2018 Area of Concern Plankton Monitoring Project

Citizens Advisory for the Remediation of the Environment (CARE)

Workgroup Meeting

February 27, 2020

Beneficial Use Impairment (BUI) #13 Removal Target

- Originally developed by Environmental Consulting & Technology (ECT), a U.S. EPA contractor, in 2008.
- Vetted through the CARE Committee

13. Degradation of Phytoplankton and Zooplankton Populations

This BUI can be considered for removal when:

- There are no violations of the minimum dissolved oxygen concentrations established in 327 IAC 2-1.5-8 in the AOC;
- Levels of chlorophyll-a are consistent with IDEM "fully supporting" levels throughout the AOC; and
- Waters within the Grand Calumet River AOC are not listed as impaired due to degradation of phytoplankton or zooplankton in the most recent Indiana Integrated Water Monitoring and Assessment Report (submitted to U.S. EPA every two years) and/or the most recent Indiana Fish Consumption Advisory.

Actions

- Develop appropriate scientifically-based monitoring scenarios to establish a baseline and trends.

Dr. Simon Study

- In 2011, IDEM commissioned Dr. Tom Simon to study the plankton communities in the Grand Calumet River/Indiana Harbor Ship Canal Area of Concern (AOC)
- Dr. Simon's study used a three-pronged approach:
  - Taxonomic identification, diversity, and biomass analysis of zooplankton and phytoplankton from AOC water samples at 10 core sites
  - General and nutrient chemistry sampling and analysis of AOC water samples at 32 sites
  - Toxicity bioassays of zooplankton and phytoplankton at 32 sites
- Dr. Simon also evaluated the existing BUI removal target and noted several concerns:
  - The measures are indirect and do not directly target the trophic levels or species directly impacted by this BUI
  - The measures reflect a point measurement, which is difficult to track through time to note improvements
  - The measures do not account for seasonal variations in planktonic communities

Proposed BUI #13 Removal Target

- Dr. Simon proposed a new removal target to address his concerns:

  BUI #13 can be considered for removal when:

  - Phytoplankton and zooplankton population targets are met for species richness, diversity indices (Shannon-Weiner, evenness [Pielou's J], and Jaccard Similarity Coefficient [SJ]) consistent with Lake Michigan measures and expected seasonal differences.
  - No significant difference in mortality, mobility, or algal stimulation is demonstrated compared to an appropriate control or Lake Michigan.
  - Additional Lake Michigan species richness and diversity indices measurements from Non-AOC sites (Mt. Baldy, Dune Acres, or other appropriate sites) are compared with those from the AOC. By virtue of being outside the GCR AOC, such non-AOC sites are presumed to reflect unimpaired ambient conditions.

- Finally, Dr. Simon evaluated the AOC waters relative to his suggested BUI #13 removal target
  - Recommended removal of BUI #13 for:
    - All reaches for phytoplankton populations, except the north shore of the East Grand Calumet Lagoon
    - All reaches for zooplankton populations, except the mouth of the West Branch of the Grand Calumet River and the East Branch west of Bridge Street

IDEM 2018 Monitoring

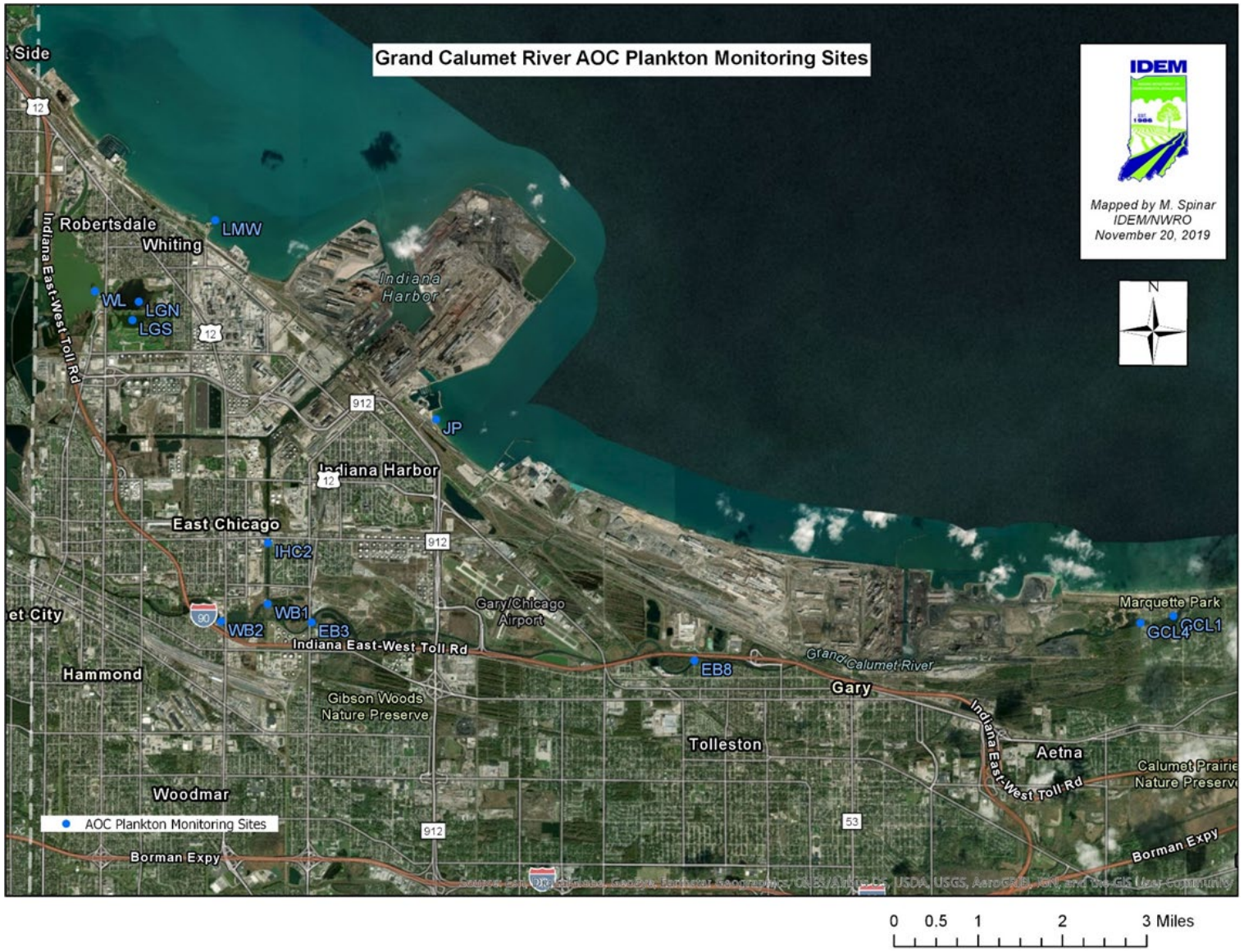
- IDEM requested Great Lakes Restoration Initiative (GLRI) direct funding to conduct follow-up monitoring at 12 sites, including the three sites for which Simon (2015) did not recommend removal of BUI #13.
- Funding amount: $107,584
- Subawards/contracts to:
  - Indiana University's Shaw Lab (Toxicity Bioassays)
  - PhycoTech, Inc. (Taxonomic/Biomass Analyses)
  - U.S. Geological Survey (Chlorophyll-a/Pheophytin-a analysis)
- Sampling conducted by IDEM's Office of Water Quality (12 sites)
  - June 4-6, 2018 sampling (physical parameters; general chemistry, nutrient, chlorophyll samples)
  - June 25, 2018 sampling (water samples in 9L cubitaners for toxicity bioassays)
  - August 13-14, 2018 sampling (physical parameters; general chemistry, nutrient, chlorophyll samples)
  - August 20, 2018 sampling (water samples in 9L cubitaners for toxicity bioassays)

IDEM 2018 Monitoring Sites

Site Code	IDEM ID	Site Description	Latitude (degrees N)	Longitude (degrees W)
WB1	UMC-04-0014	Mouth of the West Branch of the GCR (WBGCR)	41.617969	87.471902
WB2[1]	UMC-05-0005	WBGCR, West of Indianapolis Boulevard	41.614037	87.480157
EB3	UMC-04-0016	East Branch of the GCR (EBGCR), East of Kennedy Avenue	41.615507	87.460295
EB8	UMC-04-0017	EBGCR, West of Bridge Street	41.608973	87.372361
GCL1	LMG-06-0015	East Grand Calumet Lagoon, north shore	41.617084	87.263062
GCL4	LMG-06-0016	Middle Grand Calumet Lagoon, south shore	41.614659	87.273070
IHC2[2] (IHC)	LMG-06-0022	IHSC, South of Chicago Avenue	41.638447	87.471049
JP	LMG-06-0018	Lake Michigan - Jeorse Park Beach access	41.649360	87.433240
LGN	LMG-20-0037	Lake George, North of 125th Street	41.668331	87.503216
LGS	LMG-20-0038	Lake George, South of 125th Street	41.668331	87.503216
WL	LMG-06-0020	Wolf Lake, behind Aquatic Center	41.675297	87.510331
LMW[3] (WLPP)	LMG-06-0023	Lake Michigan - Whihala Lake Front Park Pier	41.687340	87.496986

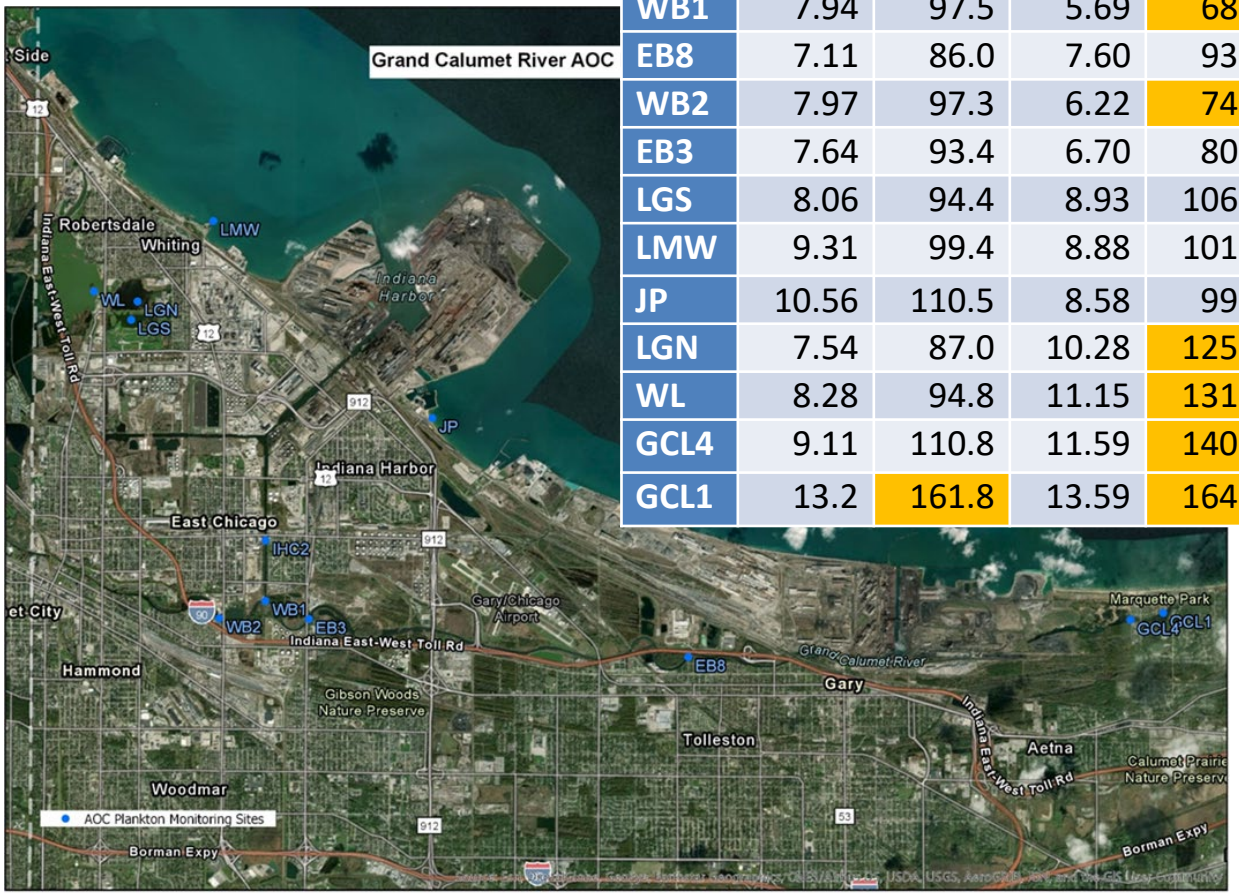
Note: for simplicity, the same site codes are used as for Simon (2015), with the exception of IHC2. Site identifiers used by Shaw (2019) are provided in parentheses.

IDEM 2018 Monitoring Sites (Map)



Dissolved Oxygen Field Measurements

	June				August			
Site	DO 1 (mg/L)	DO 1 (% Sat)	DO 2 (mg/L)	DO 2 (% Sat)	DO 3 (mg/L)	DO 3 (% Sat)	DO 4 (mg/L)	DO 4 (% Sat)
IHC2	6.50	77.2	5.64	67.4	6.93	90.2	4.74	59.7
WB1	7.94	97.5	5.69	68.1	8.52	112.3	5.31	67.0
EB8	7.11	86.0	7.60	93.4	6.50	87.2	6.77	90.1
WB2	7.97	97.3	6.22	74.2	8.57	111.0	5.74	71.5
EB3	7.64	93.4	6.70	80.6	8.57	113.0	5.60	70.8
LGS	8.06	94.4	8.93	106.2	9.38	120.9	8.11	99.6
LMW	9.31	99.4	8.88	101.8	8.76	106.7	8.41	101.5
JP	10.56	110.5	8.58	99.6	8.73	106.0	8.10	97.3
LGN	7.54	87.0	10.28	125.7	11.04	140.6	9.54	113.4
WL	8.28	94.8	11.15	131.9	11.58	148.0	7.72	95.1
GCL4	9.11	110.8	11.59	140.0	10.92	143.9	10.66	132.8
GCL1	13.2	161.8	13.59	164.3	12.60	162.5	9.24	116.3

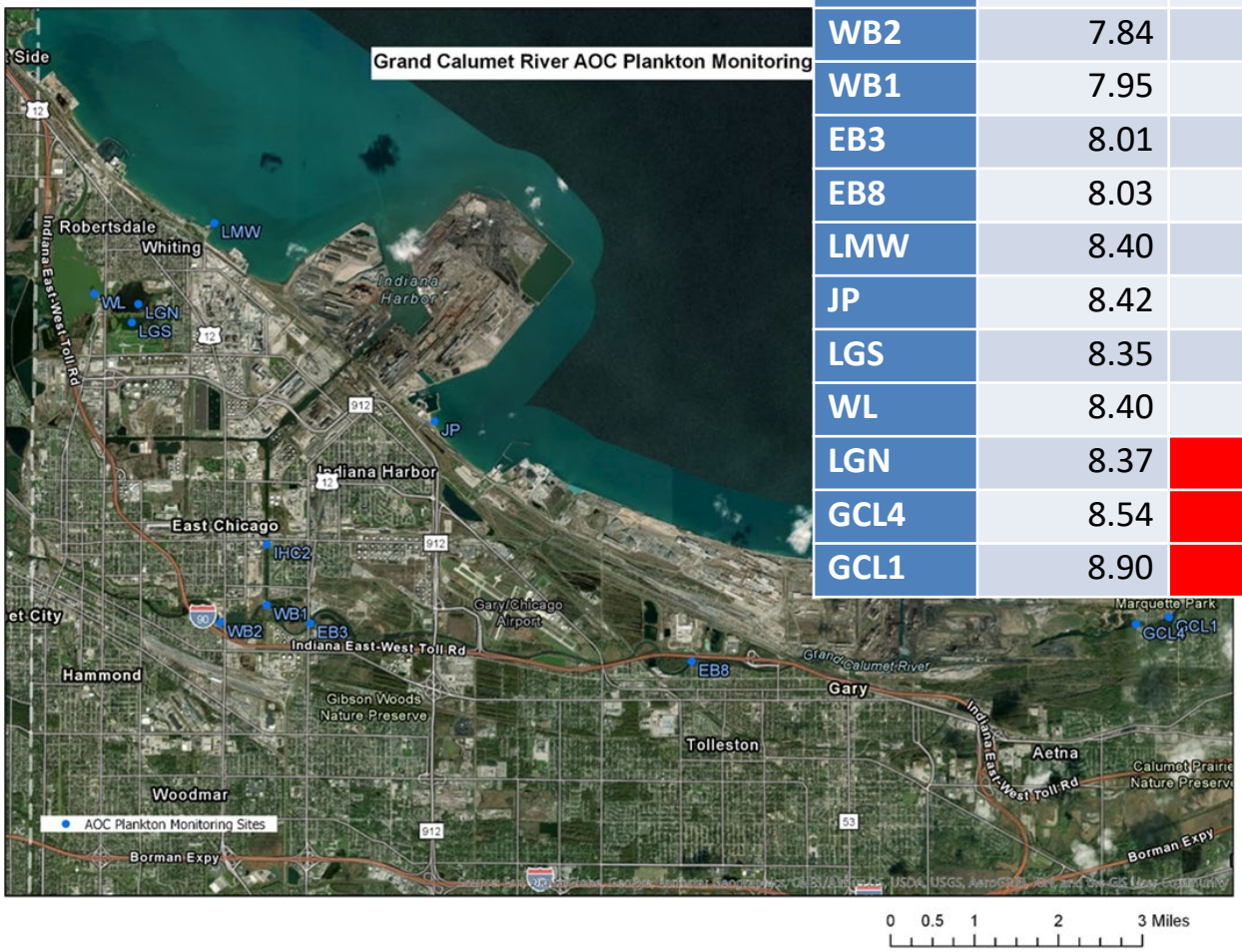


DO < 5 mg/L

%Sat < 80% or >120%

pH Field Measurements

	June		August	
Site	pH 1 (S.U.)	pH 2 (S.U.)	pH 3 (S.U.)	pH 4 (S.U.)
IHC2	7.84	7.63	7.97	7.61
WB2	7.84	7.67	8.09	7.63
WB1	7.95	7.61	8.18	7.68
EB3	8.01	7.74	8.22	7.69
EB8	8.03	8.12	8.24	8.45
LMW	8.40	8.32	8.60	8.51
JP	8.42	8.40	8.61	8.54
LGS	8.35	8.51	8.90	8.87
WL	8.40	8.73	9.10	8.74
LGN	8.37	9.07	9.89	9.88
GCL4	8.54	9.49	9.93	9.82
GCL1	8.90	9.81	9.97	9.51



pH > 9.0 S.U.

Other Field Measurements

- Temperature
  - Lake Michigan < Wolf Lake < George Lake < GC Lagoons < Riverine Sites
  - Generally WB2 (Indianapolis Blvd.) was coolest and EB8 (Bridge St.) was warmest of the riverine sites; however, during the June 4-6 period, the WB1 site was the warmest.
  - Cool weather during August 20 sampling led to Wolf Lake, George Lake, GC Lagoons being cooler than Lake Michigan

- Specific conductance
  - Ranged from 267 to 740 μmho/cm; lowest values at Lake Michigan, highest at Wolf Lake

- Turbidity
  - Generally fairly clear – 0.7 to 14.5 Nephelometric Turbidity Units (NTUs)
  - June 5, 2018 observation at George Lake North of 86.6 NTUs – outlier

Noteworthy Field Observations

- During the June 2018 sampling event, samplers noted:
  - The green, murky nature of Wolf Lake (WL)
  - An oil sheen at the IHC junction site (WB1)
  - The smell of sewage at the upstream Grand Calumet River site (EB8), which was in the vicinity of a combined sewer overflow site (Bridge St at E Interceptor)
- In August 2018, samplers noted the prevalence of submerged aquatic macrophytes, particularly Myriophyllum sp. (watermilfoil) and Chara sp. (muskgrass) at the Grand Calumet Lagoons.

Phytoplankton Functional Groups – Bluegreen Algae

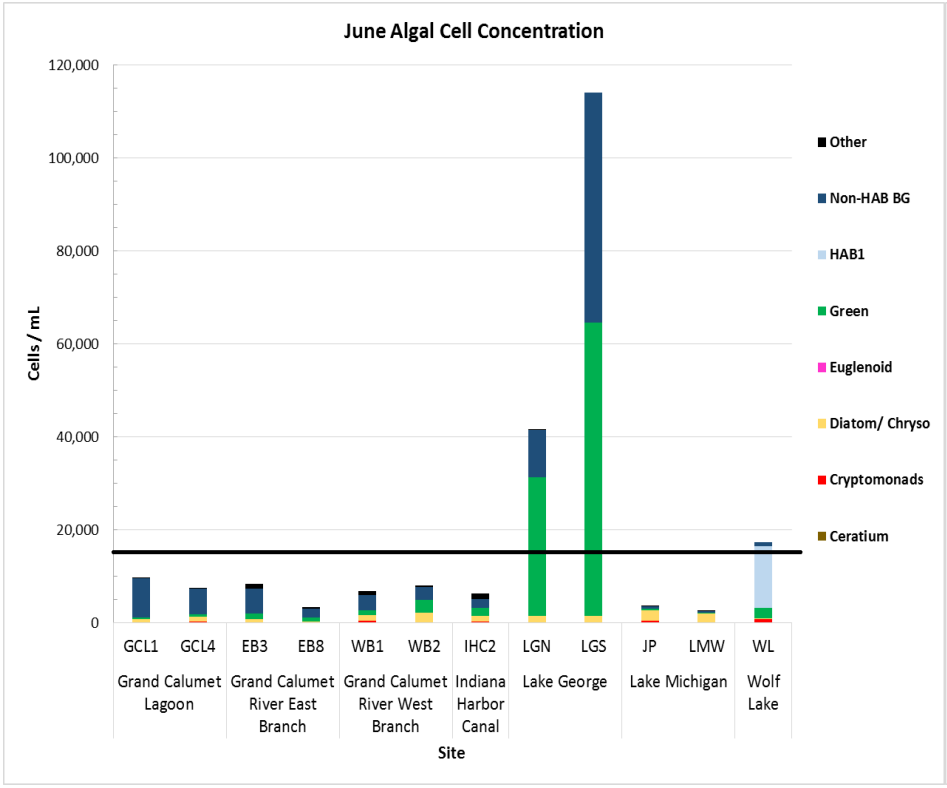
- Bluegreen Algae (Cyanophyta)
  - Non-HAB: Nontoxic Bluegreen Algae (Cyanophyta)
  - HAB1: Non-heterocystic Bluegreen Algae that can produce toxins or taste / odor compounds (Cyanophyta)
    - *Microcystis*
    - *Planktothrix*
    - *Pseudanabaena*
    - *Woronichinia*
  - HAB: Heterocystic Bluegreen Algae that can produce toxins or taste / odor compounds (Cyanophyta)
    - *Dolichospermum*
    - *Raphidiopsis* (*Cylindrospermopsis*)
    - *Aphanizomenon*
    - *Cuspidothrix*

Additional Phytoplankton Functional Groups

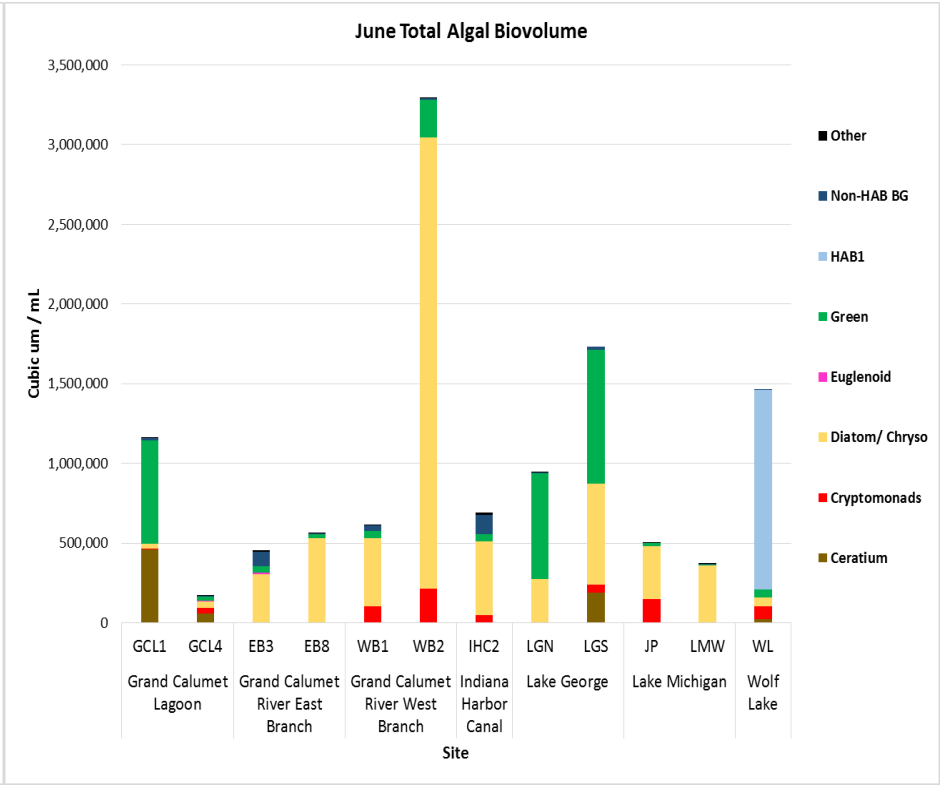
- Green Algae (Chlorophyta)
- Euglenoid Algae (Euglenophyta)
- Diatoms/Chrysophytes (Bacillariophyceae/Chrysophyta)
- Cryptomonads/Non-Ceratium Dinoflagellates (Cryptophyta/Pyrrhophyta)
- Ceratium (Pyrrhophyta)
- Other

Plankton Taxonomy: June 2018

Concentration



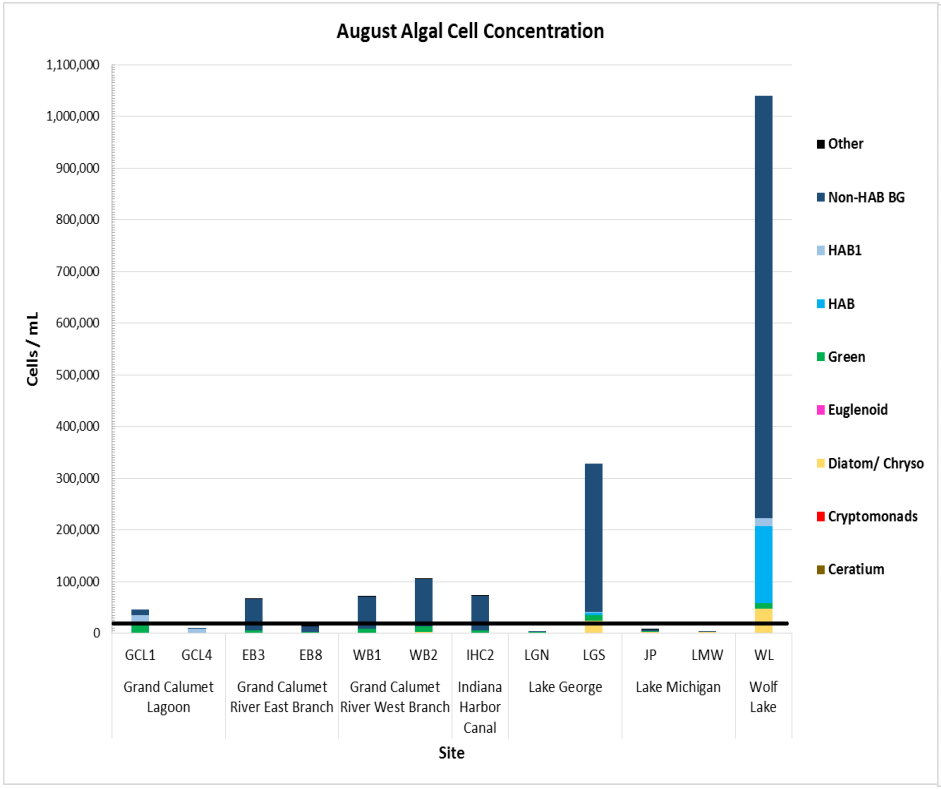
Biovolume



Source: St. Amand (2019)

Plankton Taxonomy: August 2018

Concentration



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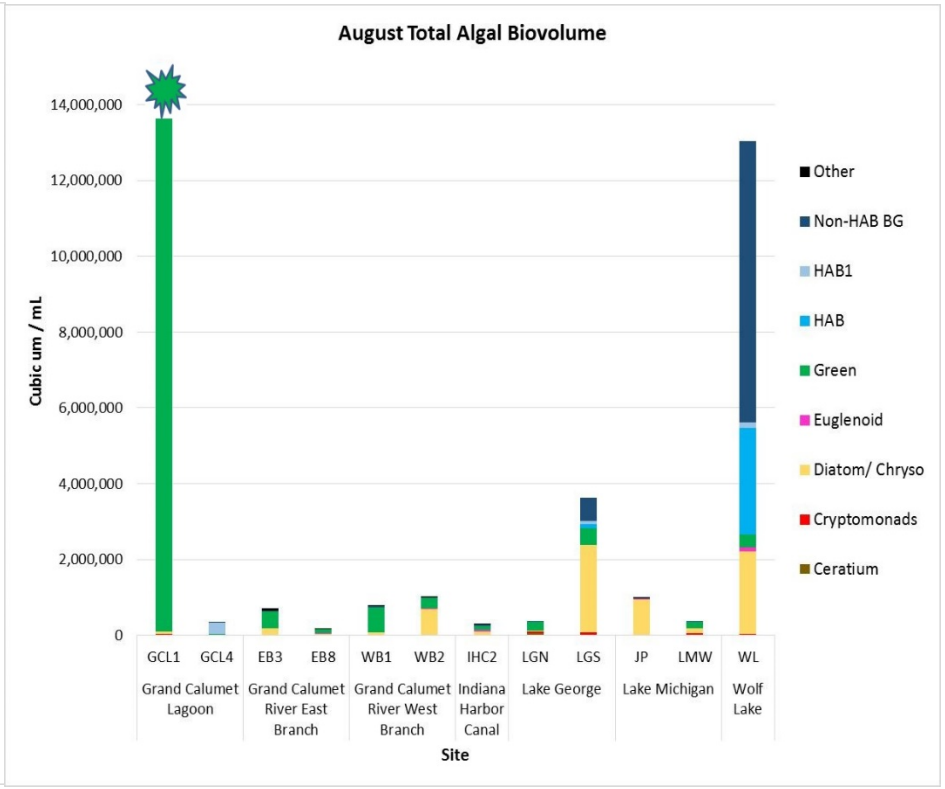


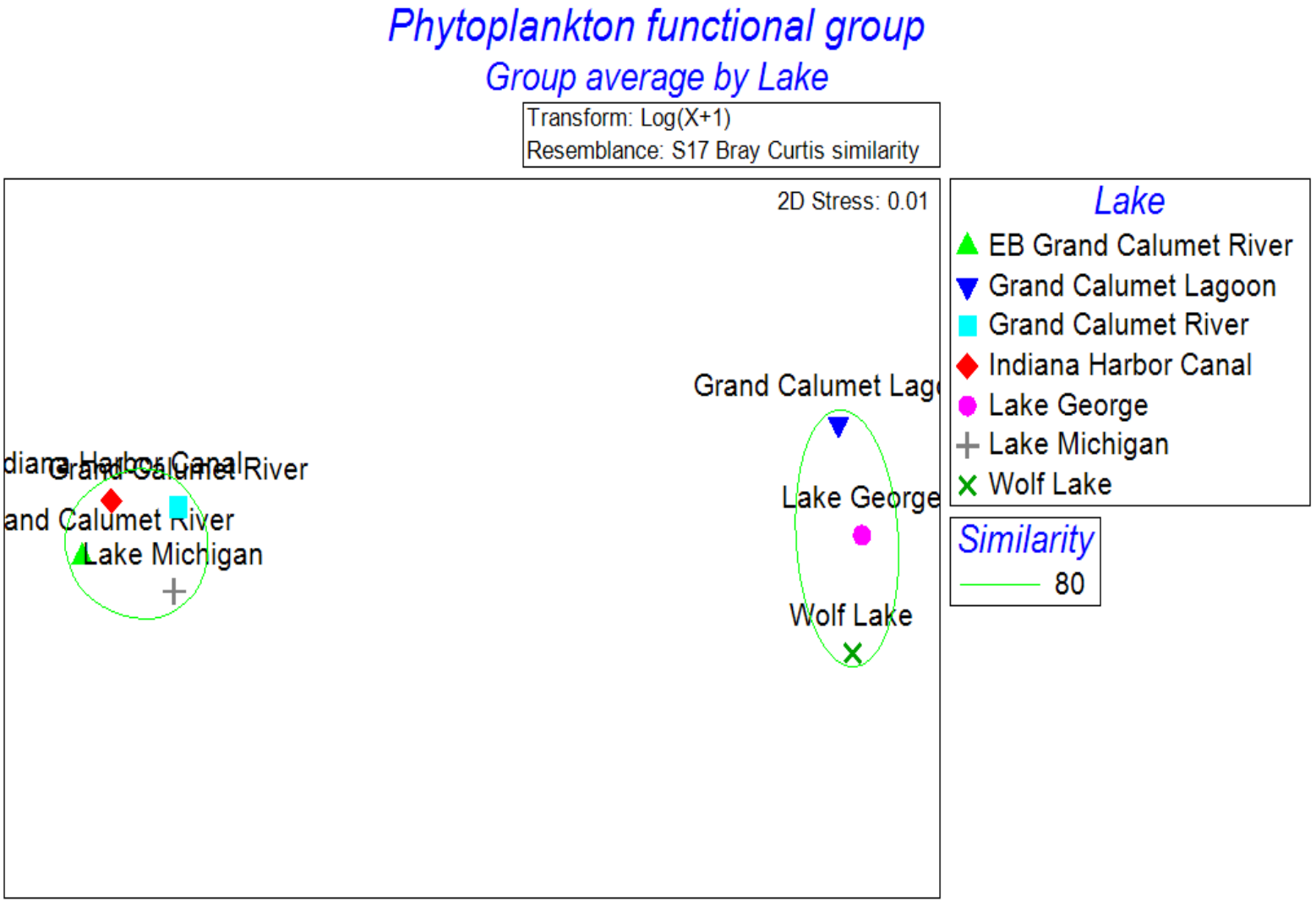
Source: St. Amand (2019)

Diversity Indices

Phytoplankton Richness and Diversity					
Location	Site	Date	Richness	Shannon-Weiner Index (H')	Evenness (E)
Grand Calumet Lagoon	GCL1	June	17	0.7797	0.2764
		August	25	2.0518	0.6378
	GCL4	June	24	1.1709	0.3707
		August	22	1.4871	0.4825
Grand Calumet River East Branch	EB3	June	32	2.3524	0.681
		August	28	0.834	0.2505
	EB8	June	26	2.2901	0.7075
		August	24	1.5825	0.4989
Grand Calumet River West Branch	WB1	June	36	2.2343	0.6264
		August	31	1.3607	0.3965
	WB2	June	46	3.0828	0.8081
		August	34	1.0737	0.3047
Indiana Harbor Canal	IHC2	June	38	2.8395	0.7838
		August	30	0.987	0.2904
Lake George North	LGN	June	31	1.4817	0.4319
		August	23	1.7374	0.5583
Lake George South	LGS	June	24	1.9314	0.6079
		August	35	1.7524	0.4929
Lake Michigan at Jeorse Park	JP	June	30	2.4162	0.7152
		August	35	2.658	0.7503
Lake Michigan at Whihala Beach	LMW	June	30	2.6836	0.7955
		August	26	2.7573	0.8502
Wolf Lake	WL	June	33	1.1873	0.3407
		August	44	2.3227	0.6138

Source: St. Amand (2019)

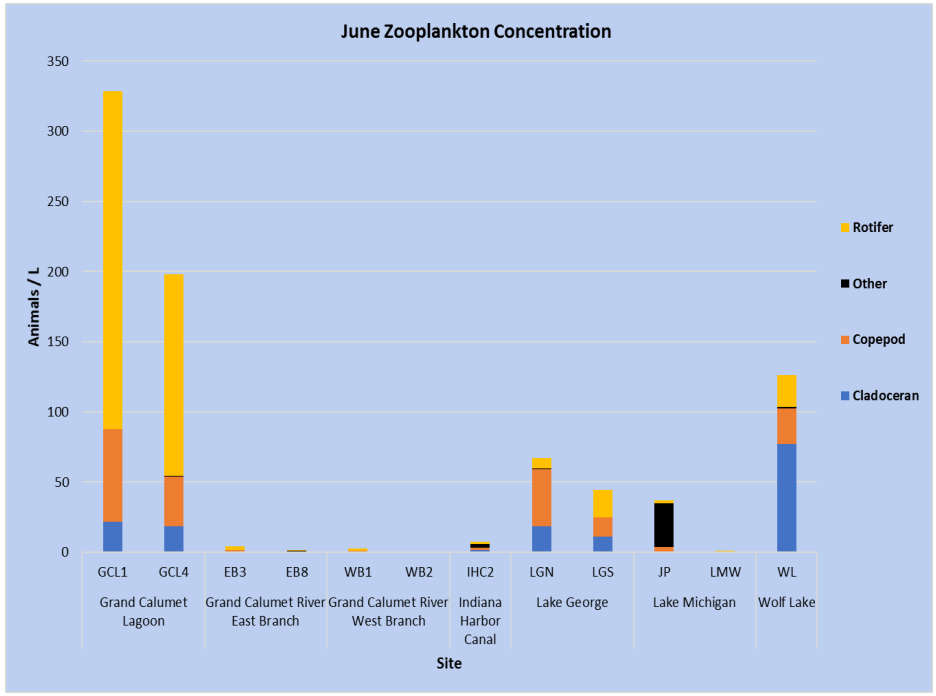
Plankton Taxonomy: Algal Group Assemblage



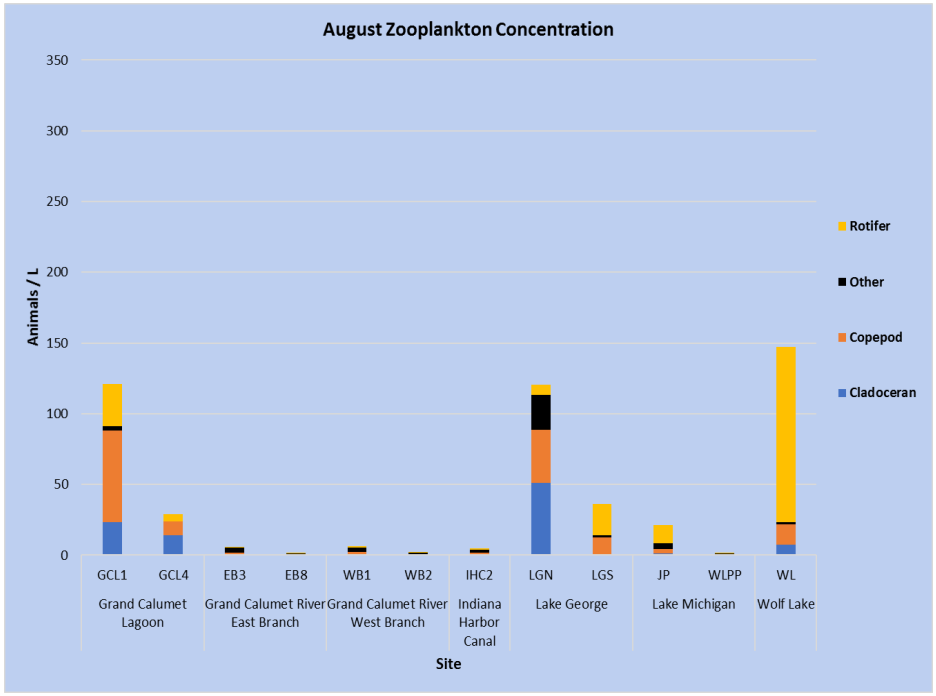
Source: St. Amand (2019)

Zooplankton Concentration

June 2018



August 2018



Source: St. Amand (2019)

Chemistry Sample Results

- Samples indicated generally well-buffered moderately hard to hard water.
  - Alkalinity ranged from 66 to 137 mg/L (expressed as calcium carbonate, $CaCO_3$)
  - Hardness ranged from 77 to 196 mg/L (as $CaCO_3$)
- Chloride ranged from 13 to 145 mg/L
  - All chloride values were below Indiana's Chronic Aquatic Criterion (CAC) value.
  - Lowest values: Lake Michigan and EB8
  - Highest values: The Grand Calumet Lagoons and Wolf Lake
- Sulfate ranged from 11 and 80 mg/L
  - Values were well below the pertinent statewide Indiana water quality standard (no separate standard is provided for the Great Lakes watershed).
  - Lowest values in Lake Michigan and the Grand Calumet Lagoons
  - Highest values in George Lake and the junction between the Grand Calumet River and the IHC

Chemistry Results - Solids

- Total solids: Suspended + Dissolved Solids; can impact water taste & clarity
  - Ranged from 182 to 460 mg/L
  - Lowest values at the Lake Michigan, the far end of the East Branch of the Grand Calumet River (EB8), and the Grand Calumet Lagoon sites.
  - Highest values were at the George Lake South Basin, the West Branch Grand Calumet River (June 4 sample only), and the Wolf Lake site.
- Total Suspended Solids: Do not pass a 2 μm filter; can serve as carriers of toxics
  - Most sites were non-detect (< 10 mg/L)
  - Wolf Lake (on August 14), the West Branch GCR site (June 4), and the George Lake North Basin (June 5) showed detectable values, ranging from 10 to 17 mg/L.
- Total Dissolved Solids: Pass a 2 μm filter; can impact organism osmotic balance
  - Ranged from 170 to 441 mg/L
  - Lake Michigan and EB8 sites had the lowest values.
  - George Lake South and Wolf Lake had the highest values.
  - There was a significant difference between the value at the WB2 (Indianapolis Blvd.) site in June (371 mg/L) and August (279 mg/L). The cause of this variation is unknown.

Chemistry - General Notes

- The general chemistry results broadly indicated that the waters of the entire system met the applicable water quality standards.

- There was a distinct tendency for decreases in water quality between Lake Michigan and the other sites, particularly the lacustrine sites (George Lake, the Grand Calumet Lagoons, and Wolf Lake).

- Some indicators (e.g., hardness) showed considerable sample-to-sample variability, even at the same site. Others (e.g., sulfate) showed very low values for the Grand Calumet Lagoon samples.

Nutrient Measurements - COD

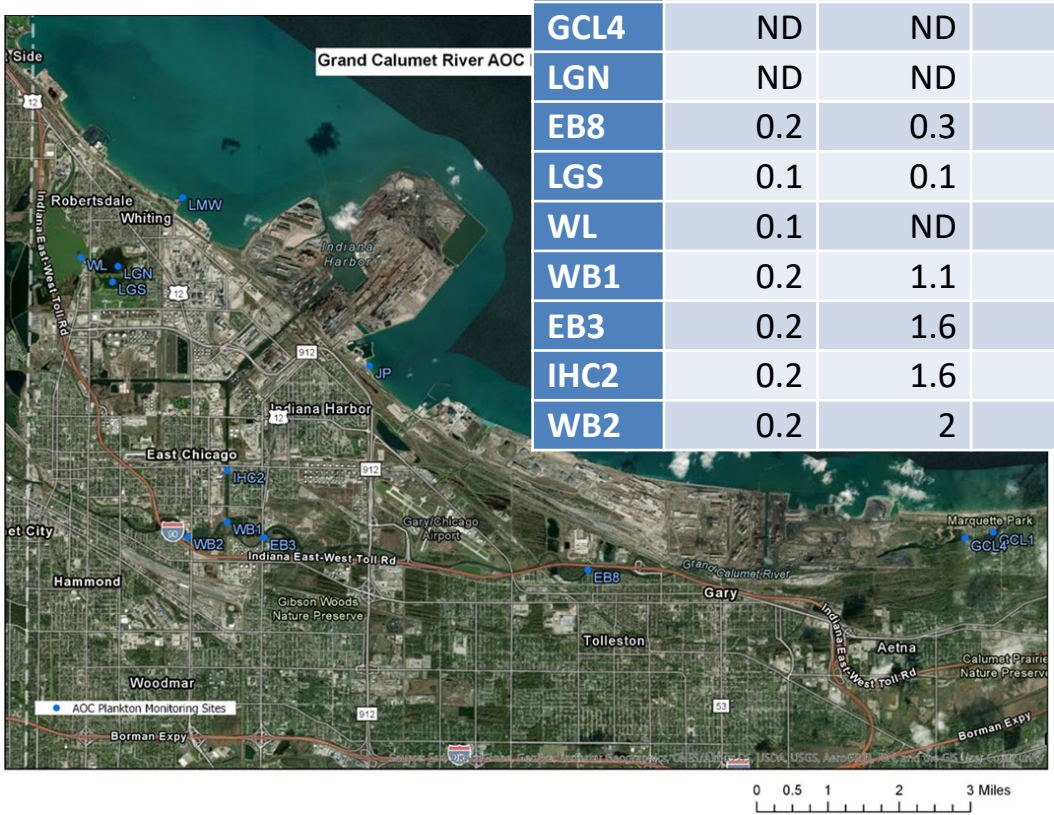
- Chemical Oxygen Demand (COD): oxygen required to chemically oxidize soluble and particulate organic matter in water
- June Results:
  - Non-detects were found at both Lake Michigan sites (LMW and JP) and the Grand Calumet River EB8 site (downstream of Bridge Street in Gary).
    - EB8 likely reflects discharges of Lake Michigan noncontact cooling water by U.S. Steel's Gary Works facility
  - The highest values, between 25 and 30 mg/L, were found in George Lake and Wolf Lake
  - Mid-range values of approximately 10-15 mg/L located at the IHC and remaining Grand Calumet River sites, as well as at the two GCR Lagoon sites.
- August Results:
  - Non-detects were again present at the LMW, JP, and EB8 sites, but also at the IHC2 and WB2 sites.
  - The Wolf Lake and George Lake sites again showed the highest values, clustered around 30 mg/L.
  - The East Lagoon site, GCL1, increased markedly to approximately 25 mg/L by the time the August sample was collected, indicating a dramatic increase in organic matter.
  - Values at WB1, EB3, and GCL4 were relatively consistent with the June results.
  - The WB1 (IHC Junction) and EB3 (Kennedy Avenue) sites both showed a result of 10.7 mg/L in the August sampling event, while the upstream site WB2 (Indianapolis Boulevard) and downstream site IHC2 (the IHC south of Chicago Avenue) both showed non-detects.

Nutrient Measurements - TOC

- Total organic carbon (TOC) reflects the total organic carbon content of water
  - Can reflect natural organic content or chemical contamination.
- June Results:
  - The highest TOC values (between 5 and 8 mg/L) in Wolf Lake and George Lake.
  - Lowest values (between 1.5 and 2.0 mg/L) at the Lake Michigan sites. The EB8 site also showed a low value of 1.8 mg/L, possibly reflecting the origin of much of the East Branch flow as non-contact cooling water from Lake Michigan.
  - The remaining Grand Calumet River, IHC, and GCR Lagoon sites showed values of between 2.9 mg/L and 4.0 mg/L, with the higher values in the GCR Lagoon sites.
- August Results:
  - Higher TOC values were found at most sites relative to June.
  - Again, the Wolf Lake and George Lake sites showed the highest values, between 6 and 9 mg/L, potentially reflecting more eutrophic conditions at those sites.
  - This was followed by the GCR Lagoon sites (4.6 mg/L), IHC/GCR sites (2.0-3.4 mg/L), and the oligotrophic Lake Michigan sites (1.8-1.9 mg/L). Again the EB8 site showed the lowest TOC value of any of the riverine sites.

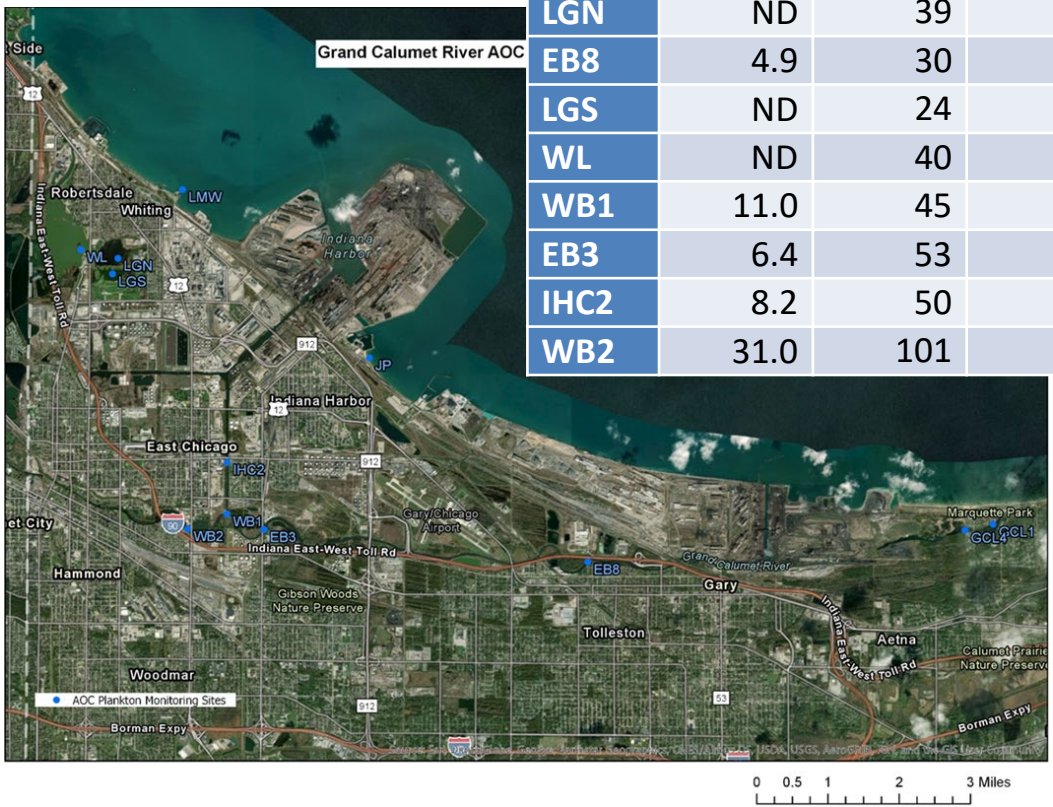
Nutrient Measurements - Nitrogen

	June				August			
Site	NH3-N (mg/L)	Nitrate/ Nitrite (mg/L)	TKN (mg/L)	Total N (mg/L)	NH3-N (mg/L)	Nitrate/ Nitrite (mg/L)	TKN (mg/L)	Total N (mg/L)
LMW	ND	0.2	ND	0.2	ND	0.2	ND	0.2
JP	ND	0.2	ND	0.2	ND	0.2	ND	0.2
GCL1	ND	ND	0.3	0.3	ND	ND	0.5	0.5
GCL4	ND	ND	0.4	0.4	ND	ND	0.9	0.9
LGN	ND	ND	0.8	0.8	ND	ND	1.0	1.0
EB8	0.2	0.3	0.4	0.9	0.1	0.3	0.4	0.8
LGS	0.1	0.1	0.9	1.1	ND	ND	0.9	0.9
WL	0.1	ND	1	1.1	ND	ND	1.2	1.2
WB1	0.2	1.1	0.6	1.9	ND	1.0	0.6	1.6
EB3	0.2	1.6	0.7	2.5	ND	1.0	0.6	1.6
IHC2	0.2	1.6	0.8	2.6	ND	1.1	0.5	1.6
WB2	0.2	2	0.7	2.9	ND	1.5	0.5	2.0



Nutrient Measurements - Phosphorous

	June				August			
Site	SRP (µg/L)	Total P (µg/L)	Total N (mg/L)	N:P Ratio	SRP (µg/L)	Total P (µg/L)	Total N (mg/L)	N:P Ratio
LMW	ND	11	0.2	18	2.1	9	0.2	22
JP	ND	11	0.2	18	ND	ND	0.2	N/A
GCL1	ND	20	0.3	15	2.3	21	0.5	24
GCL4	3.0	15	0.4	27	2.8	18	0.9	50
LGN	ND	39	0.8	21	2.6	16	1.0	63
EB8	4.9	30	0.9	30	5.3	23	0.8	35
LGS	ND	24	1.1	46	ND	19	0.9	47
WL	ND	40	1.1	28	3.5	33	1.2	36
WB1	11.0	45	1.9	42	9.6	48	1.6	33
EB3	6.4	53	2.5	47	9.4	41	1.6	39
IHC2	8.2	50	2.6	52	11.0	33	1.6	48
WB2	31.0	101	2.9	29	32.0	66	2.0	30



Chlorophyll-a Measurements

Monitoring Site	Waterbody	June (mg/L)	August (mg/L)	Net Change
LMW	Lake Michigan	0.50	0.53	+0.03
LGN	George Lake, North Basin	3.90	0.90	-3.00
JP	Lake Michigan	1.07	0.95	-0.12
EB8	Grand Calumet River, East Branch	0.63	1.30	+0.67
GCL4	Grand Calumet River Lagoon, Middle Lagoon	0.93	1.53	+0.60
IHC2	Indiana Harbor Ship Canal	1.33	3.43	+2.10
EB3	Grand Calumet River, East Branch	1.87	3.78	+1.91
WB1	Grand Calumet River, West Branch	1.63	5.10	+3.47
WB2	Grand Calumet River, West Branch	7.00	5.33	-1.67
LGS	Lake George, South Basin	3.23	7.83	+4.60
GCL1	Grand Calumet River Lagoon, East Lagoon	1.87	11.60	+9.73
WL	Wolf Lake	5.00	26.90	+21.90

Chl-a >= 7.0 µg/L

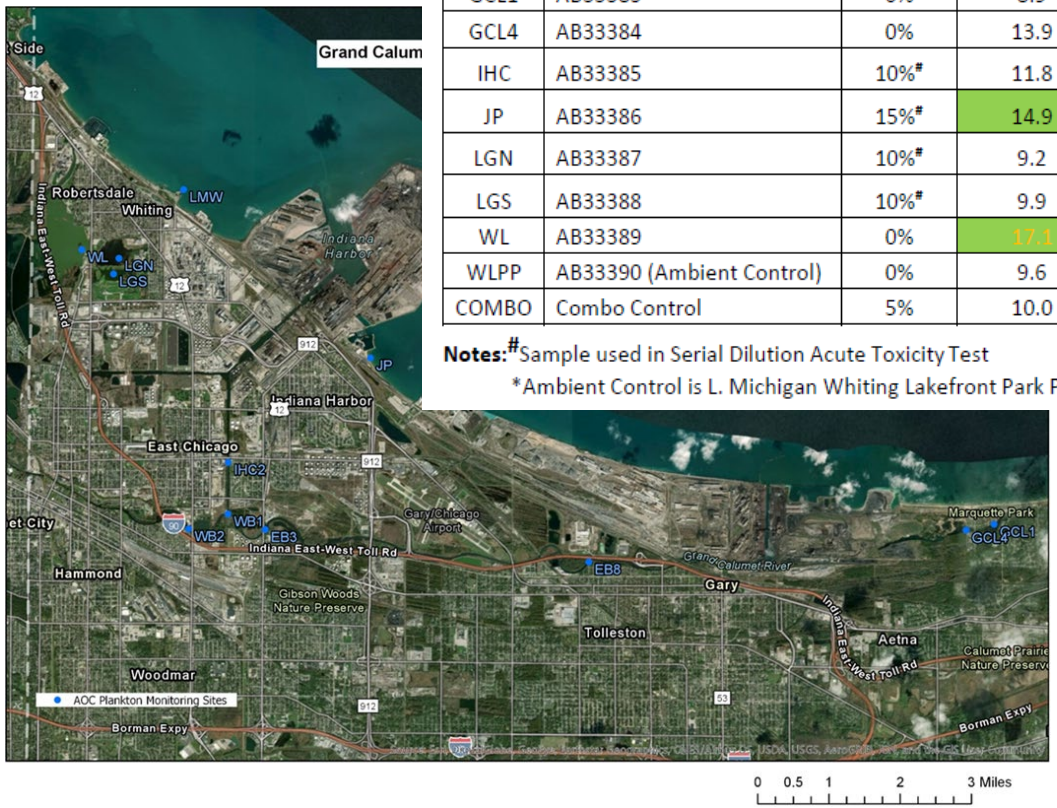
Toxicity Bioassays: June 2018

	Grand Calumet June 2018 Sampling	Acute Test	Subchronic Test	Subchronic Test	Subchronic Test	Phyto Test	Phyto Test
Site Code	Sample Site ID	Mortality	Avg # Young/Adult	Combo Control Normalized	Ambient Control Normalized*	Combo Control Normalized	Ambient Control Normalized*
WB1	AB33379	5%	14.1	0.4	0.5	-11.7	13.3
WB2	AB33380	5%	15.3	0.5	0.6	-4.5	22.6
EB3	AB33381	0%	13.6	0.4	0.4	-25.7	-4.6
EB8	AB33382	5%	6.6	-0.3	-0.3	-18.0	5.3
GCL1	AB33383	0%	8.9	-0.1	-0.1	-13.0	11.7
GCL4	AB33384	0%	13.9	0.4	0.4	-23.3	-1.5
IHC	AB33385	10%#	11.8	0.2	0.2	-23.6	-1.9
JP	AB33386	15%#	14.9	0.5	0.6	-32.3	-13.1
LGN	AB33387	10%#	9.2	-0.1	0.0	-24.0	-2.4
LGS	AB33388	10%#	9.9	0.0	0.0	-62.9	-52.4
WL	AB33389	0%	17.1	0.7	0.8	-54.3	-41.3
WLPP	AB33390 (Ambient Control)	0%	9.6	0.0	X	-22.1	X
COMBO	Combo Control	5%	10.0	X	0.0	X	28.4

KEY
Sign Higher
Sign Lower
Sign @ p≤0.1
No Sign Diff

Notes: #Sample used in Serial Dilution Acute Toxicity Test

*Ambient Control is L. Michigan Whiting Lakefront Park Pier sampling site



Source: Shaw (2019)

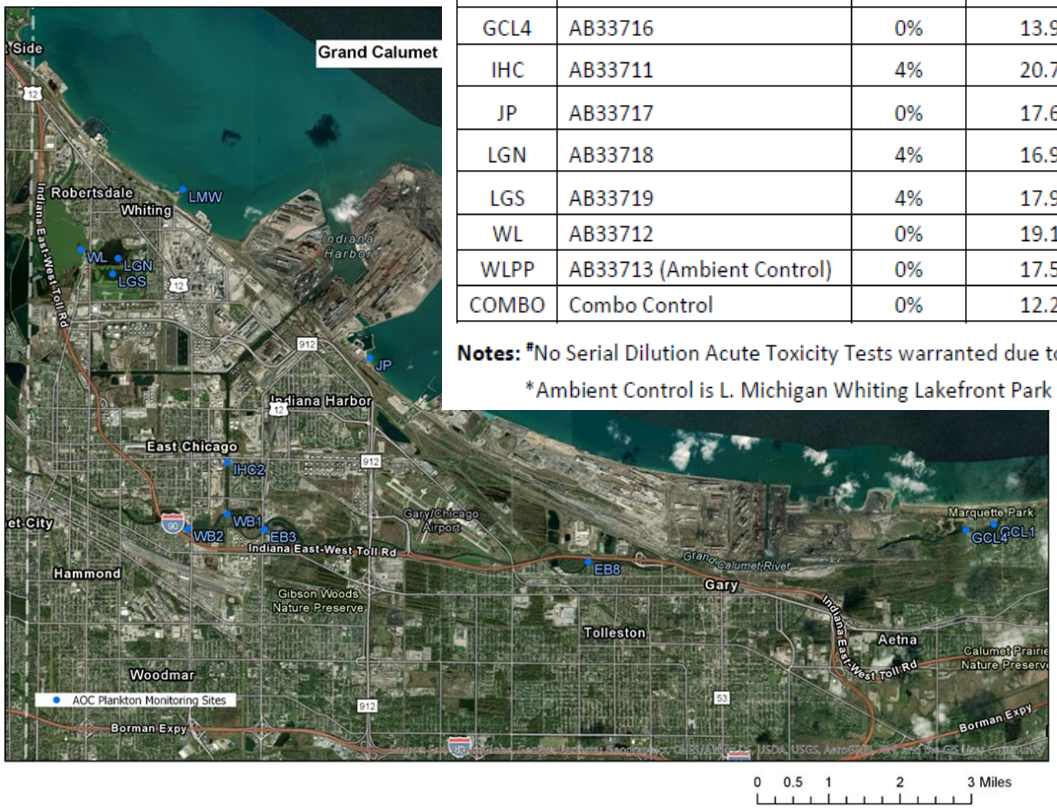
Toxicity Bioassays: August 2018

	Grand Calumet August 2018 Sampling	Acute Test	Subchronic Test	Subchronic Test	Subchronic Test	Phyto Test	Phyto Test
Site Code	Sample Site ID	Mortality	Avg # Young/Adult	Combo Control Normalized	Ambient Control Normalized*	Combo Control Normalized	Ambient Control Normalized*
WB1	AB33708	4%	31.1	1.5	0.8	36.5	43.9
WB2	AB33709	0%	19.3	0.6	0.1	111.5	123.0
EB3	AB33710	4%	24.1	1.0	0.4	71.8	81.1
EB8	AB33714	12%	29.6	1.4	0.7	35.9	43.2
GCL1	AB33715	0%	11.3	-0.1	-0.4	2.6	8.1
GCL4	AB33716	0%	13.9	0.1	-0.2	2.6	8.1
IHC	AB33711	4%	20.7	0.7	0.2	40.4	48.0
JP	AB33717	0%	17.6	0.4	0.0	-24.4	-20.3
LGN	AB33718	4%	16.9	0.4	0.0	16.7	23.0
LGS	AB33719	4%	17.9	0.5	0.0	-58.3	-56.1
WL	AB33712	0%	19.1	0.6	0.1	-63.1	-61.1
WLPP	AB33713 (Ambient Control)	0%	17.5	0.4	X	-5.1	X
COMBO	Combo Control	0%	12.2	X	-0.3	X	5.4

KEY
Sign Higher
Sign Lower
Sign @ p≤0.1
No Sign Diff

Notes: #No Serial Dilution Acute Toxicity Tests warranted due to low mortality rates and results of June 2018 tests.

*Ambient Control is L. Michigan Whiting Lakefront Park Pier sampling site



Source: Shaw (2019)

Conclusions: Toxicity

- No significant acute toxicity in *D. pulex* was observed using water column grab samples at the 12 sites.
  - Simon (2015) reported 60% acute mortality at EB8 (EBGCR West of Bridge Street) and 50% at WB1 (IHC Junction).
  - Shaw (2019) found more subtle chronic impacts at these sites.
- Possible longer term chronic/subchronic impacts to algae and *D. pulex* were observed at six sites.
  - Three riverine sites (WB1, WB2, and EB8) consistently exhibited enhanced phytoplankton growth.
  - Three lacustrine sites (JP, LGS, and WL) consistently exhibited inhibited growth.
  - The other six sites (WLPP, GCL1, GCL4, LGN, EB3, and IHC) differed between sampling periods.
  - Reduced growth is indicative of toxicity, while enhanced growth may be caused by differences in nutrients or algal competitors.
- Due to the choice of Lake Michigan as a control, it is unknown to what degree the observed impacts are similar to other waterbodies outside the Grand Calumet River AOC. Toxicity testing relative to more comparable lacustrine and riverine control sites should better illustrate whether AOC-specific toxicity remains.

Conclusions: Lacustrine Sites

- The non-Lake Michigan lacustrine sites (Wolf Lake, George Lake, and the Grand Calumet River Lagoons) are warm, shallow water bodies that appear to be impacted by nutrients, resulting in daytime spikes of dissolved oxygen and the growth of harmful algal bloom (HAB) phytoplankton species, at the expense of overall community diversity.
  - In particular, the sampling site along the east side of Wolf Lake exhibited by far the highest impacts of any of the sampling sites in this project.
    - Chlorophyll-a (Chl-a) concentration of 26.9 mg/L
    - Algal cell concentration of over 1 million cells per milliliter

- Lake Michigan exhibited the lowest impacts, with low values in all nutrient parameters, low chlorophyll, low HAB species concentrations, and consistently high population diversity.
  - Note: Lake Michigan is far colder, larger, and deeper than the other AOC waterbodies.

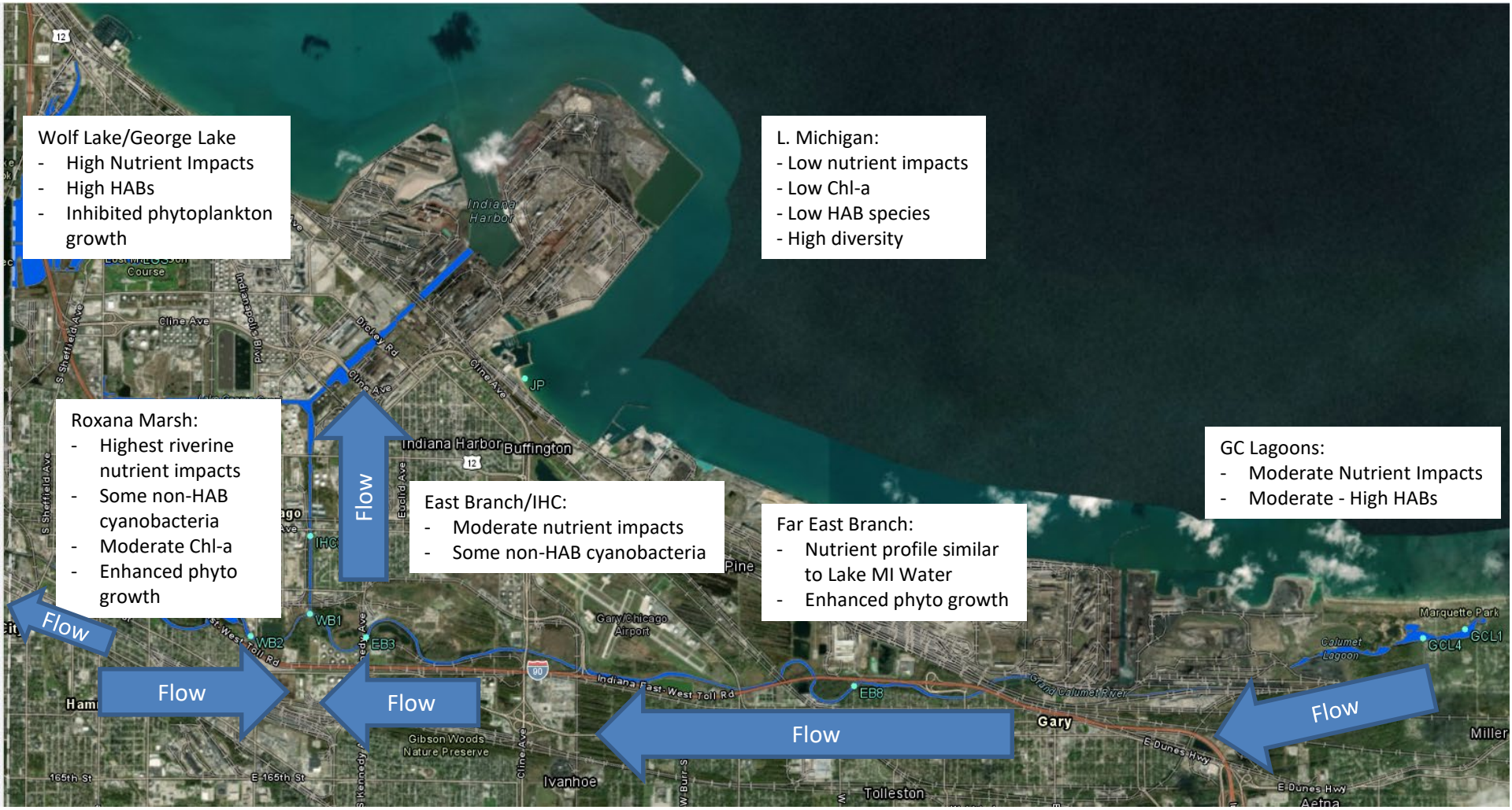
Conclusions: Riverine Sites

- The riverine sites typically had low plankton diversity
  - Note: The continual flow in shallow riverine systems often prevents the formation of large, stable planktonic communities.
- East Branch: The nutrient profile at the farthest east GCR site (east of Bridge Street in Gary) shows the lowest levels of nutrients and the lowest algal concentrations of any of the riverine sites.
  - Likely due to the discharge of vast quantities of non-contact cooling water, obtained from Lake Michigan, by the U.S. Steel Gary Works facility. As this water flows westward toward the junction with the Indiana Harbor Canal (IHC), it appears to gain increased concentrations of nutrients, as well as increased eutrophication-related impacts to plankton communities.
  - A full inventory of NPDES-permitted dischargers and their associated discharges would assist in further elucidating this trend.

Conclusions: Riverine Sites (cont.)

- The West Branch of the Grand Calumet River is nearly flat and has less flow than the EBGCR.
  - WBGCR exhibits a flow summit, and resulting drainage divide, between the Hammond wastewater treatment plant and the junction with the IHC.
  - The exact location of the divide varies due to lake levels, storms, and other factors (e.g., Brammeir et al. 2008).
  - Information on flow direction was not available for this study.
- WB2 (Indianapolis Boulevard) exhibits the most disturbed nutrient loading of any of the riverine sites in this project.
  - The total phosphorus concentrations measured during the June and August sampling events, 101 and 66 μg/L, respectively, were fairly low, but still significantly higher than those found at the other sites.
  - Did any discharges contribute to these values?
  - No CSO events were recorded in the two-week period prior to this sampling event; however, several very large releases did occur in February and March of 2018.
  - Notable values of Chl-a were seen in both the June (7.00 mg/L) and August (5.33 mg/L) sampling periods.

Conclusions – Overview



Recommendations

The following recommendations are made, based on this study and the results of Simon (2015):

1) **Identify comparable control sites for both the riverine and non-Lake Michigan lacustrine sites**
   - Riverine: Little Calumet River system, including Deep River and Burns Ditch?
   - Lacustrine: A shallow non-AOC lake with a history of urban or industrial influences?

2) **Redefine the BUI #13 removal target**
   - Should reflect the appropriate non-Lake Michigan riverine and lacustrine control sites
   - Utilize multidimensional scaling to compare plankton populations of AOC sites with those of the control sites

Recommendations (cont.)

3) Build on information from this study and Simon (2015)

- Include existing fish community data from AOC waterbodies
- Utilize higher-frequency assessments of biological communities and nutrients over a longer period of time to better determine how plankton populations respond to seasonal changes
- Develop a list of outfalls, in addition to combined sewer overflows (CSOs), permitted to discharge nutrients along the GCR and IHSC
- Coordinate with the NW Indiana Septic System Coordination Workgroup to identify areas with high densities of septic systems

4) Conduct additional monitoring

- Add assessments of benthic health and periphyton to holistically understand factors collectively impacting BUI #6 (Benthos), BUI #8 (Eutrophication), and BUI #13 (Plankton)
- Utilize sediment elutriate and/or bulk sediment testing to supplement water column samples in any future toxicity testing
- Consider toxicity identification and elimination assays to identify toxicants and sources should future evidence of toxicity emerge

Questions?

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