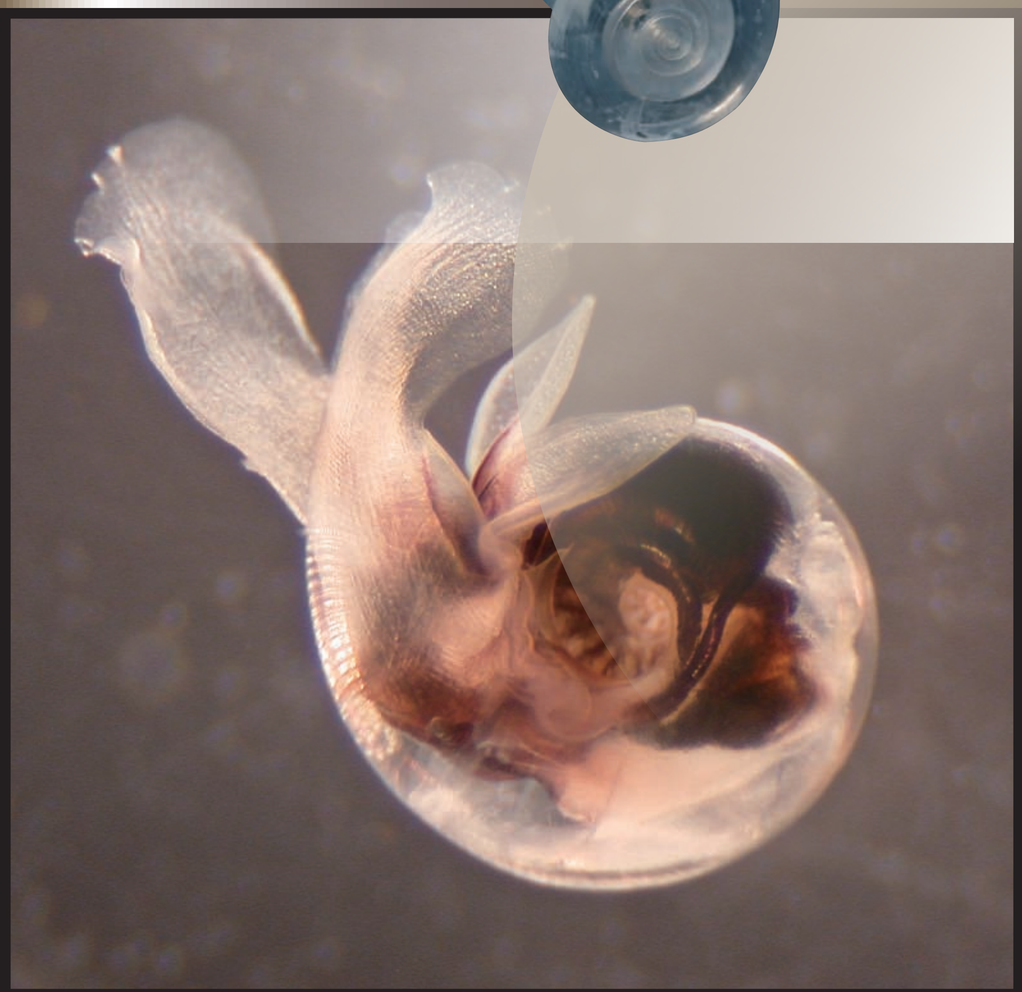

Invisible NO MORE: Scripps Investigates Ocean Acidification

WITH SHOCKING SPEED, THE INCREASING ACIDIFICATION OF THE WORLD'S OCEANS HAS BEEN TRANSFORMED FROM AN ABSTRACT PROBLEM WITH AN INDEFINITE TIME SCALE TO A CONSEQUENCE OF CLIMATE CHANGE THAT HAS TANGIBLE EFFECTS OBSERVABLE NOW. SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UC SAN DIEGO IS PART OF A GLOBAL EFFORT TO BRING PUBLIC ATTENTION TO A SUBTLE BUT PROFOUND CRISIS THAT NEEDS TO BE UNDERSTOOD AND ADDRESSED.

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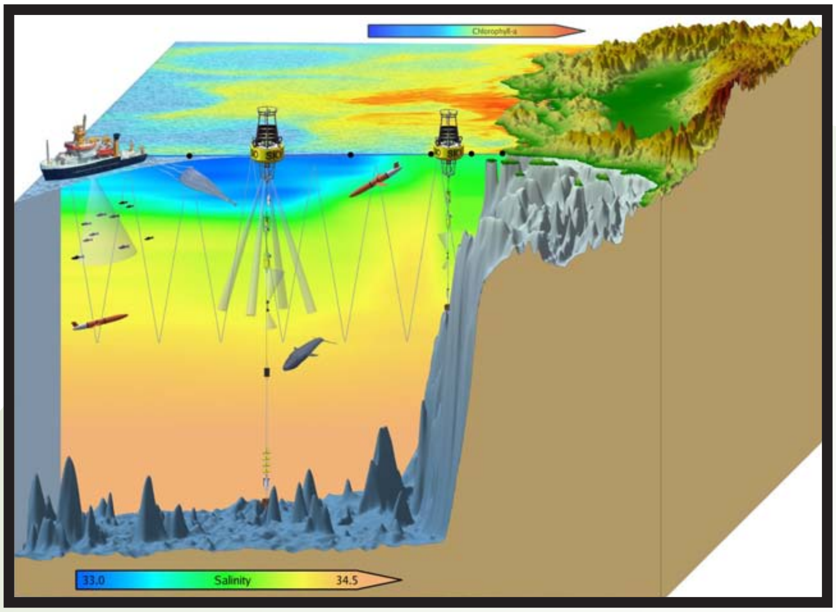


Scripps scientists and NOAA colleagues operate state-of-the-art moorings that observe carbon system parameters off the California coast with real-time data delivery from the surface and subsurface.

THE PROBLEM OF INCREASING GREENHOUSE GAS concentrations in the atmosphere is well-known, but the effects of our fossil fuel use on ocean chemistry are only now beginning to be understood.

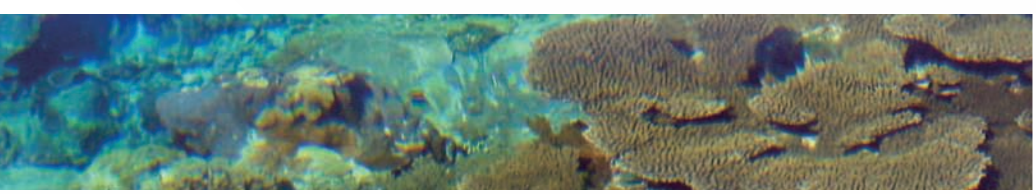
About one-third of the carbon dioxide produced every day by vehicle exhaust, industrial smokestacks, and wood-burning stoves around the world is absorbed into the oceans. The gas reacts with seawater, changing its pH and reducing the concentration of carbonate ion, an essential component in the calcium carbonate that makes up seashells and corals.

Since the late 1980s, researchers at Scripps Institution of Oceanography at UC San Diego and elsewhere have recorded a drop in pH at certain ocean locations. Recent research has since found falling pH levels in a variety of ocean regions, with particularly vulnerable systems being detected in polar waters and off the west coast of North America. The decrease is enough to put many key marine organisms at risk. The pace of acidification will likely not give many organisms sufficient time to adapt. Some estimates suggest, for example, that the growth rate of coral might be outpaced by its depletion rate by mid-century. One recent estimate indicates that some vulnerable polar ecosystems could experience initial stages of corrosive surface waters within 20 or 30 years.

Some of the species most vulnerable to ocean acidification are vital to ocean food webs. Pteropods are small marine snails that are a large part of the diet of salmon and other commercially important fish species. Some pteropod species have shells so thin that they are transparent. Increasingly corrosive waters threaten formation of these shells and could substantially reduce pteropod populations in polar and subpolar regions worldwide. Residual effects will resonate through ocean food webs.

A number of questions need to be answered as soon as possible. Scientists are attempting to discover when tipping points for widespread damage will be reached and what the effect of reducing carbon dioxide emissions will be. Researchers are trying to understand the difference in reactions to acidification among marine species. For example, why are some species sensitive to high CO_2 concentrations while others are not?

Scripps Oceanography is uniquely poised to address this growing global problem. Located adjacent to the most studied ocean region in the world, the institution's history of data collection makes it a repository of records that can help scientists retrace trends in ocean chemistry over more than 50 years. Scripps scientists have created key reference standards used in the measurement of seawater carbon dioxide levels. Most importantly, though, Scripps is home to many of today's leading ocean acidification researchers. They are bridging fields such as marine biology, physics and chemistry to bring an interdisciplinary focus to a problem that needs answers now.



The Foundation: Data Collection at Scripps

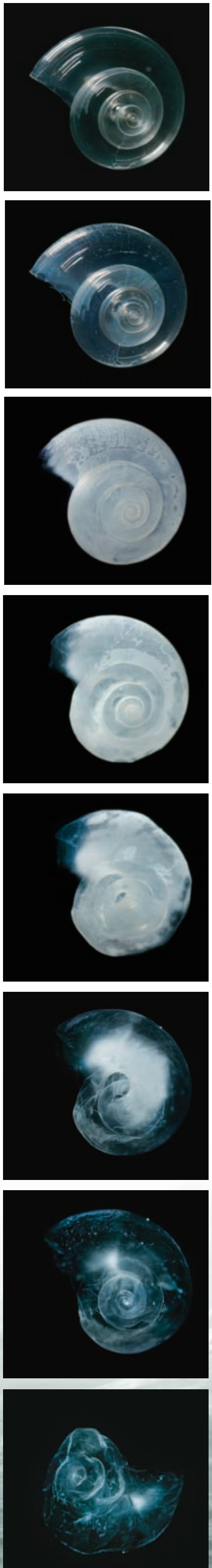
OCEAN CO_2 MEASUREMENTS

The record of rising atmospheric carbon dioxide levels is often referred to as the Keeling Curve after Charles David Keeling, the Scripps geochemist who began a steady measurement series atop Hawaii's Mauna Loa in 1958. Keeling also launched a complementary measurement series of carbon dioxide concentrations in the oceans, which today is led by Scripps marine chemist Andrew Dickson. Dickson has also created a reference standard for proper measurement of ocean CO_2 levels. It is the basis of a protocol followed by marine chemistry labs around the world. Today Dickson's lab prepares and bottles thousands of reference samples for distribution throughout the research community.

CALCOFI: LOOKING TO THE PAST

For more than 60 years, the California Cooperative Oceanic Fisheries Investigations (CalCOFI) has gathered fundamental biological, chemical, and physical data within a grid off the West Coast. Scripps biological oceanographers Mark Ohman and Ralf Goericke are cooperating with colleagues on an effort to look back through decades of CalCOFI information to estimate changes in ocean pH over time. Researchers anticipate that the endeavor will provide crucial historical context for current ocean acidification trends, and will provide a proxy relationship to estimate pH from other more commonly measured variables.

LEFT, TOP TO BOTTOM, *Seawater reference samples for use in CO_2 studies; Christina Frieder studies the effects of high-CO_2 environments on sea urchin larvae; the pteropod, ocean acidification's emblematic organism.*



LEFT, Researchers exposed a pteropod shell to carbonate ion-depleted seawater with acid levels set to the pH of Southern Ocean water expected in 2100. The shell dissolved after 45 days. BELOW, Scripps Director Tony Haymet with colleagues from Oceana and Plymouth Marine Laboratory at COP16 climate talks in Cancun, Mexico, December 2010.

Image credits: David Liittschwager, National Geographic Stock , Christian Begler.

The Future: Collaborative Research at Scripps

THREATS TO MARINE LIFE

Scripps graduate student Emily Bockmon has created a laboratory apparatus that enables studies of the effects of varying CO_2 and oxygen levels on marine organisms in a controlled setting. Students Christina Frieder and Mike Navarro in the lab of biological oceanographer Lisa Levin are using the system to mimic upwelling events off the San Diego coast and study the development of squid egg capsules and mussel larvae. California Sea Grant and the National Science Foundation support the study.

Marine biologist Martin Tresguerres investigates molecular and cellular mechanisms responsible for sensing carbon dioxide, pH and bicarbonate levels in marine organisms, and related effects on cellular and organismal biology. Tresguerres' lab has identified a group of chemosensory enzymes that may act as pH sensors in diverse marine organisms. The lab studies their physiological roles in phytoplankton, corals, oysters and fishes and how they respond to ocean acidification.

Acidification trends might begin to cause net erosion of coral reefs in this century as the calcium carbonate is broken down faster than marine calcifiers can grow. Compounds such as magnesium calcite could be especially vulnerable to dissolution. Assistant Professor Andreas Andersson is creating experiments to help understand dissolution rates. This knowledge will lead to an understanding of when reefs throughout the world will reach such thresholds. Andersson plans to create lab experiments to measure dissolution rates and to distinguish among different types of dissolution that take place in nature.

OCEAN CLIMATE MONITORING

Scripps physical oceanographer Uwe Send now operates three state-of-the-art moorings that observe carbon system parameters such as levels of dissolved CO_2 and pH off the California coast with real-time data delivery from the surface and subsurface, in cooperation with Scripps scientists Mark Ohman and Todd Martz, and colleagues from NOAA. Data can be viewed at http://mooring.ucsd.edu/CCE and http://mooring.ucsd.edu/DelMar. The moorings join an open ocean monitoring effort known as OceanSITES. Co-led by Scripps Oceanography, OceanSITES is building a network of stations around the world to collect long time-series measurements of trends in ocean climate and ecosystem dynamics.

The Mission: Creating a Prudent Response to Ocean Acidification

PREPARING INDUSTRY FOR CHANGES AHEAD

The West Coast shellfish industry has reported losses in yield and stunted development of the larvae of farmed and wild-caught oysters, clams, and other species. Scripps' Andrew Dickson chairs the California Current Acidification Network (C-CAN), a new collaboration between industry and scientists to explore what is causing shellfish losses, what role ocean acidification might be playing in this problem, and how to adapt to these changes to sustain shellfish resources. The network aims to create a resource that makes ocean acidification information easily accessible and to standardize research methods along the West Coast.

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