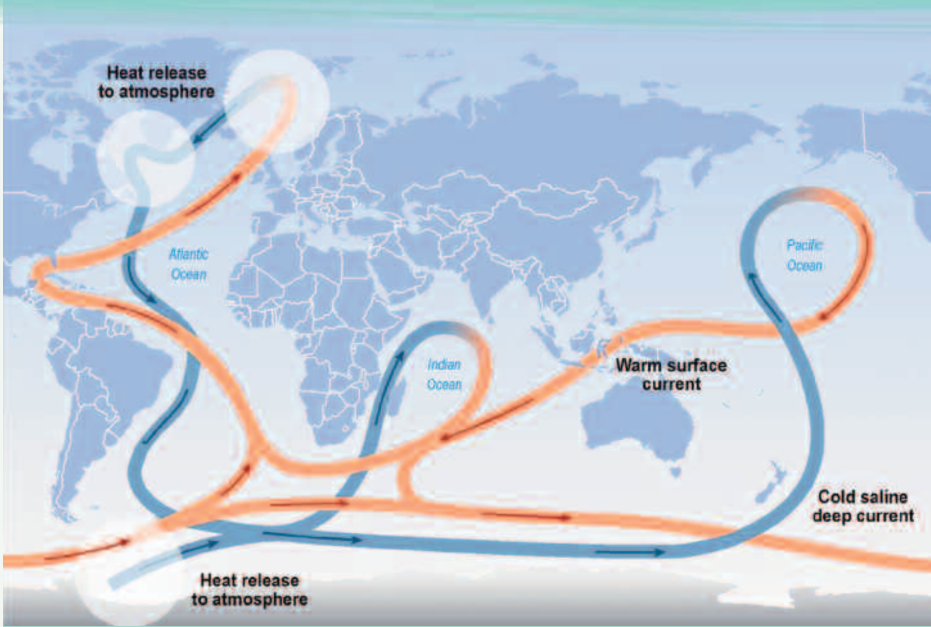
Causing a **stir**

Ocean mixing is driven by physical factors such as wind, tides and differences in salinity and temperature, right? According to **Rory Bingham**, we shouldn't write off another potentially important influence: ocean life.



The global ocean conveyor belt – a highly idealised representation of the global circulation of cold and warm waters. Much mixing occurs in the North Atlantic and around Antarctica. (Source: IPCC).

Do fish and other marine creatures mix the ocean? That was the question I put to Professor Bill Dewar after his lecture on ocean mixing during a summer school I attended in 2003 while studying for my PhD. Once the laughter from my fellow students had subsided, Bill said that he did not know, but that it was an intriguing possibility. Thus began what has been a stimulating and enjoyable transatlantic collaboration.

Oceanographers believe the mixing of water masses is an important aspect of ocean circulation, characterised by the global conveyor belt. This system – made famous by the science fiction film *The Day After Tomorrow* – moves heat from the sun towards the poles, regulating the Earth's climate. This huge circulation means the surface water of the world's oceans eventually find its way into the North Atlantic. Crossing the equator it warms and, through evaporation, becomes more salty. As it continues its journey north it releases heat to the atmosphere and so cools. This cooling combined with high salinity increase the water's density, so much so that eventually it becomes heavier than the surrounding water and sinks into the deep ocean. To complete the global circulation the water must rise up again. This requires a source of mechanical energy that can lift cooler heavier water towards the surface where it can absorb heat from the warmer lighter water surrounding it.

The power required to mix the ocean is uncertain. A rough global estimate is two terrawatts, or two trillion watts, which works out at about 20 milliwatts per metre squared when averaged over the global ocean surface. To put this in perspective, a typical hand-held kitchen mixer (100W) would provide enough energy to mix a football pitch sized area of ocean surface from top to bottom. Previous work has concluded that the wind and tides may adequately supply the required power. Yet large uncertainties in these estimates mean we can't discount the possibility that other sources of energy also play a role.

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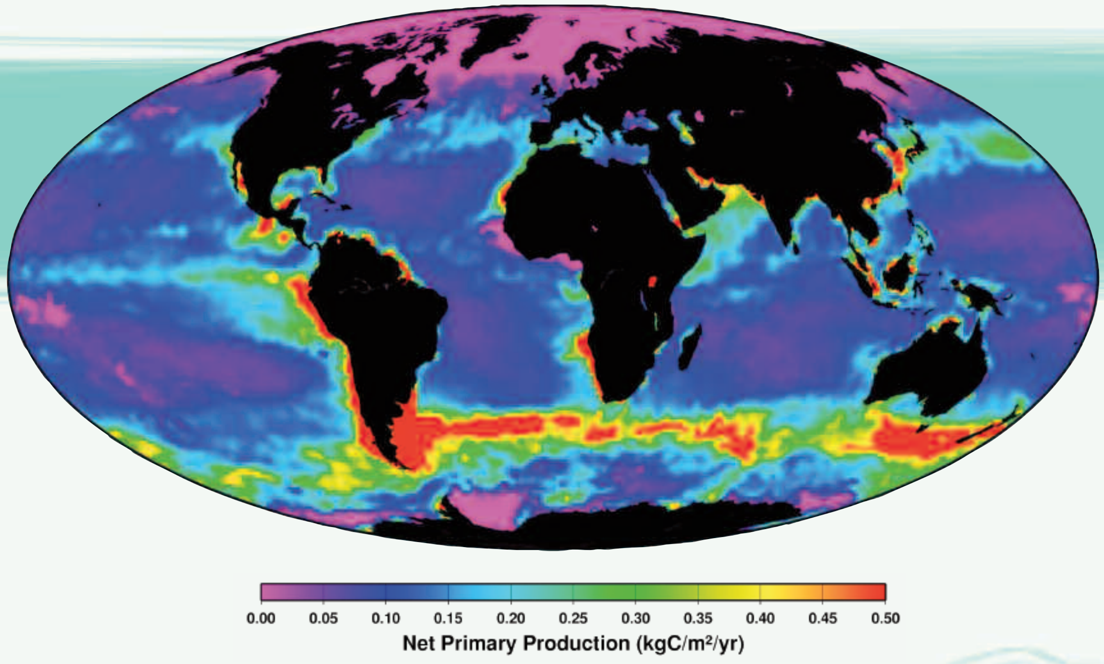
How might the marine biosphere mix the ocean? A sperm whale, for example, propels itself through the water by beating its powerful fluke. As it does so it experiences drag. This drag represents an injection of mechanical energy into the water. Of course, marine mammals, in common with fish, have evolved streamlined shapes enabling efficient movement through the water, minimising the energy they lose to the water. Nevertheless, evidence suggests that a sperm whale continually injects on average 5kW of energy to the ocean. Summing this figure over all toothed whale species gives one percent of the 2 terrawatts required to mix the ocean.

Given our limited knowledge of life in the ocean it would be impossible to determine the total input of energy by the marine biosphere using a species-by-species approach. Instead, we use satellite observations of ocean colour to estimate the chemical energy stored in phyto-plankton, which forms the base of the marine food chain. Even assuming that only one percent of this huge energy



The yearly production of phytoplankton in the surface water of the world's oceans represents a vast supply of chemical energy which could be converted to mechanical energy further up the food chain.

source is eventually converted to mechanical energy by creatures higher up the food chain, the power contribution by the marine biosphere is comparable to that of the winds and tides.

So far our research has been purely theoretical. However, Eric Kunze and colleagues at the University of Victoria, Canada, have recorded a four orders of magnitude increase in mechanical energy input to the ocean during the daily migration of krill in a coastal inlet. Our future plans include laboratory tank experiments to examine the mixing efficiency of marine organisms, and an observational campaign to measure the biosphere's contribution to mixing in the deep ocean. Meanwhile, scientists at the British Antarctic Survey are considering the possibility of incorporating the effects of the vast swarms of krill in the Southern Ocean, a key region for regulation of the Earth's climate, into an ocean model to assess their impact on the large-scale ocean circulation.

It is still too early to answer the question I initially posed to Professor Dewar. The idea that the marine biosphere can mix the ocean is contentious, as some scientists have been quick to point out. There are many factors that are difficult to determine. One concern is that the size of the motions produced by marine organisms may in general be too small to be effective. However, too little is still known about the size distribution of the marine biosphere to rule out marine life as a significant contributor. In short, we have shown that what may initially have seemed like a crazy question, as the laughter of my fellow students indicated, is worthy of serious consideration. But as yet, we still need to do more research before we can conclude with any certainty whether mixing by the marine biosphere is an important part of the ocean's circulation. ■

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More information

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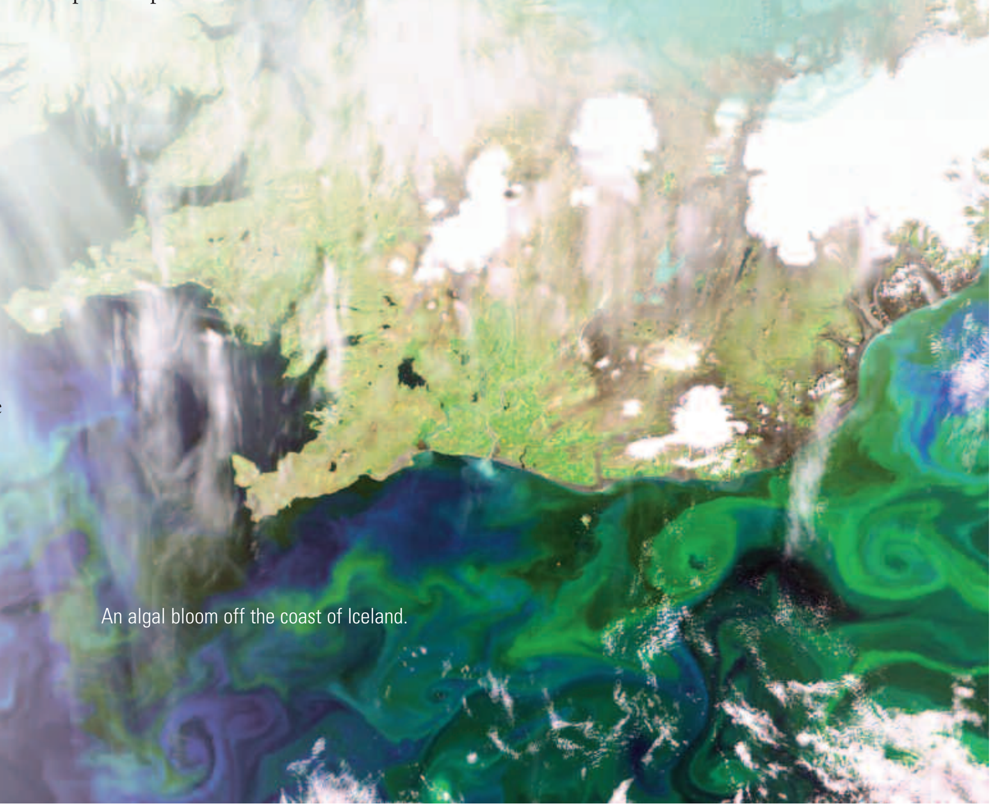

An algal bloom off the coast of Iceland.

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