MICROBIAL OCEANOGRAPHY

CENTER FOR MICROBIAL OCEANOGRAPHY: RESEARCH AND EDUCATION C-MORE

CENTER LINKS MARINE MICROBES TO ECOLOGICAL PROCESSES

Established in August 2006, C-MORE is focused on a comprehensive understanding of the diverse communities of microbes in the sea: what their genes code for, how they work together to control the flux of energy and matter in the ocean, and how all of this may change in the future.

Located at the University of Hawaii, the center is focused on “linking genomes to biomes.” So how do you connect the narrow focus of molecular genetics to the broad focus of ecology? With the “three Cs”: collaboration, cooperation, and communication.

The ultimate goal of C-MORE is to achieve a new understanding of the role of microbes in global ocean processes. C-MORE represents a sustained effort to understand how the genetics of individual microbial cells are connected with the behavior of populations, and furthermore, to understand the roles different populations play in ocean biogeochemistry, and ultimately, in global ocean processes, including climate change.

Research at C-MORE depends on cooperation and collaboration among individuals whose diverse expertise includes microbial genetics, population ecology, biogeochemistry, satellite-based oceanography, ocean ecosystem modeling, engineering and instrument development, and many other disciplines. Each component of C-MORE research contributes to the “genomes to biomes” goal.

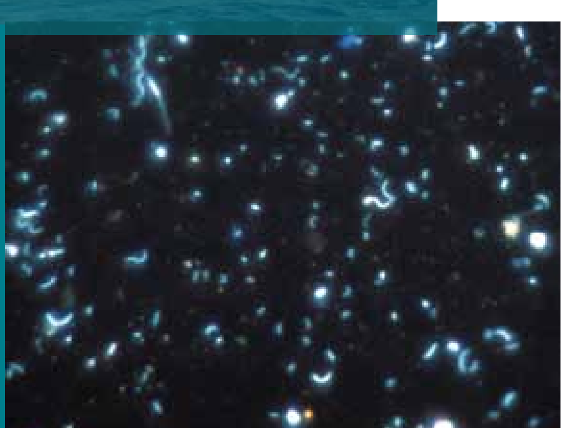
The center is headquartered at the University of Hawaii, led by center director David Karl. Investigators also are located at the Massachusetts Institute of Technology, Woods Hole Oceanographic Institute, Monterey Bay Aquarium Research Institute, the University of California, Santa Cruz (UCSC), and Oregon State University.

Many of C-MORE’s researchers have been working together for more than 10 years, notes C-MORE research coordinator Edward DeLong of MIT. “In the end, the thing that will really make everything work together in a sustained way is a deep level of trust. And I think because we are all friends, colleagues, and scientific collaborators—and have been so over a good amount of time—we have already established that,” he says. C-MORE researchers communicate daily through email, telephone, in-person conferences and teleconferences, aided by the state of the art communications capability of C-MORE Hale (“the house of C-MORE”), a new University of Hawaii building dedicated to the Center.

Microorganisms dominate the living biomass in the world’s oceans, and just like humans, they contain genes which allow particular types of activities to occur, such as taking up different types of nutrients or performing photosynthesis. Because of the enormous diversity of different types of microorganisms in the ocean, and the fact that we cannot isolate most of them, an understanding of their genetic composition and capabilities comes from analysis of all gene sequences in seawater collected at different locations, a research approach known as metagenomics.

Samples collected from several locations during a C-MORE cruise between American Samoa and Hawaii have been analyzed by Jonathan Zehr, Karl, and colleagues. This region has several distinct types of oceanic habitats. Over a million fragments of genes were analyzed from these samples using a high throughput DNA sequencing technology. In another approach, MIT researcher Sallie W. Chisholm and colleagues have examined the genetic inventory of microbial cells. Chisholm’s group uses a flow cytometer to sort individual cells based on their characteristic fluorescence as they pass through a laser beam. Each cell’s genome–the DNA that encodes all of the genes that define the cell’s ecological niche–is amplified in a way that provides enough DNA for genome sequencing. The approach can be focused on particular groups of microbes to understand their intrinsic diversity, or to look at the broad diversity of microbes. Along with metagenomics, this approach has uncovered an astounding diversity of metabolic pathways in uncultured bacteria–providing an unprecedented window into marine microbial diversity.

C-MORE scientists also study specific components of microbial communities. Matthew Church of the University of Hawaii and colleagues examined processes controlling the growth, diversity, and carbon removal of diatoms, among the most productive and wide spread of marine photosynthetic organisms. □



Above left: The Kilo Moana

Top: C-MORE Hale

Bottom: Micrograph of oceanic microbes. *Photo: Courtesy of Ed DeLong*

The Environmental Sample Processor (ESP), suspended below a surface float, drifts in the open ocean with the R/V Western Flyer nearby. *Photo: Philip Sammet copyright 2010 MBARI.*

SCIENCE AT A DISTANCE

C-MORE DEVELOPS SEA-GOING SENSORS FOR MARINE MICROBIAL RESEARCH

Traditional marine investigations all too often have required transporting samples to a laboratory for subsequent testing. What researchers really need is a sea-going instrument that could automate molecular analyses so that specific organisms, genes, and gene products could be analyzed easily in real time.

C-MORE partners have given life to this vision through the development of the Environmental Sample Processor (ESP). The ESP employs DNA and protein probe arrays along with the method of quantitative polymerase chain reaction (PCR) to analyze a wide variety of marine species and samples.

The instrument has been applied in the field on a variety of platforms including coastal moorings, a coastal pier, an open ocean drifter, research ships, and a benthic lander rated to a depth of 4,000 meters for use on deep-sea cable observatories. It supports two-way communications for transmitting results and downloading new instructions so that its mode of operation can be altered remotely.

"For the first time, ocean-observing systems that allow investigators to carry out interactive experiments and test hypotheses remotely from a molecular biological perspective are being realized," says C-MORE researcher Chris Scholin.

While Center investigators utilize the ESP in an open ocean setting to study microbial mediated cycling of nutrients and energy, other academic and government groups are currently evaluating the utility of the machine as a tool for augmenting water quality monitoring networks for ocean and freshwater systems. C-MORE, through the Monterey Bay Aquarium Research Institute, is loaning ESP instrumentation necessary to conduct these tests as one element of the Center's broader technology transfer portfolio.

A CONVERSATION WITH THE DIRECTOR

David Karl

University of Hawaii undergraduate students deploying instruments for spectral analysis observations.

Microbial oceanography is a field full of surprises. It seems every time scientists think they have it all figured out, they find out there's more to learn.

When C-MORE director David Karl graduated with a Ph.D. in 1978, he was ready to leave the field because he thought that we knew all there was to know about the ocean. "We'd been studying this for a hundred years. There were clever and intelligent people in the field and we had books and we had paradigms and we had models. And I thought all that there was left was to dot the i's and cross the t's—and I didn't like to do that kind of stuff. So I was thinking about going into some other field that might be more pioneering and more cutting-edge.

"Well, the year that I graduated, a group of scientists who are now part of our center discovered the second-most abundant group of organisms in the sea—before that, we didn't even know about these organisms. A decade later in 1988, the most abundant group of plants in the ocean was discovered.

"We established C-MORE in 2006 because we thought that a comprehensive, interdisciplinary, and collaborative approach was needed to make real progress in microbial oceanography. We have not been disappointed. Based on the extensive laboratory experiments, field observations, and ecosystem modeling conducted across the C-MORE institutions we are beginning to re-write the textbooks, but much more work needs to be done.

"New discoveries are likely as we move forward with the center. The next five years should be a thrilling experience."

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Teacher using a sextant aboard a C-MORE cruise.

Deployment of the Environmental Sample Processor (ESP). *Photo: Philip Sammet copyright 2010 MBARI.*

MICROBIAL OCEANOGRAPHY BRINGS K-12 EDUCATION ALIVE

The ocean is an integral part of island life in Hawaii; teachers capitalize on this fact by using the interdisciplinary field of oceanography to teach students about biology, chemistry, and physics.

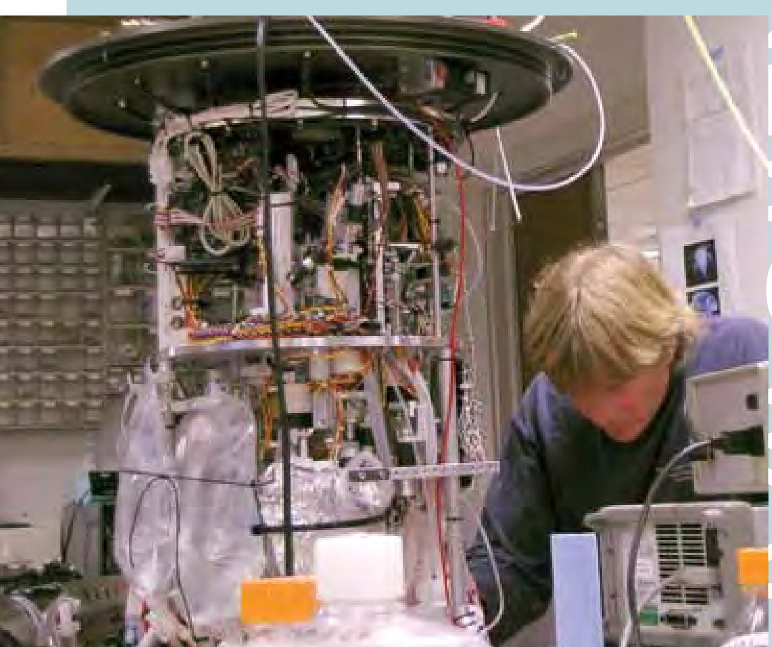
Hawaii's teachers want oceanography educational resources that they can bring into the classroom, especially those that incorporate the latest scientific research, says C-MORE Education Director Barbara Bruno.

An example is C-MORE Science Kits, which are rooted in C-MORE research and aligned with state and national education standards. Each kit contains lesson plans and all the equipment and supplies needed to conduct hands-on activities and labs on a particular topic in oceanography. They are available on loan free of charge throughout the Hawaiian Islands and at C-MORE partner institutions in California, Oregon and Massachusetts.

Teachers are also excited to participate in professional development experiences, such as research cruises. Each month, the Hawaii Ocean Time-series (HOT) program monitors the ocean's biogeochemistry at a deepwater site located 100km north of Oahu. Teachers are invited to participate on select cruises, where they work alongside HOT scientists to collect and analyze data. Teachers can communicate with their students while on board through a real-time Internet link.

C-MORE is committed to providing undergraduate research experiences, and is especially interested in serving underrepresented groups such as Native Hawaiians and Pacific Islands. C-MORE Undergraduate Scholars, most of whom are from underrepresented groups, conduct research in Hawaii during the academic year. During the summers, they can conduct research at a C-MORE partner institution, which can serve as a testing ground for graduate school. Once in graduate school, they have the opportunity to participate in a world-class summer course taught by C-MORE investigators.

NEWS WATCH



Chris Scholin working on the Environmental Sample Processor (ESP) in the laboratory. *Photo: Kim Fulton-Bennett (c) 2006 MBARI*

GLOBAL CHANGE AND THE FATE OF THE OCEANS

"Microbes are critically important to processes that influence climate change," says C-MORE associate director Paul F. Kemp, explaining that human reliance on fossil fuel combustion continues to increase atmospheric and oceanic CO_2 inventories, and the latter has made the oceans significantly more acidic.

"By the end of the 21st century, surface ocean pH is expected to drop by 0.3 pH units," says Kemp. "It remains unclear how such changes will influence ocean ecosystem structure and processes, or how the various components of the pelagic food web may affect marine elemental cycles in an increased pCO_2 world."

Center investigators are examining how marine nitrogen-fixing bacteria respond to changes in CO_2 in seawater. "These species play a pivotal role in ocean ecology by providing a biological source of new nitrogen to large parts of the ocean, and we are only beginning to understand what controls their distribution and abundance," she says.

In a CO_2-rich world, the dominant marine microorganisms and associated processes may be different than what we see today," says Kemp. "Collaborative studies within C-MORE will greatly improve our ability to predict the fate of a future ocean."