

40 YEARS OF PROGRESS IN THE URBAN OCEAN

USC Sea Grant
Celebrating 1972 - 2015




Sea Grant
University of Southern California



About USC Sea Grant

USC Sea Grant contributes to solving the problems of the Urban Ocean, while recognizing the opportunities for coastal commerce, recreation and improving the quality of life in coastal regions such as Southern California.

The University of Southern California's location in the middle of Los Angeles has made the Sea Grant program an important regional resource since 1972. The program concentrates on issues arising out of the necessity of managing people and resources in an intensely developed coastline.

USC Sea Grant funds marine and coastal research, communicates research results to leaders in government and local communities, and is a leader in integrating current research with new education initiatives throughout the region. The program serves the largest (nearly 17 million in five counties) and most diverse population of any Sea Grant program, with residents speaking more than 140 languages.

Support

This publication has been produced with support from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, under grant number NA14OAR4170089.

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Published by

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University of Southern California Sea Grant: Highlights of Achievements in the Urban Ocean

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INTRODUCTION

The Sea Grant Program at USC is one of the oldest in the country, established in 1972 out of the necessity of managing aquatic natural resources in one of the most intensely populated and developed coastlines in the country. The Southern California culture of the “endless summer” places a unique value on its beaches and coastal ocean. Los Angeles (LA) County is home to the largest and busiest commercial port-complex and recreational harbor in the U.S. It is no wonder the region became the ideal laboratory to study the effects of urbanization on our coastlines, and why, in the 1980s, USC Sea Grant first coined the term “Urban Ocean,” a theme that continues to characterize our program’s focus.

Tracking USC Sea Grant’s work through the decades, you realize how closely our program’s research, outreach and education are tied to the needs of this urban ocean environment and its residents. We are dedicated to our role as a neutral broker of science that serves the people, ecosystems and wildlife of such a diverse region; and to our role building capacity and connections across people, resources and knowledge to solve our most pressing problems. We place a high value on our extension, outreach and education efforts, ensuring that research funded by USC Sea Grant makes its way into the public realm

so that managers and policy makers have the benefit of sound science when making decisions, and educators, students and public have access to cutting-edge science.

In this 40th+ anniversary retrospective, we tell a few stories to show how USC Sea Grant’s long-term work supports achievements in several key areas of importance to Southern California. It is extremely rewarding to be able to say that some things are better than they were 20 or 40 years ago. It is not possible to say that about everything, but we *can* see improvements here along our coastline, and we are proud to have been part of the collaborations of research scientists, educators, government leaders and community stakeholders that worked on these issues.

As always, the work is not done, and the stories told here are not finished. As the realities of climate change become more challenging, we must view all of our work through a new lens. Climate change will continue to affect everything from the thickness of mussel shells, to the distribution and abundance of marine populations, to the management of critical municipal resources like water, beaches, ports, and other coastline infrastructure. It is our hope that these stories of success in the Southern California urban ocean laboratory can help facilitate the protection and

sustainable management of coastal and marine resources in other urban ocean settings.

Many of our staff members, advisory council members and partners have been part of the Sea Grant family for more than a decade, some for multiple decades, and we recognize their dedication and expertise with utmost gratitude. Without these dedicated individuals, the important work described here would not have been possible.



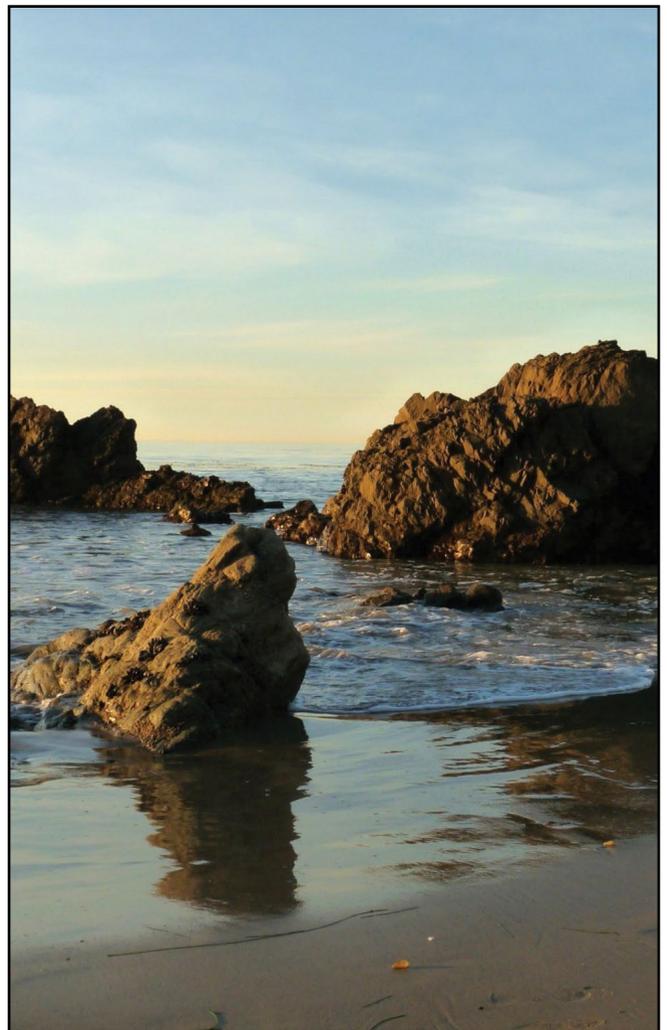
LINDA E. DUGUAY, Director



PHYLLIS M. GRIFMAN, Associate Director



JAMES A. FAWCETT, Director of Extension



Sunset at Lechuza Beach. Credit: Phyllis Grifman

15 YEARS
2001 - 2015

RESEARCH
INVESTMENTS

WILDLIFE &
ECOSYSTEMS



1.5 M

20 PROJECTS

rocky intertidal
marine protected areas
stingrays
rockfish
wetlands
beaches

WATER
QUALITY



1.5 M

21 PROJECTS

low impact development
aquatic invasive species
wastewater
stormwater
viruses
toxicology

CLIMATE
CHANGE

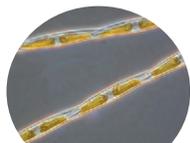


765 K

13 PROJECTS

sea level rise
vulnerabilities
adaptation
storm surge
resilience

HARMFULL
ALGAL
BLOOMS



600 K

5 PROJECTS

hypoxia
shellfish
toxins
food chains
fish kills

Total funding is rounded and shows only federal and state investments in research projects. They do not include the required 50% matching funds for each project. Additional research was funded in the categories of marine transportation, aquaculture and education for a total of 67 projects from 2001 - 2015.

WATER QUALITY

It is difficult to tell the story of LA without talking about water, and it is impossible to tell the story of USC Sea Grant without talking about water quality. Ensuring that coastal waters are safe for people and marine life has always been a priority for the state and particularly for Southern California. Over the decades, the focus for coastal water quality concerns has shifted from sewage to stormwater, since major wastewater treatment plants have improved their treatment and discharge drastically. While water

quality today in the Southern California Bight is the healthiest it has been in decades, there continues to be tremendous influence from concrete rivers and channels that rapidly deliver massive amounts of urban contaminants via stormwater to recreational beaches and marine habitats during the relatively short rainy season. Water quality research, outreach, and education have always been, and will continue to be, a cornerstone of USC Sea Grant's program.

Highlights

1980s 1990s	Sea Grant-funded research traces resuspended inorganic contaminants (DDT/PCBs) from the U.S. EPA designated Montrose Superfund Site off the coast of Palos Verdes
1999	<i>Study of Impact of Stormwater Discharge on Santa Monica Bay</i> , published by USC Sea Grant, is one of the first studies anywhere to assess stormwater effects on the marine ecosystem
2000	Independent technical review led by Sea Grant and SCCWRP of extended beach closures rule out Orange County Sanitation as the source of bacterial contamination
2005	Rapid, sensitive methods for enteroviruses developed by Jed Fuhrman's Sea Grant-funded research improve ocean water quality testing
2007	A novel, multi-institutional, multidisciplinary collaboration by Sea Grant and USC School of Engineering changes the field of ocean monitoring forever with the use of autonomous underwater 'gliders'
2006 - 2011	Sea Grant-led California Water and Land Use Partnership provides guidance and training on 'low impact development' (LID) methodologies that improve water quality
2011	Sea Grant works with the City of L.A. to develop its first LID Ordinance

THE BIG FLUSH: WASTEWATER DISCHARGE ISSUES AND IMPROVEMENTS

The Southern California region has one of the largest wastewater effluent systems in the country, contributing more than one billion gallons of treated wastewater to the ocean daily. In the early years of USC Sea Grant, until 1987, the main concern of researchers was the 25 million gallons a month of raw sewage sludge being dumped into Santa Monica Bay. It was not until 1998 that the City of LA reached full secondary treatment of its wastewater. To the City's credit, the main Hyperion Wastewater Treatment Plant has been a national leader in technological and environmental improvements when it comes to the treatment of 350 millions of gallons a day of sewage. USC Sea Grant funded research in the late 1980s and early 1990s by Drs. Burt Jones, Libe Washburn and Tom Dickey at USC, examining the extent of sewage plumes in the Bay and tracing inorganic contaminants in wastewater discharged into the ocean from the LA County Joint Water Pollution Control Plant off White's Point on the Palos Verdes peninsula.

In 1989, the U.S. EPA declared the Palos Verdes Shelf one of the largest superfund sites in U.S. history. The Montrose Chemical Corporation and a few other smaller corporations had discharged over 100 tons of DDT and PCBs for over 40 years directly through the County wastewater system, contaminating the sediment and popularly consumed fish like the white croaker. In 1990, the United States and the State of California filed a lawsuit against Montrose and a few smaller companies, and after years of court battles, Montrose and the other corporations settled their lawsuits for \$70 million.



Combined with prior lawsuit settlements, this provided \$136 million in total for the restoration and remediation of the Palos Verdes Shelf and affected natural resources. During court proceedings, some USC Sea Grant funded-researchers were called upon to give testimony based on their research regarding the resuspension of DDT and PCBs into the water column from the contaminated sediment, and the ability of these contaminants to enter the marine food chain. Subsequent USC Sea Grant research, outreach, and education on fish contamination are discussed in detail in the toxicology section of this document.

NO DUMPING: DRAINS TO BAY

By the end of 1990s, sewage was no longer the greatest water quality “enemy” of concern. At least in the scientific community, attention had turned to stormwater. USC Sea Grant, in partnership with the LA County Department of Public Works and Southern California Coastal Water Research Project (SCCWRP), funded and published the 1999 *Study of the Impact of Stormwater Discharge on Santa Monica Bay*. The research, conducted by Burt Jones (USC) and Steve Bay and Ken Schiff (SCCWRP), was one



Storm drain, Venice Beach. Credit: Charlotte Stevenson

of the first studies anywhere to assess the effects of stormwater on marine ecosystems, including benthic, water column and toxicological effects. USC Sea Grant disseminated findings of the study among managers, decision makers, interest groups and the public, and led discussions of future research and management needs.

In the winter of 2000, USC Sea Grant again found itself at the intersection of science, policy and management, when the Orange County Sanitation District (OCSD) and SCCWRP requested that USC Sea Grant convene an independent review of scientific studies and management actions taken during the previous summers' massive bacterial contamination event in Huntington Beach. For a two-month period, large sections of Huntington Beach were closed due to high levels of bacteria in the water. At the time, this closure generated one of the biggest losses of tourism income recorded in the U.S. that could be directly attributed to bacterial contamination. The costs of identifying and mitigating sources of contamination magnified the economic loss. The event caused tremendous public uproar and finger-pointing regarding potential sources of the bacteria – many assumed it was the OCSD sewage treatment facility.

USC Sea Grant's Associate Director, Phyllis Grifman, and Extension Specialist, Judy Lemus, with SCCWRP Director Steve Weisberg, convened an expert panel to conduct a review during a three-day workshop in February 2000. The issues addressed in the review and subsequently published (*Huntington Beach Closure Technical Review*, October 2000) included an evaluation of the investigative studies, the data interpretation, the need for future studies, and lessons learned to help future management. Ultimately, based on substantial evidence, the panel concluded that the OCSD facility was not the source of contamination. The most likely source was directly adjacent to a nearby stormwater channel; in fact, it was a break in the waste lines from the beach bathrooms. This is where USC Sea Grant feels most at home: as a neutral broker at the often contentious and complicated intersection of science, policy, and management.

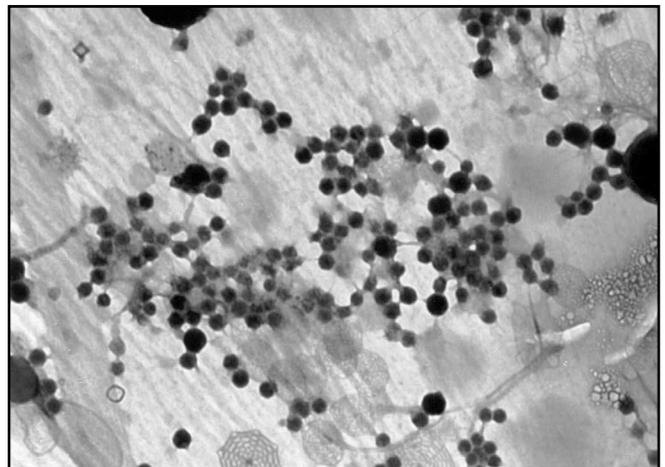
VIRUSES IN THE COASTAL OCEAN

Until recently, little was known about the existence and lifespan of viruses in the ocean, particularly those that threaten the health of people. “Classic” viral detection tests rely on large sample volumes (approximately 20 gallons), and concentration and cultivation of viruses, which take up to weeks for results - much too long to be useful for management applications such as issuing health warnings or posting beach closures. With USC Sea Grant funding, Dr. Jed Fuhrman’s USC lab - in partnership with local water quality agencies - developed and published methods for new, rapid and sensitive tests of enteroviruses (one category of pathogenic viruses) from reasonably small volumes of water.

Furthermore, Fuhrman’s research showed that the presence of viruses does not correlate with fecal indicator bacteria for which the state regularly tests during peak tourism months (Apr-Oct) and for which beach closures are required by law under State Bill AB411, passed in 1997. In other words, bacteria cannot be used as a proxy for viruses in the ocean, complicating the issues of monitoring, management, and public health. Research programs in LA and Orange Counties, coordinated through SCCWRP, are utilizing Fuhrman’s new tests to assess water quality along the coastline. The application of new methods may help revolutionize recreational water quality testing and significantly improve protection of human health by making virus-specific monitoring results more timely and useful for management.

URBAN LOW IMPACT DEVELOPMENT

The City and County of LA are covered in impervious pavement - even in riverbeds - that exacerbates pollution from run-off by funneling it to the ocean with speed and lack of any natural filtration. USC Sea Grant has put tremendous effort into working with municipal managers to address the problem of urban runoff upstream and inland before it becomes an issue for the coastal ocean. Starting in 2006, USC Sea Grant developed and co-chaired the California Water and Land Use Partnership (CA WaLUP), a partnership among state and federal agencies and non-profit organizations with a strong interest in improving water quality in the state. At the local level, CA WaLUP provided trainings and guidance in implementing Low Impact Development (LID) methodologies. Through LID, water is allowed to penetrate into soil or other natural filtering mechanisms (i.e. permeable pavement, rainwater storage tanks, infiltration swales, curb bumpouts) before it reaches coastal waters. USC Sea Grant coastal resources specialist, Susan Zaleski, worked with the City of LA Commissioner of Public Works and the Bureau of Sanitation to develop an LID Ordinance for LA that became law in 2011.



Ocean virusus under magnification. Credit: Jed Fuhrman

LOOKING AHEAD

In an effort to continue our upstream water quality work, USC Sea Grant is funding new projects related to low impact development (LID) or aimed at conserving fresh water using other methods. One underutilized set of tools to remove contaminants from runoff are biofilters, constructed to use natural processes (e.g. plant uptake) and living materials (e.g. microorganisms in the soil) to treat urban runoff before it reaches the ocean. USC Sea Grant is funding

new research at Scripps Institution of Oceanography that will study both the ecology of biofilters and how to optimize the design and locations to maximize their benefits. The results will help managers better plan and use these natural tools to provide multiple benefits including flood and erosion control, biodiversity conservation, and water detoxification.

A TECHNOLOGY STORY

Tracking stormwater in the coastal ocean is really about improving technology to help us “see” stormwater plumes. A combination of physical (temperature, salinity) and bio-optical signals differentiate a stormwater plume from natural coastal waters, allowing the plume to be followed over the course of days to weeks before it dissipates. In the 1980s, USC Sea Grant-funded researchers worked aboard the research vessel *Seawatch*, manually taking water samples from rough transects in often-turbulent coastal waters. Later, they improved sampling by dragging sensors through the water behind the ship or by attaching them to deployed moorings or buoys.

USC Sea Grant strongly encourages large-scale collaborations to better deal with the extremely complex stormwater issues along the coast. One of the best examples of this collaborative work is the USC Center for Integrated Networked Aquatic PlatformS (CINAPS), co-founded by USC Sea Grant-funded researchers Dr. Burton Jones and Dr. David Caron. This multi-institutional, multidisciplinary collaboration - oceanographers, ecologists, computer scientists, engineers and 14 agencies and groups across the west coast - has changed the field of water quality monitoring. They developed methods using autonomous underwater vehicles, or ‘gliders,’ that gather real-time data, sending it straight to the researchers’ computers via satellite communication.

From the perspective of coastal managers, this is the holy grail of cutting-edge science informing real-time management. This data is invaluable for understanding and predicting the movement of bacteria-laden urban runoff and the development and movement of harmful algal blooms.

Deployed glider. Credit: CINAPS



HARMFUL ALGAL BLOOMS

Although we rely on microscopic algae for the oxygen we breathe and the food we consume from the marine food chain, some algae can be problematic. Certain species produce toxins that can accumulate up the food chain, causing severe illness and death in marine mammals, birds, and even humans. Other species can reproduce rapidly, clogging the gills of filter-feeding organisms like mussels and oysters, or using up all the oxygen in a body of water causing hypoxic or anoxic conditions that can cause massive fish kills. In Southern California, the algae species of greatest concern have been *Pseudo-nitzschia spp.* and *Alexandrium catenella*, which can release toxic compounds (domoic acid and saxitoxin, respectively). Another species, *Lingulodinium polyedrum*, causes the

red water often seen near the beach and hypoxia in regions with low circulation (i.e. marinas, lagoons).

Scientists still do not know what conditions trigger a toxic algal species to bloom and produce toxin, but USC Sea Grant has invested in several projects over the last two decades investigating the biology and ecology of these species and the complex oceanographic processes surrounding harmful algal bloom (HAB) events. As HABs have become more frequent over the decades in urban environments like Southern California (often due to excessive nutrient run-off from land), it is clear that being able to predict these HAB events is critical for sustainably managing human use and enjoyment of the coast.

Highlights

- | | |
|------|--|
| 1985 | Improved, rapid assays for determining the presence of paralytic shellfish poisons in coastal waters allow Sea Grant to provide managers with new tools for protecting public health |
| 2005 | Ongoing monitoring for toxic algae in Redondo Beach Harbor commences with development of new, in situ tools developed with Sea Grant funding |
| 2011 | Sea Grant's rapid response capability determines the cause of massive fish kills in Redondo Beach and Ventura Harbors |
| 2011 | Community-based <i>HABWatch</i> program initiated by Sea Grant with regional partners provides protocols for citizen scientists to collect monitoring data |
| 2015 | Sea Grant funds new <i>HABWatch</i> database for use by citizen scientists and research monitoring |

DOUBLE THREAT: LONG-TERM RESEARCH AND RAPID RESPONSE

As early as the 1970s, concerns about algal borne toxins emerged because of possible toxic effects from eating shellfish. Filter-feeding organisms such as clams, oysters, scallops, and mussels can accumulate the neurotoxin produced by algae during a bloom, and humans who consume these shellfish may suffer from paralytic shellfish poisoning (PSP). PSP symptoms can appear 10-30 minutes after ingestion, and include: nausea; vomiting; diarrhea; abdominal pain; tingling lips or other extremities; shortness of breath; loss of coordination; slurred speech; and death in extreme cases. As was the case in the early 1980s, Angelinos were warned of the presence of PSP by mass strandings and illness in marine mammals, which were consuming small fish feeding on the toxic algae. Early in our awareness of the problem, USC Sea Grant funded work by Dr. Bernard Abbott that established a new, improved, rapid, and sensitive assay for determining the presence of paralytic shellfish poisons.



Millions of dead fish in Redondo Beach Harbor, 2011.
Credit: David Caron

Understandably, the public attention on HABs rises steeply when larger animals become sick or die. On March 8, 2011, the City of Redondo Beach woke up to find its harbor brimming with a million dead sardines. City officials immediately wanted to know whether the kill had been caused by algal bloom-induced hypoxia or domoic acid poisoning, as they needed to inform the public whether there was a potential human health risk. Fortunately, USC Sea Grant-funded Professors Dr. David Caron and Dr. Astrid Schnetzer had been closely monitoring and studying this harbor since 2005, the last time a large fish kill occurred in this location. Due to the lab's permanently installed sensors in the harbor, the researchers, with expedited funding from USC Sea Grant, were able to determine what had happened in the harbor within hours of the massive fish die-off. Surprisingly, the monitoring data revealed that a large volume of cold, low-oxygen water came into the coastal area and harbor (which already has slow circulation and low oxygen) cornering the huge school of fish, which died from anoxia. The mystery continued when Drs. Caron and Schnetzer found through tissue analysis that the sardines *did* indeed have detectable levels of domoic acid, although likely not enough to kill them. They quickly informed the City of the possible danger of domoic acid toxin in the dead fish so that people - who had heard the kill was from anoxia - could be discouraged from consuming the fish.

A partnership among Redondo Beach, USC Sea Grant, and the USC Caron lab now allows for continuous monitoring of the harbor, but this research has the potential to inform a much broader audience of coastal managers on the nature of toxin forming species and the initiation, progression, and demise of harmful algal blooms. In fact, weeks after the Redondo Beach fish kill, there was another fish kill in a Ventura County Harbor. Fish samples were rushed to USC



HABs affect all users of coastal waters, sometimes carrying potential health threats. Credit: Holly Rindge



USC Sea Grant funded scientist Dr. Kevin Kelley works with students to demonstrate techniques. Credit: JK Passarelli

for analysis to determine if domoic acid toxicity was a concern in that harbor. USC Sea Grant will continue to foster these partnerships linking research, management and rapid response.

ALL EYES ON THE WATER

USC Sea Grant knows that research is only one piece of the complex HAB-management puzzle. Local informal science centers such as aquaria and museums are often bombarded by questions from the public during visible HAB events, and it is challenging for these institutions to address the complex issues and questions that arise. In 2011, USC Sea Grant, the Center for Ocean Science Education Excellence West (COSEE West), and the Southern California Coastal Ocean Observing System brought together 11 Southern California informal science centers to create the community *HABWatch* program. USC Professor David Caron and his Sea Grant trainees develop resource materials and local field identification guides, present at workshops, and provide guidance to the partners who then engage with the public.

LOOKING AHEAD

USC Sea Grant is developing a new online *HABWatch* database to make the data accessible to scientists, managers, and even the public. As we move forward with new ways to engage public interest in science and stewardship, USC Sea Grant aims to become a new hub for shared data and information on a variety of marine and coastal issues. One such effort on beach ecology is developing citizen research protocols. In the near future, citizen science and stewardship programs will use established and approved scientific protocols to gather data and enter into databases, making that information easily available to scientists, students, and coastal managers.

TOXICOLOGY

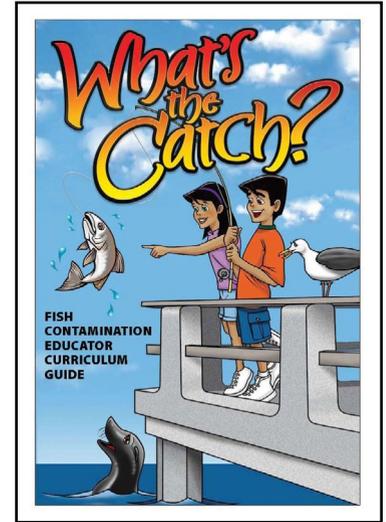
As one of the world's largest urban coastal centers, LA has always been part of the discussion about the effects and concerns over anthropogenic chemicals and pollutants in coastal waters. Coastal wastewater treatment plants in Southern California discharge close to one billion gallons of treated wastewater into the ocean every day. Although this water meets some of the highest cleaning treatment standards in the country for discharged wastewater, it still carries difficult-to-remove contaminants (e.g., estrogen in birth control, valium, and many others). Moreover, stormwater runoff, most of which does not get captured and treated, carries with it to the ocean additional contaminants, including pesticides

(e.g., bifenthrin, permethrin) and various industrial and manufacturing-related compounds (e.g., flame retardants, nonylphenol, phthalates).

Among thousands of anthropogenic compounds detectable in urban aquatic environments, less than 200 are routinely monitored and regulated by governmental agencies. Globally, wildlife and humans are exposed to increasing quantities and types of persistent industrial, domestic, and pharmaceutical chemicals, and the effects of most of these chemicals in marine organisms or humans are unknown.

Highlights

2003	Partnership between Sea Grant, EPA and Montrose Settlement develops Fish Contamination Education Collaborative for public education about safe seafood consumption
2009	Sea Grant and partners develop a curriculum guide on seafood contamination and safe seafood consumption guidelines called <i>What's the Catch?</i>
2009	Sea Grant coordinates a project to develop a chemical database for managers to assess the threat posed by copper in California marinas
2012	The LA Times features Sea Grant-funded research showing a 100-400 fold decline in several heavy metals in coastal waters since the passage of the Clean Water Act
2012	The development of a new, fast, and powerful proteomics methodology funded by Sea Grant fosters investigation of endocrine disruption from contaminants of emerging concern in urban ocean fish
2014	The Sea Grant-supported <i>Kelp Watch</i> program begins an international, collaborative research project to track radioactive iodine moving in ocean currents across the Pacific from the Fukushima Nuclear Plant



Heavy metals pose a serious threat to water quality in harbors. Credit: Phyllis Grifman

THEY PUT WHAT IN MY FISH?

Based on substantial evidence, some of which was provided by USC Sea Grant-funded research, California and the U.S. EPA filed a legal claim in 1990 and prevailed in litigation in the 2001 suit against Montrose Chemical Corporation and other companies after decades of illegally discharging DDT and PCBs into wastewater released off the LA coast. The natural resource trustees formed the Montrose Settlements Restoration Program to plan and conduct restoration of injured resources and lost services. USC Sea Grant is a partner of the Fish Contamination Education Collaborative (FCEC) developed by the EPA as part of the settlement.

Since 2003, the FCEC has worked to protect the most vulnerable populations in Southern California from the health risks of consuming DDT and PCB contaminated fish. USC Sea Grant supports the development of education curriculum, professional development for staff, and distribution of multi-lingual angler education materials. In 2008-2009, in collaboration with Cabrillo Marine Aquarium and the Montrose Settlement Restoration Program, we developed *What's the Catch?* It serves as a curriculum guide in educator workshops, in public education

campaigns on seafood contamination, and in safe seafood consumption guidelines aligned with the U.S. EPA and California's Office of Environmental Health Hazard Assessment.

HEAVY METALS TAKING HEAVY HITS

In 2006, the California Department of Pesticide Regulation determined that copper posed a serious threat to water quality in the state with almost 90% of marinas exceeding the EPA's chronic toxicity standards and 60% exceeding acute toxicity standards. This is a costly and politically challenging problem, since the main source of copper in these areas is from boat antifouling paints. Based on these findings, in 2007 the Department of Pesticide Regulation announced plans to pursue reevaluation of copper regulation. In 2009, USC Sea Grant, with California OPC funding, began a project with USC Professor Dr. James Moffett using a copper sensitive blue mussel. This study is revealing how copper behaves differently in marinas spanning the wide range of salinities found in California. A West Coast Sea Grant partnership between the USC Viterbi School of Engineering and the University of Washington expands the scope



Far left: *What's the Catch?* guide was developed to help the public make safe seafood choices. Left: Seagull. Credit: Charlotte Stevenson

of study and will provide a chemical database that moorage managers can use to assess not only the threat posed by copper in these marinas, but also the economic costs of these threats.

In 2012, the LA Times covered exciting USC Sea Grant-funded research by Dr. Sergio Sanudo-Wilhelmy of USC who found that there has been a 100-to-400-fold decline in several heavy metals in coastal water since the passage of the Clean Water Act in 1972. Dr. Sanudo-Wilhelmy's published work compares current day concentrations with results from a previous study done in the 1970s.

CONTAMINANTS OF EMERGING CONCERN

USC Sea Grant has invested resources to find more efficient and cost-effective ways to determine which contaminants of emerging concern (CECs) are present in coastal water and what negative effects they are having. Endocrine and physiological disruption, such as changes to reproductive and metabolic characteristics and changes in growth, have a strong potential to threaten survival in a variety of species residing in coastal California, including flatfish, surfperch, and

sculpin. Despite the large amount of work done on endocrine disruption in freshwater environments, very little has been done on wildlife in California's marine and estuarine environments, until recently.

USC Sea Grant researcher Dr. Kevin Kelley from CSU Long Beach, pioneered the use of a cutting-edge technology called proteomics to investigate the impacts of contaminants in urban ocean fish. Traditionally, biomarkers have been used to test for endocrine disruption in organisms suspected of endocrine disrupting chemical (EDC) exposure. This type of approach requires an initial prediction of culprit-chemicals and then trial-and-error testing if the initial prediction is wrong. This approach is time-consuming, costly, and does not provide a comprehensive picture of physiological change in an organism living in polluted water.

Alternatively, a proteomics map shows all proteins expressed in a given tissue, and each protein has its own specific position in the map. All changes in protein expression related to EDC exposure can be seen at one time in a map - especially when compared to the map of a reference fish from a non-contaminated site - and this map can be correlated to tissue analysis revealing the contaminants present in the fish (and therefore the water). As thousands of protein biomarkers are identified and added into a developing proteomics map screening method, it becomes an increasingly powerful and valuable tool. Uniquely, proteomics screening has the potential to assess the effects of otherwise undetectable trace contaminants, the synergistic effects of combinations of contaminants, and the effects of still unknown contaminants.

RAPID RESPONSE

Just 10 days after the March 2011 Japanese earthquake and subsequent tsunami, the atmospheric plume from the damaged Fukushima Nuclear Plant deposited radioactive iodine into coastal waters on the West Coast. Responding to public concern by using its “rapid response” capacity to fund quickly emerging issues, USC Sea Grant funded a study by Dr. Steven Manley of CSU Long Beach, to assess the utility of using fast growing kelp as living dosimeters for radioactivity.

USC Sea Grant then helped Dr. Manley to fund *Kelp Watch* to track another wave of radioactive iodine arriving along the West Coast via ocean currents. Volunteer scientists collected samples at coordinated time-points throughout 2014 and 2015 and shipped them to Dr. Kai Vetter at UC Berkeley for assessment. In a few months, this project grew into an international collaboration of 40 scientists, institutions, federal agencies, and small educational foundations. Luckily, while the study has shown the presence of radioactive iodine in some West Coast waters, the concentrations proved to be low enough to alleviate concerns about human health effects.

LOOKING AHEAD

There is a critical need for a scientifically-based understanding of the *impacts* of CECs on wildlife in the urban ocean, and USC Sea Grant plans to continue to fund research which addresses this need. Further development of bioanalytical technologies such as endocrine and proteomic screening methods could allow agencies and managers to develop water quality objectives in a more ecosystem-based manner, by linking endocrine disruption and other important effects directly to the anthropogenic contaminants causing the disruption.

Moreover, as USC Sea Grant sees the potential in this technology to visualize the effects of stress caused by environmental conditions like temperature and ocean acidification, we may help fishery managers generate strong predictions of population and ecosystem effects associated with impending climate change.

Giant kelp, *Macrosystis*, can be used as a living dosimeter for radioactive iodine. Credit: Charlotte Stevenson



AQUATIC INVASIVE SPECIES

The increasing presence of aquatic invasive species (AIS) poses a worldwide threat to coastal ecosystems. The story of AIS in LA is quintessential for USC Sea Grant, demonstrating how regional partnerships and close coordination of research, outreach, and education are all required to solve this pressing problem in the urban ocean.

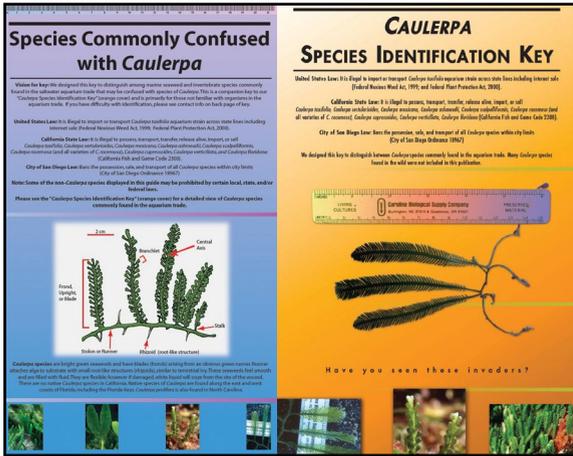
WAR OF THE WEEDS: THE STORY OF CAULERPA TAXIFOLA

Over several decades, USC Sea Grant has funded research to provide a better understanding of the conditions that foster invasions of foreign species. As a California Sea Grant Trainee in the lab of Dr.

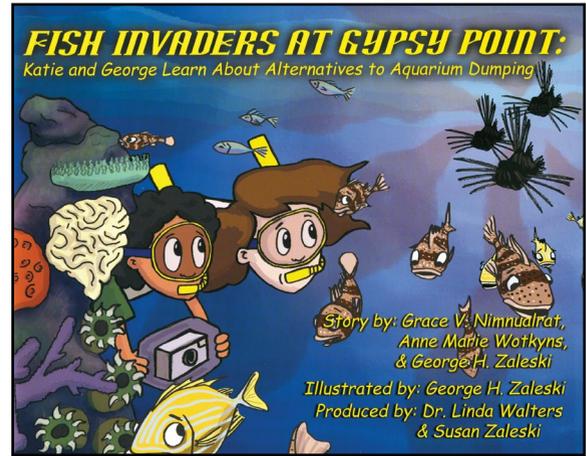
Steven Murray at CSU, Fullerton, Susan Zaleski discovered the alarming rate at which several species of invasive algae - including *Caulerpa taxifolia* - were being imported and illegally released into Southern California coastal waters by the aquarium trade, hobbyists, and school classrooms. Upon hiring Ms. Zaleski, and with funding from the U.S. Fish and Wildlife Service, USC Sea Grant was well poised to conduct a public information campaign to educate the public on the perils of releasing *Caulerpa* into the coastal ocean. USC Sea Grant helped provide evidence that resulted in the passage of state legislation in 2001 that bans the importation, possession, and sale of nine species of *Caulerpa*.

Highlights

- | | |
|------|--|
| 2001 | Invasive algae research by CA and USC Sea Grant helps support the passage of state legislation that bans the importation, possession, and sale of nine species of <i>Caulerpa</i> |
| 2001 | Sea Grant carries out a major public service campaign funded by US FWS educating thousands of aquarium retailers and hobbyists nationwide about AIS. A training program for U.S. Customs and CA DFW agents aims to reduce imports. |
| 2008 | Sea Grant produces two children's books and two DVDs on AIS to generate coordinated AIS curricula for pre-K through 6th grade students |
| 2010 | West Coast Sea Grant programs receive national funding for the ongoing project, <i>Aquatic Invasive Species Pathways</i> , to collaboratively combat AIS |
| 2015 | USC Sea Grant develops informal education kits, <i>Aquatic Invasions! Menace to the West</i> , for distribution to regional aquaria |



Caulerpa invasive species identification guide.



Book for pre-K through 6th grade students.

Since 2001, Sea Grant has successfully disseminated species keys to thousands of aquarium retailers and hobbyists nationwide. USC Sea Grant developed training for U.S. Customs and California Department of Fish and Wildlife officials in order to reduce the importation of *Caulerpa* and other AIS. Two children's books and two DVDs have generated coordinated curricula and lesson plans for pre-K through 6th grade students. The first DVD, *Invaders from Around the World*, won the Katherine Knight Award at the Earth Vision Environmental Film Festival in 2008. Now the University of Central Florida is using USC Sea Grant's methodologies to determine the availability of aquarium-traded *Caulerpa* species in Florida.

INVASIVE SPECIES KNOW NO BOUNDARIES: BUILDING REGIONAL PARTNERSHIPS

Since AIS do not respect arbitrary jurisdictional boundaries, it is critical to establish national and international partnerships to study, monitor, and investigate potential pathways of invasion, as well as to develop policies and tools to prevent the introduction and spread of AIS. In 2010, based on our close work with California Sea Grant and the success of California's reduction in the trade and spread of *Caulerpa*, USC Sea Grant and the West Coast Sea

Grant programs initiated a regional program *Aquatic Invasive Species Pathways* to collaboratively combat invasive species. This project is funded by NOAA and National Sea Grant and weaves together the expertise of USC, California, Oregon, and Washington Sea Grant programs to improve integrated research and outreach in several key areas: to predict vulnerability to AIS invasions; prevent and interdict pathways; and evaluate the economics and efficacy of best management control options. USC Sea Grant is specifically addressing the role informal science centers can take in reducing the spread of AIS through education of visitors, especially school groups.

LOOKING AHEAD

As part of the Sea Grant programs' collaboration on AIS, USC Sea Grant is releasing *Aquatic Invasions! Menace to the West* informal education kits for West Coast aquaria and science museums. The kit is designed to facilitate hands-on opportunities so that visitors to informal science centers can explore this global issue through a regional lens. The kit provides interpreters and naturalists with relevant and engaging resources, along with effective strategies for engaging the public in citizen science projects that are suitable for classroom use as well as informal education settings.

COMMUNICATIONS

Integrating communications into our work has always been a core strength of USC Sea Grant. Moreover, making what we do – our research, outreach and education – available and digestible to the public is a priority of our program. Richard Rogers, the famous architect and proponent of sustainably, said, “the only way forward, if we are going to improve the quality of the environment, is to get everybody involved.”

One such effort is a seasonal research mini-journal, *The Urban Mariner*. Since 2009, USC Sea Grant has published 14 issues featuring an array of projects funded by USC Sea Grant. Each issue provides summaries and interviews about the science, the management and policy applications, and the researchers and stakeholders involved. Every issue also links the science with new and ongoing educational efforts.

URBAN MARINER
USC Sea Grant's Urban Ocean Report, February 2014, Vol. 5, No. 1

I Know What You Did Last Summer...

USC Sea Grant's Summer Science Program for High School Students

A log bark hangs thickly across the water. One cannot see more than few yards beyond the bow of the boat, but the captain knows where they're going. A jolt comes through the gray top as a moment, crosses the bow with hardly a flap of his wings, and then disappears again. Twenty fish faces scan each other and wonder what lies ahead in the fog. And what they ahead sees a week of summer that they would never forget.

For one week each summer, USC Sea Grant hosts twenty high school students from around the country at the USC Philip H. Witkin Marine Sciences Center on Catalina Island, located 20 miles off the coast of Los Angeles. For many of these students, this is their first time near, on, and in the ocean. Through this week-long program, students are introduced to the fields of oceanography, marine biology, and island ecology and the short and long-term effects that humans can have on these delicately balanced ecosystems. Through engagement with USC's scientists, faculty and guest scientists, students learn about what it takes to pursue a degree and eventually a career in marine science as well as the vast array of applications for such a line of study, including environmental policy, research science, education, illustration, science writing and diving safety.

After leaving Catalina, these high school students know much more than the average high school student about marine ecosystems and ocean science. One 2013 program graduate, Oly Goldberg, recently told USC Sea Grant, "My AP biology class just did a two day unit on marine ecosystems and the ocean, and my teacher was very impressed with my knowledge about the various topics discussed. She even let me present some of the things I learned in Catalina to my class." (cont'd on page 3)

NOAA
Sea Grant
United States Department of Commerce

URBAN MARINER
USC Sea Grant's Urban Ocean Report, Fall 2014, Vol. 5, No. 2

The Sea Grant X-Files: Halibut Sexing and the No-Eyed, Many-Spined, Grazing, Purple, Kelp-Eaters

Collaborative, Applied Fisheries Research with the Santa Monica Bay Restoration Commission

Sometimes things happening in the ocean can sound a bit like the *Savvy 90's* sci-fi TV series, *The X-Files*. Eyes can move around on bodies as some fish get odd. Some sea creatures change gender depending on their surroundings. Giant armies of purple sea urchins mysteriously congregate and march across the sea floor moving down onto kelp forests. Unlike the *X-Files*, though, these strange, natural occurrences are not related to the jurisdiction of a top-secret FBI team; these types of occurrences are talked about by fisheries, studied by scientists, and are of interest to managers trying to find a sustainable balance for using the ocean's resources.

USC Sea Grant has recently funded two very successful research projects that have illuminated two mysterious coastal California issues. Both projects were spearheaded by The Blue Foundation, a non-profit environmental group focused on the restoration and enhancement of Santa Monica Bay and local coastal waters.

Although fishery science has come a long way in the last few decades, it is still very difficult to accurately predict the size and health of a fishery stock. You cannot simply send someone down underwater to count, sex, and estimate ages of a fish species. In fact, in the case of the purple sea urchin, California halibut (Pleuronectes californiensis), you cannot determine gender simply by sight; you have to dissect the fish to see if the fish has testes or ovaries. Using complex population models, the California Department of Fish and Wildlife can use gender discoloration data, length measurements, and catch frequency per unit time to make estimates on halibut population health and catch limits for the next season. (cont'd on page 3)

NOAA
Sea Grant
United States Department of Commerce

URBAN MARINER
USC Sea Grant's Urban Ocean Report, Spring 2015

The Call of the Running and Rising Tide

USC Sea Grant answers the call for climate change science, adaptation, planning and education in Southern California

I must go down to the sea again, for the call of the running tide
It is a wild call and a clear call that may not be denied.

—John Keats (1802), from the poem "Sea Fever"

Poet John Keats was not alluding to sea level rise in his turn-of-the-century poem, but his words ring eerily true today when we consider the clear and undeniable evidence for the running and rising tide. Just four years ago when we wrote our Spring 2011 climate change issue of the *Urban Mariner*, it felt like we were on the cusp of change—the climate change assessments were being developed by the State of California, new models were providing down-scaled climate information accessible to local municipalities, and the new concept of "adaptation," in parallel with "mitigation" (efforts to reduce GHG emissions), was being embraced by progressive communities.

Just four years later, we are deep in the middle of a changed world. In 2013, the Intergovernmental Panel on Climate Change (IPCC) released a 5th assessment report, *Climate Change 2013: The Physical Science Basis*, with a serious tone that comes with reporting undesirable facts rather than predicting an uncertain future.

Warnings of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.

(IPCC Report, Summary for Policymakers, p. 2)

In May 2014, the National Climate Assessment was published, and, following suit, documents these and numerous other cases of climate change happening now throughout the United States. In 2013, the State of California released (cont'd on page 2)

NOAA
Sea Grant
United States Department of Commerce

547

Number of stakeholder organizations
USC Sea Grant has worked with
in the past eight years

448

Number of USC Sea Grant
publications available in the
National Sea Grant Library

EDUCATION

Irish poet William Butler Yeats wrote, “Education is not the filling of a pail, but the lighting of a fire.” It is the spark of recognition, understanding, and pure excitement of a child who has made a new discovery about how the world works. Despite the importance of the ocean to the earth’s climate and as a vital source of food, ocean science education is not always available for young students. Resources are often scarce, especially for many inner-city schools. While the ocean is less than 20 miles from these communities, most families in downtown LA do not have a connection to the ocean. Education initiatives for underserved youth are of particular importance to USC Sea Grant.

REACHING TEACHERS

For every single teacher, we reach hundreds of their students, which is why USC Sea Grant has always focused on providing workshops, curricula, and educational opportunities for teachers throughout the LA area. In the 1980s, USC Sea Grant developed and disseminated marine science activity guides and *Wet and Wild*, a multi-unit marine science curriculum published in English and Spanish. Educational materials focused on hands-on science activities and correlated with state education standards. Sea Grant even produced *Tuga the Turtle*, a tidepool guide for young students, in English, Spanish, and Braille.

Highlights

1983	<i>Wet and Wild Multidisciplinary Marine Education Teacher Guides</i> published
1996 - 1997	Sea Grant’s <i>Island Explorers</i> program begins providing curricula and workshops for teachers, and field trips for students in the LA region
1998	USC’s <i>Summer Science Program</i> , a free science camp for students at the Wrigley Marine Science Center on Catalina Island, offers its first sessions led by Sea Grant educators
1999	Sea Grant’s <i>Parent Child Education Program</i> begins intergenerational programs connecting underserved students and family members with ocean and watershed science
2002	National Science Foundation provides funding to USC, UCLA, the College of Exploration and partners for the Center for Ocean Science Education Excellence West (COSEE-West) to develop marine science and literacy programs with formal and informal education partners
2003	USC Sea Grant helps to develop CA Assembly Bill 1548, mandating that environmental education be integrated into science and social science curricula
2006 - 2010	Sea Grant is a key participant in the national effort to develop principles, scope and sequence for ocean literacy

USC Sea Grant is a founding partner in Heal the Bay's *Key to the Sea* watershed education program, along with Cabrillo Aquarium, the Roundhouse Aquarium and SEA Lab. Since 1999, *Key to the Sea* has provided K-5th grade educators with the knowledge, skills and resources to incorporate watershed education into their curriculum. Teachers participate in daylong training sessions and subsequently bring students on field trips, where beach exploration provides tangible connections to real-world sites. The impacts are great; *Key to the Sea* reaches over 200 educators and 12,000 students each year.

Since 2002, USC Sea Grant and the USC Wrigley Institute, along with UCLA and the College of Exploration, have led The Center for Ocean Science Education Excellence West (COSEE West), funded by the National Science Foundation. Director Linda Duguay has served as PI of the project since its inception. COSEE West initially offered in-person lectures and workshops for formal and informal educators, which engage university researchers as lecturers and discussants, but subsequently moved to online workshops to reach a larger audience well beyond that in LA. Several 3-week online workshops on various topics were offered each semester reaching several hundred participants at many of the sessions. COSEE West also offered weeklong summer teacher institutes on ocean observing systems, retreats for scientists and educators, and professional development workshops for teachers and informal educators at many of the aquariums and science museums throughout Southern California.



Top: Teachers engage in ocean science onboard a local Tall Ship. Credit: Gwen Noda

Middle: Teachers conduct research at Catalina Island as part of the LA Charter School Science Partnership Credit: Linda Chilton

Bottom: Sea anemone along the intertidal zone. Credit: Phyllis Grifman

REACHING STUDENTS

USC Sea Grant also reaches students directly. Sea Grant's *Island Explorers* program exposes students to marine science through classroom use of curriculum uniquely focused on Southern California and Catalina Island coastal environments. The curriculum is multidisciplinary and multifaceted, introducing students to marine biology, geography, geology, physics, chemistry, and ecology. Lesson plans and hands-on projects prepare students for field trips to local beaches and aquaria. Many travel by vessel to the USC Wrigley Marine Science Center on Santa Catalina Island for single day and overnight programs. Through *Island Explorers*, USC Sea Grant has reached thousands of children in the LA region since 1996 when its first pilot program was funded by the USC Neighborhood Outreach Initiative.

In 1998, Sea Grant, working with the USC Wrigley Institute and the USC Provost's Office, developed a *Summer Science Programs for Young Women*. Held at USC's Wrigley Marine Science Center on Catalina Island, these weeklong, immersive programs exposed students to marine science, archaeology, terrestrial

biology, and science careers. A program for middle school boys began a few years later and these programs have served hundreds of students over the years, fostering multidisciplinary science learning.

Over the last four years USC Sea Grant joined with the Center for Dark Energy Biosphere Investigations and the USC Wrigley Institute to adapt the program for underrepresented students in ocean sciences by providing a free, weeklong *Summer Science Marine Lab Program*. These high school students have amazing opportunities to work with local researchers, conduct their own research projects, build their own ROVs, explore marine protected areas around the island, learn about a diversity of careers in science, and commit to taking their new knowledge and experience back to their communities. To date, the program has 57 alumni; importantly, USC Sea Grant remains connected with students who have continued their journeys in marine science to create high school projects, declare marine science majors in college, and even choose marine science careers.



Science teachers play a classroom game designed to teach concepts of sustainable fishing during a workshop at the Aquarium of the Pacific. Credit: Holly Rindge

TRAINING GRADUATE STUDENTS

USC Sea Grant has a strong commitment to training the next generation of ocean and coastal leadership through graduate and post-graduate programs. In our *Sea Grant Trainee* program, graduate students working with funded scientists participate in, and often lead, scientific research projects, culminating in Masters' and Doctoral theses. In addition, USC Sea Grant plays an active role in recruiting students for the John A. Knauss Policy Fellowship, a competitive program that places newly matriculated professionals in legislative and executive posts in Washington D.C. Former Knauss Fellows now work in nearly all NOAA offices concerned with ocean and coastal programs, in the National Sea Grant Office, in Sea Grant programs nationwide, and in our USC Sea Grant office.

REACHING THE PUBLIC

USC Sea Grant has created many programs to reach underserved urban populations in informal educational settings. Science centers and aquaria in LA County have long used Sea Grant outreach materials on marine science topics such as AIS, MPAs, climate change, and sea level rise. Educator Linda Chilton has provided educational opportunities directly to families through the *Parent Child Education Program (PCEP)*, developed in 1999 to foster intergenerational learning. Hundreds of families have participated in the *PCEP* between 1999 and the present, and the City of LA Department of Recreation and Parks EXPO Center has integrated the program into regular course offerings for families. A customized *PCEP* has been successful in helping families near the Port of LA to understand their unique connection to the Port. Alumni families report having a better understanding of the connections inland communities have with the ocean through their watersheds. Many have made lifestyle changes aimed at improving watershed health and students show an enhanced interest in science.



Top: Students show off projects at the Wrigley Institute for Environmental Studies on Catalina Island.

Bottom: Father and daughter dissect a squid during the *Parent Child Education Program*. Credits: Linda Chilton

OCEAN LITERACY

USC Sea Grant was a leader in the national effort to develop principles, scope and sequence for ocean literacy, an effort spearheaded by Lynn Whitley and Linda Chilton, USC Sea Grant and USC Wrigley Institute for Environmental Studies education leaders. The guidance has been published nationally as *Ocean Literacy: The Essential Principles of Ocean Science (K-12)* by NOAA, National Geographic, and others. USC Sea Grant and several education and science organizations in California helped with the development of the 2003 California Assembly Bill entitled *The Education Environment Initiative (AB 1548)*, mandating environmental education in all grades in science and social science curricula. Ocean literacy principles and concepts aligned with state and national standards are incorporated into all curricula we develop, in both English and Spanish.

Credit: Charlotte Stevenson



LOOKING AHEAD

As climate change infiltrates into every aspect of Southern California life, USC Sea Grant continues to influence curriculum for California teachers focused on climate change, its potential impacts on the coastline, and how students can become leaders in citizen-science-based projects. The inclusion of ocean sciences, climate, and environmental education into the statewide Next Generation Science Standards for K-12 education is a key focus of our education program.

To foster adult learning, USC Sea Grant, with the California Naturalist Program and the LA Conservation Corps Sea Lab, developed an LA Coastal California Naturalist Training program that

provides community members opportunities to learn about the natural history of the coastal region, develop effective interpretation skills, engage in restoration work, and to contribute to monitoring as citizen scientists.

To further education about aquaculture, USC Sea Grant educator Linda Chilton is working on a National Sea Grant-funded research study on seabass, conducted by Hubbs-Sea World Research Institute and California Sea Grant Extension. Curriculum developed based on this project brings topics of husbandry, policy, and environmental issues regarding aquaculture to the classroom.

PORTS, MARINE TRANSPORTATION AND COASTAL MANAGEMENT

LA County is home to the busiest port complex in the United States; close to 45% of all marine freight entering the country comes ashore through the twin ports of LA and Long Beach. Although the ports contribute more than 1 million jobs to a vibrant Southern California economy, the movement of goods to the region and throughout the nation results in environmental impacts affecting air quality, water quality and traffic congestion. With inevitable competition for coastal access from both public and private sectors, USC Sea Grant has played an important role over the years in educating stakeholders about how our coast is managed. USC Sea Grant promotes science, policy, and outreach addressing these challenges and assists policy makers

in finding an optimal balance between economic development and environmental protection.

PROGRAM GROWTH

The Paul Hall Memorial Endowment in Marine Transportation, established at USC in 1981, partially supports USC Sea Grant marine transportation programs and sponsors a lecture series to honor distinguished contributors to marine transportation. In 2002, funding from NOAA and the Bay-Delta Program allowed us to strengthen our leadership with an Extension Program focused on marine transportation, ports and harbors, and coastal management.

Highlights

1991	Sea Grant co-edits a special edition of the journal <i>Coastal Management</i> , “Port Growth and Coastal Management”
2003	Funding from NOAA and the Bay-Delta Program allows Sea Grant to strengthen its Extension Program for marine transportation, ports and harbors, and coastal management
2006	Sea Grant releases management study of the Port Community Advisory Committee for the Port of Los Angeles
2007	Sea Grant hosts a marine transportation symposium, <i>Port Continuity Planning: Maintaining the Region’s Economic Lifeblood</i> , releases <i>Proceedings of a Conference on Maritime Cargo Security</i>
2009	Sea Grant collaborates with Long Beach Aquarium on the design of NOAA’s <i>Science on a Sphere</i> exhibit; film is seen by more than 1 million people annually
2014	Sea Grant co-hosts the international <i>Symposium on Evolution of Maritime Fuels, Ship Speed and Operational Efficiency</i>



IT'S A SMALL WORLD AFTER ALL

For the last two decades, USC Sea Grant has invested in public education about the importance of our marine transportation system, including issues involving vessels not owned or operated by U.S. companies. In fact, the vast majority of the freight entering the United States through the Ports of LA and Long Beach is coming from Asian ports. Nearly every year, USC Sea Grant Director of Extension and Marine Transportation and Seaport Specialist, Dr. James Fawcett, provides lectures to professionals and academics in Asia on marine transportation, greening ports, and alternative fuels. Coordinating with China, Taiwan and Korea is critical to promoting a sustainable future for Southern California, since Asian ships have significant impacts on air and water quality, and security for West Coast ports.

CONTINUITY AND INNOVATION

After the September 11, 2001 terrorist attacks on the U.S., seaports around the world were concerned with the disruption of their services. The Ports of LA and Long Beach are vital to the whole country; thus, “business continuity” became a major focus of shippers, port managers, carriers, and cargo owners. Working with FuturePorts, a non-profit organization representing many users of the two ports, USC Sea Grant sponsored an important symposium on maintaining the flow of cargo after any kind of interruption, whether anthropogenic or natural. *Port Continuity Planning: Maintaining the Region’s Economic Lifeblood*, the proceedings of the symposium, was widely distributed to the industry and provided best practices for the region.



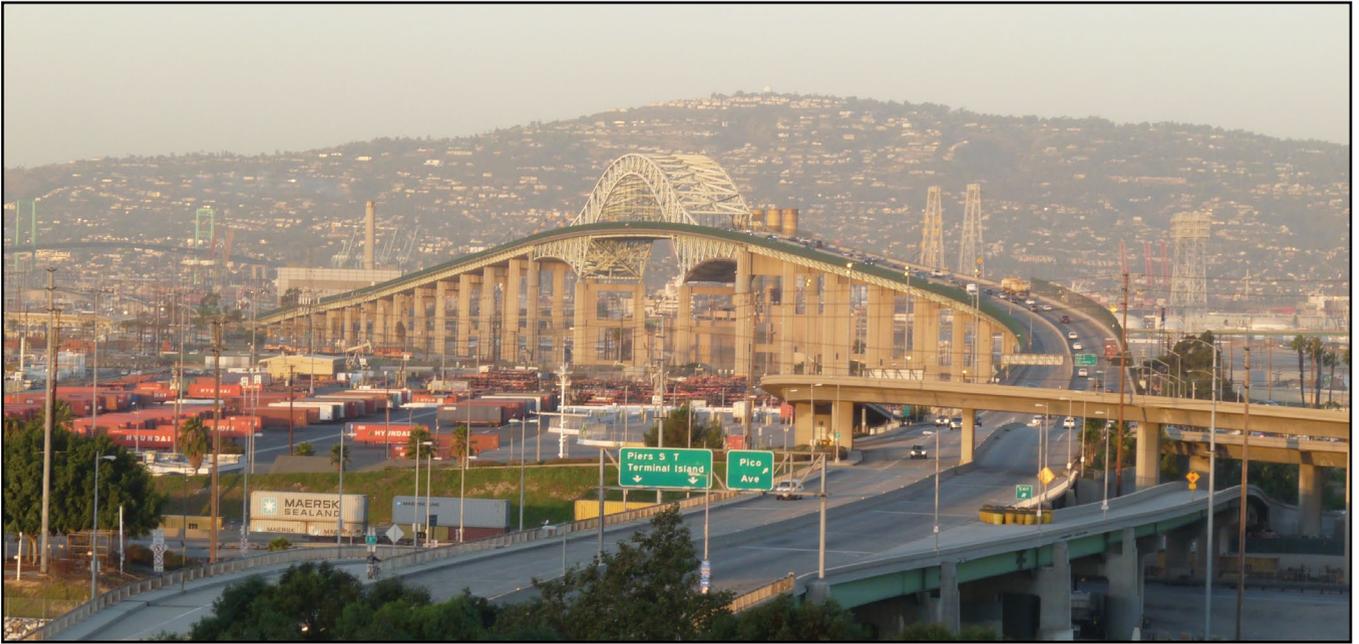
Close to 45% of all marine freight enters the United States through the twin ports of Los Angeles and Long Beach.
Credit: James Fawcett

BEYOND THE PORTS

The marine transportation system does not operate solely at sea; its landside impacts are felt as goods move through cities and rural areas of the nation by truck and train. Public understanding of the industry is critical for efforts to promote change that will be feasible for the industry and good for the environment and public health. To this end, in 2009 Dr. Fawcett worked with NOAA and the Long Beach Aquarium of the Pacific (AoP) to create a film on marine transportation and the movement of goods in our country. The film is shown daily to thousands of visitors at the AoP and is exhibited by other operators of NOAA's *Science on a Sphere* program, estimated to reach over one million visitors annually.

Moreover, seaports are only one aspect of the larger issue of how we manage coastal resources. As early as 1977, just as the California Coastal Commission was starting its work, USC Sea Grant provided assistance to the fledging agency by explaining to the public how the planning and permitting process would work, by exploring how coastal recreation would be protected, and by lending hours of organizational assistance to its Long Beach office. This work continues today in various forms, including teaching graduate level courses to students who will become the next wave of environmental practitioners.

USC Sea Grant co-hosted and co-sponsored the 2014 *Symposium on Evolution of Maritime Fuels, Ship Speed and Operational Efficiency*. This meeting brought together an international cadre of experts in engineering, financial, and policy expertise to exchange research ideas and recent findings about liquefied natural gas (LNG) and methane fuels. Beginning in 2015, the North American Emission Control Area (ECA) requires that all shipping within 200 miles of the Canadian and American coasts use ultra-clean burning fuel. The conference specifically examined the potential of both LNG and methanol to meet the challenges of the new ECA. Participants discussed issues of operational efficiency and environmental advancement as modern engine design and fuel chemistry intersect with the economics of the maritime transportation industry.



View of the Ports of Los Angeles and Long Beach showing the Gerald Desmond Bridge in the foreground and the Vincent Thomas Bridge in the background. Credit: Phyllis Grifman

LOOKING AHEAD

Eleven universities in Southern California have long shared the Southern California Marine Institute, a small marine laboratory in the Port of LA, but researchers have lacked facilities to conduct high priority marine research and inter-institutional collaborations. The Port and the Annenberg Foundation engaged Dr. Fawcett to conduct a “visioning study,” including outreach meetings with researchers, port communities, and the public, for a new laboratory to be shared by the universities. The “AltaSea” initiative continues with the active collaboration of USC Sea Grant, the Wrigley Institute for Environmental Studies, the California State University system, Occidental College, UCLA and other partners.

Acknowledging our expertise in marine shipping and coastal and marine spatial planning, the Channel Islands National Marine Sanctuary Advisory Council called upon USC Sea Grant for Working Groups

focused on ship strikes on whales and the effects of shipping on air quality. Beginning in 2008, when several ship strikes on endangered blue whales took place in Sanctuary waters, efforts have been made to engage the shipping industry on voluntary programs to reduce ship speeds when whales are present in shipping channels. The Education Working Group developed an informational campaign, to inform the industry about hazardous interactions. In 2015, a new Marine Shipping Working Group, co-chaired by Sea Grant’s Associate Director Phyllis Grifman and advised by Dr. Fawcett, is convening a series of workshops to share information on the interactions between whales and ships approaching or departing from the Ports of LA and Long Beach, and to work on mutually agreeable mechanisms for reducing these incidents.

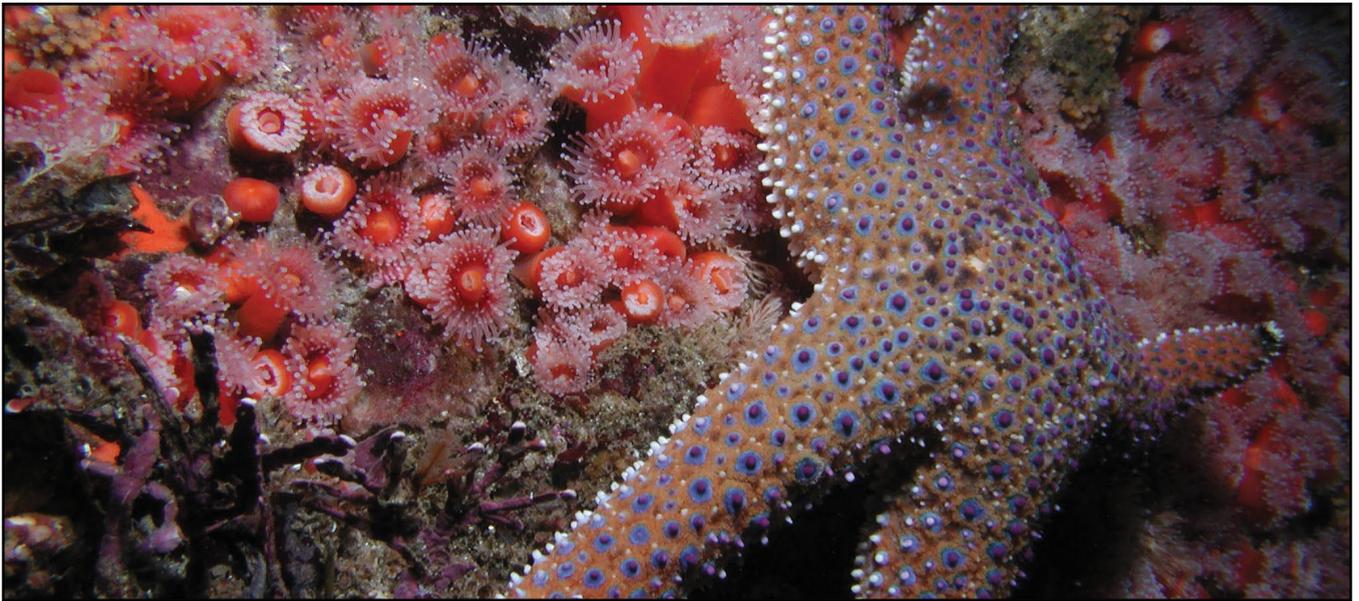
MARINE WILDLIFE & ECOSYSTEMS

A journey down our coastline reveals rocky seashores, sandy beaches and dramatic cliffs that are home to diverse plants, seabirds, and a wide variety of marine life. How do we protect and preserve marine wildlife populations and fragile marine ecosystems when millions of people depend upon the ocean for recreation, livelihoods, and a wide range of other uses? How do we balance ecological preservation

with intensive human uses of a public resource? These questions have always been central to USC Sea Grant's funded research and outreach along the urban ocean coast. We work towards a healthier urban environment, reflected by cleaner coastal waters that afford better opportunities for recreation and commerce, and the protection of human and ecosystem health.

Highlights

1990s	Sea Grant-funded research demonstrates that Orange County MPA designations alone do not protect habitat; rather, enforcement and public education are needed
2002	Continuing research funded by Sea Grant helps prioritize the creation of the Orange County MPA Council, tasked with educating beach visitors on proper stewardship
2001	Sea Grant and Crystal Cove State Park collaborate on the video <i>Between a Rock and a Hard Place</i> to educate school-sponsored field trips on tide pool stewardship
2007 - 2011	Sea Grant helps to design a new network of MPAs in Southern California through official appointment and service on the Regional Stakeholder Group
2007	Sea Grant-funded research determines an effective and ecologically sound method (the stingray shuffle, now a worldwide model) to prevent hundreds of annual injuries by stingrays on Southern California beaches
2008	As a partner in the ongoing Southern California Aquarium MPA Collaborative, Sea Grant helps coordinate regional resources and messages on MPAs and climate change
2011	Sea Grant provides pilot funding to Heal the Bay to develop the <i>MPA Watch</i> program, a citizen-science based program to monitor human uses of the coast
2014	As part of the statewide MPA Collaborative, Sea Grant co-chairs the MPA Collaborative for LA



Credit: Charlotte Stevenson

LOVING THE COAST TO DEATH

Millions of Californians and visitors explore the shores each year, enjoying the low tides to peek among the rocks and tidepools and find brilliant anemones, sea stars, and other creatures clinging tightly to the rocks. Dr. Steven Murray at CSU Fullerton has studied these coastal marine populations and ecosystems for over 40 years and analyzed the effects of visitor impacts (trampling, collecting and tide-pooling) on abundances of marine life in the intertidal zone. The State Resources Agency attempted to protect the rocky seashores of Southern California in the 1960s and 1970s by designating marine protected areas on Orange County's rocky shores, as it added other protective designations along the California coast.

Sea Grant Trainees working with Dr. Murray in the 1990s found that without proper enforcement, signage and education, MPA status did little to protect intertidal organisms, particularly those targeted by collectors on shores accessible to the public or visited during school-sponsored field trips. Informed by this research, the Orange County shoreline communities of Laguna Beach, Newport Beach and Dana Point, in

coordination with California State parks, established the Orange County Marine Protected Area Council - a management and enforcement team to patrol the coast during low tides and educate visitors on proper stewardship. A growing cadre of volunteer docents now aid these managers.

To reduce impacts on intertidal organisms, USC Sea Grant worked with Crystal Cove State Park in 2001 to produce an educational video, *Between a Rock and a Hard Place*, that teaches visitors how to explore and enjoy tidepools without causing negative impacts on these fragile environments. This video, along with more structured tidepool education programs developed along the Orange County Coast, has resulted in more educational and less impactful visits to the tidepools, fostering a greater appreciation for marine conservation among K-12 students.

A NEW NETWORK OF MPAS FOR SOUTHERN CALIFORNIA

In 1999, California passed the Marine Life Protection Act (MLPA), becoming the first in the nation to mandate a science-based, statewide network of MPAs to improve ocean health. From 2007-2012, a public, stakeholder-based process engaged scientists, fishermen, environmentalists, and other community leaders to collaboratively design and implement each regional system of MPAs. This was a contentious issue, touching on economics and deeply held values of different stakeholder groups.

Associate Director Phyllis Grifman served on the stakeholder group for the Southern California region, working as a neutral broker to bring voices to the table as well as to ensure that the best-available science was used in the decision-making on MPA boundaries. Dr. Murray was a longstanding participant in the implementation of the MLPA and sat as one of the co-chairs of the South Coast Science Advisory Team, providing scientific advice and evaluation for the stakeholders and policymakers working on the design of Southern California's MPAs. The new network of MPAs in Southern California went into effect on January 1, 2012.



MORE THAN BOUNDARIES: MPA MONITORING AND ENFORCEMENT

As we learned with Dr. Murray's tidepool research, MPA monitoring, enforcement, and public education are critical to success. USC Sea Grant is working diligently with a multitude of partners to ensure that the purpose of Southern California's MPAs is well understood and supported by the public. Two such partnerships are the *MPA Watch* program and the Southern California Aquarium MPA Collaborative. Since 2008, Sea Grant Educator Linda Chilton has helped 10 Southern California aquaria coordinate their educational resources and messaging on MPAs. *MPA Watch* is a citizen-science program, created and managed by Heal the Bay (a local nonprofit); USC Sea Grant provided the development funding for this program, which has now been adopted statewide. *MPA Watch* trains volunteers to observe and collect unbiased and consistent data on coastal and marine resource use. The 3,100 surveys completed by the end of 2014 are already providing valuable information to help managers understand how people are using the new MPAs. Data from citizen-science projects like *MPA Watch* will compliment data collected by official monitoring groups, resource managers, scientists, and the California Department of Fish and Wildlife to aid future MPA evaluation and adaptive management.

Professor Steven Murray leads data collection to analyze the impacts of trampling and collecting on tide pools in Orange County. Credit: Susan Zaleski

DO YOU KNOW THE STINGRAY SHUFFLE?

Many of our fisheries projects have led to management changes and public education campaigns, and the best example of this is the story of “Ray Bay.” In the early 2000s, Seal Beach became famous for two reasons: 1) it is the quintessential warm, sandy “endless summer” beach to which Southern Californians and tourists flock; and 2) it is the site of 200-300 stingray injuries per year, significantly more than neighboring beaches in either direction. The Round stingray uses its tail spine as a defense mechanism against predation, but in crowded waters like Seal Beach, this defense mechanism is often used against clumsy human feet. In the past, officials attempted unsuccessfully to reduce human injuries by ecologically-unsound tactics such as culling and ray-fishing competitions. The significant public hazard led USC Sea Grant to support research by shark and stingray specialist Dr. Chris Lowe at CSU Long Beach to improve overall understanding of the habitat preferences, migratory patterns and physiology of the Round stingray.

Ultimately, Dr. Lowe’s research proved that the most effective and ecologically-sound method to prevent ray-related injuries is to do the “stingray shuffle,” a simple shuffling of your feet along the bottom that warns the ray of your presence, and causes them to swim away. The findings from this research has made Seal Beach a worldwide model on managing the effects of stingrays on beachgoers. The research has been used for public education in the form of beachside posters, public aquaria displays, webpages, and K-12 education.

A surfer reads an outreach poster about the “stingray shuffle” in Seal Beach. Credit: Phyllis Grifman

LOOKING AHEAD

USC Sea Grant’s Phyllis Grifman helped co-found and now co-chairs the MPA Collaborative for Los Angeles, which coordinates MPA education (public and K-12) and enforcement. The LA Collaborative has 22 member organizations and plans to continue the *MPA Watch* program; create fishing guides and MPA information packets customized for diverse audiences who use ocean resources; and collaborate with the California Department of Fish and Wildlife to generate awareness of MPA boundaries and regulations.

In addition, over the last decade, Dr. Murray and his colleagues in the Multi-Agency Rocky Intertidal Network (MARINe) conducted a best-professional-judgment exercise to evaluate rocky intertidal communities on the West Coast and to establish an agreed-upon protocol for analyzing species abundance and environmental data. USC Sea Grant provided initial support for this effort as well as invested in intertidal research over the last two decades; now the work is culminating in the development and publication of a Rocky Intertidal Index to help officials manage these important intertidal communities.



CLIMATE CHANGE

It is more than appropriate to end this retrospective by looking forward with our climate change work, because climate change is a new lens through which scientists, managers, and policymakers must view the future. In fact, all the research, outreach, and education areas in which USC Sea Grant works – water quality, harmful algal blooms, toxicology, aquatic invasive species, ports and marine transportation, marine

wildlife, and ecosystems – will be affected by climate change in the coming decades. Over the last four years, USC Sea Grant has worked with the City of LA and other Southern California cities and counties, as well as formal and informal educators, to help build scientific understanding of climate change and sea level rise, and to enhance the capacity of local municipalities to develop adaptation strategies.

Highlights

2009 - present	Sea Grant participates on the steering committee of the LA Regional Collaborative for Climate Action and leads its Coastal Impacts and Adaptation Planning Groups
2009 - 2011	Sea Grant designs, coordinates and publishes the results from the statewide survey, <i>California Coastal Needs Adaptation Assessment</i>
2011	Sea Grant helps launch the California Coastal Acidification Network (C-CAN) with scientists and aquaculture harvesters and producers. The network is replicated on the East Coast
2010	Sea Grant partners with the U.S. Geological Survey to develop an updated version of the <i>Coastal Storms Modeling System (CoSMoS)</i> for Southern California and to develop outreach programs to build capacity for coastal jurisdictions
2013	Survey results from 2011 (above) leads the OPC to establish a \$2.5 million grant program to help communities plan for climate change
2014	Sea Grant develops, authors and releases the climate change vulnerability assessment report, <i>The Sea Level Rise Study for the City of Los Angeles</i>
2014	Sea Grant launches <i>Regional AdaptLA</i> to build scientific and planning capacity for sea level rise in Southern California



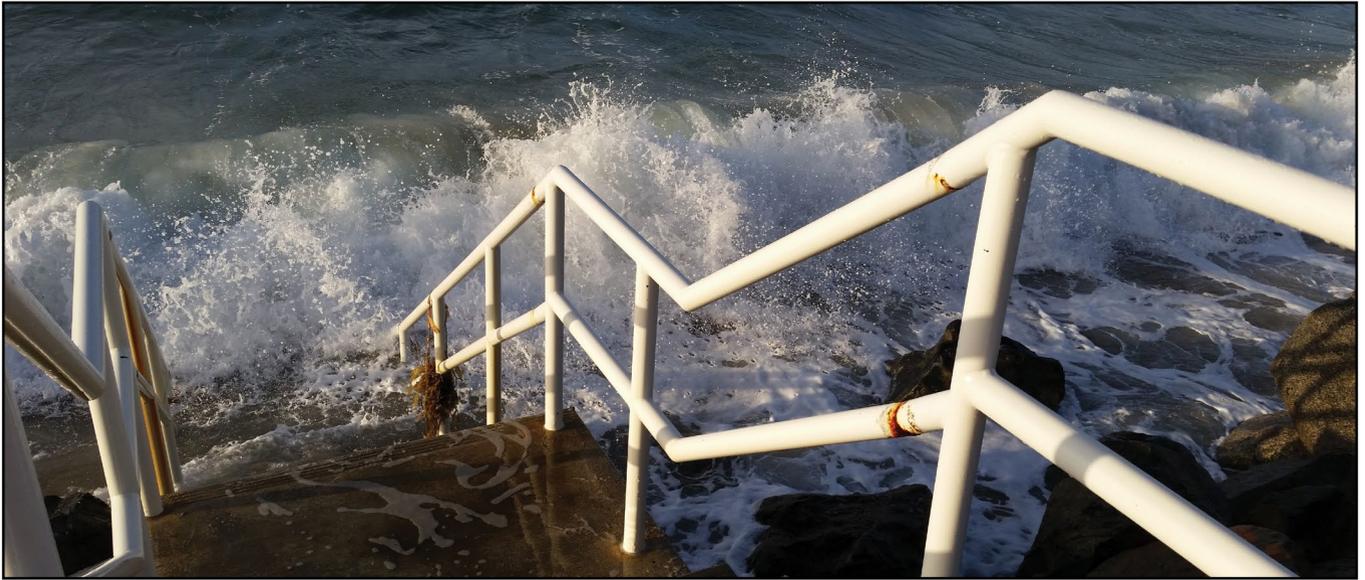
IS SOUTHERN CALIFORNIA READY FOR CLIMATE CHANGE?

Not surprisingly, the answer is: some areas are and some areas are not. But for those that are not ready, what do they need to get ready? In 2009-2011 USC Sea Grant led an effort with 15 organizations and state agencies to: 1) more precisely identify needs and barriers of coastal communities in planning for climate change; 2) develop appropriate technical assistance for communities; and 3) determine the best ways to link communities to resources and tools already available. Based on survey results, almost 90% of coastal communities had begun considering the impacts of climate change. Of those, ~50% were still trying to understand their vulnerabilities, and about 10% of communities were actively developing adaptation plans. The most common and significant barriers that communities faced in planning were lack of staff and financial resources to conduct assessments, develop plans, and then implement strategies. USC Sea Grant's survey results caught the attention of the California Ocean Protection Council, which, accordingly, developed a \$2.5 million grant program in 2013 to help provide financial resources to local communities.

IF WE CAN DO IT IN LA, THEN WE CAN DO IT ANYWHERE

We have a saying at USC Sea Grant: if we can do it in LA, then we can do it anywhere. So, we set our sights on helping LA plan for climate change. In 2011, the City of LA commissioned a sea level rise vulnerability assessment for City assets, resources, and communities. USC Sea Grant's climate team – Dr. Juliette Finzi Hart, Phyllis Grifman and Alyssa Newton Mann – recruited a team of experts in climate science, adaptation planning and social science to develop a science-based and stakeholder-supported adaptation planning process to help the City begin assessing the potential impacts of climate change. The City owns and operates coastal infrastructure that includes two power plants, two wastewater treatment plants and the Port of LA, one of the busiest ports in the world. All of this critical infrastructure is situated about ten feet above sea level and is at risk from coastal storms and sea level rise.

The final report, *The Sea Level Rise Vulnerability Study for the City of Los Angeles*, was developed and released in 2014 by USC Sea Grant with support from the



Left: Pacific Coast Highway is at risk from coastal storms and sea level rise. Credit: K. Newton. Above: King tides flood beach access stairs in Malibu. Credit: Kurt Holland

Mayor's Office. The study revealed that LA's famous beaches are the region's best defense against flooding from sea level rise. Maintaining these beaches will provide an important buffer to coastal storms and sea level rise for many years to come. Equally, the report identified an important information gap on exactly how beaches will respond to impacts long-term (a.k.a. shoreline change); understanding this response in the context of shoreline change is a critical regional need.

A social vulnerability assessment provided particularly powerful results. Using U.S. Census data, social scientists Drs. Susanne Moser and Julia Ekstrom screened for socioeconomic characteristics associated with social vulnerability – large proportions of renters, low per capita income, language barriers, persons with physical disabilities – that typically characterize a low capacity for adapting to change. Their study found that the communities of Venice, Wilmington and low-lying portions of San Pedro have the highest vulnerability to sea level rise impacts, and the study provided recommendations to work with these communities to identify potential adaptation strategies.

SEA LEVEL RISE: WHERE? AND HOW FAR?

Over the next century, sea level rise in LA is expected to match global projections with an increase of 0.1-0.6 m (5-24 inches) from 2000 to 2050 and 0.4-1.7 m (17-66 inches) from 2000 to 2100. There are also important local influences on sea level rise, including: the rise or fall of ocean inputs from land-based water (rivers, precipitation and run-off); tectonic activity; currents; tides; and storm surge, especially at or near peak high tides. Sea level rise will intensify the impacts from these events.

To help bring the best scientific information to the region, USC Sea Grant is partnering with the U.S. Geological Survey (USGS) to develop an updated version of their *Coastal Storms Modeling System (CoSMoS)* for Southern California – a model that projects sea level rise in combination with influences from storm surge and waves. The first iteration of the model served as a pilot project for the Southern California region, and USC Sea Grant used it in the sea level rise vulnerability assessment for the City of



LA. Under a California Coastal Conservancy grant co-managed by USC Sea Grant, USGS is updating the CoSMoS model to include a suite of 40 scenarios that incorporate 0-2m (and 5m as a catastrophic scenario) of sea level rise, and include storm scenarios ranging from a common annual storm to the infamous and significantly damaging 100-year storm. Filling the information gap identified in the City of LA study, CoSMoS also will consider the compounding impacts to the coastline from erosion, shoreline change, and land-based run-off.

REGIONAL PLANNING AND PARTNERSHIPS

Ultimately, outcomes from the 2011-2014 LA-focused sea level rise study became the driving force behind developing *Regional AdaptLA*, which includes USC Sea Grant, the City of Santa Monica, the LA Regional Collaborative on Climate Action & Sustainability, Heal the Bay, the Santa Monica Bay Restoration Commission, 11 coastal jurisdictions, and LA County.

As we hear from our stakeholders again and again, it is not enough to just hand over the science, so USC Sea Grant's *Regional AdaptLA* program is developing scientific and planning capacity to ensure that CoSMoS model results are accessible and understandable to coastal communities. USC Sea Grant has held introductory workshops in Santa Barbara, Ventura, Orange County, and San Diego to provide an overview of the emerging models; and training on how to develop vulnerability assessments and integrate adaptive management into planning processes.

In addition, USC Sea Grant launched a professional development webinar series that dives deeply into different topics of importance for coastal communities implementing adaptation planning. Webinar subjects include: the role of coastal storms and king tides; beach dynamics and ecology; legal and economic implications of sea level rise and adaptation planning; adaptation strategies and how these mesh with current state and federal guidance and mandates; and case studies from other communities in California and around the country.

THE MORE THE MERRIER

USC Sea Grant professionals Dr. Juliette Finzi Hart, Alyssa Newton Mann and Phyllis Grifman serve as leaders for several regional, statewide and national efforts, allowing us to share the successes and lessons learned with other communities engaged in climate adaptation planning. USC Sea Grant is a leader in the LA Regional Collaborative for Climate Action & Sustainability (LARC), a network designed to encourage greater coordination and cooperation at the local and regional levels by bringing together leadership from government, the business community, academia, labor, environmental, and community groups. USC Sea Grant leads LARC's Coastal Impacts Group and has served on its steering committee since shortly after its inception in 2009. Similarly, USC Sea Grant represents the LA region as a voting member of the Alliance of Regional Collaboratives for Climate Adaptation (ARCCA), a statewide network comprised of existing regional collaborative organizations from across California, including LARC. Through ARCCA, member collaboratives have come together to amplify their individual efforts, as well as to give a stronger voice to local and regional perspectives at state and federal levels.

USC Sea Grant also serves on the Climate Change Action Coordination Team (ACT) of the West Coast Governors' Alliance for Ocean Health, a collaboration of state leaders in California, Oregon and Washington. The Climate ACT has two primary initiatives aimed at improving climate and sea level rise science and policy. The first was the development of the National Research Council's 2012 report, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*. This study incorporated both global

Left: The El Segundo Power Station sits about ten feet above sea level. Credit: Charlotte Stevenson

Below: King tides flood a bridge in Redondo Beach. Credit: Juliette Hart



and local impacts to sea level rise and developed robust sea level rise projections for the West Coast of the U.S. The second initiative is the development of a searchable online catalogue of funding sources available for those working on the management of natural resources, public access, and public health. Together these Climate ACT projects will create economies of scale among the three states for risk assessment, comprehensive planning, and development of green infrastructure to address climate hazards.

Finally, USC Sea Grant's Alyssa Newton Mann serves as Co-Chair of the National Sea Grant Climate Network, which coordinates climate-related activities nationwide, resource-sharing, and communications with climate agencies and organizations within NOAA. In 2013, USC Sea Grant hosted the second *National Sea Grant Climate Network Workshop*, providing an opportunity for Sea Grant colleagues from all programs to share progress on their adaptation planning projects, transfer knowledge and lessons learned, and participate in joint-training on social vulnerability analysis.

CLIMATE CHANGE EDUCATION

Students *today* will inherit the *future* climate, so USC Sea Grant has incorporated climate change science into several education programs. Education Programs Manager Linda Chilton helped develop a pilot curriculum for teachers throughout California focused on sea level rise, its potential impacts on the coastline, and how students can become leaders in citizen-science-based projects. In 2014, USC Sea Grant co-hosted a *Climate Youth Summit*, in which students from across the LA region learned about the impacts of climate change through games, activities, and interactive workshops. In addition, USC Sea Grant collaborates annually with NASA's Jet Propulsion Laboratory (JPL) by providing education support and hands-on activities at the annual *Climate Day* for schools and *JPL Open House* for the general public. The public open house attracts over 45,000 visitors each year, allowing for exploration of the concepts behind satellite ocean monitoring and climate change impacts.

LOOKING AHEAD

The nature of climate change work is always “looking ahead,” and here we mention some of the new scientific research investments that will help manage impacts in the future. USC Sea Grant is funding a collaborative project between USC and Scripps Institution of Oceanography pioneering the use of a mobile beach erosion monitoring tool to: track the effects of wintertime storms on two heavily used urban beaches with erosion problems; track the effectiveness of sand berms; and use the data gathered to better calibrate models for berm design.

USC Sea Grant is also funding another Scripps research project to assess the capacity of low-flow estuaries to deal with future changes in sea level rise and extreme storm events. Sea Grant is investing in a joint research project between UCLA and the

Southern California Coastal Water Resources Project (SCCRWP) to develop methods for managers to: evaluate climate vulnerabilities at individual wetland sites; assess wetlands to identify and prioritize anticipated effects of sea level rise at specific wetland sites; and develop climate-smart adaptation strategies to guide restoration and management priorities.

Finally, building on our robust research program in ecosystem health, we are funding research to examine whether climate-related changes to our coastal and marine systems (e.g., decreased pH and/or increased water temperatures) will favor toxin-producing diatoms and dinoflagellates and potentially exacerbate the impacts from their neurotoxins.



Low tide and king tide at Pt. Dume in Malibu in February, 2015. King tides give us a glimpse of what future sea level rise may look like along our coast. Credits: Kurt Holland



CONCLUSION

At its core, USC Sea Grant is a connector and collaborator. Well known throughout California, we are relied upon by stakeholders to convene multi-institutional and multi-disciplinary symposia and working sessions for educators, policy makers, and managers. The program has grown through the years to provide guidance, funding, coordination, facilitation, training, education, neutral brokerage and mediation, all under the common goal of elevating the best-available science to support better decisions. We have told a few stories here that demonstrate the way research investments have answered pressing

questions about the impacts of urbanization on fragile coastal and ocean resources, and how the answers to those questions have been applied by policy makers and coastal managers to help solve emerging problems. As we look towards the future we are excited at the array of new ideas, research opportunities, and potential new partners who will help us build sustained, long-term progress for our urban ocean and its residents. Thank you for exploring our first 40 years with us and for being our collaborators and valued partners!

A typical summer day at Santa Monica beach. Credit: Charlotte Stevenson

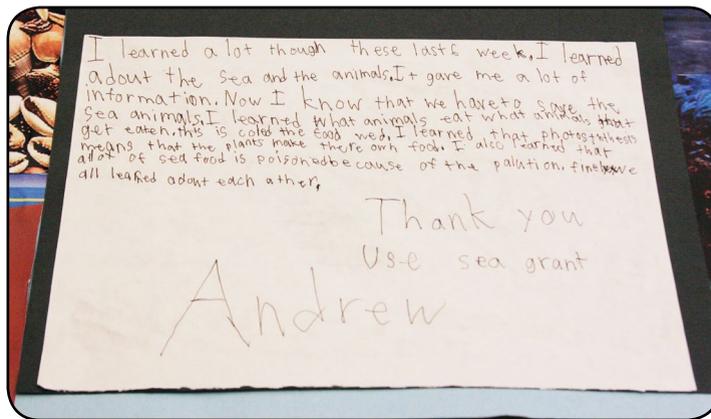


TIMELINE OF MAJOR USC SEA GRANT EVENTS AND LEADERSHIP

- 1901** USC hired its first marine biologist, Albert Ulrey
- 1910** USC carried out studies on water quality off Venice Beach
- 1965** USC created the marine lab on Catalina Island through a generous donation by the Wrigley Family and named the Wrigley Marine Science Center
- 1966** President Lyndon Johnson signs the bill establishing the Sea Grant Program through The National Sea Grant College and Program Act of 1966.
- 1972** USC Sea Grant is established as an institutional program, the seventh program established nationally
- 1972** Ron Linsky becomes Program Director
- 1976** Dr. Robert L. Friedheim becomes Program Director
- 1989** Dr. James Fawcett becomes Acting Program Director
- 1993** Dr. Douglas Sherman becomes Program Director
- 1995** Establishment of the USC Wrigley Institute for Environmental Studies
- 1999** Dr. Linda Duguay becomes Program Director and continues today
- 2012** USC Sea Grant celebrates its 40th Birthday
- 2016** Sea Grant Program celebrates its 50th Birthday

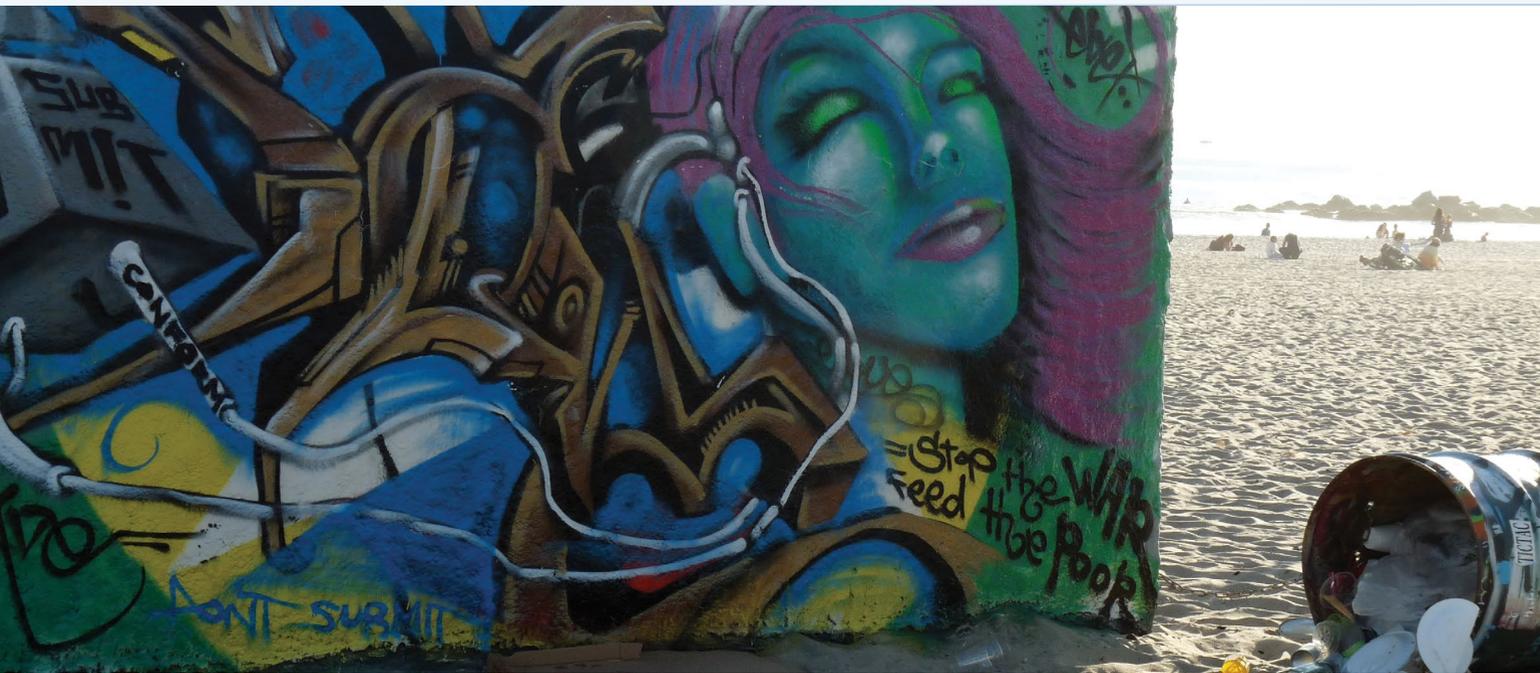
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SELECTED SOURCES

A list of selected references is available on our website, along with a downloadable version of this document:
<http://dornsife.usc.edu/uscseagrant/40-years-of-progress-in-the-urban-ocean/>



40 YEARS OF PROGRESS IN THE URBAN OCEAN