Phytoplankton and water quality in Milford, Marion, and Keith Sebelius Reservoirs: Results of paleolimnological sediment core and historical data analyses

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Thank you to collaborators!


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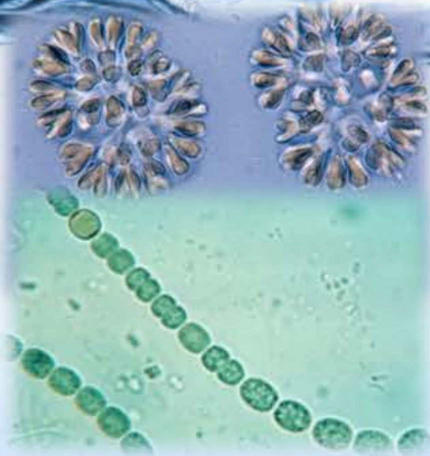
Presentation Roadmap

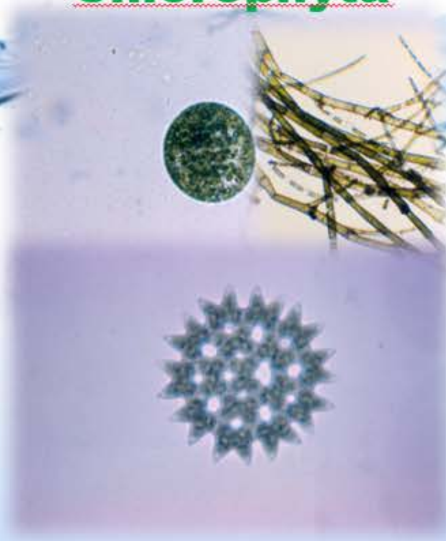
- HABs: Consequences and Causes
- Are HABs increasing?
  - Focus Milford, Marion, and Sebelius
    - Sediment cores – reconstruct history
    - Long-term WQ data
- Summary / Future Directions

Phytoplankton diversity

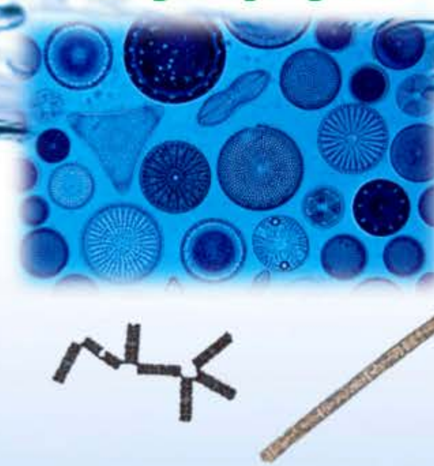
Cyanophyta



Chlorophyta

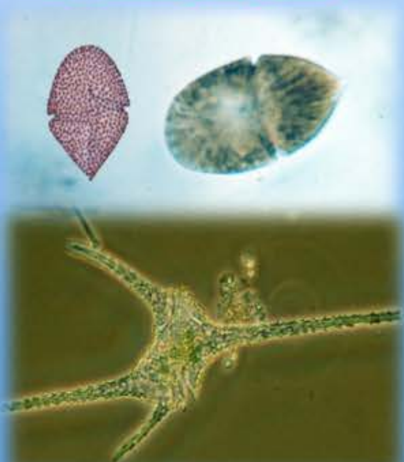


Chrysophyta

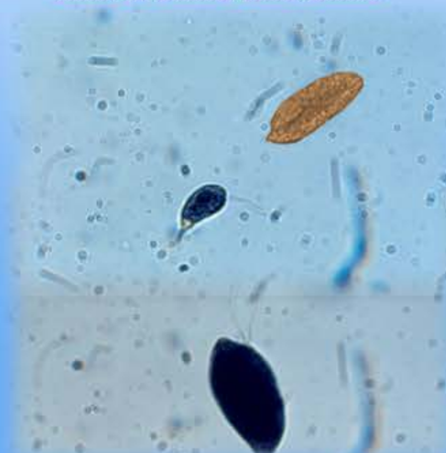


Freshwater groups of “tiny plants”

Pyrrophyta



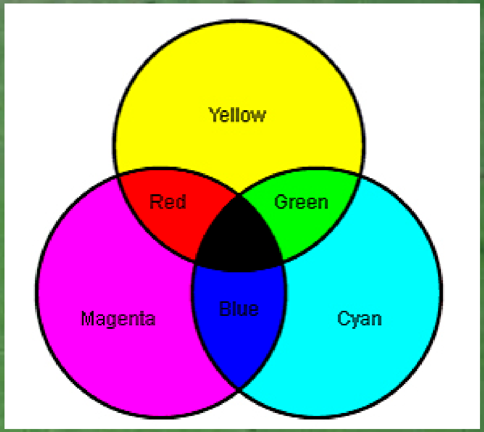
Cryptophyta



Euglenophyta

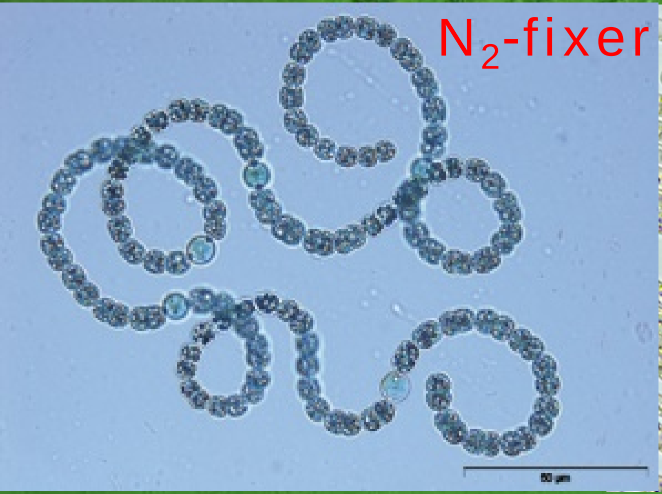
Harmful Algal Blooms (HAB) in KS

- Made of "blue-green" algae (Cyanobacteria)
- *Blue + Green = Cyan*
- Bacteria – but function like algae
- *Can* produce potent toxins (more potent than cobra!)
- *Can* produce taste-and-odor compounds
- But not always (we don't know why)

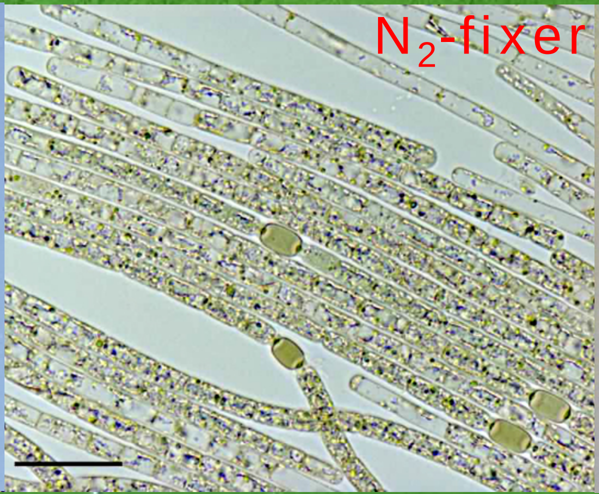


Cyanobacteria diversity

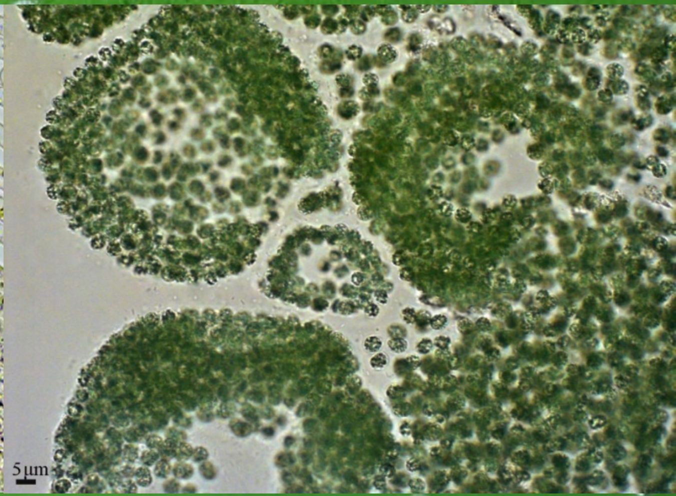
- 2000 - 8000 cyanobacteria species
- Each species has 100s/1000s of strains
- Only some <u>strains</u> capable of toxin/ T&O
- Strain must have gene(s) to produce toxin



Anabaena
<u>Marion</u>
(now *Dolichospermum*)



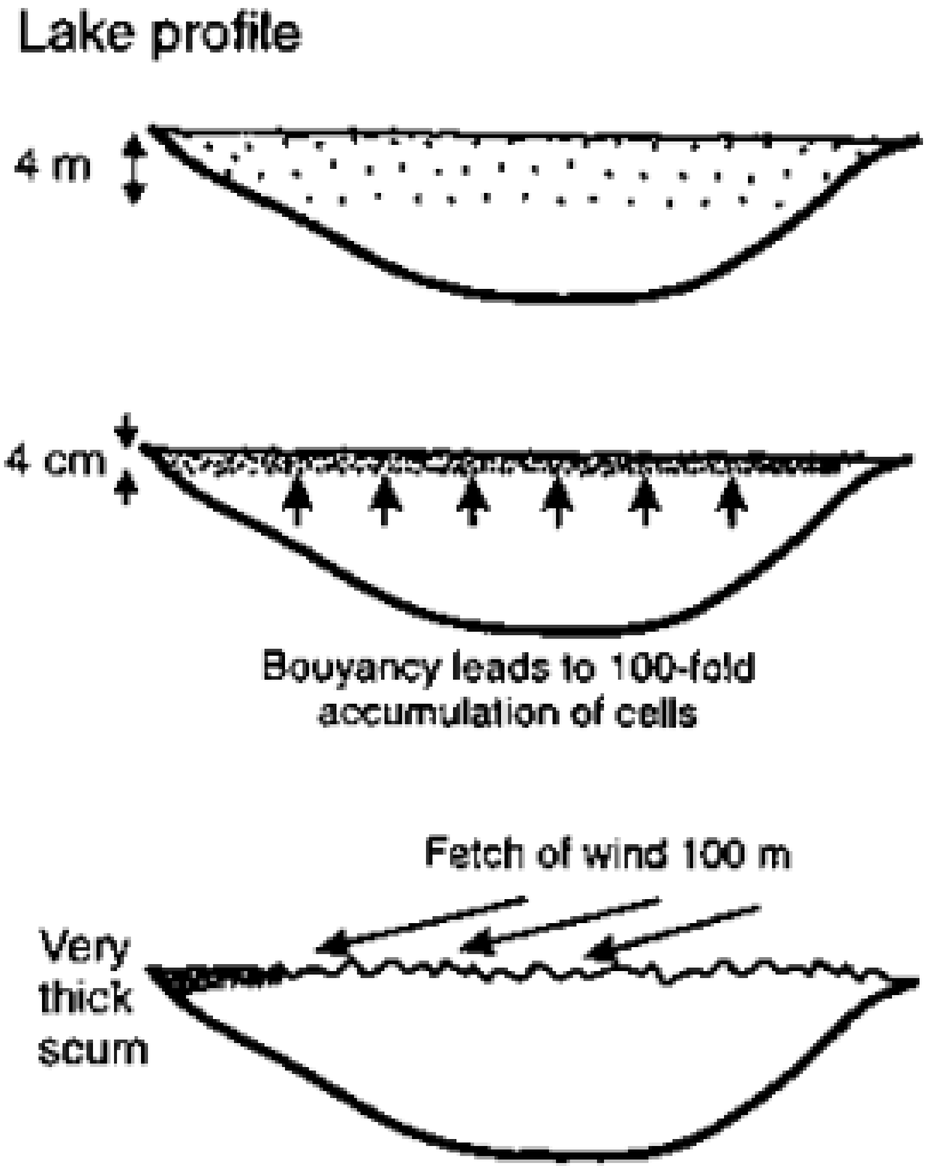
Aphanizomenon
<u>Sebelius</u>
(now *Chrysosporum*)



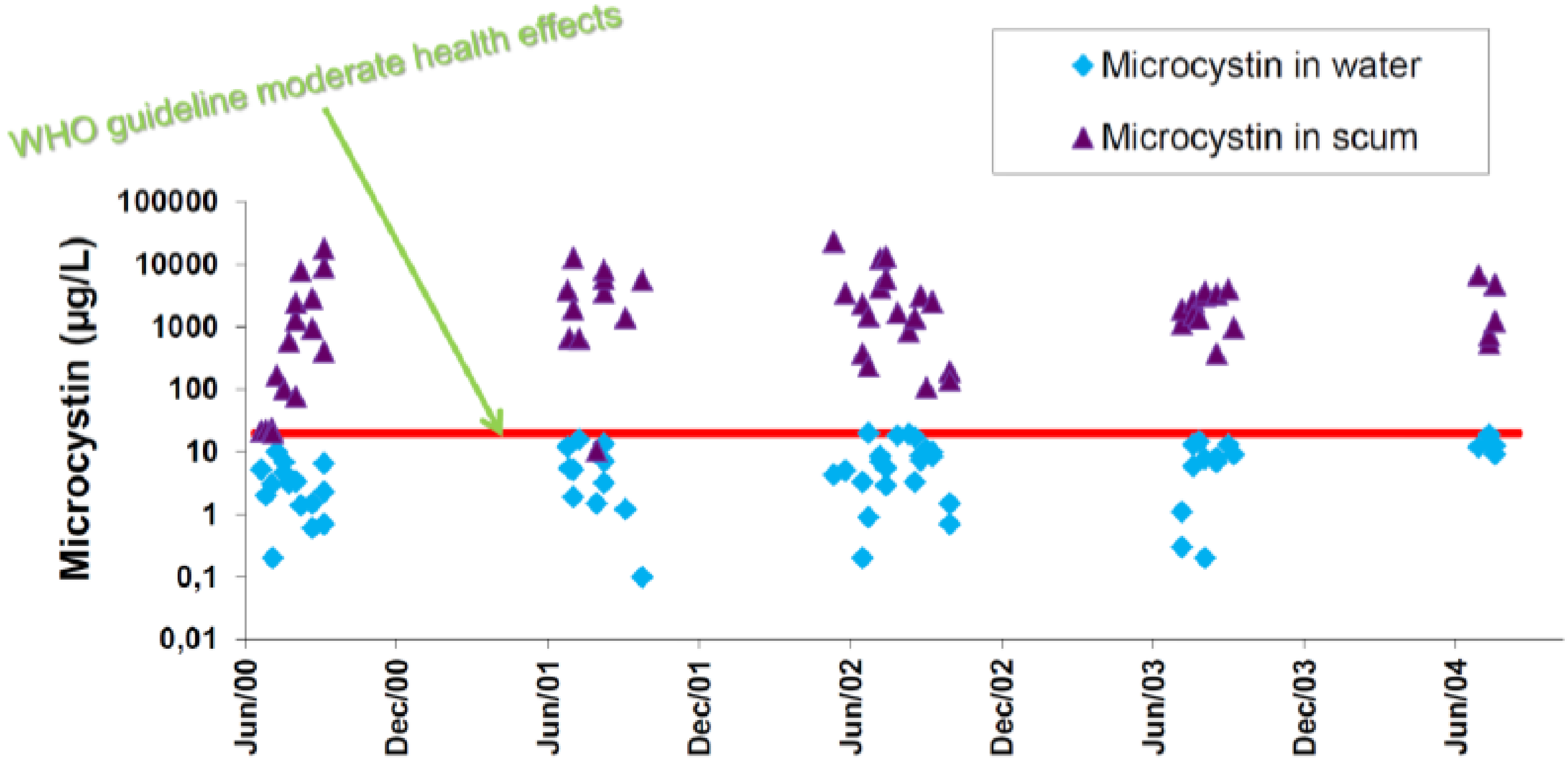
Microcystis
<u>Milford & Marion</u>

Surface scums – Cyano. specialty

Chorus & Bartram 1999

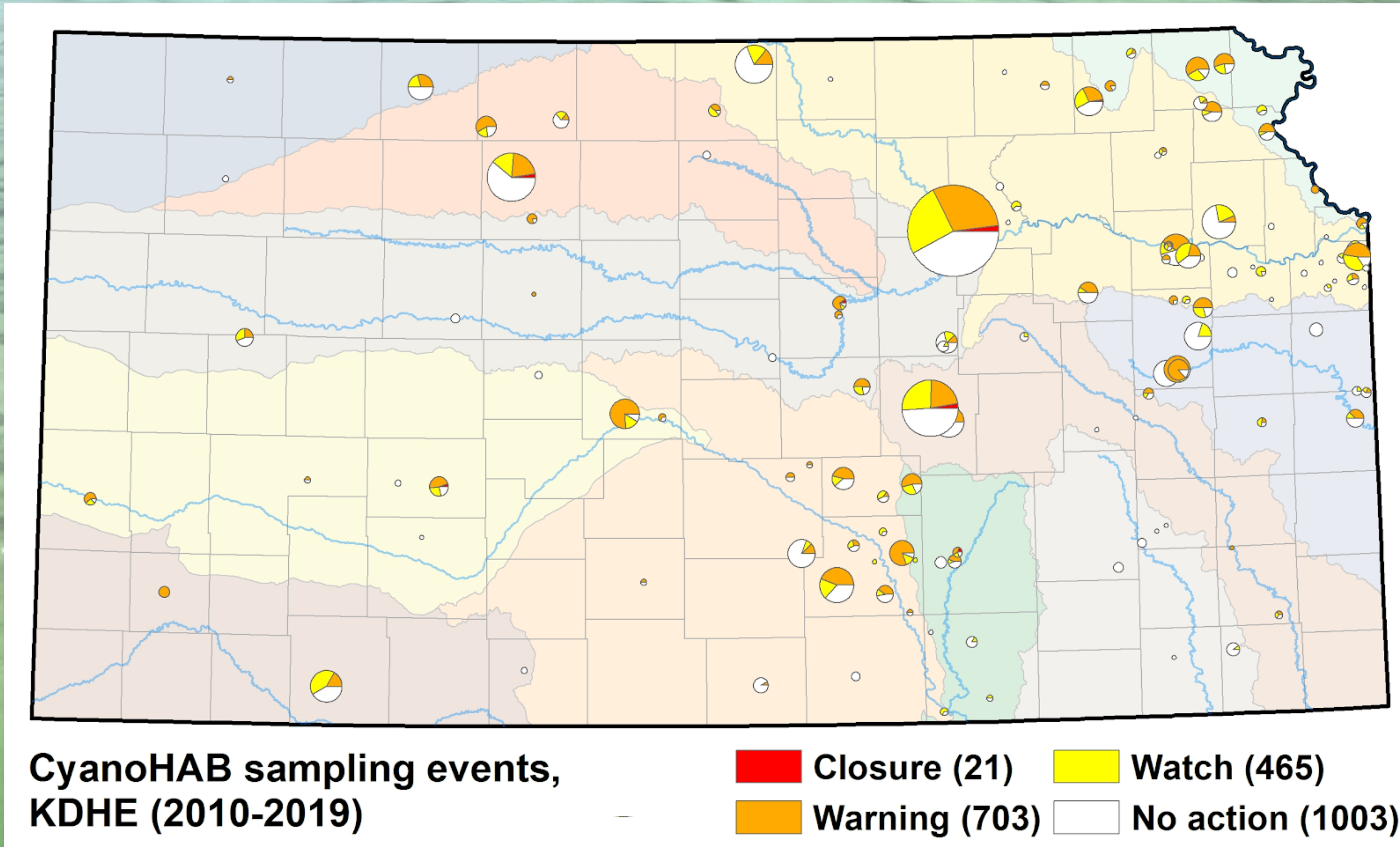


Surface scums – Cyano. specialty



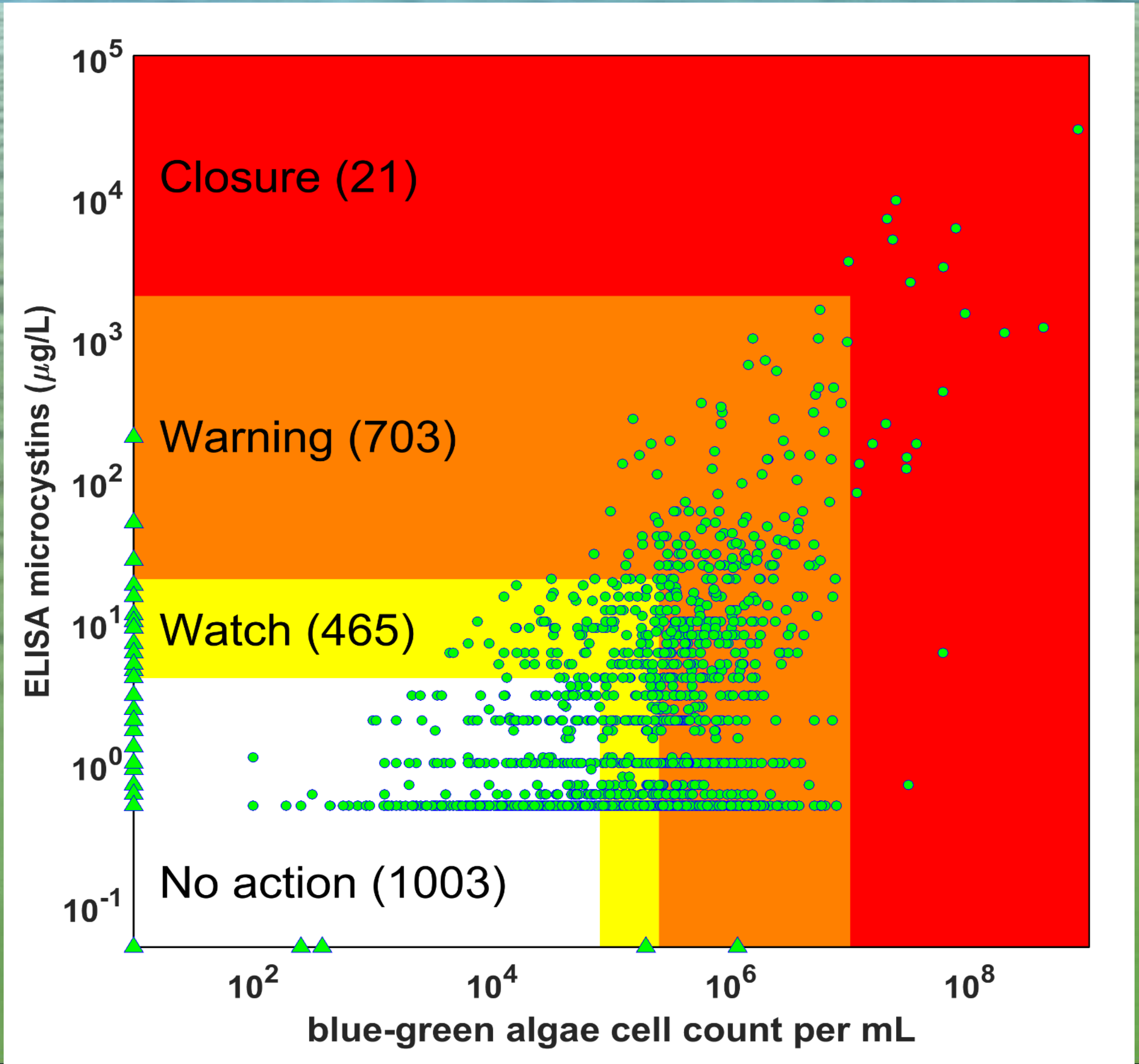
Kardinaal & Visser 2005, Dutch report

Scums are <u>major</u> health hazard



Blooms form under the right conditions

KDHE response data by advisory level 2010-2019



Consequences of Cyano blooms

- Economic
  - Aesthetically unpleasing
  - Foul odors
  - Reservoir closure/warnings

- Ecological
  - Disrupts food webs
    - large, un-nutritious → hard to eat for zoops
  - Harmful to animals & humans

Why? Algal bloom causes

- Remember → algae are tiny plants
- Plants need:
  - Light

  - Nutrients

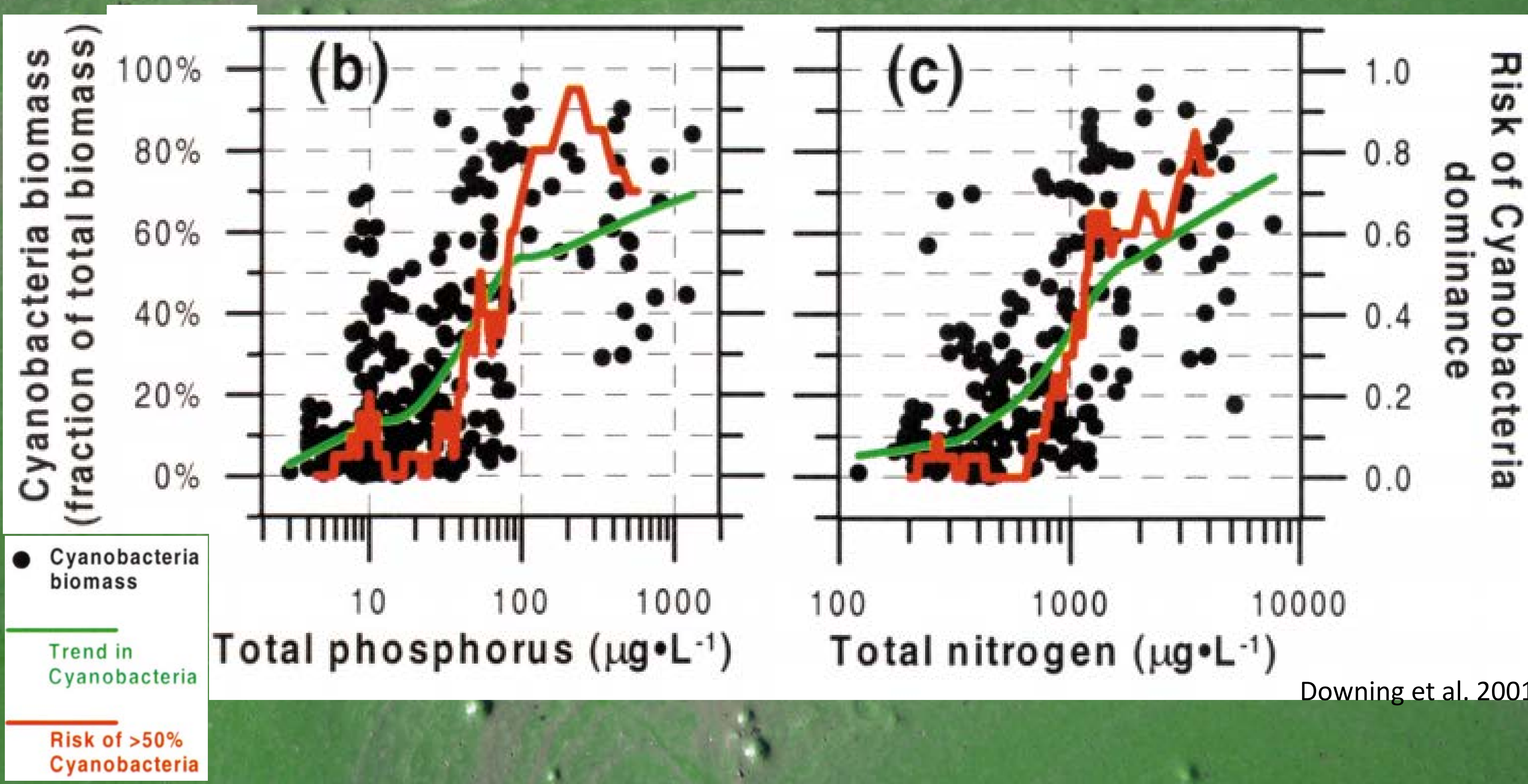
  - Water

- Each group of algae has different adaptations

What favors cyanobacteria?

Why? 2 primary factors

Nutrients = Nitrogen & Phosphorus



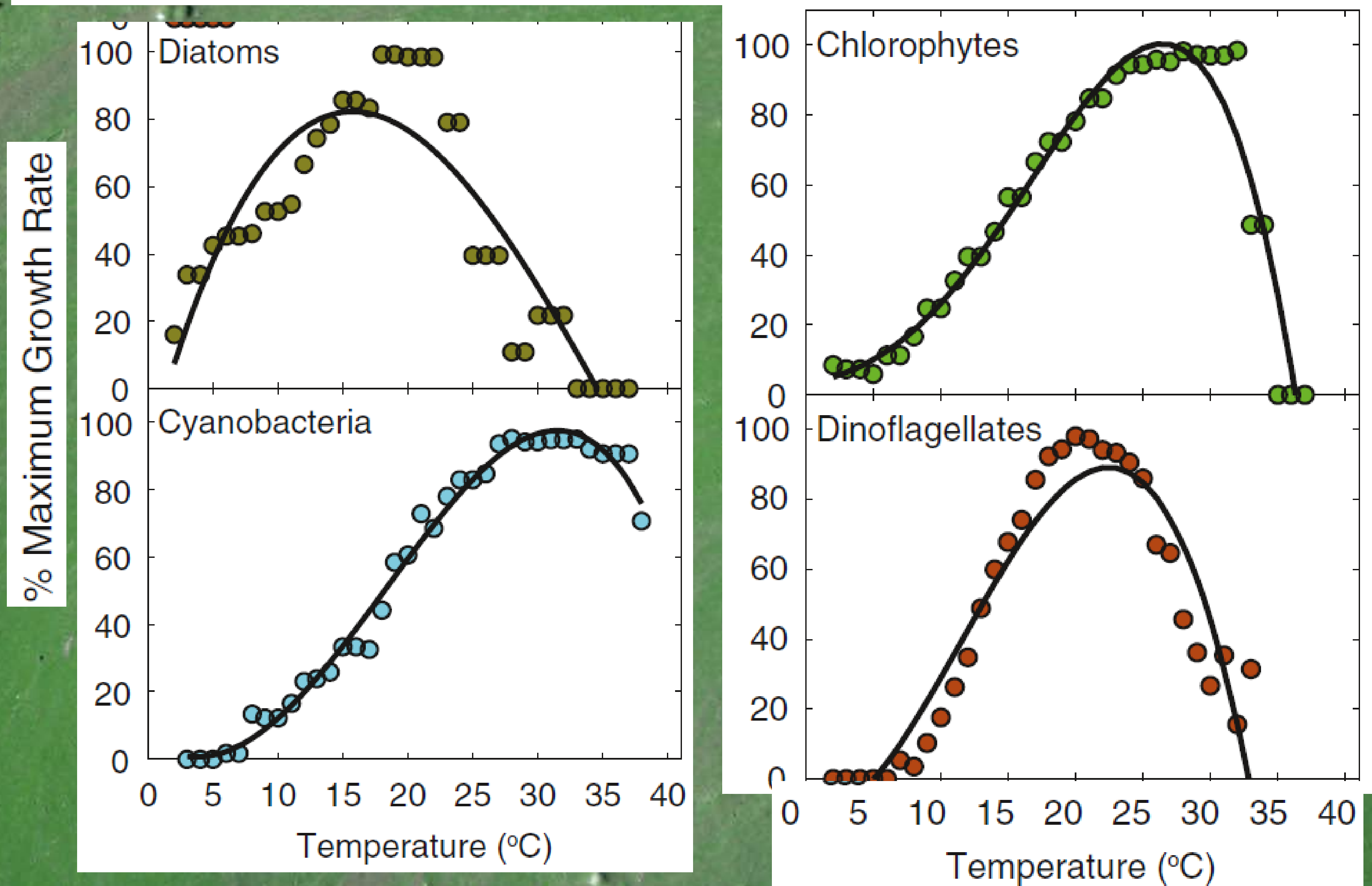
Downing et al. 2001

CLIMATE

Blooms Like It Hot

A link exists between global warming and the worldwide proliferation of harmful cyanobacterial blooms.

Hans W. Paerl[1] and Jef Huisman[2]



Other factors

Low Nitrogen to Phosphorus Ratios Favor Dominance by Blue-Green Algae in Lake Phytoplankton

Val H. Smith

Science, New Series, Vol. 221, No. 4611 (Aug. 12, 1983), 669-671.

N:P

Combined effects of nitrogen to phosphorus and nitrate to ammonia ratios on cyanobacterial metabolite concentrations in eutrophic Midwestern USA reservoirs

Ted D. Harris,[1,2*] Val H. Smith,[1] Jennifer L. Graham,[2] Dedmer B. Van de Waal,[3] Lenore P. Tedesco,[4] Nicolas Clercin[5]

N form

The selective advantage of buoyancy provided by gas vesicles for planktonic cyanobacteria in the Baltic Sea

ANTHONY E. WALSBY, PAUL K. HAYES, ROLF BOJE, LUCAS J. STAL

Float

A novel model for cyanobacteria bloom formation: the critical role of anoxia and ferrous iron

L. A. Molot, S. B. Watson, I. F. Creed, C. G. Trick, S. K. McCabe, M. J. Verschoor, R. J. Sorichetti, C. Powe, J. J. Venkiteswaran, S. L. Schiff

Iron?

Others: luxury N+P uptake & storage, pesticides/herbicides, adapt to hi/lo light...


Most Kansas waterbodies:
Have plenty of nutrients
Although nutrient reduction helps!
Get hot in summer

Why Now?

Cyano blooms always there?

But only noticing them now?

Are cyano blooms increasing?

Blooms anomaly or pattern?

What is long-term trajectory of systems?

Detecting long-term change

2 methods

Sediment cores

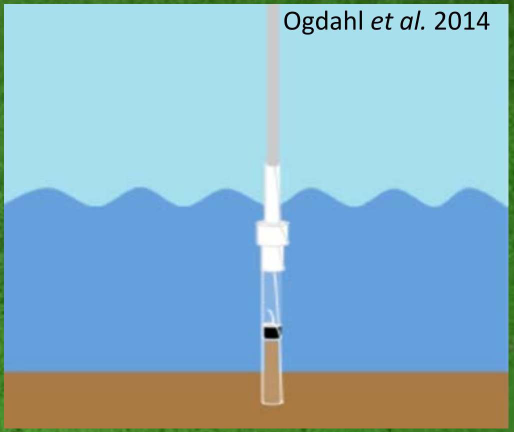
Historical reconstruction using sediments

Compile collected WQ data

Combine data from different agencies

Sediment coring

- Cores – like tree rings
- Integrated historical record of WQ (& HABs!)



Ogdahl *et al.* 2014

Reservoirs for Cores + Data

Milford (FY18)

- Large toxic blooms since 2011
- Multiple reservoir closures

Marion (FY19)

- Large toxic blooms since 2003
- Multiple reservoir closures

Sebelius (Norton - FY19)

- Several recent 2-3 week-long blooms
- Blooms since 2014 – unknown pre-2014

Focus of Results Presented

Each reservoir presented individually

Sediment cores:

- Sediment dating + mixing ($^{239+240}Pu$)
- Sediment nutrients (TN & TP)
- Terrestrial plants or algae? (Isotopes)
- Toxigenic taxa present? (eDNA)
- Algal pigments: Differ by algal groups

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Focus of Results Presented

Combined WQ data to impoundment

- -WQ Data from KDHE, USACE, USGS
- -Data on Nutrients, Algal Counts, & %Cyano
- -Data from multiple sites
- -High Freq. data

Land use data from watersheds

- -From Cropland Data Layers (USDA NASS)

Focus of Results Presented

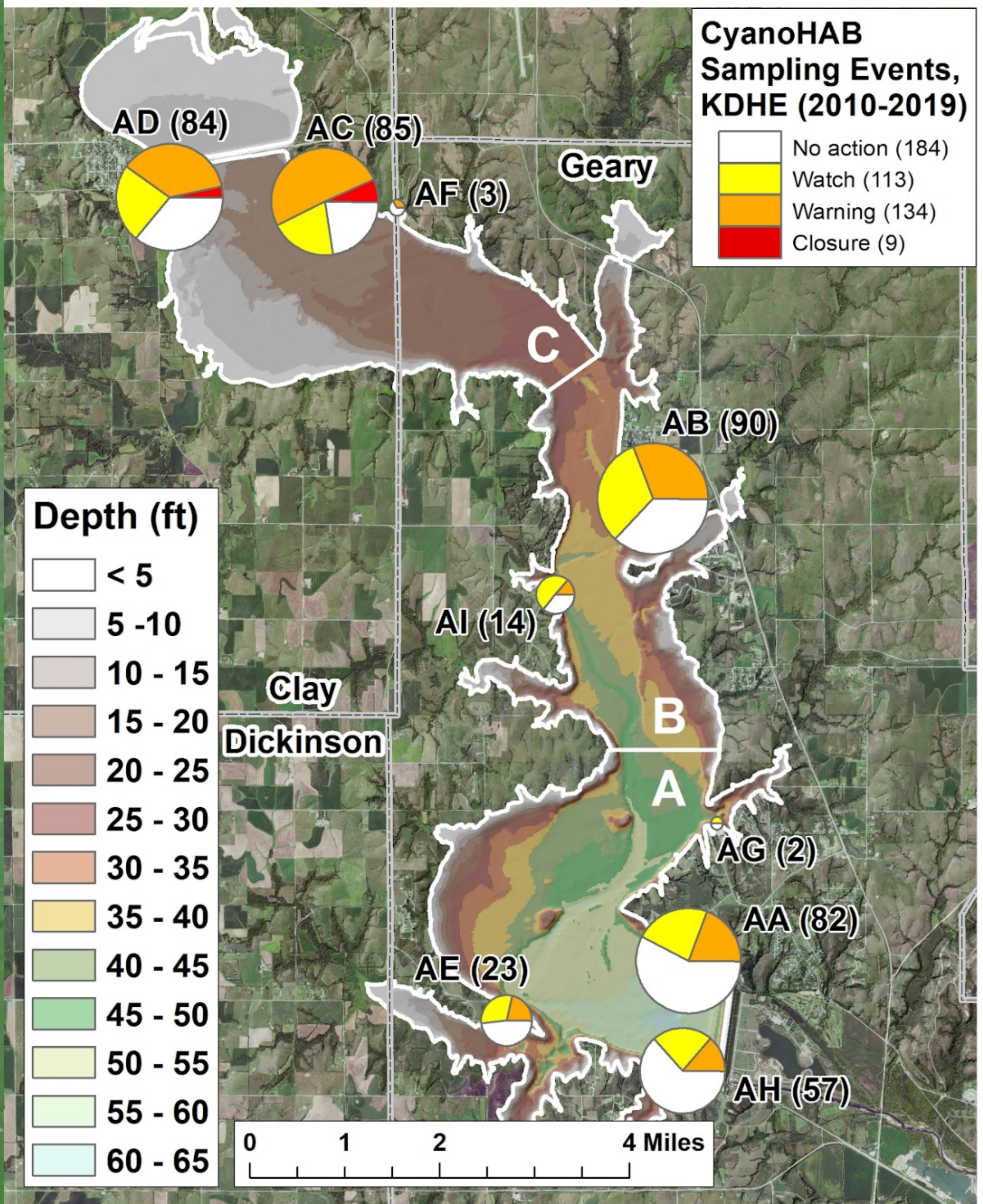
Combined WQ data to impoundment

- WQ Data from KDHE, USACE, USGS
- Near-Dam Nutrients, Algal Counts, & %Cyano
- Data from multiple sites
- High Freq. data

Land use data from watersheds

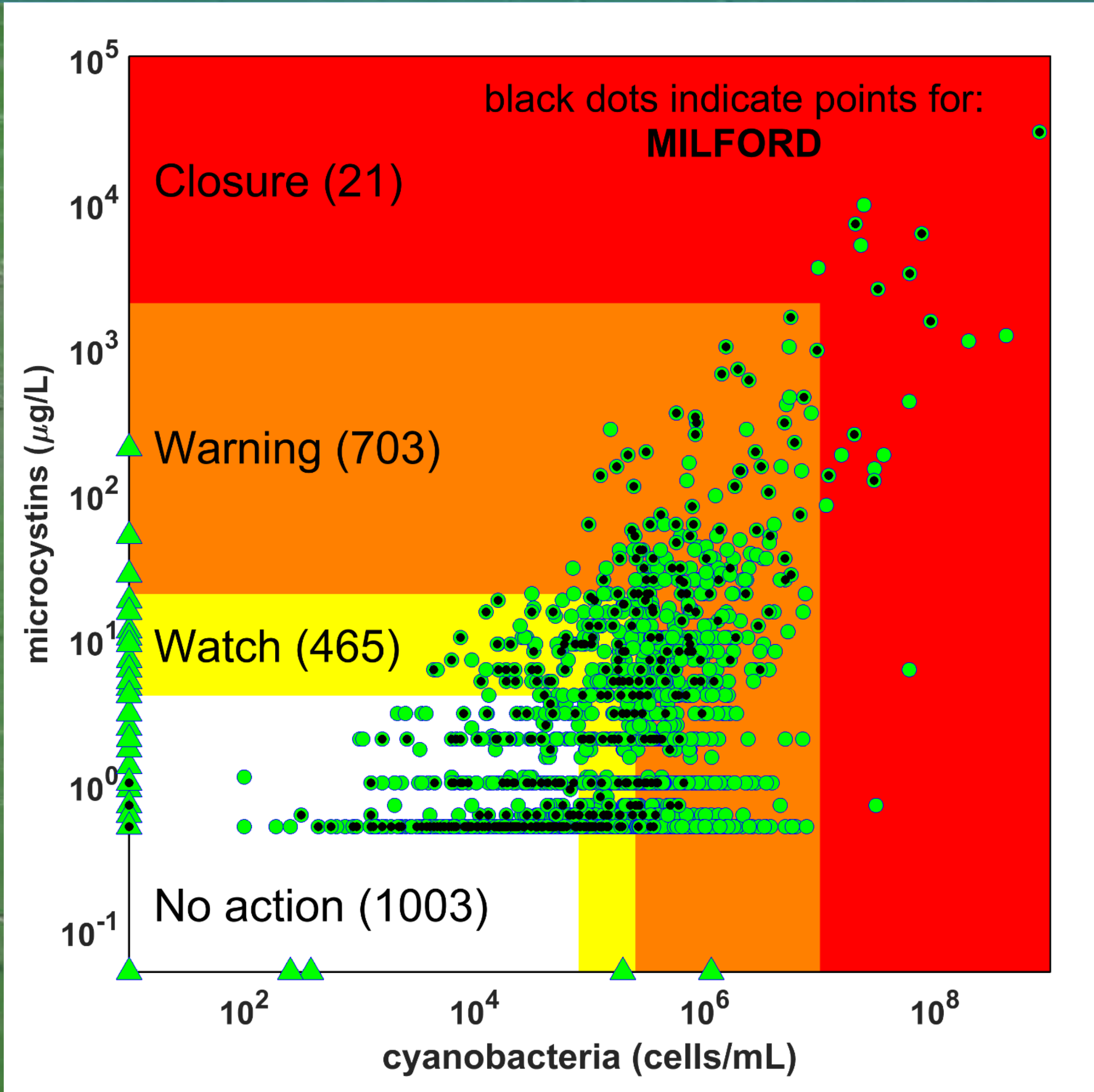
- From Cropland Data Layers (USDA NASS)

Milford



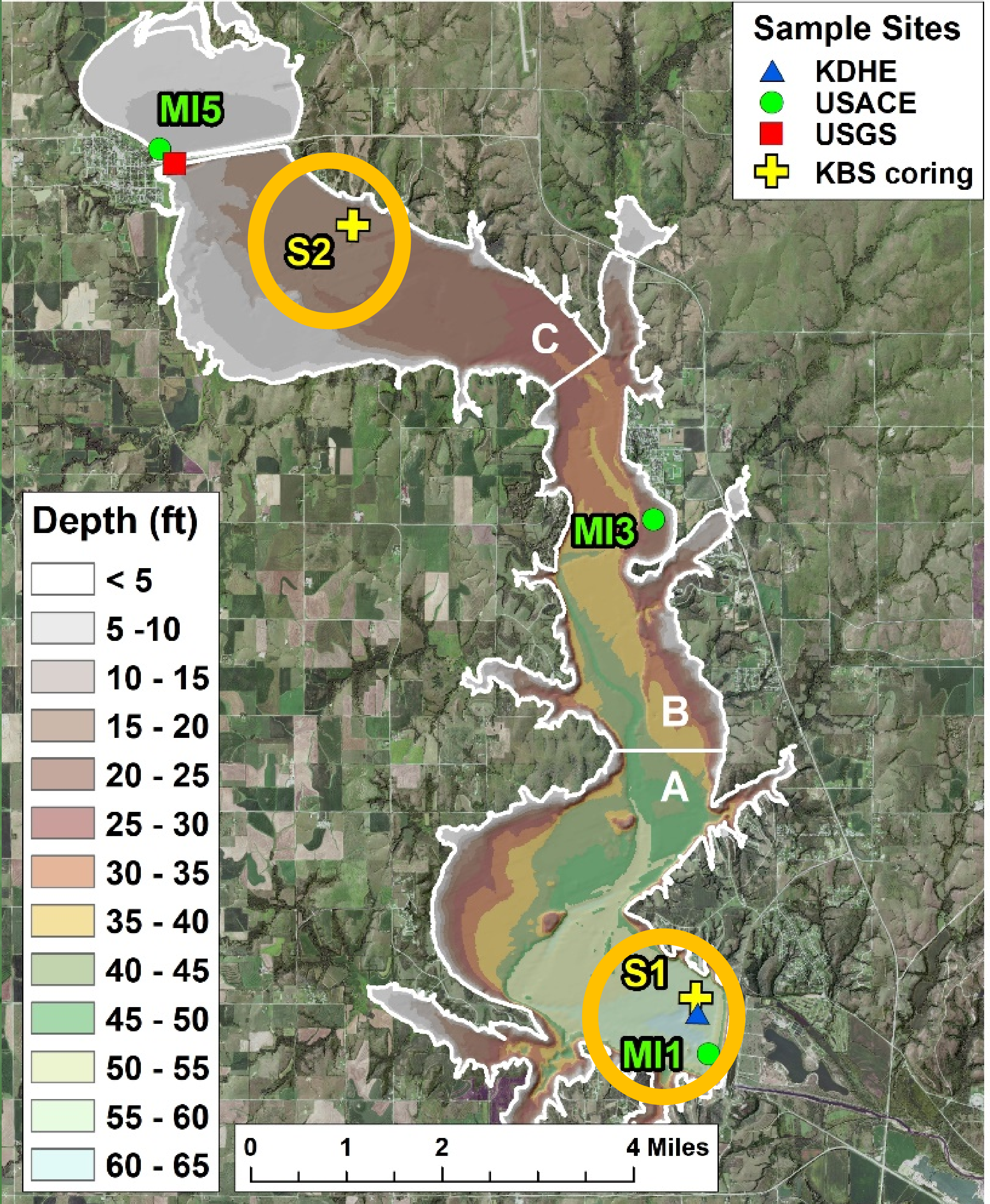
CyanoHAB Sampling Events, KDHE (2010-2019)
No action (184)
Watch (113)
Warning (134)
Closure (9)
AD (84)
AC (85)
AF (3)
Geary
C
AB (90)
AI (14)
Clay
Dickinson
B
A
AG (2)
AA (82)
AE (23)
AH (57)
Depth (ft)
< 5
5 -10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
50 - 55
55 - 60
60 - 65
0
1
2
4 Miles

KDHE response data by advisory level 2010-2019

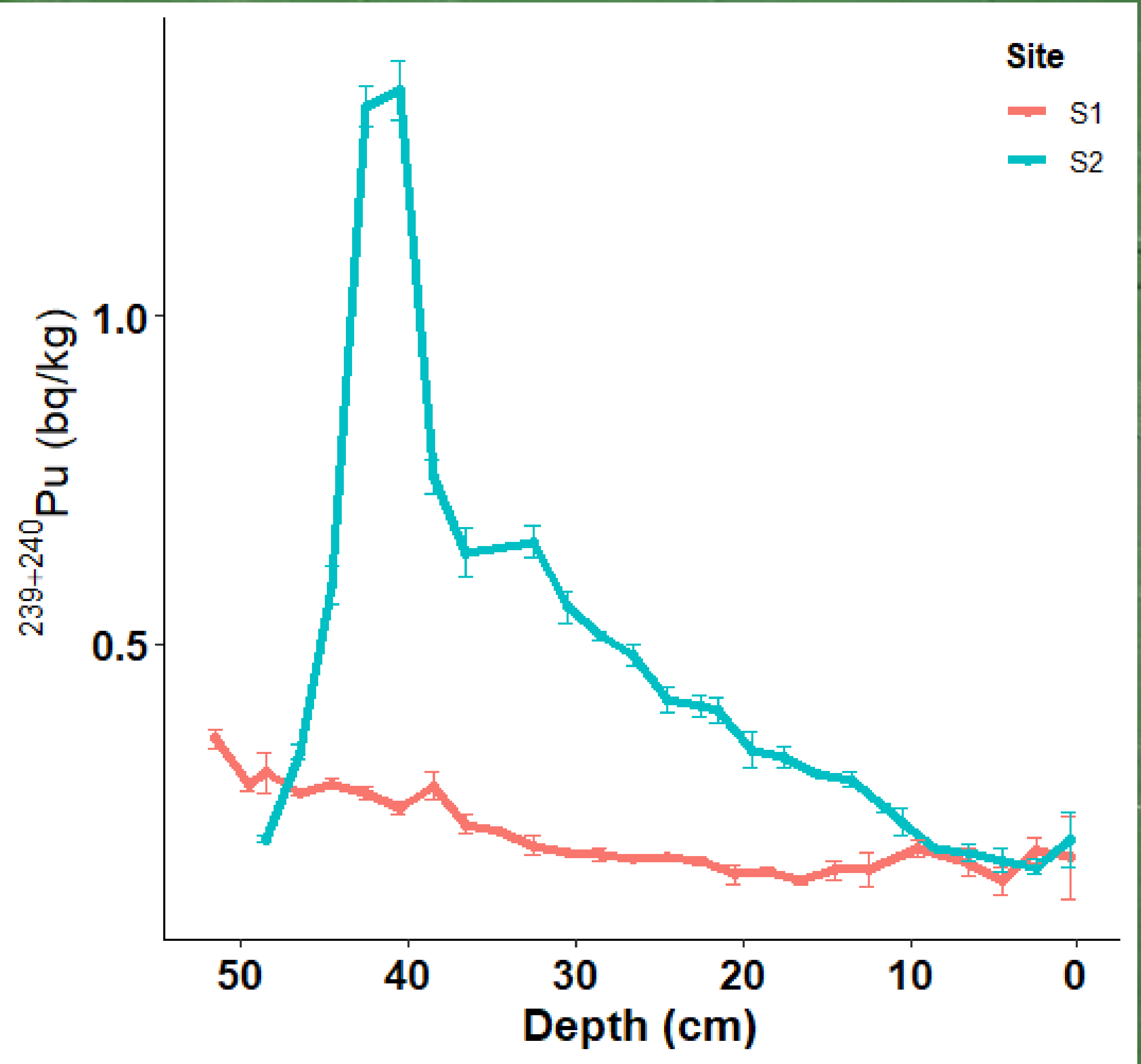


Milford: Sediment coring

Data Presented Here



Milford Cores: Date + Mixing

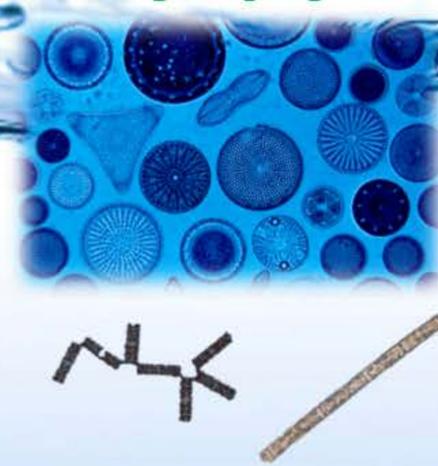


Algal Diversity

Cyanophyta

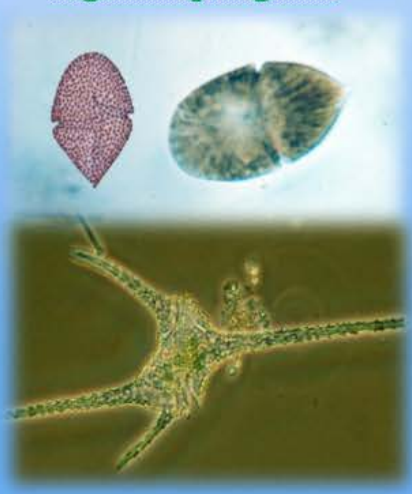
Chlorophyta

Chrysophyta

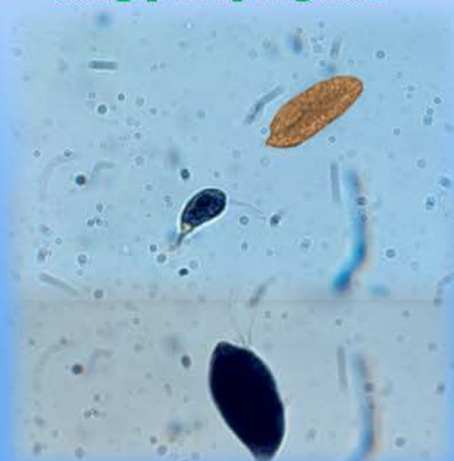


Freshwater groups of “tiny plants”

Pyrrophyta

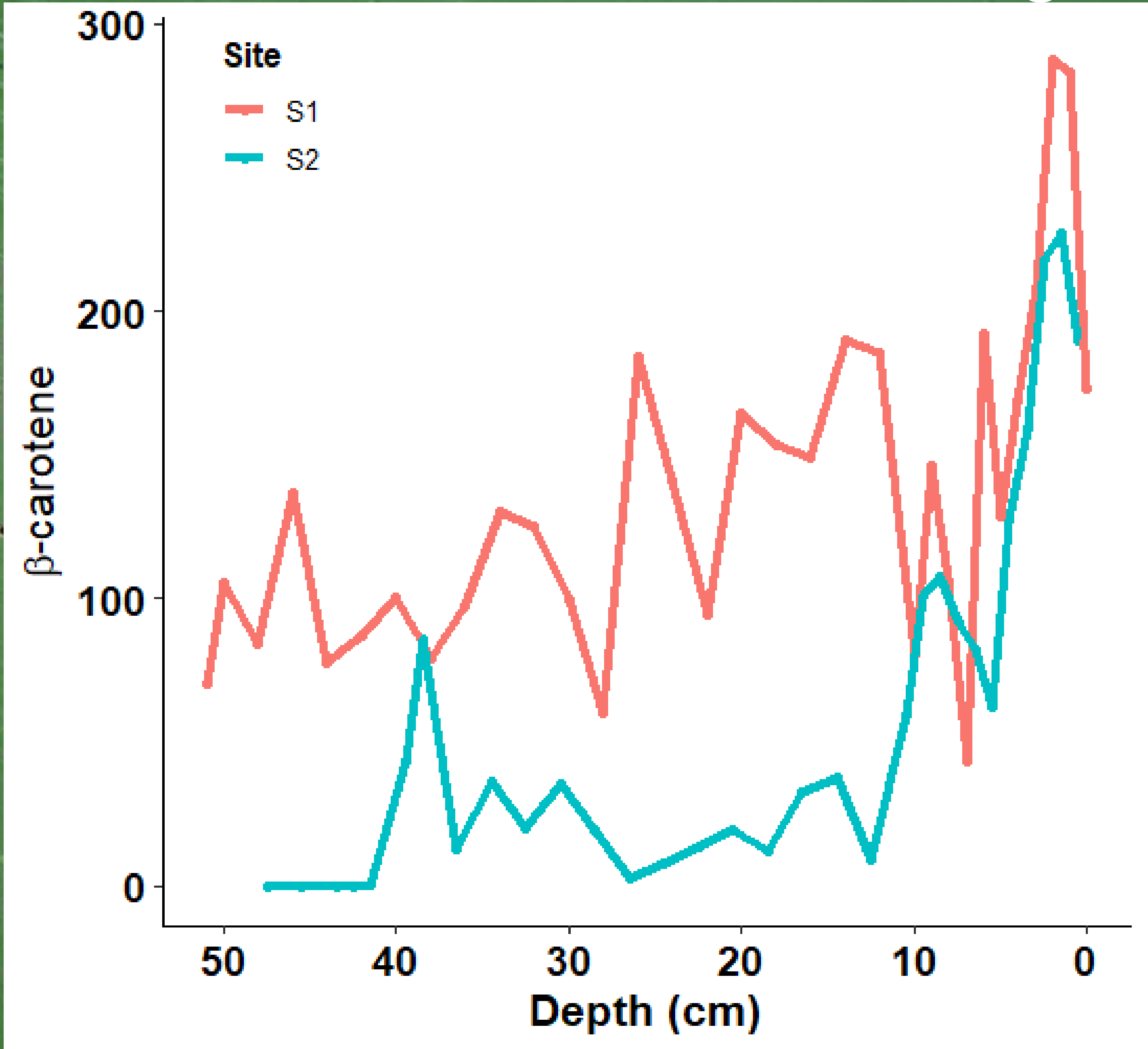


Cryptophyta

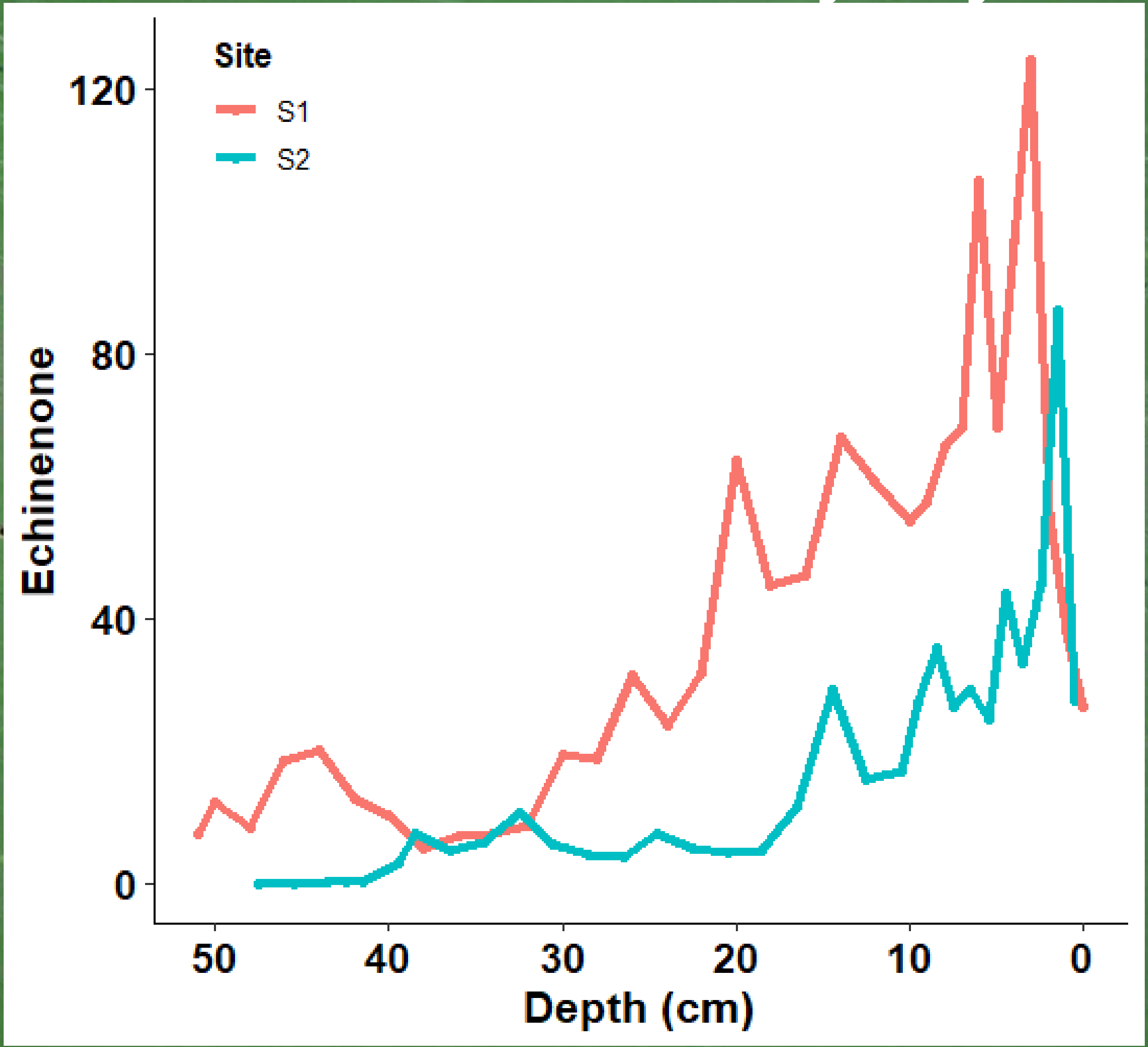


Euglenophyta

Milford Cores: Total algae



Milford Cores: Only Cyano



Pigments are not water soluble and cannot be transformed in sediment

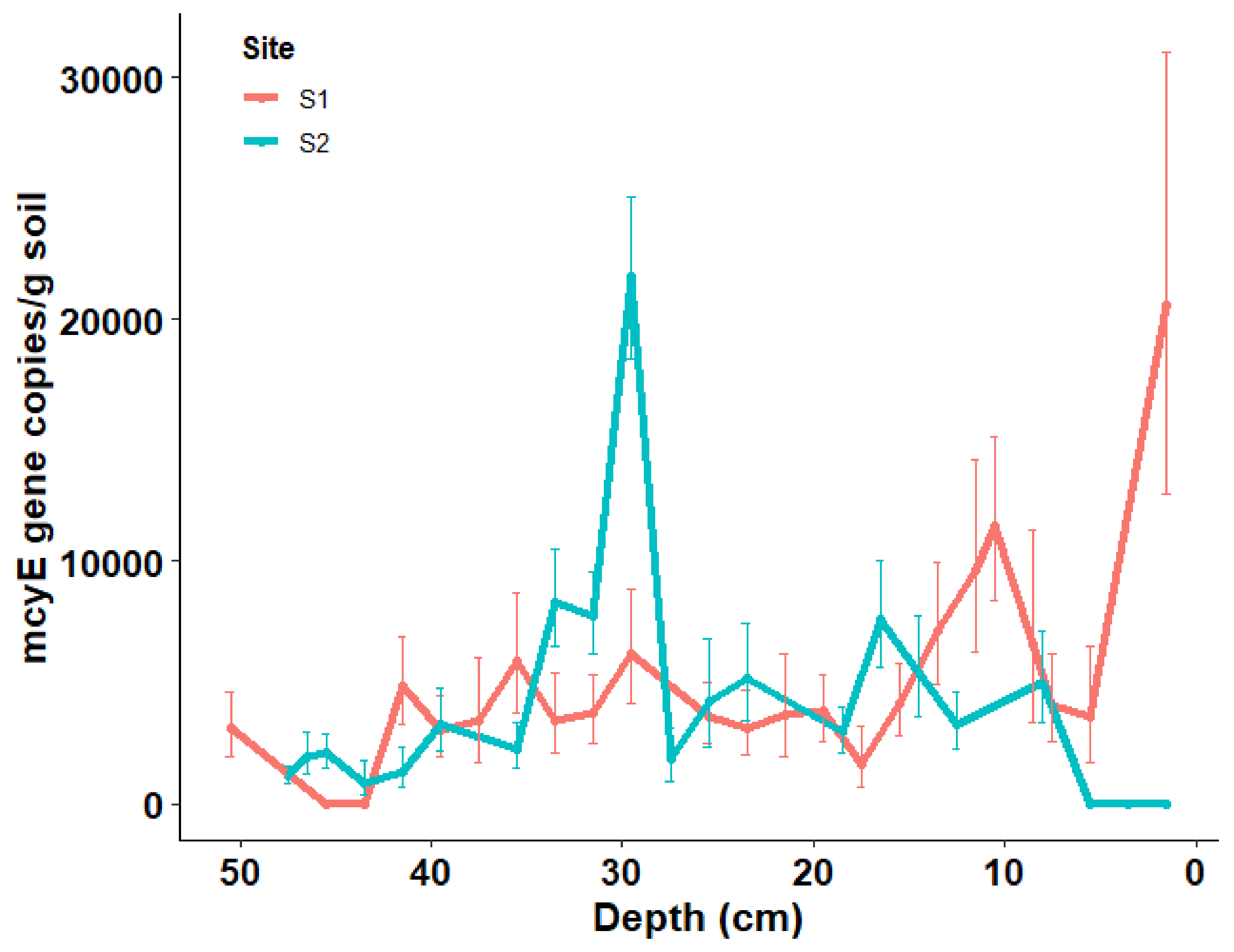
→Stable marker of past

eDNA can degrade in sediment

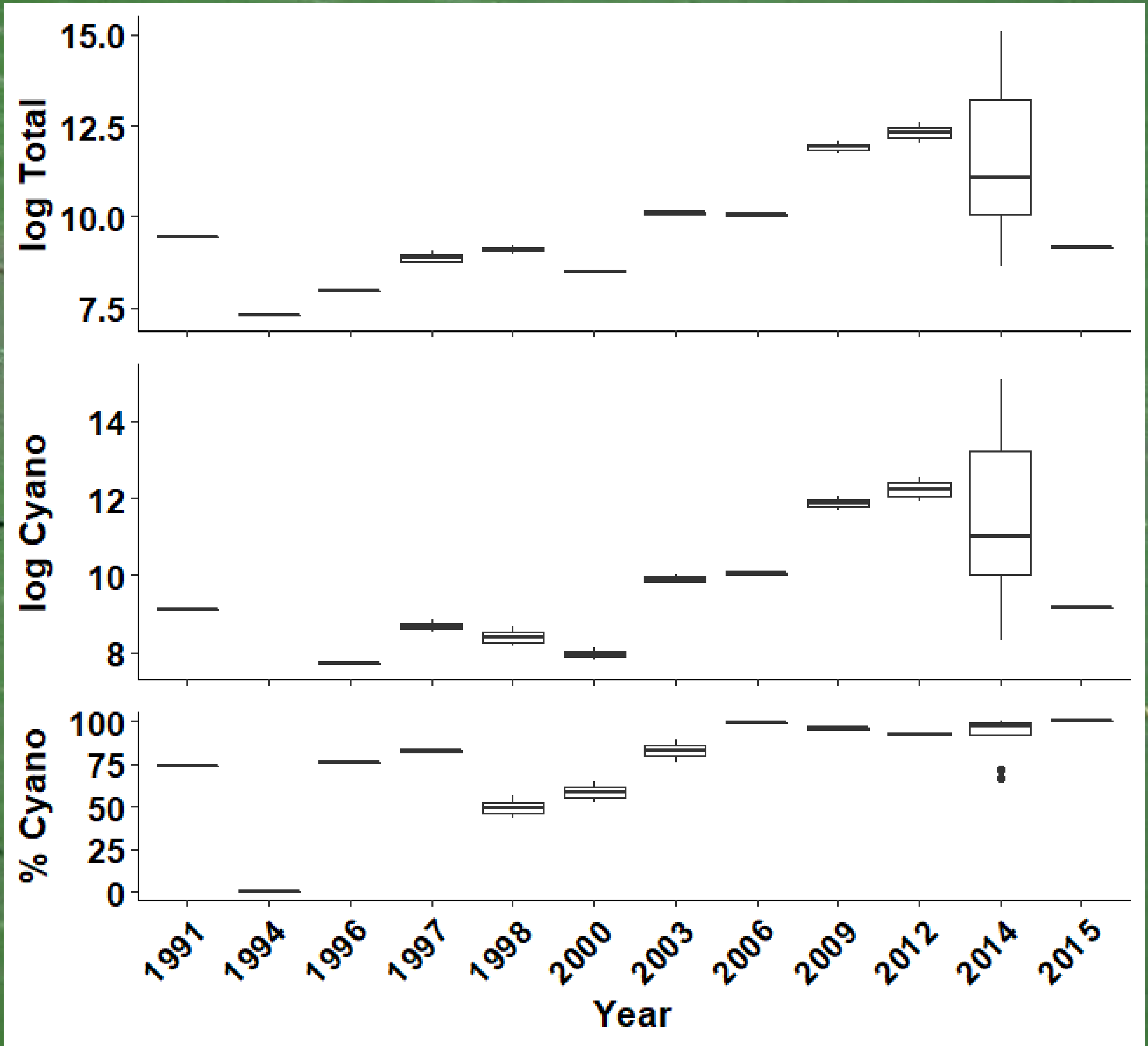
→Can be un-stable marker of past

Presence = Presence
Absence = Absence OR degradation

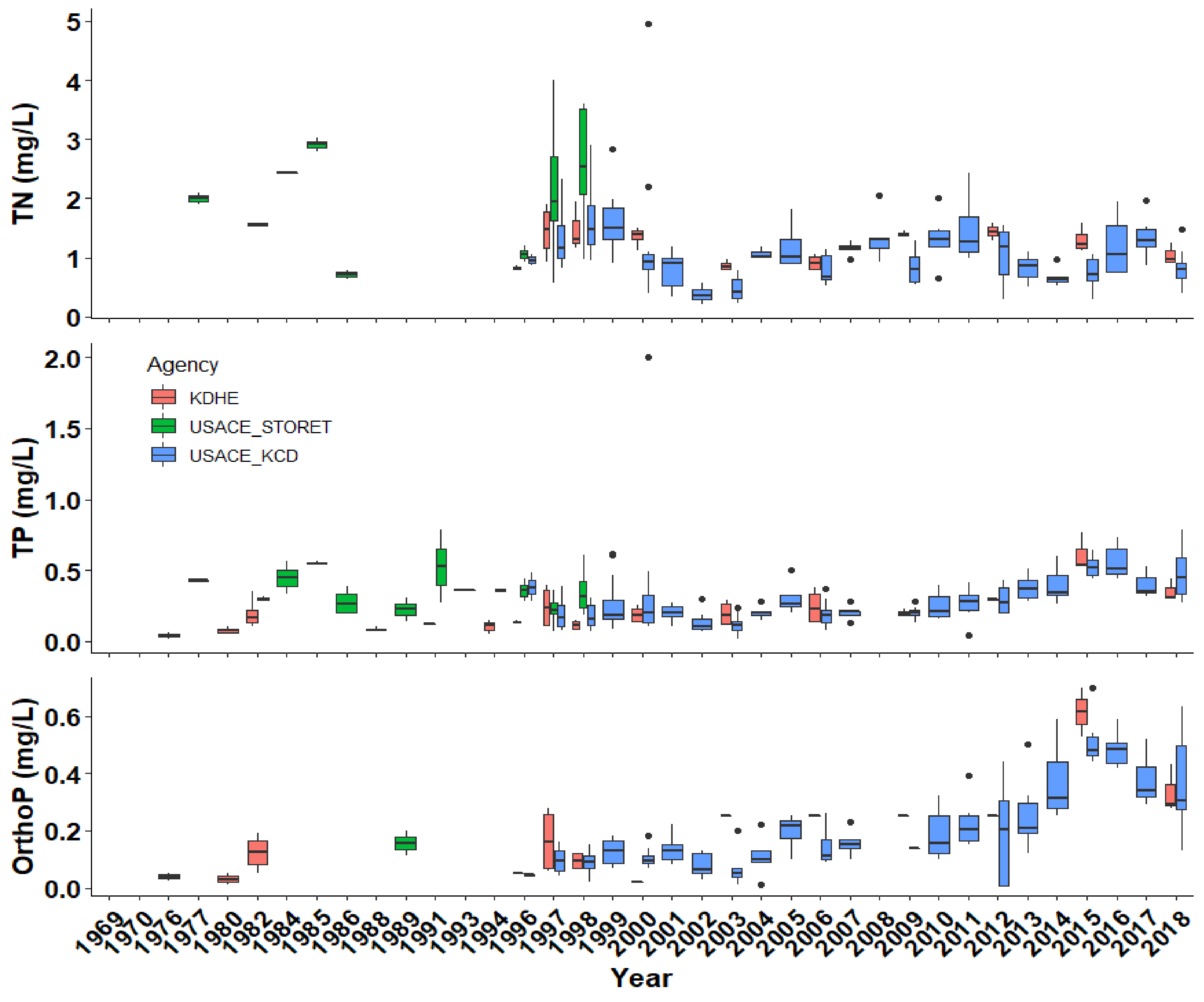
Milford Cores: eDNA toxic genes



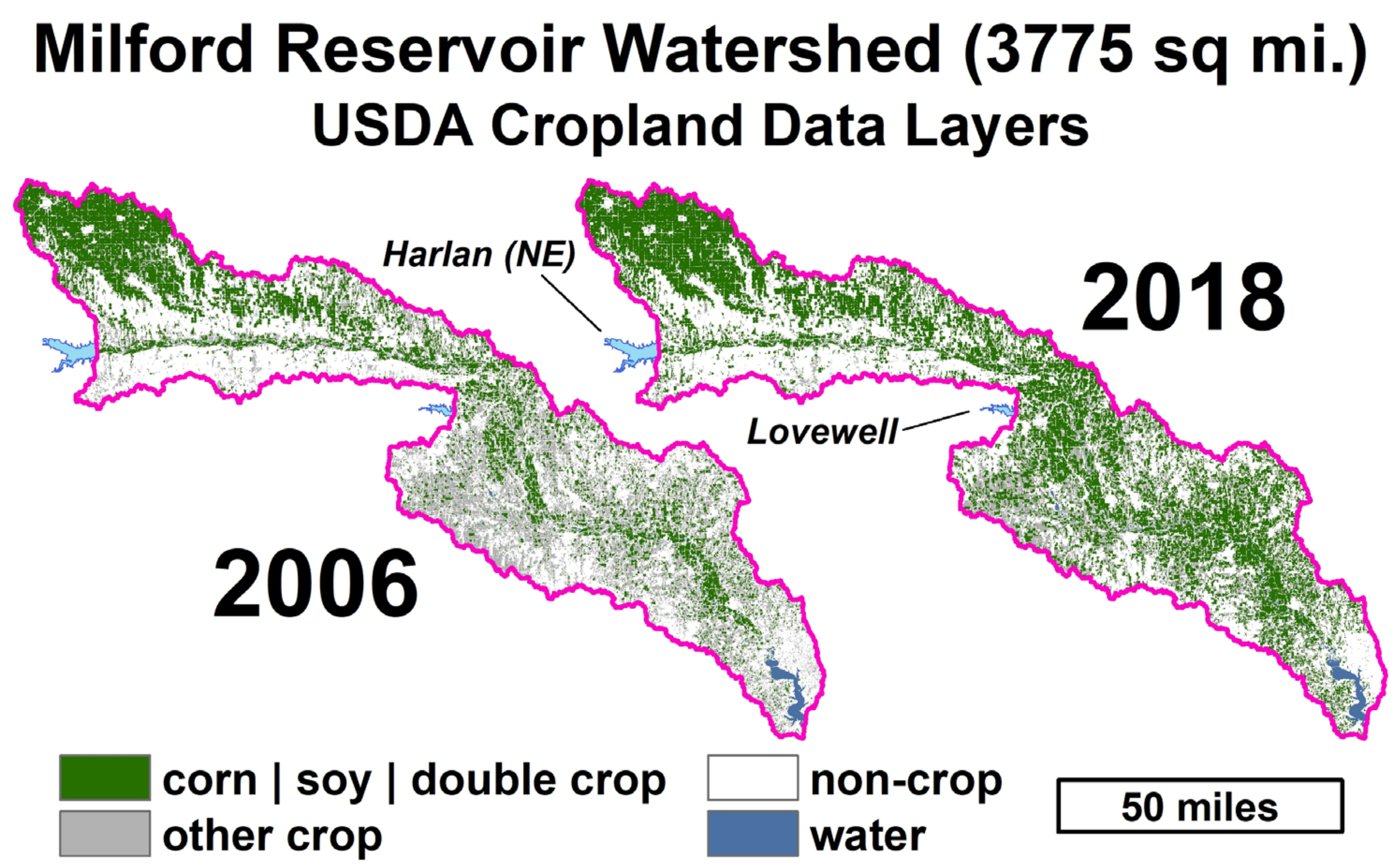
Milford KDHE: Algal counts



Milford WQ Data: Nutrients



Milford Watershed Land Use



Milford Cores + Data Summary

Pu date S2 at impoundment - little sed. mixing

eDNA shows toxic cyano there since impound

Pigments show total phyto and cyano incr.

Discrete phyto data show total and cyano incr.

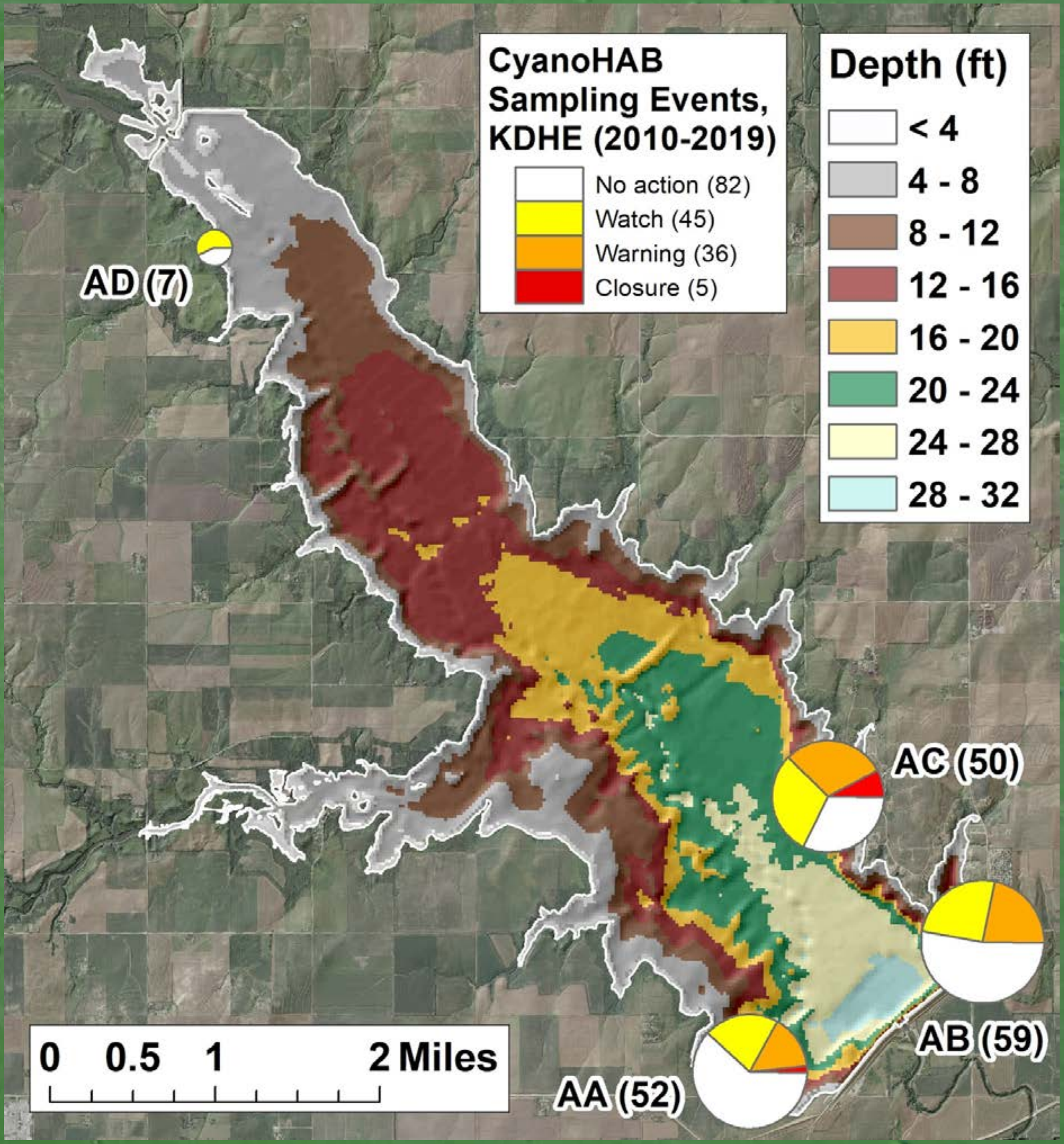
Discrete WQ data show P incr. but N consistent

Cores + data show change in early 2000s

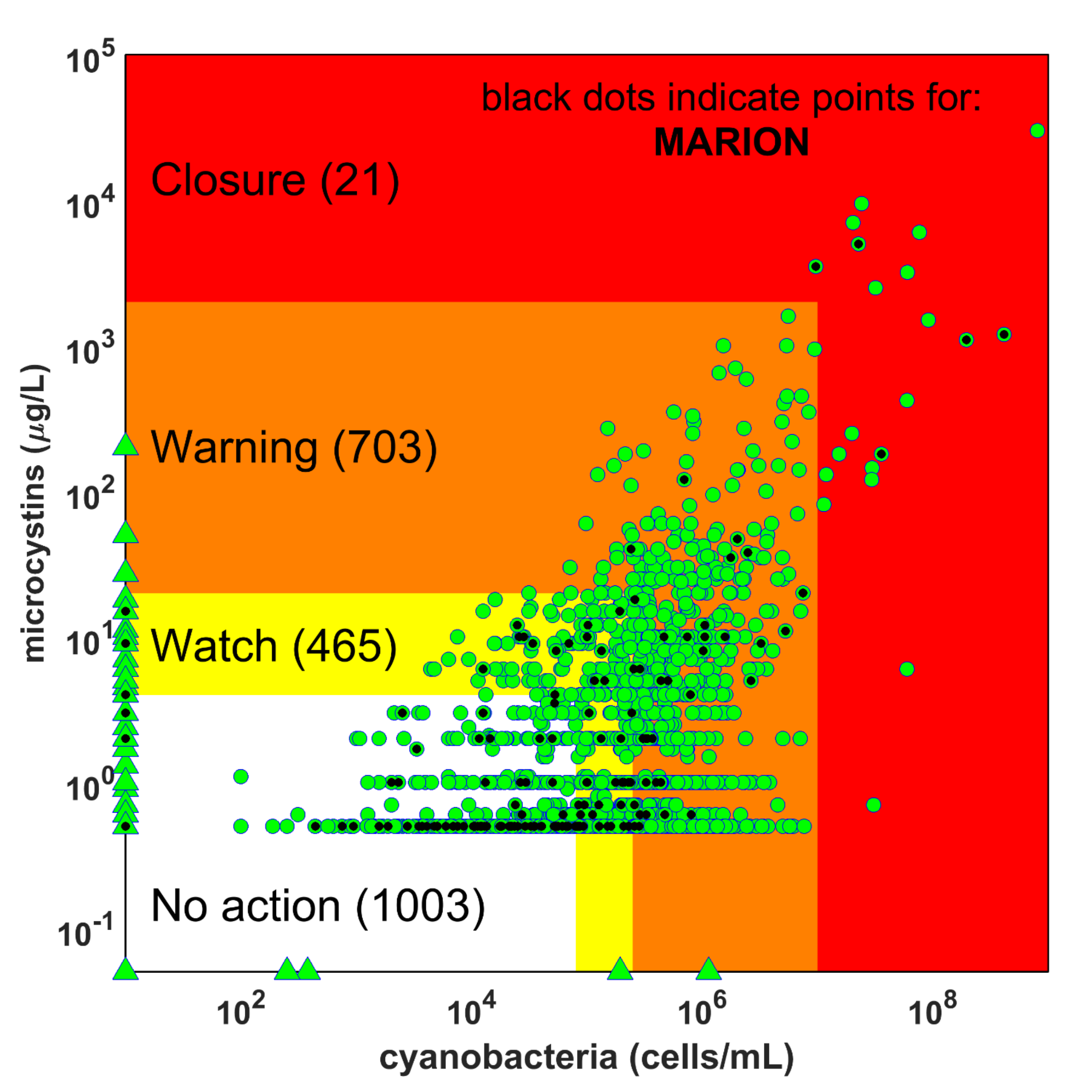
Land use changing to more corn & soy

Incr. P seems to drive incr. cyano

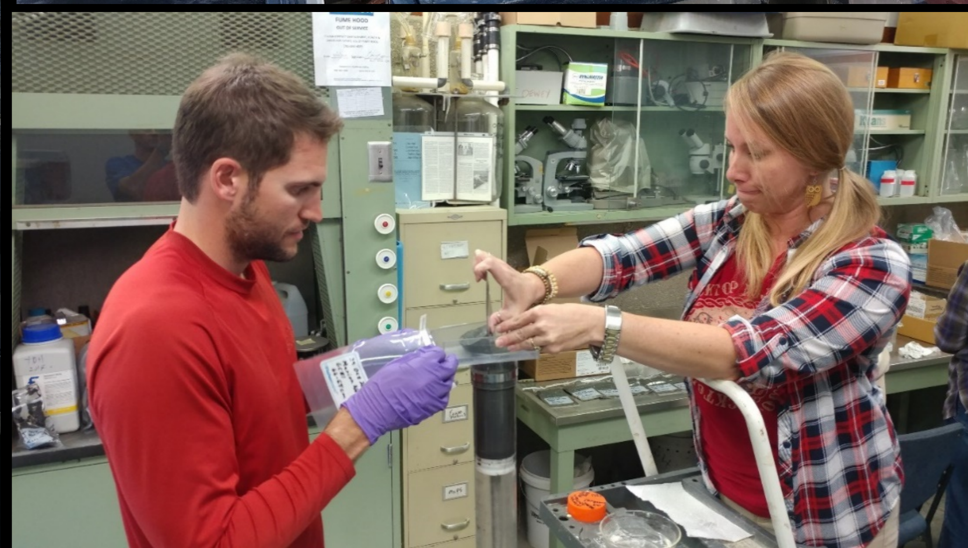
Marion

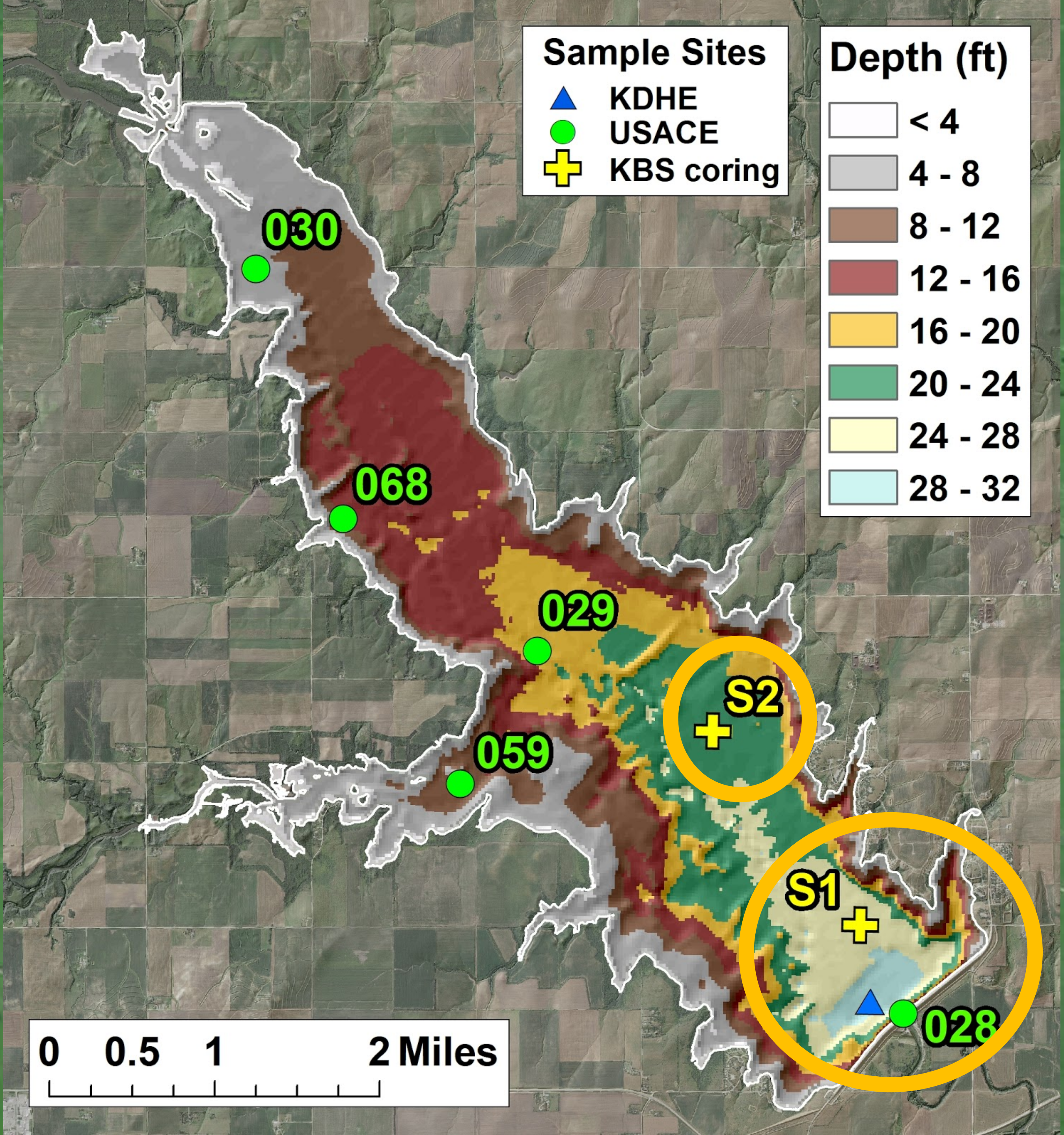

CyanoHAB
Sampling Events,
KDHE (2010-2019)
No action (82)
Watch (45)
Warning (36)
Closure (5)
Depth (ft)
< 4
4 - 8
8 - 12
12 - 16
16 - 20
20 - 24
24 - 28
28 - 32
AD (7)
AC (50)
AB (59)
AA (52)
0 0.5 1 2 Miles

KDHE response data by advisory level 2010-2019

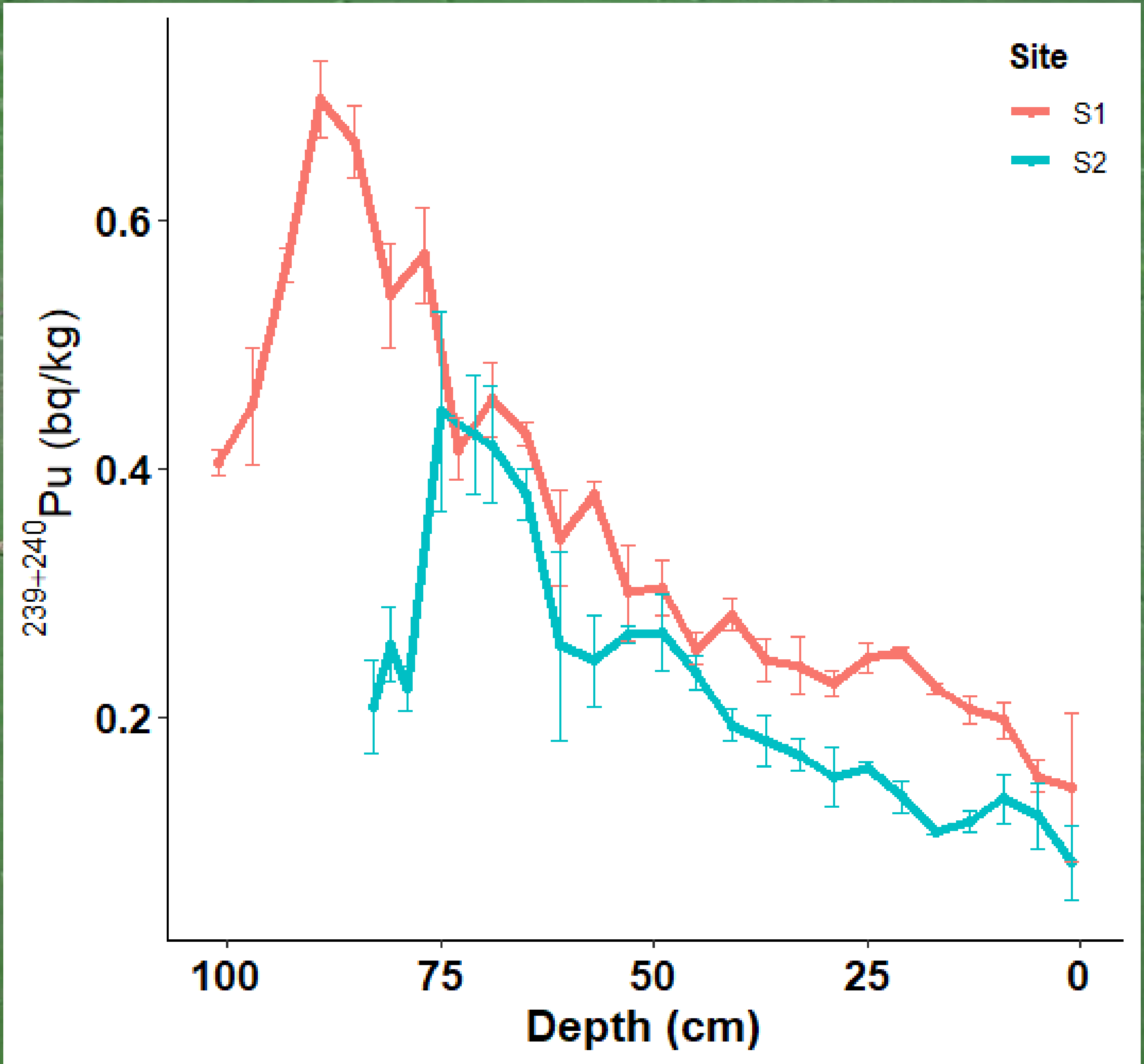


Marion: Sediment coring

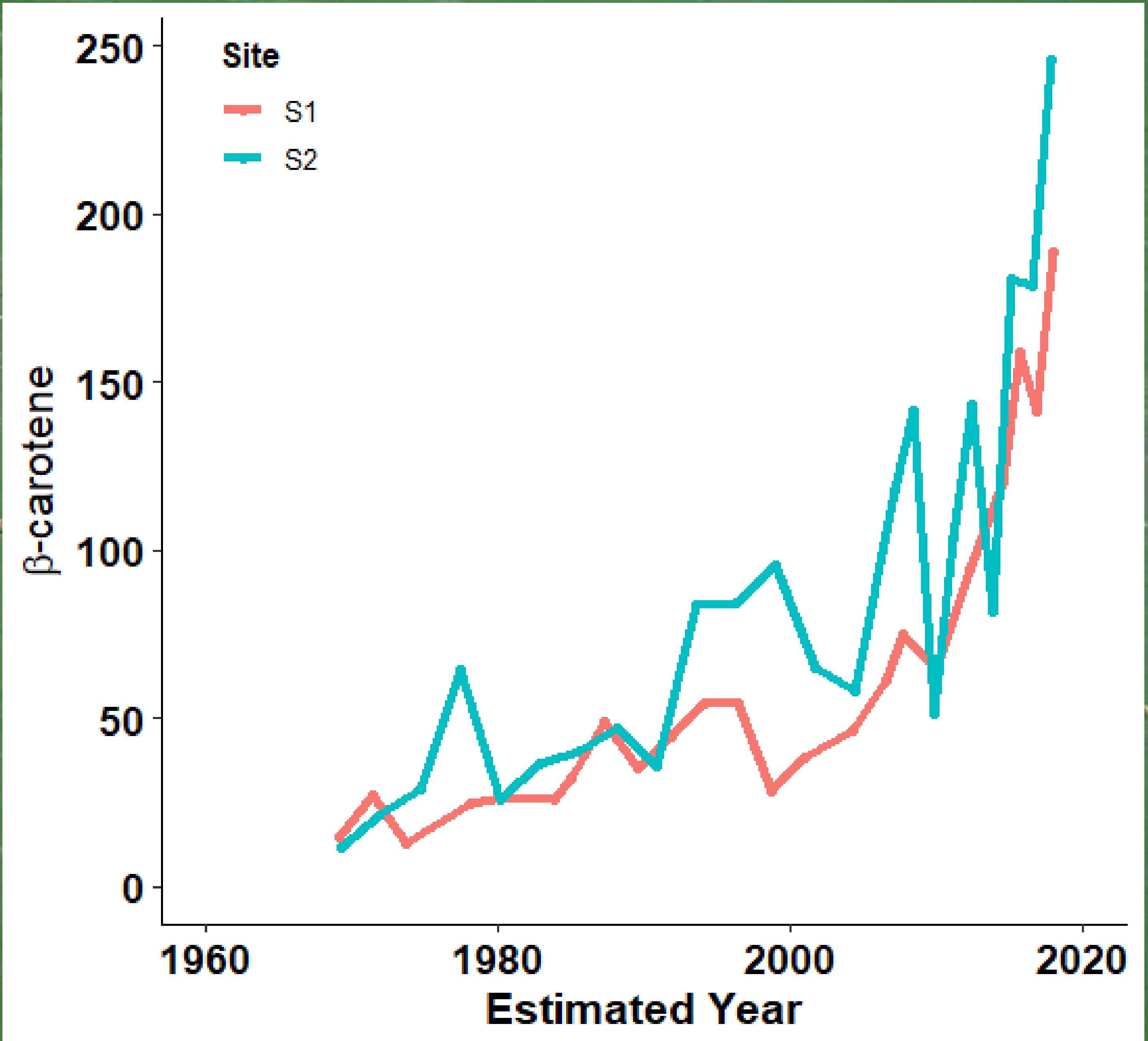



Sample Sites
KDHE
USACE
KBS coring
Depth (ft)
< 4
4 - 8
8 - 12
12 - 16
16 - 20
20 - 24
24 - 28
28 - 32
030
068
029
059
S2
S1
028
0 0.5 1 2 Miles

Marion Cores: Date + Mixing



Marion Cores: Total algae



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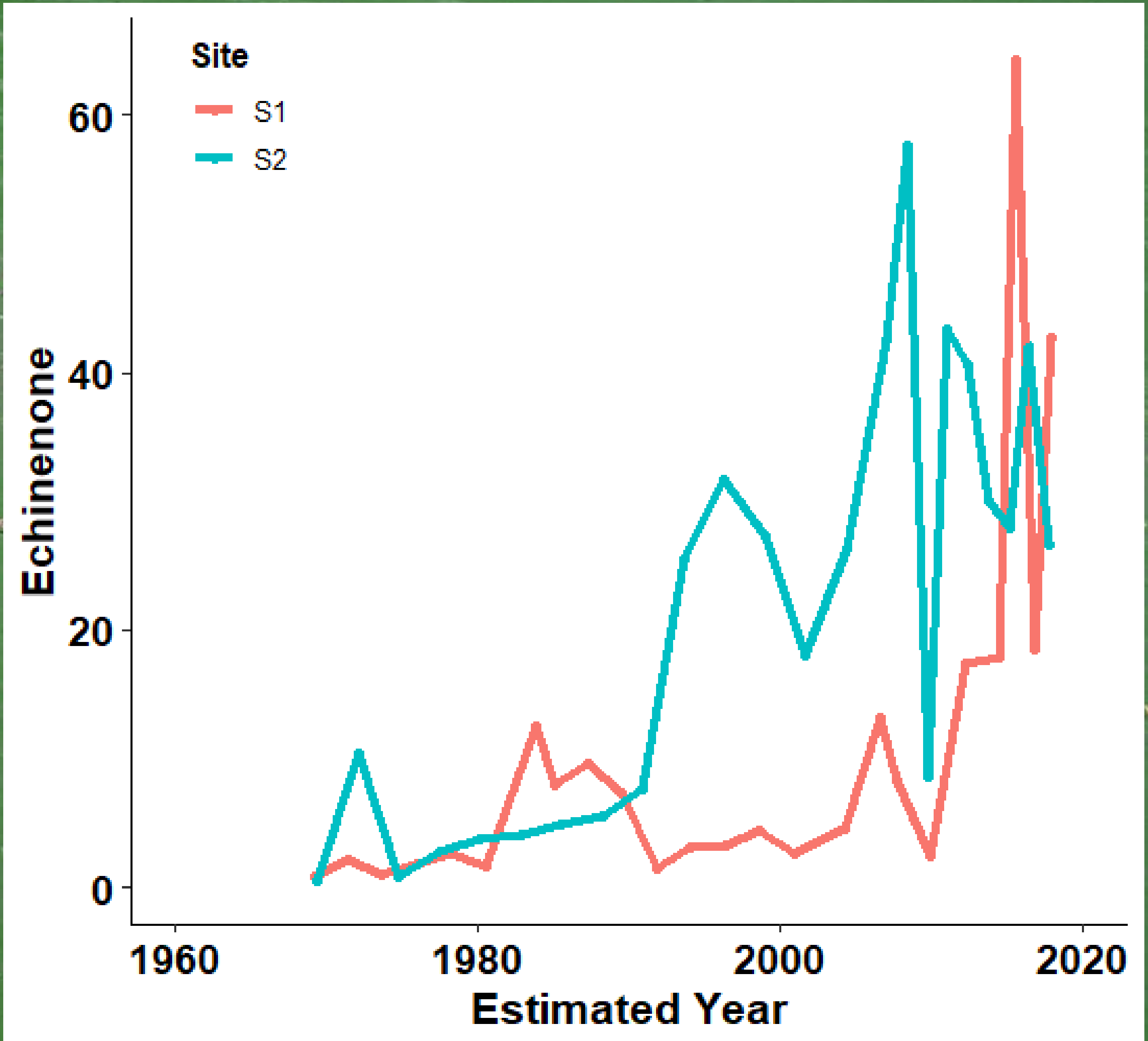
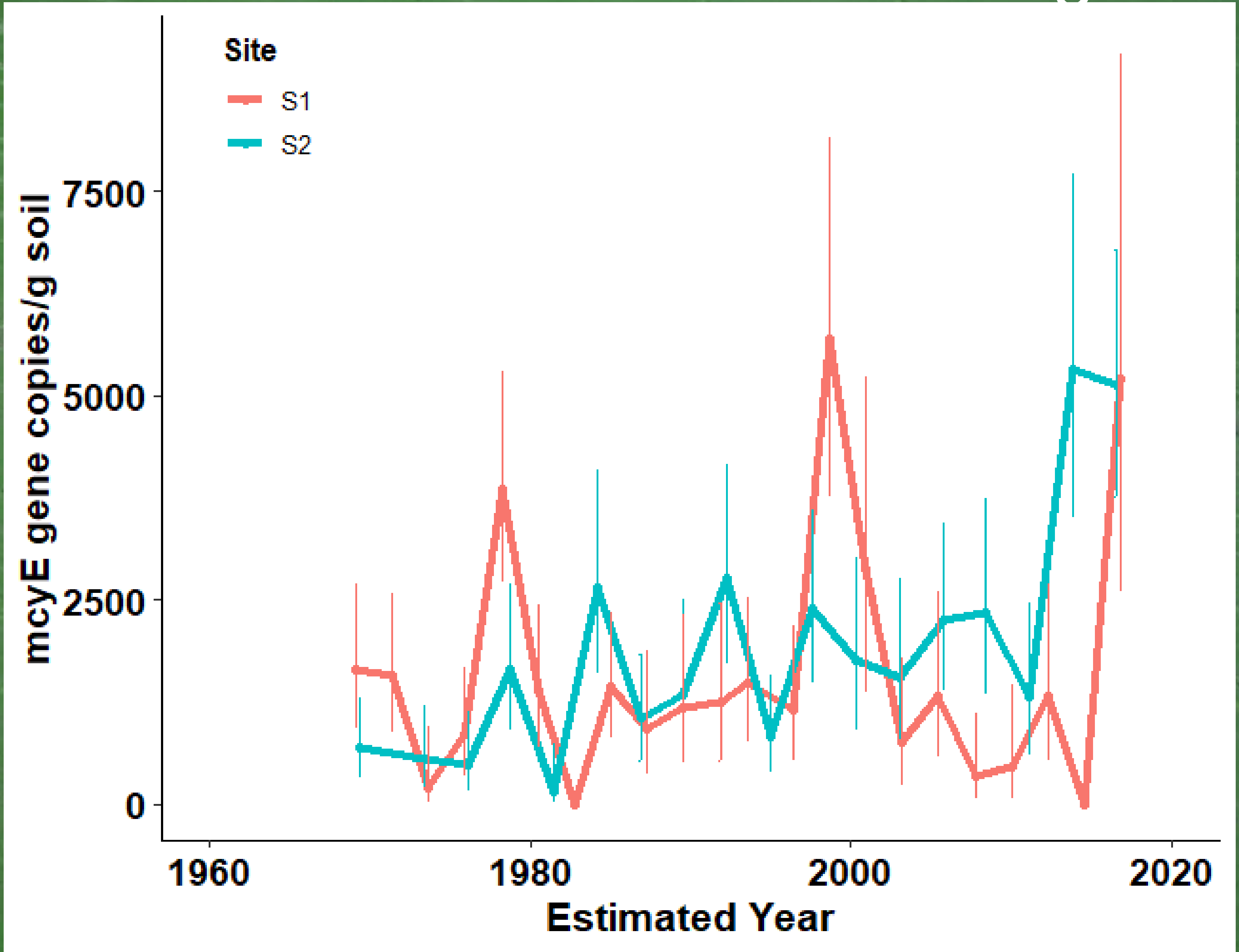


Marion Cores: eDNA toxic genes



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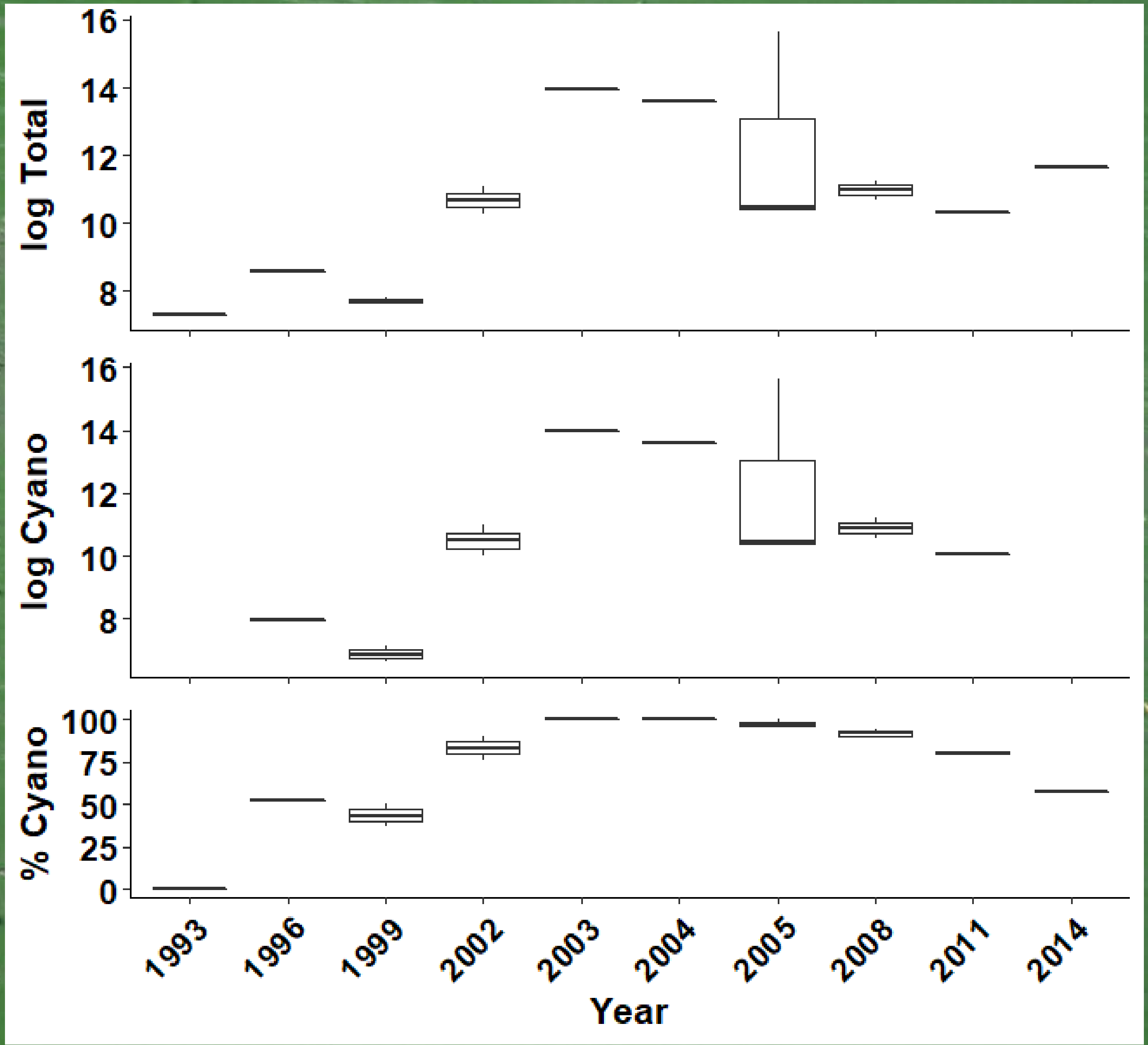
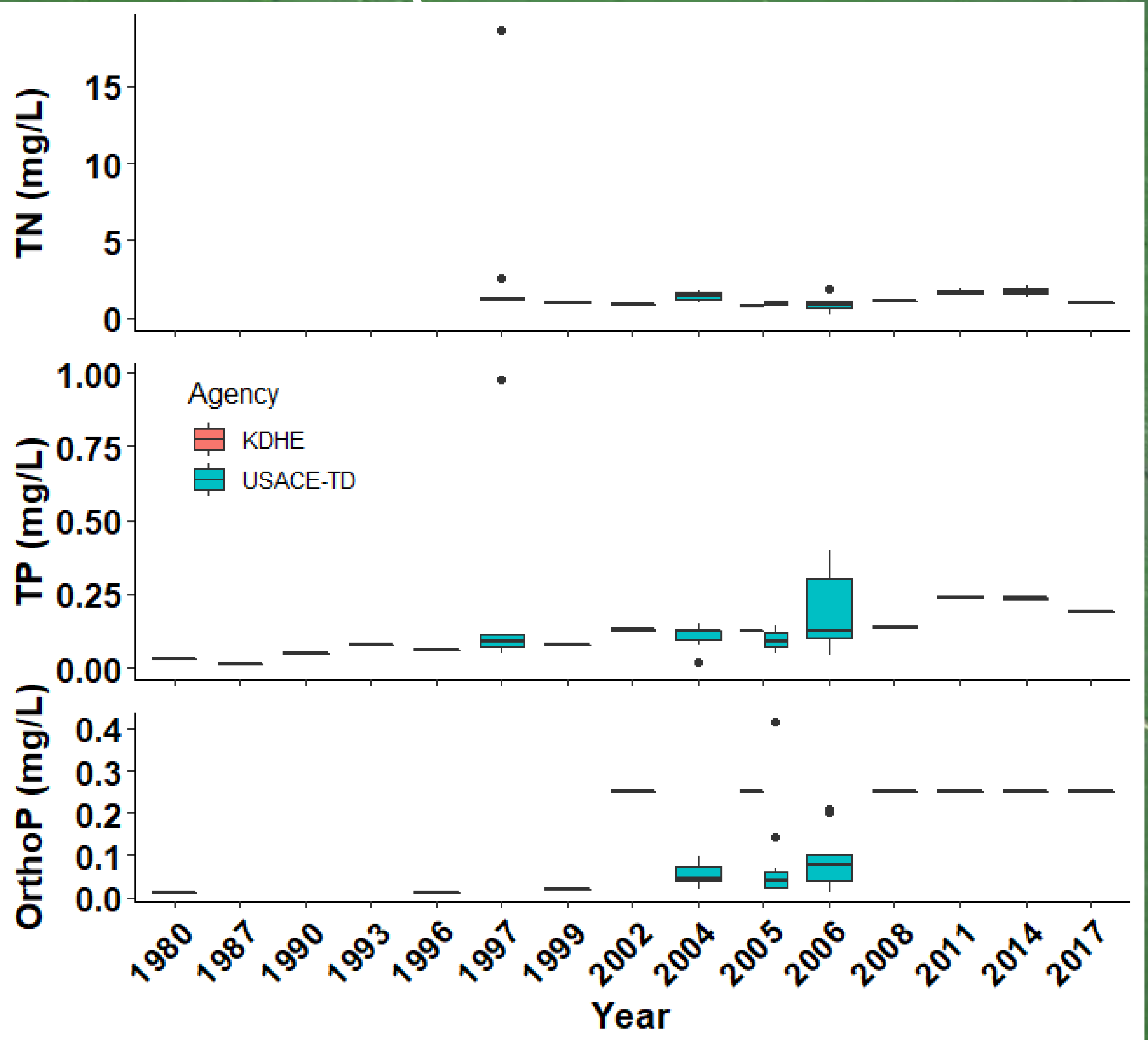
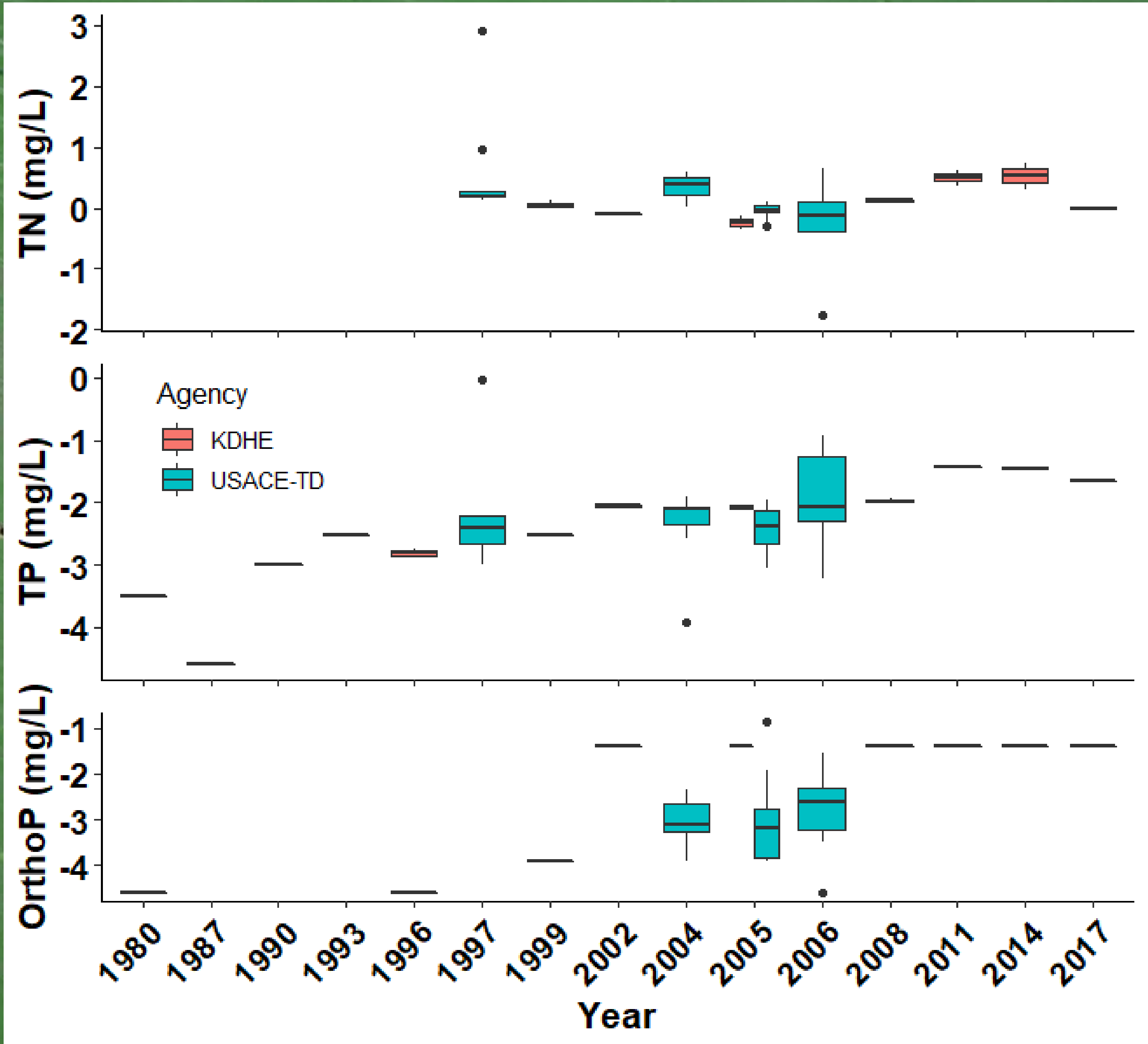


Marion WQ Data: Nutrients



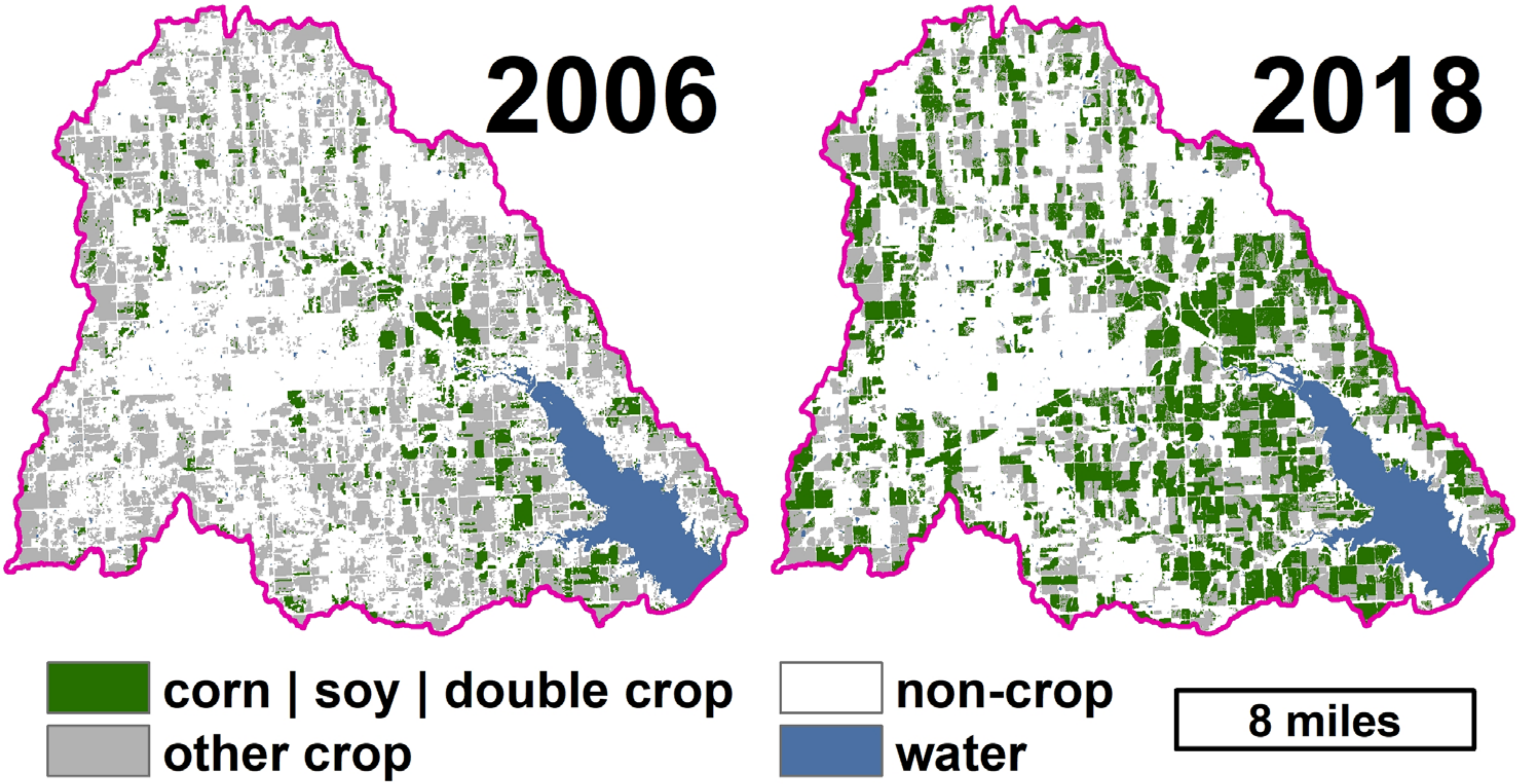
Marion WQ Data: log Nutrients



Marion Watershed Land Use

Marion Reservoir Watershed (207 sq mi.)

USDA Cropland Data Layers



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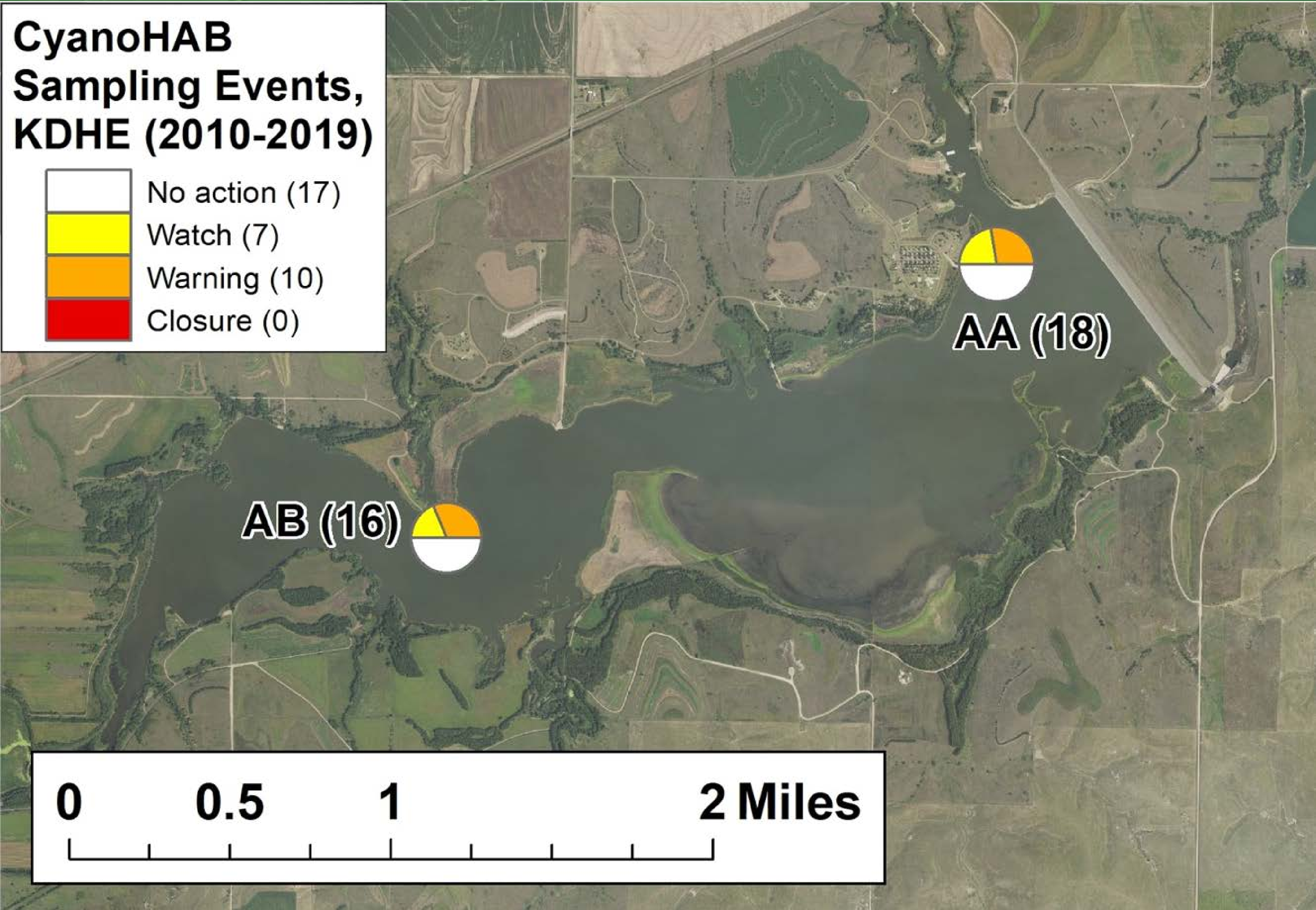
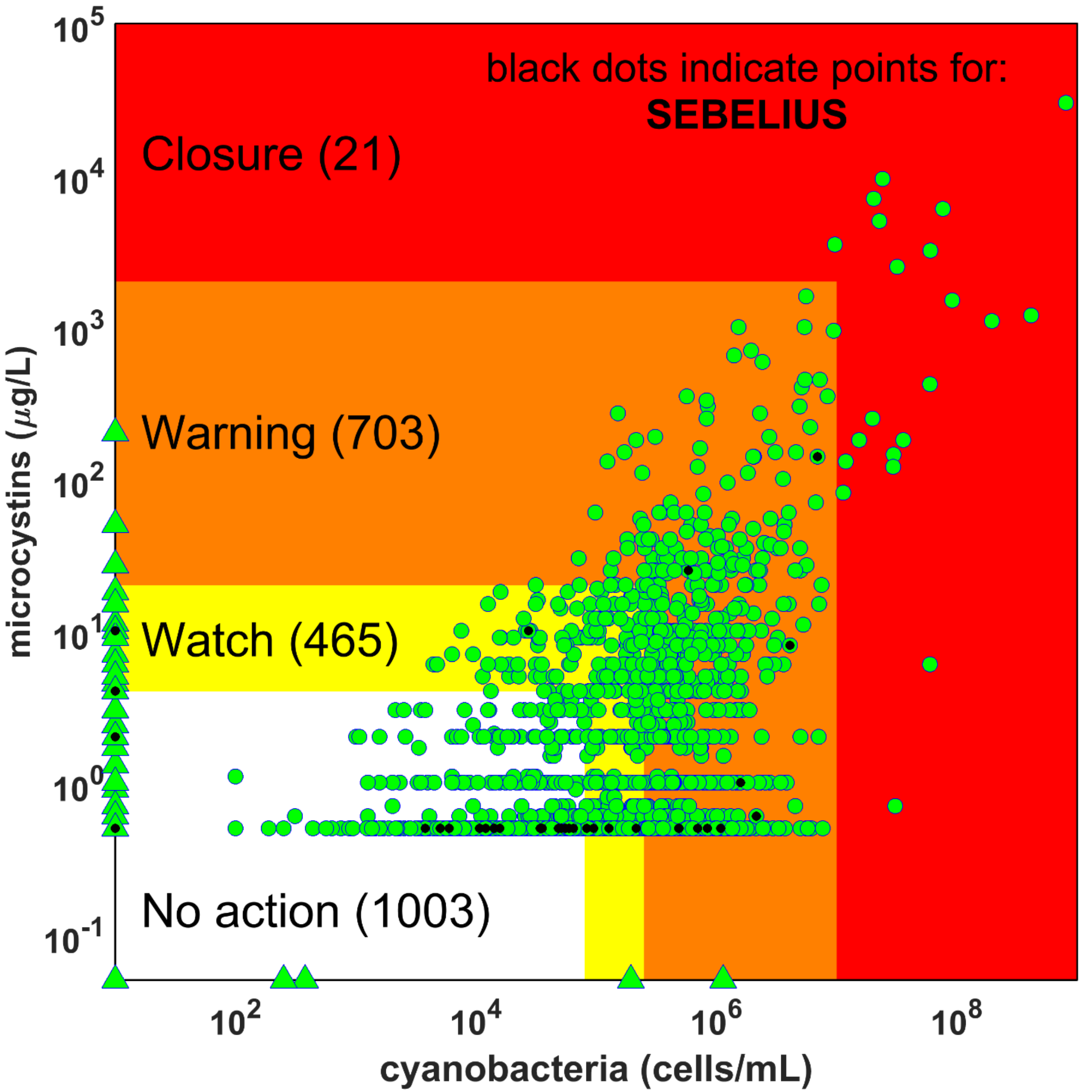
Sebelius

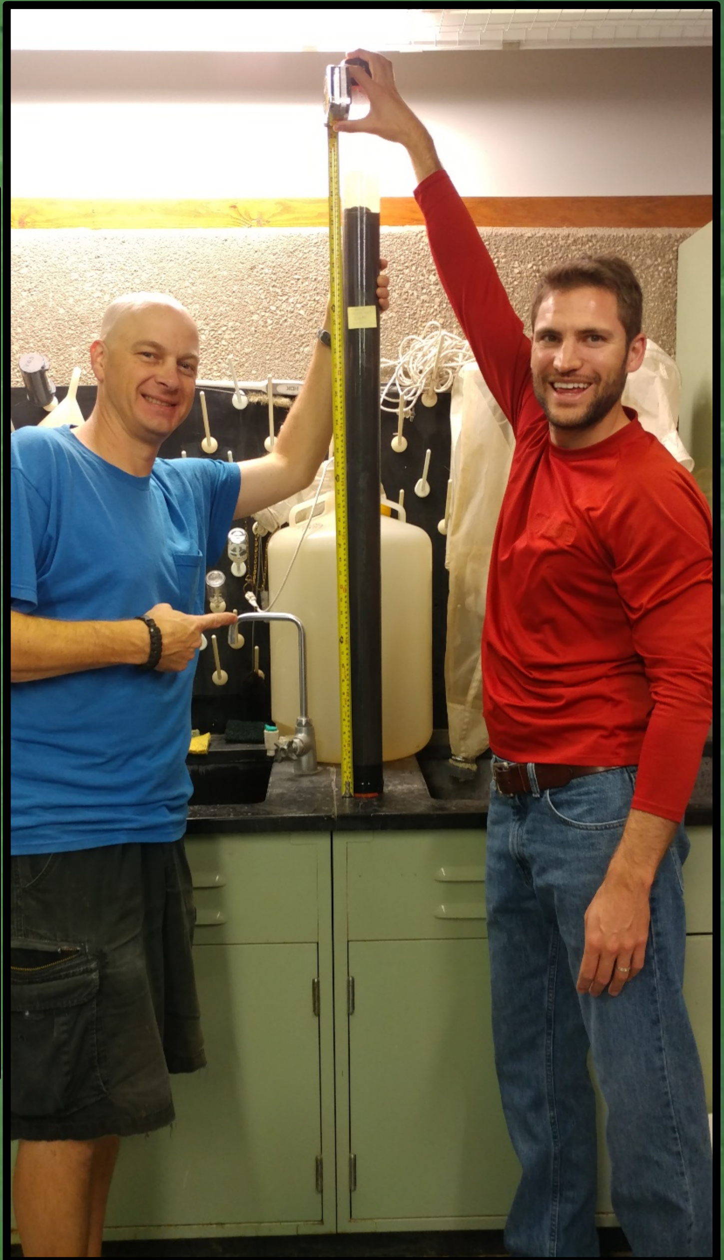


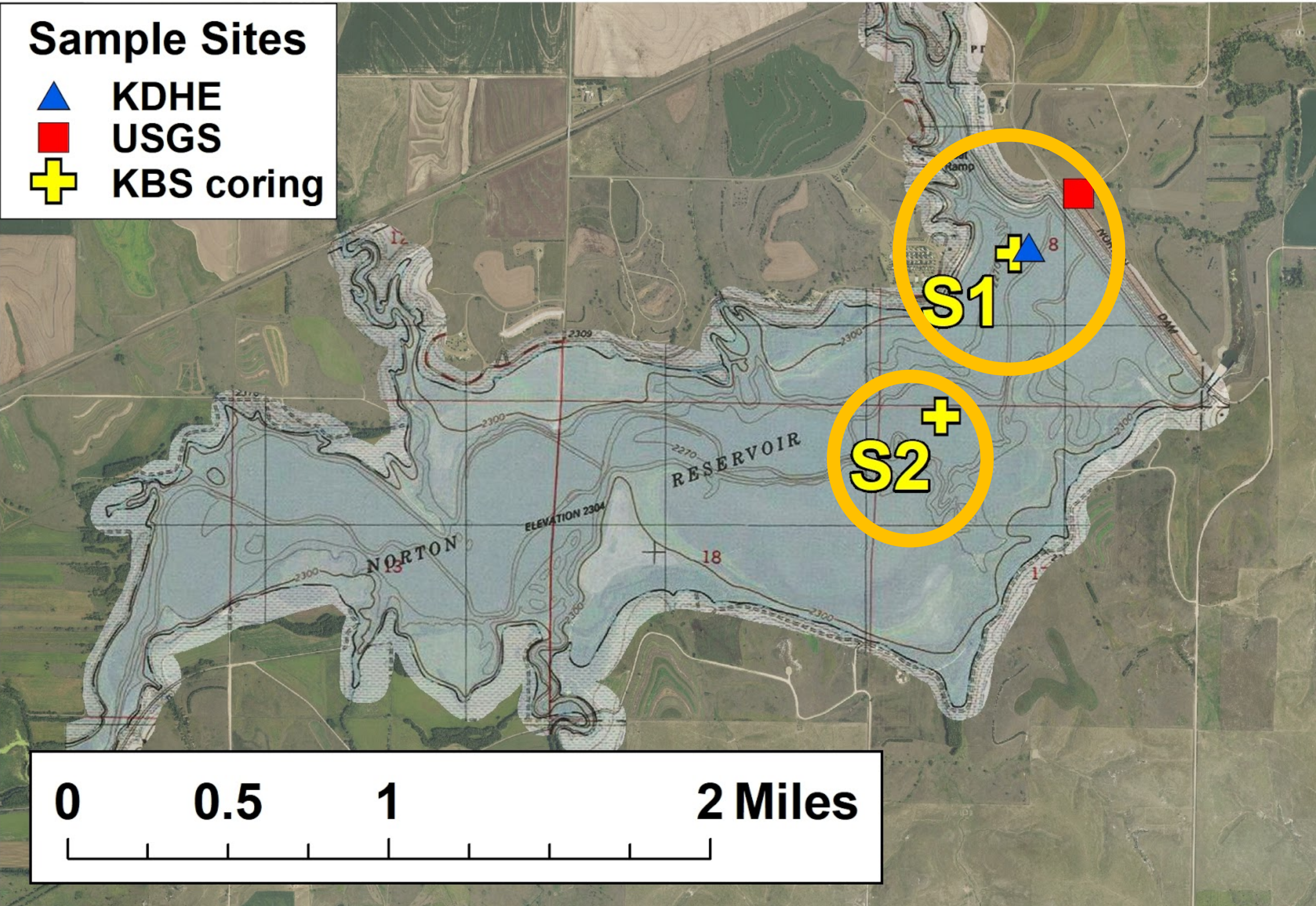
CyanoHAB Sampling Events, KDHE (2010-2019)
No action (17)
Watch (7)
Warning (10)
Closure (0)
AA (18)
AB (16)
0
0.5
1
2 Miles

KDHE response data by advisory level 2010-2019

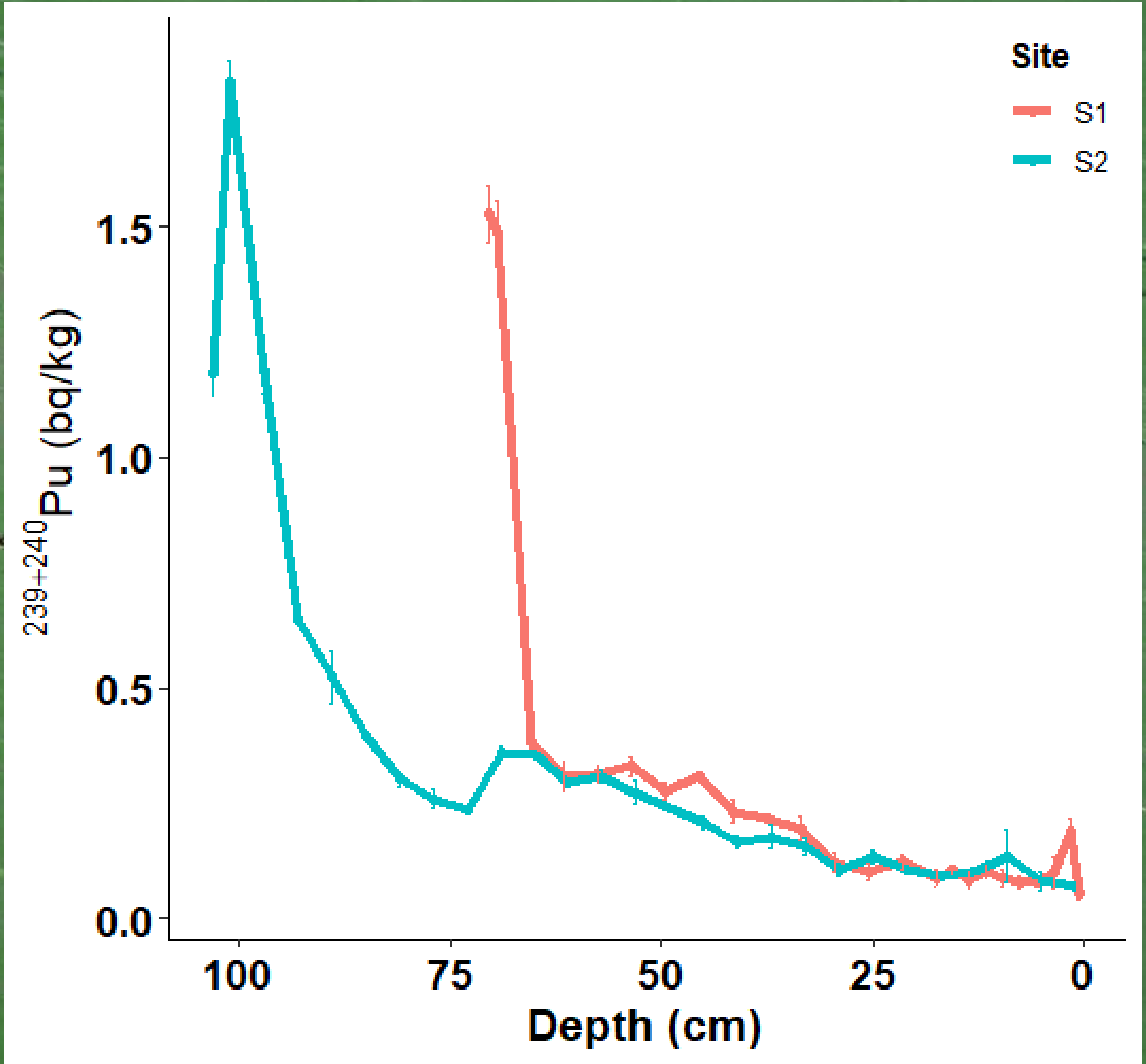


Sebelius: Sediment coring

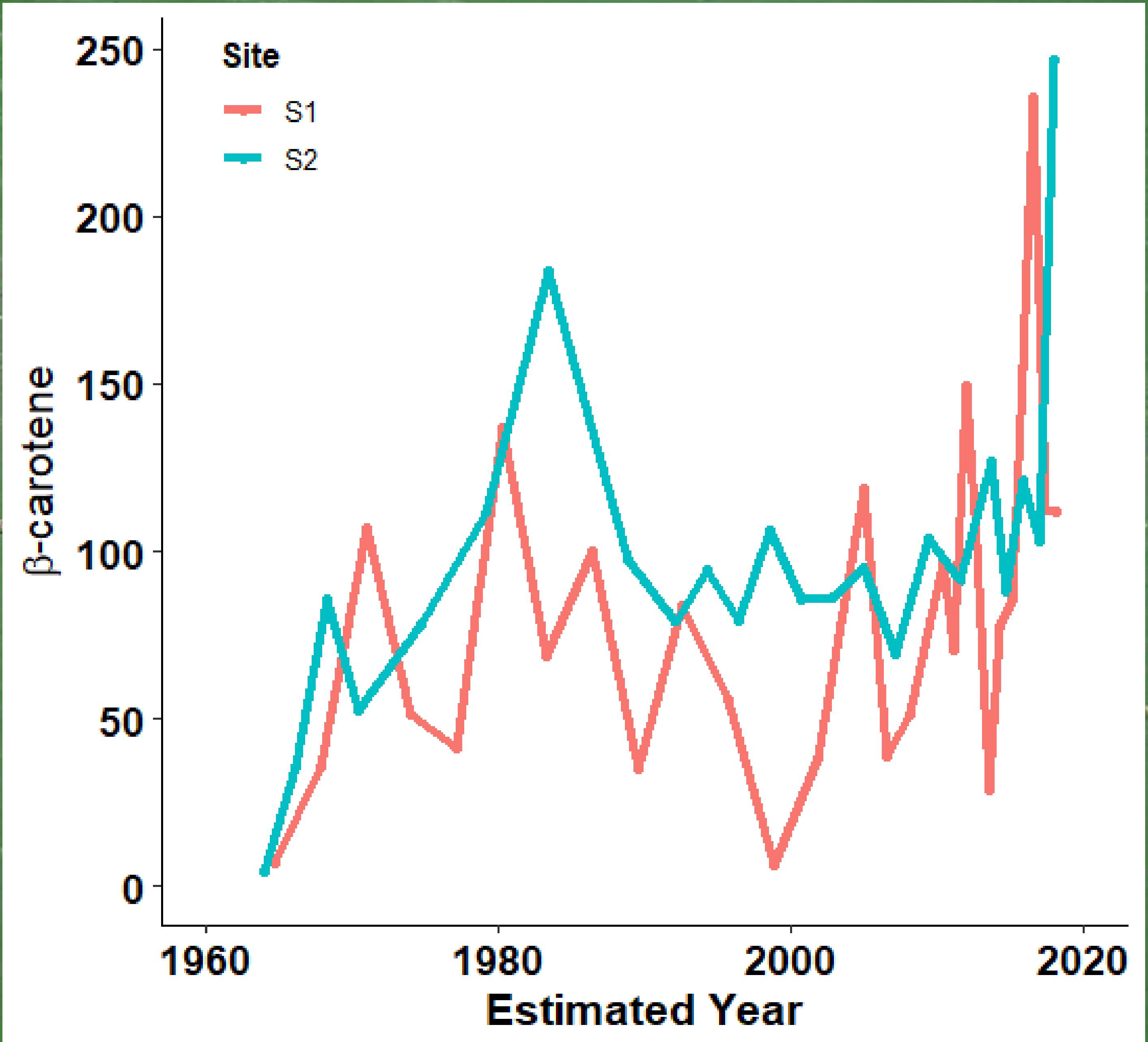



Sample Sites
KDHE
USGS
KBS coring
S1
S2
Ramp
NORTON
RESERVOIR
ELEVATION 2304
DAM
2300
2309
2270
18
0
0.5
1
2 Miles

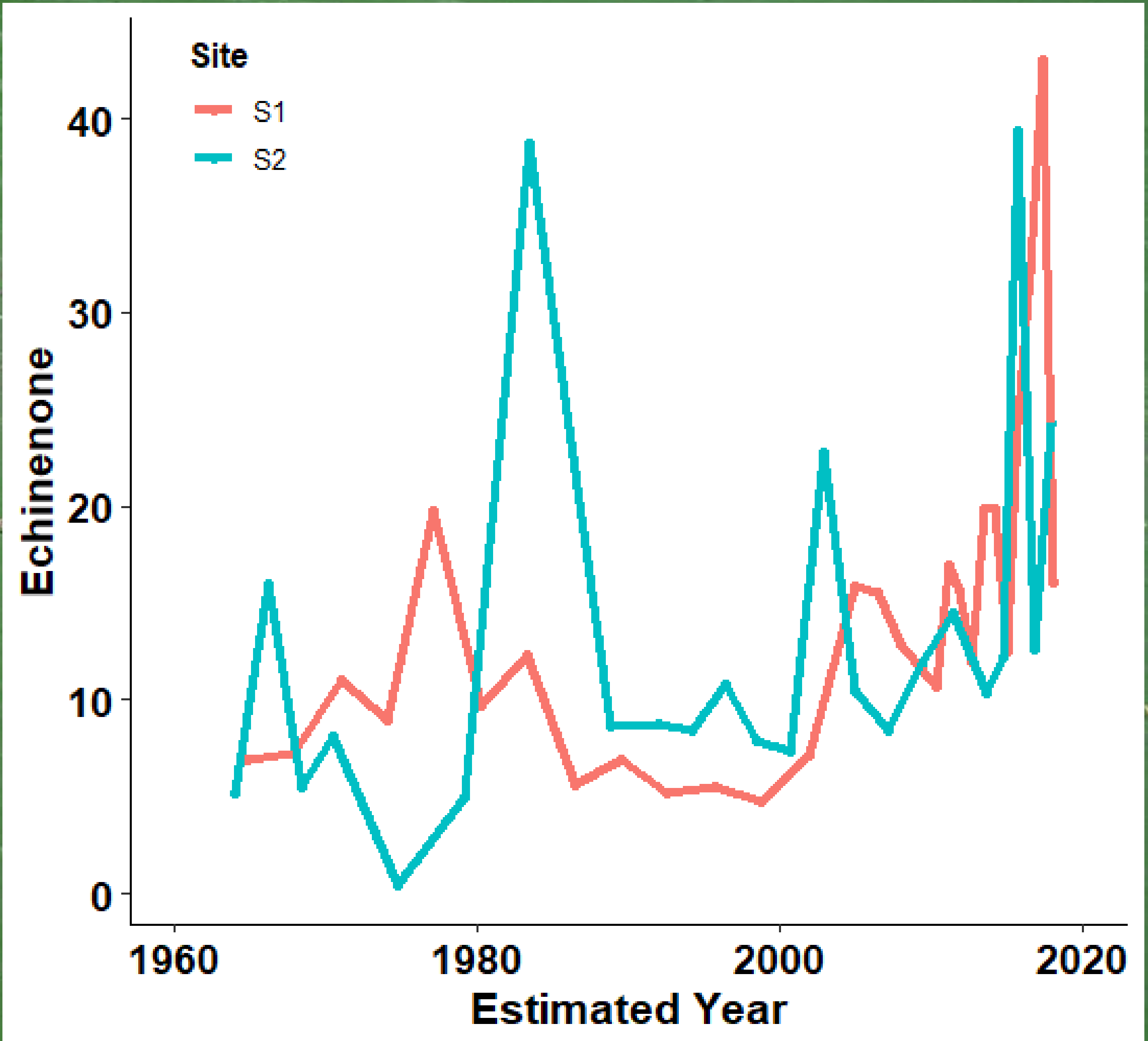
Sebelius Cores: Date + Mixing



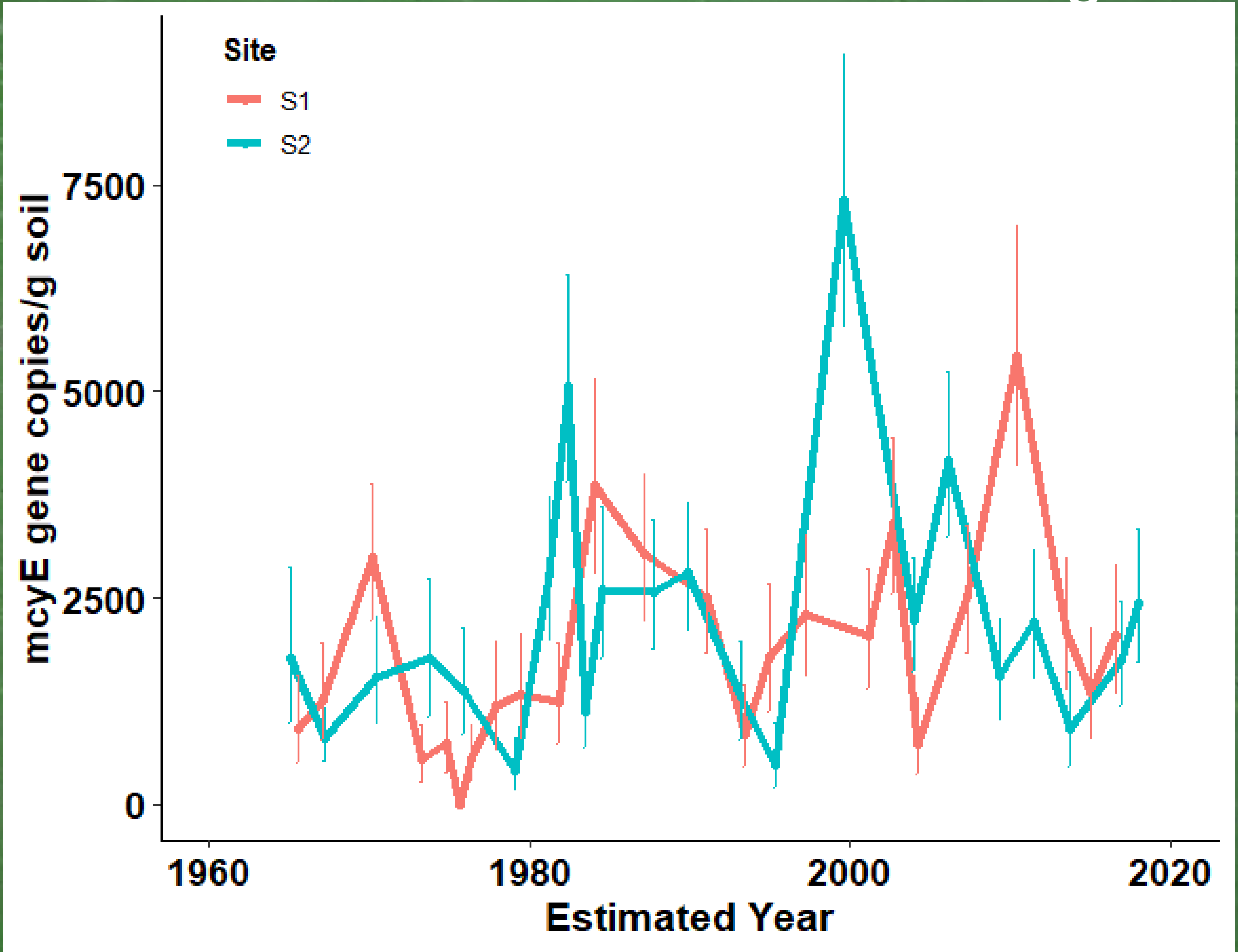
Sebelius Cores: Total algae



Sebelius Cores: Only Cyano



Sebelius Cores: eDNA toxic genes



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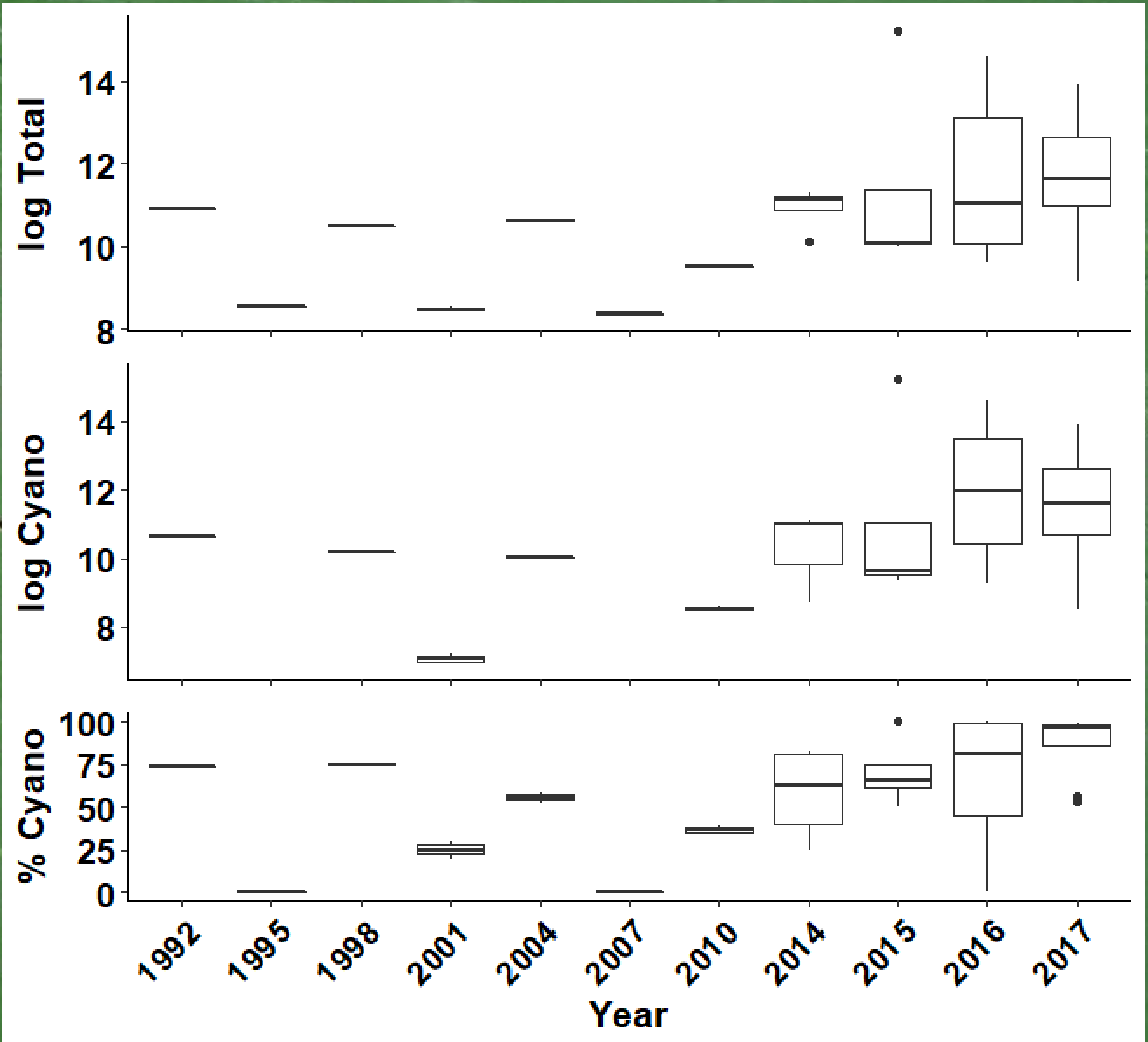
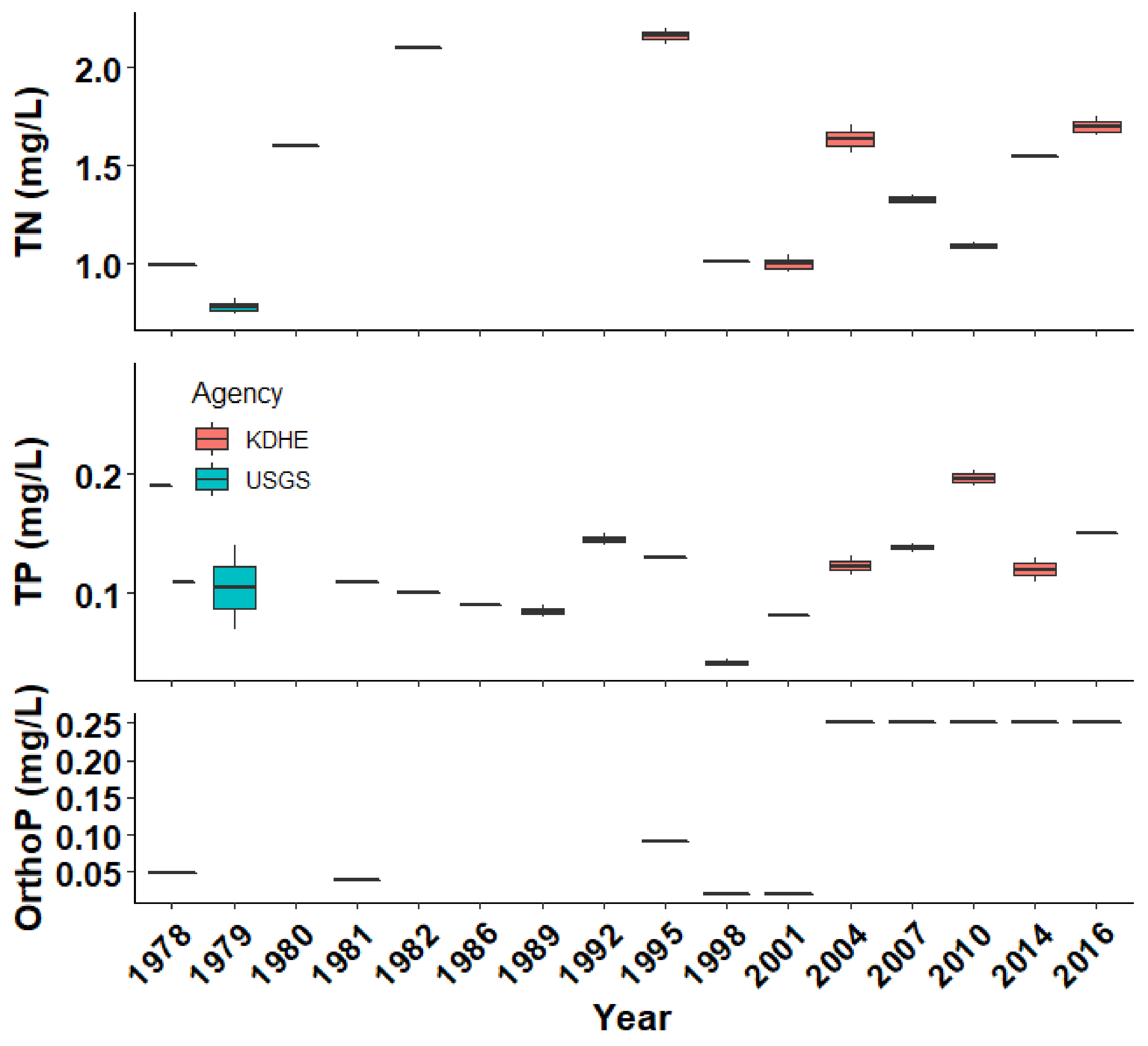
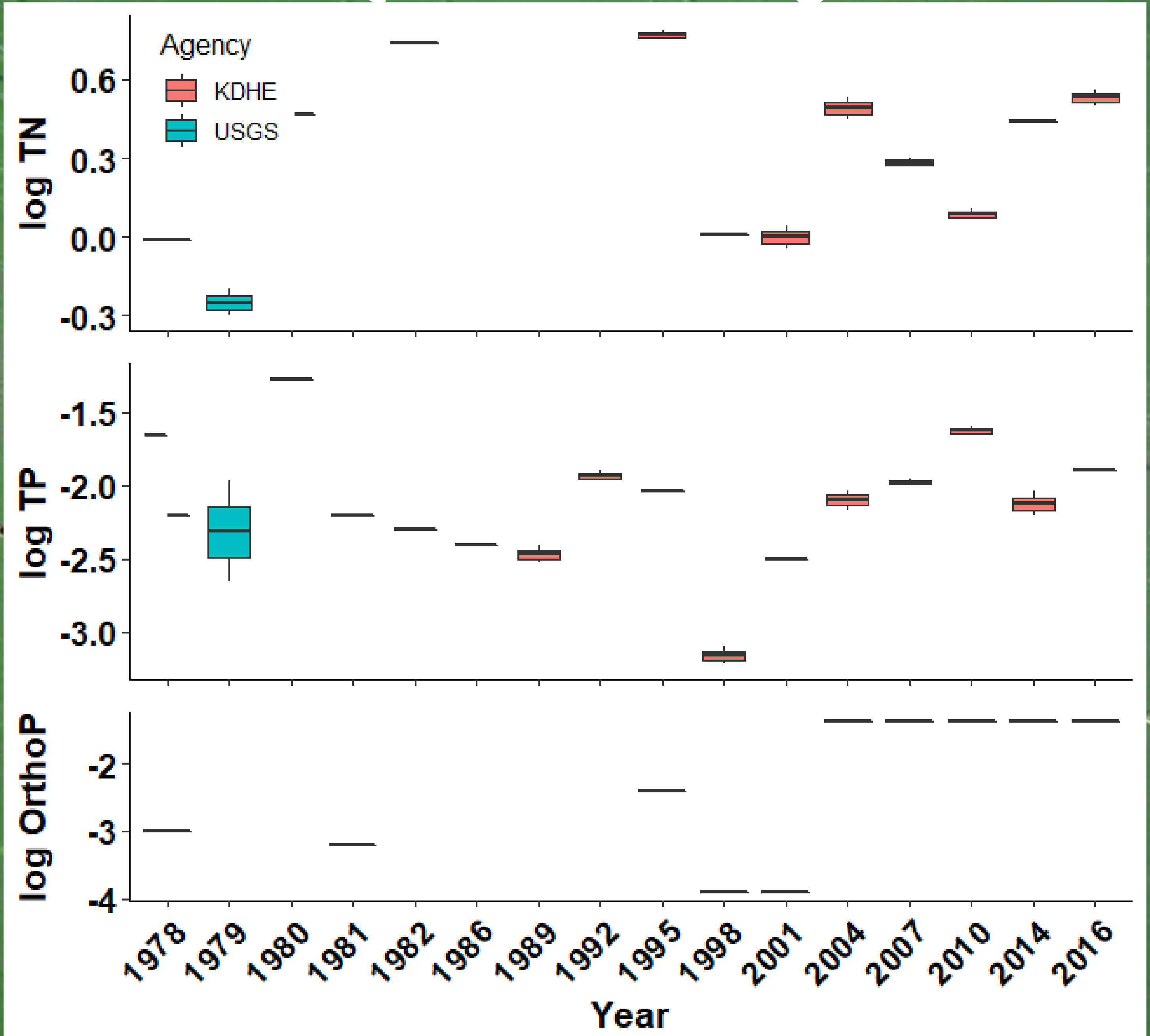


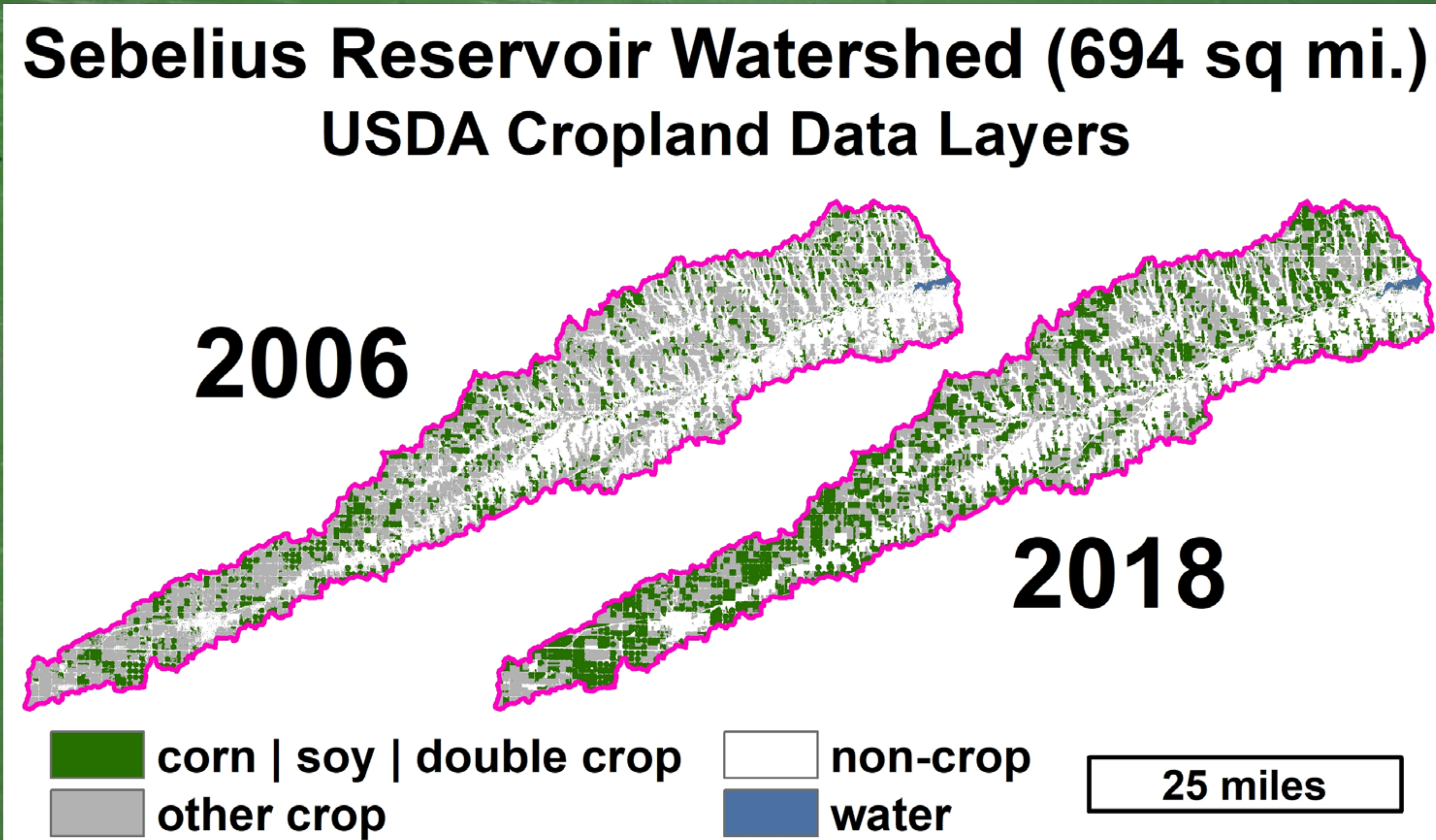
Sebelius WQ Data: Nutrients



Sebelius WQ Data: log Nutrients



Sebelius Watershed Land Use



Sebelius Cores + Data Summary

Pu dated impound in both - little sed. mixing

eDNA shows toxic cyano there since impound

Pigments show large mixed blooms in 1980s

Discrete phyto data variable,slight cyano incr.?

Discrete WQ data variable

Overall dynamic, few trends – hydrology?

Land use changing to more corn & soy

Dynamic hydro. -> dynamic conditions

Summary

- Milford & Marion are increasing in HABs
  - HAB incr. concurrent with P incr.
  - Incr. started 90s/early 2000s in both
  - 20-30 year “push” towards cyanoHAB
- Sebelius dynamic but slight HAB incr.
  - Hydrological signal?
  - Short-term conditions?

Trajectory of Milford & Marion seem to be progressively favoring cyano

Future Directions

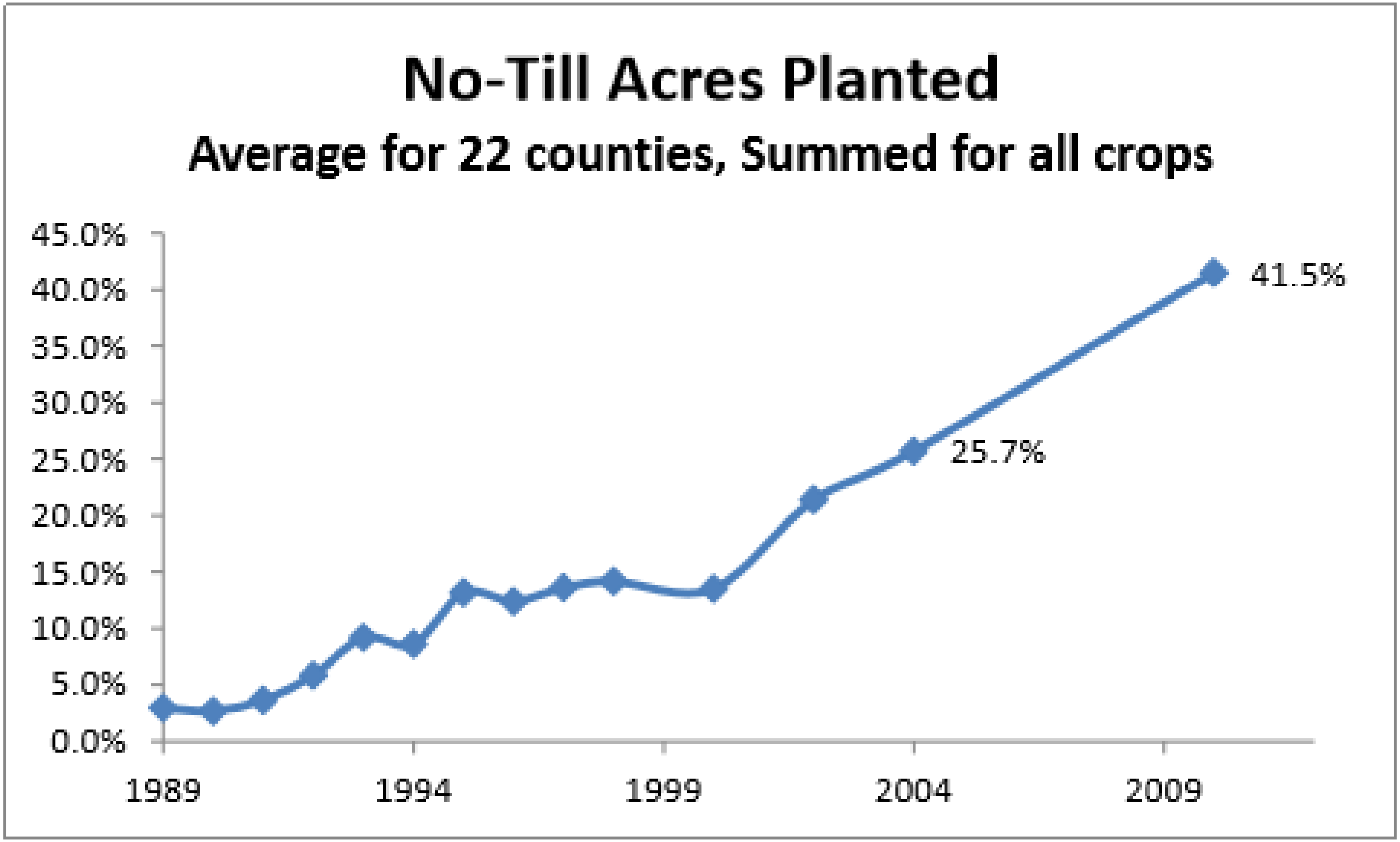
- External P loading differences??
- Are land use trends important to P?
  - Does it matter what crop is planted?
  - Does double cropping matter?
  - Related to tillage practice?

Tillage differences?

Tillage Practice Survey

Cooperating Agencies and Staff:
Kansas State University, DeAnn Presley, Dan Devlin, Ron Graber, Stacie Minson, Will Boyer, Herschel George, Dustin Fross, and 23 county extension agents; Kansas Department of Health and Environment, State Conservation Commission, Don Jones, and No-Till on the Plains, Brian Lindley.

Figure 2. Acreage planted no-till, 1989 to 2010, for a sample of KS counties.



Tillage differences?

Agricultural & Environmental Letters

Commentary

Phosphorus and Soil Health Management Practices

Emily W. Duncan,* Deanna L. Osmond, Amy L. Shober, Laura Starr, Peter Tomlinson, John L. Kovar, Thomas B. Moorman, Heidi M. Peterson, Nicole M. Fiorellino, and Keith Reid

Core Ideas

- Trade-offs exist in nutrient losses for soil health management.
- Combining soil health practices and other BMPs can exacerbate or mitigate P losses.
- There are limitations of soil health practices and reducing P losses.
- Educators should discuss BMP trade-offs associated with P loss.

Abstract: Soil health has gained widespread attention in agronomic and conservation communities due to its many purported benefits, including claims that implementation of core soil health practices (e.g., conservation tillage, cover crops) will improve water quality by curtailing runoff losses of nutrients such as phosphorus (P). However, a review of the existing literature points to well-established findings regarding trade-offs in water quality outcomes following the implementation of core soil health practices. In fact, both conservation tillage and cover crops can exacerbate dissolved P losses, undermining other benefits such as reductions in particulate P (sediment-bound P) losses. Soil health management must be pursued in a manner that considers the complex interaction of nutrient cycling processes and produces realistic expectations. Achieving water quality goals through soil health practices will require adaptive management and continued, applied research to support evidence-based farm management decisions.

Tillage differences?

Phosphorus and Soil Health Management Practices

Emily W. Duncan,* Deanna L. Osmond, Amy L. Shober, Laura Starr, Peter Tomlinson, John L. Kovar, Thomas B. Moorman, Heidi M. Peterson, Nicole M. Fiorellino, and Keith Reid

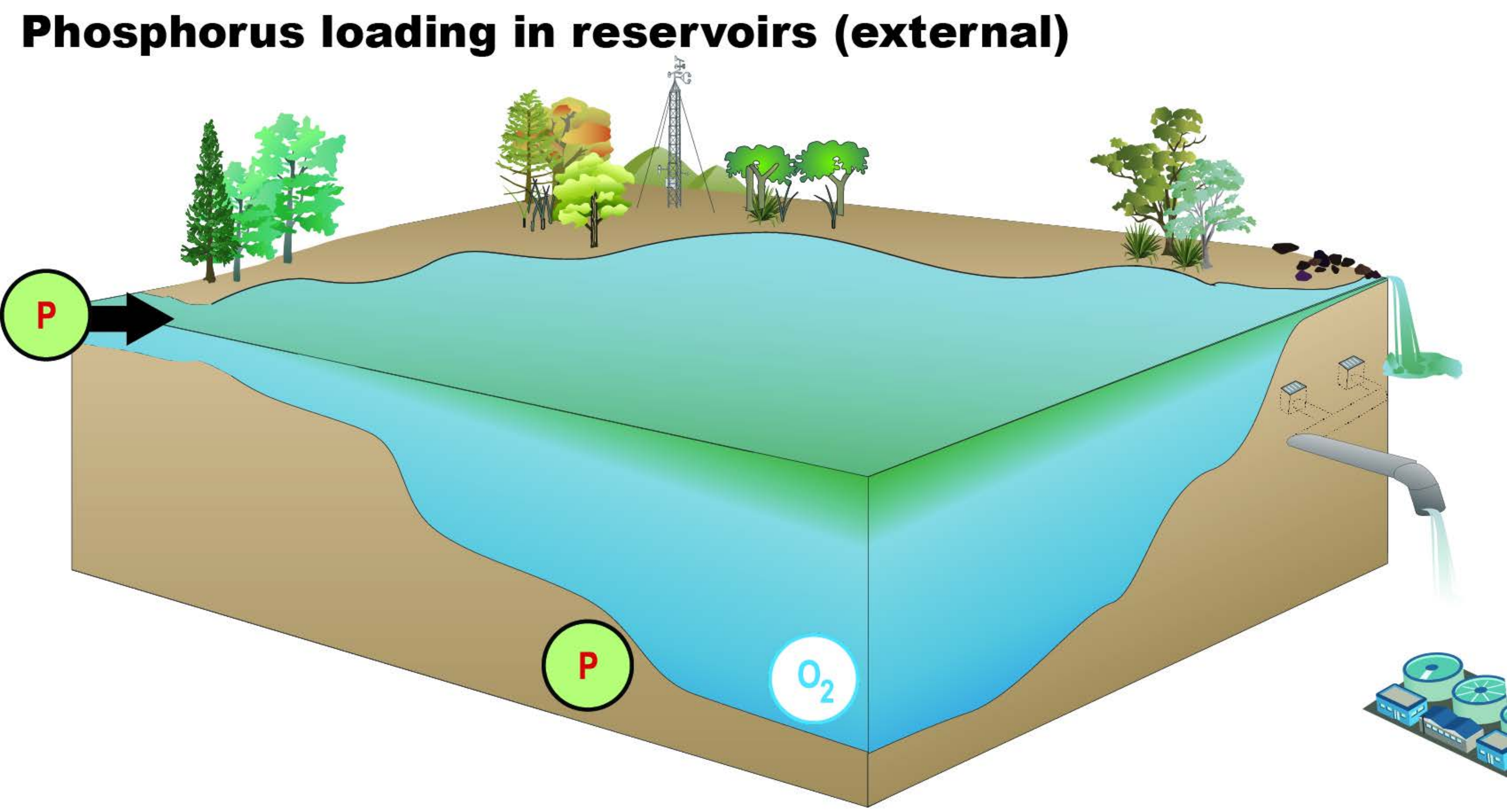
Recognizing the Limitations of Soil Health Practices to Control Phosphorus Losses

The agroecological benefits of soil health practices such as conservation tillage and cover crops are demonstrable; however, implementation of these soil health practices will not always reduce P loss from agricultural landscapes. Reducing soil disturbance and increasing ground cover decrease sediment leaving the field, but reduced sediment losses do not always translate to meaningful decreases in total P leaving the field (Bullerjahn et al., 2016). While there are positive trade-offs associated with soil health practices relative to N (e.g., cover crops mitigate N leaching), the effects on P losses are more nuanced (Aronsson et al., 2016; Bullerjahn et al., 2016; Jarvie et al., 2017).

Future Directions

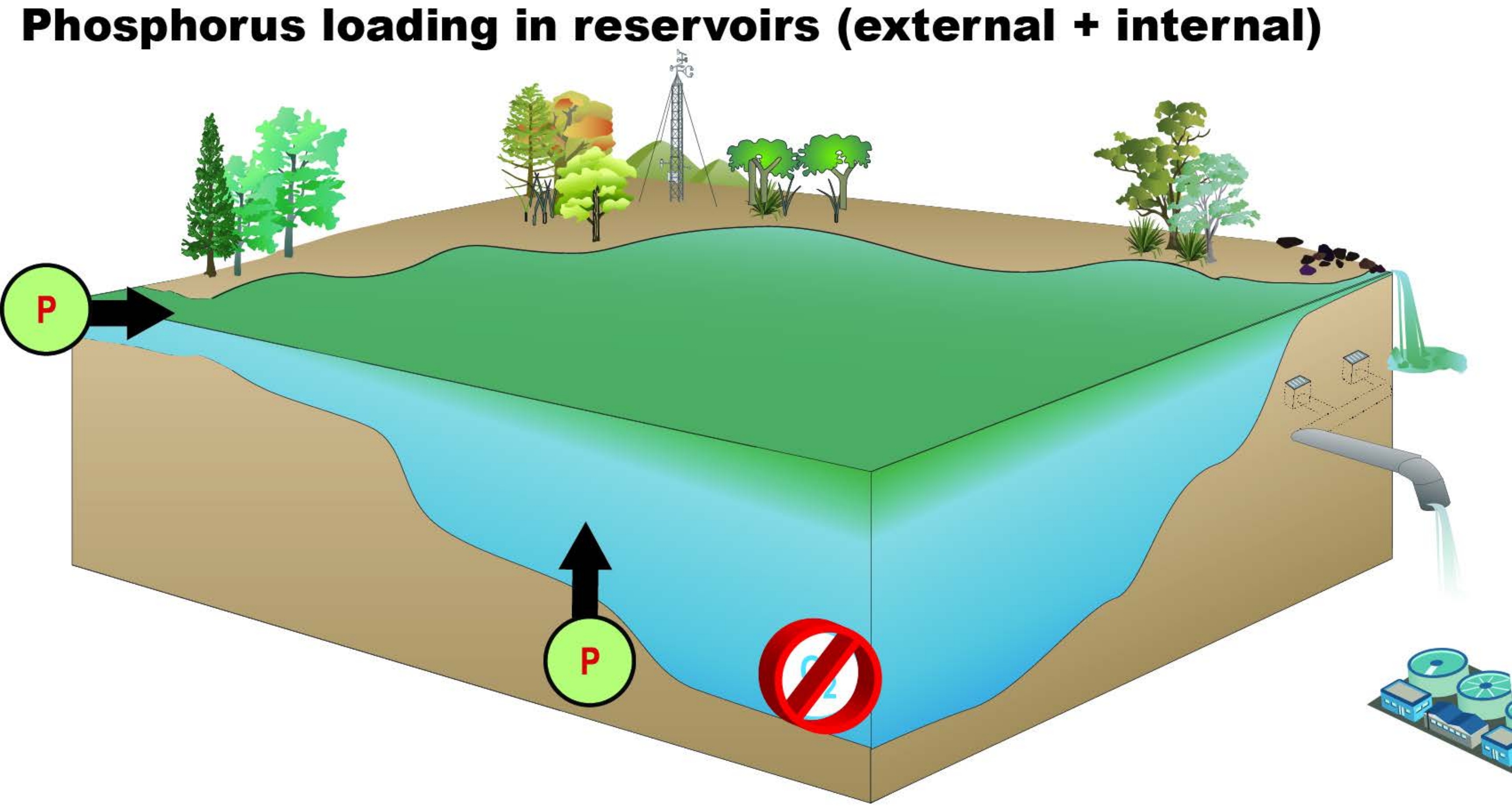
- External P loading differences??
- Are land use trends important to P?
  - Does it matter what crop is planted?
  - Does double cropping matter?
  - Related to tillage practice?
- How much P is internally loaded?
  - Currently finding out in Marion

What is internal loading?



internal loading = P from sediment

Occurs under anoxia→ No oxygen



16 October 2012

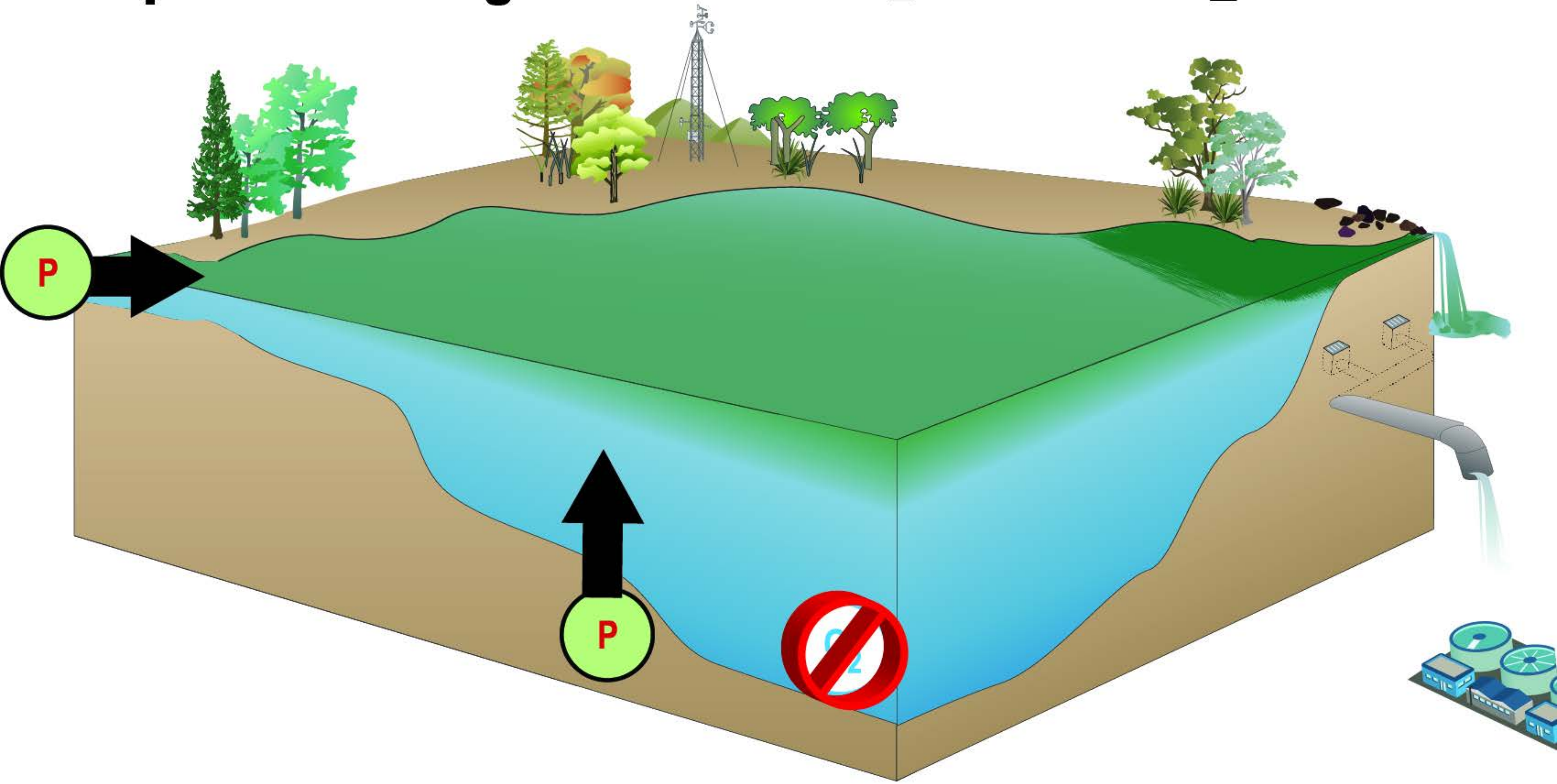
Translator Disclaime

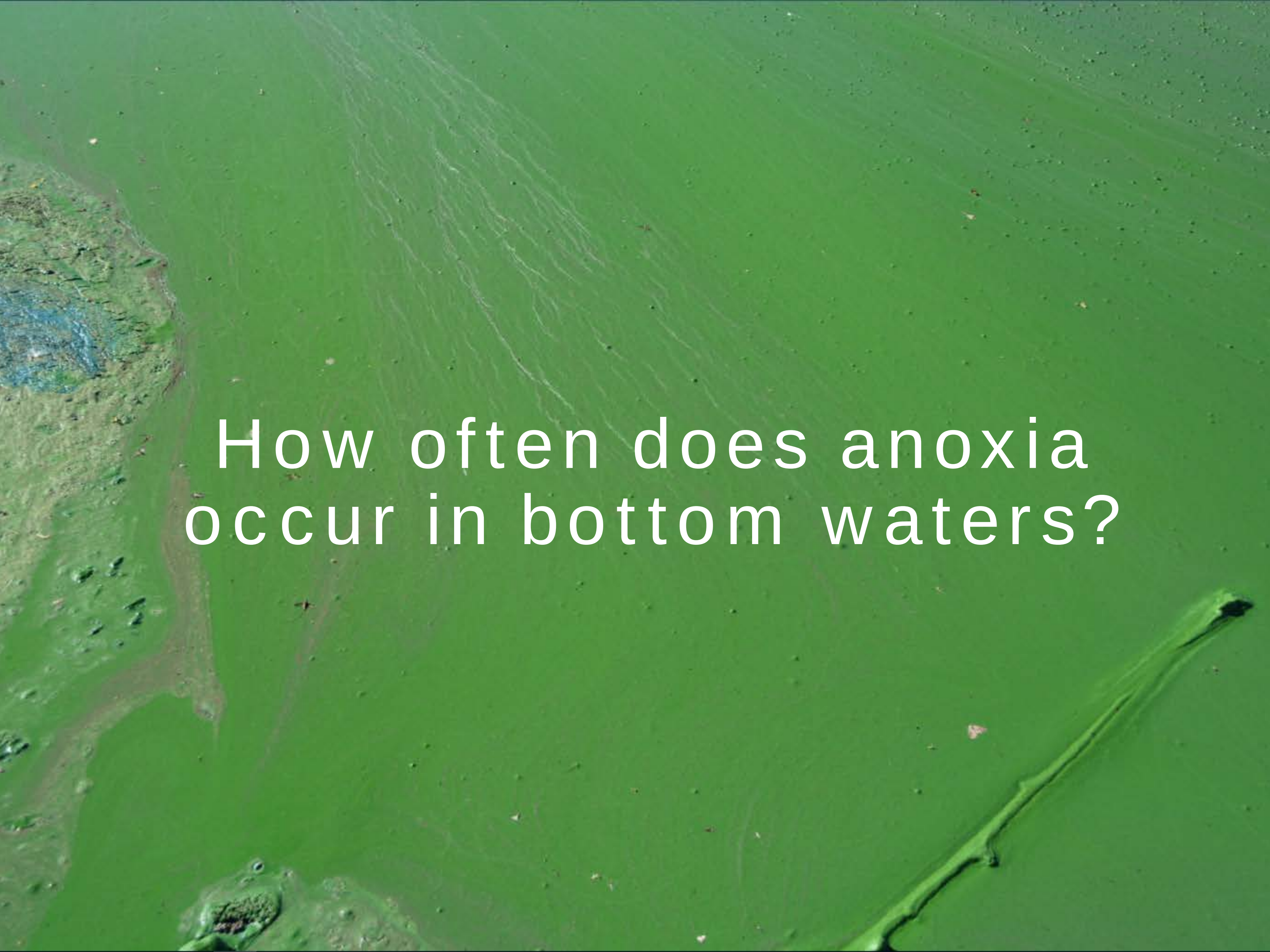
Predicting sediment phosphorus release rates using landuse and water-quality data

Lindsey D. Carter, Andrew R. Dzialowski

Internal P incr. with external loading

Phosphorus loading in reservoirs: ⬆ external = ⬆ internal

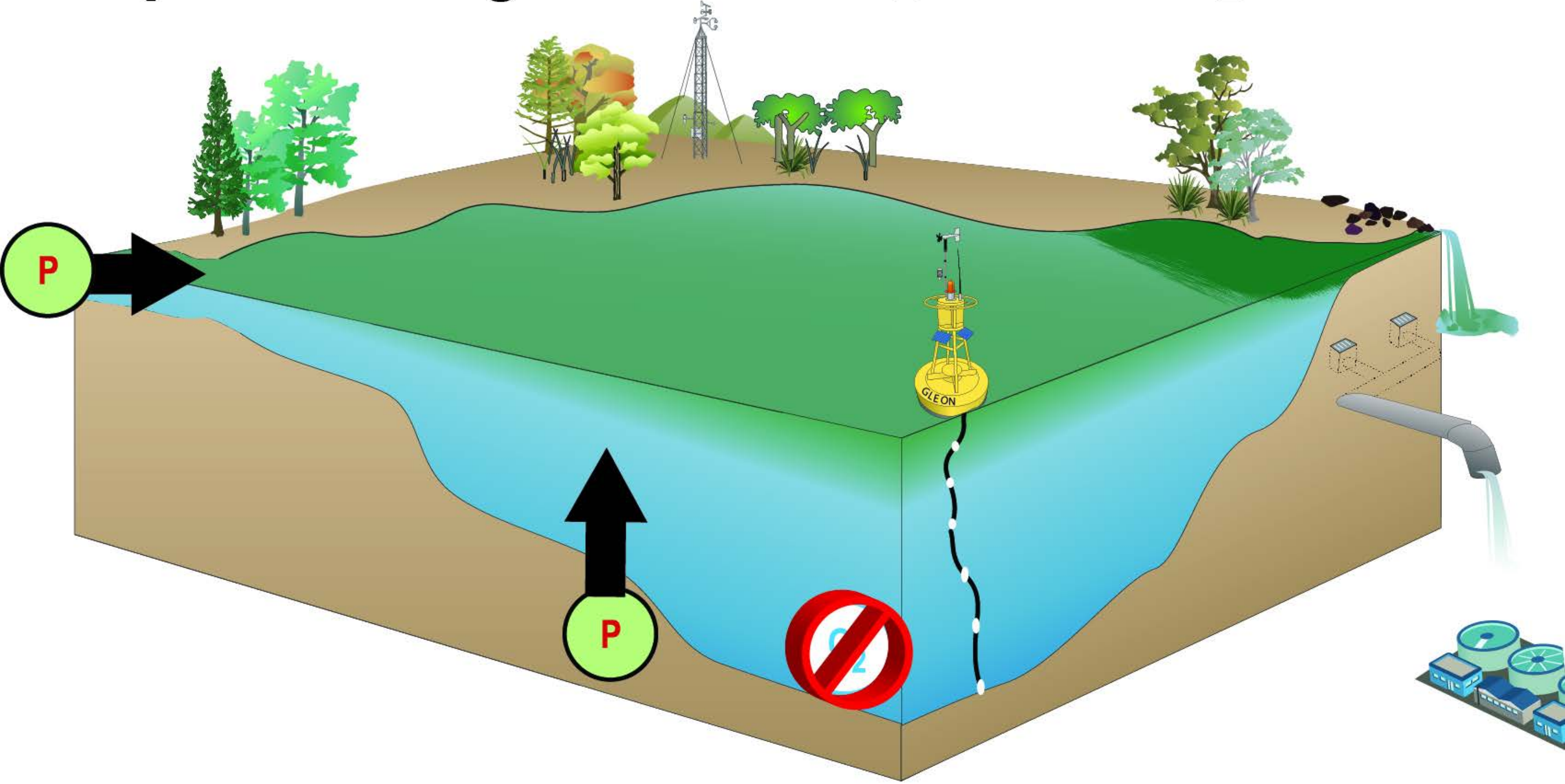




How often does anoxia occur in bottom waters?

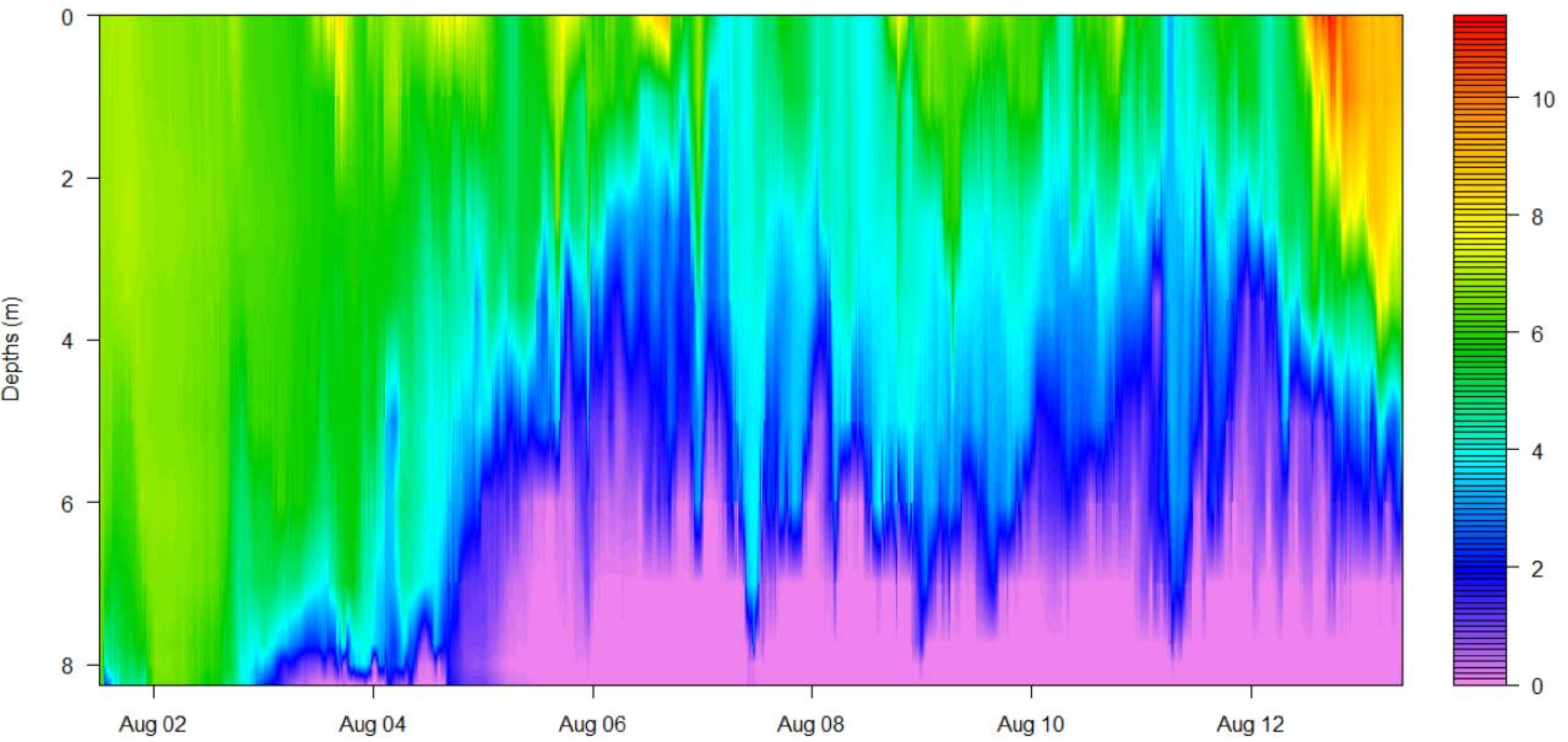
High Freq. monitor w/ depth
Can determine when O_2 absent

Phosphorus loading in reservoirs: ⬆ external = ⬆ internal



High Freq. monitor: Marion Ex.

Dissolved O_2 with depth – Aug. 2019



Big Picture Summary

- Coring can determine:
  - Are cyanoHABs are increasing?
  - If yes, when did increase start?
  - How dramatic was change?

Help characterize the long-term

trajectory of a system

Started unraveling Kanopolis & Webster history in 2019!

Kanopolis

Started unraveling Kanopolis & Webster history in 2019!

Webster

Big Picture Summary

- Why have some lakes increased in HABs while others have not???

- Sediment coring can help gain insights into past & why/how HABs change over time
  - Could be discouraging…. But can bring <u>hope</u>
    - Decades w/ less cyanobacteria in Milford/Marion
      - Can lakes reverse or return?

- More cored lakes, experiments, HF data, & data collection/aggregation → better understand long- and short-term processes that help change risk of HABs

Thank you!

Questions?

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Pictures from Milford 2017