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Exposure of Santa Cruz Wharf Anglers to Domoic Acid Toxins

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Abstract

The goals of this pilot project were to determine the extent of the public health threat posed by pier anglers' consumption of self-caught seafood containing domoic acid (DA), and to lay the foundation for further research, education and outreach to address the threat. Year 1 project objectives were to: 1) design, test and initiate an intercept survey of SCW anglers to identify and characterize their seafood consumption patterns; and 2) determine the concentrations of HAB toxins in the species targeted by SCW anglers, while monitoring ambient DA toxins and toxic Pseudo-nitzschia species in the SCW area and at a more open-water site. Year 2 project objectives were to: 1) determine whether a quantitative link exists between toxic phytoplankton in the water and DA contamination of commonly caught fish at the SCW; 2) determine the relationship between SCW anglers' seafood consumption patterns and their socio-cultural and economic characteristics; 3) identify subpopulations of SCW anglers whose seafood consumption patterns put them at risk for exposure to DA; and 4) work with state agencies and other interested parties to determine how best to export these results to support their efforts to protect public health.

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Exposure of Santa Cruz Wharf Anglers to Domoic Acid Toxins

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Project Hypotheses
1. Plankton-feeding fish in the SCW fishery will contain the highest levels of DA compared to levels in omnivorous fish.
2. Plankton feeding fish in the SCW fishery will have DA patterns that are in phase with DA patterns in the phytoplankton.
3. Bottom feeding fish from the SCW fishery will have DA patterns that generally will not be in phase with DA levels in the water and plankton.
4. Fishing and consumption patterns will differ among socially-, culturally- and economically- defined subpopulations of SCW anglers.
5. The fish consumption patterns of some of these subpopulations will put them at greater risk of exposure to DA than SCW anglers overall.

Project Goals and Objectives
The goals of this pilot project were to determine the extent of the public health threat posed by pier anglers' consumption of self-caught seafood containing domoic acid (DA), and to lay the foundation for further research, education and outreach to address the threat. Year 1 project objectives were to: 1) design, test and initiate an intercept survey of SCW anglers to identify and characterize their seafood consumption patterns; and 2) determine the concentrations of HAB toxins in the species targeted by SCW anglers, while monitoring ambient DA toxins and toxic Pseudo-nitzschia species in the SCW area and at a more open-water site. Year 2 project objectives were to: 1) determine whether a quantitative link exists between toxic phytoplankton in the water and DA contamination of commonly caught fish at the SCW; 2) determine the relationship between SCW anglers' seafood consumption patterns and their socio-cultural and economic characteristics; 3) identify subpopulations of SCW anglers whose seafood consumption patterns put them at risk for exposure to DA; and 4) work with state agencies and other interested parties to determine how best to export these results to support their efforts to protect public health.

Briefly describe project methodology
We conducted a pilot study of Santa Cruz Wharf (SCW) angler demographics and consumption patterns, coupled with toxicity testing of the water column and the seafood species and parts (i.e., viscera, muscle tissue) that anglers consume.

To characterize anglers and their SCW catch and consumption patterns, we conducted a seafood consumption survey (SCS). The SCS was an intercept survey conducted at the wharf, about anglers' social, cultural and economic characteristics, their seafood catch, disposition and consumption patterns, as well as motivations for catching and consuming species. To determine whether anglers were exposed to seafood-borne toxins, we collected and analyzed water samples to determine the seawater levels of the toxin-producers (Pseudo-nitzschia) and their DA, as well as specimens of fish, using the same methods as the pier anglers, specimens of crabs from pots deployed at the pier, and shellfish bagged and deployed at the pier using California Department of Public Health (DPH) methods (with whom we collaborated). For fish and crabs, we removed viscera for separate testing on the pier and returned them to the lab for DA determination, using our standard methods. The SCS and fish sampling were done simultaneously over a 1-year period. Statistical analysis of SCS data characterized angler demographics (e.g., ethnicity, age, income) and seafood consumption patterns and rates, including those of "high-consuming" subpopulations. We are integrating the results of these two efforts, using statistical analyses to determine correlations between angler consumption patterns (overall and by subpopulation) and DA toxicity exposure.

Describe progress and accomplishments toward meeting goals and objectives
After a delayed start, we began work on the project in earnest in September 2006. We drafted the seafood consumption survey, and sent it to colleagues for their review. We conducted informational interviews and meetings with relevant local and state agency staff to discuss the project and to gain their insights about SCW fisheries and related topics to inform the survey sampling design and fieldwork. We initially recruited 11 UCSC student interns and trained them. Following a pre-test and revisions, we began the full 12-month survey, and completed it in May 2008. During that time, an additional 12 student interns were trained and assisted with the survey.

Our survey team conducted 746 interviews with SCW anglers over a 12-month period, and found that nearly half (44%) consumed their catch. The species anglers most often reported consuming were jacksmelt (*Atherinopsis californiensis*), Pacific mackerel (*Scomber japonicus*), Pacific sardine (*Sardinops sagax*), white croaker (*Genyonemus lineatus*) and Northern anchovy (*Engraulis mordax*). Anglers came from a diversity of ethnic and socio-cultural backgrounds, and prepared and consumed their catch in a variety of ways, some of which may put them at particular risk of exposure to DA toxins.

We began sampling the water for toxic phytoplankton in September 2006 and obtained weekly samples for the toxic species of Pseudo-nitzschia that produce domoic acid (DA) until the beginning of 2009. We are also monitoring water at the pier for the dinoflagellate *Alexandrium catenella*, which produces saxitoxin, another potential fish contaminant of concern. During the project, we initially recruited Mr. Casey Curtis for several quarters as our Sea Grant intern, and Ms. Fernanda Mazzillo, initially supported on her own fellowship (and later taking over as the designated SG trainee) to work on the project. Curtis focused on sampling the toxic phytoplankton and Mazzillo coordinated the fish sampling program through the study. In early 2007, she recruited seven students who began sampling fish from the pier, and drafted a fish guide, now being used to identify fish caught in the program.

The field data on toxic species and the associated toxin levels are nearly all collected. During the study period, there was, unusually, only one major DA

event in the first year of the study (late March to May 2007), and the only fish caught that contained worrisome levels of DA were the filter-feeding northern anchovy, which contained DA in both the viscera and the flesh. Other fish had low or non-detectable DA levels. In the second year of the study, another DA event occurred in late July and early August 2008. During that time, the highest DA levels were detected in viscera and in the flesh of Pacific sardines. All other species caught during the 2008 DA event had low or non-detectable DA levels in their viscera. However, fish species such as jacksmelts, shiner surf perch, staghorn sculpins and speckled sanddabs also had low but detectable DA levels when no DA was detected in the water, suggesting that these species may acquire DA not directly from water, but from alternative sources. The results of this study show that the presence of DA toxins and the diatom species that produce them, *P. australis* and *P. multiseries*, can indeed lead to conditions where pelagic filter feeding fish, particularly the northern anchovy and Pacific sardine, can become contaminated and pose a human health risk, as well as ones to marine birds and mammals that consume them.

We are integrating results of the toxicology and survey research components of the project, and presented selected, preliminary results at the 2008 CalCOFI Conference. This work continues, and will also incorporate the results of lipid analyses on samples of commonly consumed SCW species found to also have DA in the viscera and/or tissue.

Project modifications

Our primary modification to the project was the shifting of our timeline by about six months due to the late receipt of Year 1 funds (in June 2006), and an unexpectedly lengthy recruitment for the seafood consumption survey (SCS) traineeship. The person expected to take the traineeship declined it. After a failed search for another graduate student trainee to serve as SCS coordinator, we obtained permission to convert the position to a specialist position. Following an open recruitment, we hired Dr. Veronica Long, a geographer with survey research and extension experience. Once she joined our project team in September 2006, we were able to move forward with the project. For the toxin monitoring component of the project, we recruited a Sea Grant trainee, Mr. Casey Curtiss, who helped us out with the phytoplankton part of the project from its onset until summer of ’07. At that point, his interest switched to another area of work in Silver’s lab, and he no longer could participate in the program. At that point, Ms. Fernanda Mazzillo, had completed her one-year fellowship (awarded on a merit basis upon her entry into graduate school). She was then made the SG trainee, and took over the operation of the field toxicology part of the project. She had already been involved in the project from its onset, and we decided that the study would be a major part of her PhD dissertation. She initially focused on the fish toxin work, but subsequently became involved in all aspects of the field program related to toxins in phytoplankton and in fish. In addition, we began a collaboration with CalEPA staff scientists Margy Gassell and Susan Klasing on lipid analyses of the most commonly consumed species from samples collected at the wharf. These analyses are enabling us to address the potential health benefits as well as the risks of consuming seafood caught at the Santa Cruz wharf. We contracted with an external firm to conduct the lipid analyses, and received those results at the end of the project period. We are working with Gassel and Klasing at OEAHHA to interpret this information, and will integrate it with other results of this project.

Project outcomes

We have provided physical samples of shellfish (mussels) to the California Department of Public Health, which has analyzed them for domoic acid and saxitoxin derived from phytoplankton, throughout the course of this study. The results of their analyses of our samples are included in their routine, public reports of the levels of the phycotoxin in mussels, which protect the California public from shellfish poisoning. These data are available on the DPH website and in special warnings they provide regarding shellfish closures.

The survey results are undergoing further analysis and integration with other project results, and will be summarized and made available to DPH, OEHHA, the Santa Cruz community and the larger public. We are also discussing with DPH and OEHHA possible use of the disaggregated data (which are anonymous).

Briefly describe how this project has contributed to a discipline
One immediate impact has been the education of undergraduates who served as our trainees and/or wrote theses based on their participation in the project. Examples (all completed in June 2008) include: David Kim, an undergraduate in Silver's lab, wrote his senior thesis for the Bachelors degree in Marine Biology titled "Feeding behaviors and population dynamics of 3 Cancer crab species in Monterey Bay, California". Joanne Wong wrote her senior thesis for the Bachelor's degree in Environmental Studies, with a minor in Marine Biology, titled "Shape variations within Pseudo-nitzschia due to iron availability." Suzanne Garcia, an undergraduate Marine Biology major, wrote her senior thesis based on her work on the project, "Domoic acid in benthic communities of the Santa Cruz Municipal Wharf in Monterey Bay, California." Seven other students were part of the undergraduate team that worked in Silver's lab and on the pier on the toxicology part of the project. Twenty-three undergraduate student interns worked on the SCS for periods from 3 to 12 months. Through their training, they learned about the Santa Cruz wharf, its history and community; the potential benefits and risks of seafood consumption; social science survey research methods; and research ethics. Although they have completed fieldwork for this project, several students have stayed involved in the project. Julie Kuo was a particularly dedicated undergraduate working in Silver's lab, helping both with the preparation of samples for the lipid analyses, as well as studying the food items found in the stomachs of the various fish caught from the pier. In summer 2009, will use the skills and knowledge she acquired through this work as an Assistant Instructor at the USC Catalina Marine Island program for high school students.

Also in the immediate term, local, regional and international colleagues and others interested in HABs and exposure through consumption of self-caught seafood have become more aware of the relationships among HABs, marine species and anglers who consume their catch. Our presentations, involvement in workshops and other activities enabled us to share information about the project's conceptual and methodological foundations and results to date. For example, NOAA NCCOS's Harmful Algal Research and Response: A Human Dimensions Strategy, to which Pomeroy contributed, is being used by communities and planners within the US and in other countries to enhance efforts to address and deal with the impacts of HABs.

In the longer term, we expect the project will have far-reaching impacts. We have begun preparing manuscripts on the integrated methodology and results of the project for submission to natural science and social science journals. For one publication, trainee Mazzillo is compiling the data on the levels of toxin found in the commonly caught pier fish, and will link those DA levels to fish

foraging behavior and toxin levels in the water (the latter are now generally available along the California coast). She will then work with Pomeroy, Long and Prado on a second manuscript indicating the potential for contamination of pier anglers, given their seafood preparation techniques and consumption patterns. These and other results will be presented at suitable fisheries and health-related conferences to further publicize the results of this study. Pomeroy, Prado and Long will prepare a third manuscript that describes the survey methodology and results. In addition, Pomeroy is drafting a UC Delivers piece on the team-based survey research effort, and will prepare a second piece on the larger project and its results. We also are working with CalEPA and CDPH scientists toward making our data and results directly useful in their efforts to protect human health. For example, we are seeking the advice of Dr. Greg Langlois, head of the phytoplankton pier monitoring (algal toxins) for the state and others about how and where to publicize our findings, for the benefit and protection of pier anglers. One likelihood is that Langlois will work with us to place information about the dangers (from DA contamination) and benefits (based on lipid data) of consuming commonly (recreationally) caught fish along the California coastline on the CDPH website he maintains.

Ultimately, we expect the results of this project to inform local, state and regional interests about the potential for DA exposure, and opportunities for limiting that exposure based on the new information about the biophysical and human dimensions of the Santa Cruz Wharf fishery generated by this project. Moreover, we expect it to result in efforts elsewhere to build more integrated understanding of the human and biological dimensions of HABs, and thereby improve efforts to monitor and protect ecological and human health.

Benefits, commercialization and application of project results
Silver was a contributor and participant to the NOAA-funded Regional Workshop for Harmful Algal Blooms (HABS) in California Coastal Waters, April 2-3, 2008. (The workshop was held by the NOAA-supported Southern CA Coastal Water Resources Project.) Silver participated as an expert in the transmission through food webs and to humans. Contact: Dr. Meredith Howard, meredithh@sccwrp.org, (714) 755-3263.

In addition, Pomeroy has provided information and insights related to the human dimensions of HABs and seafood consumption to: Marybeth Bauer, NCCOS Human Dimensions Research Coordinator, nccos.hd@noaa.gov, (301) 593-4724; Alyce Ujihara, California Department of Public Health, Environmental Health Investigations Branch (EHIB) Scientist, AUjihara@dhs.ca.gov, (510) 620-3663; Margy Gassel, CalEPA, Office of Environmental Health Hazard Assessment, mgassel@oehha.ca.gov, (510) 622-3166.

As the information generated from this project is shared with the people and organizations above and others, those seeking to mitigate or prevent exposure to DA toxins though consumption of angler-caught seafood as well as anglers and consumers themselves will benefit.

Economic benefits generated by discovery
N/A

Issue-based forecast capabilities
See the information under "Benefits, commercialization and application of results" above.

Tools, technologies and information services developed
The survey training manual, developed by C. Pomeroy and V. Long, has been shared with others seeking to do survey research on the human dimensions of fishing and seafood consumption, and will be made available to others.

Publications
Conference papers, proceedings, symposia
Title: Domoic acid toxins in the oceanic Pacific. Amer. Soc.
Authors: Silver, M.W., S. Bargu and others.
Date: Jan. 2009
Conference Title: Limnolog and Oceanography (ASLO)
Location: Nice, France

Title: Risk of Exposure of the Recreational Fishing Community to Amnesic Shellfish Poisoning
Authors: Mazzillo, F., M.W. Silver, C. Pomeroy, R. Prado, V. Long and J. Kuo
Date: Nov. 2008
Conference Title: CalCOFI Annual Conference
Location: La Jolla, CA

Title: Algal toxins in the deep blue sea: is it an environmental concern? (Invited Lecture, the "Rachel Carson" lecture for the year)
Authors: Silver, M. W., and S. Bargu
Date: 28 May 2008
Conference Title: American Geophysical Union, Joint Assembly
Location: Ft. Lauderdale, FL

Title: Domoic acid in oceanic Pseudo-nitzschia is it an issue?
Authors: Silver, M. W., and S. Bargu
Date: Oct 2007
Conference Title: US Symposium on Harmful Algae in the U.S.
Location: Woods Hole Oceanographic Institution, Woods Hole, MA

Title: Recent ecosystem shift in central California alters harmful algal bloom patterns.
Authors: Jester, R., V. Vigilant, G. Langlois, and M.Silver.
Date: Oct 2007
Conference Title: US Symposium on Harmful Algae in the U.S.
Location: Woods Hole Oceanographic Institution, Woods Hole, MA.

Title: Spatial distribution of phytoplankton groups and toxic species in a nearshore frontal zone system in Monterey Bay, California.
Authors: Mazzillo, F., and M. W. Silver
Date: Oct 2007
Conference Title: US Symposium on Harmful Algae in the U.S.
Location: Woods Hole Oceanographic Institution, Woods Hole, MA

Peer-reviewed journal articles or book chapters
Title: Recent ecosystem shift in central California alters phycotoxin exposure to food webs.
Authors: Jester, R., V. Vigilant, G. Langlois, K, Lefebvre, and M. W. Silver. 2008
Date: 2008
Journal Name: Harmful Algae
Issue/Page Numbers: 8:291-98

Title: Human dimensions research strategies for harmful algal bloom response: Enhancing scientific support for coastal decision-making
Authors: Bauer, M., T.M. Leschine, P. Hoagland, D.L. Ayres, B.G. Blount, L.L. Lamp, C. Pomeroy, C.W. Scherer, J. Schumacker, K.G. Sellner, M.R. Sengco, and P.A. Tester.
Date: 2009
Journal Name: Frontiers in Ecology and the Environment
Issue/PageNumbers: 7

Title: Natural and iron-fertilized oceanic communities contain toxic phytoplankton
Authors: M. W. Silver, S. Bargu, S. L. Coale, C. R. Benitez-Nelson, A. C. Garcia, K. J. Roberts, E. Sekula Wood, K. W. Bruland, and K. H. Coale
Date: 2009 (in review)
Journal Name: Nature Geoscience
Issue/PageNumbers: in review

Theses, dissertations
Title: Red Tides and Toxic Events on Monterey Bay, CA: Physical-Biological Dynamics and Food Web Implications
Authors: Mazzillo, Fernanda
Schools: UC Santa Cruz
Date: expected Oct. 2009

Miscellaneous documents
Title: Tiny Drifters: Basic & Beautiful, UCSC Seymour Center exhibit
Date: July - November 2008

Title: Sport Fish Contain Toxin Produced During Algal Blooms: Sea Grant to Study Anglers' Exposure. California Sea Grant news release by Johnson, C.; reported in six regional newspapers)
Date: Feb 16 2006

Media
Santa Cruz Sentinel
City: Santa Cruz
State: CA
Date of publication/broadcast: Mar. 5 2006
Headline or topic: Domoic acid study underway in Monterey Bay.

KUSP
City: Santa Cruz
State: CA
Date of publication/broadcast: Jan. 29, 2007
Headline or topic: Troubled waters? Part of 1-hr radio interview on coastal marine conditions in California, especially Monterey Bay (Silver and 2 other regional scientists interviewed)

Please list any workshops/presentations given
Pomeroy, C. 2006. Chemical Hazards in Seafood, Recreational/Subsistence Fishing and Public Health Concerns. UC Cooperative Extension Fish Safety Update for Agriculture, Community, Health, and Nutrition Educators, Nov. 2, Woodland, CA. About 30 attendees. Provided background on the issue and challenges related to safe seafood consumption given anthropogenic and naturally occurring toxins in

fish, and the social, cultural and economic drivers of fishing and seafood consumption.

Dissemination of results
M.W. Silver. Oct 2007. "The Birds": a real event demonstrating algal poisoning, presentation for A Celebration of Alfred Hitchcock , San Juan Bautista (Dr. Sandy Lydon, M.C.) Presentation to the Monterey Bay community, a public interest/historical meeting

M.W. Silver. Oct 2007. "Plankton, global warming, and shellfish" presented to staff and residents of Dominical Oaks, Retirement Community in Santa Cruz, California. (General public, generally elderly, but active community members)

M.W. Silver. Nov. 2008, La Jolla, CA CALCOFI meeting. Invited presentation: Recent patters of Pseudo-nitzschia in Monterey Bay, CA: Nearshore and offshore records of a newly recognized HAB phenomenon. M. W. Silver, F. Mazzillo, C. Pomeroy and others.

Students
Fernanda Mazzillo
UC Santa Cruz
Ocean Sciences
Degree program enrolled in: Ph.D.
Theses/dissertation title: Red Tides and Toxic Events on Monterey Bay, CA: Physical-Biological Dynamics and Food Web Implications
Supported by Sea Grant funds? [X] yes [] no
Start date: 10/01/2007
End date: 02/28/2009

How many student volunteers were involved in the project? 32

Cooperating organizations
Federal
Cindy Thomson, Economist, NOAA Fisheries, Southwest Fisheries Science Center, reviewed draft survey.

Regional
W. Van Buskirk, RecFIN manager, Pacific States Marine Fisheries Commission, Recreational Fisheries Information (RecFIN) Program, provided RecFIN data to support survey sampling and input on survey design, and is reviewing the draft survey.

Local and state
Margy Gassel, Scientist, CalEPA Office of Environmental Health Hazard Assessment. Reviewed the survey and provided helpful input on the study as a whole. We have collaborated to pursue testing of fish samples for lipid content. In addition, we are continuing discuss ions about our results and how they can be used to support education and outreach for safe seafood consumption.

Alyce Ujihara, Diana Lee and Emily Silver, Scientists, California Department of Public Health (CDPH), Environmental Health Investigations Branch. They have provided extensive input on the survey plan, including review of the draft survey. We are continuing discussions about our results and how they can be used to support education and outreach for safe seafood consumption.

Greg Langlois, Senior Environmental Scientist, CDPH, Marine Toxin Monitoring Program, maintains continuing contact with Silver on the presence and abundance of toxic phytoplankton at the Santa Cruz Wharf. Silver and Pomeroy provide quantitative data to CDPH through Langlois, and Langlois provides information to them regarding the presence of toxin producers along the entire central California coastline and any needs for additional sampling.

Todd Phillips, California Recreational Fisheries Survey Coordinator, Monterey Bay Region, provided us with advice on designing and conducting the survey (including survey review).

Danette Shoemaker, Director, Santa Cruz Department of Parks and Recreation, and wharf management personnel Dan Buecher and John Bombaci, provided very helpful feedback on our research plan.

Nongovernmental
Elliot Ponchick, William C. Bannerman Foundation, provided funding support for the seafood consumption survey field program.

Academic Institutions
Dr. Raquel Prado, Associate Professor, UC Santa Cruz, is our co-PI, and has contributed her expertise in statistics and applied research to both the natural and social science project components, as well as the overall effort
Dr. Barbara Knuth, Professor, Cornell University, reviewed our draft survey.

International implications
The human and biophysical dimensions of HABs are a topic of global interest and concern. This project is producing data and methodological insight that contribute to understanding of and efforts to address this broad-ranging problem. The toxin studied here, domoic acid (DA), is of unusual importance, as it is not just a shellfish contaminant, but also a contaminant of fisheries products, as we determined here. Hence our results indicate that toxin testing, especially of filter-feeding fish like sardines and anchovies, should be regularly done as part of a consumer protection program, especially where consumers do not eviscerate the fish before preparing and consuming them – which our survey results indicate occurs among SCW anglers, and we expect occurs in other settings worldwide.

Awards
Silver was chosen to give the annual “Rachel Carson” lecture at the Pan-American meeting of the American Geophysical Union at Ft. Lauderdale, FL in 2008. (Lecture listed above.)

Keywords
seafood consumption, survey research, subsistence fisheries, recreational fisheries, domoic acid, harmful algal blooms, anchovy, jacksmelt, white croaker, sculpin, perch, sanddabs, Pacific sardine, human dimensions, Santa Cruz Wharf, *Pseudo-nitzschia australis*, *P. multiseries*