Bear Lake Monitoring Overview

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Outline

- Brief History of AWRI Involvement
  - TMDL
  - Willbrandt restoration
- 2022 Data/Comparison to prior data
- Summary/Implications

Bear Lake:

- 1.66 km^2 (410 ac)
- 2.1 m mean depth
- 3.6 m max depth
- Polymictic
- HRT = 78 days

What is a TMDL?

- Total Maximum Daily Load
- Required by Clean Water Act and U.S. EPA for water bodies not meeting water quality standards
- Establishes the allowable loadings of pollutants for a water body
- Identifies pollutant reductions necessary to restore and maintain water quality

Bear Lake TMDL

- MDEQ: need to reduce mean TP concentration from 44 µg/L to 30 µg/L
- Requires a total reduction from 3,387 to 1,313 lbs P/yr:
  - External Load: 1839 lb/yr → 50% reduction required (920 lb/yr) based on data
  - Internal Load: 1548 lb/yr → 80% reduction required (322 lb/yr) based on estimates
  - MOS: ~79 lb/yr

http://www.michigan.gov/documents/deq/wb-swas-tmdl-bearlake_258228_7.pdf

Estimated Annual Internal TP Load (lbs/yr)

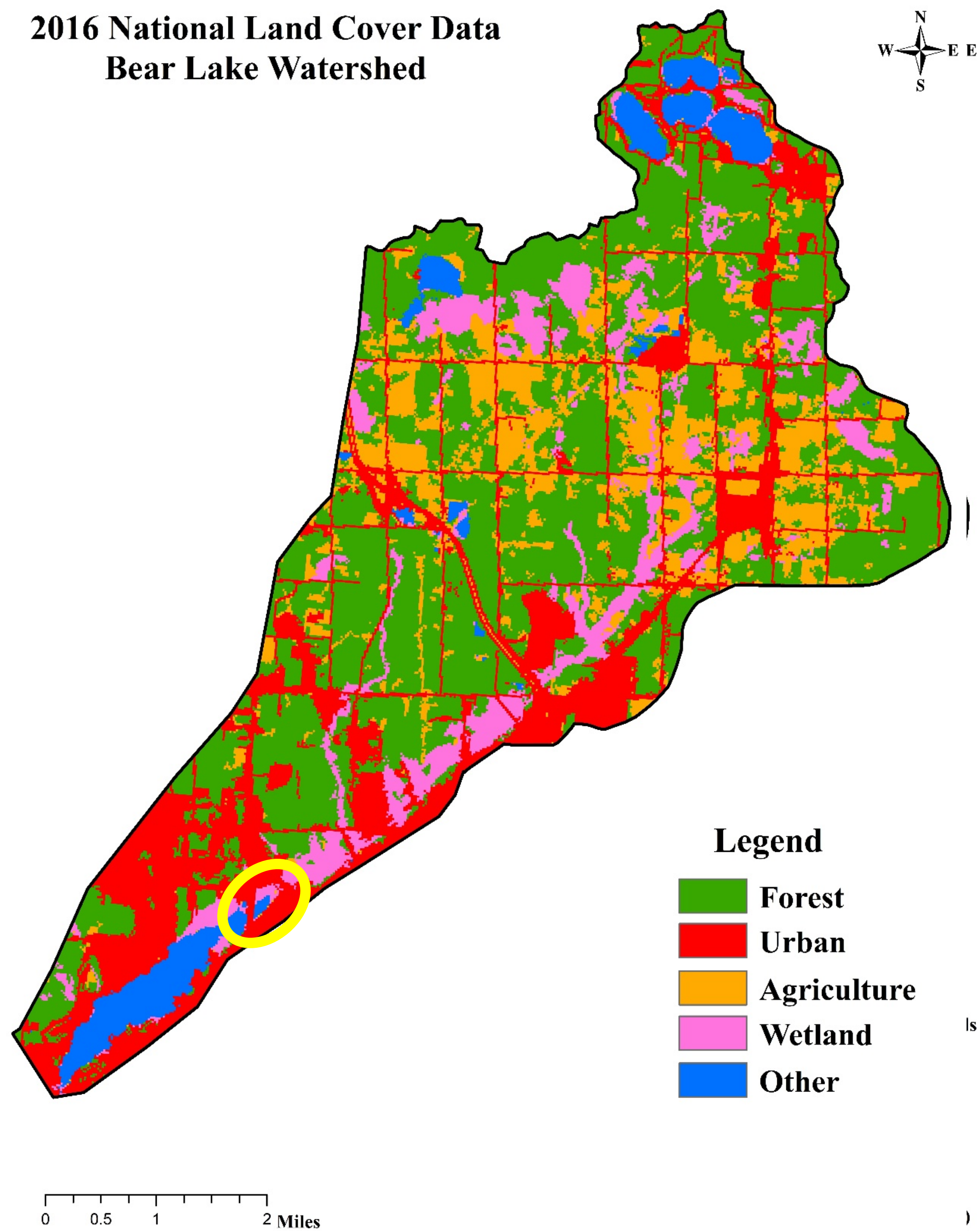
1. All Oxic	2. Anoxic > 10 ft	3. Anoxic > 9ft	4. Polymictic Lake Estimate	5. All Anoxic	MDEQ
169	224	513	1,166	1,931	1,548

TMDL internal load target = 322 lbs/yr

Steinman and Ogdahl (2015) Lake and Reservoir Management 31: 115-126

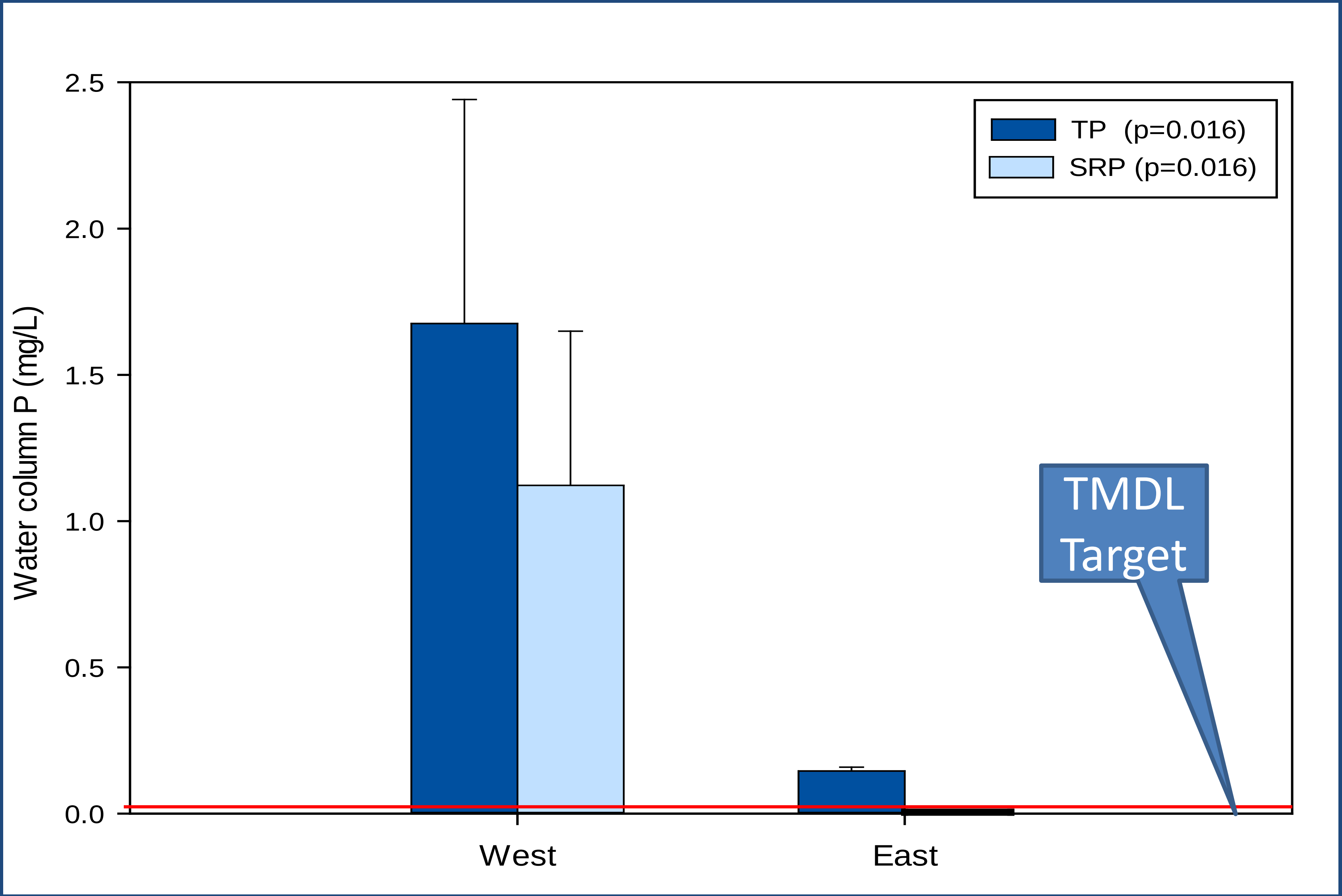
Summary: TMDL study

- Internal loading in Bear Lake is already meeting the TMDL reduction
- TMDL estimates for internal loading are too high (perhaps by 3-5 fold)
- TMDL needs to focus more on external P loading reductions



Land Use	Percent
Forest	47
Urban	25
Agriculture	15
Wetland	9
Other	5

Pre-Restoration Water Column Phosphorus Concentrations



July 2015

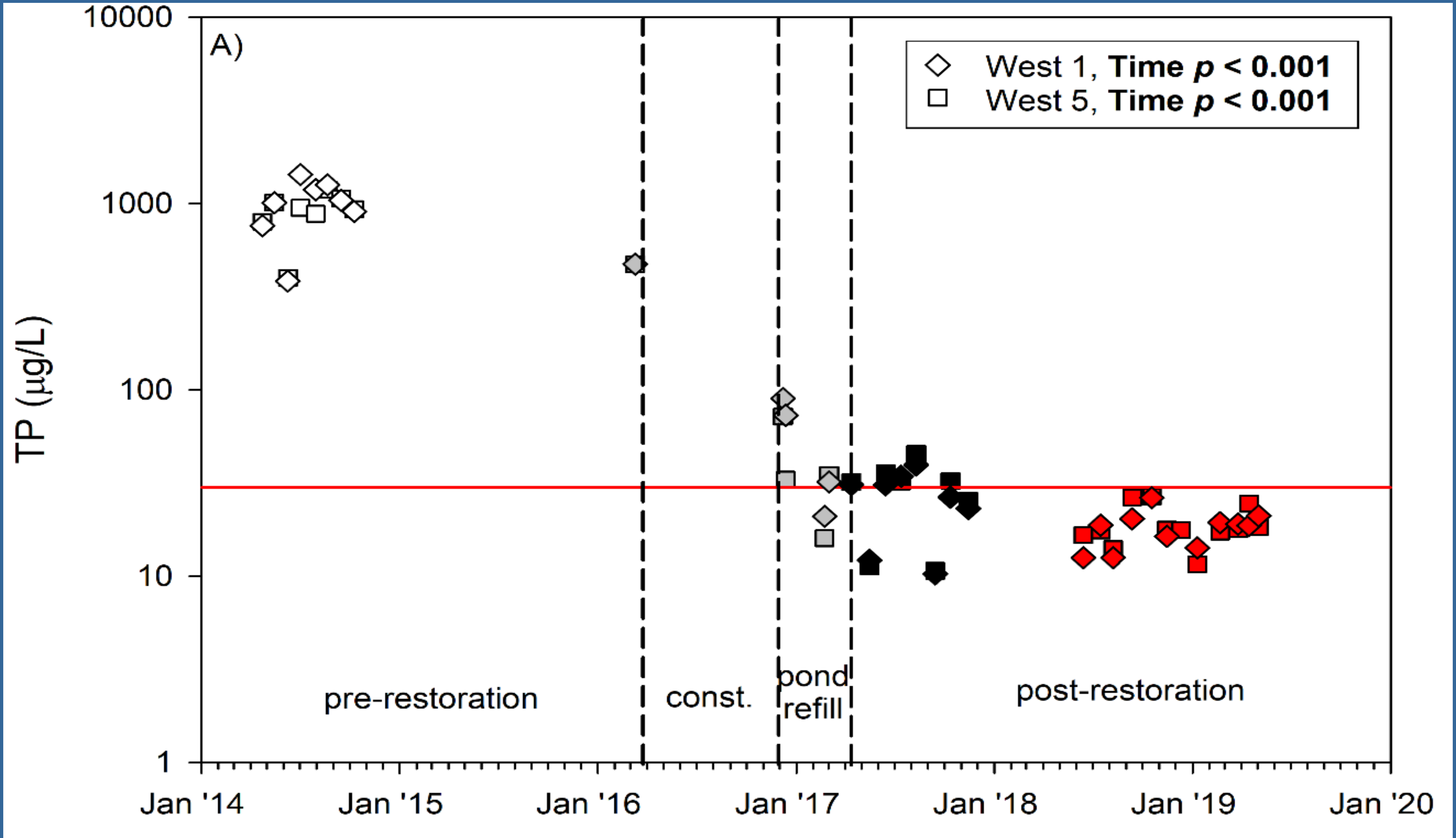
Photo credit:
Brian Majka, GEI

June 2016

Photo credit:
Brian Majka, GEI

Total Phosphorus: West Pond

Jan 2014 – August 2019

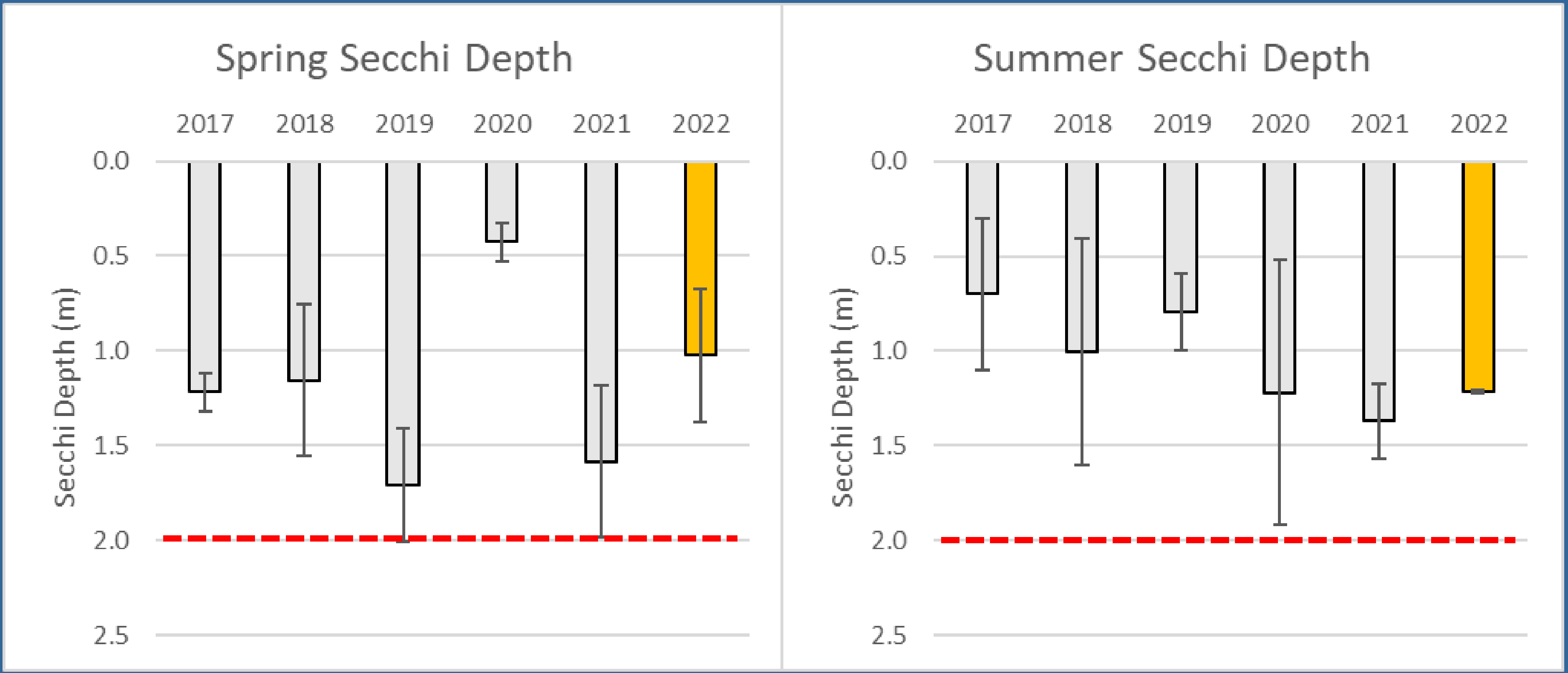


Hassett and Steinman (2022) Land 11(9): 1559

Bear Lake: 2022 Study

- Sampled 4 sites (Sites 1 and 3 same as RLS; Sites 2 and 4 same as AWRI prior studies)
- Sampled once/month May through October

Secchi Disk Depth (clarity): 2017- 2022

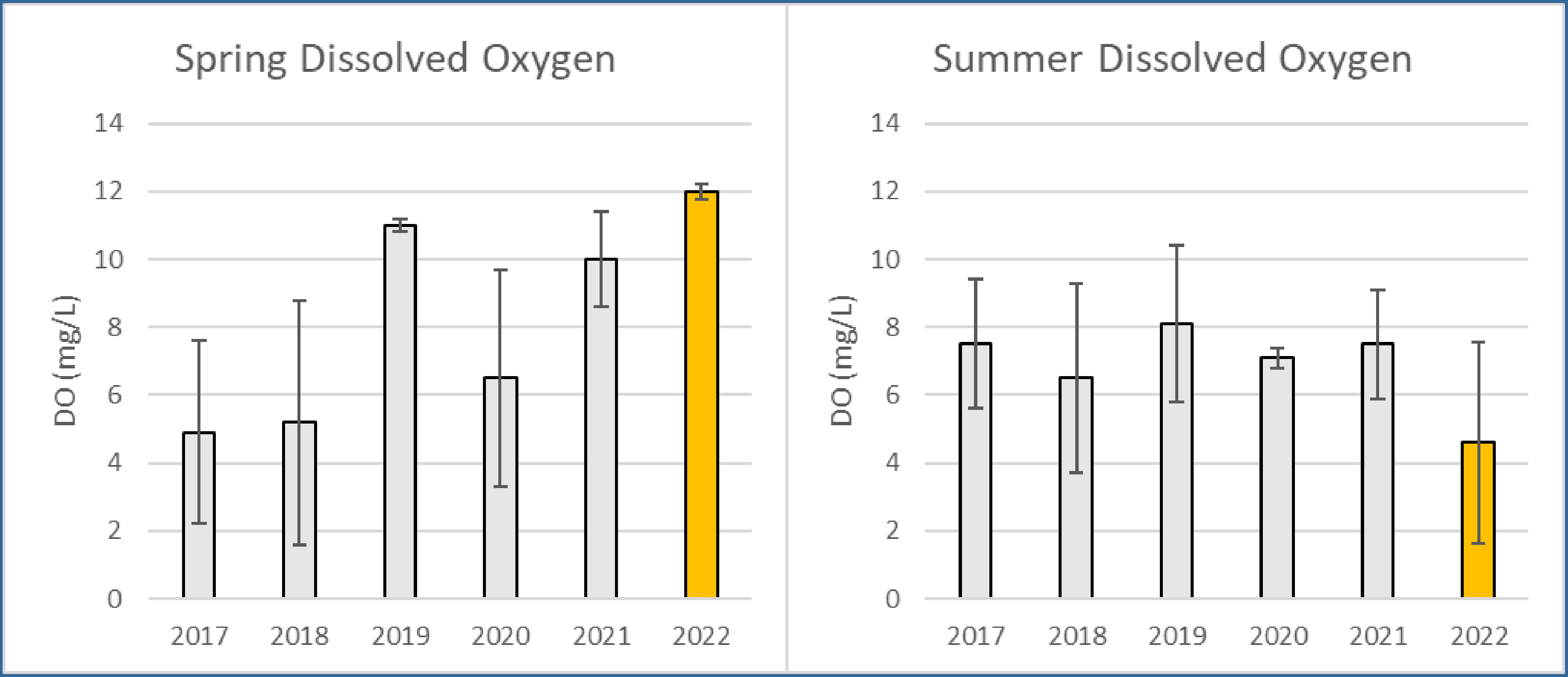


Data Source:

2017-2021: RLS

2022: AWRI

Dissolved Oxygen: 2017- 2022

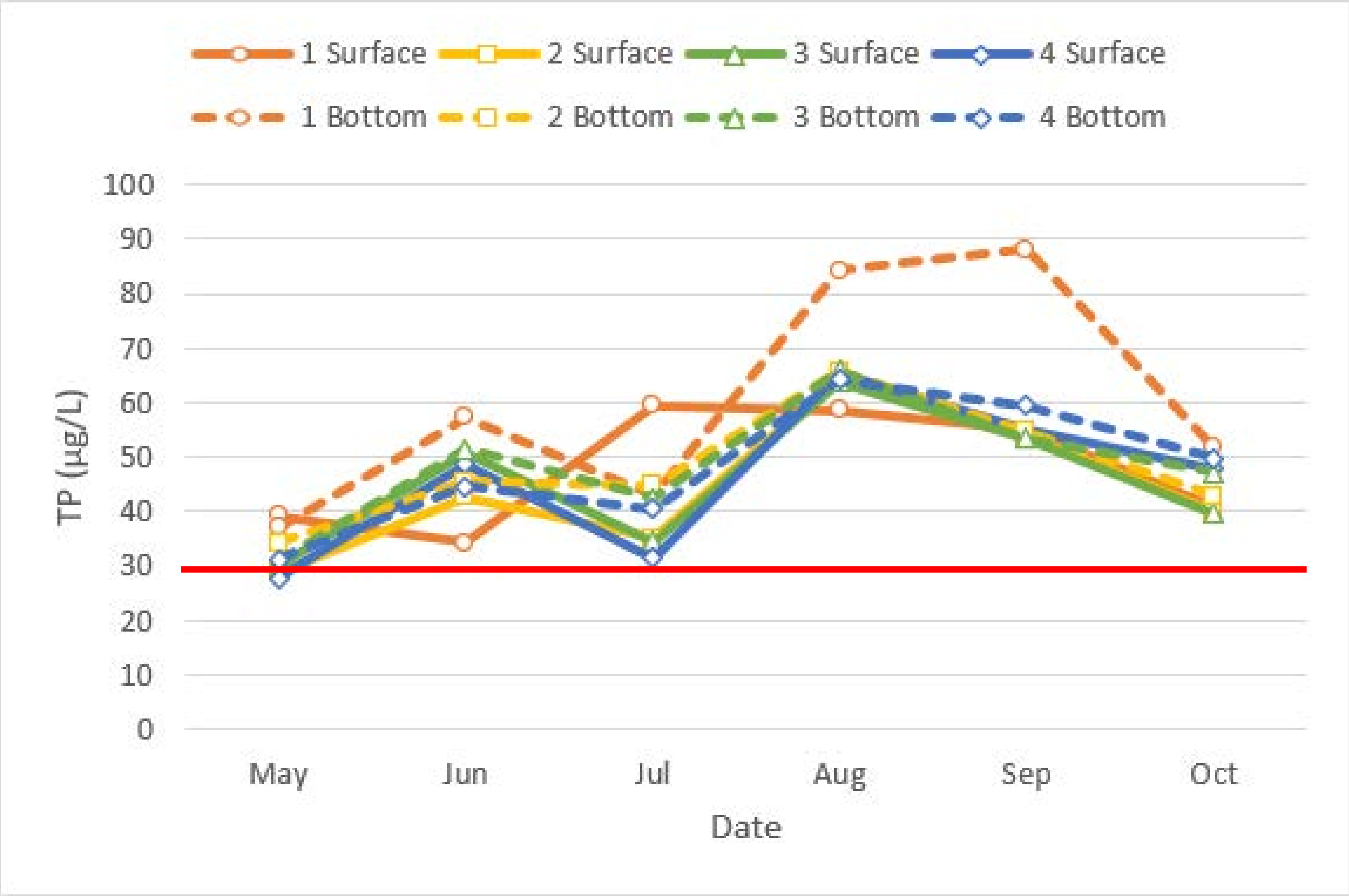


Data Source:

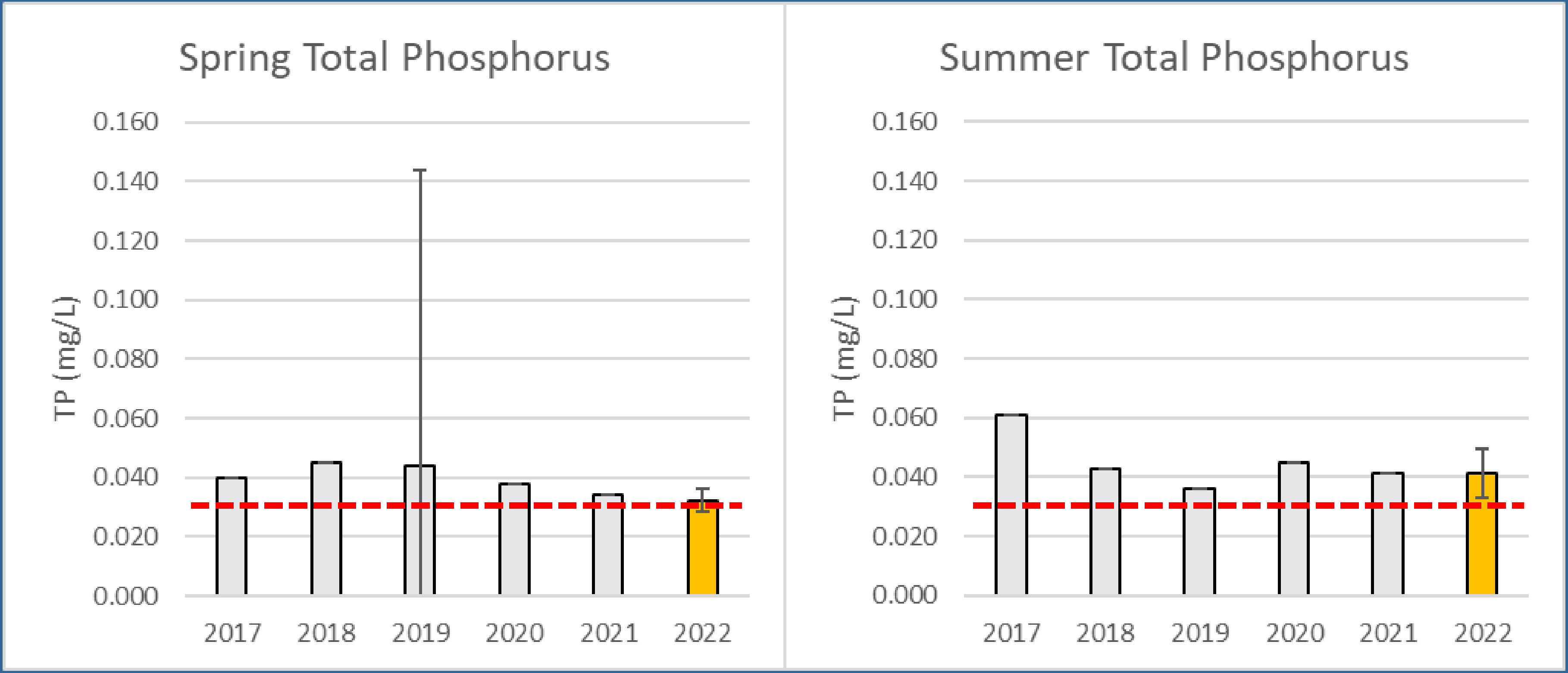
2017-2021: RLS

2022: AWRI

Total Phosphorus: 2022



Total Phosphorus: 2017-2022

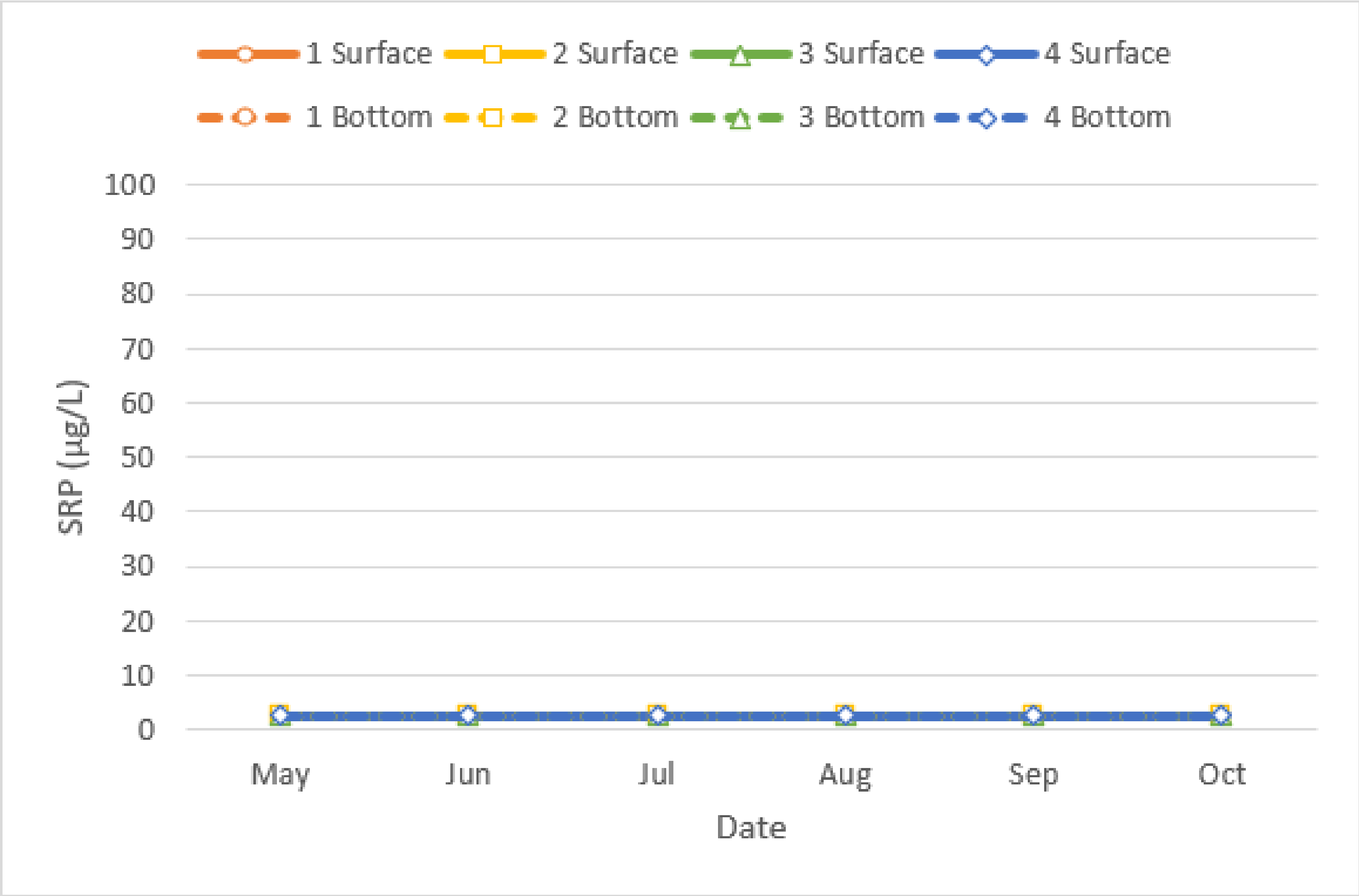


Data Source:

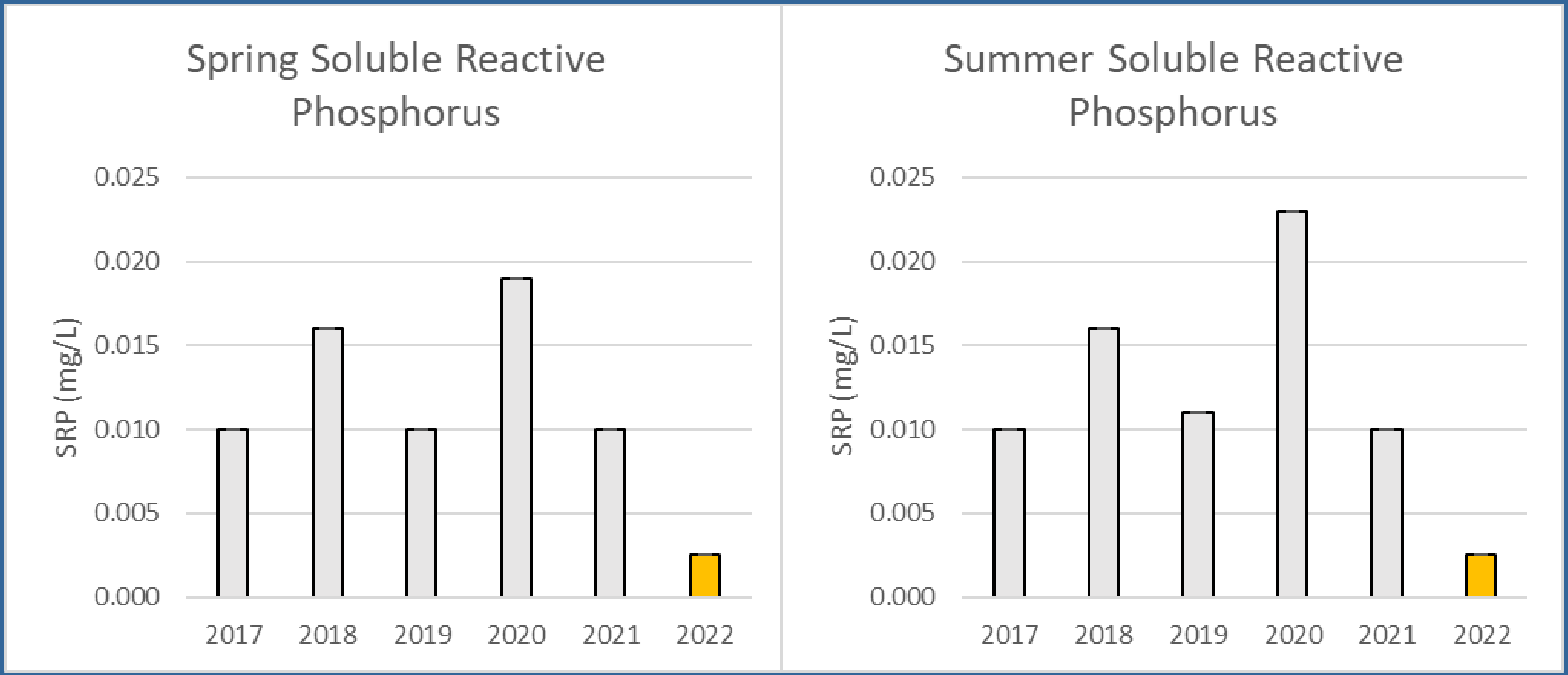
2017-2021: RLS

2022: AWRI

Soluble Reactive Phosphorus: 2022



Soluble Reactive Phosphorus: 2017-2022

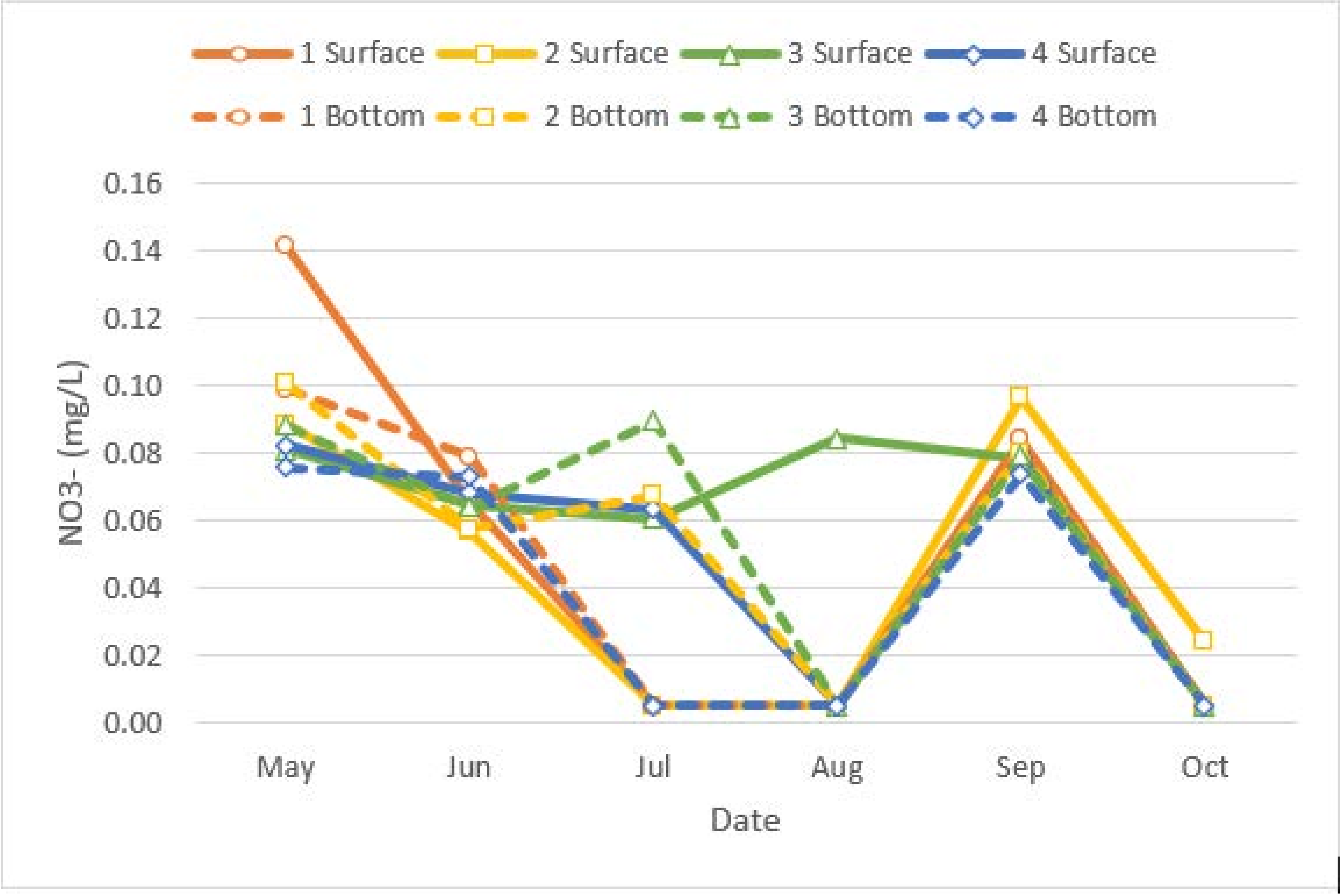


Data Source:

2017-2021: RLS

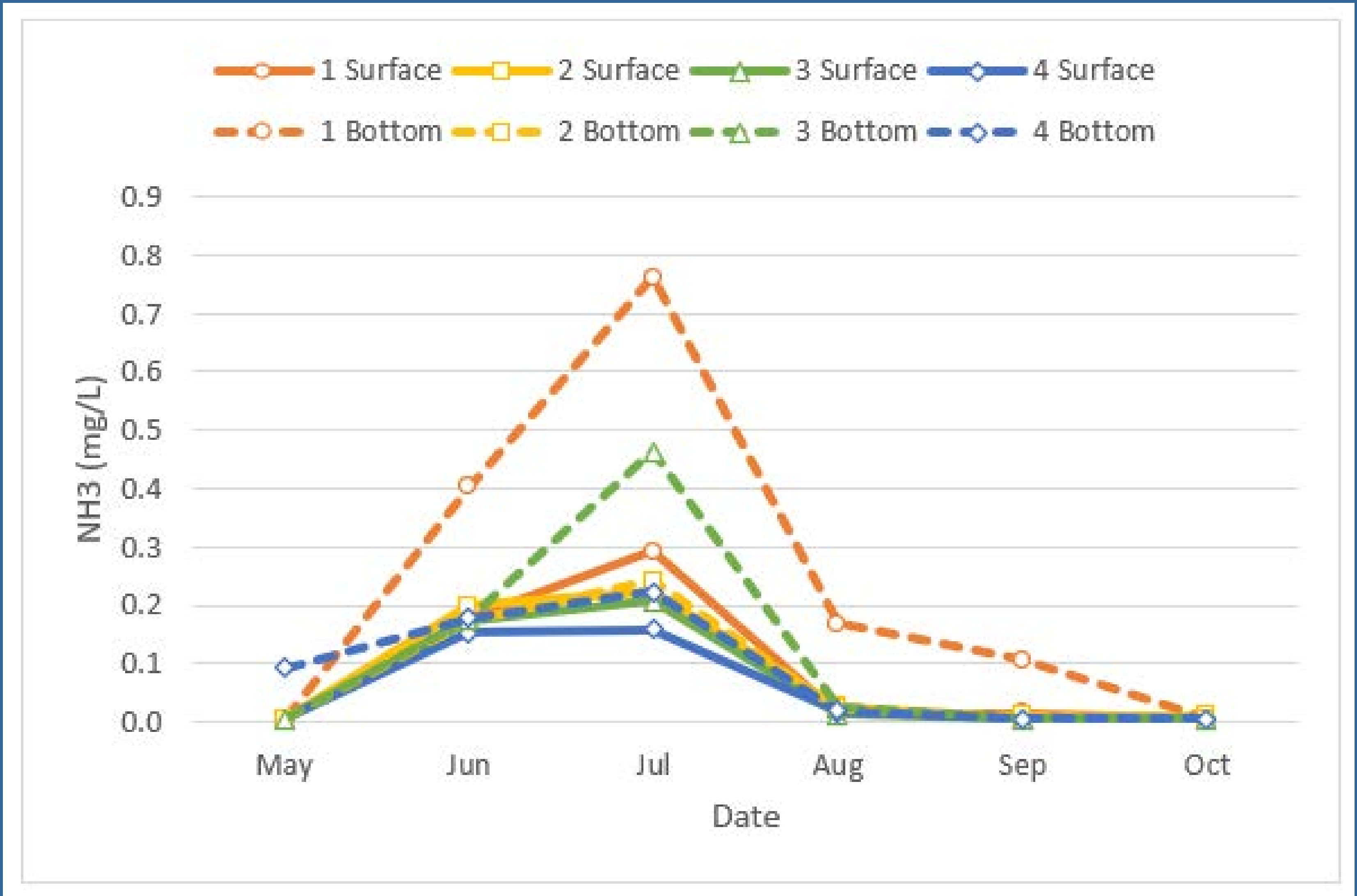
2022: AWRI

Nitrate: 2022



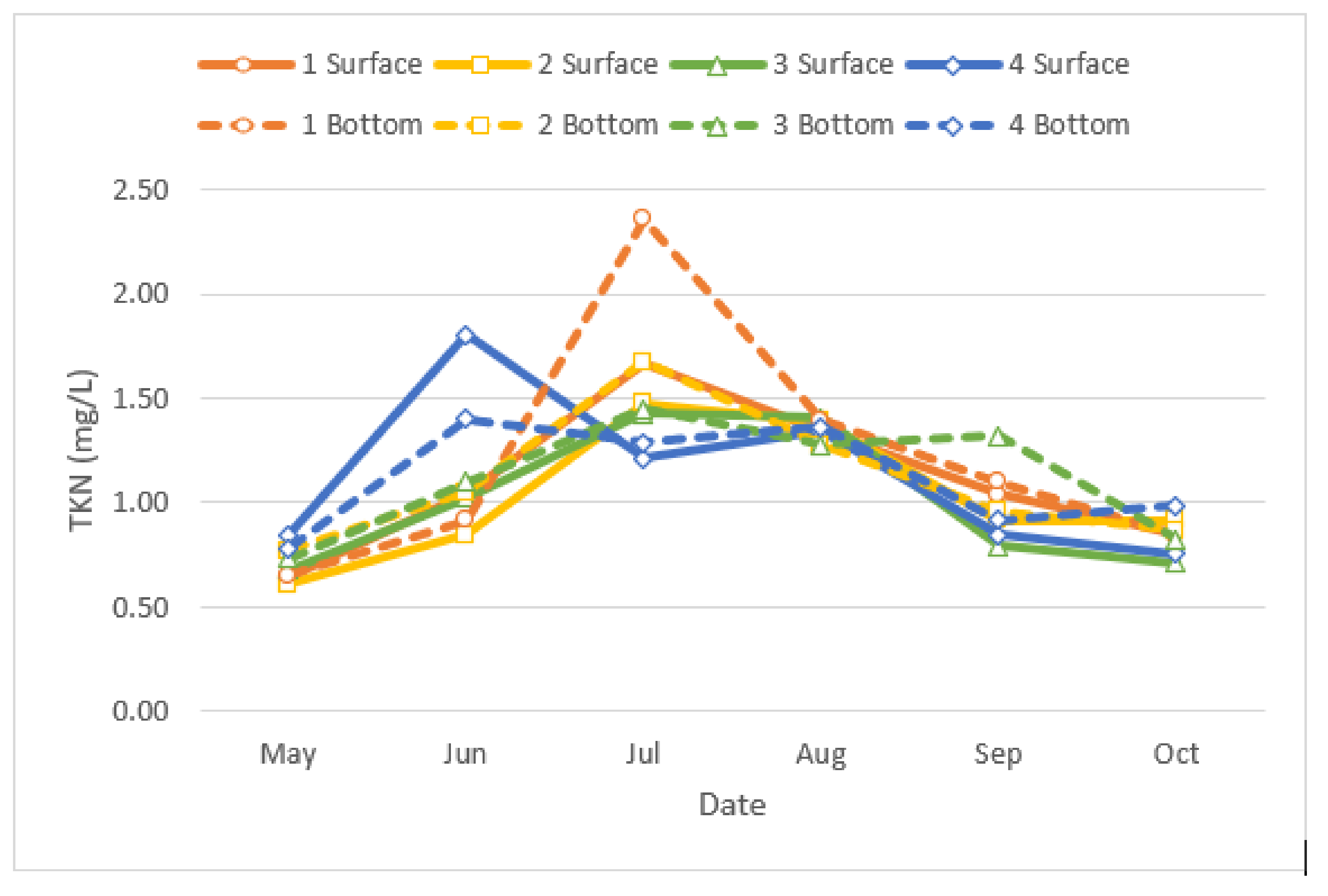
No nitrate data from RLS

Ammonia: 2022

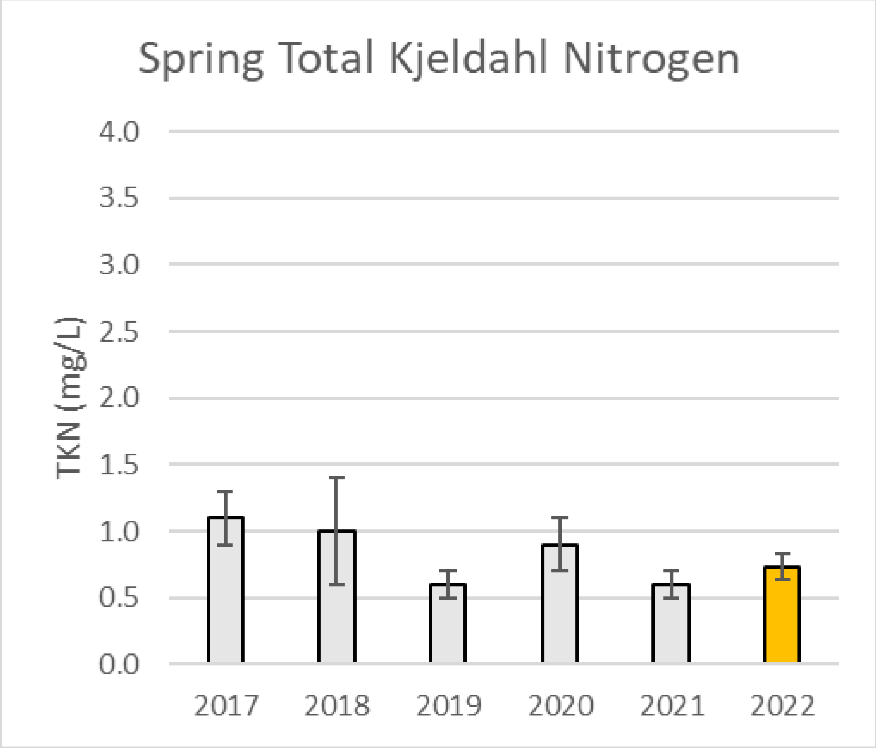


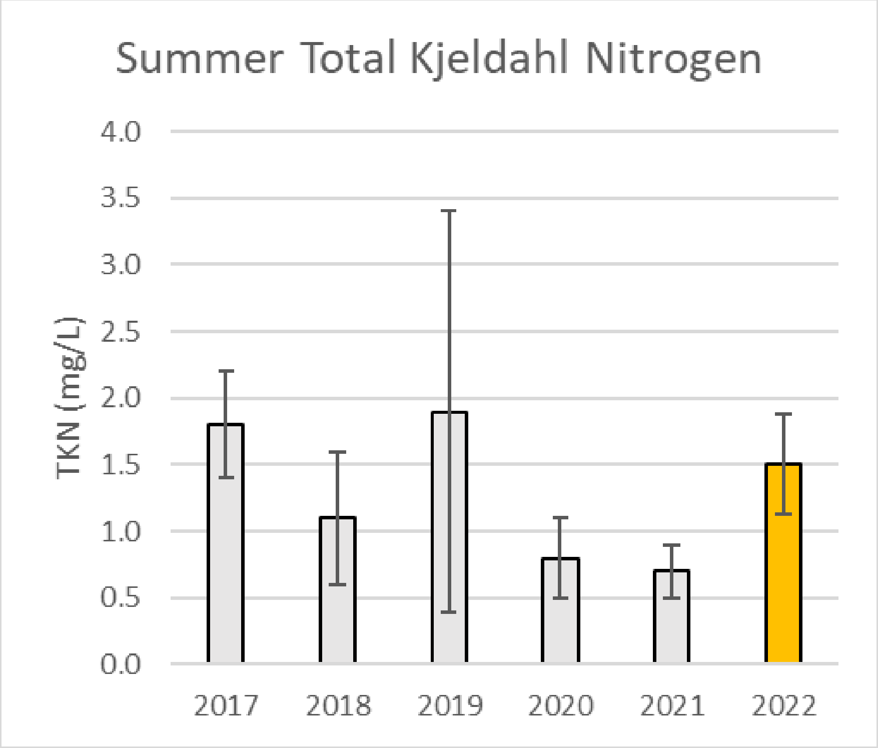
No ammonia data from RLS

TKN (Total Kjeldahl Nitrogen): 2022
(ammonia and organic N)



Total Kjeldahl Nitrogen: 2017-2022



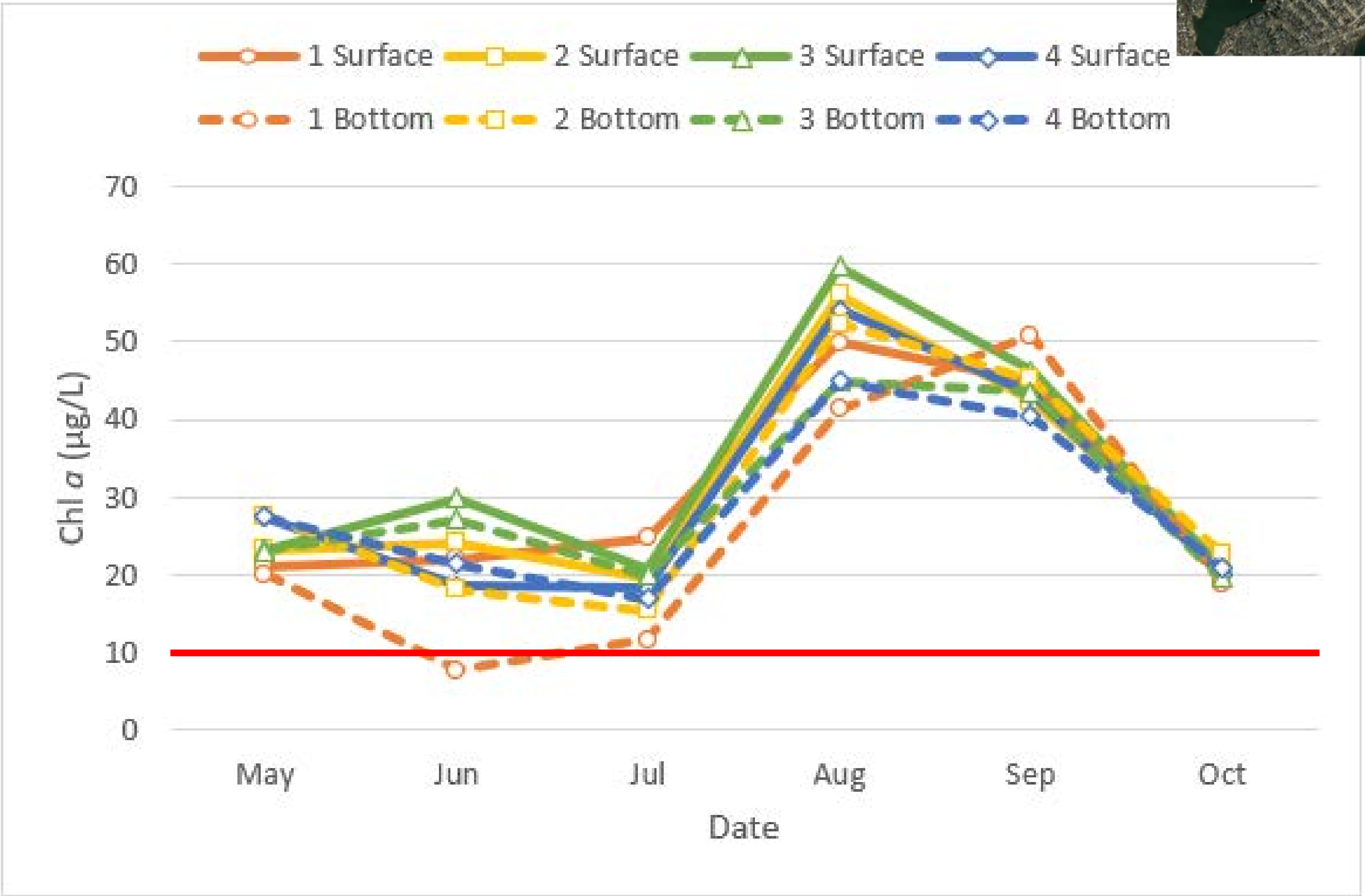


Data Source:

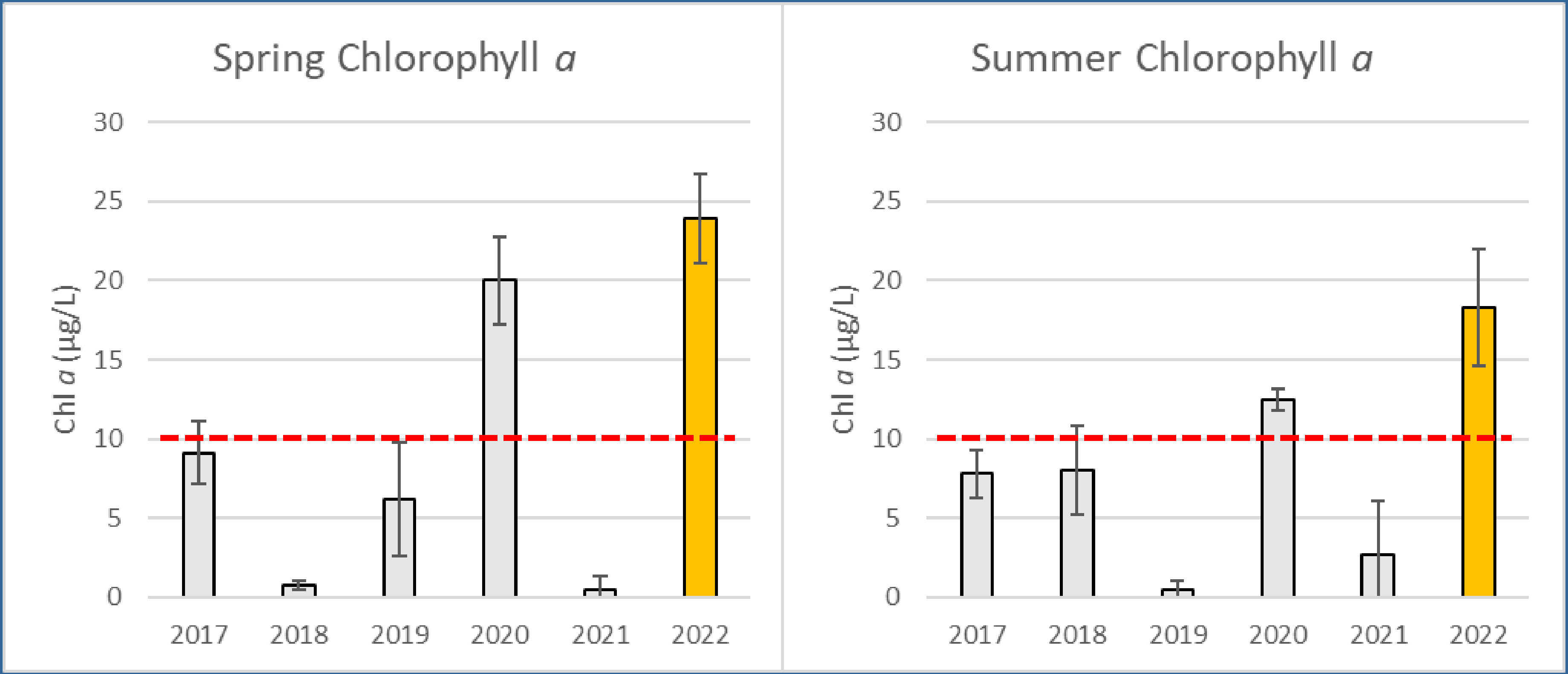
2017-2021: RLS

2022: AWRI

Chlorophyll *a*: 2022



Chlorophyll *a*: 2017-2022

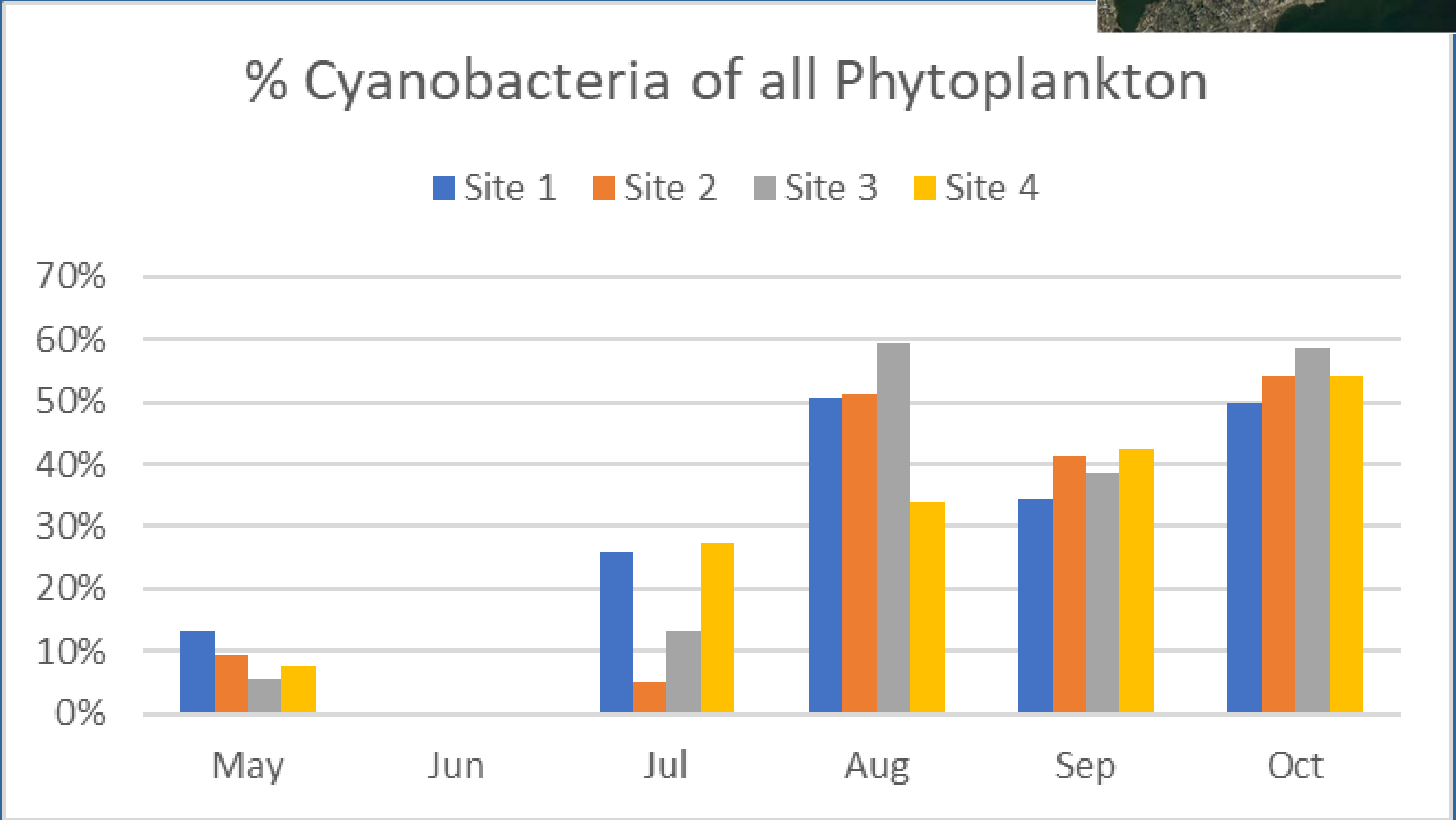


Data Source:

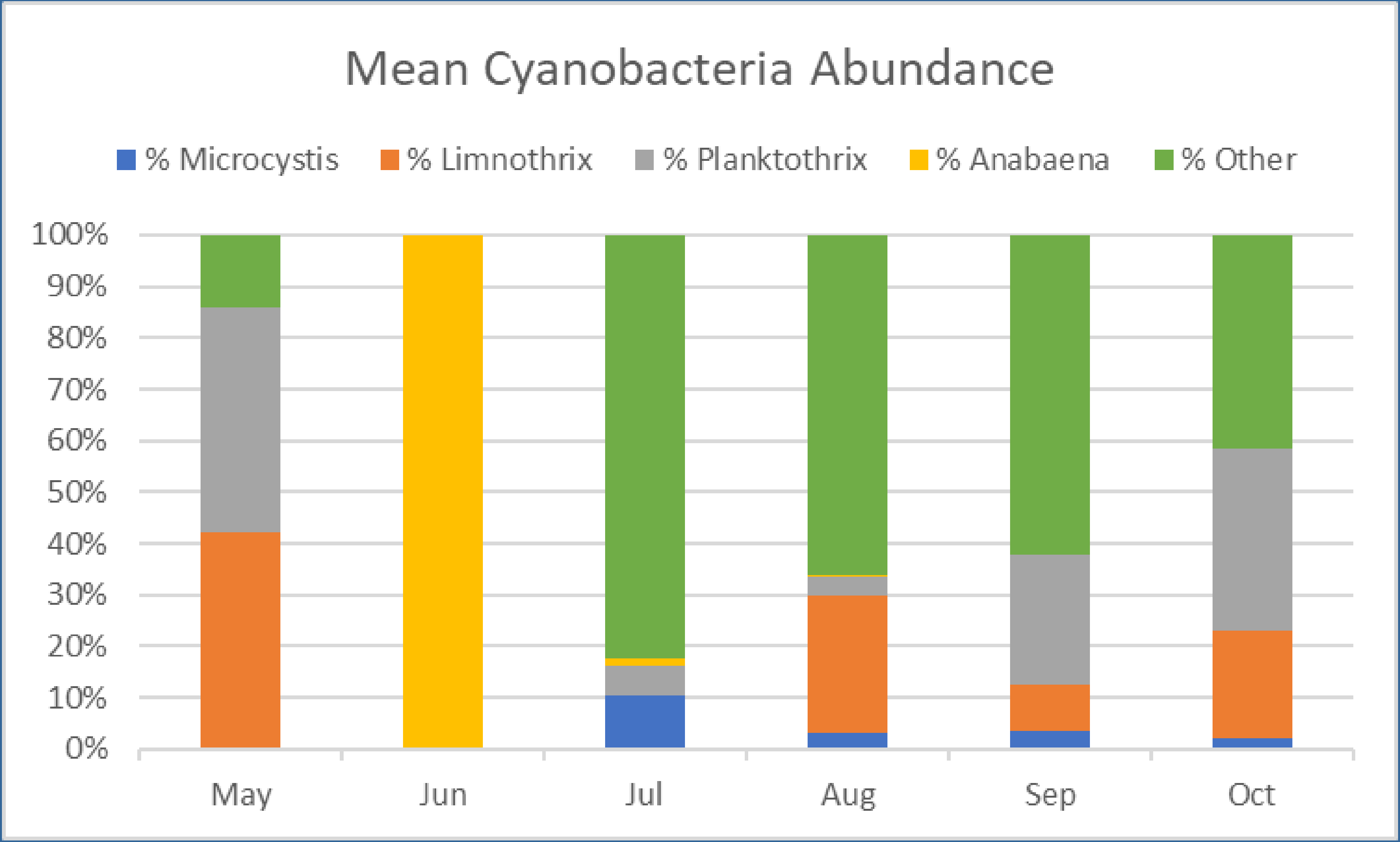
2017-2021: RLS

2022: AWRI

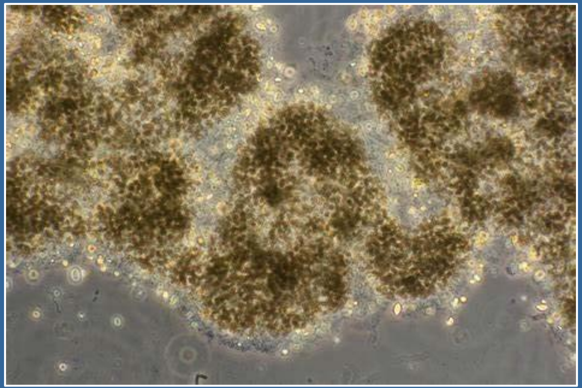
Percent Cyanobacteria: 2022

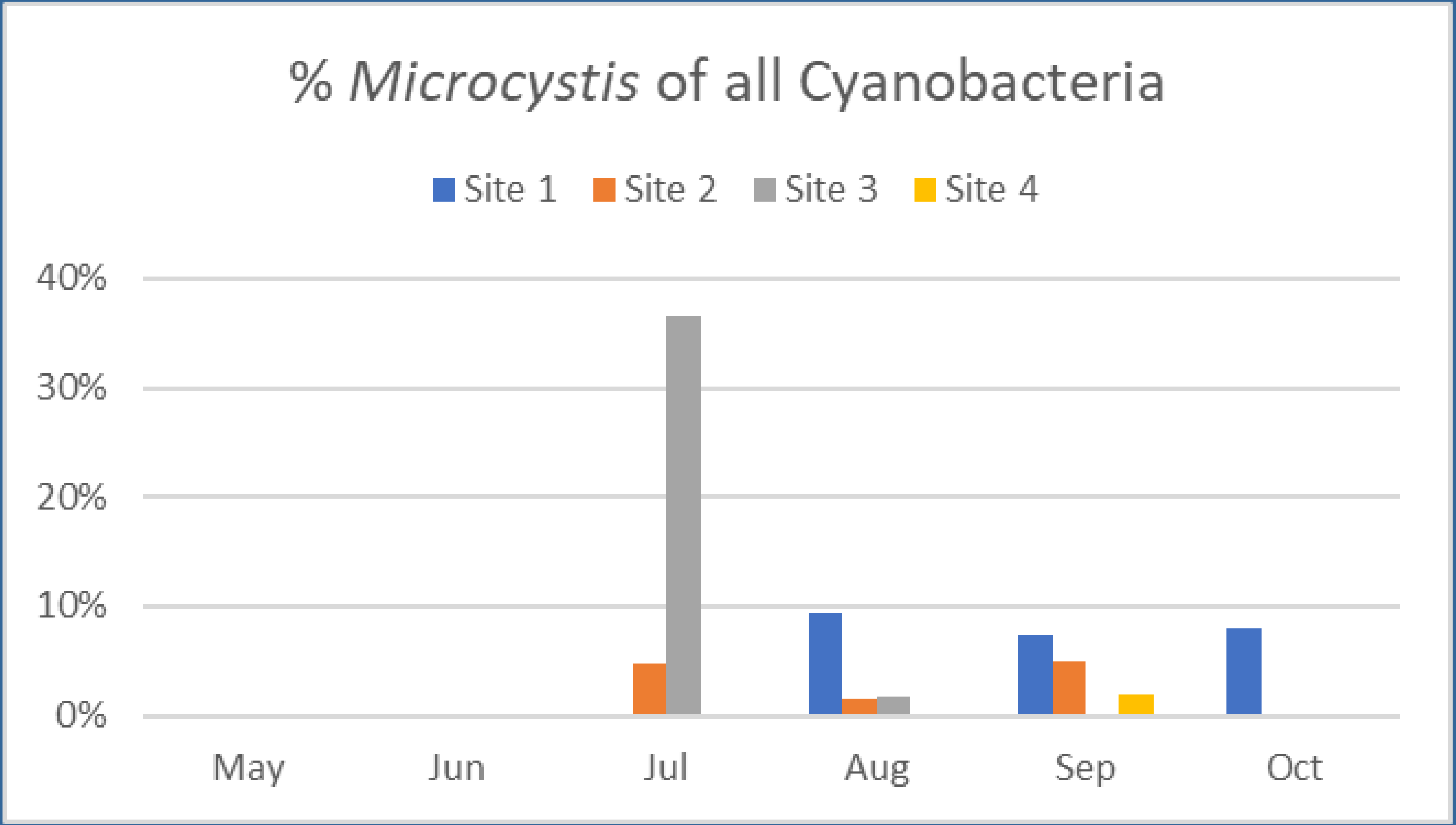


Cyanobacteria Genera: 2022



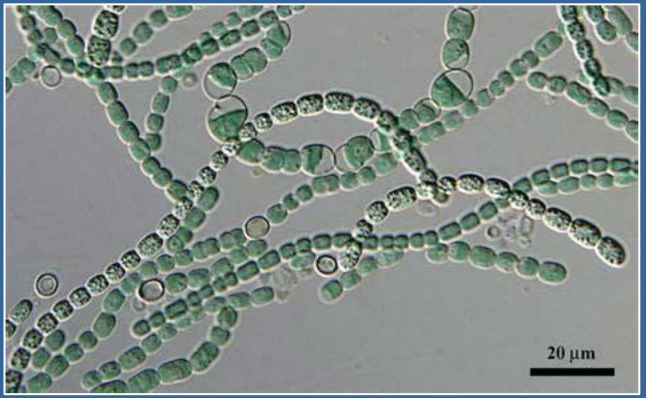
Percent *Microcystis*
(can produce microcystins)

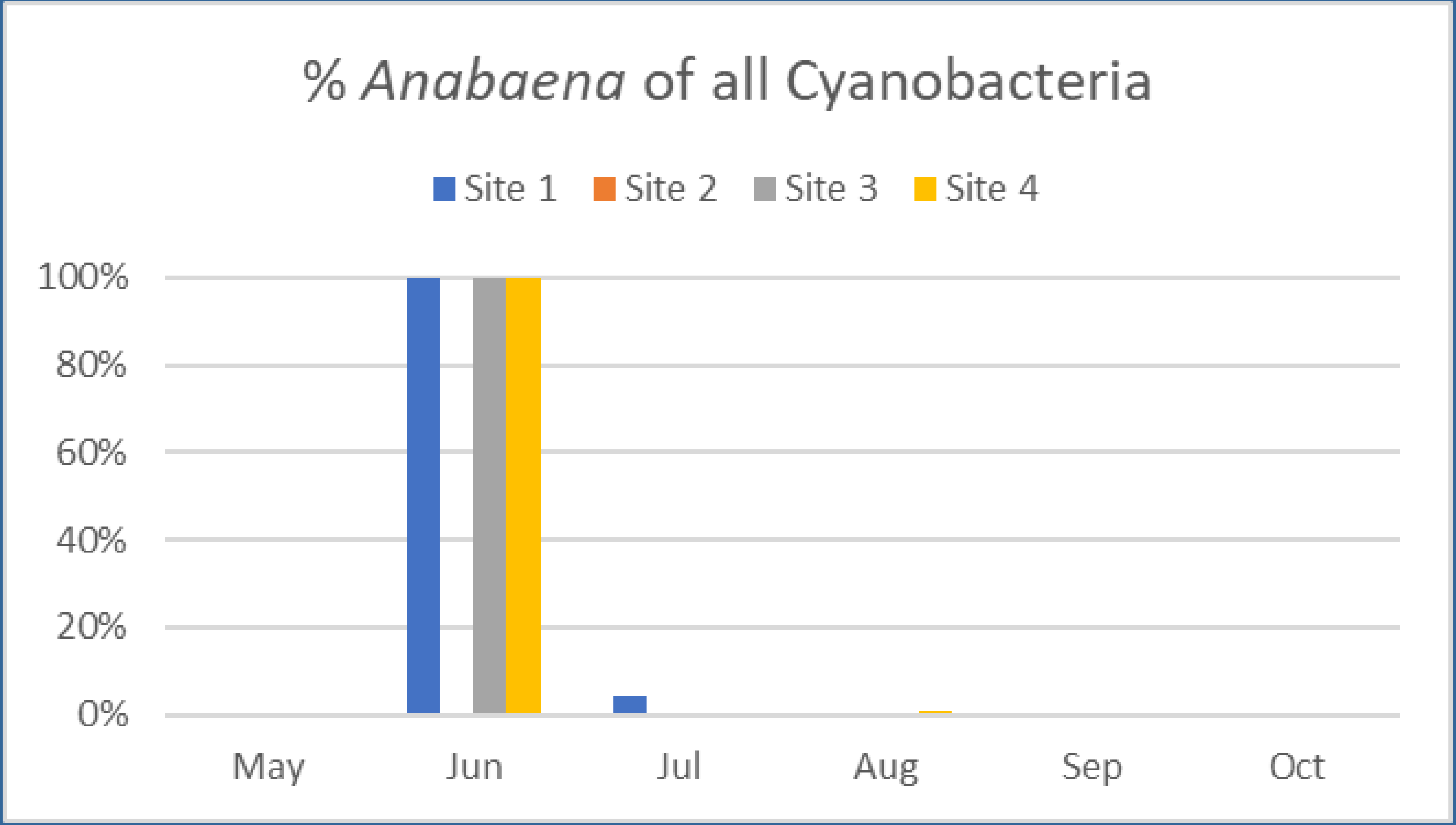




Percent *Anabaena*

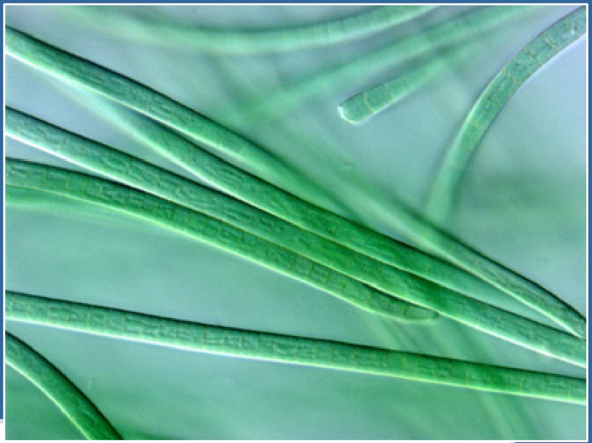
(can produce anatoxins)

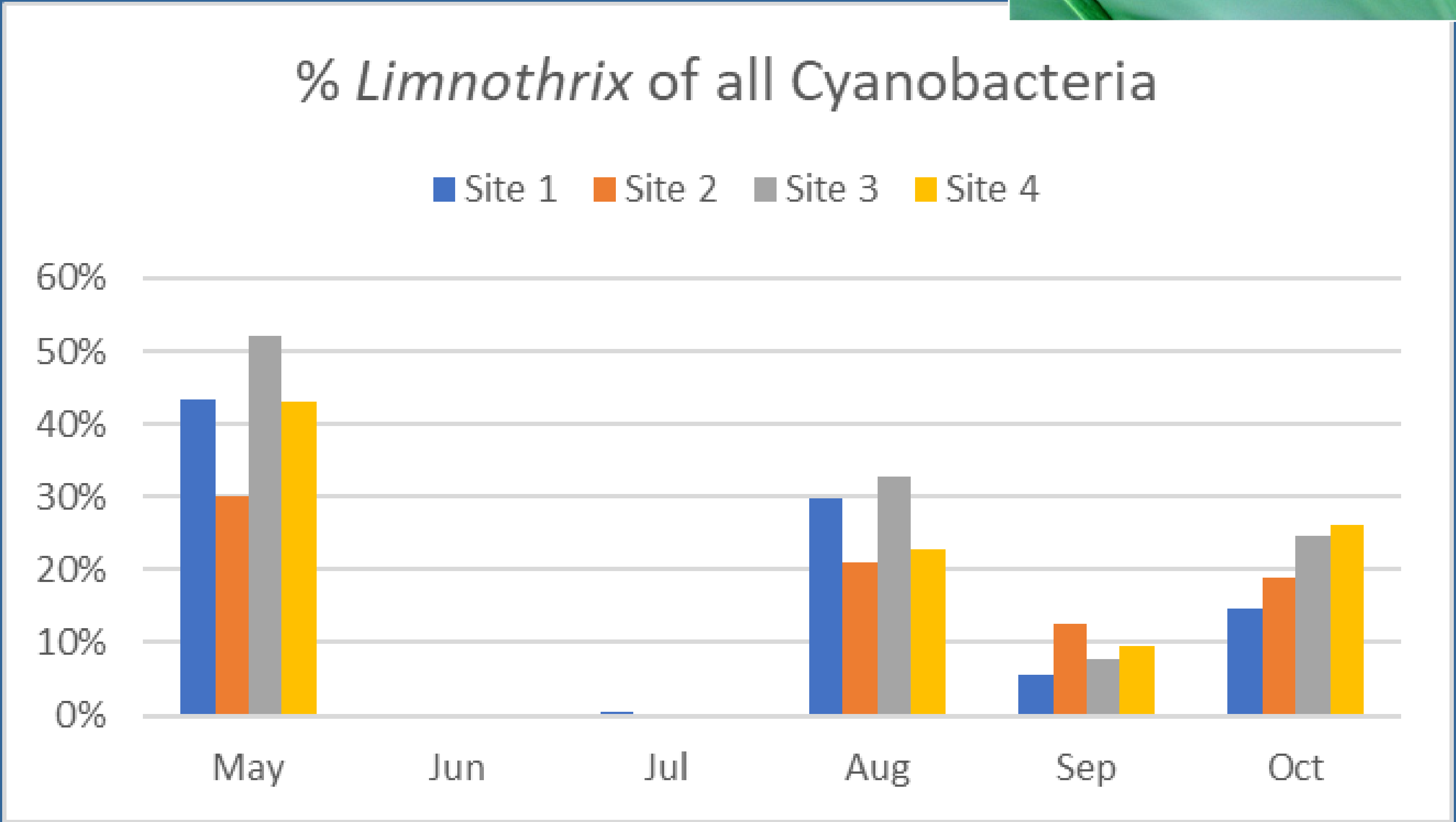




Percent *Limnothrix*

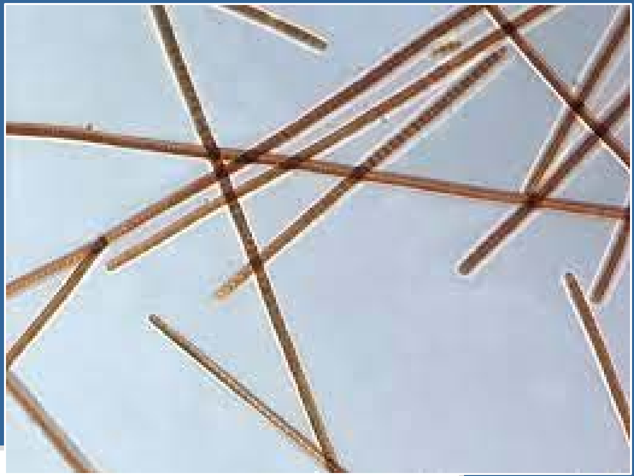
(can produce limnothrixin)

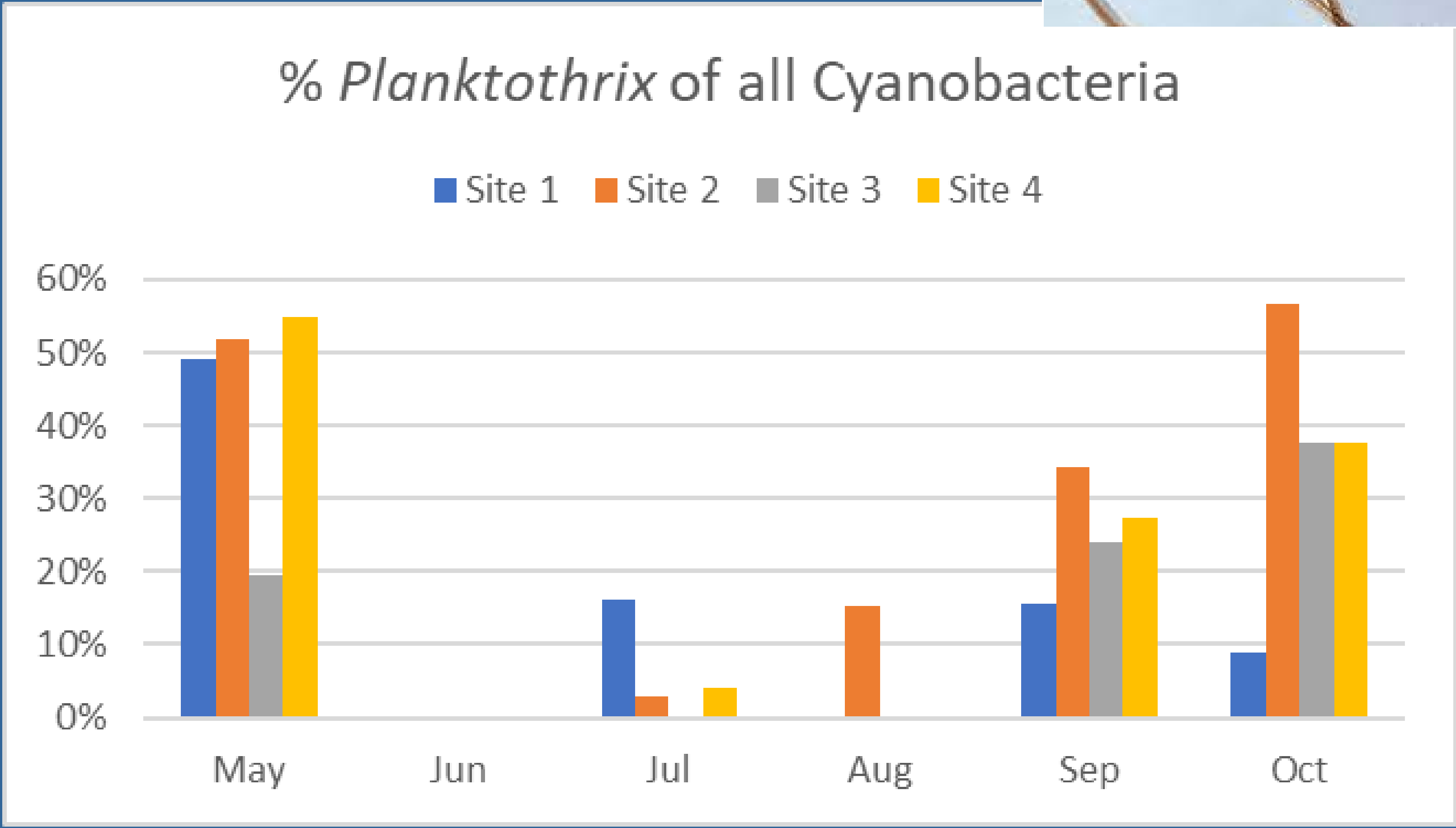




Percent *Planktothrix*

(can produce microcystins)





Microcystin is the most common cyanotoxin produced by HABs → hepatoxin and tumor promotor.

Use	WHO	US EPA*
Drinking Water	1 µg/L	0.3 µg/L (infants/pre-school) 1.6 µg/L (school children/adults)
Recreation	20 µg/L	8 µg/L

*guidance only

Microsystin: 2022

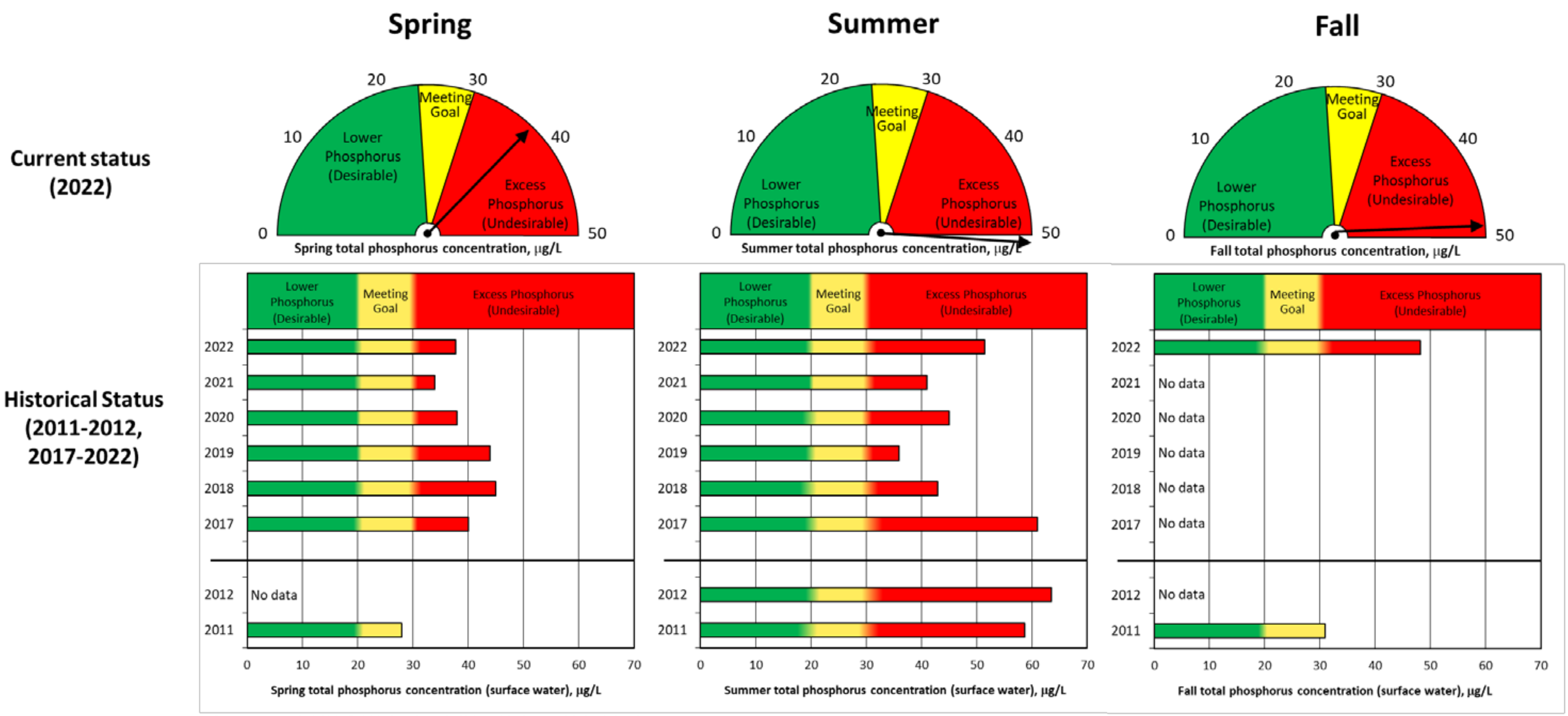
Site	Depth	ELISA Microcystin (µg/L)
1	Surface	0.011 (0.022)
	Bottom	0.005 (0.026)
2	Surface	0.027 (0.032)
	Bottom	0.037 (0.035)
3	Surface	0.001 (0.026)
	Bottom	0.015 (0.02)
4	Surface	0.041 (0.029)
	Bottom	0.026 (0.027)
Grand Mean	Surface	0.02 (0.018)
	Bottom	0.021 (0.014)

E. coli: 2022

Site	Depth	*E. coli* (cfu/100 mL)
1	Surface	4.3 (4.5)
	Bottom	NA
2	Surface	2.8 (2.6)
	Bottom	NA
3	Surface	1.7 (1.2)
	Bottom	NA
4	Surface	1.7 (1.6)
	Bottom	NA
Grand Mean	Surface	2.6 (1.3)
	Bottom	NA

MI's water-quality standard: *E. coli* concentrations at bathing beaches **must not exceed 300 cfu/100 mL**, as determined by the geometric mean of culture-based concentrations in three or more representative samples from a given beach on a given day.

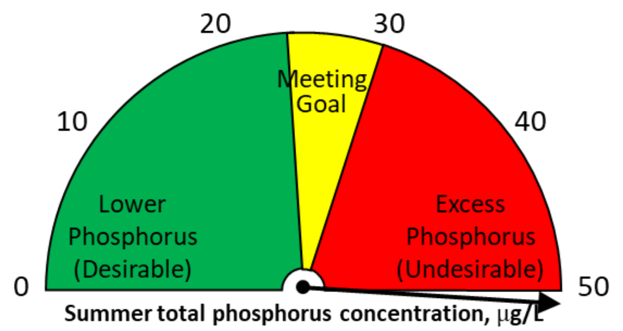
TP Dashboard

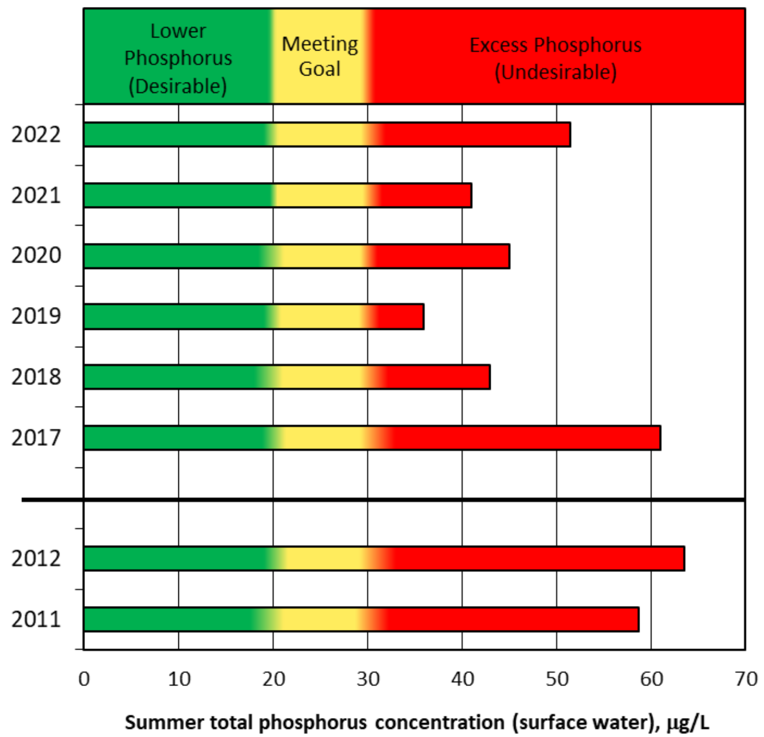


Data sources: RLS (2017-2021) and AWRI (2011-2012; unpublished data)

TP Dashboard

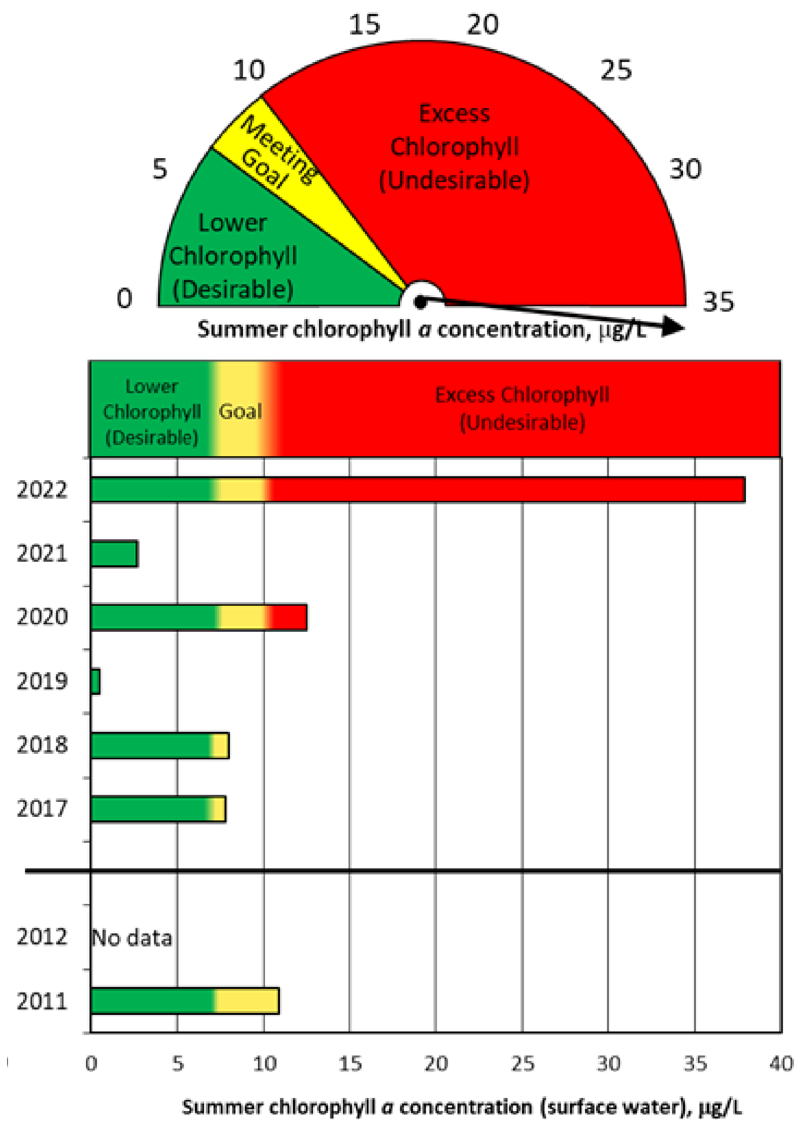
Summer





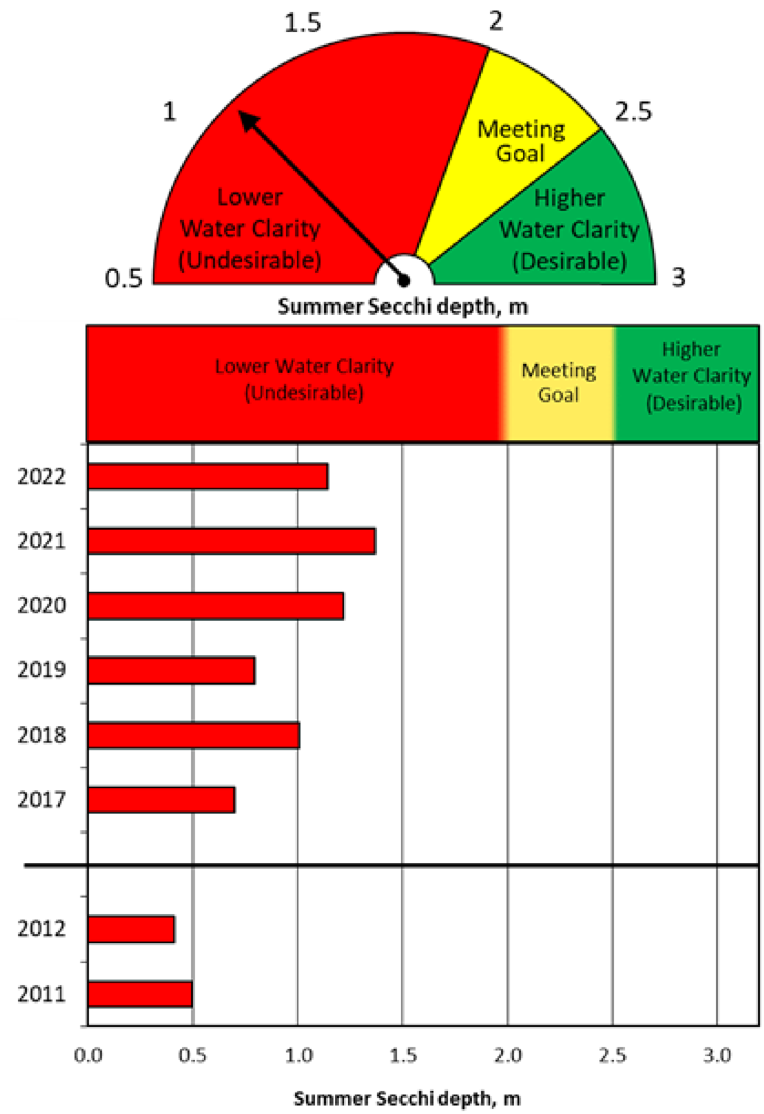
Chlorophyll Dashboard

Summer



Water Clarity Dashboard

Summer



Bear Lake: 2022 Status Summary

- TP concentrations still high, especially in summer/fall;
- Internal P and N loading limited overall, but most detectable at site 1;
- Excess algae present, but the good news is very low cyanotoxins and *E. coli.*;
- High Chlorophyll levels are consistent with the low water clarity but chlorophyll is very dynamic—monthly sampling may not capture full picture

Bear Lake: Recommendations

- Continue water quality monitoring;
- Examine possible sources of P from direct runoff into lake (septage, yard runoff, restored ponds);
- Consider a watershed survey to determine lake user priorities (target future monitoring around priorities)

Acknowledgements (2022)

- **Mike Hassett; Rachel Orzechowski; Brian Scull; Mark Luttenton, Travis Ellens, Ellen Foley, Paris Velasquez, Jacquie Molloseau, Allison Passejna, and Kate Lucas.**

- **Project partners:**
  - PLM

- **Funding:**
  - Bear Lake – Lake Board
  - Allen and Helen Hunting Research and Innovation Fund (GVSU)

Questions?!

Extra Slides

BUIs for Muskegon Lake AOC

Impairments	
Restrictions on fish and wildlife consumption	Beach Closings
Degradation of Fish and Wildlife Populations	Groundwater Contamination
Degradation of Benthos	Degradation of Aesthetics
Restrictions on Dredging	Eutrophication and Undesirable Algae
Loss of Fish and Wildlife Habitat	

Bear Lake Water Quality

- Eutrophic
  - Mean TP = 44 µg/L (turnover)
  - Chl *a* = 10 - 65 µg/L (summer)
- Suffers from nuisance algal growth caused by elevated phosphorus (P)
  - Muskegon Lake Area of Concern (AOC)
  - Michigan 303(d) list
- Total Maximum Daily Load (TMDL) for P

Phosphorus Loads to Bear Lake

External P Load = 1,839 lb/yr

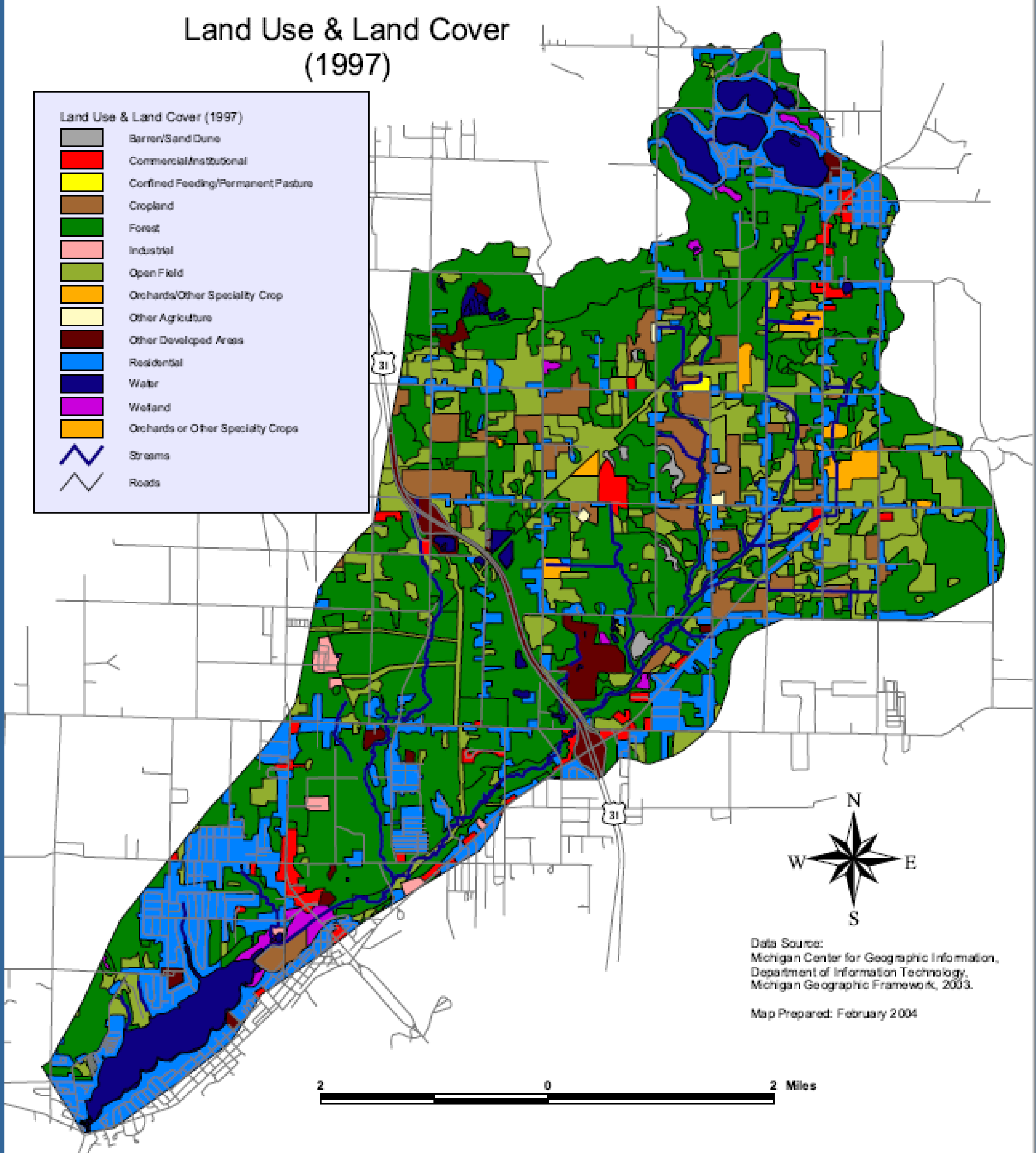
Internal P Load = 1,548 lb/yr*

*Based on Sediment TP (Nürnberg 1988, CJFAS):

TP release rate ($mg/m^2/d$) = -4.18 + 3.77(TP)

Total P Load = 3,387 lb/yr

Figure 9. Bear Creek & Bear Lake Watershed



Land Use	Percent
Forest	44
Urban	22
Agriculture	6
Wetland	1
Other	27


N
Bear Lake
Muskegon Lake
Lake Michigan

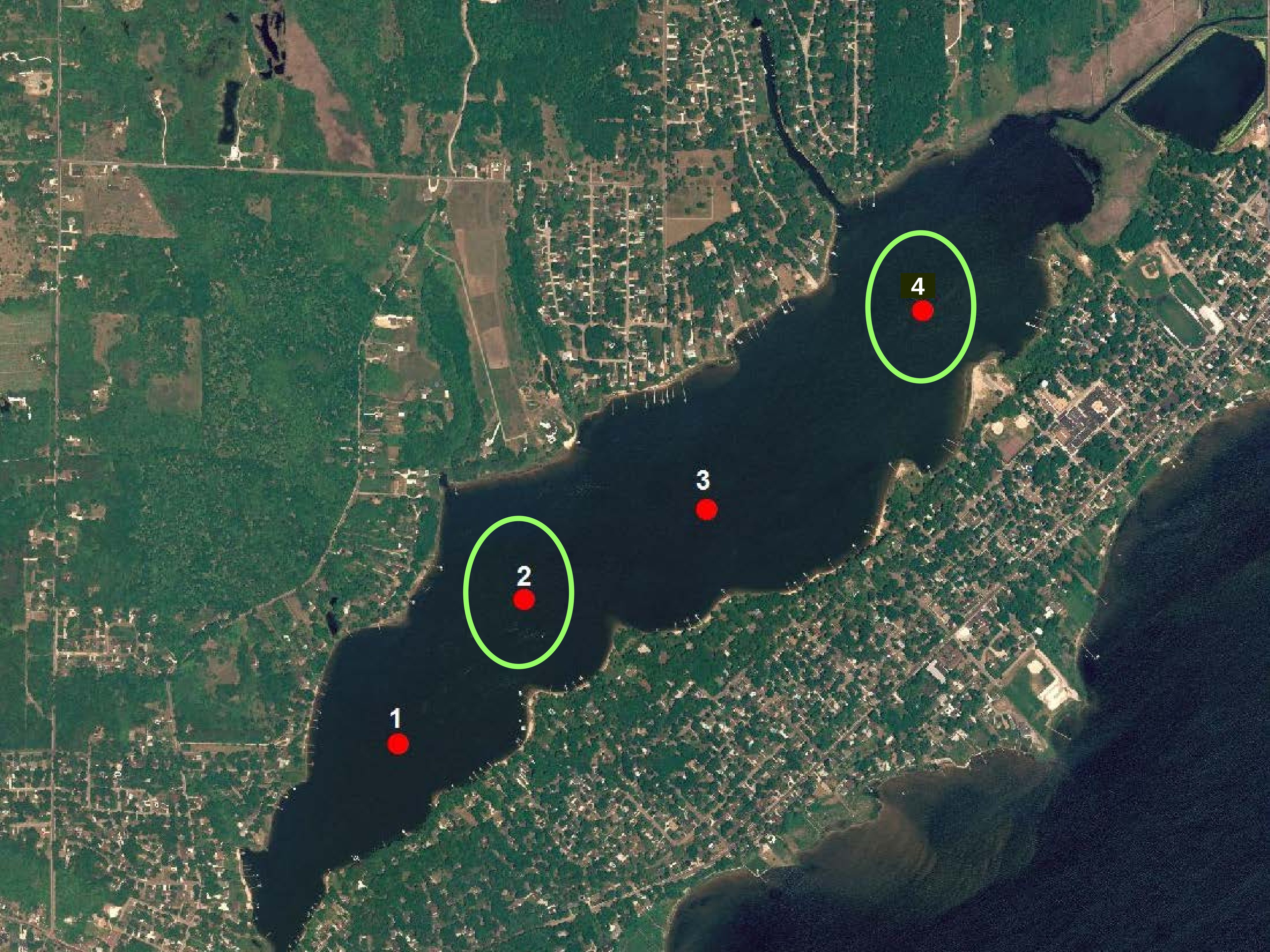

Michigan
Muskegon County

Summary: Willbrandt Restoration

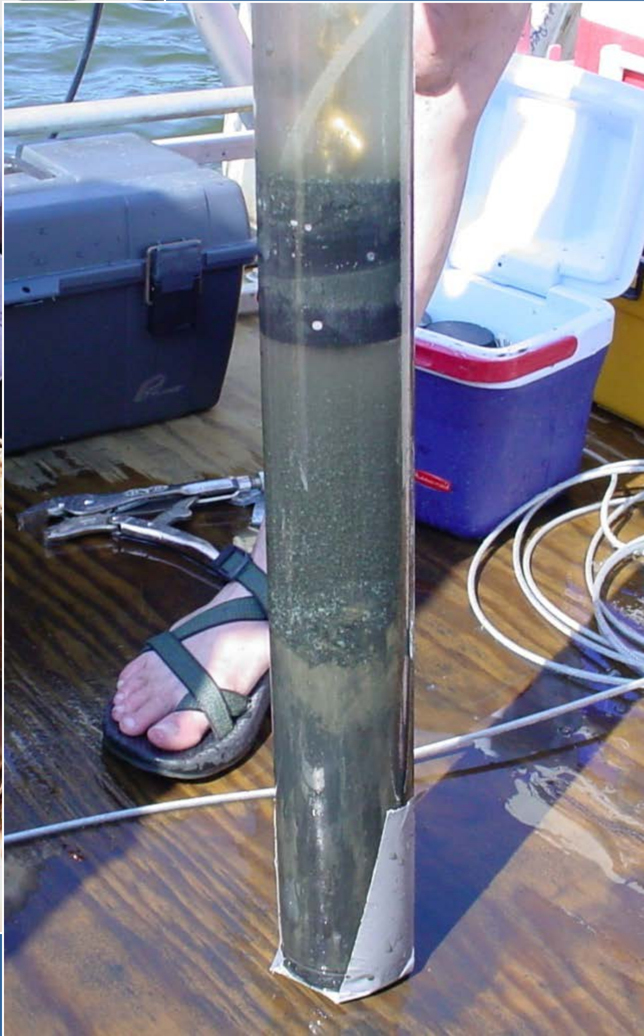
- Celery farms stored a significant amount of phosphorus, which likely contributed to Bear Lake P concentrations
- Removal of muck soils has dramatically reduced P concentrations in restored marsh area
- As lake levels decline, more of this lower-P water will reach Bear Lake

Strategy

- Collect sediment cores from 4 sites over 3 seasons
  - spring, summer, and fall, 2011; summer 2012
- Measure internal P loading under oxic and anoxic conditions
- Measure diel DO concentrations at 2 sites
  - summer 2011; spring and summer 2012


4
3
2
1





Hydrography and TP Concentrations