Making the Paper

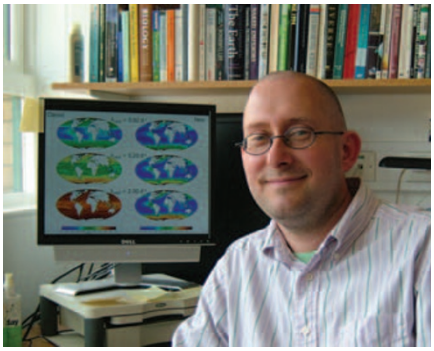
ANDREW YOOL

A study challenges the method used to estimate carbon transport by phytoplankton to the deep sea.

Twenty-eight years ago, in an attempt to quantify primary production by oceanic phytoplankton at the global scale, Richard Eppley and Bruce Peterson developed a technique to separate nitrogen nutrients that are recycled quickly at the sea surface from those that sink into the deep ocean. Writing in *Nature* in 1979, they coined the *f*-ratio to distinguish this sinking material, reasoning that the transport of nutrients to the deep ocean should, at equilibrium, balance their upwelling supply. More significantly, because phytoplankton growth couples nitrogen and carbon, their work framed the 'biological pump', the mechanism by which biology enhances the ocean's storage of carbon dioxide. However, in formulating the *f*-ratio, they included a caveat about the role of a then poorly quantified process known as nitrification, a caveat which Andrew Yool and his research team have now re-examined (see *Nature* **447,** 999–1002 (2007) and the associated highlight in this issue).

Yool's first run-in with the *f*-ratio came while he was working towards his PhD in the mid-1990s. "At that time I was working with a basic model of the plankton ecosystem, and the *f*-ratio was just this strange diagnostic I had no use for but which other people got excited about," says Yool. After completing his PhD, and switching to three-dimensional ocean models, the *f*-ratio was quietly forgotten about. However, when a poster appeared outside his office describing possible flaws in the *f*-ratio at a time-series station near Bermuda, Yool was hooked again. Written by co-author Adrian Martin with Phillipe Pondaven, the research looked at the supply of nutrients to the ocean's surface in subtropical oligotrophic waters, a topic that was still puzzling researchers worldwide, and found that something wasn't adding up.

Instead of the supply of nitrate coming mostly from upwelling of deep water, nitrification of surface ammonium — itself a recycled nutrient — seemed to be playing an often dominant role. Realizing that they could pool Martin's Bermuda work with Yool's three-dimensional models, they decided to broaden the canvas to examine the importance of nitrification at the global scale.



"We were very aware that we didn't have any field experience between us, but in trying to make sense of published measurements we were joined by Camila Fernández and Darren Clark, two experts in the field," says Yool.

With a collection of global measurements, Yool's team created an ecosystem model that included nitrification and an accountancy trick to separate nitrate transported from the deep ocean from that produced at the surface. "The nitrification data covered several orders of magnitude, but fortunately for us the model behaved almost the same everywhere," he says. Unfortunately for the *f*-ratio, however, it revealed that most nitrate was supplied near the surface, thus implying that *f*-ratio measurements have largely over-estimated the sinking flux.

"Our results suggest that the *f*-ratio isn't as good a proxy as we'd like, and that if we want to quantify the sinking flux to the deep ocean, we'll need to do it in more time-consuming and difficult ways," says Yool. Although the biological pump is believed to be thus far unaffected by increasing atmospheric carbon dioxide, climate change may affect nutrient supplies to the ocean's phytoplankton, and could alter the balance of species that drives the pump. "Hopefully our work will persuade oceanographers to develop more reliable 'odometers' for the biological pump, but we'd also like it to focus people more on nitrification. There's still a lot — too much — that's not known about it."

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