Coastal Ocean Institute

And Rinehart Coastal Research Center

2006 Annual Report

Message from the COI Director Don Anderson

Photo by J. Kleindinst

These are exciting and challenging times for coastal scientists. It is now widely accepted that Earth is going through a period of warming; some believe at an alarming rate. Scientists and government officials disagree on the causes for this change – whether it is linked to human activities or is, instead, a natural cycle – but most acknowledge that it is indeed happening.

From an oceanographic standpoint, the effects of this warming are numerous. Accelerated sea-level rise is but one manifestation, leading to inundation of wetlands and other coastal habitats. Rapid shoreline erosion can lead to destruction of homes, roads, and other coastal infrastructure. Changes in weather patterns can also occur, resulting in more frequent and more intense storms, which can have a major impact on coastal regions.

Concurrently, coastal waters are subjected to growing pressures from pollution, over fishing, development encroaching on marshlands, and other stresses that alter ecosystem function as well as the aesthetic value of the coastal zone. As population and associated development along the coasts expand, these pressures and their impacts will continue to increase.

The news is not all bad, however. Scientific knowledge and technology have much to offer, by providing the information and data needed for informed policy decisions, and by identifying design features and strategies that can reduce future impacts. The coastal science community is eager to take on these many challenges.

The Coastal Ocean Institute (COI) was established to facilitate such work. The COI provides support for research projects, fellowships, postdoctoral investigators, and students. It also hosts workshops and symposia, and provides facilities that make coastal research possible. This support is critical to the productivity of many coastal scientists at WHOI. Funds provided as modest seed money are often leveraged five- or ten-fold into large government grants that would not have been awarded without preliminary data or the development of essential equipment. We recognize that our scientists also need resources to formulate and implement major scientific programs that can be supported by the government, industry or private foundations. Thus, we are supporting "New Initiative" activities that give scientists salary and travel support to develop large collaborative programs.

In this annual report, we highlight three programs currently supported by the COI. One project addresses the economic impacts of erosion and shoreline change. Another takes on the challenging problem of measuring the volume of groundwater entering the coastal ocean and the concentrations of any potentially hazardous chemicals it contains. The third article describes how measuring the frequency of major storm events in the distant past can provide an indication of what we may face in the future. These projects represent just a few of many ongoing programs being undertaken by WHOI's talented coastal scientists – all through the support of the COI.

Challenging times can present exciting opportunities. The COI is here to facilitate such opportunity, building the base of scientific knowledge and expertise that is so critical to our ability to respond to these challenges. We truly appreciate the support of dedicated friends of coastal science – those who see the challenges and help us take the steps to address them. □

- Don Anderson

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Evaluating the Economic Consequences of Shoreline Change

Shoreline change has potentially large social and economic consequences. Its causes can be either natural or man-made, or a combination of the two. Changes occur through erosion and deposition, both of which can alter the risks associated with other natural hazards, such as flooding and wave damage. These hazards may result from short-term storm events, longer-term movements of sediments from one location to another, or even longer- term changes in sea level.

Growing human populations in coastal settings are likely to intensify the economic consequences of shoreline change. More than 155 million people in the U.S. (53% of the population) now reside in coastal counties, and this number is expected to grow to 168 million over the next decade. Another 180 million people visit the U.S. coast every year. Studies have estimated that between 300,000 and 350,000 homes and buildings are located within 500 feet of the U.S. shoreline, including 85,000 homes that are located within 60-year erosion-hazard areas. As many as 1,500 homes and land parcels may be lost to erosion each year in the U.S.

Leading coastal geologists at WHOI and elsewhere have called for a national science program to enhance our capacity to understand long-term shoreline change. Estimates of the costs of shoreline change at local and regional scales, such as those we are developing in our work, will help strengthen the case for this much-needed program.

Several studies have examined the costs of sea level rise due to global climate change. As the planet warms, so does the ocean; and, as warm water expands, global sea levels rise. Higher sea level can lead to accelerated shoreline changes. Depending upon local conditions, sea level may rise as much as one half of a meter, on average, over the next century. Local changes in sea level may be more or less than this average, depending upon local topography and geology.

Recent estimates of the cost of sea level rise incorporate assumptions of adaptation, such as the possibility of allowing structures to depreciate in anticipation of sea level rise. These estimates will amount to about one-half billion dollars annually by the year 2065, and do not include the costs of storm events, damage to natural areas, or losses due to erosion.

Eroding shoreline in study area on Cape Cod. Shoreline change in all forms may cost billions of dollars annually. A team of scientists at WHOI is developing estimates of shoreline changes on Cape Cod to predict the position of the coast in the future. Photo by Jim O'Connell.

The risk of coastal erosion may be at least as large as the risk from flooding, and, in some cases, prolonged erosion and land loss can increase vulnerability to flooding. Coastal erosion may decrease the value of coastal properties as a function of the expected number of years away from inundation. The actual loss of property, including structures, due to coastal erosion, may amount to as much as one-half billion dollars annually at the national level.

With support from the Coastal Ocean Institute, our group has begun developing estimates of the rates of shoreline change based upon geological measurements (taken during the past 30 years) that show the changing position of the coast.

The U.S. Geological Survey has begun to map shoreline changes using similar data in areas including portions of the Gulf of Mexico, California and the New England coasts. We are focusing our attention on the Cape Cod shoreline, which has been ignored in recent national studies of the costs of shoreline change. We are using estimated rates of shoreline change to predict the position of the coast in the future.

We collected data from Cape Cod towns on the location and use of coastal properties, as well as the assessed property values. This information forms the basis of our estimates of the costs of shoreline change in these towns.

Additional work will involve the potential incorporation of topological data, evaluating the relationship between property assessments and market values, and simulations over varying time periods and shoreline change rates. We will also compare our estimates with those compiled by the U.S. Geological Survey. This work will provide coastal managers with essential data that will guide future planning in coastal communities. □

- Porter Hoagland, Di Jin, Rob Evans, Hauke Kite-Powell, and Jim O'Connell

Identifying Coastal Pollution from Submarine Groundwater

Expanding residential and commercial development near the shore is leading to increased nutrient inputs to groundwater. Several-decades-long research shows that nitrogen input over large areas of the coastline causes the decline of its ecological health and may support harmful algal blooms.

According to today's estimates, groundwater discharge into coastal waters worldwide represents up to one tenth of total global river flow. In some areas it might be as high as one third as large as the river discharge. How can we measure the "invisible" submarine groundwater discharge and, more importantly, identify its composition?

The problem we are facing is that we do not have effective methods to directly measure submarine groundwater discharge and corresponding nitrogen fluxes, because groundwater discharges very slowly over large areas. The flow differs depending on location, with water preferentially discharging through underground conduits in sediments or rocks. Furthermore, its magnitude is influenced by tidal and seasonal cycles. Marine processes like tides and waves force some seawater into the sediments and underground aquifers, and this water eventually discharges back to the surface creating a second, saline component of submarine groundwater discharge. These marine processes also influence the transport of potential pollutants from the land to the coastal zone.

Postdoctoral scholar, Henrieta Dulaiova, taking ground water samples in Waquoit Bay, Massachusetts. She and colleagues are measuring the amount of chemicals such as radon and nitrate in groundwater to determine the volume and pollution levels of groundwater discharge to coastal waters. Photo by Peter Fuleky.

Aerial view of Waquoit Bay. Dark blue circles represent low radon levels where no groundwater discharge occurs. The light blue, yellow and red circles symbolize increased radon concentrations—red representing the highest levels. The red circles in the Childs River (upper left) indicate intense groundwater discharge in an area of heavy residential development. Photo by Peter Fuleky.

Our research has shown that quantitative information on the magnitude of submarine groundwater discharge on a regional scale can be obtained from chemical tracer studies. Due to their enrichment in groundwater relative to surface water, chemicals such as radon and methane serve as universal indicators of both fresh groundwater and re-circulated seawater inputs into the coastal zone.

The chemical element, radon, naturally occurs in the ground as a result of seepage from soil and rocks, which contain minute quantities of radium. (Radium is a natural decay product of uranium present in various types of rocks.) Groundwater carries radon to the coast; so, by measuring the levels of radon in the groundwater at various locations, we can determine the rate at which groundwater is flowing to the coast.

For our COI-funded project, we constructed a radon/methane/nitrate mapping system that measures the concentration of these components in the surface water along the coast. The survey system is complemented by a GPS and a salinity probe. The advantage of this system is that we can see the radon and methane levels in the water immediately during mapping. Once we locate sites where submarine groundwater discharge is occurring, we can obtain precise chemical concentration distributions and define the extent of the area of groundwater discharge.

In addition to collecting methane and radon data at these sites, a mini-mass spectrometer is used to identify other dissolved gases (carbon dioxide, oxygen, nitrogen, and hydrogen). With the system we devised, we can map miles of coastline in one day while selectively collecting more detailed tracer information at groundwater discharge sites. We then calculate a radon and methane "mass balance" to decipher submarine groundwater discharge rates and corresponding nitrate fluxes for each area. This approach also proves to be very effective in distinguishing groundwater nitrate fluxes from surface runoff inputs or other sources, because only the groundwater nitrate is accompanied by radon. Such information is useful for coastal managers who have to consider the relative importance of submarine groundwater discharge compared to other factors considered in management activities.

We tested our system in September 2006 in Waquoit Bay, Massachusetts. Over the years, we have collected a substantial amount of background information about the hydrology and geochemistry in this Bay, which is why we chose to test our mapping system there. From this survey, we could clearly identify high submarine groundwater discharge and groundwater-derived nitrate in the nearby Childs River, moderate fluxes at the head of Waquoit Bay, and moderate groundwater fluxes in nearby Quashnet River, which had a much lower nitrate flux. We will repeat the same survey in May 2007 during the wet season to contrast submarine groundwater discharge and nitrate fluxes to the dry season (September). We are confident that the survey system we developed will be very effective in revealing areas where pollution is carried to the coast in groundwater. This work will serve as a basis for larger-scale regional submarine groundwater discharge mapping projects. In this sense, COI "seed" funding can leverage significant federal and state funds in the future. □

- Henrieta Dulaiova, Matt Charette, and Rich Camilli

Examining Records of Typhoon Events

Graduate student, Jon Woodruff (left), with his father on the island of Kamikoshiki, Japan, where typhoon records were examined from sediment cores taken in lagoons, such as the one on the upper left. Photo by Akiko Okusu.

On average, over a third of all intense tropical cyclones in the world occur within the Western North Pacific. Regionally termed "typhoons," these extreme storms routinely batter the coastlines of Japan, China, Korea, Taiwan, and the Philippines, resulting in substantial losses in both human life and economic resources. Historical records for this region of the globe extend back for hundreds of years; however, these archives are often incomplete. Accurate instrumental records are generally limited to the last 30-50 years. This relatively short record results in significant uncertainty in determining how climate governs the frequency, intensity and paths of typhoons. Longer records are required in order to confidently identify the processes associated with centennial- and millennial-scale tropical cyclone variability for the Western North Pacific.

Working with Dr. Jeff Donnelly in the Geology and Geophysics Department, I have been trying to extend typhoon records for the Western North Pacific using storm layers preserved within coastal lagoons on Kamikoshiki, a remote island located off the southwestern coast of the Japan mainland. Locally nicknamed "Typhoon Ginza" after Tokyo's most popular shopping district, Kamikoshiki is frequently struck by typhoons. The island contains deep lagoon systems in which sediments well suited for recording periods of extreme storm events have accumulated.

During a vacation trip with my family in 2005, I collected preliminary sediment cores from some of the Kamikoshiki lagoons. These samples revealed well preserved, fine-grained organic sediment punctuated by coarser-grained layers. The coarser-grained layers represent denser sediment that accumulated episodically, most likely during extreme tropical cyclone events. Due to the great depths of Kamikoshiki's lagoon systems (15-20 meters in most locations), the preliminary work in 2005 was limited to only a few shallow cores collected along the lagoon banks.

To obtain a more complete sedimentary record, I returned to Kamikoshiki this past summer with support from the COI Graduate Student Research Fund (sponsored by an individual donor). This time, I was armed with an arsenal of deep water coring equipment, including a portable sub-bottom profiling sonar device called a CHIRP. Assisted by invaluable Japanese colleagues, I obtained high-resolution images of more lagoon sediments.

The sonar data collected by the CHIRP system was used to effectively determine where cores should be taken within the lagoons of Kamikoshiki—a key component of the field work. Laboratory analysis of these cores later confirmed that coarse-grain layers originally identified by the CHIRP system were composed of beach and marine material most likely carried into the lagoon during intense tropical cyclone events.

Preliminary measurements made by the X-ray Fluorescence (XRF) core scanner at WHOI reveal that the concentration of titanium within the Kamikoshiki's sediments correlate to modern regional precipitation records. This suggests that a reconstruction for past fluctuations in the strength and/or location of the East Asian Monsoon Trough (a climatic phenomenon that has been hypothesized to be one of the major influences for steering typhoons in the North Pacific) can also be determined from Kamikoshiki's sedimentary record.

Although still in its preliminary stages, the work on Kamikoshiki has the potential to yield the longest reconstruction for tropical cyclone activity ever developed for the Western North Pacific. When used in conjunction with proxy records for climatic phenomena known to influence modern typhoon activity, including those for the strength and location of East Asian Monsoon trough, we hope to learn more about how these phenomena have influenced typhoon variability in the Western North Pacific during our recent geologic past. In doing so, we will help to make informative predictions for how typhoon activity may vary in the future in Earth's most prolific tropical cyclone region. □

- Jon Woodruff

Jon Woodruff examining a sediment core from the lagoons of Kamikoshiki. Data from the cores revealed layers of coarse sediment most likely deposited episodically by intense tropical typhoon events. These records may help scientists better predict storm patterns in the future. Photo by Tom Kleindinst, WHOI.

Friends of Coastal Science

Nancy Newcomb

Two years ago Nancy Newcomb joined the WHOI Board of Trustees. Her extensive experience in the corporate world, education, and the arts is now being brought to bear in the world of oceanography. She has plunged in with her usual dedication and enthusiasm, helping to guide the Board, the Institution's Campaign Committee, and the Coastal Ocean Institute Committee.

Nancy comes to us from a distinguished career in financial services at Citigroup, serving as a senior corporate officer in risk management, and before that as co-head of the multinational corporate group.

She has served in executive positions at the New York Historical Society, Young Concert Artists, and Connecticut College, and is a corporate director of Moody's, the DIRECTV Group, and Sysco Corporation.

Nancy and her husband, John Hargraves, a literary translator, live in Manhattan and Lyme, Connecticut. They are among WHOI's newest "friends," and we applaud their committed involvement in the Institution's governing boards and scientific community.

WHOI Trustee, Nancy Newcomb, aboard the coastal research vessel, *Tioga*. Photo by Judy Kleindinst, WHOI.

Financial Information

Campaign Progress

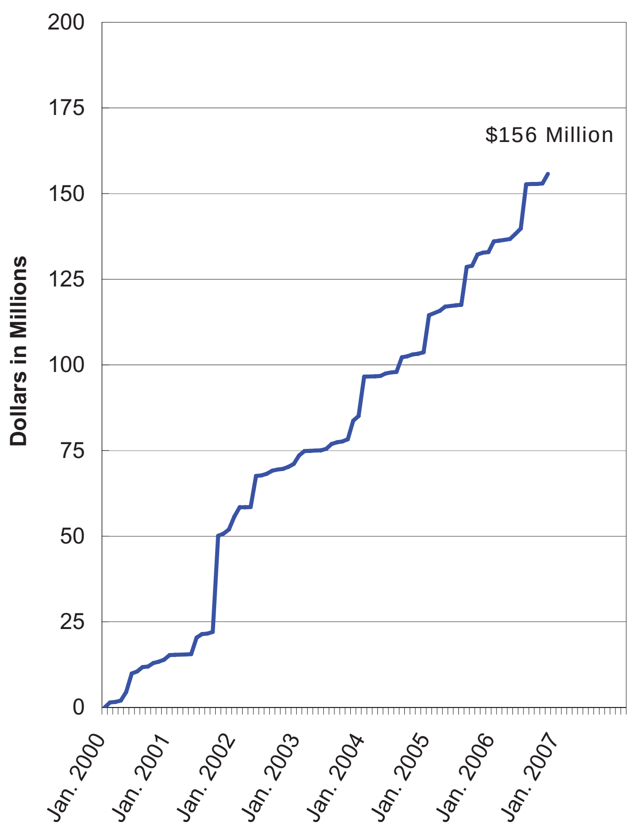
As 2006 nears to a close, we are approximately $44 million from our $200 million goal for the campaign. Highlights of the past few months include a $10 million gift for Arctic Research from Jim and Ruth Clark and $2 million for two grants from the Gordon and Betty Moore Foundation to fund specialized instruments for coastal ocean research, microbial ecology and chemical analysis. □

Allocation of COI Funds

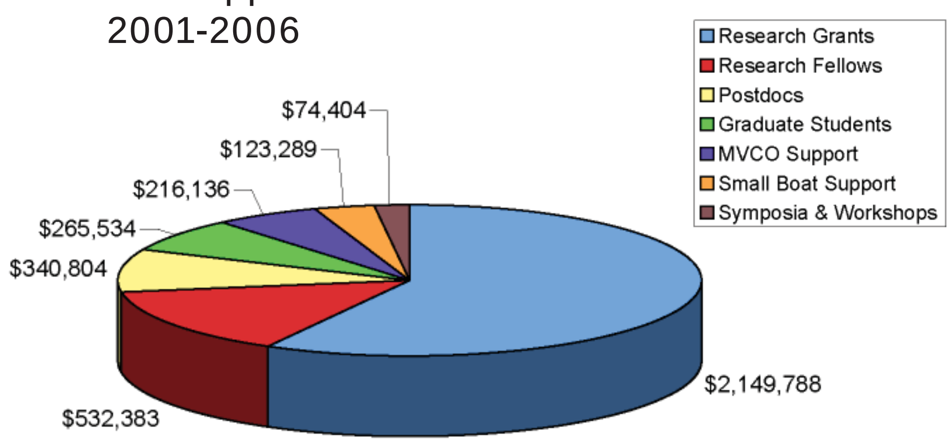
Over the past five years, the Coastal Ocean Institute has funded a total of 40 individual research awards, which enabled 73 investigators to conduct specific projects. Eleven research fellows have been supported, including one specially sponsored by WHOI board and corporation members on the Coastal Ocean Institute Committee. In addition, five postdoctoral scholars, and twelve graduate students have benefited by funding from the COI.

At the same time, the Coastal Ocean Institute has supported the Martha's Vineyard Coastal Observatory, allocated funds for access to small boats for research, sponsored a number of symposia and workshops, supplied some critical cost-sharing funds to special projects and allocated a number of small discretionary grants for a variety of purposes. This year, the COI also gave two New Initiative awards to fund groups of coastal scientists to collaborate on major thematic projects. □

Woods Hole Oceanographic Institution
Campaign Funds Raised to Date
$156,337,627
As of November 30, 2006



COI Support
2001-2006



$3,702,338

COI Leveraging

The majority of funds that support the COI and its research have come from generous individual donors. These donations add up and ultimately leverage additional federal and private support.

Since 2001, COI-funded research has leveraged over $9.5 million from federal agencies to further support the work. For example, the COI provided $45,800 to Rob Olson and Heidi Sosik to field test their "imaging Flow Cytobot" at the Martha's Vineyard Coastal Observatory. The data they obtained with this plankton-identifying instrument leveraged four separate federal grants (from NASA, NOAA and NSF), totaling $2.8 million. The same work leveraged the team $1.5 million from the Gordon and Betty Moore Foundation in California.

This is only one example of the powerful effect that our donors have on the Institution's overall success. We cannot over emphasize how grateful we are to those who contribute to our cause. Thank you! □