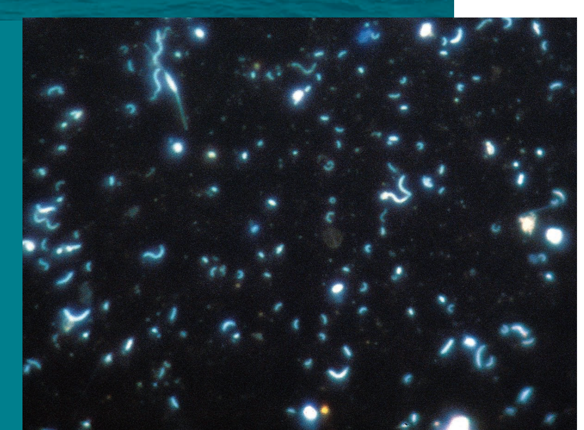
MICROBIAL OCEANOGRAPHY

CENTER FOR MICROBIAL OCEANOGRAPHY: RESEARCH AND EDUCATION C-MORE

CENTER LINKS MARINE MICROBES TO ECOLOGICAL PROCESSES

BY JEN SCHRIPSEMA

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.



Above left: The Kilo Moana

Top: On deck of the Kilo Moana

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

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 a lot organization and communication, it turns out.

Research at C-MORE is organized into four interconnected themes. The first thrust focuses on the diversity of microbial life in the ocean. "One of the discoveries we are going to make at our center is to finally, once and for all, have an accurate, ecumenical, comprehensive inventory of the structure and function of the microbial populations in the sea," says center director David Karl. "This might take us a decade, but it's a target that is well within our reach, at least for the open ocean where we are focusing our fieldwork."

Researchers use conventional cultivation techniques to isolate, identify, and characterize the major microbial species present in the ocean to develop theoretical models of ocean ecology. New genome sequencing techniques are allowing researchers to look directly at the genetic code of these organisms.

"Looking at these genomes is a lot like looking at a parts list, but we never had the parts list for the microbes in the ocean before," says research coordinator Ed DeLong. Having that "allows us to get much more fine-grained information about what makes up these microbes."

Information gathered from this research contributes to the second theme, which focuses on biogeochemistry—how the cycling of carbon, nitrogen, phosphorus, and other elements is driven by microbial activities. The rise in levels of atmospheric carbon dioxide is an area of particular concern. "It's hard to even imagine, but because microbes move large amounts of greenhouse gases through their combined physiological activities, microbes can actually have an effect on weather, for example," says DeLong.

Research in the third theme has an applied engineering focus: development of remote and continuous sensing technology. Currently, oceanographers must go out on the ocean for a certain length of time to gather samples and then return to the lab for testing. Being able to monitor various ocean processes continuously greatly speeds up hypothesis-testing and allows researchers to ask different questions—for example, how the expression of genes relate to circadian rhythms or the lunar cycle or a particular meteorological event, notes theme leader Chris Scholin.

The final, broadest research thrust at the center integrates all the relevant research into computerized models that can predict how the ocean will change in the future. One major concern is that the increased level of carbon dioxide in the atmosphere is dissolving in the ocean, increasing its acidity. "More-acidic conditions could select for or against certain microorganisms; it could cause massive death of calcium-carbonate-bearing organisms like corals," says Karl.

These four themes keep everyone organized, but DeLong emphasizes that these "bins" are artificial constructs. "The goal is really that they are all conducted in synergy to understand the complexity of the system of the living ocean." The key to making that happen is communication, which can be a challenge at a center as dispersed as C-MORE.

Although the center is headquartered in Hawaii, investigators are located at the Massachusetts Institute of Technology, Woods Hole Oceanographic Institute, Monterey Bay Aquarium Research Institute, the University of California, Santa Cruz, and Oregon State University. "So we are spread out both geographically and with respect to our expertise, and that again requires a sort of glue to hold things together," says DeLong. "Part of the research coordination is making sure the right people are talking to one another and research efforts are coordinated."

C-MORE may be new, but many of its researchers have been working together for at least 10 years. DeLong says, "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." □

Divers working on the second-generation environmental sample processor in the Monterey Bay Aquarium Research Institute (MBARI) test tank. *Photo: Todd Walsh (c) 2006 MBARI*

SCIENCE AT A DISTANCE

CENTER DEVELOPS REMOTE SENSING INSTRUMENT

At the most basic level, the goal of C-MORE research is to understand how small-scale microbial genomic information connects to large-scale ecological and biogeochemical processes. "Conducting experiments to answer questions like that in the ocean currently requires a physical presence. You have to be there to acquire the samples, which are then brought back to a laboratory, which are then subjected to all kinds of tests," says theme leader Chris Scholin.

"We go out to sea for a relatively short period of time. You just go gangbusters on sample collection, and then you bring them back and retrospectively try to reconstruct what was happening at this molecular level." While at sea, researchers cannot alter their experiment based on the metabolic processes taking place because they are still awaiting the laboratory results. "You really have little opportunity to respond dynamically," says Scholin.

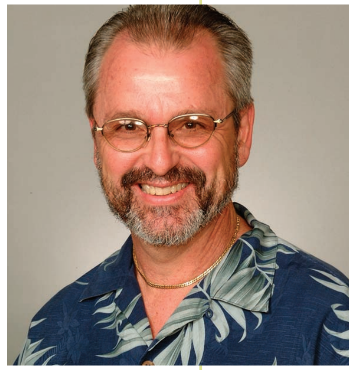
To remove this limitation, Scholin is working on a remote sensing instrument called the Environmental Sample Processor (ESP). "So I'm dialed into my machine, which is sitting in the water in Hawaii, while I'm sitting here in California directing an experiment. I'm testing a hypothesis without physically being at that site, without acquiring the samples and filtering the bugs and bringing it back and so on."

Work on the ESP is still preliminary. But Scholin predicts that within a couple of years he will be able to analyze the microbial community in a sample of water for the presence and expression of a broad range of genes, all from the comfort of his office.

Remote sensing technology like this could have a variety of applications outside C-MORE as well, both in and out of the research community. For example, public health agencies could monitor beaches for fecal bacteria, red tide, or cholera remotely, instead of relying on the current tests accepted by the EPA, which are relatively slow.

A CONVERSATION WITH THE DIRECTOR

David Karl



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.

"As recently as five years ago, a whole new group of organisms was discovered in the ocean that is able to absorb sunlight just like green plants do. But these are not green plants; they don't fix carbon dioxide. What they do is absorb sunlight and use that energy directly for their metabolism. So, in effect, we have to rewrite all the basic biology textbooks because green plant photosynthesis is now not the only solar energy capturing process on the planet.

"So we are still in this very formative and very embryonic discovery stage in oceanography and in microbial oceanography. New discoveries are likely as we move forward with the center."

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On March 16, 2006, the second-generation version of an underwater, robotic DNA lab called the Environmental Sample Processor (ESP) was deployed in Monterey Bay, Calif. *Photo: (c) 2006 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. "So we have a very strong interest on the part of many teachers to learn everything they can about the ocean," says C-MORE education coordinator Barbara Bruno. "But when they do this, often microbial oceanography is left out."

Bruno is working directly with secondary school educators and curriculum developers to support the development of education programs and to update teacher training and science curricula to include the role of microbes. One program just getting off the ground that has garnered considerable interest is the teacher-at-sea program.

Secondary school teachers or peer educators will accompany scientists on monthly research cruises, working as scientists themselves for four days. "In the summertime, we will have [a] more consolidated effort where we take groups of teachers out there," says center director David Karl. They will conduct specially designed experiments and then work with C-MORE researchers to convert what they have learned into lesson plans for class.

"We are setting up a real-time Internet link [with video] from the ship into the classroom, so that the kids in the classroom can see what's going on in the ocean as we collect samples and analyze the samples for various parameters of interest," says Karl.

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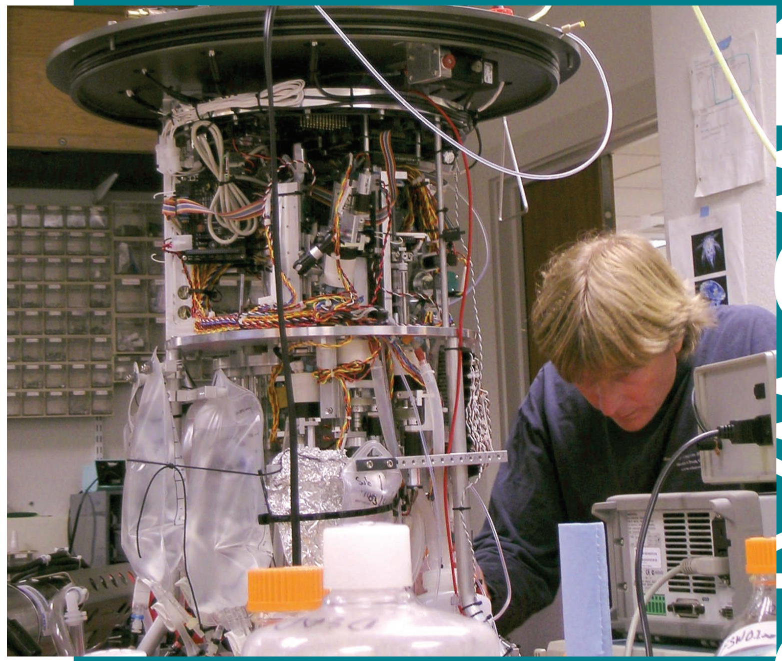
>
> — ED DELONG
> C-MORE RESEARCH COORDINATOR

NEWS WATCH



Chris Scholin working on the second-generation environmental sample processor in the laboratory. *Photo: Kim Fulton-Bennett (c) 2006 MBARI*

EARLIER DETECTION OF RED TIDES

A small percentage of microbial algae in the ocean produce toxins such as those found in "red tides." Harmful algal blooms can lead to massive deaths among fish and shellfish, disruption of marine ecological structure, and human illness and even death.

The current EPA standards for detecting the presence of these algae or their toxins are relatively slow because they rely on ship-based testing and "wet chemistry" tests. Detecting harmful algal blooms and closing beaches more quickly could prevent many human illnesses. C-MORE researcher Chris Scholin is currently researching ways to use remote sensing technology to do just that. He has several articles currently in press on the subject.

A project like this requires more than just bringing together scientists from different fields; it requires bringing together engineers to build the equipment and technicians to install and repair it. "This is a real exercise in interdisciplinary work and bringing very disparate types of people and talents together," says Scholin.

The effort will require further studies and acceptance by regulatory agencies before it can be used in practice, but Scholin is working hard to make implementation a reality.