Harmful Algal Blooms and Hypoxia in the Pacific Coast Region

Problem

Along the Pacific Coast of the United States, harmful algal blooms are mainly caused by two recurring genera of algae (*Alexandrium* and *Pseudo-nitzschia*) which produce potent neurotoxins that accumulate in fish and shellfish. States monitor seafood toxin levels and, if toxins accumulate above regulatory limits, both commercial and recreational harvesting is closed to prevent paralytic shellfish poisoning (PSP) and amnesic shellfish poisoning (ASP) in humans. Transfer of algal toxins through the food web has been linked to significant wildlife mortality events of fish, birds, and marine mammals, especially protected species like sea lions. Other harmful algae in the region include macroalgae, which harm seagrasses, fish, and invertebrates in coastal waters, and and fish-killing raphidophytes, which impact finfish aquaculture operations.

Sign posted on Washington beach indicating shellfish closure.

The second largest hypoxic area in the U.S. resides on the Oregon-Washington inner continental shelf and has been associated with climate influenced upwelling of nutrient rich water. Massive mortalities of marine life and transport of this hypoxic water into coastal embayments are both issues of concern. In addition, Hood Canal, Washington, has experienced several severe fish-killing hypoxic events in recent years.

CSCOR Program Description

NOAA's Center for Sponsored Coastal Ocean Research (CSCOR) supports multi-year, interdisciplinary research in the Pacific Coast Region through the **Ecology and Oceanography of Harmful Algal Blooms** (ECOHAB), the **Monitoring and Event Response for Harmful Algal Blooms** (MERHAB) Programs, and the **Coastal Hypoxia Research Program** (CHRP). CSCOR provides immediate assistance to managers and public health officials to respond to emerging HAB events through the **HAB Event Response Program**.

These programs involve Federal, state, and academic partners and aim to address the issues of HABs and hypoxia in an ecosystem context by:

- Uncovering factors that regulate HAB growth in order to develop models needed for ecological forecasts;
- Improving understanding of HAB toxin effects on organisms and toxin transfer in food webs to prevent and mitigate ecological and human health impacts;
- Developing HAB cell and toxins detection methods;
- Improving early warnings through use of models, satellite remote sensing, and in-water detection technology
- Determining the causes and impacts of hypoxia, developing the capability to predict its occurrence, and evaluating the impacts in order to assess management alternatives;
- Establishing partnerships to improve regional monitoring and event response capabilities.

Accomplishments

Increased scientific understanding coupled with recent successes in detection, forecasting, and event response demonstrate the value of NOAA's research investments for helping managers reduce and prevent the detrimental effects of HABs.

More than 30,000 clam diggers may descend on the Washington coast in a single weekend, filling beaches, restaurants, and motels.

Understanding HAB Dynamics and Impacts

Recent research on West Coast HABs and their toxins has helped to reveal causes of blooms and toxicity and clarify toxin impacts on marine life as well as in humans. One important discovery revealed a genetic mutation in some commercial shellfish that makes them resistant to PSP toxins. Because resistant shellfish become more toxic than non-resistant ones, these findings will improve prediction and management of shellfish toxicity.

HAB Detection and Forecasts

The Olympic Region HAB Monitoring Network (ORHAB) focused on early warning of domoic acid in razor clams, allowing state officials to ensure the safety of this important recreational and cultural resource. ORHAB has been in place since 2004 and is now fully operational and funded by Washington State.

A regional ECOHAB project built on the ORHAB effort by developing a biological-physical model to clarify causes and develop capabilities for more advanced predictions. Results confirmed the Juan de Fuca Eddy as a toxic phytoplankton source and illustrated mechanisms for transport of HABs to the coast. A new project will advance predictive capabilities further by exploring additional potential sources and how the plume of the Columbia River estuary may influence movement of toxic patches inshore and along the coast.

CSCOR has supported the development, testing, and commercialization of a number of methods for HAB cell and toxin detection, both for regulatory and environmental applications. These include a rapid, low-cost domoic acid test kit, developed by NOAA and transferred to a private company for production. MERHAB researchers are also working to establish cost effective and coordinated HAB monitoring strategies that employ a range of detection technologies in California and Oregon. These strategies are already increasing lead time of warnings.

Preparing a shellfish sample extract for the Jellett rapid test for toxins that cause paralytic shellfish poisoning (Jellett Rapid testing Systems, Ltd.)
Photo: Gregg Langlois, California Department of Health Services

Event Response

The CSCOR HAB Event Response Program provides immediate assistance to coastal resource managers and public health officials to mitigate bloom impacts during events. Event Response projects along the west coast have benefited state shellfish monitoring in Oregon and helped responders deal with ill and dying marine animals in Southern California.

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Current and Recent HAB and Hypoxia Projects on the Pacific Coast Supported by CSCOR

Ecology and Oceanography of Harmful Algal Blooms (ECOHAB)

PNWTOX–The Columbia River plume and HABs in the Pacific Northwest: bioreactor, barrier, or conduit? (Ongoing) University of Washington; Department of Fisheries and Oceans, Pacific Region, Institute of Ocean Sciences, Sidney, B.C., Canada; University of California, Santa Cruz; Funding Partner: National Science Foundation. Improving predictability of HAB events on Pacific Northwest coastal beaches by advancing our understanding of HAB development/dissipation and transport and mixing processes using existing data in parallel with state of the art physical and bio-physical models that include, for the first time, both the Columbia River plume and potential HAB source regions off both Oregon and Washington.

Understanding Shellfish Resistance Strategies as a Means to Predict and Manage PSP Toxicity (Ongoing).. University of Washington, NOAA Northwest Fisheries Science Center. Characterizing mechanisms underlying bivalve susceptibility to paralytic shellfish toxins and species-specific toxin accumulation to understand factors contributing to shellfish toxicity in the presence of HABs and reduce impacts by providing tools to predict toxin retention by shellfish.

Identifying Regulatory Mechanisms for *Heterosigma akashiwo* Bloom Formation: Predation Interactions With Algal Behavior and Resource Use (Ongoing). Western Washington University. Identifying protistan predators of the HAB species *Heterosigma akashiwo to regulate blooms* which cause fish kills yearly in coastal waters of the Pacific.

Dynamics and Mechanisms of HAB Dinoflagellate Mortality by Algicidal Bacteria (Complete). University of California, San Diego/Scripps Institution of Oceanography. Identifying in economically important shellfish species what compounds are implicated in the overall shellfish toxicity and evaluating the performance of the ELISA antibody-antibody methodology where shellfish will be monitored and prepare standardized material to perform independent multi-laboratory evaluation of the assay.

Harmful Ulvoid Macroalgal Blooms in Washington State: Distribution, Environmental Effects, and Toxin Production (Complete). Western Washington, University, Seattle Pacific University. Ulvoid green macroalgae that occur in Washington coastal waters (e.g., *Enteromorpha spp, Ulva fenestrata*, and *Ulvaria obscura*) produce toxins detrimental to macroalgae, microalgae, and invertebrates. Determining when/where ulvoid blooms occur, physical, chemical, and biological factors associated with blooms and examining toxin production and impacts.

Relationship Between Paralytic Shellfish Toxins and *Alexandrium* Cysts in Puget Sound, WA (Complete). University of Washington. Addresses relationship between paralytic shellfish toxins in shellfish based on historical records from the Washington Dept. of Health and the distribution of cysts and vegetative cells of the dinoflagellates *Alexandrium spp*. in Puget Sound.

Ecology and Oceanography of Toxic Pseudo-nitzschia in the Pacific Northwest Coastal Ocean (Complete). University of Washington, San Francisco State University, NOAA, University of Maine. Developing a forecasting capability to predict toxic *Pseudo-nitzschia* species bloom development off Washington and in other similar coastal regions in Eastern Boundry upwelling systems off the Pacific Northwest Coast.

Effects of Algal Toxin Exposure in the Early Life History Stages of Fish (Complete). NOAA Northwest Fisheries Science Center. Investigates chronic effects of HABs on the viability, fecundity, and recruitment of key fish species in the marine environment to provide insight into the relationships between HABs and the productivity of marine fish populations

Monitoring and Event Response for Harmful Algal Blooms (MERHAB)

Integrated HAB monitoring and event response for coastal Oregon (Ongoing) Oregon State University, U. of Oregon, Oregon Departments of Fish and Wildlife and Agriculture, and NOAA Fisheries Newport Oregon. Providing the data needed to understand the ecological mechanisms underlying the occurrence of HABs along Oregon coast and employing this new understanding, new operational methods, and partnerships to improve Oregon state shellfish monitoring and response to toxic algal events.

RAPDALERT - Rapid Analysis of Pseudo-nitzschia and Domoic Acid, Locating Events in Near Real Time (Ongoing). University of Southern California, University of California. Pilot project for shifting much of the burden of HAB monitoring to an automated system to ensure early warning of impending blooms while minimizing unnecessary and expensive field-based sampling and lab-based testing. Results will advance understanding and ability to predict HAB events.

California Program for Regional Enhanced Monitoring of Phyco-Toxins (Cal-PReEMPT) (Ongoing). University of California. Expands the current capabilities of the California Department of Health Services by incorporating new in-field monitoring technology, implementing a tiered decision-making process, and relying on a volunteer network to enhance monitoring capabilities on HABs of *Alexandrium* and *Pseudo-nitzschia*. Couples to remote sensing to allow for better detecting, tracking, and study of HAB events.

Monitoring Toxic Alexandrium in Puget Sound Using qPCR (Ongoing). Woods Hole Oceanographic Institution. nus, Alexandrium catenella is widespread in the northwestern part of North America, including the Puget Sound, and is responsible for seasonal harmful algal blooms. Incorporates a proven, high-sensitivity detection method for A. catenella into existing PSP monitoring efforts and examines efficacy in predicting or serving as an early warning of shellfish PSP toxicity.

Olympic Region Harmful Algal Bloom (ORHAB) Project (Complete). The ORHAB partnership ultimately developed and adopted a combination of techniques to provide managers an effective early warning of domoic acid toxicity in shellfish. The forecasts generated by ORHAB are now sustained through state funding and have increased the commercial, subsistence, and recreational harvest of razor clams while minimizing the health risks to consumers.

Quinault Indian National Shellfish HAB Sampling and Monitoring Project (Complete). Quinault Indian Nation. As domoic acid continues to threaten QIN shellfish resources and health of tribal and surrounding communities, the project expands and improves the current monitoring program established in 2000 for *Pseudo-nitzshia* and domoic acid in water and shellfish beds along the Quinault Indian Nation coastline in Washington State.

Quilleute Indian Tribe Monitoring Domoic Acid in Marine Food Webs and Water (Complete). Quileute Indian Tribe, NOAA Northwest Fisheries Science Center. The project continues, expands and improves the

current monitoring program for *Pseudo-nitzshia* and domoic acid in water and shellfish beds along the Quileute Indian Tribe coastline in Washington State.

Harmful Algal Bloom Event Response

Mitigating Impacts of Fish Killing Algal Bloom in Puget Sound, Washington. HAB Event Response provided emergency funds to coordinate efforts for mitigating impacts of a fish killing bloom of the harmful alga, Heterosigma, in Puget Sound

Harmful Algal Bloom Training in Oregon. The highest levels of domoic acid in mussels ever observed in Oregon (more than eight times the safe limit) prompted Oregon health and shellfish managers to initiate a program based on the successful ORHAB Project in Washington. HAB Event Response funding sponsored a workshop in which 12 environmental and human-health officials from Oregon learned new techniques to use for providing early warnings for potential toxin-related shellfish bed and beach closures.

Cyanobacterial Toxicity in Upper San Francisco Bay. HAB Event Response supported an assessment of toxicity related to a bloom of the cyanobacteria *Microcystis aeruginosa* in upper San Francisco Bay.

Coastal Hypoxia Research Program (CHRP)

Historical Trends of Hypoxia in Three Basins of Puget Sound (Complete). Batelle Memorial Institute, Bryn Athyn College, University of Washington, U.S. Geological Survey. Supports research to reconstruct the history of hypoxia in three basins of Puget Sound by examining the chemical and biological record of past hypoxic events recorded in age-dated sediment cores. Tools in the form of either biomarkers or chemical parameters will allow a predictive capability for given current conditions and potential natural or anthropogenic scenarios, including management alternatives, such as nutrient removal and river flow control.