Frequently Asked Questions:

Harmful Algal Blooms and California Fisheries

Developed in Response to the 2015-16 Domoic Acid Event

CALIFORNIA OCEAN SCIENCE TRUST

California Ocean Science Trust

AUGUST 2016

CALIFORNIA OCEAN SCIENCE TRUST

About this Document

GOAL : The goal of this document is to provide clarity for members of the fishing industry, consumers, non-governmental organizations, state agencies, and the Legislature on the California's current practices (through August 2016) in regards to harmful algal bloom (HAB) monitoring and management, and seafood toxin sampling and testing protocols. This document is intended to bring diverse audiences together around a common pool of information, and support more engaged conversations where everyone can move forward together.

Recent California fishery closures and health advisories during 2015-2016, resulting from elevated seafood toxin levels, have raised questions among California's coastal communities about the science supporting current biotoxin monitoring and fishery management practices. In response, the California Ocean Protection Council (OPC) and the Interagency Marine HAB Task Force[1] (HAB Task Force) have asked California Ocean Science Trust to develop a frequently asked questions (FAQ) document to address questions focused on:

I. HABs and seafood toxin monitoring efforts in California
II. Domoic acid and California fisheries
III. Human health and seafood safety concerns
IV. California's fishery and seafood toxin management

Questions were submitted to Ocean Science Trust by the HAB Task Force, along with input from the California Dungeness Crab Task Force (DCTF) Executive Committee, Commercial Fishermen of Santa Barbara, the office of California Senator Mike McGuire, and the Joint Committee on Fisheries and Aquaculture. Additionally, a public conference call was held on July 27, 2016 to further engage with the fishing industries involved and other interested parties. The majority of the questions included in this FAQ originated from these conversations, public comment, emails, and/or direct calls from stakeholders to agency or legislative staff. For the full list of questions submitted to Ocean Science Trust, visit here[2].

Ocean Science Trust compiled responses to the questions in this FAQ document based on existing scientific literature and consultation with representatives from the HAB Task Force, Ocean Protection Council Science Advisory Team "Harmful Algal Blooms and California Fisheries" working group (see below), and additional scientific experts (university researchers, and state and federal agency scientists). Additionally, this FAQ document prioritizes addressing questions that did not require additional research, due to the timeframe set by the California Legislature to begin addressing this issue.

This document is complementary to the work of an Ocean Protection Council Science Advisory Team (SAT) working group[3], convened by Ocean Science Trust to provide longer-term recommendations that can help California agencies and the Legislature prioritize future science-informed actions focused on better understanding and predicting fishery and human health impacts related to HABs.

An overview and more general scientific information about HABs in California can be found in a report created by leading academic experts in the field titled "A Primer on California Harmful Algal Blooms: Common questions and answers for stakeholders, decision-makers, coastal managers, and the education community," available here[4].

1 The HAB Task Force membership includes representatives from California Department of Public Health, California Fish and Game Commission, California Department of Fish and Wildlife, Ocean Protection Council, and the Office of Environmental Health Hazard Assessment.

2 http://www.oceansciencetrust.org/wp-content/uploads/2016/07/Full-List-of-Submitted-questions-HABs-and-fisheries-2016.pdf

3 For more about the SAT working group, visit here: http://www.oceansciencetrust.org/project/harmful-algal-blooms-and-california-fisheries/

4 McGaraghan et al., 2012: http://fisheries.legislature.ca.gov/content/august-10-2016-progress-reports-crab-season-domoic-acid-and-disaster-declaration

List of Acronyms

ASP – Amnesic Shellfish Poisoning
CDFW – California Department of Fish and Wildlife
CDPH – California Department of Public Health
CeNCOOS - Central and Northern Ocean Observing System
DCTF – Dungeness Crab Task Force
DSP – Diarrhetic Shellfish Poisoning
EMB – Environmental Management Branch of the California Department of Public Health
EPA – United States Environmental Protection Agency
FAQ – Frequently Asked Questions
FDA – United States Food and Drug Administration
FDB - Food and Drug Branch of the California Department of Public Health
FGC – Fish and Game Commission
HAB – harmful algal bloom
ISSC - Interstate Shellfish Sanitation Conference
MSA - Magnuson-Stevens Fishery and Conservation Management Act
NOAA – National Oceanic and Atmospheric Administration
OPC - California Ocean Protection Council
PSMFC – Pacific States Marine Fisheries Council
PSP – Paralytic Shellfish Poisoning
SAT - Ocean Protection Council Science Advisory Team
SOP - Standard Operating Procedures
Spp. - species
Task Force – California Interagency Marine Harmful Algal Bloom Task Force
WARNN-West – Wildlife Algal Toxins Research and Response Network for the West Coast

About Ocean Science Trust

Ocean Science Trust is an independent non-profit that brings together governments, scientists, and citizens to build trust and understanding in ocean and coastal science. We empower participation in the decisions that are shaping the future of our oceans. We were established by the California Ocean Resources Stewardship Act to support managers and policymakers with sound science. For more information, visit our website at www.oceansciencetrust.org.

About the Interagency Marine HAB Task Force

The Interagency HAB Task Force was established by the Ocean Protection Council in early 2016. Task Force members include Sonke Mastrup (California Department of Fish and Wildlife), Susan Ashcraft (Fish and Game Commission), Patrick Kennelly (Department of Public Health), Gregg Langlois (Department of Public Health, retired), Susan Klasing (Office of Environmental Health Hazard Assessment), Valerie Termini (Fish and Game Commission), and Jenn Phillips (Ocean Protection Council). During the winter of 2016-17, the Task Force will help guide the working group in developing a longer term management document about what information is needed and what investments are needed to help to better predict and plan for future events. The Task Force will also work together to review and update standard operating procedures (SOP) that will be utilized by the agencies responsible for oversight of public health and the fisheries.

About the Ocean Protection Council Science Advisory Team Working Group

The Harmful Algal Blooms and California Fisheries SAT working group was convened by Ocean Science Trust to develop scientific guidance and options for adding capacity to the California's existing HAB monitoring and sampling efforts, as well as advance our understanding and ability to predict HAB events and fishery impacts. Members include Raphael Kudela (UC Santa Cruz), William Cochlan (San Francisco State University), Dave Caron (University of Southern California), and Gregg Langlois (California Department of Public Health, retired).

Contacts

Errin Ramanujam, Senior Scientist, errin.ramanujam@oceansciencetrust.org
Hayley Carter, Program Scientist, hayley.carter@oceansciencetrust.org

Acknowledgements: In addition to members of the HAB Task Force and SAT working group, Ocean Science Trust would like to thank the following individuals for their contributions to this FAQ: Vera Trainer, Robert Dickey, Pete Kalvass, Jerry Borchert, Kimberly Selkoe, Carrie Pomeroy, Carrie Culver, Joe Tyburczy, Kathi Lefebvre, Stacey Degrasse, and Emily Knight.

Recommended Citation: Frequently Asked Questions: Harmful Algal Blooms and California Fisheries, Developed in Response to the 2015-2016 Domoic Acid Event. 2016. California Ocean Science Trust, Oakland, CA.

Table of Contents

About this Document 2
Timeline of Events: Domoic Acid and the California 2015-16 Fishing Season 5
Background 6

I. Harmful Algal Bloom and Biotoxin Monitoring Efforts in California 7
- How are harmful algal blooms and associated biotoxins being monitored along California's coast? 7
- What harmful algal species and associated toxins are routinely monitored by the State and how? 8
- Are HAB events increasing in frequency? Are there links between climate change and HAB events? 10
- Can we predict future HAB events and impacts to fisheries? 10
- Where can HAB monitoring and active bloom information be found? 11

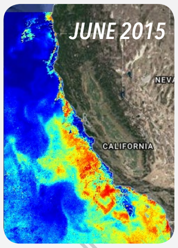
II. Domoic Acid and California Fisheries 12
- What is the history of domoic acid toxicity in seafood in the U.S.? 12
- What are the current (2016) domoic acid action levels in California? 13
- What is the scientific rationale behind the action levels for domoic acid toxicity in seafood? 13
- What are the current criteria for opening and closing the Dungeness crab fishery based on the domoic acid action levels? 14
- Where can information be found on California's current domoic acid monitoring plans? What plan do other West Coast states adhere to? 16
- Where are the domoic acid biotoxin monitoring sites in California? 16
- How were the Dungeness crab sites selected? 17
- How frequently are biotoxin sites sampled? What determines how frequently sampling occurs? 17
- How is spacing of sites considered? 18
- How are samples collected within a site (distance, including buffer zones)? Does sampling control for potential differences in domoic acid levels between male and female Dungeness crabs? 18
- How is domoic acid detected in seafood samples? How are the samples processed during testing? 18
- How long does it take to process crab samples once they have been received by CDPH? 19
- How are government agencies responding to the 2015/16 shellfishery closures in California (e.g., Dungeness and rock crab, razor clam)? 19

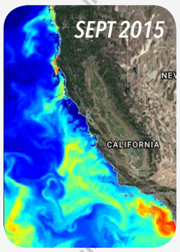
III. Health and Seafood Safety Concerns 21
- After consumption of crab meat, is toxin accumulation additive if multiple crabs are eaten? 21
- What are the long-term effects of low levels of domoic acid exposure? 21
- Do some fished species accumulate domoic acid toxin more than others? 21

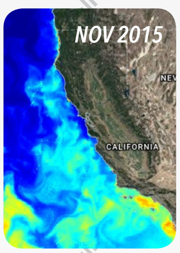
IV. California's Fishery and Seafood Toxin Management 23
- What agency leads California's seafood biotoxin monitoring and sampling programs, and how are these programs funded? 23
- What are the roles of the California government agencies and state bodies with regard to HAB response, monitoring, and fisheries management? 23
- How do HAB and fishery management measures in California, specifically for domoic acid and Dungeness crab, link to what is being done in Oregon and Washington? 23
- How does Dungeness crab management differ between the recreational and commercial sector, and what is the rationale for this difference? 23
- What do differences in Dungeness crab management between the commercial and recreational sectors mean for opening and closing of each sector? (i.e., Why did the commercial sector have to wait while the sport sector was opened?) 24
- What is the process for testing Dungeness and rock crab for domoic acid in advance of the season opener? When will domoic acid testing for the 2016-17 season commence? 25
- Why was a "two clean test" system required most of the time and a "one-test" system at other times? Describe CDFW's rationale for opening the District 10 line without the two consecutive clean tests required elsewhere. 25

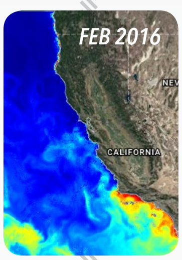
References 27

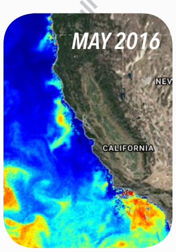
Timeline of Events: Domoic Acid and the California 2015-16 Fishing Season



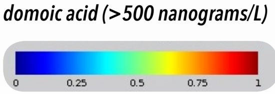








Historical probability of particulate domoic acid (>500 nanograms/L)



Map data: CeNCOOS

2015

JUNE 1, 2015
CDPH advised consumers not to eat recreationally harvested mussels and clams, commercially or recreationally caught anchovy and sardines, or the internal organs of commercially or recreationally caught crab taken from Monterey and Santa Cruz counties due to elevated domoic acid levels.

JUNE 8, 2015
CDPH expanded the warning to include the internal organs (viscera) of scallops due to domoic acid.

JULY 3, 2015
CDPH expanded the warning to include Santa Barbara County.

AUGUST 26, 2015
CDPH advised consumers not to eat recreationally harvested bivalve shellfish (mussels and clams) from Humboldt or Del Norte counties due to elevated domoic acid.

SEPTEMBER 11, 2015
CDPH and CDFW began preseason Dungeness crab meat quality and toxin testing.

NOVEMBER 3, 2015
CDPH issued health advisory not to consume Dungeness and Rock crabs caught in waters between OR border and the southern Santa Barbara County line.

OEHHA and CDPH recommended delaying opening of Dungeness crab season and closing the rock crab fishery due to unsafe levels of domoic acid.

NOVEMBER 5, 2015
FGC held an emergency meeting and voted to delay the opening of the recreational Dungeness crab fishery.

NOVEMBER 6, 2015
Director of CDFW enacted an emergency rulemaking to delay the opener of the commercial Dungeness crab season and close commercial rock crab.

NOVEMBER 13, 2015
CDPH lifted advisory for bivalve shellfish (mussels and clams) and small finfish (anchovies and sardines) caught in the Santa Cruz, Monterey, or Santa Barbara County areas.

DECEMBER 9, 2015
CDPH lifted advisory for bivalve shellfish (except razor clams) from Humboldt and Del Norte Counties.

DECEMBER 31, 2015
CDPH lifted advisory for Dungeness and rock crabs caught along the coasts of Santa Barbara and San Luis Obispo counties. CDFW opens commercial and recreational rock crab, and recreational Dungeness crab in these regions.

2016

FEBRUARY 9, 2016
Governor Brown requested that the federal government declare a fishery resource disaster and commercial fishery failure under the Magnuson-Stevens Act in order to seek federal assistance.

FEBRUARY 11, 2016
CDPH lifted health advisory for Dungeness crabs caught in all areas south Point Reyes. CDFW and FGC opened recreational Dungeness crab fishing in areas south of Point Reyes.

MARCH 18, 2016
CDPH lifts health advisory for Dungeness crabs caught in areas south of the Sonoma/Mendocino County line. Recreational Dungeness crab fishery opens in this region, and CDFW provides commercial Dungeness crab fishermen seven days' notice of opening.

MARCH 26, 2016
Commercial Dungeness crab season opened south of the Sonoma/Mendocino County Line.

MARCH 28, 2016
CDPH lifted health advisory for rock crabs caught in state waters off the Channel Islands, with the exception of one area between Santa Rosa and Santa Cruz Islands. Recreational and commercial rock crab fisheries open in these regions.

APRIL 22, 2016
CDPH lifted Dungeness crab health advisory in Mendocino and portions of Humboldt Counties. Rock crab advisory lifted for Monterey County.

APRIL 27, 2016
FGC closed recreational razor clam fishery in Humboldt and Del Norte Counties.

MAY 2, 2016
Dungeness Crab health advisory lifted along Northern California Coast. California coast is open for recreational Dungeness crab, except one area within Humboldt county.

MAY 12, 2016
Commercial Dungeness crab fishery opened in Mendocino, portion of Humboldt and Del Norte counties.

MAY 19, 2016
Recreational Dungeness crab fishery opened statewide, Commercial fishermen given seven days' notice of opening.

MAY 26, 2016
Commercial Dungeness crab fishery opens statewide.

JUNE 3, 2016
Commercial and recreational rock crab fisheries open in remainder of Channel Islands.

JULY 6, 2016
CDPH lifted advisory for rock crab in portions of San Mateo County. Recreational and commercial rock crab fisheries open south of Pigeon Point.

Background

Harmful algal blooms (HABs) are extreme biological events that can result in negative impacts to fisheries, coastal ecosystems, economies, and public health via the production of natural toxins. These toxins can accumulate in meat and organs of shellfish and other seafood species and, when consumed by marine wildlife and humans, can result in various illnesses or death. It is generally accepted that HABs are increasing in frequency, intensity, and duration in all aquatic environments on a global scale. In California, the prevalence and intensity of HABs is a growing concern.

In 2011, a HAB event in coastal areas of Sonoma County led to the mass mortality of red abalone, urchins, sea stars, chitons, and crabs, and was the largest invertebrate die-off recorded for the region[5]. In the spring and summer of 2015, an unprecedented HAB of the marine algae *Pseudo-nitzschia* stretched from central California to the Alaska Peninsula, resulting in some of the highest concentrations of the toxin domoic acid ever observed in California. This particular event even exceeded domoic acid levels researchers had previous thought could occur in the natural environment. This most recent HAB was a consequence of a series of abnormal ocean changes in the Pacific Ocean, including a large mass of warm and nutrient-poor water, named "the blob," combined with warm water driven by El Niño.

As a result of this West Coast-wide HAB event, elevated levels of domoic acid were observed in major commercial and recreational California fisheries in 2015 and 2016, including Dungeness crab, rock crab, anchovies, mussels, and razor clams. This led to multiple fishery and aquaculture closures and health advisories during the 2015-2016 season, including California's commercial and recreational Dungeness crab and rock crab, and recreational razor clam fisheries. These closures resulted in extensive impacts and economic hardships on the commercial fishing and seafood industry, prompting Governor Brown to request[6] a fishery resource disaster and commercial fishery failure declaration under the Magnuson-Stevens Act on behalf of the commercial Dungeness crab and rock crab industries.

Given California's changing ocean conditions and increasing threats to coastal industries, communities, and economies, the State is interested in better understanding and predicting HAB events, as well as exploring opportunities to bolster its existing seafood toxin sampling and monitoring programs.

In this document, we focus on addressing frequently asked questions related to California's current practices for HAB monitoring, management, and seafood toxin sampling and testing protocols. In some sections, we address questions about California's HAB and shellfish monitoring efforts, broadly. In others, we focus more specifically on domoic acid and California's crab fisheries. Where possible, we attempt to distinguish between bivalve and crustacean shellfish. **Bivalve shellfish** (mussels, clams, oysters), are routinely monitored year round by the California Department of Public Health and have strict requirements for commercial shellfish growing areas in compliance with the National Shellfish Sanitation Program (NSSP)[7]. **Crustacean shellfish** (e.g., Dungeness and rock crab) and finfish (e.g., Pacific sardine, northern anchovy) are tested for toxins when there is an indicator present (see Box 1) and/or during routine monitoring, such as the preseason meat quality testing that takes place for Dungeness crab.

---

5 De Wit et al., 2014. Available at: http://www.nature.com/ncomms/2014/140416/ncomms4652/full/ncomms4652.html

6 Governor Brown Letter: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=116284

7 The National Shellfish Sanitation Program (NSSP) is the federal/state cooperative program recognized by the U. S. Food and Drug Administration (FDA) and the Interstate Shellfish Sanitation Conference (ISSC) for the sanitary control of shellfish produced and sold for human consumption. Participants in the NSSP include agencies from shellfish producing and non-producing States, FDA, EPA, NOAA, and the shellfish industry. For more information, visit here: http://www.fda.gov/Food/GuidanceRegulation/FederalStateFoodPrograms/ucm2006754.htm

Photo: NOAA

I. Harmful Algal Bloom and Biotoxin Monitoring Efforts in California

▪ *How are harmful algal blooms and associated biotoxins being monitored along California's coast?*

California has the longest-standing biotoxin monitoring program in the U.S., beginning in 1927 in response to a massive paralytic shellfish poisoning (PSP) episode. That event resulted in several deaths and over 100 illnesses that were associated with mussel consumption. In 1991, the California Department of Public Health (CDPH) began monitoring state fisheries for domoic acid after it was first detected in Monterey Bay.

CDPH has implemented a prevention program that has traditionally been comprised of the following basic elements:

1. a coastal bivalve shellfish monitoring program (see *CDPH Shellfish Monitoring Program* below) that serves to protect recreational harvesters and serves as an early warning for HABs that could be transported into the bays and estuaries used for commercial shellfish aquaculture;
2. a coastal phytoplankton monitoring program (see *CDPH Volunteer-based Phytoplankton Monitoring Program* below) for early detection of toxin producing species that could impact shellfish and other seafood resources. Early bloom detection, coupled with the ongoing bivalve shellfish monitoring, inform and direct the need for sampling other seafood species (e.g., crab, anchovy);
3. frequent monitoring of commercial bivalve shellfish growing areas;
4. an annual statewide quarantine on sport harvested mussels (from May 1 through October 31);
5. mandatory reporting of disease cases;
6. public information and education activities.

CDPH Shellfish Monitoring Program

Bivalve Shellfish

The shellfish monitoring component of the Marine Biotoxin Monitoring Program (Biotoxin Program) relies on participation of people from a wide variety of local, state, and federal agencies, Tribal biologists, educational organizations, researchers, and, increasingly, citizen volunteers. Program participants collect shellfish samples, primarily mussels, and ship them to the CDPH laboratory in Richmond, California where they are tested for the PSP toxins and domoic acid. Sampling frequency is often dependent on exceptionally low tides and calm seas, varying from once to twice per month. Approximately 1200 bivalve shellfish samples are collected annually by over 60 samplers at more than 100 sampling sites. Sites are selected based both on being representative of a coastal region's fishing sites (or embayments) and safety of access.

Commercial shellfish growers, who account for approximately two-thirds of the total number of samples, are required to submit shellfish samples at least weekly for toxin testing as a condition of their certification by CDPH. Some commercial bivalve shellfish companies operating in high-risk areas for domoic acid are required to conduct weekly field tests for this toxin in addition to shipping the sample to the CDPH laboratory. These qualitative tests (which only indicate presence/absence of domoic acid) provide the industry valuable information on the initial occurrence of toxin and can guide harvesting plans to ensure public health. This information also allows CDPH to prioritize samples that have tested positive in the field to be tested first when they arrive in the laboratory to confirm the positive test as well as ascertain levels of domoic acid in the samples.

It is also worth noting that commercial bivalve species fall under the protocol outlined in the FDA's National Shellfish Sanitation Program (NSSP). The NSSP only applies to commercial bivalve shellfish and requires each state to have a Biotoxin Contingency Plan that consists of the following:

- Initiate an emergency shellfish sampling and assay program.
- Close growing areas and embargo shellfish.
- Prevent harvesting of contaminated species.
- Provide for product recall.
- Disseminate information on the occurrences of toxic algal blooms and/or toxicity in shellfish meats to adjacent states, shellfish industry, and local health agencies.
- Coordinate control actions taken by authorities and federal agencies.

Crustacean Shellfish and Finfish

For most crustacean shellfish and finfish species, CDPH will initiate testing for HAB-induced toxins when there is an indicator that the toxin may be present or has entered the food chain (see Box 1 for indicators). Once CDPH learns of an indicator they consult with California Department of Fish and Wildlife (CDFW) to learn of any active commercial or recreational fisheries in the same geographical region where the indicator is present and determine whether or not sampling is needed.

Box 1. List of indicators that prompt CDPH to consider sampling seafood species (other than bivalves) for HAB-induced toxins in a given area.

- Increased toxin levels in CDPH bivalve sampling program, typically mussels
- Active toxin-producing bloom observed by CDPH, academic researchers or the public
- HAB species detected through CDPH phytoplankton monitoring
- Marine mammal strandings and bird die-off events, etc.
- Notifications from independent academic researchers who are conducting their own research and monitoring efforts

Typically, if there is an indictor present, CDPH will first check existing or new bivalve samples to see if the toxin has entered the food chain in an area where an indicator is observed. Bivalves are particularly good indicator species because they are efficient filter feeders, they are ubiquitous along the coast and easily accessible on low tides, and will often show presence of HAB-related toxins in their tissue before other non-bivalve species. If a toxin is present at high levels in the bivalves, CDPH will take necessary public health actions for the commercial and recreational bivalve fishery in question CDPH will also take into consideration whether additional indicators are also present while also consulting with CDFW to learn if there are other active fisheries in the area that could be impacted and initiating sampling for those species as necessary.

In addition to the above, for Dungeness crab, CDPH will work with CDFW during the pre-season meat quality testing to secure samples for toxin testing in advance of the season opener. If elevated toxin levels are observed, or if an active bloom on fishing grounds is present, then bi-weekly to weekly testing occurs until the bloom is no longer observed and/or toxin levels are no longer detected near the action level.

For rock crab, testing is implemented when a bloom is observed, if mussels test positive in the area, or other indicators signify testing is warranted (see Box 1). If the fishery is closed due to elevated toxin levels, sampling occurs weekly to bi-weekly.

CDPH Volunteer-based Phytoplankton Monitoring Program

CDPH initiated a volunteer-based phytoplankton monitoring program in 1991 to detect an initial increase of a toxin-producing species before shellfish and other seafood resources are impacted. This program draws on a wide range of participants as detailed for the shellfish sampling program. Phytoplankton monitoring participants are provided nets for collecting concentrated seawater samples, which are sent to the CDPH laboratory for examination under a microscope. This effort allows CDPH to focus additional attention on those coastal areas experiencing an increase in toxin-producing phytoplankton or an increase in toxins in shellfish. When phytoplankton levels are on the rise, additional samples are requested. Observations of high levels of toxin-producing phytoplankton are one of the indicators that can prompt CDPH to expand seafood sampling to other (non-bivalve) potentially impacted seafood species like crab and anchovy (see Box 1) in the area.

▪ *What harmful algal species and associated toxins are routinely monitored by the State and how?*

CDPH's phytoplankton monitoring program is focused primarily on the early detection of three toxin-producing species most prevalent in California and the West Coast (Figure 1, Table 1):

- *Alexandrium spp.,* a dinoflagellate responsible for the PSP toxins
- *Pseudo-nitzschia spp.*, a diatom that produces domoic acid, the toxin responsible for amnesic shellfish poisoning (ASP)
- *Dinophysis spp.*, a less common dinoflagellate species that produces toxins responsible for diarrhetic shellfish poisoning (DSP)

Other less common toxin-producing species are tracked via CDPH's phytoplankton monitoring efforts and, if warranted, CDPH will pursue shellfish testing. Common non-toxic species are also identified and tracked and can provide insight into other HAB events being investigated by researchers and other agency scientists. General trends in the relative abundance and geographic distribution of major phytoplankton groups (diatoms, dinoflagellates) can provide insight into the likelihood of a given toxin-producer being present. Summary data for toxin and phytoplankton monitoring is provided in monthly reports (see link in section *Where can HAB monitoring and active bloom information be found?* below).

HAB monitoring occurs in several ways in California, including a number of university researchers and the CDPH phytoplankton monitoring program. CDPH equips its program participants with a standard net (20 micrometer mesh size) for collecting concentrated seawater samples, which are sent to the CDPH laboratory. Samples are collected at varying frequencies, ranging from weekly to monthly. Approximately 1700 samples are collected each year by over 80 samplers at more than 150 sampling sites. Sites are selected based on safe access (e.g., piers) and being representative of a given region. Samples are examined microscopically and data collected on the presence of any known or suspected toxin-producer. Data is also collected on the percent composition of toxic and non-toxic genera.

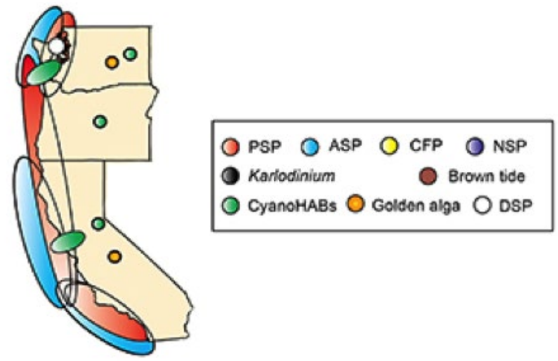
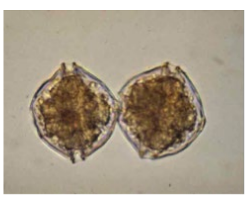


Figure 1. A generalized view of west coast states depicting the various HAB poisoning syndromes and other impacts that occur in specific areas. Note: all 50 states are impacted by cyanobacterial HABs, thus these areas are depicted using a single green and/or gold dot. Larger green areas denote widespread cyanoHAB problems. (Credit: modified from WHOI)

Table 1. Harmful algal species and their associated biotoxins routinely

Species	Biotoxin	Disease / Symptoms	Action Levels*
Alexandrium spp.  (WHOI / D. Anderson)	Saxitoxin and its derivatives	**Paralytic Shellfish poisoning (PSP)** Numbness and tingling of the lips, mouth, face, and neck; nausea; and vomiting. Severe cases result in paralysis of the muscles of the chest and abdomen possibly leading to death.	0.8 ppm (80µg/100g) saxitoxin equivalent
Pseudo-nitzschia spp.  (J. Rines)	Domoic acid	**Amnesic Shellfish Poisoning (ASP)** Nausea, vomiting, diarrhea, headache, dizziness, confusion, disorientation, short-term memory deficits, and motor weakness. Severe cases result in seizures, cardiac arrhythmia, respiratory distress, coma, and possibly death.	20 ppm domoic acid, except in the viscera of crustaceans, where 30 ppm is the action level**
Dinophysis spp.  (WHOI / D. Anderson)	Okadaic acid and its derivatives	**Diarrhetic Shellfish Poisoning (DSP)** Nausea vomiting, severe diarrhea, and abdominal cramps	0.2 ppm okadaic acid plus 35-methyl okadaic acid

*Current action levels in California, which are also recognized by all food safety authorities (for example, the U.S. Food and Drug Administration, the Canadian Food Inspection Agency, and the European Union). US FDA, 2011, available at http://www.fda.gov/downloads/Food/GuidanceRegulation/UCM251970.pdf

**While the FDA specifically lists 30 ppm action level for Dungeness crab viscera, California applies this to all harvested crustacean viscera.

Are HAB events increasing in frequency? Are there links between climate change and HAB events?

There is increasing recognition that the effects of HABs on public health, marine and freshwater ecosystems, economies, and human social structures are worsening[8]. It is generally accepted that HABs are increasing in frequency, intensity, and duration in all aquatic environments on a global scale[9]. Eutrophication (excessive nutrients that lead to dense algal growth and subsequent oxygen declines), climate change, ballast water dispersal, and improved monitoring are the most cited factors for the increased frequency of reported blooms.

Much is still unknown regarding the link between climate change and HAB events. Warmer sea surface temperatures are projected to broaden the seasonal period over which phytoplankton can grow, as well as expanding the ranges of warm water HAB species, potentially enhancing the risk of negative impacts and exposure to dangerous toxins. Scientists are still working to understand not only when HAB events occur, but what physiological characteristics of the phytoplankton and physical characteristics of the ocean cause them to start producing toxins. Changes in seawater carbon dioxide concentrations (ocean acidification) are also likely to influence phytoplankton species assemblages. More research is still needed in this area.

Scientists at the National Oceanic and Atmospheric Administration (NOAA) and the Wildlife Algal Toxins Research and Response Network for the West Coast (WARRN-West) are studying samples (2004 to present) from bowhead whales in the arctic to determine whether there is a link between climate factors and toxin levels, and whether there is a trend of increasing toxins over time[10].

Can we predict future HAB events and impacts to fisheries?

The short answer to this questions is that is it difficult to predict with certainty that a HAB will or will not occur in a specific year. However, scientists can make broad generalizations based on conditions that are favorable for blooms (see below). Scientists are refining models that can assist with forecasting when and where HAB events are likely to occur in California, and over what time frames. While there is no way to know for sure, it is unlikely to see another bloom to the scale of the 2015/16 event (magnitude, duration and geographical reach) again this year. Though scientists do expect unusual HAB events to occur with greater frequency.

Factors Contributing to *Pseudo-nitzschia* Blooms

Along the West Coast of California, Oregon and Washington, *Pseudo-nitzschia* blooms cause problems almost every year, related in part to upwelling of deep ocean water in these regions[11]. Upwelling brings waters with elevated nutrient levels to the top 300 meters of the ocean where light penetrates – ideal conditions for phytoplankton growth. There is no direct evidence to link land-based nutrient sources to *Pseudo-nitzschia* blooms on the CA coast[12]. This does not, however, preclude the possibility that the growth of these HAB species, their toxicity, and the frequency or duration of toxic events may be exacerbated by anthropogenic nutrient inputs since nitrogen sources traditionally associated with cultural eutrophication (e.g., ammonium and urea) have been shown to support equal or greater cellular growth rates and domoic acid production rates by many species of *Pseudo-nitzschia* in controlled laboratory studies[13] and have been suggested to sustain non-bloom concentrations of HAB species during upwelling-free periods[14].

For additional information on history, trends, causes, and impacts on *Pseudo-nitzschia* and other species, see here[15].

Predictive Modeling Efforts

Researchers at UC Santa Cruz, led by Dr. Raphael Kudela, have partnered with CeNCOOS to produce predictive "nowcasts" and forecasts of *Pseudo-nitzschia* blooms and domoic acid probabilities along the California coast. Nowcasts of HAB conditions are created through a combination of 1) sophisticated circulation models that predict the ocean physics, 2) satellite remote-sensing data of the ocean "color" and chlorophyll patterns, and 3) statistical models for predicting bloom and toxin likelihoods. These predictions are generated daily to provide a snapshot of where you might encounter a *Pseudo-nitzschia* bloom and/or domoic acid event. Predictions are also generated daily to provide a forecast of where you might encounter a *Pseudo-nitzschia* bloom and/or domoic acid event in the next one to three days. Data and additional information are available here: http://www.cencoos.org/data/models/habs.

---

8 Anderson et al. 2015, available at: http://oceandatacenter.ucsc.edu/home/Publications/2014/Anderson_Coastal&MarineHazards_2014.pdf
9 Moore et al. 2008, available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2586717/
10 Kathi Lefebvre, personal communication
11 Mos 2001, available at: http://ic.ucsc.edu/~kudela/OS130/Readings/DA_review.pdf
12 Anderson et al., 2005; Lewitus et al. 2012, available at: http://www.sciencedirect.com/science/article/pii/S1568988312001175
13 Auro and Cochlan, 2013, available at: http://onlinelibrary.wiley.com/doi/10.1111/jpy.12033/abstract
14 Cochlan et al., 2008, available at: http://www.sciencedirect.com/science/article/pii/S1568988308001005
15 Lewitus et al. 2012, available at: http://www.sciencedirect.com/science/article/pii/S1568988312001175

- ***Where can HAB monitoring and active bloom information be found?***

CDPH Monthly Biotoxin Report

The CDPH Environmental Management Branch (EMB) publishes a monthly biotoxin report that is distributed via email and posted on its web page: http://www.cdph.ca.gov/healthinfo/environhealth/water/Pages/Shellfish.aspx

This site also contains a web map with selectable weekly layers of data showing the distribution and relative abundance of toxin-producing species: http://cdphdata.maps.arcgis.com/apps/MapTools/index.html?appid=42a78fba680c4c43970cfc5dfe878d8d

Current Quarantines and Health Advisories

A toll free number (1-800-553-4133) is maintained that contains up-to-date information on current quarantines and health advisories. Messages can be left for a call-back by program staff. The CDPH Food and Drug Branch (FDB) web page will contain ongoing monitoring results for Dungeness crab and other commercial species: http://www.cdph.ca.gov/HealthInfo/Pages/fdbDomoicAcidInfo.aspx

Advisories are also posted on the CDFW website here: https://www.wildlife.ca.gov/Fishing/Ocean/Health-Advisories

CalHABMAP

The California Harmful Algal Bloom Monitoring and Alert Program (CalHABMAP)[16] is a proactive HAB alert network that provides information on current algal blooms and facilitates information exchange among HAB researchers, managers and the general public throughout the State of California. CalHABMAP hosts a website where weekly algae and toxin data from eight California piers can be accessed. The eight sampling locations are:

- Santa Cruz Wharf
- Monterey Wharf
- Cal Poly Pier
- Goleta Pier
- Stearns Wharf
- Santa Monica Pier
- Newport Pier
- Scripps Pier

CeNCOOS

Central and Northern California Ocean Observing System (CeNCOOS) is a collaborative that enables sustained and coordinated measurements, model "nowcasts" and forecasts, and integrated products to inform decisions about our regional ocean. CeNCOOS helps support routine algae and toxin sampling at coastal locations throughout the region. Algae samples are currently being collected weekly at wharves in Santa Cruz and Monterey with the aid of CeNCOOS funds. Samples are also being collected at a Tiburon station in San Francisco Bay. Additionally, UC Santa Cruz frequently analyzes HAB toxins for government agencies (for informational purposes only), conservation groups, scientists, and others with the help of CeNCOOS support.

16 McGaraghan et al., 2012, available at: http://fisheries.legislature.ca.gov/sites/fisheries.legislature.ca.gov/files/u8/Primer%20on%20HAB%20westcoast.pdf

II. Domoic Acid and California Fisheries

- ***What is the history of domoic acid toxicity in seafood in the U.S.?***

Domoic acid is a neurotoxin produced under certain conditions by the diatom *Pseudo-nitzschia* that can result in the illness called amnesic shellfish poisoning (ASP). It was identified as the toxin responsible for the first human domoic acid poisoning event, reported in 1987 in Prince Edward Island, Canada[17,18]. About 145 people became ill after eating blue mussels that had accumulated the toxin as a result of a *Pseudo-nitzschia* bloom present in the water. Nineteen people were hospitalized and 16 were treated in the Intensive Care Unit. Three people died (71, 82, and 84 years of age) while hospitalized and a fourth patient died of a heart attack three months later. Information from 10 of those people, ranging in age from 60 to 84, was used to estimate the levels of domoic acid that people consumed[19] (see question *What is the scientific rationale behind the action levels for domoic acid toxicity in seafood?* below for how this level was determined).

Pseudo-nitzschia is a phytoplankton species of global importance. It has been recorded in nearly every major marine and estuarine environment, and domoic acid has been found in the tissue or feces of organisms in multiple trophic levels in the oceans[20]. *Pseudo-nitzschia* has been present on the West Coast since at least the 1920s[21]. Domoic acid has been frequently observed in seafood around the U.S. (Figure 2), and events have occurred almost every year over the last decade in California (Figure 3).

Domoic acid enters the marine food chain by contaminating species such as mussels that filter their food out of the water[22] (Box 2). This water can contain both the algae and the toxin itself, which is released to the water column. The toxin accumulates in the digestive gland and certain other tissues of shellfish. For example, razor clams accumulate and retain the toxin in the edible portions (siphon, foot) as well as the viscera. ASP symptoms are characterized by gastrointestinal disorders (vomiting, diarrhea, abdominal pain), neurological problems (confusion, loss of short-term memory, disorientation, seizure, coma) and potentially death.

Box 2. Potential Vectors for Domoic Acid

Bivalves

razor clams, mussels, Pacific littleneck, geoduck, manila clams, oysters

Crustaceans

Dungeness, rock, and pelagic red king crab, spiny lobster, krill

Finfish

Pacific sardines, northern anchovies

Other invertebrates

market squid and other benthic invertebrates

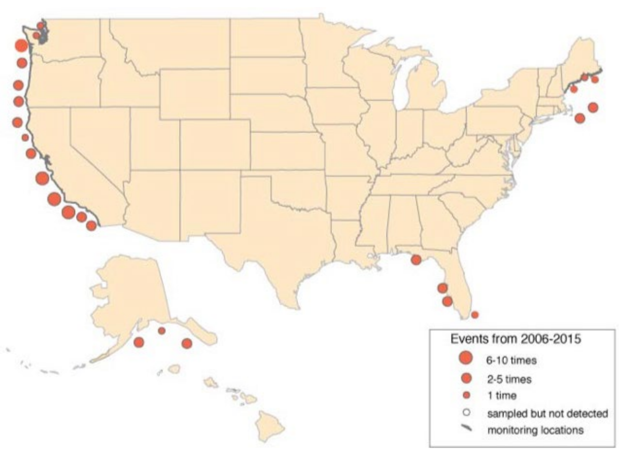


Figure 2. Presence of ASP toxins (i.e., domoic acid) in seafood in the U.S. from 2004-2015. (US National Office for Harmful Algal Blooms, Woods Hole Oceanographic Institution)

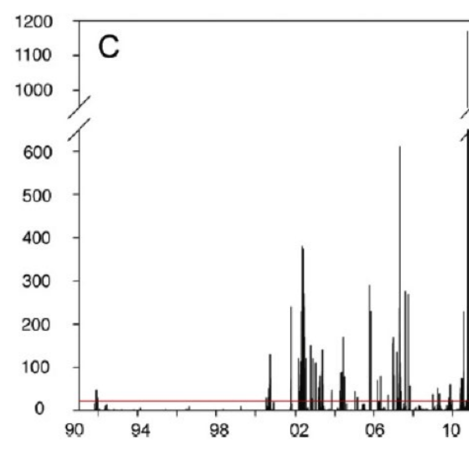


Figure 3. Historical time series of domoic acid toxins (ug/g shellfish meat) in California. The regulatory action level of 20 ug/g is shown in red. (CDPH Data. Figure taken from Lewitus et al. 2012)

17 Bates et al. 1989, available at: http://www.nrcresearchpress.com/doi/abs/10.1139/f89-156#.V5EtopOANBc

18 Perl et al. 1990, available at: http://www.nejm.org/doi/pdf/10.1056/NEJM199006213222504

19 Todd, 1993, available at: http://www.marearoja.cl/IMG/pdf/AMNESIC_SHELLFISH_POISON_REVIEW_BLOOM_CANADA_1987.pdf

20 Thessen, 2007, available at: http://bit.ly/23bVdLf

21 Lewitus et al. 2012, available at: http://www.sciencedirect.com/science/article/pii/S1568988312001175

22 Mos 2001, available at: http://ic.ucsc.edu/~kudela/OS130/Readings/DA_review.pdf

As a result of the 1987 acute toxicity episode, the Canadian government implemented a regulatory level of 20 mg DA/kg of meat (i.e., 20 ppm)[23] for all seafood. There have been no further documented human illness cases of ASP since 1987.

Although the regulatory level has been successful in preventing other human episodes of ASP, there are reports of domoic acid intoxication in marine animals, including sea lions, whales, sea otters and sea birds, as well as reports of coastal water contamination in many world regions[24]. A number of shellfish and finfish have been reported as potential vectors of the disease (Box 2), leading to widespread transfer through marine food webs and potentially to humans[25].

▪ *What are the current (2016) domoic acid action levels in California?*

Current action levels for domoic acid in seafood in California, which are also recognized by all food safety authorities (for example, the U.S. Food and Drug Administration[26], the Canadian Food Inspection Agency, and the European Union) are:

- ≥ 20 ppm in all seafood; except,
- ≥ 30 ppm in viscera (i.e., guts) of Dungeness crab

The U.S .Food and Drug Administration (FDA) sets policy for interstate and international commerce (i.e., transport and sale of seafood over state boundaries), which the states must follow as a minimum requirement. States can adopt more stringent standards and requirements, but cannot lower the action levels.

The FDA regulatory actions[27] to be considered by the states when the action levels are met are:

- closure of harvest areas found to produce crabs with such levels of the toxin; and/or
- evisceration of contaminated crabs.

▪ *What is the scientific rationale behind the action levels for domoic acid toxicity in seafood?*

The results of the first outbreak of amnesic shellfish poisoning that occurred in 1987 in Canada (see above) provided the best basis for the acute (short-term exposure) reference dose used to set the currently adopted domoic acid action levels in California[28,29] as mandated by the FDA.

During this outbreak, impacted individuals increased in the severity of signs and symptoms based on their dosage received (i.e., the amount of domoic acid a person consumed based on the levels in the mussels eaten), allowing experts to calculate a relationship between the amount of domoic acid ingested and the observed severity of symptoms[30]. The ***lowest observed adverse effect level*** (i.e., the lowest concentration of domoic acid ingested that caused symptoms of amnesic shellfish poisoning) was determined to be 1 mg/kg of body weight. This value was then divided by a precautionary "safety factor" of 10 to derive a precautionary ***reference dose*** of 0.1 mg/kg body weight. The Canadian authorities used the reference dose to establish the ***maximum residue limit*** (MRL) of 20 µg DA/g (20 ppm) shellfish (i.e., the threshold or guidance level) for domoic acid, the highest level that is tolerated in or on food for human consumption. The MRL was developed based on an average serving of shellfish (300 grams, approximately 0.7 pounds) for a person with a body weight of 60 kilograms (approximately 132 pounds). See Table 2 for a walk through of the action level calculation.

Health and Welfare Canada established 20 µg DA/g tissue (20 ppm) above which shellfish commercial operations should be closed. At present, this level has also been adopted by the U.S.[31], European Union, New Zealand, and Australia.

Action level adjustment for Dungeness crab viscera

In 1993, new data was presented in a memo[32,33] to the Health Hazard Evaluation Board (Board) at the U.S. Department of Health and Human Services suggested the tolerable level of domoic acid, applied to whole crab, was unnecessarily stringent. The Board agreed that a better estimate of consumption

23 Toyofuku 2006, available at: http://www.sciencedirect.com/science/article/pii/S0025326X06002797
24 Pulido 2008, available at: http://www.mdpi.com/1660-3397/6/2/180/htm
25 Lewitus et al. 2012, available at: http://www.sciencedirect.com/science/article/pii/S1568988312001175
26 US FDA, 2011. Available at: http://www.fda.gov/downloads/Food/GuidanceRegulation/UCM251970.pdf
27 Department of Health and Human Services. 1993a, available at: http://www.oceansciencetrust.org/wp-content/uploads/2016/07/DA_Crabs_93.pdf
28 Toyofuku, 2006, available at: http://dx.doi.org/10.1016/j.marpolbul.2006.07.007.
29 Pulido, 2008, available at: http://www.mdpi.com/1660-3397/6/2/180/htm
30 Todd, 1993, available at: http://www.marearoja.cl/IMG/pdf/AMNESIC_SHELLFISH_POISON_REVIEW_BLOOM_CANADA_1987.pdf
31 US FDA, 2011, available at: http://www.fda.gov/downloads/Food/GuidanceRegulation/UCM251970.pdf
32 Department of Health and Human Services. 1993a, available at: http://www.oceansciencetrust.org/wp-content/uploads/2016/07/DA_Crabs_93.pdf
33 Department of Health and Human Services. 1993b, available at: http://www.oceansciencetrust.org/wp-content/uploads/2016/07/DA_Crab.pdf

of Dungeness crab is to assume that one person consumes one whole crab in any one meal, which is (on average) equal to eating 300 grams of crabmeat, and 150 grams of crab viscera (in other words, a crab contains more meat than viscera). Therefore, since less viscera is consumed, a higher level of domoic acid is tolerated in the viscera. The FDA subsequently raised the action level for Dungeness crab viscera from 20 ppm to 30 ppm.

Table 2. Walking through the domoic acid action level calculation.

Value	Units	Toxicity Description	Supporting Date
1	mg domoic acid /kg tissue	**Lowest observed adverse effect level** (LOEL): this was the lowest dose amount that resulted in observable symptoms in one of 10 patients during the 1987 outbreak in Canada	Data from patients in the 1987 outbreak in Canada (Perl et al. 1990 ; Todd 1992; Toyofuku 2006)
0.1	mg domoic acid/kg tissue	**Acute reference dose:** the maximum acceptable oral dose of a toxic substance. "Acute" refers to a short term (single exposure) period or event. *Calculation: This was calculated by applying a precautionary safety factor of 10 to the LOEL above (i.e., 1mg/kg divided by 10). This level was then converted into an allowable level in shellfish tissue.*	
300	g	Average weight of shellfish consumed during the 1987 outbreak event	
60	kg	Average human body weight used to set the action level	
6	mg domoic acid	Acute dose for 60 kg person *Calculation: 0.1 mg/kg domoic acid * 60 kg body weight*	
20	mg domoic acid / kg shellfish tissue	Action level implemented in Canada and adopted internationally, including in California and the U.S. *Calculation: 6 mg acute dose divided by 300 g shellfish multiplied by 1000 (to convert to kg)*	

- ***What are the current criteria for opening and closing the Dungeness crab fishery based on the domoic acid action levels?***

Table 3. Dungeness crab season opening and closing criteria (as of August 2016).

	Seafood Testing Requirement
Season Opening Criteria	All crab collected during pre-season quality testing from each area (minimum of six), tested individually, have viscera levels of less than 30 ppm domoic acid. Each port has 2 or more sampling areas, depending on the geographical size of the fishing area it covers. Currently, three or more crab have to test above the limit to delay opening the fishery (see below)
Closing Criteria	3 or more crab viscera (of 6) from one area ≥30 ppm *or* 1 of 6 crabs with meat ≥ 20 ppm domoic acid. *Note: As of August 2016, the Tri-State Dungeness Crab Committee is updating the criteria related to closing so that closing and opening criteria are consistent.*
Re-opening Criteria	2 sets (6 crabs per set) collected one week apart, with all viscera samples testing below 30 ppm domoic acid

- ## *Where can information be found on California's current domoic acid monitoring plans? What plan do other West Coast states adhere to?*

Dungeness Crab Monitoring Plan

CDPH adopted the Washington Department of Health's protocol "Strategy for Preventing Consumer Exposure to Domoic Acid from Dungeness Crab,"[34] with some variances in implementation (Table 4). The Washington Department of Health's protocol was reviewed and approved by the FDA and conforms to the U.S. Environmental Protection Agency (EPA) standards[35]. The Oregon Department of Agriculture (ODA) and CDPH have also adopted this protocol, although California samples more frequently then set forth in the Washington protocol.

The current protocol is under review by the West Coast states that are working with the Tri-State Dungeness Crab Committee[36] to make sure rational and justifiable standards are applied across the three states. The committee is composed of state agency, processor, and fishermen representatives from each state. The protocol will be posted on agency web sites when that process is completed.

Bivalve and Phytoplankton Monitoring Plans

CDPH maintains specific protocols for bivalve shellfish sampling and phytoplankton sampling procedures. Sampling plans for commercial bivalve shellfish aquaculture areas are contained in the management plans for each area.CDPH also has a biotoxin contingency plan for bivalve shellfish in compliance with the National Shellfish Sanitation Program guidelines. For more information on any of these documents contact EMB's biotoxin information line at 1-800-553-4133, or email redtide@cdph.ca.gov.

- ## *Where are the domoic acid biotoxin monitoring sites in California?*

Commercial Bivalve Aquaculture/ Recreational bivalves

Commercial bivalve shellfish aquaculture sampling sites are based on active harvest locations. In some shellfish growing areas additional sentinel mussel stations may be established as early warning sites, typically near the entrance to the bays and estuaries used for shellfish production. Recreational bivalve shellfish sampling locations are representative of the region with respect to biotoxin exposure. Other factors include the ease of public access and safety of access to the intertidal zone, and of course the presence of significant shellfish resources.

CDPH monitors all five commercial bivalve shellfish aquaculture sites in the state year round, some with multiple sampling locations, and over 100 coastal sites.

Maps of bivalve shellfish and phytoplankton sampling locations can be found in the annual biotoxin reports located here: http://www.cdph.ca.gov/HealthInfo/environhealth/water/Pages/Shellfishreports.aspx

Commercial Finfish

When sampling is initiated because of an indicator(s) present (see Box 1), samples of commercial finfish, such as anchovy, will be obtained by CDPH FDB or CDFW when landed. Locations can vary as the fish population moves; CDFW block numbers are recorded for each catch sampled.

Dungeness and Rock Crab

When sampling is initiated because an indicator(s) is present (see Box 1), CDPH will monitor and test Dungeness and rock crab samples from up to 19 ports with multiple sampling locations: Mission Bay, Oceanside, Newport Beach, San Clemente, San Nicolas, LA/Long Beach, King Harbor, Ventura, Santa Barbara, Channel Islands, Avila, Morro Bay, Monterey, Half Moon Bay/SF, Bodega Bay, Fort Bragg, Eureka, Trinidad, Crescent City.

Dungeness and rock crab are also sampled in the same places and locations as the preseason crab quality testing (see section *What is the process for testing Dungeness and rock crab for domoic acid in advance of the season opener?*).

---

34 Washington State Department of Public Health, 2008, available at: http://www.ifrfish.org/wp-content/uploads/2016/02/Crab-DA-Monitoring-Plan-2008-2009.pdf

35 USEPA. 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories: Volume 1, Fish Sampling and Analysis, 3rd Ed. EPA 823-B-00-007

36 Under the Pacific States Marine Fisheries Commission Dungeness Crab Tri-state process, the three state Fish and Wildlife agencies consult on issues affecting the commercial Dungeness crab fishery.

Table 4. Dungeness crab domoic acid sampling strategy comparison between the three West Coast states. (Tri-State Dungeness Crab Committee, May 2016)

	WASHINGTON	OREGON	CALIFORNIA
DOMOIC ACID ACTION LEVEL / VISCERA	30 ppm	30 ppm	30 ppm
DOMOIC ACID ACTION LEVEL / MEAT	20 ppm	20 ppm	20 ppm
NUMBER OF CRAB PER SAMPLE	six legal size male crab	6-8 legal size male crab	six legal male crab preferred; sub-legals and females secondary
DEPTH STRATA	Best reflect current fishing activity; Shallow (5 - 15 fms) Deep (30-45 fms) or as directed by WDOH	5-10 fa, 15 fa, 30 fa, 45 fa or as directed by ODA	Best reflect current fishing activity; Shallow (15 fms), Mid (25-30 fms) Deep (45 fms)
CLOSURE CRITERIA FOR VISCERA	3 of 6 crab with viserca ≥ 30 ppm or 1 crab with viscera ≥ 80 ppm	3 of 6 crab with viserca ≥ 30 ppm or 1 crab with viscera ≥ 80 ppm (ODA currently trying to get FDA guidance)	3 of 6 crab with viserca ≥ 30 ppm
CLOSURE CRITERIA FOR MEAT	1 of 6 crab with meat ≥ 20 ppm	1 of 6 crab with meat ≥ 20 ppm	1 of 6 crab with meat ≥ 20 ppm
REOPENING CRITERIA	Reopening a zone requires two (2) consecutive sets of crab samples, not less than seven (7) days apart, with all crab in each sample, testing below 30 ppm in the viscera	Reopening a zone requires two (2) consecutive sets of crab samples, not less than seven (7) days apart, with all crab in each sample, testing below 30 ppm in the viscera, or 20 ppm in meat	Reopening a zone requires two (2) consecutive sets of crab samples, not less than seven (7) days apart, with all crab in each sample, testing below 30 ppm in the viscera
NORMAL SAMPLING FREQUENCY	Monthly or as directed by WDOH	Started coastwide monthly sampling in May 2016	During Pre-season quality testing or as directed by CDPH
TRIGGER FOR EXPANDING SAMPLING FREQUENCY	Increased domoic acid levels in razor clam samples as directed by WDOH	Increased domoic acid levels in razor clam samples as directed by ODA	Developing DA-producing HAB, increasing DA levels in mussels/seafood samples, as directed by CDPH
EXPANDED SAMPLING FREQUENCY	10 days to 2 weeks or as directed by WDOH	Bimonthly or as directed by ODA	1-2 weeks depending on DA concentration
GEOGRAPHIC SAMPLING AND CLOSURE ZONES	Five Zones; WA/OR Border to Pt. Chehalis; PT. Chehalis to Destruction Is.; Destruction Is. to US/Canada Border; Grays Harbor; Willapa Bay	Six Offshore Zones: Astoria, Garibaldi, Newport, Charleston, Port Orford and Brookings. Bays and Columbia River as directed by ODA	Up to 20 Port areas with multiple sampling locations (depending on area of the bloom): Mission Bay, Oceanside, Newport Beach, San Clemente, San Nicolas, LA/Long Beach, King Harbor, Ventura, Santa Barbara, Channel Islands, Avila, Morro Bay, Monterey, Half Moon Bay/SF, Bodega Bay, Fort Bragg, Eureka, Trinidad, Crescent City

The number of ports sampled during a given biotoxin event is based on the geographic extent of the bloom (Table 2)[37]. CDFW used the existing pre-season crab quality test sites as a baseline with input from CDPH and modified some of these areas, e.g. Mendocino County to San Mateo County to get more complete coverage. Each port has two or more sampling locations to ensure adequate representation of the areas where the respective species are typically fished. Additional areas may be sampled for other species (e.g., shrimp).

- ***How were the Dungeness crab sites selected?***

Dungeness crab sampling locations from Half Moon Bay northward were determined by CDFW, based on previous experience with the annual preseason sampling for meat quality and domoic acid levels. Sampling sites south of Half Moon Bay for Dungeness and rock crab were determined with input from the industry and based on the location of the crab resources and hence the greatest fishing activity. Sampling locations were selected to represent the nearshore fishery, as well as the fishery offshore around the northern Channel Island chain.

- ***How frequently are biotoxin sites sampled? What determines how frequently sampling occurs?***

Dungeness and Rock Crabs

Prior to season opening for Dungeness crabs, samples are collected for domoic acid toxin testing during the meat quality testing. Although not required, preseason meat quality testing has occurred in the southern region for informational purposes only. In addition, domoic acid levels have also been tested in this region during the same time period. If the season has opened, sampling can be initiated mid-season if a bloom is observed and/or other indicator(s) are present (see Box 1). If sampling indicates high levels of toxin are present in crab samples, bi-weekly to weekly testing occurs. Sampling frequency may be decreased or delayed if there is continued bloom activity in an area tied with recent crab samples testing well above the action level.

For rock crab, since the season is open year round, testing is only implemented when a bloom is observed and/or other indicator(s) are present (see Box 1). Depending upon the overlap in presence of the indicators with fishing grounds, monitoring may occur monthly under low toxicity conditions, with sampling increasing as toxin concentrations in rock crab tissue and viscera increase. Sampling occurs weekly or bi-weekly when a fishery closure is in place, based on the prevailing levels of domoic acid being found in the samples. Previous sampling efforts show that extremely high levels of domoic acid will not clear from the system of the crabs within a week. Therefore, when crabs are still testing high, bi-weekly sampling was considered appropriate. However, when sampled crabs within an area are nearing the action level, weekly sampling was considered appropriate. These sampling time frames are subject to weather conditions. As of July 2016, CDPH continues domoic acid testing for rock crab since the commercial and recreational rock crab fisheries remain closed north of Pigeon Point.

Due to previous sampling and testing efforts along the West Coast, along with independent research on the depuration ("clearing") rate of domoic acid in Dungeness crab[38], it is known that the toxin is not likely to clear from crab meat and viscera within a week or two if samples have been consistently testing well above the action level and there is still a toxic bloom present in the water. As samples start approaching the action level, more frequent testing will be conducted to ensure that the health advisories can be lifted as soon as it is safe to do so. Inclement weather and adverse ocean conditions can significantly delay sample collection. When the fishery was closed this year, sampling frequency was determined, in part, by weather and the ability of fishermen to go out and collect samples.

Razor Clams

Razor clams are a high-risk species since they appear to handle domoic acid differently than other bi-valves, some holding on to the toxin for over a year even in the absence of a bloom. Razor clam samples are requested by the CDPH Marine Biotoxin Monitoring Program from local CDFW biologists and program volunteers when routine coastal mussel and phytoplankton monitoring indicates the presence of a toxin or a potential toxic bloom developing. When a toxin is detected in razor clams, sampling is increased as tides and ocean conditions allow. The frequency of sample collection is based on the availability of adequate low tides. Twice per month is the greatest frequency and in some months the tides or inclement weather will not support any sampling. Due to the ability of razor clams to retain domoic acid for considerable periods of time (months to over a year), sampling frequency may be decreased until toxin concentrations decline closer to the action level.

37 Source: Tri-State Dungeness Crab Committee, May 2016

38 Lund et al., 1997, available at: http://www.ifrfish.org/wp-content/uploads/2015/11/Domoic-Acid-Update-and-Deputation-in-Dungeness-Crab.Wekellpdf.pdf

Additional species

Marine mammal strandings, mass seabird die-offs, or other environmental factors indicative of an offshore bloom may trigger extra sampling in designated areas, or sampling of a localized species, despite the lack of current biotoxin activity (See Box 1).

Opportunistic sampling of other species may be done for public health protection in consultation with CDFW, Tribal representatives, or local county health departments. CDPH works with CDFW to determine what species are being fished in an area, and then collect species at the dock for testing to ensure public health before that product makes it to the market for human consumption.

▪ *How is spacing of sites considered?*

Bivalve Shellfish

Sampling locations representing recreational harvest areas for bivalve shellfish can vary from one to several sites per coastal county, depending on the number of suitable access points and available program participants. Commercial bivalve shellfish growing areas are sampled intensively, with each major growing area having several locations in close proximity sampled at least weekly.

Dungeness and rock crab

Dungeness crab sampling locations are based on those used by CDFW for pre-season assessment of quality and previous domoic acid sampling. Sites are representative of the fishery range, with multiple sites sampled per landing port. Sampling locations are also selected to be representative of different depths and distance from shore. Rock crab sampling locations are selected based on resource location and are representative of CDFW fishing blocks located nearshore and offshore around islands such as the Channel Islands, Catalina, etc.

▪ *How are samples collected within a site (distance, including buffer zones)? Does sampling control for potential differences in domoic acid levels between male and female Dungeness crabs?*

Bivalves

Recreational bivalve shellfish samples are collected as low as possible in the intertidal zone while ensuring the safety of the collector. Sentinel mussel stations are preferably located subtidally to represent maximum exposure to toxin-producing phytoplankton. Commercial bivalve shellfish samples are representative of current harvest locations and can include multiple species (mussels, oysters, and clams).

Dungeness and rock crab

Crab samples are obtained along transect lines predetermined by CDFW. Samplers are required to stay within one mile of the transect coordinates. Three different depths are sampled along the transect. At each depth two samples are collected, for a total of six crabs. The priority is on the collection of legal-sized male crabs since take of only males are allowed in the commercial fishery. If inadequate numbers are available, then a sample may be supplemented with female and/or undersized crab to ensure an adequate sample size. There is no scientific information to suggest differences in toxicity between male and female Dungeness crabs.

▪ *How is domoic acid detected in seafood samples? How are the samples processed during testing (i.e., are whole crabs homogenized in seawater or freshwater? Are viscera tested separately from crab tissue?)?*

CDPH uses the most accepted regulatory method for detecting domoic acid in seafood, which is a reversed-phase high performance liquid chromatographic (HPLC) method with ultraviolet (UV) detection[39]. This method is approved by AOAC International and FDA. The CDPH Food and Drug Laboratory has a reporting limit of 2.5 micrograms per gram of tissue (μg/g or parts per million [ppm]). There is also an AOAC International approved enzyme-linked immunosorbent assay (ELISA) for the detection of domoic acid in mussels, oysters and clams. This method has not been validated for crab tissue or other seafood species.

Crab viscera are analyzed separately from the meat. Samples are not diluted in either freshwater or seawater. Crabs are steamed so as not to be contaminated by the cooking medium, and each crab is individually wrapped in foil to avoid any cross-contamination during steaming. The homogenized tissue is mixed with a solvent (methanol) to extract any domoic acid that is present. This extract is then analyzed by the HPLC method mentioned above.

39 Dhoot et al., 1993, available at: http://www.cdph.ca.gov/pubsforms/Documents/fdbSSdaMeth.pdf

How long does it take to process crab samples once they have been received by CDPH?

During pre-season testing samples are processed with sufficient time to recommend opening or closing of the fishery for Dungeness crab. Once the Dungeness crab or other fishery is closed or, for fisheries like rock crab that are open year round, the following process and timeline is typical:

1. **Sample request**
   (approximate time = 1 – 2 days, weather and availability of fishermen permitting)

   CDFW staff contact volunteer fishermen and request samples from the areas of interest. If the fishermen are not in port, it can take a day or two to connect with them to make the request. After contact, CDFW sets the sampling schedule and specifying sampling date window, location, and disposition of samples.

2. **Sample collection**
   (approximate time = 1 – 5 days, conditions permitting)

   Fishermen or CDFW staff collects samples as permitted by CDFW and as ocean conditions, scheduling, and mechanical issues allow. Sometimes fishermen freeze and retain samples overnight depending on when they return to shore (0-1 days). Samples are delivered directly to CDPH lab in Richmond, California or a local CDFW field office.

3. **Samples shipped and delivered to CDPH lab**
   (approximate time = 2 – 5 days, depending on day of the week samples are brought to CDFW offices for shipping)

   If samples are brought/delivered to a CDFW office, the samples are frozen and packaged and shipped within one business day depending upon the time received. If a sample was received on Friday, it is often not shipped until the following Monday to ensure viability of frozen sample(s) upon arrival (i.e., if shipped on a Friday, samples may sit in an office at CDPH and thaw out until they open Monday morning) (0-4 days, depending on time and day received). Once samples are shipped they are in the mail and received by CDPH the next day (1 day).

4. **Laboratory toxicity testing and results available**
   (approximate time = 2 – 4 days)

   Once CDPH receives the sample(s), they run laboratory tests for domoic acid, run quality assurance testing, and post the results online (2-3 days; max 4 days). The only time that CDPH does not turn specific samples around within 2-3 days is when certain blocks of samples were prioritized for testing over other samples, even if they had been received first. Samples are given priority for the following reasons:

   - Samples for areas that had a clean test the previous week and therefore a second set of clean crabs would result in opening the fishery in that area.
   - Samples for areas where crabs from the previous week were at or near the action level of 30 ppm for viscera and/or 20 ppm for meat.

   The rationale for prioritizing of certain blocks of samples is to test those for which an area might be opened (already had one week of clean samples) or for those which might have their first set of clean samples (previous samples had been near action level). By prioritizing these sample sets, CDPH ensure areas that can be opened are opened as quickly as possible while also prioritizing sample sets that could give fishermen an indication that they may be able to fish an area in the near term should the area test clean again the following week. Additionally, even if a sample set is delayed due to de-prioritization, it was still processed before the second set of samples, thus not delaying the opening of a clean area.

How are government agencies responding to the 2015/16 shellfishery closures in California (e.g., Dungeness and rock crab, razor clam)?

CDPH has and continues to deliberate with counterparts in Oregon, Washington, and the FDA to discuss the recent unprecedented domoic acid event and potential modifications to future monitoring and regulatory efforts. Currently, this effort is taking the form of CDPH and CDFW participating in the Tri-State Dungeness Crab Committee work group meeting to discuss potential changes in sampling criteria and decision criteria, as well as to consider alternatives for managing impacted fisheries. The goal is for all three West Coast states to agree upon and utilize the same sampling and operating standards.

In addition, in early 2016, the Ocean Protection Council convened the HAB Task Force, composed the following members:

- **Sonke Mastrup**, California Department of Fish and Wildlife
- **Susan Ashcraft**, California Fish and Game Commission
- **Patrick Kennelly**, California Department of Public Health

- **Gregg Langlois**, California Department of Public Health (retired)
- **Susan Klasing**, Office of Environmental Health Hazard Assessment
- **Valerie Termini**, California Fish and Game Commission
- **Jenn Phillips**, California Ocean Protection Council

The HAB Task Force requested that Ocean Science Trust develop this FAQ document, as well as convene an Ocean Protection Council Science Advisory Team (SAT) working group[40] to provide scientific guidance on ways to the State's existing HAB and biotoxin monitoring in California. In addition, during the winter of 2016-17, the HAB Task Force will work together to review and update standard operating procedures (SOP) that will be utilized by the agencies responsible for oversight of public health and the fisheries.

40 More information on the SAT working group can be found here: http://www.oceansciencetrust.org/project/harmful-algal-blooms-and-california-fisheries/

III. Health and Seafood Safety Concerns

- ***After consumption of crab meat, is toxin accumulation additive if multiple crabs are eaten? In other words, if toxin levels are below the threshold of concern, but still >0 PPM, how many crabs or pounds of crab meat are safe to eat for an average adult, a child, or an elderly person?***

  Because the action level is based on limited data and does not estimate levels for sensitive populations such as the fetus and young children, the threshold between safety and non-safety is not precise enough to make detailed recommendations for specific populations. The original action level was based on a consumption of 250 - 300 grams (about 8 ounces) at which negative impacts were observed to human health. OEHHA recommends limiting consumption of seafood that tests positive for domoic acid, but at levels below the action level, to 8 ounces, and less than that for children. OEHHA also recommends that guts (viscera) not be consumed during a domoic acid event. Additionally, consumers can consider it best practice to not consume the viscera at any time since this is where the majority of the toxin is present in the crab.

- ***What are the long-term effects of low levels of domoic acid exposure?***

  It is not known whether repeated exposure over several days, months or years will make someone more susceptible to the toxic effects of domoic acid. Researchers have explored the effects of low-level domoic acid exposure in sea lions[41] and zebrafish[42,43]. This work suggests repetitive, low-level exposure could contribute to chronic health consequences. However, there are still significant gaps in knowledge of the health effects of chronic exposure.

  Researchers are working to better understand responses in humans. An ongoing study funded by the National Institute of Health is looking at domoic acid neurotoxicity in native Americans in the Pacific Northwest[44].

- ***Do some fished species accumulate domoic acid toxin more than others?***

  Research into this question is currently underway by researchers at Oregon Department of Fish and Wildlife, as well as California Sea Grant Extension program.

- ***What is known about angler exposure to domoic acid via consumption of contaminated fishes?***

  A study conducted by California Sea Grant measured domoic acid in 11 fish species targeted by Santa Cruz Wharf anglers in Monterey Bay, California, USA, and sur-veyed anglers regarding their fish consumption patterns[45]. In this geographically limited study, results suggested that anglers who consume their catch are exposed to asymptomatic domoic acid doses, and that exposure is a function of the species and parts consumed, as well as storage methods and domoic levels in the seawater when the fish are caught.

For additional questions on human health and consumer safety concerns, see California Sea Grant's FAQ report *Natural Biotoxins in California Crabs: Domoic Acid, Frequently Asked Questions on Human Health, Fishery Closures, and Biotoxins in Crabs*[46].

41 Goldstein et al., 2008: http://www.sciencedirect.com/science/article/pii/S1568988313000139#bib0065
42 Lefebvre et al., 2012: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0036213
43 Hiolski et al., 2015, available at: http://www.ncbi.nlm.nih.gov/pubmed/25033243
44 More information on this work http://tools.niehs.nih.gov/portfolio/index.cfm/portfolio/grantDetail/grant_number/R01ES012459
45 Mazzillo et al., 2010, available at: http://www.int-res.com/articles/feature/b009p001.pdf
46 California Sea Grant's FAQ report https://caseagrant.ucsd.edu/sites/default/files/Biotoxins-SU16-FAQ-v2.pdf

Table 5. Overview of jurisdiction and roles of the various state bodies involved in California's fishery and seafood toxin management.

Agency / Body	Jurisdiction / Mission	Authority / Role
California Department of Public Health, Food and Drug Branch	Protect and improve the health of all California residents by assuring that food, drugs, medical devices and certain other consumer products are safe for public consumption and use	• Seafood monitoring • Sample commercial fisheries such as Dungeness crab, rock crab, and anchovies. • Communication with OEHHA toxicologists when dangerous levels of toxin are detected • Regulate human food supply (ensure products in marketplace are safe for human consumption) • Laboratory toxin testing
California Department of Public Health, Environmental Management Branch	Seeks to create a safer environment through advanced public health protection	• Manage the Marine Biotoxin Monitoring Program for bivalve shellfish • Bivalve shellfish biotoxin sampling and monitoring • Phytoplankton monitoring
California Department of Fish and Wildlife	Responsible for implementing regulations as set forth by the Fish and Game Commission and State Legislature	• Director has authority to open or close the commercial Dungeness crab fishery in the event of toxic substances upon recommendation of the public health agencies (CDPH and OEHHA) • Engage in preseason Dungeness crab testing
California Fish and Game Commission	Manage the recreational Dungeness crab fishery	• Authority to open or close the recreational Dungeness crab fishery in the event of toxic substances upon recommendation of the public health agencies
California State Legislature	Manage and regulate the commercial Dungeness crab fishery	• Authority to regulate the fishery including setting seasons, size limits, management boundaries, etc. • Establish limited entry and trap limit programs • Set permit fees and tax rates • Establish advisory bodies
Office of Environmental Health Hazard Assessment	Protect and enhance public health and the environment by scientific evaluation of risks posed by hazardous substances	• Advise CDPH on human health risk and then consult with CDPH Director, if necessary to advise CDFW and FGC to close or re-open an affected commercial or recreational fishery when action levels are exceeded or fall below action levels, respectively
Tri-state Dungeness Crab Committee, Pacific States Marine Fisheries Commission	Consult on issues affecting the commercial Dungeness crab fishery in California, Oregon and Washington	• Create opportunity for West Coast states to collaborate and coordinate on common sampling protocols and best practices

IV. California's Fishery and Seafood Toxin Management

- ***What agency leads California's seafood biotoxin monitoring and sampling programs, and how are these programs funded?***

As the shellfish control authority for California, CDPH manages the State's marine biotoxin monitoring program. CDPH is responsible for ongoing bivalve shellfish (e.g. mussels) and phytoplankton monitoring, and does a limited amount of environmental sampling for other seafood species (e.g., crab, lobster). These samples are largely volunteer-based and help inform the program of offshore events that may not be detected at nearshore sampling stations. When dangerous levels of toxin are detected in recreationally-harvested species, EMB will issue a health advisory for the affected species and region. If commercial bivalve shellfish aquaculture is impacted, CDPH EMB will implement a harvest closure until toxin concentrations decline to safe or undetectable levels. CDPH FDB is responsible for processing the samples of commercial fisheries species such as Dungeness crab, rock crab, and anchovies.

There are no dedicated funding sources for domoic acid monitoring in California. As events occur, limited support is provided by the redirection of General Funds from other programs to cover the necessary activities.

- ***What are the roles of the California government agencies and state bodies with regard to HAB response, monitoring, and fisheries management?***

See table 2 for an overview of the various state bodies involved in California's fishery and seafood toxin management.

Bivalve shellfish sampling for biotoxin testing is organized by CDPH EMB's Biotoxin Monitoring Program. Monitoring of other commercial seafood species is coordinated by both CDPH FDB and CDFW. The testing is done at CDPH laboratories in Richmond, California, the only NSSP-certified laboratory in California that can conduct biotoxin analysis for regulatory purposes relative to human health impacts.

When dangerous levels of toxin are detected in commercial seafood, CDPH FDB communicates with toxicologists in the Office of Environmental Health Hazard Assessment (OEHHA), who determine the risk to human health. The OEHHA Director consults with the CDPH Director before recommending to the CDFW and the Fish and Game Commission (FGC) to close the affected commercial or recreational fishery, respectively.

During the 2015-2016 domoic acid event, CDFW worked closely with CDPH and OEHHA to determine when and where fisheries could safely be sampled and reopened.

- ***How do HAB and fishery management measures in California, specifically for domoic acid and Dungeness crab, link to what is being done in Oregon and Washington?***

Regulatory issues that affect more than one state's fishery are negotiated through the Tri-State Dungeness Crab Committee coordinated by the Pacific States Marine Fisheries Commission (PSMFC). The Committee comprises one member from each state management agency, each with five industry advisors, and is chaired by the PSMFC. The committee signed an interstate Memorandum of Understanding (MOU, 1996) stating that all three state management agencies will develop consistent and complementary management actions for Dungeness crab.

The current crab monitoring plan "Strategy for Preventing Consumer Exposure to Domoic Acid from Dungeness Crab," developed by Washington State and implemented, with some variances in California and Oregon is under review by the West Coast states working with the Tri-State Dungeness Crab Committee to make sure rational and justifiable standards are applied in the three states.

- ***How does Dungeness crab management differ between the recreational and commercial sector, and what is the rationale for this difference?***

The commercial Dungeness crab fishery is managed by the State Legislature, while the recreational fishery is managed by the FGC. Unlike most of our other major commercial fisheries, the Legislature has not delegated its management authority to the FGC, in part because the industry has opposed it.

CDFW is responsible for enforcement of regulations for both fisheries. However, when it comes to public health, regulations state that the Director of CDFW has the authority to close a commercial fishery when CDPH issues a health advisory and the Director of OEHHA, in consultation with the Director of CDPH, recommends closure of a fishery to ensure public health. SB1287 has a provision to give the Director of CDFW more authority in the recreational fishery should an event like this occur again. As of July 2016, SB1287, is currently being considered in the State Legislature.

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) exempts the Dungeness crab fishery from the requirement of a federal fishery management plan (FMP). Instead, it authorizes the States of California, Oregon and Washington to adopt and enforce state laws and regulations governing Dungeness crab fishing and processing in the federal exclusive economic zone adjacent to each state. Under the MSA, California, Oregon and Washington have jurisdiction over their respective permit holders and permit conditions (such as gear and seasons), as well as control over conditions for making landings within a state.

- ***What do differences in Dungeness crab management between the commercial and recreational sectors mean for opening and closing of each sector? (i.e., Why did the commercial sector have to wait while the sport sector was opened?)***

While commercial Dungeness crab management is typically under the authority of the California State Legislature, the FGC Code section 7715[47] currently gives the Director of CDFW authority to open or close the commercial fishery in the event of toxic substances upon recommendation of the public health agencies. Otherwise, all regulatory authority lies with the California State Legislature. The FGC has regulatory authority over the recreational fishery and does not need directive from CDPH and/or OEHHA to close a fishery under their jurisdiction due to public health or other concerns.

During the 2015-16 Dungeness crab fishery closures, the commercial and recreational sectors had requested the CDFW allow approximately one week notice before opening the commercial fishery to allow commercial fishermen time to gear up, and to allow recreational fishermen time to fish before commercial crabbers dropped their gear. Current law requires the FGC to open the recreational fishery immediately upon being notified by the health agencies that a health risk no longer exists. Logistically, the FGC must also come together to meet in person in order to decide upon opening a fishery, which can also cause delays in the opening of the recreational fishery. Emergency regulations[48] also stipulated that fisheries open in an orderly fashion, and an effort was made to avoid opening the recreational fishery in a patchwork manner, with some contiguous counties open while others were not.

With regards to the commercial Dungeness crab fishery, the State initially consulted with some members of the commercial industry (via the DCTF, and later in the season through the DCTF public calls) at the start of the regular season in October 2015 when the first samples came back above the action level for domoic acid. At this time, some members of the industry stated that their desire was to open the fishery coast-wide, rather than in sections, with the caveat that they would reconsider this request if the domoic problem persisted for a long period[49]. When the problem did persist longer-term, with crabs testing above the domoic acid action level well into the 2015-16 crabbing season, it became evident that delaying season until the whole coast could be opened might result in no areas of the fishery being opened at all. Some members of the fishing industry began requesting that the State consider opening traditional management areas of the fishery rather than delaying until the whole coast could be opened. There was not consensus among fishermen in these regions as to which management option was preferred[50].

As sampling areas began having crabs decrease in toxin levels, nearing the action level, CDPH would inform CDFW. CDFW and CDPH worked collaboratively to identify enforceable boundaries for the area to be opened while ensuring their were sufficient buffer zones to account for crab mobility. If there were data gaps within that particular geographic area, CDPH and/or CDFW would request and process extra samples from an area not previously sampled to ensure no crabs were found with elevated levels of domoic acid. If the first data gap verification sample set was clean, CDPH did not require a second set.

In addition, the fair start statute (FGC Code Section 8279.1) that prevents permit holders who had fished in other states or locations in California from fishing for 30 days from the start of the delayed season opener, was applicable to the domoic acid fishery delay.

---

47 Fish and Game Code section 7715. (a) If the Director of Environmental Health Hazard Assessment, in consultation with the State Director of Health Services, determines, based on thorough and adequate scientific evidence, that any species or subspecies of fish is likely to pose a human health risk from high levels of toxic substances, the Director of Fish and Game may order the closure of any waters or otherwise restrict the taking under a commercial fishing license in state waters of that species. Any such closure or restriction order shall be adopted by emergency regulation in accordance with Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code. (b) Any closure or restriction pursuant to subdivision (a) shall become inoperative when the Director of Environmental Health Hazard Assessment, in consultation with the State Director of Health Services, determines that a health risk no longer exists. Upon making such a determination, the Director of Environmental Health Hazard Assessment shall notify the Director of Fish and Game and shall request that those waters be reopened for commercial fishing.

48 Emergency regulations for Dungeness and rock crab are posted here: https://www.wildlife.ca.gov/Conservation/Marine/Invertebrates/Crabs

49 Dungeness crab Task Force Executive Committee letter: http://www.opc.ca.gov/webmaster/_media_library/2009/04/DCTF_EC_FINAL_DAMemo_Nov2015.pdf

50 Letters from the fishing community:
http://www.opc.ca.gov/webmaster/ftp/project_pages/dctf/ec-meeting-15/DCTF-EC-DAMemo-FINAL-Feb2016.pdf
http://www.opc.ca.gov/webmaster/ftp/project_pages/dctf/ec-meeting-15/HMBSMA-CDFW-2-15-16.pdf
http://www.opc.ca.gov/webmaster/ftp/project_pages/dctf/ec-meeting-15/DomoicLetter-CCEurTrin-Feb2016.pdf
http://www.opc.ca.gov/webmaster/_media_library/2009/04/crab2016.pdf

- ***What is the process for testing Dungeness and rock crab for domoic acid in advance of the season opener? When will domoic acid testing for the 2016-17 season commence?***

In advance of season opener for Dungeness crab in 2016, CDFW, Washington Department of Fish and Wildlife, and Oregon Department of Fish Wildlife conduct a test fishery in the area from Point Arena California to the U.S. Canadian border for meat quality and yield to inform commercial Dungeness crab season opening date(s)[51]. During this time, six additional crab samples are also collected from each site and shipped to CDPH laboratories in Richmond, California for domoic acid testing. While quality testing is not required in the southern region of California, crabs are also taken from the area south of Point Arena for domoic acid testing and meat quality (for informational purposes only) during this same time period.

As of August 5, 2016, the date for commencement of pre-season crab testing has not been set. The criteria in Box 1 will help determine the exact time, with consultation with public health agencies and industry[52].

In California, preseason testing typically occurs in late October and November of each year. However, during the 2015-16 season, the preseason testing for domoic acid was initiated in September. This was a joint decision of the CDFW based on high domoic acid levels observed during the summer months, and the concerns voiced by some crab fishermen. CDPH agreed to process the samples and began designing a sampling plan in collaboration with CDFW.

The 2015-16 sampling was conducted coast-wide from Crescent City to Santa Barbara and the Northern Channel Islands (as opposed to Half Moon Bay and northward, which is the case in a typical year), and included domoic acid testing for both Dungeness and rock crab, in their respective fishery ranges, and testing continued on a near weekly basis through July (the end of the Dungeness crab season). As of July 2016, CDPH continues domoic acid testing for rock crab since the commercial and recreational rock crab fisheries remain closed north of Pigeon Point.

CDFW staff and leadership are currently determining an appropriate time to begin preseason testing for the 2016-17 season based on CDPH data. Preliminary observations from CDPH phytoplankton sampling (as of late June 2016) suggest that *Pseudo-nitzschia*, the species responsible for domoic acid production, may be present in high concentrations along portions of the California coast, though this does not always mean that domoic acid levels will be elevated in seafood. Contact Pete Kalvass, Senior Environmental Scientist Supervisor at California Department of Fish and Wildlife with additional questions about preseason testing (Peter.kalvass@wildlife.ca.gov).

There are challenges associated with preseason testing sampling for domoic acid. First, preseason testing relies largely on the efforts of commercial fishermen volunteers able and willing to collect samples at the various ports on their own vessels. These fishermen often incur the cost of sample collection (time, crew, and operational expenses), though in recent years the crabs collected during preseason quality testing have been allowed to be sold to pay for some of the expenses associated with crab quality testing only. In addition, there are chain-of-custody procedure requirements that may necessitate an on-board observer on sample collection vessels. In the future, if extensive sampling efforts are required (additional sites, samples, and species) as was the case in 2015, this method of sample collection may not be a long-term solution.

Because rock crab is open year round, toxin testing will begin when or if any of the indicators in Box 1 are present in the same region as rock crab fishing grounds, or during the preseason testing for Dungeness crab (which was the case in 2015), and on recommendation of CDPH.

- ***Why was a "two clean test" system required most of the time and a "one-test" system at other times? Describe CDFW's rationale for opening the District 10 line without the two consecutive clean tests required elsewhere.***

The standard requirement to re-open a closed Dungeness crab fishery due to elevated toxin levels in California is two consecutive clean tests: two sets (6 crabs per set) collected at a site one week apart, with all viscera samples testing below 30 ppm and meat testing below 20 ppm domoic acid. (Note: CDPH did not test both meat and viscera in most situations because once one of the crab viscera samples tested above 30 ppm, the levels in the meat did not make a difference. If samples were testing very high (>90 ppm) in the viscera, CDPH did test domoic acid levels in some of those meat samples.)

However, there were two instances (in Sonoma and Trinidad locations) where the health agencies, in consultation with CDFW, recommended opening an area to crab fishing without the "two clean test" system. There were several factors that went into the adaptive management decisions that led the health agencies to conclude that they could confidently assume that all crab in the area were below the federal domoic acid action levels in both meat and viscera and therefore safe for entering the marketplace.

---

51 The preseason crab testing protocol is available here: http://www.psmfc.org/crab/2013_FINAL_PreSeasonTestingProtocol.pdf

52 Pete Kalvass, Senior Environmental Scientist Supervisor, CDFW, personal communication

Both Sonoma and Trinidad locations had the same sampling history:

- One week of all six crabs tested well below the action levels,
- immediately followed by one week where five of the six crabs tested well below the action level, and one crab tested above the action level (but in the 30 ppm range) ;
- followed by one week where all crabs tested well below the action level again.
- Additionally, the two sampling locations immediately above and below these areas had also been testing well below the action levels for several weeks.

Because of this sample history, the health agencies determined that it would be safe to open the fishery in these areas without conducting and testing another round of samples. The health agencies would not have made this recommendation if any one crab had tested well above the action level or if any of the "clean" crabs in the sample had tested near the action level, rather than in the low 20s or below. Similarly, they would like have not made this recommendation if the areas immediately north and south had not also been testing consistently clean, thus assuring that crab moving in and out of the fished area were also safe for consumption.

References

Anderson, C.R., Moore, S.K., Tomlinson, M.C., Silke, J. and Cusack, C.K., 2015. Living with harmful algal blooms in a changing world: strategies for modeling and mitigating their effects in coastal marine ecosystems. Coastal and Marine Hazards, Risks, and Disasters. Elsevier BV, Amsterdam, pp.495-561. Available at: http://oceandatacenter.ucsc.edu/home/Publications/2014/Anderson_Coastal&MarineHazards_2014.pdf

Anderson, D.M., 1994. Red tides. Scientific American, 271(2), pp.62-68. Available at: https://www.researchgate.net/profile/Donald_Anderson/publication/15133680_Red_tides/links/53d3a3db0cf220632f3cd975.pdf

Anne E. Thessen. 2007. "Taxonomy and ecophysiology of *Pseudo-nitzschia* in the Chesapeake Bay" Thesis Dissertation. Available at: http://bit.ly/23bVdLf

Auro, M.E. and Cochlan, W.P., 2013. Nitrogen Utilization and Toxin Production by Two Diatoms of the *Pseudo-nitzschia* pseudodelicatissima Complex: P. cuspidata and P. fryxelliana. Journal of phycology, 49(1), pp.156-169.

Bates, S.S., Bird, C.J., Freitas, A.D., Foxall, R., Gilgan, M., Hanic, L.A., Johnson, G.R., McCulloch, A.W., Odense, P., Pocklington, R. and Quilliam, M.A., 1989. Pennate diatom *Nitzschia pungens* as the primary source of domoic acid, a toxin in shellfish from eastern Prince Edward Island, Canada.Canadian Journal of Fisheries and Aquatic Sciences, 46(7), pp.1203-1215. Available at: http://www.nrcresearchpress.com/doi/abs/10.1139/f89-156#.V5EtopOANBc

California Sea Grant. 2016. Natural Biotoxins in California Crabs: Domoic Acid, Frequently Asked Questions on Human Health, Fishery Closures and Biotoxins in Crabs. Available at: https://caseagrant.ucsd.edu/sites/default/files/Biotoxins-SU16-FAQ-v2.pdf

Cochlan, W.P., Herndon, J. and Kudela, R.M., 2008. Inorganic and organic nitrogen uptake by the toxigenic diatom *Pseudo-nitzschia* australis (Bacillariophyceae). Harmful Algae, 8(1), pp.111-118.

De Wit, P., Rogers-Bennett, L., Kudela, R.M. and Palumbi, S.R., 2014. Forensic genomics as a novel tool for identifying the causes of mass mortality events. Nature communications, 5. Available at: http://www.nature.com/ncomms/2014/140416/ncomms4652/full/ncomms4652.html

Department of Health and Human Services. 1993a. Memorandum – Marine Biotoxins in Dungness crab. Available at: http://www.oceansciencetrust.org/wp-content/uploads/2016/07/DA_Crabs_93.pdf

Department of Health and Human Services. 1993b. Memorandum – Health Hazard Evaluation Board, Center for Food Safety and Applied Nutrition. "The Problem: Domoic Acid in Dunegess Crab" Available at: http://www.oceansciencetrust.org/wp-content/uploads/2016/07/DA_Crab.pdf

Goldstein, T., Mazet, J.A.K., Zabka, T.S., Langlois, G., Colegrove, K.M., Silver, M., Bargu, S., Van Dolah, F., Leighfield, T., Conrad, P.A. and Barakos, J., 2008. Novel symptomatology and changing epidemiology of domoic acid toxicosis in California sea lions (*Zalophus californianus*): an increasing risk to marine mammal health. Proceedings of the Royal Society of London B: Biological Sciences, 275(1632), pp.267-276. Available at: http://www.sciencedirect.com/science/article/pii/S1568988313000139#bib0065

Hiolski, E.M., Kendrick, P.S., Frame, E.R., Myers, M.S., Bammler, T.K., Beyer, R.P., Farin, F.M., Wilkerson, H.W., Smith, D.R., Marcinek, D.J. and Lefebvre, K.A., 2014. Chronic low-level domoic acid exposure alters gene transcription and impairs mitochondrial function in the CNS. Aquatic Toxicology, 155, pp.151-159. Available at: http://www.ncbi.nlm.nih.gov/pubmed/25033243

Klasing, Susan, Office of Environmental Health Hazard Assessment, personal communication.

Lefebvre, K.A., Frame, E.R., Gulland, F., Hansen, J.D., Kendrick, P.S., Beyer, R.P., Bammler, T.K., Farin, F.M., Hiolski, E.M., Smith, D.R. and Marcinek, D.J., 2012. A novel antibody-based biomarker for chronic algal toxin exposure and sub-acute neurotoxicity. PloS one, 7(5), p.e36213. Available at: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0036213

Lefebvre, Kathi, NOAA Fisheries, personal communication https://www.nwfsc.noaa.gov/contact/display_staffprofile.cfm?staffid=230

Lewitus, A.J., Horner, R.A., Caron, D.A., Garcia-Mendoza, E., Hickey, B.M., Hunter, M., Huppert, D.D., Kudela, R.M., Langlois, G.W., Largier, J.L. and Lessard, E.J., 2012. Harmful algal blooms along the North American west coast region: History, trends, causes, and impacts. Harmful Algae, 19, pp.133-159. Available at: http://www.sciencedirect.com/science/article/pii/S1568988312001175

Lund, J.A.K., Barnett, H.J. and Hatfield, C.L., 1997. Domoic acid uptake and depuration in Dungeness crab (*Cancer magister* Dana 1852). Oceanographic

Literature Review, 12(44), p.1546. Available at: https://www.infona.pl/resource/bwmeta1.element.elsevier-ae277bad-673c-3076-aed7-728ae8c0f454

McGaraghan, A., Kudela, R., and Negrey, K. 2012. A Primer on California Harmful Algal Blooms, Common questions and answers for stakeholders, decision makers, coastal managers, and the education community. Available at: http://fisheries.legislature.ca.gov/sites/fisheries.legislature.ca.gov/files/u8/Primer%20on%20HAB%20westcoast.pdf

Moore, S.K., Trainer, V.L., Mantua, N.J., Parker, M.S., Laws, E.A., Backer, L.C. and Fleming, L.E., 2008. Impacts of climate variability and future climate change on harmful algal blooms and human health. Environmental Health,7(2), p.1. Available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2586717/

Mos, L. 2001. Domoic acid: a fascinating marine toxin. Environmental Toxicology and Pharmacology, 9(3), pp.79-85. Available at: http://ic.ucsc.edu/~kudela/OS130/Readings/DA_review.pdf

Perl, T.M., Bédard, L., Kosatsky, T., Hockin, J.C., Todd, E.C. and Remis, R.S., 1990. An outbreak of toxic encephalopathy caused by eating mussels contaminated with domoic acid. New England Journal of Medicine, 322(25), pp.1775-1780. Available at: http://www.nejm.org/doi/pdf/10.1056/NEJM199006213222504

Pulido, O.M., 2008. Domoic acid toxicologic pathology: a review. Marine Drugs, 6(2), pp.180-219. Available at: http://www.mdpi.com/1660-3397/6/2/180/htm

Todd, E.C., 1993. Domoic acid and amnesic shellfish poisoning-a review.Journal of Food Protection®, 56(1), pp.69-83. Available at: http://www.marearoja.cl/IMG/pdf/AMNESIC_SHELLFISH_POISON_REVIEW_BLOOM_CANADA_1987.pdf

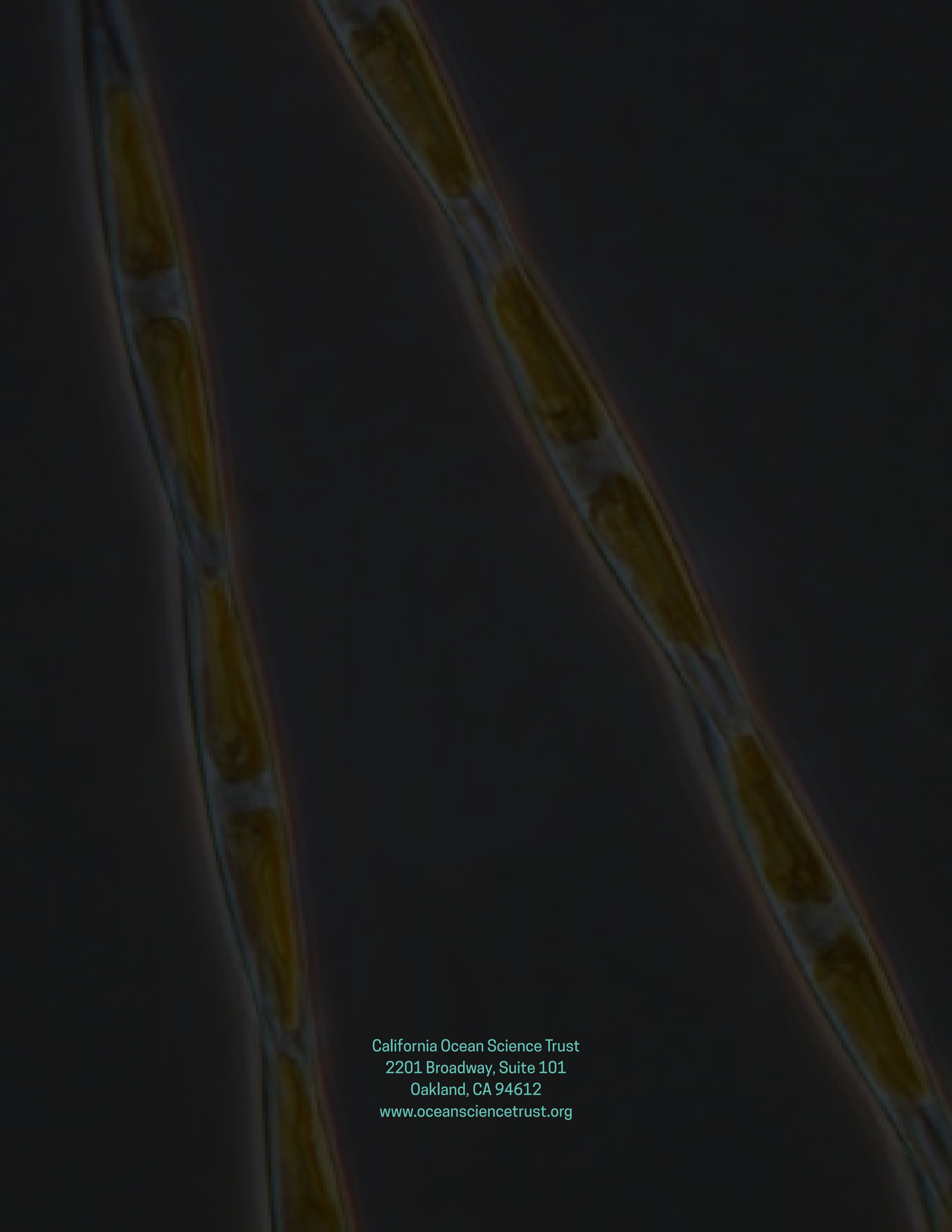
Toyofuku, H., 2006. Joint FAO/WHO/IOC activities to provide scientific advice on marine biotoxins (research report). Marine pollution bulletin, 52(12), pp.1735-1745. Available at: http://www.sciencedirect.com/science/article/pii/S0025326X06002797

US EPA. 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories: Volume 1, Fish Sampling and Analysis, 3rd Ed. EPA 823-B-00-007. Available at: https://www.epa.gov/sites/production/files/2015-06/documents/volume1.pdf

United States Food and Drug Administration (US FDA), Center for Food Safety and Applied Nutrition Office of Food Safety. 2011. 4th edition of the FDA Fish and Fisheries Products Hazards and Controls Guidance, Available at http://www.fda.gov/downloads/Food/GuidanceRegulation/UCM251970.pdf

US National Office for Harmful Algal Blooms, Woods Hole Oceanographic Institution, http://www.whoi.edu/redtide/page.do?pid=14898&tid=542&cid=47899&c=3

Washington State Department of Health, Washington State Shellfish Treaty Tribes, Washington State Department of Fish and Wildlife, Washington State Department of Agriculture. 2008. Strategy for preventing consumer exposure to domoic acid from Dungeness crab. Available at: http://www.ifrfish.org/wp-content/uploads/2016/02/Crab-DA-Monitoring-Plan-2008-2009.pdf



California Ocean Science Trust
2201 Broadway, Suite 101
Oakland, CA 94612
www.oceansciencetrust.org