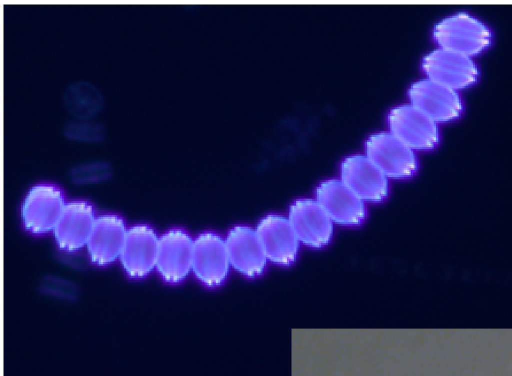
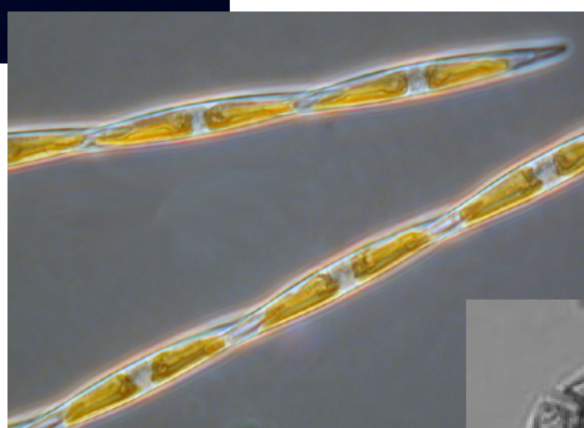
SCCWRP #565

# THE REGIONAL WORKSHOP FOR HARMFUL ALGAL BLOOMS (HABS) IN CALIFORNIA COASTAL WATERS

## April 2-3, 2008 Workshop Proceedings





Center for Sponsored
Coastal Ocean Research

Harmful Algal Bloom Monitoring and Alert Program (HABMAP) Working Group. 2008. The regional workshop for harmful algal blooms (HABs) in California coastal waters. Report #565**.** Southern California Coastal Water Research Project, Costa Mesa, CA.

**Cover Acknowledgements:** Cover photos provided courtesy of (Top to bottom), Susan Coale (Silver Lab), Rozalind Jester (Silver Lab) and Astrid Schnetzer (Caron Lab).

# THE REGIONAL WORKSHOP FOR HARMFUL ALGAL BLOOMS (HABS) IN CALIFORNIA COASTAL WATERS

## April 2-3, 2008 Workshop Proceedings

*National Oceanic and Atmospheric Administration*
*California Ocean Science Trust*
*Southern California Coastal Water Research Project*

3535 Harbor Blvd.
Costa Mesa, CA 92626
***www.sccwrp.org***

**June 2, 2008**

Technical Report 565

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# EXECUTIVE SUMMARY

## Overview

Within California there are numerous programs for studying and monitoring harmful algal blooms (HABs); however, these programs are largely uncoordinated with respect to each other. To assess the interest in, and potential impediments to, the formation of a coordinated statewide HABs monitoring network, the National Oceanic and Atmospheric Administration's Center for Sponsored Coastal Ocean Research and the California Ocean Science Trust convened a workshop that included 42 invited participants representing the leading HAB research groups in California and a diverse range of interest groups, including: water quality management, shellfish management and public health protection, and animal rescue communities. Overall, workshop participants made signification contributions to a more comprehensive understanding of HAB events and expressed a desire to improve regional monitoring communication and data sharing.

The workshop consisted of four sessions. The first plenary session was comprised of presentations summarizing the work of 18 organizations presently collecting HAB related data with the potential to form the backbone of a coordinated statewide program. In the second session, participants broke into two working groups to assess the extent to which methodological differences in toxin detection and species identification among programs poses an impediment to the development of a statewide network. The third session involved two working groups discussing data sharing and information management potential impediments. The final session was a plenary discussion to identify the next steps necessary to begin forming a statewide HAB alert network.

Following the summary presentations, the second and third sessions included breakout groups that outlined and examined current methods of toxin detection, species identification, and data management used in California. Participants agreed that method incompatibility was not a major impediment to establishing a statewide network, but that an intercalibration study to better assess methodological differences would significantly benefit the program design. Similarly, participants in the third session, the data sharing breakout group, concluded that there are no major impediments with respect to data structures or data storage. Notably, this group did identify concerns about data sharing, particularly as it affects loss of publication rights, but developed an approach to resolve this issue and indicated a willingness to share data as part of a statewide network.

The final session focused on assessing the interest among the HAB community in implementing a statewide alert network and discussing requisite next steps if such a system were desired. The community strongly agreed that there is a need for an integrated system and identified the many benefits to a variety of end users, including the participants and their respective organizations. The group agreed that the primary impediment to such a network is not technical, but the lack of a mandate for such a system to be designed and implemented. The group felt that the California Ocean Protection Council (OPC) would be the appropriate group to express such interest and that their interest should be assessed.

## Conclusions and Recommendations

There was widespread agreement among the participants that the development of an integrated statewide HAB alert network would be of value to both researchers and end user communities. The participants further determined that the impediments identified at the workshop were primarily organizational and motivational, rather than technical. Based on this conclusion, the workshop participants agreed that the following next steps should be implemented:

- The workshop participants should formalize their interaction by electing a steering committee and facilitator that would organize the group, implement the recommendations from the workshop, and centralize information from all groups in the state.
- A summary of the workshop and recommendations should be communicated to the OPC to gauge their interest in having a coordinated network and potentially funding the initial steps of developing the network.
- Initiate interaction tools, such as an e-mail list server, a website, and a summary of existing programs.
- Develop study plans and seek funding for an interlaboratory intercalibration study of toxin detection and species identification methods.
- Conduct a regional data pilot study building on one of the programs with a regional mission, such as the SCCOOS HAB pier program or the MERHAB Cal-PREeMPT program.

# WORKSHOP GOALS

California has a number of phytoplankton species capable of releasing toxins during periods of rapid growth, which are referred to as harmful algal blooms (HABs). From a management perspective, *Pseudo-nitzschia* and *Alexandrium* are species that raise the most concern. These species can produce the potent neurotoxins domoic acid and saxitoxin. While these toxins cause no direct harm to shellfish, the shellfish serve as vectors that transfer the toxins to humans. The State monitors toxin levels in shellfish and may close both commercial and recreational harvesting to avoid outbreaks of shellfish poisoning. Domoic acid poisoning can cause memory loss, brain damage and fatalities; saxitoxin poisoning can lead to numbness, respiratory failure and fatalities. Bioaccumulation of algal toxins through vector organisms (such as krill and filter feeding fish) in the food web has been linked to erratic behavior in birds and marine mammals, as well as marine animal mortality events. There are numerous research programs throughout California, as well as a few outside the state, that collect data on California HABs, most of which are not coordinated within the research community and focus on different aspects of HABs. For example, most of these programs do not formally collaborate with the California Department of Public Health, which is responsible for monitoring shellfish resources, closing commercial shellfish beds, and alerting the public via quarantines, health advisories and press releases when HAB events occur. Moreover, these programs employ a variety of collection and analysis methods, and it is unclear whether they provide compatible data for integration into a common data set. Furthermore, there is no system to facilitate the rapid exchange of information and data for event response, leading to underutilization of these data by resource managers such as animal rescue facility operators and shellfish managers.

To assess the feasibility of creating an integrated HAB alert network in California, the National Oceanic and Atmospheric Administration's Center for Sponsored Coastal Ocean Research and the California Ocean Science Trust sponsored a workshop involving regional experts (Appendix C). The workshop had three main goals:

- Facilitate information exchange among the California HAB community. The workshop was intended to identify the HAB-related research and monitoring programs in the State, including the focus, type, and extent of each program, such as the geographical regions studied, the temporal dynamics, the HAB species examined, and the multidisciplinary aspects.
- Identify the major impediments to synchronizing these data sets and integrating HAB programs into a coordinated statewide HAB alert network. There were two main classes of potential impediments evaluated: (1) compatibility of methods used to collect the data and (2) challenges in combining data into a common data set.
- Identify the next steps, necessary to forming a coordinated statewide HAB alert network.

The organizing committee intended the workshop to be the first in a series aimed at creating an integrated and coordinated HAB alert network in California.

# WORKSHOP STRUCTURE

The workshop was held at the Southern California Coastal Water Research Project (SCCWRP) offices in Costa Mesa, California on April 2 - 3, 2008. There were 42 invited participants representing the leading HAB researchers in California and a variety of interests, including: water quality management, shellfish management related to public health, animal rescue communities and universities and local agencies (Appendix A).

The workshop consisted of four sessions, the first of which was a plenary session to describe present HAB monitoring efforts within the State. Thirteen individuals presented summaries of ongoing programs within the State that measure marine HABs or the effects of HABs (Appendix B). Each presenter described program details, such as location of sampling, frequency of sampling, sampling methods, laboratory analytical methods, and the type of samples collected.

The second session involved two breakout groups that assessed the extent to which methodological differences among ongoing programs serve as an impediment to combining programs into a statewide network. The first breakout group discussed the methods currently employed for marine toxin detection. The second breakout group focused on methods used to measure phytoplankton species abundance.

The third session involved two breakout groups that discussed potential information management impediments to creating a statewide network. The first breakout group focused on data sharing with regard to data structure and data storage. The second breakout group focused on determining how the data could be disseminated to meet the needs of end user groups.

The final session was a plenary discussion to identify the next steps needed to form a statewide HAB alert network. The discussion focused on identifying major research needs, establishing forums to facilitate interactions among researchers, and continuing these information exchanges beyond the workshop.

# BREAKOUT SESSION SUMMARIES

## Toxin Detection

The overall goals of this breakout session were to determine whether the methods currently used to detect marine toxins are sufficiently compatible that they can be merged into a coordinated statewide network. The participants agreed that toxin methods incompatibility was not a major impediment to establishing a statewide network, but that an intercalibration study to better assess methodological differences would significantly benefit the program design.

The toxin detection session started with participants listing the methods that are presently used in California for toxin detection and quantification. Two classes of methods are presently being applied to measure five classes of toxins (Table 1). Analyte-based methods directly measure analytes and include High Performance Liquid Chromatography (HPLC) and Liquid Chromatography Mass Spectrometry methods (LCMS). Assay-based methods involve non specific measurement of constituents and include Enzyme Linked Immunosorbent Assay (ELISA), Receptor Binding Assay, Mouse Bioassay, and qualitative lateral flow immunoassays (Jellett Rapid Testing) methods. The Mouse Bioassay is the only method approved for use by regulatory agencies for identification of paralytic shellfish poisoning (PSP) toxins conducted in governmental agency laboratories. The HPLC method is the only approved regulatory method for detecting domoic acid in shellfish. The various methods in use, both regulatory and non-regulatory, measure substantially different end points and most are applicable to a wide array of toxins.

**Table 1. Marine toxins and analytical detection methods currently in use in California.**

| MARINE TOXINS | METHODS | | | | | |
|---|---|---|---|---|---|---|
| | Analyte-based | | Assay-based | | | |
| | HPLC | LCMS | Receptor Binding Assay | ELISA | Mouse Bioassay | Jellett Rapid Testing |
| Domoic Acid | X | X | X | X | | X |
| Paralytic Shellfish Toxins (especially Saxitoxin) | X | | X | X | X | X |
| Cyanotoxins (microcystins, anatoxins and cylindrospermopsins) | | X | | X | | |
| Okadaic Acid | | X | | | | |
| Yessotoxin | X | X | | X | | |

The discussion next focused on whether data produced by these methods are compatible enough to be integrated into a statewide network. Participants determined that the degree of method compatibility depends on the purpose for which the data would be used and identified three main uses of the data: (1) quick and reliable screening information, (2) shellfish closure decisions, and (3) spatial and temporal comparisons.

Both regulatory agencies and scientific researchers screen environmental samples initially to determine the presence of toxins. Small subsets of samples are screened using one of the less expensive assay methods, with the remaining samples analyzed with more costly analytical methods required for closure decisions should the screening be positive. This process reduces the cost of regulatory analysis and allows processing of a large number of samples from a spatially extensive area to provide information to rescue centers that respond to HAB events. The workshop participants determined that the methodological differences were not of concern for the screening application as most of the positive samples are analyzed using multiple methods to confirm the presence of toxins.

Workshop participants agreed that methodological differences were of substantial concern for the shellfish closure applications, spatial comparisons, and trend assessments. The data for the latter are used to assess the relative strength of blooms among areas in the State; trend assessments are used to determine whether the intensity of blooms are changing over time. There have been limited intercalibration studies to assess methodological differences as well as differences among investigators applying the same methods.

Participants concluded that the best way to resolve concerns about method differences affecting these applications was to conduct an interlaboratory intercalibration study. This study would determine the precision of these methods and compatibility among datasets in order to ultimately synchronize and combine data. While some small comparative studies have been conducted, the participants agreed there is a need for a more comprehensive intercalibration study of toxin detection methods. Additional issues to be addressed by this study are sample stability and matrix differences (water samples, shellfish tissue, sediments etc.). The interlaboratory intercalibration would assess the need for standardization to a smaller set of methods in establishing a statewide network and would allow development of a Quality Assurance Quality Control Plan template to guide any laboratory in minimum acceptable practices to ensure data validity and compatibility.

## Species Identification

The goal of this breakout session was to assess whether differences in methods used for quantifying cell abundance represented an impediment to combining these data into a statewide network. The participants agreed that methods incompatibility was not a major impediment to establishing a statewide network, but that an intercalibration study to better assess methodological differences would significantly benefit the program design.

Discussion in the species identification breakout group followed a similar pattern to that of the toxin identification group. The group first identified methods that are presently employed within the State, with four major classes of methods identified (Table 2). The microscopy class includes both traditional and electron microscopy. The second class was molecular methods, which cover a wide variety of both whole cell (viewing intact cells with a microscope) and homogenate applications. The participants broadened the discussion beyond species identification to include biomass and cell abundance indicators (which are a precursor to species identification). The next two classes of methods resulted from this discussion. The third class of methods was the flow cytometry methods, such as FlowCAM® and Imaging Flow Cytobot. The fourth class of methods was biomass indicators such as HPLC, chlorophyll detection, optical measurements, and remote sensing. As with the toxin methods, these cell abundance methods measure different aspects with regard to cells and provide different types of information.

**Table 2. Methods for species identification, cell abundance, and biomass indication.**

| Method Class | Information Type |
|---|---|
| **Microscopy** | |
| Traditional Microscopy | Qualitative and quantitative; absence/presence, percent composition, cells/L |
| Electron Microscopy | Absence/presence, percent composition |
| **Molecular** | |
| Whole Cell (fluorescence *in situ* hybridization) | Quantitative, absence/presence |
| Homogenate (sandwich hybridization, quantitative polymerase chain reaction) | Quantitative, absence/presence |
| **Flow Cytometry** | |
| FlowCAM® | Quantitative |
| Imaging Flow Cytobot | Quantitative |
| **Biomass** | |
| High Performance Liquid Chromatography | Phytoplankton |
| Chlorophyll Detection | Biomass indication |
| Optical Measurements | Biomass indication |
| Remote Sensing | Biomass indication, spatial extent |

The species identification breakout group identified specific ways that data could be used in a statewide network. The participants determined that there were three main purposes for which the data is used: (1) to provide quick and reliable screening information, (2) to evaluate long-term trends, and (3) to predict and forecast long-term trends.

The first application requires rapid, qualitative abundance estimates that cover a broad range of spatial areas that will determine the need for follow-up toxin sampling. As these data do not lead to regulatory decisions, participants agreed that numerous methods could be used interchangeably without data compatibility issues relevant to screening methods.

Workshop participants agreed that trend analysis and forecasts require improvements in accuracy, consistency, and coordination among species identification methods. The feeling was that previous studies to assess reliability and consistency among methods were too limited to determine which methods should be included in the design of a statewide program. Similar to the toxin breakout group, the species identification group determined that there is need for an interlaboratory intercalibration study to determine data compatibility. This calibration is needed both across the four different classes of methods and particularly among molecular methods.

## Data Sharing

The goals of this session were to identify potential impediments with regard to (1) the underlying data structures used by various researchers and (2) organizational issues that would interfere with data exchange. The participants concluded that there were no major technical impediments. Notably, the group did identify concerns about data sharing, particularly as it affects loss of publication rights, but developed an approach to resolve this issue, and all participants indicated a willingness to share data as part of a statewide network.

This breakout session began with a discussion of the types of data that would need to be shared and identification of a wide array of data that could be included in a statewide network, including: species abundance measurements, region-specific measurements, California Department of Public Health information, bird and mammal events, CTD measurements, chlorophyll *a*, nutrient concentrations, dissolved oxygen, mooring and pier sensor data, toxin data, vector species information (e.g., krill, sardines etc.), watershed (land-sea) data and proxies for emerging events (such as sea surface temperature, chlorophyll, wind and current data).

The discussion expanded to examine potential impediments for implementing a statewide system, such as whether participating organizations presently record the same fields, parameters, and units. The group also discussed data storage software and determined that there are no structural impediments; data is presently stored in spreadsheet form. Some small data structure issues were identified, but the group concluded that these issues are minor and could easily be resolved by a small committee.

Participants next addressed organizational hesitancy to share data based on competition among researchers for funding, publication rights, and recognition. Although the group acknowledged that release of data could have negative effects, several solutions were identified. The concept of a central data location with two portal interfaces to accommodate different user needs was decided to be the best mechanism. There would be a ‘front room’ designed for the general public and some management users and a ‘back room’ with restricted access for HAB researchers and managers who had agreed to respect the publication rights of the data originator. This would limit the data sharing to only those scientists in the network, as opposed to any scientists in the field obtaining data from an unrestricted website. Once this approach was established, no further impediments to implemention of a statewide HAB network were found.

## Data Dissemination

For this breakout session, the goal was to identify the types of data and information needed by end users and the best way to transmit data should a statewide HAB network be established. This group primarily consisted of end users who identified many data and information needs. As a group, the participants were enthusiastic about receiving data and information from a coordinated statewide HAB alert network.

The breakout session began by identifying the types of organizations that would be users of data if a statewide network was established (Table 3).

**Table 3. End user groups and informational needs.**

| End user Groups | Time Frame | Informational Needs |
|---|---|---|
| Public Health Sector | Near real-time | Qualitative, relative abundance |
| | Within 24 hours | Quantitative toxin concentration |
| Resource Managers | Near real-time | Marine mammal and bird effects |
| | Weekly basis | Trend and forecasting |
| Water Quality Regulators | Annual basis | Location, duration and trends of HAB events |
| General Public | Near real-time | Recreational, food safety and state of the environment |

The breakout group determined that most of these user groups need results on different time scales and with varying levels of certainty. From the list of identified user groups, participants focused on identifying the specific needs of four representative groups, the public health sector, resource managers, water quality regulators and the public. The public health sector requires near real-time information on species composition, relative abundance (e.g., whether *Pseudo-nitzschia* has increased since the last sampling period), and location. This information may be qualitative, as it will be primarily used to identify locations requiring more intensive, targeted sampling. On a slightly longer time-frame (~ 24 hours), quantitative toxin concentration are required to aid the public health sector decision making process, such as whether to close a shellfish bed. Resource managers, especially for marine mammals and birds, require similar real time information, but also need medium-term trend and forecasting information over a weekly basis. This information is particularly important for determining where and when to release protected species that have been rehabilitated from toxin exposure. Water quality regulatory agencies (such as those interested in the development of Total Maximum Daily Loads's, TMDL's, or determining whether waters should be listed under the 2002 Clean Water Act Section 303(d) program) require information regarding location, duration and trends of HAB events, but require them to be quantitative over longer time-scales. Finally, it was concluded the public are primarily interested in information on recreational, food safety, and state of the environment issues. Communication of this information would require dissemination through multiple outlets, including: the web, press releases, the media, and multilingual community bulletins, depending on the time frame that information is needed.

Based on these needs, the breakout session members identified three ideal characteristics of a statewide system. First, real time alerts would be disseminated in the short-term via an email list serve or distribution list. Second, medium-term reports or "thencasts", would be comprised of spatially referenced data and information on HAB events from the previous day or week and include forecasts of bloom conditions. Third, long-term analyses on HAB events and ecosystem health would be released yearly.

# NEXT STEPS FOR IMPLEMENTING A STATEWIDE HABS ALERT NETWORK

The final session was focused on assessing the interest among the HAB community in implementing a statewide alert network, determining research needs and the next steps necessary if such a system was desired. The community strongly agreed that there was a need for an integrated and coordinated system and that such a system would facilitate more HAB research. The discussion shifted towards identifying next steps needed to implement a statewide network.

The workshop participants identified many benefits to a coordinated statewide network for HABs. First, a HAB network could provide improved and coordinated monitoring of species abundance and toxin concentrations for many matrices (plankton, shellfish, fish etc.), which would increase timely public health warnings as well as increase the efficiency and decrease the cost of sampling by the Department of Public Health. Second, trend analysis for multiple years would assist in regulator decisions, particularly 303(d) and TMDLs, by determining if HAB events are increasing, decreasing or remaining consistent over time. Third, the network would educate the public thereby preventing unnecessary tourism concerns. Participants identified the network in Florida as exemplifying this benefit, by directing tourists to unaffected areas and educating the general public in order to reduce unwarranted fears and reduce the loss of tourist revenue. Fourth, it would provide increased protection for marine resources by improving the efficiency of marine mammal and bird rescue efforts, preventing aquariums from using contaminated seawater and increasing favorable location of aquaculture facilities. Fifth, the network would increase the quality of long-term research data since the academic researchers, monitoring agencies and nongovernmental organizations will be coordinated. The coordination and cooperation of these three sectors will help to create models for prediction, to assess long-term ecosystem health, effects on marine organisms and whether blooms are natural occurrences or whether cultural eutrophication and/or storm water have impacted the frequency and duration of blooms. By forecasting and predicting blooms, state, county and local agencies would sample more strategically, trends would be identified more readily, the protection of wildlife and marine resources would be improved, loss of tourism revenues would be minimized and research focused on causes, effects and trends would be more robust and lead to more efficient management of resources in the state.

Next, the group agreed that that there are no major technical impediments to implementing a coordinated system in California. They identified that the primary impediment is the lack of a specific mandate for such a system to be designed and implemented. While there are numerous benefits of a coordinated statewide system, no organization is demanding this network be created in California. The group agreed that the California Ocean Protection Council (OPC) would be the appropriate group to express such interest and that their interest should be assessed.

The group determined that there were several steps that should be taken immediately to maintain the momentum for interaction and data sharing that was begun at the meeting. The first several were organizational, including establishing a steering committee, a facilitator to lead that committee and name for the entity. Three organizations were suggested as candidates to facilitate the network: the Ocean Observing systems, the Ocean Science Trust and the Southern California Coastal Water Research Project. Participants agreed to vote on steering committee members, facilitating organization and name for the network, with Russ Moll agreeing to tally the votes.

The participants next identified some low cost tools that could be initiated to facilitate communication exchange, such as an e-mail list server to email current species and toxin information and construction of a website that identifies programs that are collecting data throughout the state.

The workshop participants also agreed on three additional steps that were desirable but would require funding: (1) design and implement an intercalibration study for toxin detection and species identification, (2) convene a workshop to design the statewide network, and (3) apply the agreed upon design to create an integrated statewide network for HAB data and information exchange.

# WORKSHOP CONCLUSIONS AND RECOMMENDATIONS

There was widespread agreement among the participants that the development of an integrated statewide HAB alert network would be of value to both researchers and end user communities. The participants further determined that the impediments identified at the workshop were primarily organizational and motivational, rather than technical. Based on this conclusion, the workshop participants agreed that the following next steps should be implemented:

- The workshop participants should formalize their interaction by electing a steering committee and facilitator that would organize the group, implement the recommendations from the workshop, write a workshop report and centralize information from all groups in the state.
- A summary of the workshop and recommendations should be communicated to the OPC to gauge their interest in having a coordinated network and potentially funding the initial steps in developing the network.
- Initiate interaction tools, such as an e-mail list server, a website, and a summary of existing programs.
- Develop study plans and seek funding for an interlaboratory intercalibration study of toxin detection and species identification methods.
- Conduct a regional data pilot study building on one of the programs with a regional mission, such as the SCCOOS HAB pier program or the Cal-PREeMPT program.

# APPENDIX A. WORKSHOP AGENDA

<u>*Wednesday, April 2*</u>

8:30 - 8:45 Introductions and goals of the workshop (Steve Weisberg)

- Welcome from meeting co-sponsors:
  - Marc Suddleson, NOAA
  - Amber Mace, California Ocean Science Trust

8:45 - 12:00 HAB researcher presentations on existing programs in CA

Detecting HAB Species and Toxins Along California's Central Coast
*Peter Miller*
Time-Series Monitoring of Pseudo-nitzschia spp. and Domoic Acid in Southern Monterey Bay: Methods, Patterns and Archival Resources
*G. Jason Smith*
Collaborative HAB Research and Toxicity on the San Pedro Shelf
*David Caron*
Scripps Pier Chlorophyll and HAB Time Series
*Melissa Carter*
Observations and Sampling of Harmful Algal Species along the Central Coast of California
*Mark Moline*
The Who and How of HAB Research in the Santa Barbara Channel
*Clarissa Anderson*
Abiotic Controls of Potentially Harmful Algal Blooms in Santa Monica Bay, California
*Rebecca Shipe*
Observations of HAB Species and Domoic Acid Using Environmental Sample Processor
*Chris Scholin*
Persistence of the Marine Biotoxin Domoic Acid at Depth in the Santa Barbara Basin, CA
*Claudia Benitez-Nelson*
Detecting Domoic Acid in Marine Food Web
*Wayne Litaker*
Effects of Domoic Acid on California Sea Lions
*Frances M.D. Gulland*
Proposal National System of Operational Harmful Algal Bloom Forecasts
*Richard Stumpf*
Marine Biotoxin Monitoring in California for Public Health Protection
*Gregg Langlois*

12:00 - 1:00 ***Lunch on site***

1:00 - 1:15 Charge to breakout groups (Weisberg)

1:15 - 4:00 Simultaneous breakout sessions on methods synchronization:

- Species Identification (Moderator: Peter Miller)
  - Consistency of results from traditional microscopy and molecular methods
- Toxin Detection (Moderator: Dave Caron)
  - Various approaches and potential intercalibration needs

4:00 - 5:00 Groups reconvene; session moderators summarize discussion/conclusions

6:00 ***Group Dinner - Location TBD***

*Thursday, April 3*

| | |
|---|---|
| 8:30 - 8:45 | Summary of previous day; Charge to Breakout groups (Weisberg) |
| 8:45 - 12:00 | Simultaneous breakout sessions on data exchange:<br>➢ Data Sharing (Moderator: Dave Caron)<br>• Identify types of data and existing data sets<br>• Discuss barriers to combining data sets<br>➢ Data Dissemination Strategy (Moderator: David Kidwell)<br>• Define a mechanism for dissemination of information on HABs on a regular basis and during events (towards an alert network)<br>• Discuss needs of the user community |
| 12:00 - 1:00 | ***Lunch on site*** |
| 1:00 - 2:30 | Groups reconvene; session moderators summarize discussion and conclusions |
| 2:30 - 3:00 | ***Break*** |
| 3:00 - 4:30 | Planning the next steps to achieve an integrated CA event response network (Moderator: Steve Weisberg)<br>• Research priorities<br>• Need/objectives of subsequent workshops |
| 4:30 | Adjourn |

# APPENDIX B.  PRESENTATION SUMMARIES

## Detecting HAB Species and Toxins Along California's Central Coast

Peter Miller, Raphael Kudela and Mary Silver
*University of California, Santa Cruz*

In Monterey Bay, we have been monitoring toxic *Pseudo-nitzschia australis* and *P. multiseries,* as well as associated DA, continuously since 10/99 using species-specific molecular probes on water samples from the Santa Cruz Wharf. Average abundance of toxic cells dropped over an order of magnitude since 6/04, but one bloom event has occurred each spring since then, with associated DA. We have also have monitored *Alexandrium catanella* from the same site since 6/00, also using species-specific probes; its average abundance appears to have increased when toxic *Pseudo-nitzschia* declined, and blooms have become more frequent: the 6/04 switch coincided with an entire phytoplankton community shift. We also have >5 years of STX data from water at the wharf. Furthermore we recently found diarrhetic shellfish poison in mussels at the wharf, which is associated with several *Dinophysis* species, though the toxins are below danger level.

We have found DA and STX in pelagic and benthic organisms in Monterey Bay, including herbivores and carnivores. Benthic species are more persistently contaminated, whereas pelagic species usually have toxin only during a bloom. DA was found in anchovies and sardines, flatfish, blue and humpback whales, multiple pinniped species, and krill. Benthic species with DA included the innkeeper worm, flatfish, and *Cancer* spp. crabs. STX contaminated clupeiods and flatfish.

We are working in partnership with the California Department of Public Health (Gregg Langlois) on a MERHAB-funded effort to implement an economically sustainable harmful algal bloom monitoring plan for the California coastline that exceeds current capabilities of the CDPH. We have established pilot project field sites in Marin County, Monterey Bay, and Avila Beach where new technologies for rapid toxin and species detection and bloom tracking are incorporated into an intensive monitoring program, in combination with a tiered decision-making protocol that dictates specific steps to take in response to field observations. We collect samples as frequently as three times per week (Avila Beach site) and analyze them in the field for HAB species using field scopes, in addition to sending samples to the CDPH and UCSC labs for analysis by compound microscopy and by species-specific molecular probes. When cell abundances detected in the field indicate the density of HAB species may sufficient to pose a threat, samples of shellfish tissue are analyzed in the field using Jellett kits for DA and saxitoxin detection. The power of this approach is that it paves the way for ultimately shifting much of the monitoring effort to the field, where a network of volunteers, with overall guidance from the CDPH, prescreen samples, thus ensuring early warning of impending blooms while avoiding un-necessary and expensive lab-based sample testing. Using the best available remote sensing data in conjunction with field data provided by the volunteer force will enable tracking the inception, proliferation, advection and decline of bloom events in real-time along the California coast. In turn, this provides managers necessary information to make informed decisions on when and where to direct the field force to increase their efforts.

**Time-Series Monitoring of *Pseudo-nitzschia* spp. and Domoic Acid in Southern Monterey Bay: Methods, Patterns and Archival Resources**

G. Jason Smith

*Moss Landing Marine Laboratories*

Our lab group's HA efforts are based on an interest is unraveling the molecular and physiological processes contributing to production of phycotoxins. This 'inward-outward' approach offers the promise of identification of novel markers for active toxin production by HA species, tools which might enhance efficiency of monitoring efforts and of course, provide insight as to why these diverse microorganisms produce such potent toxins in the first place. As means to support these laboratory based discovery efforts and place results in a real world context, our lab moved from an event-response sampling scheme and established a weekly monitoring program which has been in operation since May 2003 off of the Monterey Wharf (MWII; 36.50.993N, 121.49.970W) in the southern cusp of Monterey Bay, CA. In addition to providing a source of fresh species isolates, this monitoring program has been focused on the assessment of temporal variability in *Pseudo-nitzschia* community dynamics and domoic acid (DA) toxicity.

Station location was selected on a convenience basis (on the way to work) to minimize transport costs and time. Sampling conducted at least every 7 days between 0900 and 1000 PST. Briefly we use vertical net hauls (nominal mesh size = 20 μm) to obtain an integrated 0 - 5 m sample of the surface community. Each sample is comprised of two hauls and a second sample is taken 5-10 m from the first. Water samples are transported back to the lab in coolers at ambient seawater temperatures and processed within 1 hour of collection. Water is partitioned into (1) formalin fixed aliquots for microscopic enumeration of cell abundance, (2) frozen whole water for nutrients or total toxin load, (3) In vivo chlorophyll fluorescence and turbidity using an Aquafluor, (4) GF/F filtered for subsequent pigment analysis (5) polycarbonate filters extracted and stored in 80% MeOH for analysis of particulate domoic acid and free amino acid content and (6) polycarbonate filters extracted and stored in TriZol reagent for isolation of particulate DNA and RNA for molecular analysis. Although the student project-based focus is on a single genus, our sample archives should support hindcast studies of other HA or phytoplankton taxa from this region.

As expected from the upwelling dominated production cycles in this region development of *Pseudo-nitzschia* communities >1000 cells $L^{-1}$ is restricted to the March – October. Inter-annual variation is significant and revealed by comparison of cumulative cell abundance and DA loads. DA accumulation varied by >20 fold from 2003 through 2006 associated with a shift to a dinoflagellate dominated community. Both early (Mar. - Apr.) and late season (Jul. - Sep.) spikes is DA accumulation are observed with no obvious environmental signal associated with these events. The utility of our nucleic acid time series will be highlighted by discussion of two applications developed in our lab. A set of QPCR assays using *Pseudo-nitzschia* species specific rDNA-ITS primers can be used to assess influence of community composition on bloom toxicity and progress towards development of gene expression assays for identification of actively toxic *P. australis* isolates will be reviewed.

**Collaborative HAB Research and Toxicity on the San Pedro Shelf**

David A. Caron

*University of Southern California*

Awareness of the occurrence of harmful algal blooms along the coastline of the greater Los Angeles area of the Southern California Bight has increased dramatically in recent years. Our lab participates in a number of highly collaborative projects that focus on HAB issues within this region, and particularly on research involving the diatom genus *Pseudo-nitzschia* and the production of the neurotoxin, domoic acid. The overall goals of our research programs are to understand the timing, geographical distributions and types of harmful blooms, the environmental forcing factors leading to toxic blooms and toxin production, and to link harmful/toxic events with impacts on populations of marine animals and potential threats to human health. These studies have demonstrated some of the highest concentrations of domoic acid recorded from natural coastal ecosystems (up to approximately 25 $\mu g\ L^{-1}$), particularly in the area of the San Pedro/Long Beach harbor area, and have helped link these events to massive poisoning events of marine animal populations along the coast. This information has assisted several marine animal care centers within the regions that are responsible for responding to seabird and marine mammal strandings. Support from NOAA (MERHAB), EPA (STAR: EcoHAB) and USC Sea Grant has allowed documentation of the spatial and temporal extent of these harmful incidents. Our studies have entailed ship-based and pier-based sampling to enable the collection of samples for physical and chemical parameters, phytoplankton taxonomic composition and toxin measurements. An environmental sensor network has been deployed in King Harbor of the City of Redondo Beach to monitor water quality and study harmful algal blooms that have caused fish kills in the harbor. The latter study has been supported by an NSF Science and Technology Center grant (Center for Embedded Networked Sensing). Collaborative entities for our work include the CA Department of Public Health, the Southern California Coastal Ocean Observing System, the Southern California Coastal Water Research Project, the Southern California Marine Institute, the LAC Sanitation District, the OC Sanitation District, the Wrigley Institute for Environmental Studies of USC, the Fort McArthur Marine Mammal Care Center (San Pedro), the Pacific Marine Mammal Center (Laguna Beach), the National History Museum, Section of Mammalogy (Los Angeles), the International Bird Rescue Research Center (San Pedro), Wetlands and Wildlife Care Center (Huntington Beach), the Whale Rescue Team(South Bay), and numerous universities within the state.

## **Scripps Pier Chlorophyll and HAB Time Series**

John McGowan and Melissa Carter

*University of California, San Diego – Scripps Institution of Oceanography*

We have measured chlorophyll concentration, temperature, salinity, and nutrients from the surface water off Scripps Pier twice a week since 1983. Qualitative phytoplankton community composition and enumeration of potentially harmful algal cells (*Alexandrium spp., Dinophysis spp., Gymnodiniumspp. , Lingulodinium polyedrum, Prorocentrum spp.*, and *Pseudo-nitzschia spp.* were also conducted using light microscopy on a weekly basis since 2005. We measured the abundance of toxic *Pseudonitzschia* species using molecular probes at times where the genus *Pseudo-nitzschia* showed high abundances. We also coordinated our sampling efforts with the phytoplankton and mussel volunteer program of the California Department of Public Health (CDPH). Mussels (primarily *Mytilus californianus*, occasionally *M. edulis*) were collected locally and incubated off the Scripps Pier for 1-2 weeks before harvesting. On a weekly basis we sent mussel tissue and phytoplankton samples to CDPH for algal toxin measurements, and the results from these samples are published in the Monthly Biotoxin Report from CDPH.

Our long term measurements at Scripps Pier provide us with the unique opportunity to calculate a long-term mean and standard deviation for chlorophyll and nutrient concentrations. Using these parameters we can quantitatively define what is meant by “bloom” and compare our variations with available cell counts by Allen 1930 to 1939. We can estimate the frequency of blooms observed at Scripps Pier, but a more rigorous definition of the word is needed. There has been a long-term upward trend for an increase in the chlorophyll concentration, but neither this trend nor the interannual variations are well correlated with temperature anomalies, coastal upwelling indices, or Pacific Decadal Oscillation (PDO). Some of the El Nino (La Nina) events show high (low) SST anomalies and low (high) chlorophyll that are correlated, but not all of the time. In general, there is10x more chlorophyll at the pier than in the main body of the California Current. There is a steep offshore gradient in chlorophyll concentration, but variations are coherent to at least 11.5 km.

Comparing our cell counts to those taken by W.E. Allen in 1930-39 indicate there has been a switch from the diatom dominance of the flora to dinoflagellate dominance. We are also seeing dinoflagellate genera, *Cochlodinium spp.* and *Alexandrium spp*., on a yearly basis at Scripps Pier, which are rarely documented for this area. Blooms of *L. polyedrum* appear to be more persistent and low concentrations of yessotoxin were measured during the 2005 bloom. Domoic acid has also been documented in fish and mussel tissue samples from the San Diego area.

Further information on these programs can be found on the Southern California Coastal Ocean Observing System website: http://www.sccoos.org/data/chlorophyll/?page=intro.

**Observations and Sampling of Harmful Algal Species along the Central Coast of California**

Mark Moline

*California Polytechnic State University (Cal Poly), San Luis Obispo – Center for Marine Sciences*

Observations of harmful algae species along the central coast of California have been sporadic despite the evidence that the area is frequently impacted by exceptionally high concentrations of toxic species. Although the State of California has integrated monitoring domoic acid, the link to the algal speciation in the local waters is often lacking. With the acquisition of the Cal Poly Pier in 2003, direct access to a sampling location offshore has increased the amount of phytoplankton sampling. This includes student projects, Cal-PReEMPT, HAB-TrAC, targeted sampling for genetic analysis of population structure, and a recent effort to obtain long term record of relatively high frequency phytoplankton community fluctuations in the area. Targeted species in these studies include *Pseudo-Nitzschia spp., Lingulodinium polyedra, Alexandrium* sp., *Prorocentrum* spp., *Cochlodinium* spp.; *Heterosigma* spp., and *Dinophysis* spp. Examples of these datasets illustrate that the central coast of California frequently experience high concentrations of both toxin producing algae and related toxins. A plan to integrate expertise sampling along the California coast is underway, which will provide a more comprehensive regional picture of algal dynamics, the potential causes for HAB events, and the impact this knowledge can have on the local communities in the area.

## The Who and How of HAB Research in the Santa Barbara Channel

Clarissa Anderson[1], Mark Brzezinski[2], Nathalie Guillocheau[2], Raphael Kudela[3], David Siegel[2] and Libe Washburn[2]

[1]*NOAA-University of Maryland*
[2]*University of California, Santa Barbara*
[3]*University of California, Santa Cruz*

Two programs at the University of California, Santa Barbara have provided much of the infrastructure for gathering and assimilating data on *Pseudo-nitzschia* blooms in the Santa Barbara Channel (SBC); these are the NASA supported Plumes and Blooms project headed by Dr. David Siegel and the Santa Barbara Coastal- Long Term Ecological Research Project, now in its second term as part of the NSF-funded LTER network. To date, this work has not been funded by ECOHAB but does help fill in some of the regional pieces of the larger CA puzzle on HABs. Data include cell abundance (inverted light microscopy, some SEM) and domoic acid concentrations (HPLC, some ELISA) from both synoptic, seasonal LTER cruises (most comprehensive from May 2003) as well as monthly Plumes and Blooms cruises across a 7-station transect in the middle of the channel that overlaps the SBC CALCOFI station. For all of these samples, there are concurrent environmental measurements covering the standard range of biological, chemical, physical, and optical (IOPs, AOPs) parameters. Chlorophyll concentrations are available from both fluorometry and HPLC for all cruises. The majority of the *Pseudo-nitzschia* spp. counts and domoic acid data are stored in Excel and Matlab files and are currently not in the public domain. Hydrographic and optical data from monthly Plumes and Blooms cruises can be accessed through queries on the project website (http://www.icess.ucsb.edu/PnB/PnB.html). Analysis of *Pseudo-nitzschia* bloom dynamics has included investigation of the large May 2003 DA event and a statistical modeling study using the Plumes and Blooms HAB time series of surface data (Nov. 2004 – Jun. 2006). Complementing this work, optical detection and mooring measurements of HAB related parameters have been studied by Grace Chang and Erika McPhee-Shaw in collaboration with Tommy Dickey. Future plans in the SBC focus on the flux of *Pseudo-nitzschia* blooms and DA from surface to deep waters as well as sediments in both the nearshore and anoxic portions of the SBC (in collaboration with Claudia Benitez-Nelson & Robert Thunell).

**Abiotic Controls of Potentially Harmful Algal Blooms in Santa Monica Bay, California**

Rebecca F. Shipe, Anita Leinweber and Nicolas Gruber

*University of California, Los Angeles - Department of Ecology and Evolutionary Biology*

Physico-chemical conditions contributing to the growth of potentially harmful bloom taxa are assessed through twice monthly measurements in the upper 50 m over three annual cycles (2004 - 2006) in the Santa Monica Bay, California. Potentially harmful taxa were present in every surface sample and were numerically dominant during the largest observed blooms, contributing up to 92% of the total phytoplankton abundance >5 μm. Large interannual variation was observed in the dominant taxa and bloom seasonality; *Pseudo-nitzschia sp.* dominated blooms in early 2004 (February and April), whereas *Prorocentrum micans* blooms occurred in May of 2005 and 2006 and *Lingulodinium polyedrum* blooms in September of 2005. The *Pseudo-nitzschia sp.* blooms were associated with elevated nitrate, dissolved silicon and phosphate concentrations throughout the euphotic zone; the first bloom followed a strong upwelling and the second occurred during the onset of seasonal stratification. In contrast, the blooms of *P. micans* were associated with highly stratified, low nutrient waters. Multivariate analysis supports the roles of temperature, mixed layer depth and nutrient concentrations as primary controls of bloom growth. The strong presence of potentially harmful bloom species in the Santa Monica Bay during this study appears unusual in comparison to limited studies over the last several decades.

**Observations of HAB Species and Domoic Acid Using the Environmental Sample Processor**

Chris Scholin

*Monterey Bay Aquarium Research Institute (MBARI)*

The advent of ocean observatories is creating unique opportunities for deploying novel sensor systems. Members of the Scholin lab and their collaborators are exploring that potential through the development of the Environmental Sample Processor (ESP; http://www.mbari.org/esp). The instrument is an electromechanical/fluidic system designed to collect discrete water samples, concentrate microorganisms or particles, and automate application of molecular probe technologies (e.g., Greenfield et al. 2006[1], Roman et al. 2007[2], Jones et al. 2007[3]). Near realtime observations are achieved using low density DNA probe and protein arrays. Filter-based sandwich hybridization methodology enables direct detection of ribosomal RNA sequences indicative of groups of Bacteria and Archaea, as well as a variety of invertebrates and harmful algal species. An antibody-based technique is used for detecting domoic acid, an algal toxin. To date the ESP has been deployed in ocean waters from near surface to 1000 m. Shallow water deployments have emphasized application of assays for all targets noted above in a single deployment for durations up to 30 days. Deep-water applications have focused on detection of Bacteria and Archaea in the water column as well as invertebrates associated with cold seeps and whale falls, with operations lasting several days. Current work emphasizes new methods for printing moderate density probe arrays for use with the ESP, direct detection of mRNA (i.e., without purification or amplification), development of a microfluidic stage for supporting a reusable nucleic acid solid phase extraction column and 4-channel real-time PCR module, extending operations to 4000m depth and increasing deployment duration. Animations showing operation of the instrument in surface water (http://www.mbari.org/ESP/espworks.htm - no audio) and a vision for how it may be applied in the future (http://www.mbari.org/ESP/espdeepmovie.htm - with audio) are served on the ESP web site, as is example data from recent deployments. An example of time series measurements showing detection of a variety of harmful algae found in Monterey Bay and changes in their abundance over time can be viewed at: http://www.mbari.org/ESP/field_data/2007/HAB_2007.htm. A graphical user interface for the instrument and means of displaying data for researchers and resource managers is in the early stages of development. Three copies of the ESP are operational now, and at least two additional units will be built later this year (2008). Field operations for 2008 include 3 months of continuous surface water operation at station M0 in Monterey Bay (see http://cimt.ucsc.edu/) beginning April, including 1 month with 2 ESPs fielded simultaneously in June. These deployments will include arrays for bacterioplankton, invertebrates, harmful algae and domoic acid. By September the team hopes to field the ESP fitted with the PCR module. In November and December, that same unit will be tested for use in deep-waters (up to 1000 m) in preparation for field trials at Axial Seamount hydrothermal vent field in '09 or later.

[1] Greenfield, D.I., et al. *Limnology and Oceanography: Methods* **4**: 426-435.
[2] Jones, W.J., et al. 2007. *Molecular Ecology Notes* (avail on-line).
[3] Roman, B., et al. 2007. *Journal of American Laboratory Automation* 12: 56-61.

**Persistence of the Marine Biotoxin Domoic Acid at Depth in the Santa Barbara Basin, California**

C.R. Benitez-Nelson[1], E. Sekula[1], A. Schnetzer[2], D. Caron[2], C. Anderson[3], R. Thunell[1], S. Morton[4], J. Gully[5], J. Burns[6] and J. Ferry[6]

[1]*Department of Geological Sciences, University of South Carolina*
[2]*Department of Biological Sciences, University of Southern California, Los Angeles*
[3]*Earth System Science Interdisciplinary Center/Cooperative Institute for Climate Studies, University of Maryland*
[4]*Center for Coastal Environmental Health and Biomolecular Research, NOAA NCCOS*
[5]*Ocean Monitoring and Research, Los Angeles County Sanitation Districts*
[6]*Department of Chemistry and Biochemistry, University of South Carolina*

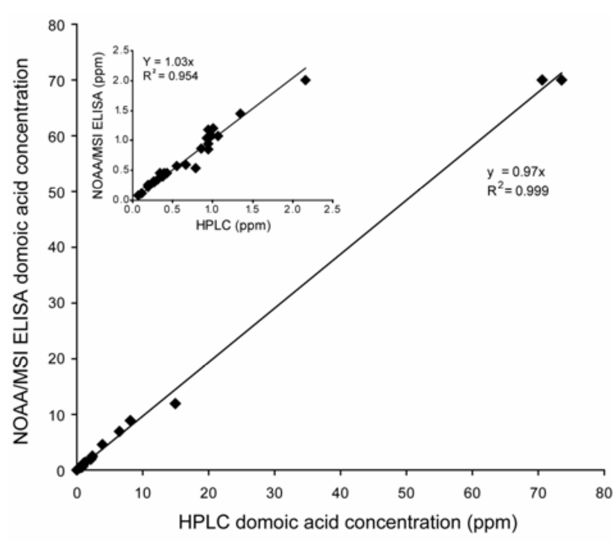
Toxic blooms of a variety of algal species (harmful algal blooms (HABs)) have been documented throughout the world's coastal oceans, ultimately impacting shellfish, finfish, marine mammals and birds over large areas. Several species within the genus of *Pseudo-nitzschia*, a group of marine diatoms, produce the neurotoxin domoic acid (DA), and have been identified as common members of algal assemblages along the coast of California. Most *Pseudo-nitzschia* research has focused on the upper water column in near-shore environments. However, recent, albeit limited, evidence suggests that live cells containing toxin rapidly sink to the ocean floor (>800 m) and can even survive entrainment into underlying sediments. These cells may potentially act as seed populations for future blooms or as a source of DA poisoning in filter and deposit feeding benthic communities. As such, there may be long lasting effects associated with DA that persist well after the demise of a toxic *Pseudo-nitzschia* bloom. Here, we examine the vertical flux of DA and *Pseudo-nitzschia* in bimonthly sediment trap samples collected from 2002 to 2007 at 550-m depth in the center of Santa Barbara Basin (SBB) as well as in underlying and coastal sediments. Trap solutions and particulate matter were determined using both ELISA and LCMS and the methods agreed to within 14 - 29%. Sediment trap DA concentrations range from below detection (7 ppb by LCMS) to as high as 35.6 ppm in dried sediment trap material, with high DA concentrations coinciding with known coastal shellfish toxin events or with simultaneous measurements of high DA concentrations in overlying surface waters. DA fluxes typically range from 0.02 to 2.5 μg DA $m^{-2}$ $d^{-1}$, although three extremely high flux events exceeding 200 μg DA $m^{-2}$ $d^{-1}$ were also documented. Scanning electron micrographs during these DA peaks confirm the presence of well-preserved *P. australis*, a DA producing diatom commonly linked to toxic events along the West Coast. In an anoxic sediment core collected from 2005 beneath the trap site (total depth 600 m), we measure DA concentrations of 0.17 ppm in dried sediment from the top 0.25 cm. DA exponentially decreases downcore and is undetectable by 1.5 cm. We are currently in the process of analyzing substantially shallower oxic cores off the California coast to determine how DA preservation varies with water column depth and oxygen level. Combined, our results suggest that significant DA reaches the deepest part of SBB and is incorporated into sediments. Given the exponential decrease in sinking particulate matter with depth in the water column, our results suggest that substantial DA likely reaches shallower sediments as well, thus having serious implications for benthic community health and the possible release of DA back into overlying waters during bottom-water disturbances.

**Detecting Domoic Acid in Marine Food Web**

Wayne Litaker and Pat Tester

*National Ocean Service*

Domoic acid (DA) is a potent toxin produced by bloom-forming phytoplankton in the genus *Pseudo-nitzschia*. DA, is a glutamate analog which acts as a potent excitatory neurotransmitter causing amnesic shellfish poisoning (ASP) in humans. Symptoms include included vomiting, diarrhea, and in more severe cases confusion, loss of memory, disorientation and even coma or death. NOAA scientists in conjunction with Mercury Scientific have developed a rapid sensitive enzyme linked immunosorbent assay (ELISA) for detection of domoic acid. The assay for is a standard competitions monoclonal antibody. Free DA in the sample competes directly with a DA–horseradish peroxidase (HRP) conjugate for a fixed number an anti-domoic acid monoclonal antibody binding sites. The assay is optimized so that the amount of both the monoclonal antibody and the domoic acid – HRP conjugates produce a maximal signal (Bo) signal at approximately 3 ppb in the absence of any free DA. The lower detection limit of detection is 0.1 ppb. A 1:25 dilution was sufficient to eliminate any matrix affects that would inhibit the assay in all the samples tested. Results can be obtained within 1.5 h following the completion of the tissue or cell extraction step. The internal controls used in this assay make it unnecessary to run a standard curve each time the assay is performed. This feature in conjunction with removable well strips means that as few as 3 or as many as 36 duplicate samples can be run at a time. This makes the assay cost-effective relative to whole or half plate assays which utilize standard curves. The assay has been used successfully to quantitatively measure domoic acid in razor clams, mussels, scallops, phytoplankton, whales and porpoises. The underlying principles and application of the assay will be presented. This accurate, rapid, cost-effective, assay offers environmental managers and public health officials an effective tool for monitoring DA concentrations in environment samples.




Domoic acid concentrations in razor clam tissues determined from replicate tissue extracts analyzed using HPLC and NOAA/Mercury Science (NOAA/MSI) ELISA. The insert shows an expanded version of the regression analysis for tissue sample containing less than 2.5 ppm domoic acid.

**Effects of Domoic Acid on California Sea Lions**

Frances M.D. Gulland

*The Marine Mammal Center*

Domoic acid toxicosis was first identified in California sea lions in 1998. Since then, sea lions showing a variety of neurological signs have stranded in California, and efforts have focused on identifying the role domoic acid exposure may play in more subtle chronic disease pathogenesis. Sea lions found ill along the California coast between San Luis Obispo and Humboldt Counties were taken to The Marine Mammal Center in Sausalito, CA for treatment. Examination of 715 sea lions with neurological signs between 1998 and 2006 revealed two separate clinical syndromes: acute domoic acid toxicosis as documented by Scholin *et al.* (2000) and Gulland *et al.* (2002) ($n$ = 551); and a novel chronic epileptic syndrome characterized by behavioral changes, seizures and atrophy of the hippocampal formation ($n$ = 164). Acute cases were characterized ataxia and seizures that varied in severity, lasting about one week followed by recovery if treated, or death; they stranded in clusters and had histopathological findings that included hippocampal neuronal necrosis. Chronic neurologic cases were characterized by animals that developed intermittent seizures (suffering from seizures at least two weeks apart and/or seizures after at least two weeks following admission) but were asymptomatic between seizures, exhibited unusual behaviors such as wandering inland or swimming in tight circles, had periods of central blindness, stranded individually and duration of clinical signs from initial presentation to death varied from 25 to 1,525 days. EEGs were abnormal, showing numerous epileptiform discharges. MRI showed varying degrees of hippocampal atrophy and lesions were unilateral in 24 cases (left 11, right 13) and bilateral in 17 cases. Histologic examination revealed chronic lesions affecting first the hippocampal formation and then the parahippocampal gyrus. Sixty-eight cases had atrophy of the parenchyma due to neuronal loss and astrocytosis, which in 12 cases was confounded by active neuronal necrosis. The dentate gyrus and sector CA3 were affected most consistently and severely and could be affected independently of each other. When possible, samples were collected within 24 hours of admission from animals upon admission for domoic acid testing. Domoic acid was detected in 54% (60/112) of samples collected from 80 of the 551 acute cases and from only 5 of 31 samples submitted from cases with chronic neurologic sequellae. Twenty of these 80 acute animals that tested positive went on to develop neurologic sequellae typical of chronic cases. The number of acute cases fluctuated each year and did not show an overall increasing trend, whereas the number of chronic cases increased significantly each year. Five clusters of acute domoic acid related stranding events were identified, one in the spring of 1998, while the other four occurred in the mid to late summer of 2000, 2001, 2002 and 2005. The 1998 event was centered in Monterey Bay, while the other four were all centered off the coast of San Luis Obispo and Santa Barbara counties. In contrast to the acute stranding events, chronic neurological cases stranded individually in varied locations, both inland and along the coast, throughout the year following an acute event and the number of these cases increased each year from four in the year following the 1998 event to 45 in year following the 2005 event.

Although the history of exposure to domoic acid in individual wild sea lions is mostly unknown, this study demonstrates that impacts of domoic acid on California sea lions are increasing and that effects can be more subtle than death, such as epilepsy and severe behavioral changes. Atrophy of the hippocampal formation and parahippocampal gyrus results from a combination of neuronal loss and astrocytosis and may be a result of the initial toxic insult and the progressive and cumulative effects from seizure propagation.

**Proposal National System of Operational Harmful Algal Bloom Forecasts**

Richard P. Stumpf

*National Oceanic and Atmospheric Administration (NOAA)*

The Harmful Algal Bloom Forecast System (HAB-FS) is an operational system intended to provide advance warning of harmful algal blooms (HABs) with the goal of reducing the impact by increasing the options for managers in responding to these events. The HAB-FS is viewed by NOAA as a national system of regional operational forecasts that are developed through collaboration with state, regional, local, tribal, and federal partners. This system would include the currently operational eastern Gulf of Mexico forecast system, as well as the western Gulf of Mexico, the lower Great Lakes, the Gulf of Maine, California, the Pacific Northwest, and Chesapeake Bay.

A national system allows us to leverage analytical capabilities across state and regional boundaries, while assuring that the unique problems and capabilities in each region are incorporated. Many requirements for operational forecasts are common across regions. The commonality of data types in different regions (e.g., cell counts, moored instruments, transport and ecological models, and satellite imagery) means that data integration tools that merge field data, model fields, and imagery can be leveraged nationally, even with data types that are regionally or locally unique. The HAB-FS would depend on analysts; analysts who would be co-located with expertise in each region. These analysts would provide (based on user input) semi-weekly comprehensive analyses and forecasts, as well as 8/5 support to users. NOAA will also develop and maintain a national HAB “event response” nowcast—a capability of providing data to those responding to unusual HAB impacts. This capability could be deployed to regions without a full operational system, as well as addressing unusual events such as mass mortality of endangered species.

In each region, the HAB-FS would do some or all of the following forecasts: predict conditions for HAB initiation, detect and distinguish new HAB or non-HAB events, monitor or nowcast identified HABs, forecast the transport and intensity of identified HABs, and identify types of impacts to be expected. It will also assess skill and value, and work with the monitoring and research community on filling identified gaps. The total system effort will involve: transitioning of existing research capabilities to an operational status; developing products that are relevant and valuable to managers, producing the operational forecasts, and evaluating the forecasts. The forecasts will be distributed through bulletins and web-sites that maximize value to managers. It will also anticipate that other sources will provide data dissemination.

As an example, the existing operational system for the eastern Gulf of Mexico has been in place for three years. NOAA has issued over 400 bulletins in that time in response to HABs that have impacted some 1000 km of coast, with 90% weekly utilization by over 190 resource managers representing more than 50 organizations. The bulletins have been used by managers for purposes such as guiding sampling and improving public hazard advisories. The Forecasts reach a broad audience of the general public through the South Florida Poison Information Center hotline (most of the 5000 calls per year are on Florida HABs), and through the NOAA HAB Web-site (2000 hits per month during events).

**Marine Biotoxin Monitoring in California for Public Health Protection**

Gregg W. Langlois

*California Department of Public Health*

California has a long history of experience with the marine biotoxins (saxitoxin and its numerous analogs) responsible for the human health syndrome known as paralytic shellfish poisoning (PSP). This experience predates written history as coastal native American tribes were the first to contend with these lethal toxins. California has the distinction of having the longest established monitoring program for PSP in the U.S., initiated in 1927. Early groundbreaking research on method development and PSP toxin characterization was conducted in California.

In 1962 the State and coastal County health departments coordinated efforts. The local health agencies agreed to collect shellfish samples at key locations and the State provided the infrastructure for analytical support, issuance of quarantines and public health advisories, and overall coordination of the program. The efforts of the local health departments to provide routine samples remains the backbone of the monitoring program, which has traditionally relied on analysis of shellfish samples to detect the presence of toxins and alert the public. This approach has proven to be an effective tool for public health protection and remains an essential part of all monitoring programs in the U.S. (as well as most international programs).

In the wake of the identification of domoic acid in Monterey Bay, demands on the California Department of Public Health's biotoxin program doubled overnight. Routine analysis of samples commenced statewide in the fall of 1991, documenting the occurrence of domoic acid in shellfish from all coastal counties over the next several months. To meet the challenge presented by the presence of a second marine neurotoxin, combined with the potential for other toxins to occur, CDPH began developing a volunteer-based phytoplankton monitoring program as a potential early warning tool. This effort was initiated and supported by the U.S. Food and Drug Adminstration's Office of Seafood, which also assisted in coordinating with the NOAA CoastWatch program to access and evaluate the utility of remote sensing data for both real time monitoring and retrospective analysis of past events.

A review of the shellfish toxicity data collected along the California coast over the past 20 years supports earlier conclusions by CDPH regarding spatial and temporal patterns of PSP toxicity. Analysis of this toxicity data in conjunction with remote sensing information and phytoplankton distribution and abundance data has provided insight into the relationship of upwelling and relaxation events with the onset of PSP toxicity. Qualitative data generated by the volunteer phytoplankton monitoring network have greatly improved our understanding of the distribution of toxigenic species, which in turn has allowed a basic refinement in the focus of the monitoring programs. Analysis of the past 16 years of domoic acid data reveals seasonal and geographic patterns of toxicity complementary to those for the PSP toxins.

# APPENDIX C. WORKSHOP PARTICIPANT BIOPICS AND CONTACT INFORMATION

**Dr. Clarissa Anderson**
NRC Research Associate
NOAA, ESSIC/CICS University of Maryland
College Park, MD 20742
(301) 405-6568
clarissa@umd.edu

Dr. Anderson received her undergraduate degree in Biology and Art History at UC Berkeley in 1999 and a Ph.D. in Marine Science from UC Santa Barbara in 2007. Her dissertation focused on the dynamics of toxic *Pseudo-nitzschia* blooms in the Santa Barbara Channel under the direction of Mark Brzezinski, David Siegel, Raphael Kudela, and Libe Washburn. In 2004, she received a NASA Earth System Science Fellowship to investigate possibilities of remotely detecting *Pseudo-nitzschia* blooms in the SBC using a statistical rather than optical approach. As a National Research Council postdoctoral associate for NOAA, she is currently working on empirical habitat models for harmful algal blooms in the Chesapeake Bay in association with Christopher Brown. They are applying methods established for forecasting *Karlodinium micrum* blooms to the nowcasting and forecasting of *Pseudo-nitzschia* spp. blooms and potentially for *Microcystis aeruginosa* blooms in the future.

**Dr. Claudia Benitez-Nelson**
Associate Professor, Department of Geological Sciences
University of South Carolina
Columbia, SC 29205
(803) 777-0018
cbnelson@geol.sc.edu

Claudia Benitez-Nelson is an Associate Professor in the Department of Geological Sciences and Director of Undergraduate Studies in the Marine Science Program at the University of South Carolina. She received B.S. degrees in Chemistry and Oceanography from the University of Washington and a Ph.D. from the Woods Hole Oceanographic Institution/Massachusetts Institute of Oceanography Joint Program. She was a UCAR/NOAA Climate and Global Change Postdoctoral Fellow and a University of Hawaii SOEST Young Investigator. Her research focuses on understanding phosphorus biogeochemistry and mechanisms of water column particle formation and export using short-lived radionuclides and sediment traps. She has recently started investigating the export of particulate domoic acid from surface waters to the seafloor off the California coast. Claudia has conducted research in numerous environments in coastal and open ocean waters as well as the Great Lakes. In 2006 she received the AGU Early Career Award in Ocean Sciences. She currently serves as a member of the NSF Advisory Committee for Geosciences, as Associate Editor of *Marine Chemistry*, and as the Chemical Oceanography representative on the *Oceanography Society* Council. Known for her high energy and enthusiasm, she is heavily involved in education and outreach activities to increase minority participation in marine science.

**Dr. Lilian Busse**
Environmental Scientist
San Diego Regional Water Quality Control Board
9174 Sky Park Court, Suite 100
San Diego, CA 92123-4340
(858) 467-2971
lbusse@waterboards.ca.gov

Lilian Busse received her M.A. in Freshwater Ecology in 1993 from the Technical University Munich, Germany, and her Ph.D. in Aquatic Ecology in 1999 from the Technical University Berlin, Germany. From 2000–2002, she was a postdoctoral researcher at the University of California, Santa Barbara. From 2002–2006, Lilian Busse was working as a researcher at the Scripps Institution of Oceanography in La Jolla. Since 2006, she is working as an Environmental Scientist at the San Diego Regional Water Quality Control Board. Lilian Busse's research focuses on freshwater, brackish and marine algae. She was working on the relationships between freshwater algae, grazers, nutrients and landuse in Southern Californian streams. At the Scripps Institution of Oceanography, Lilian Busse studied the biodiversity of diatoms and dinoflagellates from a 10 year time series at Scripps Pier, and was part of a multi-campus research grant studying *Pseudo-nitzschia* and *Alexandrium* along the Californian Coast. In 2005, she established the HAB monitoring program at Scripps Pier with funds from the Southern California Coastal Ocean Observing System (SCCOOS). In her current position, she is leading the freshwater periphyton committee for the Surface Water Ambient Monitoring Program (SWAMP), and is part of the Statewide Algae Work Group.

**Dr. Mark Brzezinski**
Chair, Interdepartmental Graduate Program in Marine Science
University of California Santa Barbara - Department of Ecology Evolution and Marine Biology
Santa Barbara, CA 93106
(805) 893-8605
brzezins@lifesci.ucsb.edu

Mark Brzezinski is a Professor of Biological Oceanography in the Department of Ecology Evolution and Marine Biology at the University of California, Santa Barbara. He received his Ph.D. in Biological Oceanography from the College of Oceanic and Atmospheric Sciences at Oregon State University and his Bachelors of Science degree in marine science From Southampton College of Long Island University. His research is focused on phytoplankton ecology with an emphasis on diatom silicon metabolism and the marine silicon cycle. His publications address issues of how silicon limitation affects the distribution and abundance of diatoms and their role in the ocean carbon cycle. His work spans a broad range of disciplines from paleoceanographic reconstructions of past patterns of diatom Si use, to studies of upper ocean silicon cycling in the modern ocean and to studies of diatom-dominated harmful algae blooms. He currently serves as the Chair of the interdepartmental Graduate Program in Marine Sciences and is the acting Director of the Marine Science Institute at UCSB.

**Dr. David A. Caron**
Professor, Department of Biological Sciences
University of Southern California
3616 Trousdale Parkway, AHF 301
Los Angeles, CA 90089-0371
(213) 740-0203
dcaron@usc.edu

David A. Caron is a Professor in the Marine Environmental Biology section of the Department of Biological Sciences at the University of Southern California. He has degrees in Microbiology (B.S.) and Oceanography (M.S.) from the University of Rhode Island, and in Biological Oceanography (Ph.D.) conferred jointly by Massachusetts Institute of Technology and Woods Hole Oceanographic Institution. His research interests involve marine and freshwater microbial ecology. Ongoing research programs include studies of harmful bloom-forming species of microalgae, and investigations of the biodiversity and physiology of tropical, temperate and polar microbial communities. He has authored or co-authored over 140 scientific articles and book chapters. He is Fellow of the American Academy of Microbiology, and a member of the American Society for Microbiology, the International Society of Protistologists, The Oceanography Society, the International Society of Microbial Ecology and the Estuarine Research Foundation.
Laboratory Website: http://www.usc.edu/dept/LAS/biosci/Caron_lab/index.html

**Melissa Carter**
Graduate Student
University of California, San Diego - Scripps Institution of Oceanography
9500 Gilman Dr., Dept 0227
La Jolla, CA 92093-0227
(858) 534-6304
mlcarter@ucsd.edu

Melissa Carter graduated with an undergraduate degree in Oceanography from Humboldt State University and since then has been working at Scripps Institution of Oceanography on a wide variety of projects related to physical and biological interactions in coastal areas. Some of her current projects include a chlorophyll and harmful algal bloom monitoring program at Scripps Pier for the Southern California Coastal Ocean Observing System. She is also currently working on her Master's of Marine Science at the University of San Diego, which is focused on chlorophyll distribution in the Southern California Bight using both in-situ and satellite measurements.

**Dr. Grace Chang Spada**
Associate Researcher, Ocean Physics Laboratory
University of California Santa Barbara
6487 Calle Real Unit A
Goleta, CA 93117
(805) 681-8207
grace.spada@opl.ucsb.edu

Dr. Grace Chang is an Associate Researcher in the Department of Geography at the University of California, Santa Barbara. Her primary research interest is the use of optical properties for inferring physical processes and biogeochemical properties (e.g., bottom boundary layer dynamics, harmful algal blooms). She has also been active in the area of ocean technology: sensor development and testing, real-time data acquisition, and observatory systems. She was an invited instructor for three courses at the 2003 HABWatch Workshop, "Real time coastal observing systems for ecosystems dynamics and harmful algal blooms" in Villefranche-Sur-Mer, France. Dr. Chang received a B.S. in Geology and a B.G.E. in Geological Engineering from the University of Minnesota, Twin Cities, in 1995, a M.S. in Mechanical and Environmental Engineering in 1997, and a Ph.D. in Marine Science 1999 from the University of California, Santa Barbara.

**Dr. William Cochlan**
Senior Research Scientist
San Francisco State University - Romberg Tiberon Center
3152 Paradise Drive
Tiburon, CA 94920-1205
(415) 338-3541
cochlan@sfsu.edu

William Cochlan is a biological oceanographer who studies the physiological ecology of marine phytoplankton; specifically the utilization and dynamics of macro- and micro-nutrients. Dr. Cochlan received his BS (H) and PhD from UBC, and MS from Dalhousie University. His Postdoctoral training was conducted at SIO and USC, before moving to the Romberg Tiburon Center, SFSU in 1998. Dr. Cochlan works with a number of HAB species, including raphidophytes (*Heterosigma akashiwo*), dinoflagellates (*Lingulodinium polyedrum*) and numerous *Pseudo-nitzschia* diatom species. Most recently, he was part of a collaborative 5-year Pacific Northwest ECOHAB project (www.ecohabpnw.org) to study the nutritional and ecological factors associated with toxigenic diatom bloom development. His group has quantified the physiological capacity for nitrogen uptake by a number of HAB species and their relationship to ambient nutrient conditions. Dr. Cochlan is a U.S. representative to the HAB section of PICES, and is involved in their HAB database effort (HAEDAT) and HAB training efforts for developing nations. He has conducted phytoplankton research in the Antarctic (JGOFSAESOPS), and during mesoscale iron enrichment experiments conducted in the equatorial Pacific (Iron Ex II), the northwestern Pacific Ocean (SEEDS-II), and the Southern Ocean (SOFeX). Dr. Cochlan teaches at SFSU, and is the faculty coordinator of educational outreach at RTC.

**Joe Cordaro**
Wildlife Biologist, Protected Resources Division
NOAA National Marine Fisheries Service (NMFS), Southwest
501 West Ocean Blvd, Suite 4200
Long Beach, CA 90802-4213
(562) 980-4017
Joe.Cordaro@noaa.gov

Joe Cordaro graduated from Arizona State University in 1984 with a Bachelor's Degree in Wildlife Management. In 1988, began working as a wildlife biologist in the NMFS Long Beach Regional Office, Protected Species Management Branch, as the stranding coordinator for the California Marine Mammal Stranding Network. His job responsibilities include documenting all live and dead pinniped, cetacean, and sea turtle strandings in California; ensuring that biological information is collected from the strandings, and ensuring that specimens from stranded animals are made available to the scientific and educational communities. Recently, over the last 10 years, he has observed harmful algal blooms in California progress from occasional to yearly events, and has been attempting to correlate California sea lion and common dolphin strandings with the occurrence of harmful algal blooms in California.

**Hugo Cornejo**
Program Specialist
California Department Public Health, Food and Drug Branch (CDPH-FDB)
P.O. Box 997435, MS 7602
Sacramento, CA 95899-7435
(916) 650-6704
hugo.cornejo@cdph.ca.gov

Hugo Cornejo has been with the State of California for fifteen years. He has extensive experience in regulatory work and as a trainer to industry, academia, and other governmental agencies in Seafood HACCP, Good Manufacturing Practices, and Sanitation Standard Operating Procedures. Currently, he oversees the Seafood and Shellfish program for FDB and is the State's Shellfish Standardization Officer. During increase activity of HABs, such as Domoic acid, he coordinates and plans sample collection of crab, lobster, anchovies and sardines along the California Coast. He also provides guidance and makes recommendations as to the release of public advisories associated with HABs.

**Dr. Quay Dortch**
Program Coordinator, Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) Program
NOS/NCCOS/CSCOR/COP
N/SC12, 1305 East West Highway, Building IV Rm 8220
Silver Spring, MD 20910
(301) 713-3338 X157
Quay.Dortch@noaa.gov

Quay Dortch is the Coordinator for the Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) Program (http://www.cop.noaa.gov/stressors/extremeevents/hab/current/factecohab.html) in the National Oceanographic and Atmospheric Administration (NOAA) National Ocean Service (NOS) National Centers for Coastal Ocean Science (NCCOS) Center for Sponsored Coastal Research (CSCOR). She is also the NOAA Co-Chair of the HABS and Hypoxia Subcommittee of the Interagency Working Group on HABs, Hypoxia, and Human Health, which is leading the effort to implement the requirements of the 2004 amendment to the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998, including writing four reports on HABs in the U.S. (http://www.cop.noaa.gov/stressors/extremeevents/hab/habhrca/). Dortch received her Ph.D. from the University of Washington in Oceanography, M.S. in Chemistry from Indiana University and B.A. in Chemistry from Randolph-Macon Woman's College. She held research positions at the University of Washington and Bigelow Laboratory for Ocean Sciences before joining the faculty at Louisiana Universities Marine Consortium from 1986-2002. Her research has examined nutrient utilization by marine phytoplankton, focusing most recently on studies of harmful algal blooms, hypoxia and eutrophication in Louisiana coastal waters, especially those influenced by the Mississippi River. Dr. Dortch is the author or co-author of approximately 90 scientific papers, including some on *Pseudo-nitzschia*.

**Terry Fleming**
Environmental Scientist
US Environmental Protection Agency (WTR-2)
75 Hawthorne Street
San Francisco, CA 94105
(415) 972-3462
fleming.terrence@epa.gov

Mr. Fleming is an environmental scientist for the US Environmental Protection Agency Region 9. He earned Bachelor of Science degree in Marine Biology from the University of California at Berkeley and his Master of Science degree in Environmental Sciences from the University of Massachusetts at Boston. He worked for five years at the New England Division of the US Army Corps of Engineers in their Impact Analysis Branch. He has been at EPA since 1991. He currently works in the Monitoring and Assessment Office of the Water Division where his duties include coordination of the water quality standards program in Region 9, oversight of the California's Monitoring Program and the development of TMDLs in the Los Angeles Area. He is also the Region 9 coordinator for the BEACH program.

**Dominic Gregorio**
Senior Environmental Scientist, Ocean Unit, Division of Water Quality
State Water Resources Control Board
1001 I Street
Sacramento, CA 95814
(916) 341-5488
dgregorio@waterboards.ca.gov

Dominic Gregorio has been with the California State Water Resources Control Board for eight years, where he is a Senior Environmental Scientist managing the Board's Ocean Unit. The Ocean Unit is responsible for ocean and coastal water quality standards including the California Ocean Plan, Areas of Special Biological Significance, Sediment Quality Objectives, and Once through Cooling at Coastal Power Plants. The Ocean Unit is also involved in addressing beach and shellfish contamination, harmful algal blooms, vessel discharges, ocean monitoring, and marine debris. Previously, Mr. Gregorio was a marine biology instructor at California State University, Dominguez Hills and at Cypress College, in Orange County, California. During that period he was also affiliated with the Southern California Marine Institute, where he was a principle investigator on projects including harmful algal blooms, marine pollution, and aquaculture. Prior to working in academia, Mr. Gregorio was an environmental coordinator for Texaco, USA, where he managed a number of marine biological surveys and pollution studies for offshore oil drilling projects, and was also responsible for oil spill contingency planning. Mr. Gregorio holds a M.S. in Environmental Biology, from California State University, Dominguez Hills.

**Dr. Frances M.D. Gulland**
Director of Veterinary Sciences
The Marine Mammal Center
1065 Fort Cronkhote
Sausalito, CA 94965
(415) 289-7344
gullandf@tmmc.org

Frances M.D. Gulland is the Director of Veterinary Services at The Marine Mammal Center, Sausalito, CA. She received her veterinary degree from the University of Cambridge, UK, in 1984; and her Ph.D. in Zoology, also from the University of Cambridge, in 1991. Her research focuses on determining the causes of stranding and disease in pinnipeds in central California, veterinary care of stranded marine mammals, effects of domoic acid on California sea lions, and health monitoring of harbor seals in San Francisco Bay. She currently serves as the Chair of the Southern Sea Otter Recovery Implementation team, the Scientific Advisor for the Marine Mammal Commission, and on the Working Group on Unusual Marine Mammal Mortality Events for the National Marine Fisheries Service.

**Dr. Sherwood Hall**
U.S. Food and Drug Administration (FDA), Center for Food Safety and Applied Nutrition
HFS-717, 1500 Paint Branch Parkway
College Park, MD 20740
(301) 436-1653
sherwood.hall@fda.hhs.gov

Dr. Hall was born in San Francisco, grew up in Los Angeles, and has never gotten his fill of the coast between, the most beautiful in the world. During 1963/64 he was a tech on the Pollution Project at Hancock Foundation, USC, learning to get seasick doing oxygen titrations below deck. In 1968/69, he worked as a tech at Pacific Mariculture, Pigeon Point, primarily growing algal cultures to feed oyster spat. In 1970 he emigrated to Alaska, eventually doing research that elucidated the origin and nature of paralytic shellfish poisoning along the Alaskan coast. In 1982 he moved from the University of Alaska to WHOI and then, in 1984, to the FDA in Washington DC. At the FDA, his focus has been on the management of marine biotoxins to minimize their impact on consumer health and the seafood industry. He continues to do research on marine biotoxins, notably the saxitoxins and domoic acid, deals with marine biotoxin crises as they arise, and assists in the development of biotoxin management programs. One of his principle concerns is the coordination of existing resources to optimize their effectiveness as assets in monitoring programs, the challenge being to afford monitoring at sufficient temporal and spatial density to ensure seafood safety.

**Dr. Meredith Howard**
Post-Doctoral Scientist
University of Southern California and Southern California Coastal Water Research Project
3535 Harbor Blvd., Suite 110
Costa Mesa, CA 92626
(714) 755-3263
mhoward@sccwrp.org

Meredith Howard received her B.A. in Finance from Lehigh University in 1995, her B.S. in Biology from Rutgers University in 2001, and her Ph.D. in Ocean Science from the University of California, Santa Cruz in 2007 (Thesis Committee: Raphael Kudela, advisor, Mary Silver, G. Jason Smith, and Kenneth Bruland). Her dissertation research focused on the physiological response of toxin production in several HAB species and the role of anthropogenically derived nitrogen sources in the development and maintenance of HABs. Her work evaluated the nitrogenous preference and toxicity of the diatom, *Pseudo-nitzschia australis* and measured the presence of the emerging marine toxin, yessotoxin, on the U.S. west coast in both mussel and phytoplankton samples. Meredith is currently a joint Post-Doctoral Research Associate at SCCWRP and at the University of Southern California, where she works with Dr. David Caron. She is part of the Southern California Bight ’08 Regional Monitoring Project, Water Quality group and the Caron MERHAB project, and she continues to focus her research on improving HAB monitoring, detecting and identifying emerging and established HAB species and evaluating the oceanographic conditions, particularly nutrient sources, which lead to the development and maintenance of algal blooms.

**Dr. Burton Jones**
Research Associate Professor
University of Southern California
3616 Trousdale Parkway, AHF B-30
Los Angeles, CA 90089-0371
(213) 740-5153
bjones@usc.edu

Burton Jones is a Biological Oceanographer in the Marine Environmental Biology section of the Biology Department at the University of Southern California. His research interests include biooptical oceanography, physical-biological interactions, coastal processes, and coastal ocean observing systems. He received his B.S. in biological engineering from Rose-Hulman Institute of Technology and his Ph.D. in biological oceanography from Duke University. After a postdoctoral fellowship at Bigelow Laboratory he joined the research faculty at University of Southern California. He has been involved in studying the dynamics of physical/bio-optical interactions in a variety of environments that include coastal California, the Arabian Sea, Japan/East Sea, and the Adriatic Sea. Recently, as part of the Southern California Coastal Ocean Observing System (SCCOOS) and USC MERHAB research in harmful algal bloom monitoring, Dr. Jones has been involved in implementing a coastal observing system that includes both fixed sites and autonomous vehicles. This includes participation in the development of an intelligent network of fixed and mobile nodes capable of adaptive mapping and sampling strategies.

**Dr. Rachel Wisniewski Jakuba**
AAAS Science & Technology Policy Fellow
USEPA Office of Research and Development, National Center for Environmental Research
1200 Pennsylvania Avenue, NW
Washington, D.C. 20460
(202) 343-9811
Jakuba.Rachel@epamail.epa.gov

Rachel Wisniewski Jakuba is a 2007-2008 AAAS Science & Technology Policy Fellow in EPA's National Center for Environmental Research. Rachel has a scientific background in marine science. As an undergraduate, Rachel attended the University of Georgia, where she focused on Marine Science and Chemistry. Rachel worked on nitrogen cycling in salt marshes, measuring microbial denitrification rates and porewater ammonia concentrations. Rachel completed her Ph.D. in chemical oceanography from the Massachusetts Institute of Technology-Woods Hole Oceanographic Institution Joint Program in 2006. Her thesis research focused on how several nutrients (zinc, cobalt, and phosphorus) influence photosynthesis in the open ocean. Specifically, she was interested in how the chemical speciation of elements influences their bioavailability and whether or not the cycles of zinc, cobalt, and phosphorus are linked. Rachel's research involved measuring the concentrations of these elements in ocean surface waters, performing shipboard incubation experiments with the natural phytoplankton community, and performing lab experiments with cultures of model phytoplankton organisms. As an AAAS Science & Technology Policy Fellow, Rachel is learning how basic scientific research is used to formulate environmental policy and is working on a synthesis of the first 10 years of ECOHAB research.

**Susan A. Kaveggia**
Wildlife Biologist and Rehabilitator
California Council for Wildlife Rehabilitators
P.O. Box 434
Santa Rosa, CA 95402
(714)322-4309
SKaveggia@aol.com

Susan has been rehabilitating wildlife for the past 11 years and specializes in pelagic birds. She currently is board member of the California Council for Wildlife Rehabilitators (CCWR) which acts as a liaison between rehabilitators and regulatory agencies. Her interests lie in the etiology of "seabird wrecks" and the conservation of endangered birds, such as, the Light-footed Clapper Rail and the Brown Pelican. She also is on the oil response team for International Bird Rescue Research Center and the Oiled Wildlife Care Network. Susan is the lead avian coordinator for gathering domoic acid samples and the transfer between The Wetlands and Wildlife Care Center, International Bird Rescue Research Center, and the University of Southern California Caron Lab. She participates in the educational outreach to fellow biologists, wildlife rehabilitators, state and county agencies of Domoic Acid.

**David Kidwell**
Hypoxia and HAB Specialist
NOAA, Center for Sponsored Coastal Ocean Research
N/SCI2, SSMC4, Rm. 8326, 1305 East-West Hwy
Silver Spring, MD 20910
(301) 713-3338 X148
David.Kidwell@noaa.gov

Mr. Kidwell is currently a Hypoxia and Harmful Algal Bloom Specialist at NOAA's Center for Sponsored Coastal Ocean Research (CSCOR). Since joining CSCOR in early 2007 as a Knauss Marine Policy Fellow, David has spent considerable time on coastal hypoxia issues, especially in the Gulf of Mexico. Through the course of his work with hypoxia, he has participated in the Gulf of Mexico/Mississippi River Watershed Nutrient Task Force's reassessment of the 2001 Action Plan, the development of a hypoxia monitoring implementation plan and stakeholder web site, workshop planning, and NOAA efforts to including coastal impacts in the 2008 Farm Bill. In 2008, David transitioned to his current position where, in addition to his hypoxia efforts, he is involved in harmful algal bloom program activities that include workshop development and program planning. David completed his graduate work at the University of Maryland, College Park while working at the U.S. Geological Survey Patuxent Wildlife Research Center, where he conducted research on waterfowl ecology in estuarine and marine ecosystems.

**Dr. Raphael Kudela**
Associate Professor, Ocean Sciences and Institute for Marine Sciences
University of California Santa Cruz
1156 High Street
Santa Cruz, CA 95064
(831) 459-3290
kudela@ucsc.edu

Raphael Kudela is a biological oceanographer who focuses on phytoplankton ecophysiology, particularly the interplay of light and nutrients. Recent HAB-related research includes development of monitoring programs in California (e.g. Cal-PreEMPT, CeNCOOS, and partnerships with California Water Boards and CDFG), optical and remote sensing methods for identifying true red tides as well as less visible HAB events, toxin production by various organisms, and more generally the ecophysiological conditions (from genomics to decadal timeseries analysis) leading to HAB events. Kudela serves on the US HAB National Committee, is the Vice-Chair of the GEOHAB program, and serves on the GEOHAB Core Research Program: HABs in Upwelling Systems committee.

**Gregg Langlois**
Senior Environmental Scientist
California Department of Public Health
850 Marina Bay Parkway, G165
Richmond, CA 94804
510-412-4635
Gregg.Langlois@cdph.ca.gov

Mr. Langlois is a Senior Environmental Scientist with the California Department of Public Health (CDPH). He has managed the state's marine biotoxin monitoring program since 1990 and has supervised the state's preharvest shellfish program since 1997. Biotoxin program responsibilities include: coordination of program participants responsible for the routine collection of shellfish samples; coordination of a volunteer network of phytoplankton samplers; liaison with the CDPH regulatory laboratories responsible for toxin analyses; declaration of commercial shellfish harvest closures and reopenings; drafting of quarantines and health advisories; collection of ancillary environmental data; routine reporting. He also supervises a small staff of four people who are responsible for classifying commercial shellfish growing areas statewide. This involves the conduct of sanitary surveys for pollution source identification; water quality data collection and analysis; development of management strategies for implementing harvest closures for public health protection; ensuring compliance with the National Shellfish Sanitation Program administered by the U.S. Food and Drug Administration. Recent focus has been on cost-effective approaches to improve early detection capabilities for harmful algal events. A joint project with UC Santa Cruz is currently evaluating the reliability and utility of field-based tools for identification of toxigenic phytoplankton species and toxin detection in shellfish.

**Dr. Wayne Litaker**
Research Scientist
NOAA National Ocean Service
101 Pivers Island Road
Beaufort, NC 28516
(252) 728-8791
wayne.litaker@noaa.gov

Wayne Litaker holds a B.S. in botany and zoology from Duke University, an M.S. in natural resources from the University of Michigan, and a Ph.D. in botany from Duke University. From 1986 until 1991, Wayne did postdoctoral training in molecular immunology and served as a research associate in the Department of Immunology and Microbiology at UNC Chapel Hill. From 1991 to 2002 has was on faculty at the UNC School of Medicine's Program in Molecular Biology & Biotechnology. In 2002 he joined NOAA as a research scientist. His research focuses on the molecular biology and ecology of harmful algal bloom species and the development of detection technologies for certain algal toxins. Ongoing projects include the development of a cost effective, rapid and accurate domoic acid test kit and assays to identify the dinoflagellates responsible of ciguatera fish poisoning. Other projects include investigating an alternative mechanism for the development of red tide blooms off Florida, and a quantitative assay for detection of human enteroviruses in recreational waters. Wayne participates in a number national and international collaborations and holds adjunct appointments at the North Carolina State College of Veterinary Medicine and the School of Public Health at the UNC School of Medicine.

**Dr. Amber Mace**
Executive Director
California Ocean Science Trust (OST)
1330 Broadway, Suite 1135
Oakland, CA 94612-2525
(510) 251-8323
amber.mace@calost.org

Dr. Amber Mace serves as the Executive Director of the California Ocean Science Trust (OST). The OST is a non-profit that strives to connect science to ocean management solutions. As the OST ED, Amber serves as the Science Advisor to the California Ocean Protection Council. Amber came to The OST after having served as a John D. Knauss Sea Grant Marine Policy Fellow in the Senate Commerce, Science, and Transportation Committee. Prior to the Knauss position, she served as a California Sea Grant State Fellow with the California Ocean Resources Management Program. Amber earned a B.A. in Geography from University of California, Berkeley in 1994 and a Ph.D. in Ecology from University of California, Davis and the Bodega Marine Laboratory in 2005. During this time, Amber investigated how larval transport and nearshore circulation patterns can inform the placement of marine reserves. Prior to completing her doctorate, she worked with the Farallones Marine Sanctuary Association in support of outreach activities for the National Marine Sanctuary Program. Amber has spent her life along the shores of northern California and the past 12 years working actively to improve communication and collaboration among scientists, resource managers, policy makers, and the public.

**Dr. John A. McGowan**
Research Professor of Oceanography, Integrative Oceanography Division
University of California, San Diego – Scripps Institution of Oceanography
9500 Gilman Dr., Mail Code 0227
La Jolla, CA 92093
jmcgowan@ucsd.edu

John McGowan received his B.S. and M.S. in Zoology from Oregon State University. He received his Ph.D., in oceanography from Scripps Institution of Oceanography (SIO). From 1956 – 1958, Dr. McGowan served as a marine biologist for the Trust Territories of the Pacific Dept. Interior. He became an assistant to professor of oceanography at SIO in 1952 and has supervised twenty-one Ph.D. candidates, one Masters student and served on fifty-six Ph.D. committees. He has taught a variety of classes on biological oceanography and pelagic ecology at SIO, invertebrate zoology at the Pacific Marine Station and General Oceanography at the Oregon Institute of Marine Biology. His research interests are the following: large-scale pelagic biogeography, pelagic community structure, diversity maintenance, biophysical time-series, the role of climate in regulating populations and communities, near-shore biophysical processes, red tides and change in the ocean.

**Danielle Luttenberg Meitiv**
NOAA, Center for Sponsored Coastal Ocean Research
NSC12, 1305 East West Hwy, Building IV Rm 8116
Silver Spring, MD 20910
(301) 713-3338 X155
Danielle.Meitiv@noaa.gov

Danielle Luttenberg Meitiv works on program development, support and strategic planning for the National HAB Program at NOAA Center for Sponsored Coastal Ocean Research (CSCOR). She returned to NOAA in 2007 after spending six years working on fisheries, Middle East environmental issues and political training for non-profit environmental organizations including Environmental Defense, the Coalition on the Environment and Jewish Life (COEJL) and the Massachusetts Public Interest Research Group (MASSPIRG) and teaching in the Genesis Program at Brandeis University. Her previous work for NOAA included developing and managing the Monitoring and Event Response for HAB (MERHAB) program and acting as National Event Response Coordinator for HAB events. She received a BS in biology from the University of Buffalo and an MS in oceanography from the University of Rhode Island's Graduate School of Oceanography.

**Dr. Abdou Mekebri**
Chief Chemist
California Department of Fish and Game, Water Pollution Control Laboratory
2005 Nimbus Road
Rancho Cordova, CA 95670
916-358-0317
amekebri@ospr.dfg.ca.gov

Abdou Mekebri, Staff Chemist with the California Department of Fish and Game (DFG), has more than 20 years of public and private sector environmental laboratory experience with extensive experience in pesticide analysis and methods development. Mr. Mekebri is the lead chemist for the Water Pollution Control Laboratory's Pesticide Residue Laboratory. Mr. Mekebri is currently finishing his Ph.D. in chemistry and holds both MS and BS degrees in Biochemistry. He has extensive experience in all areas of environmental analysis including field sampling, sample preparation, sample analysis, and analytical methods development and validation. His experience includes analysis of water, air, sediment, soil and biological fluids and tissues using advanced analytical equipment. Recently, Mr. Mekebri has been researching new methods using HPLC-MSMS instrumentation including the analysis of freshwater and marine toxins such as domoic acid and microcystins in water, sediment and biological fluids and tissues and pharmaceuticals in wastewater.

**Dr. Peter Miller**
Assistant Researcher, Institute of Marine Sciences
University of California, Santa Cruz
1156 High Street
Santa Cruz, CA 95064
(831) 459-5005
pemiller@ucsc.edu

Peter Miller received his Ph.D. in Biology (1999) from the University of California, Santa Cruz. In 2000 he was awarded an AAAS Science and Technology Diplomacy Fellowship to work with the U.S. Agency for International Development. In this position he was a technical and management advisor for a competitive grants program funding scientific research broadly focused on topics relevant to international development. In 2002 Miller returned to science as an Assistant Researcher with the Institute of Marine Sciences at UCSC. His research interests include: Phytoplankton ecology, harmful algal blooms, development of molecular genetic methods for species detection, traditional morphology-based taxonomy, technology transfer of traditional and modern methods to end users and coastal managers. Current research includes NOAA- and EPA-funded projects to: (1) implement an economically sustainable harmful algal bloom monitoring plan for California that exceeds current capabilities of the California Department of Public Health by using new technologies for toxin and species detection and bloom tracking, (2) establish a fine-scale in-situ sensor network for monitoring the spatiotemporal distribution of algal blooms in coastal waters of southern California to implement state-of-the-art technology for quantifying *Pseudo-nitzschia* species and domoic acid concentrations in southern California, (3) investigate the relationship between freshwater inputs from the LA harbor region and blooms of the toxic diatom *Pseudo-nitzschia*.

**Dr. Mark Moline**
Associate Professor, Biological Sciences Department
California State Polytechnic University (Cal Poly), San Luis Obispo
San Luis Obispo, CA 93407
(805) 756-2948
mmoline@calpoly.edu

Dr. Moline is the Director of the Center for Marine and Coastal Sciences and Professor of Biology at California Polytechnic State University. His general research areas of interest include biological oceanography, phytoplankton ecology, phytoplankton physiology, photobiology, biooptics, remote sensing, and biogeochemistry, coastal oceanography, harmful algae, polar ecosystems, and climate change. Dr. Moline is an expert in emerging in situ and remote sensing techniques including: autonomous underwater vehicles (AUVs), high frequency radar (HFR) surface current mapping, profiler-based studies of phytoplankton bioluminescence, and hyperspectral remote sensing of coastal and shallow benthic environments. Dr Moline is an active member of the two California regional observation systems, SCCOOS and CeNCOOS, CICORE and COCMP. Dr. Moline received his Ph.D. in biology in 1996 from UC Santa Barbara, and followed with a postdoctoral fellow at Rutgers University. In 1998, he joined the faculty of California Polytechnic State University and became Director of the Center for Marine and Coastal Sciences in 2004. Dr. Moline was recently named a fellow of the California Council of Science and Technology and a member of the Science Advisory Team for the California Ocean Protection Council.

**Dr. Russell Moll**
Ocean Science Trust Board Chair and Director California Sea Grant
University of California, San Diego
9500 Gilman Dr., Dept 0232
La Jolla, CA 92093-0232
rmoll@ucsd.edu

Russell Moll has worked as a member and director of research teams, administrator of research programs and Program Officer in a federal agency. All of these activities have been in aquatic sciences. He conducted research in the nearshore marine environment, salt marshes, African mangrove systems, the Great Lakes, small lakes, and temperate and tropical rivers. In 1989, Dr. Moll became Director of the Cooperative Institute for Limnology and Ecosystems Research at the Univ. of Michigan. In 1994 he took a leave to serve as an Associate Program Director in the Biological Oceanography Program at the National Science Foundation (NSF). Upon return to Michigan from NSF, Dr. Moll was appointed Director of the Michigan Sea Grant Program. In 1998, he assumed duties as Associate Director of the University of Michigan Biological Station in charge of the Center for Great Lakes and Aquatic Studies. In 2000, Dr. Moll moved to the University of California, San Diego to become Director of the California Sea Grant Program. Dr. Moll has a B.A. from the University of Vermont, M.S in marine science from Long Island University, M.S. in biostatistics from the University of Michigan and Ph.D. in marine ecology from Stony Brook University.

**Dr. Shamitha Kusum Perera**
Chief
California Department of Public Health, Sanitation & Radiation Laboratory Branch
850 Marina Bay Parkway G 164
Richmond, CA 94804-6403
(510) 620-2915
Kusum.Perera@cdph.ca.gov

Shamitha Kusum Perera, Ph.D., serves as the Chief of California Department of Public Health's, Sanitation and Radiation Laboratory. The Laboratory's role is to perform needed tests to protect the public from exposure contaminants in California's water and in particular drinking water. It also serves as the State's laboratory for emergency response relating natural disasters and terrorism events that impacts drinking water supplies and human health. In addition, the laboratory also performs testing relating to environmental radiation.

**Dr. Rick Pieper**
Director
Southern California Marine Institute
820 South Seaside Ave.
Terminal Island, CA 90731
(310) 519-3172, Ext. 977
rpieper@csulb.edu
or pieper@usc.edu

Dr. Pieper's research interests in biological oceanography encompass much of the field. Early work focused on zooplankton and micronekton ecology. This included the measurement and understanding of high-resolution temporal and spatial scales of biological interactions in the sea, and the interactions of the biological structure with physical oceanographic structure and variability. High frequency acoustics (0.1-10 MHz) sensors were developed and used to detect and quantify the distribution and abundance of the smaller zooplankton, and related these distributions to physical oceanographic parameters, including thin layers. Similarly, he has always been interested in red tides, blooms and the initiation and maintenance of them, coauthored a short paper, and organized a symposium at the SCAS meeting in 2006. Recent work concerns environmental monitoring of water properties in inner Los Angeles Harbor and in Long Beach at the terminus of the Los Angeles River. High resolution measurements (data taken at high-data rates) are needed to determine and monitor short term, episodic events which, for example, might correlate with bloom initiation, maintenance, and termination. For example, termination of the domoic acid toxicity event of 2007 occurred with an observed rise in water temperature at the mouth of the Los Angeles River.

**George Robertson**
Senior Scientist
Orange County Sanitation District
P.O. Box 8127
Fountain Valley, CA 92728-8127
(714) 593-7468
grobertson@ocsd.com

Mr. Robertson received an M.S. in Environmental Studies from California State University, Fullerton in 1990 and a B.A. in Applied Ecology from the University of California, Irvine in 1983. He is a Senior Scientist with the Orange County Sanitation District's ocean monitoring and research program. In this capacity, Mr. Robertson assigns, oversees and coordinates the work of in-house scientists, technicians and interns, and several consulting firms. Additionally he is responsible for developing and maintaining relations with other government and university research and monitoring groups. He develops specifications for contracts for the ocean monitoring program and sets short- and long-term goals and objectives for the project. He produces reports and contributes to the publication of scientific papers in peer-reviewed journals. He has been with OCSD for over 19 years.

**Dr. John Ryan**
Scientist
Monterey Bay Aquarium Research Institute (MBARI)
7700 Sandholdt Road
Moss Landing, CA 95039
(831) 775-1978
ryjo@mbari.org

John Ryan received a B.S. in Biology from the University of Massachusetts at Boston. He received M.S. and Ph.D. degrees in Biological Oceanography from the University of Rhode Island Graduate School of Oceanography, on Narragansett Bay. In 1998, John switched coasts for a postdoctoral fellowship at the Monterey Bay Aquarium Research Institute (MBARI) in Moss Landing, California, and he has continued to work at MBARI as a Scientist since 2001. John's research integrates remote sensing, in situ sensing, and models to study bloom processes in open ocean and coastal environments. His research in coastal California waters is focused on understanding the nature of a "red tide incubator", a region of Monterey Bay in which extreme blooms are frequently observed, and from which they can rapidly spread to larger regions. Of particular interest is the intersection of natural and anthropogenic influences in determining bloom frequency and severity.

**Dr. Astrid Schnetzer**
Research Assistant Professor, Department of Biological Sciences
University of Southern California
3616 Trousdale Parkway, AHF 301
Los Angeles, CA 90089-0371
(213) 821-1800
astrids@usc.edu

Dr. Schnetzer completed my undergraduate degree in Zoology and Ecology at the University of Vienna, Austria, where I also received a Masters in Marine Biology and a Ph.D. in Biological Oceanography. Field work for her Ph.D. thesis was conducted at the Bermuda Biological Station for Research, Bermuda, where she studied the impact of open ocean zooplankton on biogeochemical cycles mainly carbon and nitrogen export flux from surface waters. She was awarded a Postdoctoral fellowship from the Austrian Science Foundation to investigate trophic food web dynamics between protistan and metazoan planktonic populations using molecular research techniques at the University of Southern California. She worked in the Caron laboratory at USC for a total of four years as a Postdoc and was promoted to Research Assistant Professor in early 2006. Much of her research over the past years has focused on the ecology of harmful algal blooms, specifically blooms caused by members of the toxic diatom genus *Pseudo-nitzschia*. The examination of environmental conditions that favor growth of *Pseudo-nitzschia* species and/or the production of domoic acid, a neurotoxin that is transferred through the food web and causes sickness and mortality in pinniped and seabird populations, is at the core of these research efforts. Investigating these topics has given Dr. Schnetzer and other members of the Caron laboratory the opportunity to join coastal monitoring efforts by the Southern California Coastal Water Research Project together with local Sanitation Districts and has lead to close collaborations with Mammal Care and Bird Rescue Groups to examine the impact of toxic blooms on species such as the California sea lion and the brown pelican. She is also involved in a multi-disciplinary, multi-institutional research effort between USC, UCLA and UCSC which focuses on the establishment of a coastal sensor network that allows real-time monitoring for algal blooms in the Southern California Bight.

**Dr. Chris Scholin**
Senior Scientist/Research Division Chair
Monterey Bay Aquarium Research Institute (MBARI)
7700 Sandholdt Road
Moss Landing, CA 95039
(831) 775-1779
scholin@mbari.org

Chris Scholin's work focuses on development and application of the Environmental Sample Processor (ESP; http://www.mbari.org/esp), a device that allows for autonomous application of molecular probe technology below the ocean surface. His research interests are centered on detection of water borne microorganisms including and bacterioplakton, invertebrates, harmful algae and associated toxins. Chris received a Ph.D. from the Massachusetts Institute of Technology-Woods Hole Oceanographic Institution Joint Program in Biological Oceanography in 1993, a M.A. in Molecular Biology and Immunology from Duke University in 1986, and a B.A. in Biology from the University of California at Santa Barbara in 1984.

**Dr. Rebecca Shipe**
Assistant Professor, Department of Ecology and Evolutionary Biology
University of California, Los Angeles
Los Angeles, CA 90095
(310) 794-4903
rshipe@ucla.edu

Dr. Shipe's primary research interests are the ecology and physiology of marine phytoplankton. The major focus of her work has been directed at determining the relationships between diatoms (Bacillariophyceae) and their environment, with specific attention to factors that control phytoplankton growth (from nutrient physiology to large scale climatic conditions such as ENSO cycles), and how these factors affect the contributions of phytoplankton to global matter budgets. Her work emphasizes the importance of species-specific processes and knowledge of the individual players in natural communities of plankton. Currently ongoing projects in the Santa Monica Bay focus on the roles of stormwater runoff, organic versus inorganic N sources and upwelling conditions in supporting algal blooms and harmful algal bloom taxa. The techniques that we use include laboratory and culture work, cruises in local coastal waters and observations from the Santa Monica Bay Observatory interdisciplinary mooring station.

**Dr. Mary Silver**
Professor, Ocean Sciences
University of California Santa Cruz
1156 High Street
Santa Cruz, CA 95064
(831) 459-2908
msilver@ucsc.edu

Mary Silver holds a faculty position in the Ocean Sciences department at the University of California, Santa Cruz, where she has been studying the ecology of phytoplankton and zooplankton in California coastal waters since 1972. For several decades her work focused on marine snow, aggregates of detritus and small plankton and on the descent of these aggregates into the deep ocean – a principal source of organic matter at depth. In 1991, she participated in the discovery of the role of the toxin produced by the diatom *Pseudo-nitzschia* in the death of seabirds in Monterey Bay. Since that time, she and her students have focused on the movement of phytoplankton toxins into the pelagic and benthic food webs of coastal California, focusing on toxic species of *Pseudo-nitzschia, Alexandrium*, and *Dinophysis*, and red-tide producing *Cochlodinium*. Additionally she and her students have studied the temporal patterns of these species in Monterey Bay. Recently she has begun to study offshore, oceanic phytoplankton species, including smaller oceanic *Pseudo-nitzschia* that produce toxins (domoic acid) and on the flux of intact cells of these into the subsurface, mesopelagic communities of the north Pacific ocean.

**Dr. G. Jason Smith**
Associate Research Scientist/ACT -Pacific Coast Technical Coordinator
Moss Landing Marine Laboratories
8272 Moss Landing Rd.
Moss Landing, CA 95039
(831) 771-4126
jsmith@mlml.calstate.edu

G. Jason Smith, Ph.D. is an Associate Research Scientist at the Moss Landing Marine Laboratories. Jason received his Ph.D. in Zoology from the University of Georgia in 1984 and his ongoing research program stems from his fascination with the molecular physiological ecology of marine algae. Specific research projects have ranged from nutrient regulation of coral-dinoflagellate symbioses, to investigation of the molecular regulation of nitrogen assimilation in marine phytoplankton, and biotechnology applications with diatoms and yeast. Current research seeks to identify molecular and biochemical markers associated with production of the neurotoxin domoic acid (DA) by diatoms in the genus *Pseudo-nitzschia*. His research group is developing molecular bioassays enabling identification of species actively metabolizing DA and well and genetic markers for robust enumeration of *Pseudo-nitzschia* population and community dynamics. These research efforts helped Jason recognize the need for reliable and user friendly technologies for characterizing water quality variation over fine temporal and spatial scales, leading to his commitment to the ACT program. Since the program's inception, he has served as the Technical Coordinator for the ACT-Pacific Coast Region by providing liaisons between resource managers, environmental scientists and the private sector, with the goal of fostering reliable and appropriate application of new technologies for monitoring water quality and ecosystem health in coastal waters. An important part of these regional efforts is coordinating the design and management of ACTs Technology Performance Verification trials. Jason was recently nominated to the ACT Board of Directors helping guide the national program's future activities.

**Dr. Richard P. Stumpf**
NOAA National Ocean Service
1305 East-West Highway code N/SCI1
Silver Spring MD 20910.
301-713-3028 x173
richard.stumpf@noaa.gov

Dr. Stumpf has over twenty years experience in coastal oceanography, with particular interest in the detection and monitoring of algal blooms. His research includes developing methods to incorporate satellite data into solving such coastal problems as habitat and eutrophication assessment and algal bloom monitoring and forecasting, and has applied these methods over most of the US coast. He develops methods for developing operational forecasts of harmful algal blooms from research programs. In particular, Dr. Stumpf started NOAA's first operational monitoring program for harmful algae in 1988, which led to NOAA's CoastWatch program, and he led the effort to develop NOAA's operational Harmful Algal Bloom Forecast System for the Gulf of Mexico. Dr. Stumpf leads Remote Sensing activities in the Center for Coastal Monitoring and Assessment in NOAA's National Ocean Service. From 1989-1998, he headed remote sensing programs for the USGS Center for Center for Coastal & Watershed Studies in St Petersburg, Florida, and he developed assessment capabilities for the NOAA Satellite and Data Service from 1985-1989. He has authored or co-authored some 50 peer-reviewed publications. He received a B.A. degree in the Environmental Sciences from the University of Virginia, and M.S. and Ph.D. degrees in Marine Studies from the University of Delaware.

**Marc Suddleson**
Program Manager, Monitoring and Event Response for Harmful Algal
NOAA Ocean Service, National Centers for Coastal Ocean Science - Center for Sponsored Coastal Ocean Research (CSCOR)
1305 East West Highway SSMC#4, 8331
Silver Spring, MD 20910
Phone: 301 713-3338 x 162
Marc.Suddleson@noaa.gov

Mr. Suddleson has worked at NOAA for 12 years. Since joining CSCOR, he has worked for eight years as a program manager. He provides management oversight for a portfolio of projects funding researchers and managers located in universities, state and tribal agencies around the country. He oversees projects that range from developing new monitoring and observation technologies to regional, multi-disciplinary, multi-institutional efforts that help mitigate impacts of harmful algal blooms on coastal communities. In this position, Mr. Suddleson has worked to strengthen NOAA science programs by building strong and lasting partnerships between NOAA scientists, the academic community, and public health and coastal resource risk managers. He has also contributed to the development of a number of HAB community plans including the Harmful Algal Research and Response: A National Environmental Science Strategy 2005–2015. Prior to joining CSCOR, he worked for the NOAA Office of Ocean and Coastal Resource Management where he represented NOAA interests on the interagency Federal Clean Water Action Plan Steering Committee and documented progress in the NOAA Coastal Zone Management Program. Mr. Suddleson earned a Master of Science degree in Marine Policy from the University of Delaware in 1997, and completed a Bachelor of Science degree in Marine Science and Biology from the University of Miami, Rosenstiel School of Marine and Atmospheric Sciences in 1992. For more information about CSCOR and other NOAA HAB Programs visit: http://www.cop.noaa.gov/stressors/extremeevents/hab/welcome.html

**Dr. Stephen B. Weisberg**
Executive Director
Southern California Coastal Water Research Project (SCCWRP)
3535 Harbor Blvd., Suite 110
Costa Mesa, CA 92626
(714) 755-3203
stevew@sccwrp.org

Dr. Stephen Weisberg is specializes in the design and implementation of environmental monitoring programs. He is the Chair of the Southern California Bight Regional Monitoring Steering Committee, and serves on the Governing Boards of the California Ocean Science Trust and the Southern California Coastal Ocean Observing System. In addition, he serves on advisory committees for numerous programs, including: the California Ocean Protection Council, the University of Southern California Sea Grant Program, the State of California's Clean Beach Task Force, the Alliance for Coastal Technology, and the Hollings Laboratory Oceans and Human Health Program. Dr. Weisberg received his undergraduate degree from the University of Michigan and his Ph.D. from the University of Delaware.