Ocean Life Institute

April 2008 Report

Woods Hole Oceanographic Institution

Message from the OLI Director

Tom Kleindinst, WHOI

The past year was an exciting and dynamic one for the Ocean Life Institute (OLI). A wide array of research on topics from bacteria to whales, in the tropics to the poles, was supported. Through a combination of fellowships, postdoctoral and graduate student awards, research grants and initiatives, scientists pursued questions about life in our oceans.

Research in the tropics has been especially active, with several projects supported through the Tropical Research Initiative. Seven new research projects have begun at the Liquid Jungle Laboratory (LJL) in Panama, on topics ranging from ocean currents and modeling to ground water nutrients, plankton, and fish populations. A study of native sea squirts is providing a baseline for potential future colonization by invasive species. Panama Laboratory Underwater Tropical Observatory (PLUTO) has been upgraded with new sensors and cameras and is generating real-time data on temperature, salinity, and other environmental variables.

The OLI also has been actively involved in helping to transition the scientific information and models developed as part of the Global Ocean Ecosystem Dynamics (GLOBEC) program into operational tools that ocean resource managers can use.

OLI is partnering with WHOI's CICOR—a NOAA-funded climate program—and the Coastal Ocean Institute (COI) to develop a new ocean ecosystem initiative that will focus on the connections between the northwest Atlantic shelf ecosystem and the changing climate in the Arctic. The work will address critical issues including fisheries, pollution, and red tides, and will provide input for the design of ocean observing systems.

Research projects of three OLI Fellows are described in this report. Anne Cohen is studying the impact of ocean acidification on skeletal growth in corals and has found that the acidity caused by increasing atmospheric carbon dioxide levels could have a devastating effect on coral reefs by the end of this century. Sonya Dyhrman is studying the DNA of marine microbes to determine the causes of harmful algal blooms (HABs). Her work on the species responsible for brown tides is providing new insights into the versatility of this species. Jesús Pineda is pursuing the long-standing question of what determines the successful growth of coastal marine animals from larvae to adulthood. His group is studying populations of barnacles near the Liquid Jungle Lab. His student, Joanna Gyory, describes her related thesis work on larvae at LJL as well.

– Cabell Davis

Coral Reef Health

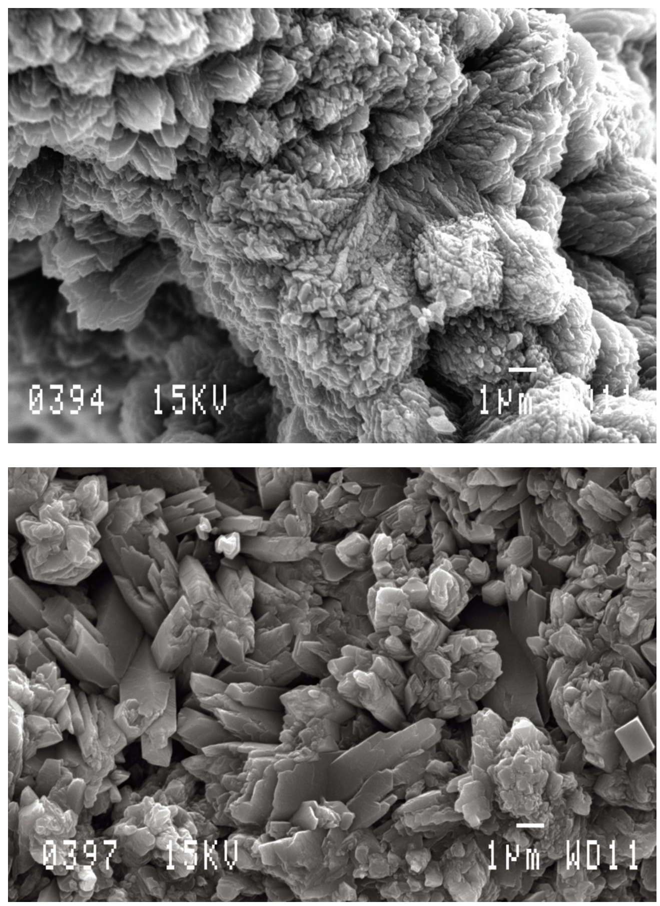
Can a More Acidic Ocean Harm Corals?

Miles of tropical coastline are comprised of coral reefs that are valued not only for their natural beauty but for their great biological diversity. Coral animals are actually polyps – soft organisms that resemble tiny sea anemones. Coral polyps build their hard external skeletons by secreting calcium carbonate, and coral reefs represent years of accumulated building. These reefs persist primarily because coral animals can make calcium carbonate crystals faster than the resulting skeletons are eroded by the sea.

As concentrations of carbon dioxide (CO_2) in Earth's atmosphere continue to rise due to fossil fuel combustion, the surface oceans are becoming more acidic, prompting questions such as: Will ocean acidification affect the ability of corals to produce calcium carbonate? Will coral skeletons simply dissolve as seawater becomes more acidic? Will rising ocean temperatures offset or enhance the effects of ocean acidification on coral calcification?

Answering these questions requires an understanding of the underlying mechanisms by which corals produce their calcium carbonate skeletons. Although there are a superabundance of calcium and carbonate ions (CO_3^{2-}) in seawater, it is actually very difficult, if not impossible, to grow calcium carbonate crystals without intervention. So how do corals do it?

With funding provided by my OLI fellowship, I have brought the principles and analytical tools of geochemistry and mineralogy to shed light on this fundamentally biological problem. One of my efforts has been to grow calcium carbonate crystals experimentally from seawater in different ways and under different conditions. To do this, I enlisted the help of WHOI experimentalist Glenn Gaetani. Our collaboration, which subsequently received additional funding from the National Science Foundation, immediately produced important results. First, we discovered that elevating the carbonate ion concentration (CO_3^{2+}) about 5 times above that of ambient seawater produced bundles of calcium carbonate crystals that are morphologically and compositionally similar to the organized bundles of fine crystals that corals produce.



Courtesy of Anne Cohen, WHOI

Scanning electron micrographs of crystals produced by corals reared in normal seawater (middle) and in acidified seawater (bottom). The normal skeleton consists of organized sturdy bundles of long, fine crystals; whereas, corals grown in acidified seawater produced a disordered aggregate that quickly disintegrated when touched. Scale Bar = 1 micron

This finding is important because it tells us that corals most likely produce calcium carbonate by bringing a batch of seawater into an isolated compartment and removing protons to elevate the CO_3^{2-}. If this is true, then ocean acidification could work against corals by lowering the CO_3^{2-} of the starting seawater. In addition, we found that, as we tried to grow crystals in seawater with lowered CO_3^{2-} (thus mimicking ocean acidification), the fine, orderly fiber bundles gave way to stocky single crystals with random orientation. This finding suggests that, in addition to slowing the rate of calcium carbonate production, future changes in seawater CO_3^{2+} could affect the ability of corals to produce a normal, robust skeleton of highly organized crystals that hold their strength.

During Summer 2008, at the Bermuda Institute for Ocean Sciences (BIOS), I worked with WHOI chemical oceanographer Dan McCorkle, and BIOS coral biologist Samantha de Putron to test these ideas on real corals. The black and white photos illustrate what we found. Corals reared in acidified seawater do not dissolve, but they take longer to build their skeletons. More importantly, skeletons produced in acidified seawater are built from crystals that are irregularly shaped and lack the careful organization and strength characteristic of normal skeletons. The results from this project have provided critical insights into the mechanism by which corals build their skeletons, and how ocean acidification, due to rising levels of atmospheric CO_2, could affect this process. Based on these findings, we expect that by the end of this century, many tropical coral species will grow more slowly and build weaker skeletons than they do today. This could have important consequences for the health of tropical coral reef ecosystems. – *Anne Cohen*

Tom Kleindinst, WHOI

Ann Cohen (center) working with a student and research assistant in her laboratory.

Genomic Revolution

Gene Sequencing Unlocks the Mysteries of Marine Microbes

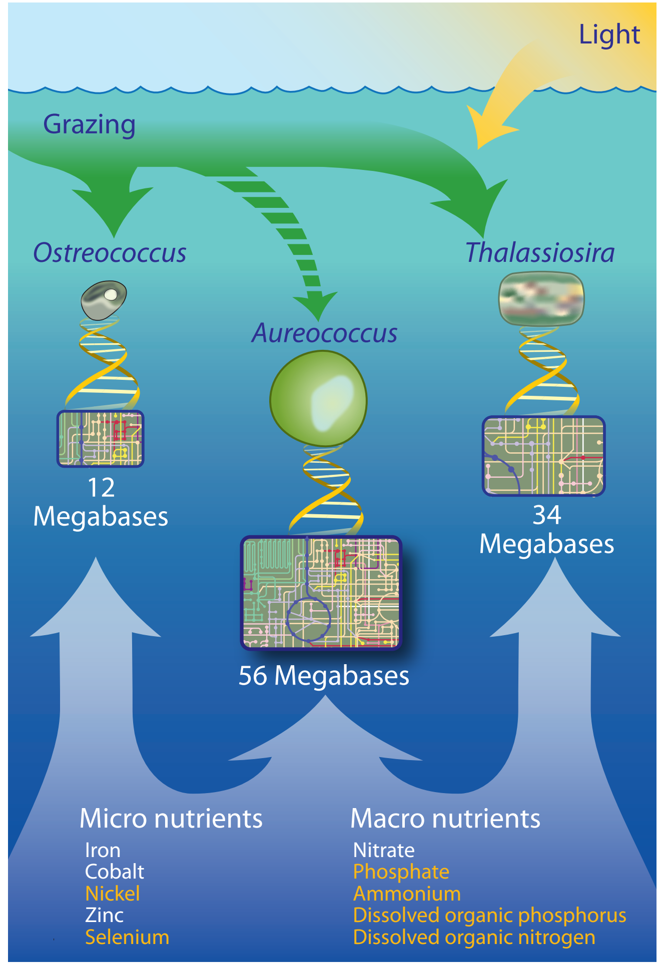
The sequencing of the human genome is a widely recognized milestone in biology, with obvious consequences for medicine and other disciplines. What is not as widely appreciated is how the technological advances that led to unlocking the human genome are impacting our understanding of the marine environment and marine microbes in particular. Marine microbes are abundant, diverse, and globally significant, producing and consuming green house gases, bolstering the base of the food chain, and affecting our planet in profound ways.

The wealth of genomic information about microscopic organisms in our ocean is growing, as DNA sequences are being deciphered for many marine microbes. Microbial oceanographers such as myself have been participating in this "genomic revolution." With my OLI Fellowship, I have been re-evaluating our understanding of marine microbes and their activities in the sea. I am interested in what genome sequences can tell us about how microbes process resources such as carbon, nitrogen and phosphorus in the ocean, and which geochemical conditions allow specific organisms to thrive and proliferate.

During the last year I have been working with the genomic sequences of several marine microbes. My efforts and those of a graduate student, Louie Wurch, have focused on the *Aureococcus anophagefferens* genome. *Aureococcus* is a species of algae responsible for the harmful algal blooms (HABs) known as "brown-tides". Brown tides are a serious and recurrent problem in Long Island Sound and other coastal areas, resulting in deleterious impacts to the ecosystems in which they occur. In collaboration with a consortium of other investigators, we have been studying the *Aureococcus* genome sequence for clues as to how this species is able to proliferate so rapidly in some areas.

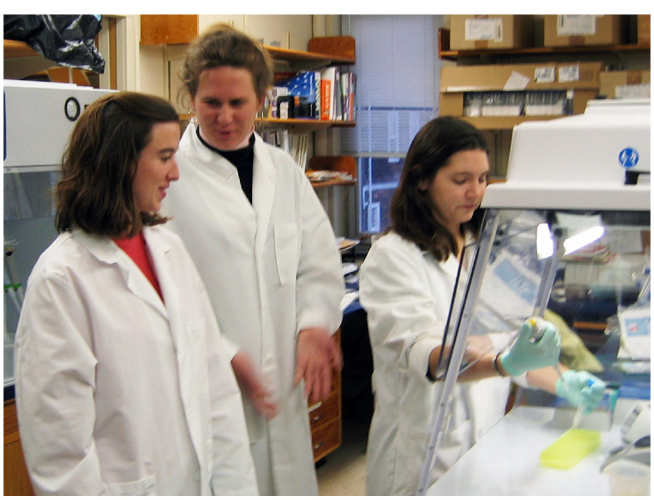
The genomics results to date suggest that *Aureococcus* may have a broader ability to cope with fluctuations in the availability of light, carbon, nitrogen, and phosphorus than other algae (Figure 1). We have also identified mechanisms that might allow *Aureococcus* to deter grazers – marine animals that might eat them. Taken together, this is our first insight into how this harmful species, and potentially others, are able to thrive under certain conditions.

To complement this work, Louie and I have also been studying how the genes in the genome are expressed. The genome sequence indicates the capacity *Aureococcus* may have for metabolizing nitrogen and phosphorus, etc., but it does not tell us when this capacity may be used. Our gene expression studies so far suggest that *Aureococcus* has a robust and widespread response to fluctuations in nitrogen and phosphorus. These data emphasize the resiliency of this organism and highlight one possible mechanism for how this organism is able to grow to such high densities. We hope that our observations with *Aureococcus* can now be expanded to other HAB and non-HAB algae to better understand the common features of different species and better predict how carbon, nitrogen, and phosphorus drive the activities of these microbes in the sea. – *Sonya Dyhrman*



Jack Cook, WHOI

Figure 1: In our genome sequence study of the harmful algae Aureococcus, *we found that it is well adapted to harvest light, deter grazers, and scavenge macro- and micro-nutrients. The genome of* Aureococcus *is larger than the genome sequences of its competitors,* Ostreococcus *and* Thalassiosira *(56, 12 and 34 megabases respectively). For the factors indicated in yellow/orange lettering,* Aureococcus*either has more genes than its competitors or has genes conferring unique capabilities. The genome sequence thus illustrates how* Aureococcus *is able to proliferate, beating out its competition.*



Sonya Dyhrman (center) working with two students in her laboratory.

Population Studies

What Controls the Survival of Young Marine Animals?

The question of how many young join the adult populations of marine animals every year – how many young mussels, clams, barnacles, lobsters or fish "recruit" – has motivated hundreds of studies. Recruitment is often the most important process determining population change from year to year. If recruitment of a fish, clam, or crustacean is good, an abundant supply is expected; if it fails, expect higher prices of your favorite seafood at the fish market. This problem has vexed entire generations of marine biologists, ecologists and oceanographers. Why is this question so hard, even after one hundred years of research? Marine crabs, clams, and fish living near coral reefs have complicated lifestyles. The grownups are large and spend their life near home; but their progeny are born very small, and the larvae drift at the mercy of the ocean currents.

Researchers have found that a multitude of factors determine recruitment. For example, for northern rock barnacles – a model species that behaves like many other marine organisms – researchers have found that up to 9 different factors can influence how many young reach adulthood. These factors include how many barnacles set on rocks, natural agents killing the young, predation by snails and crabs, young barnacles competing against each other and crushing their neighbors, heat in summer, etc. With so many factors operating at the same time, it is practically impossible to assess their relative role. An experiment where all factors are dealt with simultaneously, repeated, and performed over a wide range of environments and years, "la rigueur scientifique," would be of such a magnitude and cost what a small version of a NASA-like agency would be needed to fund it. Imagine a NASA-like agency for studying barnacles – the headlines, and the disputes over funding!

Can timing be the "Rosetta stone" for understanding recruitment? A few years ago we discovered that young barnacles that survive to adulthood set on rocks only at particular times of the year within a "recruitment window." This finding is important, because the number of factors that could determine the recruitment window – the health of the individuals, the quality of their home, and the weather – are fewer than the factors that have been traditionally implicated in determining recruitment. With OLI support, our lab is pursuing this idea, aiming to find out whether "recruitment windows" occur every year. We are also investigating whether they occur for other species and in different geographic settings, including near the Liquid Jungle Lab in Panama. We are excited about the potential of this new research for resolving the recruitment problem – important to basic and applied science. There is still much to be learned, but this research offers a new avenue of understanding marine animals and a new tool to study them. – *Jesús Pineda*

larvae recently settled (the torpedo-like shape in the center of the shot), small juveniles, and adult northern rock adult barnacles.

Graduate Student Thesis Work

How Do Tiny Larvae Cope with Ocean Currents?

Many coastal marine animals exist for minutes to months as tiny planktonic larvae early in their life cycles. These larvae are so small that they cannot swim against the horizontal ocean currents they encounter. Why is it, then, that they don't get swept out to the open sea? How do planktonic larvae return to the near shore environment to grow into adults?

At the Liquid Jungle Lab (LJL) in Panama, we have observed a special kind of oceanic front called an internal tidal bore front. My advisor, Jesús Pineda, has shown that, off the coast of California, larvae can accumulate at the surface in these fronts if they swim upward against the downward currents. As the fronts travel onshore, they can transport larvae back to the habitat they seek. Is the same mechanism aiding larvae in Panama?

In April 2007, I spent a month at the LJL collecting plankton samples and oceanographic data. I found many kinds of larvae – crabs, barnacles, mantis shrimp, fish, and others. I am now working to identify the larvae and determine whether they reached my study site in highest concentrations at the same time that the fronts arrived. This work will be central to my PhD thesis and would not have been possible without the generous support of the Ocean Life Institute. – *Joana Gyory*

Photo above: Planktonic larvae from Panama. Clockwise from the top: Anomuran crab, mantis shrimp, brachyuran crab, euphausiid, and a second type of anomuran crab.

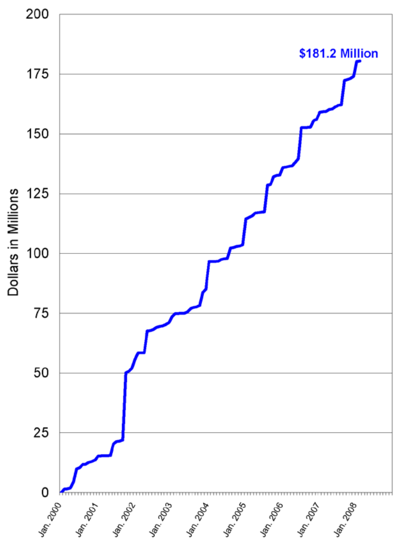
Financial update

Our campaign to support the Ocean Institutes had raised in excess of $181 million by the end of March 2008. We are within 10% of completing our $200 million campaign goal! To all those who have contributed to this success, thank you so much.

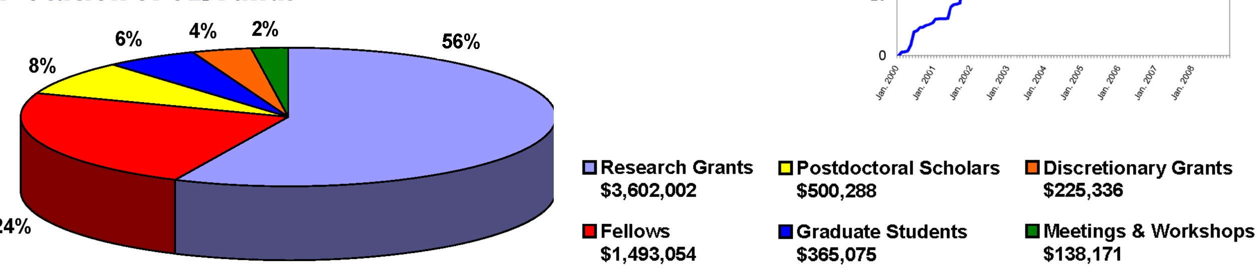
OLI allocates the majority of its funds toward research grants (56%) and fellowships (24%), supporting dozens of WHOI scientists. The next generation of oceanographers – postdocs and students – benefits from OLI support as well. Finally, OLI produces podcasts and hosts workshops on topics such as biological sensors, pharmaceuticals, invasive species, coral reefs, whales, and more.

Campaign Funds Raised to Date: $181,201,619

As of March 31, 2008



Allocation of OLI Funds



About the Ocean Life Institute

The Ocean Life Institute (OLI) explores the oceans' extraordinary diversity of life—from microbes to whales—to identify ways to sustain healthy marine environments and to learn about the origin and evolution of life on Earth and perhaps other planetary bodies. Institute researchers pursue biological questions that affect natural ecosystems and/or human society. Our objective is to advance the understanding of marine organisms and biological processes with new technologies and approaches, to develop new opportunities for research, to convene local and national discussions on important ocean-life questions, and to communicate scientific results in a timely, objective, and effective manner to other segments of society.

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Front cover: Underwater view of a pristine tropical reef with brilliantly colored hard and soft corals Photo by Tommy Schultz, Dreamstime.com
Back cover: View from the Liquid Jungle Laboratory in Panama. Photo by Mary Carman, WHOI.