

Water Quality and Harmful Algal Blooms: A Brief Primer

Raphael Kudela

University of California Santa Cruz



Questions & Answers

- **What is a Harmful Algal Bloom? Is this the same thing as a red tide?**
- **Are HAB events more common?**
- **Are they related to humans through eutrophication, Checkmate spraying, etc?**
- **Are they being spread by ballast water?**
- **What is happening now?**

HARMFUL ALGAL BLOOMS

The definition of a HAB is not clear-cut, since it is a societal term, not a scientific term, that describes a diverse array of blooms (both microscopic and macroscopic) that can cause detrimental effects to national economies.



Red Tides

- Blooms of single-celled microorganisms (phytoplankton) that attain such densities that they discolor the seawater; the most common 'red tides' are motile, **dinoflagellates**

Exodus, Chap. 7, Vs 20-21

"... all the water that were in the river were turned to blood. And the fish that were in the river died; and the river stank, and the Egyptians could not drink of the water of the river; and there was blood throughout all the land of Egypt."





La Jolla red tide, Lillian Busse

Most Red Tides are harmless



Santa Barbara News-Press (non-intensified digital camera photo)

The Rogue's Gallery-- Regulated

Alexandrium catenella

- Dinoflagellate
- causes Paralytic Shellfish Poisoning



Pseudo-nitzschia spp.

- Cosmopolitan
- Causes Amnesic Shellfish Poisoning



Microcystin producers (blue-green algae)

- Previously a freshwater problem
- Recently monitored in coastal waters



The Rogue's Gallery-- Regulated

Microcystin: An emerging problem?



Pinto Lake Park



451 Green Valley Road, Watsonville, CA 95076

Facilities & Activities
<ul style="list-style-type: none">• Launch Ramp• Group Picnic Areas• Pavilion (covered group BBQ)• Softball Diamond• Volleyball• Horseshoes• Children's Playground• Pedal and Row Boats (Seasonal)• Fishing (Trout, Catfish, Crappie, Bluegill, and Bass)• Variety of Birds• Kids (under 16) Fish Free

The Rogue's Gallery-- Regulated



Toxins >> Drinking water limit (1000x)

The Rogue's Gallery-Unregulated

***Cochlodinium fulvescens* ***

- Fish/shellfish killer

**Red Tide producers*

***Lingulodinium polyedrum* ***

- Produces yessotoxin (Howard 2006, 2007)

***Akashiwo sanguinea* ***

- “Harmless” red tide (produces peroxides?)

Dinophysis spp.

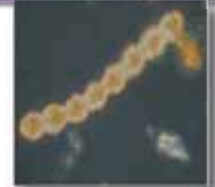
- Diarrhetic Shellfish Poisoning (Caldwell, 2007)

***Ceratium spp.* ***

- Generally harmless

Heterosigma akashiwo

- Bays and estuaries—causes fish kills



Paralytic Shellfish Poisoning (PSP)

- Caused by Saxitoxin
- Produced by dinoflagellates such as *Alexandrium spp.*, *Gymnodinium catenatum*, *Pyrodinium*
- Numbness, incoherence, respiratory paralysis and death
- One of 12 natural toxins on the list of potential agents of biological warfare!

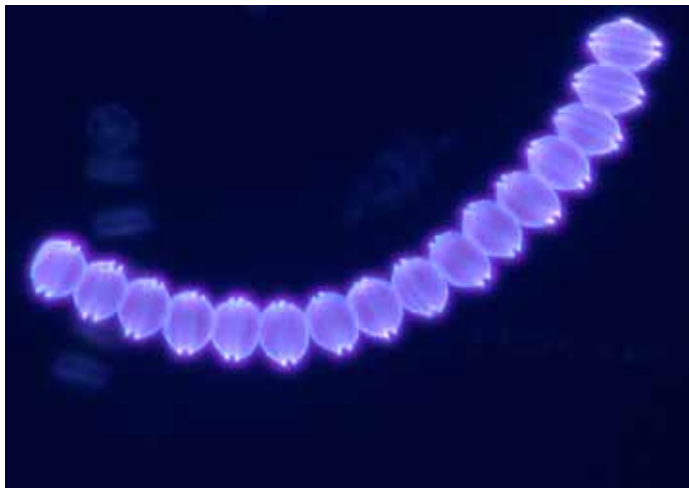
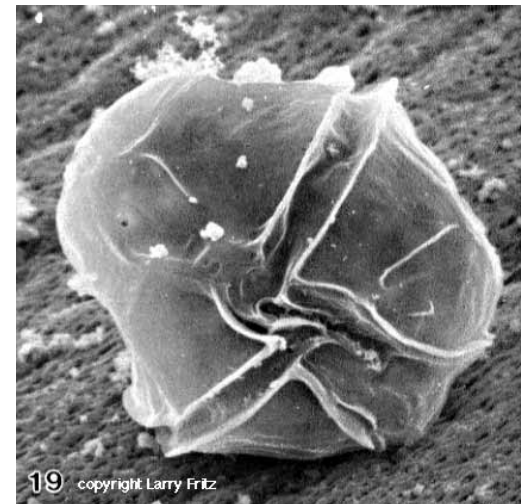
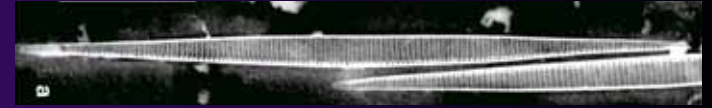


Photo Credit: Susan Coale



www.whoi.edu

Pseudo-nitzschia

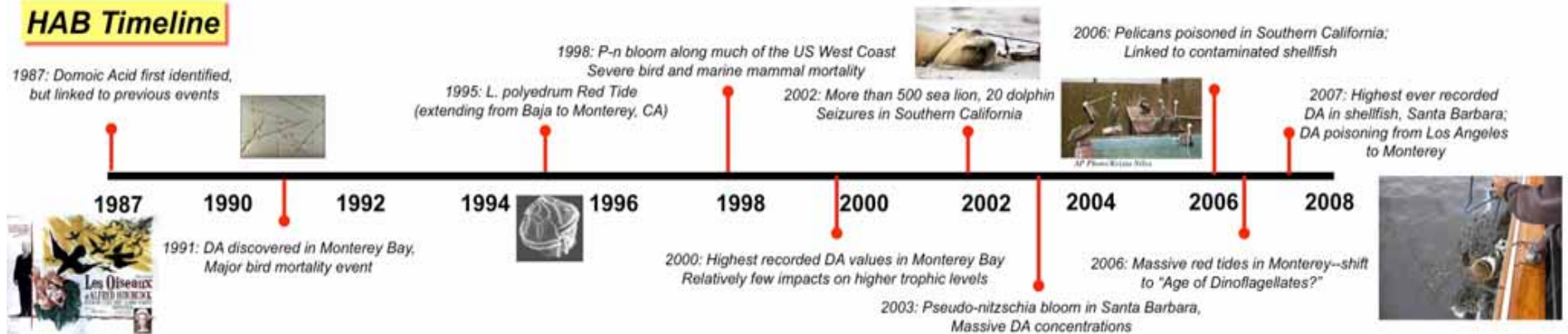


- **Nausea**
 - **Vomiting**
 - **Abdominal Cramps**
 - **Headache**
 - **Dizziness**
 - **Confusion**
 - **Disorientation**
 - **Short-term memory loss**
 - **Motor weakness**
 - **Seizures**
 - **Profuse respiratory secretions**
 - **Cardiac Arrhythmia**
 - **Coma**
 - **Death**
-
- **LD₅₀ = 4 mg/kg**



California sea lion undergoing stomach pumping after poisoning (photo courtesy Dr. Francis Gulland, Marine Mammal Center, Sausalito, CA)

HAB Timeline



- Are HAB events more common?
- Are they related to humans through eutrophication, Checkmate spraying, etc?
- Are they being spread by ballast water or other means?
- What's up with the red tides, particularly last year?

Not covered—the numerous monitoring groups and regulations associated with HABs

Are HAB events more common?

- 1927, contamination of mussels in San Francisco
- 102 illnesses and 6 deaths
- *Alexandrium* determined to be responsible
- Regulatory limit established as $80\mu\text{g}/100\text{g}$ of tissue
- Lethal (human) dose is 1-4 mg toxin
- No really large toxin events since 1980's



Are HAB events more common?

- Domoic Acid Poisoning first described in Prince Edward Island, Canada
- Caused by contaminated PEI mussels
- Referred to as 'Amnesiac Shellfish Poisoning'
- Identified in Monterey in 1991



Are HAB events more common?

- 2002--first evidence for shift to Southern California
- more than 500 sealion, 31 dolphin seizures in Southern California
- 2003: Pseudo-nitzschia bloom in Santa Barbara Channel exceeded $30 \mu\text{g/L}$ chl, massive DA concentrations

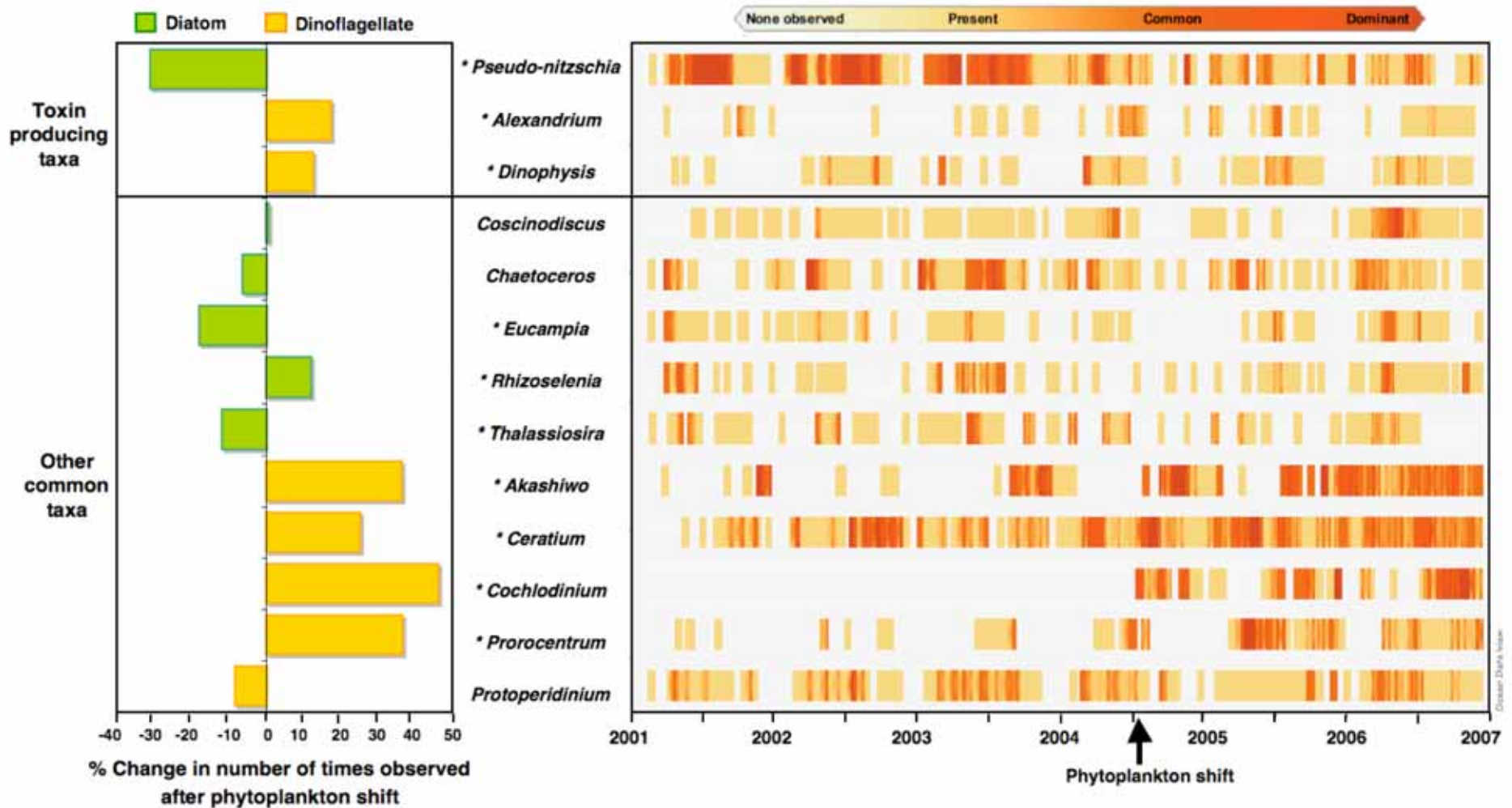
AP Photo/Krista Niles



Toxic Algae Poisoning Los Angeles Pelicans

LOS ANGELES Apr 13, 2006 (AP) Pelicans are falling ill and dying from the same toxic algae bloom that is sickening sea lions and making shellfish unsafe for human consumption, wildlife rescuers said.

Are HAB events more common?



Source: R. Jester, G. Langlois, M. Silver

Are they related to humans?

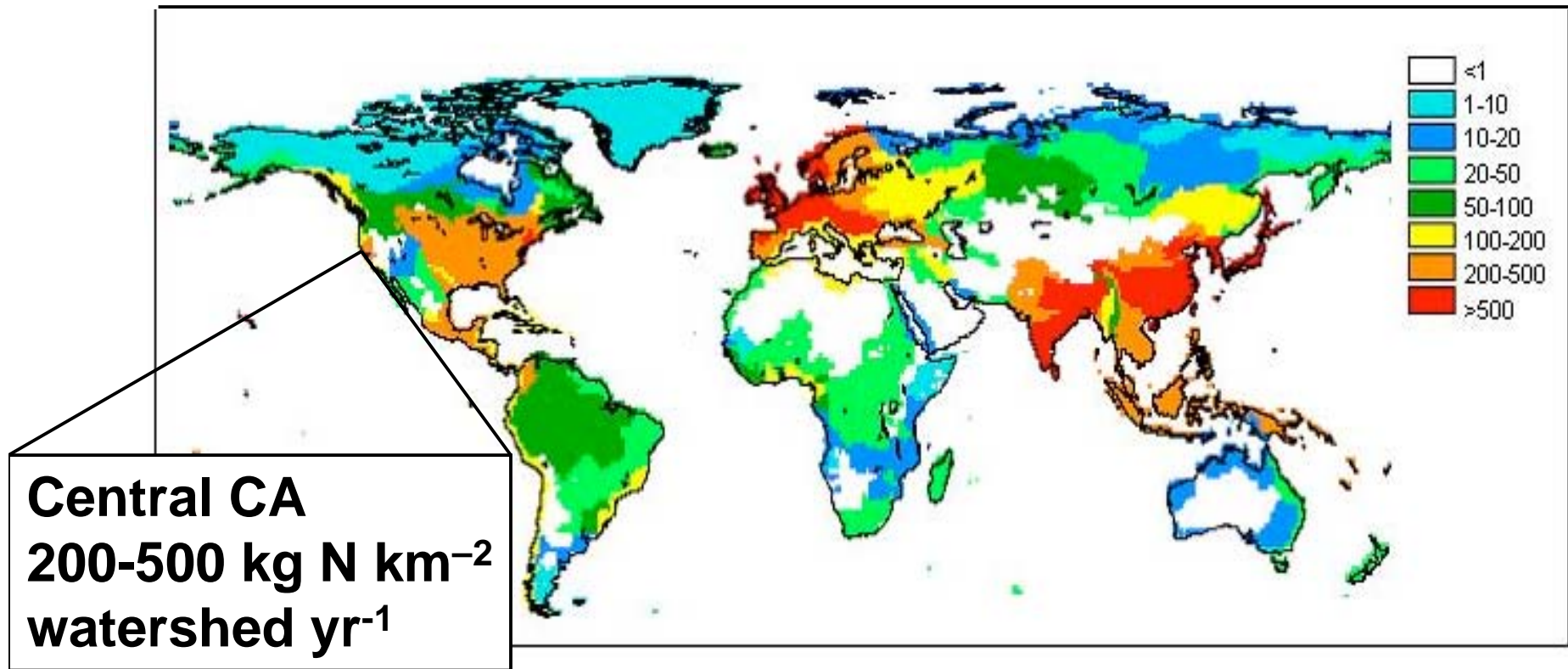
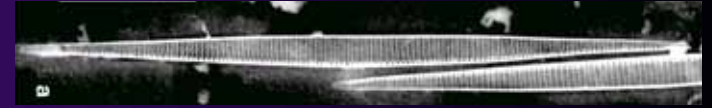
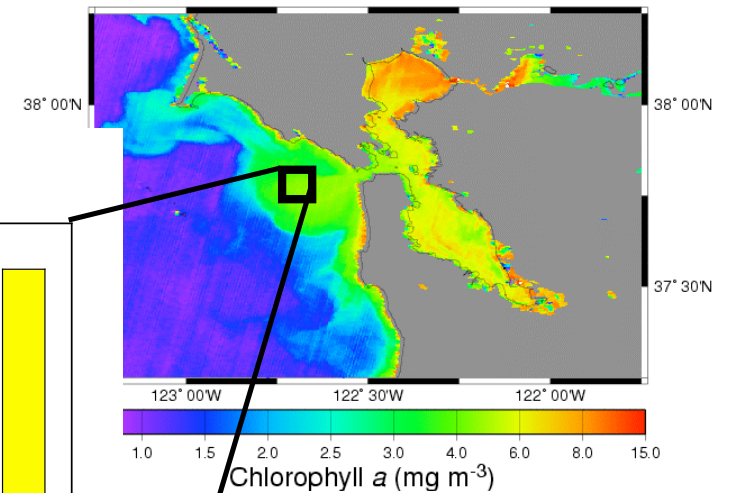
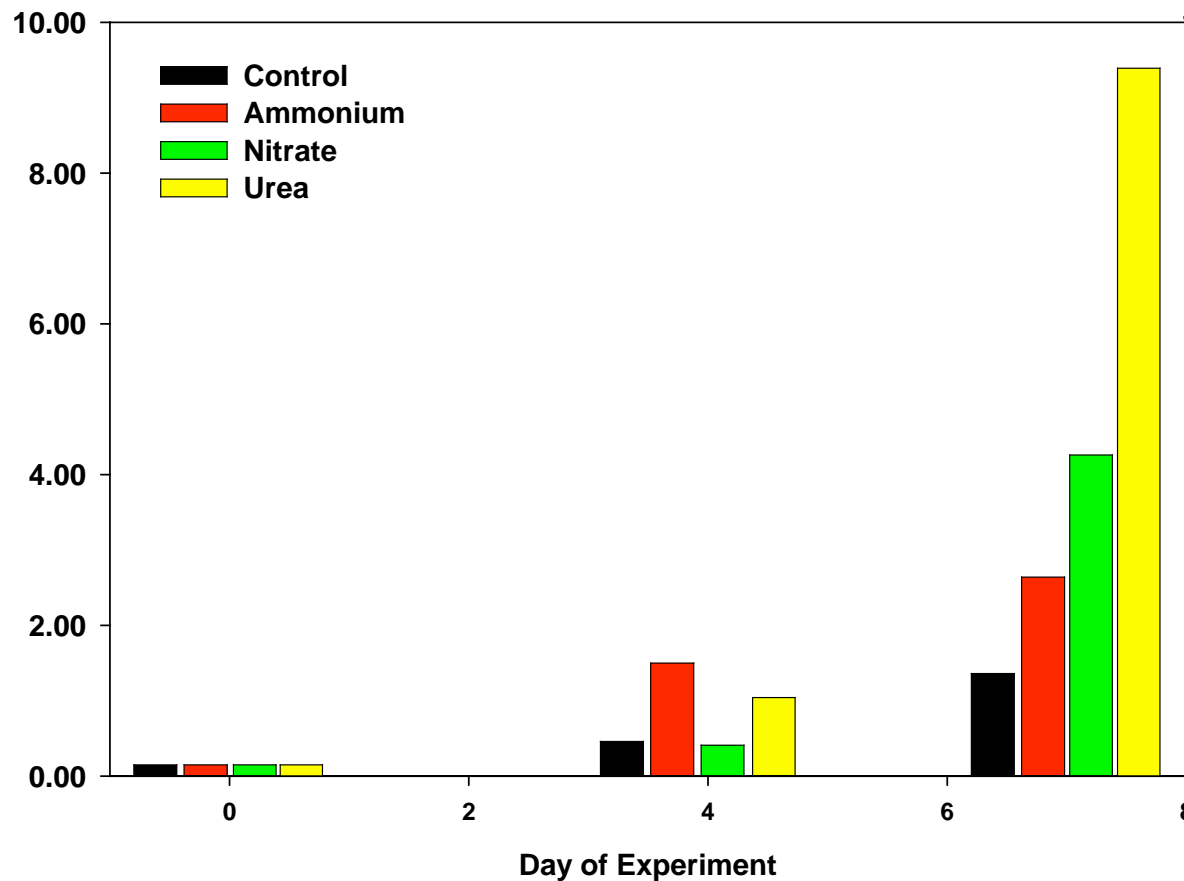


Figure courtesy of Dr. Patricia Glibert, adapted from Seitzinger & Kroeze, 1998 and Glibert & Burkholder, 2006.

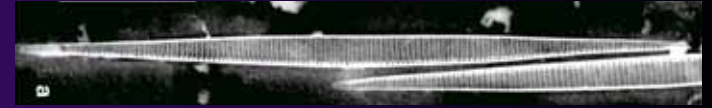
Pseudo-nitzschia



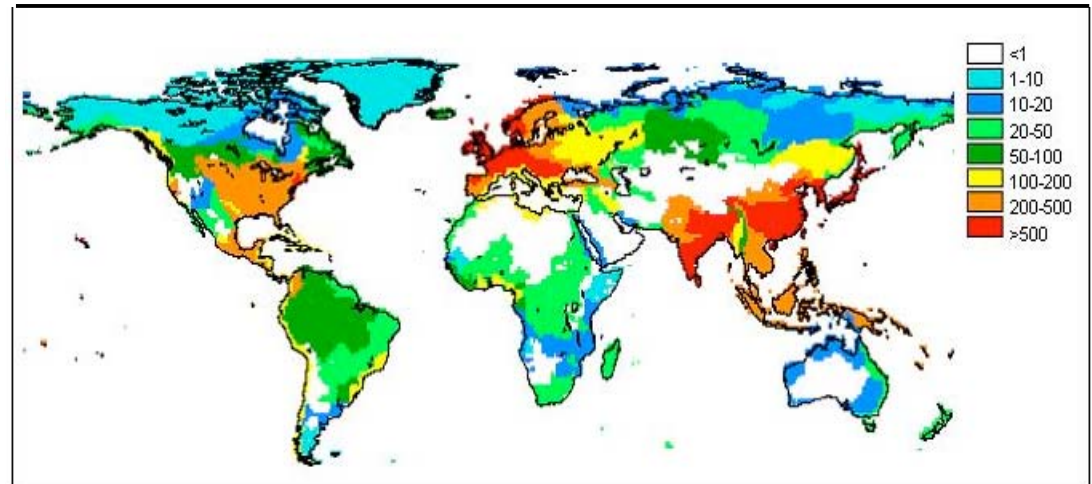
When given urea, toxicity goes up!



Pseudo-nitzschia



**When given urea,
toxicity goes up!**

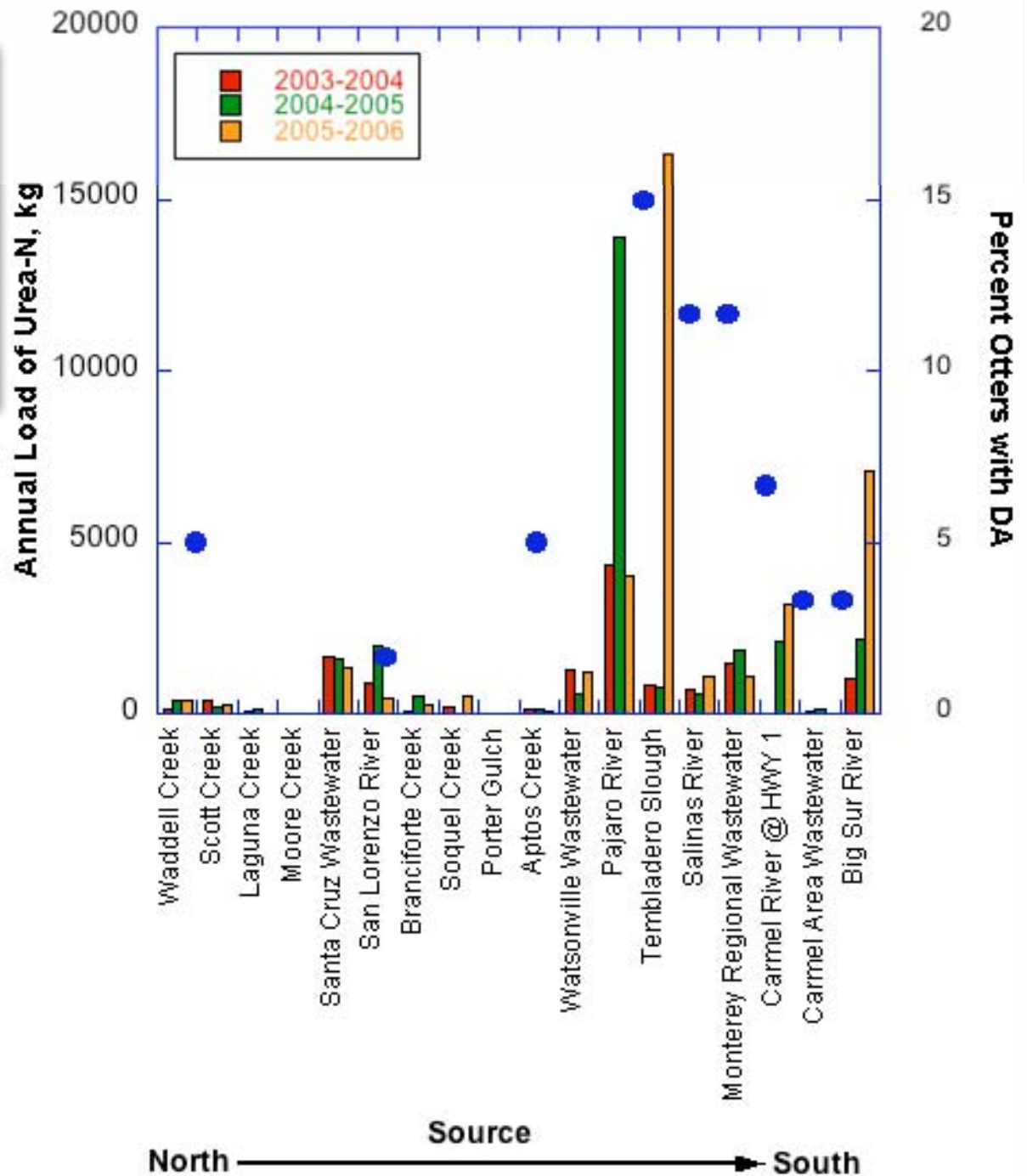


- Originally tested in one field study, and with one laboratory culture (one species)
- Since then, repeated with additional algal strains (confirming results) and additional field data are being collected
- Too early to make a direct link, but urea loading IS high



About 50% of stranded California Sea Otters show signs of Domoic Acid Intoxication

Stranding locations may be linked to urea discharge....



Is it ballast water?

Generally, NO...

but one of the new red tide organisms in Monterey Bay showed up suddenly in 2004, and is closely (genetically) related to a strain found in Japan, Korea, and is linked to ballast water transport in Canada.



Cochlodinium bloom at Avila Pier



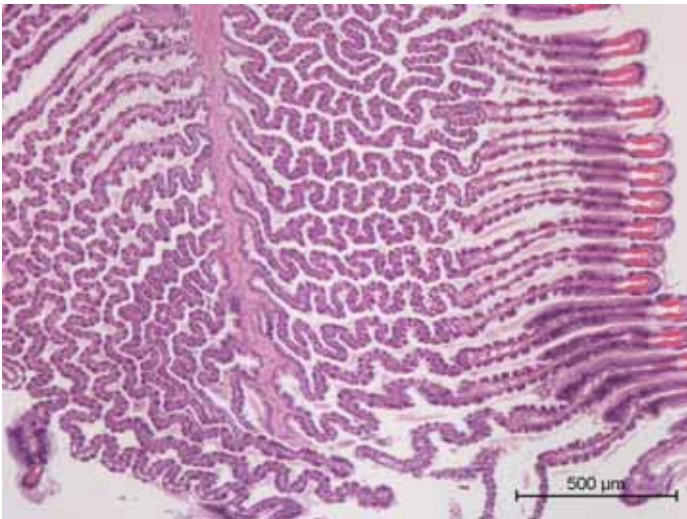
Success

Central and Northern California Ocean Observing System

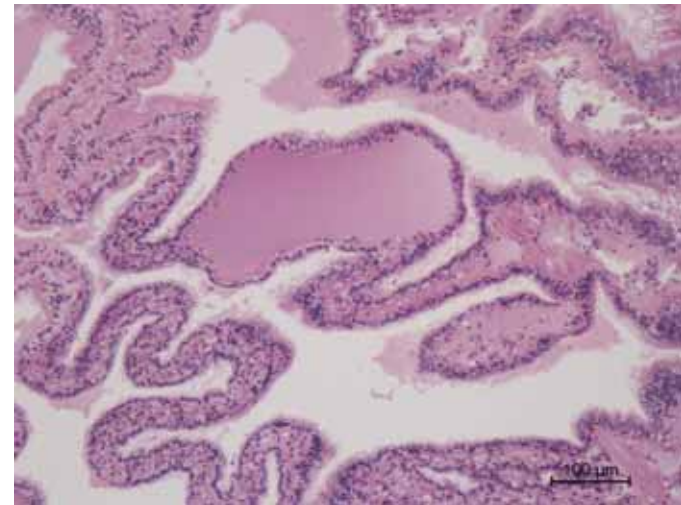
CeNCOOS

www.cencoos.org

Red Tide Response: Ocean Observations Benefit Local Abalone Industry



Healthy abalone gill



Abalone exposed to *Cochlodinium*

http://www.cencoos.org/Abalone_success.pdf

2007—What happened?

November 28, 2007

Santa Cruz County seabird die-off linked to red tide, state officials say

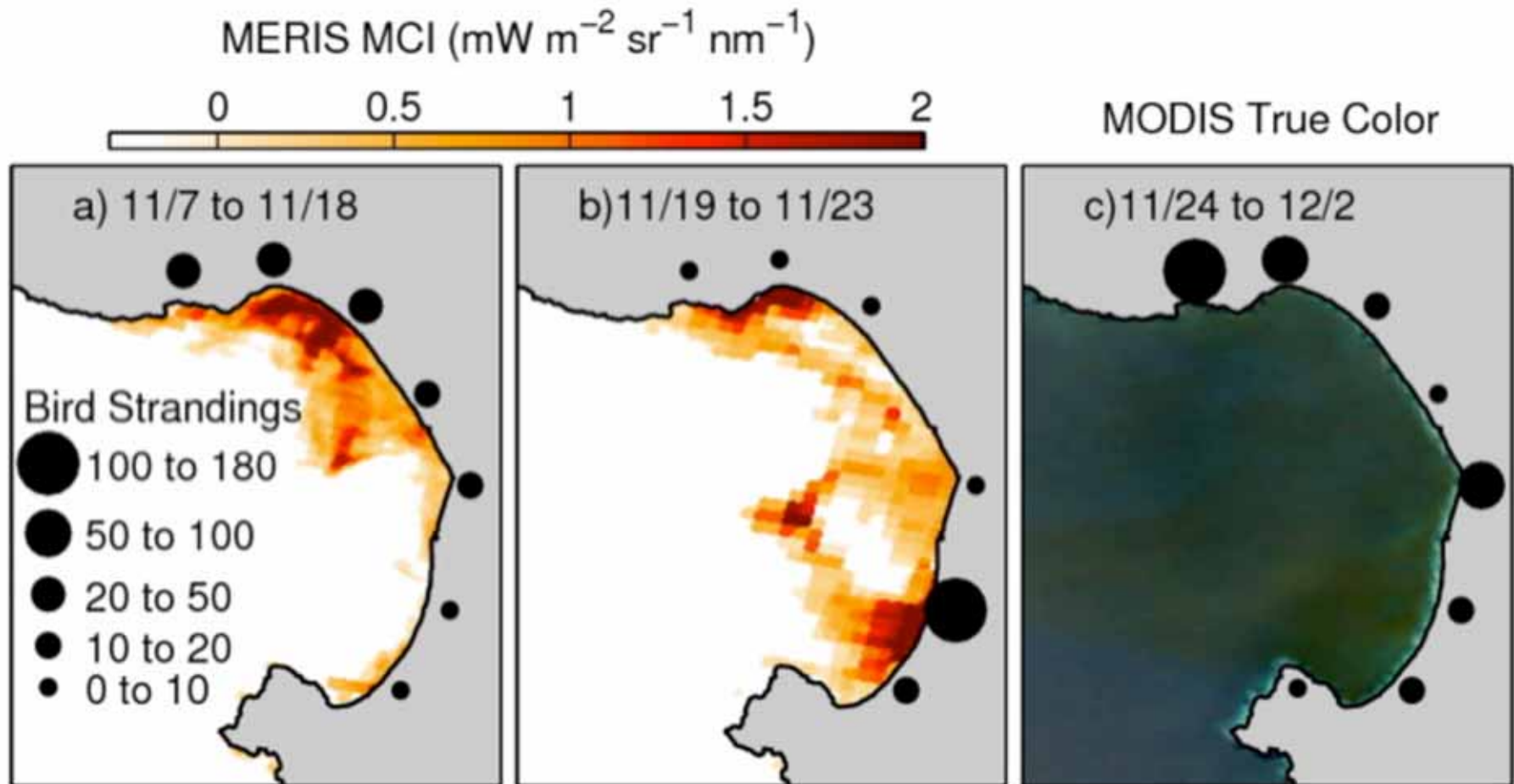
JENNIFER SQUIRES
SENTINEL STAFF WRITER

SANTA CRUZ -- Another wave of dead and sick seabirds washed up on Monterey Bay beaches this week, and state officials believe the birds' mysterious illness comes from the red tide.

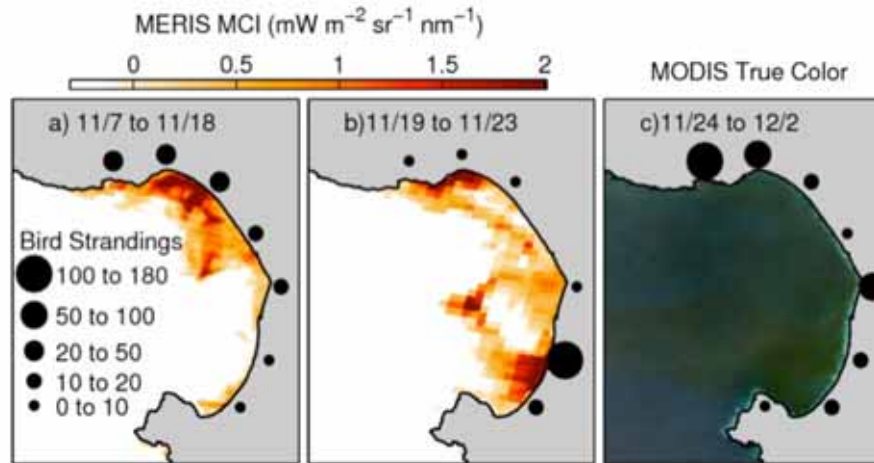
Cosco Busan Oil Spill (San Francisco): 2300 known bird mortalities

Monterey Red Tide: >700 beached birds

Mortalities Linked to Red Tide

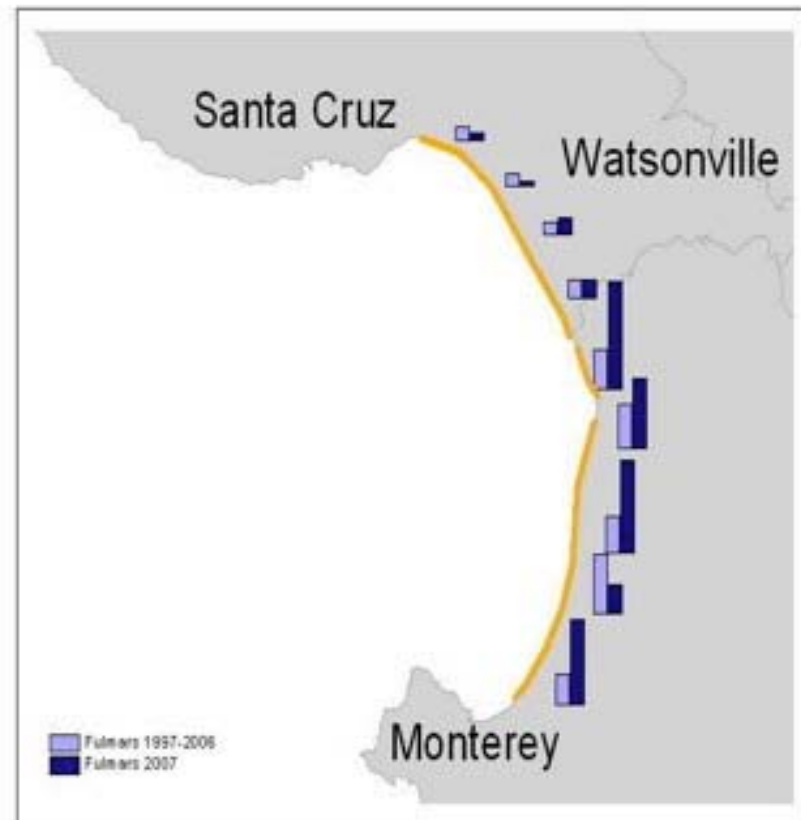
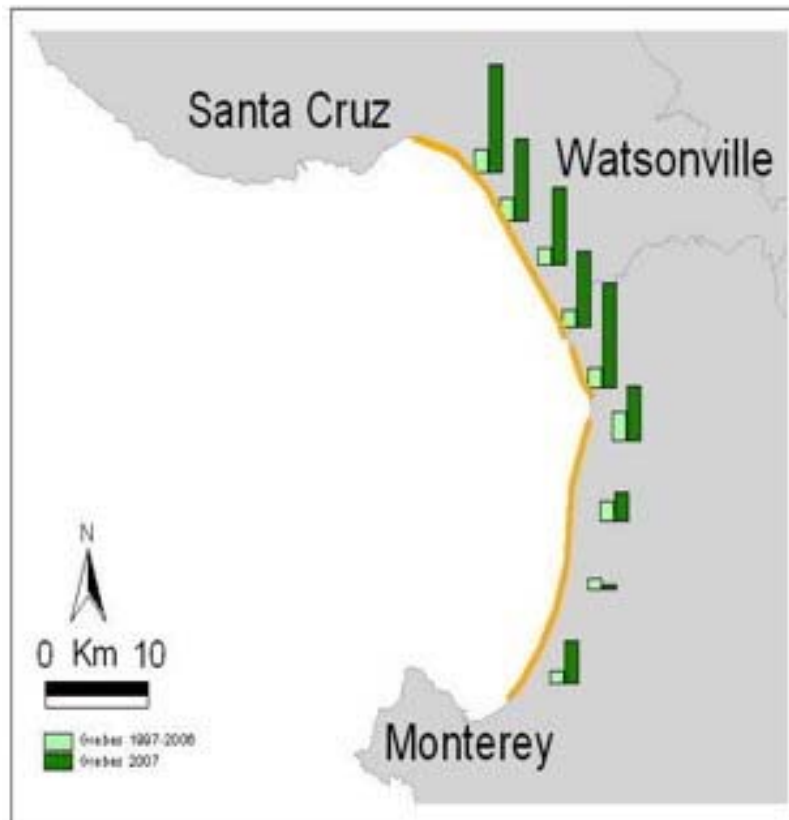


Source: Jessup et al., in prep.



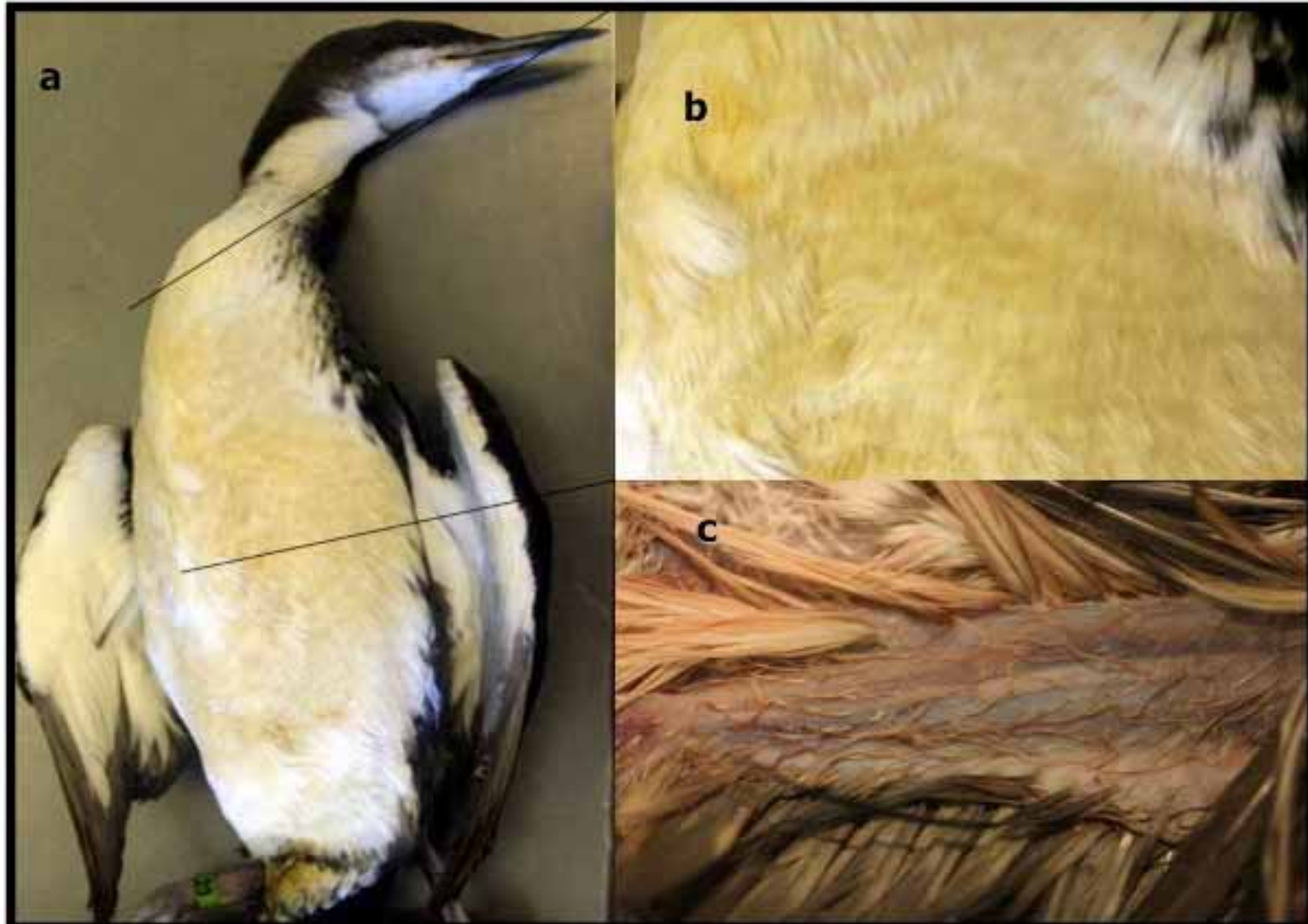
Western/Clark's Grebes (Nov)

Northern Fulmars (Nov/Dec)



Source: Jessup et al., in prep.

Mortalities Linked to Red Tide



Source: Jessup et al., in prep.

2007—What Happened?

Long-term changes in local oceanography have resulted in more red tides from about 2004 onwards—in 2007 intense waves made a “foam” that coated the bird feathers, resulting in hypothermia.

No direct connection to:

- CheckMate spraying
- Unusual nutrient loading
- Oil spills



Santa Cruz Sentinel, 12/5/07

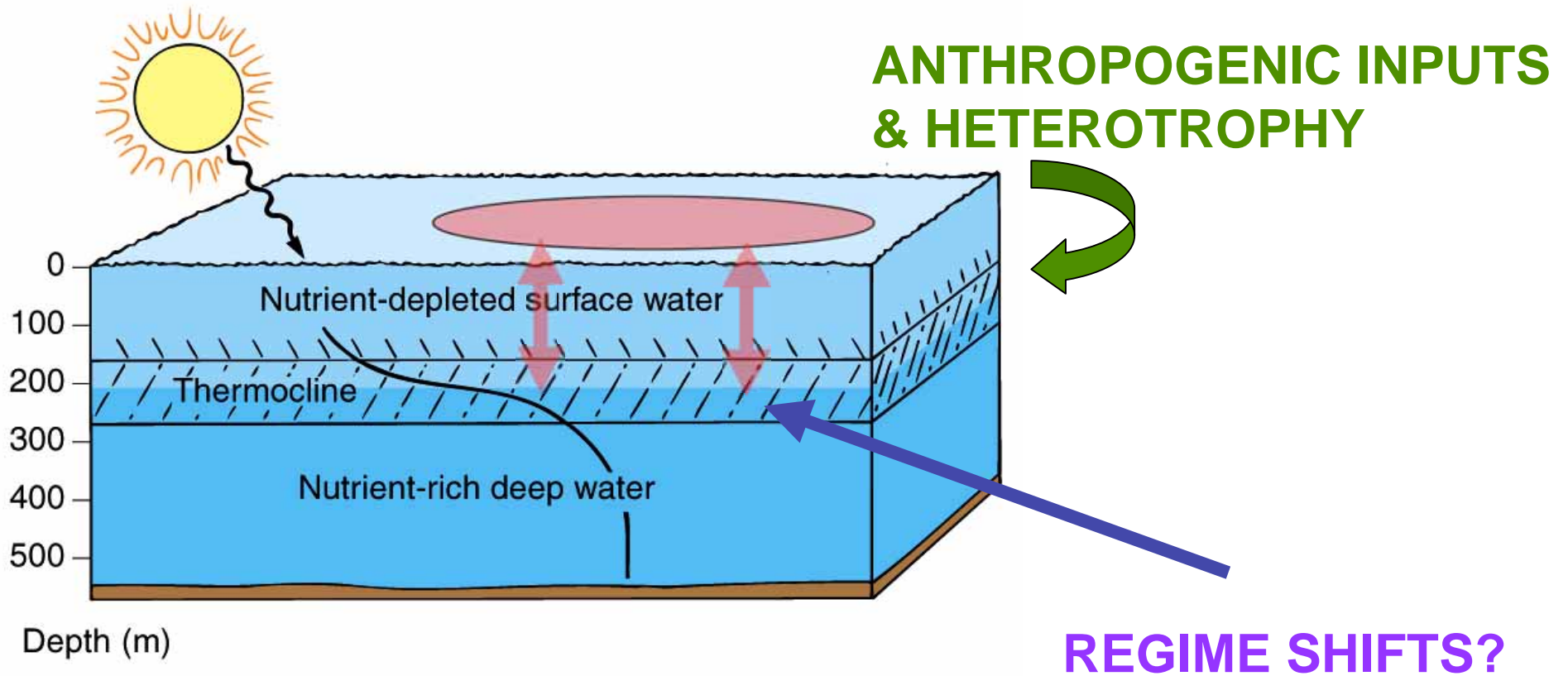


More Red Tides = New Problems

- The increase in all dinoflagellates has resulted in an increase in saxitoxin, yessotoxin, okadaic acid, pectenotoxins, etc.
- *Cochlodinium fulvescens* appeared in Monterey at bloom concentrations in 2004--in 2007, it resulted in a \$60,000 shellfish loss to the Monterey Abalone Company
- November 2007, the “harmless” dinoflagellate *Akashiwo sanguinea* is linked to massive bird mortalities
- 2008—coldest ocean temperatures on record—switch back to *Pseudo-nitzschia*? We have a domoic acid event in July/August (very unusual)

2007--A view of the future?

GLOBAL WARMING



Conclusions

- *Are HAB events more common?* Depends on where you are monitoring, but yes, red tides have increased.
- *Are they related to humans through eutrophication, Checkmate spraying, etc?* There is potential for these factors to make it worse, but they are probably not driving the HAB events.
- *Are they being spread by ballast water?* Maybe, in one case.
- *What now?* There are no simple answers, nor any particular group to blame, but we are experiencing more and different problems