Scientists Test 'Artificial Upwelling' to Learn More About Complex Ocean Ecosystem Behavior

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(PhysOrg.com) -- A team of scientists is studying the complex ocean upwelling process by mimicking nature – pumping cold, nutrient-rich water from deep within the Pacific Ocean and releasing it into surface waters near Hawaii that lack the nitrogen and phosphorous necessary to support high biological production.

The researchers are harnessing the power of the ocean to conduct their experiments, using the up-and-down motion of waves to pump deep water to the surface. Their next step is to create a pump that can withstand the rigors of the rugged Pacific and then see if the biology follows the physics.

“During our first test, the ocean destroyed our pump in one day,” said Angelicque “Angel” White, a post-doctoral researcher at Oregon State University and a member of the scientific team. “Initially, the system worked and we were able to bring cold water to the surface and control the depth of its release. Now we need to work on the engineering aspect.”

The theory behind the experiment has just been published in the journal, *Marine Ecology Progress Series*. The initial test of the pumps and their effect in the open ocean is the focus of a documentary that is scheduled to be broadcast Sept. 5 on the Discovery Channel.

This experiment was funded in part by the National Science Foundation and the Betty and Gordon Moore Foundation. White and lead investigators Ricardo Letelier of OSU and David Karl of the University of Hawaii are part of the NSF-funded Center for Microbial Oceanography: Research and Education (C-MORE) based in Hawaii, which Karl directs.

The scientists stress that the goal of creating artificially induced upwelling is to understand how marine microbial ecosystems respond to large-scale perturbations, "a critical step if we want to understand the risks of manipulating these large ecosystems in order to solve global greenhouse buildup," said Letelier, a professor in OSU's College of Oceanic and Atmospheric Sciences.

"This is not a new concept," Letelier said. "It was proposed in 1976 that scientists could use wave energy to pump water from the depths to the surface and fuel plankton growth. But there are many nuances; simply bringing nutrients to the surface can result in the wrong kinds of biological growth. It also can bring water enriched with carbon dioxide, which can de-gas into the atmosphere.

"If you're adding more CO2 than subtracting by fertilizing the ocean," he added, "you're running the wheel in the wrong direction."

The answer, Letelier says, may be to pump water that contains specific ratios of nutrients – particularly nitrogen and phosphorous – to carbon dioxide by targeting different depths. At their research site north of Hawaii, where the ocean is about 4,500 meters deep, the bottom layers of water have too much CO2 because of the decaying organisms that have sunk to the floor.

Their studies have shown, however, that water at a depth of 300 to 700 meters has the proper ratio of nitrogen and phosphorus to trigger a twostage phytoplankton bloom. The researchers believe that upwelling with water from that depth will first cause a bloom of diatoms, which are a common type of plankton – often single-celled. The diatoms will consume the nitrogen, leaving some amount of phosphorus in the water, which will stimulate a second-stage bloom of nitrogen-fixing cyanobacteria. These blooms are often observed during summer months in open ocean waters, Letelier said.

In previous field experiments, the researchers were able to create stage-one diatom blooms by mixing deep and surface water in large incubation bottles, but they need to conduct additional studies in the ocean to see if the second stage of blooms actually occurs following additions of deep water. If the pumps had survived the ocean, White said, they may have been able to generate these blooms.

“We were able to pump about 50 cubic meters of water per hour using the wave energy,” she said, “which is a small amount compared to the vastness of the ocean. If we want to generate a bloom in an area of one-square kilometer, we would need to replace about 10 percent of the surface waters with upwelled water, which would take about a month at the rate we pumped.”

The scientists used undersea gliders in their Hawaii study to monitor the water from the pump so they have an idea how widely and quickly it disperses, and how much of an impact it can have on surface waters.

“We know a lot about how upwelling works and the physics of the ocean,” Letelier said, “but there also are things we don’t know, which is why this study is so important. In this open ocean area near Hawaii, for example, phytoplankton blooms occur in the summer when there are almost no nutrients at the surface and the winds generally are calm. What triggers the blooms and where are the nutrients coming from? We need to know.

“These vast, seemingly barren regions comprise more than two-thirds of our oceans and nearly 40 percent of the entire Earth,” he added. “It is a large area of exchange between the atmosphere and the ocean and understanding large-scale interactions is critical to understanding climate change.”

Some scientists have looked at iron fertilization as a way to trigger biological growth in nutrient-poor areas of the ocean, but “everything responds to iron,” Letelier said. “You can’t control what grows.”

The researchers believe they can control plankton growth by determining which species respond to specific nutrients, and then adjusting the rate of nutrient feeding by the frequency and duration of water pumping.

“These vast regions of the open ocean may be perfect for sequestering carbon,” Letelier said, “but before we can begin to seriously consider a large-scale intervention, we must better understand how the biology responds by using perturbations on a small scale. We’re getting there.”

Provided by OSU

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