

# Impacts of harmful algal blooms on fish & shellfish harvest

**Vera L. Trainer**

**NOAA Northwest Fisheries Science Center**

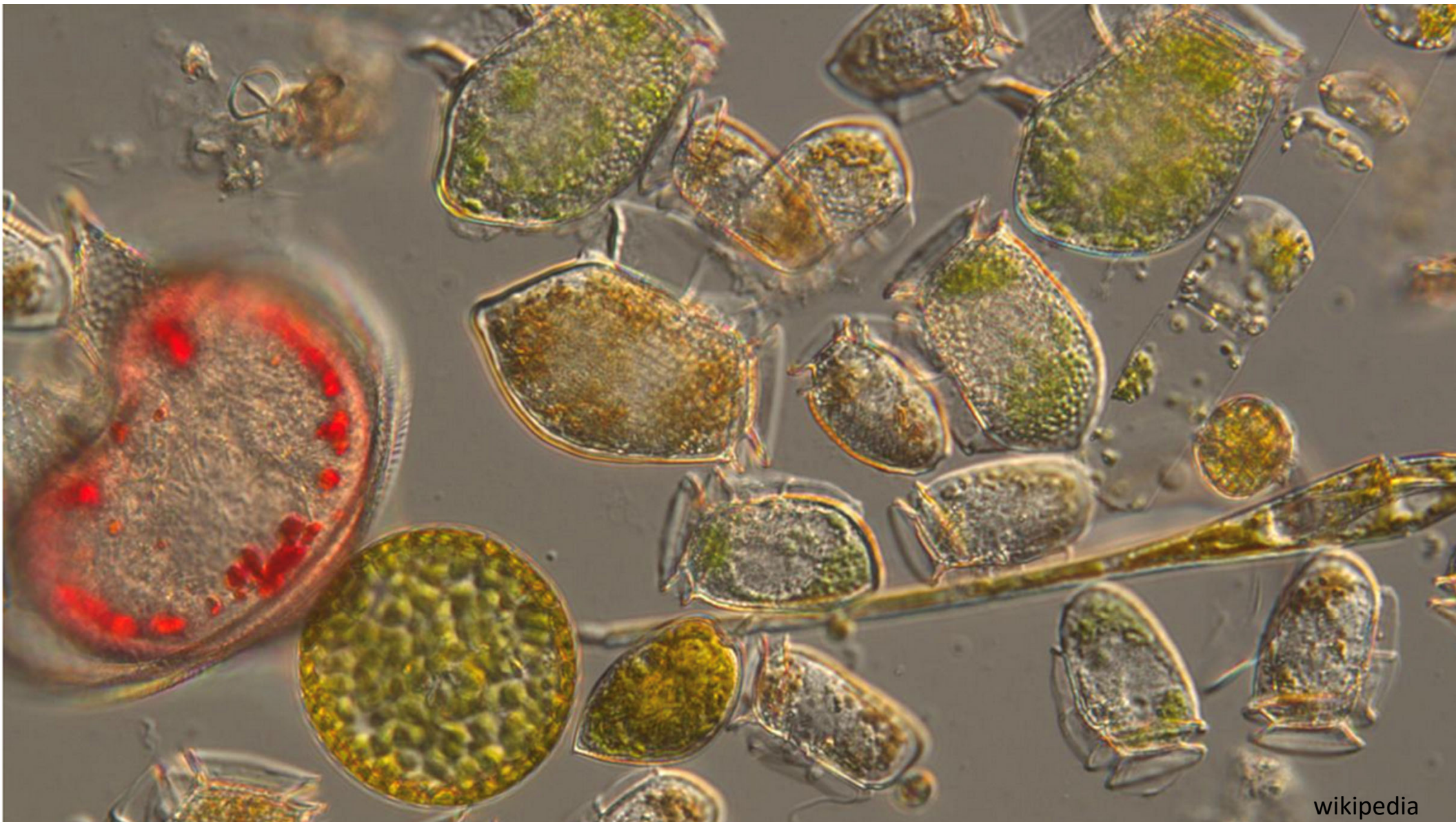
**Seattle, WA**



*Photo courtesy: Bill Dewey, Taylor Shellfish*







# “All fish is diatom”

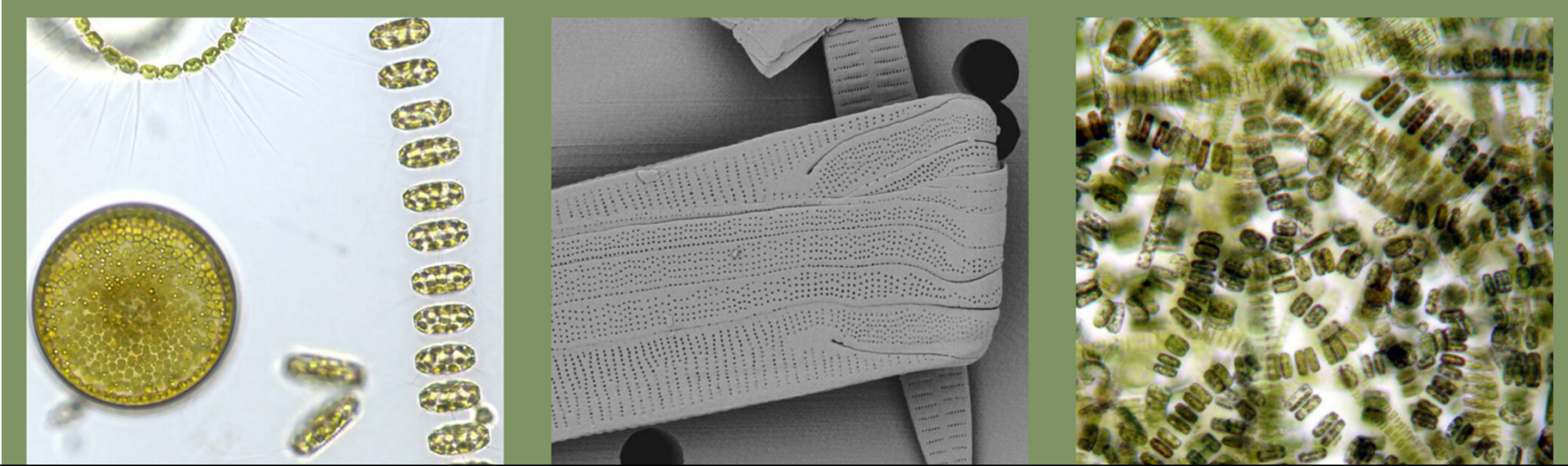
Bostwick Ketchum  
1881-1954



globalseafood.org

*Thalassiosira weissflogii* cultures for shellfish farming





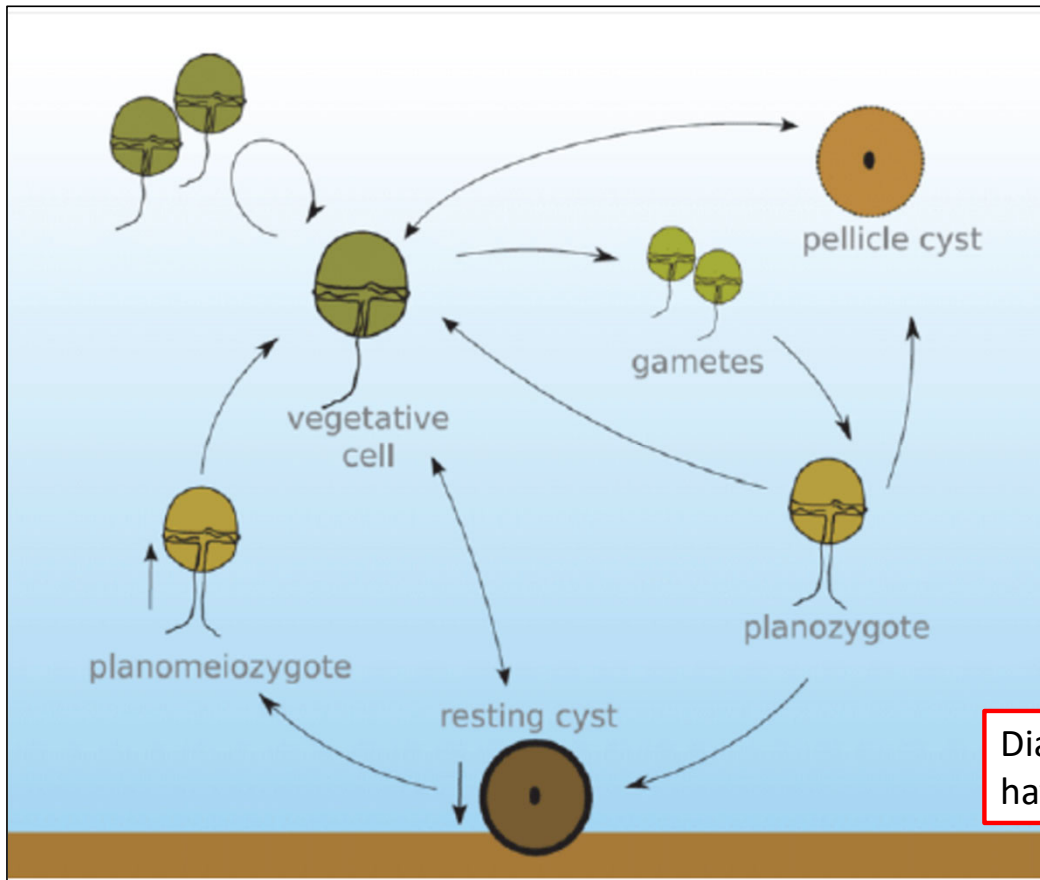
Diatoms are a major component of plankton, free-floating microorganisms of marine or freshwater environments





**It is likely that the frequency, duration and intensity of marine dinoflagellate blooms will increase as a result of a warming climate**

Gustaaf Hallegraeff

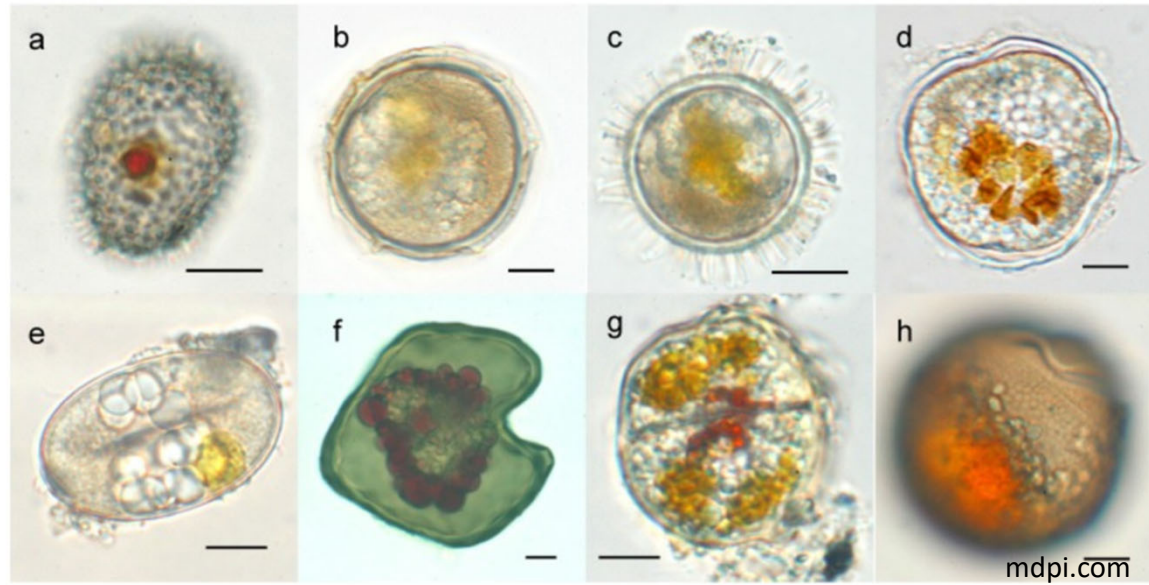


Diatoms do not have a cyst stage

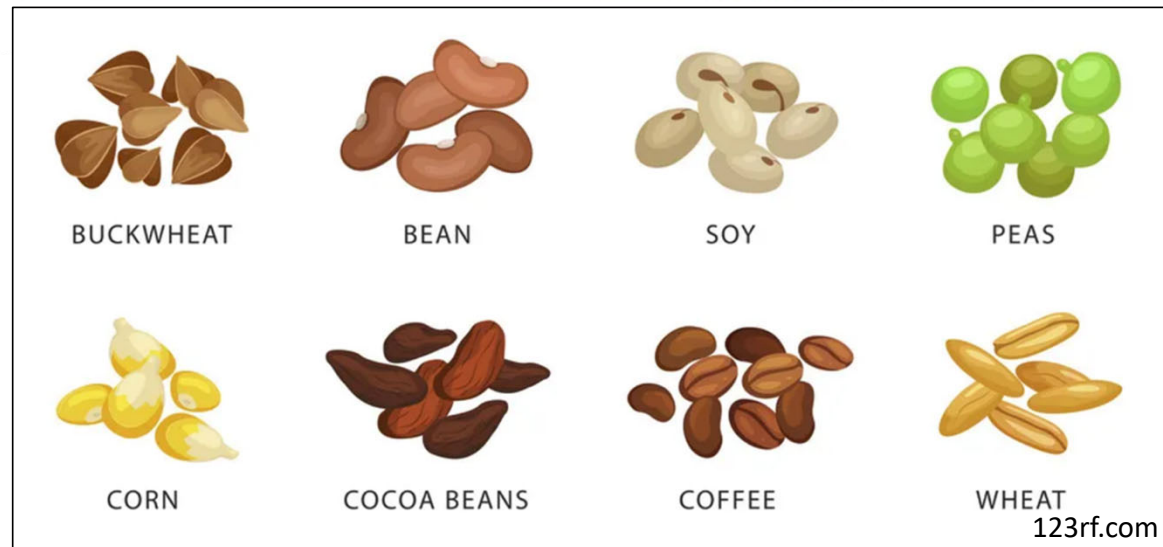
**Dinoflagellate life cycle**

*Anke Kremp modified from Warns et al. 2013*

Marine  
cysts



Terrestrial  
seeds





In Washington State, shellfish aquaculture is an important piece of our heritage and culture, contributing **\$270 million to the annual economy** and 2,700 local jobs

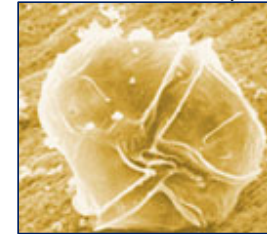


*Photo courtesy Manuscripts, Special Collections, University Archives, University of Washington Libraries, CUR801*

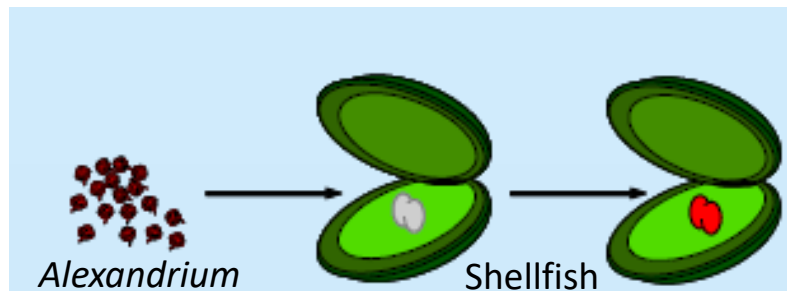
**J.J. Brenner Oyster Company harvesting Olympia oysters, 1910**

# Alexandrium catenella

*Alexandrium sp.*



- *Alexandrium* produce **saxitoxin** that accumulates in filter-feeding shellfish during blooms, or “**red tides**”
- Consumption of contaminated shellfish causes **paralytic shellfish poisoning**



Human  
consumption





# Diseases and conditions caused by eating seafood contaminated with algal toxins

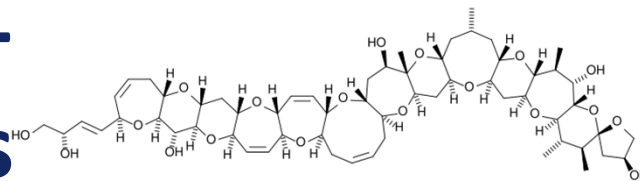
Accessible link: [www.cdc.gov/habs/illness-symptoms-marine.html#contaminated-seafood](http://www.cdc.gov/habs/illness-symptoms-marine.html#contaminated-seafood)



	Disease or Condition					
	Ciguatera fish poisoning (CFP)	Neurotoxic shellfish poisoning (NSP)	Paralytic shellfish poisoning (PSP)	Domoic acid poisoning and amnesiac shellfish poisoning (ASP)	Diarrhetic shellfish poisoning (DSP)	Azaspiracid shellfish poisoning (AZP)
Toxin-producing organism	Dinoflagellates: <i>Gambierdiscus toxicus</i> , possibly others	Dinoflagellates: <i>Karenia brevis</i> and other <i>Karenia</i> species	Dinoflagellates: <i>Gyrodinium catenatum</i> , <i>Pyrodinium bahamense</i> , <i>Alexandrium</i> species	Diatoms: <i>Pseudo-nitzschia</i> species	Dinoflagellates: <i>Dinophysis</i> species, <i>Prorocentrum lima</i>	Dinoflagellates: <i>Proroperidium</i> species
Toxin(s)	Ciguatoxins, Maitotoxin, Scaritoxin	Brevetoxins	Saxitoxins	Domoic acid	Okadaic acid	Azaspiracid
Foods likely to be contaminated	Reef fish such as barracuda, grouper, red snapper, and amberjack	Shellfish, primarily mussels, oysters, scallops	Shellfish, primarily scallops, mussels, clams, oysters, and cockles, Some fish and crabs	Shellfish, primarily scallops, mussels, clams, oysters, Possibly some fish species	Shellfish, primarily scallops, mussels, clams, oysters	Shellfish

# Foodborne HAB-Related Illnesses

## Ciguatera Fish Poisoning

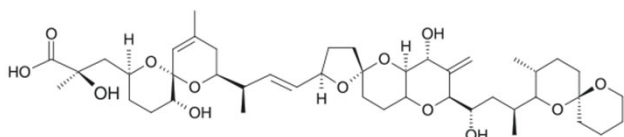


Ciguatoxins

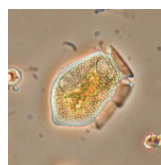


*Gambierdiscus toxicus*

## Diarrhetic Shellfish Poisoning



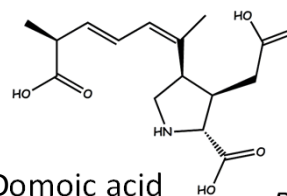
Okadaic acid



*Dinophysis spp.*

*Prorocentrum spp.*

## Amnesic Shellfish Poisoning

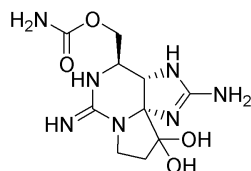


Domoic acid



*Pseudo-nitzschia spp.*

## Paralytic Shellfish Poisoning



Saxitoxin

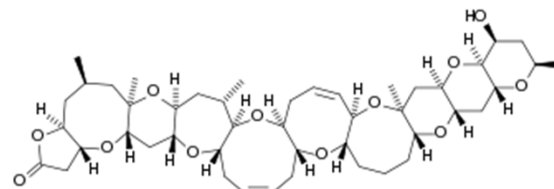


*Alexandrium spp.*

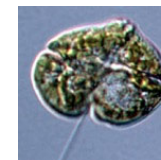
*Gymnodinium spp.*

*Pyrodinium spp.*

## Neurotoxic Shellfish Poisoning



Brevetoxins



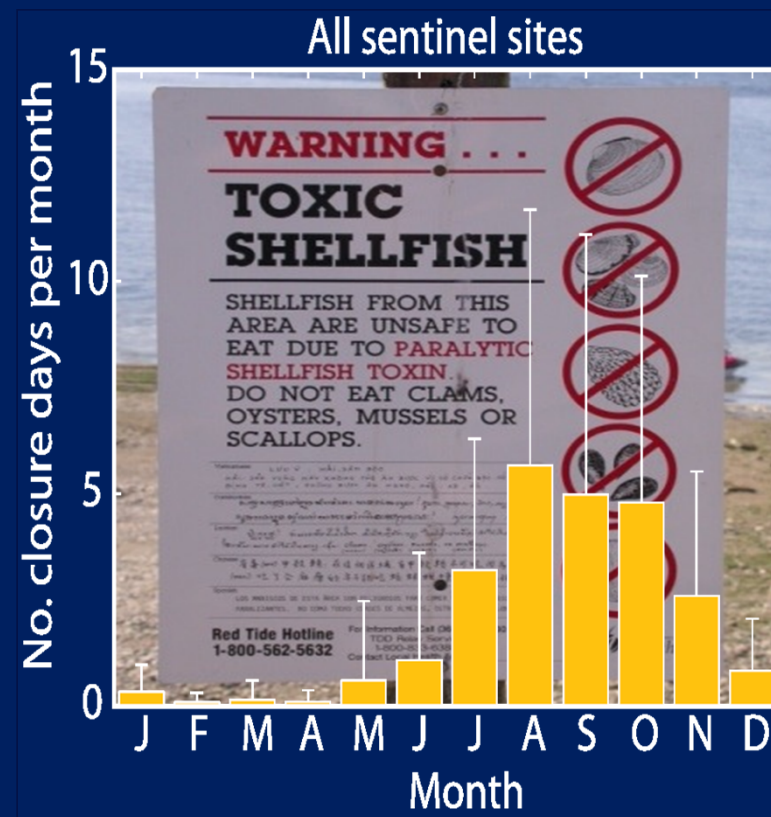
*Karenia brevis*

Images from Florida Fish and Wildlife Conservation Commission; NOAA CORIS; Oceanography Vol.18, No.2, June 2005: *Images courtesy NOAA Fisheries, Seattle, WA, the Center for Integrated Marine Technology, T. Moita, and F. Figueiras .*



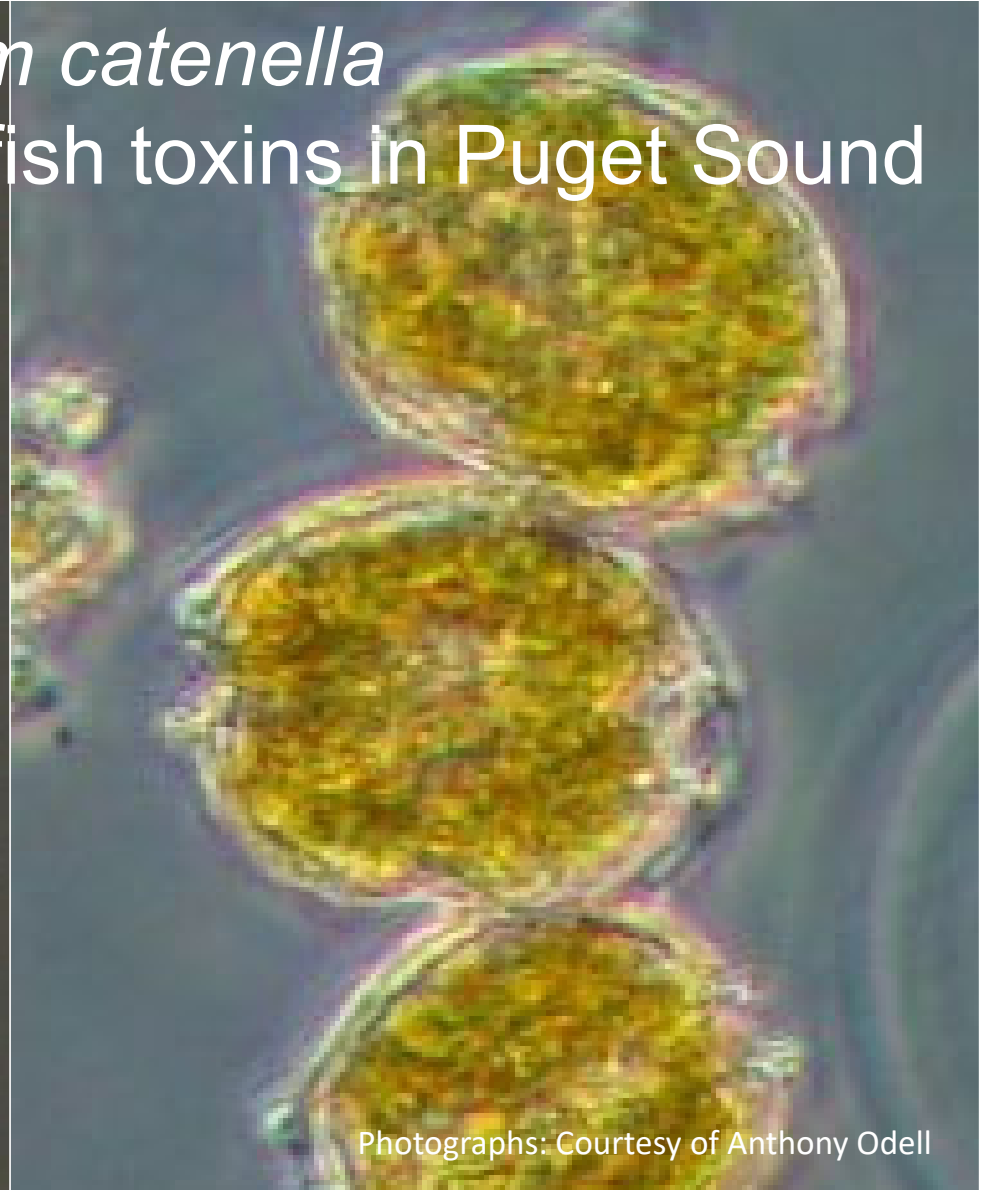
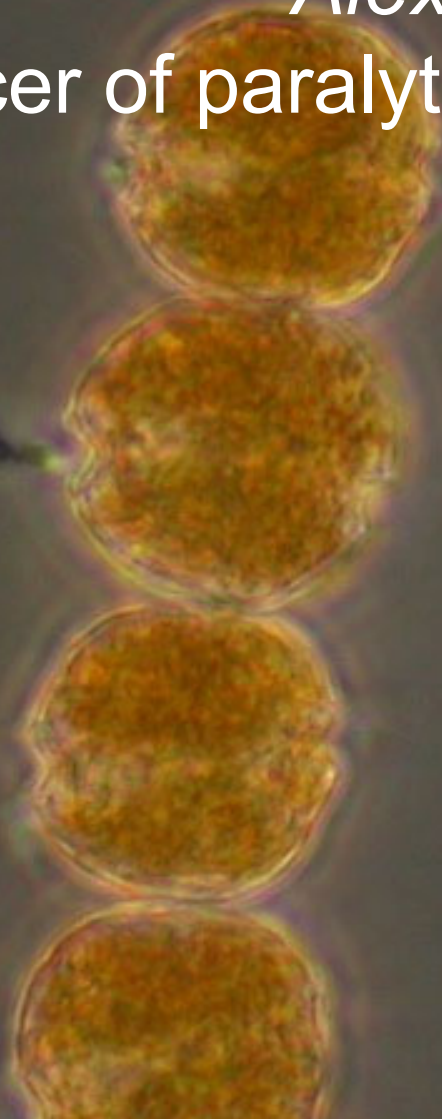
# Paralytic Shellfish Toxins (PSTs)

- Suite of neurotoxins (saxitoxin most potent)
- $>80 \mu\text{g STXeq } 100 \text{ g}^{-1}$  shellfish meat
  - Closures typically occur from July to November annually
- Accumulate in filter-feeding shellfish during blooms, or “red tides”
  - Favored by water temperatures  $>13^\circ \text{ C}$  in Puget Sound



*Alexandrium catenella*

Producer of paralytic shellfish toxins in Puget Sound

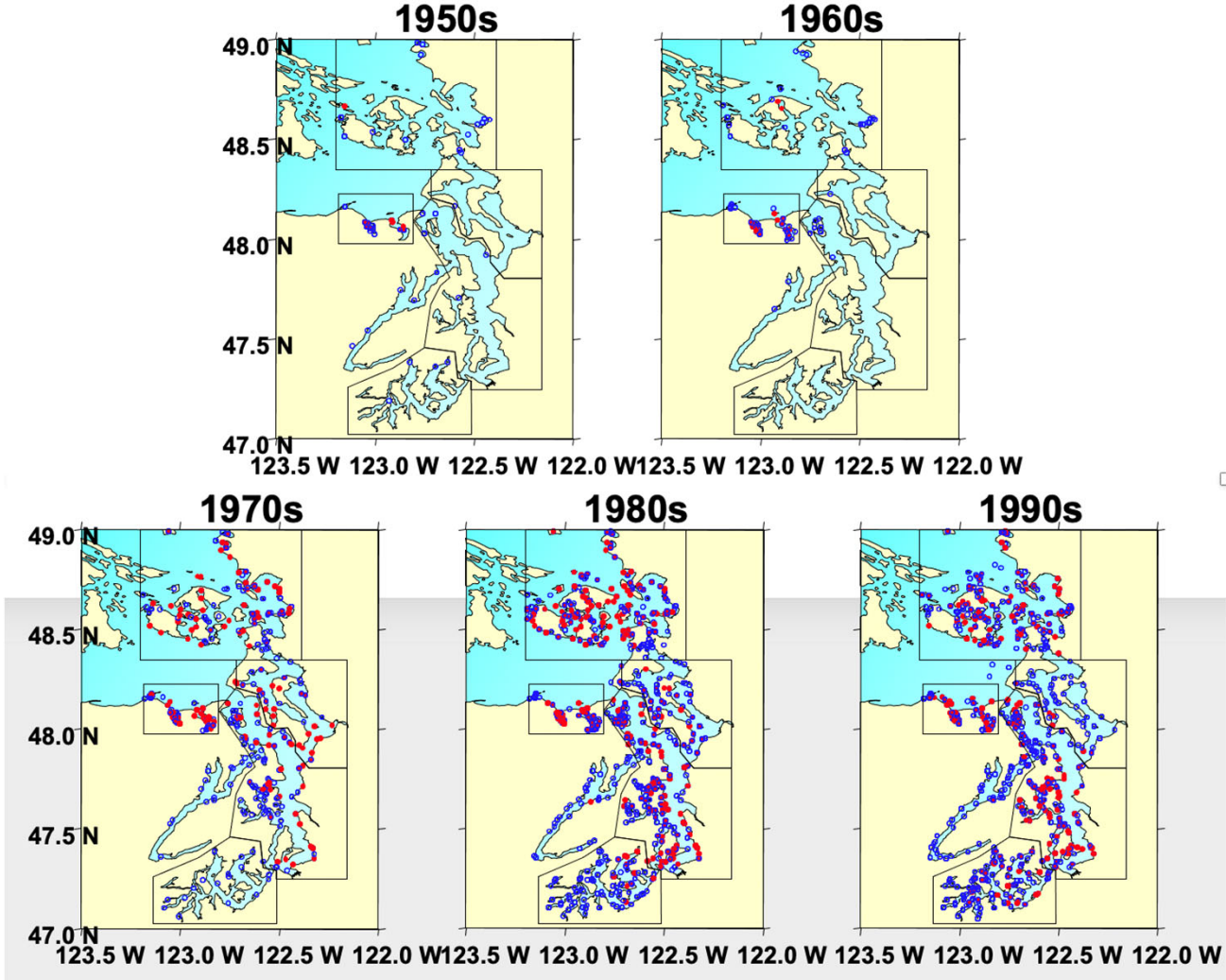


Photographs: Courtesy of Anthony Odell



# Southward spread

- Closed site
- Sampled site



# West Coast Harmful Algal Bloom (Pseudo-nitzschia)



- Breadth – Channel Islands to Aleutian Islands
- Length – Longest lasting (mos)
- Levels – Highest toxin concentrations ever measured in anchovies
- “Super” *Pseudo-nitzschia* – large chains, chloroplasts bulging

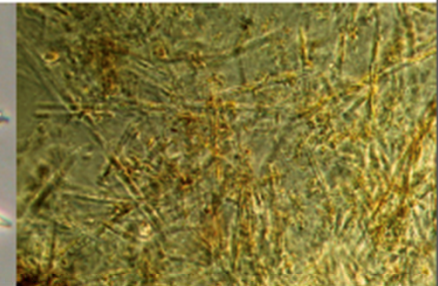
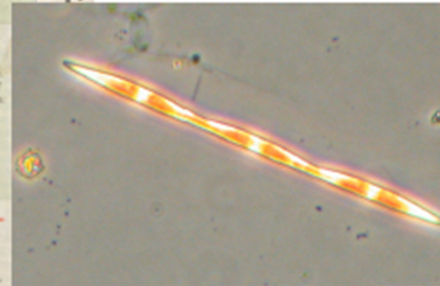


**Paralytic shellfish poisoning.** Symptoms include tingling in lips, arms and legs, followed by trouble breathing and paralysis. Can be fatal.

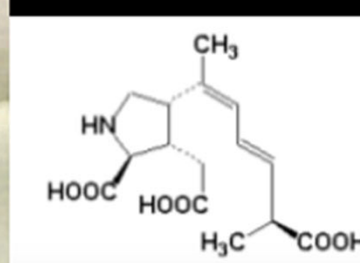
**Domoic acid poisoning,** also called amnesic shellfish poisoning. Caused by *Pseudo-nitzschia diatoms*, symptoms include vomiting, nausea,

The fact that we're seeing multiple toxins at the same time, we're seeing high levels of domoic acid, and we're seeing a coastwide bloom — those are indications that this is unprecedented," Trainer said.

Scientists suspect this year's unusually high temperatures are playing a role, along with "the blob" — a vast pool of unusually warm water that blossomed in the northeastern Pacific late last year. The blob has morphed since then, but offshore waters are still about two degrees warmer than normal, said University of Washington climate scientist Nick Bond, who coined the blob nickname.



**Domoic acid**



Clogged Bongo nets – June 25, 2015 Sta. Barbara Channel



# Impacts of North Pacific Coast Domoic Acid Event



Closure of razor clam fishery  
~\$23 million USD lost in lost spending



**Toxic Algal Bloom Spurred by Pacific ‘Warm Blob’ Wreaks Havoc for West Coast Crab Fisherman**

## Dungeness Crabbers Hit Hard By Algae Bloom On Washington Coast

By ASHLEY AHEARN · 18 HOURS AGO

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Crabber Tom Petersen would rather have his crab pots on the floor of the Pacific, but a toxic algae bloom has

Dungeness crab fisheries closed in multiple states. West coast crab fishery valued at \$180 million USD




Dan Ayres

Seizuring sea lion (first ever observed on WA coast)  
Many sea lion, seal mortalities in Monterey Bay



Anchovy and sardine fisheries health advisory in California due to high toxins



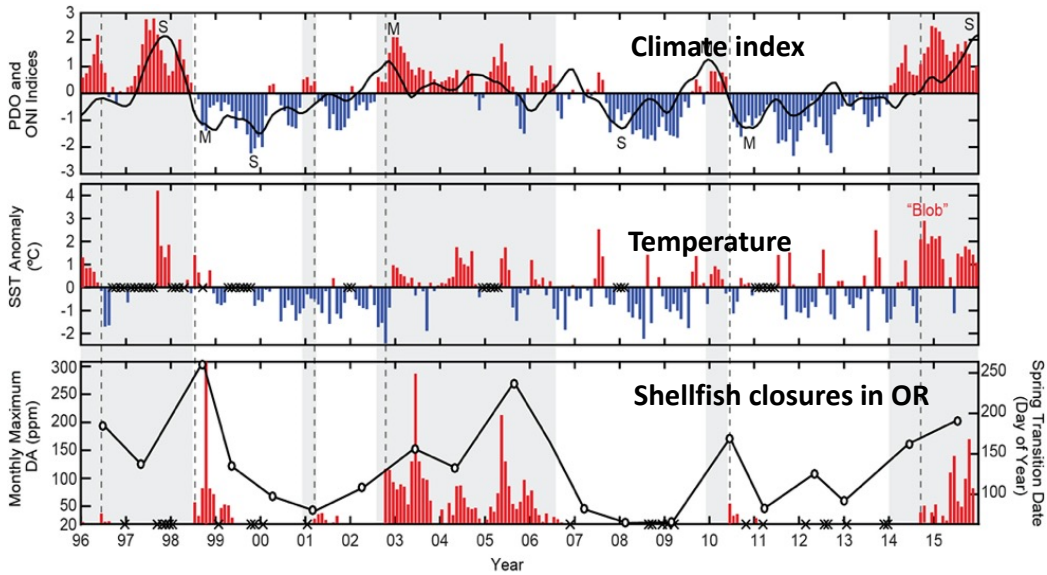
A microscopic view of a diatom bloom, showing intricate, golden-brown, needle-like structures. The structures are highly organized and form a complex, lattice-like pattern. The colors range from light yellow to dark brown, with some greenish tints. The background is a dark, almost black, color, which makes the intricate structures stand out. The overall appearance is that of a highly complex, crystalline structure.

Anthony Odell

- Blooms signal environmental stress
- “Dress rehearsal” for climate impact
- Tailored forecasts enable management action
- Short-term bloom conditions inform long-term projections

# Pseudo-nitzschia (domoic acid)

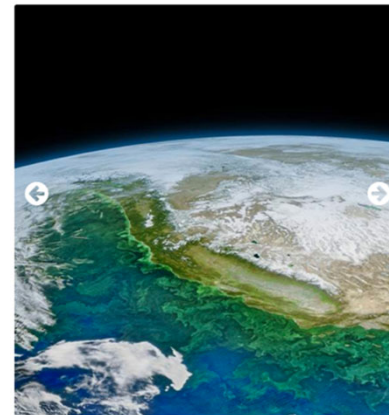
- Since first identified in 1991, periodic closures of shellfishing
- Severity of annual blooms highly variable but unprecedented coastwide closure in 2015
- Forecasting movement from “hotspots” important
- Linkage to warm ocean (Climate Change)



McKibben et al. 2017

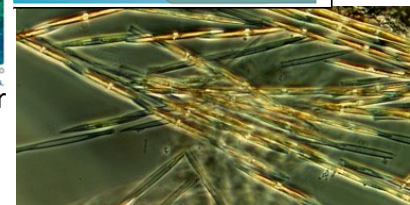
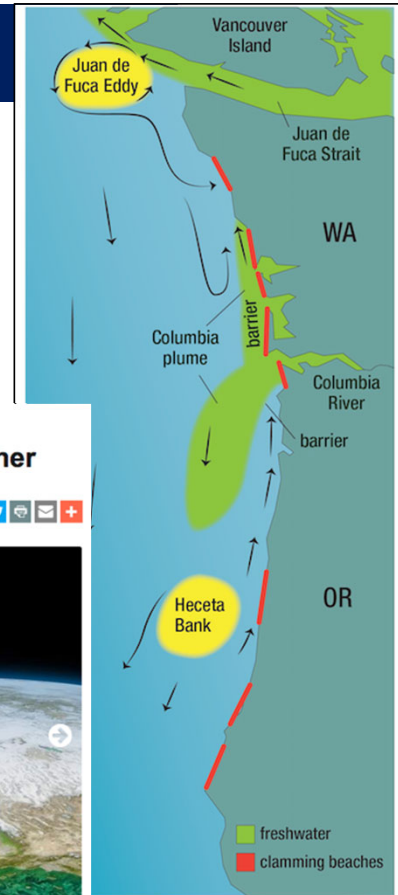
## Scientists: Clam toxin, warmer ocean go together

Published on January 17, 2017 2:45PM



Dark green colors near the West Coast of the U.S. reflect blooms of phytoplankton and high algal levels, some of which are toxic.

Chinook Observer

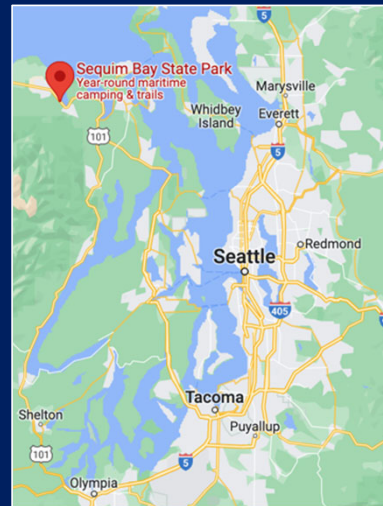




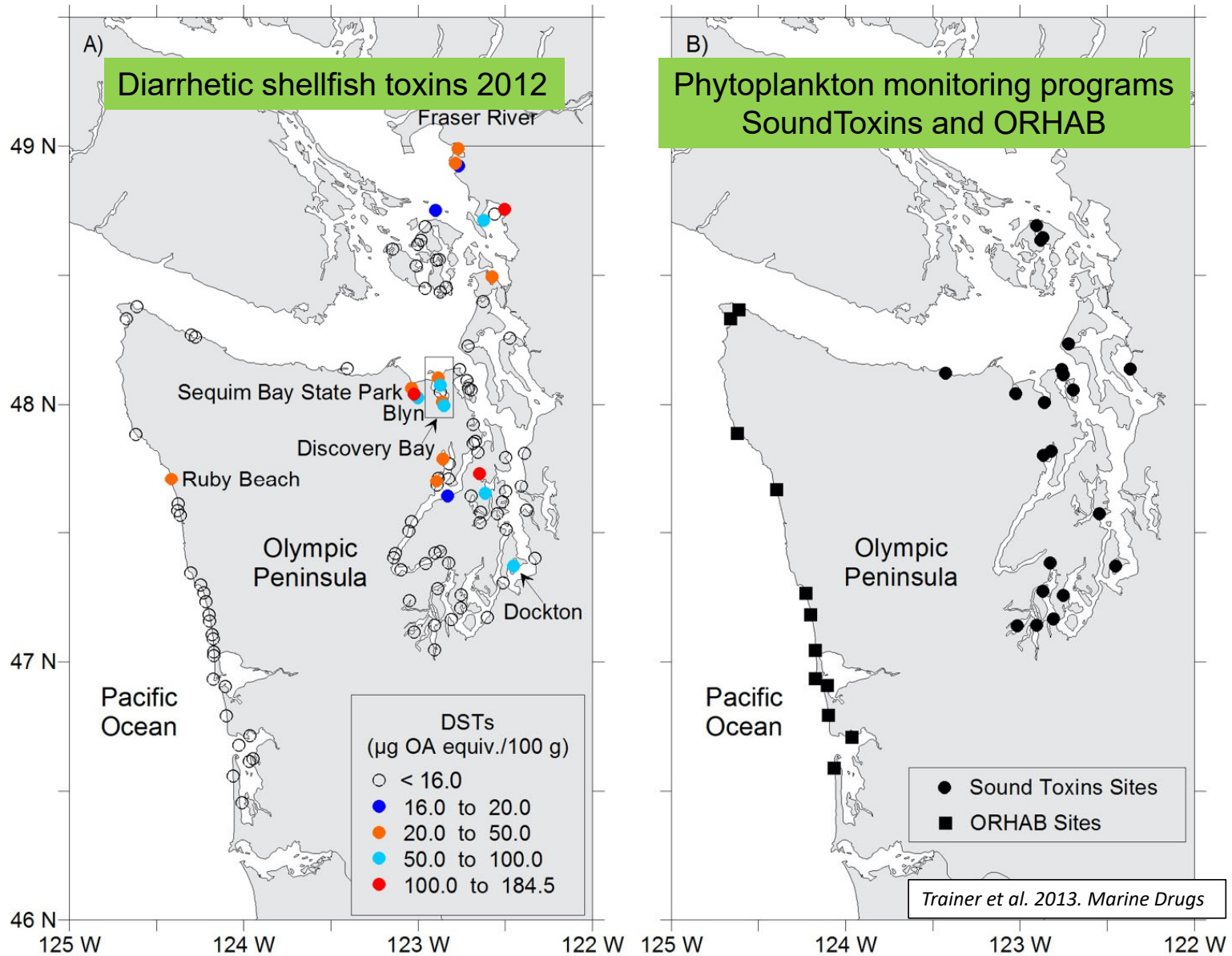
# FIRST CONFIRMED CASES OF DIARRHETIC SHELLFISH POISONING IN THE UNITED STATES

- Family at Sequim Bay State Park – June 29<sup>th</sup>, 2011
- Shellfish harvest closures implemented in early August
- Led to recalls of clams and oysters and subsistence harvest closure
- 60 illnesses in British Columbia

Photo courtesy of KUOW, Seattle









**Office of Environmental Health and Safety**

243 Israel Road SE, P.O. Box 47824

Tumwater, WA 98501

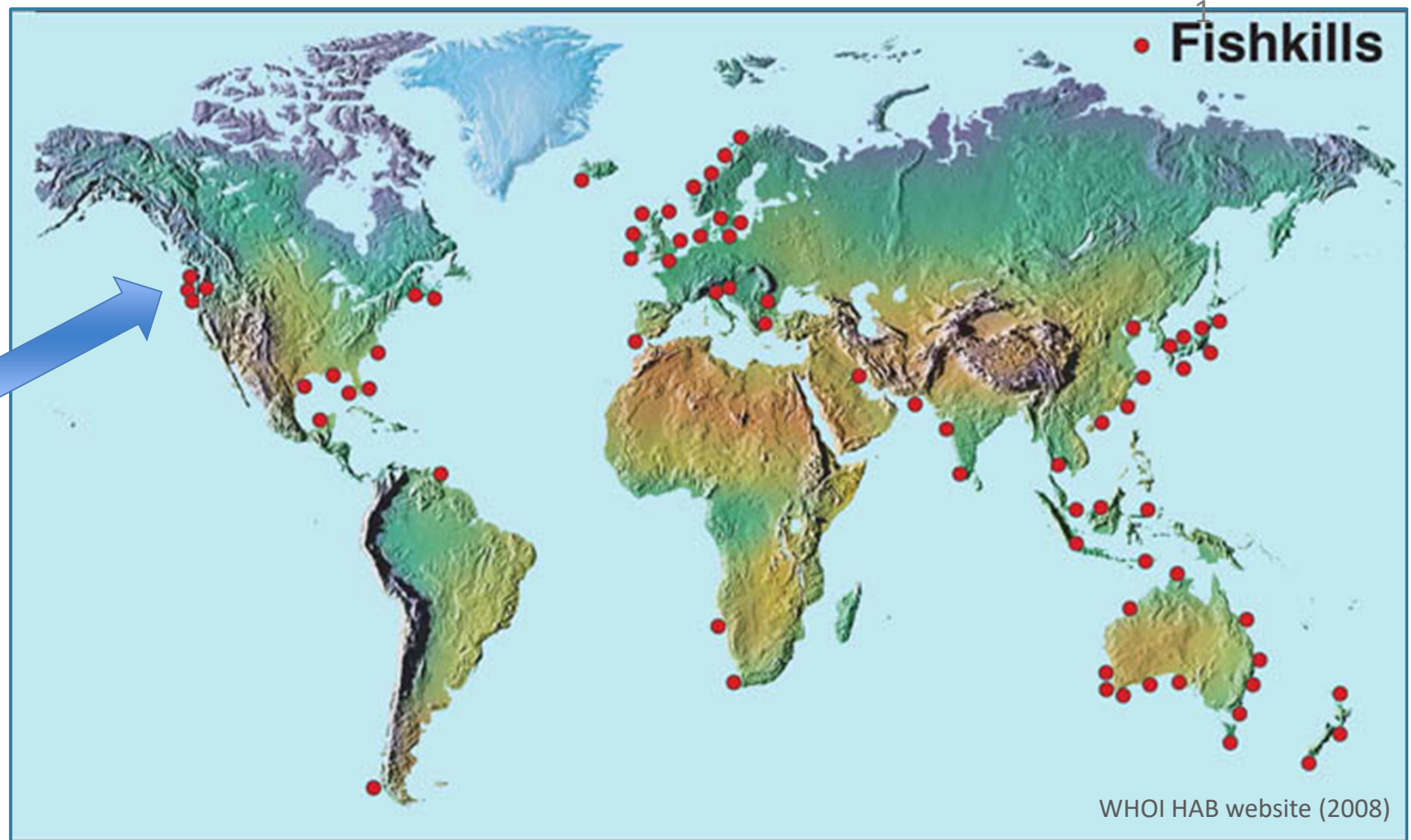
Mainline: (360) 236-3330

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**SUBJECT: PSP, DSP and Domoic Acid Test Results for Coastal Beaches**  
**DATE: August 20, 2021**  
**FROM: Marine Biotoxin Program**

Standard testing of shellfish for diarrhetic shellfish toxins began in 2012 (regulatory limit = 16 micrograms/100g)

<u>Lab#</u>	<u>Date of Harvest</u>	<u>Location</u>	<u>Species</u>	<u>Domoic Acid *</u> <u>(ppm)</u>	<u>PSP MEAT **</u> <u>(µg/100g)</u>	<u>DSP ***</u> <u>(ug/100g)</u>
202102687	08/18/2021	Bay Center Dock	California Mussel	NTD	NTD	
202102665	08/16/2021	Tokeland Marina	California Mussel	NTD	NTD	2
202102664	08/16/2021	Westport	California Mussel	NTD	NTD	1
202102662	08/18/2021	Copalis Area XL	Razor Clam	10	NTD	NTD
202102661	08/18/2021	Mocrocks Area BC	Razor Clam	5	NTD	NTD
202102660	08/18/2021	Quinault Res B	Razor Clam	6	NTD	NTD



*Heterosigma akashiwo*

Fish kills due to Harmful Algal Blooms (HABs), including toxin-producing raphidophytes, are common in coastal regions worldwide.



# Deadly plankton invasion takes toll on fish

Jul 11, 2006

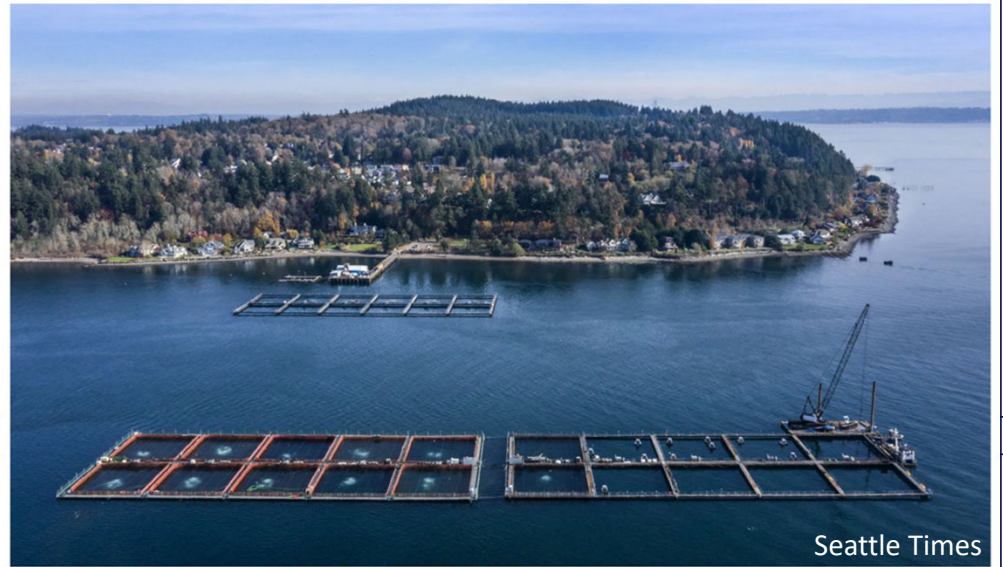


*Heterosigma*, a type of algae

Sound.

## Cooke Aquaculture seeks to farm native steelhead in Puget Sound after 2017 Atlantic salmon escape

Nov. 1, 2019 at 6:00 am | Updated Nov. 1, 2019 at 8:03 am



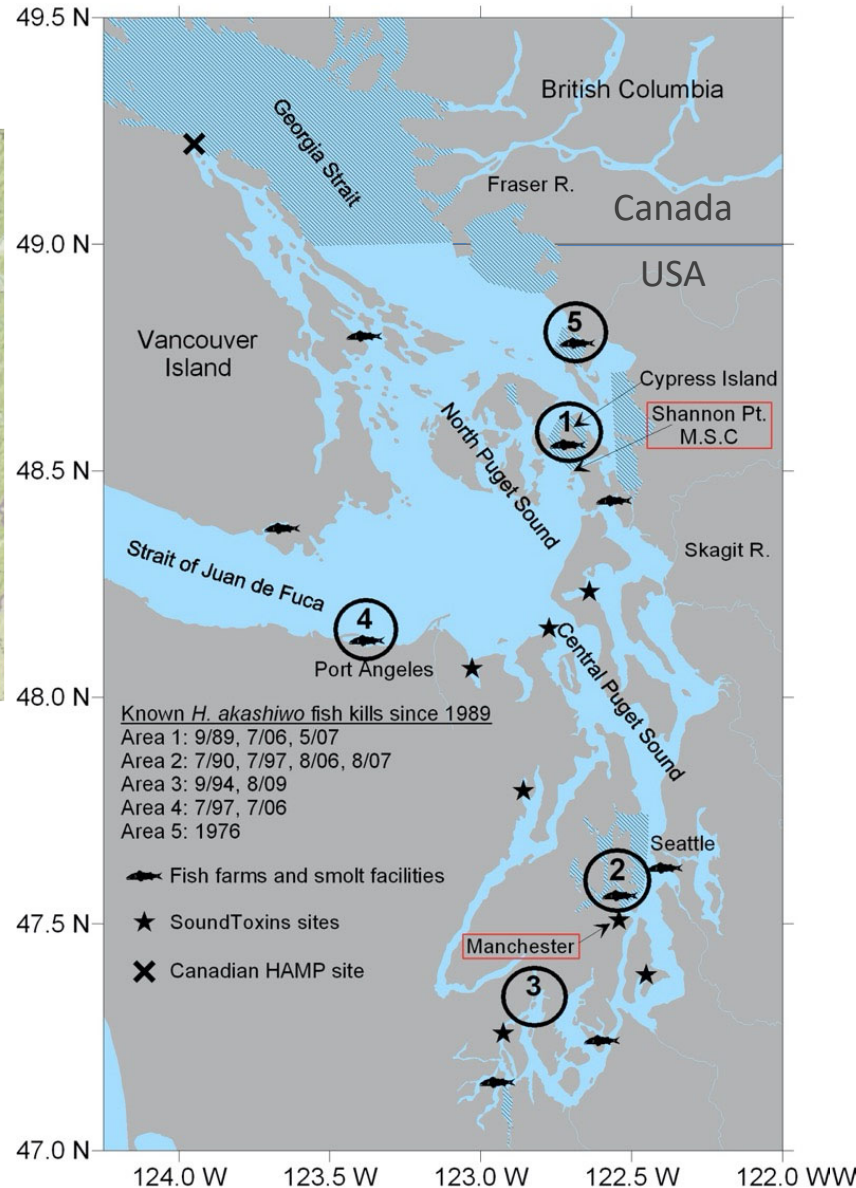
## Newsroom

# King County scientists see large scale algal bloom, known to be harmful to fish, in central Puget Sound

June 26, 2020



## Puget Sound



Death of Farmed Fish	
1989 – 360,000 deaths	
1990 – 2,000 deaths	
1990 – 650,000 deaths	
1994 – 750 deaths	
1997 – 400,000 deaths	
1997 – 60,000 deaths	
1999 – 400,000 deaths	
2006 – 280,000 deaths	
2007 – 4,000 deaths	
2009 – 60,000 deaths	

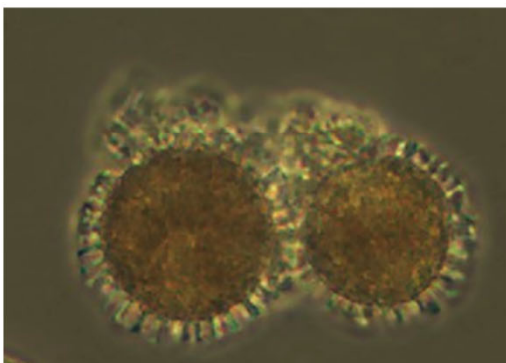
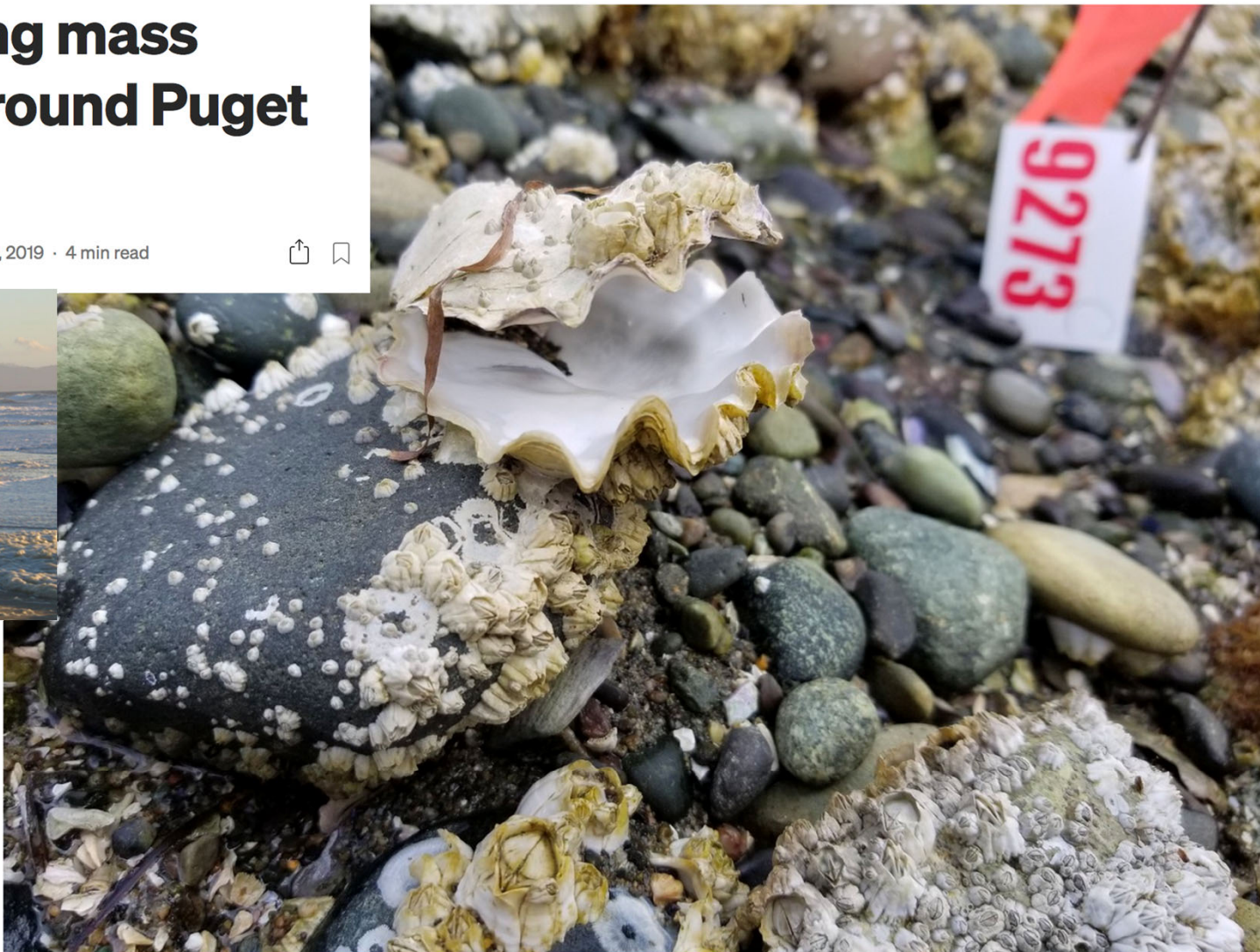
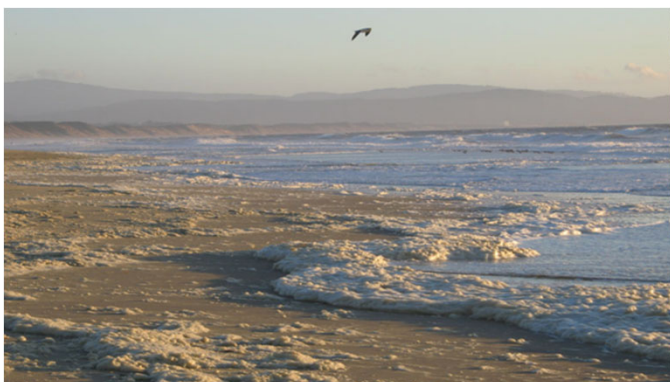
**Combined losses of > 1.9 million farmed fish since 1989.**



# What's been causing mass shellfish die-offs around Puget Sound?



The Washington Department of Fish and Wildlife Aug 19, 2019 · 4 min read

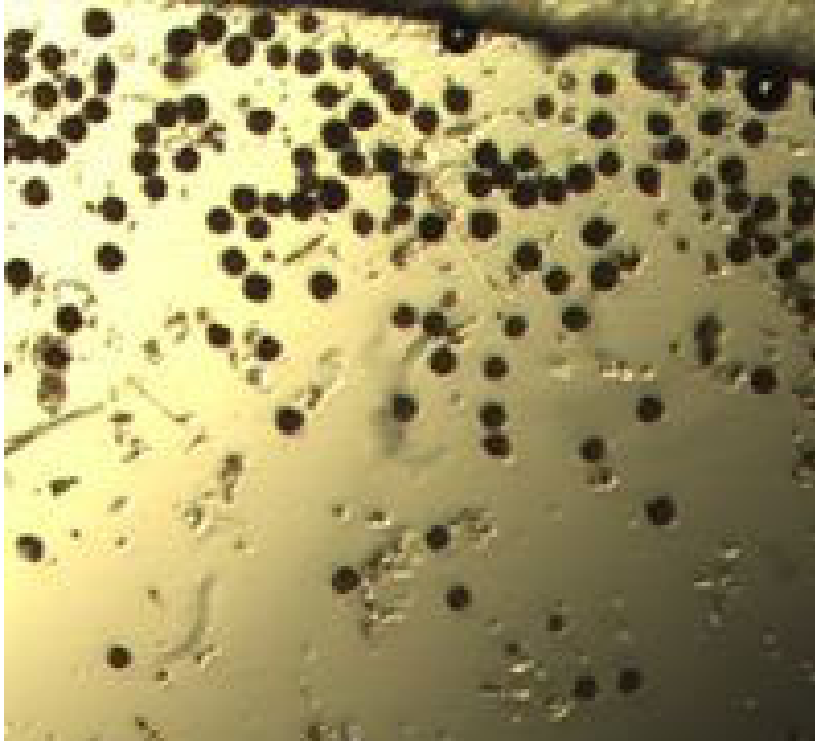


Teri King

An example of oyster mortality. Photo credit: Doug Rogers/WDFW



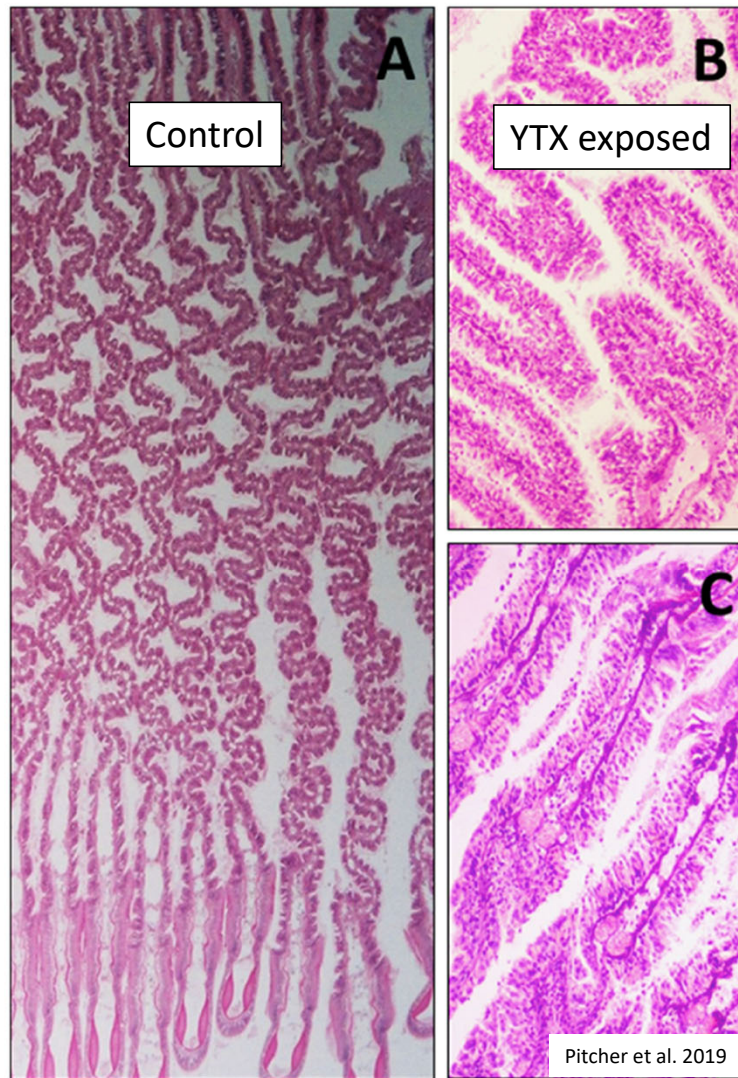
***Protoceratium reticulatum***



- Produces Yessotoxin (YTX)
- YTX has different toxicity oral vs. IP
- YTX regulated in EU but not US
- The EU directives specify regulatory toxin level of 3.75 mg YTX per kg
- 2.2 mg/kg measured in Puget Sound blue mussel (2012)

Evidence for numerous analogs of yessotoxin in  
*Protoceratium reticulatum*

Christopher O. Miles <sup>a, b</sup>  , Ingunn A. Samdal <sup>a</sup>, John A.G. Aasen <sup>c</sup>, Dwayne J. Jensen <sup>d</sup>, Michael A. Quilliam <sup>e</sup>, Dirk Petersen <sup>f</sup>, Lyn M. Briggs <sup>b</sup>, Alistair L. Wilkins <sup>g</sup>, Frode Rise <sup>f</sup>, Janine M. Cooney <sup>d</sup>, A. Lincoln MacKenzie <sup>h</sup>



- Disrupted gill epithelium
- Cell debris
- Increased inflammation

**Fig. 8.** Histology of abalone gills showing (A) normal gills that are well defined, of regular form, and have clear areas between the filaments, whereas gills exposed to yessotoxins (B and C) display disrupted epithelium, cell debris between the filaments and increased inflammatory cells.

# Researchers discover yessotoxins, produced by certain phytoplankton, to be a culprit behind summer mass shellfish mortality events in Washington

[Samantha Larson](#)

Washington Sea Grant

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Dying clams on Hood Canal, Rocky Bay, 2019. *King et al, Harmful Algae, 2021*



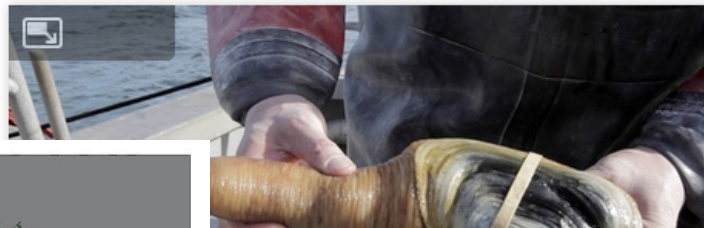
# New Challenges

## New Shellfish Poison Found In U.S. Waters Caused By Algal Bloom

## Mysterious shellfish biotoxin surfaces In Sequim

## NW Lawmakers Urge Quick Action To Resume Shellfish Trade

May 29, 2014 | AP



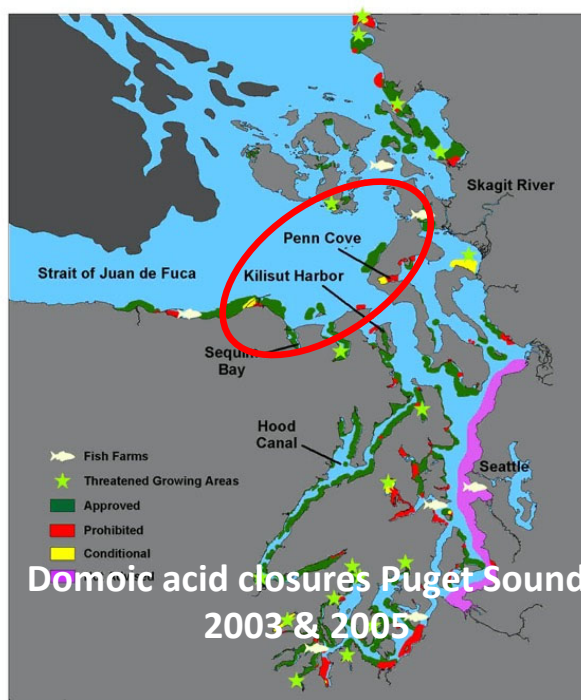
CONTRIBUTED BY:  
AP

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Facebook 0

Twitter 0

by GARY CHITTIM / KING



Ban of US shipment of geoduck to China  
Dec 2013

A geoduck farm near Totten Inlet, Washington.

## Toxin shuts down Sequim Bay shellfish

A new biotoxin found on the Olympic Peninsula has caused a shellfish closure after a when they harvested and ate mussels from Sequim Bay.

By Craig Welch Diarrhetic shellfish poisoning  
Seattle Times environment reporter June 2011

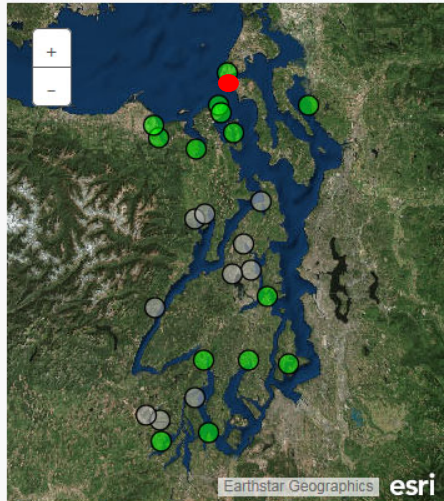
# SoundToxins Alerts



SoundToxins.org Volunteer Data Entry

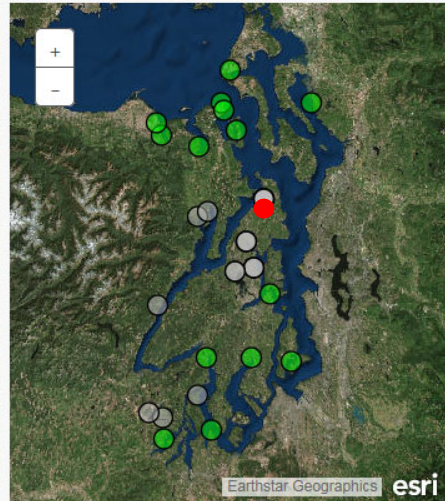
Sites Visits Observations

## Harmful Algal Bloom Alert Levels



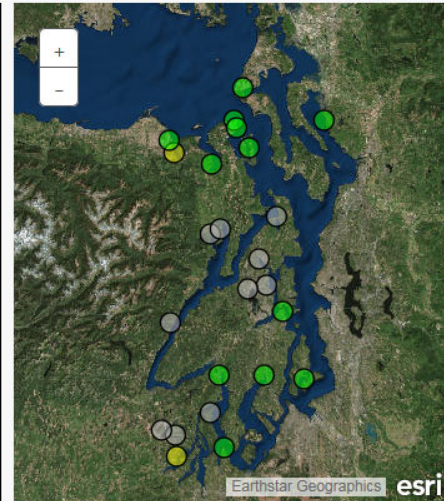
**Alexandrium Detailed Map**  
[Click here to view in a larger map](#)

**Red:** Present with cell count above 100 cells/L.  
**Yellow:** Present with cell count between 1-99 cells/L.  
**Green:** Absent.  
**Grey:** April - October: not sampled for more than 15 days.  
November - March: not sampled for more than 30 days.



**Dinophysis Detailed Map**  
[Click here to view in a larger map](#)

**Red:** Present with cell count above 1,000 cells/L.  
**Yellow:** Present with cell count between 1-999 cells/L.  
**Green:** Absent.  
**Grey:** April - October: not sampled for more than 15 days.  
November - March: not sampled for more than 30 days.



**Pseudo-nitzschia Detailed Map**  
[Click here to view in a larger map](#)

**Red:** Present with small cell count greater than or equal to 1,000,000 cells/L or large cell count greater than or equal to 50,000 cells/L.  
**Yellow:** Present with small cell count below 1,000,000 cells/L and large cell count below 50,000 cells/L.  
**Green:** Absent.  
**Grey:** April - October: not sampled for more than 15 days.  
November - March: not sampled for more than 30 days.





# Summary

Impacts of HABs on fish and shellfish

HABs can sicken or kill:

- Humans (*Alexandrium*, *Pseudo-nitzschia*, *Dinophysis*)
- Shellfish (*Protoceratium reticulatum*)
- Fish (*Heterosigma akashiwo*)



# Acknowledgments

- NOAA CSCOR for ECOHAB, MERHAB funds
- Coastal managers
- SoundToxins & ORHAB personnel

