A Little Urban Harbor Reveals Big Mysteries

Ship to Shore: Linking Science to Policy and Management

When the City of Redondo Beach woke up on Tuesday morning March 8th, 2011 to find its harbor brimming with a million dead sardines, the questions on every person's mind were: what happened and who can find out quickly? Luckily, the last question was the easiest to answer because Sea Grant-funded USC Professors, Dr. David Caron and Dr. Astrid Schnetzer, have been closely monitoring and studying King Harbor in Redondo Beach since 2005, the last time a large fish kill occurred in the harbor. By taking water samples by hand each week and more recently by relying on permanently installed sensor technology in the harbor, Drs. Caron and Schnetzer have learned that there are several toxic species of algae that regularly live in the harbor and that the population levels of these species can change rapidly over short time periods. Similar to other marinas and harbors along the Southern California coast, King Harbor is occasionally the site of algal blooms, although most blooms have not been accompanied by large fish kills.

Given its history of algal blooms, Redondo Beach residents were quick to assume that the 170 tons of dead sardines floating in their harbor on March 8th were the result of an algal bloom or domoic acid poisoning. Domoic acid is a neurotoxin produced by the algae *Pseudo-nitzschia* and is known to cause short-term memory loss, seizures, paralysis, respiratory failure, and even death in marine mammals. Humans can be impacted as well as they can be exposed to the neurotoxin by eating contaminated shellfish, which bioaccumulate (accumulate in the tissues of an organism over time) the neurotoxin while filter feeding on the bloom of algae.

Surprisingly, what Drs. Caron and Schnetzer revealed through their monitoring data was that there was low algal biomass and no domoic acid in the harbor at the time of the fish kill on March 8th. In fact, the monitoring data revealed that on Monday the 7th, a large volume of cold, low-oxygen water came into the coastal area and harbor (which already has slow circulation and low oxygen levels) and the huge school of fish died from anoxia, or lack of oxygen. Even four days later on Friday the 11th, monitoring data documented that the harbor remained anoxic. (Con't on page 2)

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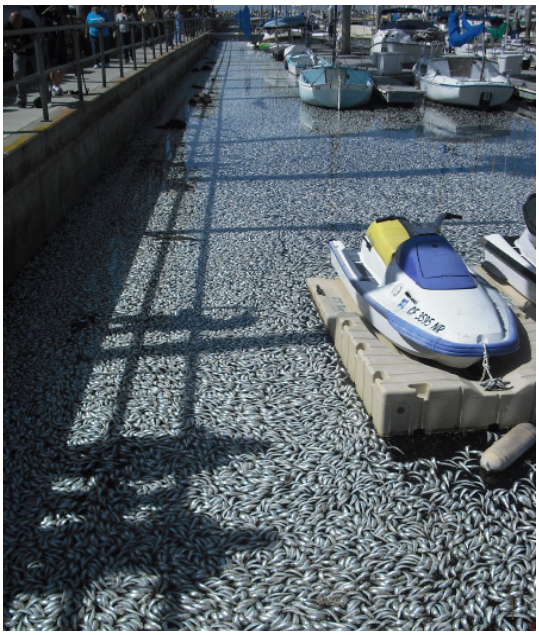
Ship to Shore: (con't from page 1)



One million dead sardines in King Harbor, Redondo Beach. (Photo credit: Dr. Caron's lab)

The mystery of the sardine kill continued, however, when Drs. Caron and Schnetzer found through tissue analysis in their labs that the sardines did indeed have detectable levels of domoic acid in their system, although likely not enough to kill them. This finding was critical from a public health perspective, as the close-working relationship between the researchers and the Redondo Beach city managers allowed the city to quickly issue warnings to its residents, many of whom had begun to collect the fish to eat once hearing that a toxic algal bloom was not the main cause of death. Although there was no domoic acid in the harbor, satellite imagery revealed that there was a massive greenish-brown *Pseudo-nitzschia* bloom off-shore from Santa Barbara down to the Mexican border at this time. Drs. Caron and Schnetzer hypothesize that in order to avoid the bloom and/or the large volume of low-oxygen water heading toward the coastline, the sardines may have been forced into the small area of the harbor. With the arrival of the low-oxygen volume of water into the harbor, the large school of trapped sardines quickly consumed all the remaining oxygen in the water. It is possible, although virtually no data exist on the effects of domoic acid on fish like it does for mammals, that the small amounts of domoic acid in the fish was there from feeding farther offshore and possibly could have contributed to the unusual behavior of so many fish congregating in the harbor. Despite the unknown effects of the domoic acid in the fish tissue, however, it is clear that the depleted oxygen levels alone were enough to kill the fish once they were in the harbor.

> *"The City of Redondo Beach was fortunate to have forged a partnership with USC..the years of work by Dr. Caron created a new base of information and helped explain the complex ocean processes we experience in operating the Harbor's waterways. I especially appreciated Dr. Caron connecting his research with the practical decisions we have had to make in managing the Harbor. He was our marine science expert whom could be relied upon by the community, media and other public agencies. I am looking forward to expanding the work of USC in King Harbor."*
>
> -Bill Workman, Redondo Beach City Manager

For the city of Redondo Beach, understanding the science and causes behind what is happening in its harbor is critical for preventing or mitigating any of these blooms. The continuous monitoring research of King Harbor by Drs. Caron and Schnetzer is aimed at understanding the complex algal community dynamics naturally occurring in the harbor, the main role that toxic species play in this community, the role these toxic species play in blooms, and whether these blooms are originating inside the harbor or being advected into the harbor from the surrounding coastal waters. The event on March 8, 2011 shows how complex the interaction between the coastal marine ecosystem and oceanography can be along the Southern California coast. In simple visual terms, the problem of 170 tons of dead sardines may have looked as though it was confined only to Redondo Beach Harbor. In reality, the research and monitoring conducted by Drs. Caron and Schnetzer and their students demonstrated more complex and mysterious interactions between the offshore and inshore environments, as well as between oceanographic processes and marine organisms.

The long-term monitoring and tight association between the USC lab and the City of Redondo Beach allow for quick, coordinated action and dispersal of accurate information in the event of a possible health threat like the March 8th fish kill. King Harbor is not unique in having to deal with harmful algal blooms or anoxia, and the research of Drs. Caron and Schnetzer has the potential to inform a broad audience of coastal managers on the nature of toxin forming species and the initiation, progression, and demise of harmful algal blooms. This kind of information is urgently needed, as rates of harmful algal blooms seem to be increasing along the coastline of areas like Southern California; and the public is increasingly aware of the adverse and often severe impacts these blooms can have on marine organisms as well as human health.

At the Helm: From USC Sea Grant

Phyllis Grifman, Associate Director, USC Sea Grant

Welcome to the seventh issue of the Urban Mariner, *USC Sea Grant's Urban Ocean Report.* In addition to the research support that USC Sea Grant and other research organizations like the National Science Foundation (NSF) Center for Embedded Networked Sensing (CENS) have provided for the Caron lab for a number of years, Sea Grant is also able to mobilize a small grant very quickly in response to emergent events like the March 8th fish kill in Redondo Beach. We were able to provide additional support to the Dr. Caron's lab immediately, enabling them to investigate the critical situation in King Harbor in Redondo Beach and to provide the city with accurate information as soon as possible.

The Community HABwatch program is another great example that demonstrates how Sea Grant connects current research, educators, and the public. In coordination with COSEE-West, a national network of science and education professionals that integrates ocean sciences research and education and works with informal and formal education partners, USC Sea Grant connects current research and researchers with the education community in the broader Los Angeles area. This program has provided educators with the knowledge and skills to teach about harmful algal blooms and to train students and citizen volunteers to take water and biological samples themselves. Not only are educators up-to-date with the latest research and information, but they also have the skills and resources to give students hands-on experience with plankton sampling.

Previous issues of the Urban Mariner can be found at: http://urbanmariner.urbanocean.org

Scientist's Quarters: About the Researchers

Dr. David Caron

Dr. David Caron, USC

Dr. Caron has been a professor in the USC Department of Biological Sciences since 1999. He was Chair of the department from 2003-06 and recently served as Interim Director of the Wrigley Institute for Environmental Studies, which operates on USC's main campus and the Wrigley Marine Science Center on Catalina Island off the coast of Los Angeles. Dr. Caron received his Ph.D. in the Joint Program in Biological Oceanography coordinated between the Massachusetts Institute of Technology and the Woods Hole Oceanographic Institute. He received a Master's and Bachelor of Science in oceanography and microbiology respectively from the University of Rhode Island. In addition to his busy teaching schedule and prolific research, Dr. Caron serves on several local advisory boards, such as the Santa Monica Bay Restoration Commission Science Advisory Committee, applying his expertise to pressing local issues.

Dr. Astrid Schnetzer

Dr.Astrid Shnetzer, USC

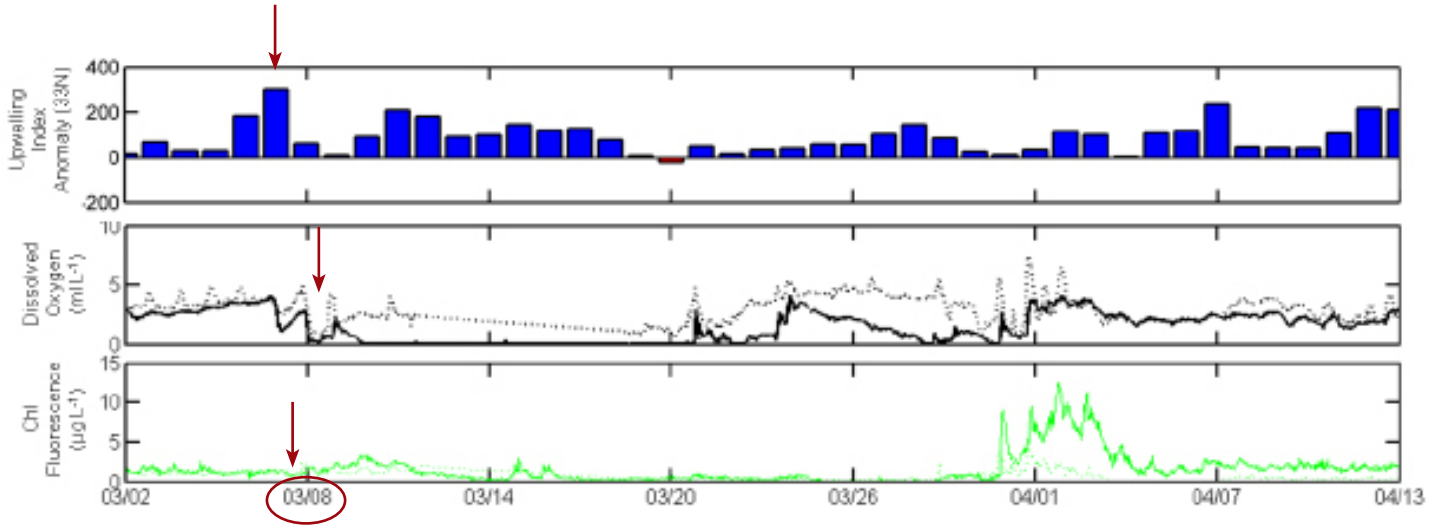
Dr. Schnetzer has been a Research Assistant Professor at USC since 2006. She received her Master's and Ph.D. from the University of Vienna in the active transport of particular organic carbon and nitrogen by vertically migrating zooplankton in the Sargasso Sea. Dr. Schnetzer is currently the lead principal investigator on an NSF-funded research grant, conducting experimental studies to understand and evaluate the acclimation of marine plankton assemblages to increased CO2 and sea surface temperature, increases both likely to occur given the current climate change projections. Dr. Schnetzer is also the lead PI on a Sea Grant project (discussed in the In Depth section of this Urban Mariner) studying the impacts of algal toxins on diversity and species composition of coastal plankton communities. She is a co-PI on several other collaborative projects. Despite her rigorous research schedule, Dr. Schnetzer also finds time to teach both undergraduate and graduate research courses and seminars at USC.

In Depth: About the Research

> *What Is a Bloom? A "bloom" is when an algal species grows to an impressive abundance. When the species blooming also has the capability of producing a toxin, the event is called a "harmful algal bloom" since it can make other marine organisms (and sometimes humans) very sick. Why and when these blooms occur is still a mystery.*

Drs. Caron and Schnetzer and their students have been monitoring and studying water chemistry and algal communities in King Harbor in Redondo Beach, CA since 2005. This monitoring has been supported by grants from a number of agencies including USC Sea Grant, the National Oceanic and Atmospheric Administration (NOAA), and the National Science Foundation (NSF) Center for Embedded Networked Sensing (CENS), the latter of which helped install permanent sensors in King Harbor to monitor temperature, salinity, dissolved oxygen, and chlorophyll abundance. The sensor network is a collaborative research project between Dr. Caron's lab and Professor Gaurav Sukhatme of the Department of Computer Science at USC. The sensors collect data every 30 minutes, allowing the Caron lab to track any changes in water chemistry or algae abundance (algae produce chlorophyll) over the course of a day. In addition, an underwater robot or EcoMapper—nicknamed "Boomer"—can roam the harbor freely and collect data while on the move. The data collected by these sensors and "Boomer" give the lab a detailed and continuous picture of the water chemistry in the harbor, providing the critical backdrop for understanding (and even predicting) algal bloom events.

Using traditional methods such as counting by microscope and cutting edge technology such as real-time PCR (qPCR), the Caron lab can track the presence and abundance of the most dominant algal species in King Harbor. Real-time PCR is a technique that allows researchers to determine if and how much of a certain type of DNA is present in a water sample; once a DNA signature of a particular species of algae is known, then using qPCR to search for its presence in a water sample can be quick (within ~3 hours). (Con't on next page)



Top: One million dead sardines weighing 170 tons in King Harbor, Redondo Beach, CA on March 8, 2011. (Photo credit: Beth Stauffer)

Bottom: This figure shows the upwelling index, dissolved oxygen, and chlorophyll fluorescence for the month surrounding the fish kill. Just before the height of the fish kill on March 8, 2011, the sensor recorded increased upwelling, but no elevated chlorophyll. Elevated chlorophyll would have indicated a plankton bloom in the harbor, since phytoplankton produce chlorophyll. Around March 8, there is a significant drop in dissolved oxygen in the harbor water, which lasts almost through March 20. (Graph courtesy of the Dr. Caron's lab).

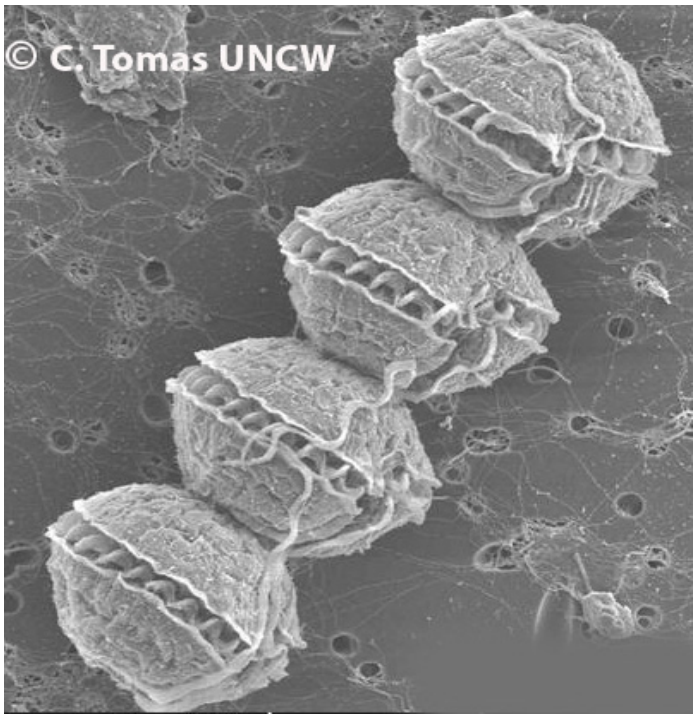
In Depth: About the Research (continued)

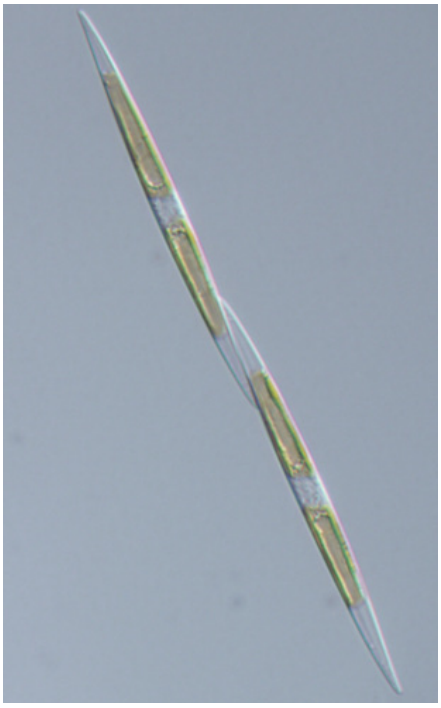
The presence of algae-produced toxins in dozens of water samples are then quantified using enzyme-linked immunosorbent assay (ELISA), a biochemical technique that uses antibodies to show how much of a substance (the toxin in this case) is present in a water sample. The ELISA provides results within three hours, whereas previous methods (high performance liquid chromatography or HPLC) could take a day or more.

Dr. Schnetzer taking water samples during the March 2011 fish kill in King Harbor. (Photo credit: Dr. Caron's lab)

Although many species have been documented as recurring in King Harbor, Dr. Caron's lab has focused recent efforts on the resident toxic algal species, *Alexandrium catenella. A. catenella* produces a neurotoxin called saxitoxin but it is not known to form blooms in Southern California. However, *A. catenella* cells continuously produce toxin at high enough concentrations that even low population numbers can produce enough saxitoxin to be transferred and bioaccumulated up the food web, causing sickness and mortality in marine mammals. Dr. Caron's lab was able to adapt and sensitize the qPCR approach to be able to detect *A. catenella* at very low abundances as well as use the ELISA to measure levels of saxitoxin. The lab found that saxitoxin is detectable in more than 10% of water samples taken from the harbor (ranging in concentration from 2.6 to 18.8 ng L-1), even in non-bloom conditions.

Dr. Caron's lab is also conducting complex lab experiments coupled with qPCR ELISAs to investigate whether the production of toxins by certain species such as *A. catenella* actually inhibit the growth of other co-occurring species of algae. In short, the lab is trying to determine whether toxins are used as a form of chemical warfare between species of algae! This chemical warfare, termed allelopathy, is the basis of one theory for why toxins are produced and possibly answers the questions of why and how toxic algal blooms occur in a place like King Harbor. Coupling these types of experiments with careful monitoring of the water chemistry in the harbor may ultimately give the Dr. Caron's lab the practical ability to predict when these blooms may occur.





Left: Alexandrim catenella. (Photo credit: C. Tomas UNCW);

Right: *Pseudo-nitzschia* chain. (Photo credit: Dr. Caron's Lab)

Getting Underway: Young Researchers

In addition to funding and facilitating research and developing partnerships to address some of the critical issues facing the Los Angeles' urban ocean environment, USC Sea Grant places great importance on developing the next generation of scientists, policymakers, and educators. Below we feature two of Dr. Caron's students, Beth Stauffer and Erica Seubert. Also featured is one of Sea Grant's outreach programs that enables informal education centers to run citizen-science programs for the purposes of monitoring coastal waters and educating the public about harmful algal blooms (HABs).

Beth Stauffer, Ph.D. Candidate, USC

Beth Stauffer

Ms. Stauffer is completing her Ph.D. at USC and soon will begin a Lamont-Doherty Post-doctoral Fellowship at the Lamont-Doherty Earth Observatory of Columbia University. While at USC, Beth has received multiple distinctions and awards, including the Anita Brown Scholarship for Environmental Studies and an Outstanding Teaching Assistant Award through USC. Prior to being at USC, Beth received her B.S. in Biology and Marine Science from the University of Miami. Her research interests include: the roles of physical, behavioral, and physiological processes in the initiation and maintenance of algal blooms in marine and aquatic environments as well as the use of networked and autonomous sensing to investigate freshwater and marine phytoplankton community dynamics. Beth's Ph.D. research at USC was primarily funded through the National Science Foundation (NSF) Center for Embedded Networked Sensing (CENS).

Dr. Schnetzer and Beth Stauffer deploying the EcoMapper "Boomer" in King Harbor in the week following the fish kill.
(Photo credit: Carl Oberg)

Erica Seubert, USC

Erica Seubert

Ms. Seubert is currently pursuing her Ph.D. at USC in Marine Environmental Biology. While at USC, Erica has been awarded two Sea Grant Trainee Fellowships, in 2008 and 2010. Despite her busy research schedule, she has also worked as an undergraduate teaching assistant for several classes. Erica's Ph.D. work to date has concentrated on how the toxins domoic acid and saxitoxin, produced by the diatom genus Pseudo-nitzschia and the dinoflagellate Alexandrium catenella respectively, are functioning as allelochemicals. In other words, she is trying to find out whether these toxins are produced to inhibit the growth of other competitive plankton species, especially in low-nutrient environments. Erica's laboratory component of this research involves a fascinating set-up of pairing a toxin producing species and a non-toxin producing species in a jar with a mesh that prevents interaction of species but allows for toxin flow. In this way, she can see if adding the toxin allows one species to grow more than another. This research, coupled with field experiments, could inform her about the quick and complex changes in the community composition seen in the Redondo Beach Harbor.

Erica's divided-jar experimental set-up to test the allelopathy hypothesis. (Photo credit: Erica Seubert)

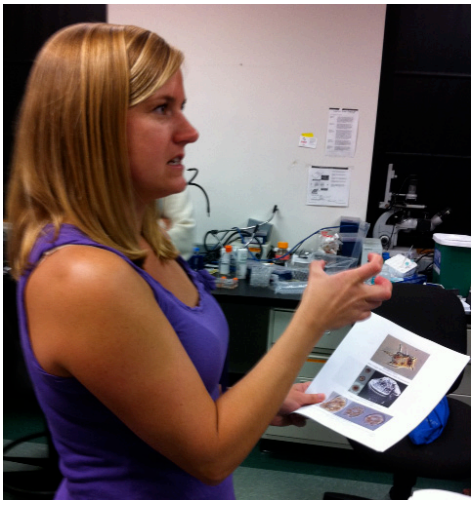
Getting Underway: (Continued)

Community HABwatch Program

It can be challenging for aquaria and informal science centers to address some of the complex issues and questions that members of the public may bring to them, especially during sudden events like harmful algal blooms or fish kills. In response, USC Sea Grant and COSEE West brought together informal (not in schools) educators and scientists to discuss how to engage their audiences, staff, and volunteers to better understand harmful algal blooms. These initial meetings led to the creation of the Community HABwatch Program in Southern California, funded by the Southern California Coastal Ocean Observing System. The participating informal science centers and aquaria include: Aquarium of the Pacific, Back Bay Science Center, Cabrillo Marine Aquarium, Channel Islands Marine Sanctuary, Los Angeles Marine Institute, Ocean Institute, Roundhouse Aquarium, Santa Monica Pier Aquarium, SEA Lab, Tole Mour, Ty Warner Sea Center.

USC Professor Dr. Dave Caron and USC graduate students—Bridget Seegers, Erica Seubert, Beth Stauffer and Adriane Jones, and laboratory technician Alyssa Gellene—developed resource materials and local field identification guides, presented training workshops, and provided guidance for the partners. The partners are reporting that they now are providing much better plankton education to the groups and individuals with whom they engage.

For more information:
http://www.usc.edu/org/cosee-west/habwatch.html



Top: Beth Stauffer giving a lecture to partners in the Community HABwatch program; Bottom: Erica Seubert demonstrating proper plankton sampling procedures to HABwatch partners (Photo credit: top, Linda Chilton; bottom, Carl Carranza)

What is Sea Grant?

Sea Grant is a nationwide network--administered through the National Oceanic and Atmospheric Administration (NOAA)--of 32 university-based programs that work with coastal communities. The Sea Grant Program at the University of Southern California has served the Southern California coastal region since 1972, funding research, transferring results to government agencies and user groups, and providing information about marine resources, recreation and education to the public.

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