The effects of cyanobacteria on animal and public health

Jan H. Landsberg¹, Andrew R. Reich², Diane Kitchen³

¹Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, St. Petersburg, FL
²Bureau of Epidemiology, Florida Department of Health, Tallahassee, FL
³Division of Animal Industry, Florida Department of Agriculture and Consumer Services, Tallahassee, FL
Seminar objectives

- To demonstrate the breadth and diversity of issues from cyanobacteria/cyanotoxins in FL
- To identify the challenges in field investigations and diagnostics
- To discuss emerging issues
Florida’s diverse cyanobacteria blooms

- Anabaena circinalis bloom, St. Johns River, 1999
- Cylindrospermopsis raciborskii bloom, Lake Munroe, 2007
- Microcystis aeruginosa bloom, Dunns Creek, 2010
- Lyngbya smothering sea fans, Florida southeast coast
- Aphanizomenon cf flos aquae bloom, St. Johns River, 2010
Cyanobacteria and cyanotoxins in Florida

> 40 potentially harmful or toxic species

**Freshwater**
- *Microcystis*
- *Cylindrospermopsis*
- *Anabaena*
- *Aphanizomenon*
- *Planktothrix (Oscillatoria)*
- *Lyngbya wolleii*
- *Stigonematales*

**Marine**
- *Trichodesmium*
- *Lyngbya spp.*
- *Geitlerinema*
- *Leptolyngbya*
- *Synechococcus*
Freshwater cyanobacteria in Florida

- Cause significant economic and ecological impacts (e.g. St Johns, Caloosahatchee rivers, Lake Munson, private ponds)
- Risk for animal and public health
- Contaminate drinking water sources
- Toxicoses (fish, wildlife, livestock, pets)
- Recreational exposures
- Chronic health effects (tumor promoters)
- Ecosystem disruption (anoxia/hypoxia [fish kills], light attenuation [SAV])
- Cyanotoxins in food webs

Williams et al. 2001
Freshwater cyanotoxins in Florida

- Neurotoxins (saxitoxins, anatoxins)
- Hepatotoxins (microcystins, cylindropermopsins)
- Dermatotoxins (lyngbyatoxins, debromoaplysiatoxin)
- Bioactive compounds (e.g. LPS, hemolysins)
- Different species can produce same toxins
  - e.g. saxitoxins (*Lyngbya wollei*, *Aphanizomenon* spp., *Anabaena*, *Cylindrospermopsis*)
- Individual species can produce diverse toxins
  - e.g. *Cylindrospermopsis raciborskii* (cylindropermopsin, saxitoxin)
- Exposure by ingestion, inhalation, dermal
Microcystins (MCYST)

- Common in freshwater (*Microcystis*, *Anabaena*)
- “Paint-green” discoloration (*Microcystis* blooms)
- Primary exposure by direct ingestion
- Hepatotoxic and tumor promoters
- Affect invertebrates, fish, birds, amphibians, reptiles, mammals
- Rapid assays (ELISA, PPIA) and confirmation (HPLC, LC/MS)
- Need to assess health risks from chronic and low level exposure
  - Temporary food chain transfer
Microcystins (MCYST) in fish

- Four lake survey, Lake County
- Bi-seasonal
- Four fish species
- Different trophic levels
- Microcystins in GI tract, liver
- Low concentrations-planktivores/omnivores (gizzard shad, bluegill)
- Negligible or below detect-piscivores/benthic fish (largemouth bass, brown bullhead)
- Transient in relation to bloom
  - Subtle hepatic pathology
Microcystins (MCYST) in fish

Mean microcystin concentrations in livers – Aug 2006 (FWC, unpub. data)

**Bluegill**

- Apopka: 10
- Eustis: 8
- Griffin: 10
- Harris: 9

**Gizzard shad**

- Apopka: 7
- Eustis: 6
- Griffin: 8
- Harris: 8

**Largemouth bass**

- Apopka: 10
- Eustis: 10
- Griffin: 10
- Harris: 10

**Brown bullhead**

- Apopka: 9
- Eustis: 9
- Griffin: 9
- Harris: 1
Cylindrospermopsis raciborskii (CYN, STX)

- Sub-tropical” species
- Detected in FL in mid-1990s
- Expanding distribution
- Associated with several animal mortality events
  - 1998–2003, alligator die-off, Lake Griffin
    - thiamine deficiency [Ross et al.], cyanotoxins?
  - 2007, mallard mortalities, Lake Munroe
    - low level cyanotoxins in liver
    - co-associated with botulism
- Multi-factorial
- Challenge to confirm cyanotoxin etiology
Saxitoxins (STXs)

- Neurotoxins (hydrophilic)
- Diverse species (*Lyngbya wollei*, *Anabaena*, *Aphanizomenon* spp., *Cylindrospermopsis*)
- STXs > 20 congeners, profiles “fingerprint” of source
dcGTX-2,3/dcSTX* in manatee stomach content
- ?Source *L. wollei* mats on SAV in freshwater
- *L. wollei* saxitoxin profile (dcGTX-2,3/dcSTX)
  (Foss et al. 2012)
- Low level STXs in SJR blue crabs*
  (source unknown)

*Flewelling et al. FWRI/FWC (unpub. data)
Mixed cyanobacteria blooms/toxins

• Common in freshwater, seasonal
• Bloom succession by dominant species
• Challenges to interpret multiple toxins
  • e.g. SJR 2010 fish kill (*Aphanizomenon* dominant)
• Chronic fish die off (low concentrations of microcystin, saxitoxin, cylindrospermopsin)
• Likely role for other bioactive compounds
• Cyanobacteriolytic bacteria
Emerging issues and challenges

- Chronic exposure/role in mortality events
- Expansion and drivers of toxic species
- Synergistic effects > multiple toxin exposures
- Accurate detection methods for known toxins
- Risk assessment of “new” toxins/disease syndromes (AVM/BMAA)
- Toxins as tumor promoters (MCYST)
- Transport of cyanotoxins into marine systems
- Dermatopathologies (debromoaplysiatoxins)
- Role of cyanoHABs as pathogen vectors
- Role of cyanobacteriolytic bacteria in disease
Avian vacuolar myelinopathy (AVM)

- Lethal neurological disease (SE USA)
- Epiphytic cyanobacterium (Stigonematales) vectored via vegetation (e. g. *Hydrilla*)
- Neurotoxin $\rightarrow$ coots $\rightarrow$ bald eagles
- AVM brain lesions, affects flight, behavior $\rightarrow$ death
- Statewide surveillance (one positive [PCR] lake [N=47])
  - AVM bird surveillance
- Dr. Wilde (SC) monitoring in Lake Toho
Beta-N-methylamino-L-alanine (BMAA)

- Reported from diverse cyanobacteria
- Freshwater and marine habitats
- Hydrophilic neurotoxin
- Interacts with glutamate receptors
- Implicated in neurodegenerative diseases
  - Alzheimer’s, Amyotrophic Lateral Sclerosis
- Putative presence in invertebrates and fish (SFL) (Brand et al. 2010)
- Significant scientific debate regarding accurate chemical identification and risk in aquatic systems
  - Requires interlaboratory validation
  - Consensus peer review – no health threat?
Diagnostic challenges

- Microcystin (e.g. MC-LR) is detected in tissues by ELISA/PPIA, confirmed by HPLC/LCMS
- Microcystin binds covalently to protein phosphatases
- Challenge for tissue extraction (traditional analyses underestimate)
- > 80 microcystin congeners (maybe environmentally relevant, not all monitored)
- Microcystin not only hepatotoxic
- Few analytical laboratories available
- Budgetary constraints for routine monitoring and investigative diagnostics
State agency resources

- FWC - Wildlife alert hotline: 1-888-404-3922
  Fish kill hotline: 1-800– 636-0511
  http://research.myfwc.com/fishkill/submit.asp
  HAB report status: 1-866-9399

- FDOH - Aquatic toxins hot line: 1-888-232-8635
  http://www.doh.state.fl.us/Environment/medicine/aquatic/

- FDACS - 1-800-435-7352

- FDEP - WQ monitoring/event response
  http://www.dep.state.fl.us/labs/biology/hab/index.htm

- WMDs - WQ monitoring/event response
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