

# Harmful Algal Blooms in North Carolina

Pat Tester, PhD  
Center for Coastal Fisheries and Habitat Research  
National Ocean Service, NOAA



# What Are HABs?

- High biomass of single cell phytoplankton
- >10,000 species
- <5% toxic

Algal toxins enter food chain

## Shellfish Poisonings

- Paralytic PSP
- Neurotoxic NSP
- Diarrheic DSP
- Amnesic ASP

Cyanotoxicity

Ciguatera Fish Poisoning

Pufferfish Poisoning



XX



# Effects of HABs

- Threat to Human Health
- Regional Economic Impacts
- Loss of Consumer Confidence
- Mass Mortality of Fin Fish
- Loss of Environmental Quality
- Marine Mammal & Bird Deaths
- Effects on Non-Commercial Species?
- Water Quality Implications?

# HABS as Emerging Issues



<http://www.start1.com/>



Florida Marine Research Inst., St. Petersburg



Image from Cyanobacterial Image Gallery, Perdue University

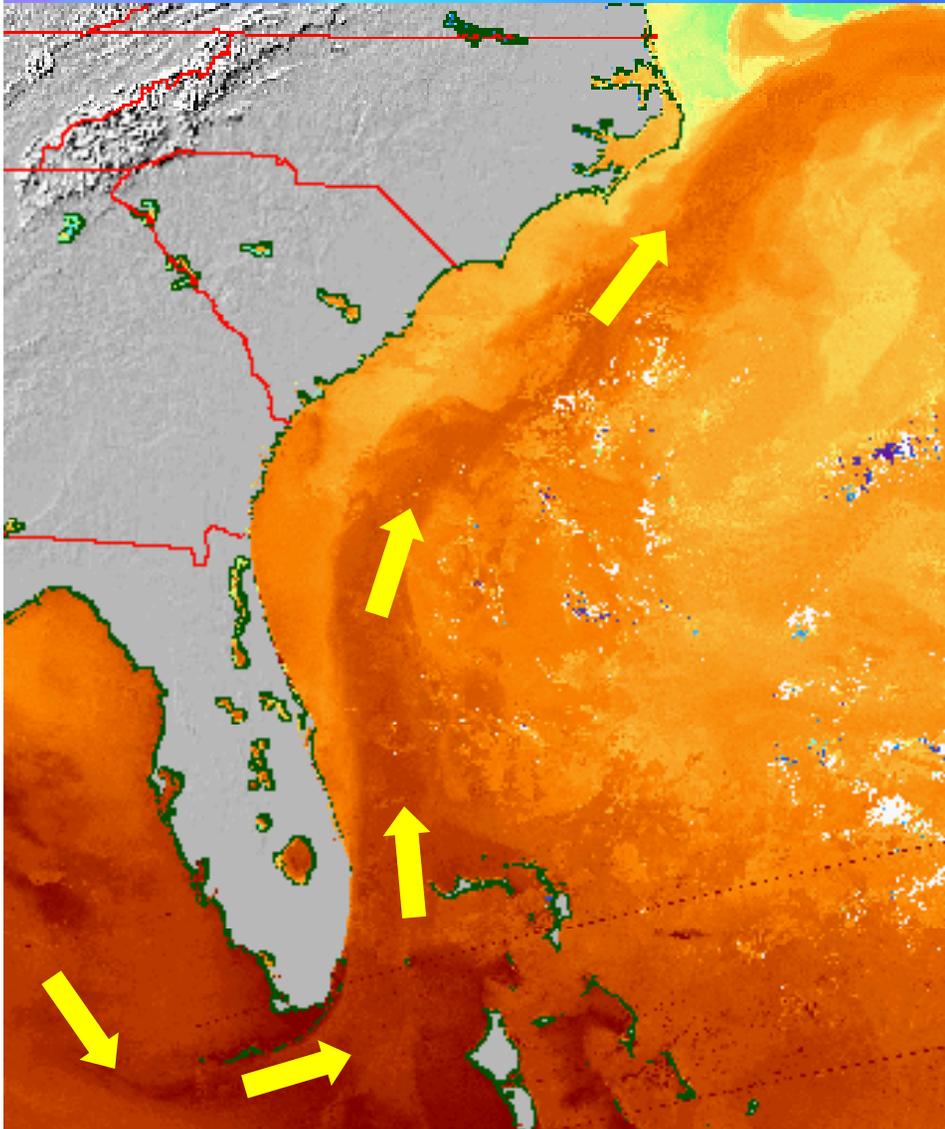


<http://animals.nationalgeographic.com/staticfiles/NGS/Shared/StaticFiles/animals/images/1024/sea-otter.jpg>



Image from Cyanobacterial Image Gallery, Perdue University

# HABs in North Carolina

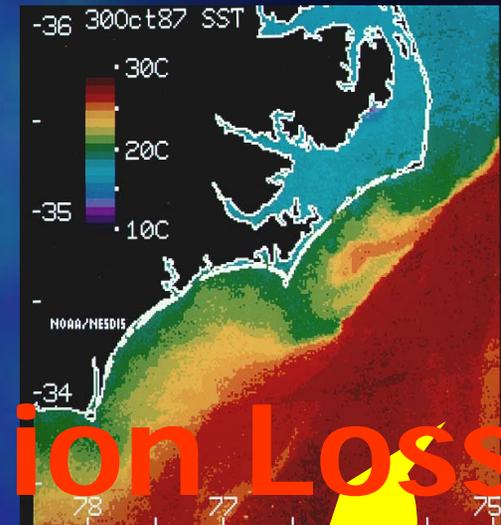


- Will reflect what is happening GOMx & FL now
- Range extensions of subtropical species
- Gulf Stream facilitated transport
- More subtropical species
- Fewer temperate species

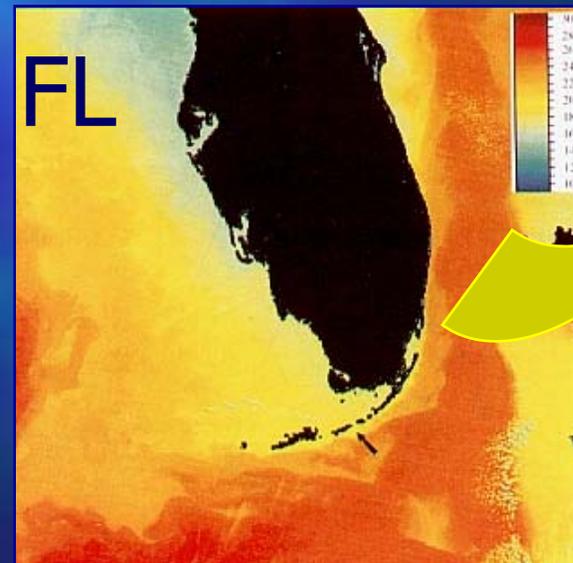
# *K. brevis* Range Extensions

- Ban on harvesting of oysters & clams for up to 6 months
- 5,000 commercial fishermen could not harvest shellfish
- Halo effect
- Tourism reduced
- 44 Cases of NSP

NC

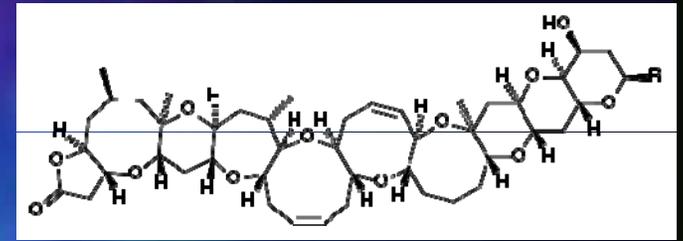


**\$25 Million Loss**



Tester et al. 1991

# *Karenia brevis*



Brevetoxin a

<b>Toxin:</b>	Brevetoxins (multiple forms 10?)
<b>Mode of action:</b>	Na <sup>+</sup> channel activator
<b>Illness:</b>	Neurotoxic shellfish poisoning
<b>Symptoms:</b>	Tingling of lip, nausea, diarrhea, ataxia Airborne toxins cause eye irritation, coughing
<b>US range:</b>	Gulf of Mexico & recently US South Atlantic Bight
<b>Limited by:</b>	Lower thermal tolerance
<b>More information:</b>	Prof. Dan Baden, UNCW Dr. Pat Tester, NOAA Dr. Jan Landsberg, FL FWC



*Karenia brevis*. NOAA

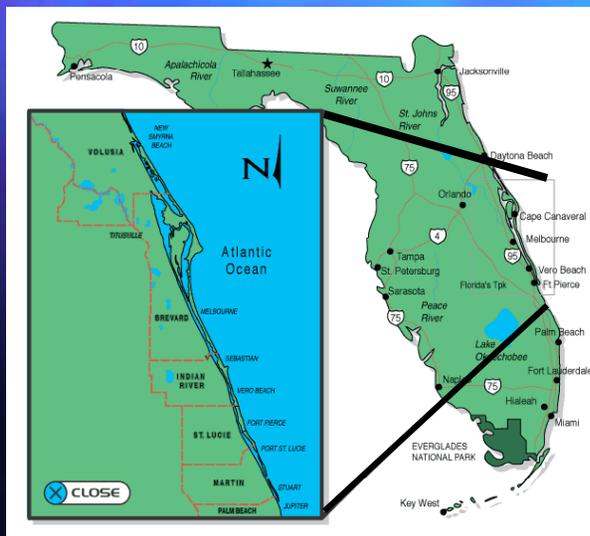
# Saxitoxin Pufferfish Poisoning



Southern puffer Photo by P. M. Leahy, Jr.

Florida Fish and  
Wildlife  
Institute

- 2002 puffer from Indian River Lagoon in FL found to be toxic
- Skin, muscle, viscera toxic, ovaries especially toxic >275 fold action level of 80  $\mu\text{g}$  STX eq 100g
- Captive puffer fish still toxic after 1 year
- *"Therefore, we confirm puffer fish to be a hazardous reservoir of STXs in Florida's marine waters and implicate the dinoflagellate P. bahamense as the putative toxin source."*  
FL FWC, Landsberg et al. 2006



Indian River Lagoon, FL

<http://www.redfishing.com/map.html>

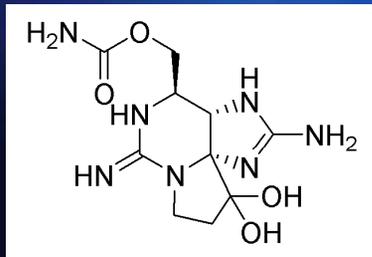
# *Pyrodinium bahamense var bahamense*

**Toxin:** Saxitoxins (multiple forms ~ 12)  
**Mode of action:** Na<sup>+</sup> channel blocker  
**Illness:** Paralytic shellfish poisoning  
**Symptoms:** Tingling of lip, nausea, diarrhea, ataxia  
Can be fatal

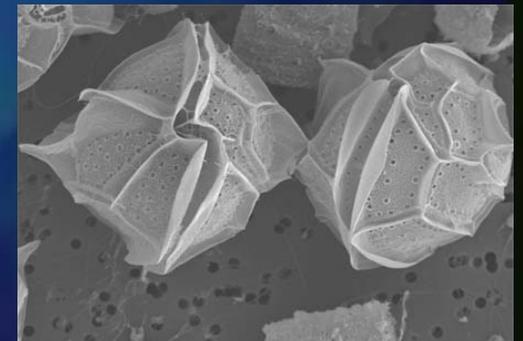
**US range:** Tropical & subtropical Atlantic

**Limited by:** Lower thermal tolerance ~ 20°C

**More information:** [research.myfwc.com](http://research.myfwc.com)  
Dr. Jan Landsberg, FL FWC

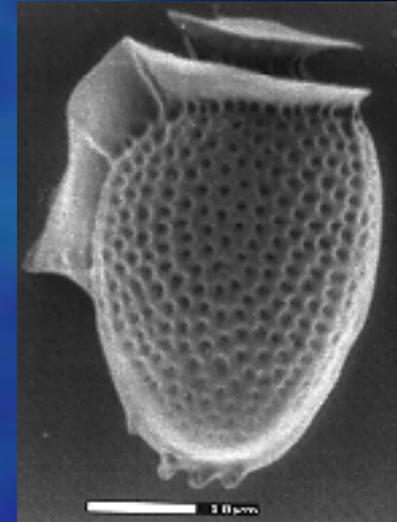


Saxitoxin

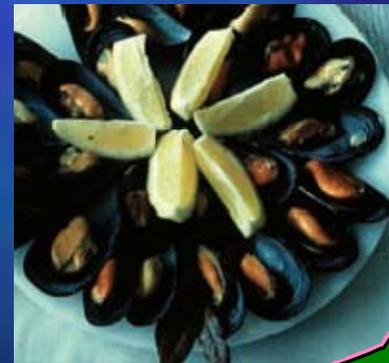


# Diarrhetic Shellfish Poisoning

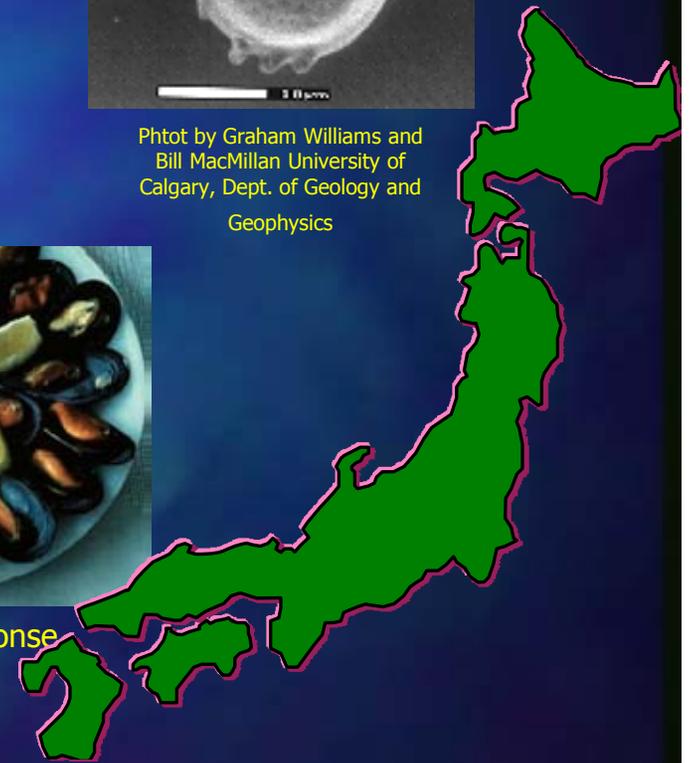
- Recognized in Holland 1970s
- 1<sup>st</sup> described 1976, Japan
- Common in the Mediterranean
- Nausea, diarrhea
- Easily mistaken as bacterial contamination
- Non-fatal, 3 day recovery
- BUT, tumor promoter!



Photot by Graham Williams and  
Bill MacMillan University of  
Calgary, Dept. of Geology and  
Geophysics



Harmful Algal Research & Response  
National Environmental Science  
Strategy (HARRNESS), NOAA

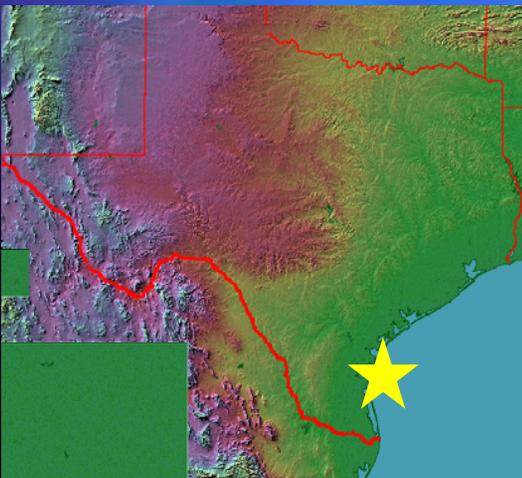


# Corpus Christi Caller Times

## March 2008

"...Texas shellfish beds, causing the Texas Department of State Health Services (DSHS) [to] close a number of bays to shellfish harvesting."

"..the state has also issued a recall of oysters, clams and mussels..."



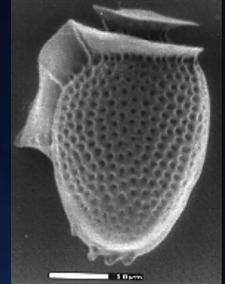
2008 First closure of shellfish beds in the US waters due to DSP

Significant economic loss



<http://w3.kunsan.ac.kr/~mogas/frame/Plankton.htm>, Kunsan National University

# *Dinophysis acuta & acuminata*

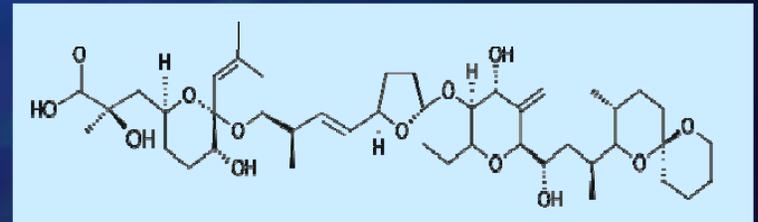


*Dinophysis*

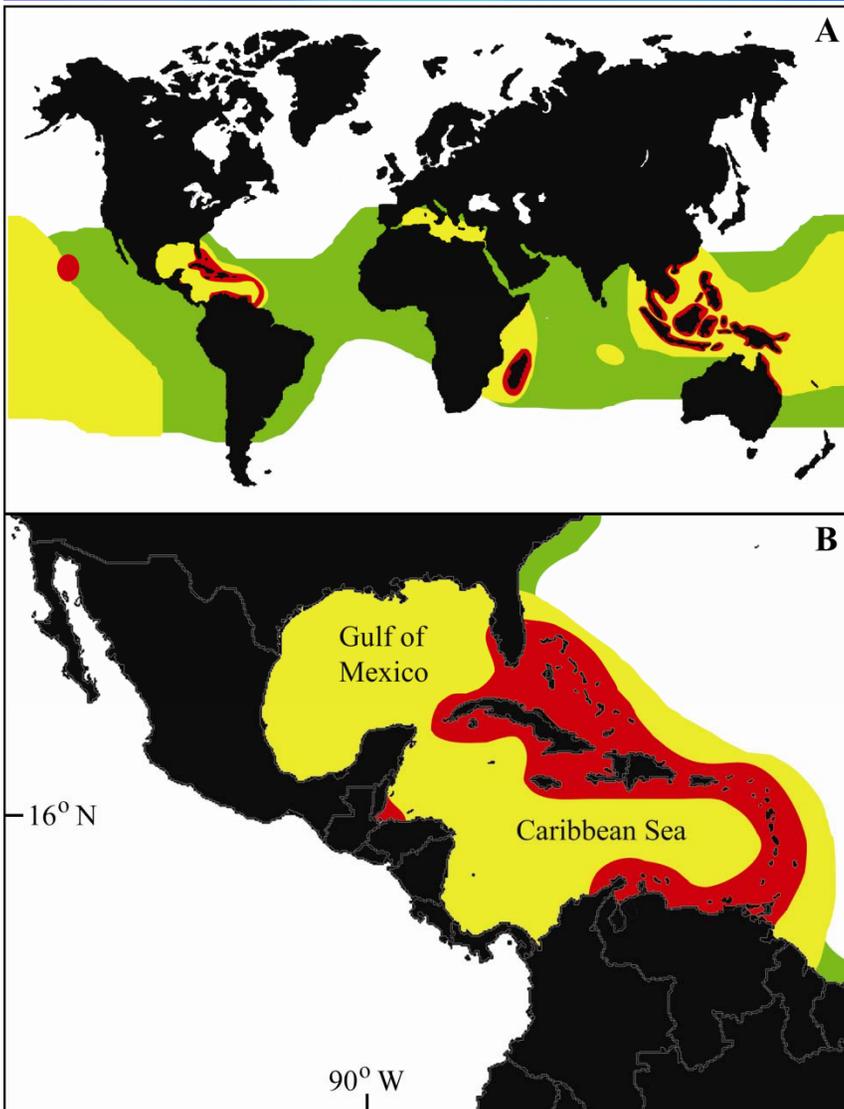
Phot by Graham Williams and  
Bill MacMillan University of  
Calgary, Dept. of Geology and  
Geophysics

<b>Toxin:</b>	<b>Okadaic acid, dinophysistoxins</b>
<b>Mode of Action:</b>	<b>Potent inhibitor of proteinphosphorylase Stimulates phosphorylation that controls Na<sup>+</sup></b>
<b>Illness:</b>	<b>Diarrhetic shellfish poisoning</b>
<b>Symptoms:</b>	<b>Onset 30 m to 2 - 3 h Diarrhea (92%), nausea (80%), vomiting Complete recovery within 3 d</b>
<b>US Range:</b>	<b>All continental US waters</b>
<b>Limited by:</b>	<b>UK</b>

Okadaic Acid



# Ciguatera Fish Poisoning Distribution



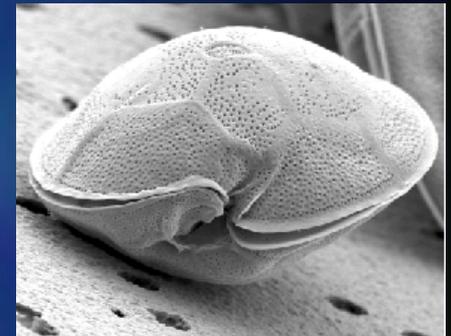
“Most common  
foodborne illness  
related to fish  
consumption.”

(Hokama 1993, Lange 1994)

NOAA

# Ciguatera Fish Poisoning

- First recognized in 1550's in Caribbean
- Causative species not identified for >300 yrs
- Suite of benthic, sessile dinoflagellates incl. *Gambierdiscus toxicus*
- Food web concentration from reef habitats
- >50,000 victims annually
- Pantropical distribution



SEM by Maria Faust





# Amnesic Shellfish Poisoning

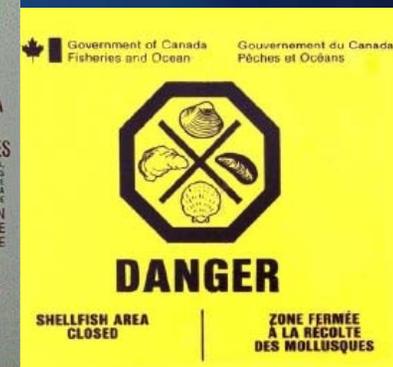
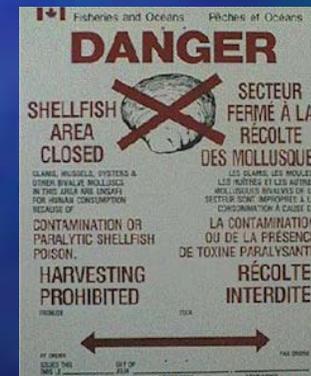
- First described from PEI in 1987
- 107 cases, 3 deaths
- Domoic acid - excitatory neurotoxic amino acid from diatoms genus *Pseudo-nitzschia*
- Vomiting, cramps, diarrhea, memory loss, disorientation, lethargy, seizures
- Short term & permanent memory loss



Photo by Rita Horner, University of Washington



[commons.wikimedia.org/wiki/File:Caduceus](https://commons.wikimedia.org/wiki/File:Caduceus)



Fisheries and Oceans Canada

# ASP or Domoic Acid Toxicity

- Early 1990's DA toxicity in CA
- Shortly after, reported in WA, OR
- Bird deaths
- Marine mammal, bird deaths
- Shellfish closures cost >\$.75M
- Persists in marine food webs



IBRRC staff treats domoic acid poisoned endangered brown pelican at bird center in San Pedro, CA.



Razor Clams, WA State Dept. Fish and Wildlife



Diatoms, NOAA



Sardine,  
[http://drinksoakedtrotsforwar.com/wp-content/uploads/2008/07/sardine\\_whitebackgrnd.jpg](http://drinksoakedtrotsforwar.com/wp-content/uploads/2008/07/sardine_whitebackgrnd.jpg)



Scholin et al. 2001

# Domoic Acid Toxicity in NC?

2007 Data indicate that recent whale and dolphin mortalities off the NC and Virginia coast may have been attributable to DA poisoning

- *Kogia breviceps* – Pigmy sperm whale
- Adults <2.5m, <300 kg
- VA to Lesser Antilles in Gulf of Mexico
- Squid eaters



Illustration credit: Wikipedia

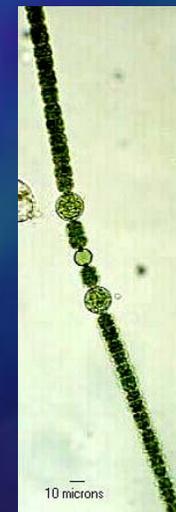
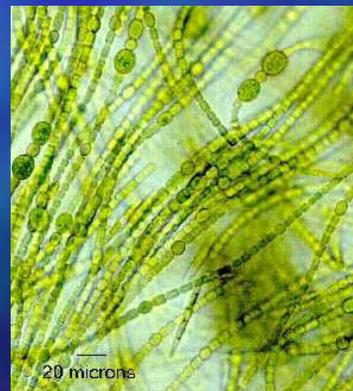
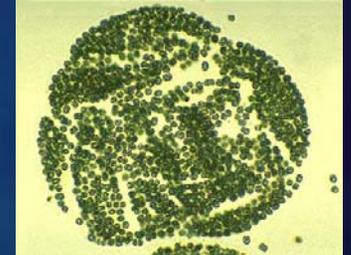
Illustration credit: Pieter A. Folkens



- *Phocoena phocoena* – Harbour porpoise
- Adults 1.4-1.9m, 61-76 kg
- Diet of small fish, herring, caplin, sprat

# Blue Green Algae (aka Pond Scum)

- World wide distribution in marine & FW
- Nutrient sensitive
- Cyanotoxins ~50
- Stable
- Toxins bioaccumulate in food web
- Neurotoxin & acute liver toxin, gastrointestinal, respiratory effects



Images from Cyanobacterial  
Image Gallery, Cyanosite,  
Purdue University,  
[http://www-  
cyanosite.bio.purdue.edu/ima  
ges/images.html](http://www-cyanosite.bio.purdue.edu/images/images.html)

# Increasing Problem Lakes, Reservoirs and Coastal Regions

- Blooms nutrient sensitive
- Favored by high temps, light
- Produce a variety of toxins
- Inhibit protein phosphatases
- Because of their mode of action the threat may come from long-term exposure causing cancer or neurological diseases rather than direct toxicity
- As aquifers are depleted more dependence surface resources that are susceptible
- Many treatment plant procedures do not totally remove these toxins
- More information: Dr. H. Paerl, UNC-CH, Inst Mar Sci

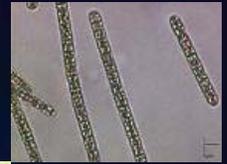


*Microcystis* bloom NOAA

Florida Drinking Water Plant Shut Down  
[http://democrats.science.house.gov/Media/File/Commdocs/hearings/2008/Energy/10july/Additional\\_document\\_Hudnell.pdf](http://democrats.science.house.gov/Media/File/Commdocs/hearings/2008/Energy/10july/Additional_document_Hudnell.pdf)

# Cyanobacteria Produce Witch's Brew of Toxins

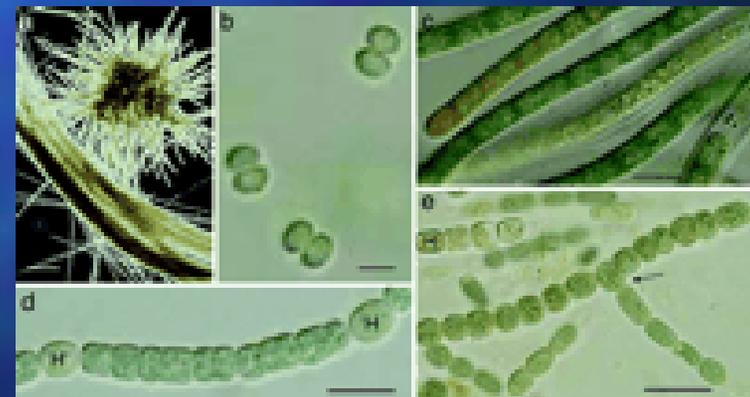
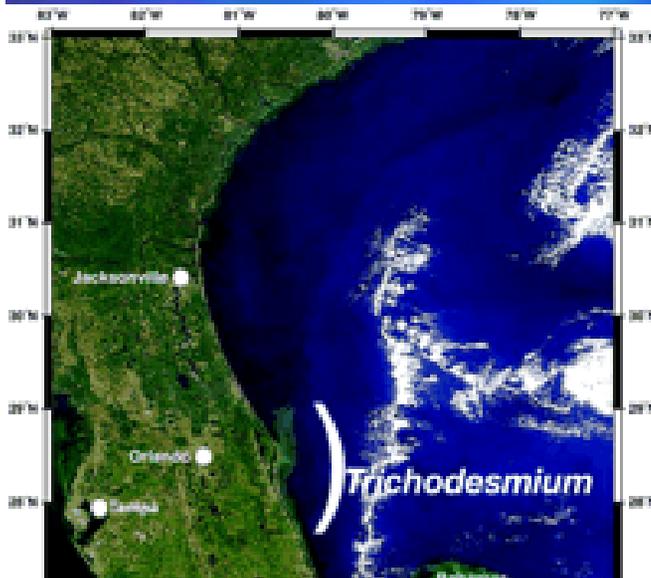
- Cyclic peptides such as microcystins
  - Produced by *Anabaena*, *Aphanocapsa*, *Microcystis*, *Nostoc*, *Oscillatoria*, *Planktothrix*, *Radiocystis* and *Hapalosiphon* species
- Anatoxin-a
  - Produced by *Anabaena*, *Aphanizomenon*, *Oscillatoria*
- Cylindrospermopsin
  - Produced by *Aphanizomenon*, *Cylindrospermopsis*, *Umezaki*
- Saxitoxin and Neosaxitoxin
  - Produced by *Anabaena*, *Aphanizomenon*, *Cylindrospermopsis* & *Lyngbya*



Images from Cyanobacterial Image Gallery, Perdue University, <http://www-cyanosite.bio.purdue.edu/images/images.html>, [www.greentiger.com](http://www.greentiger.com), <http://www.biologie.uni-hamburg.de/online/library/webb/BOT311/Cyanobacteria/Cyanobacteria.htm>, <http://www.horticulture.com/photobank/1147234570-11>

# Marine Cyanobacteria Blooms

- An uncommon, non-protein amino acid  $\beta$ -N-methylamino-L-alanine (BMAA)
- Neurotoxin, likely produced by most known groups of cyanobacteria, one of the most common organism on earth (Cox et al. 2005).
- Potential cause of the amyotrophic lateral sclerosis/parkinsonism-dementia complex (ALS/PDC)



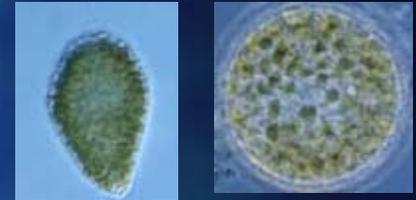
*Trichodesmium* spp.

Cox et al. 2005 PNAS, vol 102

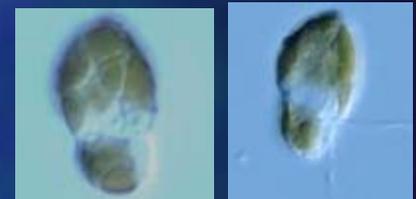


# Raphidophytes

- Small flagellates, bloom at high densities, delicate & difficult to identify
- Known to cause fish kills in North Carolina, particularly in channels & marinas, as well as elsewhere around the world
- Favored by warm, calm, nutrient enriched conditions
- Poor quality food for oysters and other shellfish
- *Fibrocapsa* devastated mariculture in Japan
- Health effects on humans UK
- More info: Dr. Carmelo Tomas at UNC-W, world expert on Raphidophytes



*Chattonella*



*Heterosigma*



*Fibrocapsa* *Gonyostoma*

Photos by Dr. Carmelo Tomas, UNC-W

# HAB Bulletin Forecasts Landfall of *Karenia* Blooms in Gulf of Mexico

- Uses Ocean Color Satellite imagery to determine high chlorophyll areas
- Uses regional algorithm to identify likelihood of *Karenia* bloom
- Wind conditions provided to estimate transport



**Gulf of Mexico Harmful Algal Bloom Bulletin**  
18 January 2007  
NOAA Ocean Service  
NOAA Satellite and Information Service  
Last bulletin: January 16, 2007

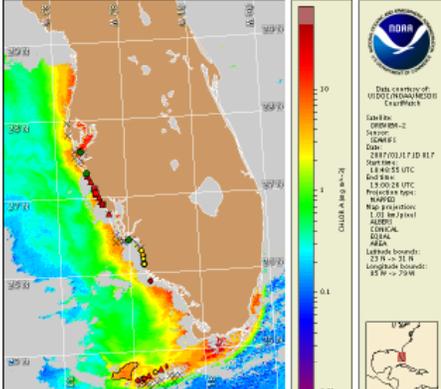
**Conditions Report**  
A harmful algal bloom has been identified in patches from northern Sarasota to central Collier County and north of the Lower Florida Keys in Monroe County. Patchy low impacts are possible today through Sunday in Sarasota and Charlotte Counties. Patchy very low impacts are possible today through Sunday for northern Lee and central Collier County. No impacts are expected in southern Lee and northern Collier County. Patchy moderate impacts are possible today through Saturday and patchy very low impacts are possible Sunday on the gulf side of the Lower Keys.

**Analysis**  
The harmful algal bloom persists from northern Sarasota to central Collier County. Recent sampling confirms the presence of *K. brevis* at medium concentrations in Sarasota and northern Lee County (FWRI, 1/15-16) and high levels of *K. brevis* at Gasparilla Pass, Charlotte County (FWRI, 1/15). In southern Lee County, recent sampling indicates no *K. brevis* (FWRI, 1/15). Satellite imagery (1/17) is obscured alongshore from Sarasota to Monroe County except for a portion alongshore northern Lee County (west of North Captiva and Captiva Islands) where chlorophyll levels are as high as 6 µg/L. Reports of fish kills in have been received from Sarasota County over the past few days. Offshore winds today through Sunday will minimize impacts at the coast; however, conditions are favorable for bloom intensification Saturday and Sunday.

The harmful algal bloom persists north of the Lower Florida Keys in Monroe County. Comparisons of satellite imagery indicate that a patch of elevated chlorophyll (up to 6 µg/L) located approximately 20 mi. north of Key West in the Lower Florida Keys (1/6) has migrated westward past the Marquesas Keys (1/17) and is now centered about 24°44.3'N 82°13.2'W. Recent sampling inside the Lower Florida Keys indicates not present levels of *K. brevis* (FWRI, 1/16). Continued sampling north of the Lower Keys as well as in the elevated chlorophyll patch is recommended. Onshore winds today through Saturday will increase the potential for impacts on the gulf-side of the Lower Keys. Continued westerly transport of the bloom is possible through Sunday.

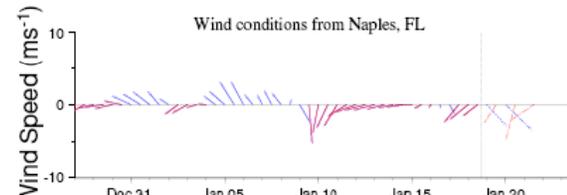
Urizar, Fisher

Please note the following restrictions on all SeaWiFS Imagery derived from CoastWatch.  
1. Data are restricted to civil marine applications only; i.e. federal, state, and local govern-



Satellite chlorophyll image with possible HAB areas shown by red polygon(s). Cell concentration categories and corresponding cell count values from Florida Fish and Wildlife Research Institute. For a key to the cell concentration descriptions, visit <http://research.myfwc.com>. Cell concentration sampling data from January 8-16 shown as red squares (high), red triangles (medium), red diamonds (low b), red circles (low a), orange circles (very low b), yellow circles (very low a), green circles (present), and black "X" (not present).

**Wind conditions from Naples, FL**

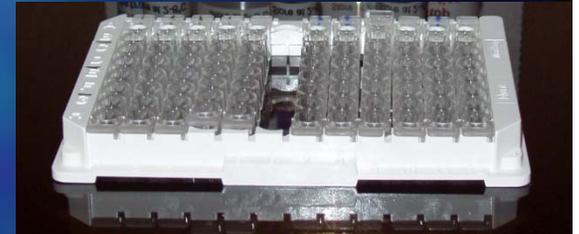


Wind speed and direction are averaged over 12 hours from buoy measurements. Length of line indicates speed; angle indicates direction. Red indicates that the wind direction favors upwelling near the coast. Values to the left of the dotted vertical line are measured values; values to the right are forecasts.

SW Florida: Northeasterly winds today (10-15 kts, 5-8 m/s). Northerly winds tonight and Friday (10-20 kts, 5-10 m/s). Northeasterly to easterly winds Saturday (10-20 kts, 5-10 m/s). Southeasterly winds Sunday (15 kts, 8 m/s).

[http://coastwatch.noaa.gov/hab/bulletins\\_ns.htm](http://coastwatch.noaa.gov/hab/bulletins_ns.htm)

# Domoic Acid Test Kit



Developed at the request of  
PNW tribes to monitor razor  
clam harvest

Monoclonal antibody, ELISA  
based

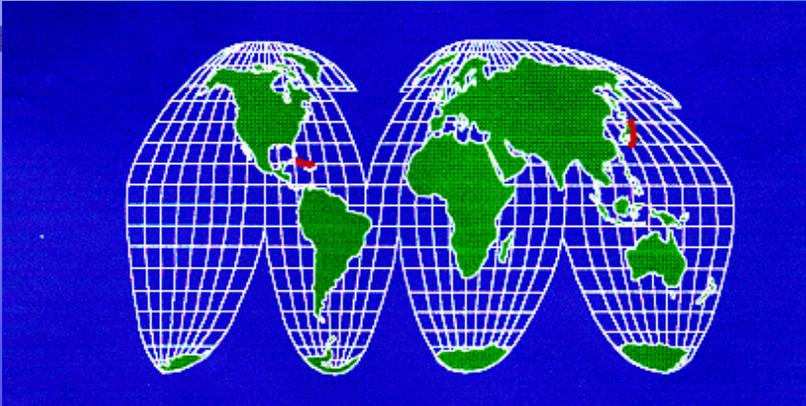


<http://www.MercuryScience.com>

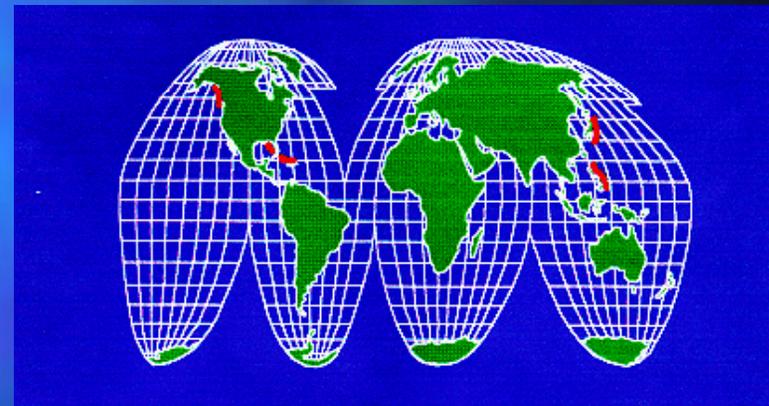
NOAA pictures

# Harmful Algal Blooms

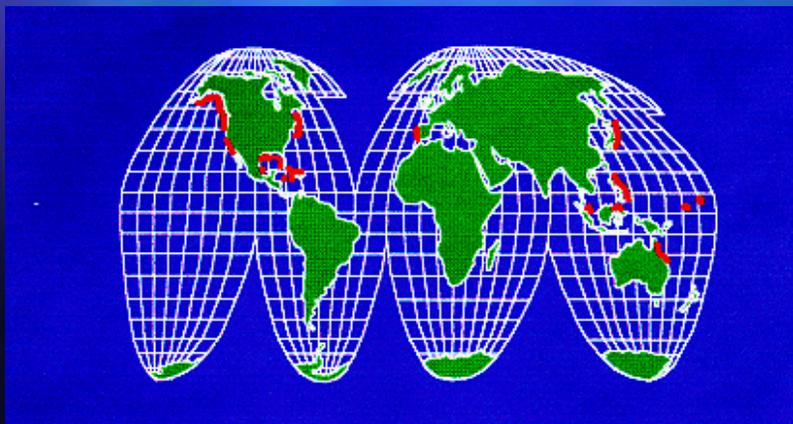
1544



1844



1972



2008

