RINEHART COASTAL RESEARCH CENTER
WOODS HOLE OCEANOGRAPHIC INSTITUTION

COASTAL RESEARCH

Volume 4, Number 1
July 2000

RCRC Tank Experiments Investigate Larval and Particle Accumulation in Internal Bore Fronts

by Jesús Pineda and Karl Helfrich

Bottom dwelling coastal marine animals face a complication on their way to establishing new colonies and replenishing old ones. The early life stages of organisms such as clams, oysters, abalone, corals, and barnacles live suspended in the water, drifting at the mercy of ocean currents in a larval phase that generally lasts a few weeks. At the end of it, the larvae must find a suitable habitat where they can mature into adults and complete their life cycles. Because ocean currents disperse the larvae far from their birthplaces, they can easily be transported several miles offshore into deep water just when they are ready to settle in the shallow coastal water—a waste of larvae because they will not survive in this situation. In fact, out of the thousands to millions of juveniles produced by an individual shellfish during its lifetime only a very few, if any, will survive to reproduce.

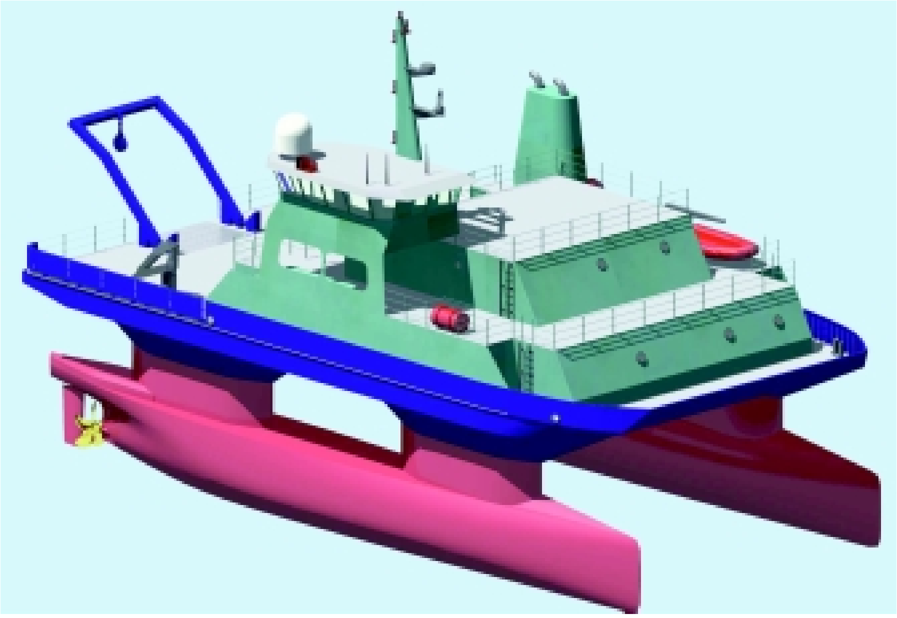
After several weeks of drifting, the probability of a larva returning to its birthplace must be very small. The abundance of colonizers at a given site is uncoupled from the living conditions of the adults. A site with no natural enemies and rich in food may be vacant because currents do not bring larvae. On the other hand, a sub-optimal habitat with scarce food may contain numerous organisms if currents bring many larvae. These situations are rare in other species whose juvenile stages do not disperse as widely. Terrestrial plants are a good example of species with restricted dispersal; in fact, differences in dispersal are probably the most important contrast in the ecology of marine and terrestrial environments.

Knowledge of ocean currents that return larvae to coastal habitats is therefore key to understanding the maintenance and dynamics of coastal species. Understanding larval transport is also important for managing fisheries and designing marine reserves. For example, it would be futile to preserve a coastal site that contains many adults if their larvae are all wasted because current circulation at that site carries all the larvae offshore.

Internal tides and waves are mechanisms that can transport larvae back to shallow coastal habitats. Internal waves are similar to the more familiar surface waves, but instead of traveling on

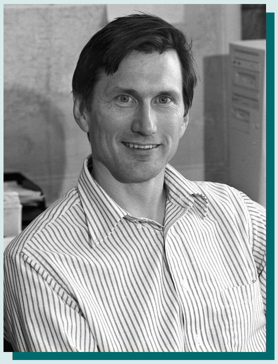
TANK EXPERIMENTS –page 10

WHOI Receives Funding for SWATH Vessel



The SWATH (Small Water-Plane Area Twin Hull) concept offers an above-water platform resting on struts supported by two submerged parallel hulls, an arrangement that dramatically reduces ship motion by decoupling the ship from surface waves. This is an artist's conception of the planned WHOI 105-foot coastal SWATH. (See story on page 2.)

A Message from the RCRC Director:



WHOI oceanographers go to sea. That is probably the most WHOI-like thing about WHOI. That is also why we are celebrating a gift from Gratia "Topsy" Rinehart Mongomery that will support the construction of a new coastal vessel for WHOI. Our commitment to excellence in seagoing oceanography is now aligned with our commitment to the coastal frontier in ocean science. The 100-foot coastal vessel will fill a niche that has not been occupied at WHOI for many years, increasing our access to the coastal ocean and offering new approaches to underway sampling and instrument deployment in a wide range of sea conditions.

WHOI's access to the coastal ocean does not just occur on ships, however. A directional drill through the dunes on Martha's Vineyard's South Beach has just provided us with another link to the sea, this one with a fiber-optic cable. The Martha's Vineyard Observatory is a new kind of access to the sea with tremendous promise for coastal research—a new way to do oceanography, with possibilities only beginning to be imagined.

WHOI also accesses the sea through a pump on Vineyard Sound, which carries seawater to our flumes at the Coastal Research Lab. Some kinds of oceanography require a little more human control than nature allows, so we create a more hospitable approximation of nature in the lab.

Whatever it takes, WHOI scientists are getting at the ocean, and coastal research has never looked better.

Awards resulting from 2000 RCRC Call for Proposals

- Mike Caruso and Steve Anderson: Implemetation of an Atmospheric Mesoscale Model in the Gulf of Maine
- Katrina Edwards, John Hayes, and Andreas Teske: Radiocarbon Analysis of 16S rRNA from Environmental Samples—A New Approach to Isotopic Biochemistry with Applications to Coastal Systems
- Rob Evans: Using Electrical Resistivity to Map Fresh Water Discharge
- Larry Madin and Sonke Johnsen: Eutrophication in Waquoit Bay—Effects on Visual Predation
- Gene Terray, Wade McGillis, and Chris Zappa: Surface Processes Controlling Aquatic-Atmospheric Gas Transfer in Estuaries

WHOI Receives SWATH Funding

Woods Hole Oceanographic Institution's planned coastal research vessel is much closer to reality with the announcement of a $5-million gift from long-time friend, Trustee, and supporter Gratia "Topsy" Rinehart Montgomery. Her 1996 gift of $5 million has benefited nearshore coastal investigations significantly and allowed the Institution to establish the coastal research center in her name. "More and more people are moving to the coast, and, as a society increasingly dependent on the sea, we must use the coastal zone wisely. I want future generations to enjoy our coast as much as I have," Mrs. Montgomery said.

Previous donations of $1 million supported design of the SWATH (Small Water-Plane Area Twin Hull) vessel, and Mrs. Montgomery's gift, along with an anonymous $1 million gift, allow WHOI to proceed with construction plans for the $10 million vessel. Glosten Associates, experienced in oceanographic vessel design, and Blue Sea Corporation, experts in SWATH technology and the offshore industry, worked with WHOI staff on the design, and input was solicited from the coastal research user community.

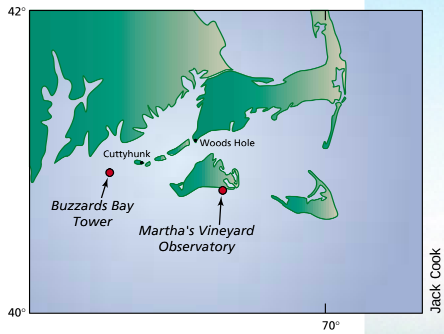
SWATH ships are extremely stable and provide a safe working environment at sea. The WHOI SWATH is specifically designed to work year-round in notoriously rough New England coastal waters. It will comfortably accommodate 16 people (usually 6 crew and 10 scientists) for 15 days at sea and offer a large working deck and at least 500 square feet of lab space. Delivery of the vessel is estimated for summer 2002.

Dissolved Carbon Dioxide in Coastal Waters

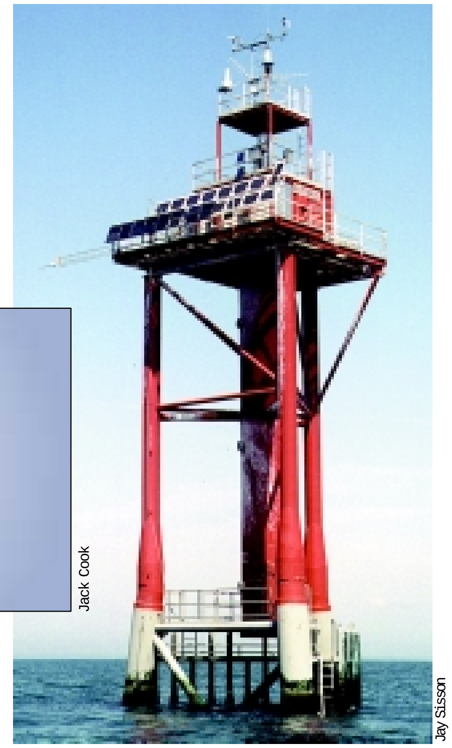
by Wade McGillis and Michael DeGrandpre

A primary objective of marine carbon cycle research is to determine the flux of carbon dioxide (CO_2) between the ocean and atmosphere. Although little is known about the spatial and temporal variability of CO_2 in ocean margin areas, gas exchange in these regions might have an important role in the global carbon cycle. The major physical and biogeochemical processes controlling the CO_2 content of coastal waters include photosynthesis, respiration, heat and gas exchange with the atmosphere, and mixing of estuarine and marine waters. CO_2 is a dissolved gas that is generally reported in terms of pressure with units of microatmospheres (µatm). Seasonal CO_2 levels in coastal areas are highly variable, ranging from 100 to nearly 1,000 µatm compared to 200 to 400 µatm for most open ocean waters. In general, estuaries and nearshore marine waters are supersaturated in CO_2. This is thought to be caused by respiration of organic matter exceeding photosynthetic production in these systems.

Short-term variability of CO_2 can also be quite large in ocean margins due to tidal cycles, which cause mixing of estuarine, nearshore, and offshore waters and diurnal biological production. Through continuous monitoring of CO_2 and related parameters, we might begin to understand and model these complex, and changing, phenomena and perhaps predict future trends. Long-term studies in coastal waters will also help us determine whether these zones are a net sink or source for atmospheric CO_2. Furthermore, because coastal waters are easily accessible and show high potential rates of air-sea exchange, experiments in these waters can also serve as test beds for the development of new methodologies for studying air-sea CO_2 fluxes.



To better understand the processes governing gas exchange in ocean margins, long term observations of the dynamics of coastal CO_2 and air-sea fluxes are currently underway at the Buzzards Bay Coast Guard Tower (see map). Its superstructure is approximately 21 meters high and 7 meters to a side. Water depth is approximately 20 meters, and the structure is sited 6.6 kilometers from the nearest shore (Cuttyhunk Island). The tower is unobstructed by land in the southerly direction, so wind and waves from that quandrant have essentially unlimited fetch. Other advantages of this site include its close proximity to WHOI—it is reachable by the WHOI boat *Mytilus* in less than 1 hour—and the supporting meteorological and oceanographic measurements made at the tower by the National Oceanic and Atmospheric Administration National Data Buoy Center (NDBC). These measurements, relayed from the tower by telemetry and available on the Internet, include the mean wind speed, wind direction, relative humidity, barometric pressure, air and water temperature, and wave heights. Although our platform measurements are still in the developmental stage, the ultimate goal of this new coastal water observatory will be to provide continuous estimates of CO_2 air-sea exchange via a number of different methodologies. The tower also allows author McGillis and colleague Jim Edson a platform for autonomous monitoring of hurricane conditions.



The Buzzards Bay Coast Guard tower supports instruments for air-sea carbon dioxide studies. The map shows the tower's location near Woods Hole and the Martha's Vineyard Observatory.

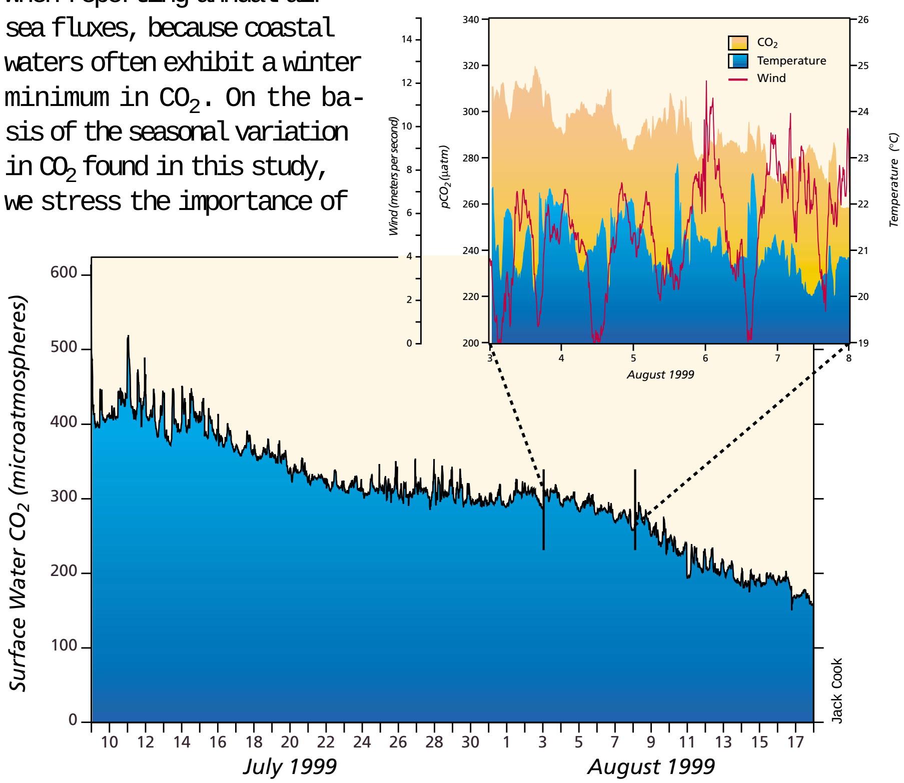
To date, we have instrumented the Buzzards Bay Tower with atmospheric flux instruments located at a height of 15.6 meters and oriented to face the prevailing summer wind. Wind speed there generally ranges from 0 to 15 meters per second. To calculate direct air-sea fluxes of momentum and heat, we have an ultrasonic anemometer extended on a metal boom 4 meters from the edge of the tower and operating continuously to obtain high-frequency wind and temperature information. This meteorological system was configured by Jonathan Ware and Jay Sisson to allow data collection and storage locally on the tower. Thus, the system can perform essentially untended, except when data is retrieved about once every month.

Additional autonomous instrumentation at the tower observatory includes a CO_2 instrument, SAMI-CO_2, designed and built by author DeGrandpre and Terry Hammar. This subsurface instrument is routinely deployed below the bottom platform of the tower at 2 meters depth. The SAMI-CO_2 measures CO_2 concentration via a pH indicator and gas permeable membrane. The membrane is directly exposed to ambient seawater and has a copper screen for protection and antifoulant. It can take measurements every 5 minutes and has an endurance of 50 days.

The lower figure at right shows the surface water CO_2 concentration time series logged from the Buzzards Bay Tower in July and August 1999. The atmospheric CO_2 was near 374 µatm in the area; thus the water was supersaturated with CO_2 for about one-third of the recorded time period. Other researchers have shown that summer supersaturation in the Middle Atlantic Bight primarily results from heating and net respiration of terrestrial organic matter. The upper figure shows that diurnal heating, which increases the CO_2 concentration by about 4 percent per degree Celcius, is offset by daytime production, resulting in a net decrease in CO_2 during the day. However, the CO_2 content rises again during the night, probably due to the net respiration of the organic matter produced during the day. These trends are combined with variability arising from the tidal mixing and episodic storm and lull events, as recorded in the wind and temperature data. The overall downward trend evident in the CO_2 signals logged during this period might arise from export of organic matter in the region or a slowed replenishment of water in these coastal waters during late summer, perhaps due to reduced freshwater input.

Variability in the coastal CO_2 system can be important on all space and time scales. The large seasonal variation in CO_2 shown in the figure is evidence that more detailed temporal and spatial coverage is needed for accurate annual air-sea CO_2 flux estimates in coastal waters. In particular, care must be taken to include winter measurements when reporting annual air-sea fluxes, because coastal waters often exhibit a winter minimum in CO_2. On the basis of the seasonal variation in CO_2 found in this study, we stress the importance of complete temporal coverage when reporting annual integrated CO_2 fluxes in temperate coastal waters. Although our work in this area is just starting, we anticipate exciting new opportunities in monitoring surface water CO_2 at both the Buzzards Bay Tower and the Martha's Vineyard Observatory. These measurements may reveal some of the mesoscale carbon dioxide characteristics in coastal waters and, simultaneously, show the differences between air-sea CO_2 flux behavior in the surface zone and coastal waters.

Wade McGillis and Jim Edson are Associate Scientists, Terence Hammar is a Research Associate, Jonathan Ware is an Engineer, and Jay Sisson is a Research Assistant in the WHOI Applied Ocean Physics and Engineering Department. Michael DeGrandpre is an Associate Professor in the Chemistry Department at the University of Montana.



Time series of surface water dissolved carbon dioxide during summer 1999. The data show long- and short-term variability of carbon dioxide levels in coastal waters. The upper figure provides a high-resolution look at a five-day time series showing the effects of surface temperature and winds on carbon dioxide levels.

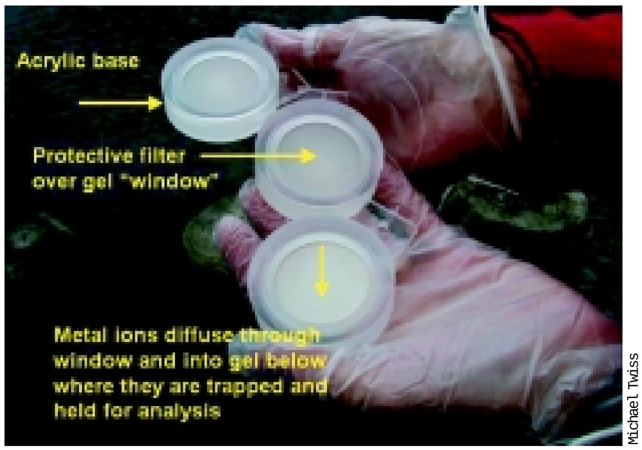
New Probe Provides Measure of Harbor Contaminants

by James Moffett

Contaminants of human origin are ubiquitous constituents of coastal waters. More and more frequently scientists and regulators ask, "How much of a given contaminant is acceptable?" "Acceptable," a rather subjective term, is often defined as a level of contaminant that does not pose a threat to the sustainability or stability of an ecosystem. In practice, this usually means demonstrating that the contaminants do not harm key, sensitive species, often by comparing toxicity data with concentrations measured in the field. However, as we learn more about coastal environments, it is clear that such simple predictive measurements are complicated by a variety of factors. These include differences in the physiology of organisms used in culture experiments and those present in the field, effects of water chemistry on bioavailability of the contaminants, which may vary from place to place, and spatial and temporal variability in the distribution of contaminants.

My group's particular interest is variability in the distribution and biological availability of contaminants in dynamic coastal environments. Coastal regimes are complex physical systems, with mixing processes that can lead to considerable spatial and temporal variability in contaminant distributions, presenting a real challenge for ecological assessment studies. Moreover, such variability leads to strong gradients in other chemical parameters that may affect toxicity. For example, copper is toxic to many organisms, but its toxicity is ameliorated by high levels of manganese and iron (which compete with copper for uptake sites on cell surfaces), whose distributions are also highly variable in coastal waters.

Currently, regulatory attention is focused on episodic inputs of contaminants into harbors and estuaries. During events like floods or harbor dredging, pulses of contaminants may be injected into the water column, raising concentrations to toxic levels. Rainstorms in urban areas generate large volumes of contaminant-laden runoff. Waste load allocation models, based on high levels of contaminants measured in discharge waters, indicate serious problems for such receiving waters as rivers, estuaries, and harbors, where these compounds end up. Applications of such models by regulatory agencies often lead to costly remediation measures.



These small passive sampling probes collect trace metals from harbor waters. Metals diffuse across a semi-permeable gel membrane and accumulate on a metal binding resin. Because reactive forms of metals pass through the probe but inert organic complexes and other nonreactive forms do not, the probes provide a useful index of bioavailability. The probes are deployed using lightweight mooring gear.

Interestingly, there are few measurements in harbors showing how contaminant concentrations change during such events, so many critical questions are now addressed only in models. For instance, how fast are contaminant pulses dissipated by physical mixing processes? For how long are sensitive organisms exposed to high levels before dissipation occurs? Where, in complex urban environments, are the worst sources?

In order to answer these questions, scientists need large data sets to determine how contaminants vary at numerous locations within an estuary or harbor during storm events. Since collection of discrete samples is costly and logistically difficult, we have been working with an in situ, passive sampling probe to study the distribution and bioavailability of trace metals in harbors.

What is an "in situ passive sampling probe?" Basically, it is a small object containing a specialized solid material that absorbs trace metals or other chemicals from the surrounding water. It involves no mechanical process, only diffusion and the chemicals' affinity for the solid phase—hence the term passive. The rate at which the target chemicals diffuse into the probe is proportional to their concentration in the water, and can be calibrated. Thus, deployment of the probes for a fixed period of time (from several hours to several days) provides a mean concentration of a contaminant at

NEW PROBE – page 8

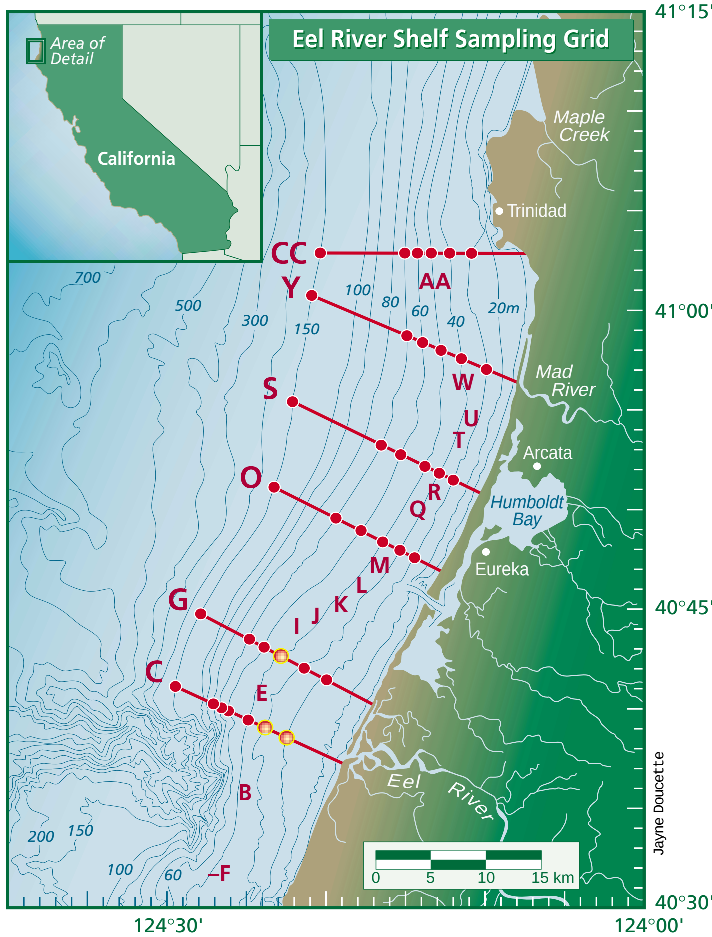
Dissolved Organic Nutrients in the Coastal Ocean

by Kathleen Ruttenberg

Phytoplankton, the photosynthetic organisms at the base of the marine food web, can readily consume dissolved inorganic nutrients, such as nitrate and phosphate, to satisfy their growth requirements. However, adaptations also allow them to access other, less readily available pools of nutrients, giving them an important advantage when concentrations of nitrate and phosphate drop to growth-limiting levels.

For example, phytoplankton employ enzymatic means to access dissolved organic nutrients, which they cannot assimilate directly. Concentrations of dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP) can actually exceed those of nitrate and phosphate in some instances, suggesting that these pools can play an important role in supporting primary productivity. Very little is known about dissolved organic nutrients in the ocean, however, so it is difficult to evaluate their role. First order questions that have yet to be answered include: What are typical DON and DOP concentrations? How bioavailable are these pools? Do concentration and bioavailability vary seasonally and/or geographically?

In a study on Northern California's Eel River Shelf (see map), we studied the seasonal dynamics of dissolved organic nutrients, and examined their role (particularly that of DOP) in supporting biological productivity. This study was supported by the Office of Naval Research, with additional funding for rapid response sampling from the Rinehart Coastal Research Center. A primary goal of this study was to determine the importance and seasonal variability of the DON and DOP pools. In addition, the alkaline phosphatase enzymatic assay allowed us to document phosphate limitation and phytoplankton's use of DOP.



Location map showing water column sampling grid on the Eel River Shelf. Ruttenberg's group occupied six shore-perpendicular transects generally taking samples every 10 meters from 30 to 70 meters. Some deeper water stations were sampled as well. Data shown in figures on opposite page are from stations denoted with open circles.

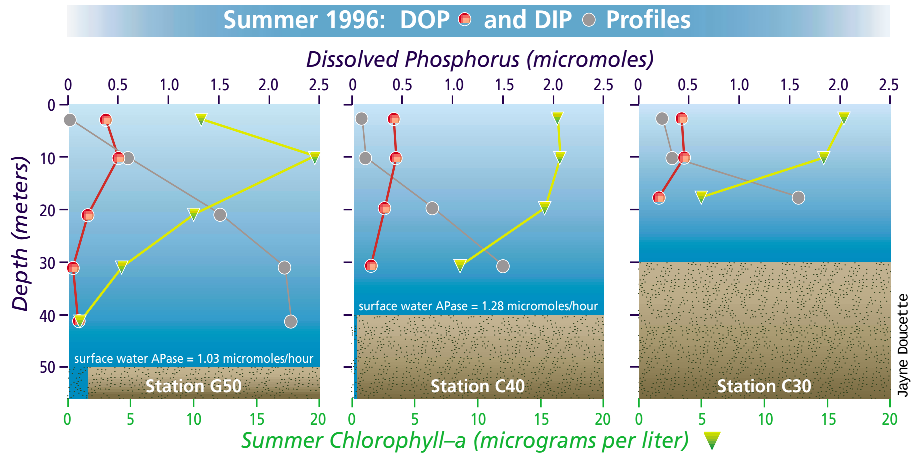
Storm-driven river runoff dominates the Eel River Shelf in winter and early spring, and upwelling dominates in summer. In spring and summer of the 1996 field season, DON and DOP comprised 26 and 38 percent, respectively, of the total dissolved nutrient pools in the water column. In summer, dissolved organic nutrients in surface waters often exceeded their inorganic counterparts (top figure opposite). The summertime surface maximum in DOP concentration typically coincided with the chlorophyll-a maximum. Chlorophyll-a is the dominant photosynthetic pigment of marine algae and is therefore a useful proxy for algal biomass. These coinciding maxima suggest that biological processes, probably excretion and microbial decomposition of organic matter, are responsible for the surface-water DOP buildup in summer.

DOP concentrations display marked seasonal variability (bottom figure opposite). Those observed during the highly productive summer season exceeded spring and winter concentration levels shelfwide. Although spring and winter concentration levels are similar, the source of DOP in these two seasons may be different. Biological productivity is extremely low in winter, and it is more likely that the DOP present in the water column at this time of year is terrestrially derived, from river runoff. In spring, fairly high levels of chlorophyll-a indicate substantial biological productivity, and associated biological processes likely contribute to the DOP pool. The trends in DOP and chlorophyll-a observed in summer leave little doubt that biological activity is responsible for the high DOP concentrations in surface water, and the low DOP levels deeper in the water column indicate that upwelled deep water contains very little DOP.

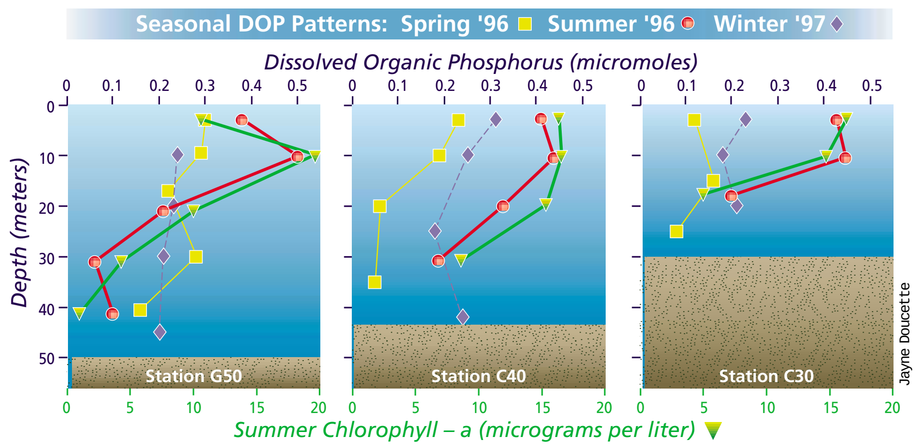
The presence of the enzyme alkaline phosphatase, observed in surface waters at some stations in summer, indicates that the phytoplankton are utilizing DOP to fulfill their phosphorus requirement, and sustain their growth. This enzyme hydrolizes DOP, producing dissolved inorganic phosphorus (DIP), which can then be assimilated by the phytoplankton. Because alkaline phosphatase is an inducible enzyme, meaning that phytoplankton only synthesize it when they are stressed by low levels of DIP, it is a very powerful tool for detecting phosphate limitation. The presence of alkaline phosphatase activity in surface waters with low DIP and high DOP indicates that conditions of phosphate limitation are present in these waters. Under these circumstances, the degree to which DOP can be rendered bioavailable will dictate the level of productivity these waters can sustain.

In coastal areas that support high biological productivity, concentrations of DON and DOP can be quite elevated during times of high productivity. Organisms able to access dissolved organic nutrient pools when the availability of dissolved inorganic nutrients drops below acceptable levels will be at an advantage under these circumstances. One consequence of seasonally evolving nutrient pools, such as those observed on the Eel River Shelf during this study, may be to provoke a shift in species composition to favor organisms adapted for utilizing DOP during the highly productive summer season. Work continues on these and additional samples from subsequent cruises and rapid response sampling trips to the Eel River Shelf to address the many unanswered questions about dissolved organic nutrient dynamics, their bioavailability, and their impact on coastal ocean ecosystems.

Kathleen Ruttenberg is an Associate Scientist in the Marine Chemistry and Geochemistry Department.



Summer dissolved organic phosphorus (DOP), dissolved inorganic phosphorus (DIP), and chlorophyll-a profiles for representative stations on the Eel River Shelf. Note that dissolved organic phosphorus exceeds dissolved inorganic phosphorus in surface waters, and the coincidence of the dissolved organic phosphorus and chlorophyll-a maxima. The high dissolved inorganic phosphorus concentrations lower in the water column reflect upwelled, nutrient-rich, deepwaters, typically observed during the summer upwelling season. High activities of Alkaline Phosphatase (APase) were detected in the particulate fraction measuring more than 0.7 microns (and corresponding to phytoplankton) from surface waters in a number of stations during the summer season. The Alkaline Phosphatase activities observed in stations C40 and G50 are given in the figure.



Seasonal dissolved organic phosphorus profiles for the same three stations shown in the top panel. *These profiles illustrate the seasonal variability in dissolved organic phosphorus concentrations and depth distributions observed shelfwide. The expanded DOP concentration scale highlights the coincidence of the surface-water maxima in DOP and chlorophyll-a during the summer season.*

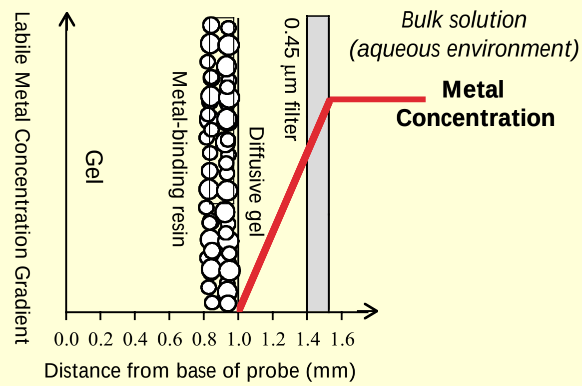
NEW PROBE–from page 5

that location over that time period.

Such a device has several important features. It is cheap (no moving parts or electronics), so it can be deployed in substantial numbers in a harbor, providing sufficient coverage to be useful to a physical oceanographer. It can be tailored to the contaminant under investigation, through selection of solid phase materials with specific properties. Finally, the devices can be coupled with sophisticated shore-based methodologies for analysis. For instance, samples collected using our device can be analyzed by inductively coupled plasma mass spectroscopy, enabling over a dozen elements to be measured on a single sample. Thus, we can track variability in several contaminants as well as other metals that influence bioavailability such as manganese and iron.

Michael Twiss, a postdoctoral fellow partially supported by RCRC, evaluated the probes for measurement of copper, zinc, cadmium, and lead in harbors of Falmouth, MA, San Diego, CA, and Norfolk, VA. He showed that in contaminated harbors the probes yield highly reproducible measurements consistent with measurements of reactive metal species by other techniques. The Office of Naval Research, one of the sponsors of this research, is particularly interested in copper, because it poses an important regulatory problem for naval installations, particularly during episodic events.

Cross Section Through Probe



The flux of metal into the probe is used to determine the concentration of "free" metal in the aqueous environment.

Several other groups in the MIT-WHOI community have active programs in this type of work, and some interesting collaborations may develop in the future. For example, Roger François and Bill Martin (Marine Chemistry and Geochemistry Department) are using similar devices to obtain high resolution profiles of metals in sediment pore waters, and Phil Gschwend (MIT) and Rocky Geyer employ a conceptually similar probe to study organic contaminants in harbors.

I am planning to use the probes to study metal mobilization in Boston Harbor and surrounding areas during such episodic events as combined sewage overflows and dredging activities, with support from the Environmental Protection Agency and in collaboration with the Massachusetts Water Resources Authority.

Jim Moffett is an Associate Scientist in the Marine Chemistry and Geochemistry Department.

RCRC Open House

Dave Gray

Dave Gray

Big and small visitors enjoyed the Rinehart Coastal Research Center's annual open house on June 16. RCRC investigators assembled posters on their work, and many of them were on hand to discuss coastal research with visitors. A special taste treat was a big, steaming kettle of blue mussels (Mytilus edulis) harvested from the Institution's "Submerged Coastal-Ocean Mussel Aquaculture System" in Rhode Island Sound.

Small Boats Provide Access to the Coastal Ocean

by Bruce Tripp

Near-shore ocean research often requires making the same measurements and taking the same kinds of samples needed for blue water research. Because coastal processes generally function on compressed scales of time and space, frequent access to ocean research sites is essential to coastal scientists' work.

The Rinehart Coastal Research Center maintains a fleet of small, outboard-powered, scientist-operated boats that are available on request to meet this need. These trailerable boats allow WHOI Scientific and Technical Staff and students to occupy coastal stations at almost any location on schedules dictated by the research projects.

The fleet serves a broad spectrum of needs from instrument testing and deployment to field surveys, scuba diving, and the occasional rescue of wayward equipment. Considerations of cost, convenience, and safety all factor into the make-up and management of the fleet.

One of the RCRC boats, *Mytilus*, is supporting air-sea gas exchange research in local waters. *Mytilus* provides a speedy and easily scheduled boat for transporting gear and personnel to the Buzzards Bay Tower (see article, page 3). *Mytilus* also serves as an at-sea platform for making instantaneous gas flux measurements to compare with those collected by tower-installed instruments. Integration of the gas flux rate, over a range of space scales may be important to the understanding of some exchange processes, and the small boats allow scientists to sample easily and quickly across a range of scales.

The RCRC fleet of scientist-operated boats complements *Asterias*, WHOI's original coastal research vessel. *Asterias* remains an essential component of the at-sea part of WHOI coastal research and occasionally works in concert with the smaller vessels when projects call for two platforms.

Jay Sisson, Chris Zappa, and Craig Johnson test the Surface Processes Instrument Platform (SPIP) from Mytilus*. SPIP was designed by engineers Glenn McDonald and Don Peters with scientists Wade McGillis and John Dacey to measure carbon dioxide and dimethylsulfide very close to the sea surface in both the air and water. Because SPIP follows the sea surface and creates minimal wind distortion, it solves some of the difficulties of measurements from large boats, which tend to surge upward and dive back into the waves.*

Dave Olmstead, captain of *Asterias*, works closely with RCRC staff to ensure the safety of the small boat operation and the adequacy of operator training. In some cases, such as with air-sea exchange research, measurements must be made at times when safety considerations become increasingly important such as under conditions with cold temperatures or high winds. At such times, a task that might normally be performed from a small outboard can be accomplished more safely and comfortably from *Asterias*. *Asterias* is also the alternative of choice when the number of essential personnel increases or the size and weight of gear outgrows a smaller boat.

A 23-foot inflatable Zodiac is a recent new addition to the small-boat fleet. It is currently operated by the WHOI Oceanographic Systems laboratory in support of the coastal observatories on Martha's Vineyard and at the Rutgers Marine Field Station (RMFS) in Tuckerton, NJ. This Zodiac is used in local waters for equipment testing and at the RMFS LEO-15 (Long-term Ecosystem Observatory in 15 meters of water) site for REMUS deployments and for making ancillary measurements in the field. (REMUS stands for Remote Environmental Monitoring UnitS, which are robotic data collecting instruments.) Also locally, the Zodiac is used for quick trips to Martha's Vineyard in support of the design and construction stages of the observatory's underwater node. Once the Martha's Vineyard observatory is functional, all of the small-boat fleet will serve the at-sea observatory research operation.

More detailed information about scheduling and vessel specifications of the RCRC fleet can be found on the RCRC website at: www.whoi.edu/coastalresearch.

In all cases, boat schedulers attempt to accommodate users' requests and will adjust schedules to meet individual needs where possible.

TANK EXPERIMENTS – from page 1

Jayne Doucette

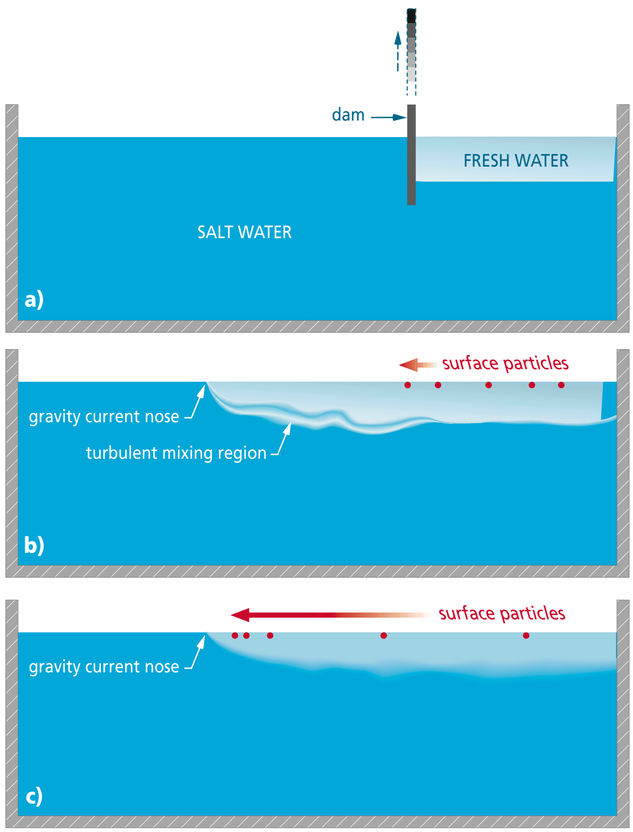
Authors Karl Helfrich, left, and Jesús Pineda conducted their investigations of larval and particle accumulation in internal bore fronts in an 18-meter-long tank at the Rinehart Coastal Research Center.

the interface between water and air, internal waves propagate in the body of the ocean due to the density stratification. They can be thought of as traveling on the interfaces of layers of different density. Just as surface waves break as they move into shallow water, internal waves may also break as they shoal and produce an internal surf.

Recent observations in California show that large internal tides can result in the exchange of warm inshore water with colder offshore water. This dramatic exchange brings larvae of coastal species shoreward and occurs in two phases. First the internal tide transports colder water found at depth towards the shore, displacing the warmer nearshore water offshore. A few hours later, in the second phase, the heavier cold water recedes offshore and is replaced by warmer offshore surface water. This warm water often returns as a "gravity current," or internal bore. A front at the sea surface identifiable as a line parallel to the shoreline marks the boundary between cold and warm water. The front is followed by other lines, or slicks, which are surface expressions of the internal waves that follow the "nose" of the gravity current. These surface slicks are characterized by high concentrations of floating debris, surf grass, and various species of larvae.

The cold and warm sides of the fronts are inhabited by different assemblages of larvae. To predict which types of larvae are accumulated and transported in those fronts, it is necessary to establish whether the larvae in the fronts originate in the cold onshore side, the warm offshore side, or both. For example, gooseneck barnacles and other crustaceans are abundant in the warm side of the fronts, are highly concentrated at the fronts, and are rare on the cold side of the fronts. This suggests that the origin of the frontal larvae is offshore. As the fronts propagate onshore, larvae approach it from the warm side and accumulate at the front. However, any accumulation of larvae at the front requires the currents behind the front to be faster than the speed of the front itself, a situation that may only occur if vigorous mixing takes place at the front.

We are currently evaluating the mechanisms of accumulation in propagating fronts with funding from the Rinehart Coastal Research Center. Our main goal is to test the idea that larvae and other particulate matter accumulate near the nose of a gravity current.



The experiment begins when the investigators add fresh water behind a temporary dam, and then remove the dam to produce a surge of fresh water down the length of the tank, simulating a gravity current. Videotaping this event allows them to analyze the motion and accumulation of buoyant spheres placed in the fresh water to represent larvae.

TANK EXPERIMENTS – page 11

Martha's Vineyard Observatory Construction Progresses

Tom Kleindinst

A technique called "directional drilling," underway here in May, allowed connection of the shore lab and other observatory components without disturbing fragile coastal habitats.

Underground fiber-optic cables to link a shore lab, constructed over the winter, with a meteorological mast and offshore instruments were installed in May at the new WHOI Martha's Vineyard Observatory. While it was possible to lay upland portions of the cable in a long trench, an approach called directional drilling (see photo) provided an environmentally safe method of installing the cable beneath fragile habitats on the island's shoreline without disturbing them.

"We are very sensitive to the site and take every opportunity to preserve the area," Principal Investigator Jim Edson said. "We worked closely with many local and state agencies to gain all the necessary approvals and permits. We are not disturbing any new surface areas. When the trenching and drilling are complete, visitors to the site will not see anything but a small cover, about the size of a manhole cover, protecting the underground junction box that links the cables. They will also see the meterological mast, where we plan to put a small sign explaining the observatory."

The 25-foot meterological mast and two offshore oceanographic nodes are under construction, and the observatory is expected to be operational by early fall. Researchers will collect data 24 hours a day and post it on the Internet for studies of coastal meteorology, air-sea interaction, sediment transport, benthic biological processes, and gas transfer.

The Martha's Vineyard Observatory is funded by the National Science Foundation and cost sharing from WHOI. It is a collaboration of scientists, engineers, and support staff headed by Edson and Wade McGillis, both Associate Scientists in the Applied Ocean Physics and Engineering Department.

TANK EXPERIMENTS – from page 10

Our experiments mimic the warm water advancing over colder water with a light, freshwater gravity current moving over heavier saltwater in an 18-meter-long experimental tank (see drawing opposite). The tank, located at RCRC, is filled to a depth of about 40 centimeters with salt water. We insert a dam at one end of the tank and carefully add 14 centimeters of fresh water on top of the salt water behind the dam to create a pool of fresh water. This freshwater pool is then seeded with buoyant spheres 4 millimeters in diameter that serve as crude mimics of passive, buoyant larvae. The experiment begins when we remove the dam and the fresh water surges down the tank. Video cameras looking from the side and top record the spheres' motion during the surge.

The tapes show that particles originating behind the nose of the gravity current sweep to the nose as the front propagates down the tank, and once they reach the nose they remain there. As noted above, this accumulation occurs because of turbulent mixing at the interface between the fresh and salt water. This mixing causes the fresh water near the free surface to flow towards the nose when viewed in the frame of the moving nose. Once the particles reach the nose, their buoyancy prevents them from being drawn down below the surface into the mixing region. Hence they accumulate at the free surface just behind the gravity current nose.

We are pursuing other questions related to internal tidal bores. In the future, we will conduct field observations to compare with our lab results. Further study should elucidate the physical effects and ecological consequences of internal tidal bores, a process with profound yet largely unexplored implications for coastal populations.

Jesús Pineda is an Associate Scientist in the WHOI Biology Department, and Karl Helfrich is an Associate Scientist in the Physical Oceanography Department.

Published semi-annually by the
Rinehart Coastal Research Center
Woods Hole Oceanographic Institution
193 Oyster Pond Road, MS#2
Woods Hole MA 02543-1525
Telephone: (508) 289-2418
Fax: (508) 457-2172
E-mail: crc@whoi.edu
http://www.whoi.edu/coastalresearch

Editor: Vicky Cullen
Designer: Jeannine Pires

RINEHART COASTAL RESEARCH CENTER
WOODS HOLE OCEANOGRAPHIC INSTITUTION

Woods Hole
Oceanographic Institution
Woods Hole, MA 02543 USA

THE RINEHART COASTAL RESEARCH CENTER is committed to the support and enrichment of coastal research activities within the WHOI community, particularly those research activities that directly affect the protection and enhancement of coastal resources. This mission is accomplished through facilitating research and education, providing facilities and equipment, and promoting interdisciplinary communication.

RESEARCH: Annual call for proposals • Rapid response • Mini-grants • Matching funds

EDUCATION: Postdoctoral support • Student project support

FACILITIES: Small boats • Coastal Research Laboratory (CRL) • Flumes and tanks (at CRL) • Coastal instrumentation

COMMUNICATION AND OUTREACH: Newsletter • Website • Scientific seminars, meetings, and workshops • Annual Open House

Nonprofit organization
U.S. POSTAGE
PAID
Permit No. 46
Woods Hole, MA 02543