Northwest Fisheries Science Center

RED TIDES

West Coast newsletter on marine biotoxins and harmful algal blooms

This newsletter has a straightforward mission: to share and expand knowledge about harmful algal blooms (HABs). This knowledge is increasing steadily, and the diverse professionals who must confront this poorly understood phenomenon need immediate access to the information. We also want to share it with the public. There's a special HAB urgency to West Coast research this year: for example, domoic acid was implicated in the deaths of sea lions in California and reached record levels in Washington and Oregon. Our HAB problems are persisting, if not worsening.

We hope this newsletter becomes an ongoing collaborative West Coast effort. Although this first issue highlights NWFSC research, we would like to include articles from West Coast colleagues in future issues. Share your ideas for newsletter articles by contacting:

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Winter 1999

"Red tide"
a long-time West Coast problem that's not going away soon

For centuries, harmful algal blooms and marine biotoxins have plagued inhabitants along coastlines of the Eastern Pacific. The first recorded bio-intoxication was in 1793: a member of Captain George Vancouver's crew died after eating shellfish from a beach in what is now British Columbia. Tales of coastal Indian tribes from southeast Alaska to the Northwest states describe deaths from eating shellfish and even the use of toxic shellfish as a poison in tribal warfare.

For some reason, West Coast toxins can be especially potent. When saxitoxin (a major component of paralytic shellfish poison, or PSP) was isolated in the 1950s, Alaska's toxic butter clams were used as the source. Saxitoxin is now used by health departments worldwide to monitor shellfish for PSP dangers. Some of the highest recorded levels of PSP toxins have been found in mussels in British Columbia (31,000 µg/100 g, which is about 16 lethal human doses per quarter pound). In Washington State and Alaska, up to 20,000 µg/100g has been recorded.

PSP may have the longest recorded history here, but we have other serious problems: domoic acid, the *Heterosigma akashiwo* alga, and ciguatera fish poisoning. Their economic cost alone can be huge. In 1997 in Washington State, for example, HABs cost oyster and salmon farmers up to $12 million, said Terry Nosho, an aquaculture specialist with the Washington Sea Grant Program at the University of Washington. Losses in 1998 from record-setting levels of domoic acid could exceed $20 million, based on calculations made during the last major outbreak (in 1991), Nosho said; cumulative impacts, such as loss of tourist dollars from recreational shellfishing and unemployment, make HABs "a real blow to those coastal communities."

Microalgae are indistinguishable to the naked eye, and there are many of them: some 4,000 species. Only about 6 percent of cause harmful blooms, and only 2 percent are toxic. Descriptions of the Eastern Pacific's most troublesome algae follow:

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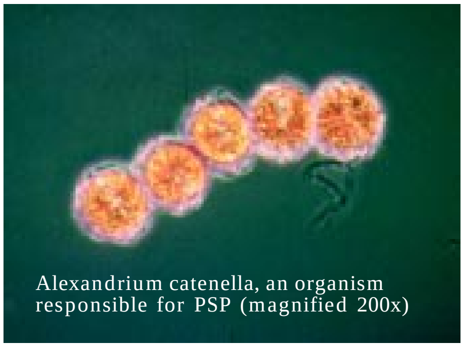
Paralytic shellfish poison



Alexandrium catenella, an organism responsible for PSP (magnified 200x)

Actually a suite of toxins (saxitoxin and gonyautoxin derivatives), PSP is produced by dinoflagellates of the *Alexandrium*, *Pyrodinium*, and *Gymnodinium* species. It accumulates in clams (particularly butter clams), mussels, oysters, scallops, whelks, lobsters, and crabs. These PSP-producing algae occur all along the North American west coast—Alaska, British Columbia, Washington, Oregon, California. In Alaska, PSP is so widespread that all beaches and waters are closed to recreational shellfish harvesting, with commercial shellfishing very limited and strictly controlled. Most West Coast blooms occur in April through November, but this varies; Puget Sound, for example, can have unusually late winter blooms.

Symptoms of PSP poisoning include tingling and numbness that start around the lips and mouth and spread to the face and neck; prickly sensations in the fingertips and toes, headache, and dizziness; muscle weakness, nausea, and vomiting can also occur. Severe poisoning can produce tingling or burning in the arms and legs; giddiness and incoherent speech, lack of coordination, and breathing difficulties.

Domoic acid

Pseudo-nitzschia australis, an organism responsible for domoic acid poisoning (magnified 100x)

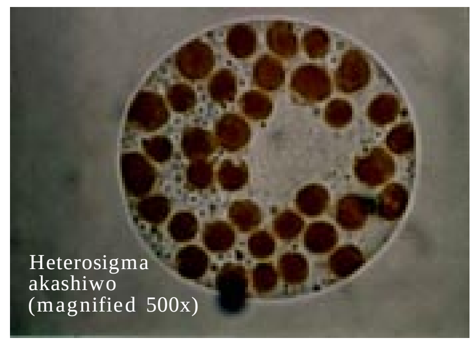
This toxin is produced by several species of the *Pseudo-nitzschia* algal genus. It accumulates in razor clams, Dungeness crab, mussels, anchovies, and sardines. It was first detected by the Japanese in red macroalgae (who used it as a deworming agent, primarily for children), but wasn't discovered as a shellfish toxin until 1987, when 3 people died and 107 others became ill from eating mussels from Prince Edward Island.

The West Coast's first recorded outbreak was in 1991, but domoic-acid-producing algae have probably been here for a long time (the Northwest Fisheries Science Center found it in razor clams frozen more than 15 years ago). The 1991 outbreak killed dozens of California pelicans and cormorants in Monterey Bay, and poisoned Dungeness crab and razor clams along beaches in Northern California, Oregon, and Washington State. Losses associated with crab fishing were estimated at $7 million in southwest Washington alone.

In the summer of 1998, domoic acid broke out on the West Coast again, with disturbing effects: the first confirmed instance of domoic acid's involvement in marine mammal deaths. More than 50 California sea lions died along the California coast from San Luis Obispo to Santa Cruz. (Sea lions eat anchovies and sardines, which can accumulate domoic acid.)

One of domoic acid poisoning's most serious symptom is a short-term memory loss that can be permanent (and is why it is also called "amnesic shellfish poisoning"). Disorientation is another symptom; that, and the apparent greater susceptability of older people, explain why it's believed that domoic acid poisoning can be misdiagnosed as Alzheimer's disease. Diarrhea, vomiting, and abdominal cramping may lead to misdiagnoses as flu.

Heterosigma akashiwo



Heterosigma akashiwo (magnified 500x)

Heterosigma blooms are not known to be toxic to humans, but are associated with fish kills around the world and have caused catastrophic losses of both cultivated and wild salmon in Washington State and British Columbia.

How *Heterosigma* kills is unknown—but a bloom can kill thousands of fish within hours. One of its many perplexing features is that it has been in the Pacific Northwest for decades, but didn't produce frequent deadly blooms until the late 1980s.

Symptoms in fish include loss of equilibrium, gill damage, and respiratory paralysis.

Ciguatera (“tropical fish poisoning”)

Gambierdiscus toxicus, an organism responsible for ciguatera fish poisoning (magnified 10,000x)
Photo courtesy Dr. Daniel Baden, University of Miami

Ciguatera fish poisoning toxin is produced by a benthic dinoflagellate (*Gambierdiscus toxicus*) that lives in tropical and subtropical reefs and is eaten by fish. Eventual consumption of contaminated fish by humans is an example of bioaccumulation of toxins through the food web.

Ciguatera is prominent in Hawaii and other Pacific Islands such as Samoa and Guam. But it is becoming a risk on the mainland too as more West Coasters visit the islands and then ask their hometown stores to stock the new kinds of fish they’ve sampled on their trip.

Right now, there’s no easy way to routinely measure ciguatoxin in seafood. Larger species of carnivorous fish (such as amberjack) are the most toxic; for this reason, in Hawaii, no amberjack over 20 pounds are sold.

Symptoms of poisoning include tingling or numbness of tongue, throat, lips, nose, hands, and feet; feeling coldness as a burning or dry ice sensation; muscle pains in the legs and back; diarrhea, vomiting, nausea, abdominal pain, dizziness, sweating, hypersalivation, teeth that feel loose and painful, insomnia, and anxiety. Potential effects are recurring neurological disturbances, premature labor or abortion, and newborn facial palsy.

Harmful algal blooms in the Eastern Pacific: a unique problem

HABs are a problem throughout the world, but those in the Eastern Pacific present unique problems.

- The sheer area involved is huge—from the Bering Sea to the southern tip of the California coast, more than 15,000 miles of Alaskan coastline, and throughout the Pacific Islands, from Guam to Samoa.

- Monitoring the extremely long and complex coastlines typical of the Eastern Pacific is virtually impossible. Instead, entire coastlines must sometimes be closed because there isn’t enough money to monitor them effectively. Collecting water and shellfish samples from remote and difficult-to-access areas, such as La Push on Washington’s Olympic Peninsula, can take many hours in addition to the time required to analyze those samples. Much of the Alaskan coastline is closed to shellfishing due to the virtual impossibility of monitoring it. The wide-scale closures necessitated by the inability to ensure safety levy great losses on both commercial and recreational shellfishing economies.

- Dollars are scarce for critical research and monitoring. Federal dollars have focused on East and Gulf Coast problems, with no funds specifically for a West Coast regional study. In 1998, less than 15 percent of the approximately $4.8 million in HAB federal funds went to West Coast research. That lack of money makes it virtually impossible, for example, for the NWFSC to research PSP problems in Alaska. Sampling the state’s enormous and remote coastline is tremendously labor-intensive, and severe weather complicates field work.

- Possibly the world’s worst PSP problem is along the British Columbian and Alaskan coastlines. In Alaska, at least one person dies every year from eating PSP-contaminated shellfish.

- This region is the only one where domoic acid is known to have killed marine mammals (California sea lions in Monterey Bay, 1998). The California sea lion is not endangered, but a similar outbreak could be devastating for endangered species such as the Hawaiian monk seal or humpback whale.

- HABs pose potentially huge economic losses for the region’s shellfish and aquaculture industries.

- *Heterosigma akashiwo* in Washington state and British Columbia is a major economic threat to fish farming (an estimated $5 million a year in losses in British Columbia alone), but the same species of alga in New England hasn’t caused any harm as far as we know.

Monitoring seafood for marine biotoxins

West Coast states follow shellfish monitoring plans similar to the Washington State plan outlined below. States with a risk of marine biotoxins are required by the Interstate Sanitation Committee (ISSC) to develop such a plan. The ISSC is made up of representatives from West Coast states and overseen by the Food and Drug Administration, which enforces ISSC regulations.

Collect shellfish samples

- Commercial shellfish farms
- County health departments
- Tribes
- Volunteers
- Department of Fish & Wildlife
- Department of Natural Resources

Analyze samples for closure levels

- Paralytic shellfish poisoning: 80 micrograms STX equiv.* per 100 grams shellfish or crustacean meat
- Domoic acid: 15 parts per million in Washington State (20 ppm in other states), 30 ppm Food and Drug Administration level for Dungeness crab in Washington State

* Usual way of expressing PSP toxicity; means equivalent to saxitoxin and similar toxins in suite of toxins that comprise PSP

Close harvests if necessary

Involves multiple regulatory agencies:

- Department of Health
  - closes beaches for health reasons
  - notifies media
  - stops commercial sales
- County health departments
  - post beaches
- Department of Agriculture
  - oversees crustacean shipments
- Department of Fish and Wildlife
  - regulates recreational crab/shellfish harvesting resources
- Department of Health (in state) and Food and Drug Administration (out of state)
  - regulate shellfish shipments

Reopen harvests

- Requires 2 consecutive sampling measurements below closure level at least 7 days apart

Biotoxin hotline phone numbers

AK	800-731-1312
BC	604-666-3169
CA	510-540-2605
HI	808-586-4725 (Food Branch)
HI	808-586-4586 (Epidemiology Branch)
OR	503-378-4307
WA	800-562-5632

Photo of algal bloom in Penn Cove, Washington, courtesy Jeff Engebretson

Investigating toxic blooms—and what we can do about them

We have a long way to go before we know enough to predict—never mind control—toxic blooms.

Because HABs are a *regional* phenomenon, it is vital to build a 5- to 10-year database about HABs throughout the Eastern Pacific region. Right now, we can't even hazard a guess about bloom activity in 1999 because we lack historical sampling data.

Gathering such data is an important part of NWFSC's HAB research, which includes regular sampling of several bloom sites in Puget Sound and off the Washington coast. This sampling will provide important baseline data to indicate how and when HABs occur and how they proliferate. This growing database is supplemented by NWFSC's rapid-response team, which is dispatched to many blooms on the West Coast. Getting to blooms quickly is critical: conditions that foster blooms, growth rates of algae, the suite of toxins they produce, and the organisms affected by toxins can all change rapidly.

Other top research priorities include developing faster and more accurate biotoxin analytical procedures and learning more about the basic nature of HABs themselves. These diverse research activities involve collaboration with academic, state, and other National Oceanic and Atmospheric Administration (NOAA) and National Marine Fisheries Service (NMFS) entities.

A 'dip-stick' test for toxins?

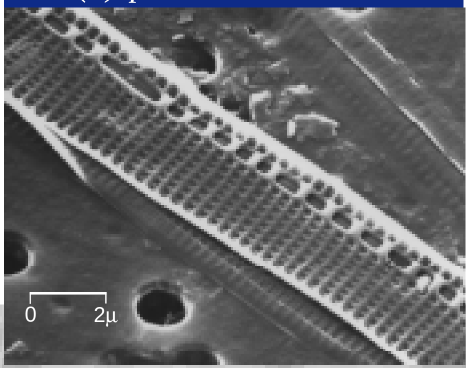
Risk management—which for now means widespread closings of harvest areas where we believe HABs to be a threat—is currently our main tool. Ideally, only specific areas *known* to be affected by toxic blooms would be closed; this, however, requires far more monitoring stations, personnel, and sample analysis than current funding and resources allow.

We need better analytical tools. Current procedures (bioassay or microscopic analysis) were developed in another era, when areas affected by HABs were smaller and there were fewer HAB events (at one time, we worried only about PSP!). These microscopic analyses require a laboratory and expensive equipment, and bioassays are politically sensitive techniques (a live mouse is injected with a toxin to determine its lethality).

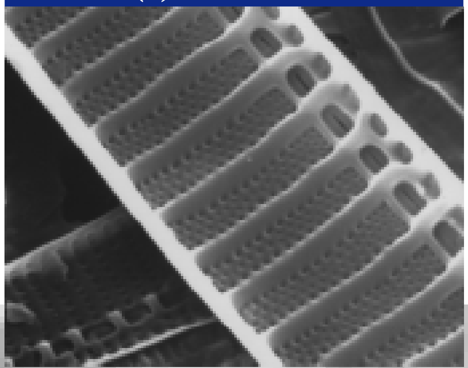
The difficulty in identification

An important step in managing toxic blooms is to be able to identify species of algae. The scanning electron micrographs (SEM) below show three species of *Pseudo-nitzschia*: (1) *pseudodelicatissima*, found in a recent record-setting toxic Pacific Northwest bloom; (2) *multiseries*; and (3) *pungens*. How can you tell which is which? Note that *pseudodelicatissima* has just 1 row of square pores between its striae (rib-like structures); *multiseries* has 3 to 4 rows; and *pungens* has 2 to 3 rows, with larger pores than *multiseries*. A magnification bar equivalent to 2µ (microns) is shown in the first photo. One thousand microns equal one millimeter. (Micrographs by Carla Stehr of NWFSC)

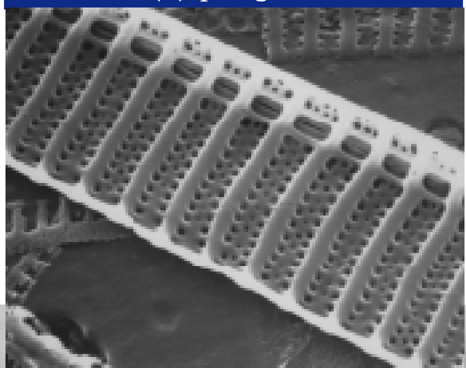
(1) pseudodelicatissima



(2) multiseries



(3) pungens



We badly need analytical procedures that can be done right where seafood is harvested, that are fast, accurate, inexpensive, and able to handle high volumes of samples.

Ideally, we are looking for a "dip-stick" test (similar to a home pregnancy test) that harvesters at all levels—commercial, subsistence, and recreational—could use to spot check catch and determine its safety right away. Work is progressing on a dip-stick test and on promising new analytical procedures, but none are ready for use in the field.

Getting to the heart of HABs

NWFSC researchers are working to help meet these important risk management needs:

- A model to predict where and when a bloom might occur and how long it will last.
- Accurate assessment of toxin levels within a bloom.
- Knowledge of factors that trigger and sustain the bloom (such as currents, weather, wind speed and direction, and nutrient inputs).

Specific NWFSC research projects:

- Studying health risks to fisheries—Fish and shellfish exposed to biotoxins have demonstrated greater incidences of carcinogens, immune system depression, and depressed growth.
- Finding out exactly which algal species produce domoic acid could help in developing a dip-stick test. It was thought that domoic acid was produced by either *Pseudo-nitzschia multiseries* or *australis*, but the NWFSC's biotoxin team in 1996 and 1997 identified *P. pungens* as a source of low levels of domoic acid and in 1998 found a fourth species that may produce this toxin.
- Determining ways that shellfish regulate toxin levels in their tissues and how they prevent intoxication.
- Identifying factors that cause *Heterosigma* toxins and blooms and developing a simple field test for this destructive alga.
- Developing ways to rapidly detect toxins at *low* levels, which will help in understanding how and where harmful algal blooms originate.
- Investigating the transfer of toxins through the food web from algae, to zooplankton, to shellfish and crustaceans, and finally to mammals.
- Understanding pollution and biotoxin interactions—How do pollutants affect algal cell growth and toxin levels? And does exposure to biotoxins compound pesticide toxicity?
- Understanding El Niño's effect on toxic blooms. Temperature and nutrients play a role in HAB events, but that role isn't clear. Continuing NWFSC research will gather environmental data before, during, and after HAB events, to help define the role of El Niño, which reoccurs every 3 to 7 years. The NWFSC biotoxin team is currently sampling off the Washington coast and in Puget Sound, and hopes to expand research to Oregon and California.
- Getting accurate information out quickly about HAB outbreaks. To meet this critical need, NWFSC is working with state agencies and universities along the West Coast to develop an early warning system on a single web site.

REGIONAL REPORTS

Unusually high levels of both PSP and domoic acid were detected in sampling Eastern Pacific shellfish and crustaceans in 1997 and 1998. The lack of resources to effectively sample the area's long (and in many cases, impossible-to-access) coastline has closed virtually all recreational harvesting in Alaska and limits it in Oregon, Washington State, and British Columbia. This worsening biotoxin problem is illustrated by the adjoining map and excerpted regional reports below. We thank our colleagues for supplying some of the following information:

Alaska

PSP problem areas in 1998 included:

- Port Althorp oyster farm (northern coast of Chichagof Island) mid-June levels as high as 234 µg/100g.
- Little Duncan Bay (on Kupreanof Island in southeast Alaska) oyster levels up to 306µg/100g for 3 weeks running.
- Entire harvest area around Kodiak Island (restricted).
- Kachemak Bay East area (closed to commercial butter clam harvesting since August 1997).

British Columbia

- The most extensive domoic acid bloom recorded in B.C. struck the west coast of Vancouver Island in the summer of 1998, subsiding in September. This was the third significant bloom in B.C. since screening began in the late 1980s. Previous closures were in 1993 (Barkley Sound, shellfish and Holberg Inlet, Dungeness crabs), and 1995 (northern Graham Island, razor clams and Dungeness crabs).
- The death of a family cat in Okeover Inlet led to plans to change the policy on rock scallops.

  The inlet was closed in the fall of 1997 to bivalve harvesting, then reopened under the usual policy (mussels under <80 µg/g and oyster and manila clams showing no detectable PSP). After reopening, a couple working a long-line oyster lease took some rock scallops for supper and fed the viscera to their dog and two cats. One cat died; the other pets showed signs of paralysis, but recovered. Rock scallop adductors from the lease tested at 340 µg/g and viscera at 1,600; oysters were 54. Rock scallops will now be treated the same as butter clams where harvests will be closed until post-bloom analyses indicate safe levels.
- The coastal community of Campbell River has its own web site on marine biotoxins (Leslie's Gazette at: http://www.crnews.bc.ca).

California

- The most striking biotoxin event in 1998 was the death of more than 50 California sea lions in the Monterey area.

  Domoic acid was detected in the urine of several sea lions using three separate analytical methods for toxin detection. Before the deaths, high levels of domoic acid were detected in anchovies and sardines (an important food source for sea lions) collected from Monterey Bay between April 9 to June 10. Levels for anchovies from central and southern California were similar to those in 1991, the last major domoic acid outbreak on the West Coast when high numbers of seabird deaths were reported.
- PSP toxicity was detected in May in mussels from every Northern California coastal county (maximum concentration 1,360 µg, at Chimney Rock) except for Mendocino (not sampled) and Del Norte. In Southern California, PSP was detected along most of the coastal counties (maximum concentration 490 µg, at Goleta Pier).

Hawaii

- Ciguatera poisoning cases have been on the increase since the 1970s; in recent years, there were 51 reported cases in 1995, 20 in 1996, and 57 in 1997, with most cases coming from recreational and subsistence fisheries. Environmental triggers for the poison are not fully understood—correlations have been noted between hurricanes and physical disturbances on the reef, but ciguatera has also been associated with calm sea conditions.

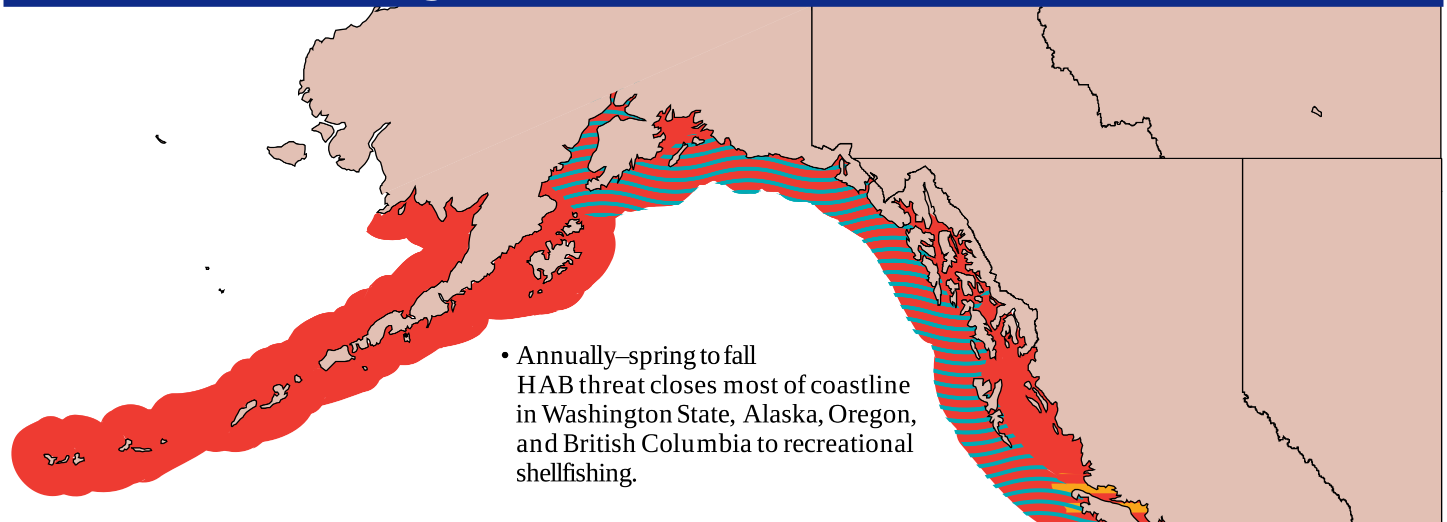
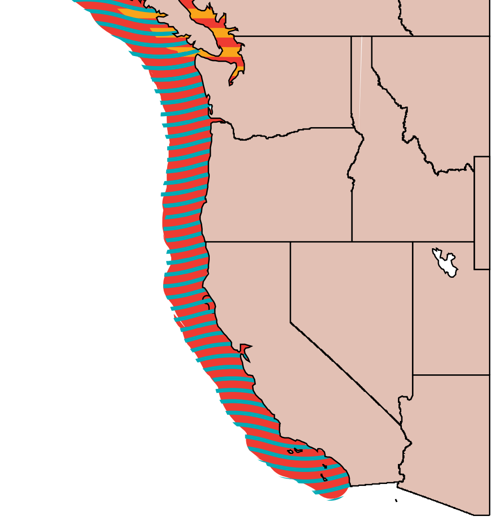
Oregon

- Record levels of domoic acid off the Oregon coast in 1998.
- Elevated levels of PSP closed all coastal beaches for the month of July in 1998.
- Domoic acid closed the state's northern beaches and ocean spits (Clatsop and Tillamook counties) to recreational and commercial shellfish harvesting late July through August, 1998 (domoic acid last exceeded alert level for Oregon shellfish in spring of 1996).

Washington State

- October 1998—Seattle person hospitalized after eating PSP-contaminated mussels harvested from Carr Inlet in south Puget Sound; first PSP case in commercially grown and certified shellfish in the state and perhaps in the nation.
- October 1998—the highest domoic acid levels ever recorded off Washington's coast (286 ppm, about twice the previously reported highest level).
- Increased toxin levels along ocean beaches prompted a special sport harvesters' advisory in 1998 that coastal shellfish could be affected by domoic acid and PSP (no further action was taken—coastal beaches were already closed).
- All areas were closed in the summer of 1998 to sport harvest of scallops.

Prevalence of harmful algal blooms on the West Coast and Hawaii

- Annually–spring to fall
  HAB threat closes most of coastline in Washington State, Alaska, Oregon, and British Columbia to recreational shellfishing.

- June 1997
  Recreational harvester dies after eating 6-8 butter clams, Karluk, Kodiak Is.—clams had 8,532 µg / g PSP.

- Summer 1997
  Heterosigma blooms cost Washington State aquaculturists up to $15 million.

- September 1997
  Family cat dies after eating PSP-contaminated rock scallops, Okeover Islet, B.C.

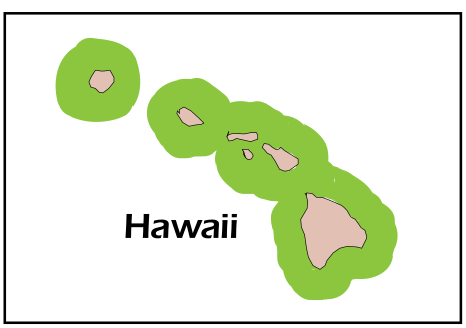
- May 1998
  Viscera from anchovies collected in Monterey Bay contain high levels of domoic acid.

- Spring–Summer 1998
  Domoic acid kills at least 50 sea lions in California.

- Summer 1998
  PSP threat closes Oregon coastline to shellfishing.
  First domoic acid threat in Oregon since spring 1996.

- October 1998
  Highest domoic acid levels ever recorded off the central Washington coast. Domoic acid in razor clams at Kalaloch Beach ranged from 144 ppm to record levels of 286 ppm.

California sea lion undergoing stomach pumping after poisoning (photo courtesy Dr. Francis Gulland, Marine Mammal Center, Sausalito, CA)



Paralytic shellfish poisoning (PSP)

Domoic acid poisoning (also known as amnesic shellfish poisoning)

Ciguatera fish poisoning

Heterosigma

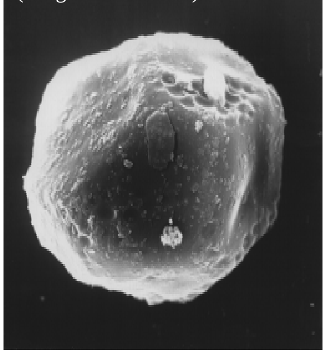
Markings depict areas where toxins are historically present and typically found, based on researchers' and state officials' observations and sampling experience

NOTES ON MEASURING MARINE BIOTOXINS

PSP is usually expressed in micrograms per gram (µg/g) STX equivalent, which refers to saxitoxin and similar compounds in the suite of toxins that comprise PSP.

The mysterious threat of *Heterosigma akashiwo*

Heterosigma akashiwo is perplexing—and dangerous to fish. It's perplexing for many reasons—for one, it's been in Pacific Northwest waters for at least 30 years, but wasn't known to produce frequent deadly blooms until the late 1980s. It's dangerous because it can kill thousands of fish within hours. Why? No one knows, but researchers at the NWFSC, the only government facility in the country researching *Heterosigma* toxicity, are trying to find out.



SEM of Heterosigma akashiwo (magnified 2000x)

Heterosigma is largely a problem for salmon farmers, especially in British Columbia but also in Washington State's Puget Sound, Norway, Scotland, Chile, and Japan. It also kills wild fish. Affected fish include chinook salmon, Atlantic salmon, yellowtail, red sea bream, rainbow trout, and sea bass. Curiously, the same species of *Heterosigma* doesn't seem to cause problems in New England waters. So why the damage here? That's yet to be determined.

The threat of *Heterosigma* forces fish farmers to hunt blooms by plane, which can cost as much as $200 an hour. If blooms are spotted, fish farmers must be ready to move the huge underwater pens (up to 300 by 800 feet, about the size of five football fields) used to raise the fish. This move is made only as a last resort (the stress can kill the fish, who also cannot be fed during this time and thus can lose weight). Meanwhile, tugboats must be paid to be on call or to actually move pens if a bloom approaches. The bills for all this can run into millions of dollars. Given the importance of aquaculture in providing food, *Heterosigma* looms as a major problem.

NWFSC *Heterosigma* research has three major goals:

- Developing simple DNA-based tests that aquaculturists could use in the field to identify *Heterosigma*. Right now, aquaculturists who fear a possible bloom have no easy way to quickly identify the alga and decide whether they must take expensive precautions.
- Determining physical factors, such as river inputs and water circulation, involved in inducing *Heterosigma* blooms. This research is in collaboration with the University of Washington's Puget Sound Regional Synthesis Model (PRISM) project.
- Investigating *Heterosigma* microbial community interactions, particularly in development of toxins. NWFSC researchers are examining the possibility that fish are killed by interactions between *Heterosigma* and bacteria—by a microbial community, not just the alga.

The inspiration for this newsletter came from the 1998 Pacific Rim Shellfish Sanitation Conference (PacRim) in Portland, Oregon. One purpose of the conference was to increase public awareness of HAB issues on the west coast of North America, an awareness essential to building badly needed resources to research and monitor marine biotoxins. Conference attendees included representatives from state health departments (Alaska, British Columbia, California, Washington, Oregon, and Hawaii), government research laboratories, universities, private and commercial shellfish growers and their associations, and Native American tribes.

The next PacRim conference is tentatively scheduled for March 21-25, 1999, in Reno, Nevada. We hope to see you there!

For more information about PacRim, contact:
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If you're online, you can keep up to date on West Coast HAB issues through the NWFSC's web site (http://www.nwfsc.noaa.gov/hab) featuring recent HAB findings from a variety of West Coast researchers, state reports on sampling and HAB occurrences, and links to many other relevant sites.

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