

Linking Pond Water Quality with Algal Bloom Dynamics: Implications for Ecosystem and Human Health

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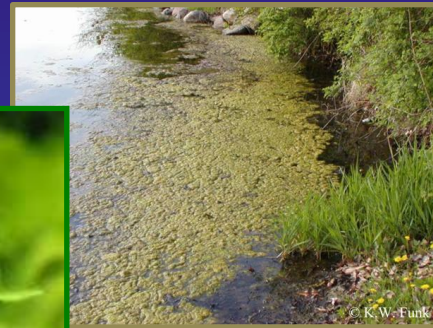
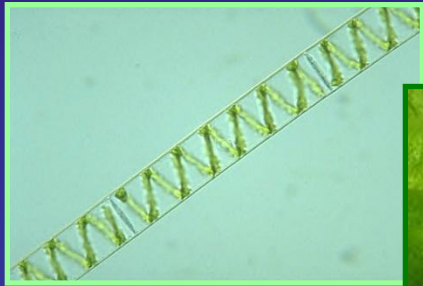


Overview

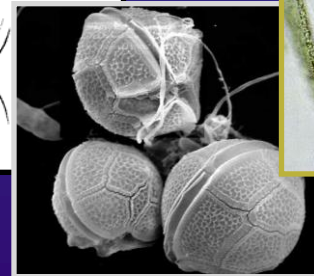
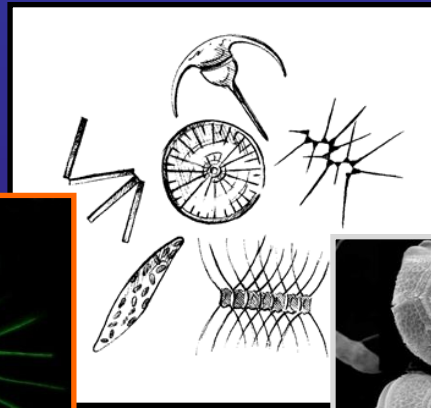
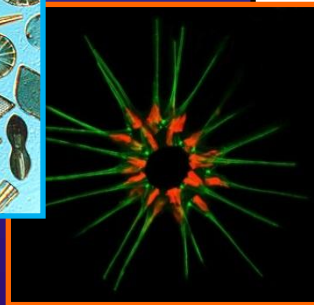
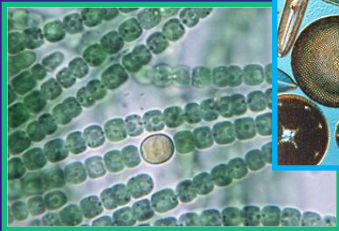
- **What are algal blooms?**
- **What is a harmful algal bloom (HAB), and what are the consequences?**
- **HAB events specific to SC pond systems**
- **What factors influence algal bloom formation?**
- **Examples of projects examining algal pond dynamics (environment, molecular tools, population assessment)**

What are algae?

Macroalgae: Visible without microscopy. Typically filamentous in ponds, can have thin 'leaves'. Conspicuous, but generally non-toxic.



Phytoplankton: Microscopic. All water types (marine, fresh, ponds, rivers, lakes). Mostly benign, but includes harmful species.



Ecological Importance

- Like plants, algae use light to convert nutrients into energy (photosynthesis)
- Uptake carbon dioxide (CO_2), produce oxygen (O_2)
- Form the base of the aquatic food web – provide necessary energy for higher organisms
- Critical for nutrient cycling

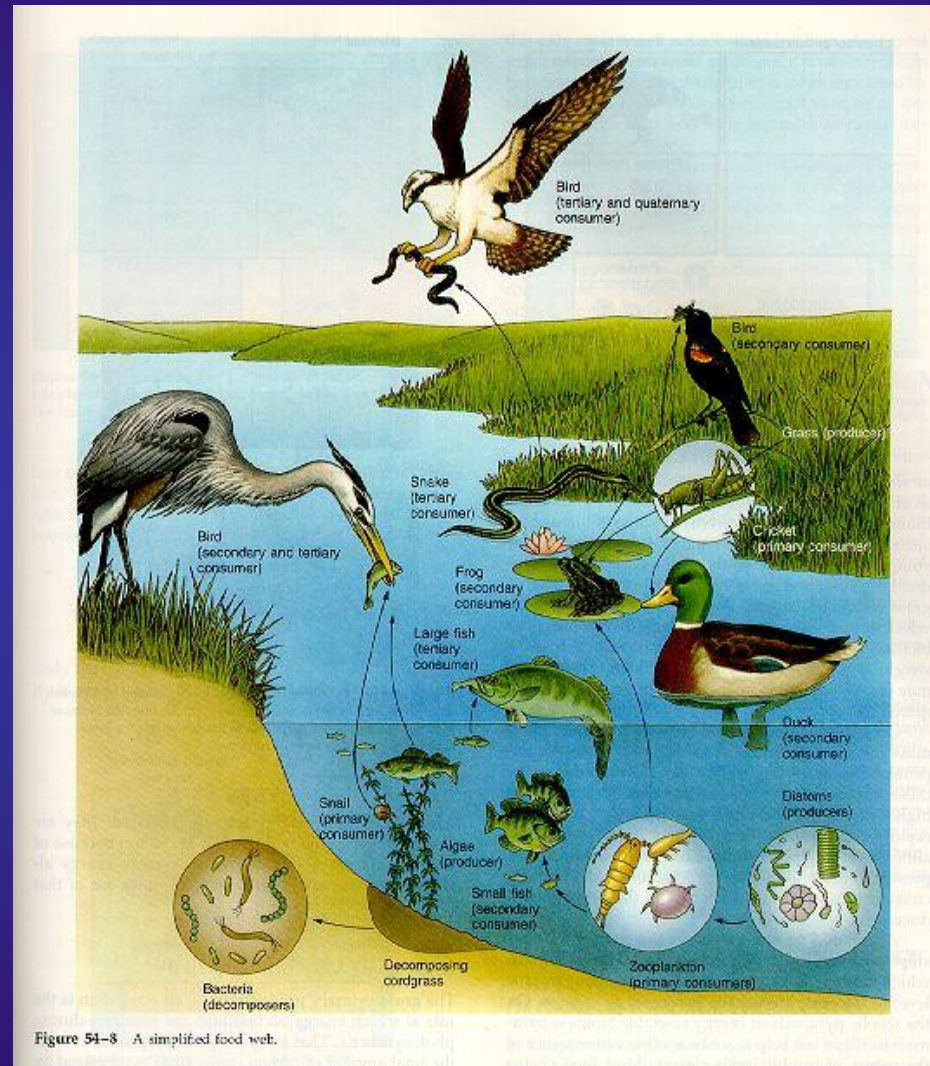


Figure 54-8 A simplified food web.

What is an algal bloom?

A significant, often rapid population increase resulting in one or more species becoming numerically and/or physiologically dominant.

A **harmful algal bloom (HAB)** causes negative ecological or health impacts, sometimes leading to economic consequences.

HAB Impacts

ECOLOGICAL

- Accumulation of toxins through the food web
- Wildlife mortalities (fish, birds, marine mammals)
- Shading, habitat loss



PUBLIC HEALTH

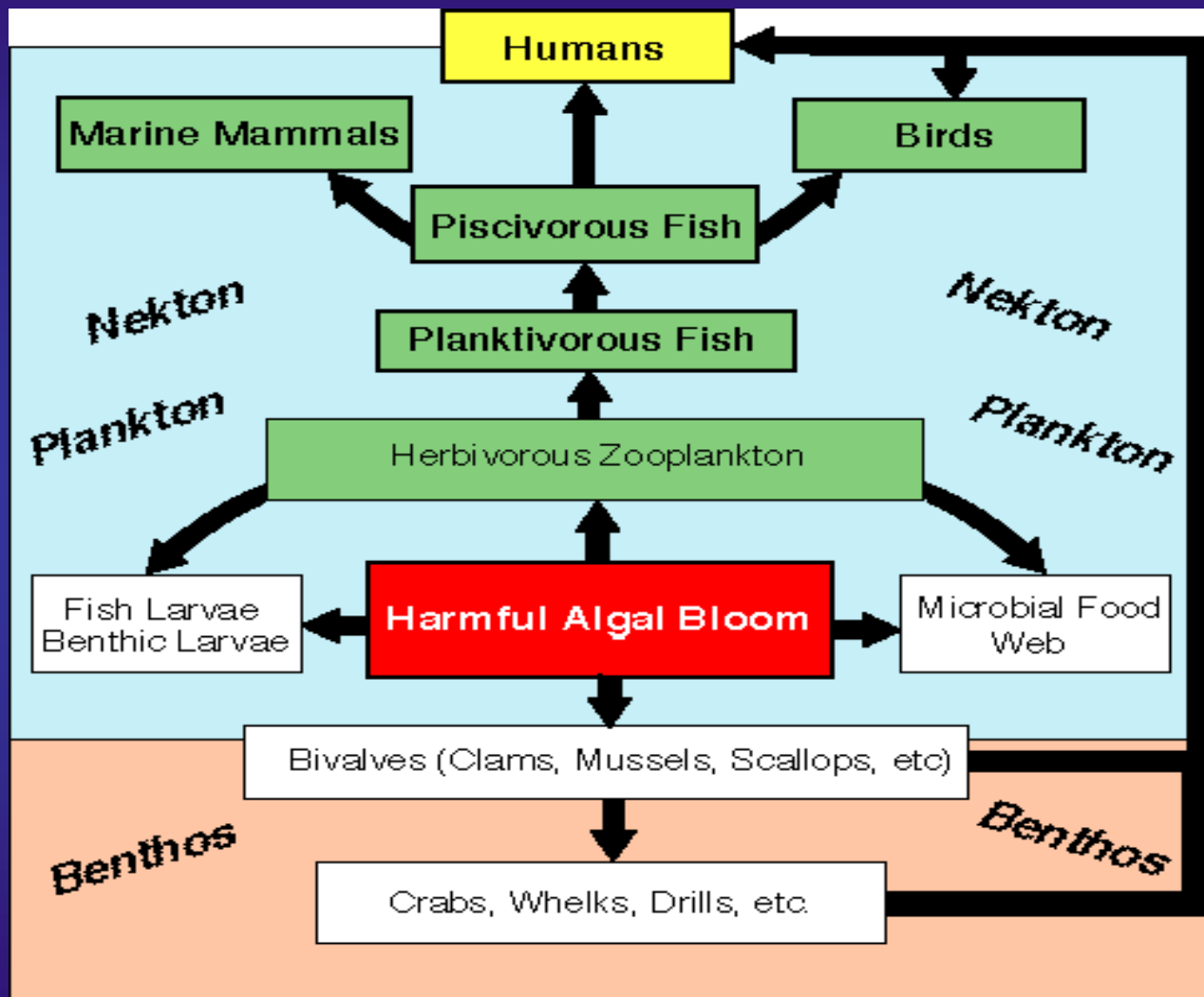
- Shellfish and finfish poisoning
- Respiratory ailments
- Rashes, other dermal conditions

ECONOMIC

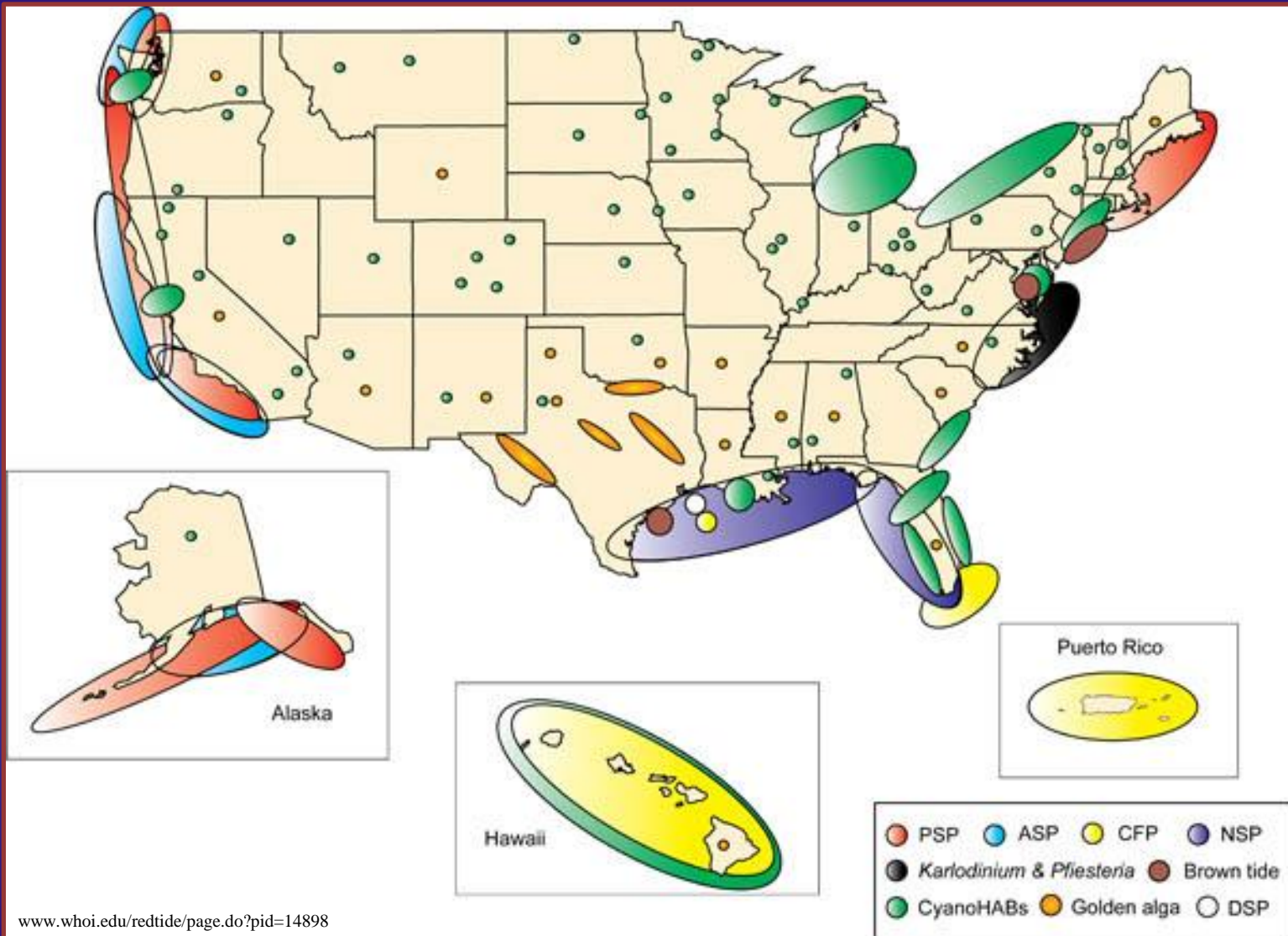
- Decreased aquaculture revenue
- Tourism (beach/recreational closures)



Food Web Linkages

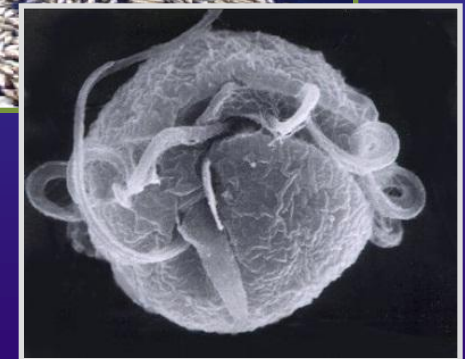


HABs in the US



HABs in SC: *Pfiesteria piscicida*

- Fish kills/lesions from mid-Atlantic-Carolinas (late 1990s - early 2000s), drawing national attention
- Estuaries and ponds
- Sewage (hog farming) & eutrophication
- Dermal & respiratory ailments in humans
- No recent blooms



How do I recognize a HAB in SC ponds, and what are the potential health hazards?

Raphidophytes

IMPACTS

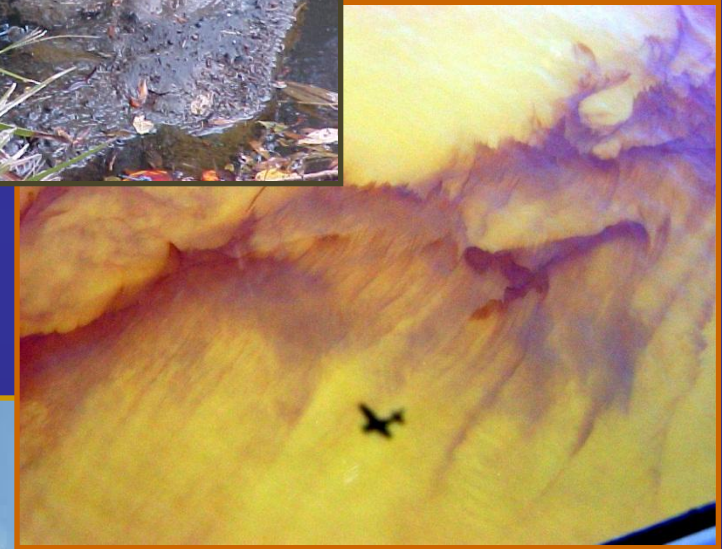
- Fish kills
- Mode of toxicity/harm unclear

HABITAT & IDENTIFICATION

- Dark coffee brown, or copper-colored blooms, occasional surface mats during senescence
- Brackish ponds and estuaries
- Spring-fall

SPECIES

- *Heterosigma akashiwo*, *Chattonella* spp., *Fibrocapsa japonica*



Heterosigma akashiwo
Bulls Bay, 2004

Cyanobacteria

IMPACTS

- Fish kills
- Humans, pets, and wildlife: rashes, respiratory illness, liver failure, gastroenteritis
- Toxigenic: microcystin, cylindrospermopsin, anatoxin, others

HABITAT & IDENTIFICATION

- Dense, green blooms, often a filmy surface
- Decaying odor
- Fresh and brackish ponds
- Summer/autumn

SPECIES

- *Microcystis*, *Anabaenopsis*, *Oscillatoria*, *Aphanizomenon*, *Anabaena*, *Cylindrospermopsis* spp.



Dinoflagellates

IMPACTS

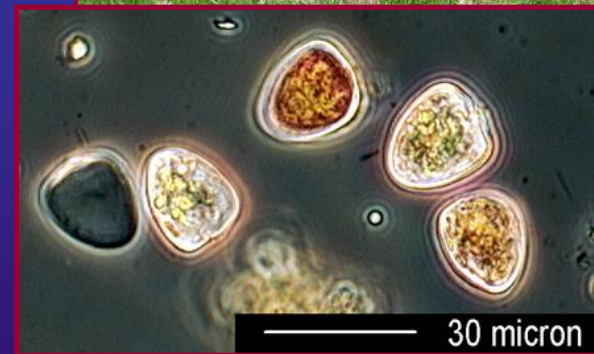
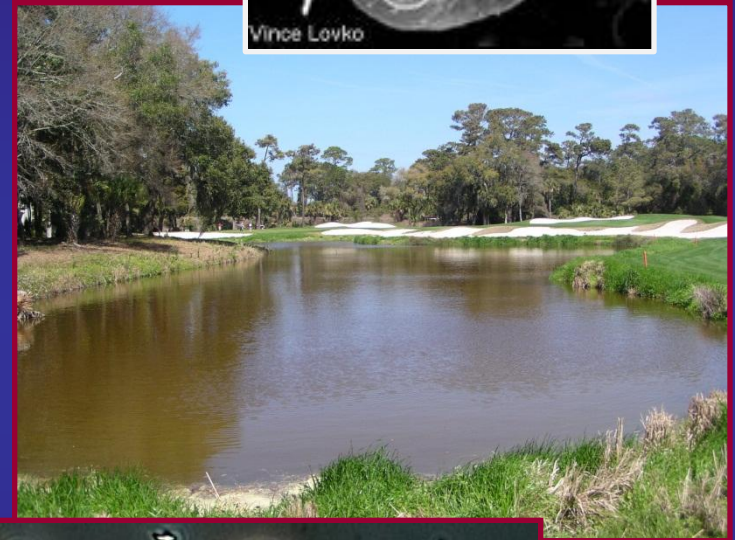
- Fish kills
- Shellfish and finfish poisoning (as gastroenteritis or neurological disorders: seizures, amnesia, disorientation), respiratory ailments
- Toxigenic: saxitoxin, brevetoxin, okadaic acid, karlotoxin, others

HABITAT & IDENTIFICATION

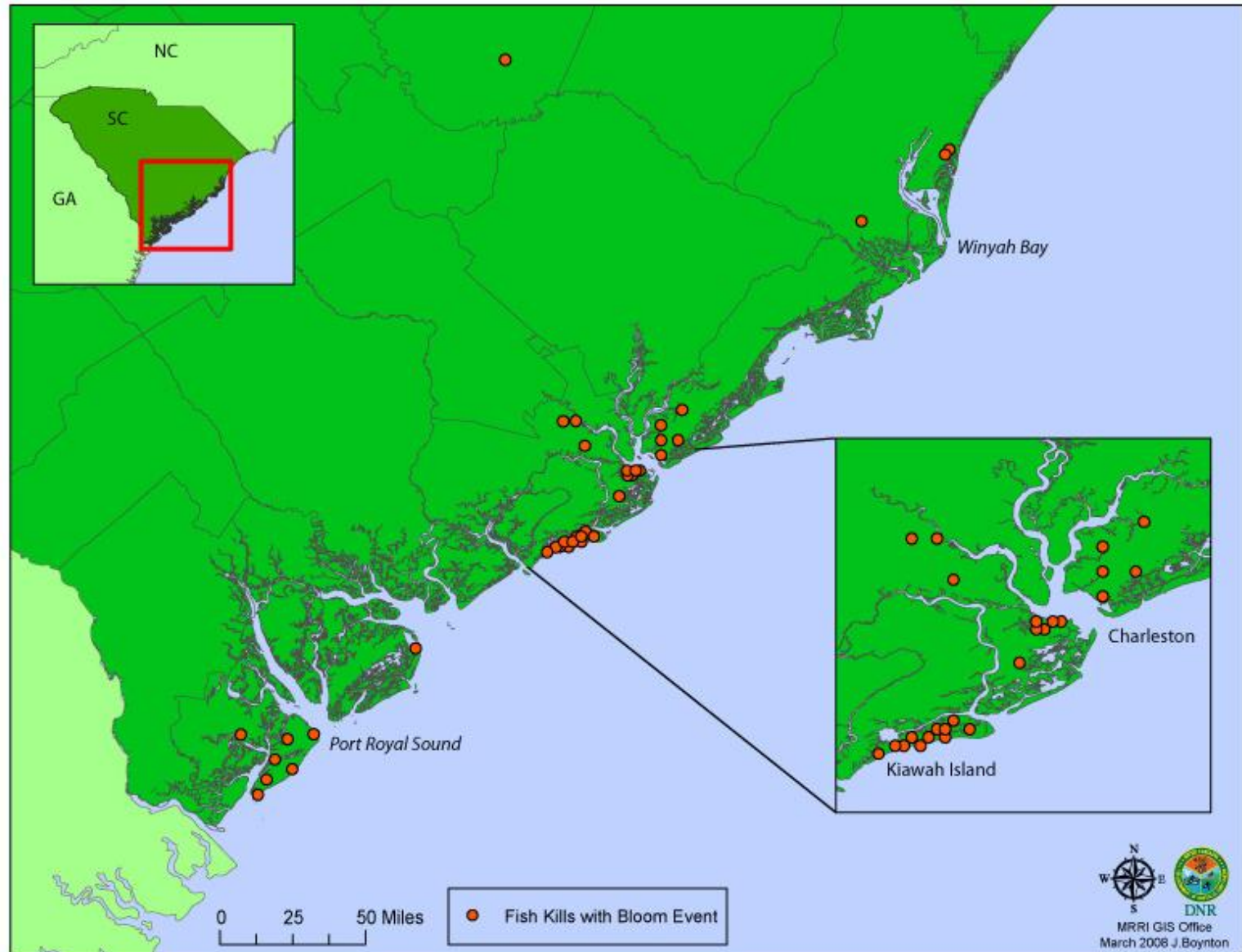
- Red, mahogany, or brown blooms
- Brackish and saline ponds
- Spring-fall

SPECIES

- *Prorocentrum minimum*, *Kryptoperidinium foliaceum*, *Karlodinium veneficum*, *Alexandrium* spp.



Major Locations of HAB-Related Fish Kills



Harmful Algae

Microscopic algae are the foundation of the aquatic food chain and produce the majority of oxygen in the water. Algae can form blooms that discolor the water, but usually these blooms are harmless to humans. A small number of algal species produce toxins that can potentially have adverse effects on humans, pets, natural habitats, and wildlife, including fish and shellfish. When these species occur in high numbers they can form harmful algal blooms.

Report signs and symptoms of toxin exposure immediately for the following:

- Skin exposed to water followed by a rash, hives, or skin blisters.
- Runny eyes and nose, sore throat, asthma-like symptoms.
- Diarrhea, vomiting, liver and kidney toxicity, and neurotoxicity (numb lips, tingling fingers and toes), or dizziness after swallowing discolored water.

S.C. Task Group on Harmful Algae

A multi-institutional collaboration to help prevent harmful algal blooms from becoming an environmental or public health problem.

Immediately contact the following people if you suspect you have an illness related to exposure to a harmful algal bloom:

For Environmental Response

Dianne Greenfield, PhD
331 Fort Johnson Rd.
Charleston, SC 29412
843-725-4823

or call Lara Brock at 843-953-9077

For Medical Concerns

Robert Ball, MD, MPH
S.C. Department of Health and
Environmental Control
843-953-0042 (office)
843-709-3779 (mobile)



DNR



SC Algal Ecology
Lab (USC/CDNR)



SC Task Group on
Harmful Algae

RESEARCH
MONITOR
RESPOND
EDUCATE

Illnesses Associated with Harmful Algae



Alligator exposed to an algal bloom in a stormwater pond, which are commonly found in residential neighborhoods. Photo: Lara Brock



Aerial image of a bloom of the raphidophyte *Heterosigma akashiwo* during 2004 in Bulls Bay, SC. Photo: Tom Murphy

SC Task Group on
Harmful Algae

RESEARCH
MONITOR
RESPOND
EDUCATE

www.scseagrant.org/hab

Fish Kill Responses

- Marine and brackish systems
- Detention ponds, lagoons, lakes, rivers
- >300 separate events since 2001, ~23% HAB-related. Additional causes include hypoxia, chemical applications, others
- Communication from residents, SCDNR, SCDHEC and others to assess appropriate response
- Sample for water quality, phytoplankton, nutrients, toxin (if necessary)
- Follow-up if warranted

Charleston Area Bloom-Related Fish Kills: Sept 2008 – Feb 2012

Station	Date	Chl <i>a</i> (ug/L)	Chl <i>a</i> (<20 um) (ug/L)	DO (mg/L)	T (°C)	Sal (ppt)	pH	Bloom Species	Count	Toxin	Concentration (ppb)
Pemberton (JI)	8-Jul-09	21.0		2.21	29.2	22.6	7.2	<i>Heterocapsa rotundata</i>	7,700 cells/ml 9,503,900		
K 2 (KI)	13-Jul-10	254.9	249.5	1.79	29.2	12.6	8.6	<i>Aphanizomenon sp.</i>	cells/ml	Microcystin	0.15
Teal Marsh Wading Heron (JI)	20-Jul-10			14.70	32.5	8.8	9.1	<i>Aphanizomenon sp.</i> <i>Chlamydomonas sp.</i> <i>Oscillatoria sp.</i>	77,300 cells/ml 1,077,100 520,600 cells/ml	Microcystin	ND
K 36 (KI)	23-Jul-10	222.1		1.60	31.8	20.7	8.1	<i>Aphanizomenon sp.</i> <i>Chlorophyte</i>	157,600 cells/ml 1,645,500 cells/ml	Microcystin	0.16
K 41 (KI)	28-Jul-10	2313.5	2,006.7	0.09	30.2	15.9	8.2	<i>Chattonella subsalsa</i>	55,100 cells/ml		
K 74 (KI)	17-Aug-10	261.6	170.8	2.90	30.6	22.6	8.5	<i>Anabaenopsis sp.</i> <i>Oscillatoria sp.</i>	142,300 cells/ml 34,200 cells/ml	Microcystin	0.93
K 7 (KI)	23-Aug-10	1230.1	524.7	8.86	31.6	19.1	8.1	<i>Chattonella subsalsa</i> <i>Microcystis (< bloom)</i>	37,600 cells/ml	Microcystin	0.21
K 118 (KI)	30-Jun-11	357.3	28.7	9.19	31.4	25.3	9.5	<i>Anabaena circinalis</i>	471,900 cells/ml	Microcystin	0.30
K 115 (KI)	30-Jun-11	553.8	113.8	11.79	34.3	24.5	9.9	<i>Anabaenopsis sp.</i>	275,500 cells/ml	Microcystin	0.38
K 5 - ORP (KI)	29-Aug-11	400.7	310.2	5.72	29.3	3.3	9.2	<i>Aphanizomenon sp.</i>	19,100 cells/ml	Microcystin	ND
K 50 (KI)	8-Sep-11			14.02	29.0	13.2	8.8	<i>Chattonella subsalsa</i>	7,200 cells/ml		
K 50 (KI)	21-Sep-11			15.70	30.1	12.8	9.3	<i>Chattonella subsalsa</i>	13,200 cells/ml		
K 100 (KI)	28-Sep-11	768.2		12.73	30.9	17.3	8.8	<i>Chattonella subsalsa</i>	17,900 cells/ml		

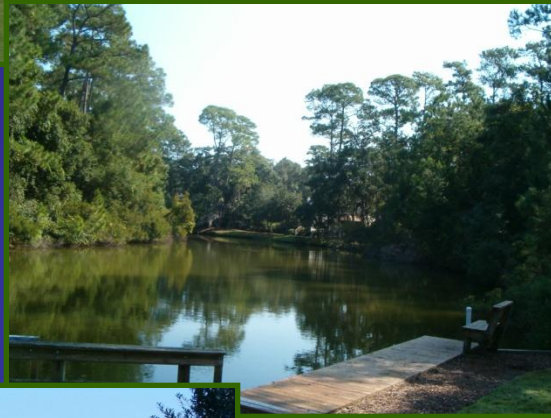
JI = James Island; KI = Kiawah Island; ND = Not Detected

DO = Dissolved Oxygen: red = anoxia (<2 mg/L), orange = hypoxia (2.01-4 mg/L), blue = high DO

Phytoplankton in red are potentially harmful species.

What influences pond algal blooms?

- Reduced exchange/flushing and aeration
- Warm, stagnant conditions, most common during summer
- Excessive ‘bottom-up’ inputs (excess nutrients, mostly nitrogen)
- Reduced ‘top-down’ predator controls (grazing by shellfish, zooplankton, larvae)
- Lack of competition by other species



**Residential/golf course activities →
stormwater detention ponds (BMP) → HABs
& fish kills.**

Detention Pond Functions

“Prevent flooding and nutrients, sediments and bacteria from urbanized areas from directly impacting the critical area”

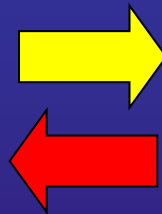
Receive piped stormwater from roadways and surrounding developments



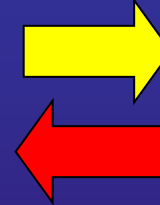
Settle contaminants (sediments, nutrients from fertilizers, and associated development pollutants), flood prevention



Pond



Piped outflow



Tidal creek

Low flow, low flushing, can produce high algal biomass

Complex Hydrography

Kiawah Pond K075

- Dimensions: area (9 ha); volume (154,850 m³); depth (1.7 m)
- History of raphidophyte blooms



- Connected to 3 adjacent ponds
- 15 entering stormwater pipes
- 4 exiting pipes
- Tidal exchange: creek to pond tides >5.3'

Surface run-off?
Groundwater?

Kiawah Island Pond System & SCAEL Projects



Golf Course

- 117 ponds
- ~340 acres water surface
- 47 mi pond shoreline
- 31 mi drainage pipe
- >430 reported fish kills, last 11 yrs



Residential

- Routine monitoring, event response, and ecosystem linkages
- Co-occurring pathogens
- Bloom ecology, genomics, and mitigation strategies
- Development/refinement of novel molecular detection methods

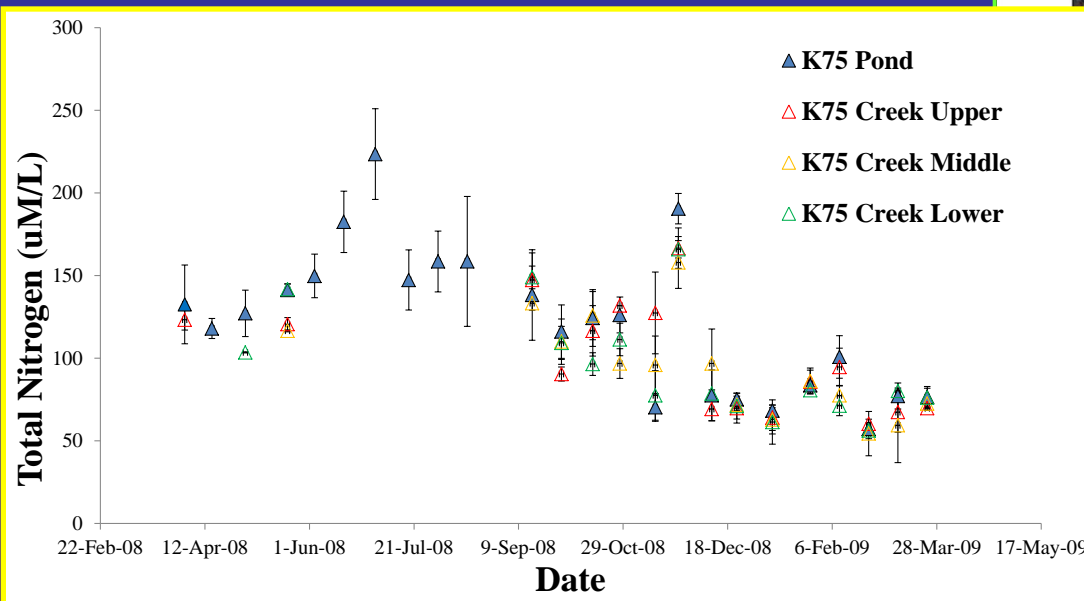
Routine Monitoring

- 2X month during warm months, monthly during winter
- Sample mid-ebb
- Measure basic water quality parameters (T, S, DO, pH) and nutrients (N, P)
- Evaluate phytoplankton community composition and chlorophyll *a*
- Additional analyses (e.g., toxin) or follow-up as needed
- 2X yr bacterial indicator monitoring



Ecosystem linkages: Are ponds sources of nutrients and HABs to tidal creeks?

- 2 terminal pond/creek systems
- Nutrients, phytoplankton, standard water quality measured twice/month during ebb tide



Tight similarities between ponds and receiving creeks strongly suggest linkages



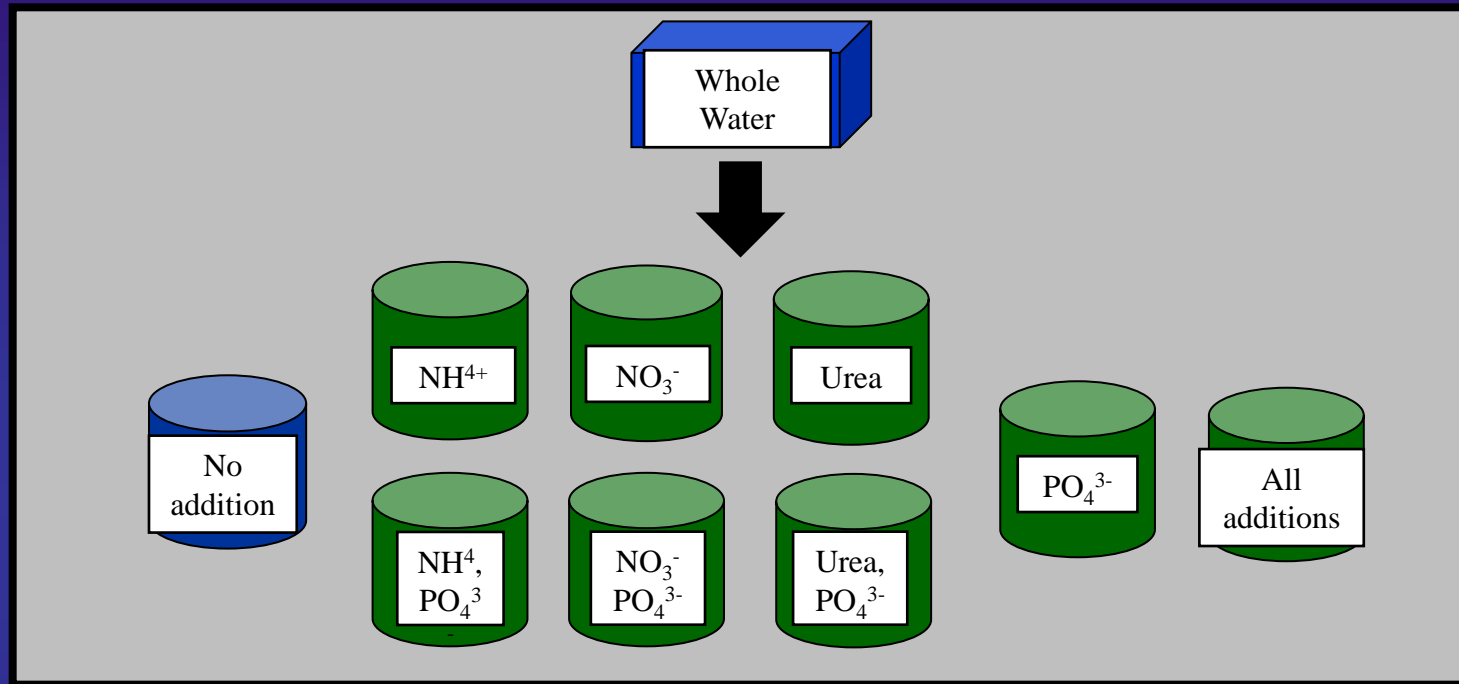
What nutrient types/levels cause blooms? Implications for management?

Problem: Elevated N and P are known to cause eutrophication. Surprisingly little is known about nutrient loading & phytoplankton growth across SC estuaries and ponds. Implications for nutrient management?

- Comparative field and experimental approach
- Determine biological responses (algal growth) to N and P in different coastal habitats
- Seasonal sampling for phytoplankton, nutrients, other water quality parameters
- Lab experiments evaluating phytoplankton responses to N levels



Nutrient Addition Bioassays



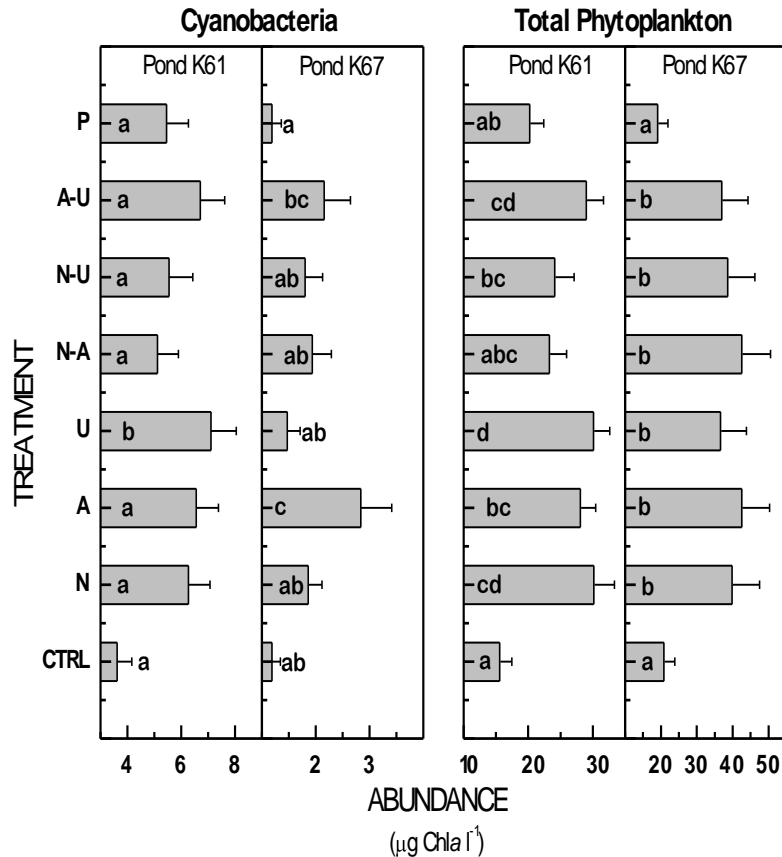
- 48 hr incubation
- N added at 20 μM , P added at 1.25 μM (Redfield 16:1)
- Net phytoplankton growth & community composition measured (chlorophyll *a*, microscopy, HPLC pigments)
- Nutrients measured for N, P, and C utilization

Other field measurements

- Automated sampling over 2 tidal cycles
- Near-continuous (15 min) water quality (T, S, turbidity, fluorometry, DO, pH) measured using deployable YSIs
- Evaluate phytoplankton assemblages & nutrients
- Coordinate sampling with other regional activities



Cyanobacteria responses to N-enrichment



- 2 ponds with bloom histories
- Ammonium (A) and urea (U) favored algal growth, including HAB species
- **Management implications:** urea is a common golf course fertilizer compound
- N-fixing species (ability to convert N₂ to NH₃) did not increase with additions

Can we understand nutrient and algal population dynamics at a gene/molecular level?

Kiawah Pond K109, Aug-Sept 2011

- Massive ($>6 \times 10^5$ cells/ml) bloom of mixed cyanobacteria genera (*Microcystis*, *Oscillatoria*, *Cylindrospermopsis*, *Aphanizomenon*, *Anabaenopsis*)
- Microcystin: ELISA (4 – 16 ppb)
- *mcyD* gene: qPCR, 454-pyrosequencing
- Environmental parameters: nutrients, chlorophyll *a*, T, S, DO, pH
- Short-term goal: evaluate phytoplankton assemblage variability and key genes regulating toxicity
- Long-term goal: Improve capabilities to predict toxic events



Developing novel molecular tools to study algal population dynamics

Why develop molecular approaches to study algae?

- Light microscopy is time-consuming
- Many species look alike and are difficult to distinguish
- Molecular approaches are often faster and enable species or gene-specific identification and quantification, enabling 'early warnings' of HAB events
- Examples: polymerase chain reaction (PCR), sandwich hybridization assay (SHA) for HABs. Protein-based for toxins (ELISAs and others)

NOAA-MERHAB Project: Compare different molecular methods for HAB research

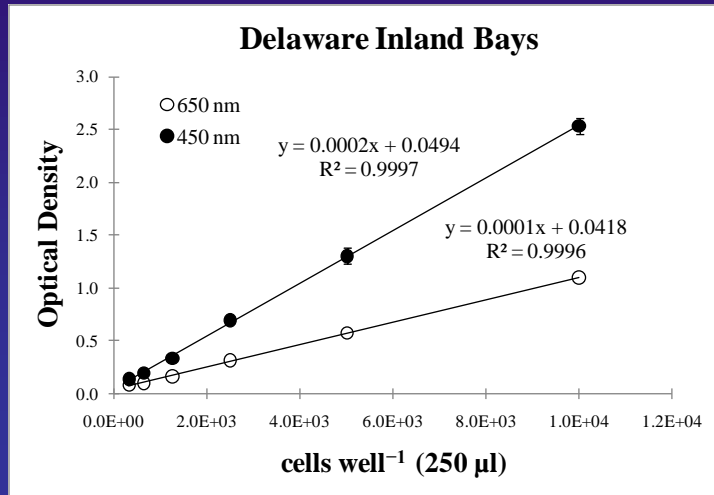
- Many methods exist for phytoplankton monitoring, but few cross-comparisons have been done
- ‘Bake-off’ between PCR and SHA
- Comparisons using a wide range of population, physiological and environmental/field conditions
- Which one should I use? Provide recommendations to researchers and managers



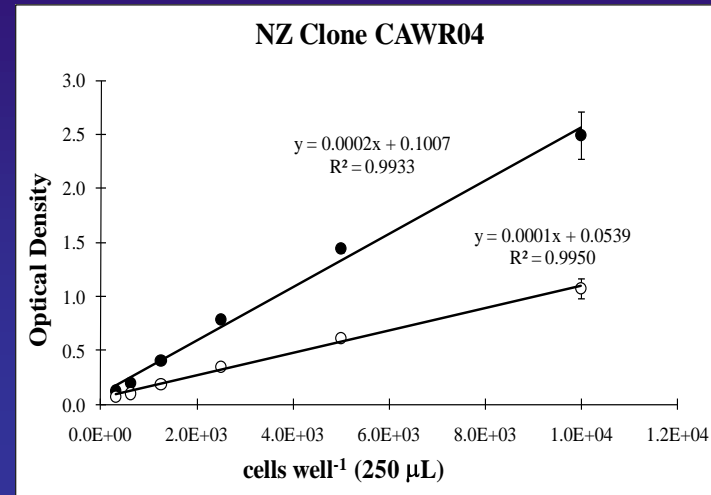
- **Ichthyotoxic**
- **Global distribution**
- **Molecular assays established**



Do different populations affect responses?



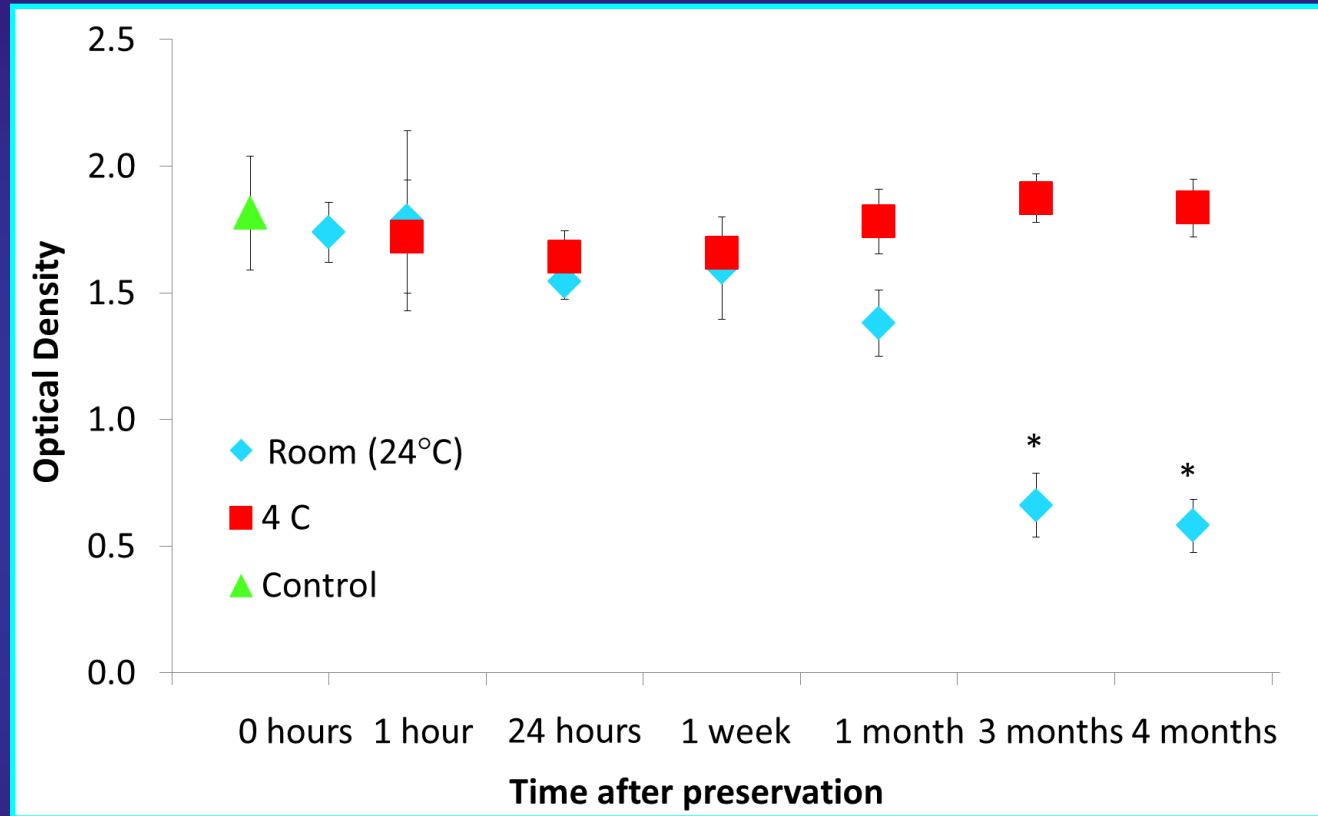
C. Doll, this study



From Greenfield et al., 2008

- Different study, year, population, and operator – yet, same response!
- Similar results using many, but not all populations tested
- Promising results using qPCR

What if I preserve a sample and analyze it later - will I get reliable results?



- Maybe, it depends upon the storage conditions
- Other questions: How do range/limits of detections compare? How does culture age or nutritional status affect results? What about field sampling?

Take-Home Messages

- **Algal blooms may be unsightly, but most are benign**
- **Some algal blooms are harmful (HABs) and pose mild to severe health and environmental threats**
- **Recognizing the signs of a HAB and prompt reporting can help safeguard public health**
- **Causative factors include poor flushing and stagnation, nutrient loading, and reduced predation**
- **Technology improvements are underway to expedite sample processing and analyses**



Acknowledgments



SCAEL Crew: Chuck Keppler, Lara Brock, Sarah Hogan, Suzie Kacenas, Cameron Doll, Michelle Reed (& all former lab members)

Norm Shea, Priscilla Wendt (& all fishkill responders), Jim Morris, Margaret Bergin, Bob Van Dolah, Mary Ellen Williams, Kathy Coyne, & all who have assisted us over the years.

SC Sea Grant, EPA, OHH, Kiawah Island Community Association, CDC, USC Research Foundation, NOAA-MERHAB



Questions?

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<http://links.baruch.sc.edu/SCAEL/index.html>