

Nutrients – How did we get here and where are we going?

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Regulatory Context

- Clean Water Act – Beneficial Uses
- Point Sources – Advanced Treatment



Effects of Harmful Algal Blooms



- Deplete oxygen
- Toxins
- Reduce light penetration
- Unnatural foam
- Aesthetics / Odor
- Loss of aquatic habitat (SAV)
- Changes in community structure
- Etc.

Beneficial Uses Affected

- Water Contact Recreation
- Commercial Fishing
- Municipal Water Supply
- Coldwater Habitat
- Warmwater Habitat
- Rare & Endangered Species
- Wildlife
- Etc.





Recreational Water Contact

- Multiple pathways
- Dermal irritation, GI, liver toxicity, ALS-like
- Pets

Fisheries

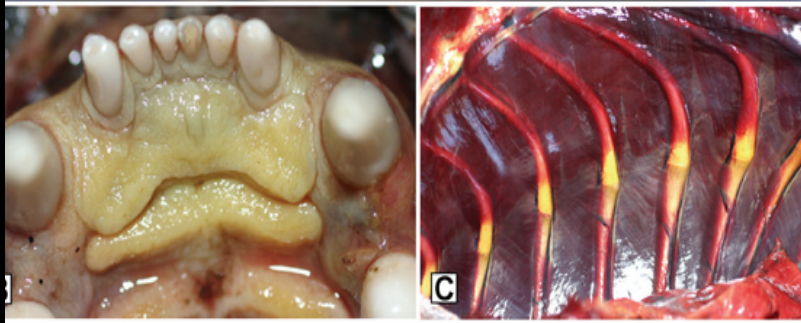
- Disruption of food webs
- Lowered DO
- Toxins





Sensitive Species

- Pelagic Organism Decline (POD)
- Avian species
- Southern sea otter





Sources of Nutrients

- Natural sources
- Anthropogenic sources
 - Agriculture
 - POTWs
 - Urban runoff

Nutrient sources that fuel microalgae

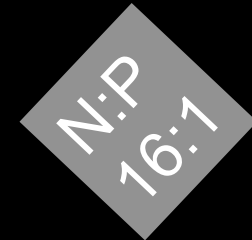
INORGANIC SOURCES:

Ammonium (NH_4^+)

Nitrate/Nitrite ($\text{NO}_3^-/\text{NO}_2^-$)

Phosphate (PO_4^{3-})

Silicate (Dsi)

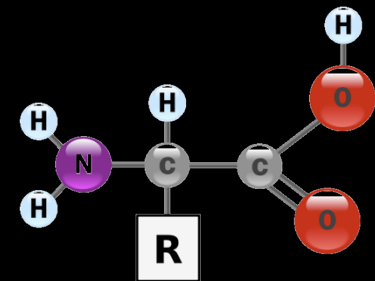


ORGANIC SOURCES:

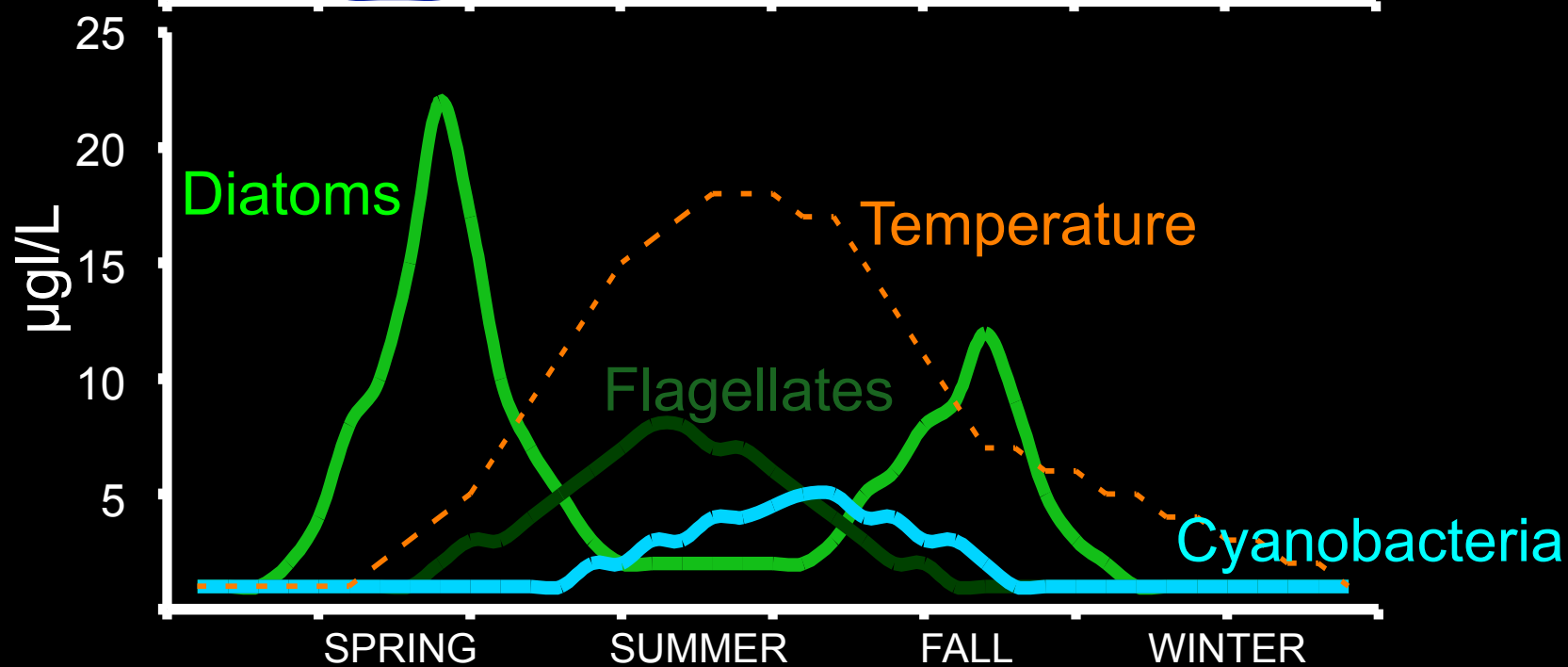
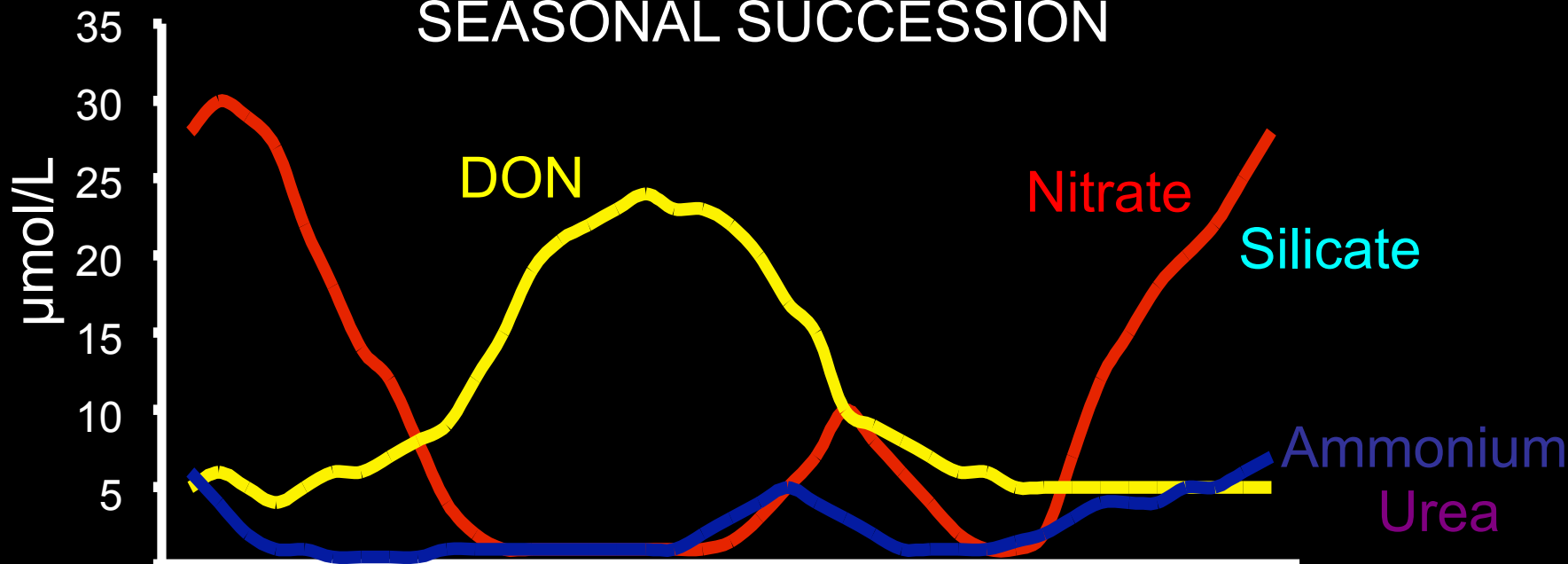
Urea ($\text{CO}[\text{NH}_2]_2$)

Dissolved organic nitrogen (DON)

Dissolved organic phosphorus (DOP)

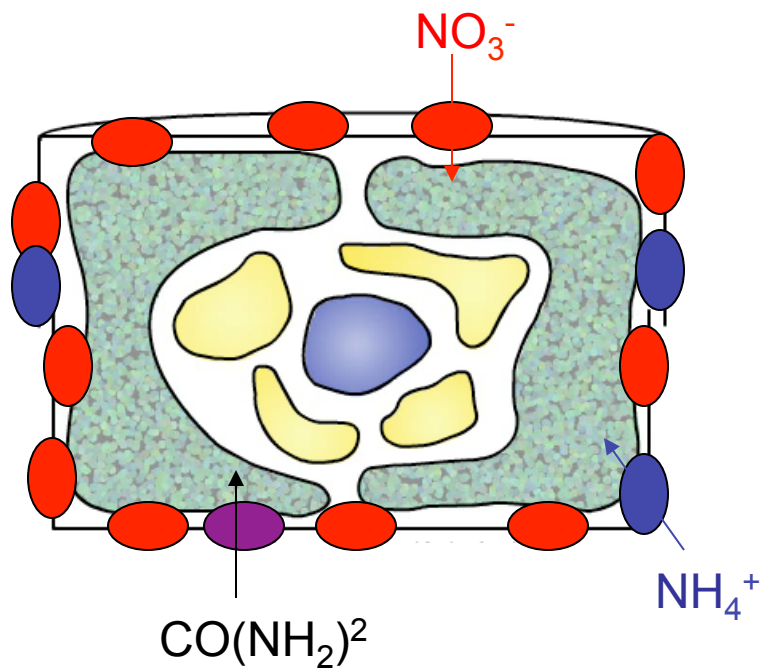


SEASONAL SUCCESSION

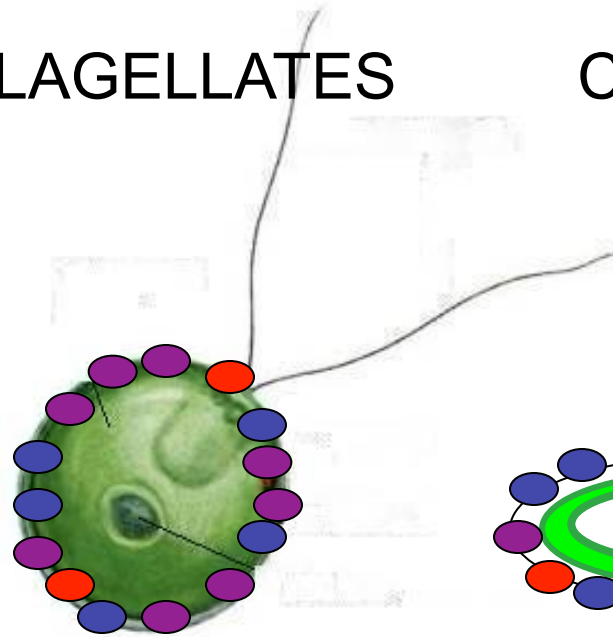


Nitrogen preferences - based on transport

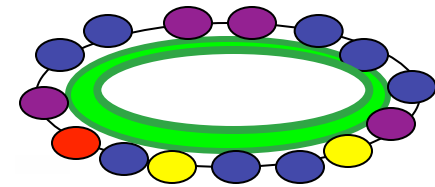
DIATOMS



FLAGELLATES



CYANOS

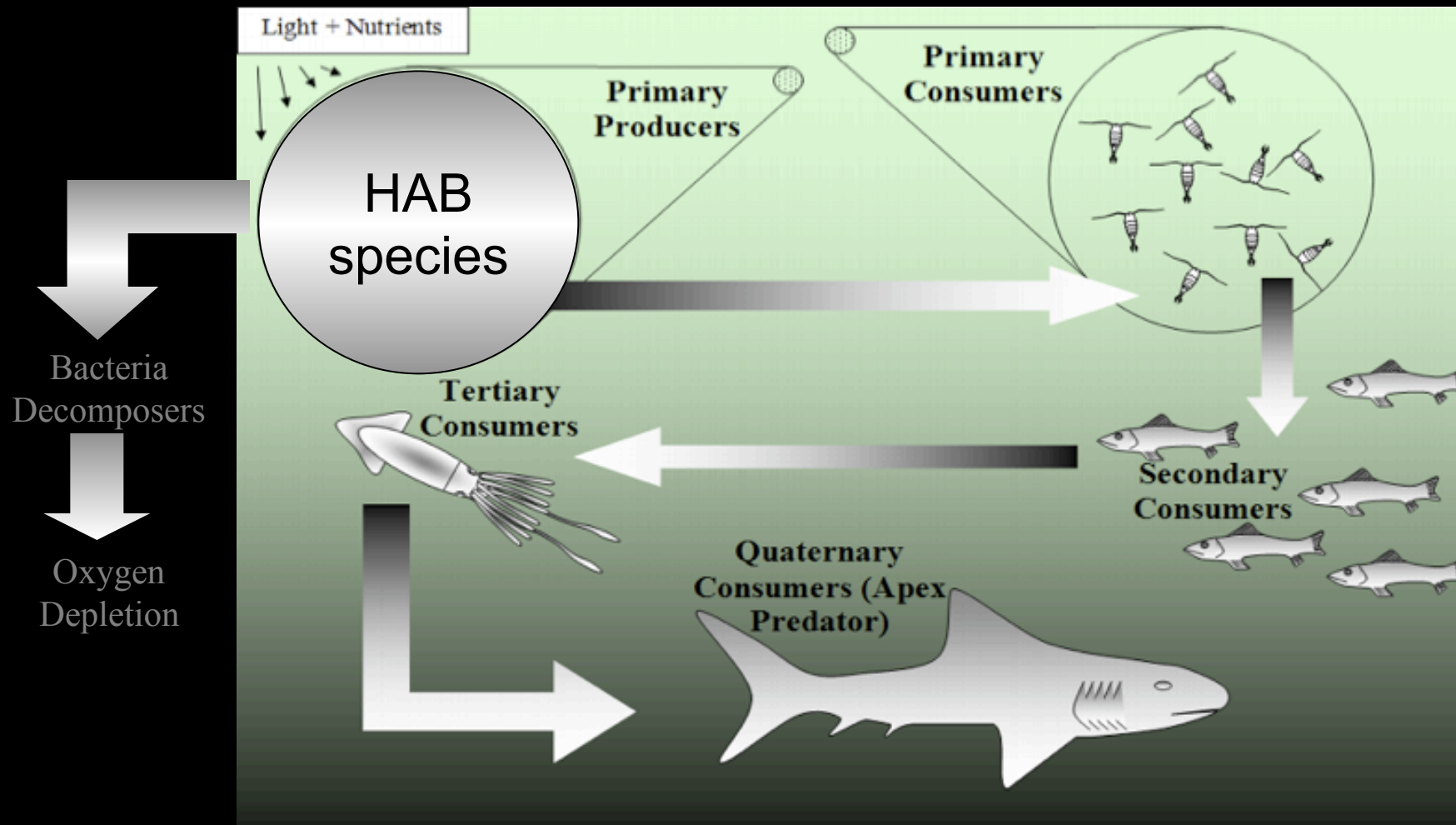


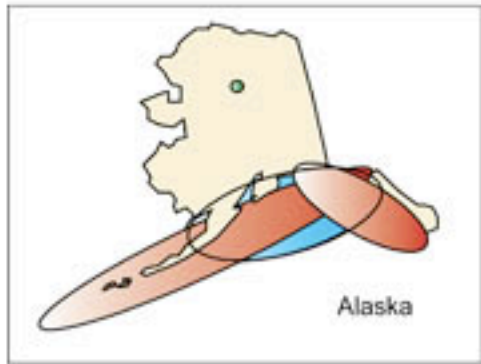
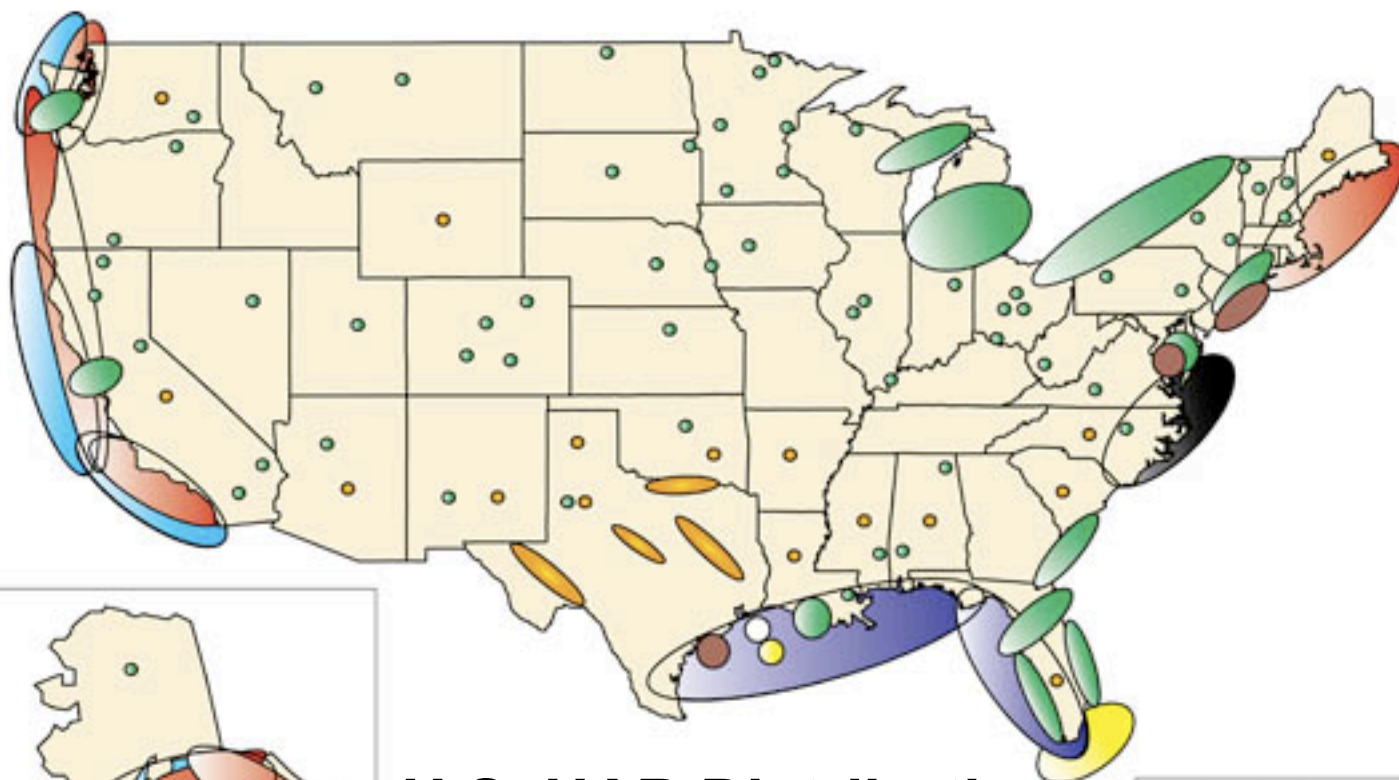
Nitrate

Urea

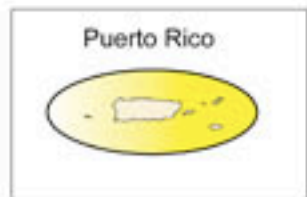
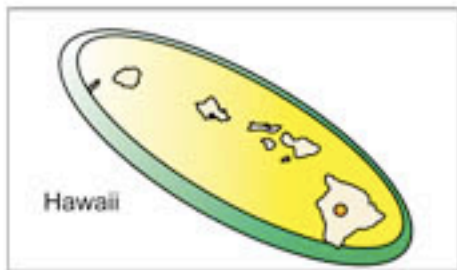
Ammonium

Does it matter what phytoplankton group dominates?





U.S. HAB Distributions

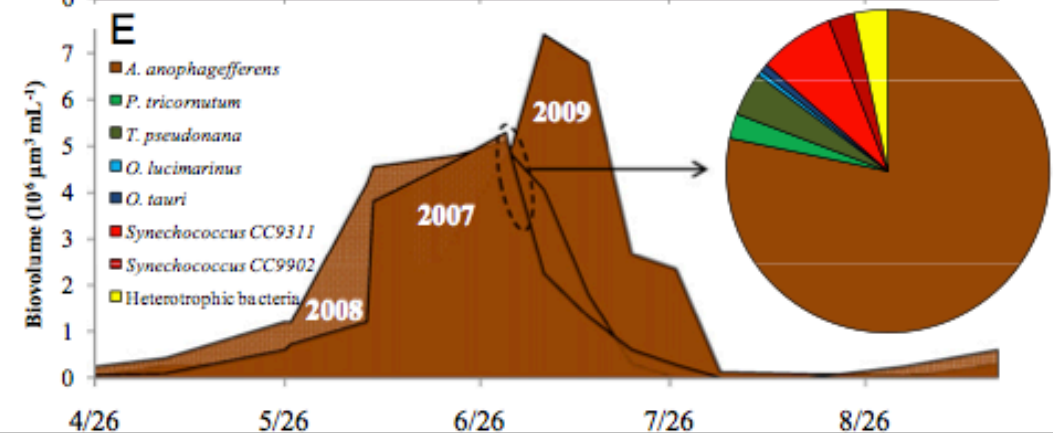
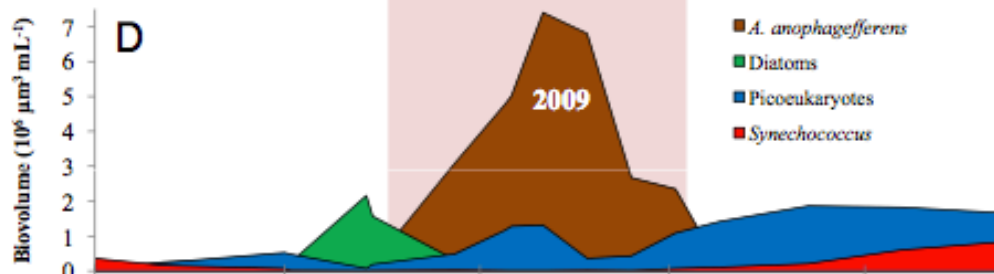
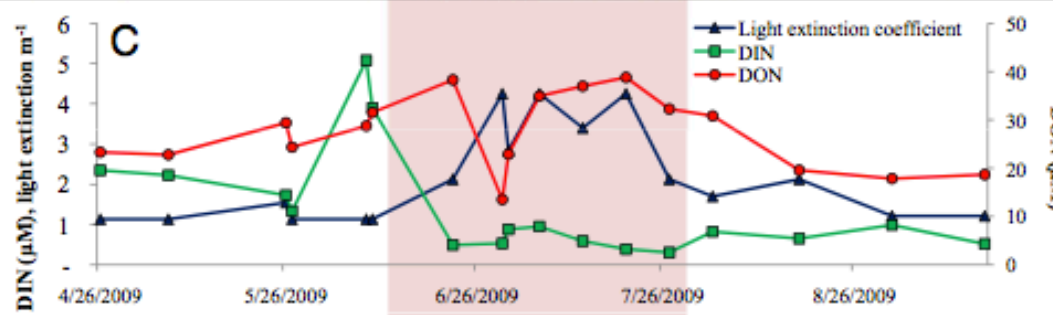
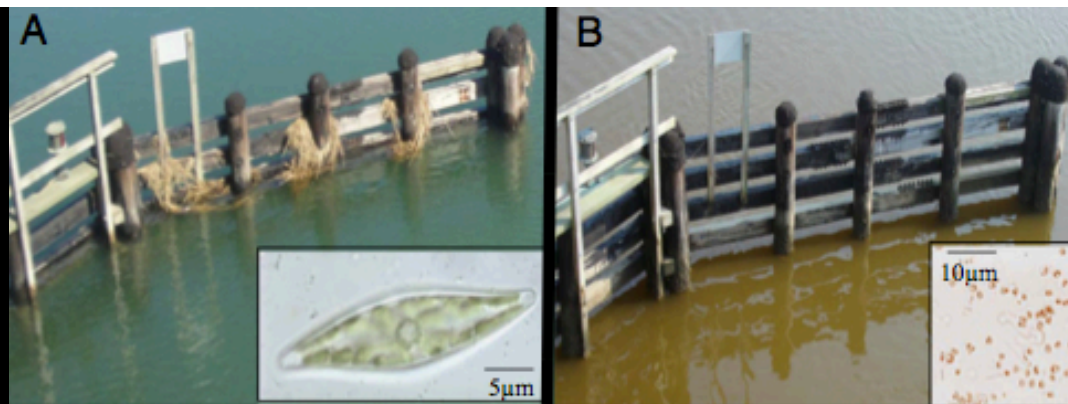


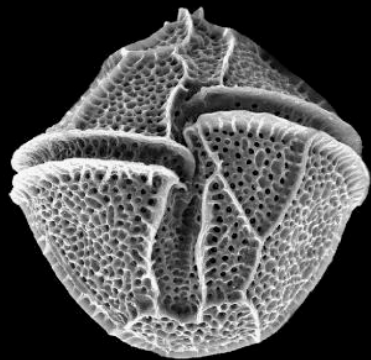
- PSP ● ASP ● CFP ● NSP
- *Karlodinium & Pfiesteria* ● Brown tide
- CyanoHABs ● Golden alga ○ DSP

Brown Tide HAB

Long Island

- A. Usual community
- B. Brown Tide year
- C. Changes in nutrients
- D. Changes in phytoplankton community
- E. Interannual changes in Brown Tide biomass

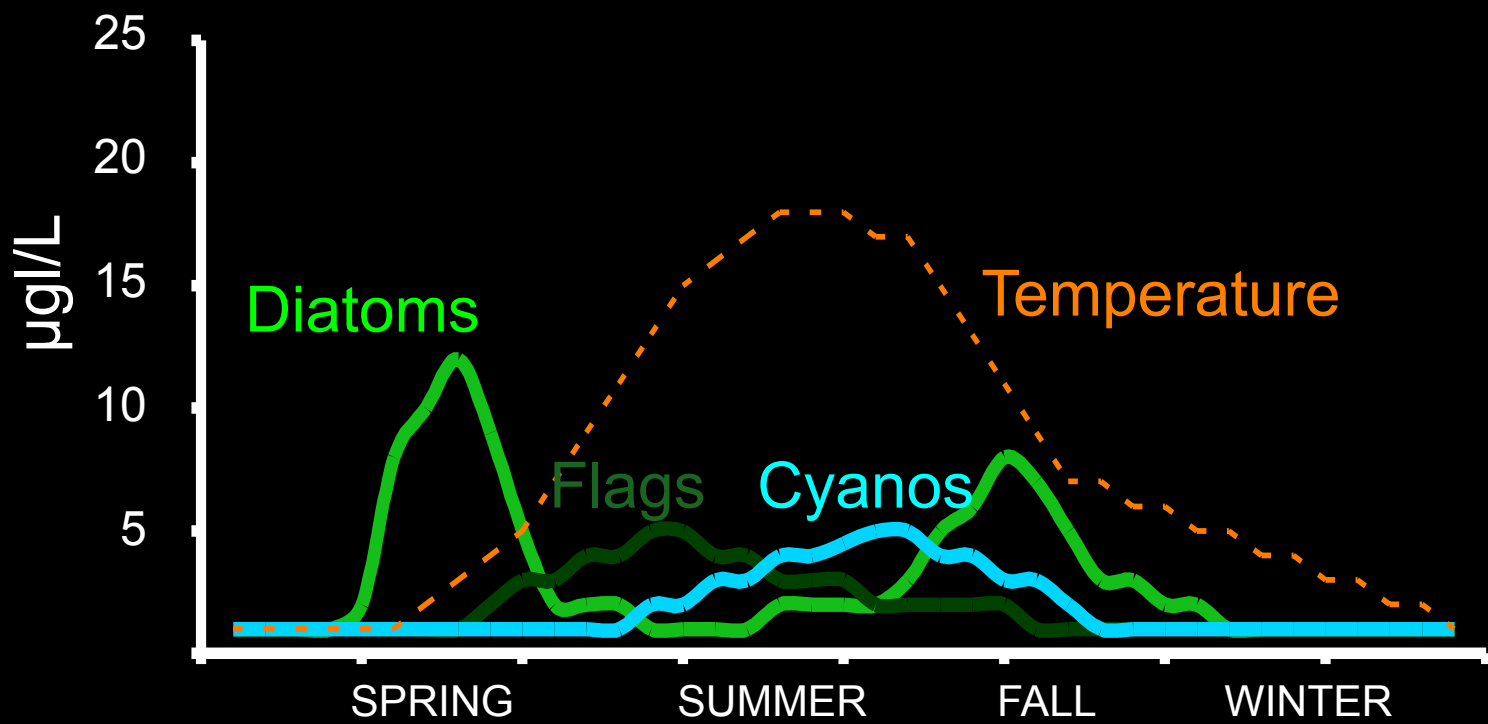
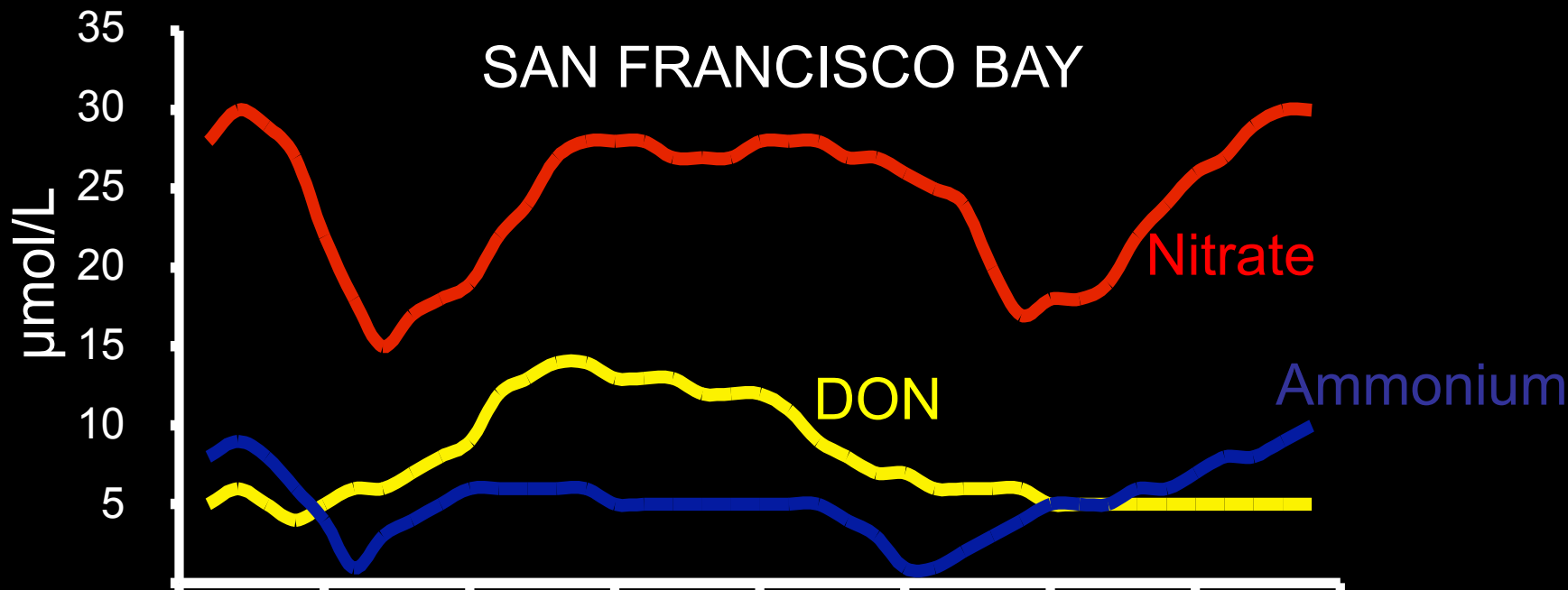




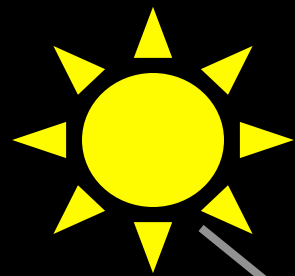
Red Tide HAB

The saxotoxin-producing dinoflagellate *Lingulodinium polyedrum* has been associated with fish and shellfish mortality events in Southern California (<http://oceanservice.noaa.gov/hazards/hab/>)

SAN FRANCISCO BAY



Why are nutrients not drawn down over the growing season in SFB?



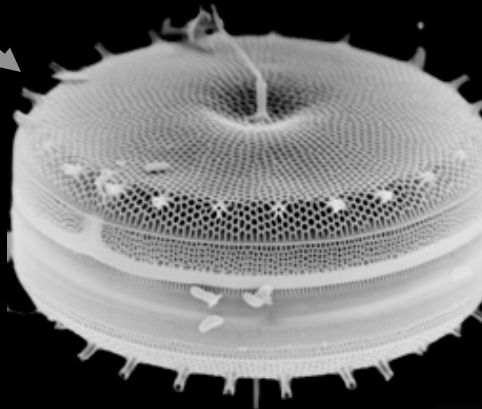
Light
limitation

SILICATE

IRON



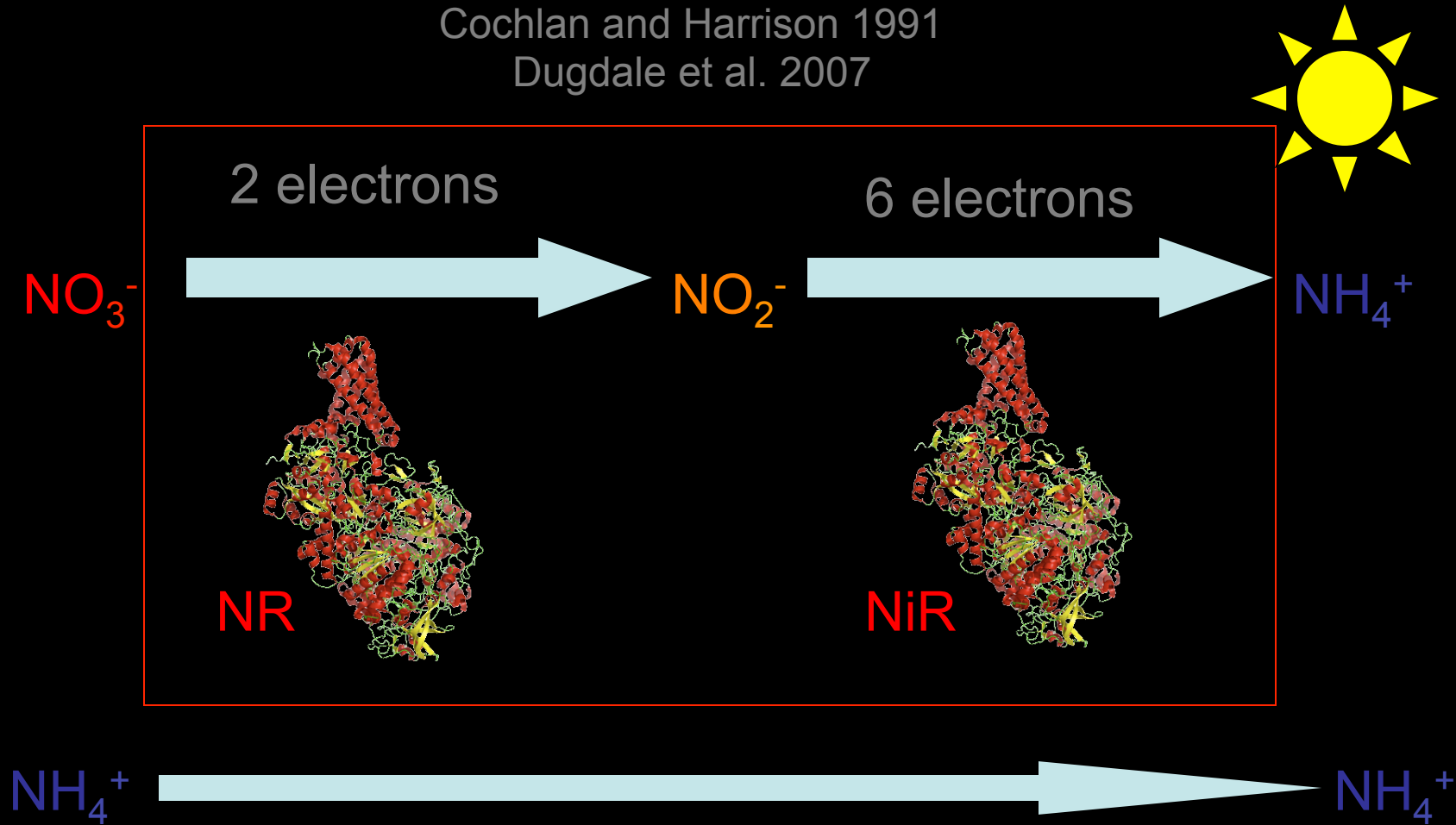
Grazing



Jassby et al. 1996
Cloern 1987

Inhibition of Nitrate uptake by Ammonium....

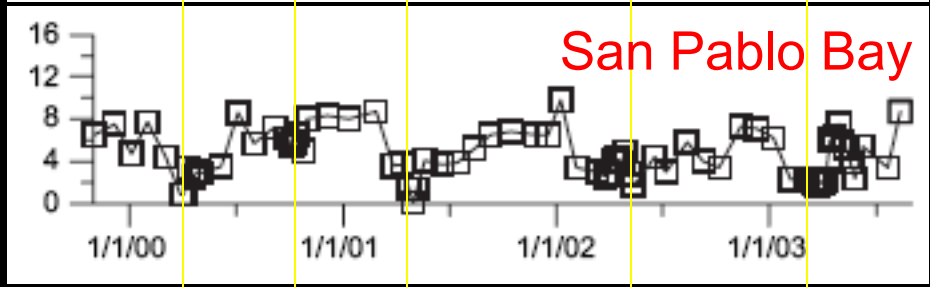
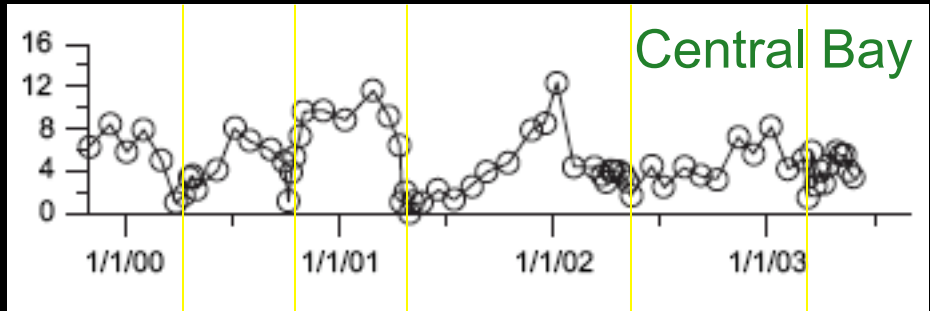
Cochlan and Harrison 1991
Dugdale et al. 2007



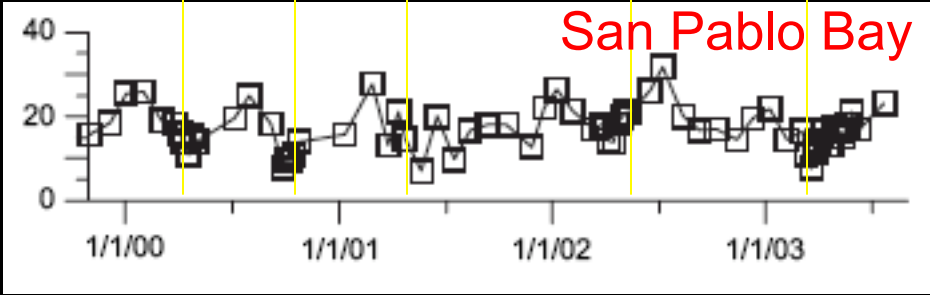
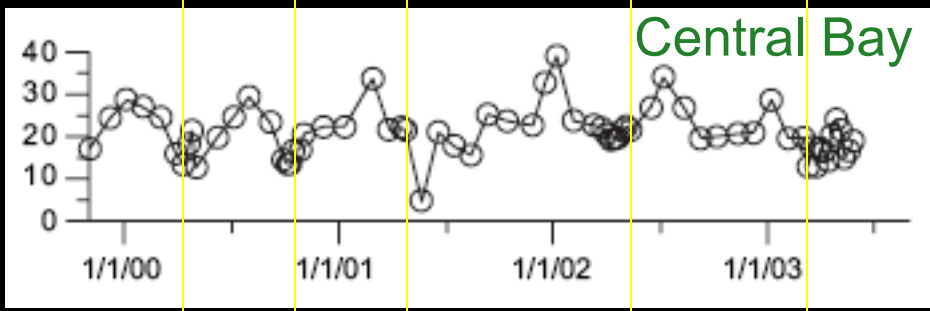
Ammonium - the low hanging fruit; always depleted first

SAN FRANCISCO BAY

Ammonium ($\mu\text{moles L}^{-1}$)



Nitrate ($\mu\text{moles L}^{-1}$)





Historic San Francisco Bay

- High nutrient loads
- Limited impacts
- Other Pollutants of Concern

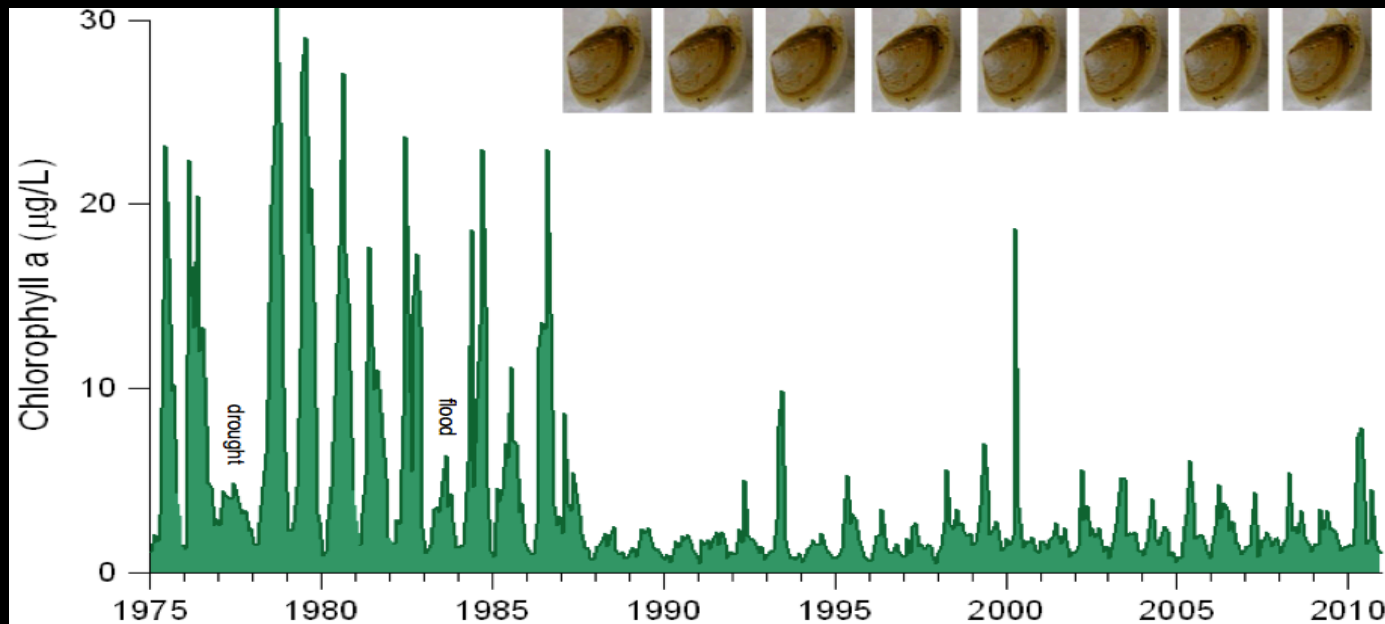


Three Whales Came in Through the Golden Gate Yesterday and Kept the Ferry-Steamer Tiburon Company for a Part of the Way on Her Run to and From San Francisco. Two Were Humpbacks and One Was Supposed to Be a Sperm.

Why Little Historic Impact?



- Tides
- Turbidity
- Biota



Cloern, 2011

Are Things Changing?



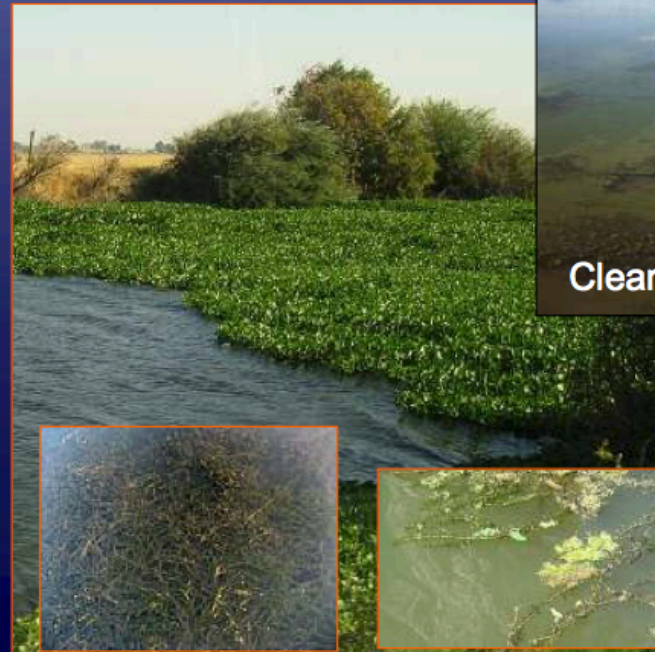
Ecological Regime Shift

“Rapid reorganization of an ecosystem from one relatively stable state to another.”

From river estuary ... to weedy “lake”



1873 → Today



Increased Grazing of Planktivores

- *C. amurensis* densities decreasing

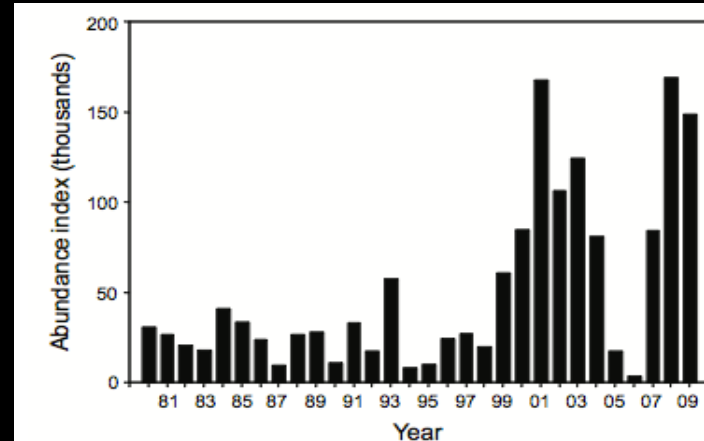


Figure 27 Annual abundance of age-0 English sole, Bay Study otter trawl, February-October.

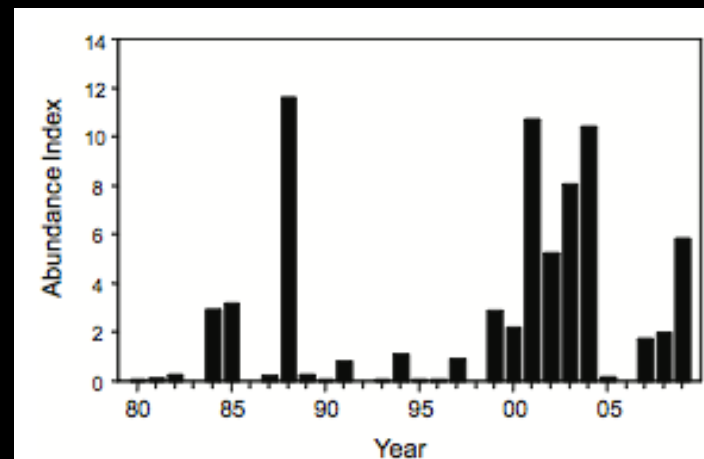
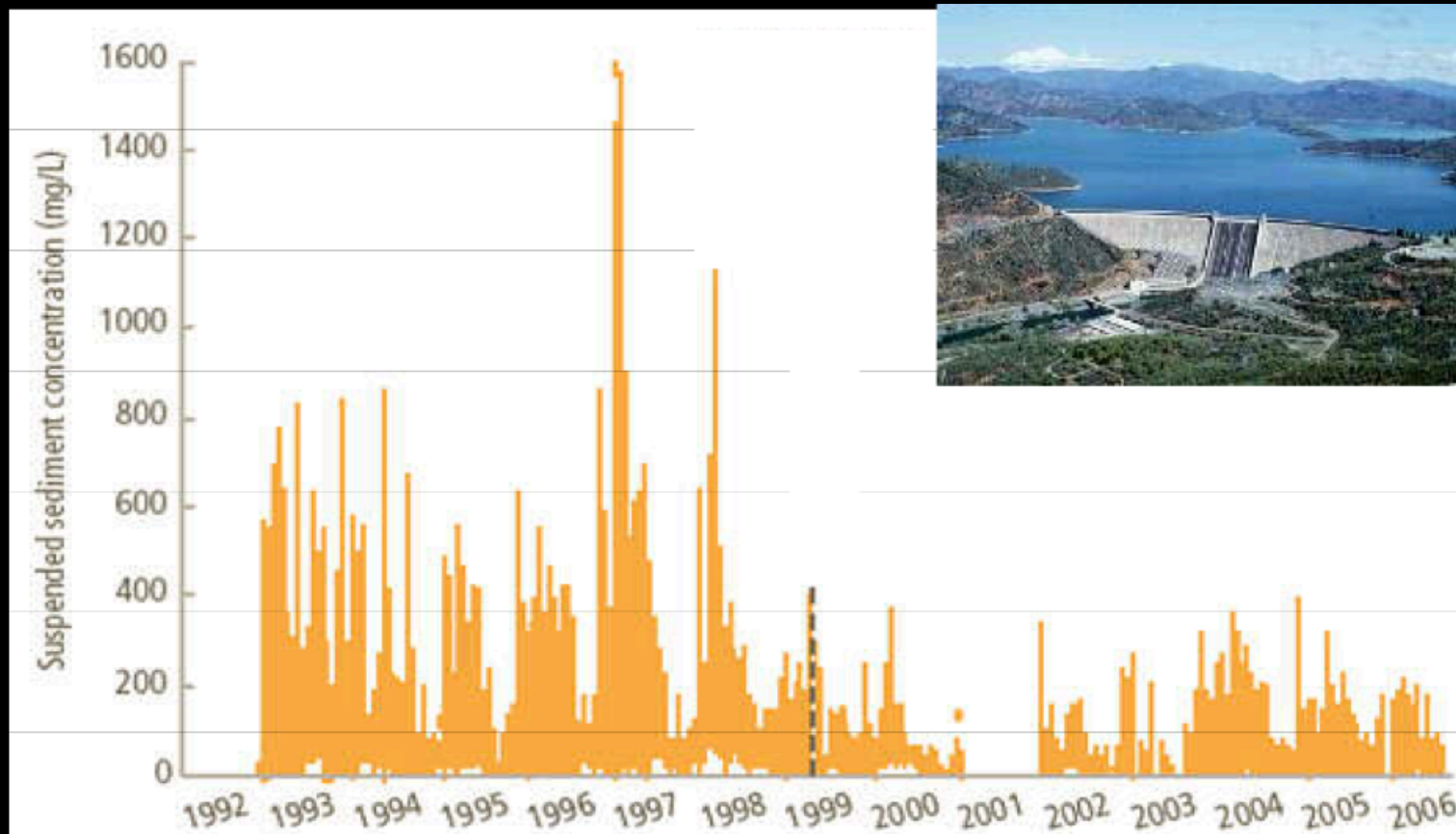


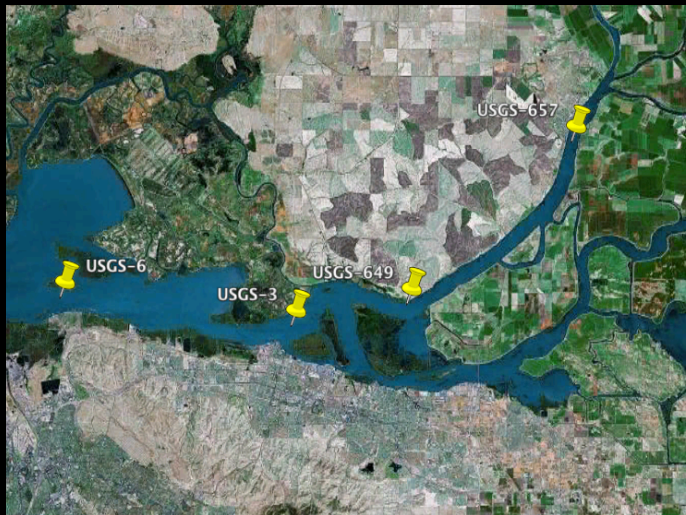
Figure 1 Annual abundance indices of age-0 *Cancer magister*, Bay Study otter trawl, May to July, 1980-2009.

Decreasing Turbidity

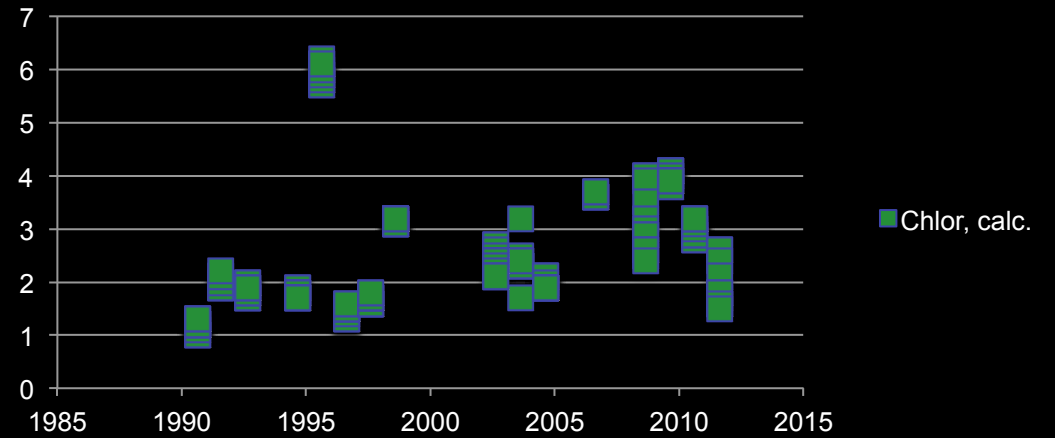


Schoellhamer, 2009

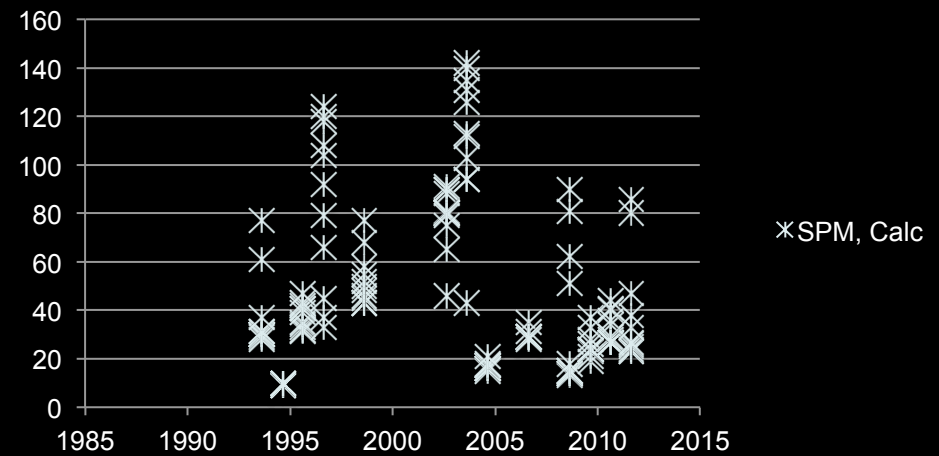
Station 6



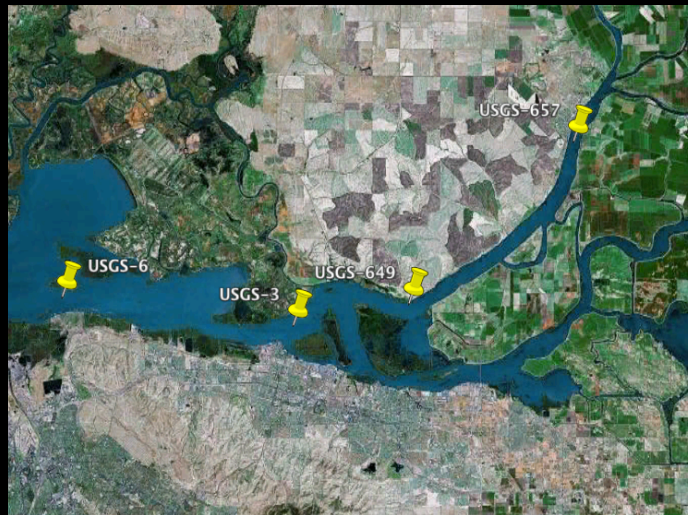
Chlor, calc.



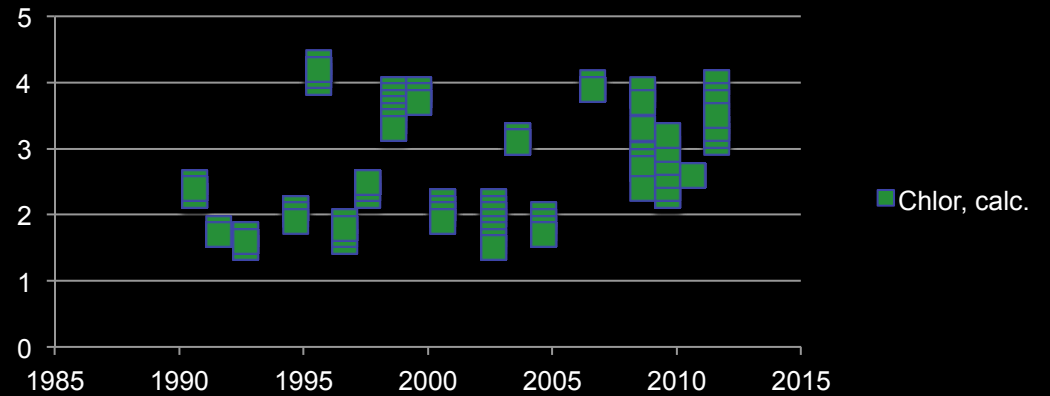
SPM, Calc



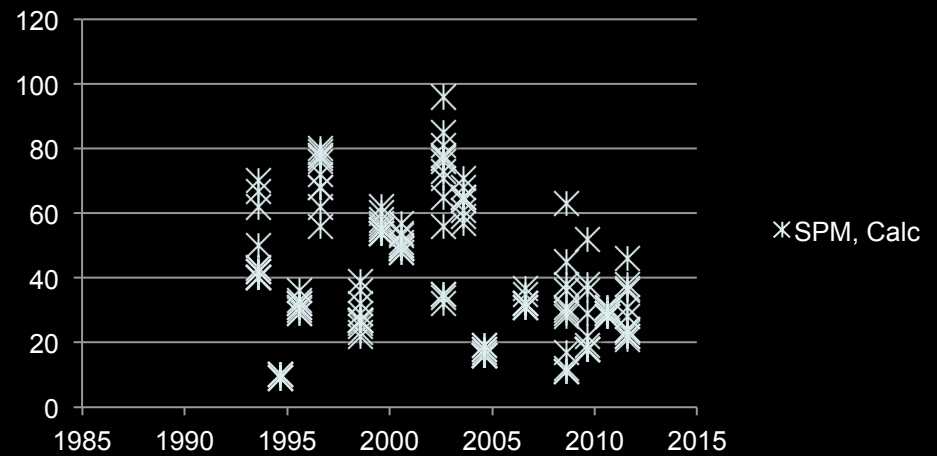
Station 3



Chlor, calc.



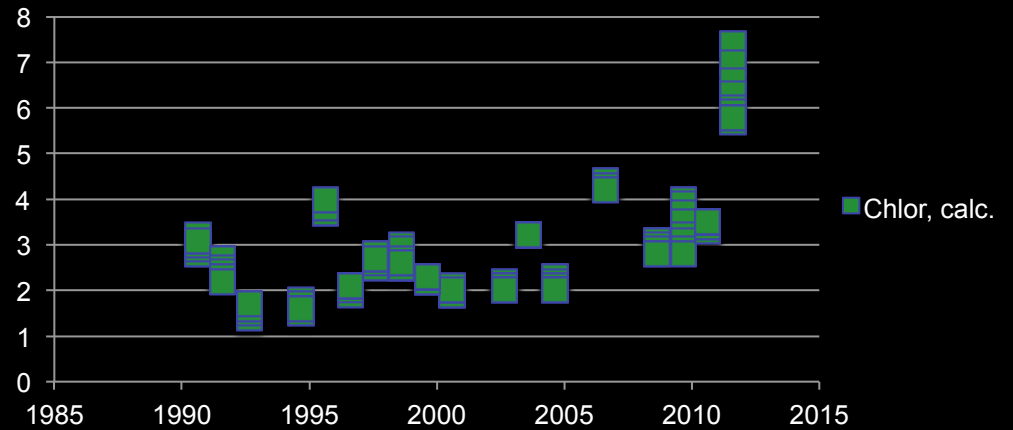
SPM, Calc



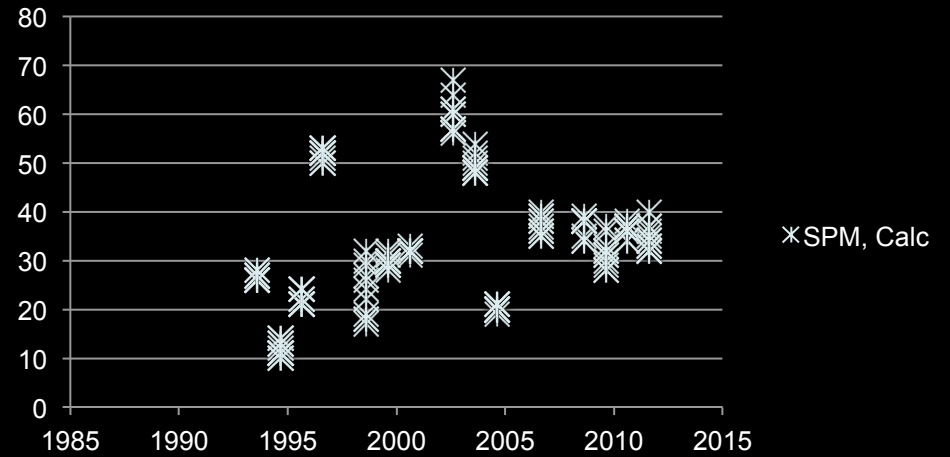
Station 649



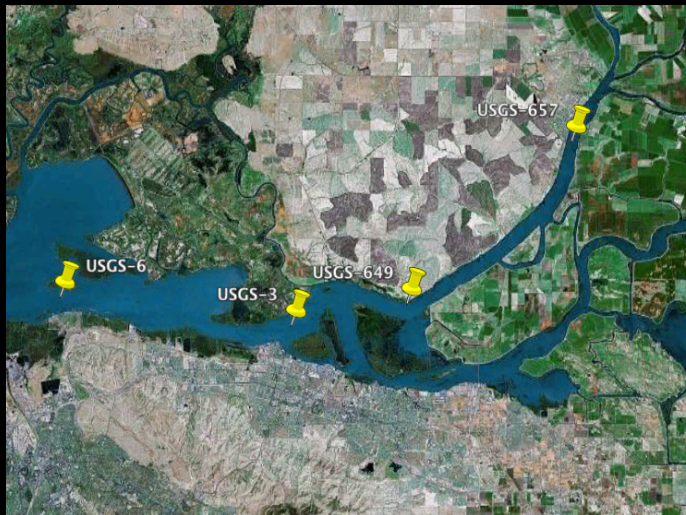
Chlor, calc.



SPM, Calc



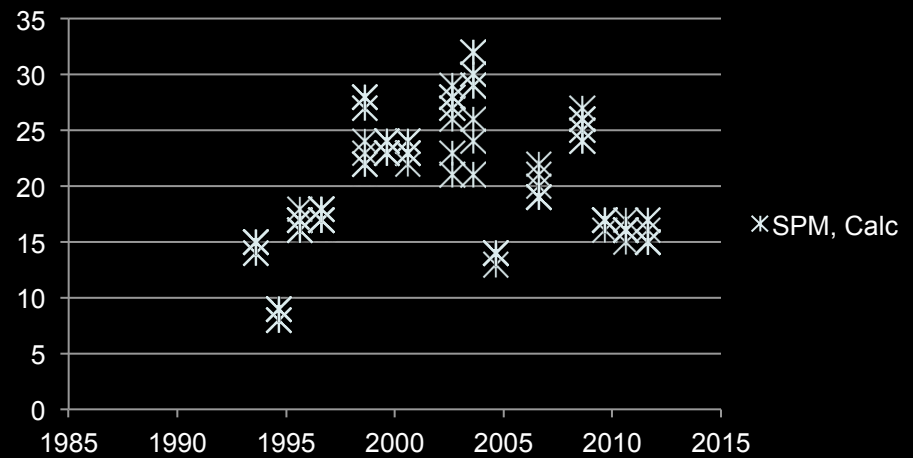
Station 657



Chlor, calc.



SPM, Calc



What's Next?

- Triennial Review:
 - *Water Board staff are currently actively involved in the process of developing the SF Bay-specific NNE framework, which will be the foundation both for assessing the Bay's impairment status relative to nutrients, eutrophication and for developing a nutrient monitoring, modeling and management strategy for SF Bay*
- RMP Nutrient Strategy
 - Support Triennial Review



Questions