Harmful Algal Blooms in the Mid-Atlantic Region

Kimberly Reece
VIMS, Aquatic Health Sciences Dept
Gloucester Point, VA
WHERE DO BLOOMS OCCUR?

• Algae blooms are found all over the world in freshwater & saltwater

• Specific problem (HABs) regions in the US:
  – Florida, Gulf of Mexico, California, Pacific NW, Alaska, New England
  – recent expansion to all coastal areas, including the mid-Atlantic

VIRGINIA BLOOMS

• Some occur in the spring, but most noticeable and widespread occur in the late summer and early fall (Aug – Sept)

• Some blooms are associated with offensive odors and respiratory irritation, and/or with fish, shellfish or crab kills due to low DO or toxin
General Bloom Pattern in VA waters

Spring
- Diatoms
  - *Heterocapsa triquetra*
  - *Dinophysis spp.*
  - *Karlodinium veneficum* (Toxin = Karlotoxin)
  - *Prorocentrum spp.*
  - Raphidophytes (Toxin = Brevetoxin?)
- *Cochlodinium polykrikoides* (Toxin = ?)

Summer
- *Pseudo-nitzschia* spp. (Toxin = Domoic acid)
- *Dinophysis* spp.

Fall
- *Alexandrium monilatum* (Toxin = Goniodomin)

Winter

NOTE: We have seen Karlodinium and Prorocentrum in filtered hatchery water. Filtration systems are not 100% effective

+ Possible human health effects
* Can be harmful to shellfish
Major Concerns for Shellfish Growers

• Survival of shellfish:
  – low dissolved oxygen (algal cells die and degradation lowers available oxygen)
  – reduced water flow to the nursery systems (physical clogging of screens)
  – physical impairment of filter feeding by the algal cells
  – toxic effects from HAB toxins

• potential for human illness:
  – consumption of shellfish that have accumulated toxins from HAB cells filtered
  – more research is needed to determine potential for human health issues from mid-Atlantic blooms.
Historic profiles and emerging patterns

Cochlodinium polykrikoides

Alexandrium monilatum

Several other toxic HABs knocking on our door.
**HAB-related human shellfish poisoning illnesses**

<table>
<thead>
<tr>
<th>HAB species</th>
<th>Toxin</th>
<th>Illness</th>
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<tr>
<td><em>Alexandrium</em></td>
<td>Saxitoxins</td>
<td>Paralytic Shellfish Poisoning (PSP)</td>
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<td><em>fundyense/tamarense</em></td>
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<td><em>catenella/minutum</em></td>
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<tr>
<td><em>Pseudo-nitzschia</em></td>
<td>Domoic acid</td>
<td>Amnesic Shellfish Poisoning (ASP)</td>
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<td><em>spp.</em></td>
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<td><em>Dinophysis</em></td>
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<td><em>Karenia brevis</em></td>
<td>Brevetoxin</td>
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<td><em>Gambierdiscus</em></td>
<td>Ciguatoxin Maitotoxin</td>
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<tr>
<td><em>toxicus</em></td>
<td>Gambieric Acid</td>
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Gastrointestinal and neurological symptoms

* Seen in the Mid-Atlantic region

* Photos: Nancy Lewis, Dr. Rozalind Jester, oceandatacenter.ucsc.edu, FL Fish and Wildlife
  Slide made by Sarah Pease
Paralytic Shellfish Poisoning-PSP  
(New England, West Coast)

• **Saxitoxin(s)-several toxins in the group**
  – mortality in wildlife and humans
  – heat stable toxin
  – ingestion-usually bivalves: mussels, clams, oysters, but also crabs, lobsters and snails can be contaminated. A few cases from finfish
  – Saxitoxins in dinoflagellates and cyanobacteria:
    – *Alexandrium tamarense* complex
    – Cyanobacteria: *Anabaena, Cylindrospermopsis, Lyngbya, Aphanizomenon, Planktothrix*, and *Raphidiopsis*
PSP (cont.)

• Symptoms can begin within minutes after ingestion
  – tingling, numbness starts in the mouth and lips
  – spreads to the face and neck
  – next to the extremities with respiratory difficulties
  – headache, dizziness, nausea, vomiting, rapid pain
  – 2-12 hours death OR recovery after 12 hours with symptoms gone in a few days
  – fatality rate ~10%
Amnesiac Shellfish Poisoning-ASP
(West Coast, Alaska)

• Domoic acid
• *Pseudo-nitzschia* spp. (diatoms), some red algae produce low levels of domoic acid
• Heat labile except in shellfish where there appears to be protection from inactivation by heating
• Causes illness and mortality in marine mammals, sea birds and finfish
• Gastrointestinal and neurological symptoms
  – nausea, vomiting, abdominal cramps, and diarrhea
  – dizziness, headache, seizures, disorientation, short-term memory loss, respiratory difficulty, and coma, death
• Mussels, bay scallops, sea scallops, razor clams, Dungeness crabs, anchovies (note: toxin is found in viscera of finfish and crustaceans)
Diarrhetic Shellfish Poisoning-DSP  
(Pacific NW, Gulf Coast)

- Okadaic acid

- *Dinophysis* spp., *Prorocentrum* spp. (Often seen in VA waters)

- The first reported cases of DSP were in the Netherlands in the 1960s, followed by similar reports in the late 1970s from Japan- now numerous cases around the world including US East coast

- Symptoms usually begin within 30 mins to a few hours of consumption

- Diarrhea, nausea, vomiting, abdominal cramps, and chills (usually not fatal and without neurological symptoms)

*Figures: Dinophysis caudata and Prorocentrum micans*
Neurotoxic Shellfish Poisoning-NSP
(Karenia brevis, also K. mikimotoi, K. brevisulcata, K. selliformis, and K. papilionacea, some Raphidophytes?)
(Gulf Coast, Florida East Coast)

- Brevetoxin
  - tasteless and odorless
  - Ingestion-shellfish and finfish (generally lower concentrations)
  - inhalation of aerosols for beachgoers; surf disrupts cells
  - Dermal exposure
  - Seldom fatal, but can result in hospitalizations

- Gastrointestinal, dermal and neurological symptoms: abdominal pain, vomiting, and diarrhea, paresthesias, reversal of hot and cold temperature sensation, vertigo, ataxia, cough, dyspnea and bronchospasm

- Can also impact many commercial and recreational species of fish, sea birds, sea turtles, manatees and dolphins-fish kills are common with *K. brevis* blooms
Ciguatera Fish Poisoning-CFP  
**(Tropical waters)**

- Ciguatoxin(s)
- *Gambierdiscus toxicus, Prorocentrum lima*
- gastrointestinal, neurological, and cardiovascular symptoms.
  - Diarrhea, vomiting, and abdominal pain usually first symptoms (within 24 hrs)
  - Reversal of temperature sensation, muscle aches, dizziness, anxiety, sweating, numbness and tingling of the mouth and extremities (1-2 days later)
  - Advanced cases cardiovascular damage
  - Variable recovery time, could be months or years

- Reef fish: grouper, snapper, mackerel, jack, barracuda, parrot fish, tang, goat fish….., gastropods
Raphidophyte Blooms
*(Chattonella subsalsa, Heterosigma akashiwo, and Chloromorum toxicum)*
Brownish-green discoloration of the water

- Potential brevetoxin production
- Low levels of brevetoxin detected in fish, shellfish and water samples from blooms
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NOTE: We have seen Karlodinium and Prorocentrum in filtered hatchery water. Filtration systems are not 100% effective.

+ Possible human health effects
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Dominant summer bloom species distribution 1994-2014
Chesapeake Bay

- *Alexandrium monilatum* blooms observed almost annually in York River region starting in 2007
- Highest densities in the York River with lower counts in samples outside the region through 2013 (expansion of *A. monilatum* in 2015/16)

Data from Egerton and Marshall/ODU; Reece/VIMS
• *Cochlodinium polykrikoides* (Cochlo) typically starts blooming in July through August/September throughout lower Chesapeake Bay

• York River region since 2007 the peak Cochlo bloom is followed 2-3 weeks later by the peak *Alexandrium monilatum* (Alex) bloom in some locations and levels of Cochlo drop dramatically.

Blooms can shift quickly and water samples change after collection: Rapid collection and analysis is very important.
Expansion of Cochlo and Alex in the lower Chesapeake Bay (CB)

- Expansion north and south of the York River region. Cochlo-40+ years, Alex 9 years
- Alex: first recent bloom in the York River in 2007, expansion started 2010-12.

- Dense blooms of Cochlo are common throughout lower CB
- Alex was found blooming in VA Beach and Outer Banks (’16)
C. polykrikoides- Aug. 5, 2016

Near Naval Weapons Station

Near Catlett Islands

York River

Elizabeth River

Photos by W. Vogelbein
A. monilatum and C. polykrikoides - Aug. 24, 2016

Lafayette River - C. polykrikoides

Elizabeth River - C. polykrikoides

Mouth of the Rappahannock - likely A. monilatum based on samples collected near Gwynn’s Island

York River mouth - A. monilatum

Photos by W. Vogelbein
Photos by W. Vogelbein

York River

Mouth of the Poquoson River

Rappahannock River

Eastern Shore looking west

Bioluminescence was reported throughout the region from Mobjack Bay down into VA Beach and NC Outer Banks in 2016.
Laboratory Bioassays with *C. virginica* larvae and spat

- **Karldinium veneficum**
  - 80-100% mortality in larvae after 72-96 hr (>1,000 cells/ml)
  - NO mortality observed in spat (diploid or triploid)

- **Cochlo**
  - 80-100% mortality in larvae after 72-96 hr (>1,000 cells/ml)
  - NO mortality observed in spat (diploid or triploid)

- **Alex**
  - 80-100% mortality in larvae after 48 hr, 100% at 72 hr (>1,000 cells/ml)
  - mortality observed in spat (diploid and triploid)
Field Observations- What can be done?

Potential Mitigations

Larvae

- Remote setting stations during blooms:
  - Low larval survival
  - Poor setting success

- Mitigation strategy:
  - Avoid setting during bloom
  - When blooms appear after larvae in tanks, cut off flow-through water during peak bloom times (high tide?) and turn on air to the tank
  - Limit water draws when bloom is abundant and if possible, pump water from an area outside the bloom

- HAB species might pass through shellfish hatchery filtration and cause larval mortality.
- Is mortality a result of toxin exposure? Mitigation is challenging and we are testing different methods of filtration to prevent toxin exposure.
Field Observations-What can be done?

Potential Mitigations

Seed

- Frequent reports of seed mortality in nursery systems during blooms

- Mitigation Strategy- Clean nursery silos daily with fresh water to:
  - Limit HAB exposure
  - Prevent loss of water flow
  - Remove dead and dying algal cells that will deplete oxygen

Adults

- Adult mortality to date is minimal (some juvenile mortality):
  - Typically close up and stop feeding during harmful blooms
  - Resume feeding when bloom patches pass
  - Starvation and low DO are concerns if the bloom persists.
  - Relocating shellfish grow-out is a possibility, but $$$?
  - Intertidal vs. subtidal? (Research project focus)
Managing the complex profile of biotoxins threatening the shellfish industry of Lower Chesapeake Bay

NOAA Sea Grant Aquaculture Research Program 2016
Juliette Smith (VIMS), Kimberly Reece (VIMS), Todd Egerton (VDH)

Project objectives:
1) identify current biotoxin threats to seafood safety (*human health*)
2) determine biotoxin breakthrough and effects in hatcheries (*shellfish health*)
3) recommend best management practices
VIMS Research Projects

Toxicity and Potential Food-Web Impacts of *Alexandrium monilatum* and its Toxins

NOAA ECOHAB Program 2017
Reece, Carnegie, Smith, Vogelbein, Reay, Small, (Hudson, Brill, Harris)

- Characterize the impacts of Alex and its toxin(s) on oysters, crabs and finfish
  - Better understand bloom dynamics

- Examine toxin transfer through trophic levels:
  - oysters to crabs
  - oysters to menhaden and striped bass (No, we don’t think striped bass eat oysters 😊, using it as a model system)
VIMS Research Projects

VA Sea Grant Research Fellowship for Graduate student: Clara Robison

Impacts of environmental stressors and harmful algal blooms on growth, performance, and survival of triploid oysters cultured in lower Chesapeake Bay

- 2 bloom sites: high and low flush, intertidal and subtidal grow-out (2 growers)
- 1 control site
- Measuring:
  - Water quality parameters
  - Growth, survival and condition

2017 NOAA Aquaculture Grant
Reece, Vogelbein, Reay (Hudson)

Identifying Strategies to Minimize Impacts of Harmful Algal Blooms on Performance and Survival of Triploid Oysters Cultured in Lower Chesapeake Bay

- Same basic study design as above
- Adding additional sites (working with 3 growers and 2 control sites)
VIMS Research Project

Imaging FlowCytobot (cytobot)- Early Warning System

HAB abundance & community
Near real-time data on dashboard
Sampling every hour
Deployment for ~6 months
VIMS Pier
Early Warning System

http://ifcb-data.whoi.edu/about

Campbell et al. 2010
Vision: Develop a Network for an Early Warning System

- Flow Cytobots
- Satellites
- Planes with sensors
- Standard water sampling