Ocean "Conveyor Belt" Sustains Sea Life, Study Says

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An estimated three-quarters of all marine life is maintained by a single ocean-circulation pattern in the Southern Hemisphere that pulls nutrient-rich waters from the deep ocean, brings them to the surface, and distributes them around the world.

"This is really something," said Jorge Sarmiento, a professor of atmospheric and ocean sciences at Princeton University in New Jersey. Sarmiento made the discovery using sophisticated computer models.

The nutrient-rich waters help feed phytoplankton, single-celled plants at the bottom of the marine food chain that live at the ocean surface. As phytoplankton die, some slowly sink, decomposing along the way and carrying nutrients to the deep ocean.

For years, scientists have wondered how these sinking nutrients, which seem lost to the deep sea, get back to the surface. Sarmiento's model, which links the resupply of the sunken nutrients to a single circulation pattern, provides an answer.

Arnold Gordon, a physical oceanographer with Columbia University in New York, said that, while the circulation patterns in the southern oceans have been known for some time, "that they play such an essential role in the large-scale nutrient budget of the upper ocean layers as proposed by Sarmiento is new and important."

Barrier Layer

Key to Sarmiento's model is the small difference in density among the three distinct layers of water in the Southern Ocean, the name some people use for the waters around Antarctica. These differences in density allow for mixing across the layers.

"Think of the ocean as consisting of three layers," he said. "At the surface to a depth of about 100 meters (330 feet), we have the layer of the ocean where there is enough light for photosynthesis to occur. Below this we have what I call the barrier layer."

The barrier layer is what oceanographers refer to as the thermocline (because it is where temperature changes rapidly with depth) or the pycnocline (because it is where density changes rapidly with depth).

Since density variations in the ocean are due mostly to temperature, the terms "thermocline" and "pycnocline" are interchangeable, according to Sarmiento.

The barrier layer averages about 500 to 1,000 meters (1,600 to 3,300 feet) in depth. The deep ocean, which has an average thickness of about 3 kilometers (2 miles), lies below the barrier layer.

The problem oceanographers faced is that any nutrients that sink past the barrier layer and into the abyss of the deep ocean have a hard time getting back up to the ocean surface, where they are of use to phytoplankton.

Without a mechanism to get the nutrients back to the surface, the oceans would lose about one-fiftieth of their nutrients to this sinking process each year, Sarmiento said.

Southern Ocean

What Sarmiento found was that the nutrient-rich deep waters are carried by deep ocean currents to the cold, hostile, storm-whipped Southern Ocean.

According to Gordon, who is an expert on the Southern Ocean currents, the westerly winds there create the greatest of all ocean currents, the Antarctic Circumpolar Current. The current "swirls water—around 140 million cubic meters (4.9 billion cubic feet) per second—around Antarctica."

For the sake of comparison, all of the rivers in the world carry only 1.3 million cubic meters (46 million cubic feet) per second, according to Gordon.

The Antarctic Circumpolar Current mixes waters from the Pacific, Atlantic, and Indian Oceans. Of equal importance, according to Gordon, is the vigorous circulation along the north-south plane across the Antarctic Circumpolar Current.

There, relatively warm waters of the deep-ocean rise to the cold sea surface just south of the current and balance the sinking of surface water along the edge of Antarctica and to the north. "As the deep ocean waters come to the surface, they bring with them all the nutrients that have been broken down and dissolved," Gordon said.

These waters are transported into the barrier layer, or thermocline, of the more northern oceans, where the nutrients are then absorbed by phytoplankton at the surface.

Climate Response

Since most scientists believe that ocean-circulation characteristics will change in response to global warming, Sarmiento's modeling results suggest that much of the world's marine life may be more susceptible to climate change than previously thought.

"If you kept water circulation going but were able to strip nutrients out before the water left the Southern Ocean, that would have a massive impact on global biological productivity," he said.

Conceptually, biological productivity is defined as the ability of a water body to support life, such as plants, fish, and wildlife. Scientifically, it is defined as the rate at which organic matter is produced. Since phytoplankton need nutrients to grow, the nutrient supply is essential to biological productivity.

Steve Rintoul, an oceanographer with the Commonwealth Scientific and Industrial Research Organization in Tasmania, Australia, said modeling results suggest the ocean conveyor belt—which allows cold, dense waters to sink and nutrient-rich waters to rise in both the Northern and Southern Hemispheres—will slow in response to climate change.

The conveyor belt would likely slow because in a warmer world more rain falls in the polar regions. The melting of sea ice and glaciers on land make surface waters fresher than they are now. Fresh water is buoyant—it doesn't sink.

"That slows down the whole pattern of currents that lead to upwelling in some regions and downwelling in others … we can speculate that this nutrient supply by the Southern Ocean would also slow down," he said.

Sarmiento and his colleagues, who published these findings in the January 1 issue of the science journal Nature, are now investigating the details of this nutrient-circulation pattern to understand how it might respond to global warming.

http://news.nationalgeographic.com/news/2004/06/0615_040614_SouthernOcean.html