Ocean currents push phytoplankton—and pollution—around the globe faster than thought

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Credit: Tiago Fioreze / Wikipedia

The billions of single-celled marine organisms known as phytoplankton can drift from one region of the world's oceans to almost any other place on the globe in less than a decade, Princeton University researchers have found.

Unfortunately, the same principle can apply to plastic debris, radioactive particles and virtually any other man-made flotsam and jetsam that litter our seas, the researchers found. Pollution can thus become a problem far from where it originated within just a few years.

The finding that objects can move around the globe in just 10 years suggests that ocean biodiversity may be more resilient to climate change than previously thought, according to a study published this week in the journal *Nature Communications*. Phytoplankton form the basis of the marine food chain, and their rapid spread could enable them to quickly repopulate areas where warming seas or ocean acidification have decimated them.

"Our study shows that the ocean is quite efficient in moving things around," said Bror Fredrik Jönsson, an associate research scholar in Princeton's Department of Geosciences, who conducted the study with co-author James R. Watson, a former Princeton postdoctoral researcher who is now a researcher at Stockholm University.

"This comes as a surprise to a lot of people, and in fact we spent about two years confirming this work to make sure we got it right," Jönsson said.

One of the strengths of the model is its approach of following phytoplankton wherever they go throughout the world rather than focusing on their behavior in one region, Jönsson said. Because most marine organisms are mobile, this particle-tracking approach can yield new insights compared to the approach of studying one area of ocean.

The resulting model works for objects that have no ability to control their movement such as phytoplankton, bacteria and man-made debris. Organisms that can control their movement even a small amount—such as zooplankton, which can control their vertical position in water—are not accounted for in the model. Nor does the model apply to objects such as boats that protrude above the water and can be pushed by surface winds.

The team applied a computer algorithm to calculate the fastest route an object can travel via ocean currents between various points on the globe. Most previous studies looked only at movement of phytoplankton within regions. The resulting database, Jönsson said, is analogous to a mileage chart one would find on a roadmap or atlas showing the distance between two cities, except that Jönsson and Watson are indicating the speed of travel between different points.

The researchers confirmed that the travel times calculated by their model were similar to the time it took real objects accidentally dumped into the ocean to be carried by currents. For instance, 29,000 rubber ducks and other plastic bath toys toppled off a Chinese freighter in 1992 and have since been tracked as a method of understanding ocean currents. A similar utility has stemmed from the "Great Shoe Spill of 1990" when more than 60,000 Nike athletic shoes plunged into the ocean near Alaska and have been riding the currents off the Pacific Northwest ever since. The researchers' model also matched the amount of time it took radioactive particles to reach the West Coast of the United States from Japan's Fukushima I Nuclear Power Plant, which released large amounts of radioactive materials into the Pacific Ocean following heavy damage from a tsunami in March 2011. The actual travel time of the materials was 3.6 years; the model calculated it would take 3.5 years.

To create the model, Jönsson and Watson obtained surface-current data from a database of modeled global surface currents developed at the Massachusetts Institute of Technology and housed at NASA's Jet Propulsion Laboratory in California. Into this virtual world they released thousands of particles that represented phytoplankton and then ran simulations multiple times, comparing past and present runs for accuracy and making tweaks to improve the model. They eventually tracked more than 50 billion positions of particles, which is just a fraction of the actual number of phytoplankton in the ocean.

Because phytoplankton mainly reproduce asexually—meaning that one organism alone can produce offspring—only one individual needs to reach a new area to colonize it. This fact led the team to look at the shortest time it takes to get around the world rather than the average time. "The rule for our phytoplankton was 'drive at fast as possible,'" Jönsson said.

To cut down the computing resources needed to track the particles, the researchers calculated the fastest way to get from one place to another using a shortcut commonly employed by smartphone apps and in-car navigation systems. The method, called "Dijkstra's algorithm" after the late Dutch computer scientist Edsger Dijkstra who developed it in the 1950s, calculates how to get from A to C if you know the route from A to B and B to C.

"Dijkstra's algorithm is a way of optimizing for the shortest path between two positions when you have a network of possible locations, and we used it to find pathways when there was no direct link from one region to another," Watson said.

Although each step in the pathway from one region to another may be unlikely, the fact that a single phytoplankton organism, which lives only a few weeks, can give rise to millions of offspring means that even unlikely paths will have some followers.

Professor of Marine Sciences Per Jonsson at the University of Gothenburg Center for Sea and Society in Sweden said that the analysis offers a new perspective on global connectivity. "This is the first attempt to identify time scales of connectivity and possible dispersal barriers for plankton across all oceans," said Jonsson, who had no role in the research and is not related to study author Bror Jönsson. "The general message is that all parts of the ocean surface are connected on surprisingly short time scales.

"This implies that regional declines in plankton fitness due to climate change may be buffered by relatively rapid immigration coupled with community sorting or evolutionary change," Jonsson continued. "The authors also offer a practical and predictive tool for a range of studies regarding global ocean dispersal, including the spread of contaminants and marine litter."

More information: The paper, "The timescales of global surface-ocean connectivity," was published online in-advance-of-print April 19 in the journal *Nature Communications*.

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