Assessing Trends and Quantifying the Internal Phosphorus Load of Lake Hopatcong Utilizing a 30-Year Continuous Database

New York State Federation of Lake Associations

29 – 30 April 2022

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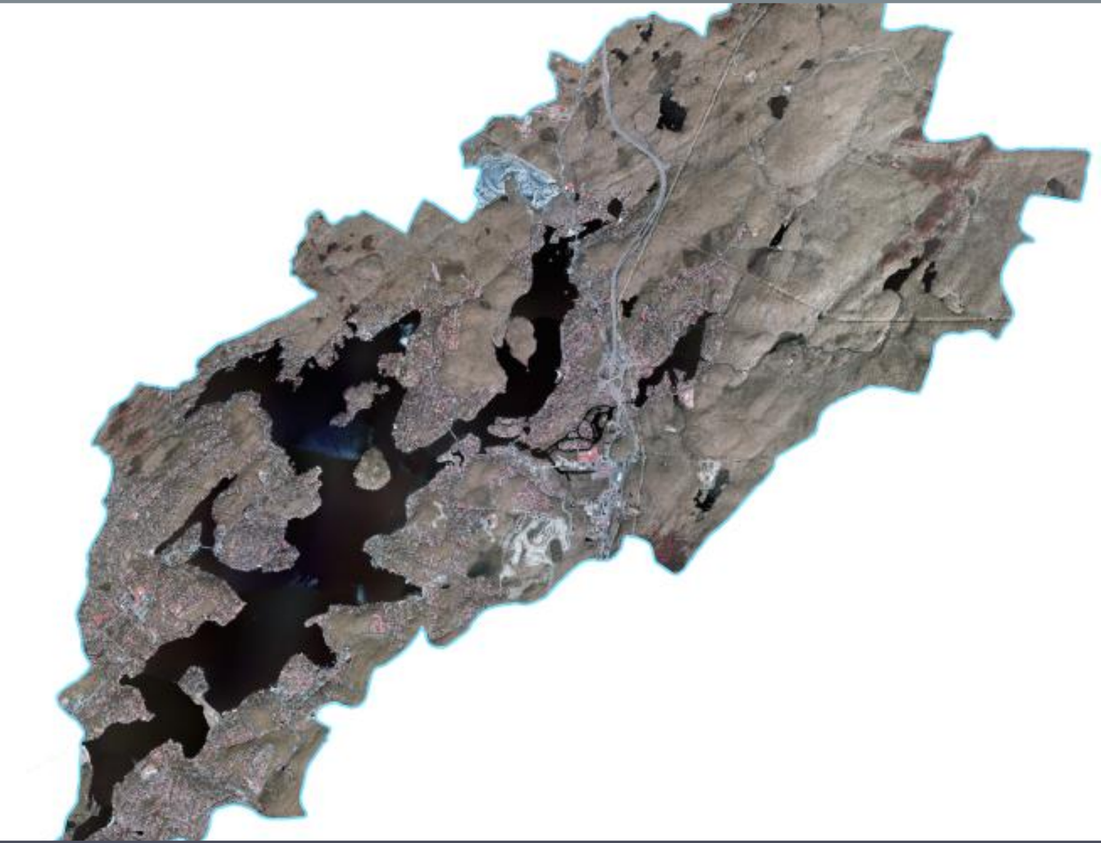
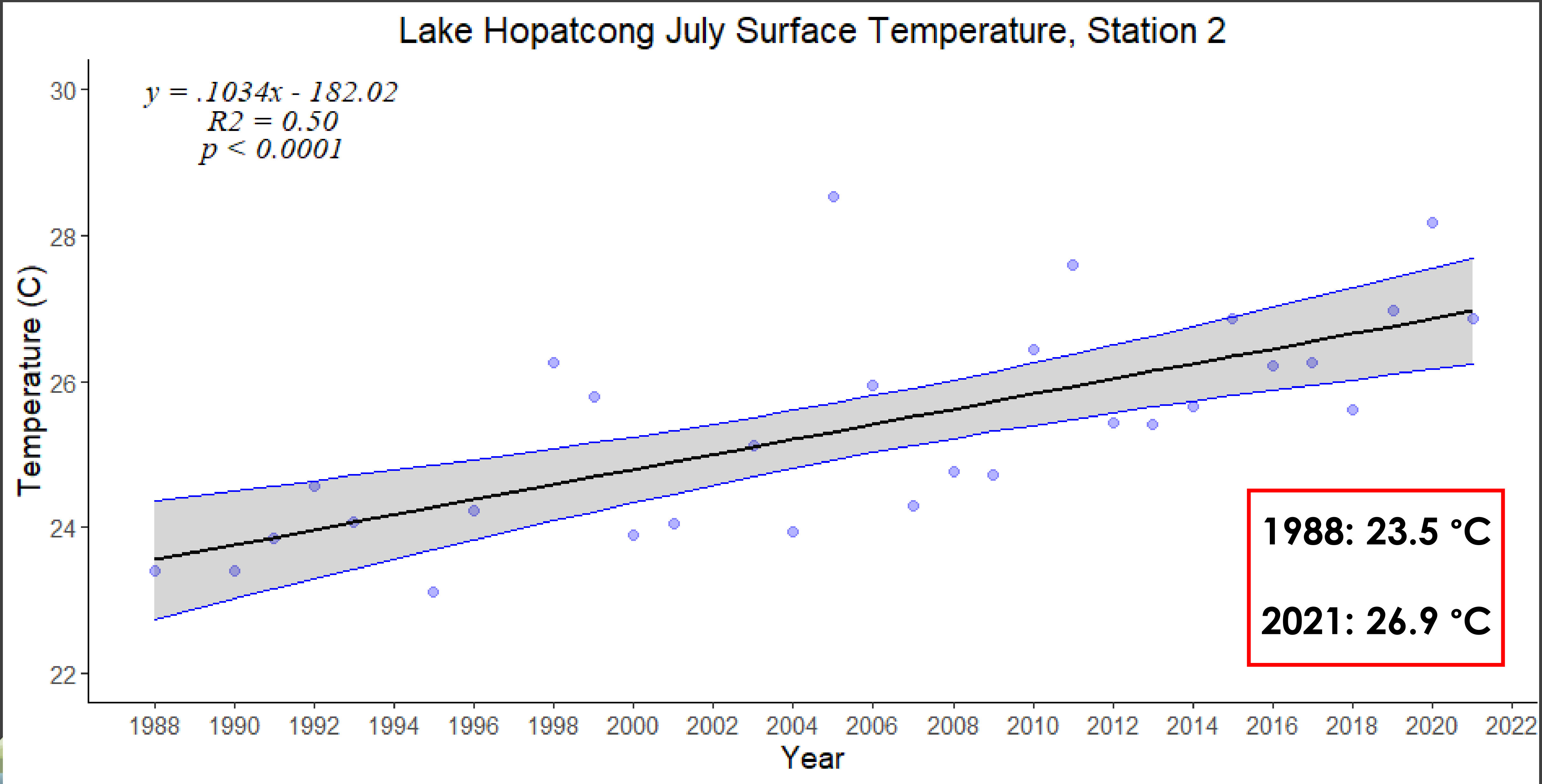
Lake Hopatcong, Sussex and Morris Counties, New Jersey

- ✓ Largest lake in NJ (2,686 acres; 1,087 ha)
- ✓ Maximum depth: 16.7 meters
- ✓ Average depth: 5.6 meters
- ✓ More than 500,000 people visit the lake or live in the watershed
- ✓ Recent increase in HABs



Factors That Lead to Cyanobacterial Blooms

- High seasonal temperatures
- Still water conditions / thermal stratification
- Elevated phosphorus concentrations
- Total phosphorus concentrations 0.03 mg/L or greater can generate nuisance blooms / scums



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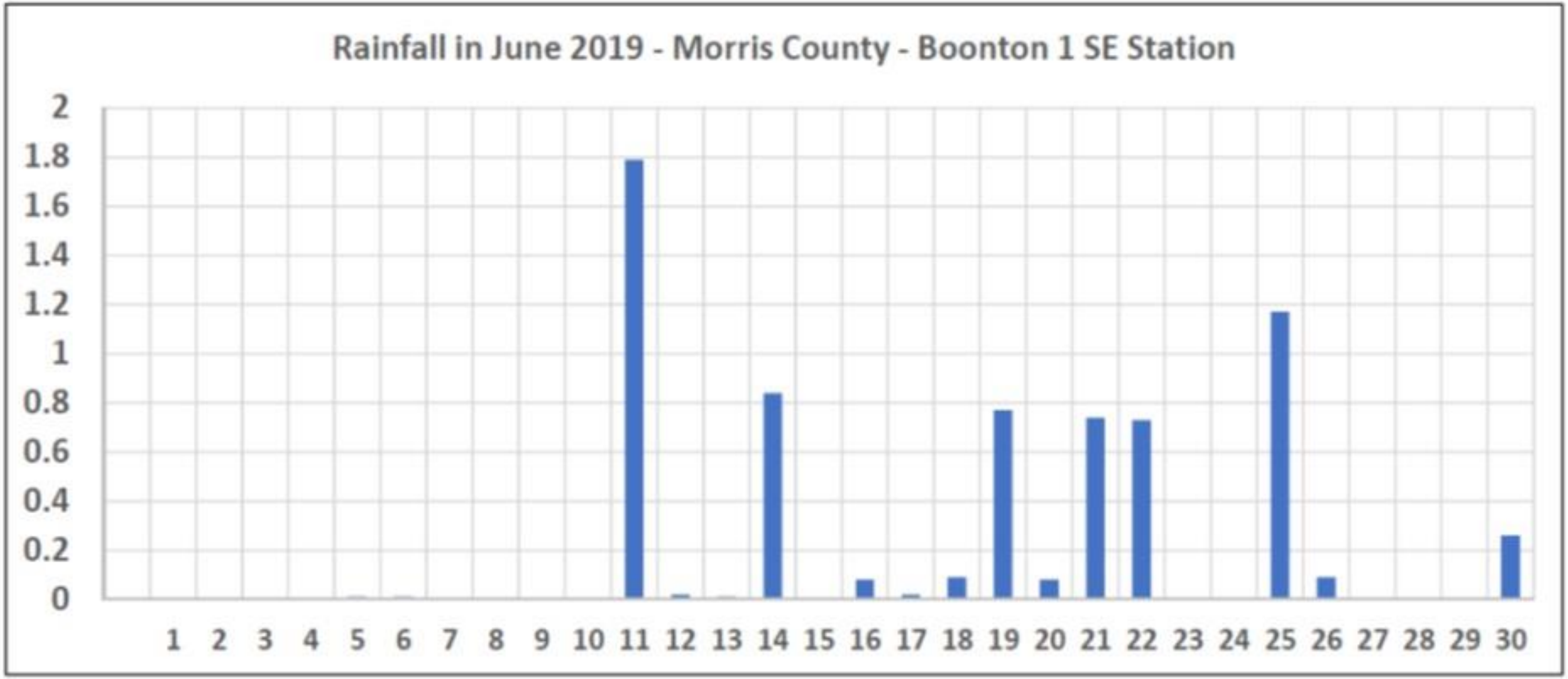
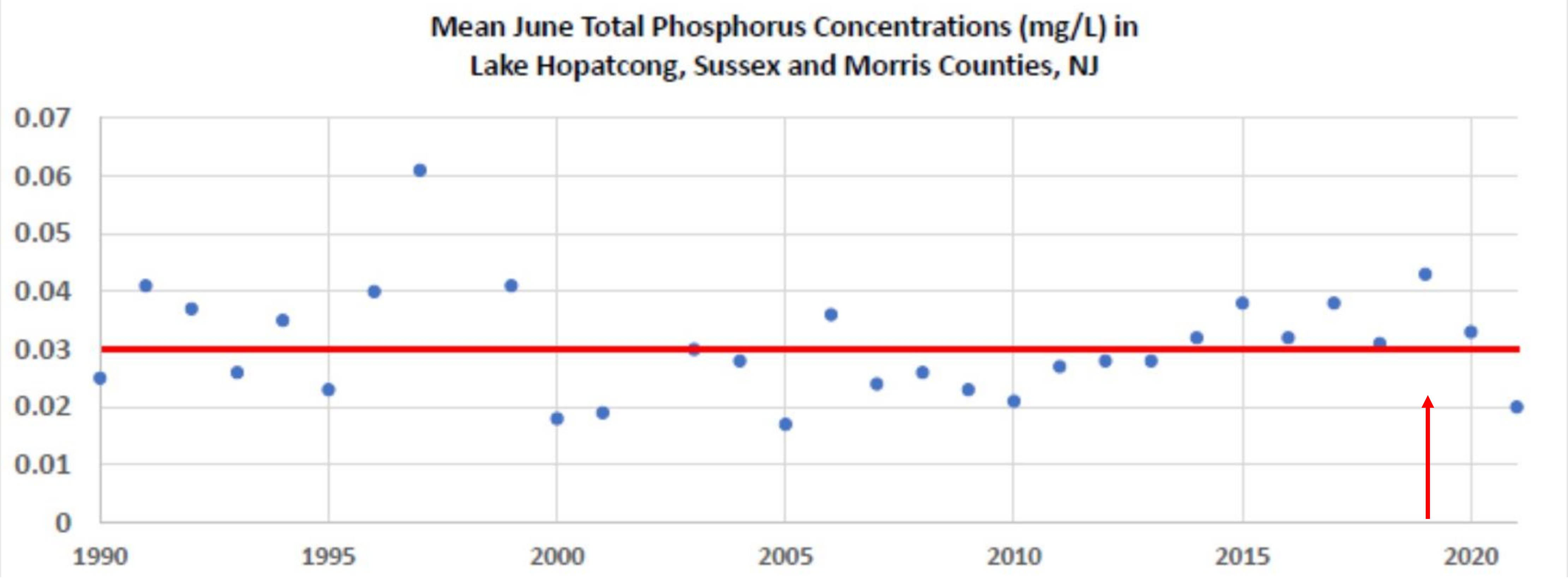
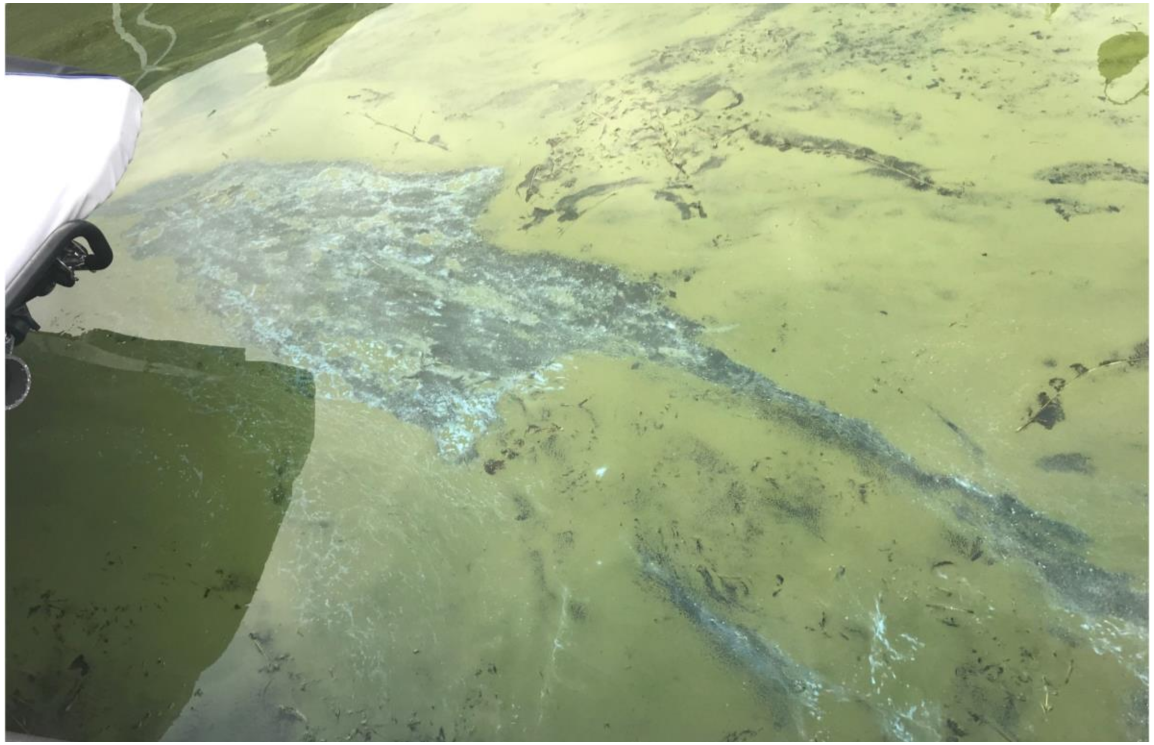


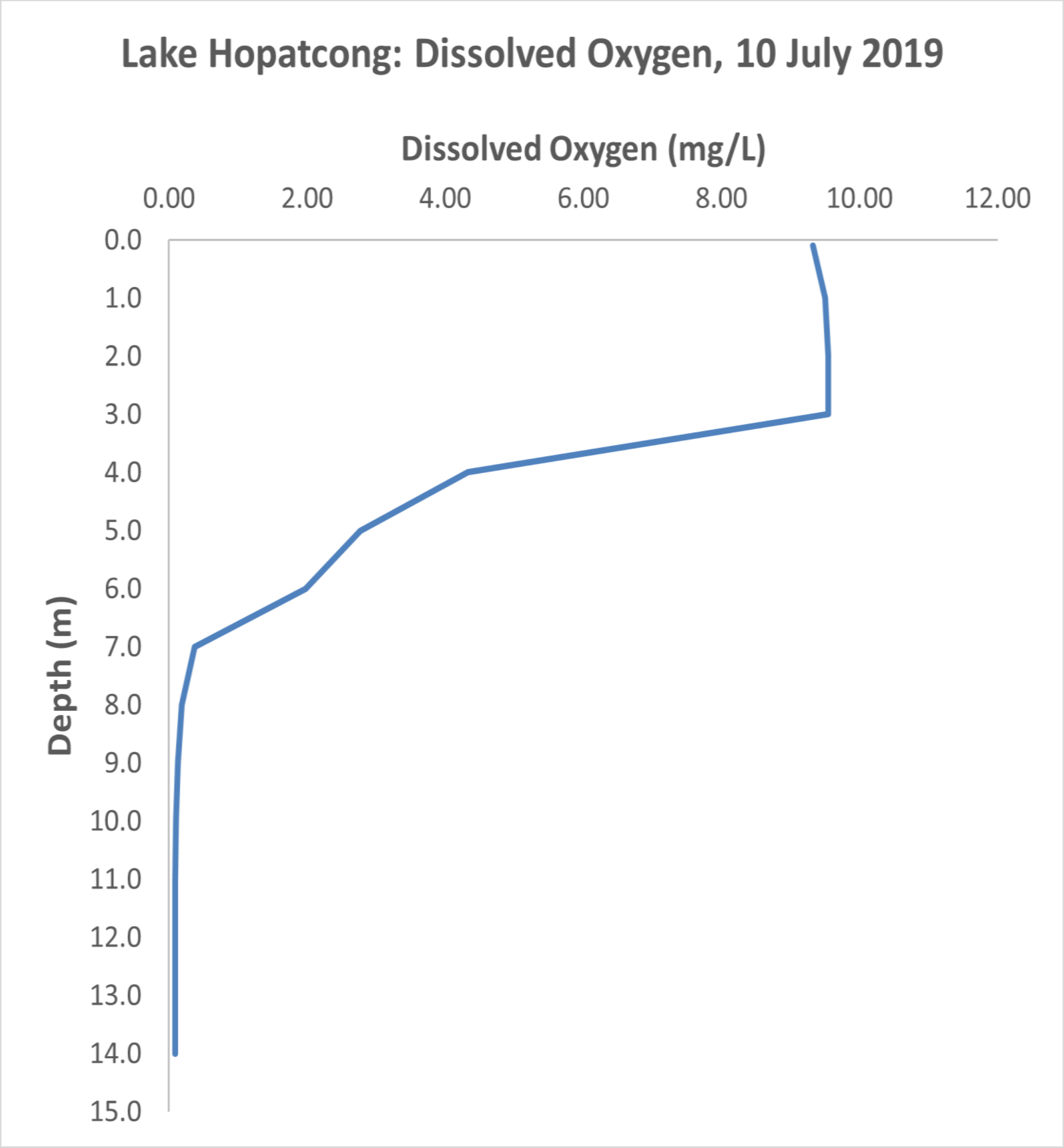
June Precipitation: 6.4 inches

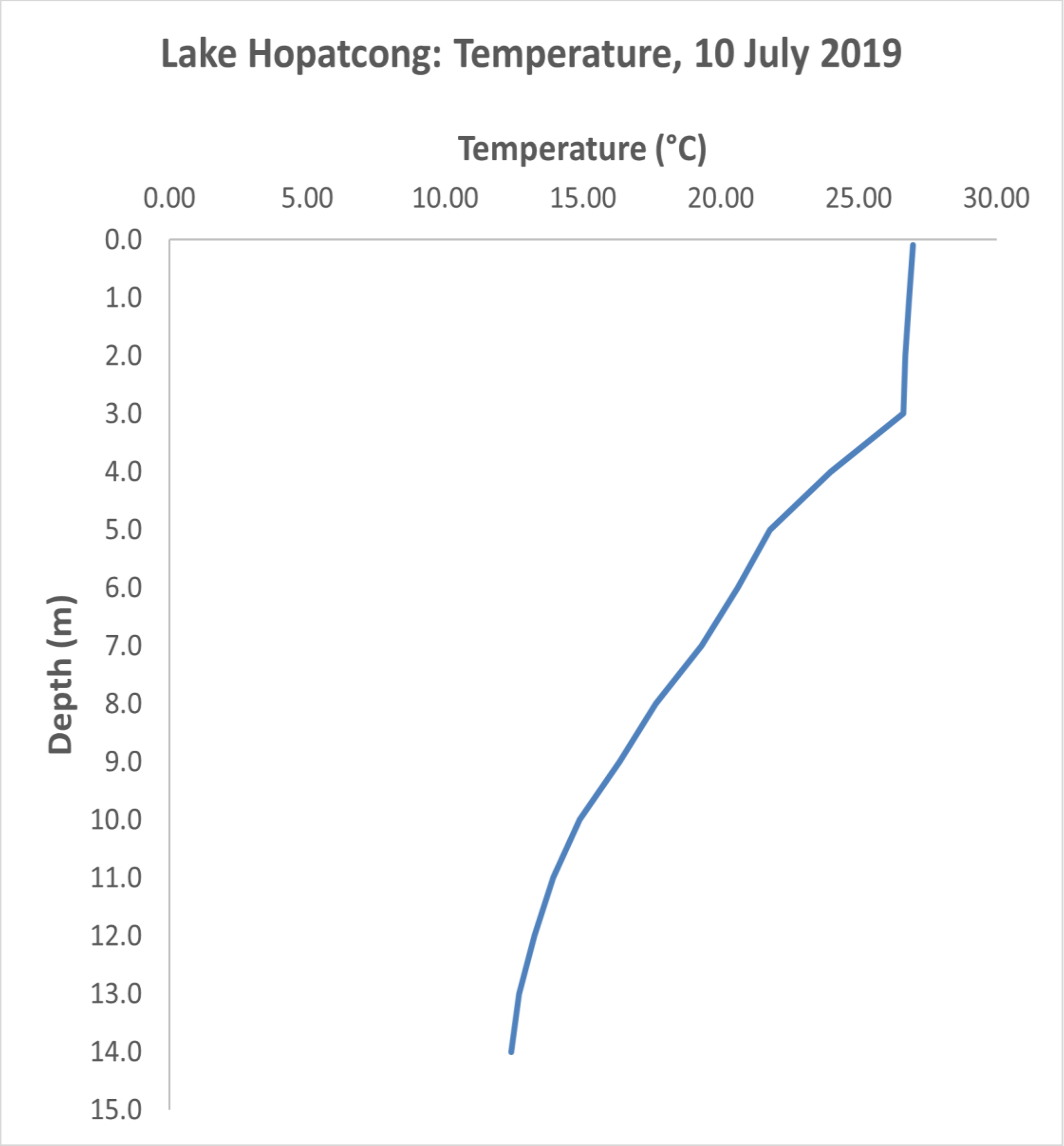

Mean June Total Phosphorus Concentrations (mg/L) in
Lake Hopatcong, Sussex and Morris Counties, NJ
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1990
1995
2000
2005
2010
2015
2020

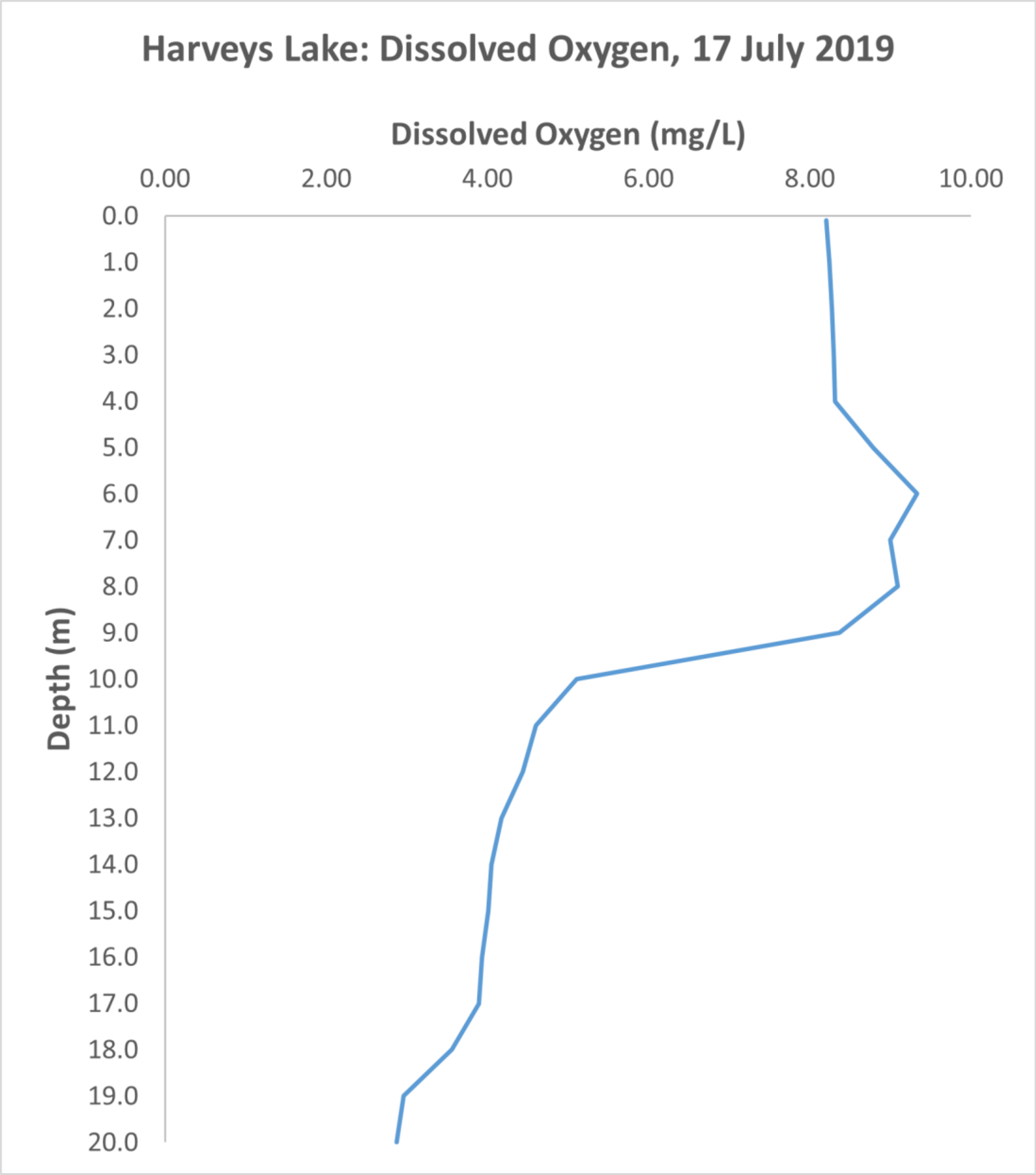
Blooms at Lake Hopatcong (June 2019)

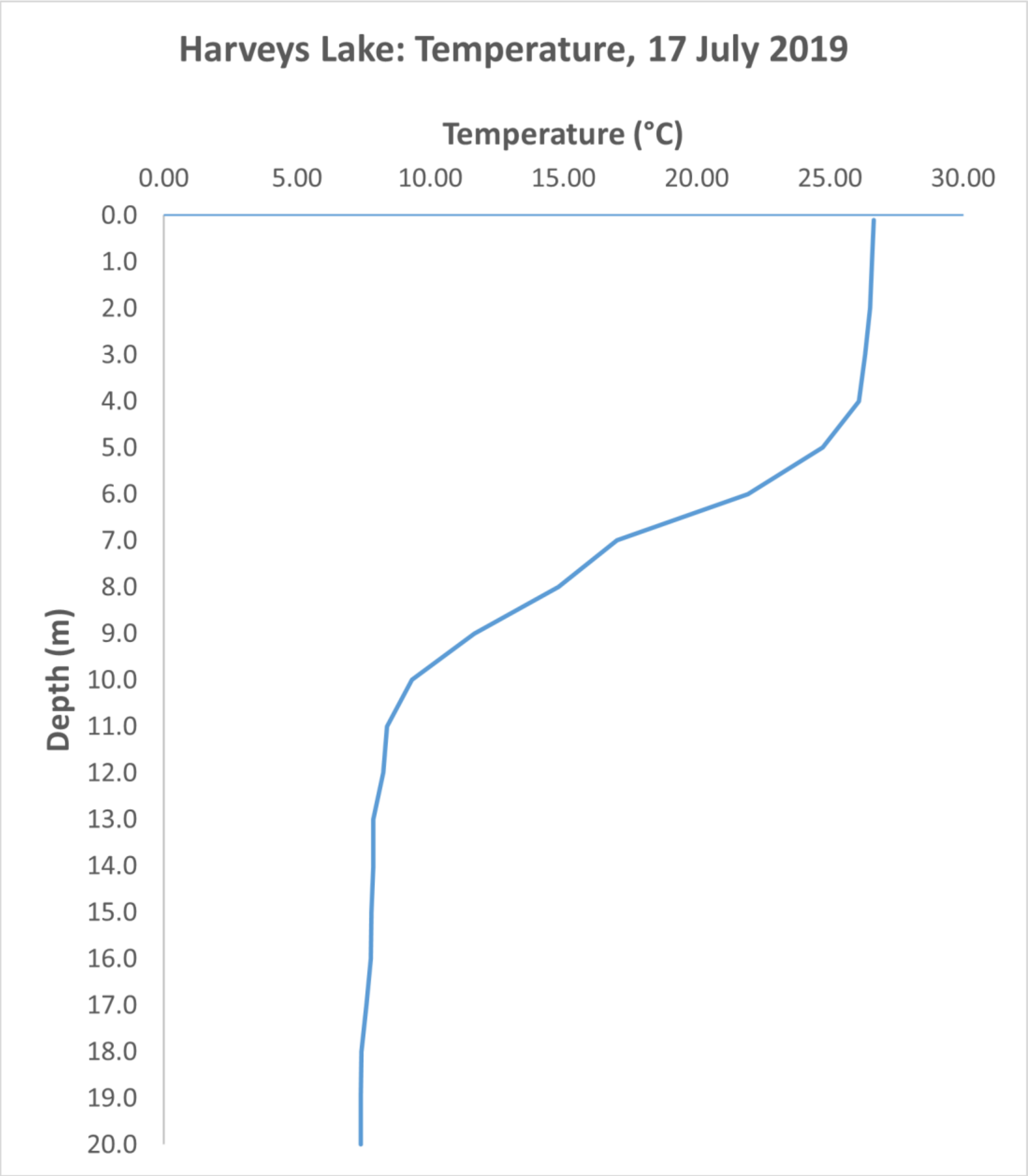


Blooms at Harveys Lake, Luzerne County, PA (June 2019)


Lake Hopatcong: Dissolved Oxygen, 10 July 2019
Dissolved Oxygen (mg/L)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Depth (m)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0


Lake Hopatcong: Temperature, 10 July 2019
Temperature (°C)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0


Harveys Lake: Dissolved Oxygen, 17 July 2019
Dissolved Oxygen (mg/L)
0.00
2.00
4.00
6.00
8.00
10.00
Depth (m)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0


Harveys Lake: Temperature, 17 July 2019
Temperature (°C)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0

Internal Phosphorous Load Study

- ✓ What are the phosphorus dynamics of Lake Hopatcong as it regards the internal load and has it changed over time?
- ✓ How does the internal load change under various hydrologic conditions?
- ✓ How is the internal load ecologically significant?
- ✓ Does the internal load merit management?

Database Construction: Measured Data

- ✓ **153 monitoring events from 1991 – 2021**
  - Each year typically consists of monthly monitoring from May – September
- ✓ **1 mid-lake, deep sampling station**
- ✓ **Sampling parameters of interest**
  - Temperature and DO profiles
  - Surface and deep TP concentrations
  - Chlorophyll *a* and Secchi depth

Database Construction: Key Metrics

✓ **Anoxic zone volume and area**
- Relative Thermal Resistance to Mixing (RTRM) -> depth to anoxia
- Depths -> volume and area using bathymetric data (adjusted for stage)

✓ **Anoxic TP Load**
- Determined using the anoxic boundary rather than the thermocline position

✓ **Equivalent Anoxic Load**
- Net change in loads between sampling events
- If no anoxia present (May), the anoxic boundary from the successive event was used

✓ **Complimentary Load (Oxic Load)**
- Incorporated the volume of the lake above the anoxic zone

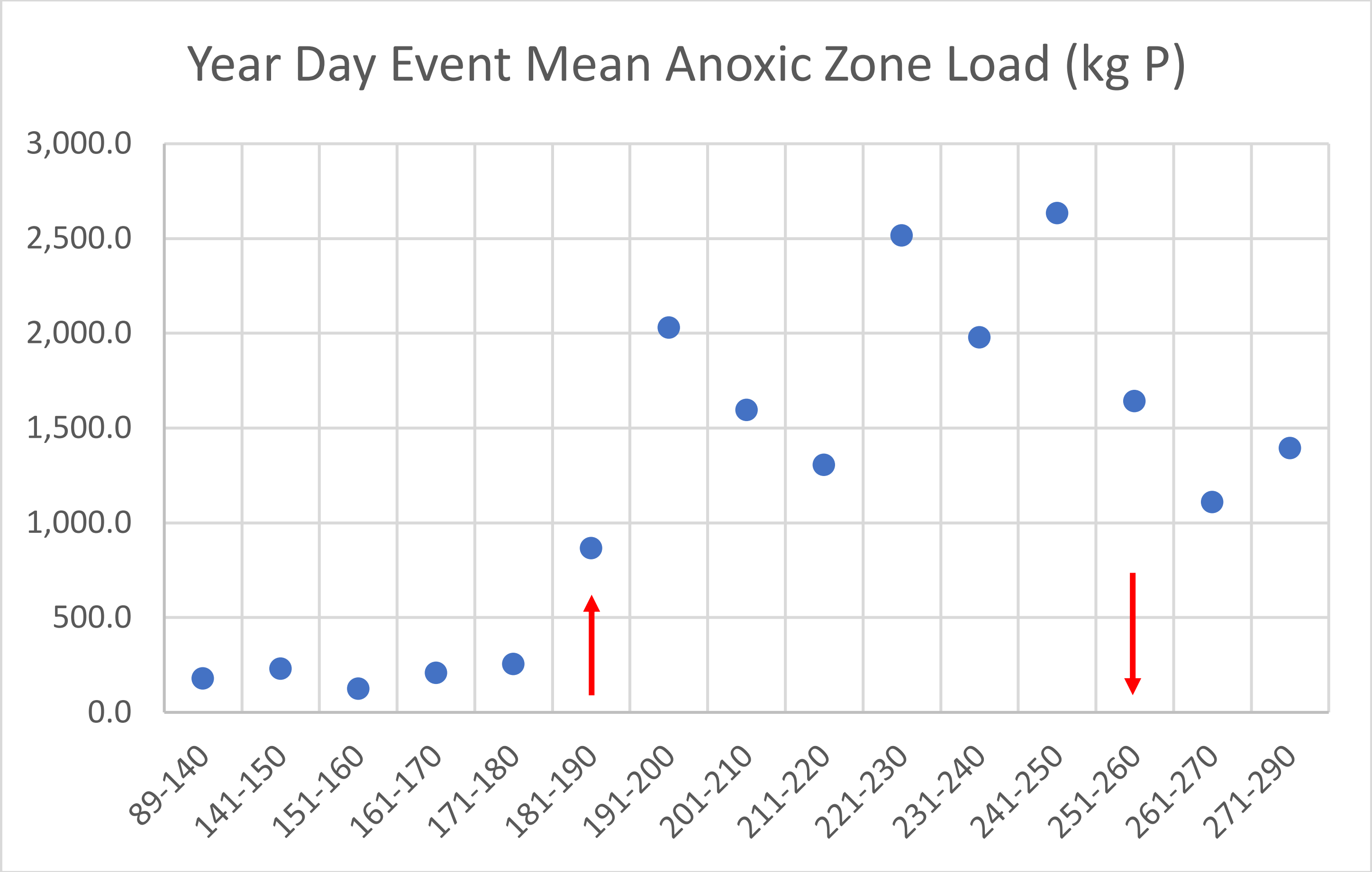
Intra- and Inter-Annual Analysis

- Anoxic TP Load and Loading Rates
- Deep TP Concentrations
- Anoxic Boundary
- Anoxic Volume
- Surface Temperature
- Oxic Load and Loading Rates
- Surface TP Concentrations
- Anoxic and Oxic Load Comparison

Year Day	Equivalent
89-140	March through Mid May
141-150	Late May
151-160	Early June
161-170	Mid June
171-180	Late June
181-190	Early July
191-200	Mid July
201-210	Late July
211-220	Early August
221-230	Mid August
231-240	Late August
241-250	Early September
251-260	Mid September
261-270	Late September
271-290	Late September through October

Intra-Annual: Mean Anoxic Zone Load

- ✓ Early July increase, mid-August Peak
- ✓ Increasing volume of hypolimnion during this time
- ✓ Metalimnetic erosion and downward migration of thermocline in early fall



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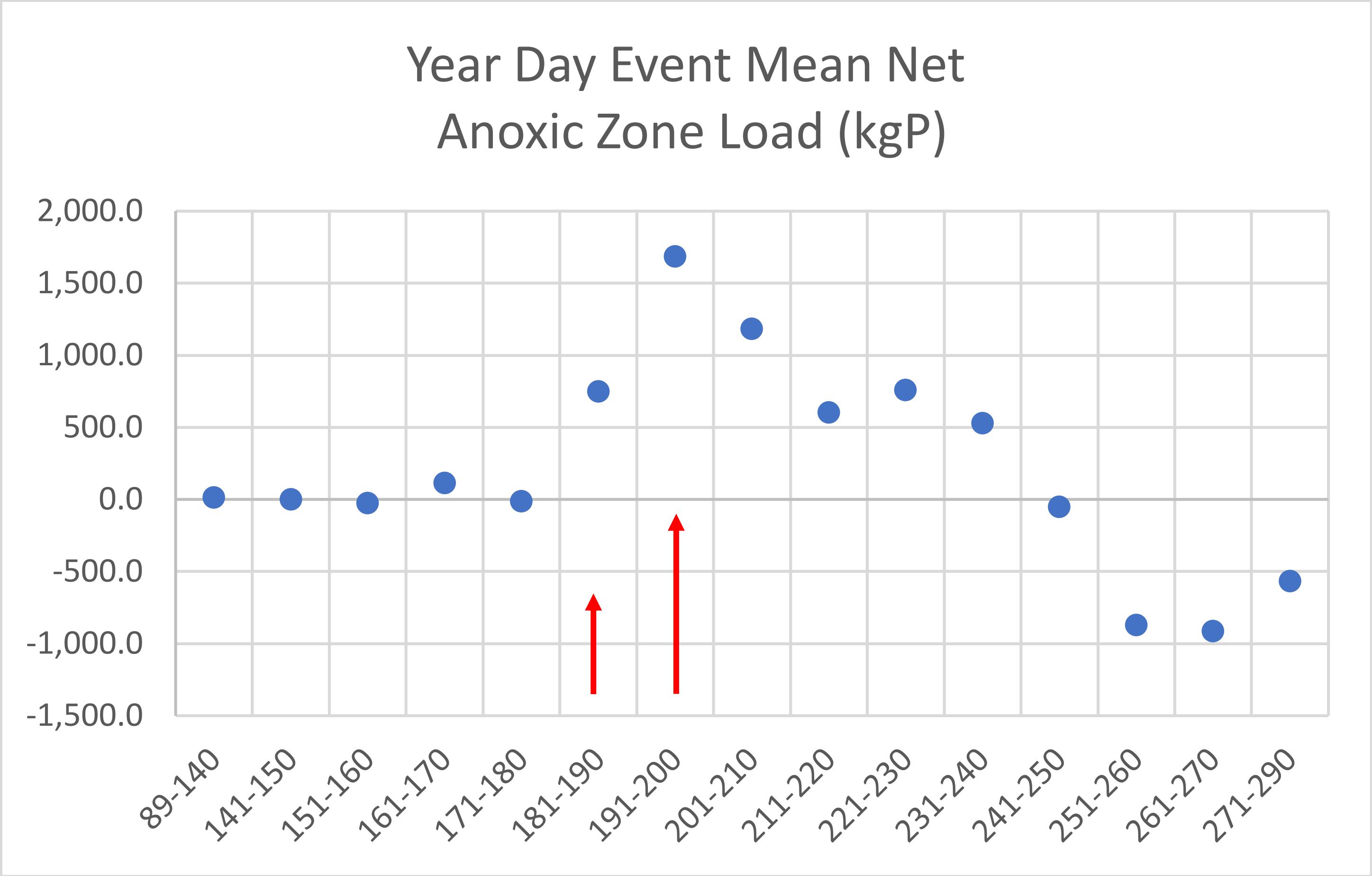
Intra-Annual: Mean Net Anoxic Zone Load

- ✓ Early July increase
- ✓ Mid-July peak due to increase in anoxic volume and TP
- ✓ Net loss by early September



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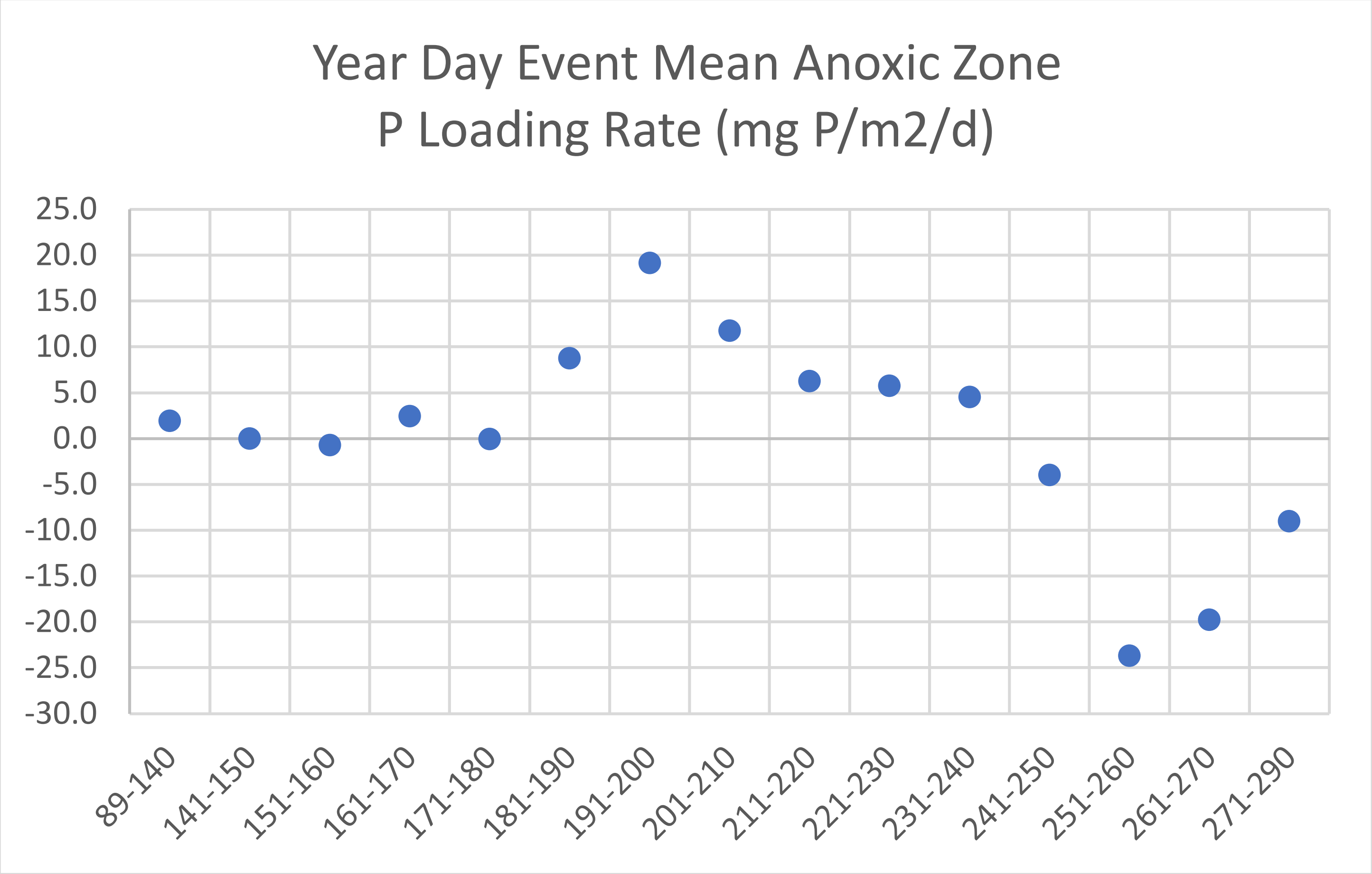
Intra-Annual: Mean Anoxic Loading Rates

- ✓ Daily TP loading rates
- ✓ Mean growing season loading rates similar to the empirically-based anoxic sediment-phosphorus release rates from Nurnberg (1982)



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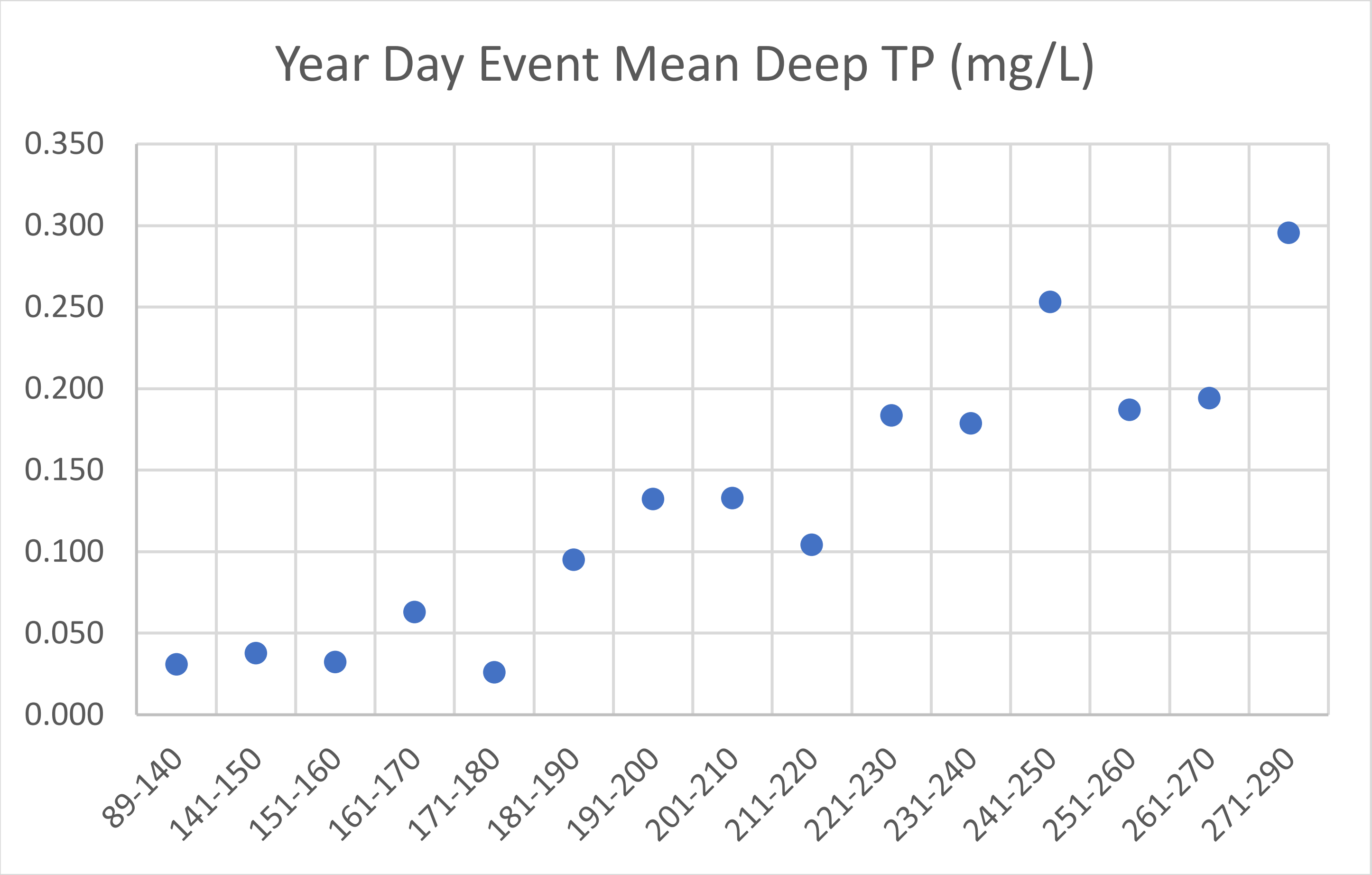
Intra-Annual: Mean Deep TP (mg/L)

- ✓ Mean hypolimnetic TP concentrations
- ✓ Increasing trend throughout the growing season
- ✓ Remain low until early July



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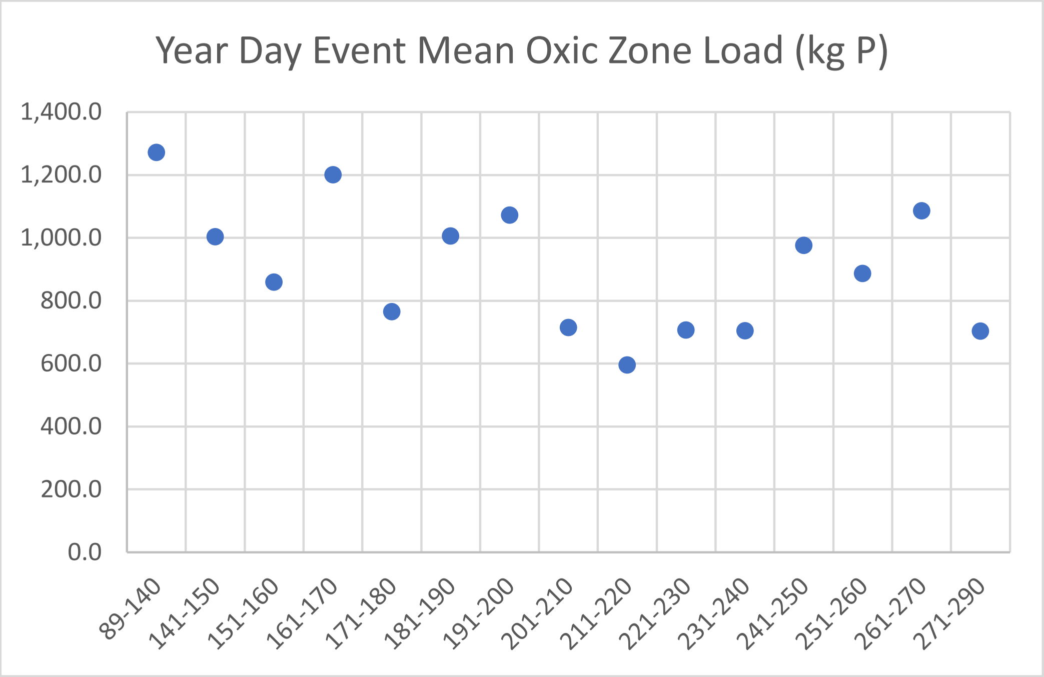
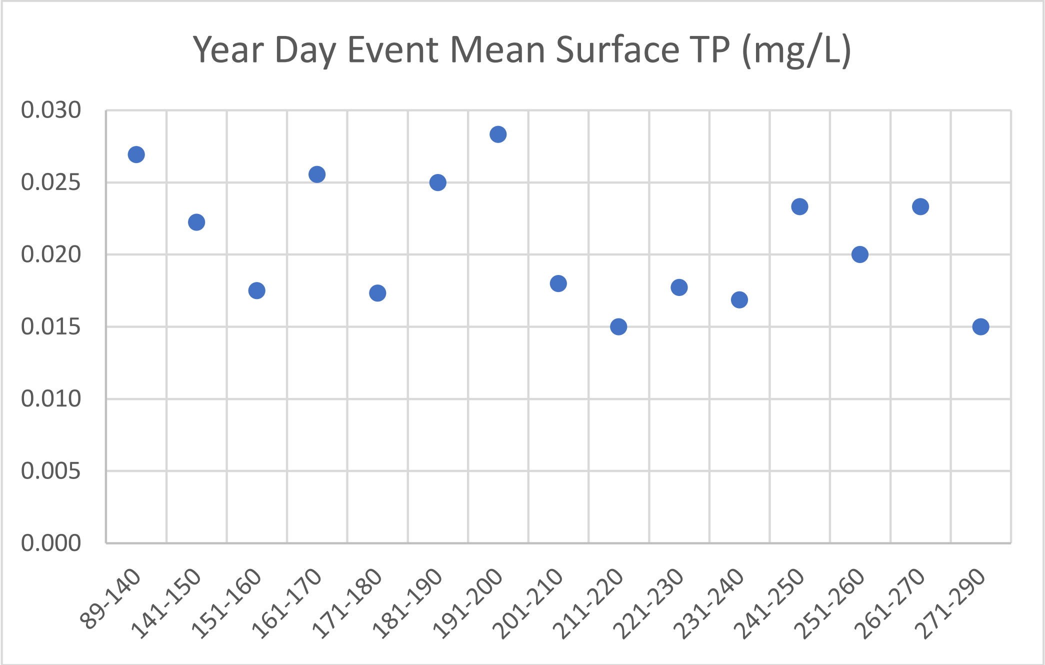
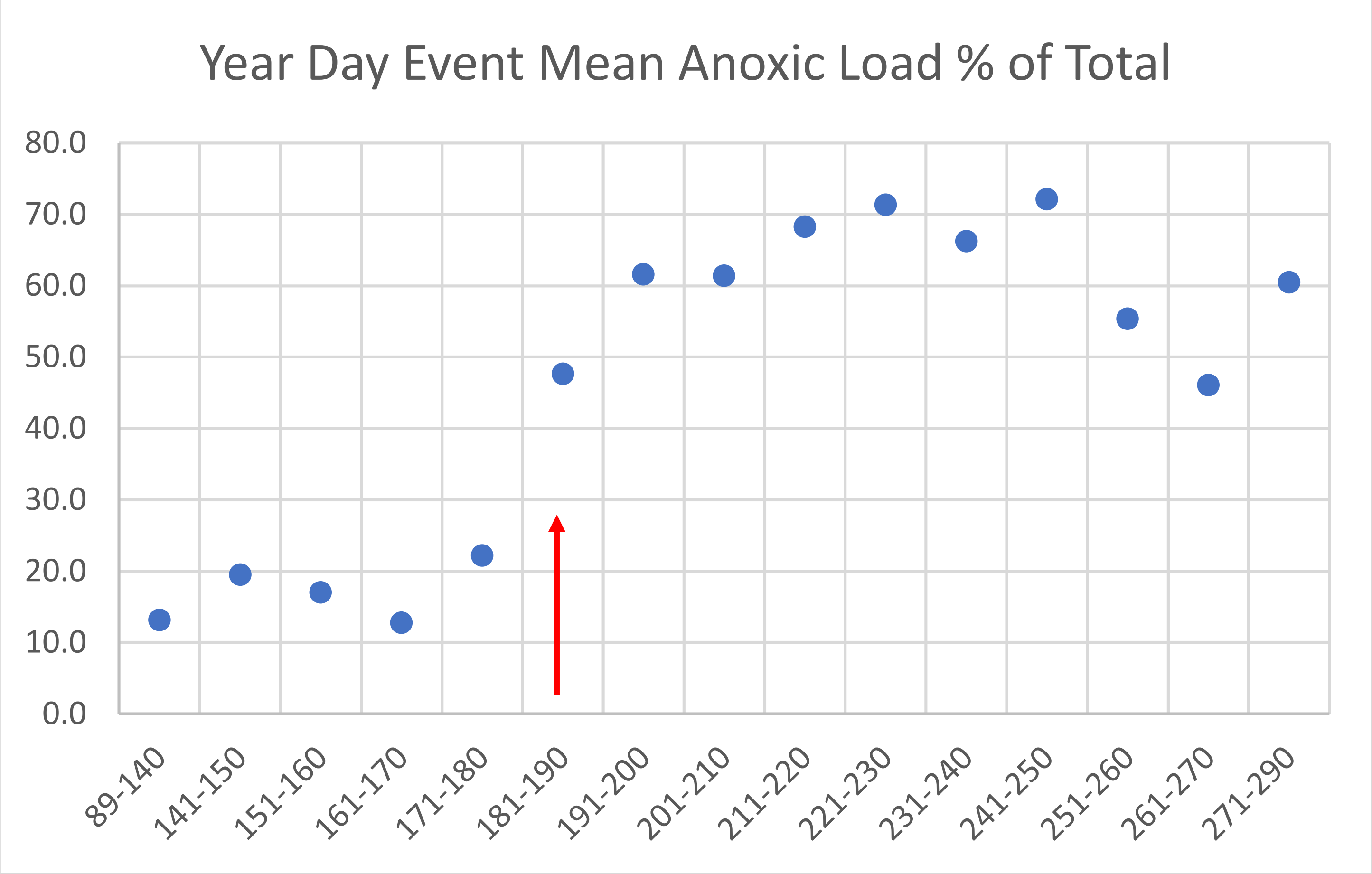
Intra-Annual: Oxic Zone Metrics





Intra-Annual: Mean Anoxic Load % of Total

- ✓ Remains below 25% through late June before increasing to ~50% in early July
- ✓ Remains above 60% through early September
- ✓ Mid-September decline



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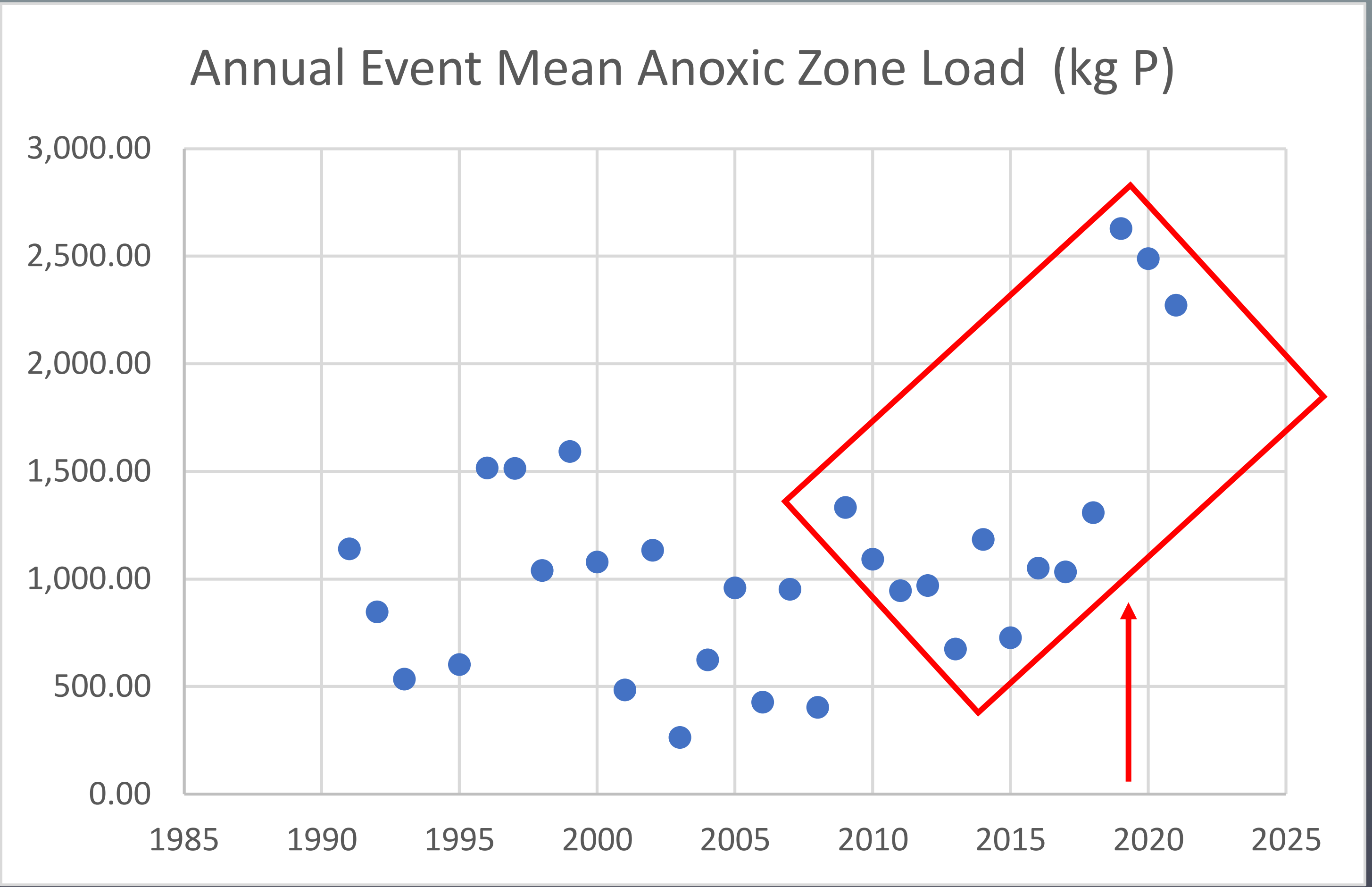
Summary of Intra-Annual Analysis

- ✓ Deep water TP metrics remain low through June
- ✓ Deep water TP metrics increase substantially from early July through early September
- ✓ Deep TP metrics decline beginning in early to mid- September due the lowering of the thermocline and its erosion.
- ✓ Oxic TP metrics generally decline over the first half of the season but begin to increase again in late summer / early fall due to a transfer of the TP from the anoxic zone.

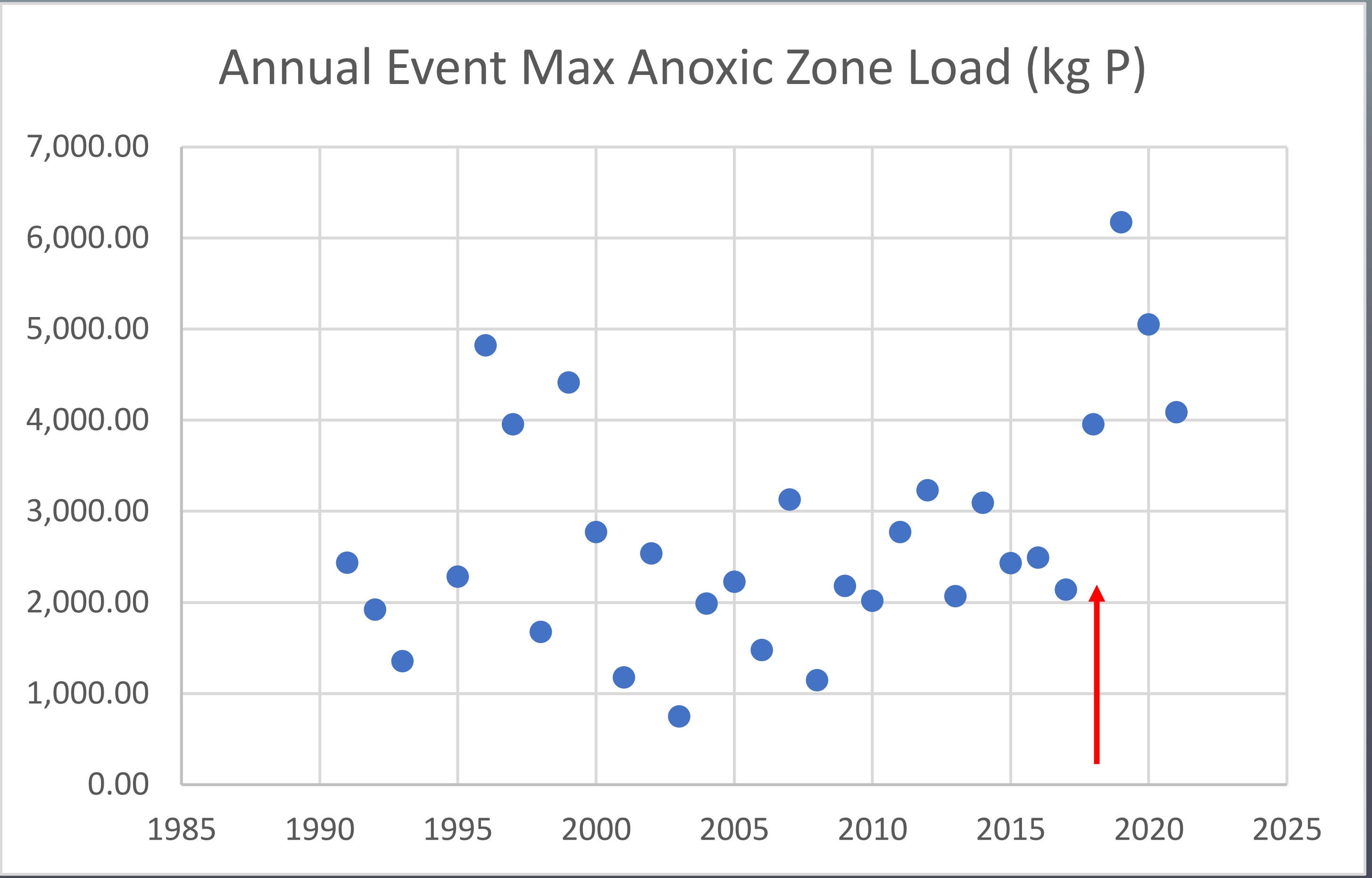
Inter-Annual: Mean Anoxic Zone Load

- ✓ Variable anoxic TP load from 1991 – 2008
- ✓ Less variability and higher mean load from 2009 – 2021
- ✓ Mean anoxic TP load was highest in 2019 and has remained high since



Inter-Annual: Max Anoxic Zone Load

- ✓ Maximum TP load better represents the accumulation of TP in the hypolimnion
- ✓ Similar pattern as the mean anoxic zone load
- ✓ Large increase 2018 - 2021



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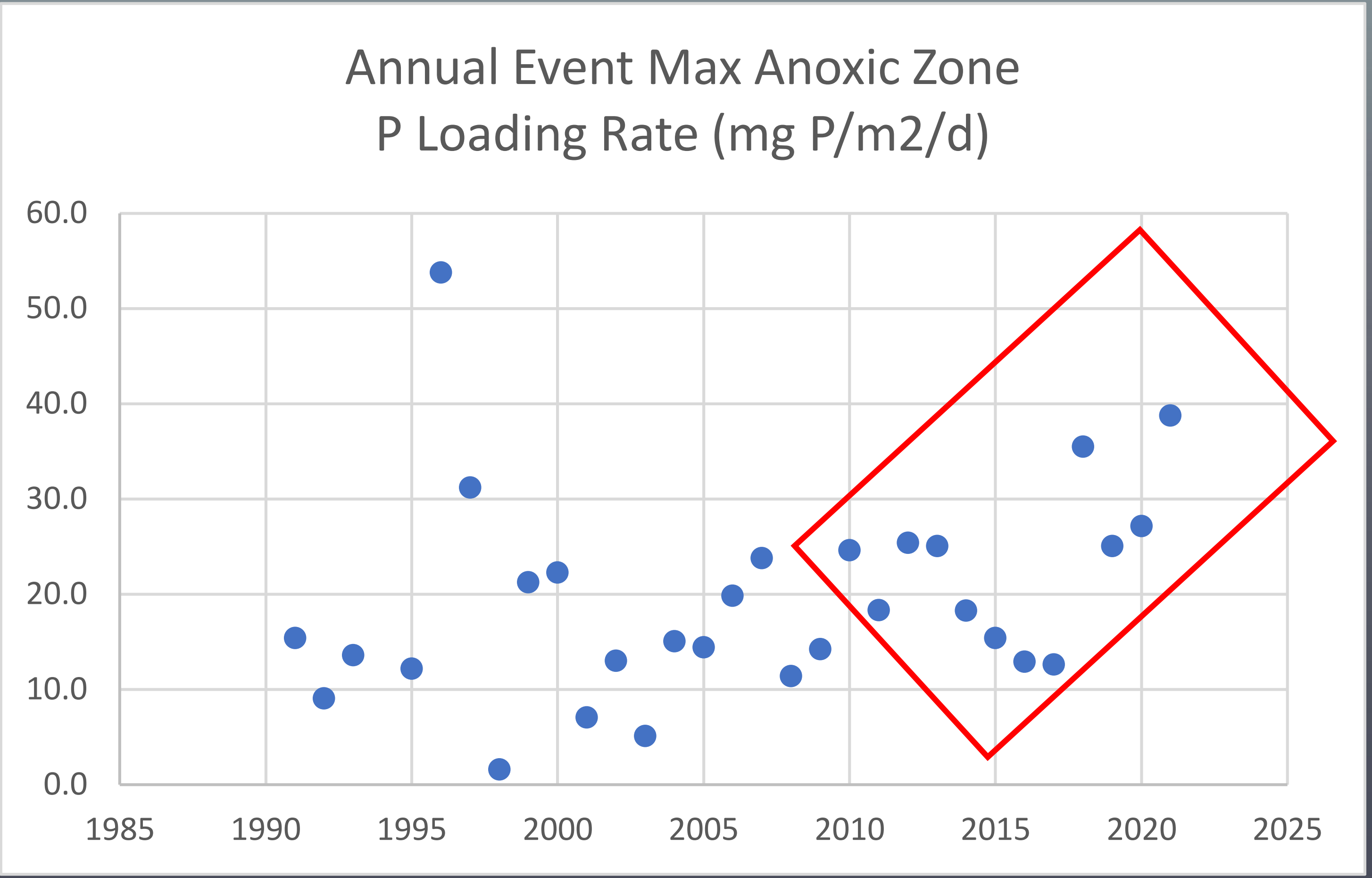
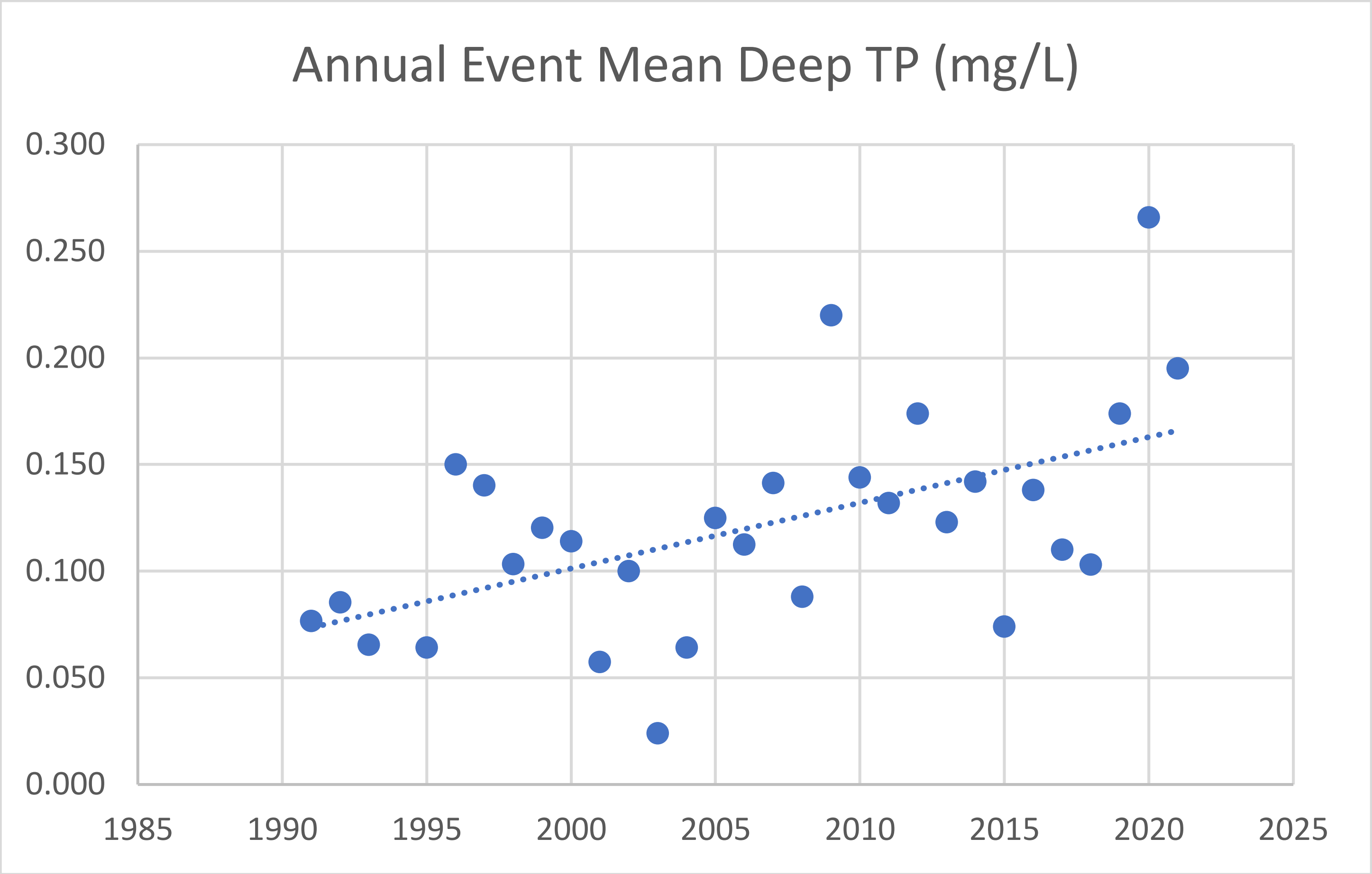
Inter-Annual: Max Anoxic Loading Rates

- ✓ Daily, maximum anoxic loading rates have been consistently high over the last 4 years
- ✓ Loading rate increasing on a unit area basis
- ✓ No deep-water temperature increase

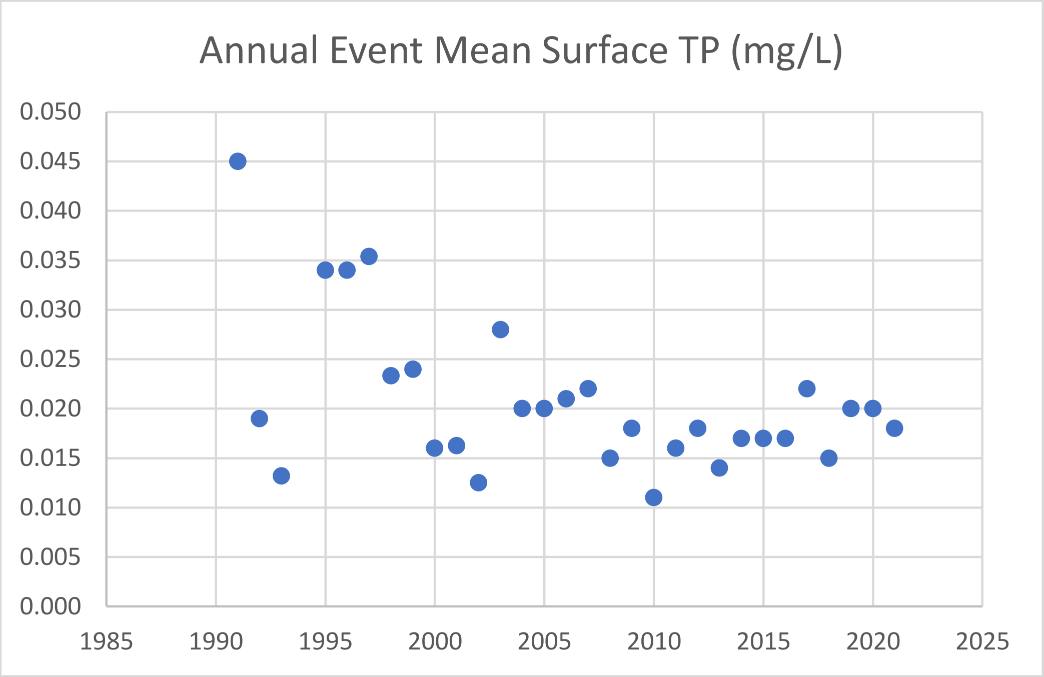


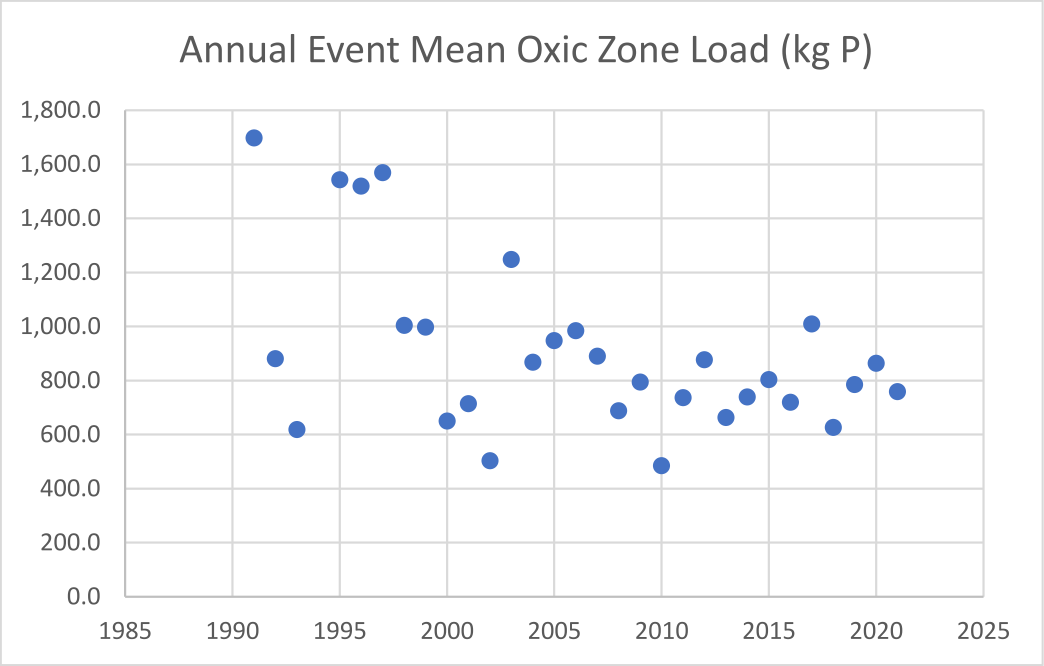
Inter-Annual: Mean Deep TP

- ✓ Mean hypolimnetic TP concentrations
- ✓ Annual variability but increasing trend
  - 1991 – 1995: < 0.10 mg/L
  - 1996 – 2021: > 0.10 mg/L (81%)
  - 2019 – 2021: 0.208 mg/L



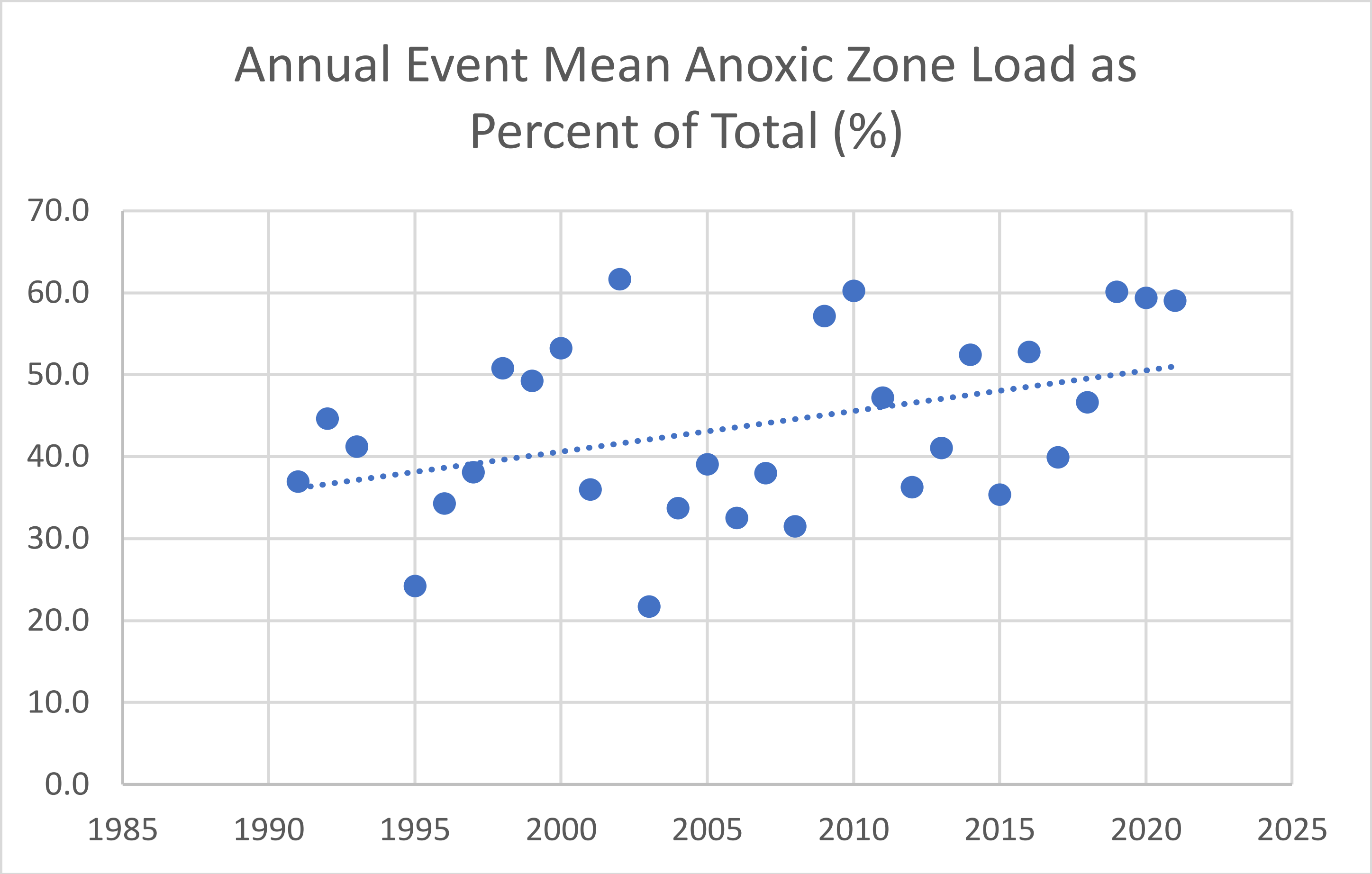
Inter-Annual: Oxic Zone Metrics





Inter-Annual: Mean Anoxic Load % of Total

- ✓ Increasing trend over the last 30 years
- ✓ Anoxic zone load has comprised approximately 60% of the total load over the last three years



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Summary of Inter-Annual Analysis

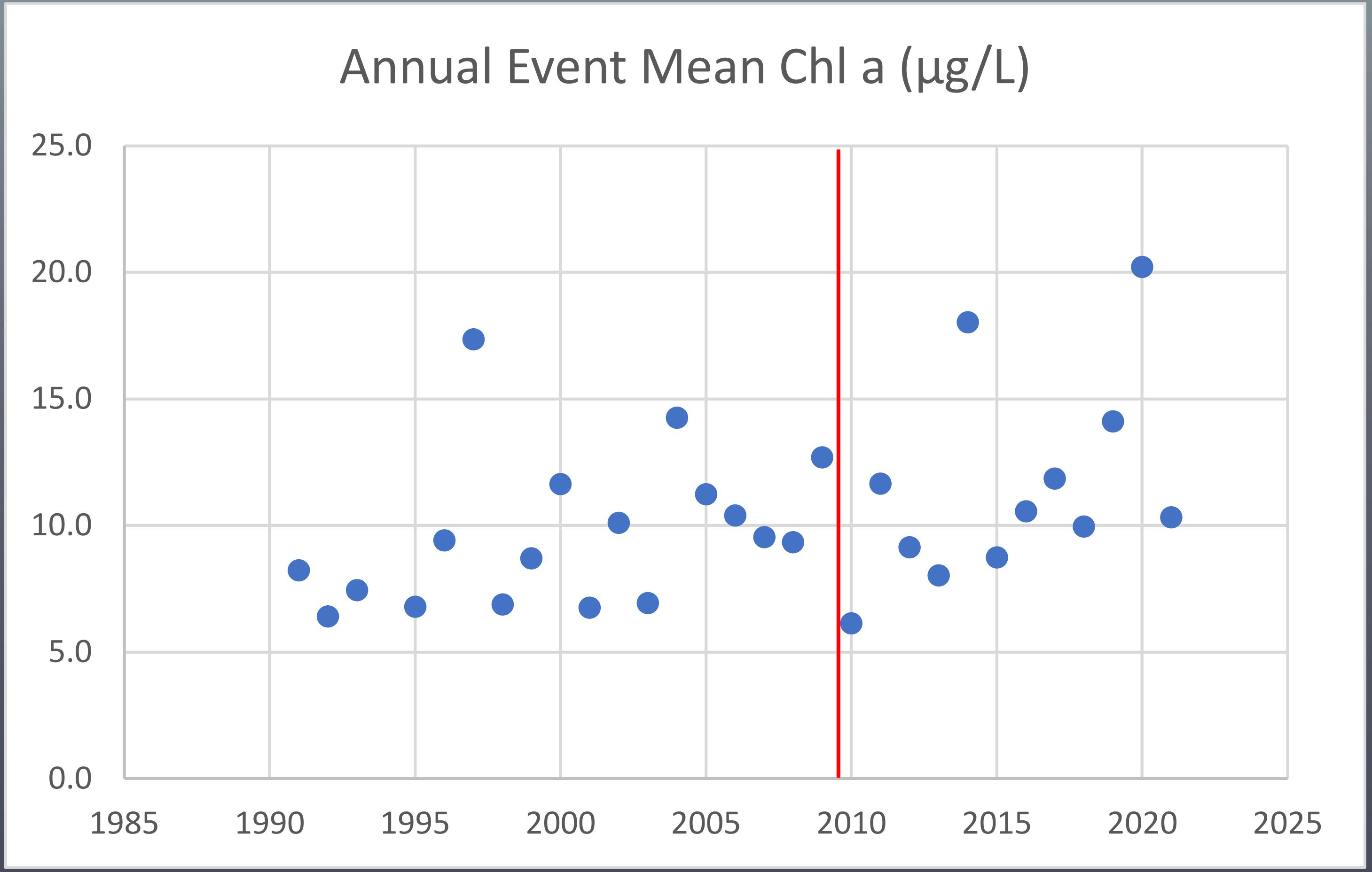
- ✓ The mean anoxic TP load has increased substantially over the last three years
- ✓ Increase is due to both an increase in deep TP concentrations and an increase in the anoxic zone volume
- ✓ Conversely, oxic zone TP metrics have declined which can be attributed to watershed restoration efforts (stormwater, septic management, sewering) over the past 20+ years

Factors Contributing to the Increased Anoxic Load

- ✓ Rise in growing season average temperature relative to climate normals
- ✓ Change in precipitation patterns
  - Wet years have been wetter and dry years not as dry
  - Frequency in warm wet years has increased substantially
- ✓ Both increasing growing season temperature and precipitation has shown correlation with increasing anoxic loads
- ✓ Eutrophication and long-term accumulation and retention of phosphorus

Lake Ecology – Chlorophyll *a*

- ✓ Increasing trend over the last 30 years
- ✓ 1991-2009: 9.74 µg/L
- ✓ 2010 – 2021: 11.55 µg/L
  - 18.5% increase
- ✓ Surface TP decreased 26% from 1991 - 2021



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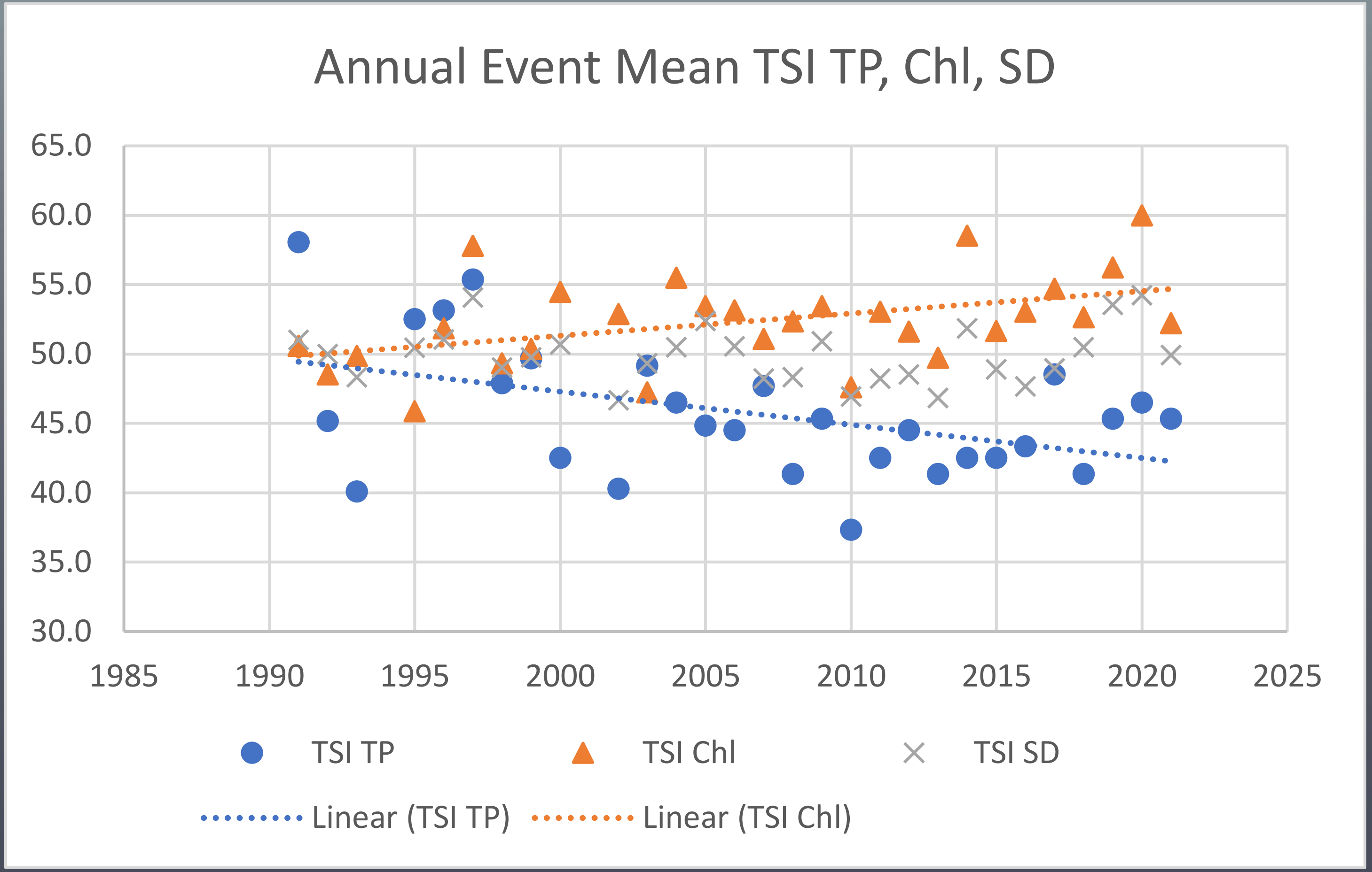
Lake Ecology – Trophic State Index

- ✓ Decline in TSI-TP
- ✓ Increase in TSI-Chl *a*
- ✓ Decrease in TSI-TP is related to successful external load management efforts



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Summary and Conclusions

- ✓ **The internal phosphorus load has increased substantially since 1991**
  - The average load from 2019 – 2021 was over 2,400 kg
  - No other year on record exceeded 1,600 kg
  - The average internal load from 2010-2021 was 57% higher than 1991-2009

- ✓ **The oxic (surface) load has decreased since 1991**

- ✓ **Algal biomass has increased since 1991**

Summary and Conclusions

✓ **What's causing the increase in algal productivity?**
- Large increase in the internal phosphorus load
- Effective utilization of available phosphorus by the plankton community
- Shift in algal community composition
- Shift in the timing and availability of phosphorus
- Climatic changes: temperature and precipitation

✓ **The internal phosphorus load merits management**
- Nutrient inactivation
- Aeration (hypolimnetic, direct oxygenation, layer-air, etc.)

QUESTIONS?

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THANK YOU!

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