

Microcystins and the Toxicity of Hazardous Algal Blooms.

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Wayne Carmichael
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And a whole
host of other
people!



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In this talk.....

What I will talk about:

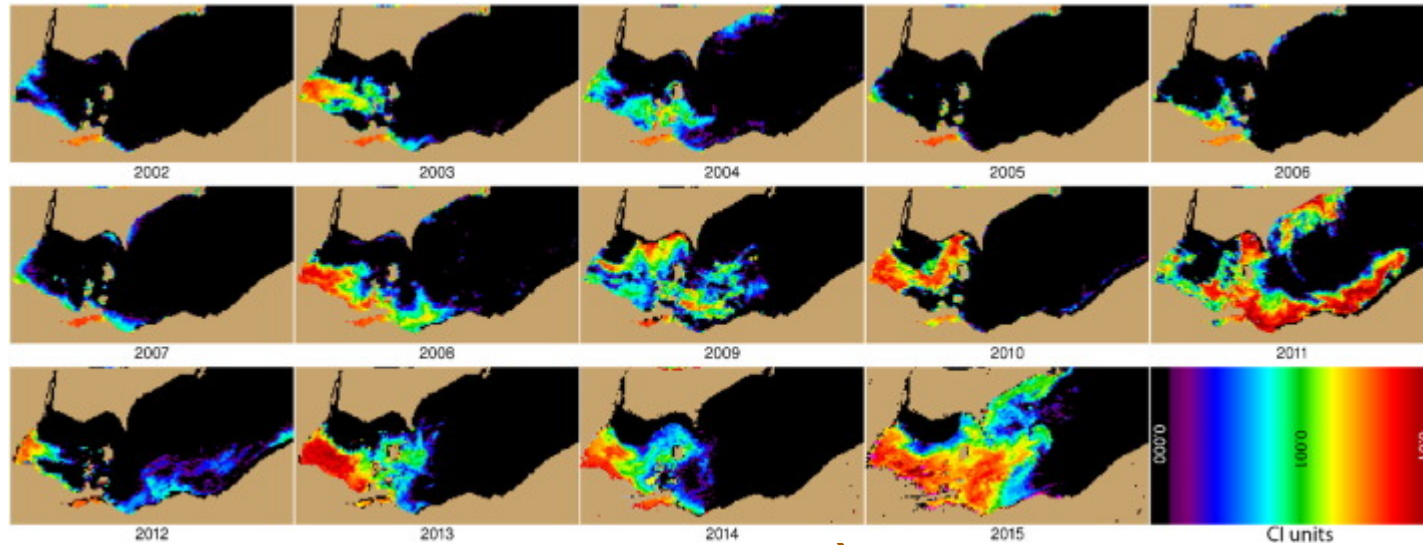
- Occurrence of the toxins
- Exposure pathways
- Reports of Human health impacts
- Unreported considerations

What I will NOT talk about:

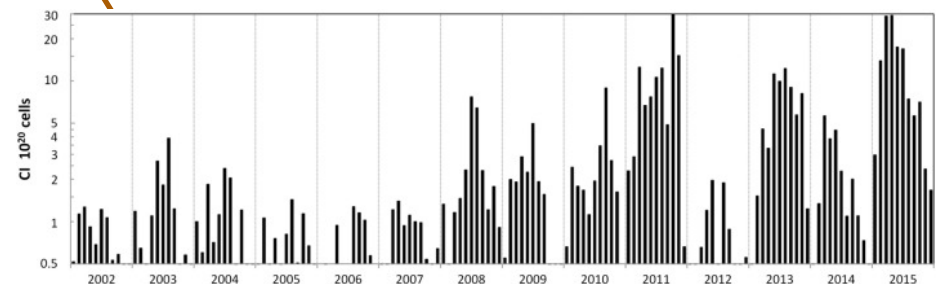
- Current Guidance values for drinking water
- Current Guidance values for recreational contact
- Broader ecosystem effects
- Detailed monitoring results

Human Health impacts = Dose x duration x toxicity

These blooms occur every year:

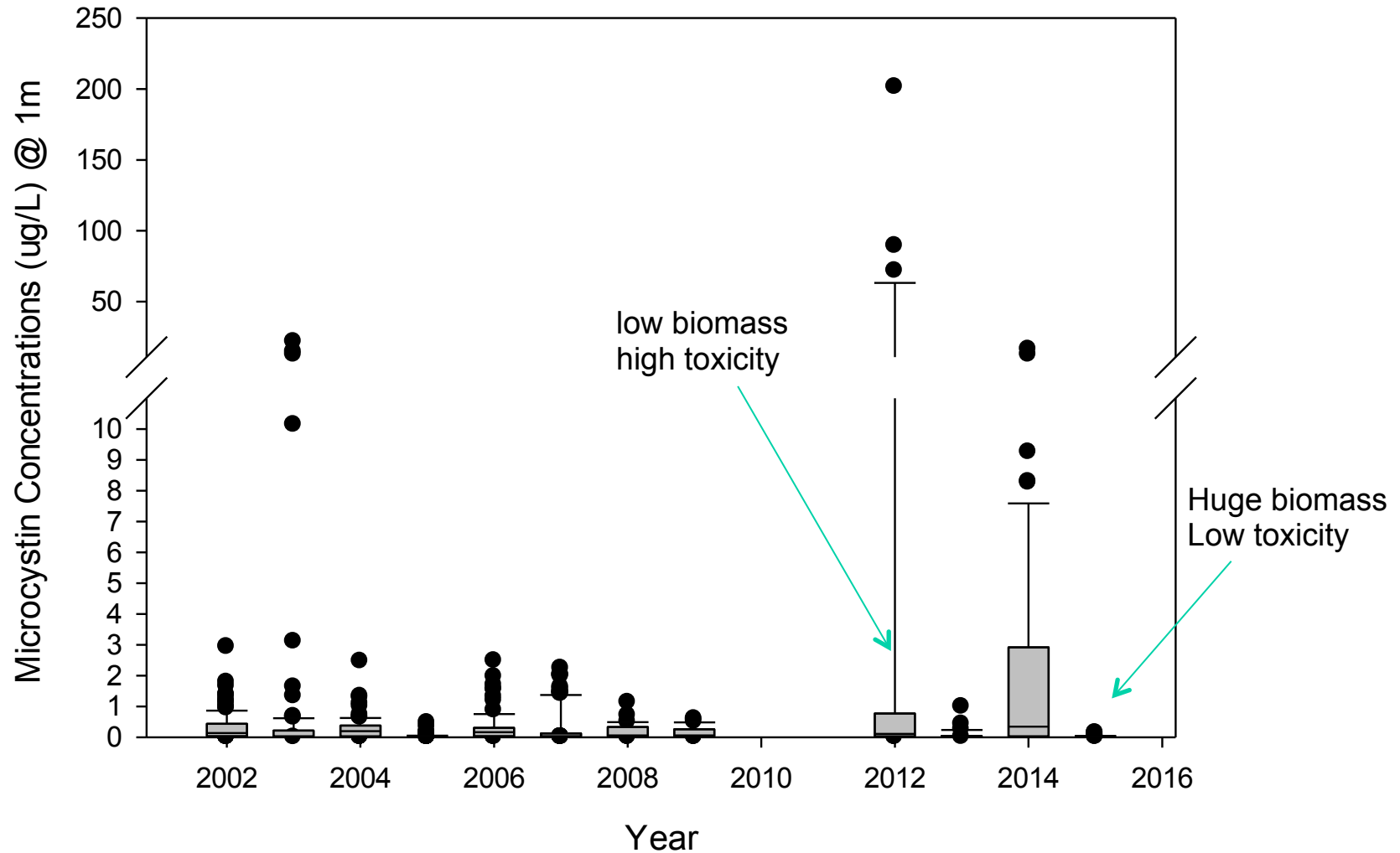


- MERIS Imagery
- Blooms generally peak in August
- Algorithm to convert the CI to biomass estimates.

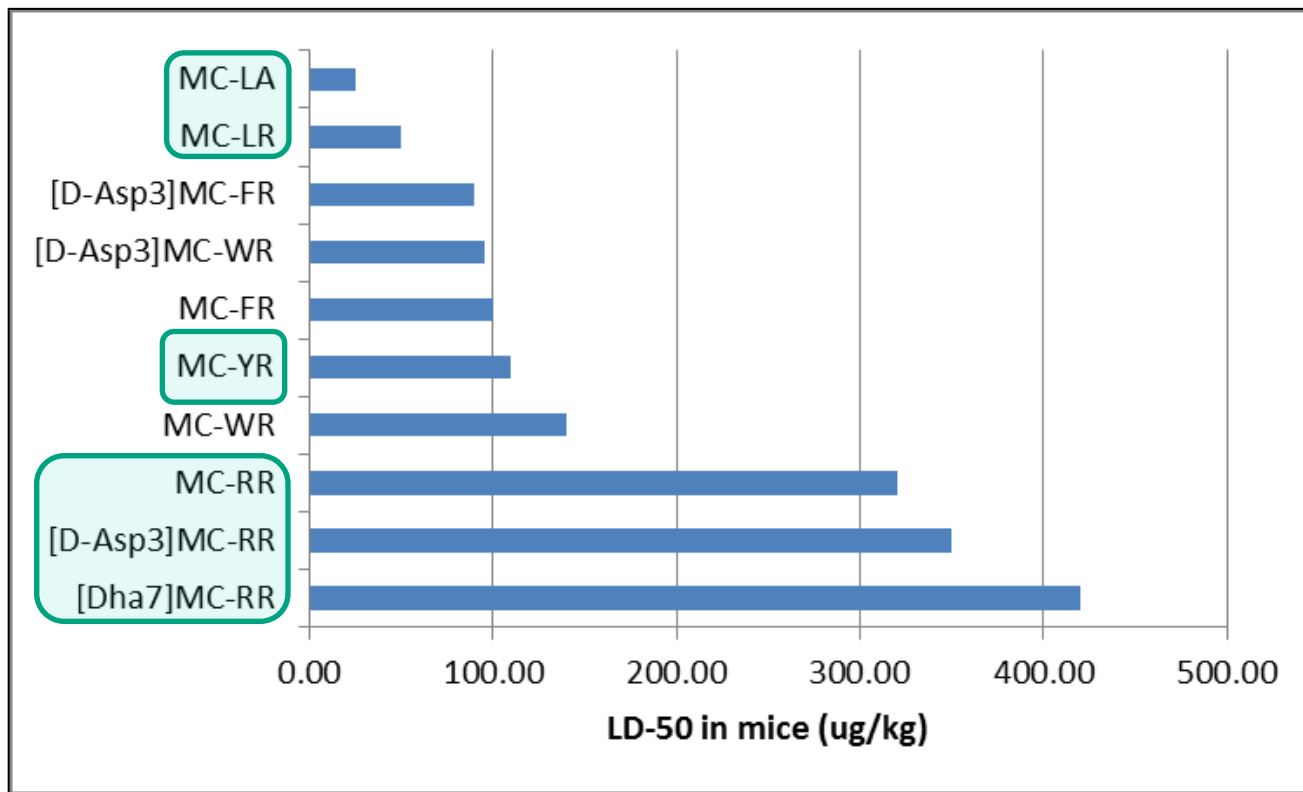


Stumpf et al. (2016). Forecasting annual cyanobacterial bloom biomass to inform management decisions in Lake Erie JGLR 42:1174-1183.

Biomass does not necessarily predict toxicity



Toxin concentration does not necessarily predict toxicity



Most of our focus has been on exposure via drinking water

State of emergency declared in Lucas County after toxins found in Toledo water - Toledo Blade#o1BSAaAKupv3UJW0.03

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State of emergency declared in Lucas County after toxins found in Toledo water

Microcystin found in samples; boiling not recommended

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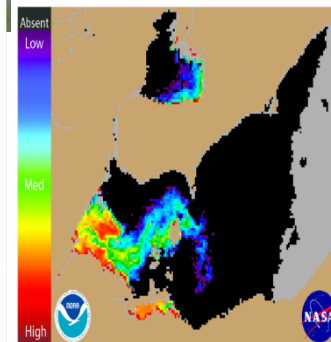
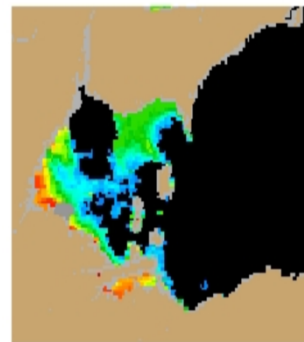
Scenes like this were comm on this morning as area residents traveled all over in search of bottled water.
THE BLADE/JETTA FRASER

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A state of emergency was declared today in Lucas County and the greater Toledo area after tests at the Collins Park water-treatment plant in East Toledo produced two toxin sample readings.

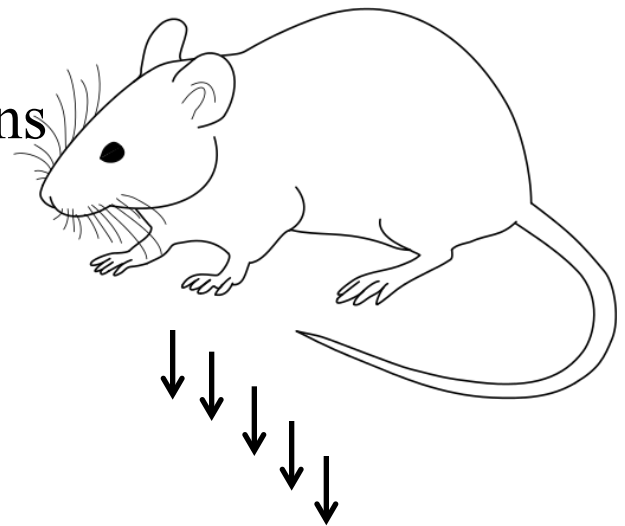
Chemists testing water at Collins Park plant found two sample readings for microcystin that exceeded the recommended "do not drink" standard of one microgram per liter standard.

Toledo Mayor D. Michael Collins and health leaders asked residents to remain calm and said they may have answers later today on when Toledo-area water supply will be safe to drink again.



How do you determine safe levels of toxin in water?

- Start with a mouse
- Measure the highest level that has no effect.
 - No Observed Adverse Effect Level (NOAEL)
 - 40 $\mu\text{g}/\text{kg}$ body weight for microcystins
- Include safety factors
 - 10x (mice are not people)
 - 10x (not every mouse is the same)
 - 10x (limited number of studies)
- Average body weight of adult (60 kg)
- Consume 2 L water per day for life



World Health Organization Guideline value:
= 1 $\mu\text{g} / \text{L}$ (ppb)
(guideline value – not regulatory)

What do we really know about the Toledo DWE?

- Source water concentrations in Lake Erie exceeded ~5-15 ug/L
- Finished water concentrations exceeded the WHO drinking water guidelines (2.5 ug/L) for approximately 2-3 days.
- Collins water treatment plant solved the “problem” by increasing carbon levels.
- ~ 200 reported cases of “microcystin” intoxication from residents of the Toledo area.

Reported Symptoms

- Nausea
- Fever
- Chill and sweats
- Diarrhea
- Vomiting
- Difficulty breathing
- Weight loss
- Nausea
- Ear, eye and skin irritation
- Diarrhea
- Vomiting
- Sore throat
- Hay fever or asthma-like symptoms

Reported Symptoms

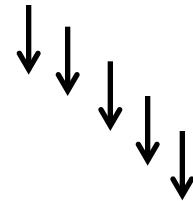
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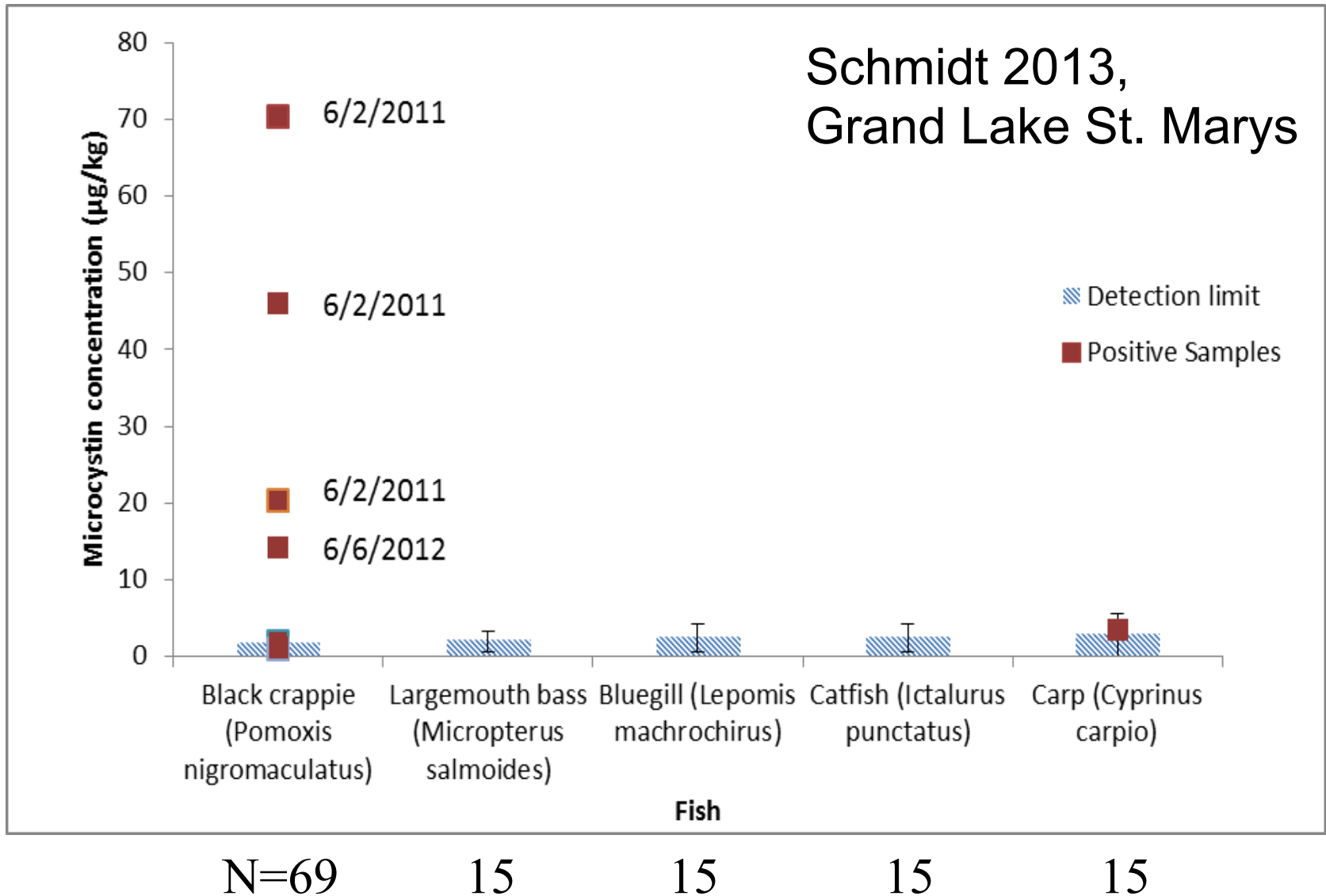
Safe levels of toxin in Fish?

- Start with a same 40 $\mu\text{g}/\text{kg}$ body weight for microcystins (NOAEL)
- Include same safety factors
 - 10x (mice are not people)
 - 10x (not every mouse is the same)
 - 10x (limited number of studies)
- Average body weight of adult
- 100 g fish/meal/day (*Ibelings & Chorus 2007*)
 - Daily: 3 $\mu\text{g}/\text{kg}$ fish (adults)
 - Seasonal: 30 $\mu\text{g}/\text{kg}$ (adults)
 - kids are 5-8 fold less

Assumes bloom is toxic all season.



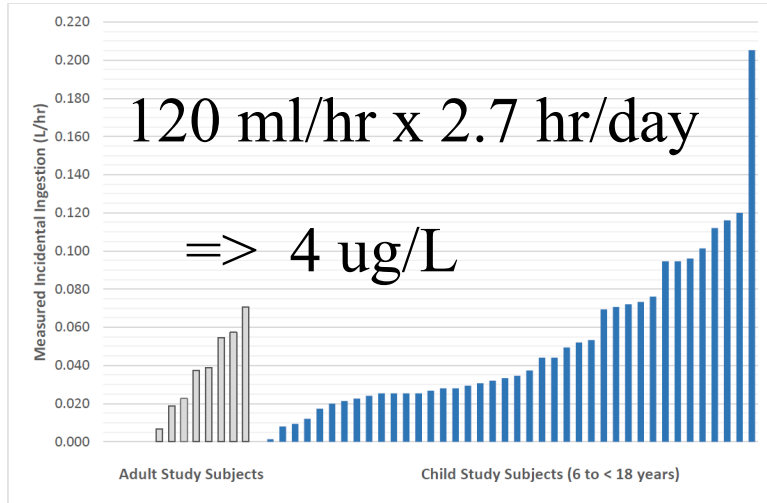
Fish results are highly variable – mostly zero



Why are the fish so variable?

- Artifact of sampling (# fish too small)
- Analytical method (ELISA >> LC-MS/MS)
- True differences between fish species
- Fish diets are different (foodweb effect)
- Fish finding refuge from blooms
 - Differential exposure
- Fish metabolizing the toxins
 - Could this explain ELISA results with natural samples?

Recreational Contact?



- Exposure through swimming
 - Ingest water
 - 1997 EPA exposure factors handbook
- Exposure through aerosol
 - Time of exposure limited to time of recreation
- Exposure through the skin (contact exposure)
 - Very polar molecules
 - Contact exposure minimal

Google: draft recreation microcystin

Are there reported Human exposures for Lake Erie?

Year	Location	Toxic Bloom?	Suspect cases*	Probable cases
2010**	Lake Erie	Yes	7	2
2011	Lake Erie (not OH)	Yes	1	
2012	Headlands Beach (CLE)	-	1	
2015	Kelley's Island (islands)	-	1 (?)	
2015	Reno Beach (WLE)	-	3 (?)	
2015	Lakeside (islands)	-	1 (?)	
2015	East Harbor (islands)	-	1 (?)	

* Suspect cases need bloom, symptoms in time, and no other cause.

**Of 44 probable cases reported 2010-2015 – 41 occurred in 2010.

How about other toxins?

- **Cylindrospermopsin** => health effects known but not reported in Lake Erie.
- **Anatoxin-a** => Common in Lake Erie but health effects difficult to evaluate.
- **PSP toxins** => Occurrence uncertain. Health effects also uncertain.
- **BMAA** => Particulate levels low – exposure pathway very uncertain.

Undiscussed Issues

- Lot of antidotal evidence for microcystin toxicity.
- Human reports of microcystin intoxication are suspect due to ease with which they are confused with flu/ food poisoning/ alcohol consumption / sea sickness.
- Exposure data must consider length of exposure (drinking, fishing or recreation).
- Human health effects due to microcystins remains an imperfect science.

So what are levels in fish?

Fish species	Range of microcystin detected (µg/kg)	FW or DW	Extraction protocol	Analytical method
Channel catfish (Ictalurus punctatus)	123-250	FW	Water:MeOH:butanol (15:4:1), C18 cleanup	ELISA
Tilapia rendalli	3-337	DW	100% MeOH	ELISA
Yellow perch (Perca flavescens)	0.12-4.0	FW	75% MeOH/H+	ELISA
	0.5-7.0	DW	100% MeOH	ELISA
Largemouth bass (Micropterus salmoides)	210-320	FW	Water:MeOH:butanol (15:4:1), C18 cleanup	ELISA
Common carp (Cyprinus carpio)	3.3-19	FW	50% MeOH, hexane	ELISA
	3-139	FW	75% MeOH, acetic acid	ELISA,LC-MS
	50-470	FW	100% MeOH	ELISA
	3.5	FW	5% acetic acid, 0.01M EDTA, charcoal	LC-MS/MS
Black crappie (Pomoxis nigromaculatus)	1.5-1.9	DW	50% MeOH	ELISA
	1.0-70	FW	5% acetic acid, 0.01M EDTA, charcoal cleanup	LC-MS/MS
White crappie (Pomoxis annularis)	270-320	FW	Water:MeOH:butanol (15:4:1) extraction, C18 cleanup	ELISA

Table from Schmidt et al, Toxins, 2013