What to do?

Aside from energy conservation and reforestation, oceanographers have hit upon an idea to use the Antarctic Ocean as part of a global cure. The solution is to add thousands of tons of ground iron to the surface water, assuming that this will stimulate phytoplankton growth. The phytoplankton will grow, use up atmospheric carbon dioxide, and then sink to deeper waters, taking the carbon out of circulation from the world's cycle for a few hundred years, until global warming could be solved in some other way. This idea sounds good, but it is possible that some other factor limits primary production in the Antarctic Ocean. If it develops, for example, that the low light levels in the Southern Ocean limit production, iron may not enhance production significantly. However, an experiment performed in 1993† in the equatorial Pacific showed that iron addition strongly stimulated photosynthesis, so at least the hypothetical effect of iron on a large scale has been confirmed. The biological details may be important, since some types of phytoplankton (e.g., nitrogen-fixing bacteria) are far more dependent upon iron than other groups.

Alas, reality sets in. During the large-scale Southern Ocean iron experiment, Buesseler and colleagues‡ measured the flux of carbon from the surface layer following iron fertilization. The rate of sinking of carbon resembled what had been observed before in blooms in the Southern Ocean, which was small relative to global ocean carbon budgets. The impact of sequestration was, therefore, not important enough to plan such large fertilization efforts. Nevertheless, experiments continue and private corporations are experimenting with iron additions. An important motivation is the awarding of carbon credits, a system designed to allow trading of emitting greenhouse gases with mitigating strategies done elsewhere. Buesseler and colleagues§ have expressed skepticism that such efforts should proceed because of the very small apparent benefits, coupled with the danger of unintended reorganizations of marine ecosystems.

*See Martin, 1991, in Further Reading.

†See Behrenfeld and others, 1996, in Further Reading.
‡See Buesseler and others, 2004, in Further Reading.
§See Buessler and others, 2008, in Further Reading.

CHAPTER SUMMARY

- Pollution has both **chronic** (long-term) and **acute** (short-term) sources that impact the marine environment. Complex interactions among human impacts from many sources can make it difficult to pinpoint the role of particular pollutants.
- Common species are often chosen as **bioassays** of pollution and its effects on mortality, population growth, physiological condition, and gene expression. Studies may correlate the release of toxic substances with their uptake by individuals. Some populations evolve resistance to toxic substances.
- Many toxic substances transfer from one trophic level to the next as predators consume prey. In the process, the concentration of some substances is biomagnified, reducing biodiversity at the highest trophic levels.