Impacts of HABs on Fish & Shellfish (and why we should care)

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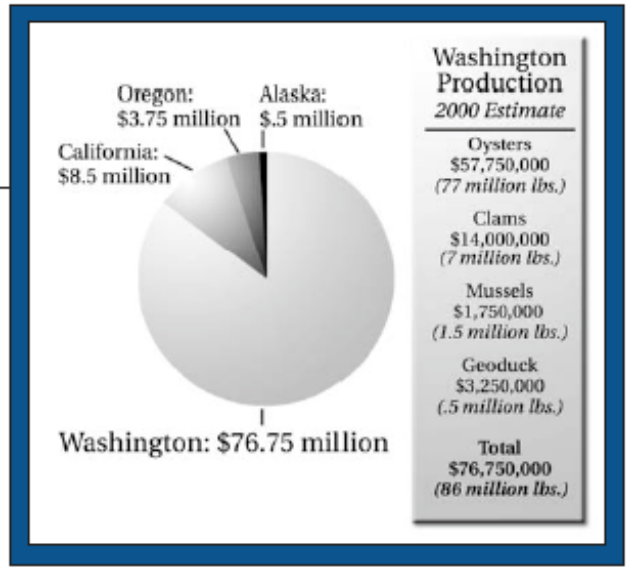
Economic & social value of Washington State shellfish



Pacific Coast Shellfish Growers Association

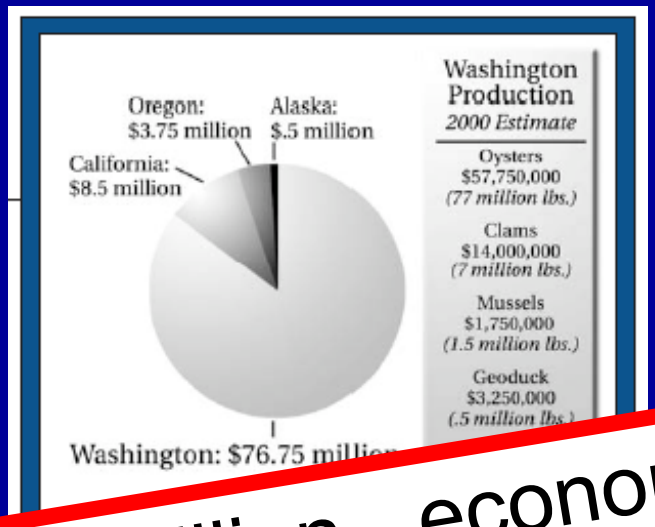
Estimated West Coast production of farmed oysters, clams, mussels and geoduck, 2000

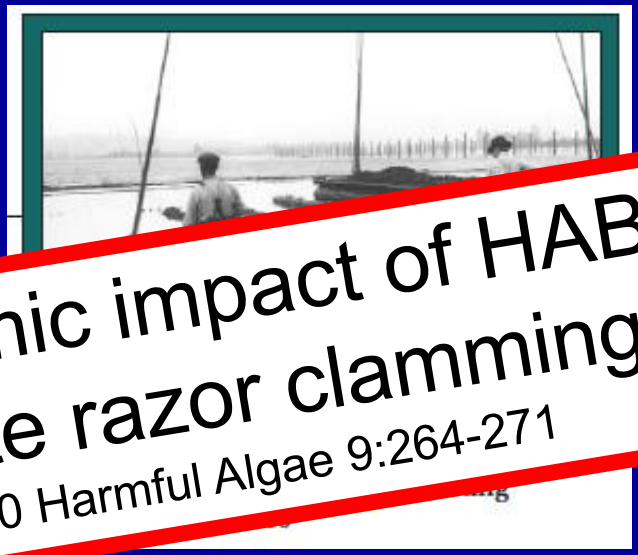
Photo courtesy Manuscripts, Special Collections, University Archives, University of Washington Libraries, CUR801

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

Photos courtesy Bill Dewey (Taylor Shellfish)

Economic & social value of Washington State shellfish harvesting

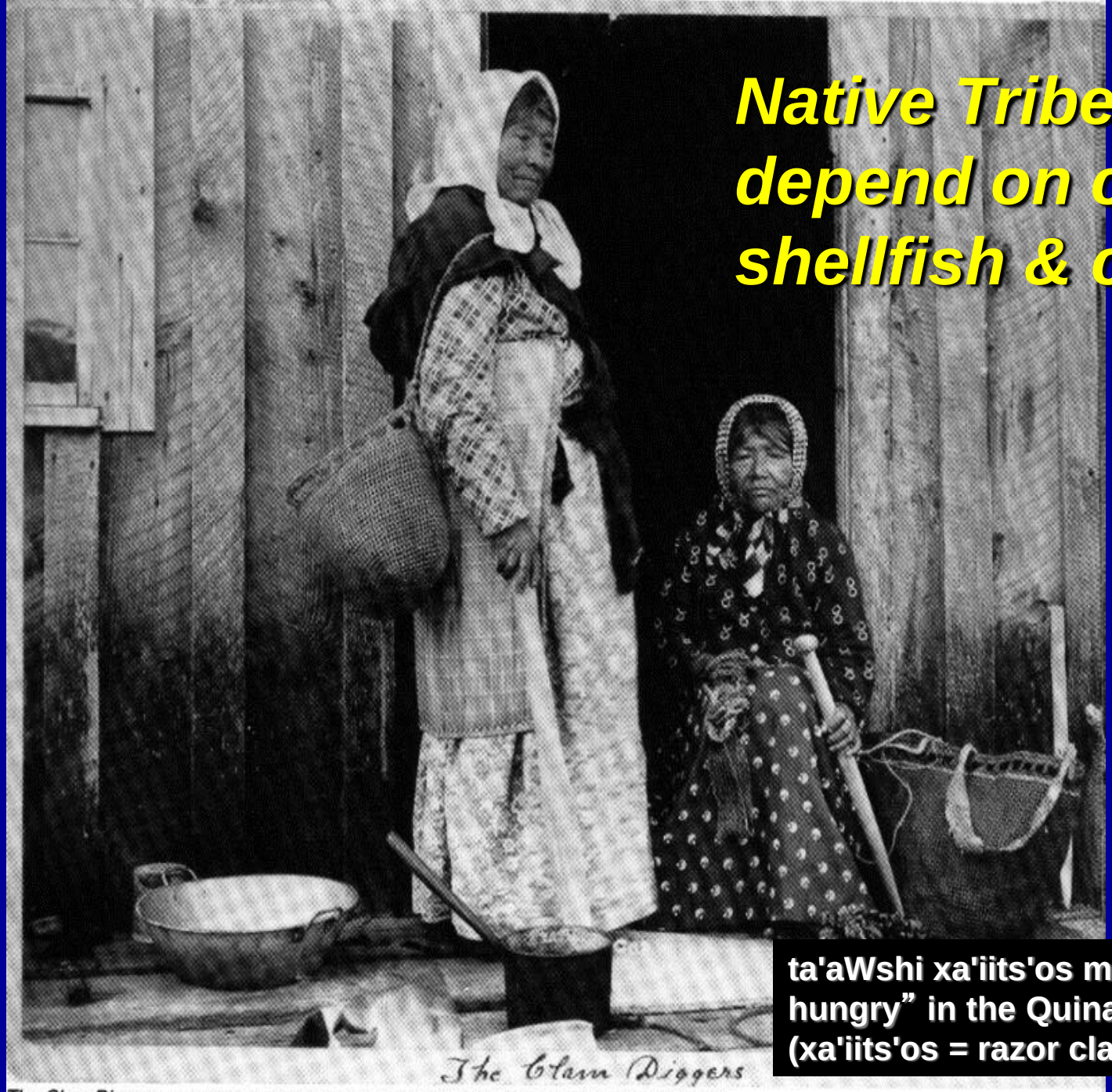




$24 million - economic impact of HABs on Washington State razor clamming

Dyson & Huppert 2010 Harmful Algae 9:264-271

Photos courtesy Bill Dewey (Taylor Shellfish)



The Clam Diggers. REPRODUCED FROM THE COLLECTIONS OF THE LIBRARY OF CONGRESS

Native Tribes depend on coastal shellfish & crabs

ta'aWshi xa'iits'os means “clam hungry” in the Quinault language (xa'iits'os = razor clams)

Sentinel Mussel Cage

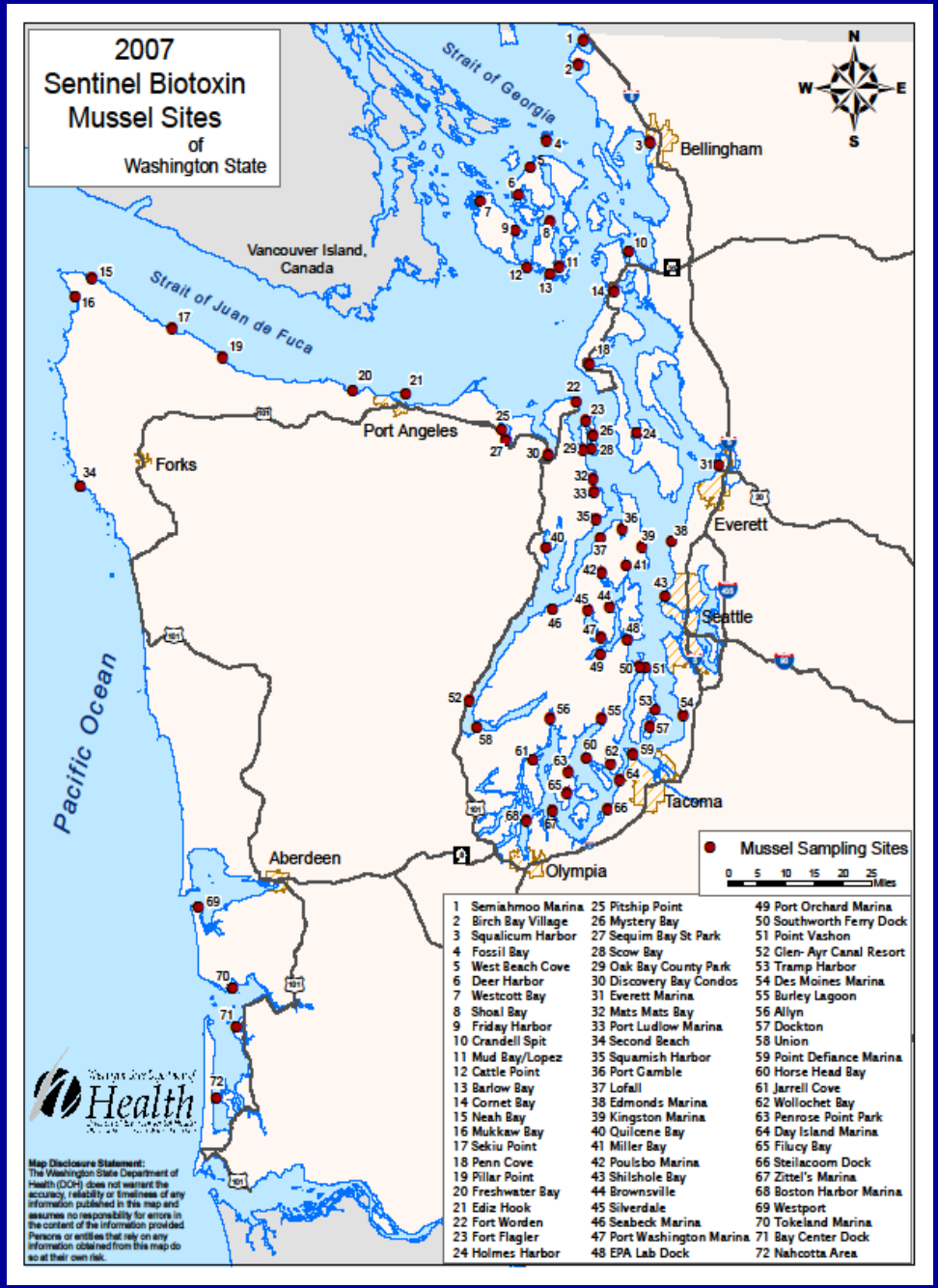
Sentinel Mussel Monitoring Program (started 1990)

Mission

- Provides an early-warning system for PSP/ASP/DSP toxin levels

Scope of Program

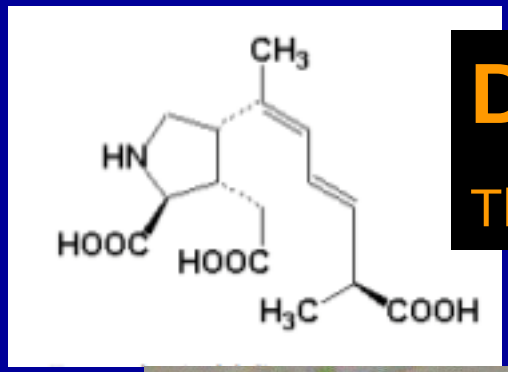
- 72 sites
- Extensive coordination between: DOH staff, tribes, DFW, DNR, local health, industry, and volunteers
- Sampled biweekly (seasonally)



Marine Biotoxins

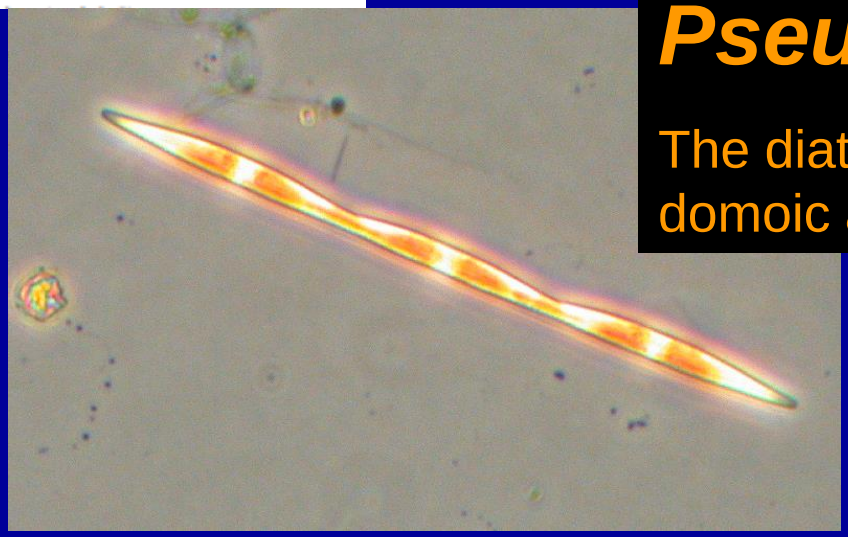
- Paralytic Shellfish Poison (PSP or “Red Tide”)
- Amnesic Shellfish Poison (ASP or domoic acid “DA”)
- Diarrhetic Shellfish Poison (DSP) ***since 2012!!***
- *Heterosigma* fish kills

Domoic Acid Poisoning



Domoic acid

The toxin



Pseudo-nitzschia

The diatom that can produce domoic acid

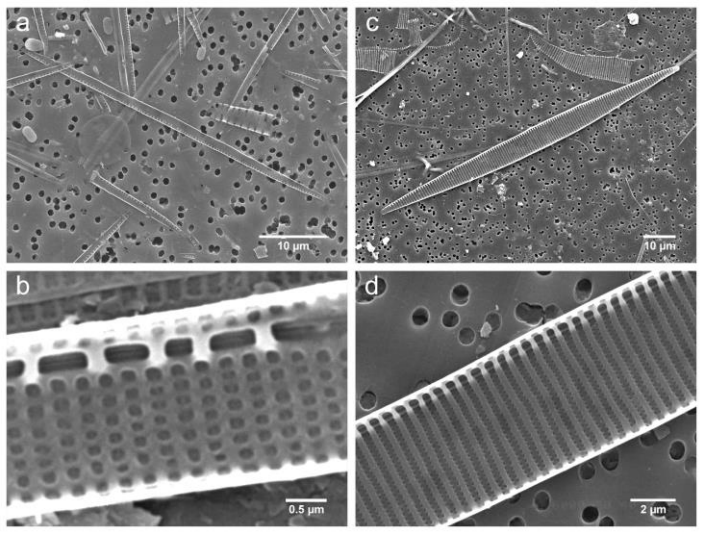
Poisoning

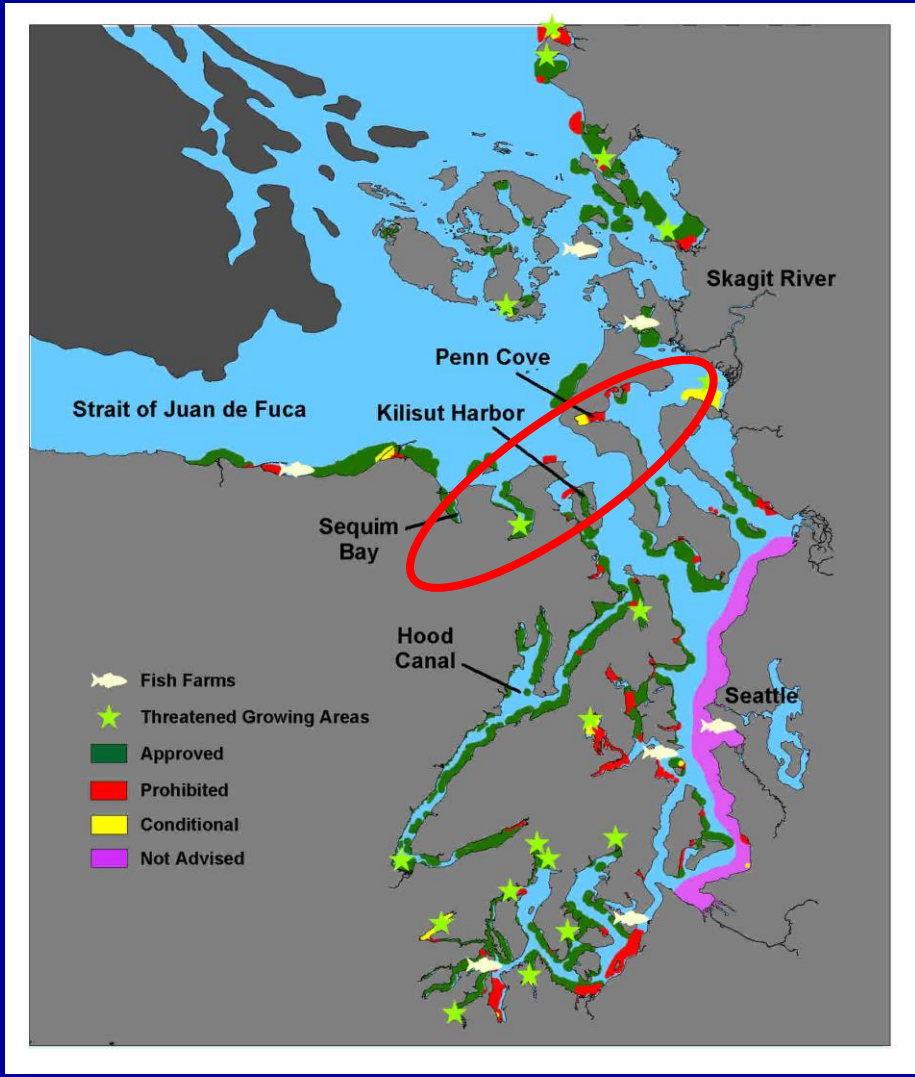
Food web transfer

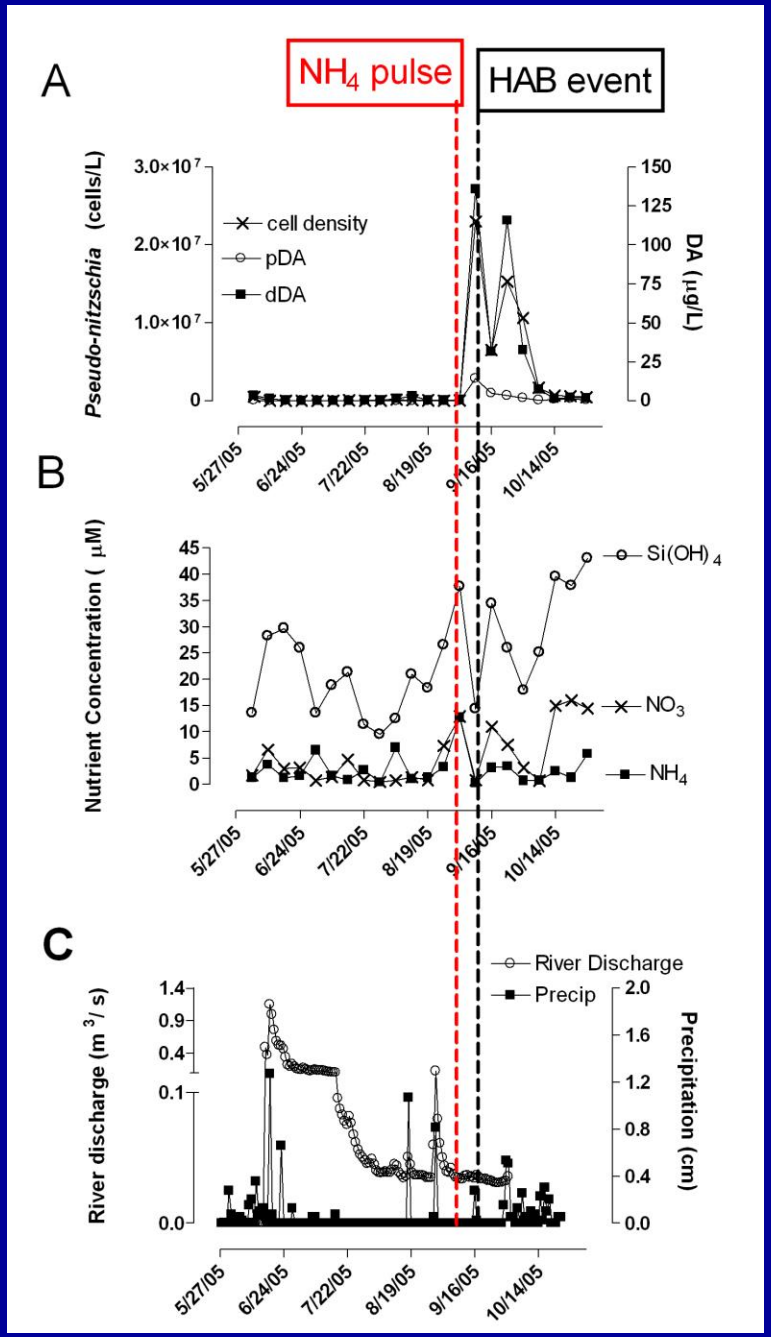
Vectors: plankton feeding shellfish & fish

Domoic acid closures in Puget Sound

- 2003
- 2005
- Future?







2005 Sequim Bay closure

Preceded by a pulse

of ammonium

(human source)

nature news

Urea pollution turns tides toxic

Kamikaze gulls that inspired Hitchcock's *The Birds* may have been doomed by leaky septic tanks.

Amy Coombs

Urea pollution can trigger ocean algae to produce a deadly toxin called domoic acid, scientists have discovered.

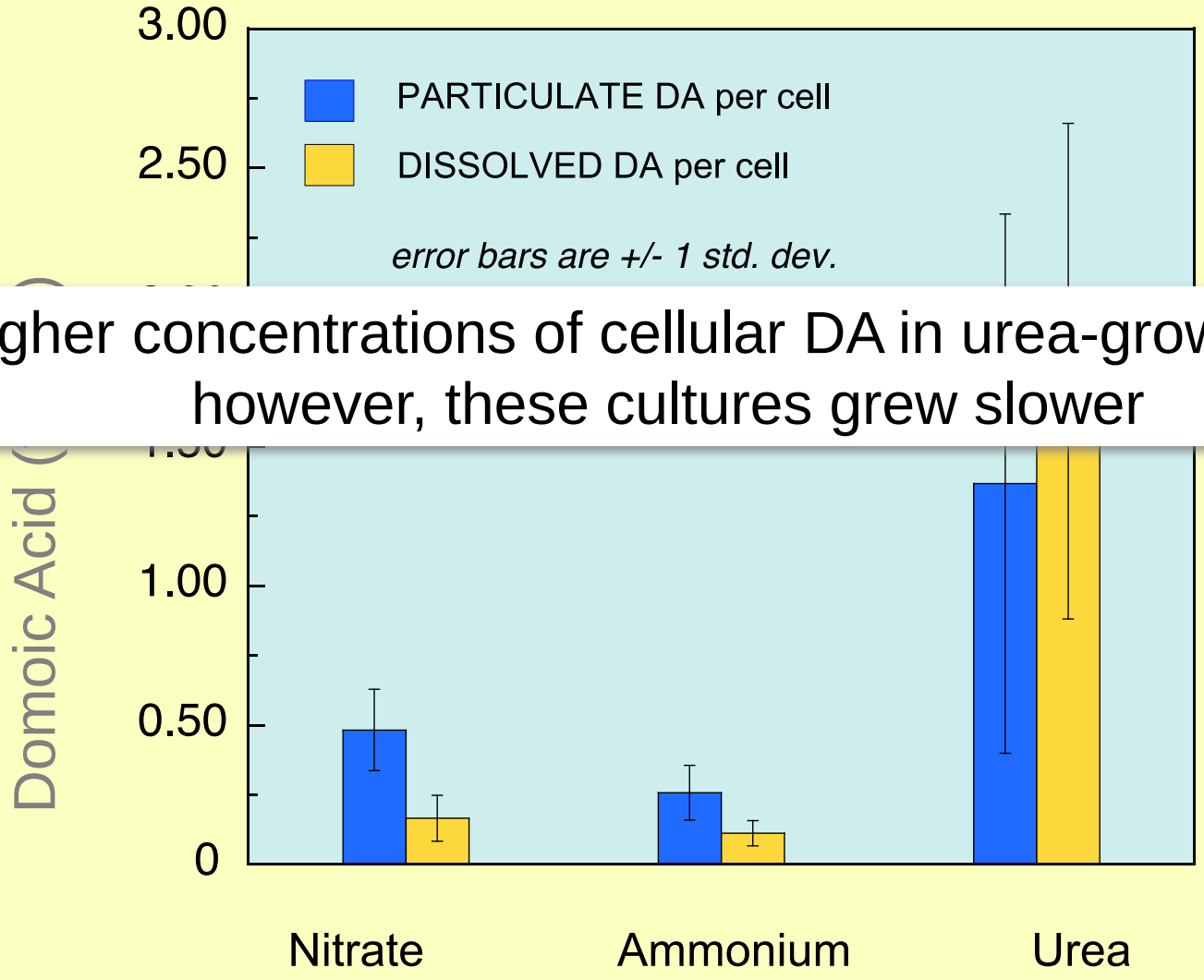
Run, Tippi, run!

UNIVERSAL / THE KOBAL COLLECTION

The research may help explain several mass animal deaths, including a historic bird stranding event thought to have inspired Alfred Hitchcock's horror film *The Birds*.

Raphael Kudela, an ocean scientist at the University of California, Santa Cruz, and his team made the discovery after studying a form of sea algae called *Pseudo-nitzschia australis*. Although the algae's blooms are normally benign, they have long been known to sometimes begin making domoic acid.

Pseudo-nitzschia australis Domoic Acid

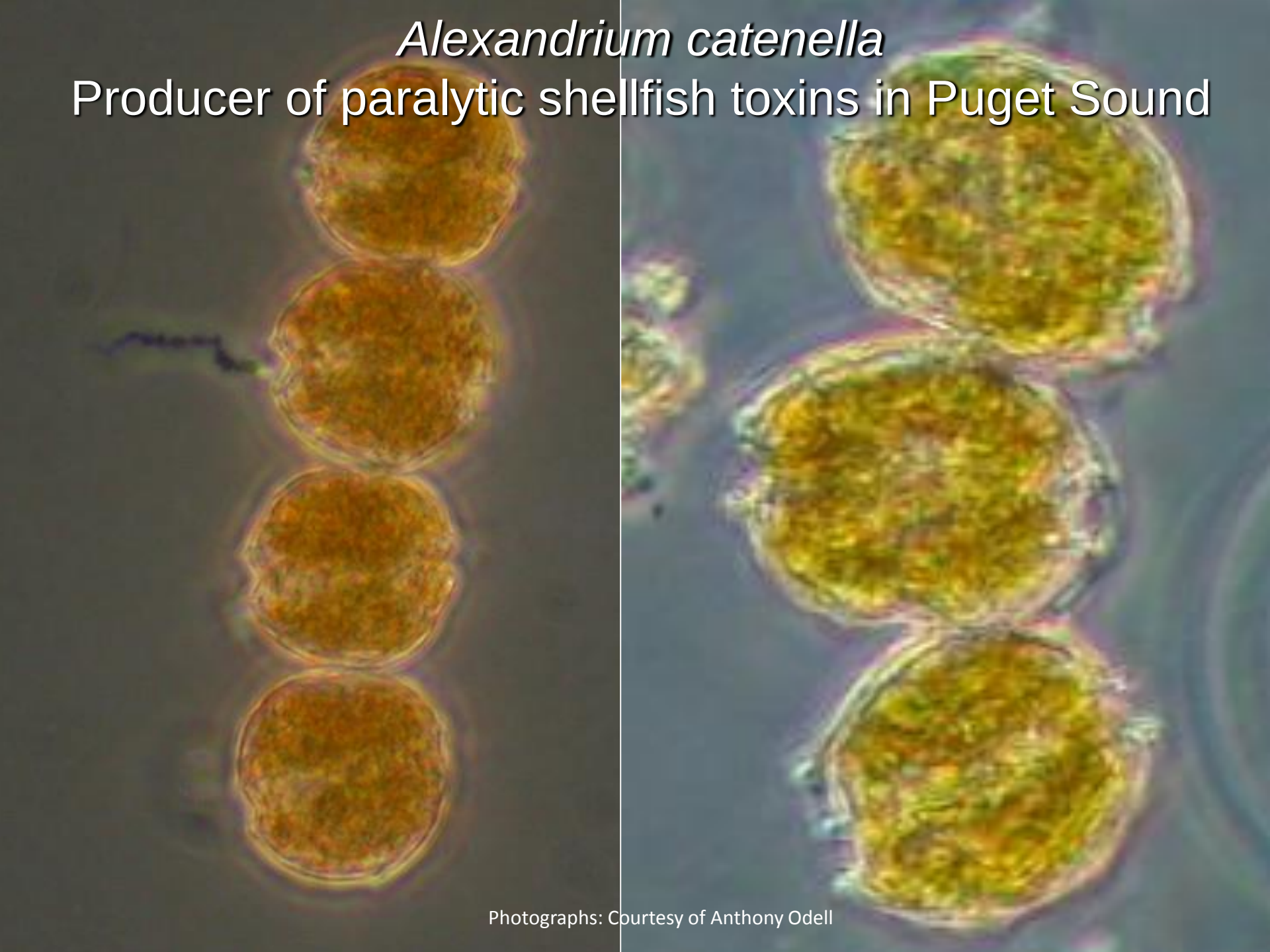


Higher concentrations of cellular DA in urea-grown cells however, these cultures grew slower

Cochlan *et al.*, 2006; 2008
Howard *et al.* 2007

Alexandrium catenella

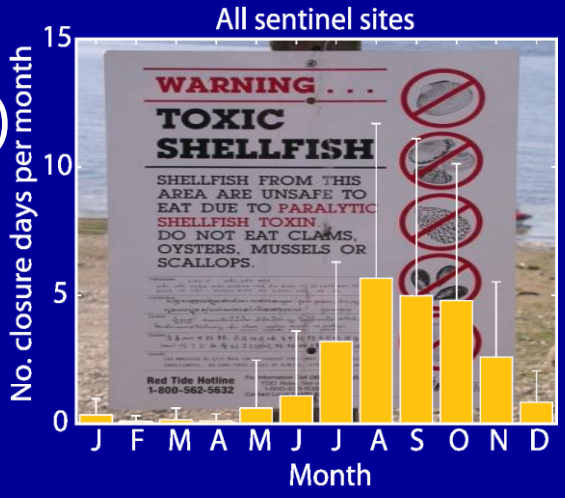
Producer of paralytic shellfish toxins in Puget Sound

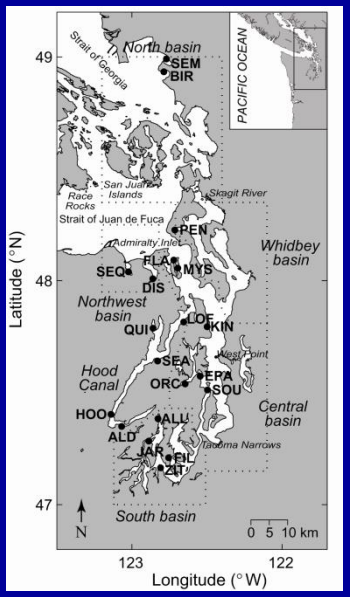


Photographs: Courtesy of Anthony Odell

Paralytic Shellfish Toxins (PSTs)

- Suite of neurotoxins (saxitoxin most potent)
- >80 µg STXeq 100 g^{-1} shellfish meat considered unsafe for human consumption
  - Closures typically occur from July to November annually
- Accumulate in filter-feeding shellfish during blooms, or **“red tides”**
  - Favored by water temperatures >13˚ C in Puget Sound (Nishitani and Chew 1984)

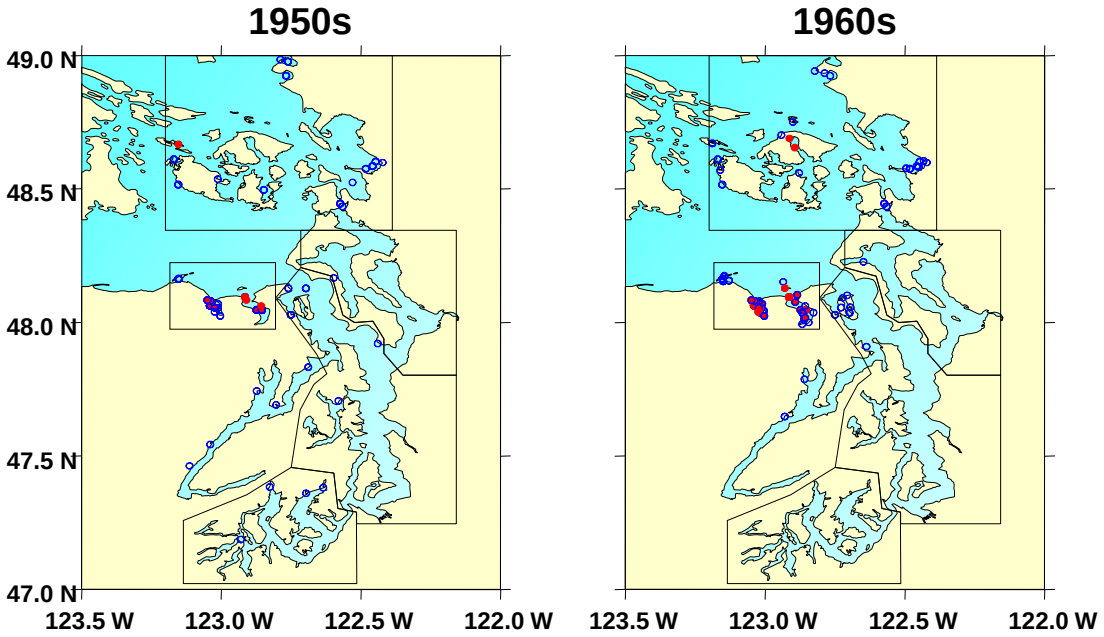


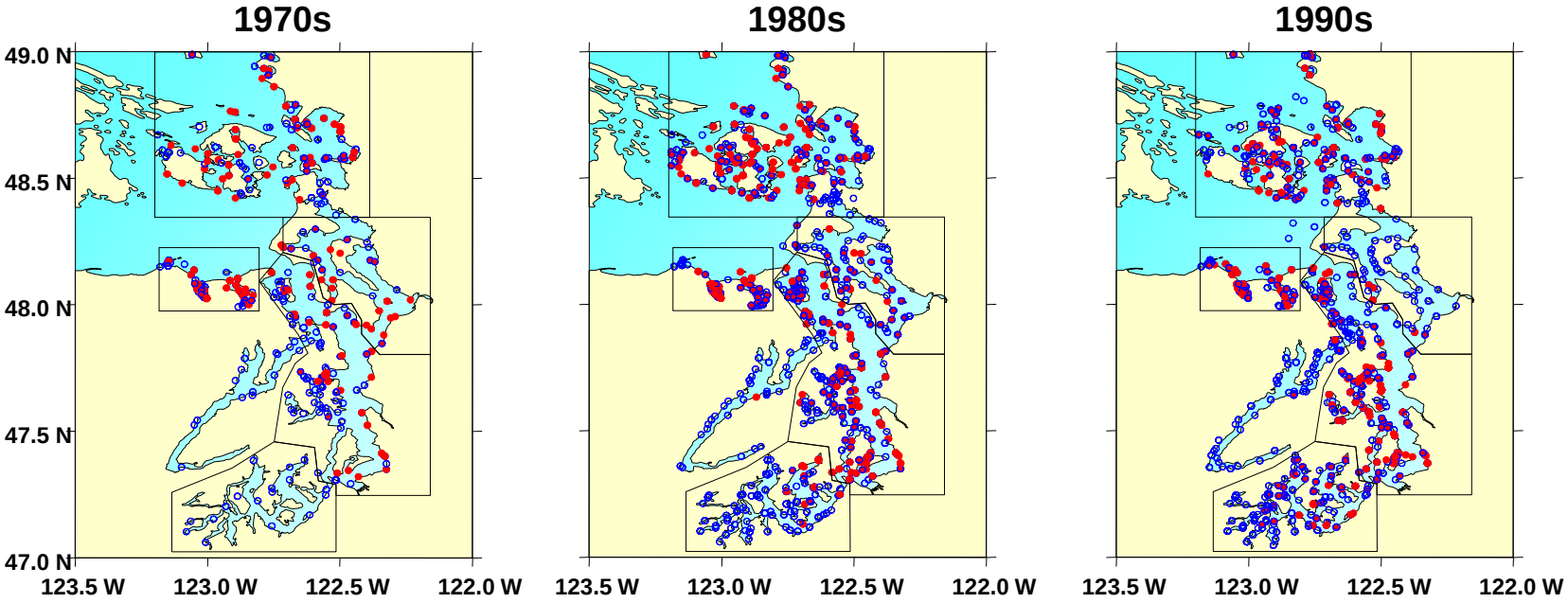


Southward creep of closures due to PSP toxins

Closed site

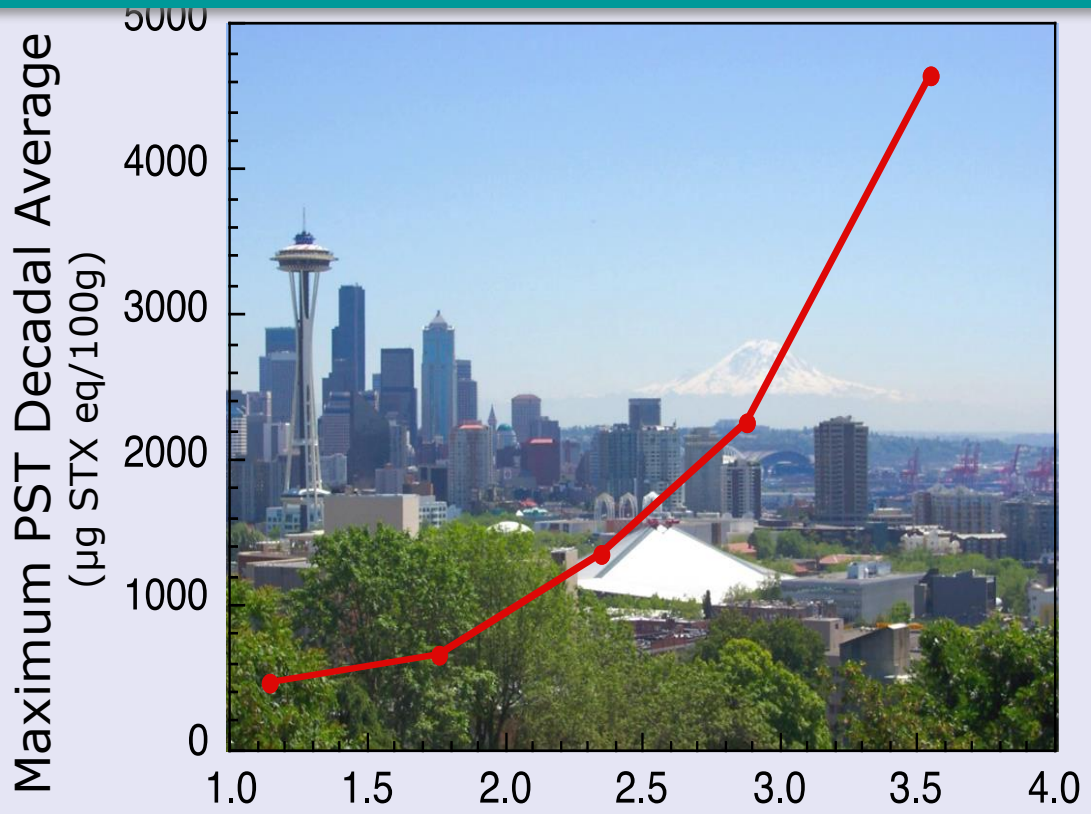
Sampled site





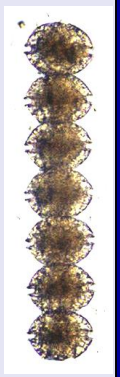
Paralytic Shellfish Toxins (PST) in Puget Sound, Washington

However the link between anthropogenic nutrient sources and HABs, especially toxigenic diatom blooms is very difficult to discern.



$r^2 = .987$

[for all counties bordering Puget Sound over the last 40 years]



Redrawn from: Trainer et al. (2003) J. Shellfish Res. 22: 213-223

FIRST CONFIRMED CASES OF DSP IN UNITED STATES

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

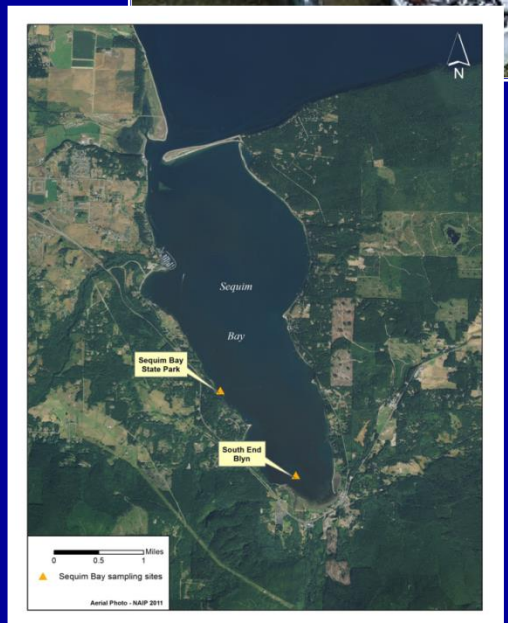
Photo courtesy of KUOW, Seattle

DSP is primarily observed as a mild gastrointestinal disorder.

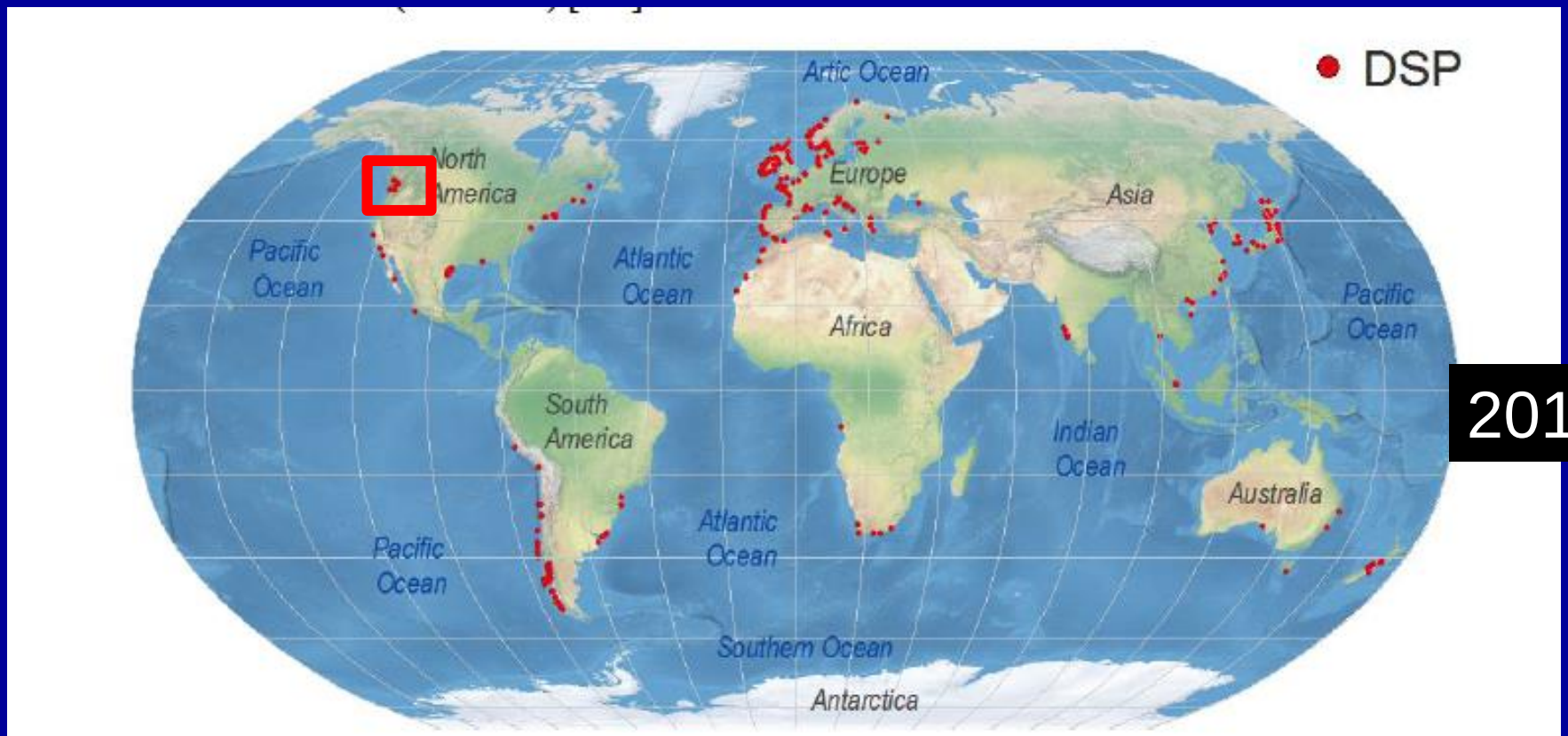
Nausea, vomiting, diarrhea, and abdominal pain accompanied by chills, headache, and fever.

Onset of the disease may be as little as 30 minutes and up to 2 to 3 hours after ingestion.

Symptoms may last 2 to 3 days and recovery is usually complete with no after effects.



2012


DSP
Artic Ocean
North America
Europe
Asia
Pacific Ocean
Atlantic Ocean
Africa
Pacific Ocean
South America
Indian Ocean
Australia
Atlantic Ocean
Pacific Ocean
Southern Ocean
Antarctica

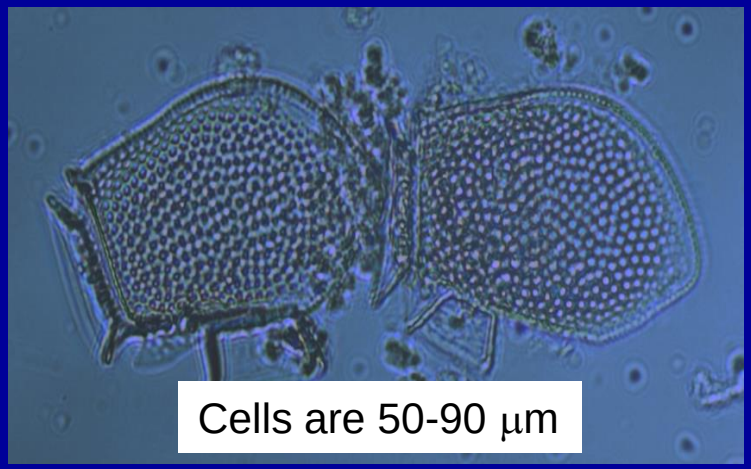
2014

Dinophysis has been present in Puget Sound for decades. Why is DSP a problem now?

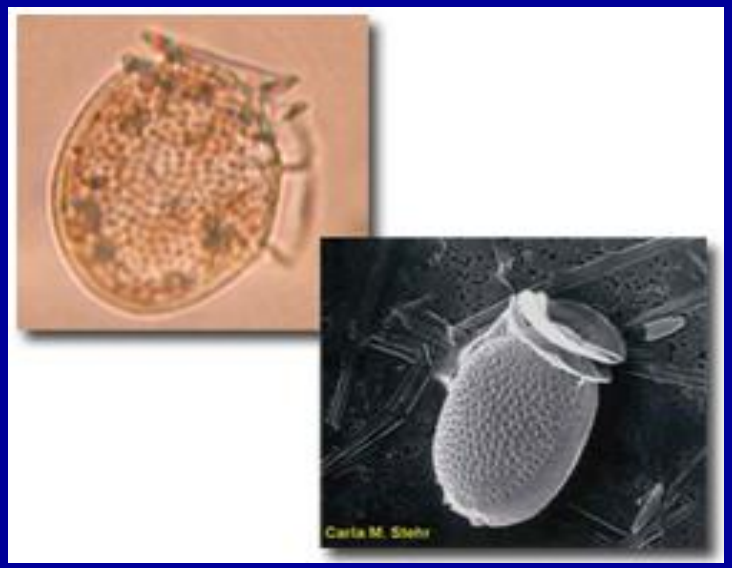
"DSP is not currently known from the west coast but the causative organisms are common"

Horner et al. 1997. Limnol. Oceanogr.

DSP Toxins

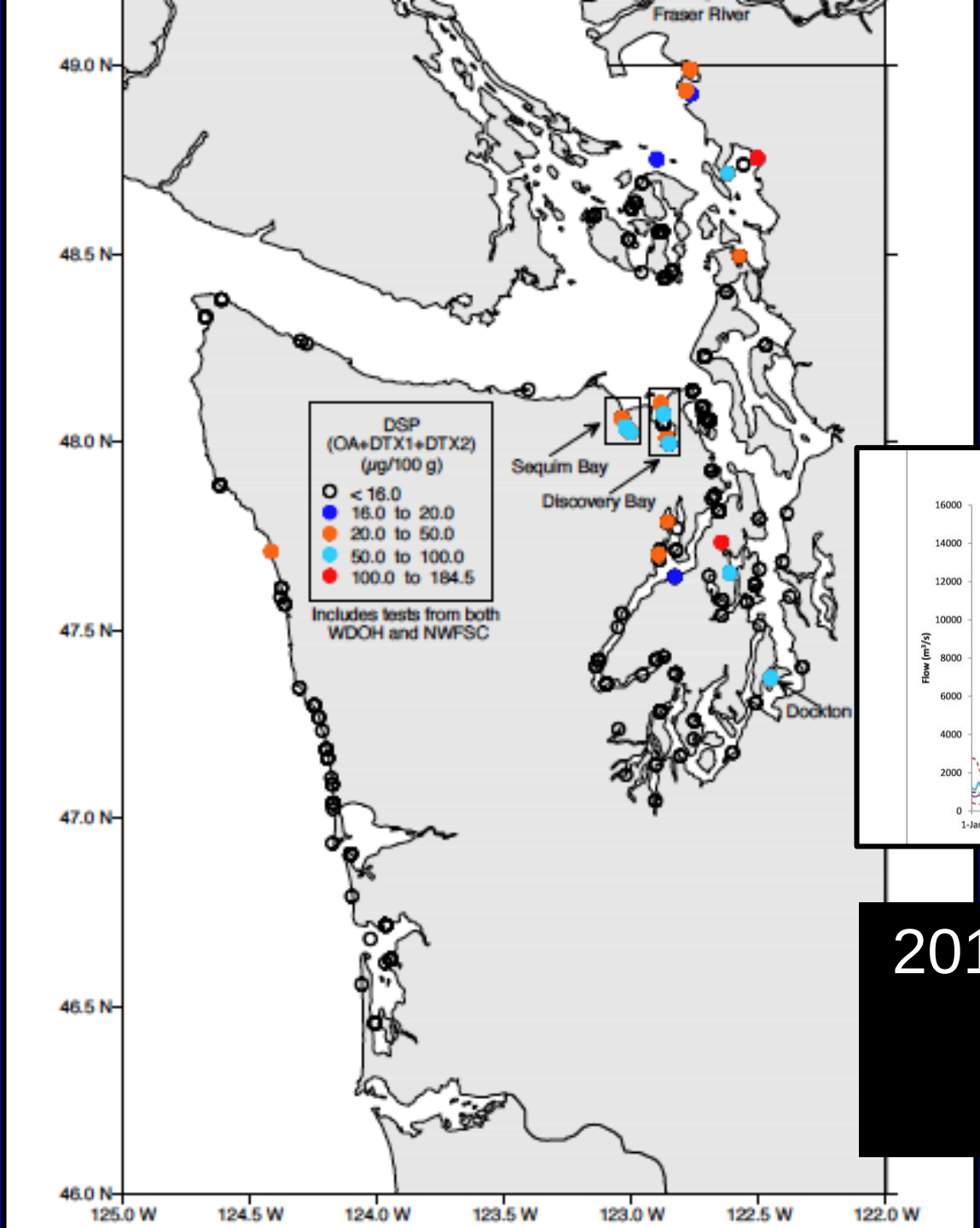


Dinophysis acuta

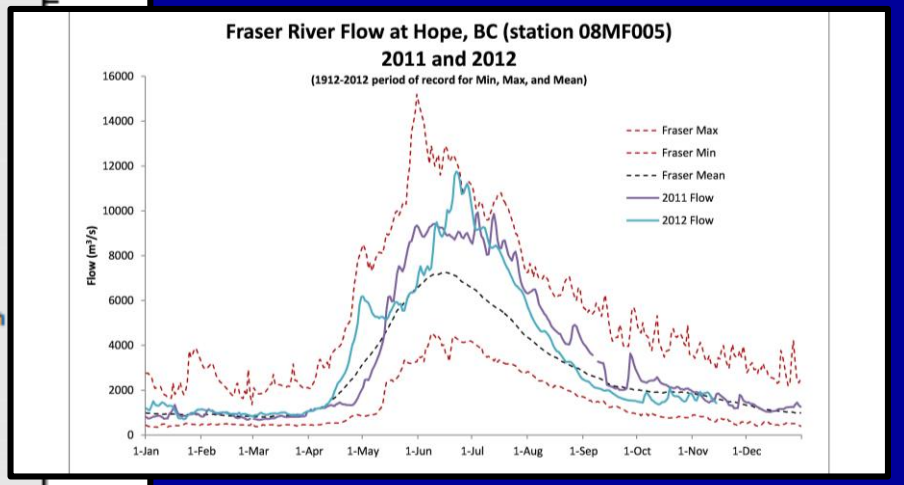


- Produced by the dinoflagellates *Dinophysis*
- Shellfish are the vector to humans
- Lipophilic, cyclic polyether, high molecular weight toxins.
- Include okadaic acid (OA), dinophysistoxins (DTXs), pectenotoxin (PTX)
- DSP toxins have been reported to be tumor promoting agents.

Photos: Pedro Costa, Brian Bill and Carla Stehr



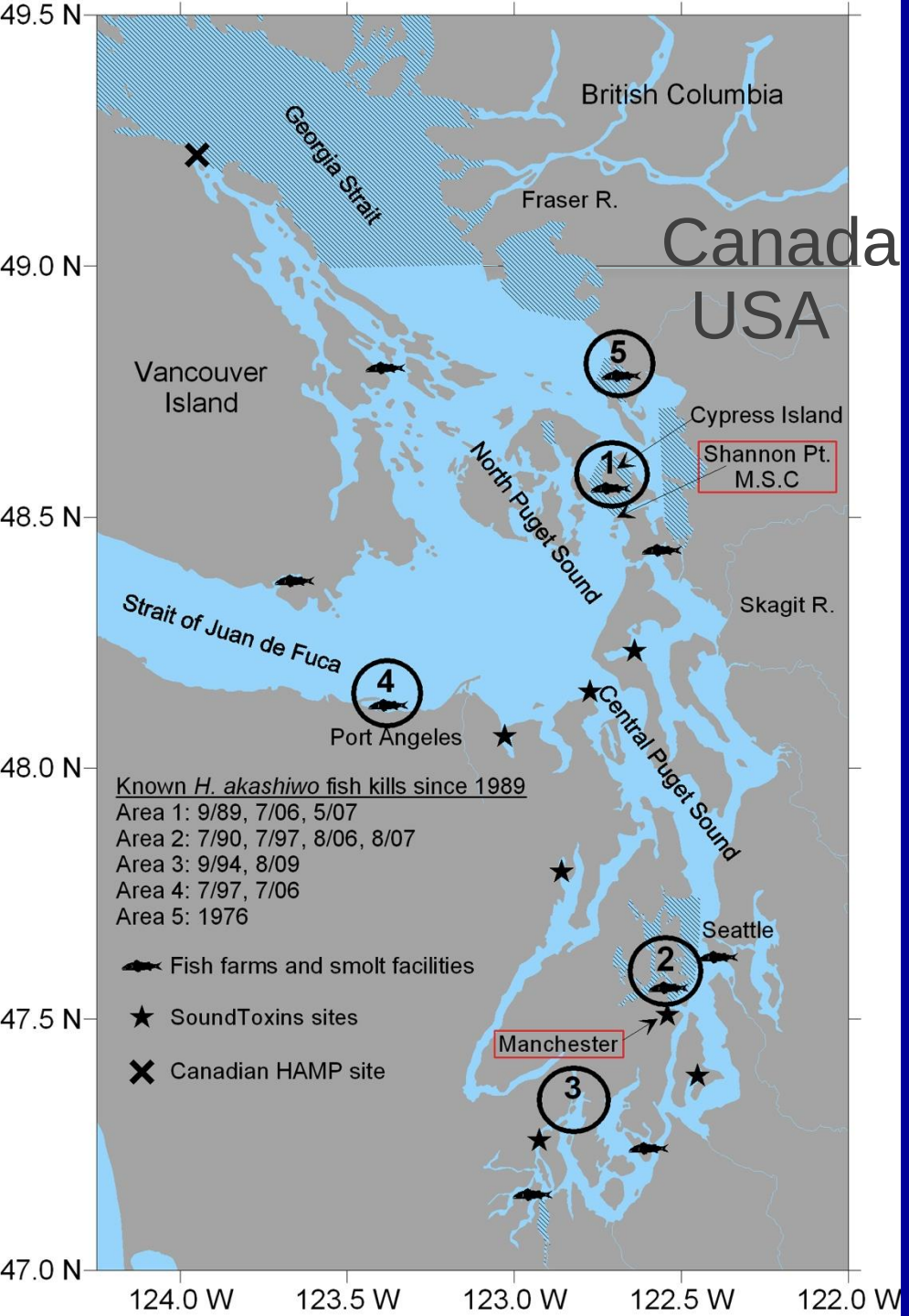
- *Dinophysis acuminata* dominant
- DTX-1 major toxin isomer
- Above average Fraser River flow
- La Niña conditions



2012 Diarrhetic shellfish toxins Washington State

Trainer et al. 2013. Mar. Drugs

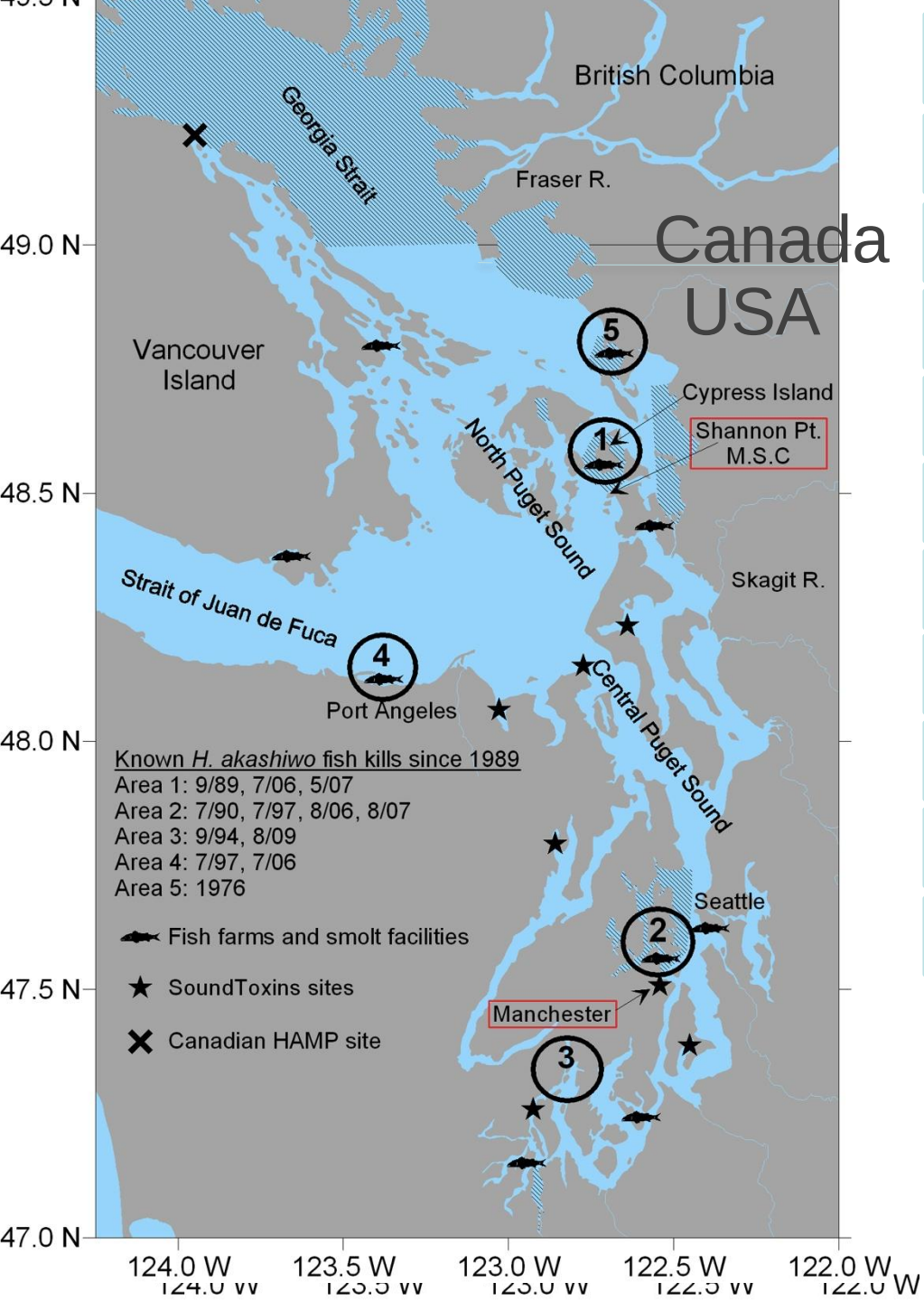
Puget Sound is Vulnerable to Fish-killing HABs



More than 100 salmon hatcheries are currently operating in Puget Sound.

Most were built to produce fish for harvest in response to declines in naturally-spawning salmon populations.

Aquaculture is the cornerstone of an $854 million annual recreational fishing economy in Washington State (ranked eighth in the United States).



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

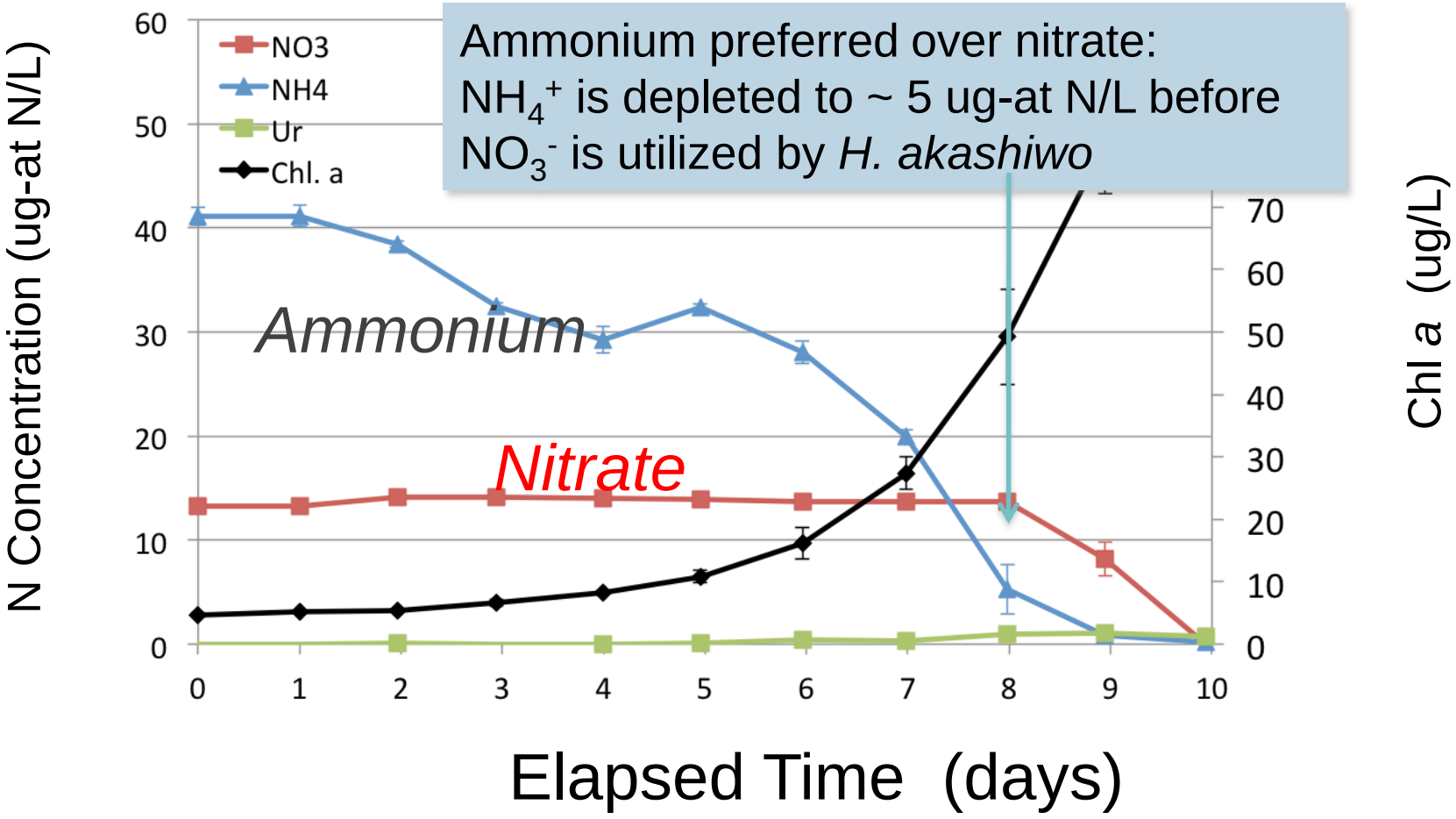
Combined losses of > 1.9 million farmed fish since 1989.

Mean exponential growth rate = 0.51 ± 0.002 d^{-1}

Ammonium-enriched Incubations (n=3)

Heterosigma akashiwo

Ammonium preferred over nitrate:
NH_4^+ is depleted to ~ 5 ug-at N/L before
NO_3^- is utilized by *H. akashiwo*



Public Health Lab Workload for Marine Biotoxin Testing

PSP

- > 3000 samples/year

ASP/Domoic Acid

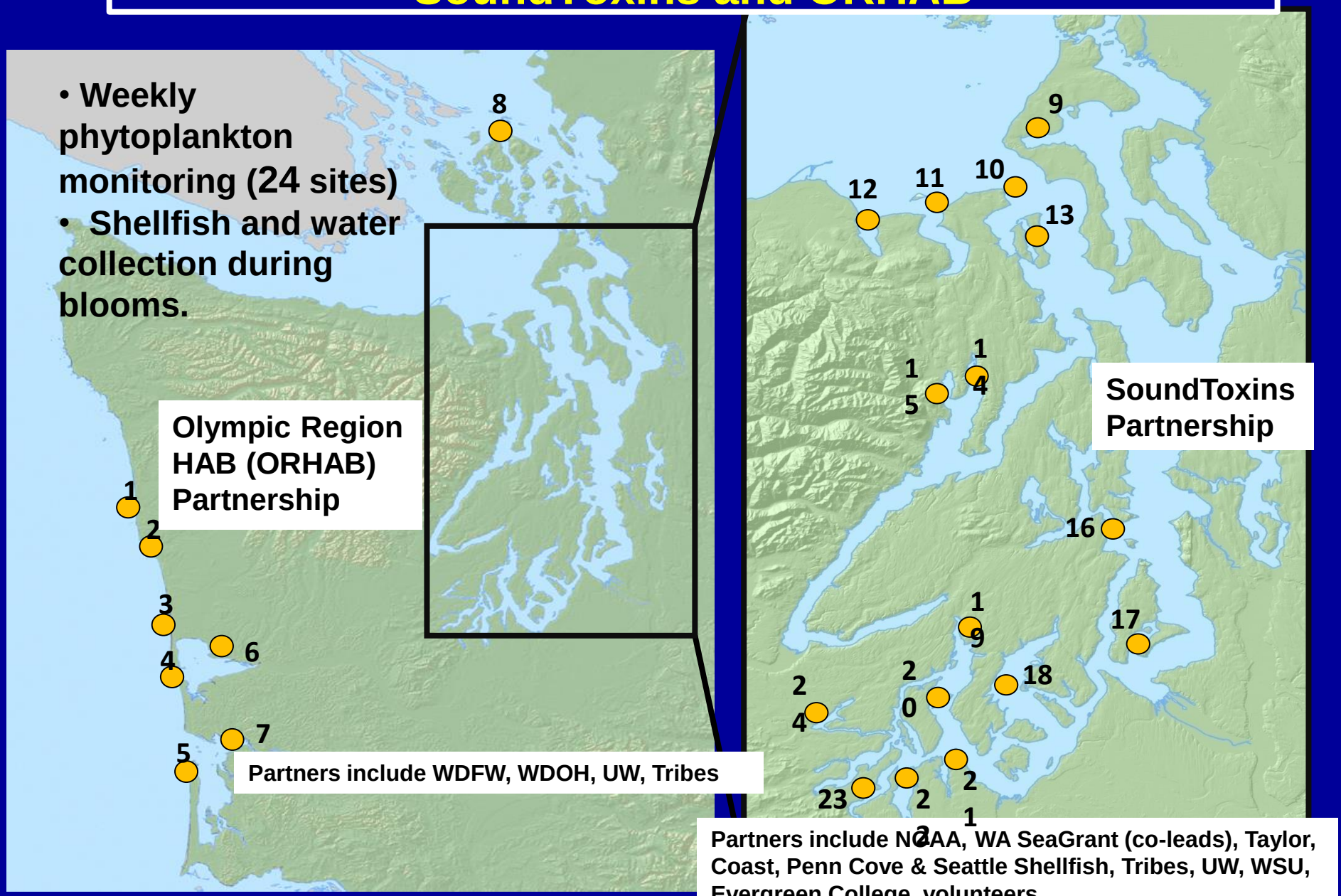
- > 1200 samples/year

DSP

- > 903 samples (2012)

Phytoplankton monitoring as early warning of HABs

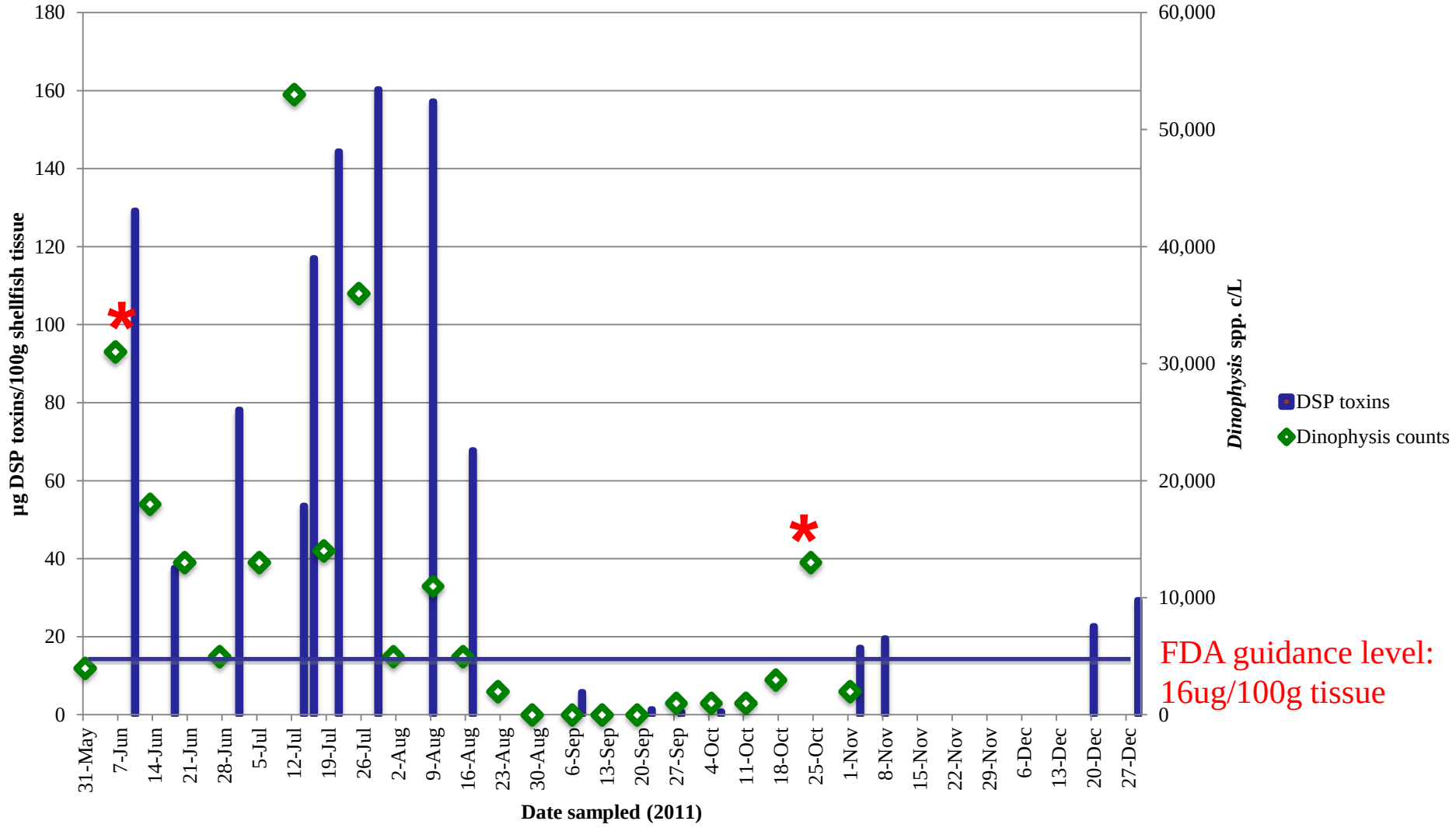
Phytoplankton monitoring: SoundToxins and ORHAB



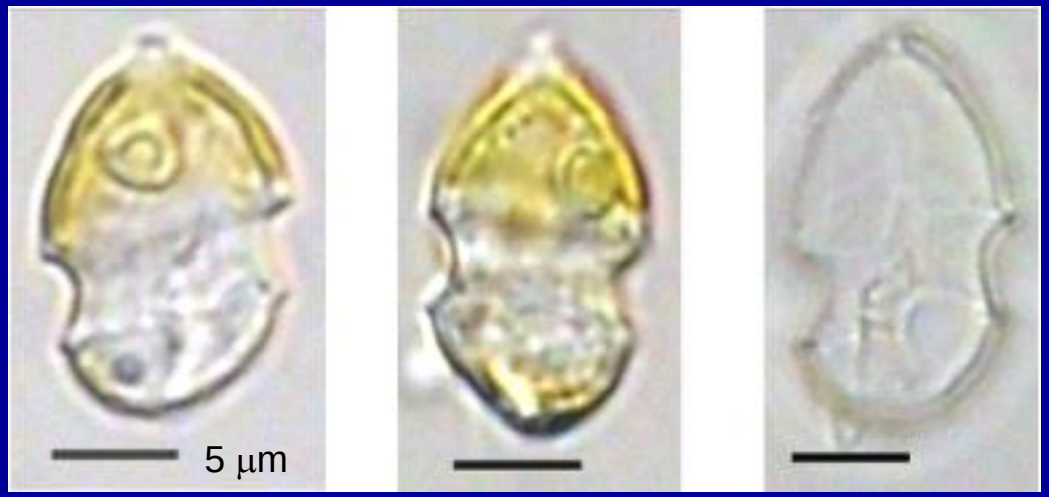
Current Phytoplankton Monitoring Programs

- ORHAB (Olympic Region Harmful Algal Bloom Project)
  - Partnership formed in 1999
  - Coastal area monitoring
  - Mature program
- SoundToxins
  - Partnership formed in 2007
  - Puget Sound monitoring – many unique areas

Sequim Bay 2011- *Dinophysis* spp. counts and DSP toxin



FDA guidance level: 16ug/100g tissue



Azaspiracids
a newly-described DSP toxin

AZA-2 in Puget Sound
0.4 μg/100g in Sequim Bay mussels
(16 μg/100g regulatory action level)

Background on azaspiracids

- In November 1995, 8 people ill in the Netherlands after eating mussels (*Mytilus edulis*), Although human symptoms such as nausea, vomiting, severe diarrhoea, and stomach cramps were similar to DSP, concentrations of major DSP toxins OA and DTXs were very low.
- Since 1996 several AZP incidents have been identified in Ireland.
- Maximum levels of AZP toxins in bivalve molluscs, echinoderms, tunicates and marine gastropods (whole body or any part edible separately) shall be 160 μg/kg.
- Size is ~10 μm – passes through typical phytoplankton nets
- Not regulated in USA

MERHAB: Clear and present danger: monitoring and management of lipophilic shellfish toxins in Washington State

The objectives of the proposed study are to:

1) Identify and characterize the distribution of phytoplankton species that produce DSP toxins and azaspiracids accumulating in Washington State shellfish,
2) Establish and validate a tiered early warning system for DSP and AZP events, including routine microscopy by SoundToxins/ORHAB partners, and rapid toxin screening in seawater and shellfish,
3) Assist State managers in establishing globally accepted protocols for quantifying lipophilic toxins as part of their biotoxin monitoring program,
4) Inform and educate stakeholders about lipophilic toxin risk and management with the goal of transitioning the project to State funding at the end of 3 years.

Summary

- Nutrient type & source impact HAB severity
- New HABs are a problem in our region
- Enhanced monitoring is essential
- Phytoplankton monitoring provides early warning

Thanks to many