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Bureau of Clean Water

Overview of the Eutrophication Cause Determination Protocol

AG Advisory Board Meeting

December 21, 2017

Charlie McGarrell

Tom Wolf, Governor

Patrick McDonnell, Secretary

Issue the Protocol Will Address

- Excessive Nutrient Enrichment Can Have Detrimental Effects on Aquatic Life
- PA and Most States Do Not Have Statewide Numeric Nutrient Criteria for Protecting Aquatic Life in Streams and Rivers
- Without Numeric Nutrient Criteria, It's Difficult to Defend Integrated Report Listings of Nutrients as a Cause of Aquatic Life Use (ALU) Impairment

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Issue the Protocol Will Address

- After an ALU-Impairment Decision is Made with an Appropriate DEP Assessment Protocol
- Eutrophication Protocol Will Provide DEP Staff with an Objective, Science-Based Method for Determining if Nutrients are a Cause of ALU Impairment

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Intended Use of the Protocol

- Listing Nutrients – Eutrophication as A Cause of ALU Impairment Under Category 5 of the Integrated Report
- Streams with Drainage Areas Up to 350 mi^2
- PA Nutrient Ecoregions IX and XI

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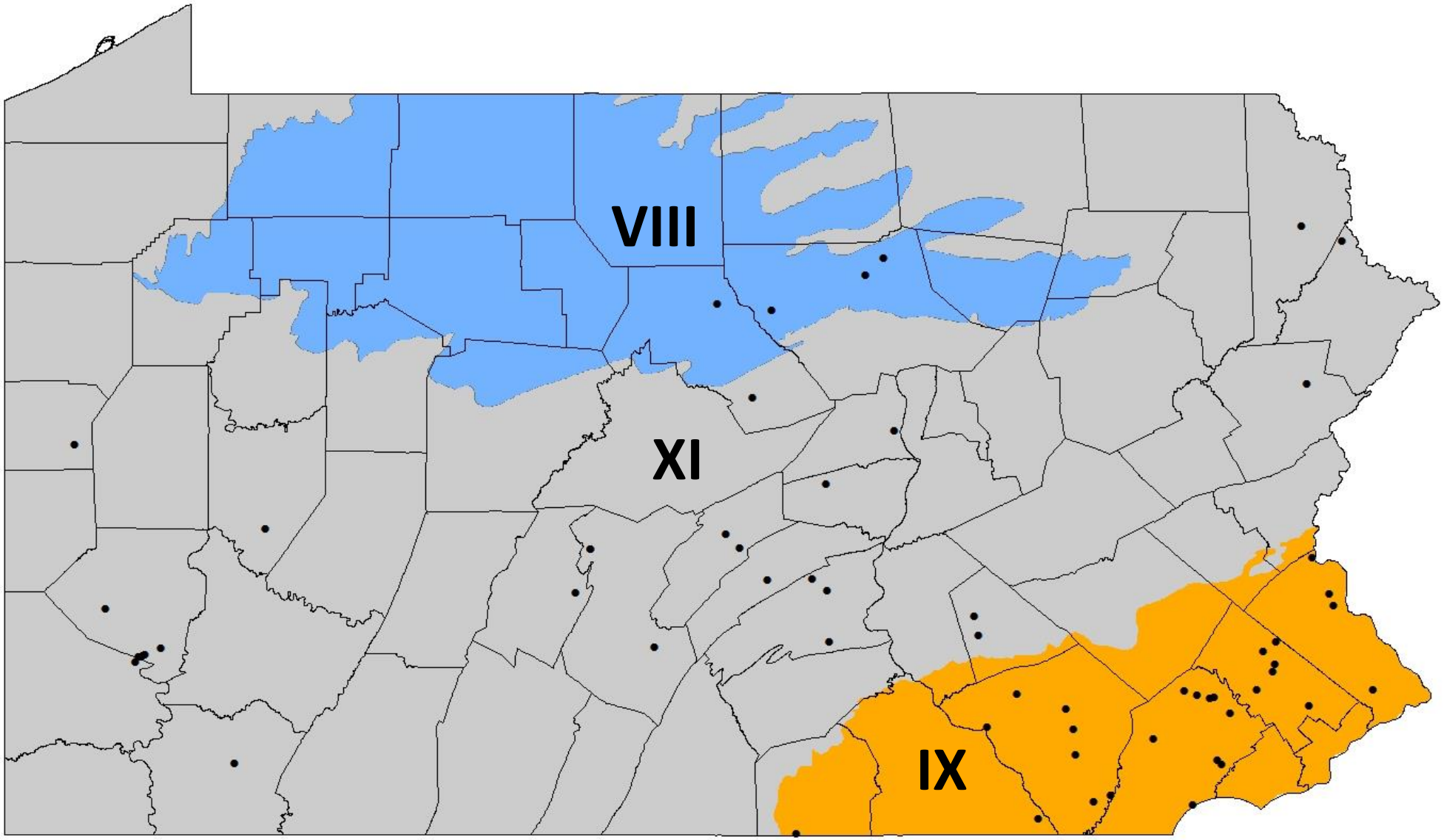
PA Nutrient Ecoregions



Why No Numeric Nutrient Criteria & the Need for the Protocol?

- Primarily Due to the Complexity of the Response of Biological Communities to Nutrient Enrichment
- Nutrients (P and N) are Not Directly Toxic
- Most Nutrient-Related Impacts Are the Result of Modifications of Aquatic Food (Trophic) Webs
- Food Web Alterations Are Influenced by Numerous Factors:
  - Shading
  - Scour
  - Depth
  - Turbidity

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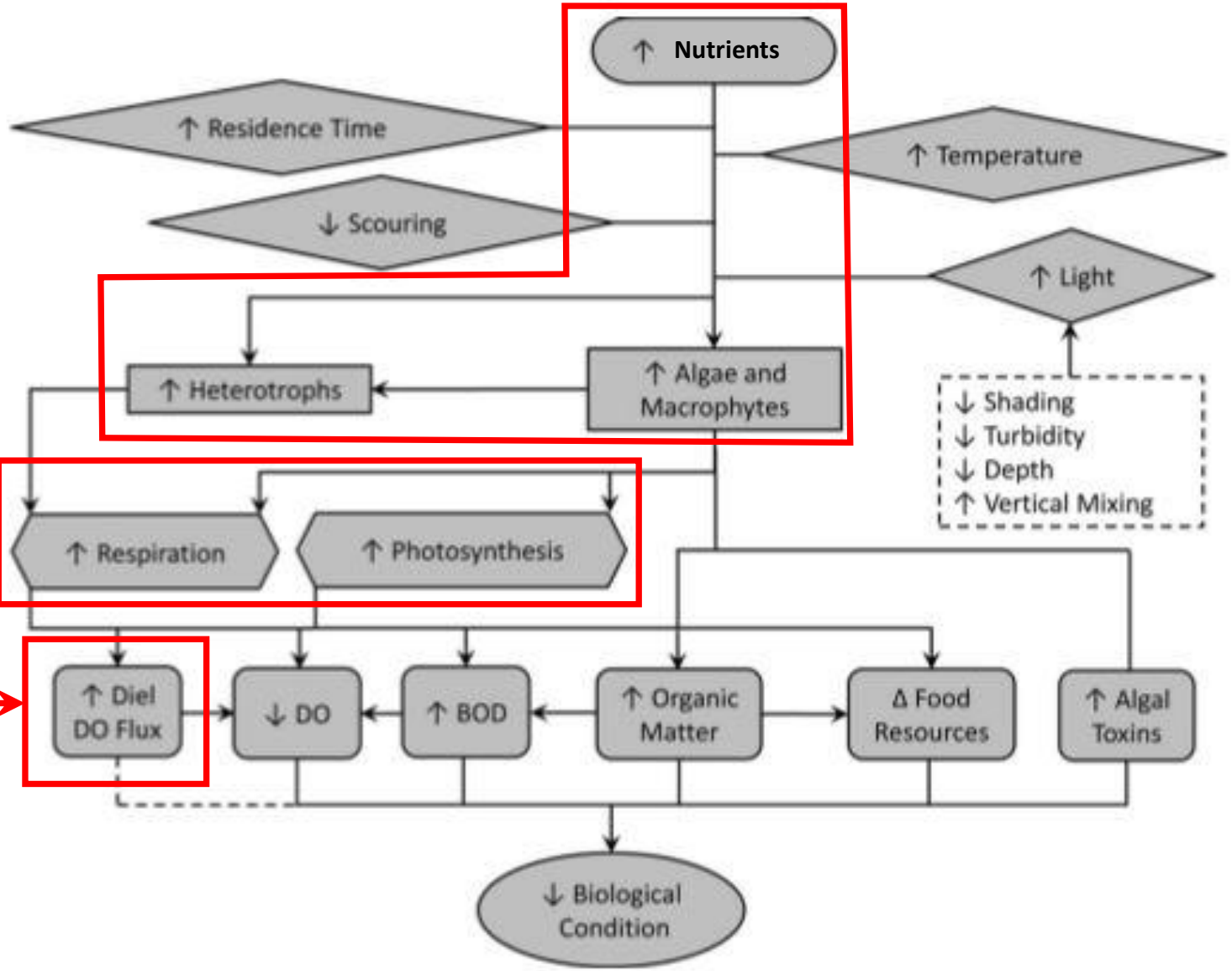
Conceptual Model of the Impact of Nutrient Enrichment on Stream Biological Condition

Stream Ecosystem Metabolism

Indicator of Metabolic Conditions



Source: Heiskary and Bouchard (2015), MN Eutrophication Criteria for Streams and Rivers

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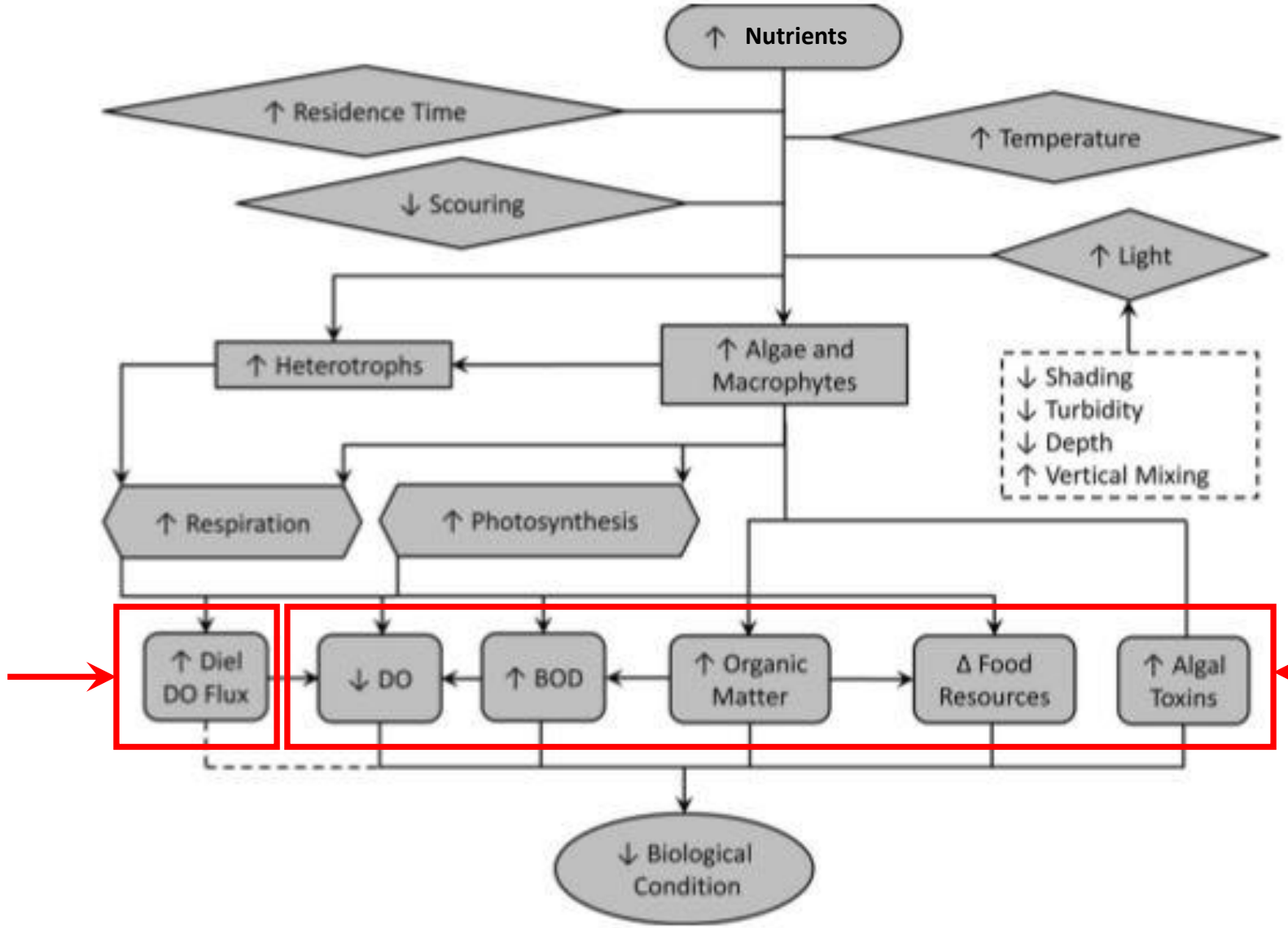

Indicator of Potential Stressors to Aquatic Life

Potential Stressors to Aquatic Life

Source: Heiskary and Bouchard (2015), MN Eutrophication Criteria for Streams and Rivers

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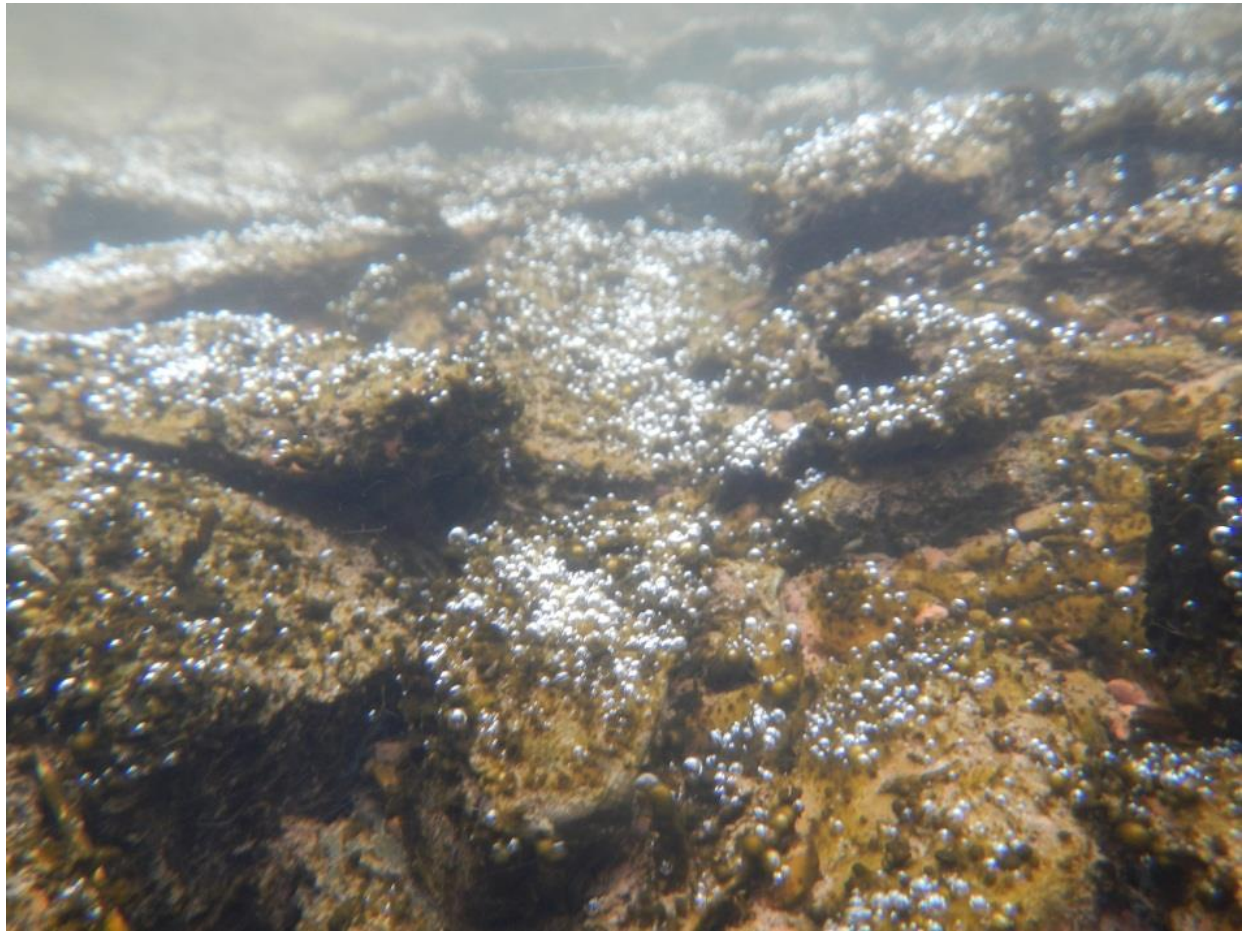
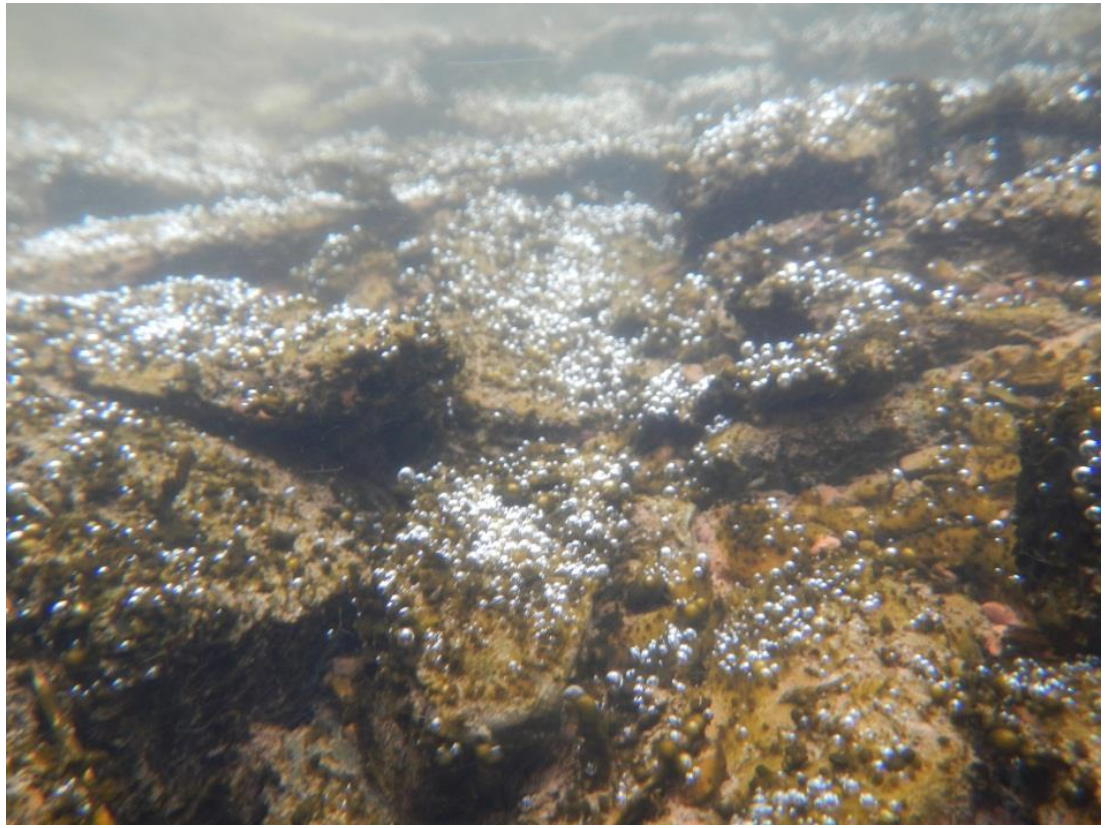
Elevated Diel DO Swings:



- Associated with Elevated Photosynthesis and Respiration Rates
- Reflect Overall Ecosystem Metabolic Conditions
- Indicate the Potential for Eutrophication-Related Stressors to Aquatic Biological Communities:
  - Intermittent Low DO Conditions
  - Modified Physical Habitat Conditions
  - Altered Food (Trophic) Webs
  - Algal Toxins

Photosynthesis and Respiration Rates Influence pH on a Diel Cycle



- Photosynthesis (Light-Dependent, Diel Cycle):

$$6CO_2 + 6H_2O \xrightarrow{\text{Light Energy}} C_6H_{12}O_6 \text{ (Organic Matter)} + 6O_2$$

- Respiration:

$$C_6H_{12}O_6 \text{ (Organic Matter)} + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$$

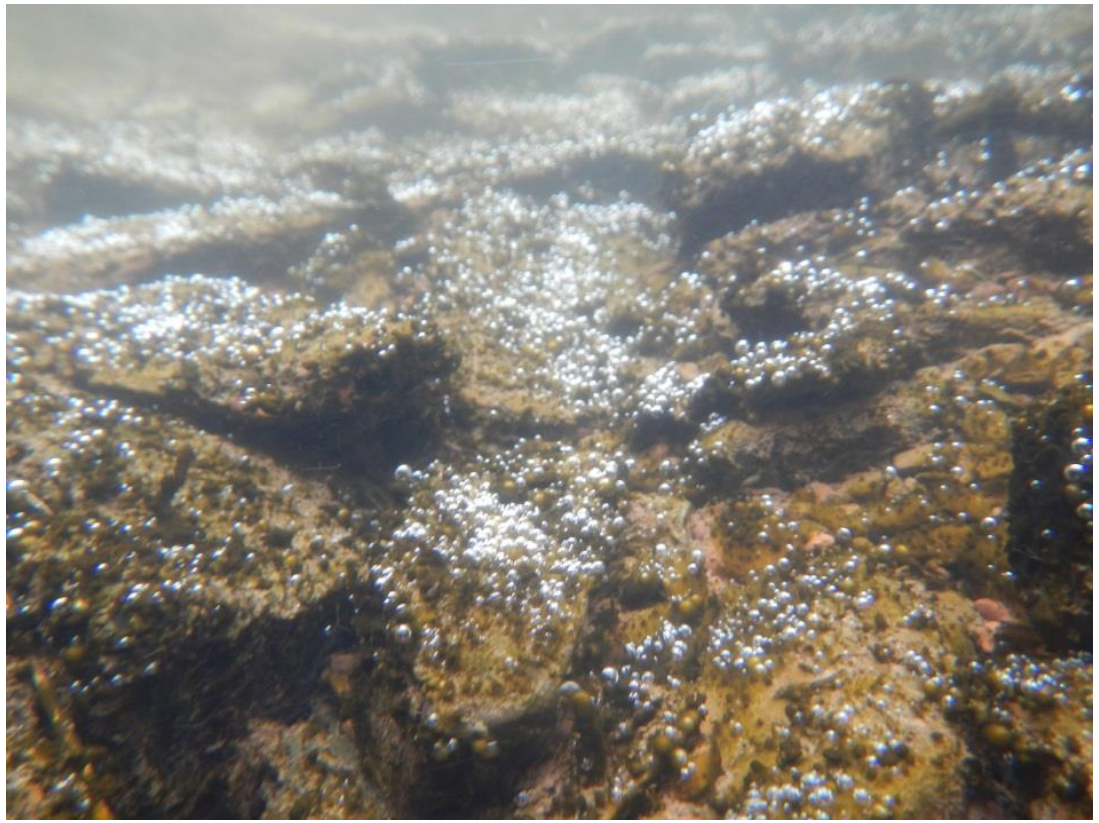
- $\Delta\ CO_2$ → Δ DIC pH Buffer System → Δ pH

Removal of CO_2 during photosynthesis shifts equilibrium (higher pH) →

$$CO_2(gas) \leftrightarrow CO_2(aq) + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^- \leftrightarrow 2H^+ + CO_3^{2-}, \text{ and } CO_3^{2-} + H_2O \leftrightarrow HCO_3^- + OH^-$$

← Addition of CO2 during respiration shifts equilibrium (lower pH)

Photosynthesis and Respiration Influence Both DO and pH on a Diel Cycle



- Photosynthesis: ↑DO ↓CO_2 and ↑pH
- Respiration: ↓DO ↑CO_2 and ↓pH
- If Photosynthesis and Respiration Are Driving Diel DO Swings, then DO and pH Swings Should be Positively Correlated
- If Diel DO and pH Swings Are Not Positively Correlated, Then Something Other Than Photosynthesis and Respiration Is Driving Diel DO Swings

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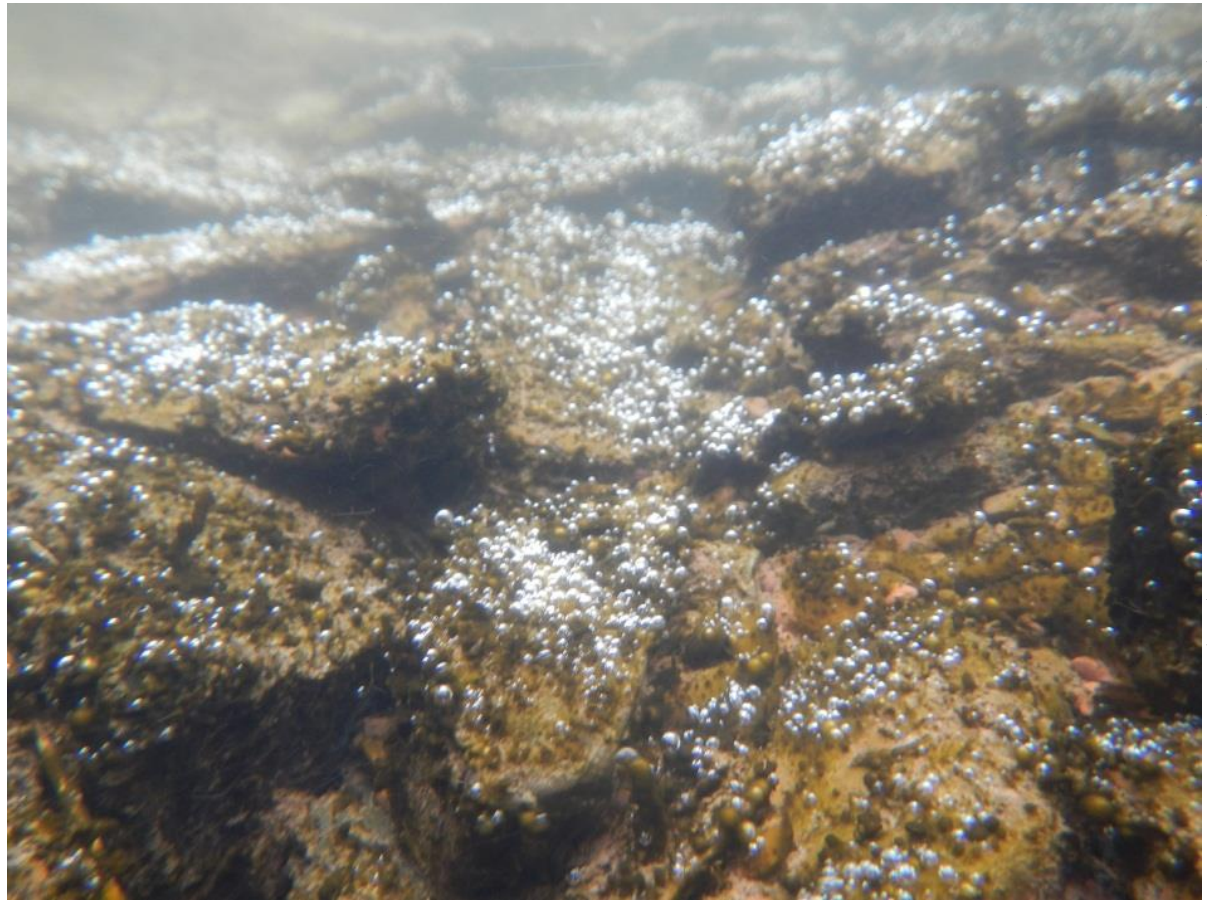
Water Temperature Also Influences Stream DO Levels on a Diel Cycle



- Water Temp Fluctuates on a Diel Cycle
- Water Temp↑ DO Solubility↓
- If Temp is Driving Diel DO Swings, Then DO and Temp Swings Should be Correlated, and
- Diel DO Max Values Should Occur Near the Time of Diel Temp Min Values (Early Morning Hours)

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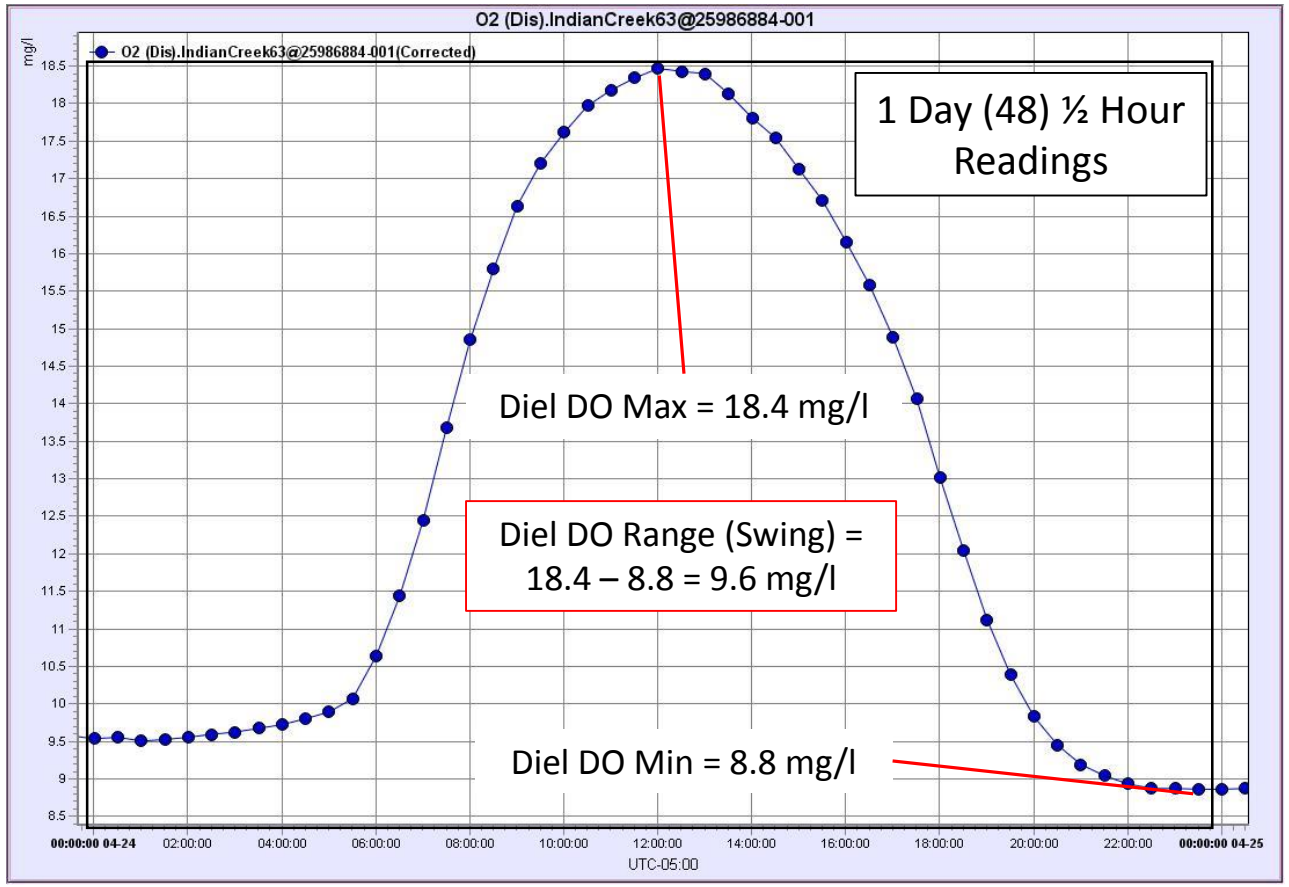
Quantification of Diel DO Conditions



- Diel DO Swing = Daily DO Max – DO Min
- Only Use Days With at Least 75% of the Day Monitored (Minimum of (36) ½-Hr Readings)

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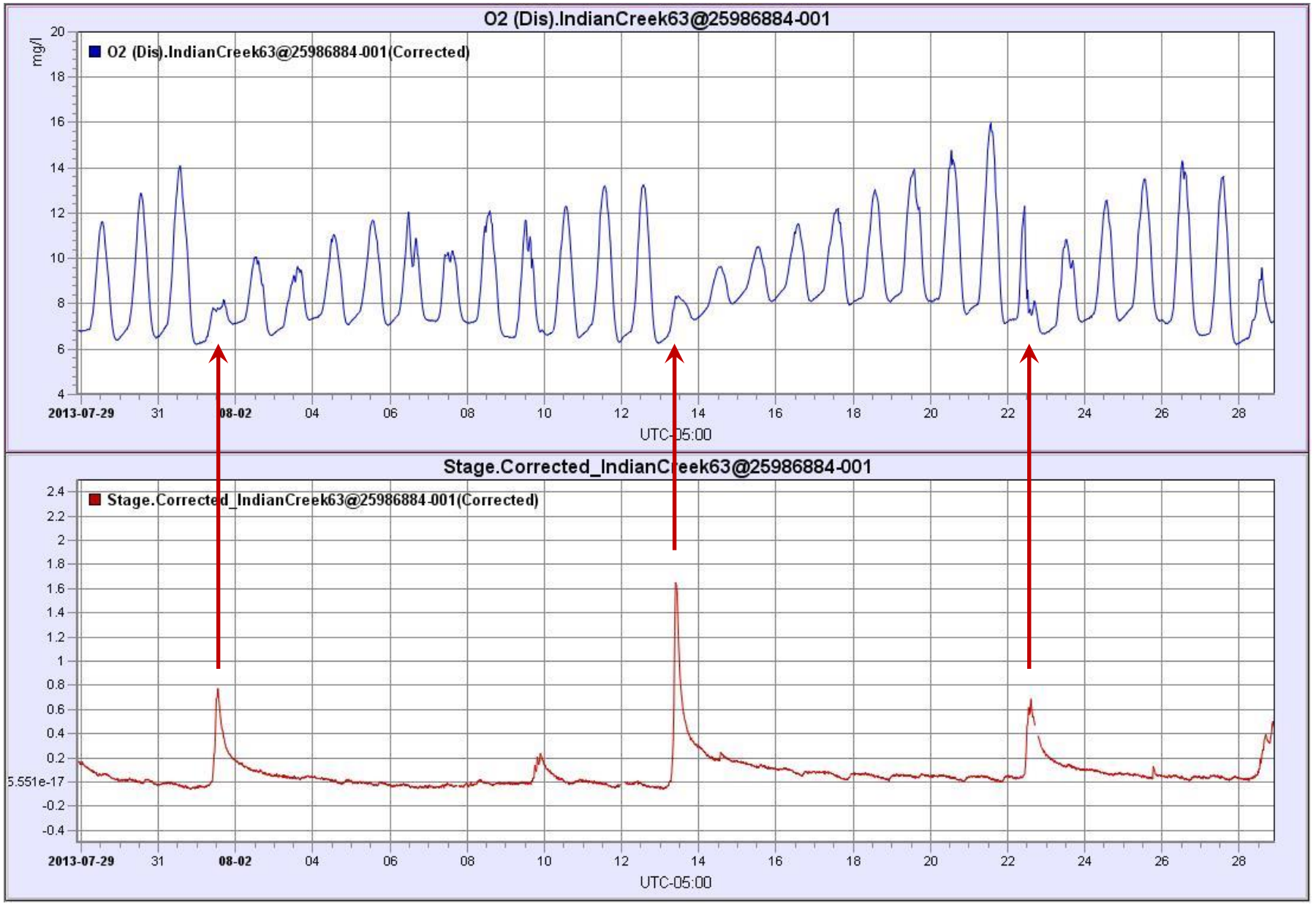
One Month of Continuous DO & Water Stage Data

DO (mg/L)

Water Stage (ft)



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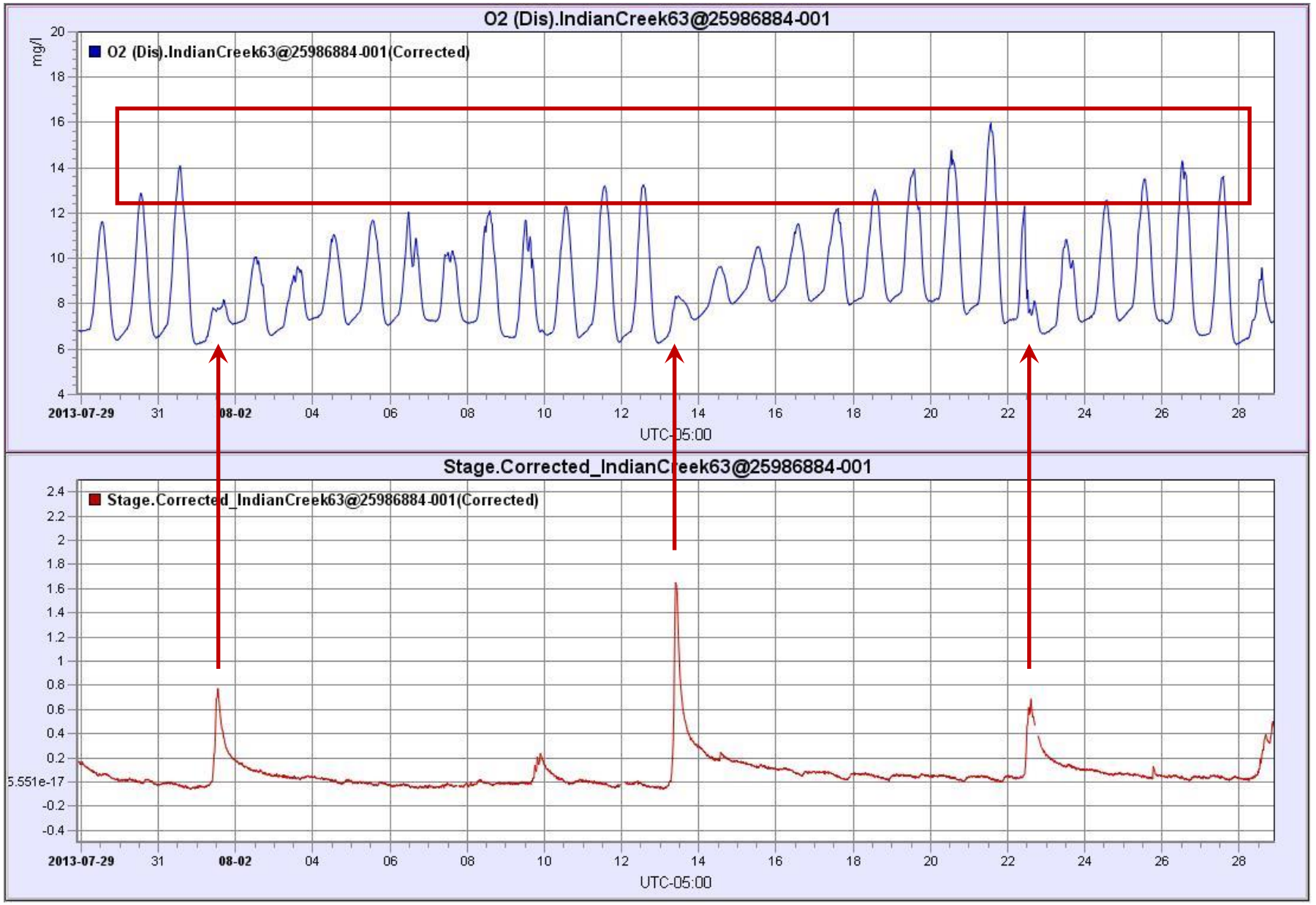
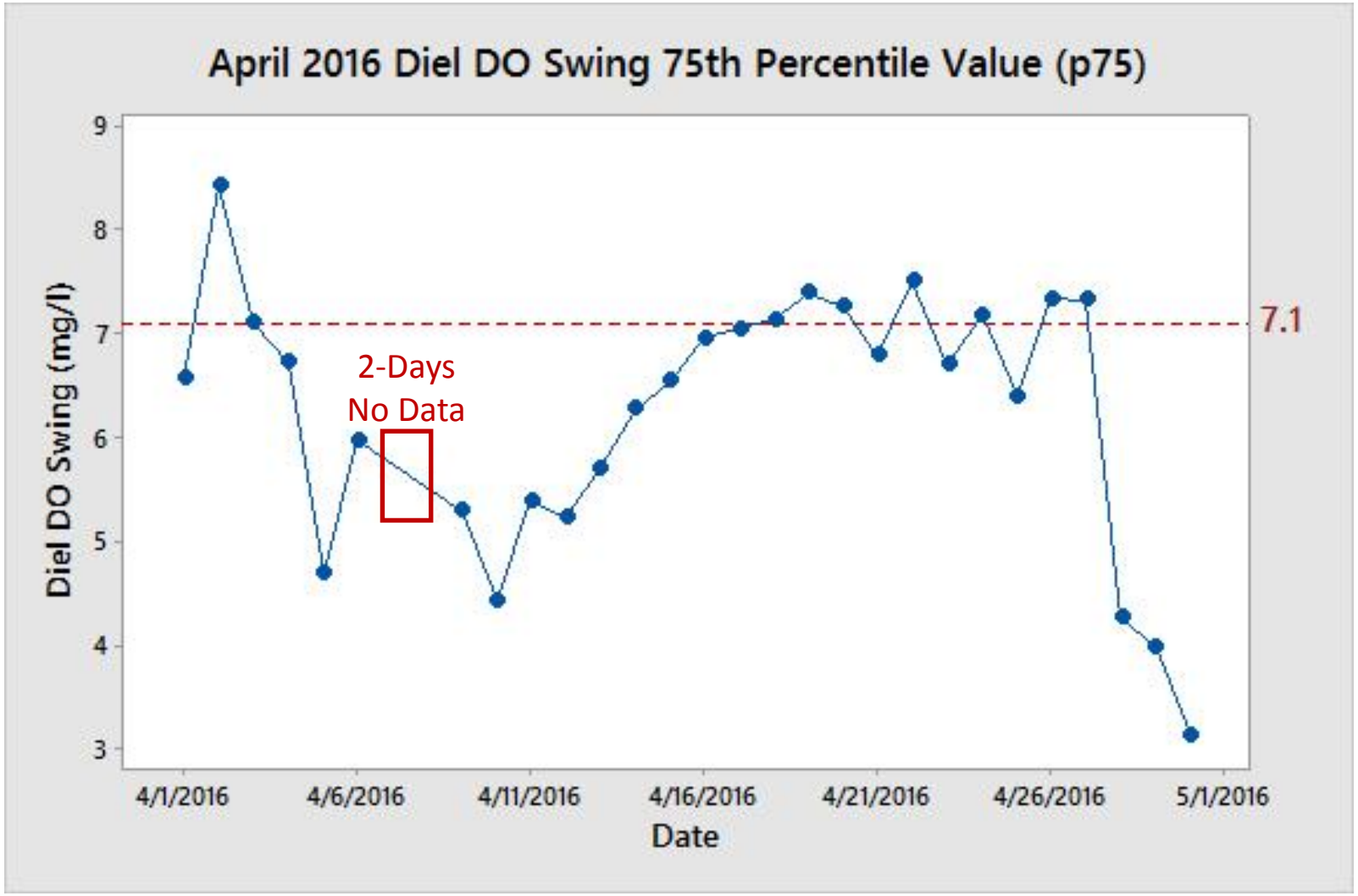


Diel DO Swings Summarized by Month



- 75th Percentile Value of Diel DO Swings Recorded Within a given Month
- Minimum of Half the Month with Diel DO Swing Values
- 1,340 ½-Hour DO Readings
- 28 Diel DO Swing Values

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Data Used to Develop the Protocol

- Continuously Monitored DO, pH, & Temp (Readings every ½ Hour)
- Sondes deployed March-November (Typically)
- 2013 thru 2016 Sample Seasons
- TP and TN Approximately Monthly
- One Benthic Macroinvertebrate IBI Sample at Each Station in November (Typically)

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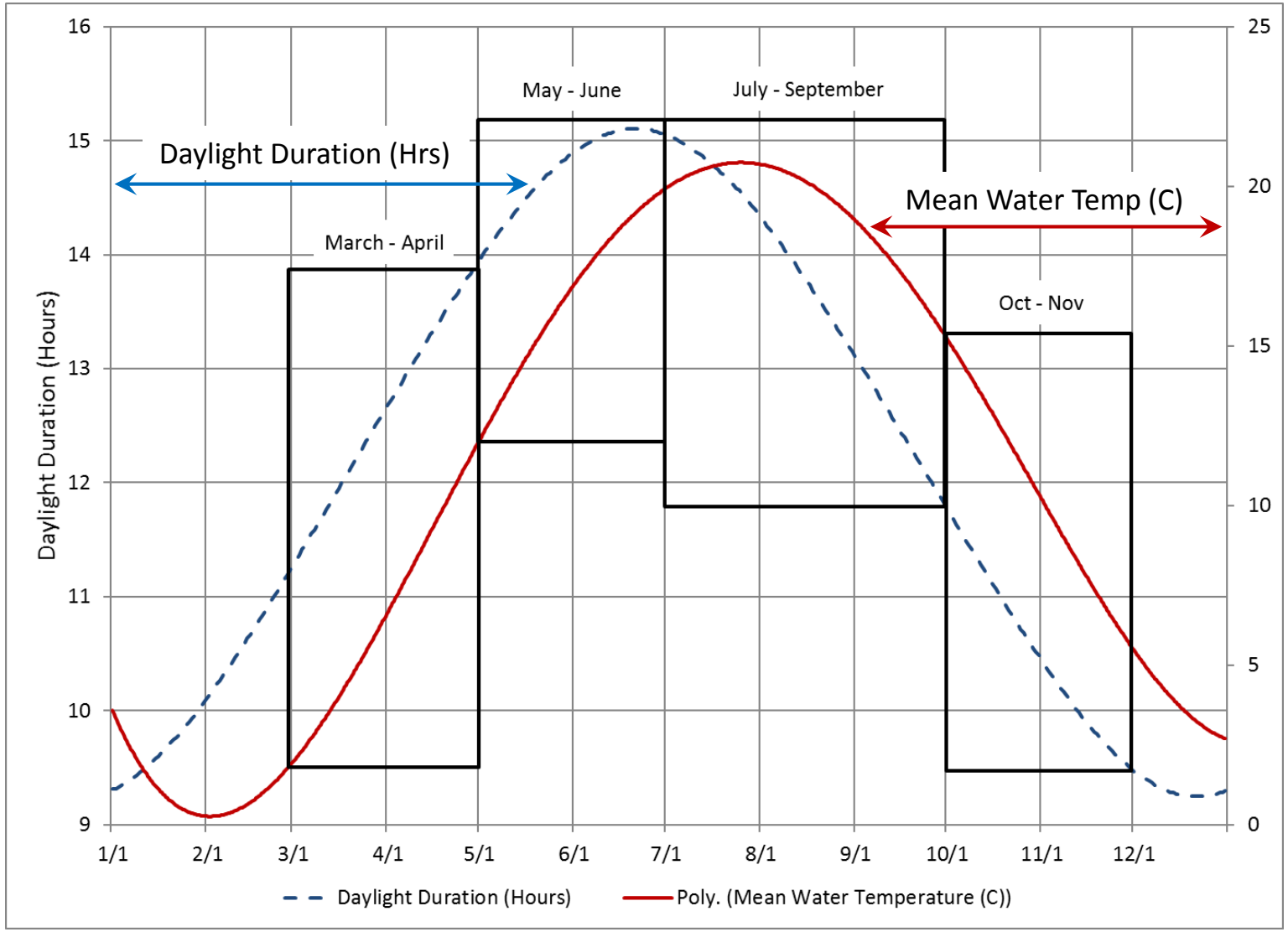
Seasonal Variability



- Leafout / Shading
- Daylight Duration
- Water Temperature
- Stream Q (Scour, Depth, Turb)

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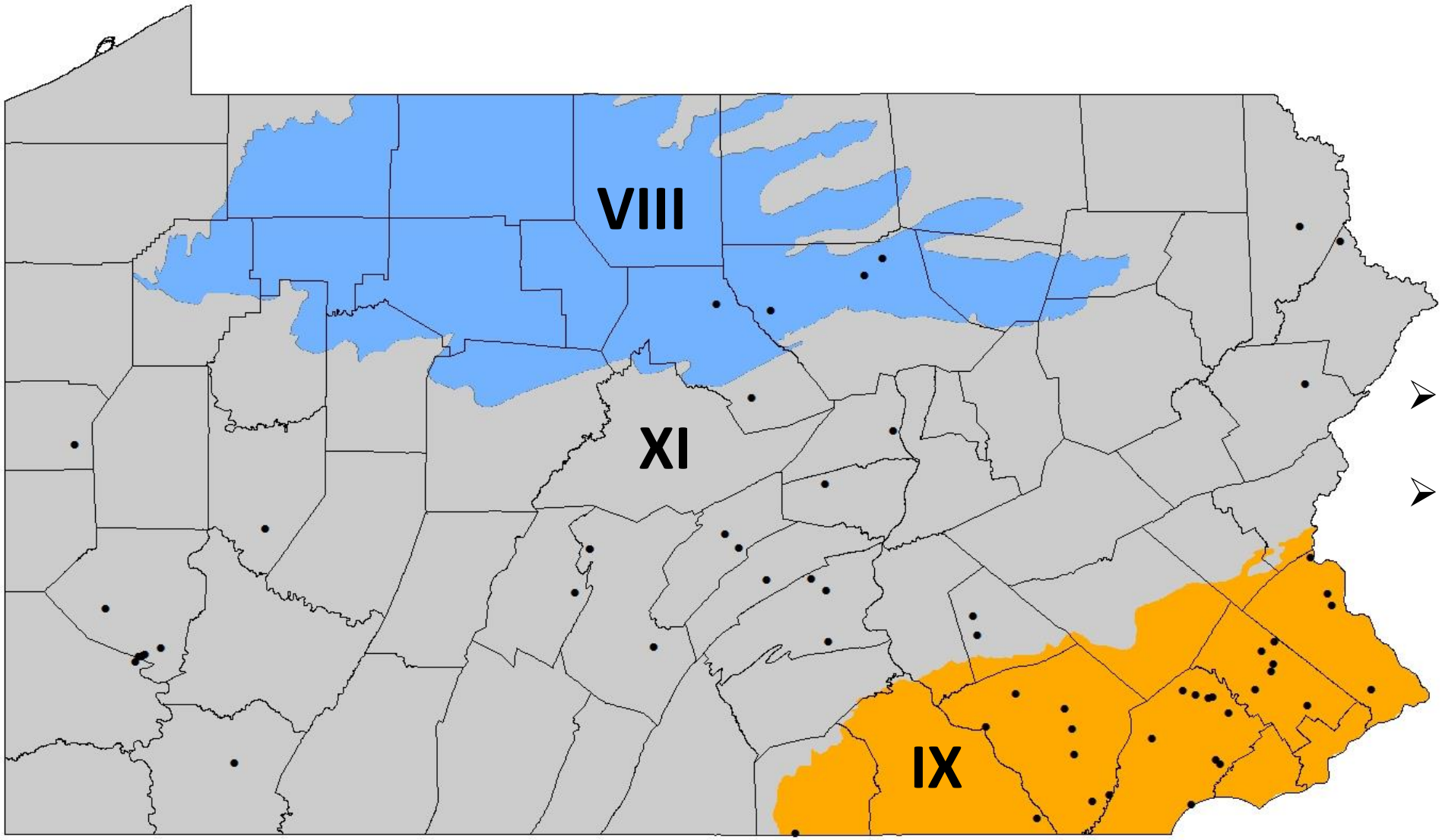
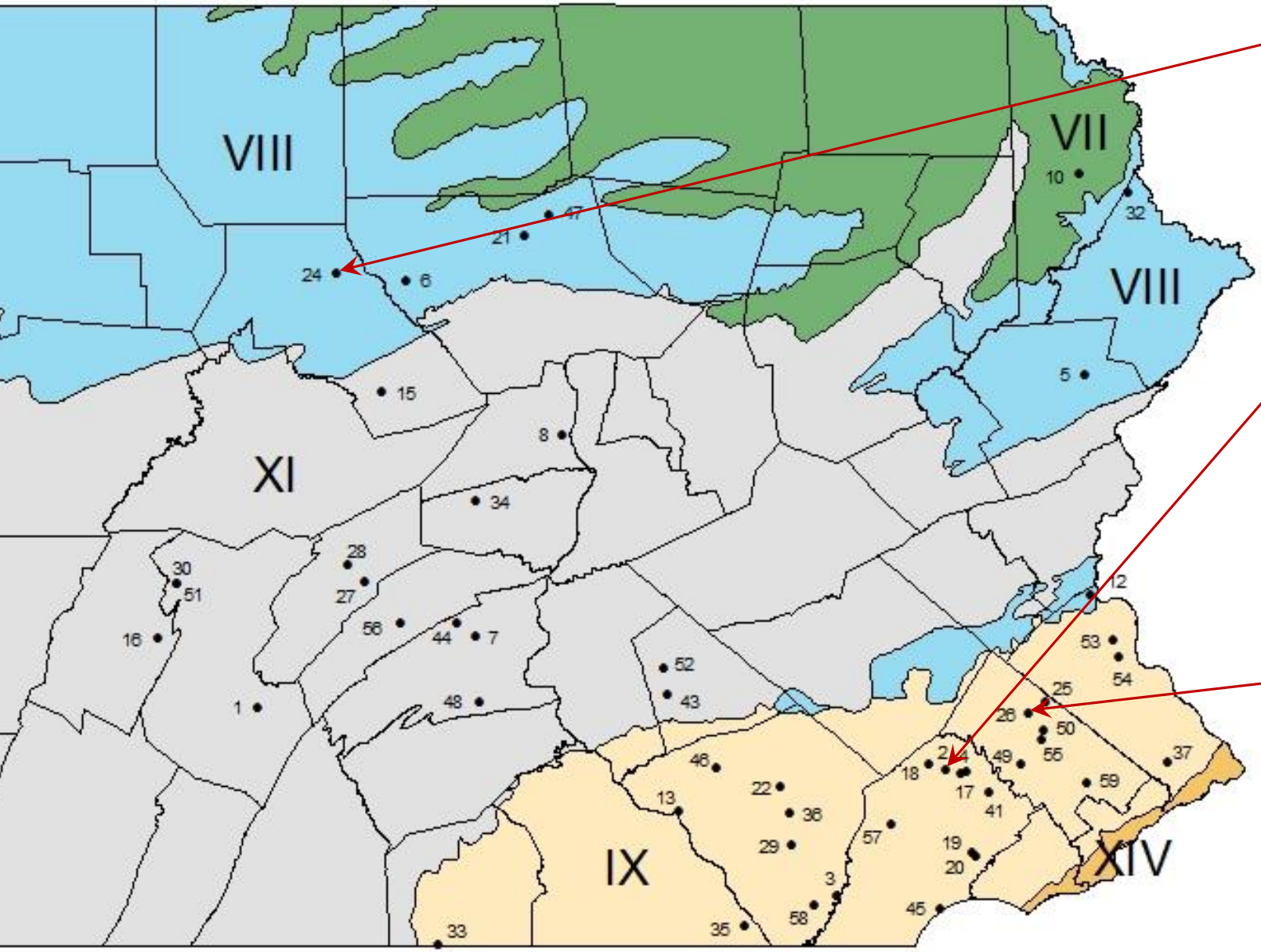
Proposed Classification Scheme



- PA Nutrient Ecoregions
- Drainage Area
  - <25 mi^2
  - 25 – 75 mi^2
  - >75 mi^2

3 Streams Subject to Different Degrees of Nutrient Enrichment



Hyner Run (Clinton Co) 2016
DA = 26.6 mi²
ALU Attaining (Macro IBI Score = 97)
Mean TP (mg/L) = 0.010
Mean Benthic Chl-a (mg/m²) = 24
April DO Swing p75 (mg/L) = 1.3
May DO Swing p75 (mg/L) = 0.7

Beaver Run (Chester Co) 2016
DA = 5.0 mi²
ALU Attaining (Macro IBI Score = 73)
Mean TP (mg/L) = 0.028
Mean Benthic Chl-a (mg/m²) = 190
April DO Swing p75 (mg/L) = 3.0
May DO Swing p75 (mg/L) = 1.3

Indian Cr (Rt 63) (Montgomery Co) 2014
DA = 5.7 mi²
ALU Impaired (Macro IBI Score = 29)
Mean TP (mg/L) = 0.092
Mean Benthic Chl-a (mg/m²) = 562
April DO Swing p75 (mg/L) = 9.3
May DO Swing p75 (mg/L) = 8.4

Hyner Run

Indian Creek (Rt 63)

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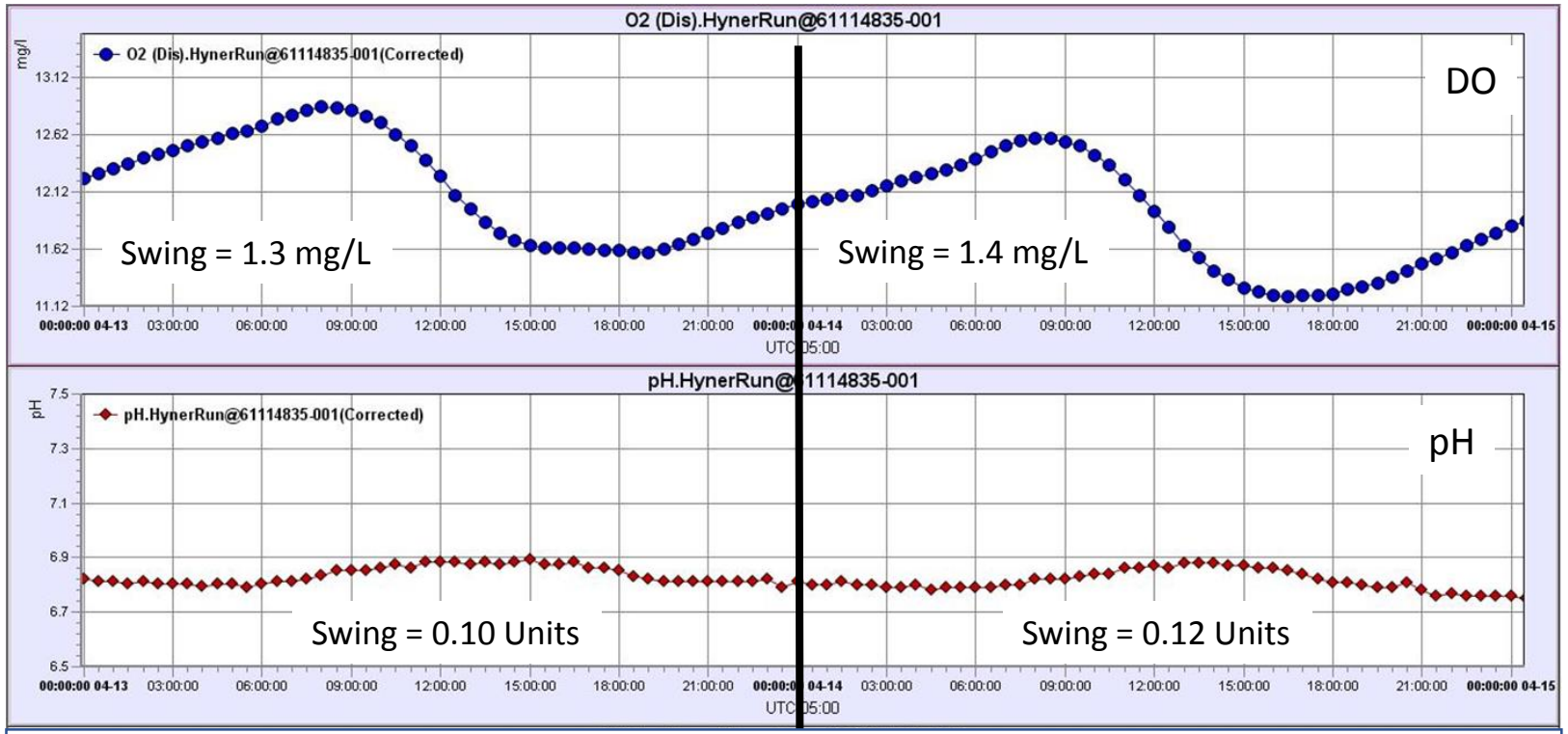
DO and pH Hyner Run (Very Low Nutrient Enrichment)



Hyner Run, Clinton Co
(Eco VIII, 26.6 mi²)
April 2016

ALU Attaining
Macro IBI = 97
Mean TP = 0.010 mg/L
Mean TN = 0.26 mg/L
Mean Chl-a = 24 mg/m²
April DO Swing p75 = 1.3 mg/L
May DO Swing p75 = 0.7 mg/L

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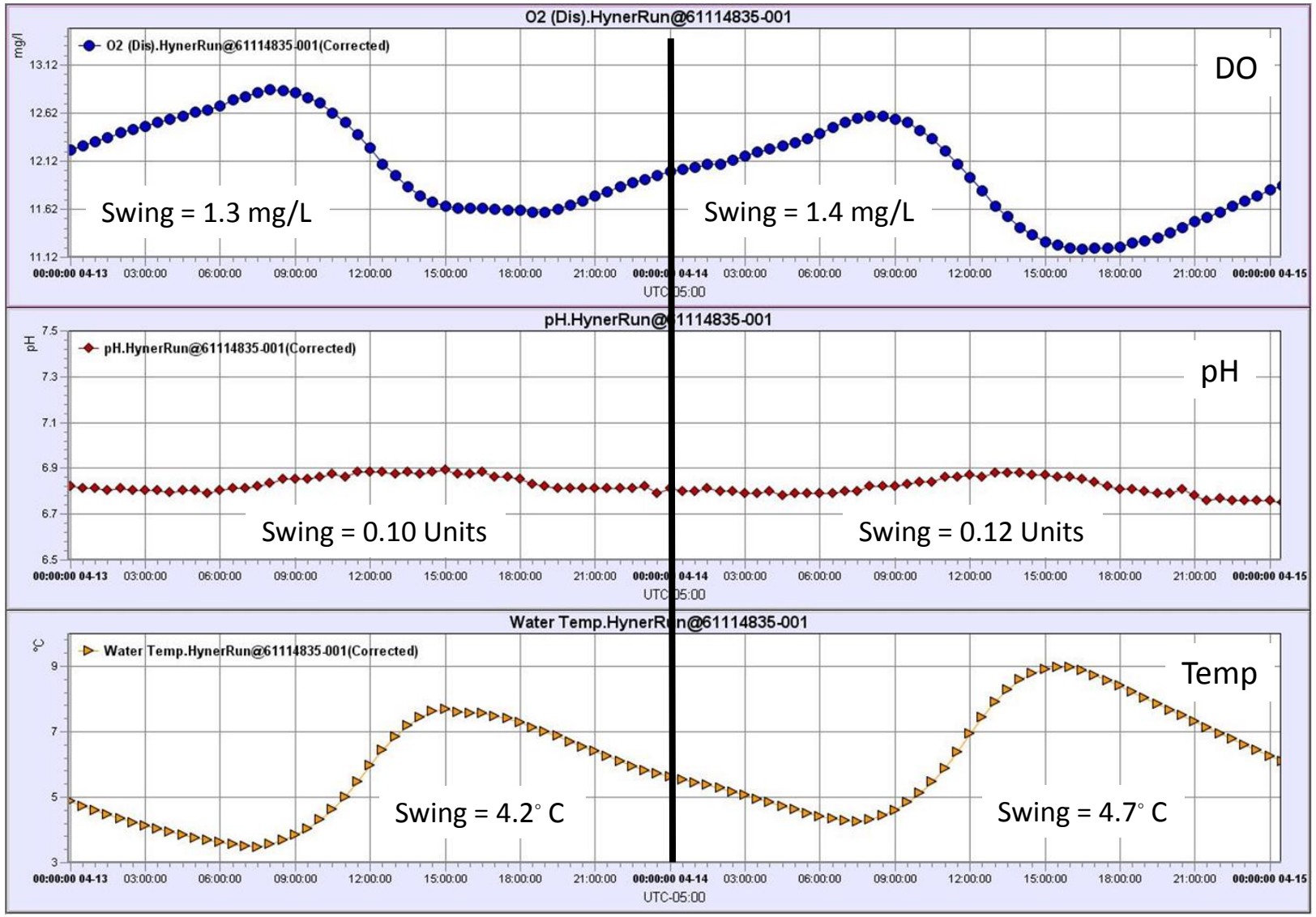
DO, pH, & Temp Hyner Run (Very Low Nutrient Enrichment)



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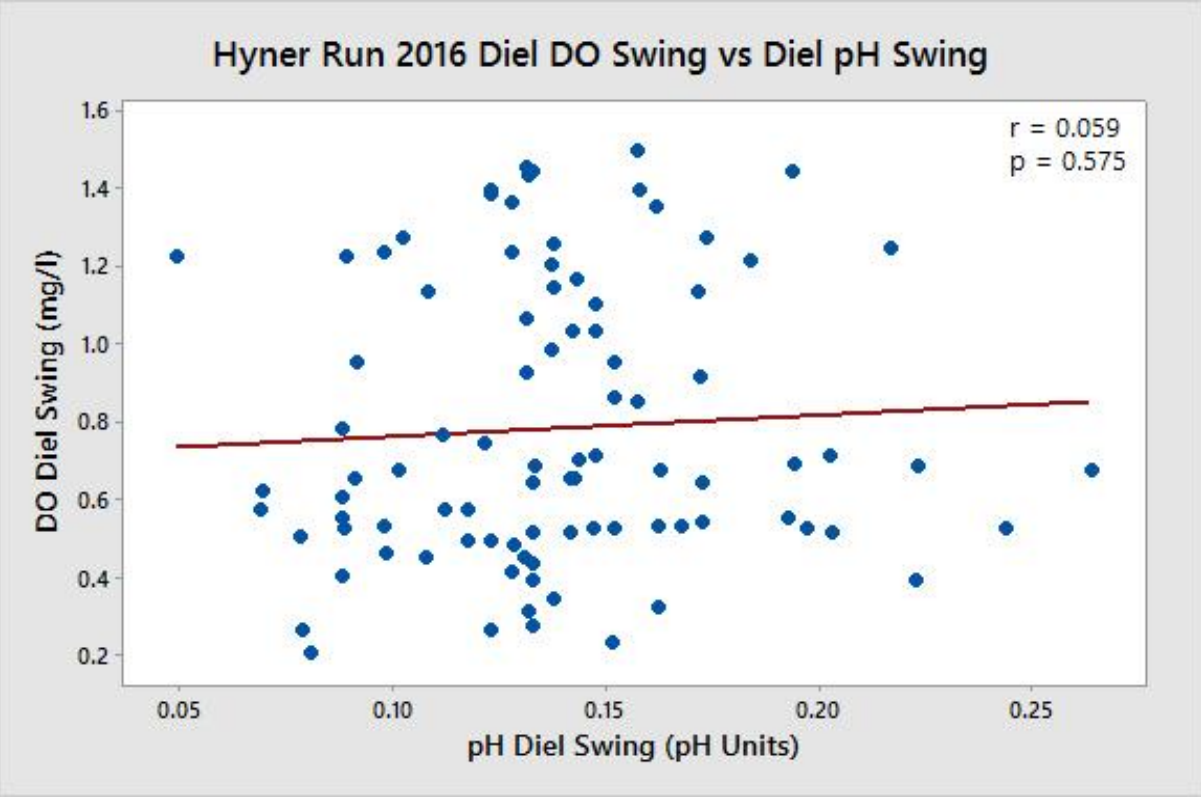
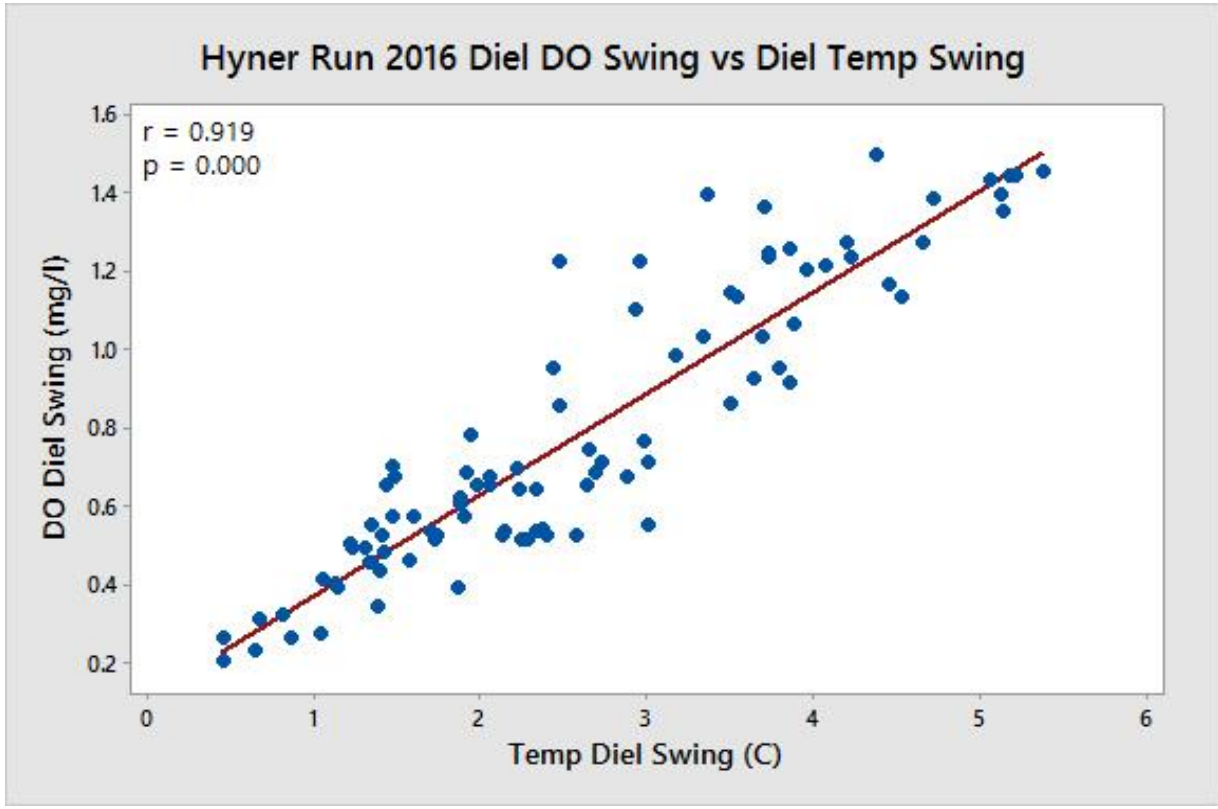
DO vs pH Swing and DO vs Temp Swing Hyner Run

Hyner Run 2016 (March – May Data)





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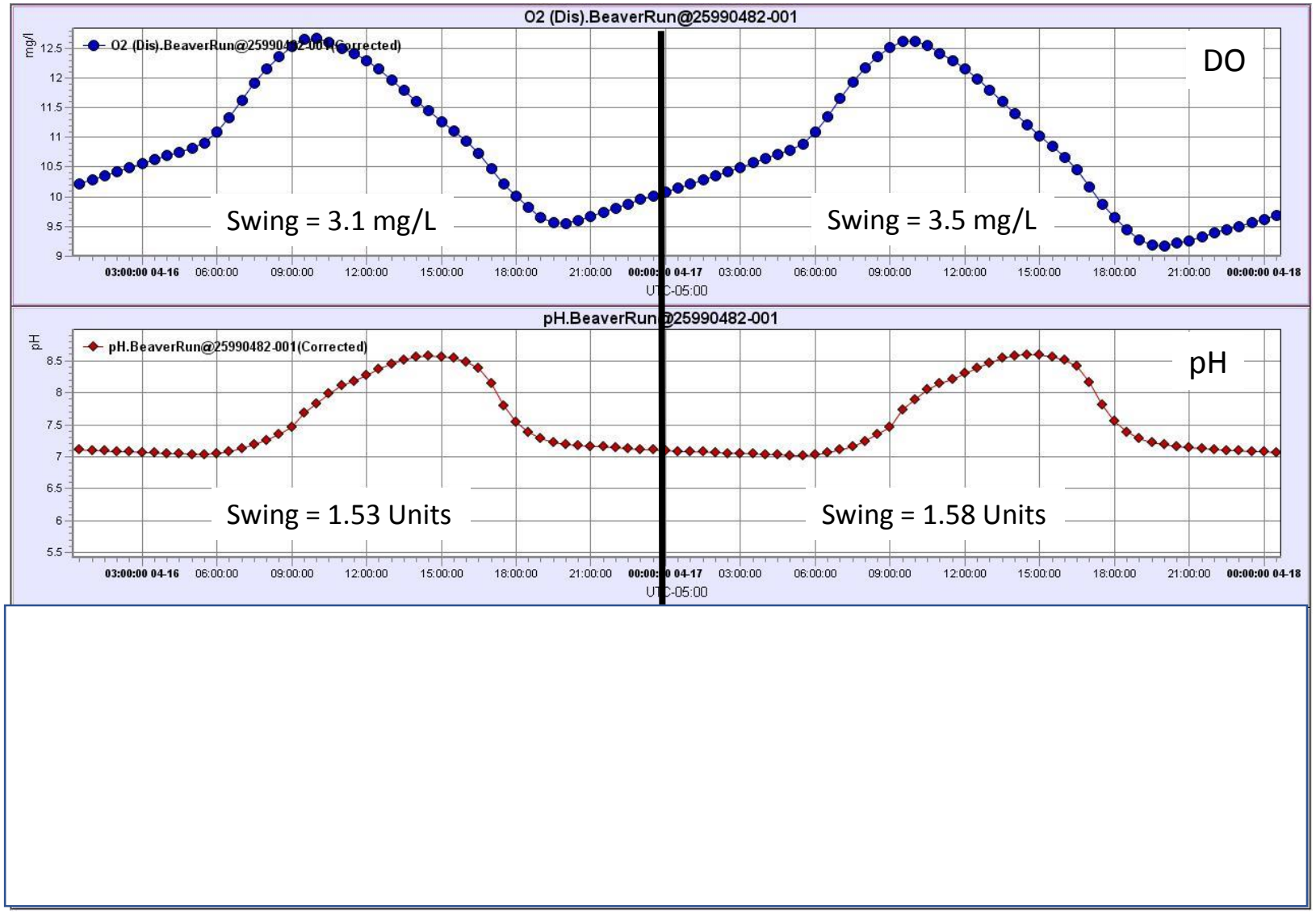
DO and pH Beaver Run (Moderate Nutrient Enrichment)



Beaver Run, Chester Co
(Eco IX, 5.0 mi²)
April 2016

ALU Attaining
Macro IBI = 73
Mean TP = 0.028 mg/L
Mean TN = 1.00 mg/L
Mean Chl-a = 190 mg/m²
April DO Swing p75 = 3.0 mg/L
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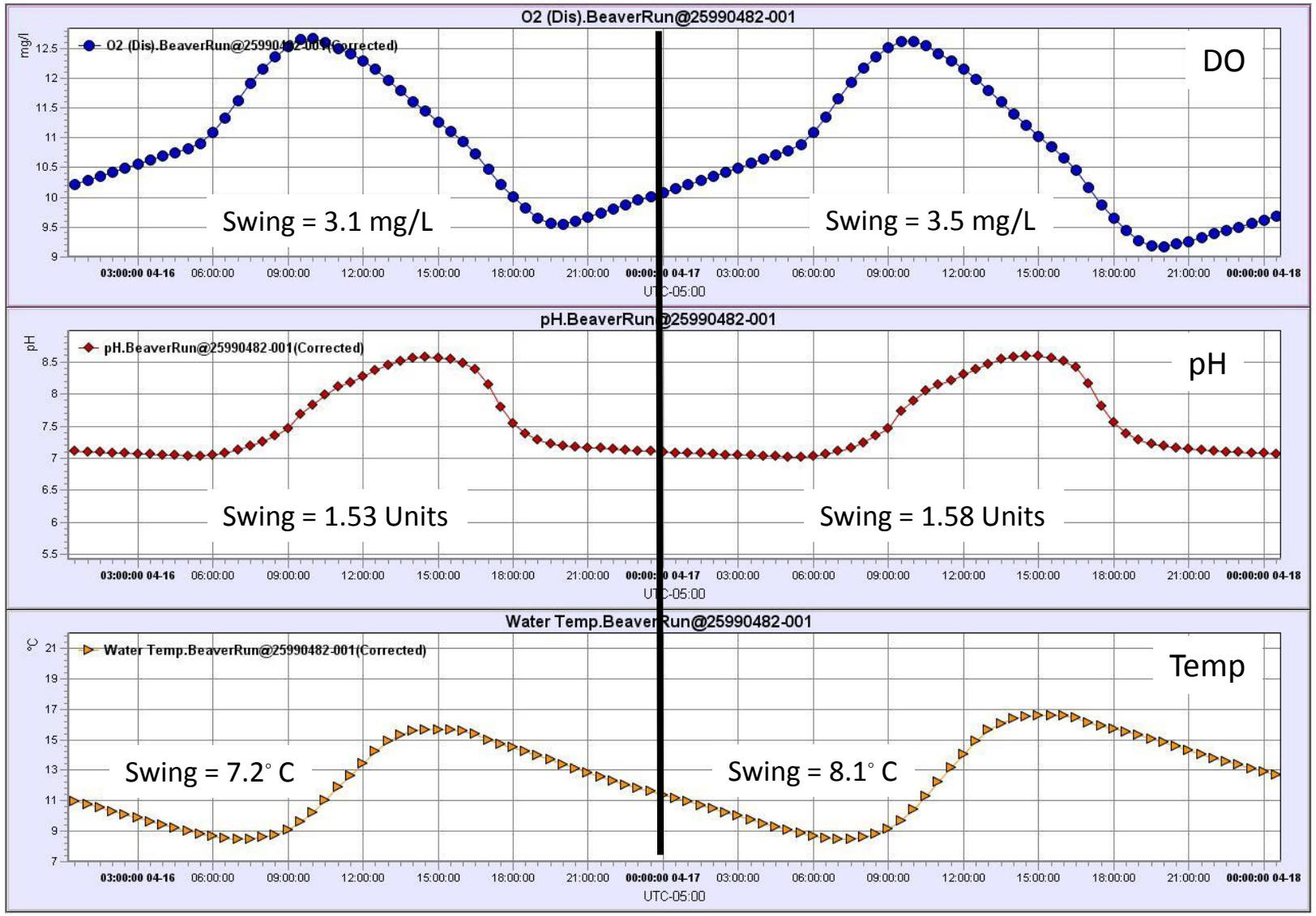
DO, pH, & Temp Beaver Run (Moderate Nutrient Enrichment)



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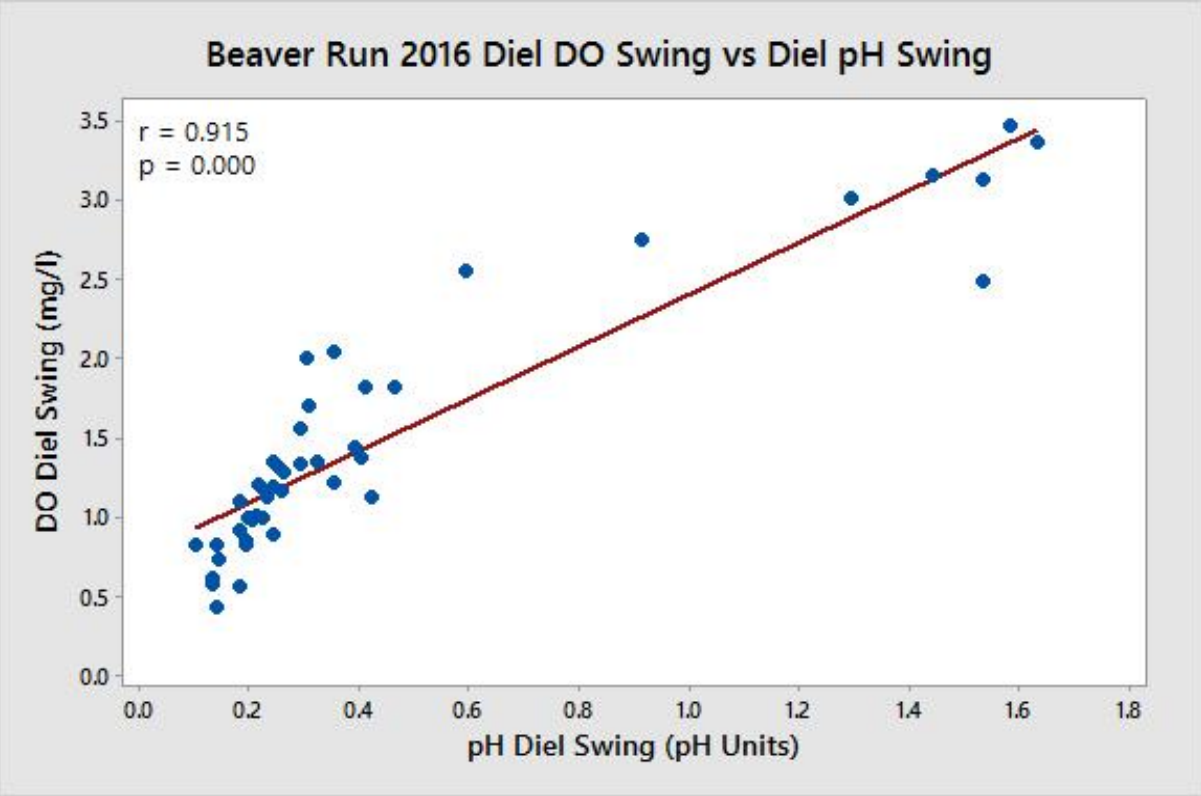
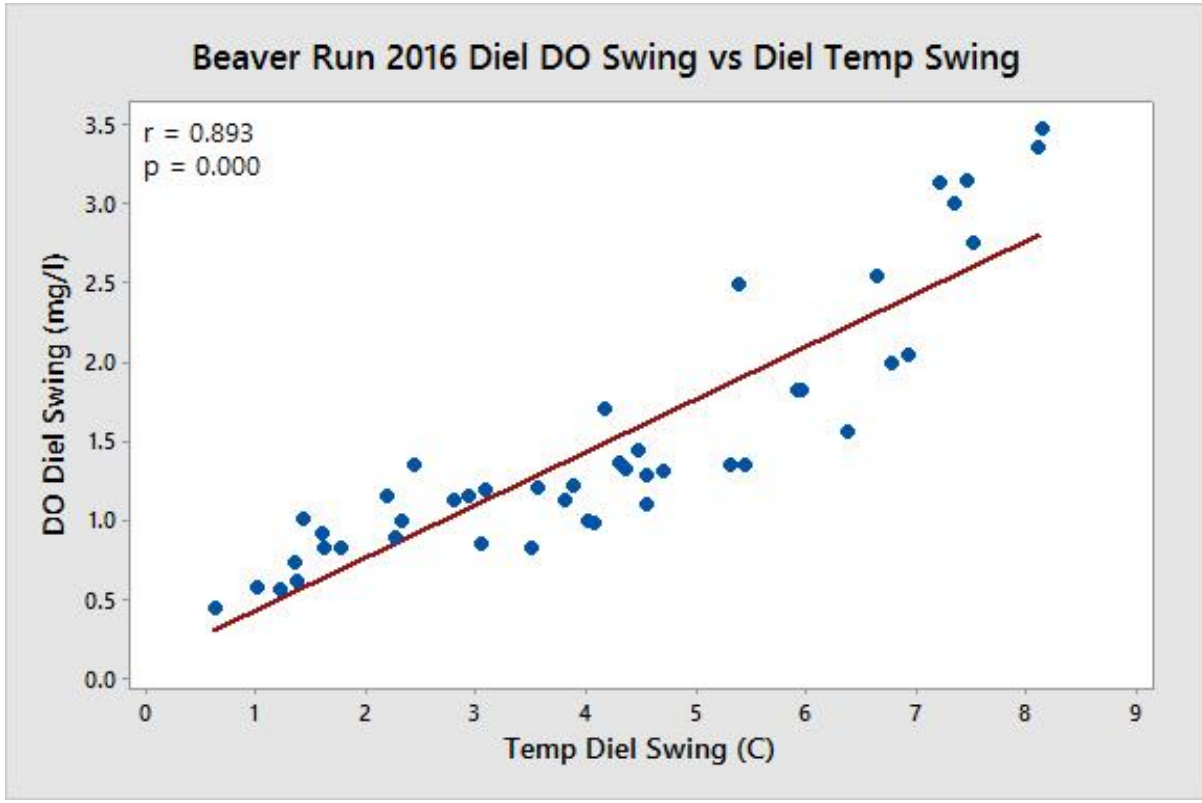
DO vs pH Swing and DO vs Temp Swing Beaver Run

Beaver Run 2016 (March – May Data)





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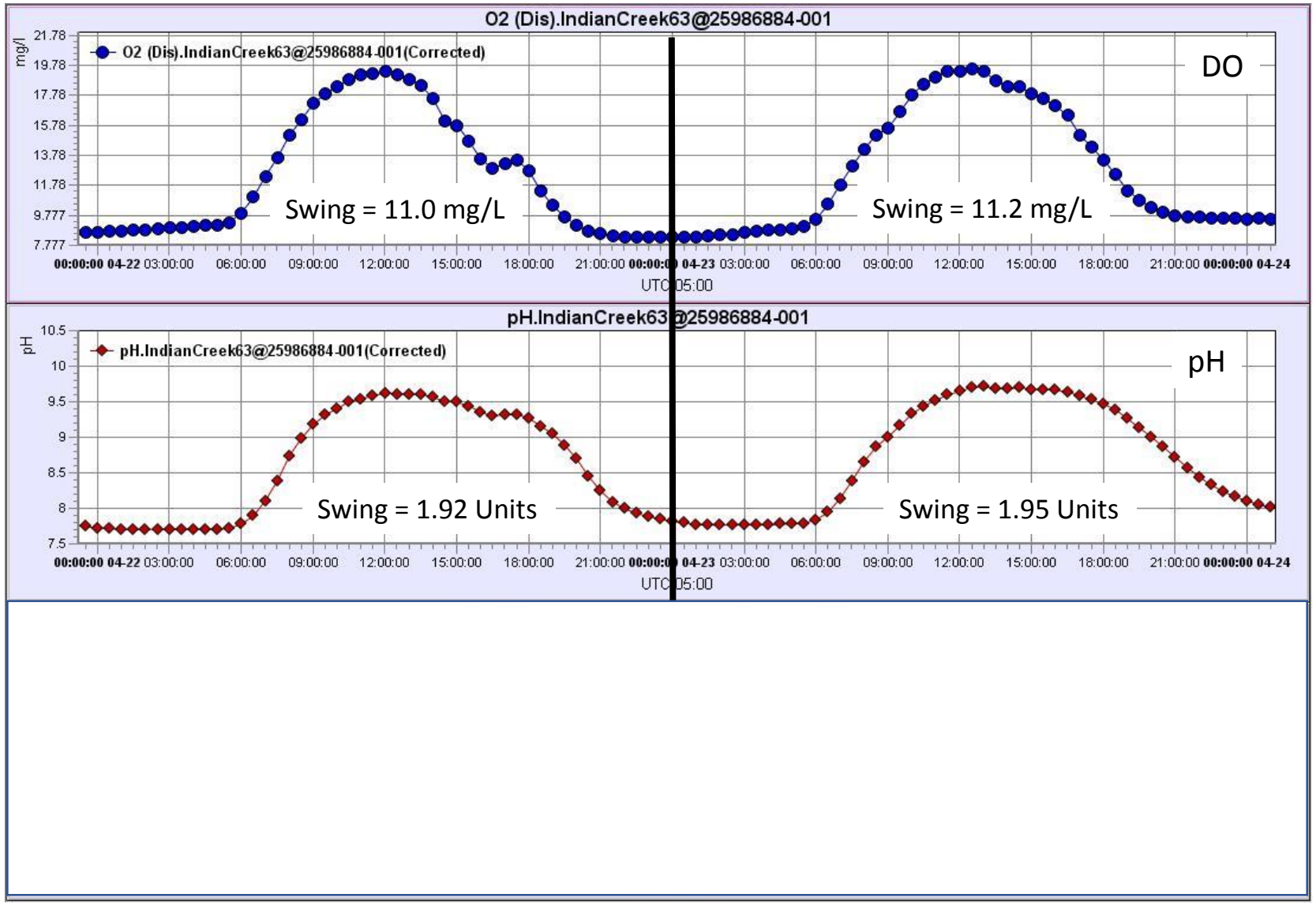
DO and pH Indian Cr (Rt 63) (High Nutrient Enrichment)



Indian Cr (Rt 63)
Montgomery Co
(Eco IX, 5.7 mi²)
April 2014

ALU Impaired
Macro IBI = 29
Mean TP = 0.092 mg/L
Mean TN = 2.23 mg/L
Mean Chl-a = 562 mg/m²
April DO Swing p75 = 9.3 mg/L
May DO Swing p75 = 8.4 mg/L

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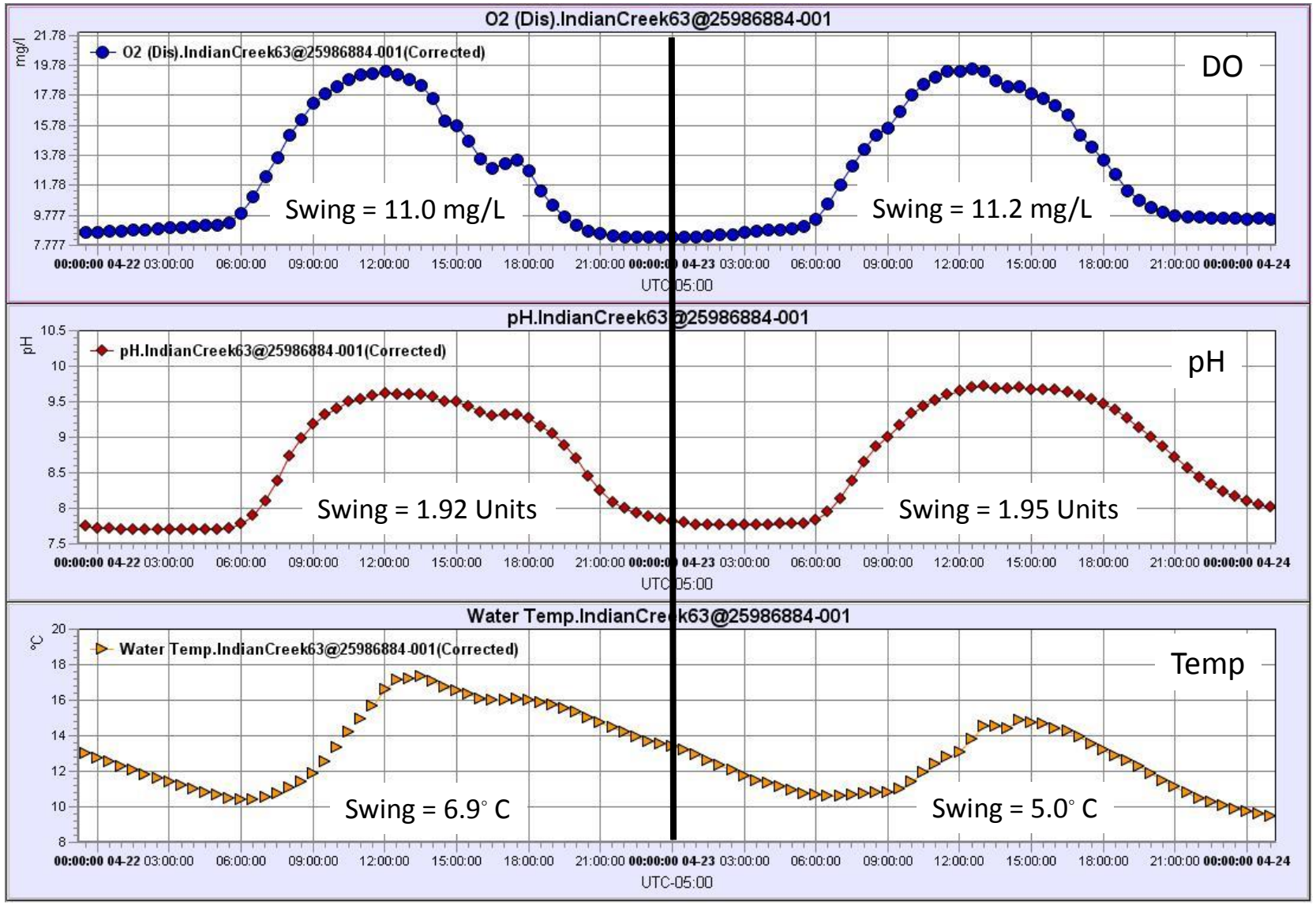
DO, pH, & Temp Indian Cr (Rt 63) (High Nutrient Enrichment)



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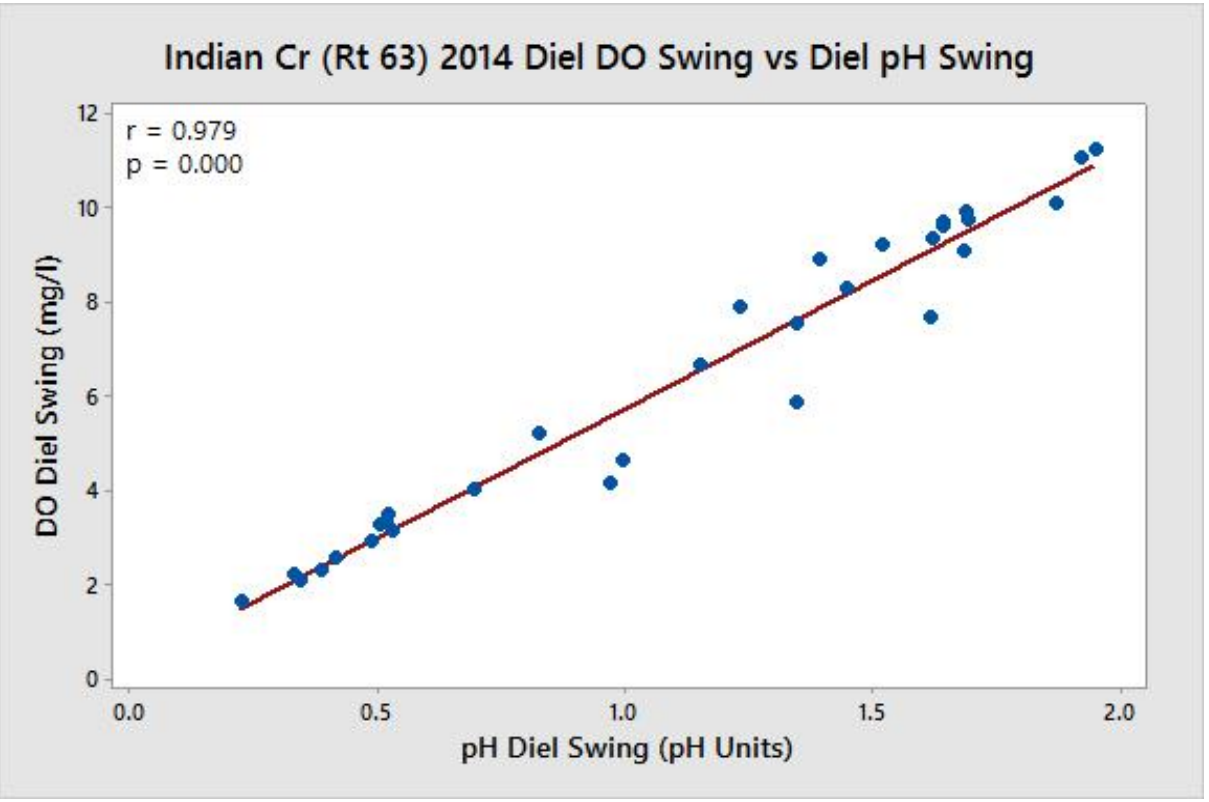
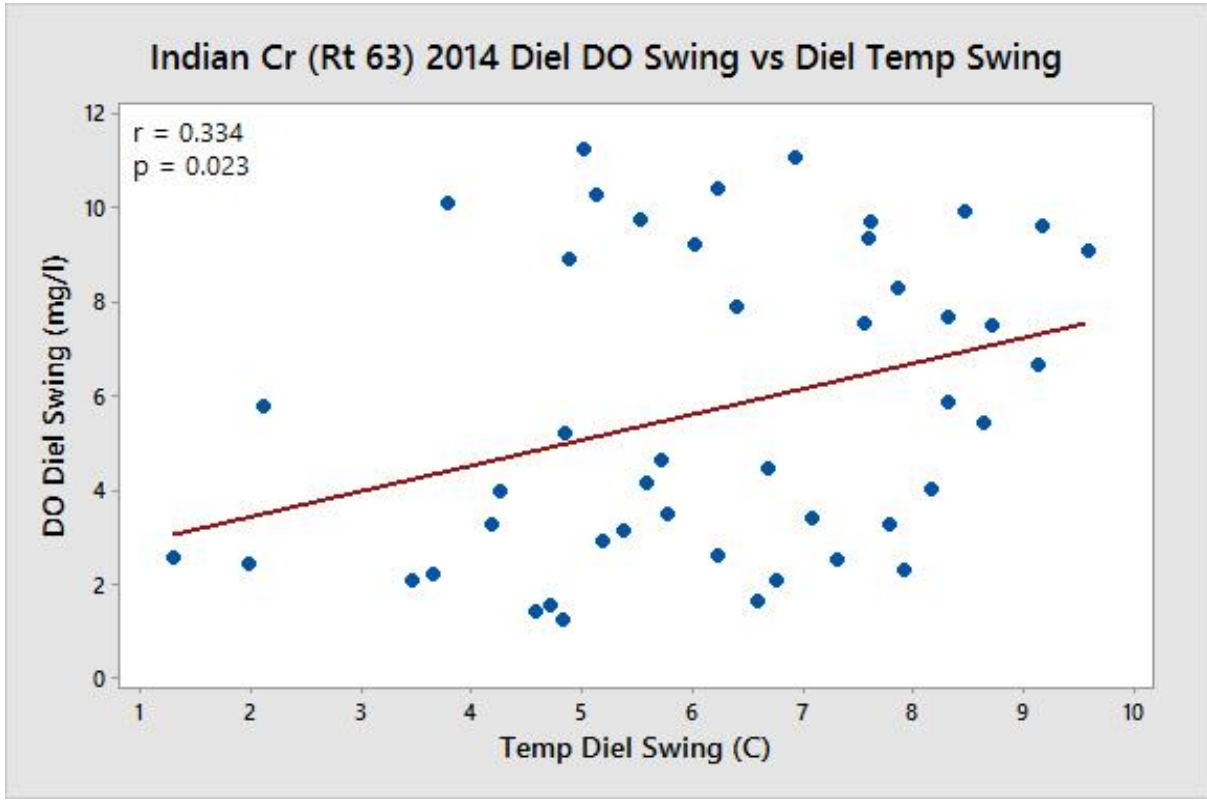
Diel DO and Temp Relationship Indian Cr (Rt 63)

Indian Cr at Route 63 2014 (March – May Data)





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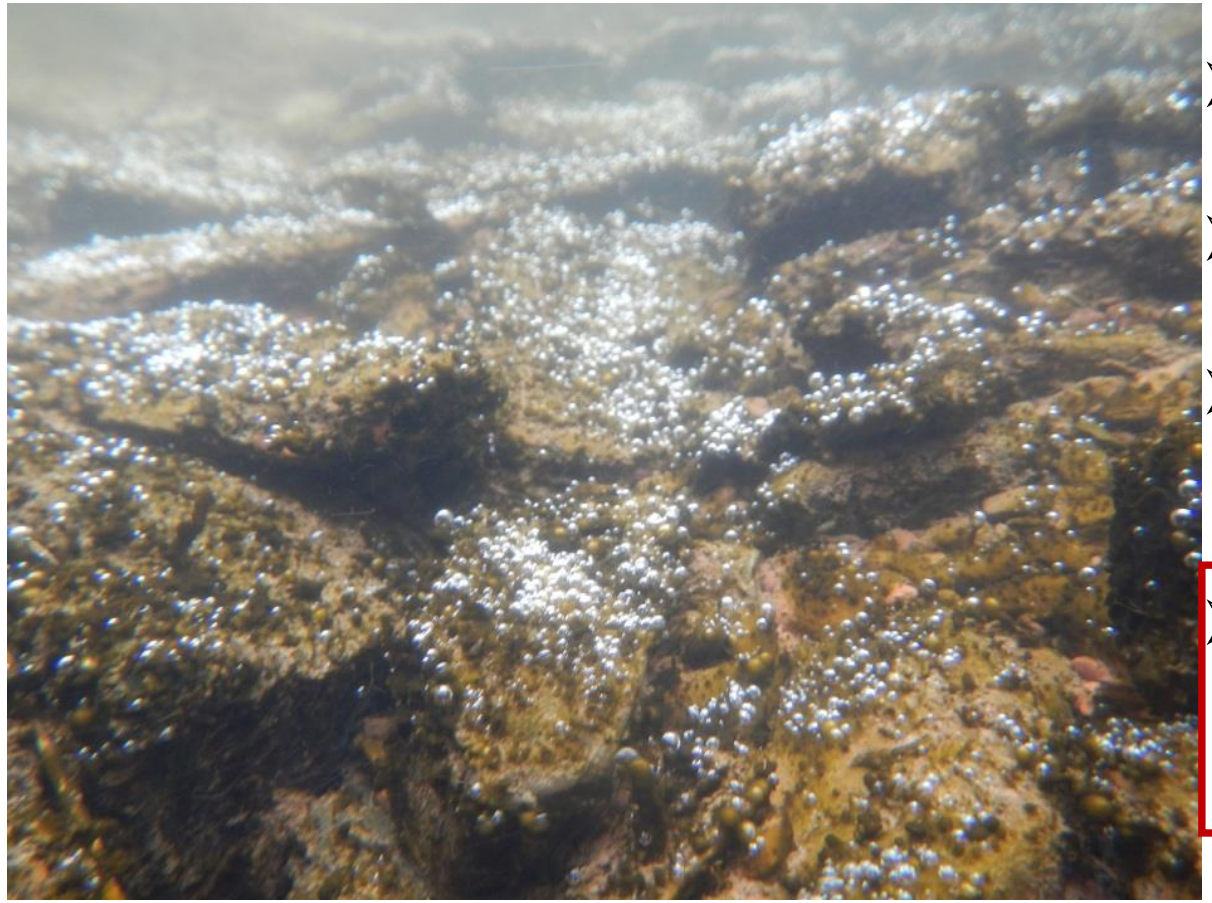
Time-of-Day of Maximum DO Values



- Water Temp Fluctuates on a Diel Cycle
- Water Temp↑ DO Solubility↓
- If Temp is Driving Diel DO Swings, Then DO and Temp Swings Should be Correlated, and
- Diel DO Maximum Values Should Occur Near the Time of Diel Minimum Temperature (Early Morning Hours)

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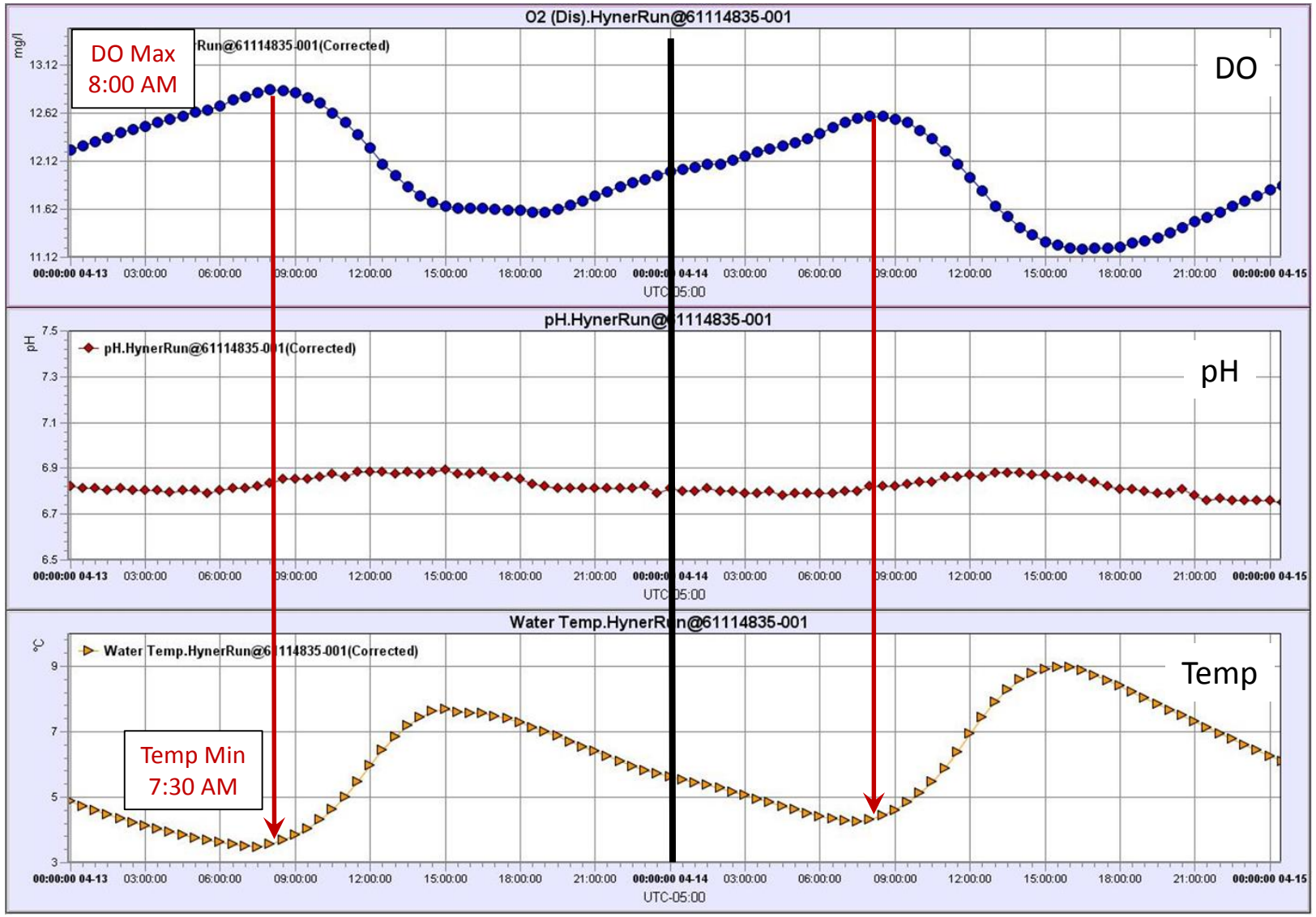
Time of Diel DO Max Hyner Run



Hyner Run, Clinton Co
April 2016

- Time of Max DO = Min Temp
- DO Swings Driven by Temp Not Photosynthesis
- **<u>Predominantly Heterotrophic</u>**
  Organic Matter (Energy) from Outside Source Not Photosyn

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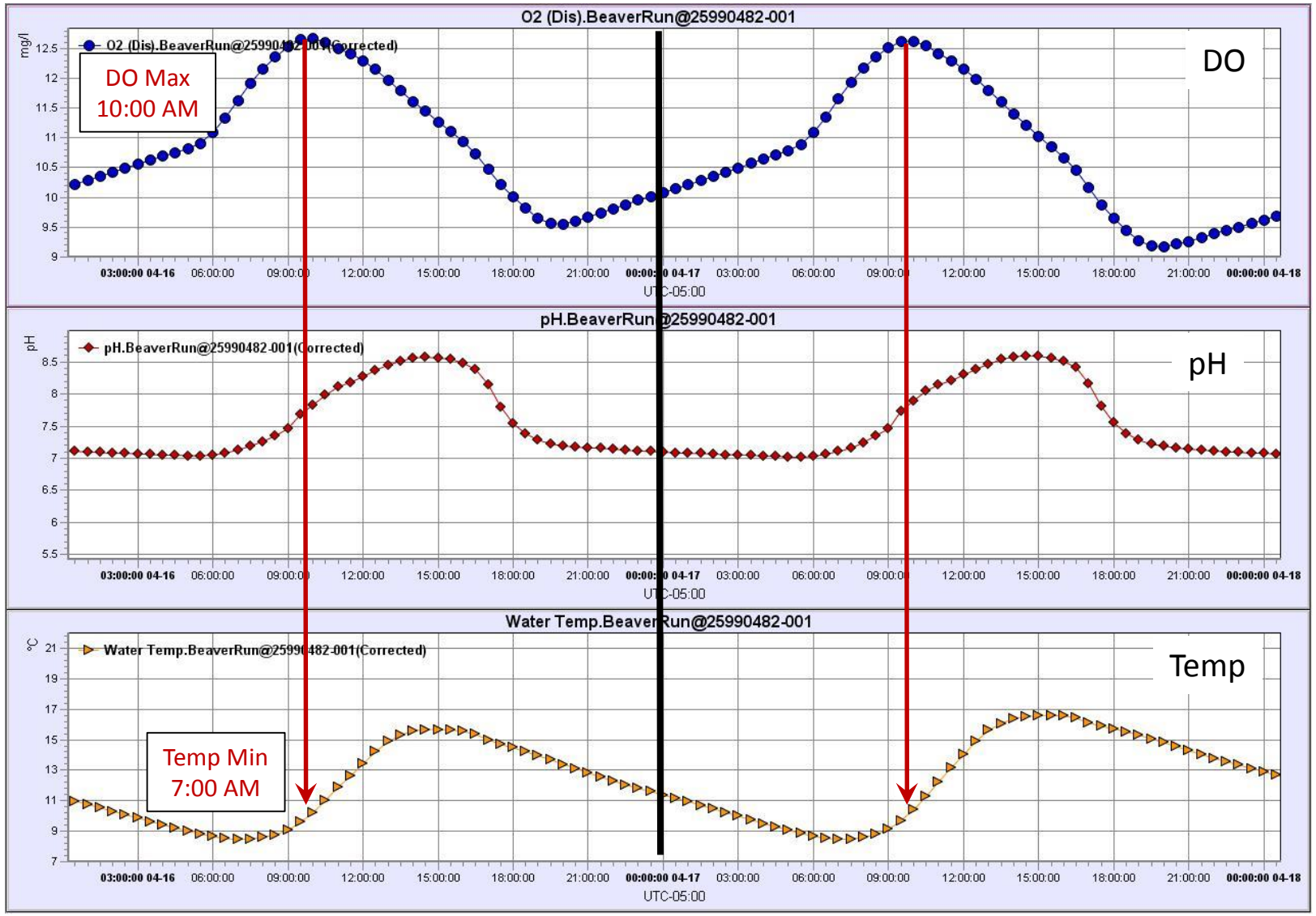
Time of Diel DO Max Beaver Run



Beaver Run, Chester Co
April 2016

- Time of Max DO 2-3 Hours After Min Temp
- DO Swings Driven by Photo-synthesis and Water Temp
- **<u>Predominantly Autotrophic</u>** Organic Matter (Energy) from Photosynthesis

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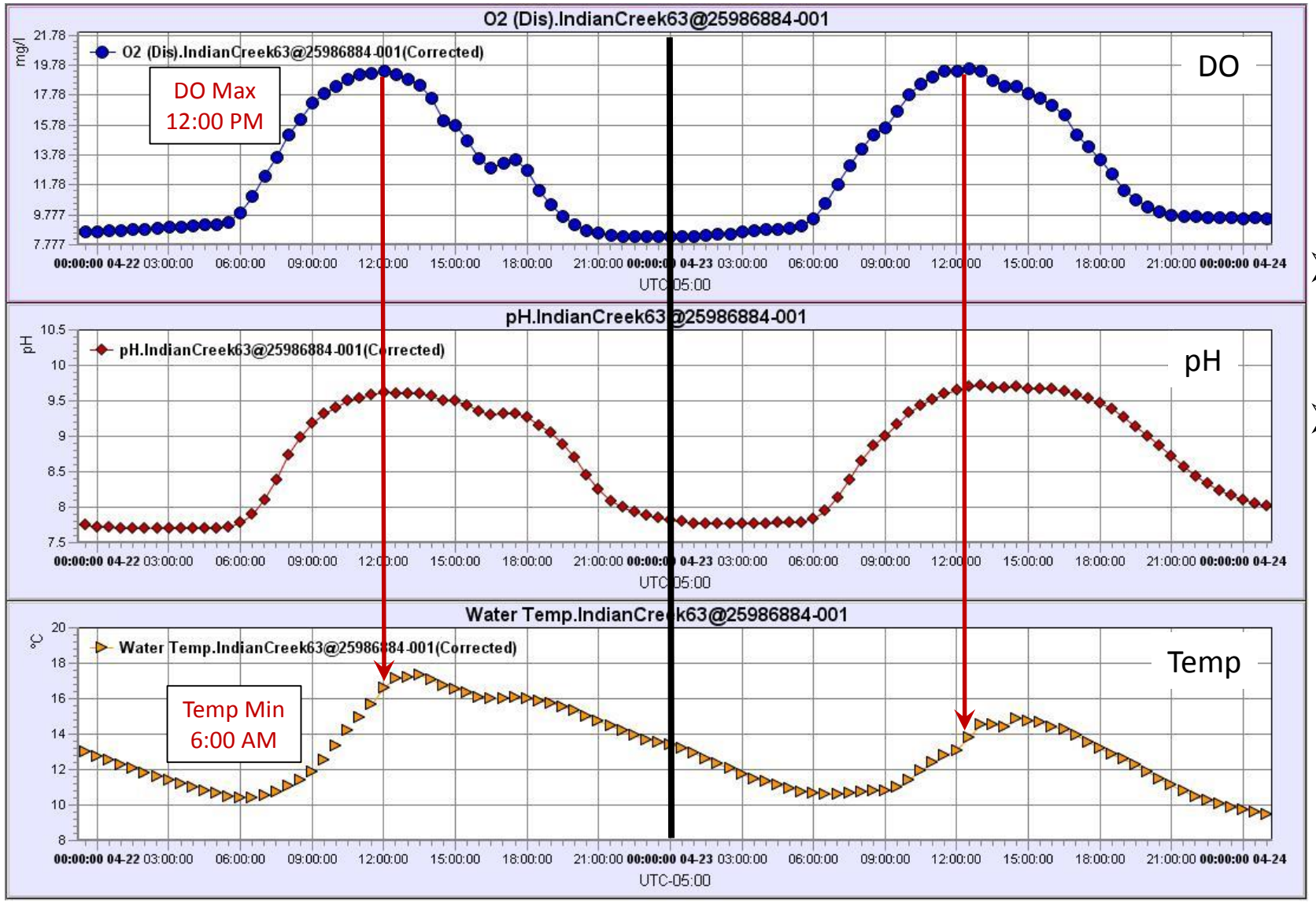
Time of Diel DO Max Indian Cr (Rt 63)



Indian Cr (Rt 63)
Montgomery Co
April 2014

- Time of Max DO Close to Time of Max Temp (Min Solubility)
- Excessive DO Swings Driven by Photosynthesis

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Questions

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