HF Radar and more: Tracking currents for spills, science, and sailors

On a cold, foggy November morning in 2007, the swift-moving currents of San Francisco Bay began to spread 50,000 gallons of bunker fuel leaking from a slash in the hull of the MV Cosco Busan. Over the next several days, as emergency responders from a range of agencies scrambled to mitigate the environmental disaster, the spilled oil was distributed around the Bay and beyond by complex surface currents. It impacted more than 3,300 acres of shoreline habitat and its resident wildlife. The dense fog prevented responders from knowing where the currents were spreading the fuel. Tracking an oil spill’s movement, especially at night or in foggy conditions, is the first challenge in mitigation efforts.

Fortunately, San Francisco Bay now has a system in place to remotely track currents carrying oil or other pollutants, without requiring direct observation. In 2005, California voters approved bond funding for the Coastal Ocean Currents Monitoring Program (COCMP). The monitoring program measures coastal circulation along the entire California coast. Led by RTC Director and physical oceanographer Dr. Toby Garfield, SF State University’s research team is the lead organization of the five institutions committed to monitoring the region north of Point Conception. COCMP, with continued support from National Oceanographic Atmospheric Association (NOAA) through the Integrated Ocean Observing System (IOOS) office, now monitors an array of 54 land-based HF or high frequency radar sensors covering the California coast from the Oregon border to the Mexican border, reaching 200 km (125 miles) into the Pacific Ocean and covering central San Francisco Bay.

Combined with instruments in Oregon and Washington, the US West Coast hosts the largest HF radar array in the world and monitors a huge expanse of coastal ocean. The ability to track and predict the

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The RTC Mission
To advance understanding of the world’s complex marine and estuarine environments through research, education, and outreach, with a focus on San Francisco Bay.
Message from the Director

I compose these notes between celebrations of two technical wonders: the 75th anniversary of the completion of the Golden Gate Bridge and the start of the America’s Cup® World Series races in San Francisco Bay. Technological innovation is one of the hallmarks of the Bay Area, and RTC is proud to be part of this tradition. Measuring surface currents with HF radar is a technology that is promoted by a local company, Codar Ocean Systems, and supported by the California State Coastal Conservancy (cover story). And this spring RTC was awarded a National Science Foundation grant to purchase a high-end, inverted optical microscope and a new generation of flow cytometer. These new instruments will enhance the Center’s recognized leadership in phytoplankton and zooplankton research and provide student training in the latest technologies.

Educating students and providing professional development to advance understanding of critical aquatic environments remains RTC’s primary mission. This past spring, 11 students who conducted their research through RTC graduated with their master’s degree and 14 new graduate students start this fall. Graduate student cohorts continue to grow, as does the summer Research Experience for Undergraduate (REU) and STEM Teacher and Researcher (STAR) programs. Our professional development workshops on climate change, offered in partnership with SF Bay National Estuarine Research Reserve, Farallones Marine Sanctuary Association and Cordell Bank Marine Sanctuary, are popular with science educators and professionals and often have wait-lists.

Our sustainability effort has taken two steps forward this year. A new, efficient natural gas furnace is being installed to replace the 25-year-old diesel furnace. Bringing natural gas onto the site will allow conversion away from diesel or propane in many of our buildings. Secondly, through two generous anonymous donations, solar panels will be installed on canopies in the parking area in front of our main laboratory building.

There have been changes to our staff. Claudio Diaz, an experienced carpenter, has joined the facilities team. The facilities staff is finally back to three people. This has enabled them to make significant progress on the backlog of facility projects. We all feel the loss of Al Marchi, one of our senior research technicians, to brain cancer. He is truly missed (please read more about Al on page 5).

Our Advisory Board has spent the year undergoing a transition to better help the Center thrive in these financially challenging times. The Board Executive Committee deserves special thanks for the significant amount of energy they have devoted to tailoring our community outreach. I thank Laurence Bekins and Ben Barnes for their board service and wish them well with their new projects. I also want to thank Hank Broderick, Jim Kelley, Bob Ohrenschall and Jim Wilson as they transition to our Honorary Board.

There is no denying that RTC is feeling the strain of the profound reduction of State support for public education. A 45% reduction in operating funds has forced the Center to become more entrepreneurial and to use reserve funds as part of the annual budget, but this model isn’t sustainable. I want to thank all of the benefactors who have contributed to the Center and to state how critical continued support is for the RTC mission. I’d also like to invite new supporters to join our efforts.
South of the Equator, RTC scientists are studying climate change where the Amazon River meets the Atlantic Ocean. Here the sediments crew waits for their coring instrument to come up against the backdrop of an Atlantic sunrise. See story on page 6. Photo: Kristine Okimura

RTC’s site has a long history and played an important role in the construction of the Golden Gate Bridge. Above, bundles of wires arrive from New Jersey and are unloaded onto RTC’s north dock. See story on page 4. Photo: RTC archives

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The projectionist worked feverishly in the hot, stuffy 10-by-12-foot tin-lined room, the hum of the 1930s projector lost in the din of the boisterous audience. Finally the overhead lights dimmed and the projector cast a beam through the thick, smoky air. As the curtains rose to reveal the silver screen, the last few Navy sailors scrambled into their seats in anticipation of the evening’s entertainment. The showing of The Maltese Falcon would transport them away from the Net Depot, to a far less complicated world, for at least a few short hours.

Just as the evening movie showings transported the US Navy’s Net Depot audiences to a different place, so too, has time transformed the theater building. The projection room still exists on the third floor of what is now known as Building 54, one of the marine research laboratories of SF State University’s Romberg Tiburon Center. Today the metal-lined room sits empty, the air stale and dusty. The auditorium’s seats are gone, but the stage - used for entertainment, awards, speeches, and religious services - is still intact. Much of the building was renovated into offices and laboratories in the 1960s.

Before evolving into a hub of innovative scientific research, the waterfront property had a rich history. Miwok Indians were the earliest documented human inhabitants; their shell middens are buried across the site. In the 1800s the site was part of the Reed family ranch used for raising cattle and dairy farming, and later large fishing schooners began coming to shore to unload their catches at the newly established codfish packing plant. At the turn of the 20th century, the US Navy purchased the property and built the naval coaling station. In 1908 President Theodore Roosevelt’s Great White Fleet bunkered at Tiburon during its cruise around the world.

During the Depression, the Navy loaned the base to the State of California, which established its first nautical training school (presently known as the California Maritime Academy). With the outbreak of World War II, the Navy took the site back, and the Maritime Academy relocated to Vallejo. Meanwhile at the north end of the property, New Jersey-based Roebling and Sons used the site to reel the wire for the main cables of the Golden Gate Bridge, which celebrates its 75th anniversary this year. The galvanized steel wire was shipped in 400-pound bundles from the Roebling Plant in New Jersey through the Panama Canal to the Tiburon site. Ships tied up to the wharf at the north end, where a crane offloaded the bundles. A crew of 150 men worked in two long warehouses (no longer standing, but visible in the top image) to wind the wire onto reels that were then barged to the bridge construction site to be spun into cables.

In 1939 the Navy added the Roebling and Sons property to its holdings in order to establish the Naval Net Depot, a construction facility for anti-submarine and anti-torpedo nets, including a 7,000 ton, 7-mile long net strung across the entrance to San Francisco Bay. Other nets were shipped to Navy bases along the West Coast and across the Pacific until the end of the Korean War. In 1958, operations were terminated.

In the early 1960s the Navy maintained the Naval Electronics Facility, and turned the majority of the property over to the Department of Interior who established two offices on site. The Bureau of Sport Fisheries and Wildlife studied migratory marine game fishes and effects of pesticides on local fishes, assisted with
In Memoriam, Al Marchi

Al Marchi joined the Dugdale/Wilkerson Lab in 1996, just after he finished his master’s degree at SF State. He had been working in one of the NMFS labs on the RTC site at that time. When not in the lab he was out on the seawall fishing, as he was an avid fisherman. Later he would have Indy, his black lab, on site and would take him for swims off the seawall...or bring his sons Paolo or Zane, who he’d shuttle around RTC in the golf cart.

Al was a great seagoing technician who never seemed to feel the pitch or roll of a ship, always working away while the rest of the scientific crew were in their bunks feeling queasy. On month long equatorial cruises, he showed his real spirit — combining working on deck, running the instruments, making movies and fishing.

Al had a knack of getting things done quietly and with patience. With all the frustrations of mastering fussy analytical instruments or stormy conditions at sea, he never complained or got angry, but took it all in stride with a positive upbeat attitude and those smiling eyes — as he did during his personal struggle over his last year.

A great mentor to all those that passed through the research lab, Al helped both graduate and undergraduate students and others at RTC, and supported many high school interns from Sir Francis Drake High School and Marin Academy. He made many friends in his 15 years as an oceanographer. He also contributed as author to many scientific papers; his name in science will live on.

Al lost his battle with brain cancer on March 16. “We will always remember Al with his beanie and Doc Martin boots, arriving a little late to most meetings, but always there when needed with his humor and positive vibe. We miss him,” said Frances Wilkerson at his memorial service held at RTC. We all miss Al.
“We made it to the mouth of the river! The water is brown, fresh and extremely shallow, yet we still can’t even see land. The water is the color of coffee, and about as fresh. Fishing boats are everywhere, so we know there’s plenty of life in the water. In most rivers, the salinity gradually drops within the estuary, inland from the ocean. Due to the volume of freshwater flowing from the Amazon, the salinity remains near zero all the way out to the sea. As this is the first time this project has come this close to the river, we’re all excited for our sampling today. Is this a riverine community? How does the sediment differ here compared to the high salinity locations? Is there any photosynthesis in this murky water? Am I working as an oceanographer or limnologist? Today, we’ll find out all of this and more.”

Though the Amazon River flows 6,400 kilometers (about 4,000 miles) over land, the flow of the largest freshwater river on earth doesn’t stop once it reaches the sea. The river continues into the tropical Atlantic Ocean as a freshwater plume, mixes with the salt water of the ocean, and covers an area of up to 2 million square kilometers (almost 800,00 square miles) with a low salinity surface lens.

Along with fresh water, the river transports nutrients into the nutrient-poor tropical waters, driving phytoplankton growth and photosynthesis. A portion of the carbon dioxide (CO₂) taken up by phytoplankton is eventually transported to the seafloor and stored in sediment, resulting in a net removal of atmospheric CO₂ (known as sequestration). Several RTC scientists are participating in an interdisciplinary research project to understand the complex interactions within the river plume that result in a yearly removal of 276 metric tons of carbon dioxide (equivalent to the EPA-estimated emission of about 5.3 million passenger cars) from the atmosphere. The project – Amazon iNfluence on the Atlantic: CarbOn export from Nitrogen fixation by DiAtom Symbioses (ANACONDAS) – brings dozens of oceanographers from across the United States and Brazil together to investigate the processes affecting carbon sequestration in the region.

I joined the project as a graduate student in Dr. Edward Carpenter’s laboratory, to investigate this complex phytoplankton ecology.

Throughout the plume, nutrients occur at different concentrations, leading to varied communities of phytoplankton and other microbes. Nearest to the river mouth, we find coastal diatoms such as Coscinodiscus spp. and dinoflagellates like Ceratium spp. Farther away, near the edges of the plume, ammonium and nitrate containing essential nitrogen are depleted, and the coastal species are replaced by diatom diazotroph associations (DDA). Diatom diazotroph associations are symbiotic associations between diatoms and nitrogen-fixing cyanobacteria (diazotrophs), and Trichodesmium, a non-symbiotic diazotroph. These diazotrophs convert atmospheric nitrogen into ammonium, and expand the biological influence of the plume into regions with lower nitrogen concentrations. One of the main goals of ANACONDAS is to measure the effects that these diazotrophic organisms have on carbon removal from the atmosphere.

Each laboratory on the research team has its own focus, contributing specific expertise to the project. The physical
oceanographers measure the physical parameters of water masses like salinity, temperature and currents. With this information they can tell us where to expect diazotrophs. During the September cruise, the plume was constantly changing. The physical oceanographers directed us to the best sampling locations based on satellite images displaying salinity and cDOM (colored dissolved organic matter that is transported by the Amazon) in the region. Chemical oceanographers measured nutrient concentrations and carbonate chemistry in seawater collected in specialized bottles. Geochemists measured the carbon being transported to the seafloor with sediments traps, and collected cores to measure the sedimentation rate.

Though each group measured their own parameters, collaboration and cooperation between labs is an integral component of ANACONDAS. RTC’s Dr. Ina Benner worked with another phytoplankton ecologist on an experiment enriching seawater with CO₂ to try to predict phytoplankton reactions to future acidified oceans. Aboard ship we work closely together, and there are ample opportunities to assist and learn from the other scientists. The ANACONDAS research team expanded for the July 2012 cruise to include additional Brazilian scientists. Hopefully, this is the beginning of a long-term collaboration to investigate the Amazon River and plume system.

An oceanographic cruise is no vacation. Work has no set hours. I was usually up well before sunrise to collect plankton net tows, and would work through the day collecting, adjusting, and filtering my samples. Some days I spent hours trying to make sense of my data, and deciding how to tweak my work. When I had time to slow down, however, I took full advantage of it – relaxing on deck or in the onboard hot tub, and socializing with the other scientists aboard. Though I would have been happy to continue working for a few weeks, I know that I and everybody aboard the ship earned our celebration night in port.

Andrew Kalmbach received his B.S. from the University of Connecticut, where he majored in environmental studies. After school, he worked as a fisheries observer in Massachusetts, and assisted with plankton sampling after the Deepwater Horizon incident. As part of the Carpenter Lab, he uses carbon-14 to measure carbon fixation and dissolved organic carbon release by various algal communities in the Amazon River Plume. Read more about his Amazon experience at radioactive.blogspot.com.

A sampling of Amazon River Plume organisms. From top to bottom: barbeled dragonfish, larval eel, mixed phytoplankton. Photos: Jason Landrum, Kristine Okimura, Andrew Kalmbach
current patterns allows early positioning of responders for maximum containment and recovery of any pollutant spills.

HF radar tracks the upper few meters of coastal surface waters from the shore out as far as 200 km from the coast. Data files of hourly estimates of the surface currents are produced automatically in numerous formats to serve the needs of the Coast Guard search and rescue, the California Office of Spill Response and Restoration, NOAA’s Office of Response and Restoration, scientific researchers and the general public. The data are made available in many locations; Google maps showing the currents in the San Francisco Bay region are hosted at http://www.norcalcurrents.org and maps of national coverage are at http://cordc.ucsd.edu/projects/maps/fullpage.php. The data files are available upon request.

Individual maps illustrate the complex currents existing at that time. Analyzing a series of maps allows tracking the water and any material carried by the currents. This “particle tracking” ability provides the data that are important to the response and regulatory agencies. Dr. Garfield’s research team is working with the Environmental Protection Agency (EPA) to create probability predictions on where debris from the 2011 Japan tsunami may wash ashore in California. In addition to search and rescue and pollutant tracking, beach monitoring can be improved by predicting the path of coastal discharges that may contain contaminants. Knowing which beach may be exposed to pollutants allows for efficient monitoring and timely decisions on potential closures.

The Garfield Laboratory is also providing Bay Area recreational boaters with an easy way to observe the currents; in 2011 they released SF State University’s first iPhone/iPad app, “Bay Currents.” The app shows the most recent map of currents in central San Francisco Bay, and allows the user to view current maps for the previous 24 hours and a projection for the next two hours. Sailors can use Bay Currents to assist in plotting a trip, racers can make tactical decisions, and kayakers can use it to find the safest and easiest routes around the Bay. Swimmers recently used Bay Currents to choose their route in the annual “Alcatraz Sharkfest® Swim.”

The coast-wide measurements of currents have enabled further scientific insight for many investigations including the development and spread of harmful algal blooms, tracking larval transport and connectivity between marine protected areas, the evolution of the seasonal upwelling system, and the coherence of the large scale coastal circulation.

The success of the HF radar system relies on the collaboration of federal, state and local institutions. The California State Coastal Conservancy funded the implementation of the state-wide COCMP system and NOAA’s IOOS office is providing financial support to the
operators and to data serving. The California coast is divided up into eight regions or “nodes,” each with a host institution responsible for the systems in their region. The region between Point Reyes and Pillar Point, including San Francisco Bay, is the SF State University node that is operated by the Garfield Laboratory. Within this node there are 11 HF radar antennas; six on the outer coast and five in San Francisco Bay. Installation of these antennas required partnerships with the National Park Service (five systems), US Coast Guard (two systems including one of the National Park systems), US Air Force and the local governments of Montara, San Francisco, and Sausalito.

Each site is unique and trips to service them are exciting. One site, Commonweal in Bolinas, is co-located with the old 1913 Marconi transmitter site for trans Pacific communications. Another site is located at Point Bonita, a lighthouse in the Golden Gate National Recreation Area. “Visiting the Point Bonita site is not for the faint of heart,” said COCAMP Operations Manager and Garfield team member Jim Pettigrew. “After a long hike, then passing through a narrow tunnel with low clearance to reach the antenna location, one needs to suppress vertigo while walking on a swaying footbridge above a perilous chasm. The antenna is bolted to a narrow ledge of pillow basalt high above surging waters and the blast of the fog horn requires ear plugs be worn at all times.”

The most recent HF radar Bay installation is located at Point Blunt on Angel Island, possibly the windiest place in San Francisco Bay. The site has an unobstructed area of coverage from the Golden Gate Bridge, along the San Francisco waterfront, past Treasure Island and up north toward Red Rock. In a joint venture with Weatherflow Inc., the Garfield Laboratory has co-located a wind sensor on the point, which will be incorporated into the array of instruments generating data for the upcoming America’s Cup® Regatta. The combination of real-time information on both winds and currents provides sailors with unprecedented knowledge of Bay conditions.

Another antenna will be located at San Francisco Piers 15/17, the new home of the Exploratorium, a museum of science and art. The museum’s unique waterfront access will allow development of exhibits and experiences related to the Bay. RTC is working closely with the Exploratorium scientists to help develop the exhibits. The antenna located at the museum will improve the monitoring of currents along the waterfront as well as provide material for Exploratorium exhibits. “While scientific investigation remains our main focus, it is exciting to work with the Exploratorium, since they bring a unique ability to transform abstract circulation data into an exciting and informative experience for the museum visitor,” said Dr. Garfield.

**HF RADAR 101** HF radar antennas emit low-energy radio signals that reflect off of ocean waves and are returned back to co-located receiving antennas. The speed of the ocean current away from or towards the antennas is determined by measuring the change in the frequency ($\Delta \lambda$), or Doppler shift, of the reflected signal. Below: $\Delta \lambda$ is equal to the sum of the speed of the ocean waves (known) and the speed of the ocean currents (unknown). Inset: The radial speed (toward or away) is determined for each antenna. The total current (speed and direction) is obtained by combining the radial measurements from multiple antennas (overlapping region).
**Keeping China Camp State Park Open for Science and Recreation**

The San Francisco Bay National Estuarine Research Reserve (NERR) is made up of two sites: Rush Ranch in Solano County and China Camp in Marin County. Rush Ranch is a little known, but fabulous place that attracts both marsh and history enthusiasts. China Camp, on the other hand, is a well-known recreation destination that also attracts people interested in human history and tidal marsh ecology.

China Camp State Park is a rare refuge along San Francisco Bay’s urbanized shoreline, with parkland extending from the forested ridge down through grasslands and on to expansive salt marshes and mudflats. The park was named to recognize its rich, recent cultural history. In the 1800s, there were two thriving villages from which Chinese immigrants and their families trawled the shallow, muddy waters in search of tiny shrimp that made up a profitable fishery. The park’s recently updated visitor center tells stories of the people who lived there and their successful fishery. Interpretive exhibits at the park’s picnic areas and along the trails educate visitors about the area’s equally rich ecological heritage. China Camp’s salt marshes, for example, are remnants of a habitat that was once common, but is now so rare that it is home to endangered species, like the California clapper rail and salt marsh harvest mouse.

Despite its historical and ecological importance, and immense popularity with mountain bikers, picnickers, and beach goers, China Camp State Park was selected to be one of 70 State Parks planned for closure this summer due to the state budget deficit. Scientists at the NERR were concerned about potential closure of the park because it is essential for researchers to have uninterrupted access to equipment and habitats where long-term studies are conducted. Additionally, there was grave concern that people would still enter the park after the official closure; without patrolling rangers and functioning services (like well-maintained bathrooms) those visitors would damage natural resources of the park.

A local group, Friends of China Camp, stepped up to “save” the park. The organization swelled its membership from fewer than 50 members to over 1400 and raised the $250,000 required to become the temporary operator of China Camp State Park. They organized an impressive variety of fundraising events, ranging from a symphony performance to a community college course. Their remarkable hard work led to State Parks signing an agreement for Friends of China Camp to become the park’s operator, and thereby keep it open to the public. Although the agreement needs final approval from the Department of General Services, in the mean time, Friends of China Camp has an Early Entry Permit to allow them to operate the park immediately. The NERR, numerous local organizations and foundations, and many people who love to play (or work) at China Camp are rallying around Friends of China Camp to offer support and expertise. Together, we can ensure the park is protected, scientists can continue their research, and visitors can be inspired by their experience in nature.

NERR Notes was written by Sarah (Davies) Ferner, SF Bay NERR Education Coordinator. The National Estuarine Research Reserve System is a network of protected areas established for long-term research, education and stewardship of the nation’s estuaries. Each NERR is a partnership between the federal and state government. The San Francisco Bay NERR is a partnership among National Oceanic and Atmospheric Administration, San Francisco State University, California State Parks, Solano Land Trust and the Bay Conservation and Development Commission. It is headquartered at the Romberg Tiburon Center for Environmental Studies. To learn more about the San Francisco Bay NERR, please visit sfbaynerr.org.

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**The RTC Wetland Science Series** offers courses in wetlands delineation (both basic and advanced), invasive species, restoration ecology, policy, geographic information systems (GIS), plant identification, experimental design, wetland restoration monitoring techniques, and statistical analysis.

For more information visit http://online.sfsu.edu/~wetlands, scan the QR code to the left, email wetlands@sfsu.edu or call (415) 819-2073.
Out & About: Teaching and Learning from RTC to Alaska

High School Students Explore Marine Science  Last summer, Sea Lion Bowl Diversity Coordinator (and RTC graduate student) Autumn Cleave and Outreach Coordinator Erin Blackwood ran a five-day summer marine science course for nine students involved in the Diversity Initiative of the Sea Lion Bowl. This was the second year RTC offered the course with funding from a Whale Tail grant from the California Coastal Commission. Student evaluations and later performance at the Sea Lion Bowl showed that the course and overall program had a positive impact on students’ confidence, leadership, teamwork, and academic knowledge of marine science. Student comments included: “this program...gave me a feel of how it would be if I was in the field of ocean science,” “we actually get to go outside and see actual things. I find it so much easier to understand if someone shows me instead of just reading it out of a textbook,” and “this course is the best summer program I ever had.”

Climate Change Workshops for Science Educators RTC’s professional development offerings have expanded in the last year due to collaborations with the Farallones Marine Sanctuary Association and Cordell Bank National Marine Sanctuary, in addition to a regular collaboration with the SF Bay National Estuarine Research Reserve (NERR). With funding from the Ernest F. Hollings Ocean Awareness Fund for a Climate Change series of workshops, RTC has been able to offer a new two-day summer workshop as well as our annual spring and fall one-day sessions. “I loved the in-depth information that was presented,” said one teacher. “As a high school teacher this is the hardest thing to find at teacher workshops. High school level science teachers need to constantly update our content.” The final workshop in the series is held on November 3 and will focus on adaptations to climate change. In addition, The Exploratorium held two workshops at RTC, as part of an ongoing collaboration to develop exhibits for its new home on the San Francisco waterfront.

SF State Summer Interns This summer also saw increased involvement in coordination of the SF State fellows in the CSU’s STEM Teacher and Researcher (STAR) Program, as well as assistance with the National Science Foundation-funded Research Experiences for Undergraduates (REU) program. The STAR program offers teacher candidates and beginning teachers the opportunity to conduct their own research projects to enhance their future STEM teaching, and to create a lesson plan related to their research. The REU program offers undergraduates a similar opportunity, to enhance their own education and help them decide if they want to pursue an education and career in science. Together with the small number of high school and other undergraduate interns we often host, our summer student population was at an all-time high this year.

National Marine Educators Association Conference Erin attended the National Marine Educators Association conference in Anchorage, Alaska. The association meets every year in a different region, and this was their first time in Alaska. The conference was packed with interesting sessions on Alaskan marine life, blending native culture and science, educational research, climate change, virtual field trips, and social media. Fortunately, there is always time for a nature walk in the land of the midnight sun.

Save the Date for RTC’s Discovery Day Last fall, RTC joined with the Bay Area Science Festival (BASF) and participated in the North Bay Discovery Day (yes, they like the name, too) at Infineon Raceway. RTC staff and volunteers educated and delighted over 1500 Bay Area families with an exploration of “What’s Under the Dock?” Save the date for RTC’s 23rd Annual Discovery Day on October 21 at our site in Tiburon, and the BASF North Bay Discovery Day on October 27 at the Sonoma County Fairgrounds.

Annie Pang from College Park High School tries out a teacher workshop demonstration of pH change in water with the addition of dry ice (frozen CO2). Photo: Erin Blackwood

After a full day of NMEA workshops in the land of the midnight sun, Outreach Coordinator Erin Blackwood takes a sunset walk at 11:30 pm! Photo: Erin Blackwood
RTC Research Directions

Collaborative Research: Dissolved Organic Carbon (DOC) Transformation in Deep Subsurface Sediments and its Role as a Source of “old” DOC in the Water Column

Carbon is essential for life, and its cycling in the environment profoundly affects the Earth’s climate. Understanding the separate components of the global carbon cycle (including the oceanic carbon cycle) is critical to understanding the whole. The dynamics of the ocean’s carbon pool are not well understood, even though the worldwide ocean holds more carbon as DOC than all the carbon locked up in land plants. What has perplexed chemical oceanographers for a few decades is that DOC in the deep ocean (where most marine DOC is found) is anomalously old: on average, the radiocarbon age of DOC is ~5,000 years, which is much greater than the 500-1,000 year mixing time of the deep ocean. DOC is produced at high rates in the surface ocean where biological productivity is high, but DOC from living organisms typically has young radiocarbon ages, making it difficult to explain if and how such DOC ages in the ocean over ~5 mixing cycles.

Dr. Tomoko Komada and her collaborators from Old Dominion University and Florida State University think they have identified an alternative potential source of the old DOC: the seafloor. The answer may be revealed by studying ocean sediments and the chemical and isotopic imprints made by the microbial communities that inhabit them. Microbes, such as bacteria living in deep-ocean sediments, rely on particulate organic matter (such as detritus and fresh sediment) that fall from above as sources of energy and carbon. For the past few years, Dr. Komada and her collaborators have been investigating the hypothesis that as microbes feed on their food source in the sediments, old organic carbon is released into the sediment pore waters in the form of DOC, and this DOC eventually escapes out into the overlying water column. With new funding from the National Science Foundation, they will continue this research. In the summers of 2012 and 2013, Dr. Komada and her team will collect sediment cores from the Santa Barbara and Santa Monica Basins to determine the radiocarbon ages of pore-water DOC, methane, and other key carbon pools. They will sample the surface sediments (from the seafloor to about 40 cm below) where microbial activity is very high, and the more deeply buried sediments (2-3 meters below the seafloor) where methane is actively produced. This project is expected to not only provide insight into the sources of old DOC in the deep sea, but also provide important clues surrounding the controls behind carbon preservation in ocean sediments.

The Role of Microcystis in the Food Web of the San Francisco Estuary: A Functional Approach

Dr.’s Alex Parker, Wim Kimmerer and Frances Wilkerson are collaborating with researchers from UC Santa Cruz and University of North Carolina, Chapel Hill to investigate an emerging problem for the San Francisco Bay-Delta – summer blooms of toxic cyanobacteria of the genus Microcystis. Cyanobacteria are the Earth’s oldest (~ 3.5 billion years ago) oxygen producing organisms, and have played a major role in shaping our modern-day atmosphere and biosphere. Their long evolutionary history has served them well; today they are able to exploit human and natural climatic disturbances, including nutrient enrichment, hydrologic modifications and climate change. For a little more than a decade, Microcystis has been abundant in the Delta. Microcystis accumulates at the water’s surface, degrading the aesthetics of the...
environment and can restrict the growth of plankton preferred as a food source. Additionally, some strains of *Microcystis* produce toxins called microcystins, which negatively affect the health of aquatic organisms and can potentially impact human health. Despite these identified problems, relatively little is known about the ecology of *Microcystis* in the Delta, and the specific environmental conditions and physiological mechanisms that allow the organism to proliferate. The research team is studying: 1) the physical and chemical conditions that promote bloom development, 2) the spatial and temporal patterns of the microcystin toxins, and 3) the growth and feeding ecology of zooplankton in areas where *Microcystis* exists. The project work plan includes two years of laboratory and field work using RTC’s research vessel, the R/V *Questuary*. Results from the project will be incorporated into comprehensive management strategies for the control of *Microcystis* blooms in the future.

**Collaborative Research: Iron Regulation of the Food Quality of Phytoplankton in Acidified Eastern Boundary Upwelling Systems**

Upwelling systems along the Continental West Coast, where deep, nutrient-rich water rises to the surface, are home to major marine fisheries that support humankind. Within the next century, these systems are expected to experience extreme acidification (decreasing pH) due to the ocean’s uptake of the increasing carbon dioxide in our atmosphere and subsequent chemical reactions that release hydrogen ions. Impacts on the bioavailability of trace metals (especially iron) and nitrogen are likely, causing potential shifts in phytoplankton species composition and physiology. One understudied aspect of ocean acidification is the stress-related change in the synthesis of total lipids and polyunsaturated fatty acids, particularly essential fatty acids (EFAs). These EFAs are needed to support production at higher trophic levels where most organisms (including humans) lack the ability to produce these compounds. Given that phytoplankton are the base of the marine food chain, such changes in the quantity and character of phytoplankton lipids could affect their quality as a food source in the ocean and the success of marine organisms occupying higher trophic levels (the position an organism occupies in the food chain) such as fish.

Dr. William Cochlan, the lead on this multi-institutional project, and collaborators (Drs. Robert Bidigare, Vera Trainer, Charles Trick and Mark Wells from the University of Hawai‘i, NOAA, Western University [Ontario] and University of Maine, respectively) were recently awarded a National Science Foundation Chemical Oceanography grant to study this critical void in the understanding of the regulation and taxonomic distribution of lipids and fatty acids in present day and future phytoplankton communities associated with our increasingly corrosive ocean. Over the next three years, Dr. Cochlan and his staff and students will utilize controlled laboratory culturing systems to subject West Coast phytoplankton from upwelling regions to varying concentrations of carbon dioxide (to mimic acidification), and iron and nutrient availability, to study their physiological response to extreme pH conditions. In addition, they will go to sea on multi-week research cruises to determine if the same physiological responses are occurring in upwelling systems along the US West Coast, where pH declines not expected elsewhere in the open ocean for many decades are already occurring. Their study hopes to provide critical insights into the effects of ocean acidification on the food quality of future phytoplankton communities in the most productive fisheries regions of our oceans.
Sarah Blaser is a recent graduate from the Wilkerson Laboratory. While working on her degree, she won numerous awards, including a 2012 Biology Department Graduate Student Award for Distinguished Achievement, the William Atchley Award for Environmental Stewardship, a Tyee Scholarship and RTC’s Bay Scholarship two years in a row.

What inspired your interest in marine and aquatic science? I always enjoyed and did well in science and math in school, but it was a trip to French Polynesia and the UC Berkeley Gump research station on Moorea that really got me interested in Marine Biology specifically. On that trip I went scuba diving for the first time and was fascinated by the marine environment. That experience lead me to study Ecology with an emphasis in Marine Biology for my undergraduate studies at Cal Poly, San Luis Obispo and study Marine Biology for my graduate work at RTC.

Why did you choose RTC for your graduate work? I was looking into various graduate programs and came to visit RTC to meet with Drs. Frances Wilkerson and Alex Parker. They really got me interested in studying phytoplankton and thinking about how important phytoplankton are to the estuarine ecosystem. I also have to admit that location was part of my decision-making process. I was excited to be able to do graduate work while living in such a great area.

Tell us about your research and why it is important. For my thesis research I investigated the effects of two herbicides (diuron and imazapyr) on phytoplankton in the San Francisco Estuary (SFE). Phytoplankton are important to study since they form the bottom of the food web and are an important food source for higher trophic levels. Herbicides are used widely within estuarine watersheds. When they are washed off the land and into waterways, they have the potential to negatively affect estuarine organisms (such as phytoplankton). Diuron is an herbicide of concern because it is used extensively and persists for long periods in the environment. Imazapyr is applied to marsh habitat adjacent to the SFE to control invasive plants. I investigated the impact of additions of diuron and imazapyr on phytoplankton productivity, nitrogen uptake and community composition of natural phytoplankton assemblages collected in the SFE. I found significant reduction in phytoplankton productivity with additions of diuron that are within the range of diuron concentrations previously reported for the northern SFE. While diuron affected phytoplankton productivity immediately, imazapyr exposure did not negatively affect productivity immediately, but did with chronic (48 hour) exposure experiments. In addition to decreasing the productivity, phytoplankton biomass and abundance was lower in treatments with diuron and imazapyr, and the phytoplankton community composition shifted with the addition of diuron and imazapyr. This work has important implications for management in the SFE, especially with concern about the generally low concentration of phytoplankton in the estuary and the effect on higher trophic levels.

In what other ways did you become involved in the RTC community? I was involved in the RTC student association (treasurer) and volunteered for various outreach activities such as Expanding Your Horizons (a program to teach young girls about science), the Northern California Regional Ocean Sciences Bowl (Sea Lion Bowl), RTC Discovery Day, beach cleanups and sustainability programs (gardening, team bike challenge, etc).

What are you up to now? I am working as a research technician in Drs. Frances Wilkerson and Dick Dugdale’s research laboratory. I’m excited to continue to do research and work at RTC. I am also writing up my thesis research for a journal article and will be presenting my research at the Bay-Delta Science conference in October.

What are your future plans? For now I am excited to work as a research technician but down the road I am thinking about working in science education.

What do enjoy most about your time at RTC? I really love the sense of community at RTC. I have always felt very supported by not just my own lab, but by everyone at RTC. I am very happy to be able to stay here after graduating.
Congrats, RTC Grads!


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