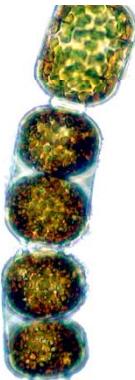
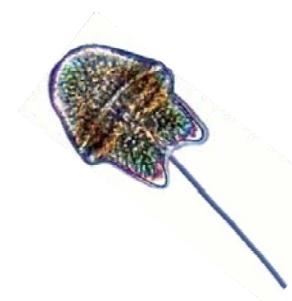


# San Francisco Bay Water Quality: Lessons Learned from Four Decades of USGS Observations



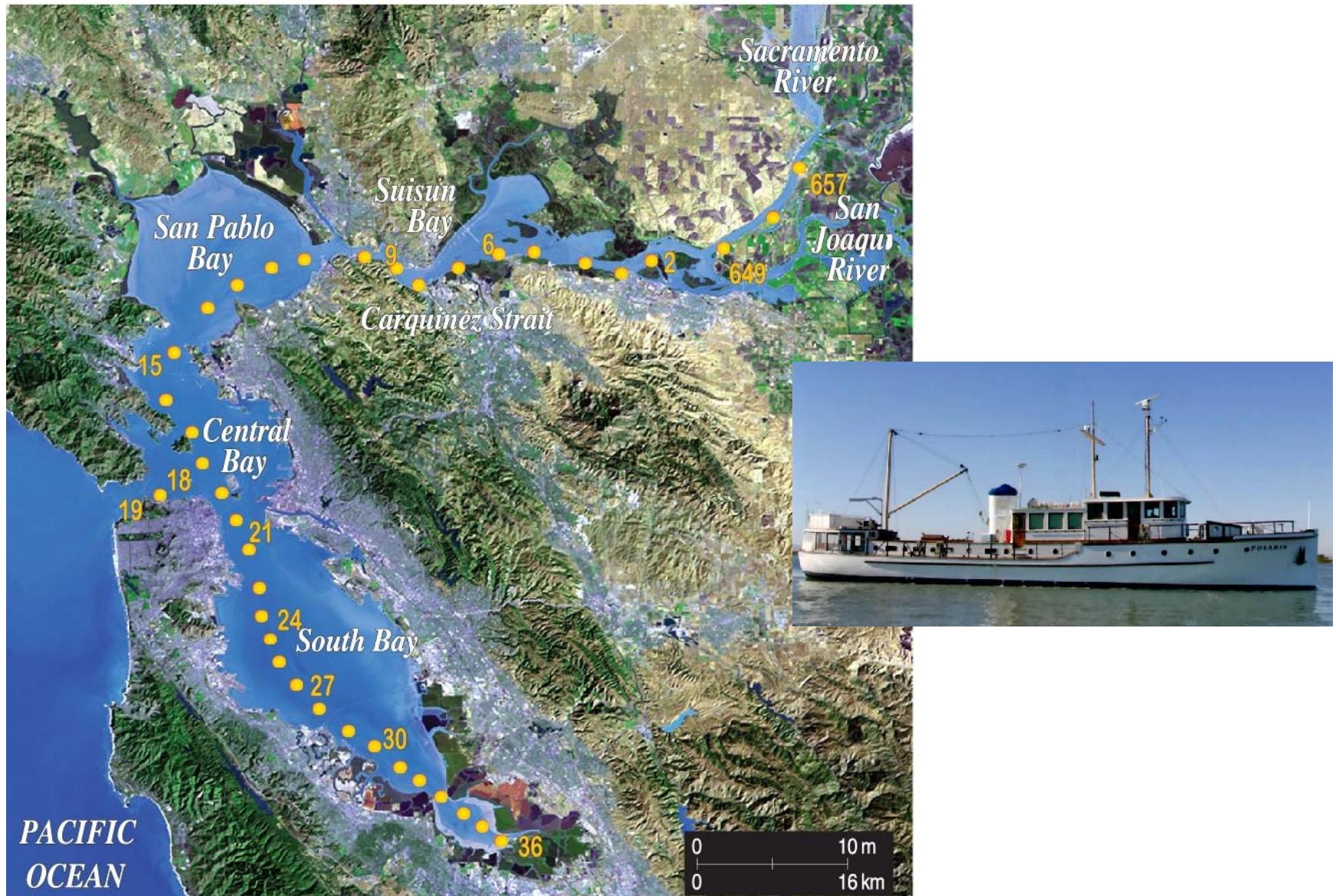
Tara Schraga, James Cloern, Sarah Foster, Caitrin Phillips

U.S. Geological Survey, Menlo Park, California



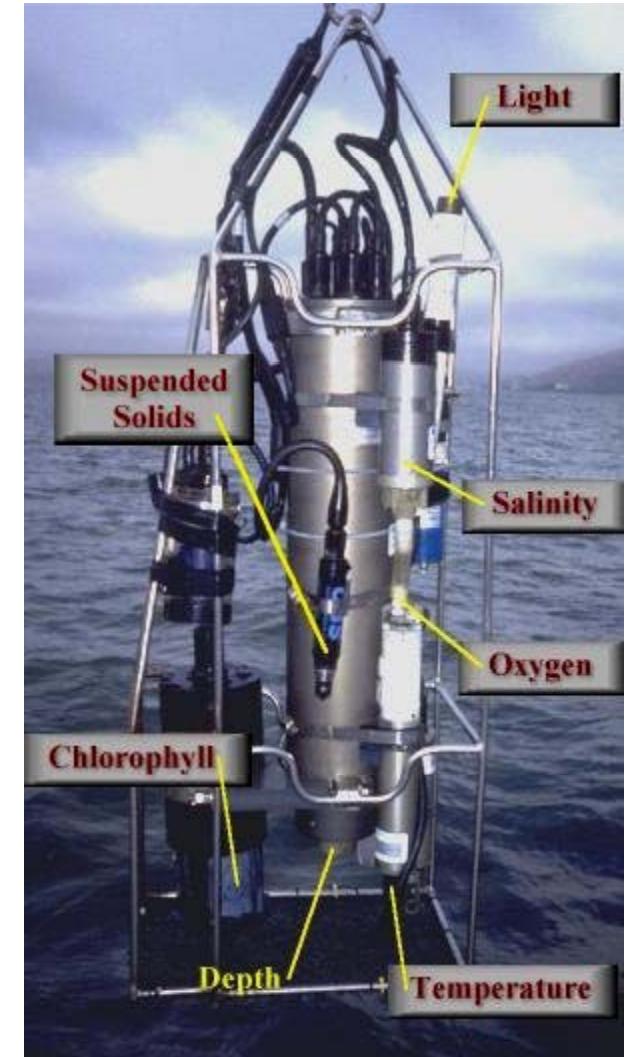
## USGS Monitoring of Water Quality in San Francisco Bay

<http://sfbay.wr.usgs.gov/access/wqdata/>



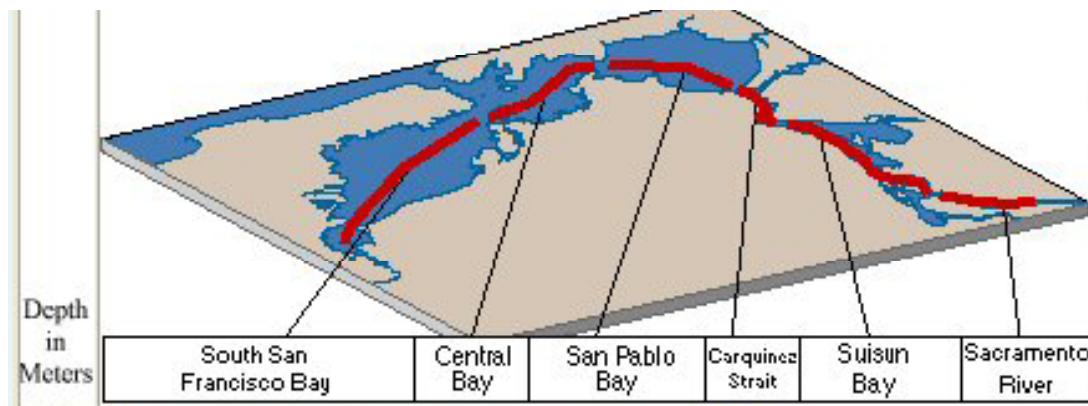
# What we measure on our cruises:

- Salinity
- Temperature
- Dissolved oxygen
- Chlorophyll *a* + fluorescence
- Suspended particulate matter + optical backscatter
- Photosynthetically active radiation (PAR) and light attenuation
- Dissolved inorganic nutrients ( $\text{NH}_4$ ,  $\text{NO}_3\text{2}$ ,  $\text{PO}_4$ ,  $\text{SiO}$ )
- Phytoplankton species composition



Submersible sensor package

# Online Data Visualization



**Cruise Date:** May 9, 2006

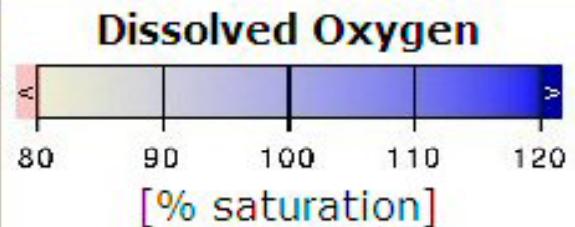
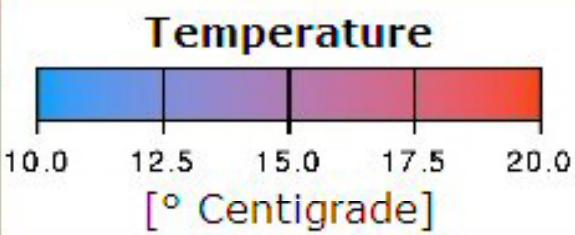
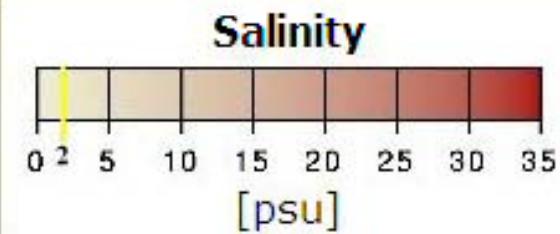
**Data Table**    **Cruise Notes**

**Cruises:** [Previous](#) | [Subsequent](#)

**Zoom:** [Full Bay](#)

**Scales:** [Dynamic](#)

[Choose another 2006 cruise](#)    [Help](#)



# Online Database – 41 years of monitoring data

**1. Columns to Show:**

Date (MM/DD/YYYY)  
 Julian Date (YYYYDDD)  
 Days since 01/01/1990  
 Decimal Date  
 Time of Day

---

Station Number  
 Distance from Station 36  
 Depth

---

Discrete Chlorophyll  
 Chlorophyll a/a+PHA ratio  
 Fluorescence  
 Calculated Chlorophyll  
 Discrete Oxygen  
 Oxygen electrode output  
 Oxygen Saturation %  
 Calculated Oxygen  
 Discrete SPM  
 Optical Backscatter  
 Calculated SPM  
 Measured Extinction Coeff  
 Calculated Extinction Coeff  
 Salinity  
 Temperature  
 Sigma-t  
 Nitrite       Phosphate  
 Nitrate+Nitrite  Silicate  
 Ammonium

**2. Refine Your Search:**

|             |                 |      |   |
|-------------|-----------------|------|---|
| Year (YYYY) | =               | 2009 |   |
| AND         | Depth           | =    | 2 |
| AND         | Optional Choice | >    |   |

---

**3. Sort By:**

Ascending?

Primary Field: Date & Time

Secondary Field: None

Tertiary Field: None

---

**4. Table format:** HTML

Show table of selected parameters  
 Calculate avg/min/max statistics for output

Number of output lines per page: 1000

5.

User- configurable and publically accessible!



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## Water Quality of San Francisco Bay

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### Database Query Results

Constructing Query...Querying database...Retrieving Row [601]...Query Complete.

**Refinements:** Year = 2009

Depth = 2

**Sorting:** Date & Time (ascending)

| Date<br>MM/DD/YYYY | Time<br>24 hr. | Station Number | Depth<br>[meters] | Calculated Chlorophyll<br>[mg/m <sup>3</sup> ] | Salinity<br>[psu] |
|--------------------|----------------|----------------|-------------------|--|-------------------|
| 1/13/2009          | 0629           | 36.0           | 2.0               | 6.6  | 25.93             |
| 1/13/2009          | 0639           | 35.0           | 2.0               | 6.5  | 26.26             |
| 1/13/2009          | 0652           | 34.0           | 2.0               | 5.6  | 26.46             |
| 1/13/2009          | 0704           | 33.0           | 2.0               | 4.9  | 27.66             |
| 1/13/2009          | 0712           | 32.0           | 2.0               | 4.5  | 28.04             |
| 1/13/2009          | 0724           | 31.0           | 2.0               | 4.0  | 28.65             |
| 1/13/2009          | 0742           | 30.0           | 2.0               | 3.7  | 29.50             |
| 1/13/2009          | 0754           | 29.5           | 2.0               | 2.8  | 29.68             |
| 1/13/2009          | 0807           | 29.0           | 2.0               | 2.6  | 29.87             |
| 1/13/2009          | 0820           | 28.0           | 2.0               | 2.4  | 30.26             |
| 1/13/2009          | 0833           | 27.0           | 2.0               | 2.4  | 30.42             |
| 1/13/2009          | 0846           | 26.0           | 2.0               | 2.4  | 30.37             |
| 1/13/2009          | 0904           | 25.0           | 2.0               | 2.5  | 30.22             |
| 1/13/2009          | 0920           | 24.0           | 2.0               | 2.6  | 29.96             |
| 1/13/2009          | 0936           | 23.0           | 2.0               | 2.7  | 29.73             |
| 1/13/2009          | 0959           | 22.0           | 2.0               | 2.2  | 29.85             |
| 1/13/2009          | 1013           | 21.0           | 2.0               | 2.4  | 30.11             |
| 1/13/2009          | 1039           | 20.0           | 2.0               | 1.6  | 30.69             |

## Who else uses these data?

- In 2009 we had **234,498** website hits  
**(avg day = 641 hits)**  
and **6,382** database queries  
**(avg day = 17 queries)**

\* These numbers exclude known web crawlers\*

- Organizations and institutions such as schools, universities, government agencies, military, non-profit groups, environmental consultants from **over 36 countries**

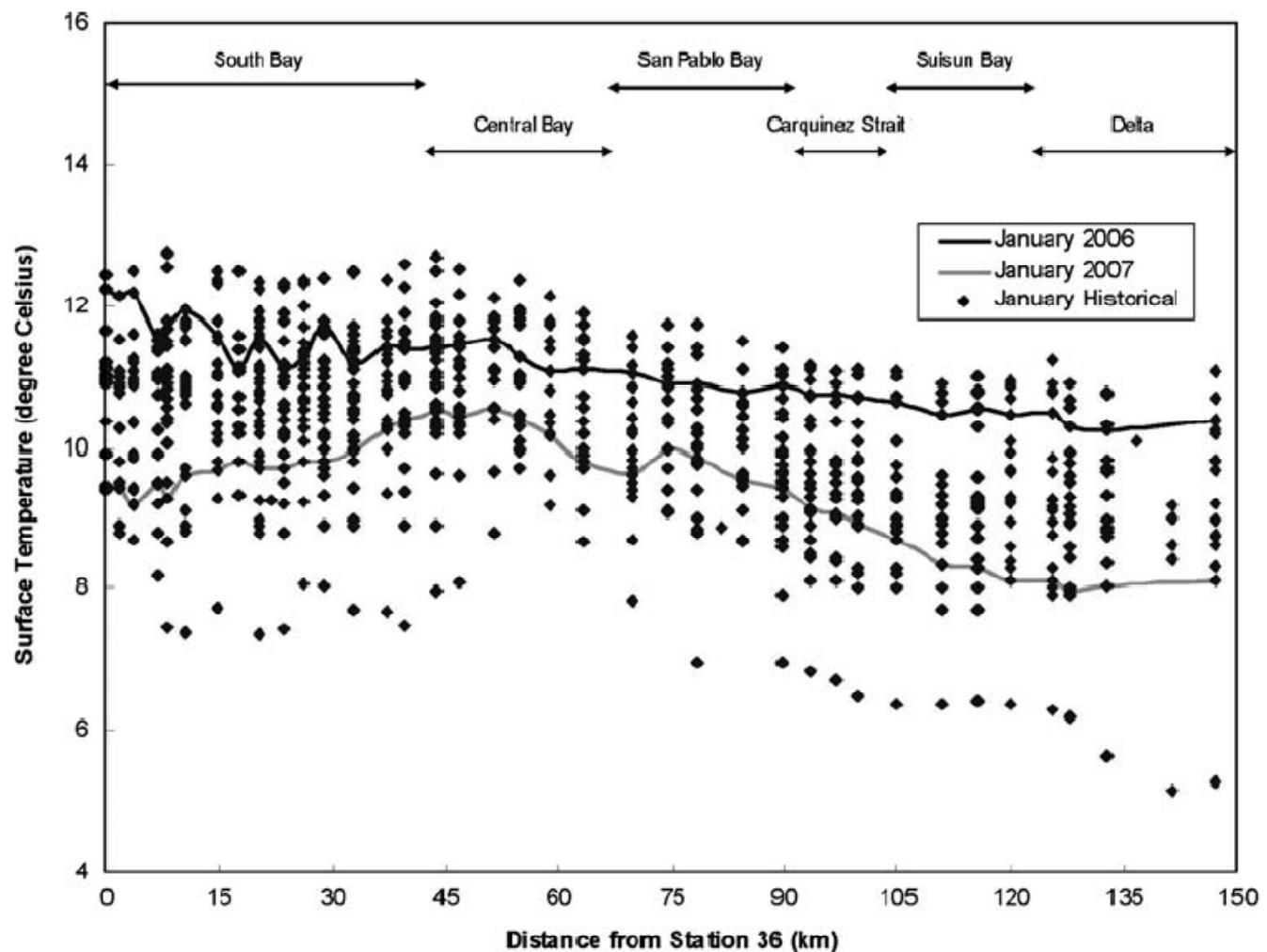


|                       |
|-----------------------|
| .fr (France)          |
| .jp (Japan)           |
| .au (Australia)       |
| .de (Germany)         |
| .uk (United Kingdom)  |
| .ca (Canada)          |
| .us (United States)   |
| .dk (Denmark)         |
| .it (Italy)           |
| .ru (Russia)          |
| .id (Indonesia)       |
| .nl (Netherlands)     |
| .sa (Saudi Arabia)    |
| .pl (Poland)          |
| .ie (Ireland)         |
| .pt (Portugal)        |
| .br (Brazil)          |
| .mx (Mexico)          |
| .ch (Switzerland)     |
| .es (Spain)           |
| .be (Belgium)         |
| .cn (China)           |
| .se (Sweden)          |
| .sg (Singapore)       |
| .in (India)           |
| .tr (Turkey)          |
| .nz (New Zealand)     |
| .ro (Romania)         |
| .za (South Africa)    |
| .no (Norway)          |
| [domain not given]    |
| .il (Israel)          |
| .tw (Taiwan)          |
| .ar (Argentina)       |
| .gr (Greece)          |
| .th (Thailand)        |
| .info (Informational) |
| .at (Austria)         |

# Teaching Estuarine Hydrology with Online Data

David H. Schoellhamer

Fig. 3 July 2006, July 2007, and historical July surface temperatures in the San Francisco Estuary (Yang 2007). Data were obtained from <http://sfbay.wr.usgs.gov/access/wqdata/>

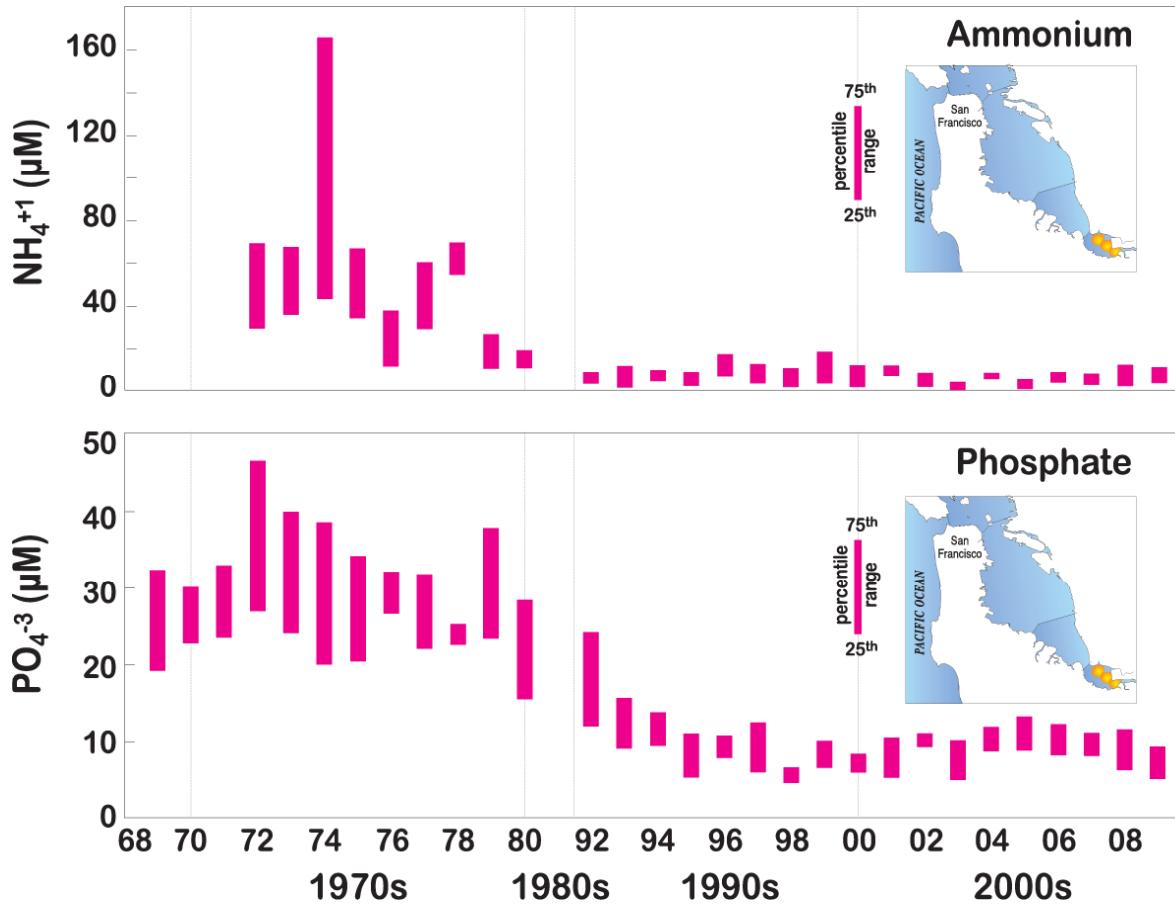


The National WQ Monitoring Network supports these critical monitoring elements:

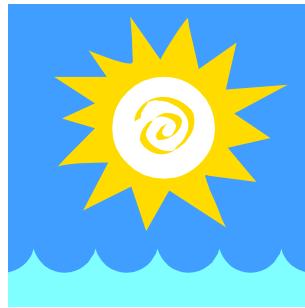
- Routine analysis of dissolved inorganic nutrients ( $\text{NH}_4$ ,  $\text{NO}_{32}$ ,  $\text{PO}_4$ ,  $\text{SiO}$ )
- Identification of phytoplankton community composition (species level density and biovolume)



# Some lessons learned from this dataset



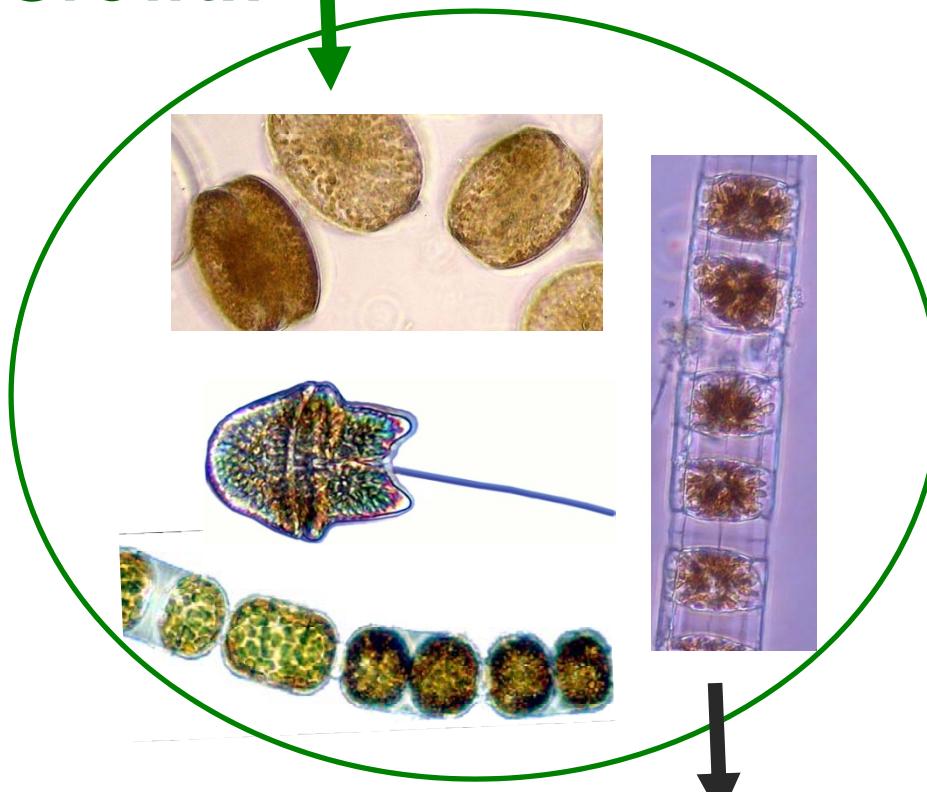
High nutrient concentrations - so why doesn't the Bay have excessive phytoplankton growth?



+

Nitrogen  
Phosphorus

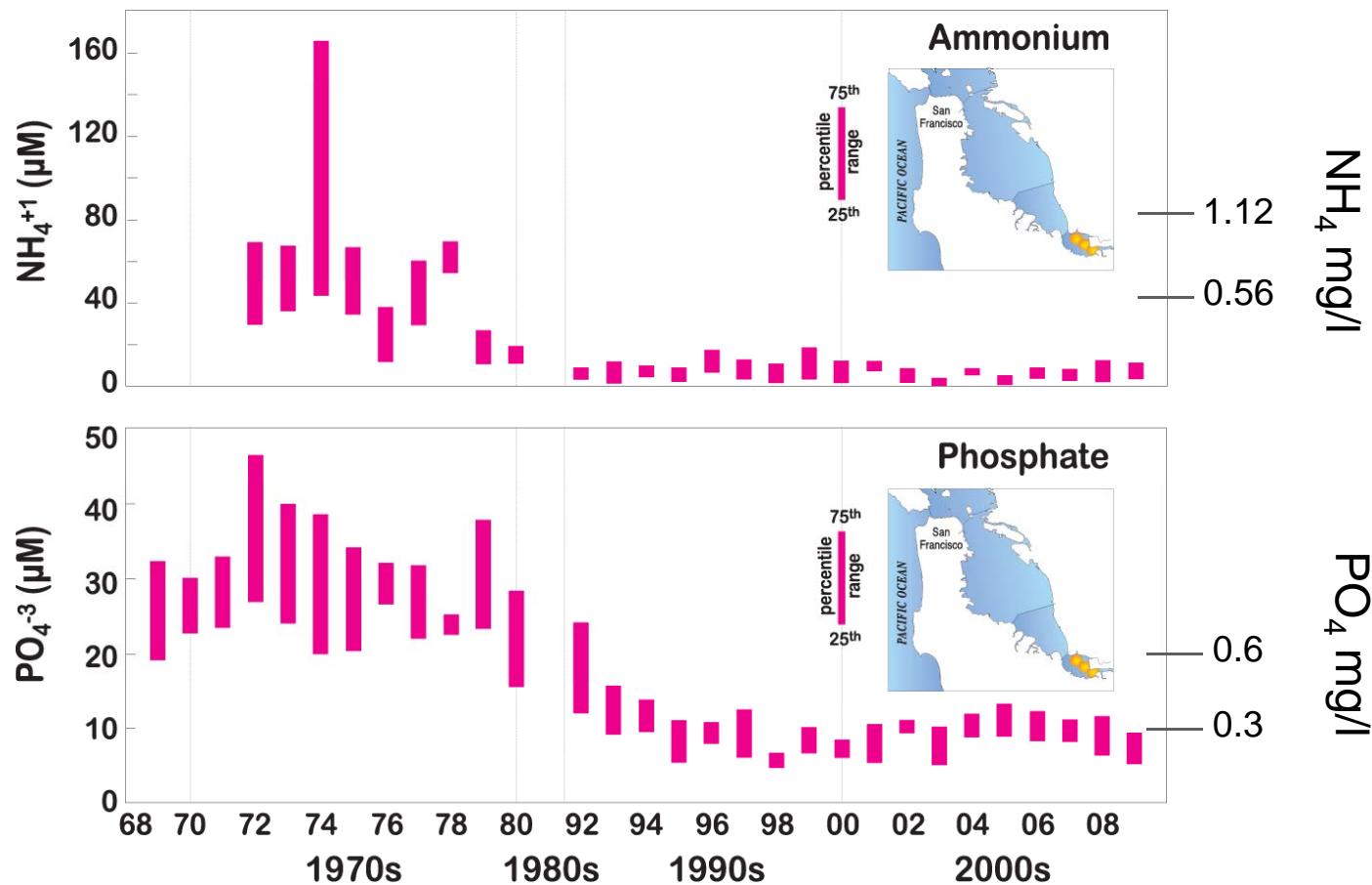
= **Growth**



**Clam  
grazing**

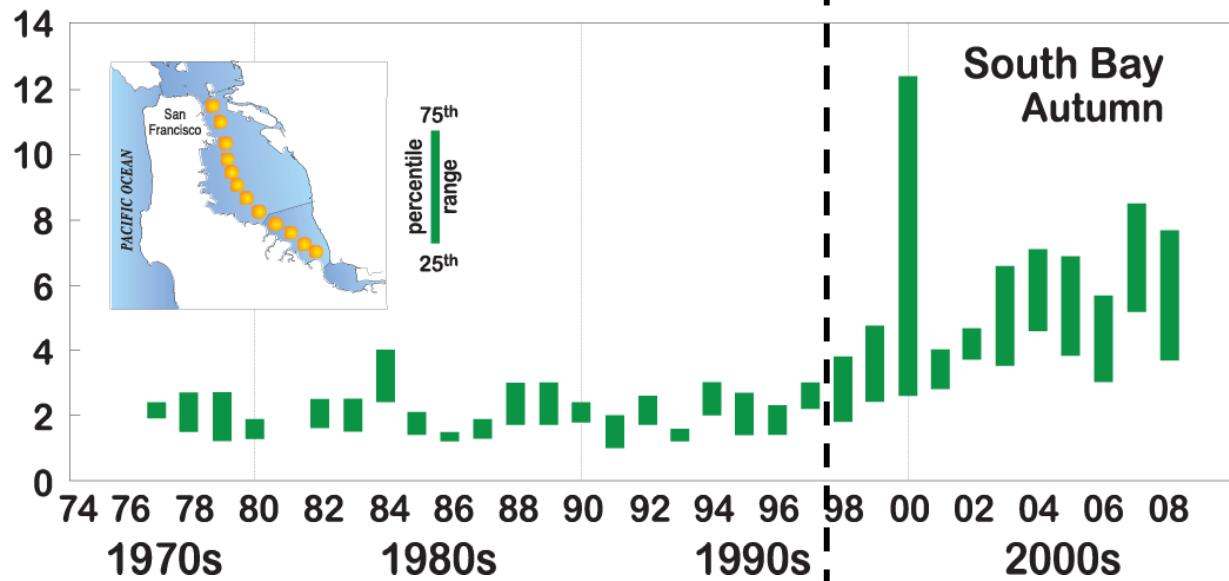
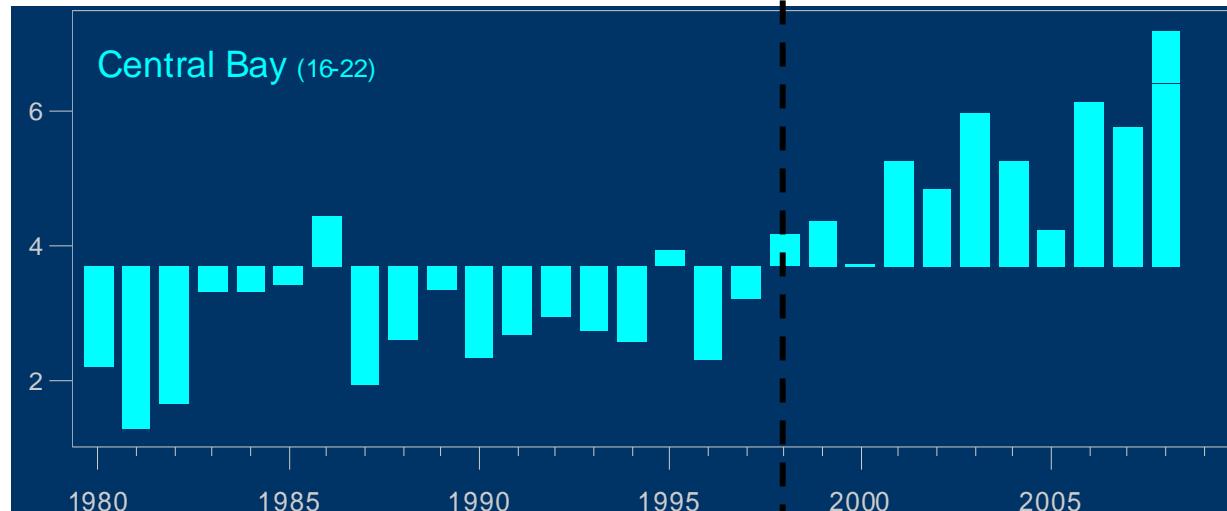


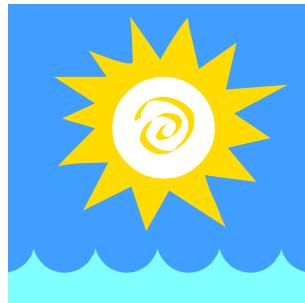
Since phytoplankton growth was limited by other factors, there was never a compelling reason to regulate N + P



# Chl-a increasing since 1998-99!

Annual Chlorophyll a ( $\mu\text{g/l}$ )



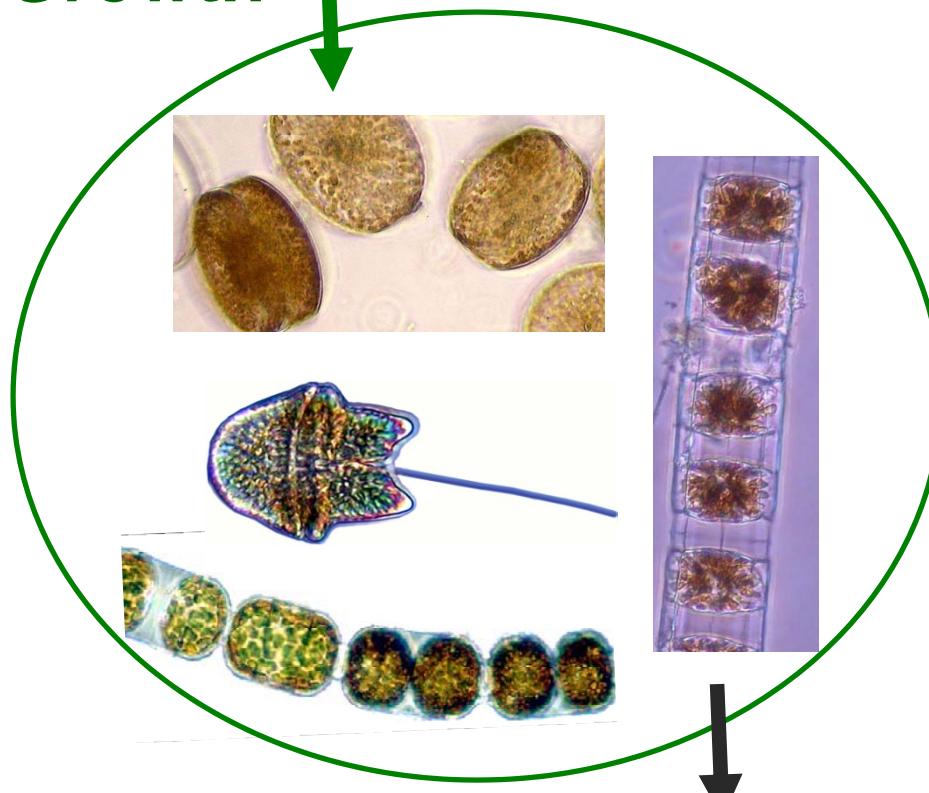


+

Nitrogen  
Phosphorus

= Growth

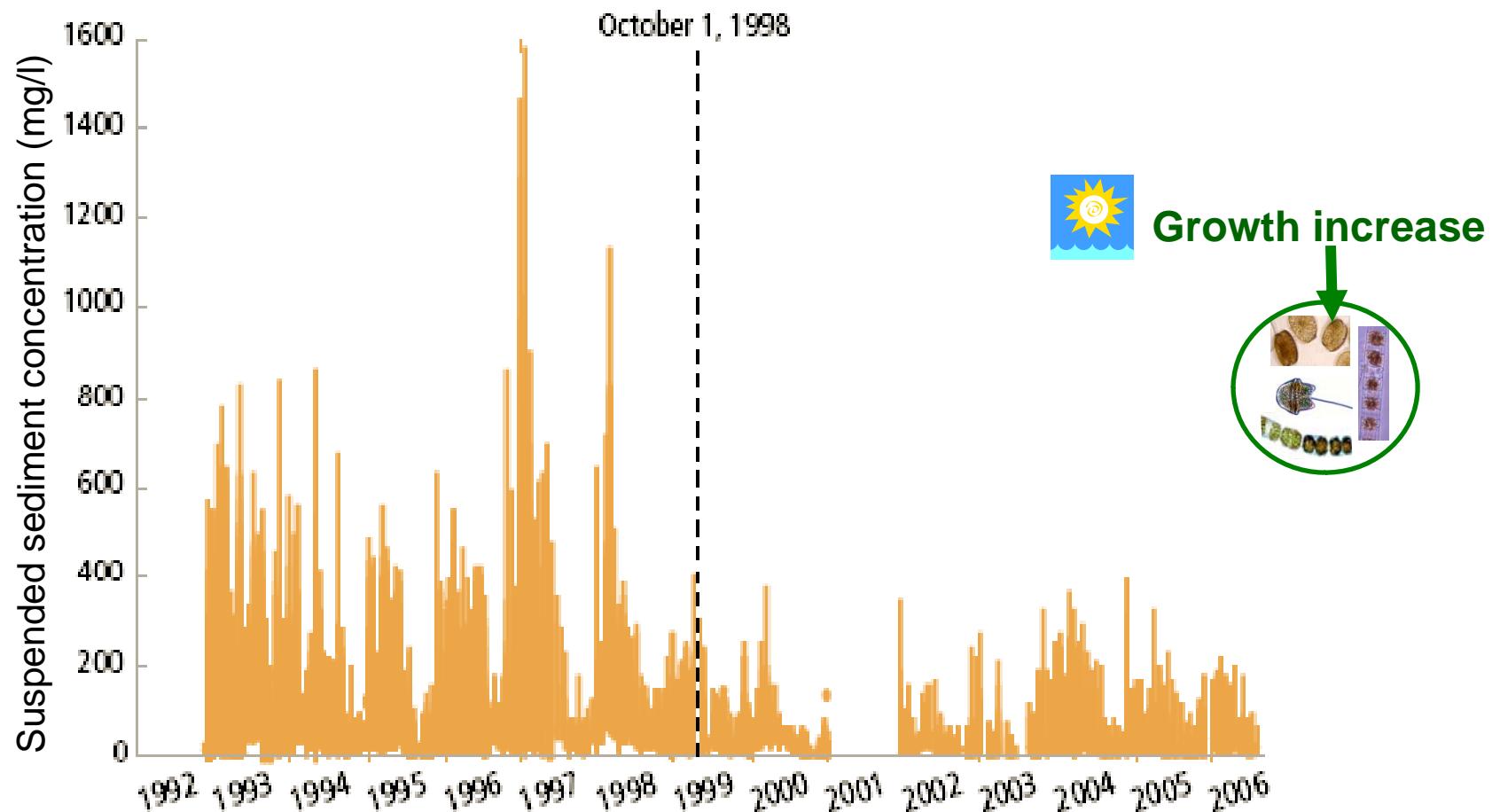
## Why is Chl-a increasing?



Clam  
grazing



**Water clarity increased due to the 40% decrease in suspended sediments**

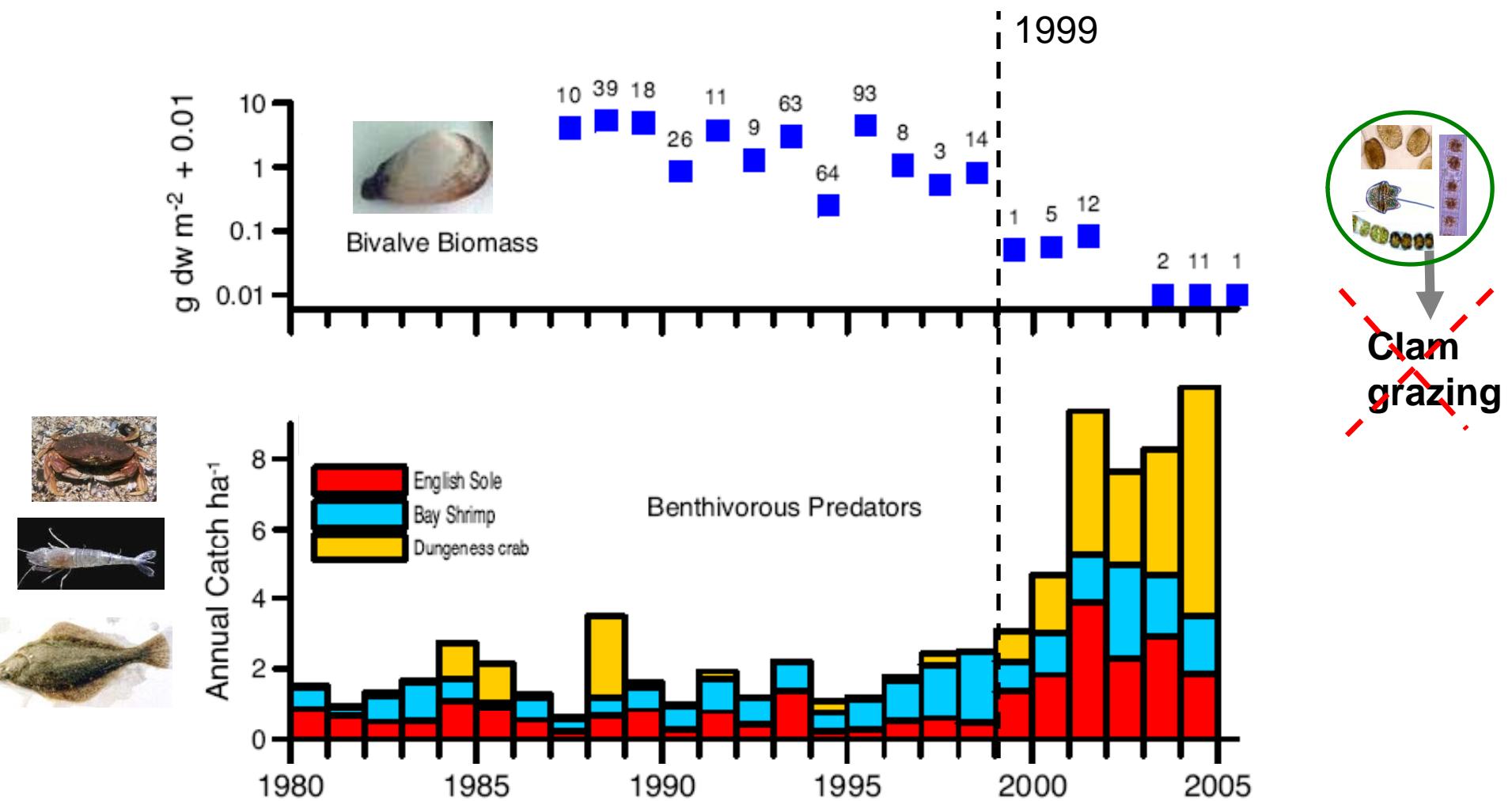


Dave is also funded by  
the NMN, see his talk  
today at 1:25pm room 17

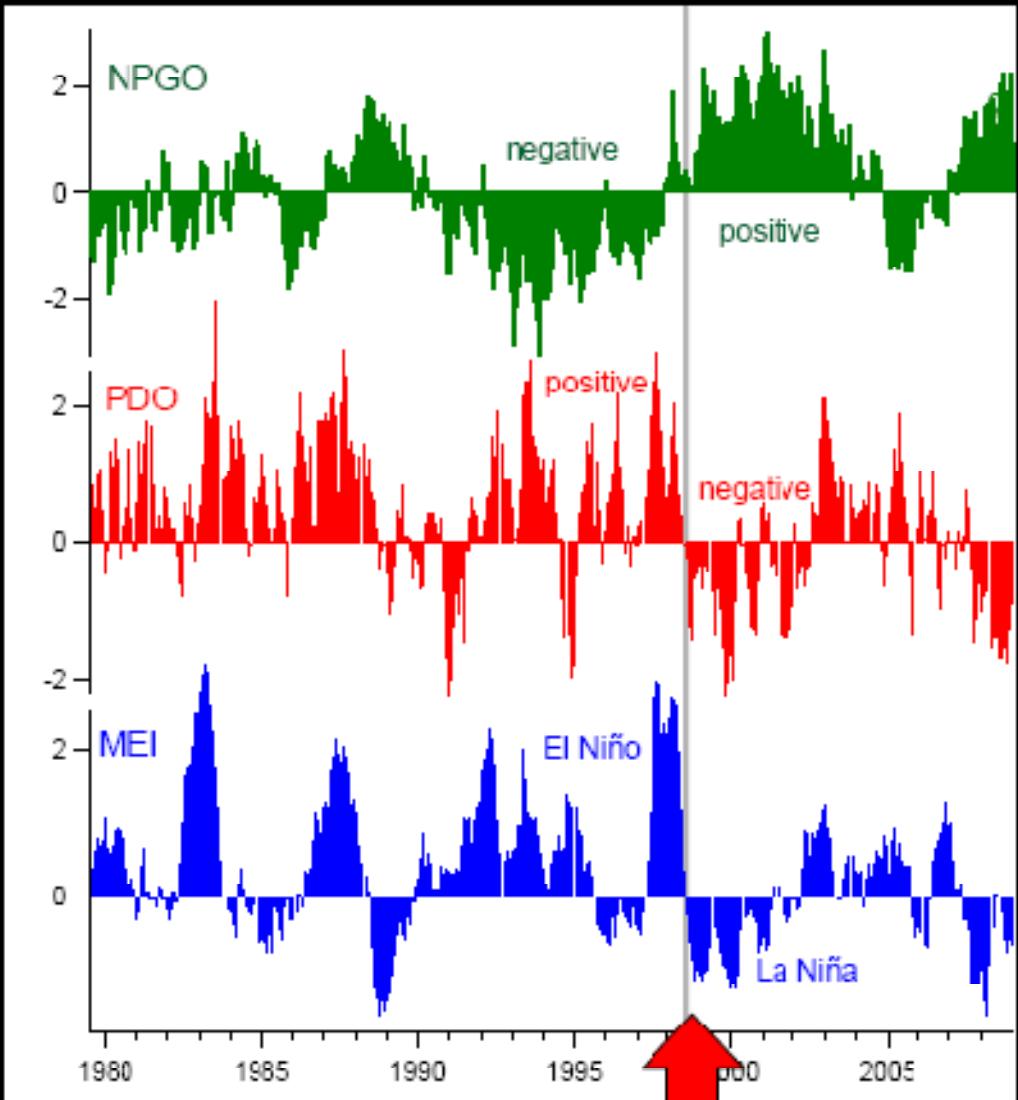
"The increase in Bay water clarity is likely to persist"

From: Schoellhamer, D.H., 2009, Suspended Sediment in the Bay: Past a Tipping Point. 2009 The Pulse of the Estuary. San Francisco Estuary Institute. <http://www.sfei.org/rmp/pulse/2006/index.html>

## Decreased Clam Grazing (ie, the predator of my consumer is my ally)



From: Cloern, J.E., A.D. Jassby, J.K. Thompson, K. Hieb. 2007. A cold phase of the East Pacific triggers new phytoplankton blooms in San Francisco Bay. *Proceedings of the National Academy of Sciences of the United States of America* 104(47):18561-18656. <http://www.pnas.org/content/104/47/18561.full.pdf+html>



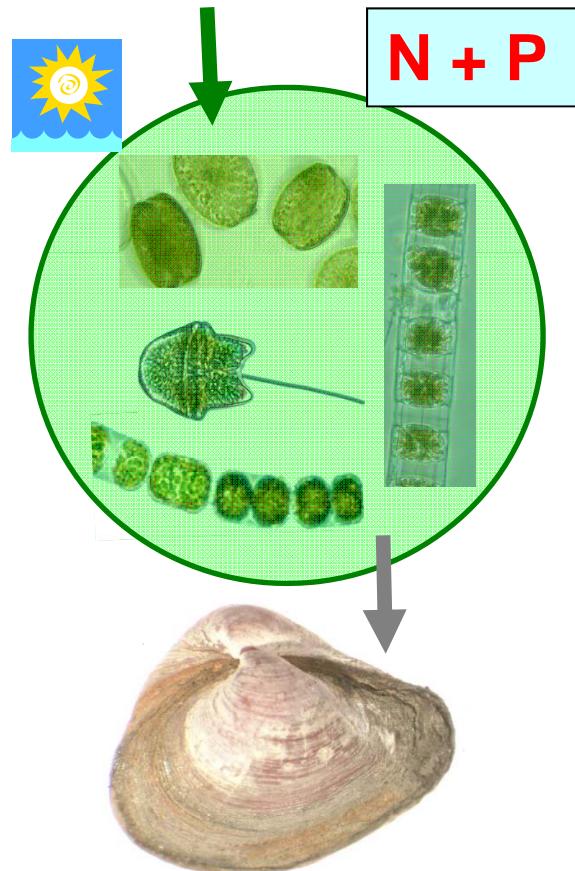
North Pacific Gyre Oscillation  
flipped from negative to  
positive

Pacific Decadal Oscillation  
flipped from positive to  
negative

Multivariate ENSO Index  
flipped from positive to  
negative

# Then

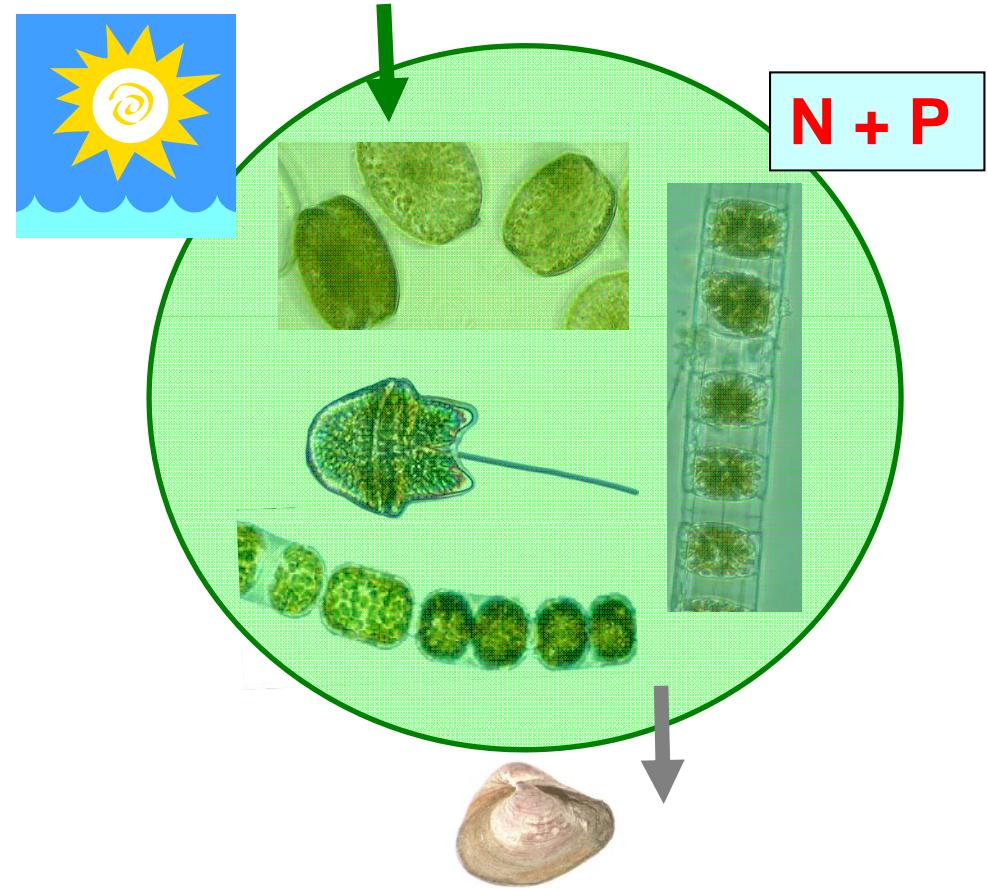
Higher turbidity/less light,  
**lower phyto growth**



Higher clam grazing rates,  
**lower phyto growth**

# Now

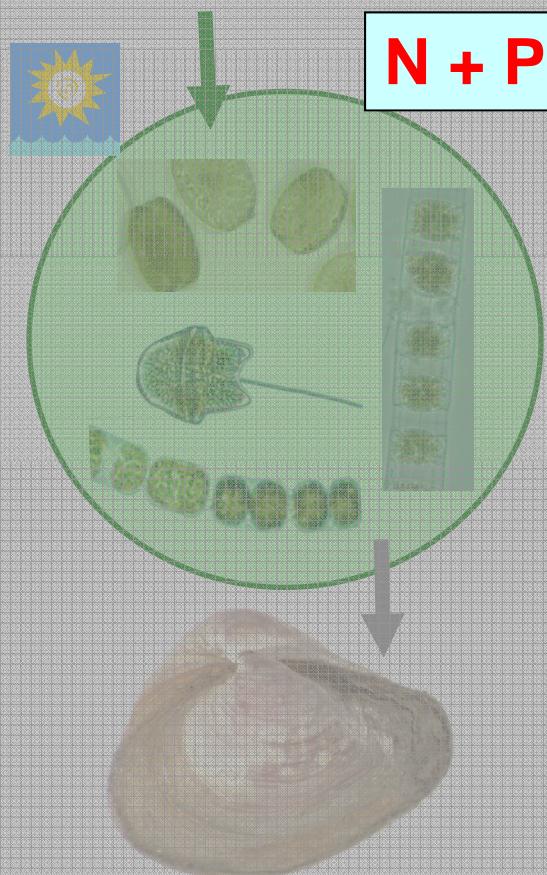
Lower turbidity/ more light,  
**higher phyto growth**



Lower clam grazing rates,  
**higher phyto growth**

# Then

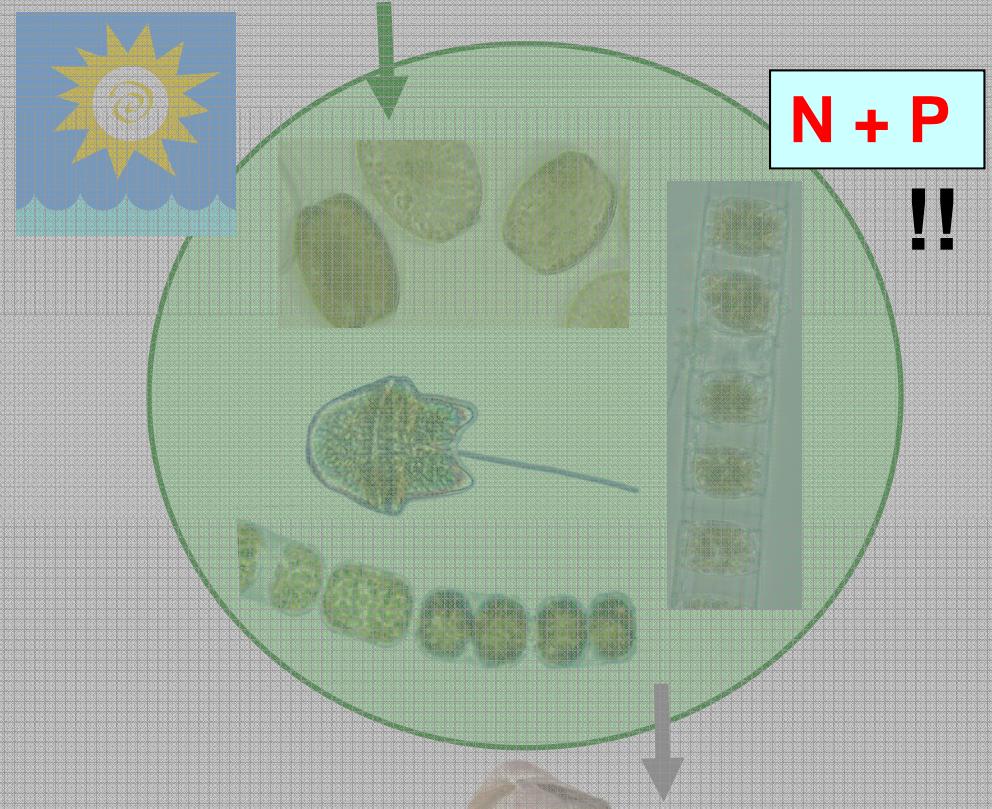
Higher turbidity/less light,  
lower phyto growth



Higher clam grazing rates,  
lower phyto growth

# Now

Lower turbidity/ more light,  
higher phyto growth



Lower clam grazing rates,  
higher phyto growth



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## Water Quality of San Francisco Bay

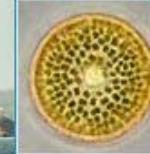
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[Project Overview](#)



[Long-term Data Visualization](#)



[Query Data 1969-present](#)



[X-Y Scatter Plots](#)



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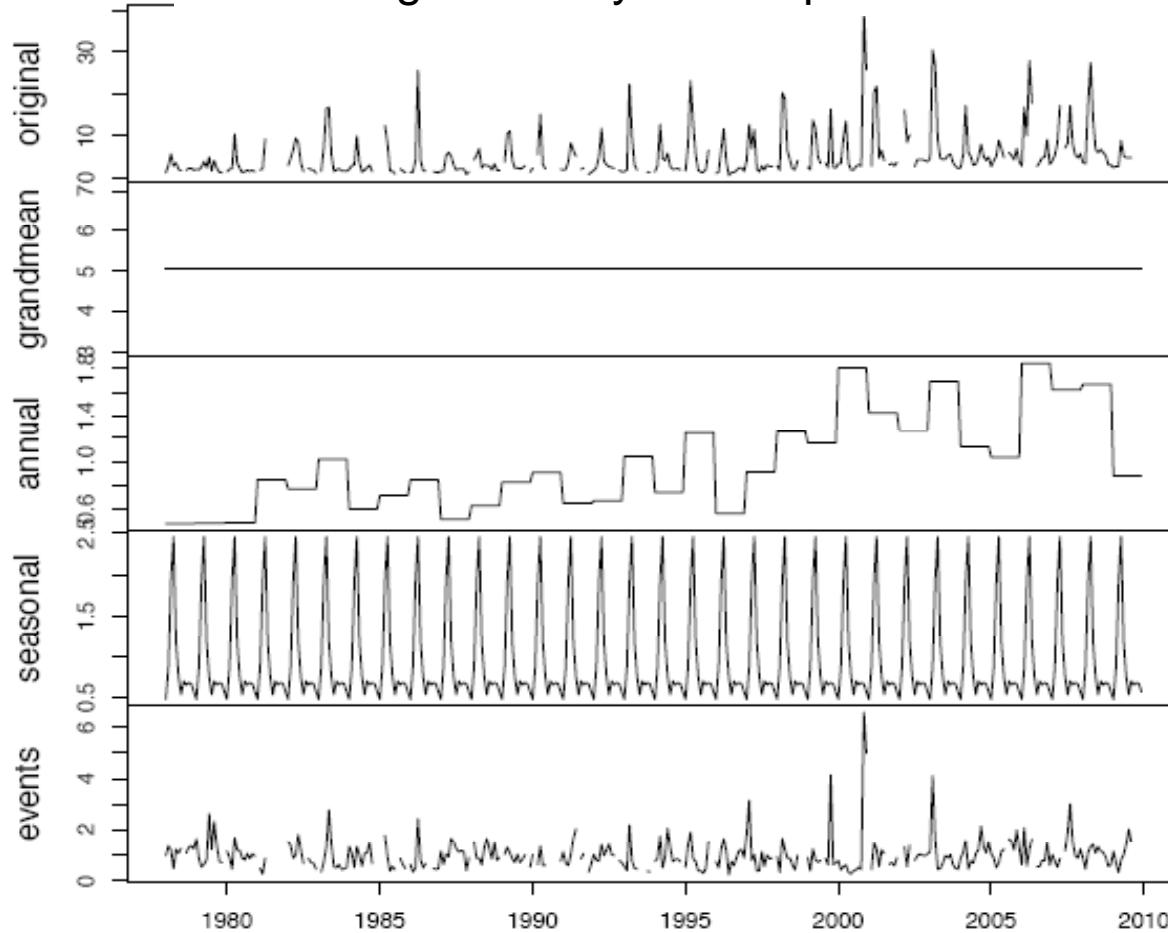
URL: <http://sfbay.wr.usgs.gov/access/wqdata/>

Page Contact Information: [tschraga@usgs.gov](mailto:tschraga@usgs.gov)



## A Statistical Toolbox for YOUR Monitoring Data

Visualizing variability at multiple scales



**“Ultimately, the package direction will be driven by the needs of people actually using it. Suggestions for revisions and additions are welcome”**

### Exploring water quality monitoring data

An R environment statistical package and reference manual by Alan Jassby and James Cloern (2009) <http://cran.r-project.org/web/packages/wq/>

\* see me for printouts of these references and links \*

We acknowledge the many individuals and groups who contributed to the San Francisco Bay monitoring program since 1969. You can read a little about the scientists and research vessel crew here:

<http://sfbay.wr.usgs.gov/access/wqdata/overview/people/>

- **Water Quality of San Francisco Bay website**

<http://sfbay.wr.usgs.gov/access/wqdata/>

- **Bibliography of SF Bay research** <http://137.227.239.52/publications.html>

- **R statistical package and reference manual**

<http://cran.r-project.org/web/packages/wq/>

- **The Pulse of the Estuary (years 2006 and 2009)**

<http://www.sfei.org/rmp/pulse/>

- **Schoellhamer, D. 2009. Teaching estuarine hydrology with online data. *Estuaries and Coasts* 32:1069-1078**

- **Cloern, J.E., A.D. Jassby, J.K. Thompson, K. Hieb. 2007. A cold phase of the East Pacific triggers new phytoplankton blooms in San Francisco Bay. *Proceedings of the National Academy of Sciences* 104(47):18561-18656.**

<http://www.pnas.org/content/104/47/18561.full.pdf+html>