Harmful Algal Blooms in North Carolina

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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
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/

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

$25 Million Loss

Tester et al. 1991
**Karenia brevis**

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

- 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 μg 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\(^+\) 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\(^\circ\)C

**More information:** [research.myfwc.com](http://research.myfwc.com)

Dr. Jan Landsberg, FL FWC

*FL Fish & Wildlife Res Inst*
Diarrhetic Shellfish Poisoning

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

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

**Toxin:** Okadaic acid, dinophysistoxins

**Mode of Action:** Potent inhibitor of proteinphosphorylase
Stimulates phosphorylation that controls Na⁺

**Illness:** Diarrhetic shellfish poisoning

**Symptoms:** Onset 30 m to 2 - 3 h
Diarrhea (92%), nausea (80%), vomiting
Complete recovery within 3 d

**US Range:** All continental US waters

**Limited by:** UK
Ciguatera Fish Poisoning Distribution

“Most common foodborne illness related to fish consumption.”

(Hokama 1993, Lange 1994)
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
Ciguatera Fish Poisoning

Toxin: Ciguatoxins, multiple forms
Mode of action: Sodium channel activator
Illness: Ciguatera fish poisoning

Symptoms: Diagnosis based on constellation of symptoms related to ingestion of fish
Tingling of lips
GI symptoms
Neurologic symptoms, weakness, ataxia, respiratory paralysis, coma

US Range: Gulf of Mexico, Florida Keys, USVI, Hawaii
2006 new species found off NC, toxicity UK

Limited by: Temperatures below ~18°C
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.

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

Razor Clams, WA State Dept. Fish and Wildlife
Diatoms, NOAA
IBRRC staff treats domoic acid poisoned endangered brown pelican at bird center in San Pedro, CA.
Scholin et al. 2001
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

- *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

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 on 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
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*
Marine Cyanobacteria Blooms

- An uncommon, non-protein amino acid β-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
**Karodinium veneficum**

*Syn. Karolidium micrum, Gymnodinium micrum, Gymnodinium galatheanum & Gyrodinium galatheanum*

- Small, mesohaline, mixotrophic dinoflagellate
- World wide distribution, common in NC where densities can exceed 200,000 cells ml\(^{-1}\)
- Produces karlotoxins (ca. 0.1 - 1 pg cell\(^{-1}\)) which cause fish kills
- Cellular toxicity occurs through non-selective permeabilization of plasma membranes, leading to osmotic cell lysis.
- Pore formation requires dependent on presence of specific sterols in the membrane
- Cells lacking certain sterols are immune to the toxin, those that have the requisite sterols are susceptible
- *K. veneficum* lacks these sterols which accounts for the immunity from its own toxins.
- Fish are particularly susceptible
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
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 updated January 16, 2007

Conditions Report

A harmful algal bloom (HAB) 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 in 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.

Analytic Report

The harmful algal bloom persists from northern Sarasota to central Collier County. Recent sampling confirmed the presence of Karenia brevissima at moderate concentrations in Sarasota and central Lee County (FWRI, 1/15-16) and high levels of Karenia brevis at Gasparilla Pass, Charlotte County (FWRI, 1/15). In southern Lee County, recent sampling indicates low Karenia brevis (FWRI, 1/15). Satellite imagery (1/17) is observed 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 mg/L. Reports of fish kills 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 mg/L) located approximately 20 mi north of Key West in the Lower Florida Keys (1/16) has migrated westward past the Marquesas Keys (1/17) and is now centered about 24°43.5'N 82°13.2'W. Recent sampling inside the Lower Florida Keys indicates low concentrations of Karenia brevis (FWRI, 1/16). Continued sampling north of the Lower Keys as well as in the elevated chlorophyll patch is recommended. Offshore 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.

Ursula, Fisher

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