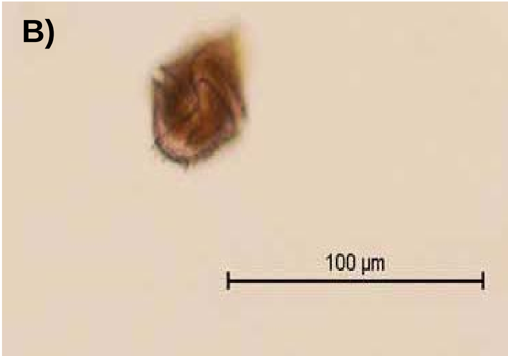
20 Harmful Algal Blooms (HABS)



A) A live (left) and dead abalone (right) in the ocean. Photo credit: D Stein, CDFW. B) A microscope photo of the dinoflagellate *Gonyaulax spinifera.* Photo credit: A Paquin.

Introduction

Marine phytoplankton populations can undergo periods of explosive growth due to favorable environmental conditions. These instances are called algal blooms. Marine phytoplankton are microscopic, single celled plants that live in the ocean. They are vitally important to the marine ecosystem and play a crucial role in providing food to the base of the food web. Similar to plants on land, phytoplankton use energy from the sun and carbon dioxide to produce sugar and oxygen through the process of photosynthesis. Some species of phytoplankton can produce potentially harmful toxins. Others can be harmful due to the size of the bloom along with other environmental conditions through depletion of oxygen levels or by creating large oily mats of foam. When algal blooms are harmful to humans and or biological resources, they are called Harmful Algal Blooms (HABs). These harmful algae are generally present year round in the water column in very small amounts, but only become a problem for humans and animals when the phytoplankton species populations reach particularly high levels. Algal blooms and HABs are often visible due to pigments produced by the phytoplankton and are often referred to as “Red tides”.

Harmful algal blooms are not new to the California coast, with records of paralytic shellfish poisoning (PSP) dating back to historical Native California Tribal knowledge. “From time immemorial it has been the custom among coastal tribes of Indians, particularly the Pomo, to place sentries on watch for *Kal ko-o* (mussel poison),” wrote Karl F. Meyer, H. Sommer and P. Schoeholz in a 1928 issue of *the Journal of Preventative Medicine*. “Luminescence of the waves, which appeared rarely and then only during very hot weather, caused shellfishing to be forbidden for two days; those eating shellfish caught at such times suffered sickness and death”.

The presence of a HAB can cause significant effects to biological resources. A snapshot of effects to biological resources is seen in a timeline of HAB events in Monterey Bay compiled by the Central and Northern California Ocean Observing

System (CeNCOOS). The timeline illustrates the effects of major HAB events on both biological resources and the economy in one specific area. The first recognized toxic algal bloom involving domoic acid (DA) from *Pseudo-nitzschia* occurred in Monterey Bay in 1991 resulting in the deaths of pelicans and cormorants that had consumed sardines containing high levels of DA. In 1998, a *Pseudo-nitzschia* bloom in Monterey was followed by over 400 sea lion carcasses appearing on shore that showed signs of neurological damage from eating infected sardines. A harmful red tide event in 2007 caused by *Cochlodinium* killed abalone at the Monterey Abalone Company, costing almost $60,000 in damage. Slimy foam that caused birds' feathers to stick together and ultimately caused a huge bird die-off was created by a red tide (*Akashiwo sanguinea*) in 2007. The slimy foam was created by a combination of the large bloom, large waves, and onshore winds.

Status of the Biological Knowledge

Phytoplankton species that can cause HABs occur worldwide, including along the entire California coast. The population of each species and toxin levels in the water change with time and environmental conditions. The California Department of Public Health (CDPH) monitors the populations of these species, and the Southern California Coastal Ocean Observing System (SCOOS) and CeNCOOS compile additional data from research laboratories along the coast.

Major Causes of Harmful Algal Blooms

It is not known exactly what causes any individual phytoplankton bloom to become a HAB event or what the exact cause of a particular algal bloom may be. It is known that high nutrient levels, bright sunlight, water temperature and salinity, time of year, number of grazers and/or predators, and calm waters with low wind circulation patterns all play a role in predicting blooms and HAB events. Nutrient rich and dynamic upwelling zones, such as the California coast, are particularly prone to blooms and HAB events for this very reason.

Algal blooms can often be visible, but not always; in fact HABs can occur when the water is perfectly clear. The reddish pigment called peridinin, most often in dinoflagellates, generally causes "Red tides" which give the ocean a reddish hue during an algal bloom. Green tides are generally caused by *Phaeocystis* which is an algae found throughout the world. Water discoloration is not an accurate way to predict if an algae bloom is toxic or dangerous because HABs can occur in clear water, and there are numerous species of phytoplankton that cause visible algal blooms, both harmful and non-harmful.

Also unknown is what causes a species of phytoplankton to release toxins during a HAB event, although CeNCOOS reports multiple hypotheses. One hypothesis is that the phytoplankton are acquiring or detoxifying nutrients in the environment. Another hypothesis is the toxins are produced to protect the algae from grazers, such as krill and anchovies. A third hypothesis is that the toxin prevents or minimizes the growth of other algae competing for the same resources.

Not all algal blooms are HAB events, meaning they do not all cause harmful effects. During a phytoplankton bloom, researchers commonly look for the presence of the organisms through cell counts and DNA sampling, presence of a toxin, and harm or impact on the ecosystem, economy and/or human health. The information researchers gather during a bloom helps in identifying whether or not a particular bloom is a HAB event or has the potential of becoming a HAB event.

Common Species in California

Listed below are the most common species of HAB-forming phytoplankton on the California Coast. Current information on the populations of these species can be found on the SCOOS and CeNCOOS websites.

Akashiwo sanguinea

Akashiwo sanguinea (formerly called *Gymnodinium sanguineum* or *Gymnodinium splendens*) does not produce a known toxin. Blooms have been observed in summer and early fall; and have been reported to kill invertebrates, fish, and birds. Mortalities are most likely due to clogging of gills, the production of surfactants (foam leading to shorebirds' inability to keep warm and dry), and to oxygen depletion when blooms decay.

Alexandrium spp.

Alexandrium catanella (formerly *Gonyaulax catanella/catenatum*) is a dinoflagellate that produces a highly potent neurotoxin, saxitoxin. When consumed, saxitoxin, causes paralytic shellfish poisoning (PSP). PSP in humans is caused primarily through eating shellfish and can result in numbness, uncoordinated muscle movement, incoherence, and, in extreme cases, respiratory paralysis and death. Now recognized as one of the most deadly algal toxins, saxitoxin was first discovered in 1927 following a poisoning event that affected over a hundred people in central California.

Cochlodinium spp.

The dinoflagellate, *Cochlodinium*, has been observed in California waters for at least 80 years. Recent blooms have been reported from San Diego to Monterey Bay. The 2007 outbreak at an abalone farm caused gill damage to the abalone as well as lowered the amount of dissolved oxygen in the seawater. *Cochlodinium* has been implicated in the deaths of salmonids and other finfish, but the toxin or mechanism which causes the harmful effects is currently unknown.

Dinophysis spp.

Dinoflagellates within the genus *Dinophysis* have been found to produce okadaic acid which can cause diarrhetic shellfish poisoning (DSP). The primarily mild gastrointestinal disorder produces symptoms including: nausea, vomiting, diarrhea, and abdominal pain accompanied by chills, headache, and fever. Okadaic acid is produced by multiple species of *Dinophysis* that occur in California and the toxin has been documented in California waters.

Lingulodinium polyedrum

The common dinoflagellate *Lingulodinium polyedrum* (formerly *Gonyaulax ployedra*) prefers warmer temperate waters and frequently produces “red tides” along the coast of southern California. During the summer and fall of 2005, a large bloom of *Lingulodinium polyedrum* extended from San Diego to Ventura. This species may produce a toxin called yessotoxin that shares numerous similarities with DSP and the species was once included in the DSP group. Subsequently, the yessotoxins are now in a separate group due to distinct differences in chemistry and toxicology.

Phaeocystis spp.

Phaeocystis can be found as a colony of cells encased within a mucus layer or as single cells. The colonies of cells can produce large blooms that create white or colored foam that can cover beaches and shallow water areas. The blooms produce dimethylsulphide (DMS), an aerosol, which is thought to possibly contribute to cloud formation and acid rain.

Prorocentrum spp.

This dinoflagellate genus contains several toxic and harmful species. One of the most common species in the genus is *Prorocentrum micans* which occurs in cold temperate waters and produces red tides world wide. Despite being considered harmless in our region due to the lack of observed toxins, this species continues to be monitored due to the production of red tides as well as toxins produced in other regions.

Pseudo-nitzschia spp.

Nine species of *Pseudo-nitzschia* produce Domoic Acid (DA) worldwide. *Pseudo-nitzschia australis* and *Pseudo-nitzschia multiseries* are the most common species in California. Naturally occurring and rare, DA is an amino acid that is toxic to marine mammals, seabirds, and humans. Domoic Acid generally causes gastrointestinal disorders and neurological problems. Amnesic shellfish poisoning is a symptom of DA with the primary symptom being amnesia. First recognized in California when the deaths of more than 100 brown pelicans and cormorants were linked to DA in September 1991 in Monterey Bay; the toxin has since been implicated in other deaths of marine mammals and seabirds between Monterey Bay and San Diego.

Status of the Population

HABs and the species listed above are tracked throughout the year by the CDPH. Information on algal blooms and toxin levels can be found in the Marine Biotoxin Monitoring Reports on the CDPH website. The toxin levels surveyed by the CDPH are obtained from mussel tissue samples. Additional information and tracking of the current status of common HAB-causing phytoplankton species can be found on the SCOOS and CeNCOOS websites. University of California, California State University, and private research stations submit regularly collected and real time data to the SCOOS and CeNCOOS data portals. The SCOOS and CeNCOOS websites allow the use and comparison of data collected in the field.

2011 Significant HAB Event

During 2011, there were multiple algal bloom events on the California coast with one significant HAB event. The HAB event occurred off Sonoma County in August 2011 and continued into September 2011. Coinciding with a large bloom event located nearshore from Bodega Bay (Sonoma/Marin counties) north to Anchor Bay (Mendocino County) and probably extending beyond, a large die-off of marine invertebrates occurred predominantly in the vicinity of Fort Ross State Park north to Salt Point State Park. Invertebrate deaths were observed from many taxa including mollusks, echinoderms, and crustaceans. Marine mammals and fish did not appear to be affected by the event. Water samples were collected; the dominant phytoplankters were dinoflagellates belonging to the *Gonyaulax spinifera* species complex. Tissue samples from affected animals were tested for toxins and trace levels of yessotoxin were present. Marine scientists investigating the HAB have not been able to directly attribute the deaths to the presence of *G. spinifera* and associated toxin, but the general consensus is that the HAB is connected to the die-off. The vector responsible for potentially transferring toxins produced by phytoplankton to the herbivores that died in this event remains unknown. Water born toxins including viruses and bacteria may also be involved, but further investigation is needed. Based on the widespread die-off as well as the unknown source and ocean residence time of the toxin responsible, the California Fish and Game Commission voted on Sept. 15, 2011 to close the recreational abalone fishery in Sonoma County for the rest of the year. Research into the event is continuing and results will be released to the public as soon as available.

Management Considerations

Harmful algal blooms create numerous management considerations for the health and safety of humans and marine animal populations. Federal and State agencies, along with public-private partnerships, are working to establish predictive models for HAB occurrences and improve response time for affected marine resources.

California's Shellfish

Annually, the CDPH's Preharvest Shellfish Protection and Marine Biotoxin Monitoring Program (formerly called Mussel Watch) places a quarantine on sport harvesting of mussels for food from May 1 through October 31. During this time of year, mussels are most likely to accumulate toxins due to increasing phytoplankton populations and potential HAB events. The mussel quarantine provides protection to humans from DA and PSP. Should monitoring activities indicate unsafe levels of toxins, the quarantine can be expanded beyond or prior to the annual timeframe and include additional shellfish. Local health officers post signs advising people of the quarantine. The signs also warn people that clams and scallops may contain toxins. During the quarantine, people should remove the viscera from clams and scallops, the siphons from Washington clams, and eat only the remaining white meat.

CDPH monitors marine toxins in sport and commercial seafood year round. This program allows CDPH to follow changes in toxin levels and to alert the public and local health agencies if necessary. If CDPH finds unsafe toxin levels in seafood, they do not allow the affected species to be commercially harvested or sold; at the same time, they will also issue public warnings for sport harvesters of these species. The annual mussel quarantine does not apply to companies licensed by the State as certified shellfish harvesters. Mussels may be harvested and sold for bait at any time.

Marine Mammals

The neurotoxin DA affects marine mammals each year in California. The neurotoxin was first identified by the Marine Mammal Center in 1998 after a large HAB event. Marine mammals are affected when they eat prey, like anchovies, that have been feeding during HAB events. The effect of DA on marine mammals depends on the amount they eat and the amount of toxin accumulated in the prey. Symptoms include severe cases of seizures and other central nervous system problems, as well as hippocampal degeneration and amnesiac shellfish poisoning. Diagnoses are difficult to establish definitively due to unknown toxicity levels of algal blooms and the unpredictable timing of DA outbreaks. The Marine Mammal Center has been studying the effects of DA on California sea lions, including the effects on memory and learning, to hopefully better understand how DA affects the human population.

In 2007, deaths of southern sea otters from Monterey Bay were linked to a new type of HAB. "Super-blooms" of cyanobacteria, normally a freshwater species, that produce potent and environmentally persistent biotoxins (microcystins) were linked to the deaths of 21 sea otters. The sea otters were found near the mouths of rivers where freshwater was released to the ocean. Additionally, bioaccumulation of the toxins was found in nearby clams, mussels, and oysters. A recent paper by Miller et al. (2010) suggests that this discovery points to the possibility that humans could be at risk from harvesting shellfish near the freshwater marine interface when high levels of cyanobacteria are present in the freshwater source.

HAB Monitoring in California

It is widely accepted that the key to management of HABs is through a statewide and regional HAB monitoring network and forecast system. A February 2009 Working Draft White Paper "Harmful Algal Blooms in the West Coast Region: History, Trends, and Impacts in California, Oregon, and Washington" strongly recommends the need for a regional network. The list of reasons for a regional network include: improving the timeliness of HAB warning by interstate dissemination of current HAB data, improving the efficiency and decreasing the cost of HAB monitoring, improving the development and validation of forecast models, improving the accuracy of data for resource managers, improving public education, and improving the predictive models on factors promoting HABs. A California Current regional network is still being created and will most likely include the efforts of the individual states (California, Oregon, and Washington), plus monitoring efforts by SCOOS, CeNCOOS, and the Northwest Association of Networked Ocean Observing Systems (NANOOS).

Currently, the greatest strides have been made at the state level for creating a HAB Monitoring Network. The California Harmful Algal Bloom Monitoring and Alert Program (HABMAP) is an effort initiated by the National Oceanographic and Atmospheric Administration (NOAA), the California Ocean Science Trust (CA OST), and the Southern California Coastal Water Research Project (SCCWRP) to develop a state-wide Harmful Algal Bloom (HAB) alert network system for researchers and end user committees. HABMAP is the culmination of multiple expert level workshops exploring the need for increased HAB monitoring. In November of 2011, NOAA awarded $4 million for a five year project to the SCOOS and CeNCOOS systems to collaborate on creation of the HABMAP monitoring network that will include real time data from multiple federal, state, and private research stations. The data will allow for a better understanding of HABs on the California coast and ultimately lead to improved management strategies for California's resources. "This new effort will help us address a critical gap in past research, namely understanding the conditions leading to toxic blooms before they become a problem." said Raphael M. Kudela, professor at the University of California, Santa Cruz and project lead. "We are particularly excited because the project combines expertise from research and state public health managers in California with the developing national observing network established by NOAA."

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Further Reading

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National Oceanic and Atmospheric Association (NOAA). 2011. NOAA awards grant to advance harmful algal bloom warnings to protect public and animal health in coastal California [Internet]. Press Release. November 10, 2011. Available from: http://www.noaa.gov/newsarchive.html.

NOAA Fisheries Service, Washington Sea Grant Program. 2002. Red Tides: West Coast newsletter on marine biotoxins and harmful algal blooms. Autumn 2002. 8 p. Available from: http://www.nwfsc.noaa.gov/hab/outreach/redtide.html.

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For more information on the Southern California Coastal Ocean Observing System – SCOOS, go to the SCOOS website at:
http://www.sccoos.org/data/habs/abouthabs.php

For more information on the Central and Northern California Ocean Observing System – CeNCOOS, go to the CenCOOS website at:
http://www.cencoos.org/sections/conditions/algal_blooms.shtml

For more information on the California Department of Public Health (DPH) – Marine Biotoxin Monitoring Reports, go to the DPH website at:
http://www.cdph.ca.gov/HealthInfo/environhealth/water/Pages/Shellfishreports.aspx

For more information on the California Department of Public Health (DPH) – Preharvest Shellfish Protection and Marine Biotoxin Monitoring Program, go to the DPH website at:
http://www.cdph.ca.gov/HealthInfo/environhealth/water/Pages/Shellfish.aspx

For more information on the Seafood Network Information Center – Sea Grant Extension, go to their website at:
http://seafood.ucdavis.edu/Pubs/natural.htm

For more information on the Marine Mammal Center, go to their website at:
http://www.marinemammalcenter.org