Alexandrium catenella Cyst Distribution in Puget Sound with a focus on Quartermaster Harbor

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University of Washington Tacoma

10/28/09

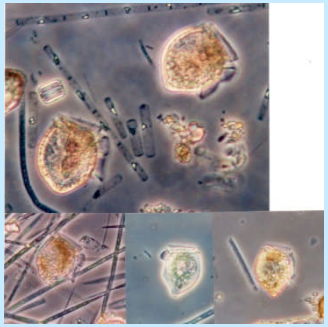
Evolution of the study of *Alexandrium catenella* in Quartermaster Harbor (QMH)

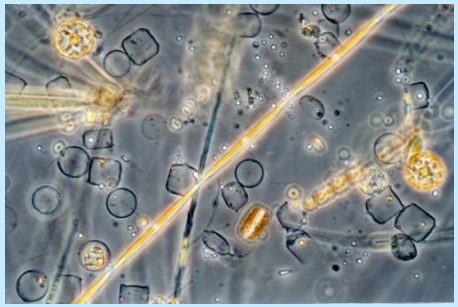
- NOAA ECOHAB (UWS & UWT) 2004-2008
  Cyst distribution in Puget Sound

- Russell Family Foundation (UWT) 2006–2009
  Water Properties in QMH

- EPA (King County, DOE, UWT & USGS) 2009-2012
  QMH Nitrogen Management Study

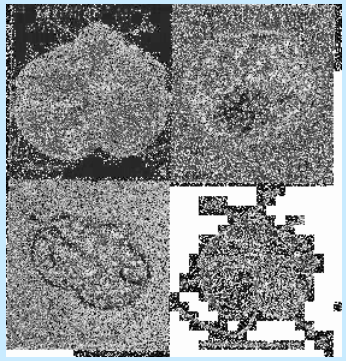
Harmful Algal Bloom (HAB) species that produce potent neurotoxins





- Diarrhetic Shellfish Poisoning (DSP)

Okadaic acid - *Dinophysis* spp. – Ireland, Mediterranean

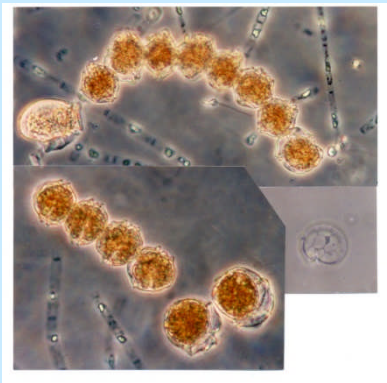


- Amnesic Shellfish Poisoning (ASP)

Domoic acid - *Pseudo-nitzschia – PNW coast*

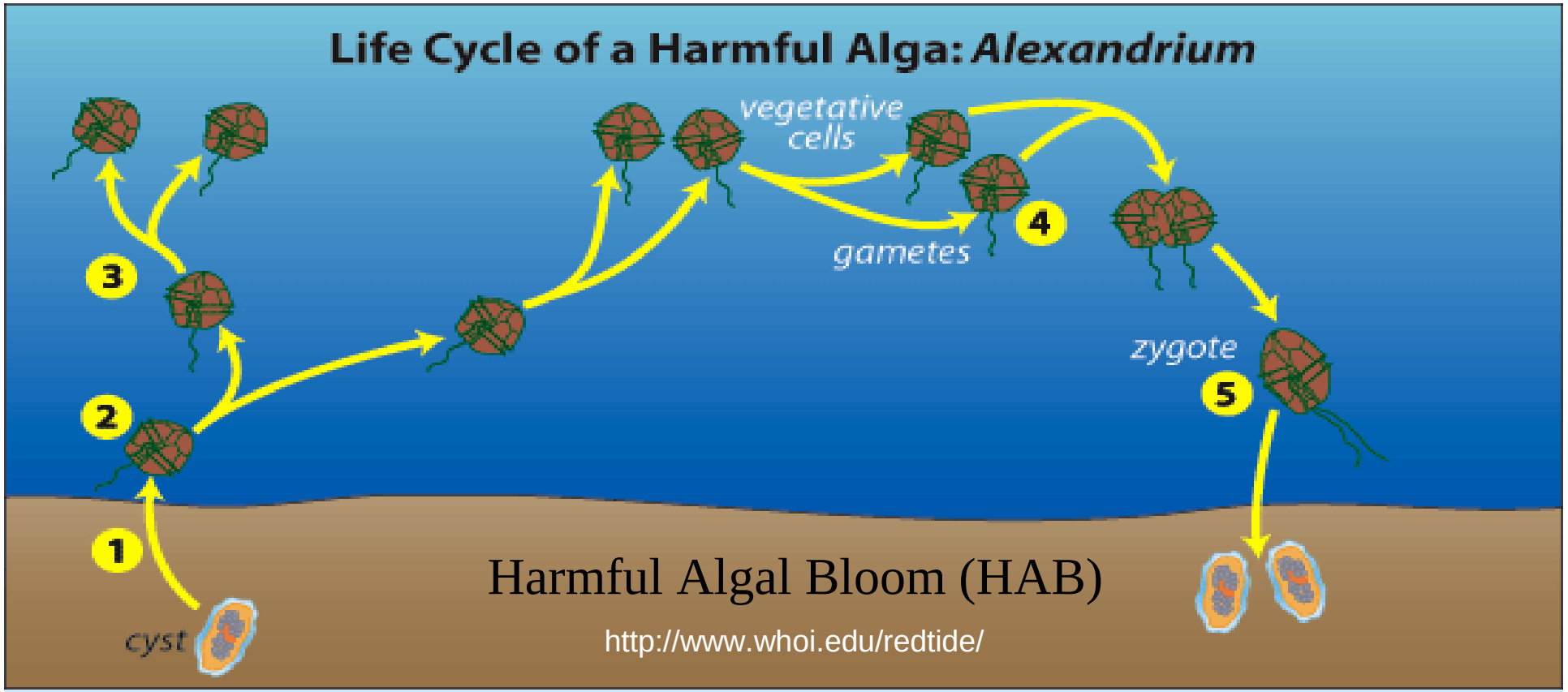
- Neurotoxic Shellfish Poisoning (NSP)

Brevetoxin - *Karenia brevis – west coast Florida*



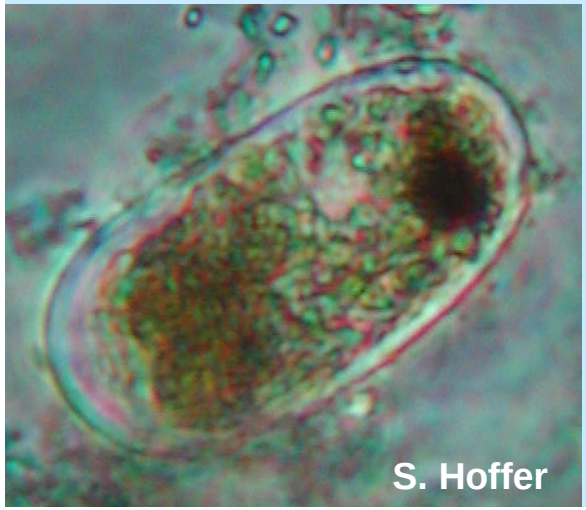
- Paralytic Shellfish Poisoning (PSP)

Saxitoxin - *Alexandrium catenella – Puget Sound*

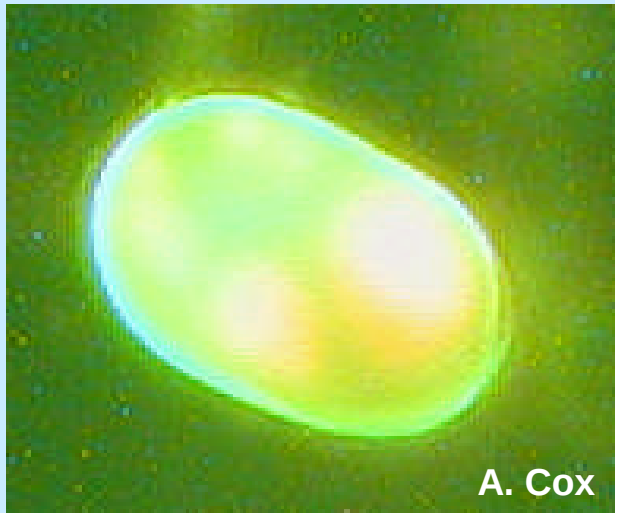


Harmful Algal Bloom (HAB)

http://www.whoi.edu/redtide/


S. Hoffer

R. Horner


A. Cox

Where is *Alexandrium catenella* in Puget Sound?

Shellfish harvesting closures due to PSP by decade in Puget Sound based on Washington State Department of Health (WDOH) monitoring data. Trainer *et al.* (2003)

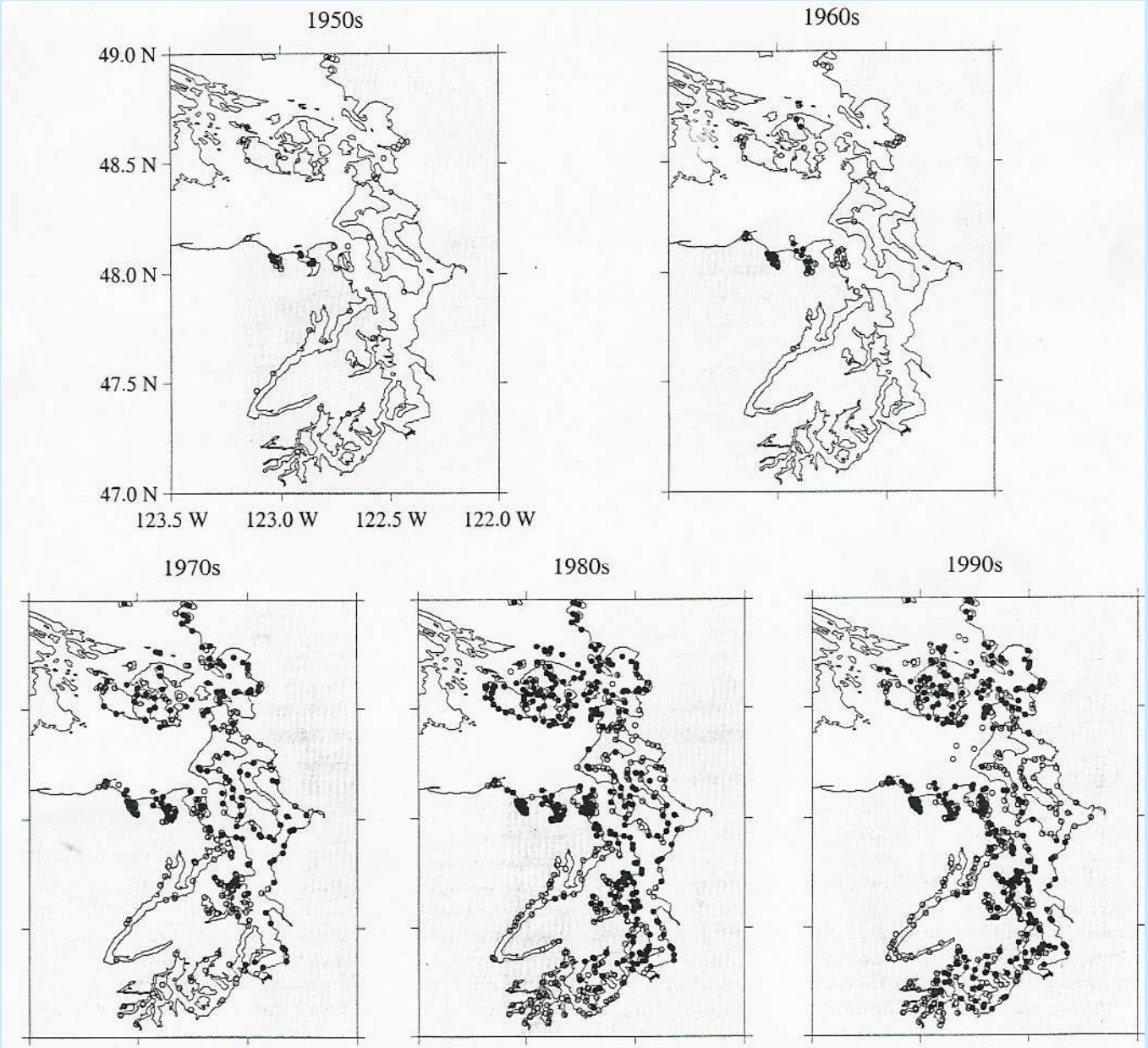


Figure 5. Closures because of PST in shellfish at all Puget Sound monitoring sites for each decade. Symbols represent maximum values for each decade shown as open circles (below 80 µg STXeq/100 g) or solid circles (greater than or equal to 80 µg STXeq/100 g). Data for the 1950s include only 1957–1959.

Alexandrium Cyst Distribution in Puget Sound

(NOAA ECOHAB Grant NA04NOS4780273)

1) What is the distribution of *Alexandrium* cysts in Puget Sound sediments? (in space and time & if related to any specific environmental conditions)
2) Are the cysts viable and able to germinate?
3) Is Paralytic Shellfish Poisoning (PSP) produced by motile cells from germinated cysts?
4) Are cysts able to be resuspended and transported across constrictions between basins?

The NOAA ECOHAB Team

(NOAA ECOHAB Grant NA04NOS4780273)

Cheryl Greengrove - UWT
Rita Horner - UWS
Jim Postel - UWS
Jim Gawel – UWT
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Bruce Frost – UWS
Annie Cox* – WWU (URI)
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Liz Tobin* - UWS
Kirsten Feifel* - UWS
Julie Masura – UWT

*Students

Special thanks to: The crew of the R/V Barnes and Frank Cox Washington State Department of Health.

What, Where & When We Sampled

YEAR 1:

March 2005

All of Puget Sound

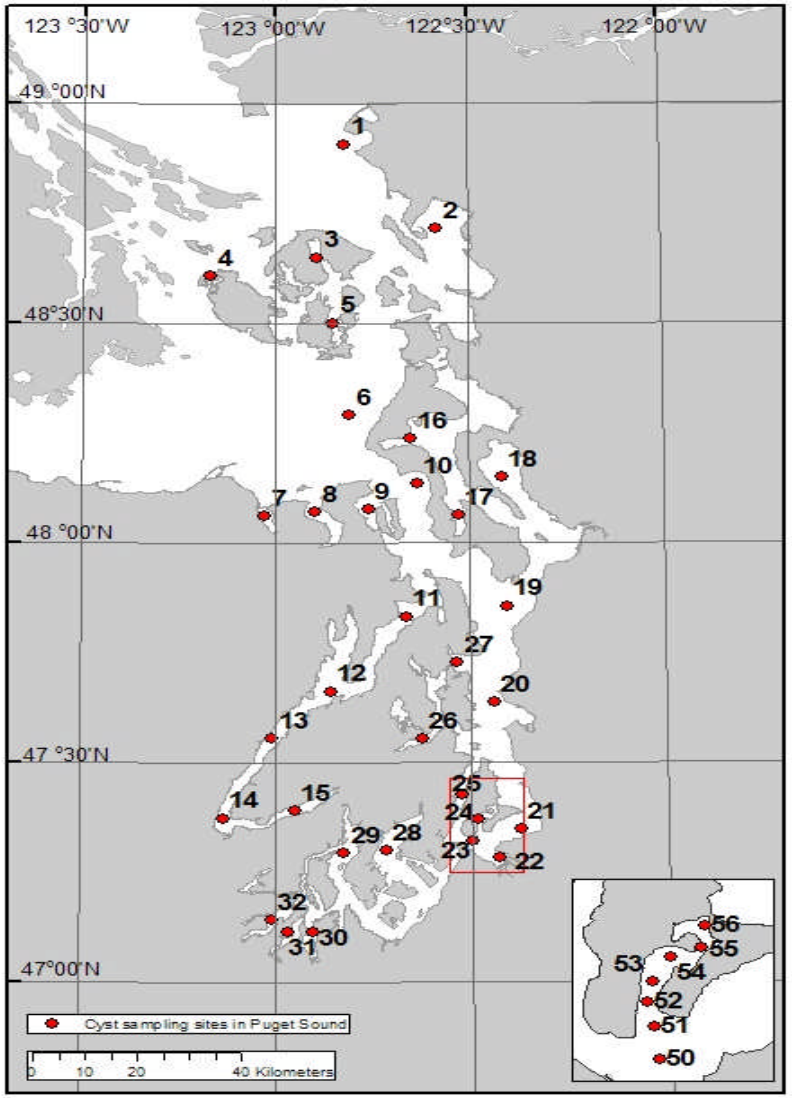
Surface Sediments

Soutar Cores

Piston Cores

Water Properties

Plankton



2005 sampling sites in Puget Sound, Washington USA.
Inset shows 2006 sites in Quartermaster Harbor.

YEAR 2:

March 2006

Dye's Inlet & QMH

Surface Sediments

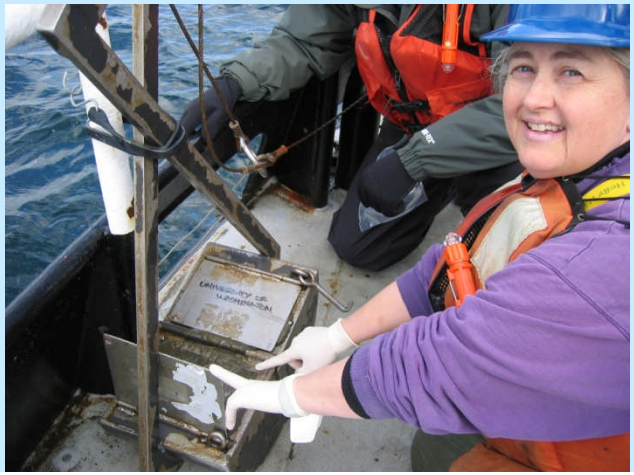
Soutar Cores

Water Properties

Plankton

Turbulence

Soutar Boxcore & Van Veen Grab



Piston Core (2005)

Transport of Cysts (2006)

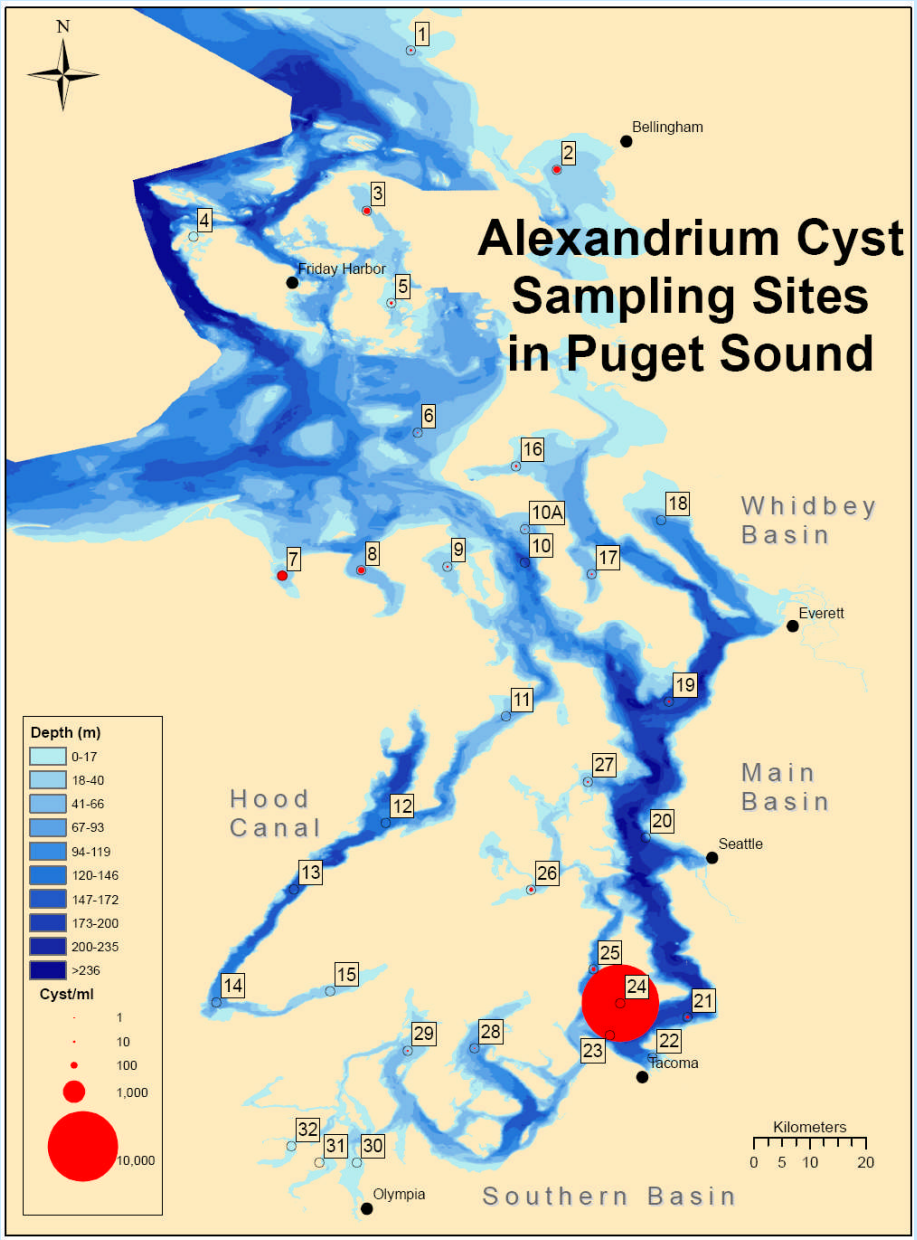
Sediment Sample Processing

CYSTS (Yamaguchi, Itakura and Ishida, 1995)
- Sonicated
- Sieved
- Preserved (formalin)
- Solubilized cell walls (methanol)
- Stained (primulin)
- Counted (in Sedgewick-Rafter slide using epifluorescence microscopy)

TOC
- Loss on ignition

GRAIN SIZE
- Beckman-Coulter LS 200 Particle Size Analyzer

METALS (Fe, Mn, Zn, As, Cu, Cd, and Pb)
- Dried and homogenized
- Strong acid digestion and quantification of metals using ICP-MS or GF-AAS in accordance with EPA method 200.7 processed by WA DOE Manchester Environmental Laboratory.



Highest cyst concentrations QMH (12,125 cysts/cm3) and Sequim (220 cysts/cm3)

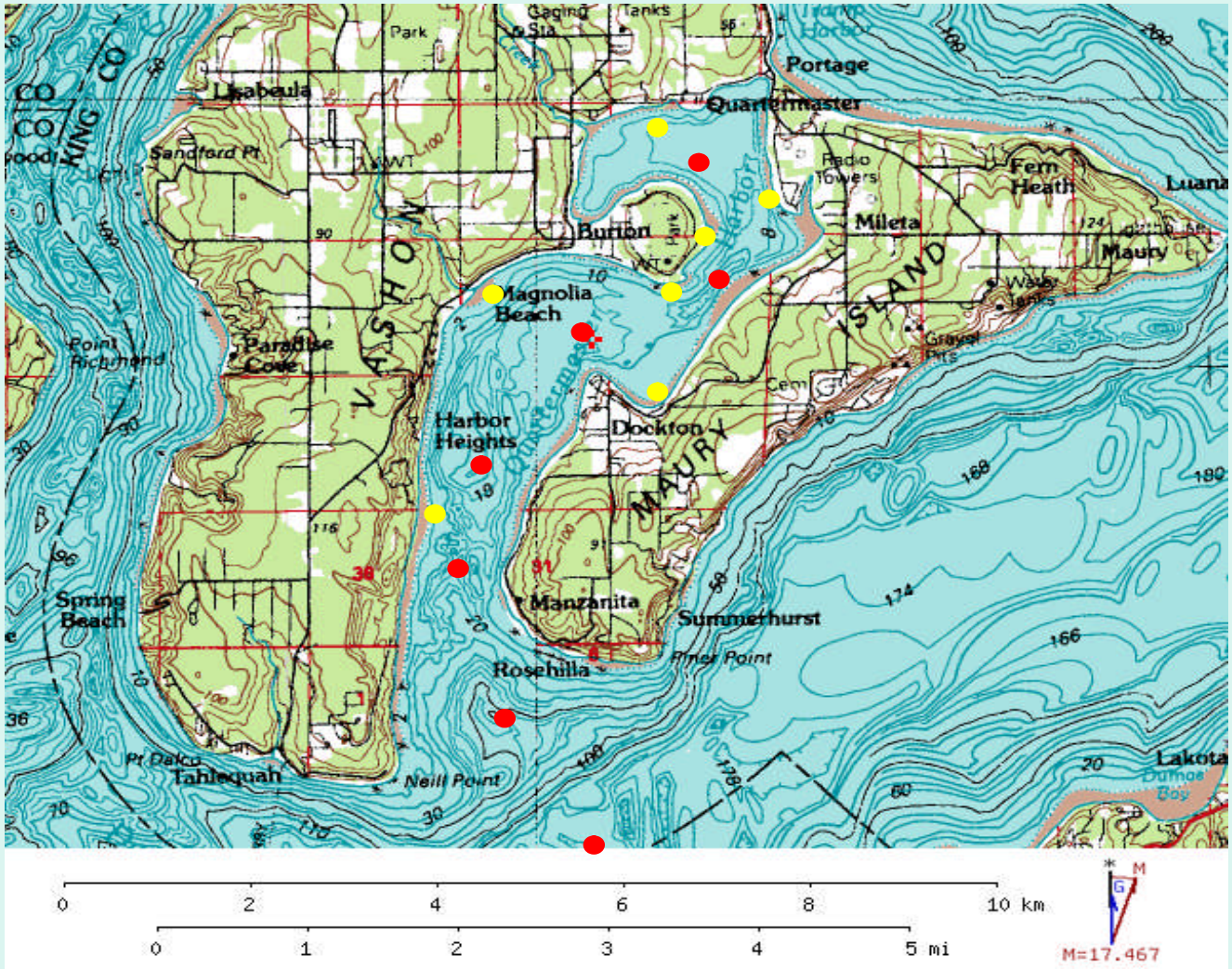
No correlation with grain size or TOC Basin wide scale

No significant correlation with metals except cadmium

Highest cyst concentration in central QMH

Surface sediment cyst concentrations

Why is QMH a hotspot for *Alexandrium catenella*? HYPOTHESIS



Nishitani & Chew (1984) Quartermaster Harbor PSP Data

Closure Limit
80 ug/100g

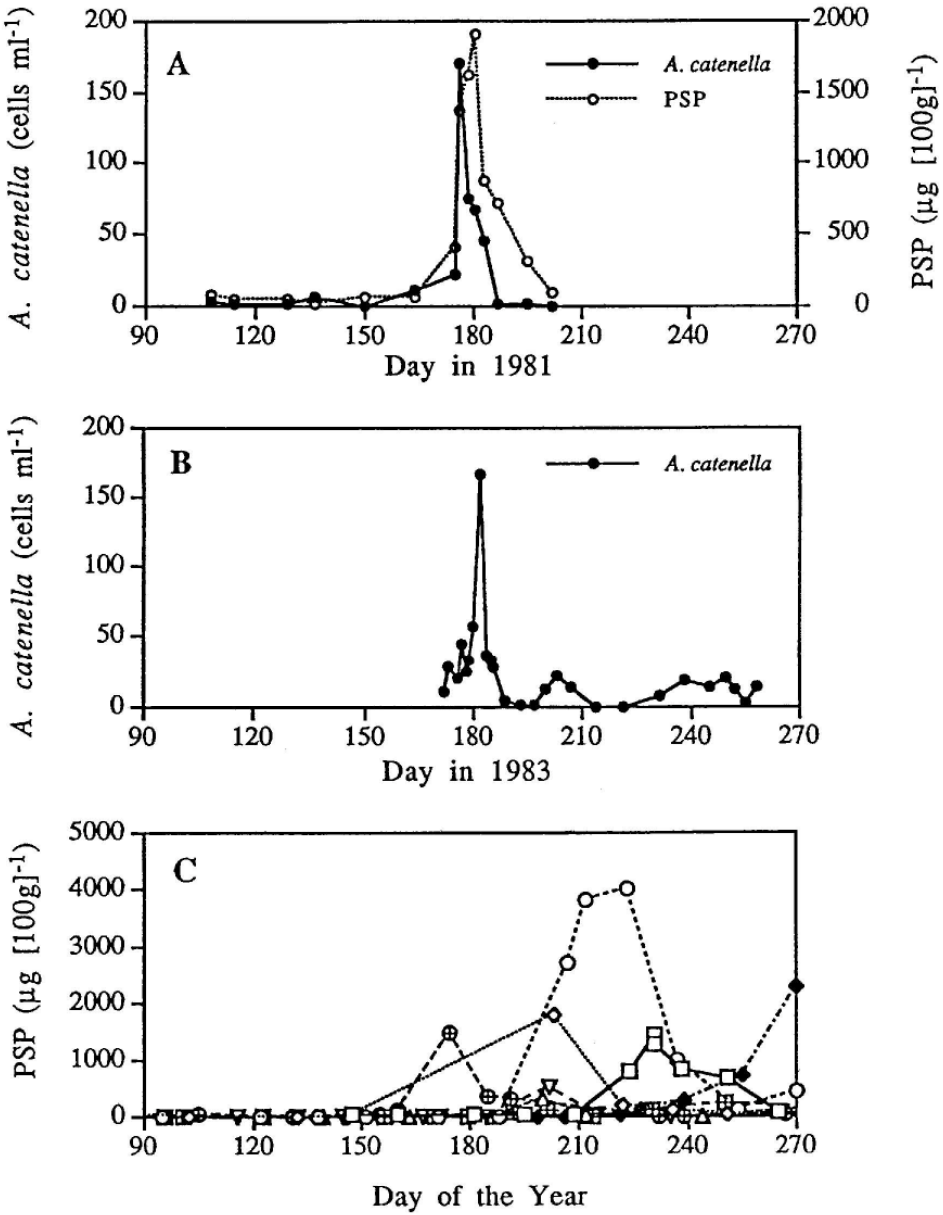
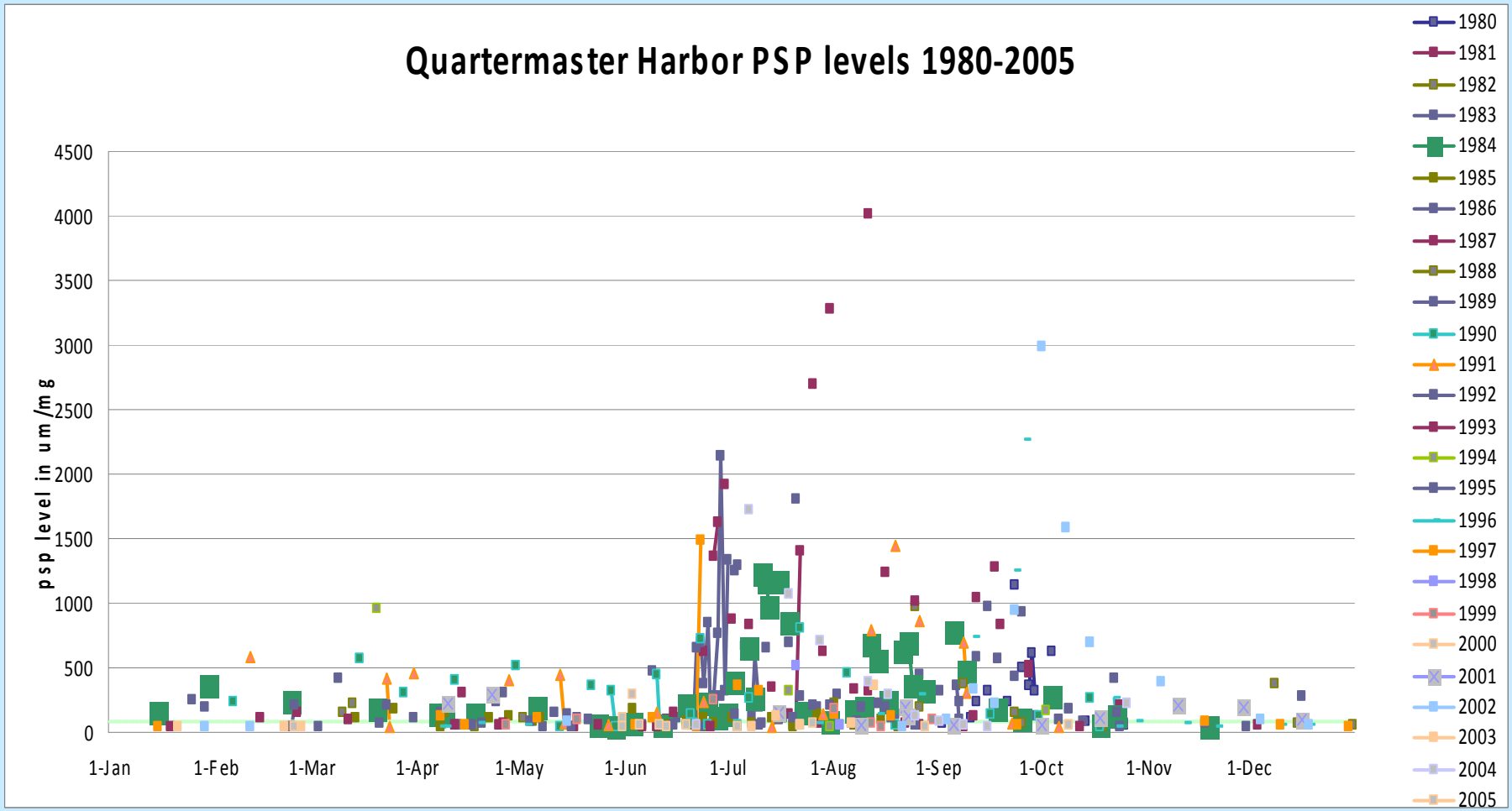


Fig. 2. *Alexandrium catenella* and PSP in Quartermaster Harbor near Dockton. A, mean cell concentrations of *A. catenella* in the water column and PSP in blue mussels (redrawn from Nishitani and Chew 1984); B, mean cell concentrations of *A. catenella* in the water column (redrawn from data in Nishitani et al. 1985); C, PSP in blue mussels, 1991-1998 (data from Washington State Department of Health, courtesy of Frank Cox). PSP levels exceeded regulatory closure levels for extended periods of every year in the 1990s.

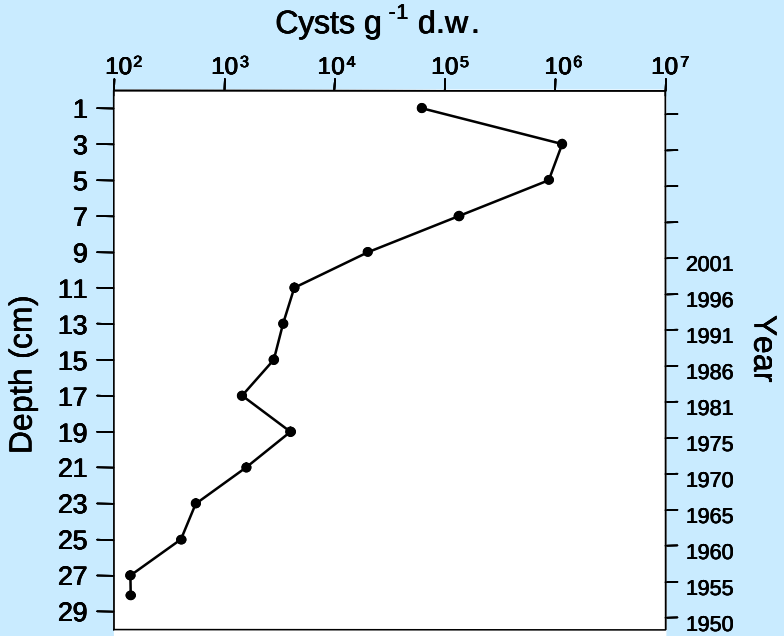
Historic Shellfish Monitoring Data from Washington State Department of Health

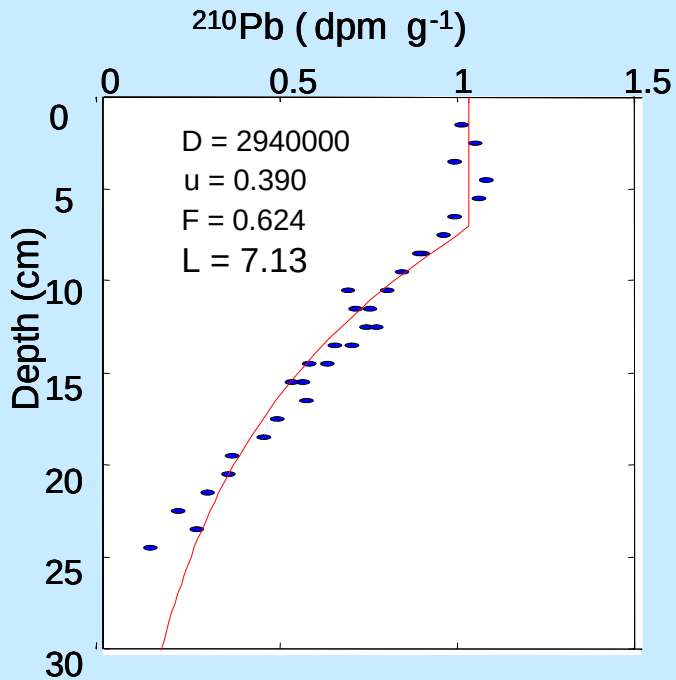


Data courtesy of Frank Cox WADOH

Graph by Audrey Hackett UWT

Quartermaster Harbor Soutar Core





Sediment core, cyst concentrations, and ^{210}Pb activity down core in Quartermaster Harbor [D= biodiffusion coefficient (cm^2y^{-1}), U= sedimentation rate (cm y^{-1}), F= ^{210}Pb flux (dpm cm^{-2} y^{-1}), and L= depth of the mixed layer (cm)]. ^{210}Pb activity was determined using the methods of Nittrouer et al. (1979) and approximate dates down core following Appleby and Oldfield (1978).

Water Properties in Quartermaster Harbor

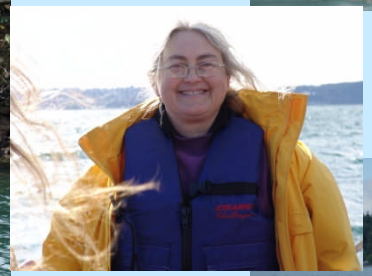
- Learn more about the environmental factors in QMH in order to advance our knowledge and understanding of this organism and factors that may govern its lifecycle and distribution.

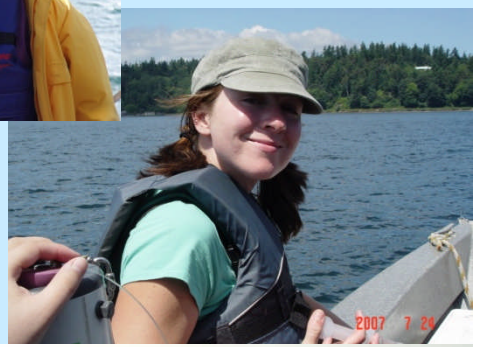
- Provide ground truth data for future hydrodynamic modeling of QMH to test our hypothesis.

Funded by:
THE RUSSELL FAMILY FOUNDATION

The QMH Team

(Russell Family Foundation)





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Audrey Hackett * – UWT
Kelly Scholting * - UWT

Ashley Nepela * - UWT
Ben Shetterly * - UWT
Mitch Schatz * – UWT

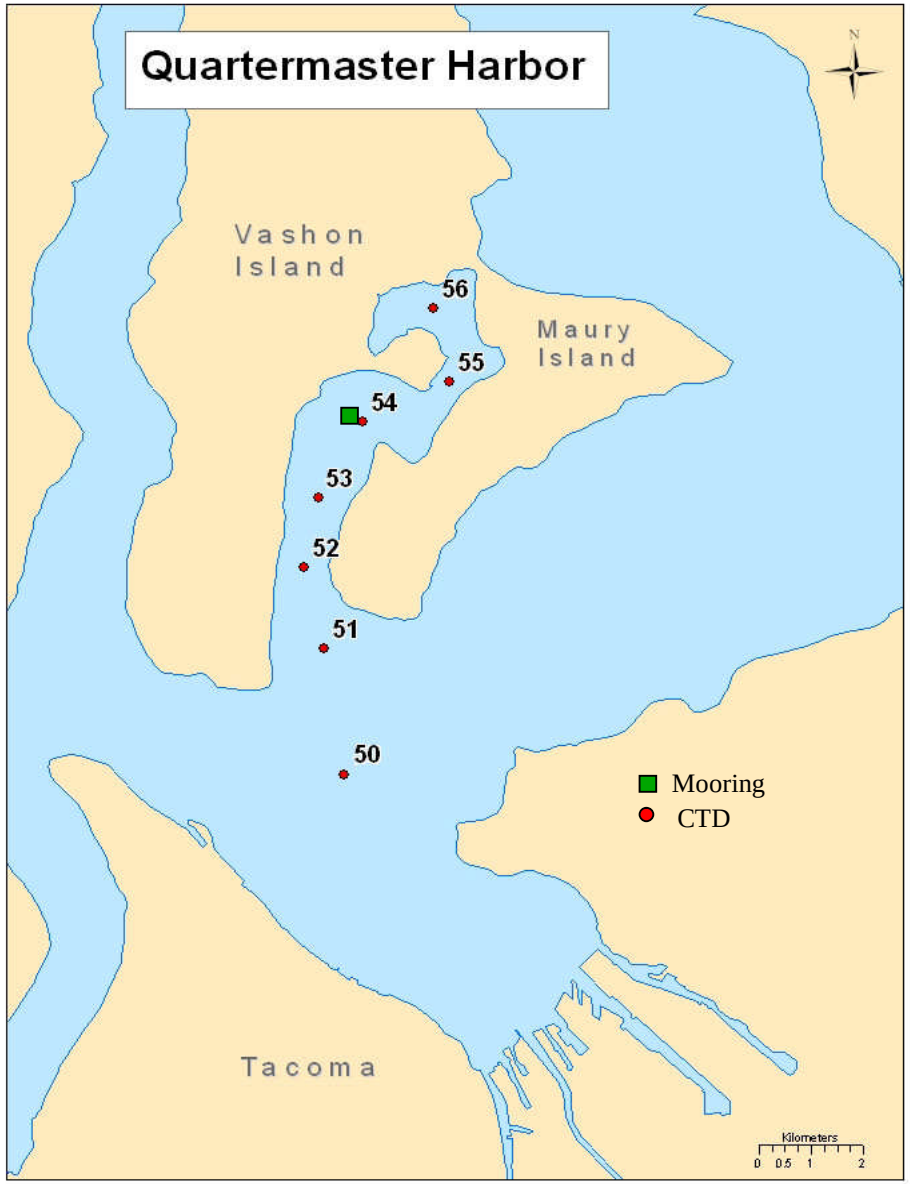
*Students

Special thanks to:
Captain Rick Fuller – City of Tacoma
Captain Dave Thoreson – UWS
Rita Horner – UWS
Frank Cox Washington State Department of Health

Sampling Program

Monthly Sampling
Oct. ’06 – present

Temperature
Salinity
Density
Oxygen
Chlorophyll
Transmissivity
Licor
Nutrients
Plankton



Moored Timeseries

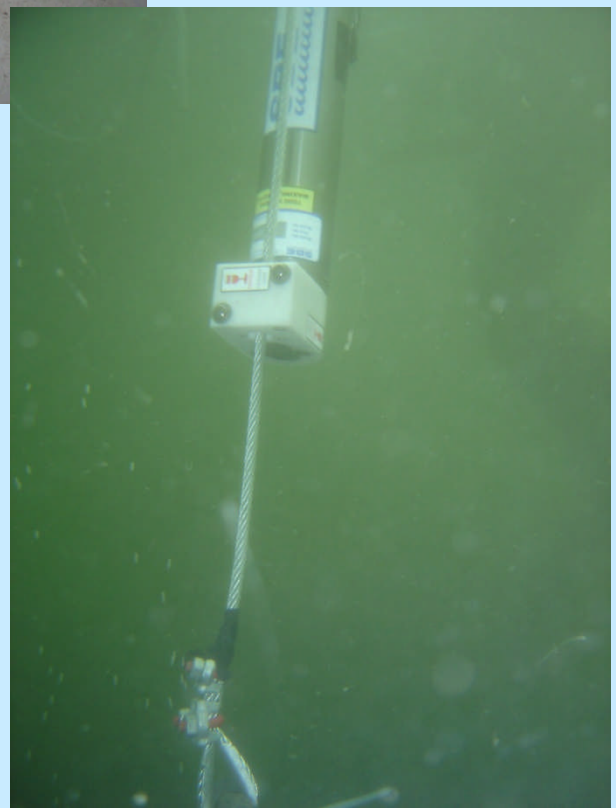
Temperature
Salinity
Density
Oxygen?

METHODS

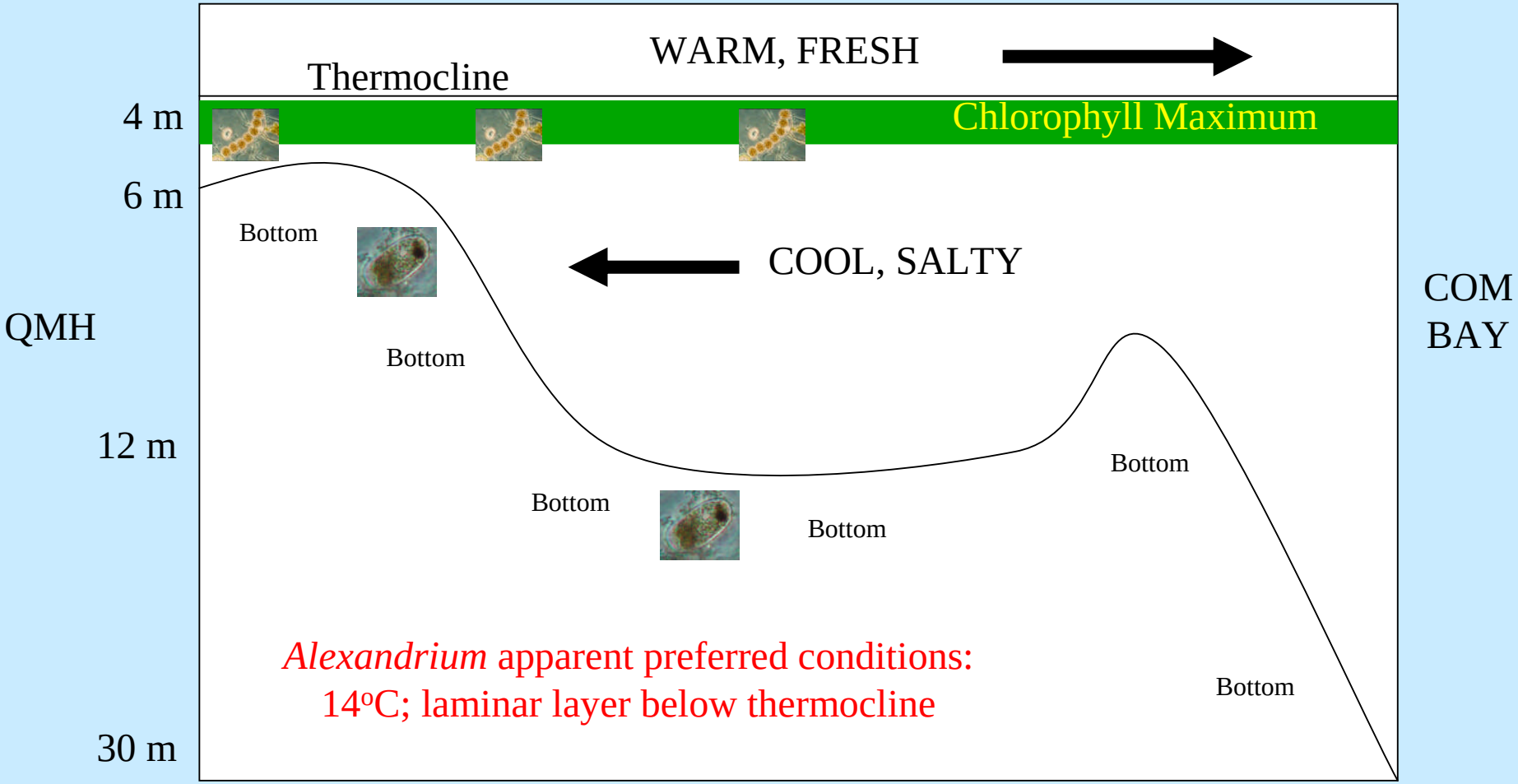
CTD & Water Sampling

METHODS

Moored Instrumentation



Estuarine Flow



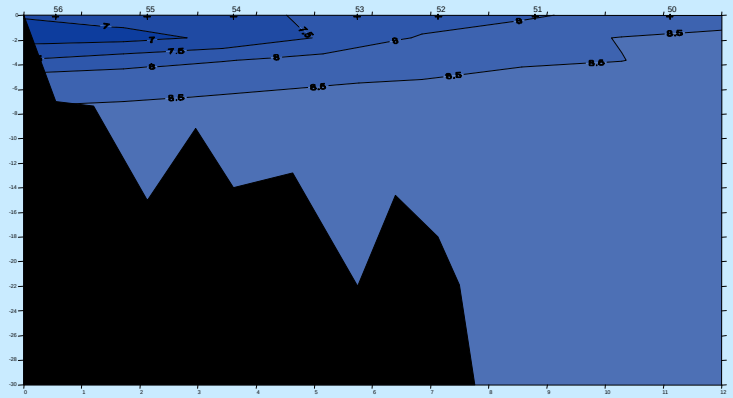
JANUARY 2007

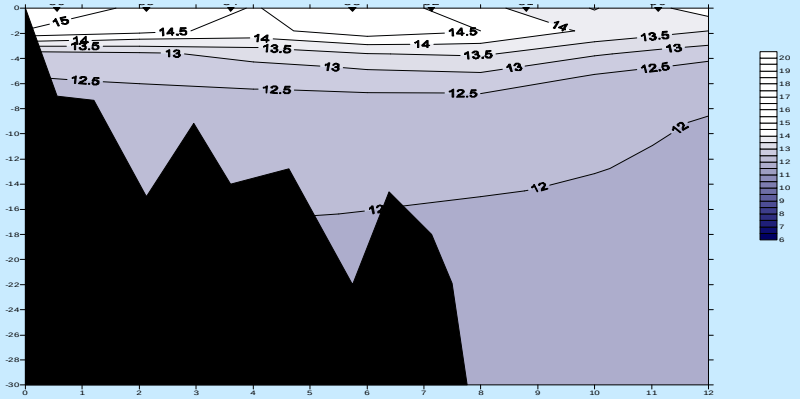
JULY 2007

0

T

30





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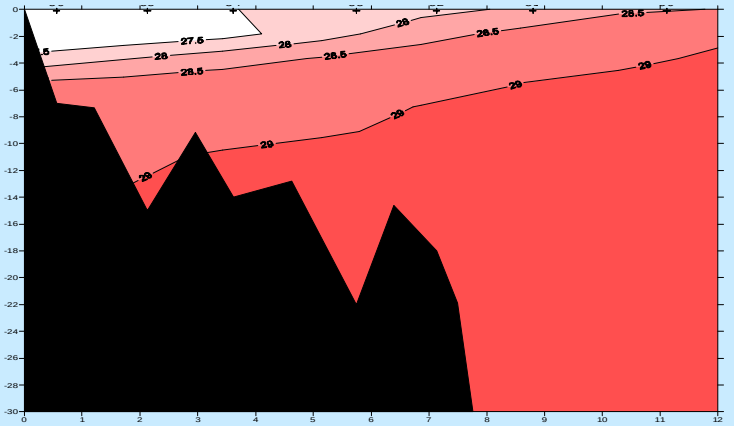
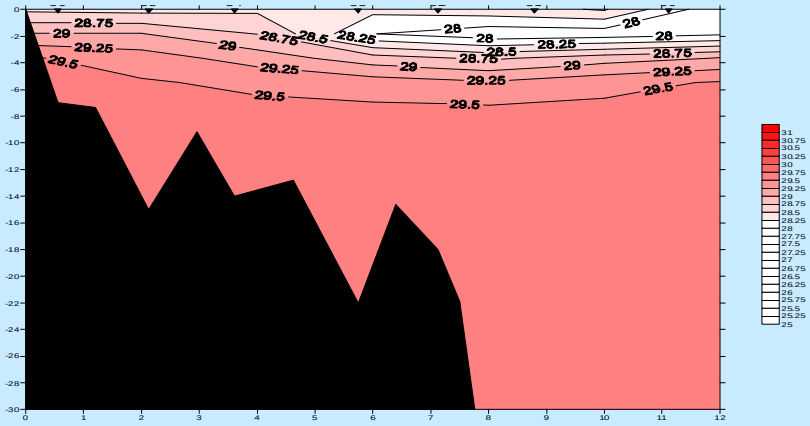
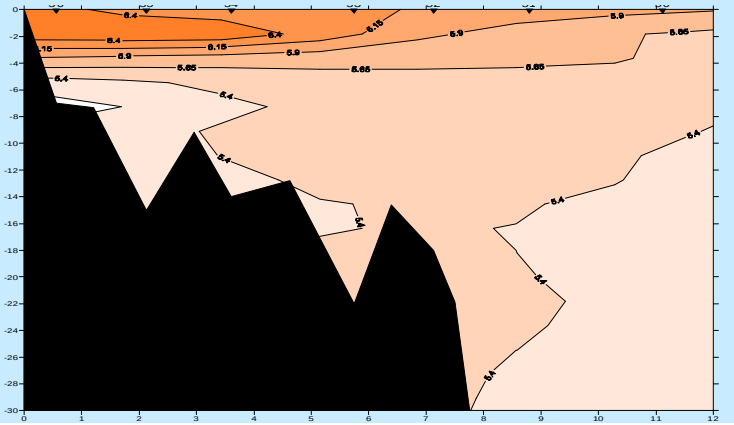
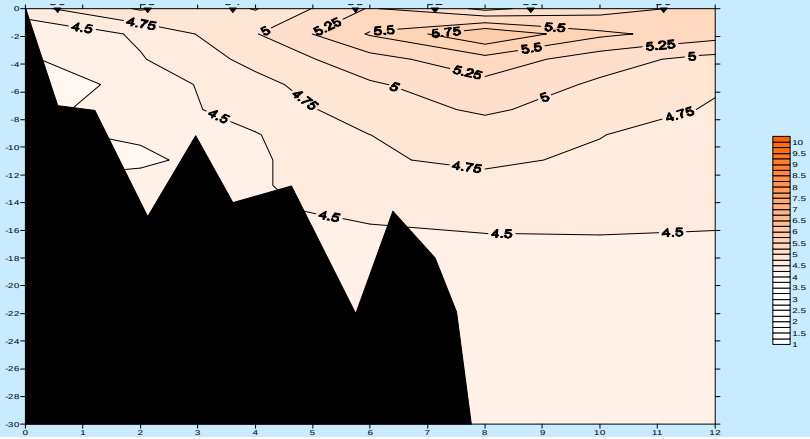




O_2





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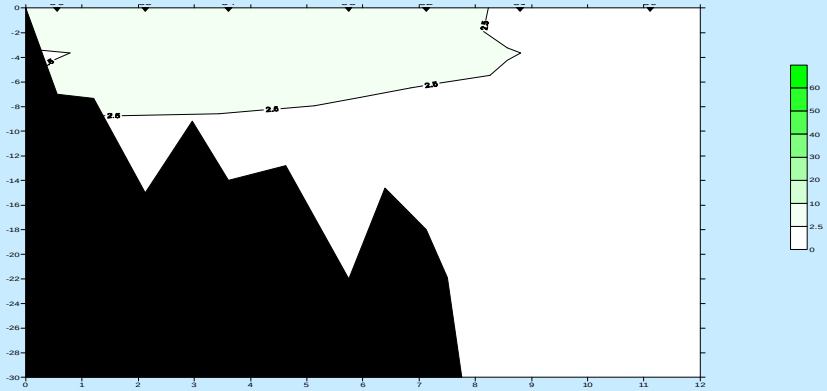
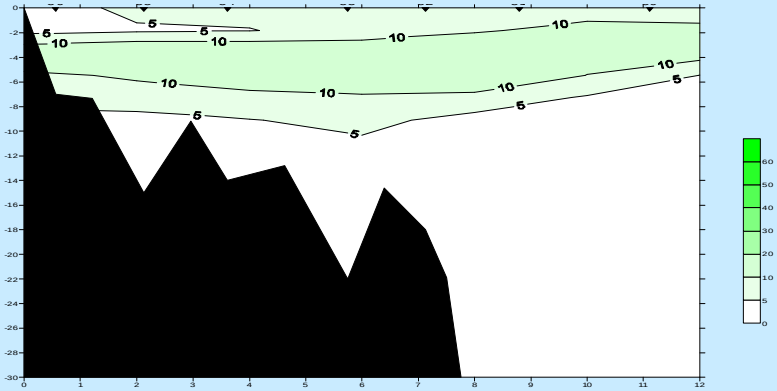
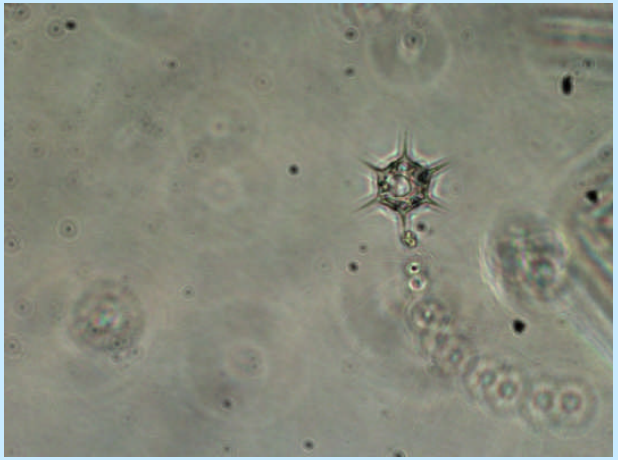
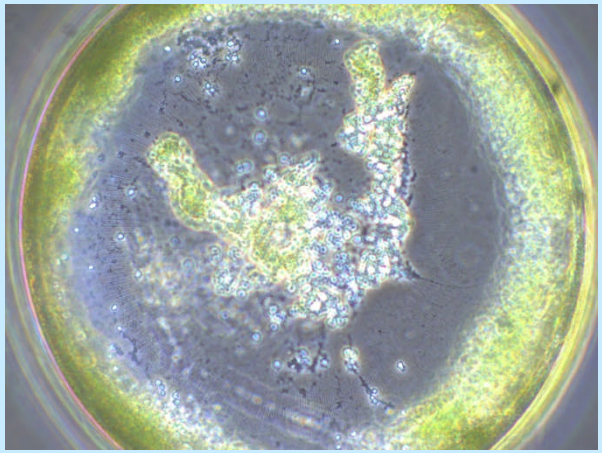






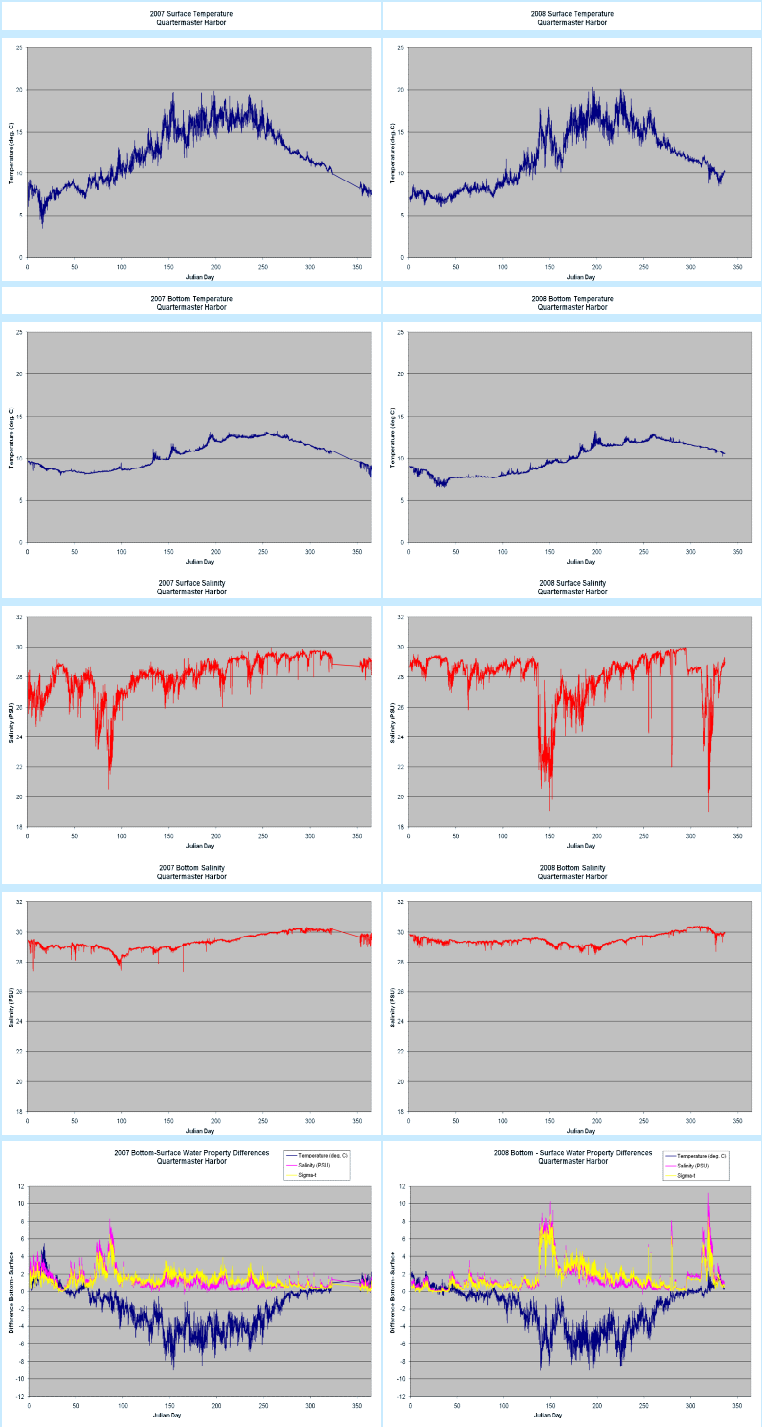
Dictyocha speculum



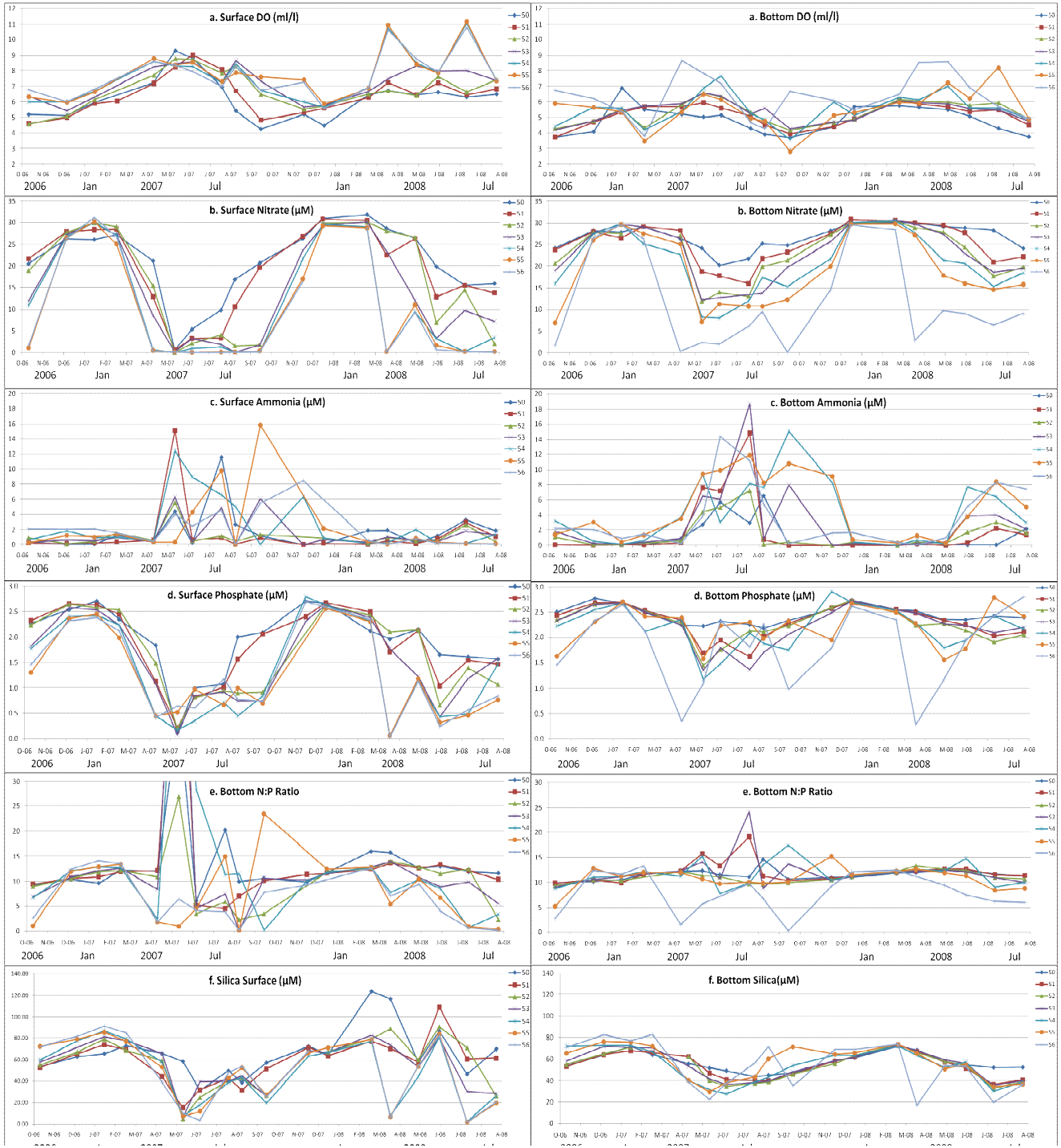
Cosinodiscus

Dominant Phytoplankton

Moored Timeseries of Temperature and Salinity



Seasonal Nutrients in QMH



Current & Future Work

- QMH Nitrogen Management Study
  (EPA Grant - King County, UWT, & DOE)
- Continued Monitoring
- Hydrodynamic Modeling
- Upgrade Mooring

References

Appleby, P.G. and F. Oldfield. 1978. The calculation of lead-210 dates assuming a constant rate of supply of unsupported ^{210}Pb to the sediment. Catena 5:1-8.

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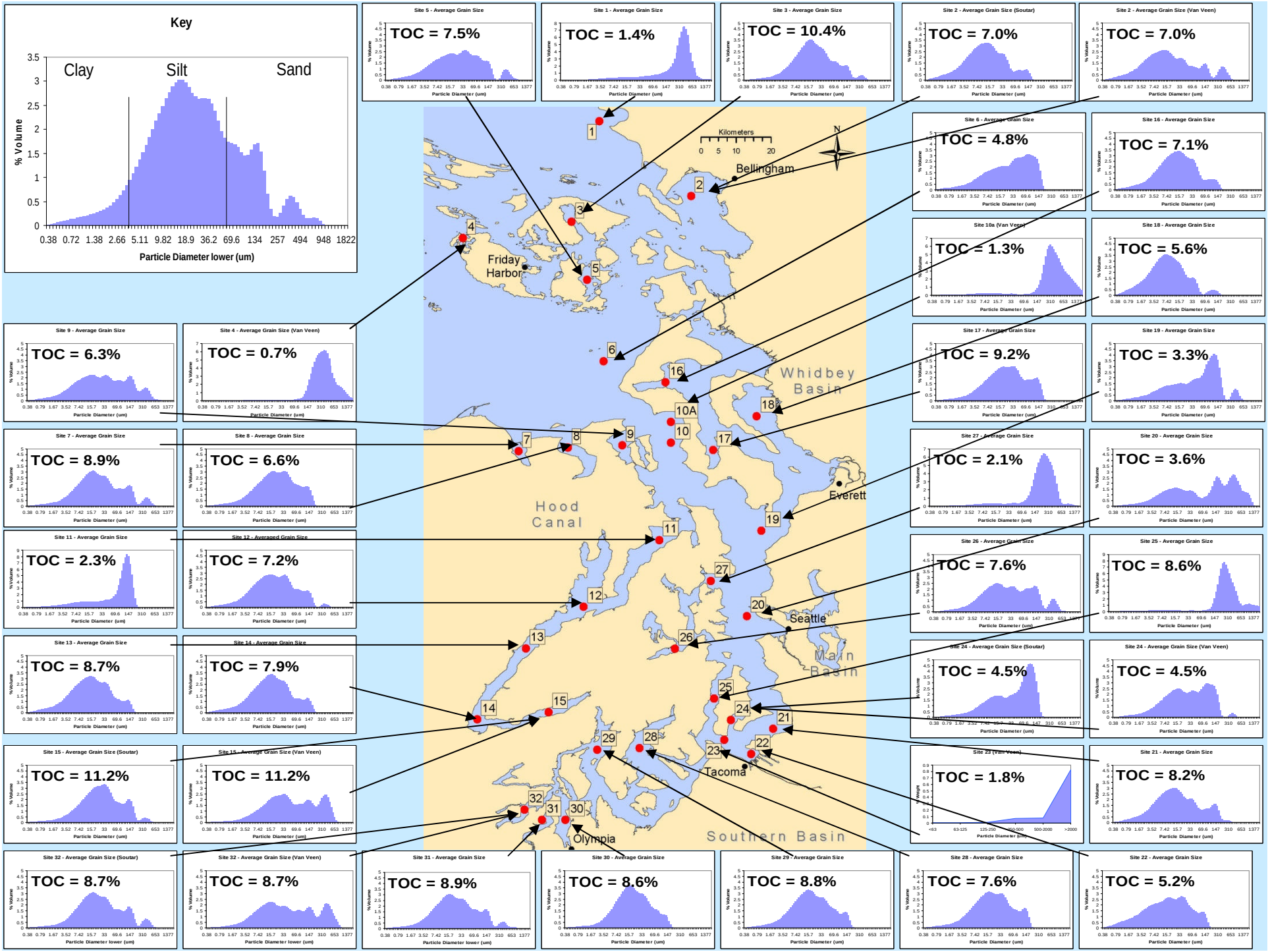
Trainer, V.L., B.L. Eberhardt, J.C. Wekell, N.G. Adams, L. Hanson, F. Cox, J. Dowell. 2003. Paralytic shellfish toxins in Puget Sound, Washington State J. Shellfish Res. 22:213-223.

Yamaguchi, M., I.I. Itakura and Y. Ishida. 1995. A rapid and precise technique for enumeration of resting cysts of *Alexandrium* spp. (Dinophyceae) in natural sediments. Phycologia 34:207-214.


Key
Clay
Silt
Sand
% Volume
Particle Diameter lower (um)
Site 5 - Average Grain Size
TOC = 7.5%
Site 1 - Average Grain Size
TOC = 1.4%
Site 3 - Average Grain Size
TOC = 10.4%
Site 2 - Average Grain Size (Soutar)
TOC = 7.0%
Site 2 - Average Grain Size (Van Veen)
TOC = 7.0%
Site 6 - Average Grain Size
TOC = 4.8%
Site 16 - Average Grain Size
TOC = 7.1%
Site 10a (Van Veen)
TOC = 1.3%
Site 18 - Average Grain Size
TOC = 5.6%
Site 9 - Average Grain Size
TOC = 6.3%
Site 4 - Average Grain Size (Van Veen)
TOC = 0.7%
Site 17 - Average Grain Size
TOC = 9.2%
Site 19 - Average Grain Size
TOC = 3.3%
Site 7 - Average Grain Size
TOC = 8.9%
Site 8 - Average Grain Size
TOC = 6.6%
Site 27 - Average Grain Size
TOC = 2.1%
Site 20 - Average Grain Size
TOC = 3.6%
Site 11 - Average Grain Size
TOC = 2.3%
Site 12 - Averaged Grain Size
TOC = 7.2%
Site 26 - Average Grain Size
TOC = 7.6%
Site 25 - Average Grain Size
TOC = 8.6%
Site 13 - Average Grain Size
TOC = 8.7%
Site 14 - Average Grain Size
TOC = 7.9%
Site 24 - Average Grain Size (Soutar)
TOC = 4.5%
Site 24 - Average Grain Size (Van Veen)
TOC = 4.5%
Site 15 - Average Grain Size (Soutar)
TOC = 11.2%
Site 15 - Average Grain Size (Van Veen)
TOC = 11.2%
Site 23 (Van Veen)
TOC = 1.8%
Site 21 - Average Grain Size
TOC = 8.2%
Site 32 - Average Grain Size (Soutar)
TOC = 8.7%
Site 32 - Average Grain Size (Van Veen)
TOC = 8.7%
Site 31 - Average Grain Size
TOC = 8.9%
Site 30 - Average Grain Size
TOC = 8.6%
Site 29 - Average Grain Size
TOC = 8.8%
Site 28 - Average Grain Size
TOC = 7.6%
Site 22 - Average Grain Size
TOC = 5.2%
Kilometers
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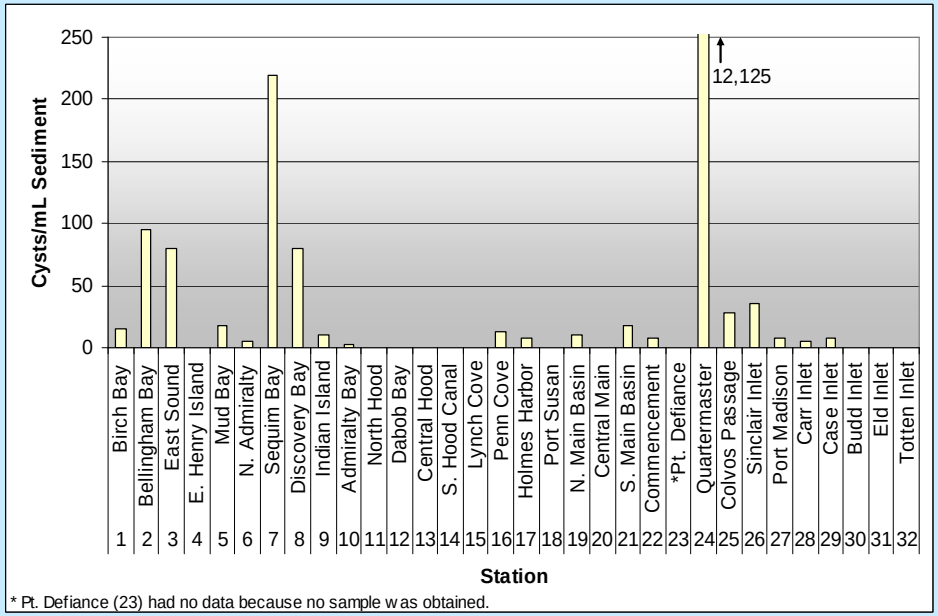
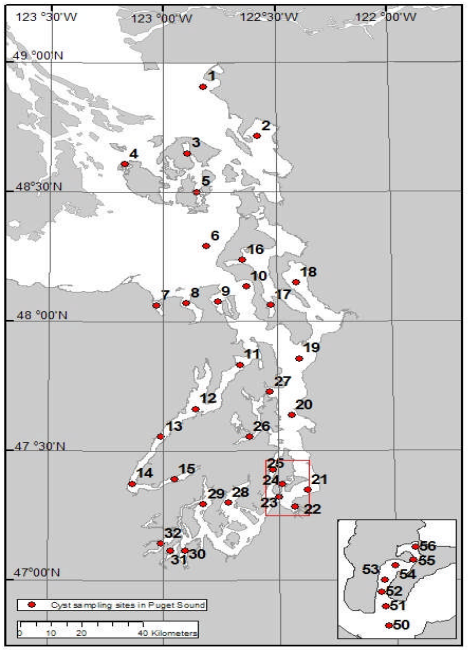
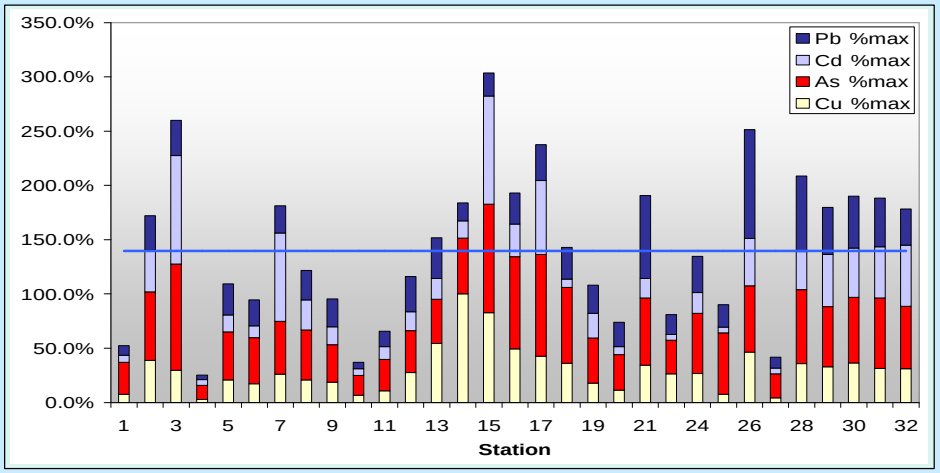
N
Bellingham
Friday Harbor
Whidbey Basin
Hood Canal
Everett
Seattle
Main Basin
Tacoma
Olympia
Southern Basin



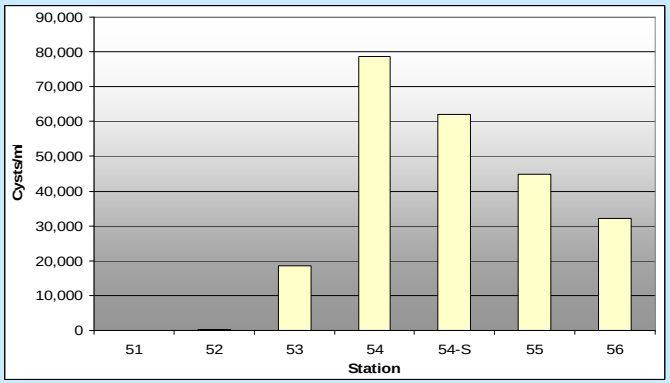
Surface cyst concentrations at all stations 2005.



Sampling stations



Cumulative toxic metal concentrations in surface sediments at all stations normalized to the maximum value found in 2005. Line is the South Puget Sound median metals value (DOE, 2002)



Surface cyst concentrations in Quartermaster Harbor 2006.

Spatial Results

Surface Distribution of *Alexandrium catenella* cysts in Puget Sound

• QMH (12,125 cysts/cm3) and Sequim Bay (220 cysts/cm3) had the two highest concentrations of cysts in surface sediments. No cysts in southern Hood Canal and some bays of South Sound.

• Highest surface sediment cyst concentrations in central QMH .

• Largest grain size occurred in more open areas with stronger currents and finer grain sediments with higher percent TOC were found in more protected areas.

• On the Puget Sound wide scale, there is no apparent correlation between cyst abundance and TOC or grain size, though there is a significant positive correlation with bottom water salinity, ammonia and sediment cadmium concentrations and negative correlation with bottom water phosphate and silicate. (Consistent with previous study in Sweden that showed a positive correlation of cyst abundance with increased stratification, total nitrogen, sediment mercury. The negative correlation is consistent with studies in Japan and Scotland and may indicate the inability of *A. catenella* to compete with diatoms for nutrients.)

• On the smaller basin scale in QMH, greater cyst abundances tended to be associated with finer grain sediments and greater percent TOC. Indicates patchiness of cyst distribution and that different factors may affect cyst abundance on different scales.

Temporal Results
Core Data

• Highest cyst abundance occurs in areas where PSP often occurs based on Washington State Department of Health shellfish monitoring data.

• Cysts were also found down core in many of the 32 sites sampled in the 2005 Puget Sound wide survey. With the exception of Quartermaster Harbor in central Puget Sound, cyst concentrations tended to be higher in the northern half of Puget Sound with consistent cyst presence extending to the bottom of the 20-40 cm long cores. Cyst presence down core in southern Puget Sound often dropped off to zero with depth. This pattern of sediment cyst abundance is consistent with the historical geographical distribution of PSP occurrences in Puget Sound from Washington State Department of Health shellfish monitoring data (Trainer *et al.*, 2003) which showed PSP occurring earlier and more frequently in northern Puget Sound.

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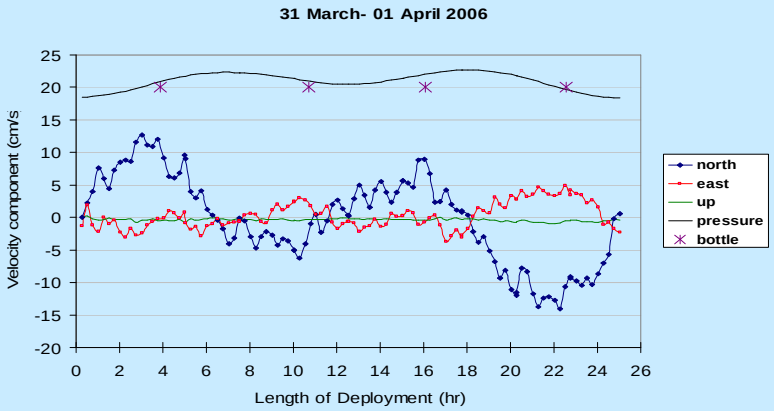
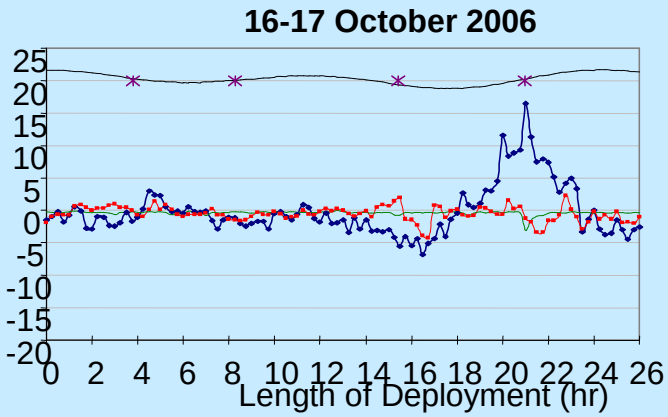
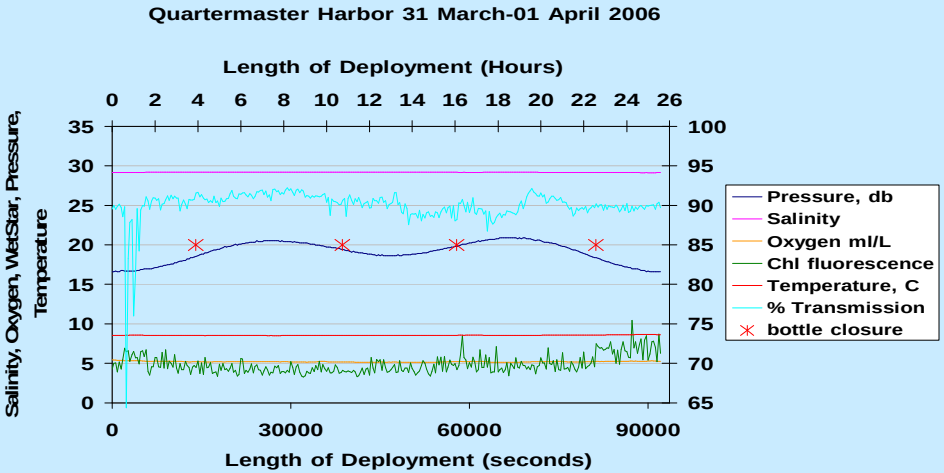
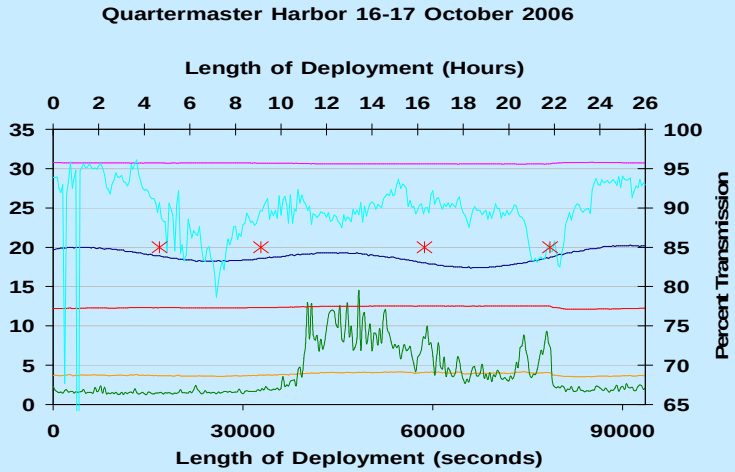
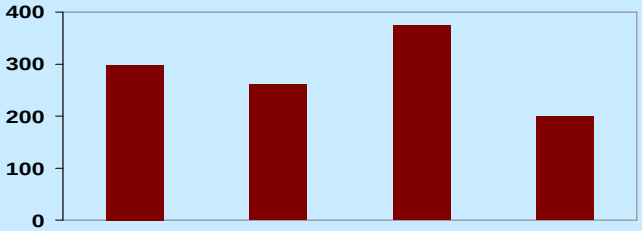

31 March- 01 April 2006
Velocity component (cm/s
Length of Deployment (hr)
north
east
up
pressure
bottle

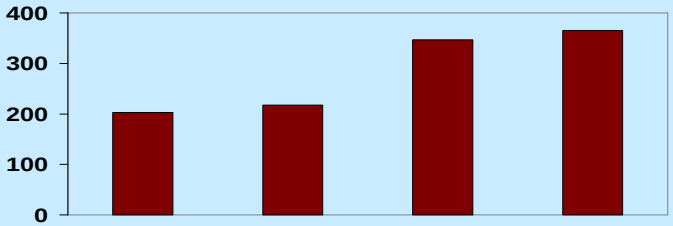

16-17 October 2006
Length of Deployment (hr)


Quartermaster Harbor 31 March-01 April 2006
Length of Deployment (Hours)
Salinity, Oxygen, WetStar, Pressure, Temperature
Length of Deployment (seconds)
Pressure, db
Salinity
Oxygen ml/L
Chl fluorescence
Temperature, C
% Transmission
bottle closure


Quartermaster Harbor 16-17 October 2006
Length of Deployment (Hours)
Percent Transmission
Length of Deployment (seconds)

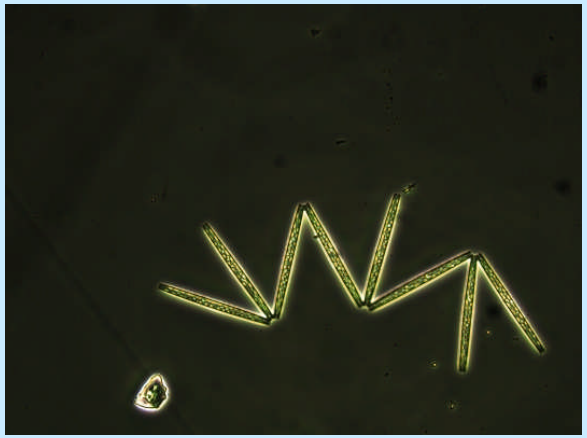


cysts/mL



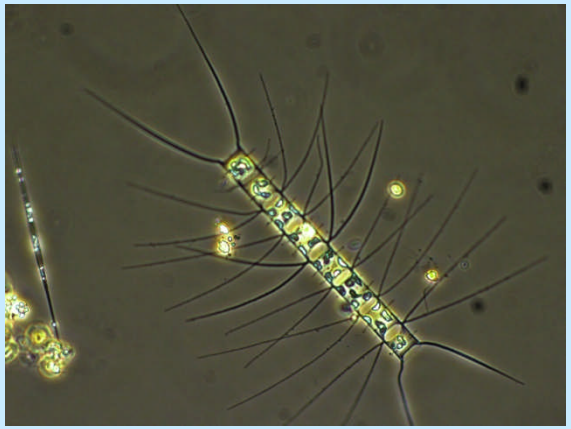
Dominant Phytoplankton by Month

FEB & SEPT



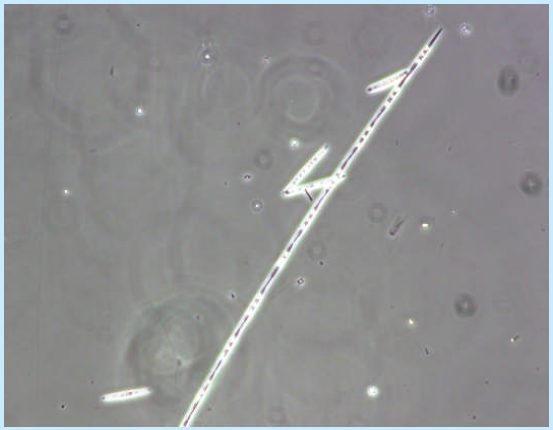
Thalassionema

APRIL -SEPT



Chaetoceros

AUG



Pseudo-nitzschia

June – *Ditylum brightwelli*

August - *Alexandrium*

Dinoflagelletes – prevalent in summer

Lots of Zooplankton in April & August

JULY-AUG

Ceratium fusus