Nutrients, viruses and the biological carbon pump

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Adding nutrients to the sea could decrease viral infection rates among phytoplankton and enhance the efficiency of the biological pump, a means by which carbon is transferred from the atmosphere to the deep ocean, according to a new mathematical modelling study. The findings, published in the *Journal of Theoretical Biology*, have implications for ocean geo-engineering schemes proposed for tackling global warming.

Tiny free-floating algae called phytoplankton dominate biological production in the world's oceans and sit at the base of the marine food web. Their population dynamics are controlled by sunlight, nutrient availability, grazing by tiny planktonic animals (zooplankton) and mortality caused by viral infection.

"Viruses are the most abundant organism in the world's oceans, and it is thought that all phytoplankton species are susceptible to infection. Our aim was to model the interaction between viruses, phytoplankton, zooplankton grazing and nutrient levels," said Dr Adrian Martin of the National oceanography Centre (NOC), who collaborated in the project with Dr Christopher Rhodes, a bio-mathematician at Imperial College London.

The researchers took an 'eco-epidemic' modelling approach, taking into account the mutual interaction between the effects of ecology and disease epidemiology. This approach has been used previously to model the effects of infection by pathogens on the population dynamics of mammals and invertebrate animals.

They considered only the case of lytic viruses, which are the commonest type of virus infecting marine phytoplankton. Lytic viruses inject their DNA into host cells and use the host's replication machinery to produce new viral particles. The host cell eventually ruptures, releasing the new viruses along with their cell contents, which are incorporated back into the ambient nutrient pool.

The interaction between viruses, phytoplankton, zooplankton grazing and nutrient levels produces subtle feedbacks and complex dynamics, which present a challenge to modellers. Rhodes and Martin therefore used three models of sequentially increasing complexity, so as to understand the key factors driving the dynamics and to increase confidence in the robustness of the model predictions.

The models predict that decreased nutrient levels correspond to high viral infection rates among phytoplankton.

On the other hand, increased nutrient levels are predicted to decrease viral infection rates. This means that more of the carbon contained in phytoplankton would be available to zooplankton and other creatures higher up the food chain.

When these organisms die, a proportion of the associated carbon would sink down to the deep ocean, where it could be locked away for centuries, rather than being released back to the atmosphere as carbon dioxide. This mechanism for exporting carbon to the deep ocean is called the biological carbon pump.

Artificial enhancement of the biological carbon pump by fertilizing the oceans with nutrients has been proposed as a possible geo-engineering 'fix' for global warming caused by the increase of atmospheric carbon dioxide from anthropogenic sources.

"The decrease in viral infection rates caused by artificially adding nutrients to the sea could in the future benefit humans by increasing the efficiency of the biological carbon pump, making these proposed ocean geo-engineering schemes more viable," said Dr Rhodes.

More information: Rhodes, C. J. & Martin, A. P. The influence of viral infection on a plankton ecosystem undergoing nutrient enrichment. Journal of Theoretical Biology 265, 225-237 (2010).

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