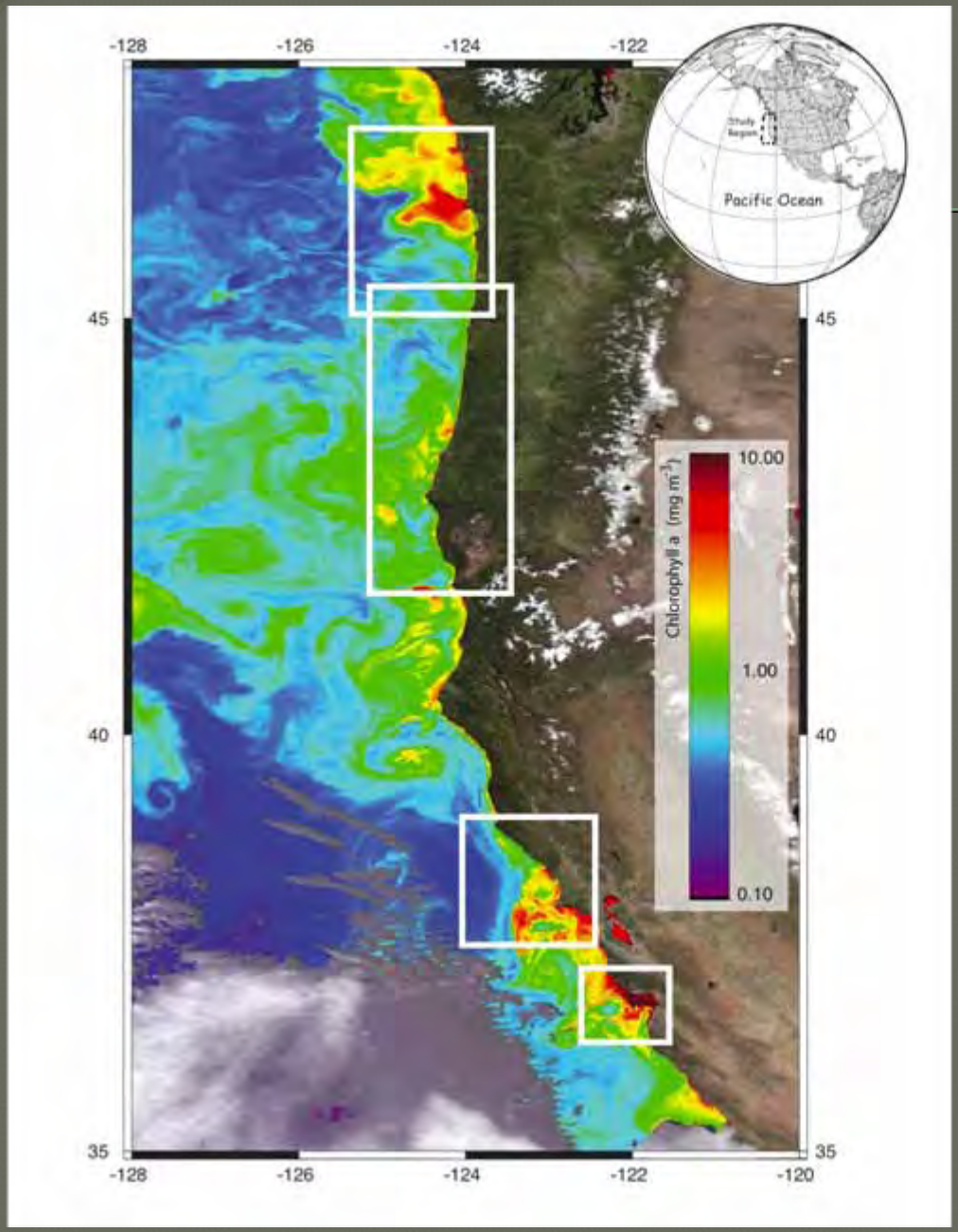
Multiple Simultaneous HAB Organisms & Toxins in the California Current: An Emerging Threat?

Raphael Kudela
John Ryan, Jenny Lane

Ocean Sciences Department
University of California Santa Cruz



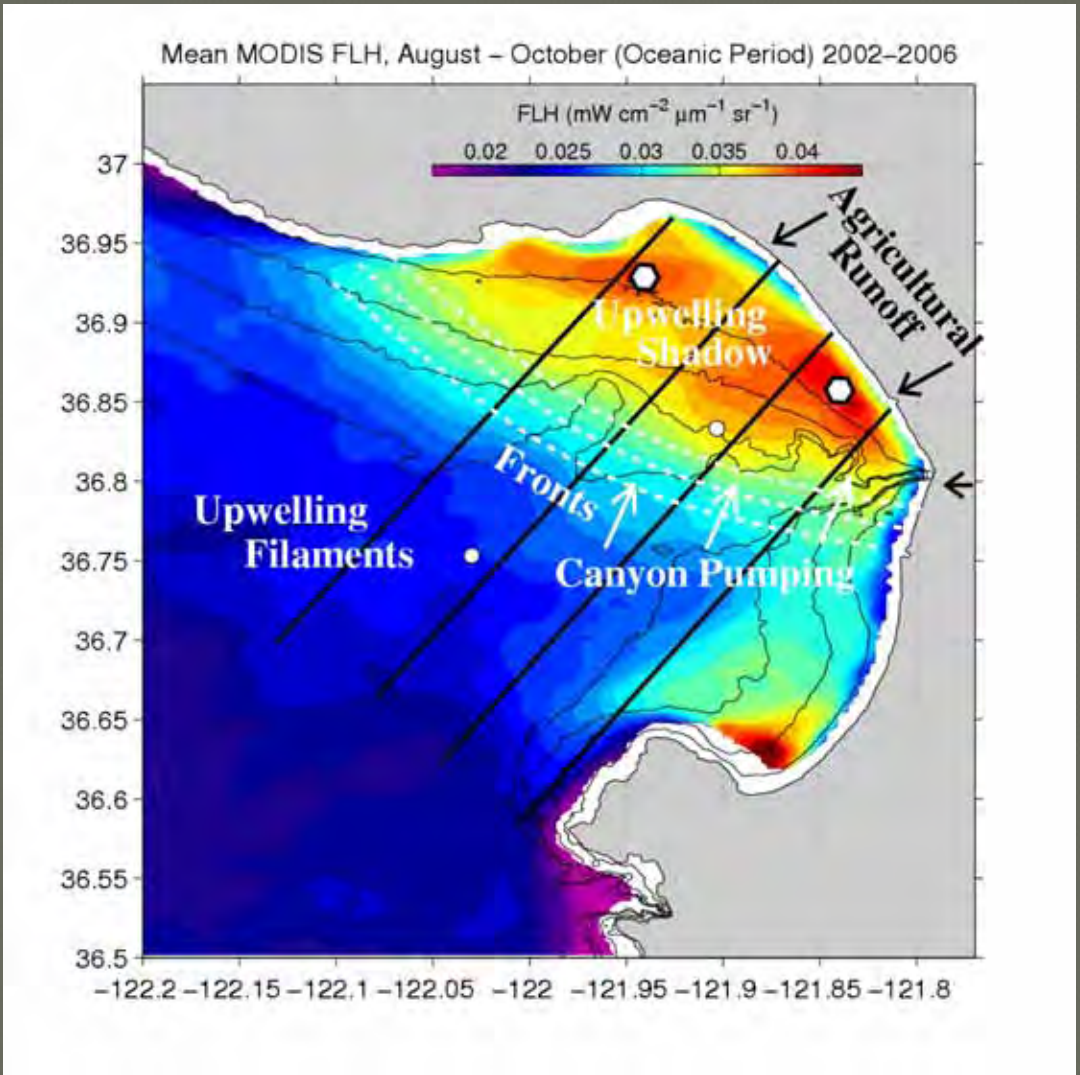
"The Solution to Pollution is Dilution…"

—OR—

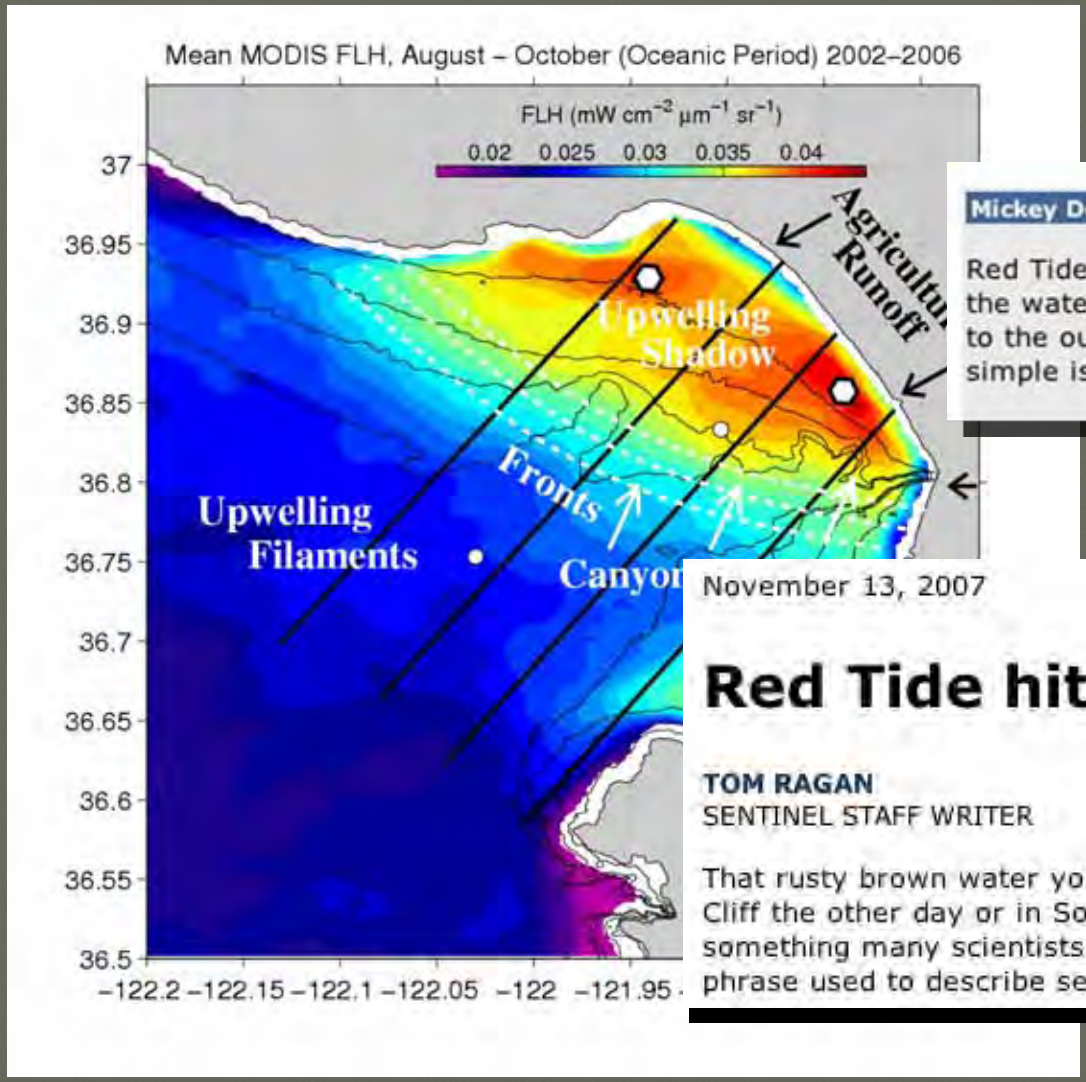
Coastal upwelling dominates the US West Coast, and water quality is not generally impaired

Kudela et al. 2008, Oceanography

Impaired Water Quality



Impaired Water Quality



Mickey Dora 11/14/2007 7:00 AM

Red Tide that's Brown? Clearly the foam on top of the water was brown and it source lead a trail right to the outflow pipe at Mitchell's cove. Plain and simple is sewage.

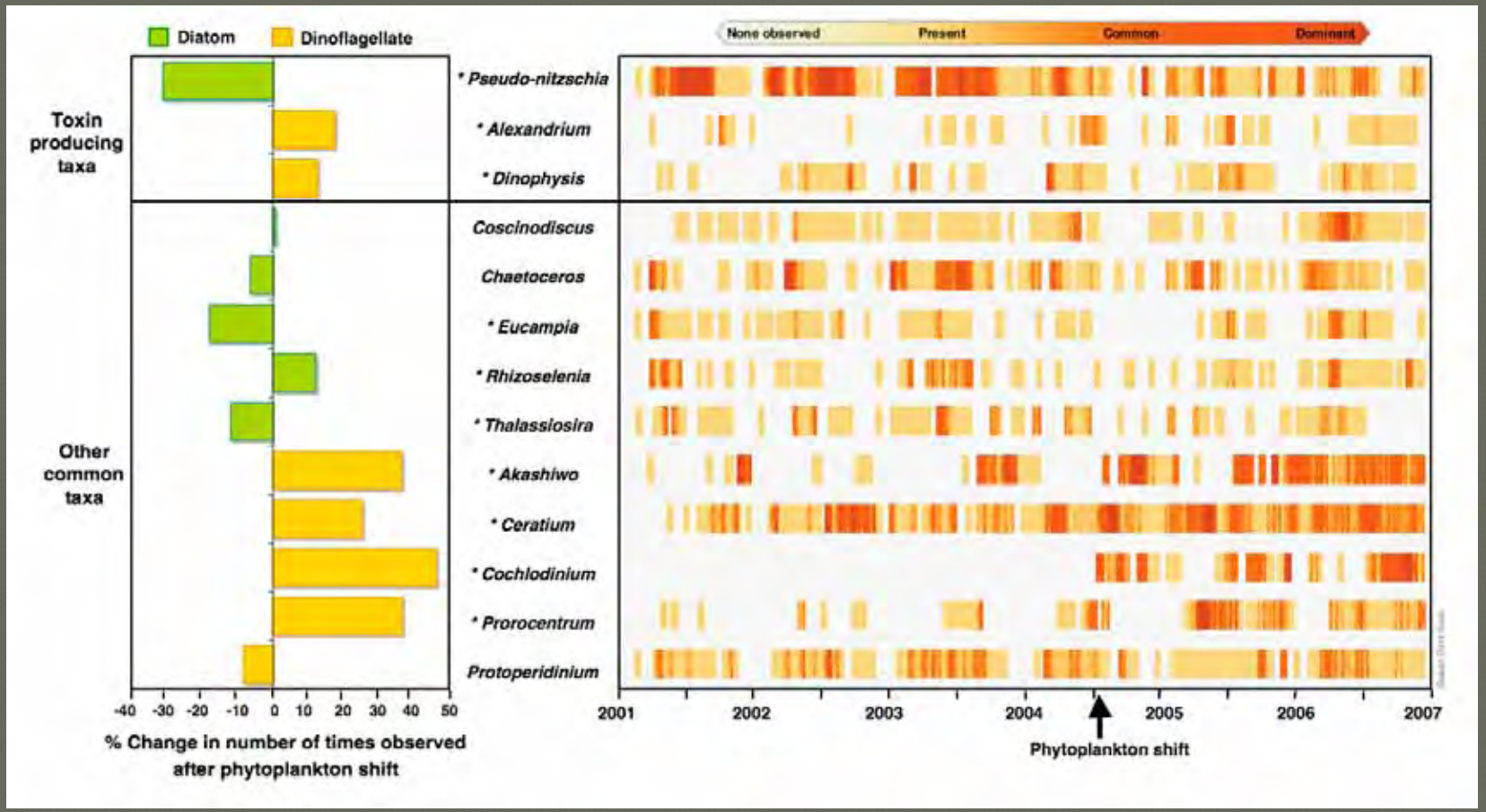
November 13, 2007

Red Tide hits Santa Cruz

TOM RAGAN
SENTINEL STAFF WRITER

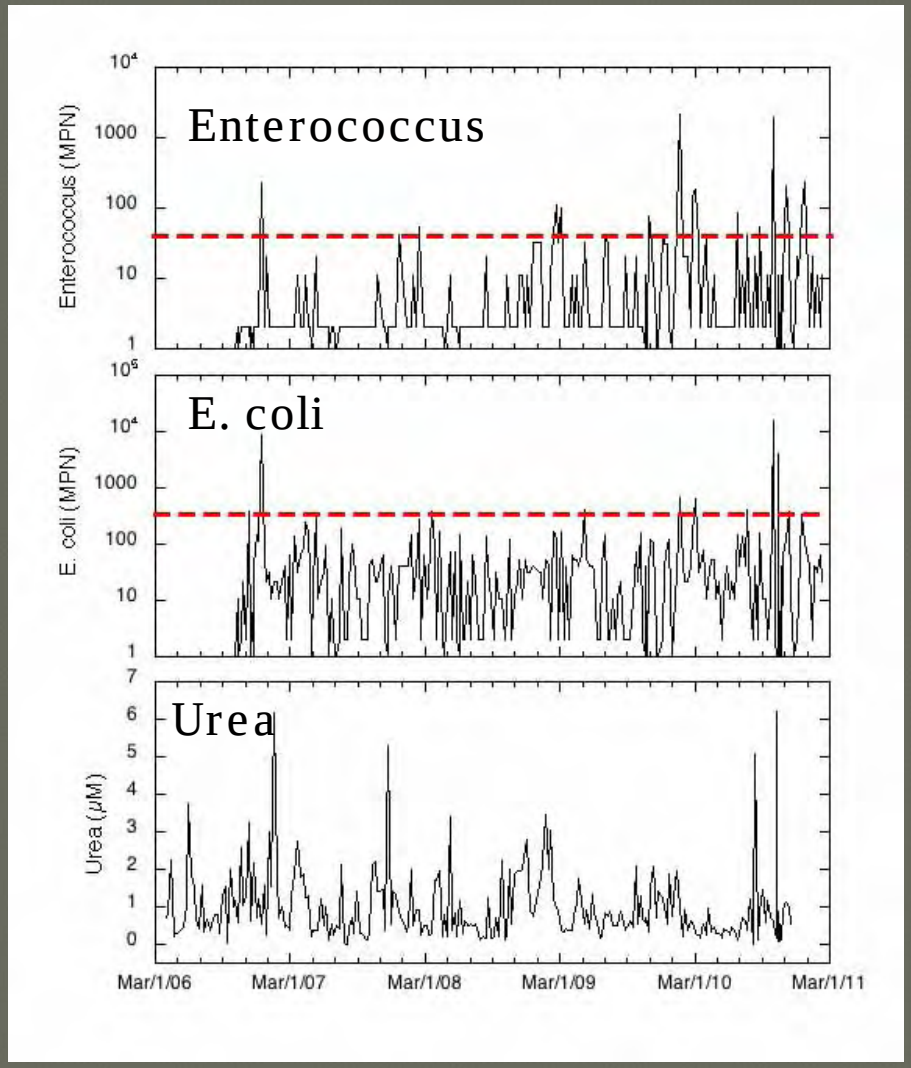
That rusty brown water you might have seen in the ocean off of West Cliff the other day or in South Santa Cruz County last week is something many scientists refer to as a "red tide" — a catch-all phrase used to describe sea water when it changes colors.

Harmful Algal Blooms



Jester et al. 2009 Harmful Algae

Water Quality Indicators



Santa Cruz Wharf Time-Series (2006-2011)

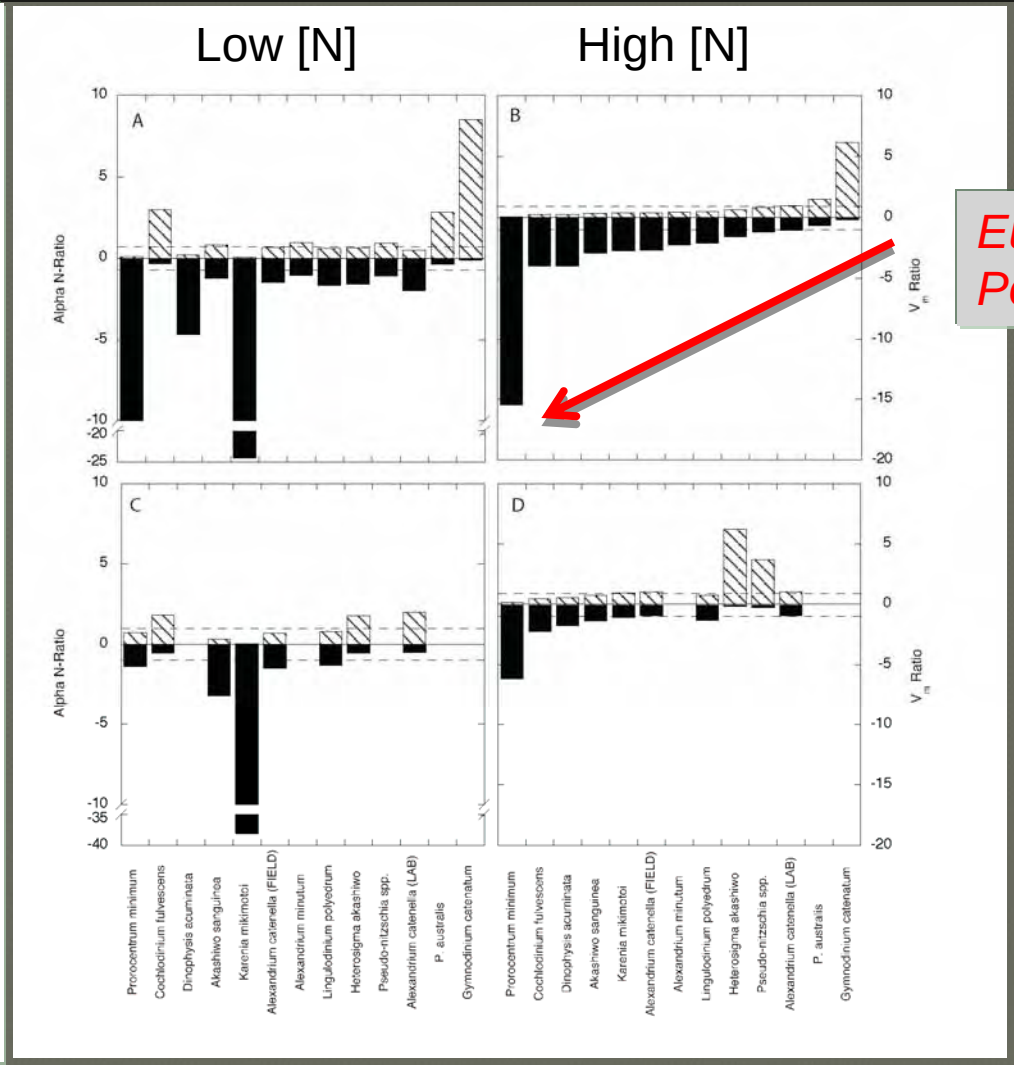
Urea and Fecal Indicator Bacteria provide a good indicator of runoff

Other measurements include heterotrophic bacteria (FCM), HABs, toxins, chlorophyll, etc.

Based on data from coastal cruises, urea and FIB are usually undetectable or very low away from shore….

HABs & WQ: Linked?

Nitrate:Urea Nitrate:Ammonium

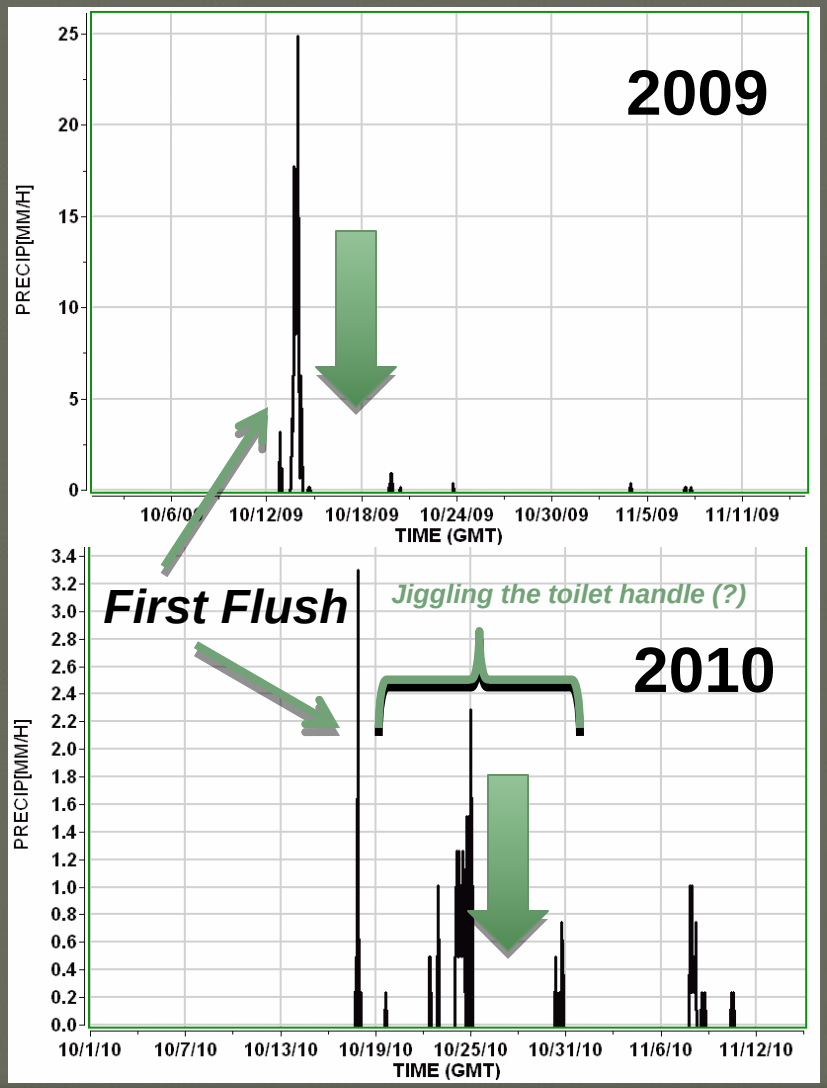


Eutrophication Potential

HAB organisms found in upwelling systems generally prefer "eutrophic" sources of nutrients.

Kudela et al., 2010

2009 vs 2010 First Flush

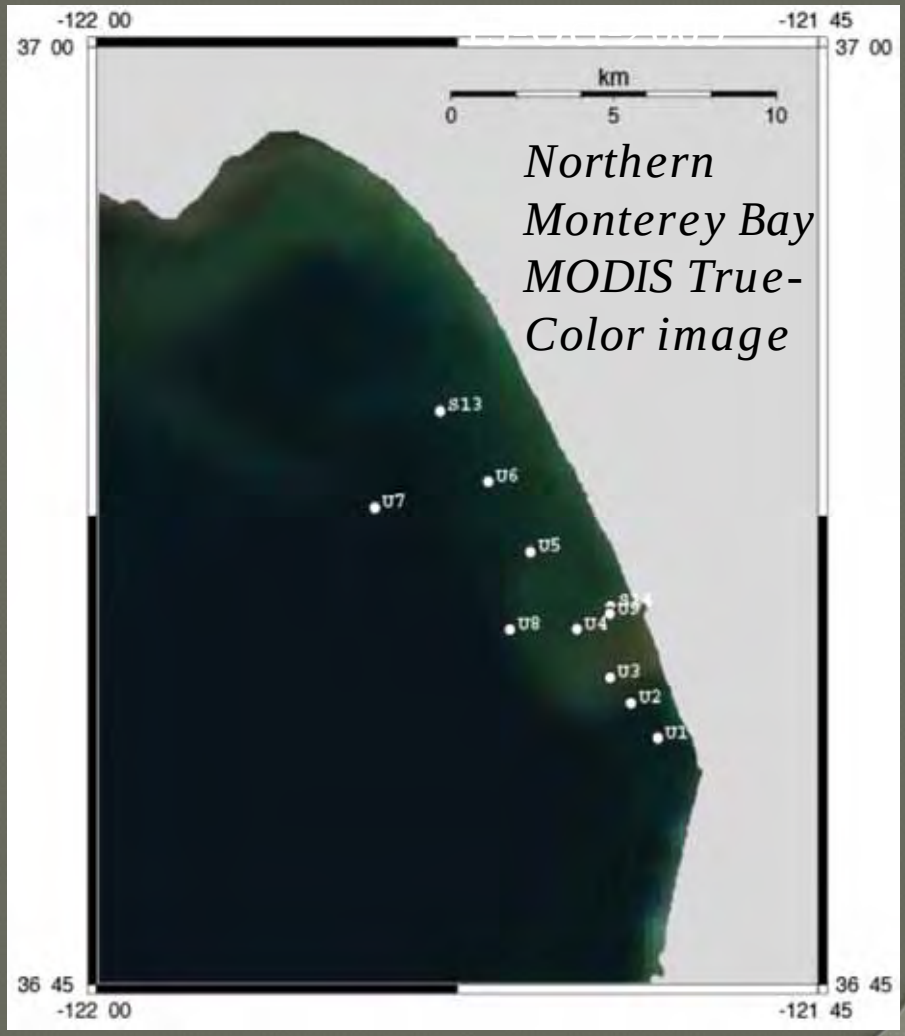


Rainfall at Pajaro (mm/h)

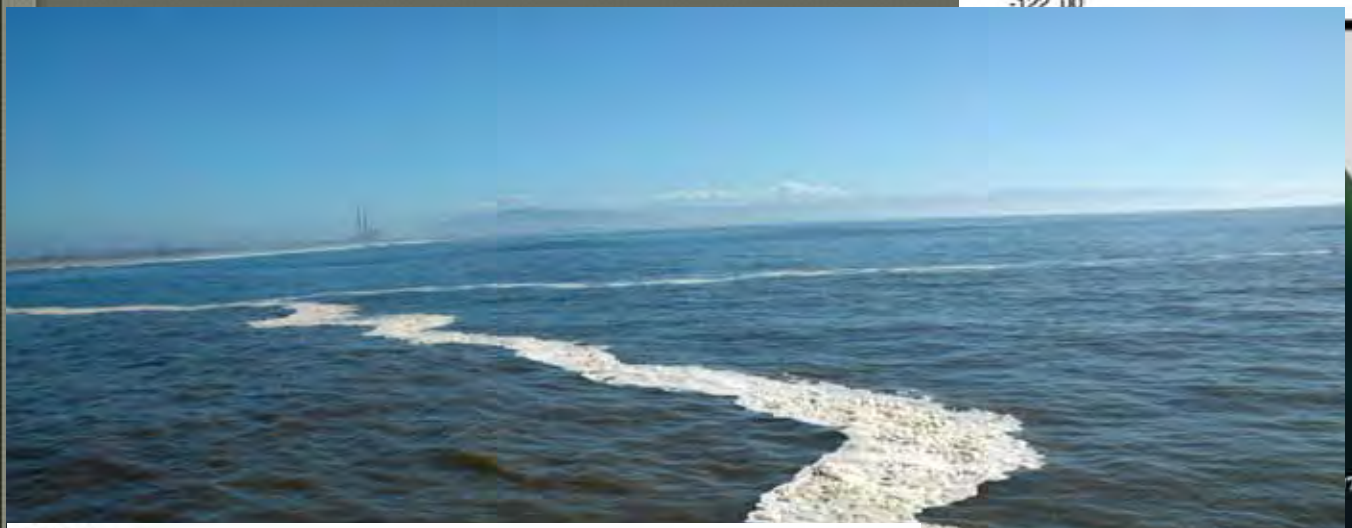
Timing is about the same but 2009 was in one pulse, and about 8x larger

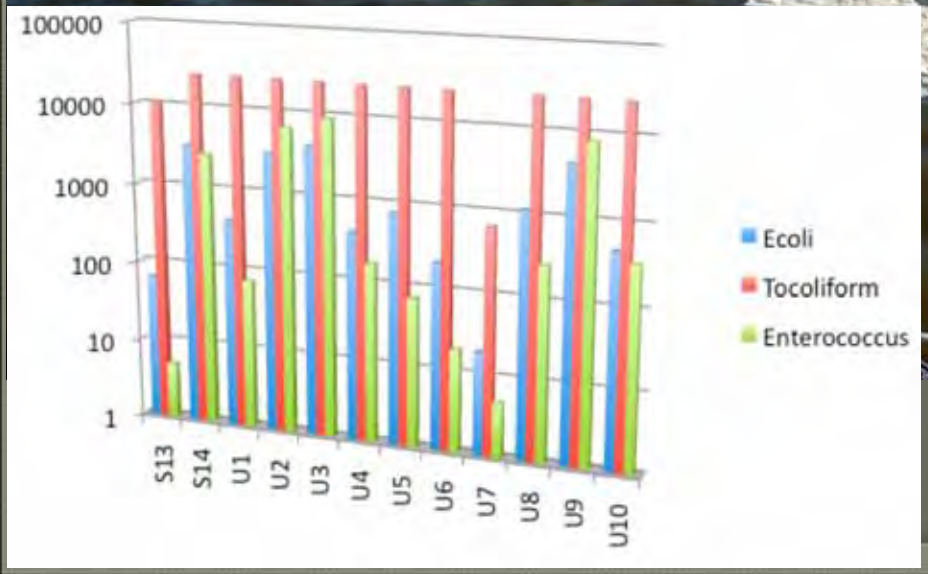
(one flush versus multiple)

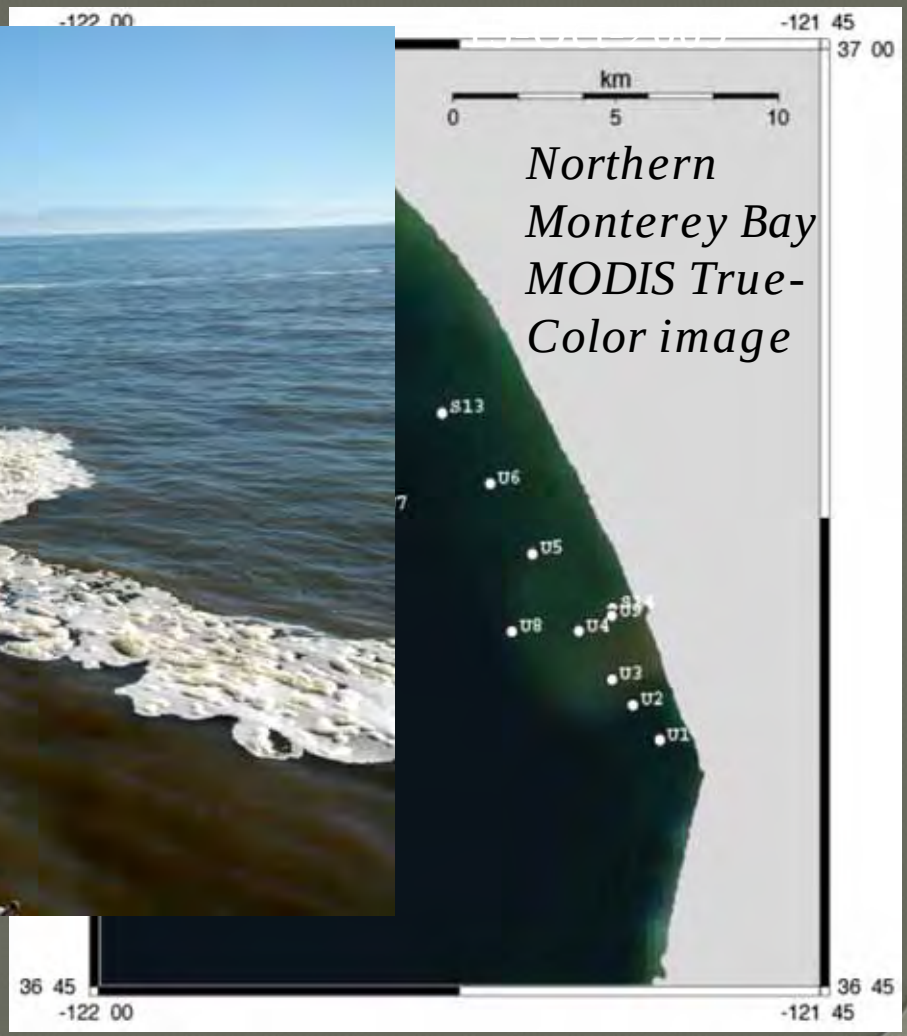
2009 First Flush



2009 First Flush







Northern Monterey Bay MODIS True-Color image

HABs & WQ: Linked?

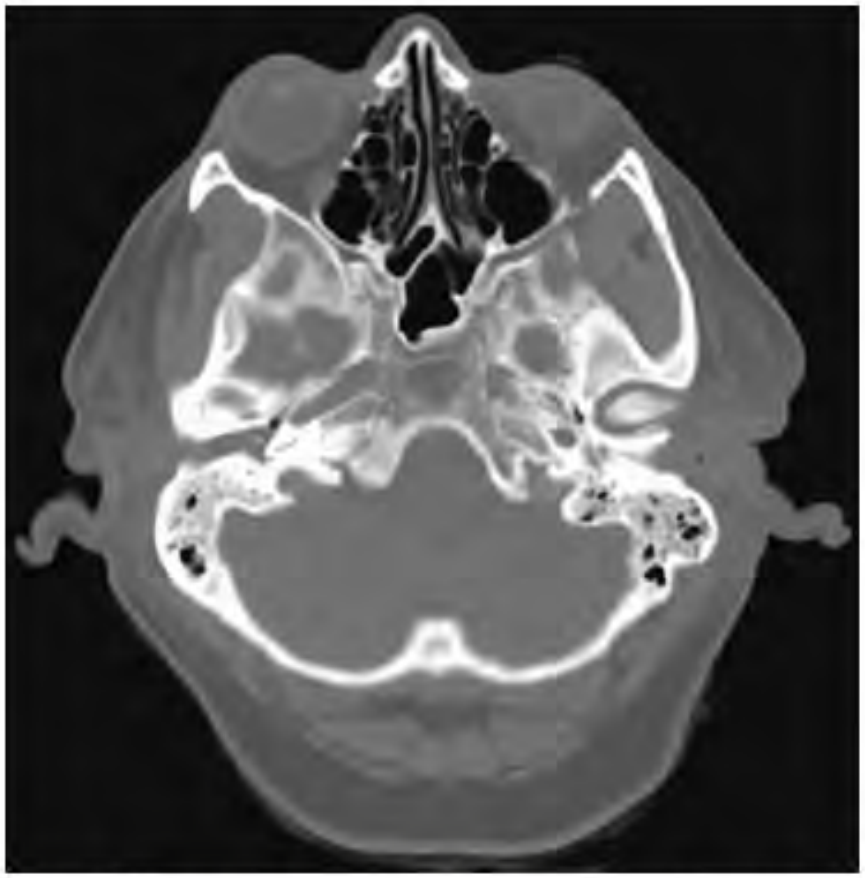


Figure 2. Computed tomography scan showing opacification of the bilateral mastoid air cells.

September 2009—53 year old woman diving in Monterey suffered from bilateral mastoiditis (ear infections penetrating to the brain)

Retrospective analysis linked high pathogen loads to red tides

Honner, Kudela & Handler (2010), J. Emergency Medicine

2009 First Flush

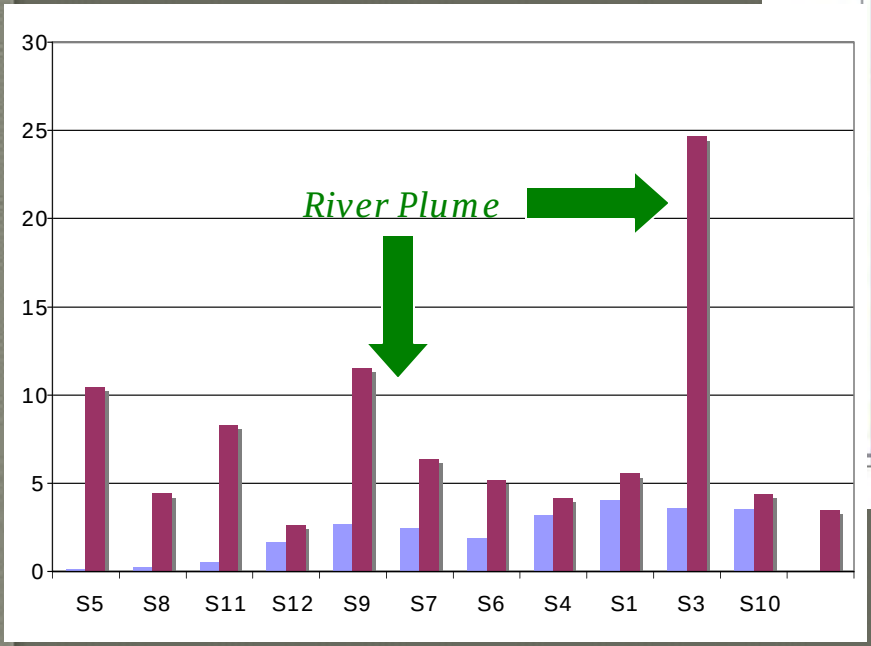
Santa Cruz Wharf, 15-Oct-09

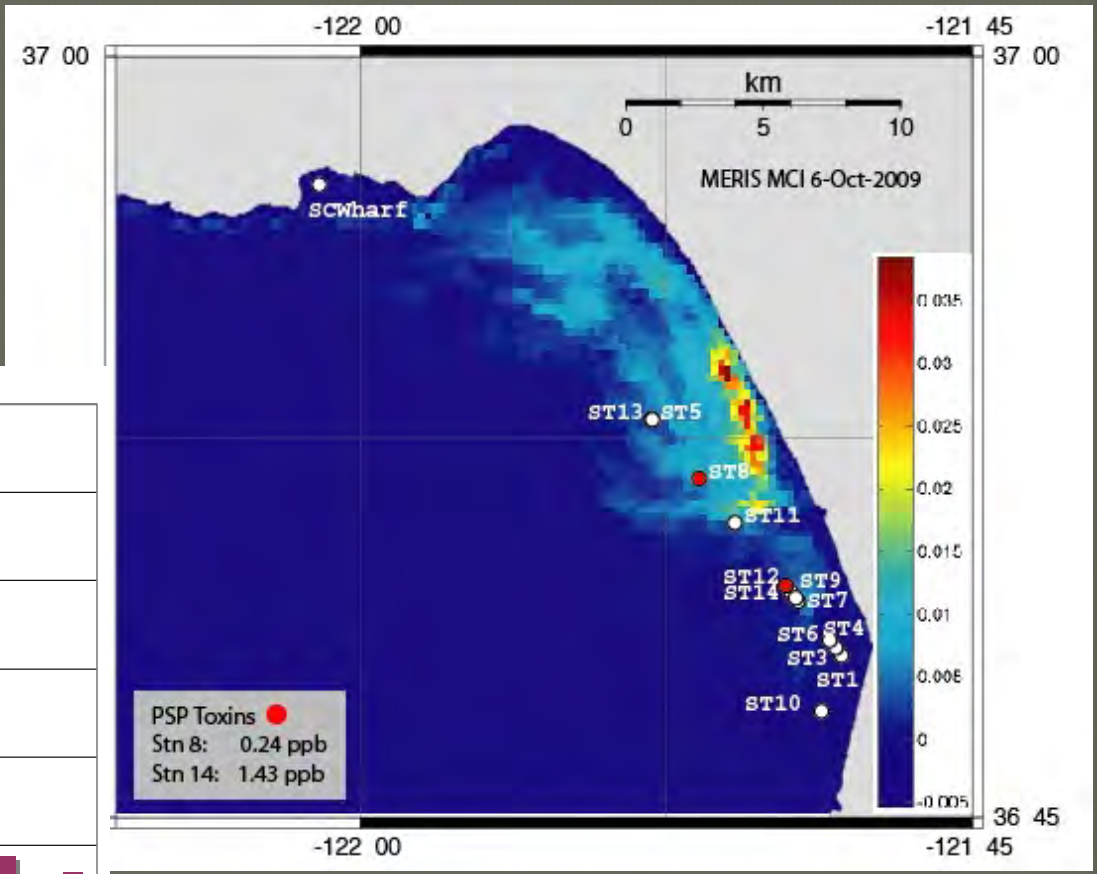
Surface bloom dominated by *Ceratium*

Peak Chlorophyll > 2,000 mg/m3 (confirmed by spectroscopy)

2009 First Flush

2009 First Flush resulted in large pulse of dissolved domoic acid (~4x increase in total DA relative to pre-flush conditions)

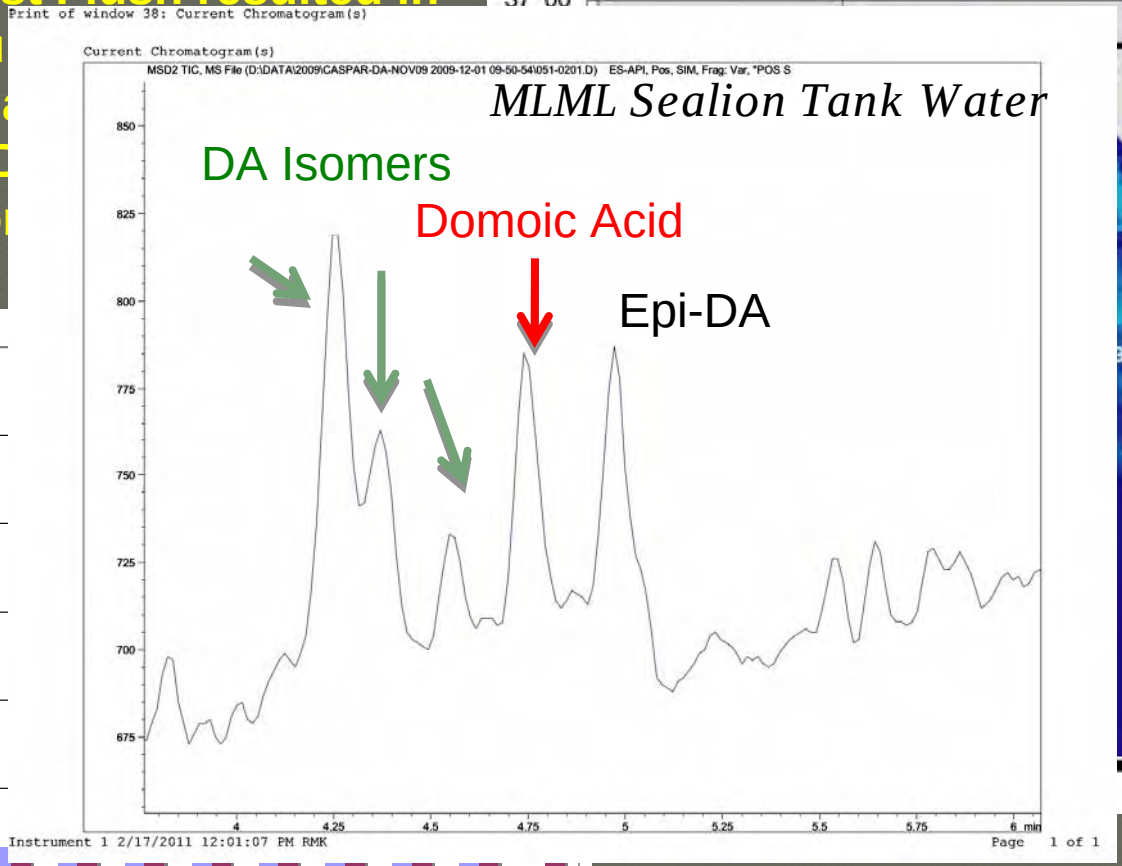


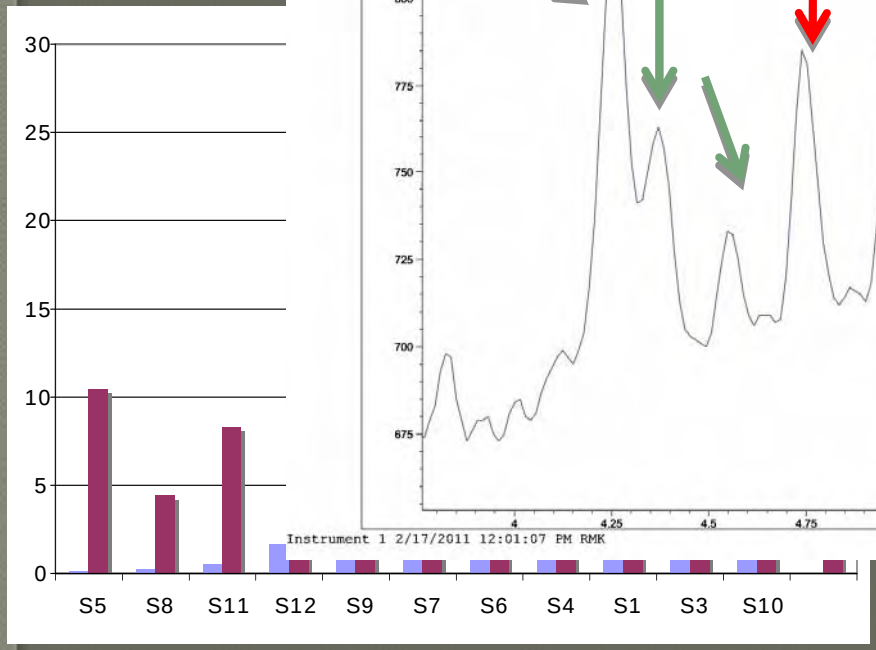


PSTs, Microcystins, and Okadaic Acid also detected

2009 First Flush

2009 First Flush resulted in large pu domoic a in total D flush co

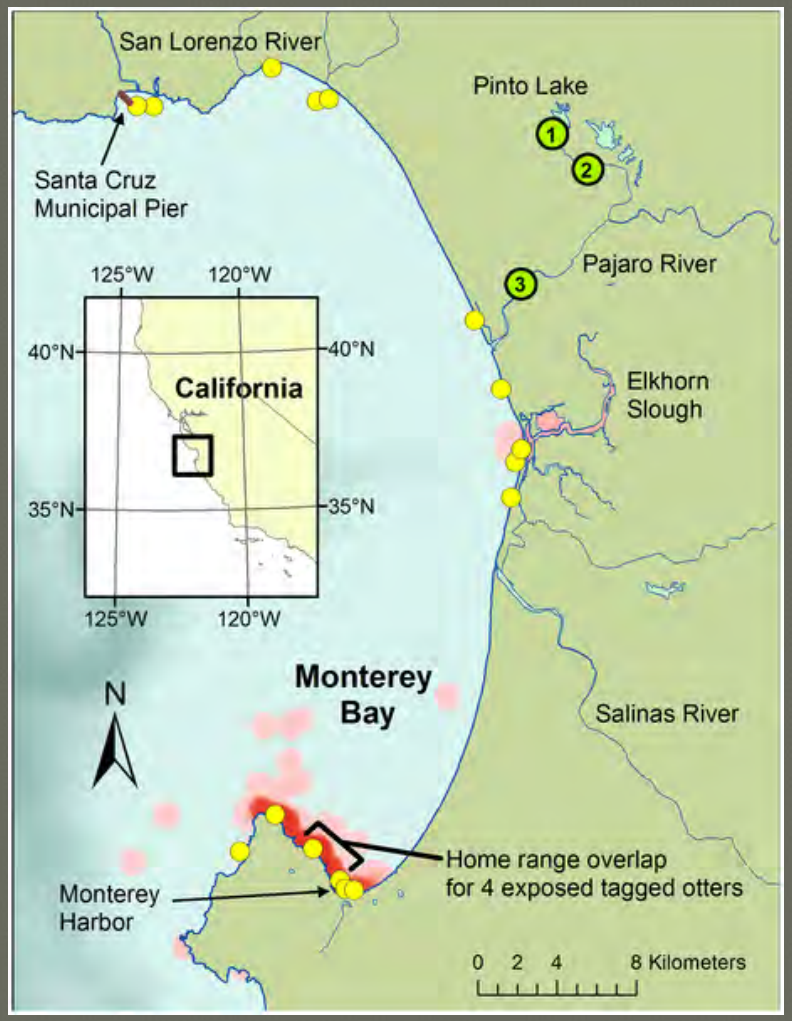




North ---> South

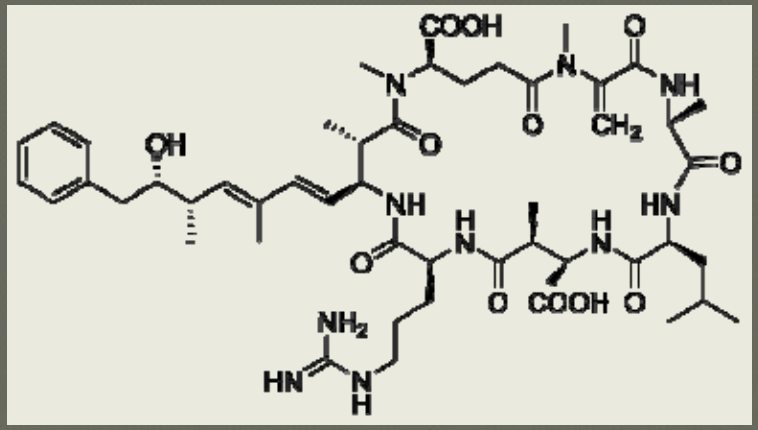
PSTs, Microcystins, and Okadaic Acid also detected

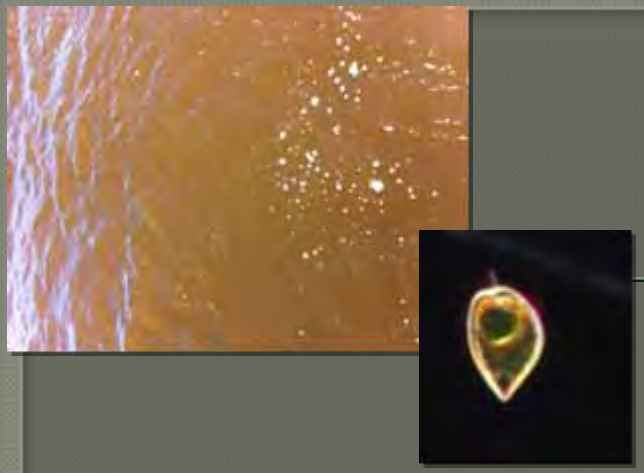
2009 First Flush



Miller et al. PLOS ONE 2010

Besides fecal indicator bacteria and nutrients, other things are coming down the rivers as well…. Including blooms of blue-green algae, also stimulated by eutrophication of the inland watersheds.





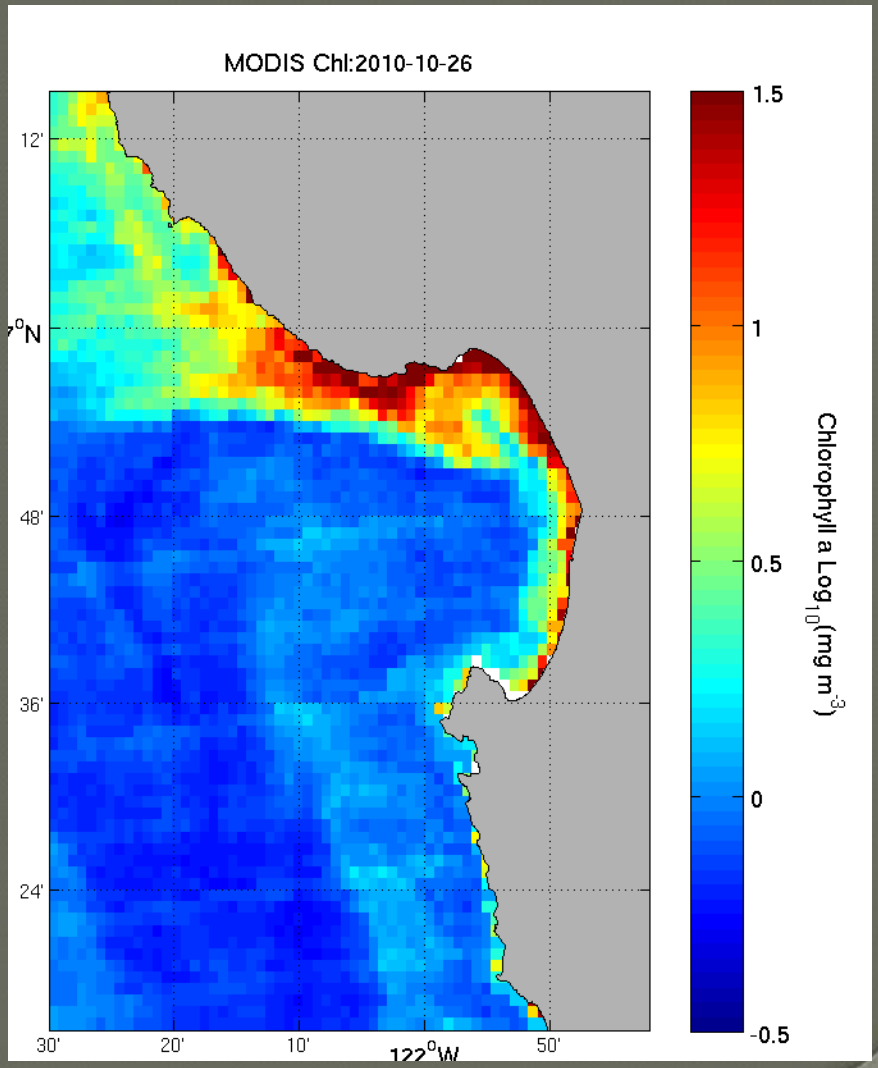
2010 First Flush

Surface bloom dominated by *Prorocentrum*

Peak Chlorophyll > 200 mg/m3

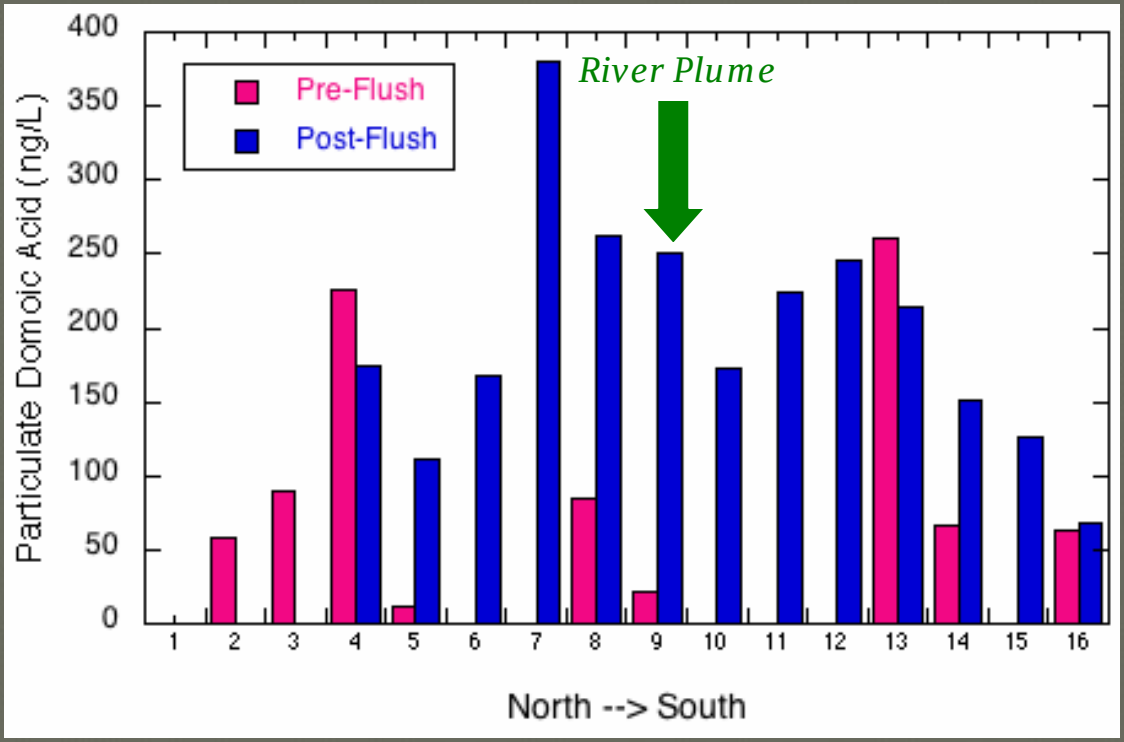
Similarities to 2009:

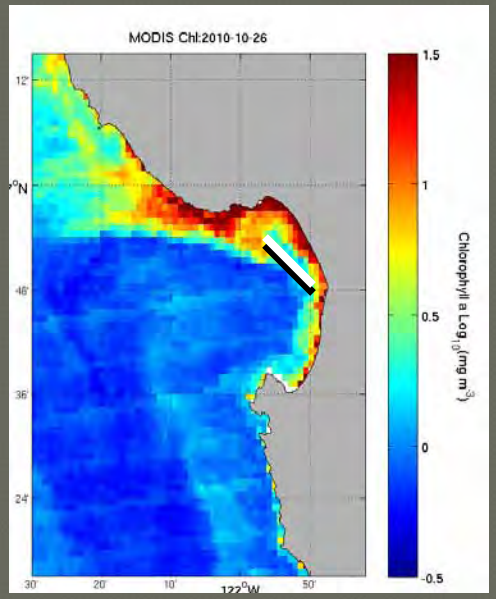
- **Red Tide of dinoflagellates**
- ***Pseudo-nitzschia* at depth**
- **near-shore intensification of bloom in response to circulation and stratification**



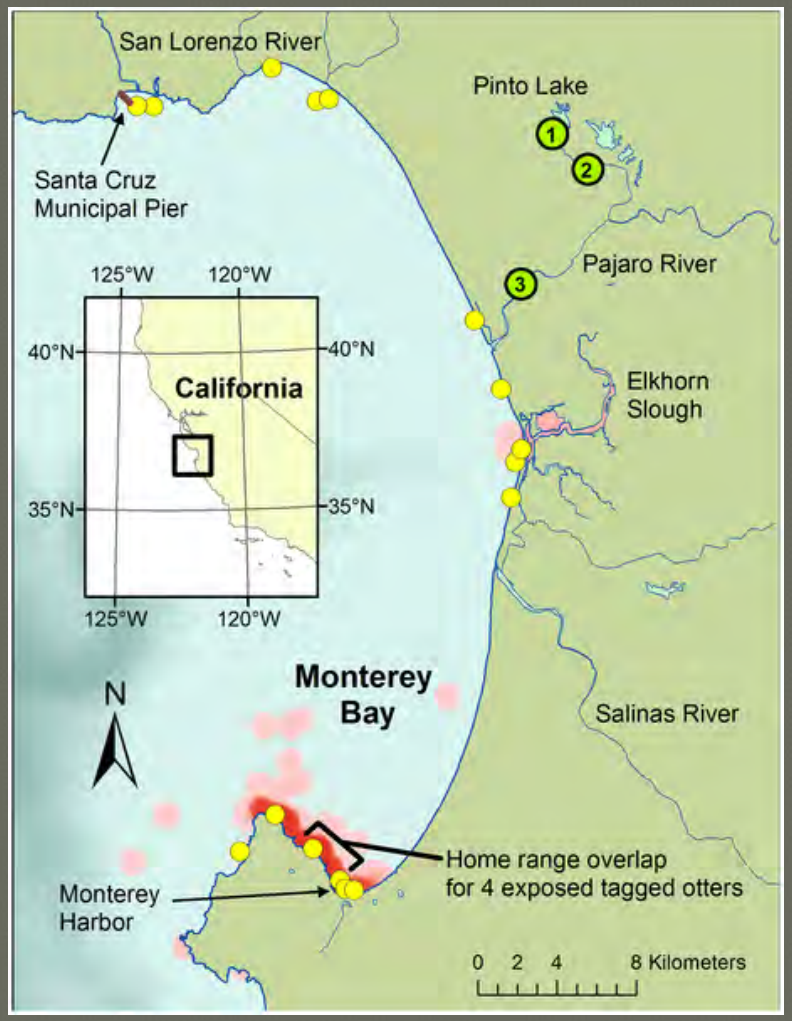
2010 First Flush

2010 Domoic Acid Samples
(post flush > pre flush, p<0.01)





2010 First Flush



Miller et al. PLOS ONE 2010

2010 generally exhibited lower levels of microcystins throughout the Monterey Bay watershed….

BUT during 2010, positive hits for microcystin in First Flush samples in Monterey Peninsula, Pajaro, Salinas, San Lorenzo, and in plume waters….

2009-2010

Rivers (2007-08)

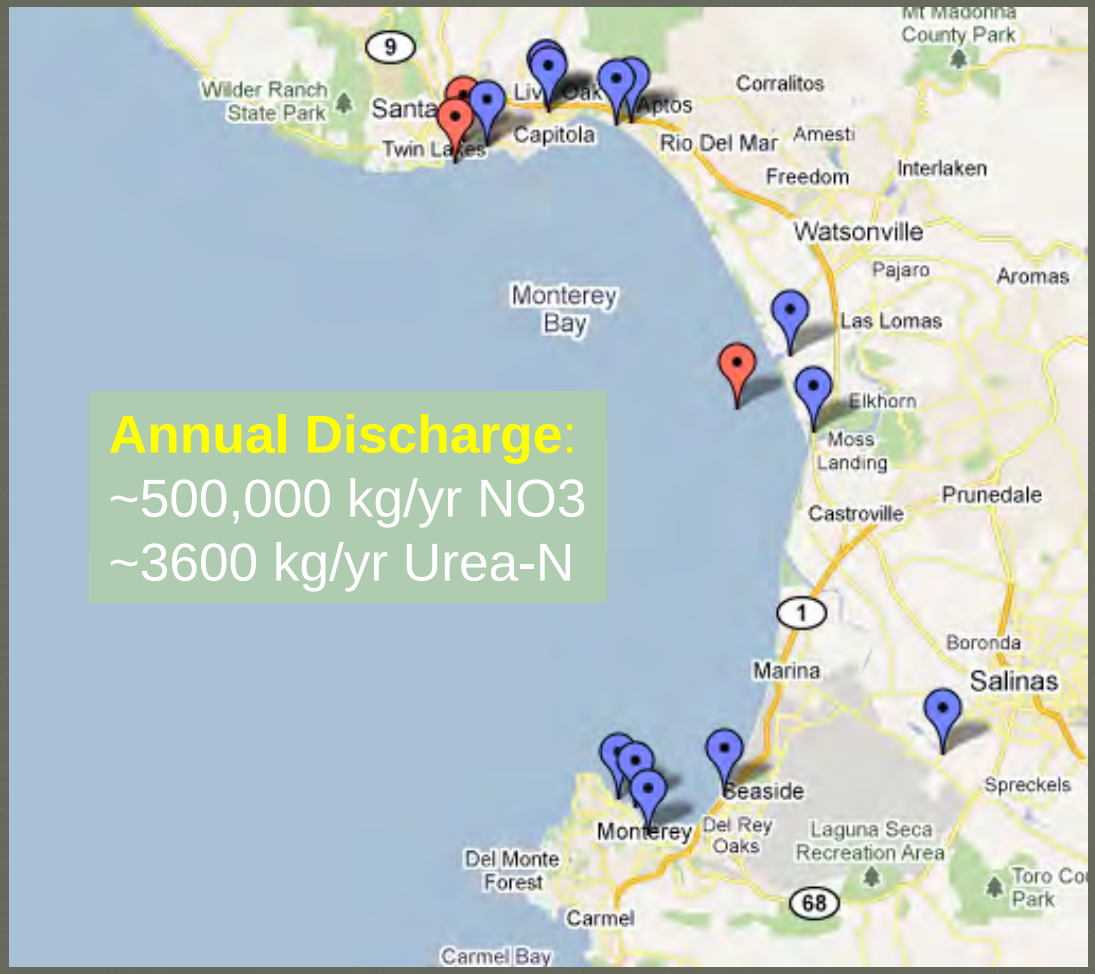
Ammonium: 2 (+/- 4)
Urea: 2 (+/- 1)
Nitrate: 328 (+/- 633)

First Flush 2009

Ammonium: 3.6
Urea: 4 (+/- 1)
Nitrate: 159

First Flush 2010

Ammonium: 43 (+/- 28)
Urea: 24 (+/- 16)
Nitrate: 1 (+/- 1)



Multiple Stressors

	Strong Flush (2009)	Weak Flush(es) (2010)
Enhance Red Tides	✔✔	✔
Enhance Domoic Acid	✔	✔
Microcystin transfer	✔	✔
Presence of other toxins (PSTs, Okadaic Acid)	✔	✔
Poor Water Quality (FIB)	✔	✗

Summary

- There are several emerging threats in the California Current, including Okadaic Acid, Microcystins, and secondary effects of otherwise harmless red tides
- Coastal discharge may be stimulating or enhancing HAB events
- There is clear evidence for multiple stressors during flush events—we don't really understand the synergistic or antagonistic effects of being exposed to this (but it's probably not good)

Photo: www.dirtreport.com