Ocean Life Institute

Annual Report ~ Spring 2006

Message from the OLI Director

Larry Madin. Photo credit: Peggy Hamner, UCLA

The biology of the seas is a broad and complex subject. At the microscopic scale, the metabolic activities of ocean microbes are responsible for most of the chemical transformations that make the global ecosystem work and hold important clues to the origin of life. At the other end of the size spectrum, failing fisheries and endangered marine mammals have direct impact on the economics and culture of human society. In between, myriad species and processes are connected with each other and with their environment in ways that we don't fully understand. We do know enough now to realize that ocean ecosystems and biological processes are vital to the maintenance of life on our planet.

The Ocean Life Institute continues to support basic research, provide new opportunities for WHOI scientists and students, and disseminate information through professional and public venues. Two special research initiatives are continuing from previous years. The North Atlantic Right Whale Initiative (page 5) launched a new project to discover the locations of whale feeding grounds by examining the chemical makeup of their baleen. The Coral Reef Fish Connectivity and Conservation Initiative held a planning workshop to map out the next stages of a program to gather information vital to the conservation and management of economically important fish species in the Caribbean. WHOI scientists also began several new research projects at the Liquid Jungle Laboratory in Panama, with support from OLI and Tropical Research Initiative grants (page 5). A major achievement there was installation of the PLUTO observatory (page 6).

In this report we highlight three OLI-supported research projects in quite different areas that reflect the interconnections among organisms and processes in the sea. At the top of the marine food chain are whales. Field research by MIT/WHOI Joint Program student Ari Shapiro and his advisor, Peter Tyack, on killer whales in a Norwegian fjord has revealed fascinating details about the social organization that these toothed whales display while feeding on herring. Acoustic recording tags placed on the whales have allowed Ari and Peter to track their movements and uncover some surprising patterns of communication and behavior.

Norwegian herring feed on zooplankton, a vital link in the ocean food web. Knowledge about the composition and distribution of zooplankton is crititcal in describing ocean ecosystems and monitoring changes. Traditional plankton sampling methods are time- and labor-intensive; but, over the past several years, Cabell Davis has been developing the Video Plankton Recorder – a towed instrument that counts and identifies small zooplankton almost automatically. With support from an OLI fellowship, Davis has been working on the next technological step – using laser holography to create even more-detailed pictures of individual organisms by imaging volumes of water in 3-dimensions with very high resolution. Installed in autonomous vehicles and combined with biochemical sensors, the holographic system may be able to provide unprecedented spatial coverage and taxonomic accuracy for plankton surveys.

Underlying all this ocean life is photosynthesis by phytoplankton, a process that turns CO_2 and sunlight into algae, the primary fodder of the food chain. Another gas, dimethylsulfide or DMS, is generated as a byproduct of phytoplankton growth and zooplankton feeding and enters the atmosphere, where its breakdown products act as "seeds" for the formation of clouds. More DMS in the atmosphere can lead to more cloud formation, which increases the reflection of solar energy back into space. This mechanism could act as a "feedback loop" that helps reduce global warming. John Dacey studies gas exchanges among organisms, the ocean and the atmosphere. The factors controlling the concentration of DMS in the surface ocean are not well understood, as many processes (biological, chemical and physical) come into play. Dacey has developed a new multiple-tracer method that *simultaneously* tracks all the key DMS-related compounds in one sample.

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Research Highlights

Foraging and Acoustic Behavior of Free-ranging Killer Whales

Ari Shapiro and Peter Tyack

Animal culture involves the transmission of behavioral patterns from one generation to the next via teaching and imitation. It has compelling implications for intelligence and learning across a wide range of species. Social learning – the phenomenon by which an individual acquires behaviors by observing others – is critical for cultural transmission. Indeed, one hypothesis proposes that some social environments place a premium on learning and its associated cognitive and behavioral flexibility. Cultural transmission of behavior can occur among animals with a variety of social relationships including parent and offspring, reproductive partners, kin or members of an age, sex or social cohort.

Most research on animal culture has focused on foraging techniques and vocal traditions. Studies of culture in cetaceans (whales and dolphins) have fueled a lively debate over the presence and nature of culture among these animals. Killer whales (*Orcinus orca*) are superb candidates for investigating animal culture and social learning because of the diversity of their population-specific foraging strategies, their stable community structure, and group-specific vocal repertoires.

Killer whales that feed on schools of herring off the Norwegian coastline display a highly coordinated group foraging behavior called "carousel feeding," during which they produce unique sequences of calls compared to other populations. While carousel feeding, these whales circle the herring to gather them into a tight school, ultimately lunging towards them and tail-slapping the crowded herring to incapacitate the fish before feeding on them.

Killer whales "carousel feeding" on a school of herring. Photo courtesy of Fernando Ugarte and Tiu Similä.

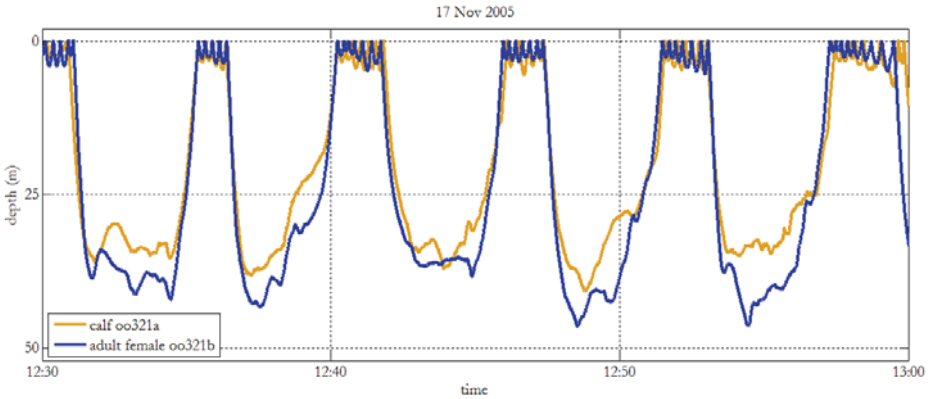
With financial support provided by the OLI, we conducted our first field season in the waters of Tysfjord, Norway, during November 2005. Collaborating with a group of Scandinavian researchers, we successfully placed non-invasive digital archival tags on eight free-ranging Norwegian killer whales. These instruments recorded the movements of the tagged individuals and the sounds produced by all group members, which permitted subsequent investigation of the contributions of individual animals to group feeding and vocal behaviors.

The primary objectives of the study were to examine: the roles played by individual whales during group carousel feeding events; how vocal interaction may help coordinate group behavior during foraging and non-foraging situations; and the way in which vocal elements are assembled syntactically into discrete calls and call sequences.

We deployed the tags from a small, inflatable boat to allow close approaches to the animals. The tags were attached to the orcas using a hollow 7-meter-long carbon fiber pole, a technique pioneered by WHOI whale researchers. At the same time, a separate crew aboard a sailing vessel took photographs and made visual and behavioral observations. Each tagged whale was tracked to record its range and bearing to the vessel when it surfaced.

The tags were programmed to release from the whales at a predetermined time so they could be collected and the data offloaded. These data are especially useful for examining how the killer whales synchronize their movements as they feed and travel (see figure below). Half of the eight tags deployed were attached to pairs of animals in the same social group at the same time. Five of the tagged animals engaged in carousel feeding during part of the time that they were tagged.

We are enthusiastic about the data that we have already collected, and we are looking forward to a second field season in November 2006 to expand our synchronous tagging of multiple killer whales. The orcas studied here engage in complex behaviors that are coordinated at the group level and produce a rich vocal repertoire, offering a biological system in which the integration of social and vocal complexity will likely help to illuminate important facets within the realm of animal culture.

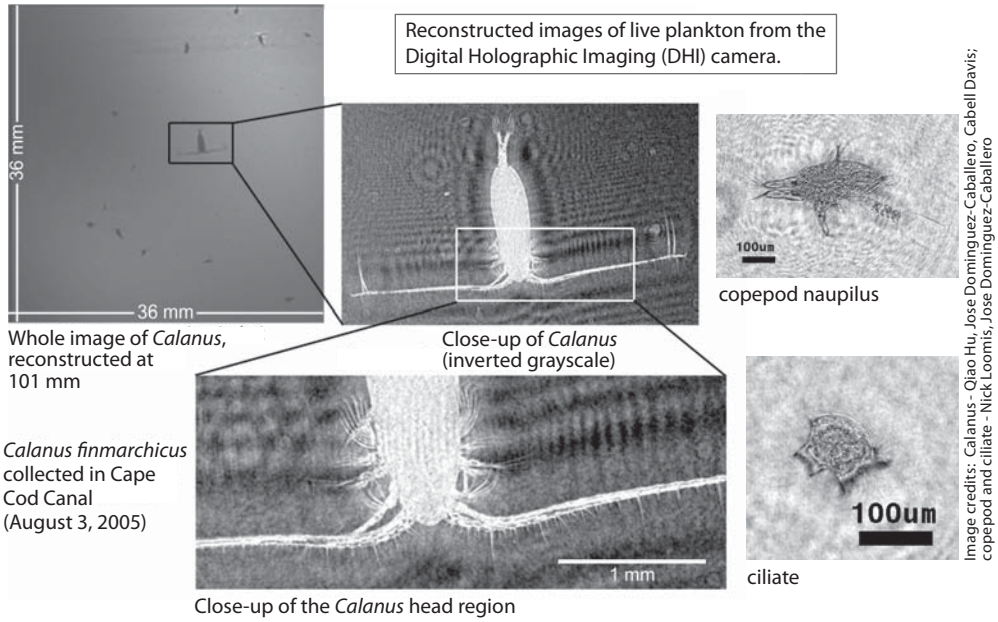


Dive records from tagged whales. This plot shows the synchronous diving behavior of two whales that were traveling at opposite ends of a coherent group. Image courtesy of Ari Shapiro.

Research Highlights

Imaging Ocean Plankton

Cabell Davis



The vast majority of marine organisms live in the form of plankton for at least part of their lives. Plankton represent the base of the ocean food web and are a vital link in the flow of food energy to larger species. It is therefore important to understand their distribution, abundance and composition. Sampling methods generally used to study plankton do not provide the high-resolution data needed to model and predict plankton population sizes and interactions. The traditional method of collecting plankton with nets is labor intensive in the field and in the laboratory, and as a result, produces sparse data coverage.

To address this problem, WHOI biologist Scott Gallager and I developed an instrument called the Video Plankton Recorder (VPR). The VPR is an underwater video microscope that provides high-resolution data on the size and composition of plankton. Unlike traditional methods, optical sampling does not damage the organisms being observed, allowing fragile plankton and particles to be quantified. VPR sampling has revealed that fragile colonies of diatoms and protozoa are 10 to100 times more plentiful than previously thought, making them very important to the biological and chemical processes in the ocean.

Recently, we towed the VPR three thousand nautical miles across the Sargasso Sea during the R/V *Knorr*'s transit from the Mediterranean Sea to WHOI. The VPR is typcally towed behind a ship, where it undulates between the surface and a depth of 130 meters. This sampling technique yielded 6,910 vertical profiles across the Atlantic Ocean. Data on delicate blue-green algal colonies (cyanobacteria, *Trichodesmium*) revealed a close association between the colonies and warm water eddies. In additon, we found greater abundances of the colonies in deeper layers than previously reported, which has important implications for global ocean productivity.

Optical sampling's key advantage is the generation of electronic images that can be automatically identified by a computer. MIT/WHOI Joint Program student Qiao Hu developed software that performs image analysis and pattern recognition to accurately and automatically classify plankton images from the VPR into major taxonomic groups. We are now able to automatically identify plankton images from the VPR and plot their distribution in near-real-time at sea.

While the VPR provides excellent data on major taxonomic groups, the image quality is too coarse to identify plankton to the level of species. With support from an OLI fellowship, I have collaborated with Jerry Milgram and George Barbasthasis (both at MIT) to develop new holographic imaging methods that produce high quality, 3-D images of plankton. Our prototype digital holographic imaging camera can capture a digital hologram of a 36 x 36 x 1000 mm volume of seawater.

Computer reconstruction is used to view virtual "slices" less than one millimeter thick through the volume. This high resolution imaging reveals very fine details of zooplankton and even microzooplankton.

In the future, we will pursue color digital holographic imaging, volume holographic imaging, and the development of automatic identification methods for holographic images. The volume holographic imaging method has the potential to yield 5-micron resolution in all three dimensions, resulting in images that will enable simultaneous identification of species and life stages. We are also exploring the combined use of spectroscopy and holography to analyze elemental and molecular structures within the organisms. These non-destructive optical methods, combined with new classification software, will enable researchers to observe, count and identify species and life stages of plankton automatically and with unprecedented resolution in time and space.

The holographic imaging systems are small and use little power, so they can be deployed on autonomous robotic platforms and ocean observing systems. The resulting high-resolution data will transform our ability to understand how the size, composition, and distribution of plankton populations are controlled in the ocean.

Research Highlights

New Tracers to Study DMS Dynamics in Seawater

John W. H. Dacey

With so much attention paid to carbon dioxide in relation to climate change, it is not surprising that the roles of other trace gases are overlooked by the public. One gas that is emitted to the atmosphere from literally every square meter of the ocean surface is considered to be a "cooling gas" in the framework of global climate. Dimethylsulfide (DMS) achieves this "cooling" effect by virtue of its readiness to oxidize in the atmosphere. The compounds formed by DMS oxidation tend to condense water from vapor into a light-reflecting aerosol. These DMS-inspired clouds cool Earth's atmosphere by reflecting incoming solar radiation back to space.

The formation of DMS begins when a broad range of planktonic algae produces the sulfonium compound dimethylsulfoniopropionate (DMSP). As DMSP travels up the food chain, one of its decomposition products is DMS, which in high concentrations, can negatively affect the flavor of seafoods.

DMSP is converted to DMS and other compounds through a myriad of processes (see figure). Much more is known about the fate of DMS once it reaches the atmosphere than is known about the dynamics of DMS in the surface water where it is formed. Its concentration in surface water is governed by complex physical, chemical, and biological interactions such as nutrient availability, zooplankton grazing, and viral and bacterial degradation.

There are several key pools of DMS-related compounds that we are studying: DMSP in the cells of living organisms, DMSP dissolved in seawater, DMS, and dimethylsulfoxide (DMSO). To examine the dynamics of these compounds we need chemical tracers. In recent years, a radiotracer method has been developed for following two important pools, DMS and dissolved DMSP. This method has increased our ability to measure rates for a few transformations in seawater samples. The turnover of DMSP and DMS, however, cannot be traced simultaneously in the same sample using this method.

With funding from the Ocean Life Institute, I have begun developing a new tracer method for measuring the turnover of four key DMS-related compounds *simultaneously* in the same sample. The method depends on replacing hydrogen atoms on the molecules of DMS, DMSP and DMSO with deuterium atoms – a stable, non-radioactive, isotope of hydrogen. By replacing different numbers of hydrogen atoms, each compound gets a readily distinguishable "fingerprint." Using a mass spectrometer it is possible to measure how many deuterium atoms there are on a compound of interest, and it is now possible to tell what its precursor was.

In my early experiments, I collaborated with Dr. Jacqueline Stefels from the University of Groningen (Netherlands) on a cruise to the Antarctic, as part of a larger project called Ice Station Polarstern (www.ispol.de). This European field experiment was designed to improve understanding of physical and biological air-sea-ice interactions. The 2004-2005 cruise involved a 50-day drift station on the icebreaker, *Polarstern*, in the western Weddell Sea, the largest perennial ice zone in the Southern Ocean. The project provided a unique opportunity because, during the Antarctic spring and summer, DMSP and DMS (and as we discovered, DMSO) appear in extremely high concentrations in the ice communities.

On that cruise, we successfully traced – for the first time ever – synthesis of DMSP by algae. By working in slush on the ice surface where concentrations were very high, we could also measure the turnover of DMSP, DMS and DMSO. Our most notable finding was the very rapid conversion of DMS to DMSO on the ice surface. This conversion is a result of photochemical oxidation, presumably due to the high levels of UV radiation in the austral summer at these latitudes.

This powerful new tracer method is proving to be very useful in understanding the dynamics of DMS and related compounds in seawater and should enable a better understanding of this "cooling gas."

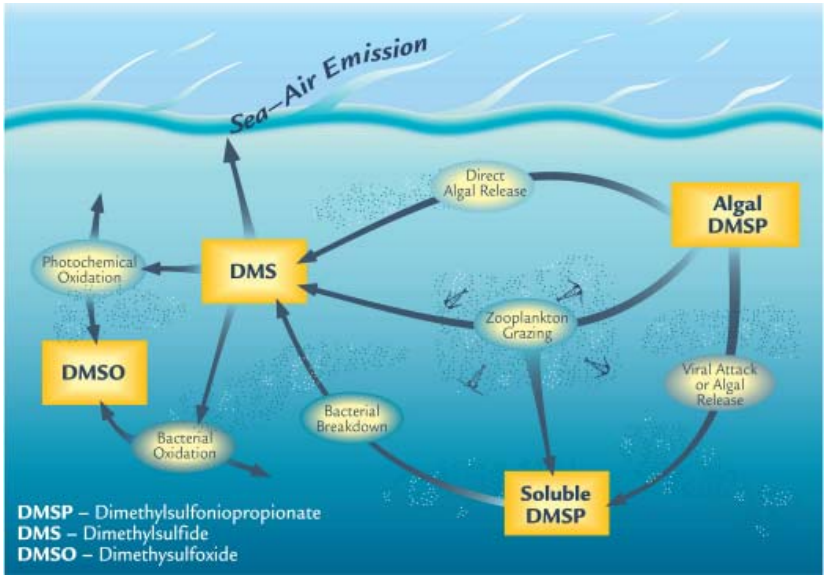


Illustration: Jayne Doucette, WHOI

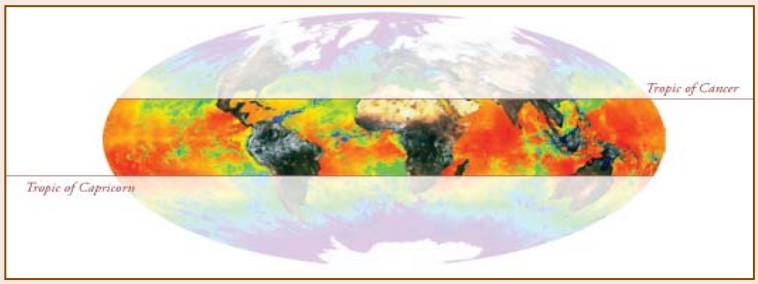
Schematic diagram showing the four key compounds and the various processes regulating DMS concentration in the ocean. By giving each compound a distinct label, Dacey's new tracer method makes it possible to distinguish and quantify the pathways of DMS production and consumption in a single sample.

Tropical Research Initiative

The Tropical Research Initiative (TRI) was launched in 2005 to support technological advances and scientific study of the oceans in the region between the Tropics of Cancer and Capricorn (in the northern and southern hemispheres, respectively). OLI is pleased to administer the TRI, which encourages participation by members of all WHOI departments, centers and institutes.

Currently, TRI grants have been awarded to study toxic poisoning in fish due to harmful algae in the Caribbean, climate change in the tropics, hurricanes and El Niño/Southern Oscillation (ENSO), chemical defenses used by snails in the ecology of coral reefs, and mangrove forest productivity. The projects address issues related to the past and present health of marine ecosystems in the tropical latitudes.

Our sincere thanks go to WHOI trustees Frank and Lisina Hoch for establishing the initiative through a generous challege grant.



Funded TRI projects in 2005

Scientists, Department	*Project Title*
Don Anderson and Deana Erdner, Biology	Population Biology of Toxic Algae in the U.S. Virgin Islands: Towards an Integrated Study of Fish Poisoning
Marco Coolen, Marine Chemistry & Geochemistry	Exploration of Fossil DNA as a Novel Tool to Reconstruct Past Microbial Diversity and Climate Change in the Tropics
Jeff Donnelly, Marine Chemistry & Geochemistry	Millenial-Scale Records of ENSO and Intense Caribbean Hurricanes
Mark Hahn and Kristin Whelan, Biology	Biochemical Ecology on Coral Reefs
Simon Thorrold, Travis Elsdon and Lea Houghton, Biology	Are Mangrove Forests Important Juvenile Nursery Areas for Coral Reef Fishes?

Friends of the Ocean Life Institute

Wick and Sloan Simmons Support OLI's North Atlantic Right Whale Initiative

Photo courtesy of Wick Simmons

Sloan and Wick Simmons

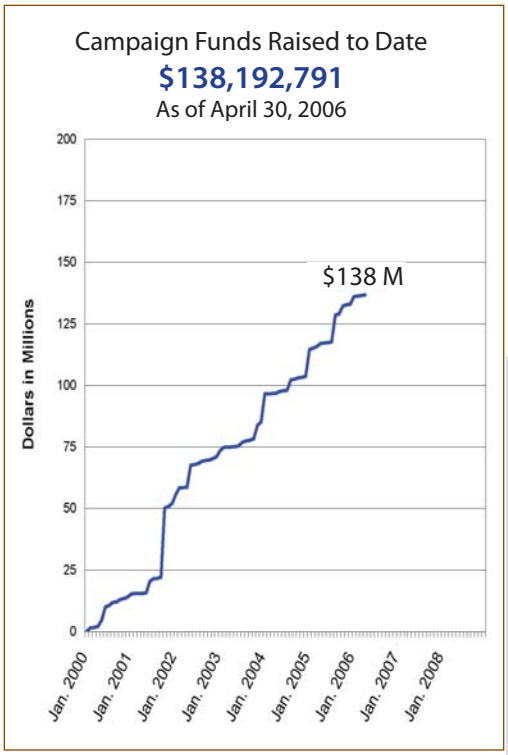
The North Atlantic Right Whale Initiative addresses the plight of a local endangered species. North Atlantic right whales spend much of the year feeding in Cape Cod Bay, the Bay of Fundy, and around Nova Scotia, while they winter and breed off the Carolinas, Georgia and Florida.

Throughout their feeding and breeding seasons and during the long migration up and down the eastern seaboard, the whales are exposed to many dangers, including ship strikes in busy shipping lanes, pollution in coastal waters, and entanglement in fishing gear. The species is struggling to prosper in the face of such hazards, and their dwindling population is anxiously monitored by numerous scientists. It is estimated that only 300 to 350 animals remain. WHOI scientists are actively seeking the knowledge and means to give the animals a needed edge in their precarious world.

WHOI trustee Hardwick Simmons and his wife, Sloan, have been ardent supporters of the Right Whale Initiative. OLI is deeply grateful to this couple and to all Initative and Institute donors.

Financial Information

Campaign Progress



Allocation of OLI Funds

The pie chart below illustrates how OLI funds were distributed between 2001 and 2005. The vast majority of funding has been used to support 35 different research projects, some of them under the auspices of OLI initiatives such as the Right Whale Initiative and the Tropical Research Initiative (page 5). Scientists, engineers and technicians from all WHOI science departments are represented in the research project pool. Altogether, 10 fellows, 5 postdoctoral scholars, and 3 graduate students were supported. OLI also sponsored a range of workshops, symposia, and conferences on topics relevant to ocean life.

In 2005, OLI appointed three new fellows who are working on topics that reflect the span of OLI interests. Sonya Dhyrman in the Biology Department will use her fellowship to pursue genomic studies of phytoplankton cells, investigating the expression of genes that are involved in nutrient uptake. On an ecological scale, Jesús Pineda, also in the Biology Department, plans to use his fellowship to investigate larval transport and distribution of benthic and intertidal organisms from temperate to tropical environments. Research specialist Anne Cohen in the Geology & Geophysics Department will be conducting studies on corals to determine the relationship between coral growth rate and environmental conditions.

PLUTO

In January 2006, WHOI biologist Scott Gallager led a small team of engineers to the Liquid Jungle Lab in Panama to install an underwater observatory known as PLUTO – the Panama Liquid Jungle Lab Underwater Tropical Observatory. Funded by a grant from OLI, the observatory incorporates sensors to record temperature, salinity, currents and other physical parameters. Underwater and terrestrial video cameras also were put in place. This is the first observatory of its kind in Central America. PLUTO can be accessed from anywhere in the world at http://4dgeo.whoi.edu/panama/. Additional instruments and sensors can be added, as needed, to support science. Data from this tropical location will become a valuable addition to the global network of underwater observatories.

OLI Leveraging

All forms of OLI research support – grants, fellowships, postdoctoral and graduate scholarships and discretionary spending – help to establish new research directions and provide additional opportunities for WHOI staff. Often these projects develop into much larger scales, both in the scope and significance of the science and in the subsequent funding provided by federal agencies. This leveraging effect is one of the most important contributions that Institute funding makes, both for WHOI scientists and frequently for the oceanographic community at large.

Recent examples of OLI leveraging include two federal grants to WHOI totaling approximately $1.2 million. One project recently funded by NASA for studies on phytoplankton population dynamics in the coastal ocean built on work Heidi Sosik did as a fellow. Another project to study genetics of red tide algae by Don Anderson and Deana Erdner garnered a ten-fold return on investment in a grant from the National Institute of Environmental Health Science. In addition, Cabell Davis's fellowship to develop holographic imaging methods (page 4) has led to external funding in the range of $625K. OLI funding in all forms has helped WHOI scientists obtain external research support at a ratio of about eight to one overall.

OLI Fund Allocation 2001 - 2005