The Young Scientist and the Sea (of Microbes)

By Barbara C. Bruno, Yoshimi M. Rii, Julie C. Robidart and Donn A. Viviani

The ocean is full of microbes: single-celled organisms that are so *tiny they can only be seen with a microscope. Although microbes are all around us, many remain undiscovered or poorly understood. Our planet's most abundant photosynthesizer is a marine microbe (a cyanobacterium) that was only discovered 25 years ago (Chisholm et al. 1988). Just last year, scientists learned that another cyanobacterium can team up with an algal cell: the cyanobacterium produces fertilizer for the algae and the algae provides food in return (Thompson et al. 2012). The symbiosis caused the cyanobacterium to evolve to have a smaller genome and lose its capacity for photosynthesis. These discoveries make one wonder: just how many kinds of microbes, and how many different functions and adaptations, remain undiscovered in the ocean?*

SCIENCE AND TECHNOLOGY CENTERS: VALUE-ADDED RESEARCH

These are just some of the research questions being tackled at the Center for Microbial Oceanography: Research and Education (C-MORE), a multi-institutional Science and Technology Center (STC). Bringing together technologies and expertise from seven partner institutions (University of Hawaii at Manoa, Columbia University, Massachusetts Institute of Technology, Monterey Bay Aquarium Research Institute, Oregon State University, University of California, Santa Cruz, and Woods Hole Oceanographic Institution), C-MORE researchers explore how marine microbes influence—and are influenced by—the world's largest biome, the global ocean. Marine microbes drive a wide range of ecological processes at all scales, including biogeochemical cycling of carbon, nitrogen, and other elements, and make significant contributions to globally important issues such as global warming and ocean acidification (C-MORE 2008).

What distinguishes C-MORE from other oceanography research groups is the STC concept, which transcends disciplinary and institutional boundaries to provide "value-added" research. The strong emphasis on education, training, and broader impacts required by the STC structure ensures that C-MORE's influence extends far beyond the lab. As part of this effort, graduate students and post-doctoral researchers participate in a professional development program (C-MORE 2010, Bruno et al. 2013), which includes critically important training in science communication. This article highlights one outcome of C-MORE's science communication training: communication pieces for the general public written by students and post-docs.

SCIENCE COMMUNICATION MANDATE

In recent years, scientists have received a strong mandate to *Escape from the ivory tower* (Baron 2010) and have been told, *Don't be such a scientist* (Olson 2009). This focus on science communication largely stems from workplace development concerns (e.g., National Academies 2007). Science, technology, engineering, and mathematics (STEM) are critical to our nation's growth, and we are simply not training enough students in these fields to maintain America's global competitiveness. Young scientists can play an important role in inspiring the next generation to pursue STEM careers. The ever-increasing presence of science and technology in society also means that everyone (regardless of career path) needs basic science literacy to make informed decisions that affect our lives and our planet. For example, individual choices regarding energy consumption may seem trivial, but can combine to significantly impact global climate and the health of our oceans. Voters also need to understand scientific issues because their decisions shape local and national environmental policies.

Thus, it is essential that we train scientists to communicate their research. The excerpts below share the stories of three young C-MORE scientists who, after receiving professional development training in science communication, were challenged to communicate their research in jargon-free language.

Donn Viviani, Doctoral Candidate at the University of Hawaii

When you were growing up, did your parents stand you against a wall each year and mark your height? The collection of those lines on the wall is an example of a time-series, showing how your height changed over time. Just like a child, the ocean constantly changes, across seasons and decades. A single measurement isn't enough to really understand the ocean: we need a time-series.

Since 1988, the Hawaii Ocean Time-series (HOT) program has been making monthly measurements at a location north of Oahu. Over that time, HOT data show increased ocean CO_2

Donn Viviani (right) demonstrates an experiment that tests how microbes respond to ocean acidification.

and decreased pH levels (Figure 1). These trends are largely explained by burning fossil fuels, which release CO_2 into the atmosphere. Some of this CO_2 dissolves in the ocean, where it triggers a series of chemical reactions that are together referred to as "ocean acidification." One aspect of ocean acidification is a reduction in the amount of carbonate in surface waters.

Aldo Leopold said, "To keep every cog and wheel is the first precaution of intelligent tinkering." Unfortunately, some of the changes happening to our planet may result in losing some cogs and wheels. Many marine organisms, like corals and some microbes, build body parts from carbonate, which becomes scarcer as CO_2 increases, making it harder for these organisms to build and maintain their bodies. Could other microbes benefit from more ocean carbon? The key to understanding how organisms respond to an acidifying ocean lies in understanding the flow of carbon.

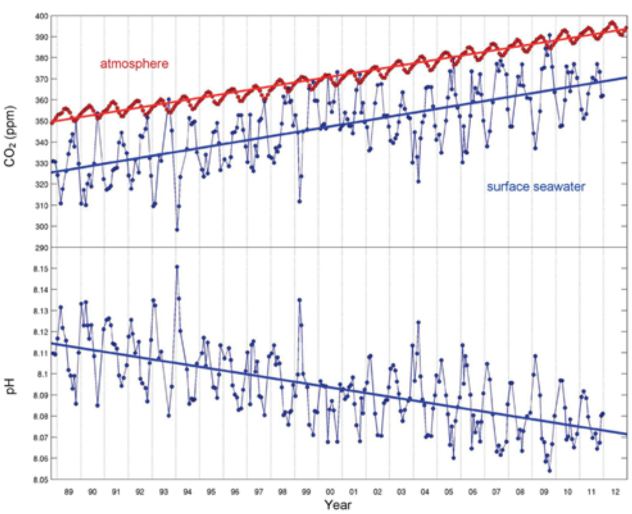
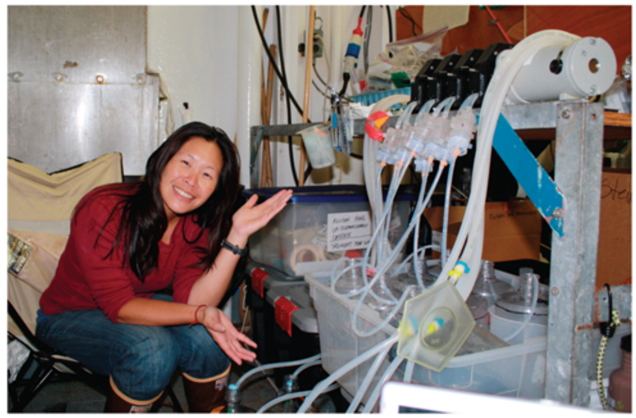


Figure 1. Atmospheric (red) and oceanic (blue) data both show an overall increase in CO_2 with time (top panel). Also shown is a corresponding decrease in oceanic pH (blue in lower panel).

I participate on HOT research cruises to try to follow that carbon flow. Photosynthetic marine microbes don't make leaves and roots like land plants, but they do make new material. I measure how much new plant material is produced inside and outside the cells: I try to count cogs and wheels. I also do experiments to test the effect of increased CO_2 on microbe growth. My research is just a tiny piece of a big puzzle, but I really like doing my part and I love watching sunrises at sea.

Yoshimi Rii, Doctoral Candidate at the University of Hawaii



Yoshimi Rii filtering seawater for phytoplankton DNA in the South Pacific aboard the R/V *Melville*.

Nowadays, cut down a tree and someone will say, "Stop! Trees produce the air we breathe!" Does anyone think about the army of single-celled oceanic phytoplankton that produce half of the oxygen on Earth (Field et al. 1998)? As global climate change looms, it is important to learn as much as possible about these unsung heroes.

Phytoplankton need light and nutrients to grow. After they bloom, their remains sink to the deep sea, where bacteria convert them into essential nutrients. Through ocean mixing, nutrients are transported back into shallower depths, where phytoplankton have enough light to photosynthesize. There, phytoplankton absorb the nutrients and the cycle begins again.

I conduct my research in the middle of the Pacific Ocean, where nutrients are scarce. To maximize their growth in these conditions, phytoplankton favor different forms of nutrients. In my experiments, I add different forms of nitrogen to bottles of seawater and incubate them in containers mimicking natural light conditions. After several days, I filter water and extract DNA to see which types of phytoplankton grew. These controlled experiments allow me to better understand the role of phytoplankton in nutrient cycling in the ocean.

My experiments are exciting, but life at sea is magical. When I stand at the bow of the ship and take in the ocean, endless to the horizon, I sigh in contentment, knowing that this is exactly where I want to be.

Julie Robidart, Post-doctoral Researcher at University of California, Santa Cruz

Julie Robidart (orange hardhat) works with colleagues to prepare the Environmental Sample Processor for deployment on a drifting platform in the North Pacific.

The oceans are full of microbes. If you were to fill a 12-ounce soda can with seawater, it would contain about 500 million microbes. These microbes have changed Earth from a place that was not habitable by animals, to a place that is.

The oceans are changing and will continue to change throughout our lifetimes. We don't know how climate change will affect the microbes of the future ocean, and hence the chemistry of the planet. I believe that studying how different ocean environmental conditions (such as ocean temperature and chemistry) affect microbes, and providing a baseline of microbial distributions over different seasons, is a good place to start. We won't know how microbes will respond to future environmental change until we know how they respond to present change.

I work with underwater robots that function like miniature labs. The robots collect seawater samples, bust open the microbial cells, and count genes (DNA) using molecular probes. Since we know the number of genes in each microbe, we can then calculate the microbes' abundances. Our vision is to deploy these robots throughout the oceans to see how microbes vary over time in different regions. Our ultimate goal is to use these data to better predict how microbes will respond to global change.

I've always been driven to explore the unknown, and the ocean is full of unsolved mysteries. Microbiology is fascinating because it reveals how much these tiny cells can do. I feel compelled to address global change, so I began studying the surface ocean because it is tightly coupled to our climate system.

JOB OUTLOOK

The job market in biological oceanography and related fields is rapidly expanding, but undergraduate enrollment in STEM is not keeping pace. Scientific jobs overall have been projected to increase 16% by the end of the decade (Bureau of Labor Statistics 2012). The projected growth of occupations related to biological oceanography ranges from 13 to 31% (Table 1, page 8). Thus, now is an excellent time for students to enter the field and do their part to help us better understand our changing oceans! Through communication and outreach, scientists and educators can play an important role in recruiting potential scientists into STEM fields by sharing information about the exciting research opportunities and favorable job outlook.

CONCLUSION

C-MORE scientists are tackling critically important research questions in microbial oceanography. By combining laboratory experiments and field investigations with high-tech instrumentation, they are making new discoveries on how marine microbes influence—and are influenced by—the global ocean. Equally importantly, they are communicating their research to the broader population and inspiring the next generation to pursue careers in oceanography and related STEM fields. These careers are not only beneficial to our planet, but are projected to rapidly expand in the future job market.

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PHOTO CREDITS

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Page 6, bottom left: Data courtesy of HOT program.
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Occupations	Employment (2010)	Projected job growth, 2010-2020			Education	Annual median wage (2010)	Sample job description
		Numeric growth	% growth	Relative to other scientific jobs			
Biochemists and biophysicists	25,100	7,700	31	Much faster than average	Doctoral or Professional Degree	79,300	Research the chemical and physical principles of living things and of biological processes (e.g., cell development, growth, and heredity).
Biological technicians	80,200	10,900	14	About as fast as average	Bachelor's Degree	39,020	Assist biological and medical scientists by conducting laboratory tests and experiments.
Environmental science technicians	29,600	7,000	24	Faster than average	Associate's Degree	41,380	Monitor the environment and investigate sources of pollution by conducting lab and field tests.
Environmental scientists/ specialists	89,400	16,700	19	About as fast as average	Bachelor's Degree	61,700	Identify problems and find solutions that minimize hazards to environmental and/or human health.
Geoscientists	33,800	7,100	21	Faster than average	Bachelor's Degree	82,500	Study the Earth's composition, structure, and processes, to learn about its past, present, and future.
Microbiologists	20,300	2,700	13	About as fast as average	Bachelor's Degree	65,920	Research the growth, development, and other characteristics of microscopic organisms.

Table 1. Projected job growth in occupations related to biological oceanography (2010–2020; Bureau of Labor Statistics, 2012)