Slide 1

Slide 2

What are "harmful" algae?

- Harmful algae are a small subset of the microscopic "plants", called phytoplankton, that occur in coastal waters
- There are thousands of kinds of algae in our coastal marine waters
- Most are diatoms (ca. 50,000 species) and dinoflagellates (2,000 species)
- A few other types of algae, such as bluegreens (cyanobacteria), also occur in our coastal and nearshore waters
- Of those roughly 52,200 microscopic organisms, 150 types form blooms, and 75 of these bloom forming species can be toxic to fish, invertebrates, and/or humans -- less than 0.15% of the phytoplankton we know about

Slide 3

What is the "harm"?

- Toxins that can kill fish, invertebrates, marine mammals, and waterfowl
- Toxins that accumulate in seafood
- Low dissolved oxygen levels
- Respiratory effects
- Discolored water

Slide 4

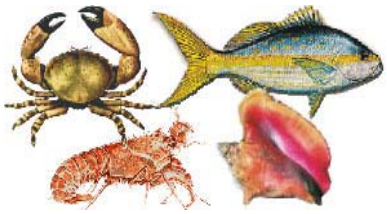
What are their impacts?

*Preliminary estimates of the overall impact of harmful algae blooms (HABs) on the U.S. economy are over **$40 million** per year, and nearly $1 billion over the past decade*

Slide 5

How "big" is this issue?

1,000 different species of fish and shellfish are harvested from the wild or raised by aquaculture



A typical seafood market contains 50 to 100 different fish and shellfish at any given time

Slide 6

Estimated annual economic impacts of harmful algae blooms:

Impact target	*Range*	*Average*	*%Total*
Public health	$18,493,800 - $24,912,500	$22,202,600	45%
Commercial fisheries	$13,400,700 - $25,265,900	$18,407,900	37%
Recreation/tourism	none - $29,304,400	$6,630,400	13%
Monitoring/mgt.	$2,029,900 - $2,124,300	$2,088,900	4%
TOTALS	$33,924,500 - $81,607,100	$49,329,800	100%

Source: National Assessment of Harmful Algal Blooms in US Waters, National Science and Technology Council, Committee on Environment and Natural Resources, October 2000.

Slide 7

Economic impacts result from:

- ❑ Shellfish bed closures or quarantines
- ❑ Wild or farmed fish mortalities
- ❑ Loss of income due to closures of reefs, facilities, and mortalities
- ❑ Consumer fear of purchasing seafood

Fish farm in the Broughton Archipelago, British Columbia, Canada

(Photo courtesy BC Salmon Farmers Association)

Slide 8

Additional economic impacts result from:

- ❑ Lost marine recreational opportunities including tourism, fishing, shellfishing
- ❑ Decreased swimming and sunbathing resulting from blooms
- ❑ Dead fish or shellfish washing up on beaches
- ❑ Discolored water, noxious odors, and human respiratory problems caused by toxins released into the air

Slide 9

Other economic impacts include:

- ❑ Costs of maintaining monitoring and testing programs designed to detect algal toxins
- ❑ Costs associated with cleaning up fish or shellfish kills when they do occur
- ❑ Medical costs and lost productivity of persons sickened by HAB toxins, either from ingestion or respiratory exposure

http://www.middle-east-online.com/English/Features/Aug2001/Kuwait%20trying%20to%20contend%20with%20massive%20fish%20kill.htm

Slide 10

So … what do phytoplankton do?

Photosynthesis
- Cycling of elements
- Source of dissolved and atmospheric oxygen

Base of food webs
- provide nutrition to zooplankton as primary consumers, and to other food web levels

http://www.cajungames.com/foodchain/

Slide 11

Phytoplankton: Vital Statistics

http://seawifs.gsfc.nasa.gov/SEAWIFS/TEACHERS/BIOLOGY

http://www.pennies.org/history/intro.html

Diameter: < 1 um to over 100 um
- If you stack 1000 one micron phytoplankton end to end, the length of the stack would equal the width of a penny (18,000 would fit across the face)

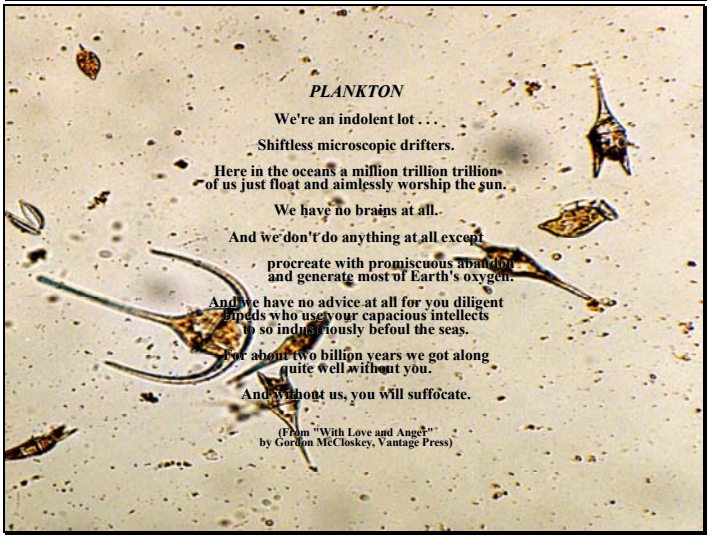
http://www.yana-chris.com/cans/images/surge.gif

Concentration: 1,000 to 1,000,000 per milliliter
- If you fill a soda can with seawater from a thick, oceanic phytoplankton bloom, the can may contain as many as 75 to 100 million cells

Global Biomass: less than 1% of the total plant biomass on earth
- BUT are responsible for at least half of the net photosynthesis (and oxygen production) of the biosphere

http://santacruz.about.com/library/graphics/TREES.JPG

Slide 12



PLANKTON

We're an indolent lot . . .

Shiftless microscopic drifters.

Here in the oceans a million trillion trillion of us just float and aimlessly worship the sun.

We have no brains at all.

And we don't do anything at all except

procreate with promiscuous abandon and generate most of Earth's oxygen.

And we have no advice at all for you diligent bipeds who use your capacious intellects to so industriously befoul the seas.

For about two billion years we got along quite well without you.

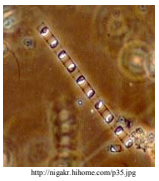
And without us, you will suffocate.

(From "With Love and Angst"
by Gordon McCloskey, Vantage Press)

Slide 13

Two dominant types of phytoplankton occur in temperate and subtropical estuarine and marine coastal systems:

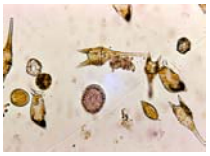
(1) Diatoms

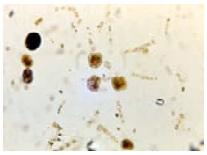


http://nigakr.hihome.com/p35.jpg

http://thalassa.gso.uri.edu/flora/arranged.htm
(Photo by Jan Rines, Acad. Nat. Sci., Philadelphia

(2) Dinoflagellates





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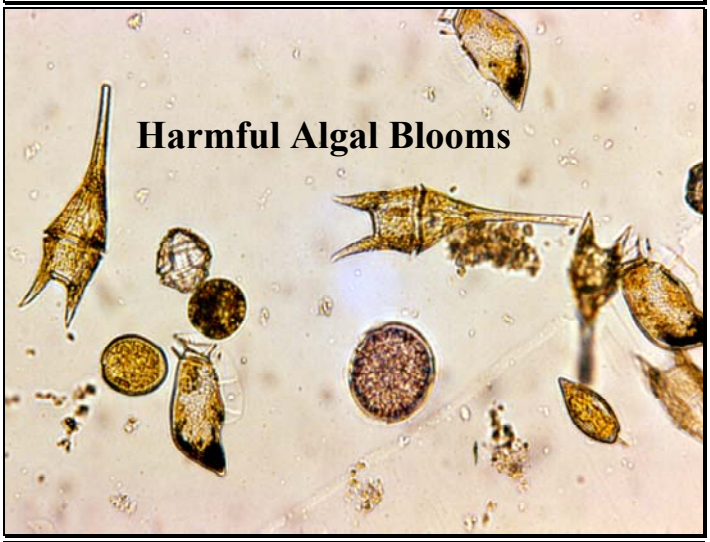

Slide 15

Conventional indicators of algal blooms:

- reports of discolored water
- "spills and kills"
  - fish kills
  - waterfowl deaths
  - marine mammal deaths
  - oyster, crab, other invertebrate dieoffs
  - oil and/or chemical "spills"

Slide 16

Possible effects of harmful algal blooms:

- Minor to massive fish kills
- Deaths of invertebrates, marine mammals, and waterfowl
- Accumulation of toxins in seafood:
  - NSP - neurotoxic shellfish poisoning (brevetoxins)
  - DSP - diarrhetic shellfish poisoning (okadaic acid)
  - ASP - amnesiac shellfish poisoning (domoic acid)
  - PSP - paralytic shellfish poisoning (not in Gulf of Mexico)
  - Ciguatera fish poisoning (ciguatoxin; tropics)
- Respiratory distress
- Low dissolved oxygen levels

Slide 17

Fish Kill Litters Local Coastline

Thousands Of Dead Fish Found

POSTED: 11:22 a.m. EDT October 8, 2002
UPDATED: 1:58 p.m. EDT October 8, 2002

NEW SMYRNA BEACH, Fla. -- Beachgoers in Volusia County discovered a smelly situation Tuesday.

Thousands of dead fish were found along a 5-mile stretch along New Smyrna Beach, WESH News Channel 2 reported.

The fish can be found anywhere between 19th Avenue and the inlet, but the largest concentration is south of Crawford Road, reports indicated.

Local observers said it's the most dead fish they've seen on the beach in 20 years.

Slide 18

Algae bloom also blamed for New Smyrna fish kill

Saturday, October 12, 2002

Associated Press

NEW SMYRNA BEACH — High concentrations of a warm-water alga were found in seawater samples taken from where tens of thousands of dead fish washed up earlier in the week, scientists said.

The alga, *Trichodesmium erythraeum*, is fairly common in tropical and subtropical waters around the globe, said Ann Forstchen, a biologist with the Florida Fish and Wildlife Conservation Commission's Marine Research Institute in St. Petersburg.

Slide 19

NAPLES DAILY NEWS

Algae may be airborne irritant reported at Brevard beaches

Wednesday, November 6, 2002

Associated Press

SATELLITE BEACH — Red tide is to blame for making beachgoers in Brevard County feel sick last weekend, health officials said Tuesday.

Several people complained of persistent coughing, irritated throats and runny noses after visiting beaches from Cape Canaveral to Satellite Beach.

The Florida Marine Research Institute tested the waters off the county's coast and found high levels of the microorganism Karenia brevis, Brevard environmental manager Cheryl Dunn said. The single-celled alga contains a powerful neurotoxin called brevetoxin. Wind and wave actions often send the microscopic cells into the air, where people can breathe them in. In heavy concentrations, the algae turns the water a brick-red color.

A red tide bloom off New Smyrna Beach, about 50 miles north, last month killed thousands of fish.

Slide 20

Toxic Red Tide Kills 60 Florida Manatees

April 17, 2003

MIAMI (Reuters) - A toxic "red tide" has killed at least 60 endangered manatees along the southwest Florida coast in the last two months, the second-largest mass death of sea cows blamed on the deadly algae bloom, state biologists said on Thursday.

The deaths, caused by a huge red tide stretching from Venice to Marco Island, represent about 2 percent of the Florida manatee population. In 1996 a red tide was blamed for 149 manatee deaths, most of them in a six-week period in March and April.

... The Florida Marine Research Institute said 60 manatee deaths between Feb. 27 and April 15 were caused by red tide ... "They can ingest the toxins when they eat or they can inhale the toxins when they come to the surface to breathe," said Tom Pitchford, a wildlife biologist with the Florida Fish and Wildlife Conservation Commission. "Once the toxin is in the animal, it affects their coordination and causes a paralysis."

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Possible causes of harmful algae blooms?

- Elevated / excess levels of nutrients
  - Pollution
  - Runoff
- Introductions of HAB organisms
  - Ballast water
  - Changes in hydrology
- Changes in regional hydrology
  - Surface flow patterns
  - Precipitation

Slide 22

Is pollution increasing the concern?

Publicity associated with HAB events is increasing public awareness

Elevated nutrient levels can exacerbate blooms

Accessible public information on water quality and on HAB events is essential to avoid the spread of misinformation

Slide 23

Clean Water Act

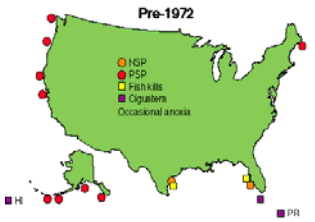
Federal Water Pollution Control Act of 1972 initiated regulated discharges of pollutants for U.S. waters

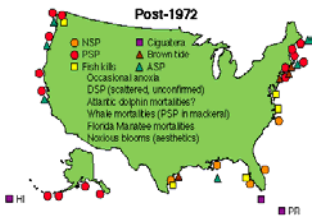
The Clean Water Act (CWA), amended to this in 1977, focused on toxic substances

The 1987 reauthorization of the CWA included sewage treatment plants

Slide 24

Pre- and post 1972 distributions of HAB events

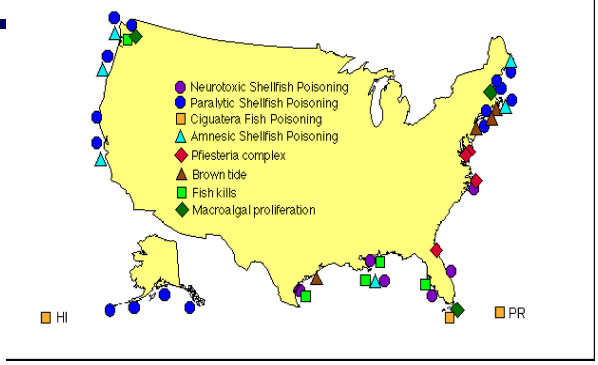




Source: WHOI HAB web site, Dr. Donald Anderson
http://www.whoi.edu/hab/HABdistribution/72toxinmap.html

Slide 25

Major HAB-related Events in the Coastal U.S.



Source: WHOI HAB web site, Dr. Donald Anderson
http://www.whoi.edu/hab/HABdistribution/HABmap.html

Slide 26

Known Harmful Algal Bloom (HAB) Species Northern Gulf of Mexico

Genus and species	Problem(s)
Akashiwo sanguinea	associated with fish kills
Alexandrium monilatum	toxic (fish & invertebrates)
Anabaena spp.	neurotoxins; low D.O.
Ceratium furca	possible cause of DSP
Ceratium hircus	low D.O.
Dinophysis caudata	DSP; tumor promoter
Gonyaulax polygramma	low D.O. (fish and shellfish)
Heterocapsa sp.	low D.O.
Heterosigma akashiwo	toxic to fish
Karenia brevis	NSP (brevetoxin producer)
Lingulodinium polyedrum	toxic; limited food value
Oscillatoria erythraea	toxic to copepods
Prorocentrum spp.	DSP (okadaic acid)
Pseudo-nitzschia spp.	ASP (domoic acid)

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Local Gulf of Mexico HAB Events

Report Date	Bloom Location	HAB Species	Cells per liter
27 June 2000	south shore, Horn Island	*Oscillatoria erythraea*	>1,000,000
12 Sept 2000	SSE of Dog Keys Pass	*Alexandrium monilatum*	551,000
15 Sept 2000	Point Cadet Harbor	*Chattonella subsalsa*	503,330
16 May 2001	Mississippi Sound	*Alexandrium monilatum*	20,000
		Ceratium hircus	260,000
		Dinophysis caudata	310,000
		Prorocentrum gracile	920,000
		Prorocentrum micans	30,000
		Prorocentrum scutellum	1,420,000
16 May 2001	East Petit Bois Island	*Alexandrium monilatum*	630
		Dinophysis caudata	1,350
		Karenia brevis	135
		Prorocentrum gracile	1,395
		Prorocentrum scutellum	1,530
28 June 2001	West tip of Horn Island	*Ceratium hircus*	500,000 to in excess of 1,000,000
		Lingulodinium polyedrum	
4 September 2001	Mississippi barrier islands	*Alexandrium monilatum*	80 to 12,900
		Ceratium hircus	530 to 680
		Dinophysis caudata	50 to 800
6 September 2001	Smuggler's Cove, Cat Island, MS	*Alexandrium monilatum*	Sample #1: 8,750,000
			Sample #2: 3,810,000
11 Sept 2001	East and West Ship Islands	*Alexandrium monilatum*	East Ship: 21,420
			West Ship: 334,000
11 Sept 2001	East tip and west tip of Horn Island	*Alexandrium monilatum*	420 - 1,708
20 Sept 2001	Northwest Horn Island	*Alexandrium monilatum*	1,410,000

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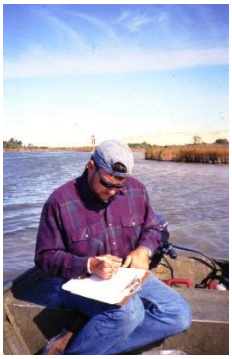
Local nutrient sources / inputs?



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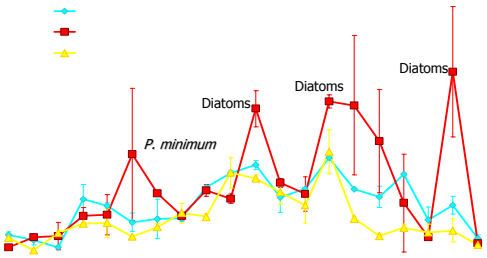
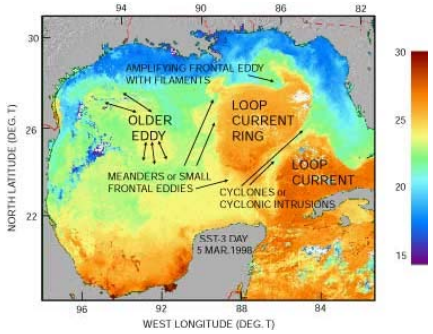
Chlorophyll *a* and phytoplankton species as elevated nutrient response variables



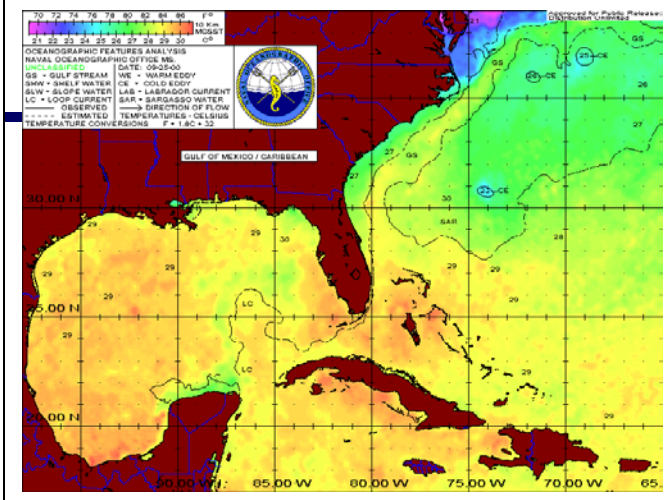
Slide 30

Changes in regional surface flow patterns?



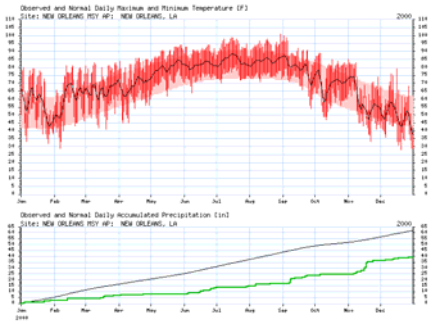
http://www.cbi.tamucc.edu/~gomcirculation/

Slide 31



Slide 32

Decreased precipitation / drought?



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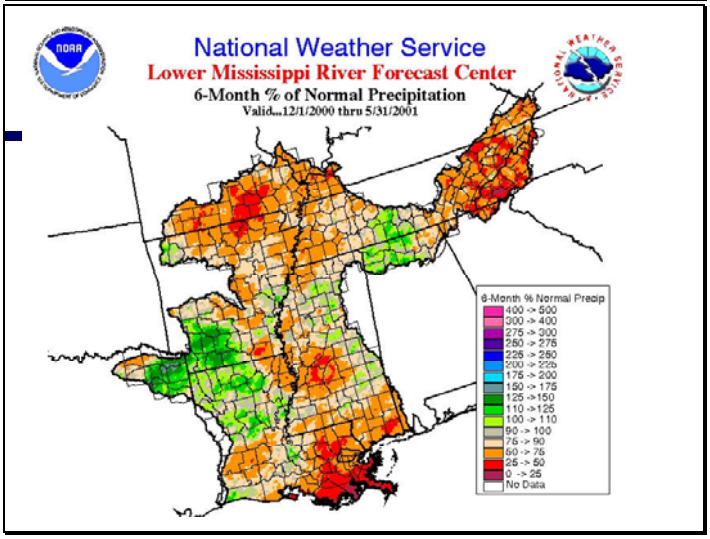
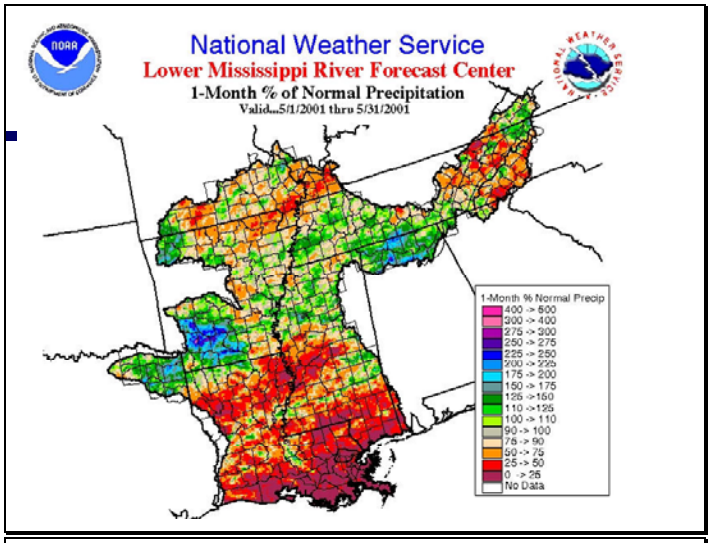


Slide 34



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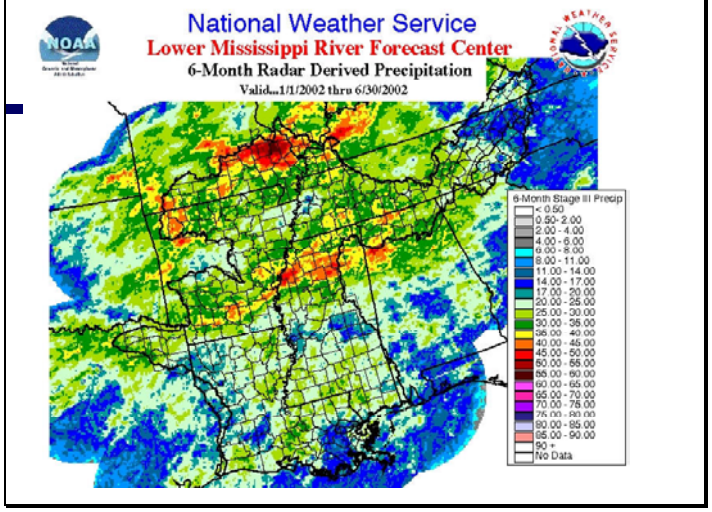
Algal Bloom Events in 2002

Only three HAB events were documented

All were blooms of *Prorocentrum micans*; cell counts ranged from 4,000 to 43,000 cells/liter

Other HAB species were detected, but not at bloom concentrations (<1,000 cells/L

Slide 36



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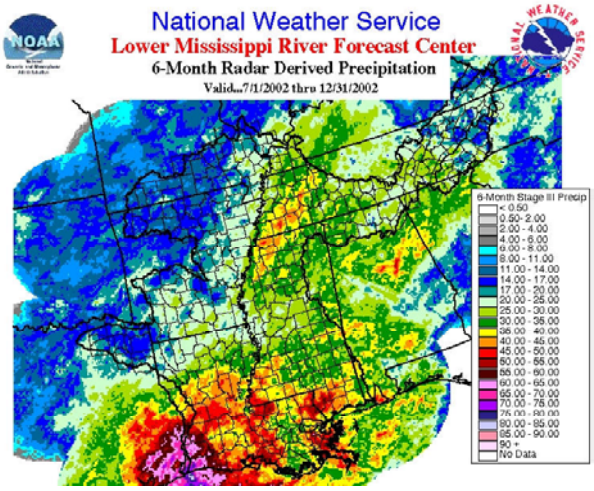
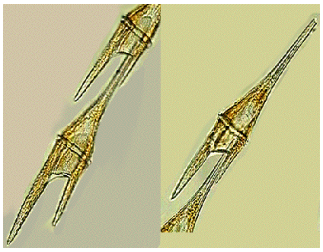


Slide 38

Other local HAB forming species:

Alexandrium monilatum and *Ceratium furca*, two harmful dinoflagellate species found in northern Gulf of Mexico waters



Illustrated checklist of Skagerrak plankton

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Summer 1999 *Alexandrium monilatum* bloom in Mississippi Sound

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K. Steidinger, FMRI

Dinophysis caudata (SEM) and *Prorocentrum micans*, two HAB species from northern Gulf of Mexico waters linked with DSP

Illustrated checklist of Skagerrak plankton

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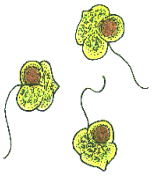
"Driver" behind investigations into HAB species:

- First recorded occurrence of a toxic "red tide" in the waters of Mississippi Sound from November - December 1996
- Toxic "red tide" species in 1996 bloom: *Karenia brevis* (formerly *Gymnodinium breve; Ptychodiscus brevis*)
- Size range: 20 - 40 um
- Comparable particle: ragweed pollen



Slide 43

1996 *Karenia brevis* Bloom History

- First ever documented bloom of *Karenia brevis* in north central Gulf of Mexico waters, with reef closures in coastal Mississippi from 4 November 1996 through 26 February 1997
- First reported occurrence in low salinity northern Gulf of Mexico estuarine systems
- Multiple factors in place which may have resulted in blooms moving inshore and ultimately affecting actively harvested oyster reefs
- Information for modeling and prediction of bloom events is being used at present

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Bloom Chronology in Mississippi Waters

- Collected south of barrier islands on 26 October 1996
- Collected along north shore of barrier islands on 31 October and on 1 November
- Observed in water samples from MS-AL border on 4 November
- Observed in water samples from MS-LA border on 7 November
- *Karenia brevis* last observed on 11 December in water samples from vicinity of oyster reefs

Slide 45

R/V *Bill Demoran*, 34' vessel in GCRL fleet during 1996 bloom event

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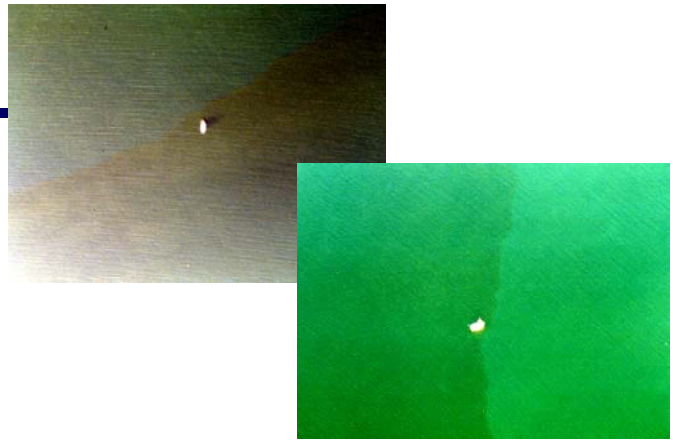
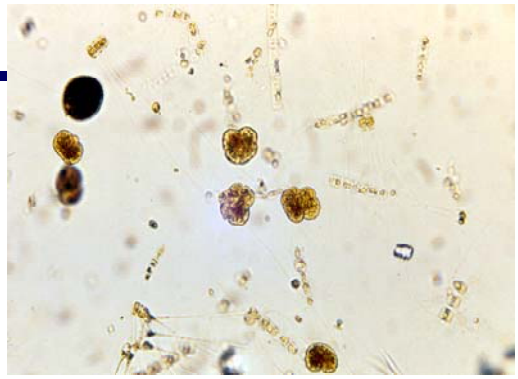


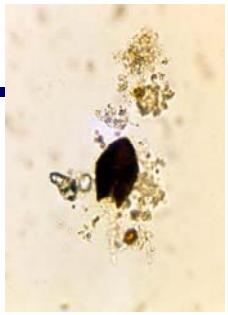
Aerial views of R/V *Demoran* near edge of the HAB in Mississippi Sound

Slide 47



Karenia brevis and diatoms (1996 bloom event)

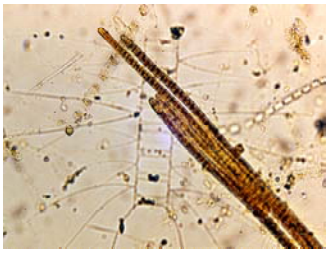
Slide 48



Akashiwo sanguinea

Other phytoplankton present included:

Oscillatoria erythraea and mixed diatoms



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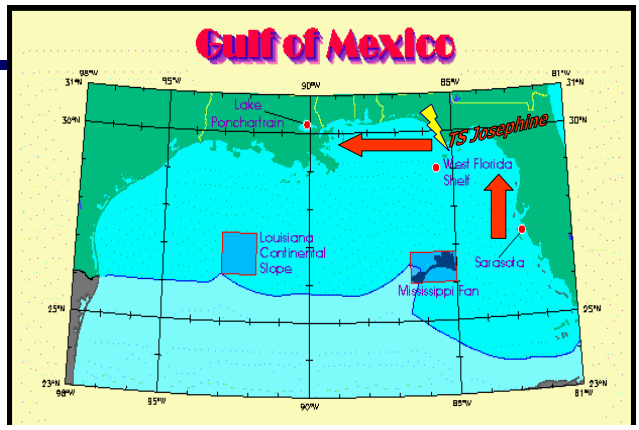
Direction of Drifter Tracks in NE Gulf of Mexico



Slide 50

Potential for Recurrent Blooms

- No blooms of *Karenia brevis* observed during 1997 in northern Gulf of Mexico
- However, *K. brevis* occasionally present at very low densities off Louisiana, Alabama and NW Florida
- Blooms occurred in FL and TX during fall of 2000
- Previous 30-year cycle for blooms in Texas
- Anecdotal account of *K. brevis* bloom in Louisiana waters in fall of 1969

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Potential for Modeling and Prediction of Future *Karenia brevis* Blooms

- Satellite imagery and detection
- SeaWifs and MODIS data
- National Data Buoy system
- Drifter buoy programs
- Meteorological/hydrological modeling
- Basic phytoplankton monitoring program

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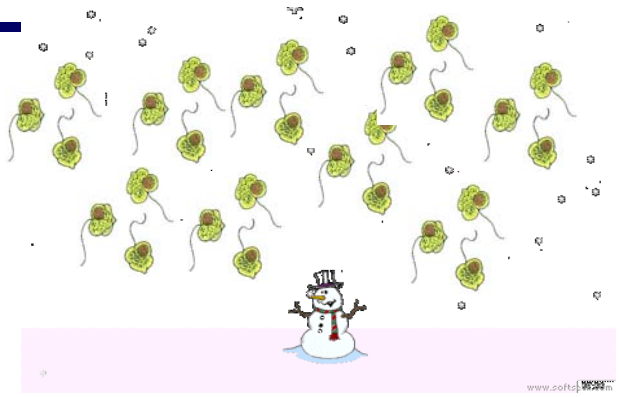
Chances for future blooms?



Slide 53

Fish Kills and Effects on Marine Resources

Slide 54

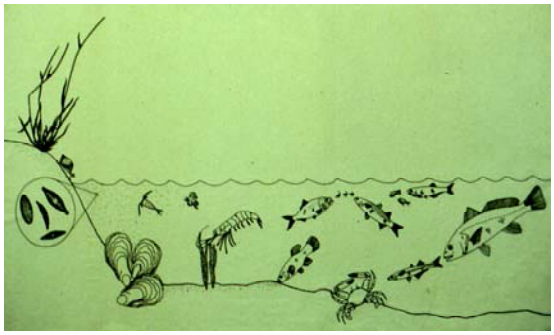
Waterfowl and Marine Mammal Deaths

Slide 55

Non-commercial fish kills

Slide 56

Effects on shellfish



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Massive fish kills

http://www.acnatsci.org/research/kye/mendw.gif

Slide 58

- Fish kills can result from toxins, low dissolved oxygen, or both
- Range in size from a few dozen floating fish in open water to tons of fish washing ashore

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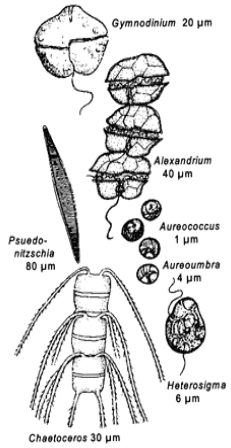
"Small cells, big headaches"

Primary types of microalgae causing HAB events are:

- Dinoflagellates
- Diatoms
- Cyanobacteria (blueegreen algae)



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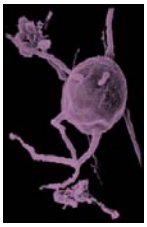
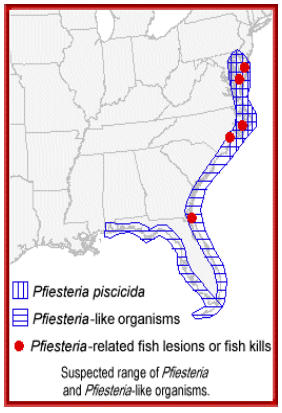
Pfiesteria piscicida



http://www.aquariums.state.nc.us/Pfiest/StrangePFILES/bugdancin.gif



http://www.epa.gov/owow/estuaries/pfiesteria/fact.html

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Current Directions in HAB Monitoring

- Use of SeaWifs satellite imagery to track progress of blooms in the Gulf
- Use of information from previous blooms to develop predictive models
- HABSOS program and goals

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HABSOS Program

- Abbreviation for "Harmful Algal Blooms Observing System"; satellite based
- Uses local knowledge of HAB events
- Application of remotely sensed data for monitoring in the northern Gulf of Mexico

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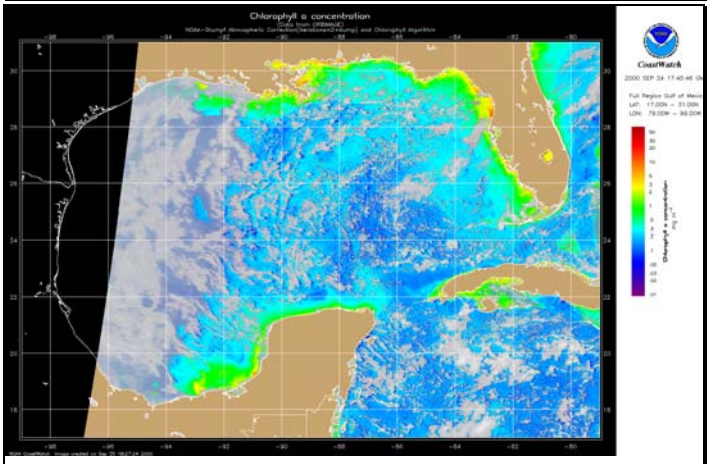

26 September 2000 Coastwatch imagery (R. Stumpf, chl a algorithm)

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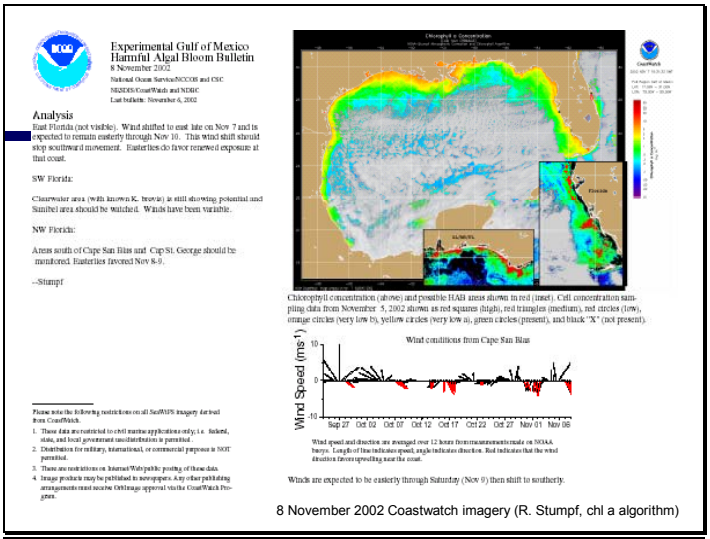

Experimental Gulf of Mexico Harmful Algal Bloom Bulletin
8 November 2002
National Ocean Service/NCCOS and CSC
NOAA/CoastWatch and NDBC
Last bulletin: November 6, 2002

Analysis

East Florida (not visible). Wind shifted to east late on Nov 7 and is expected to remain easterly through Nov 10. This wind shift should stop southward movement. Easterlies do favor renewed exposure at that coast.

SW Florida:

Clearwater area (with known K. brevis) is still showing potential and Sanibel area should be watched. Winds have been variable.

NW Florida:

Areas south of Cape San Blas and Cap St. George should be monitored. Easterlies favored Nov 8-9.

--Stumpf

Please note the following restrictions on all SeaWiFS imagery derived from CoastWatch.

1. These data are restricted to civil marine applications only; i.e. federal, state, and local government use/distribution is permitted.
2. Distribution for military, international, or commercial purposes is NOT permitted.
3. There are restrictions on Internet/Web/public posting of these data.
4. Image products may be published in newspapers. Any other publishing arrangements must receive OrbImage approval via the CoastWatch Program.

Chlorophyll concentration (above) and possible HAB areas shown in red (inset). Cell concentration sampling data from November 5, 2002 shown as red squares (high), red triangles (medium), red circles (low), orange circles (very low b), yellow circles (very low a), green circles (present), and black "X" (not present).

Wind speed and direction are averaged over 12 hours from measurements made on NOAA buoys. Length of line indicates speed, angle indicates direction. Red indicates that the wind direction favors upwelling near the coast.

Winds are expected to be easterly through Saturday (Nov 9) then shift to southerly.

8 November 2002 Coastwatch imagery (R. Stumpf, chl a algorithm)

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Sources for more information on harmful algae:

The Harmful ALGAE PAGE

http://www.whoi.edu/redtide/

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TOXIC & HARMFUL ALGAL BLOOMS

http://www.bigelow.org/hab/

National Center for Environmental Health

http://www.cdc.gov/nceh/hsb/algal.htm

National Centers for Coastal Ocean Science
Harmful Algal Blooms

http://www.habhrca.noaa.gov/