pH Regulates Phosphorus Cycling in the Colorado River

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Glen Canyon Dam Adaptive Management Program

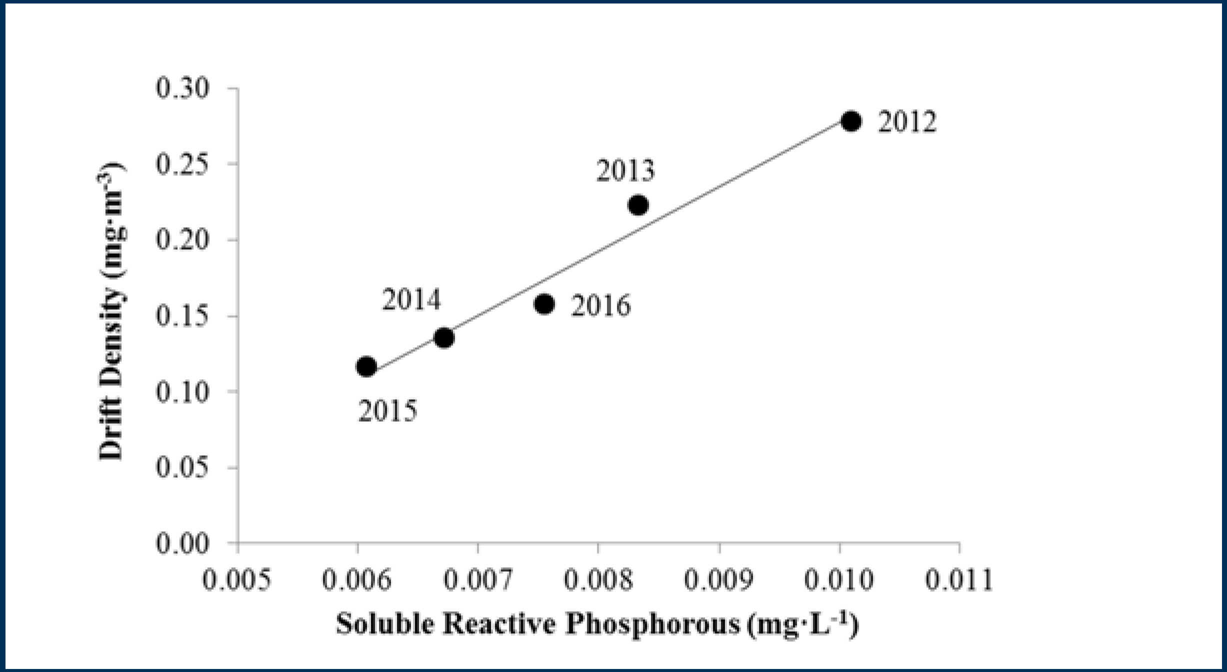
Annual Reporting Meeting

January 11, 2022, 3:30-3:45pm

Project E- Controls on Ecosystem Productivity: Nutrients, Flow, and Temperature

- **Element E.1.- Phosphorus budgeting and controls of phosphorus availability**
- **FY2021 E.1. budget: $168,074**
- **LTEMP resource goal: Natural Processes**
- **Science hypotheses:**
  - H4: A large fraction of the sediment P pool is calcite bound.
  - H6: Lower pH leads to elevated water column P bioavailability due to P release from calcium carbonates in the sediment.

Variable phosphorus release from Glen Canyon Dam controls tailwater food webs



Korman et al. 2021

USGS

Phosphorus budgeting project aims to constrain the role of tributary inputs

- Sampled one 5 hour 700 cfs storm in August 2018
- The one storm contributed ~15% of the monthly TP loading to Marble Canyon
- Extrapolating to the other storm that month, the Paria River could have contributed 50% of the August 2018 TP loading

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Ongoing Work by Tom Sabol & Somer Morris to Build a Total P Budget

- ISCO automatic sampling to capture storm flow on the Paria and Little Colorado rivers
- Community science sampling to capture smaller tributaries and mainstem sites through time

Type	Number of Sites or Storms	Total Number of TP Samples	Total Number of Dissolved P Samples	Total Number of Paired Silt and Clay Samples
Paria Baseflow	1	15	15	0
Paria Storm	6 (storms)	23	17	*
Little Colorado River	5 (storms)	34	12	*
Community Science Mainstem	8 (sites)	129	0	13
Community Science Tributary	21 (tributaries)	53	0	51

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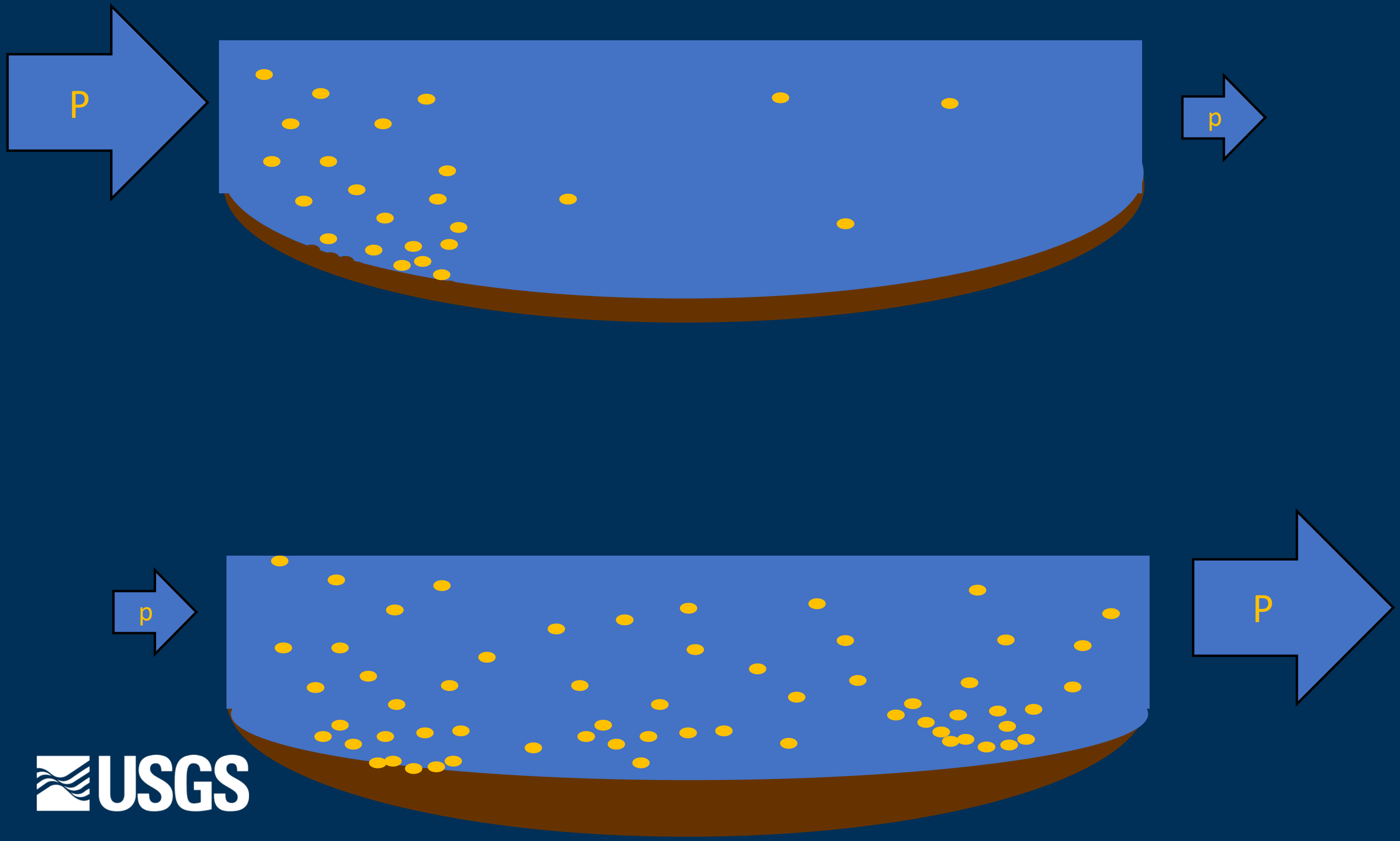
Preliminary Data, Do Not Cite

For this talk: How important might Colorado River sediments be as a phosphorus pool?



- In lakes, internal phosphorus loading is broadly acknowledged as important for ecology
- Could this be important in the Colorado River? If so, what controls it?

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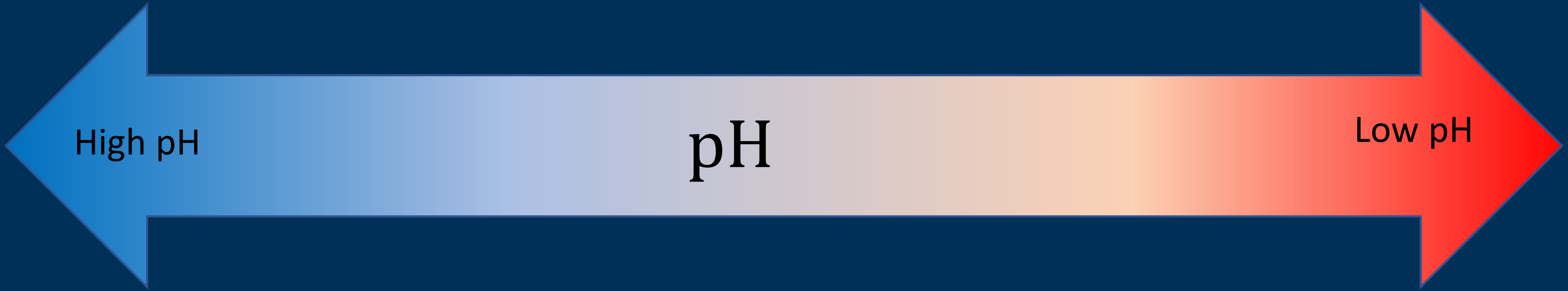
Coupled Nutrient Cycling

- **Acidic conditions (e.g. that arise from decomposition) can cause dissolution of calcite & release of SRP**

$$CaPO_4^- + H_2O + CO_2 + CaCO_3 \rightleftharpoons Ca^{2+} + 2HCO_3^- + Ca^{2+} + PO_4^-$$



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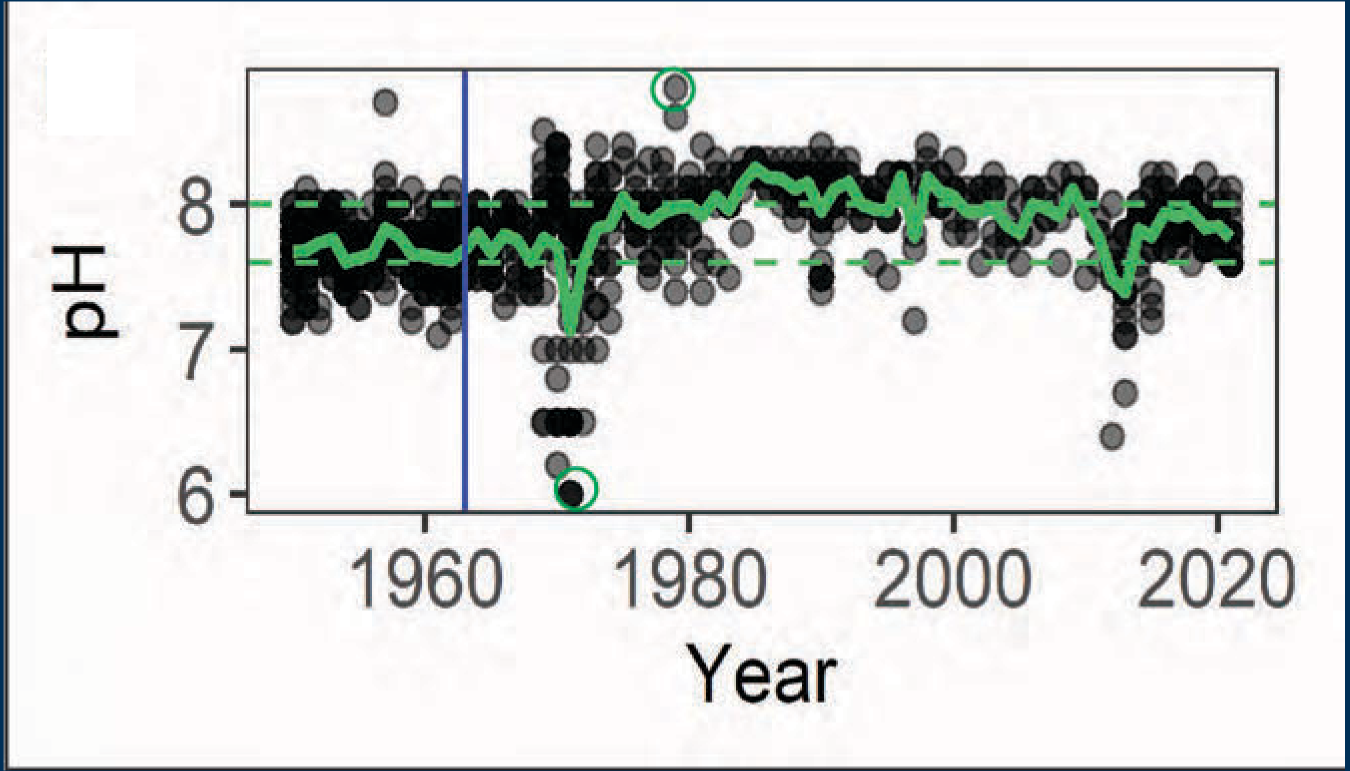
Glen Canyon Dam Has Changed Downstream pH Conditions Considerably

Variable water levels and variable productivity in Lake Powell leads to more fluctuation in outflow pH than before river damming

Dip in pH corresponds to high P and good food base, and high fish condition and recruitment in Lees Ferry and near the Little Colorado River (2012)



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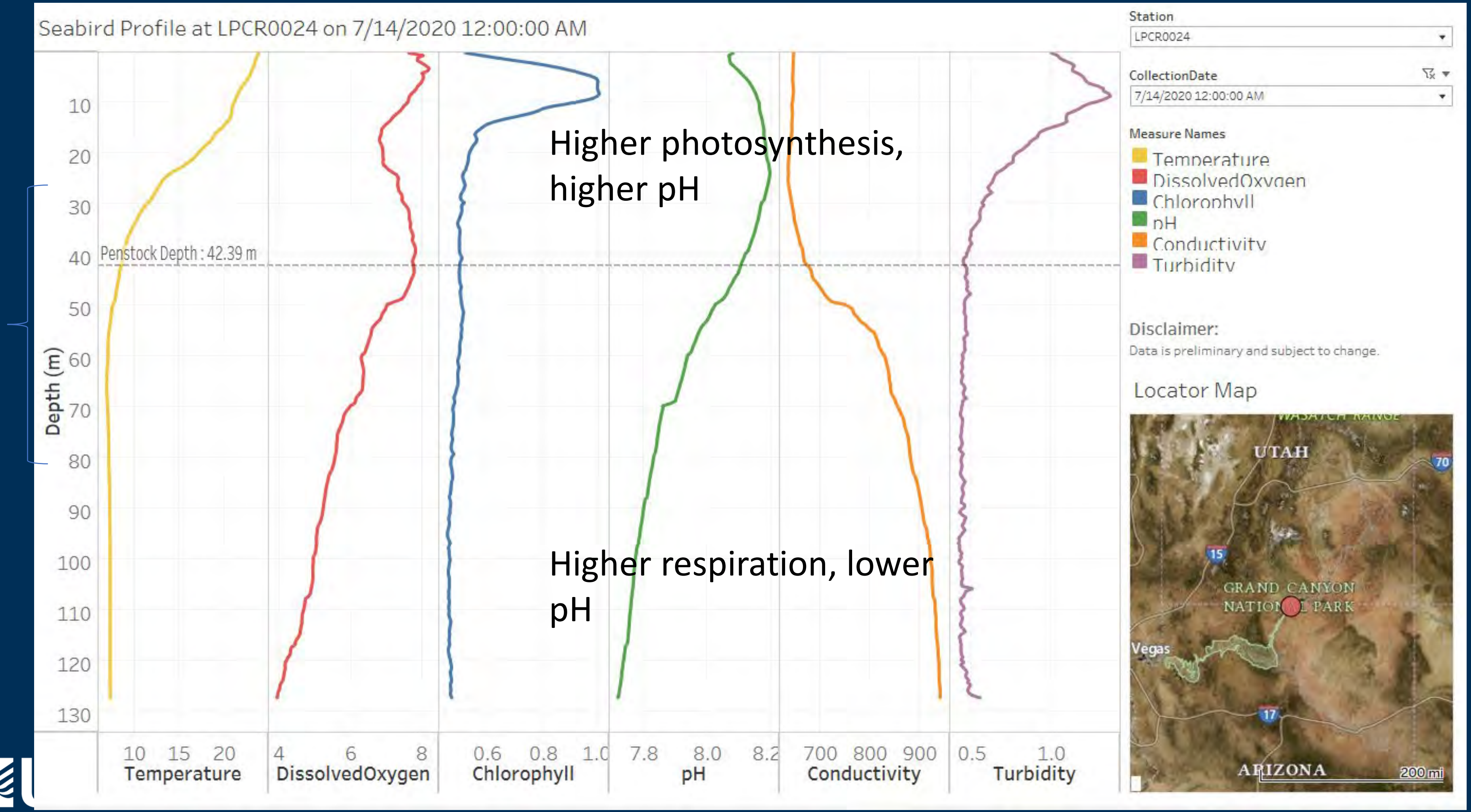
Water Levels Influence the pH of Dam Releases



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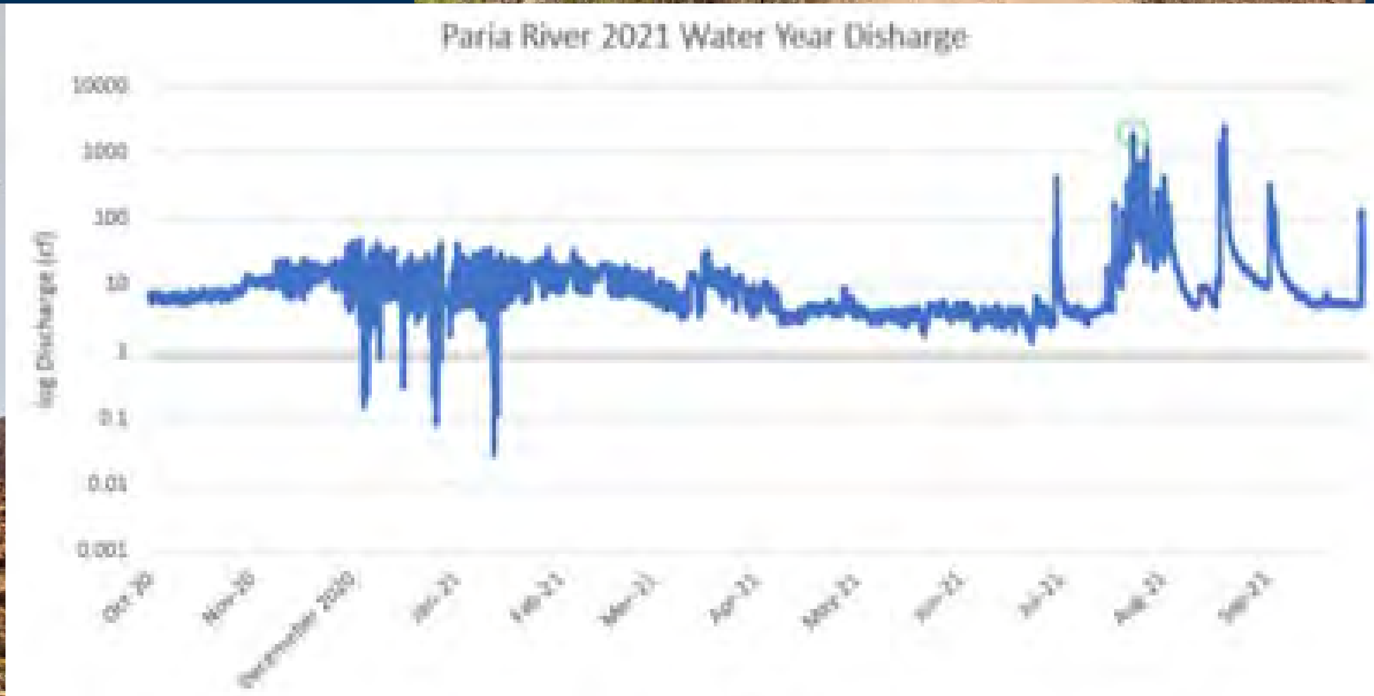
Study Questions

Q1: Is P bioavailability in the Colorado River pH-driven?

Q2: Can sediments override dam loading in terms of a P source under certain conditions?

Sediment Samples

- Glen Canyon: tailwater reach
- Paria River: sediment from storm event incubated with overlying Colorado River water
- Pearce Ferry: influenced by Kanab Creek flood



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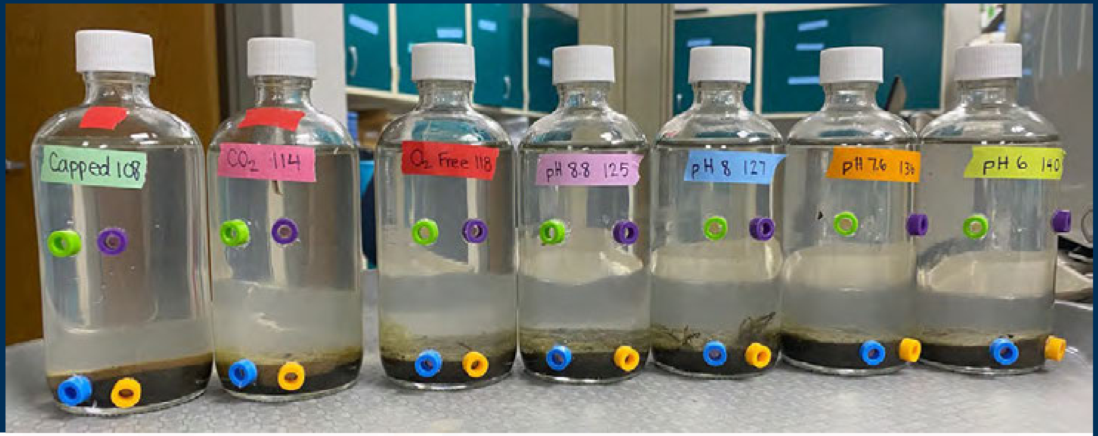
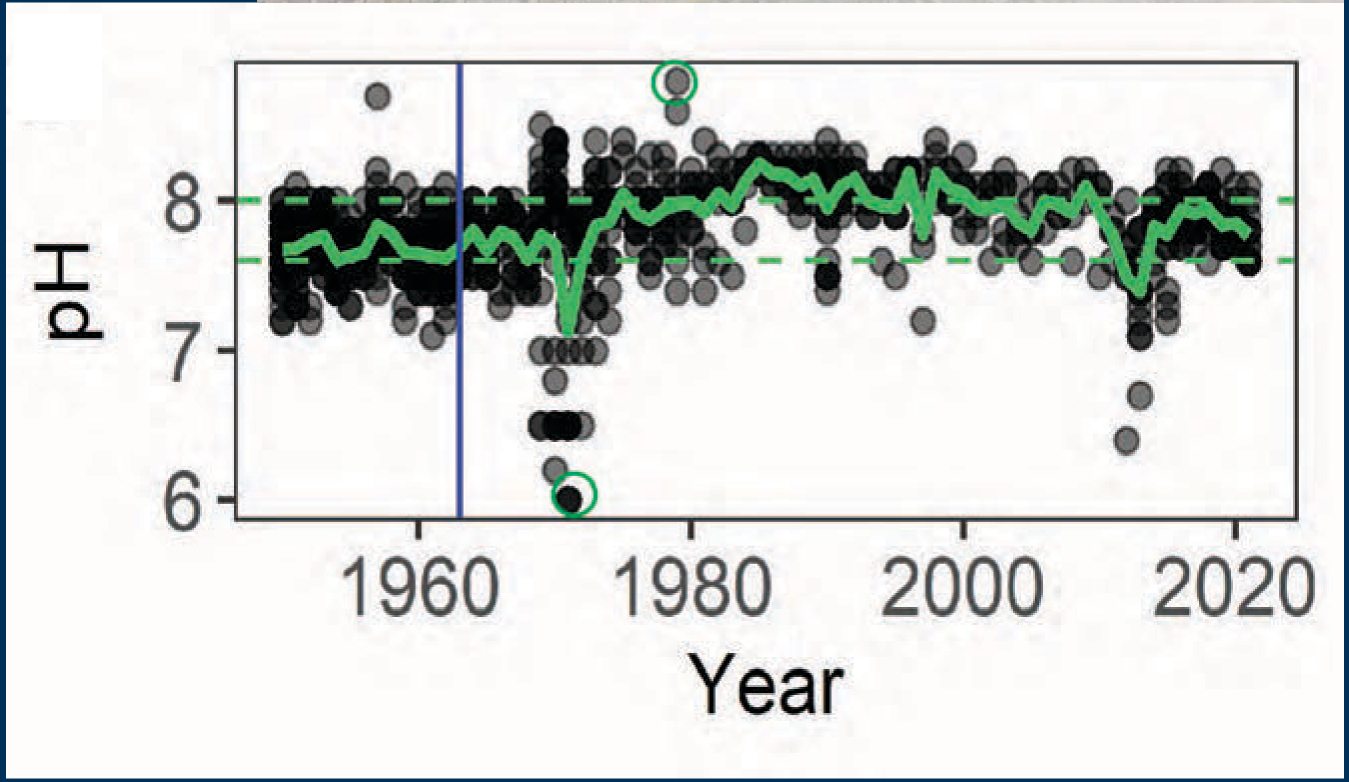
Sediment Incubation Design

- Temperature controlled incubator for 24 hours in the dark at ~13 degrees C
- 1 set of initials (5x)
- 7 treatments (5x each):
  - Control
  - CO2 amendment
  - Oxygen free headspace
  - 4 different pHs





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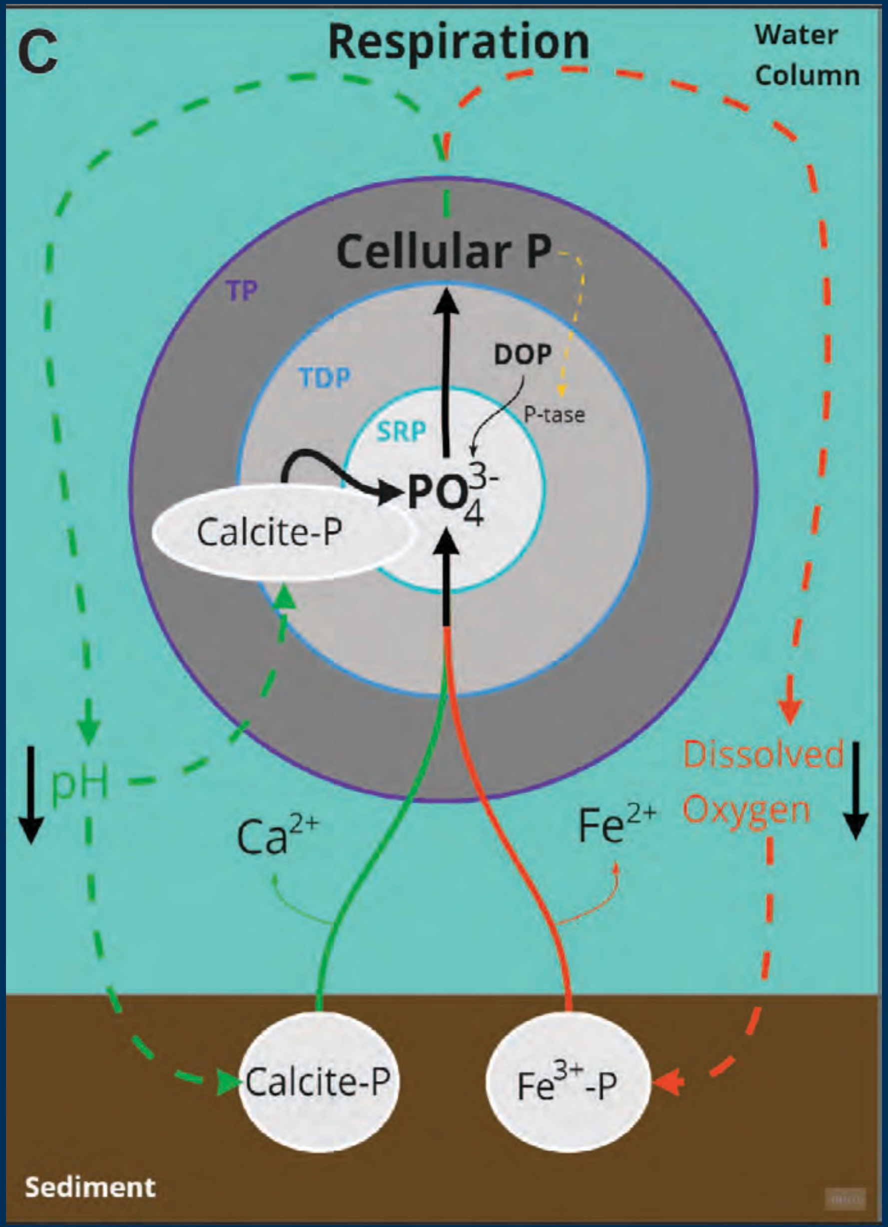
Conceptual Model

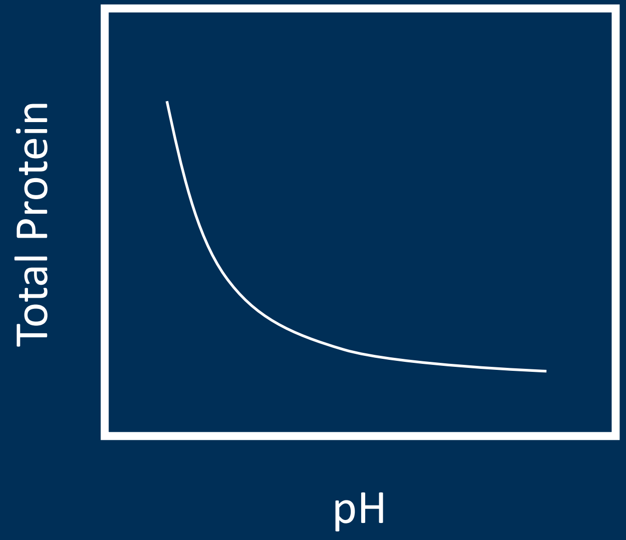
Declining pH and/or declining dissolved oxygen may cause the release of sediment bound phosphorus

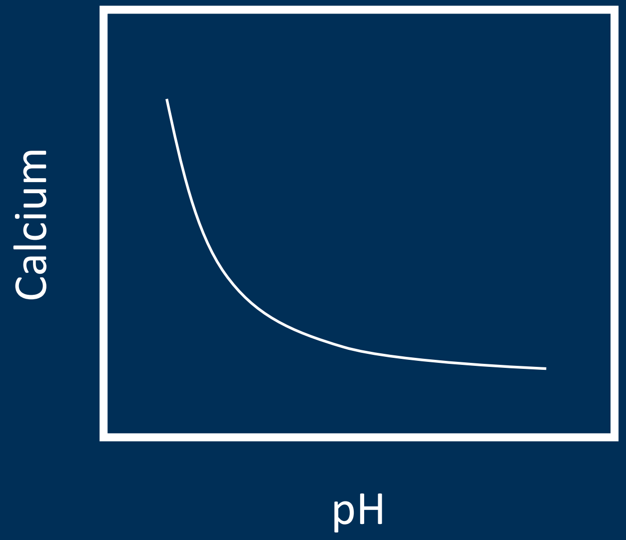
When additional phosphorus is released to the water column we expect:

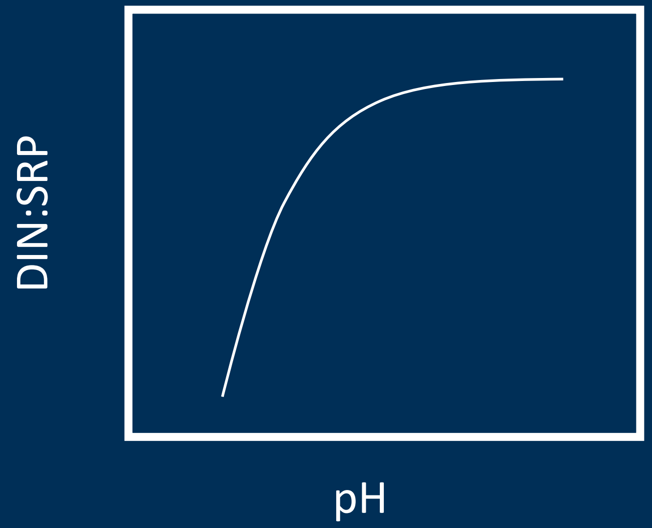
- Elevated cellular P (total protein)
- Elevated SRP & TP
- Elevated Ca (if calcite mediated)
- Reduced "P-tase" (alkaline phosphatase is an enzyme that cleaves P from organic molecules to make it more available for uptake)

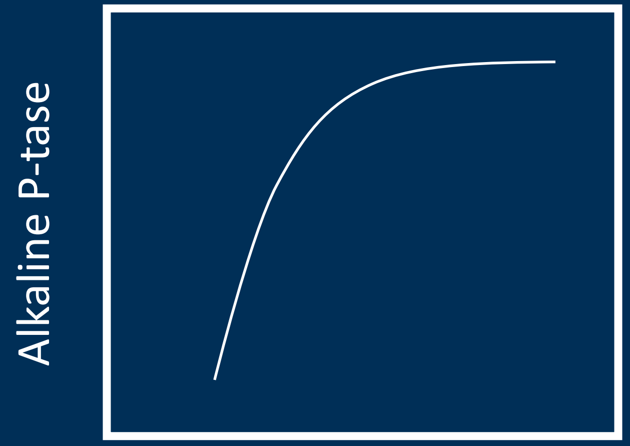


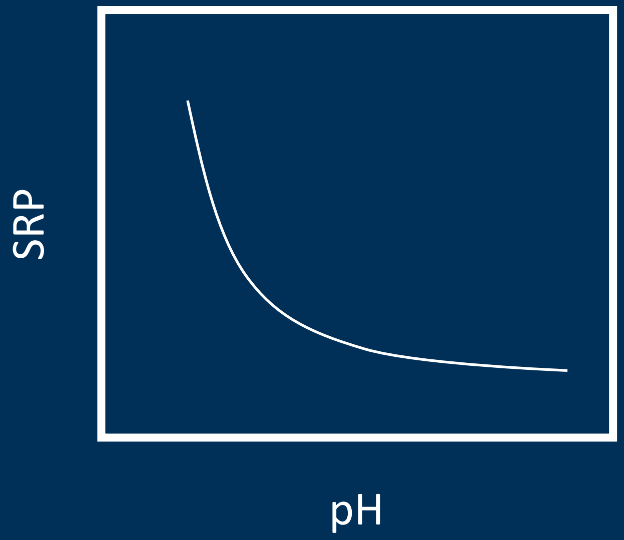
Expected Results







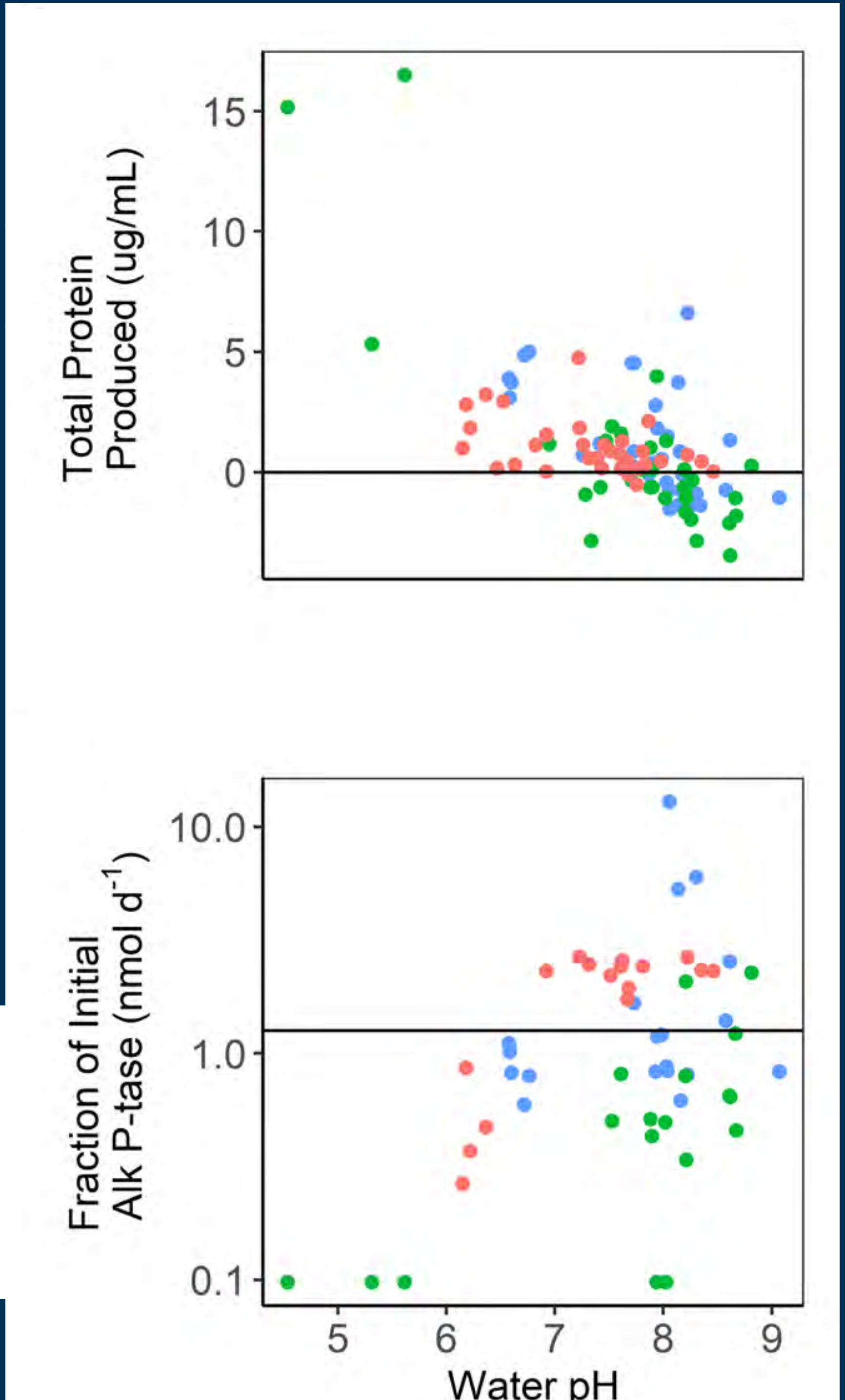


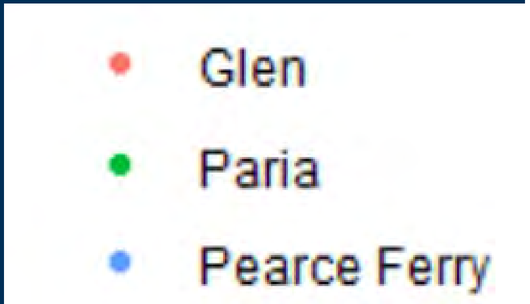


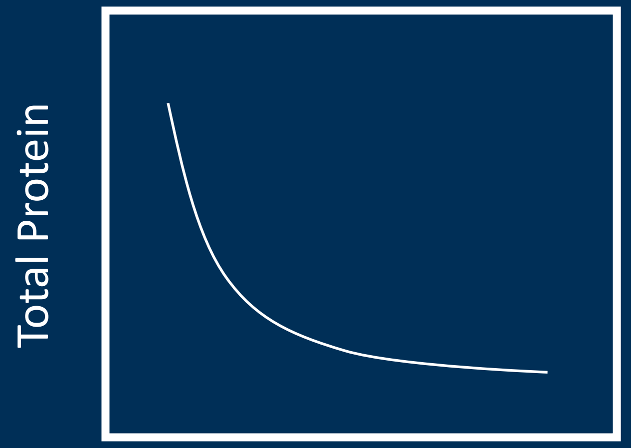
Biological Response

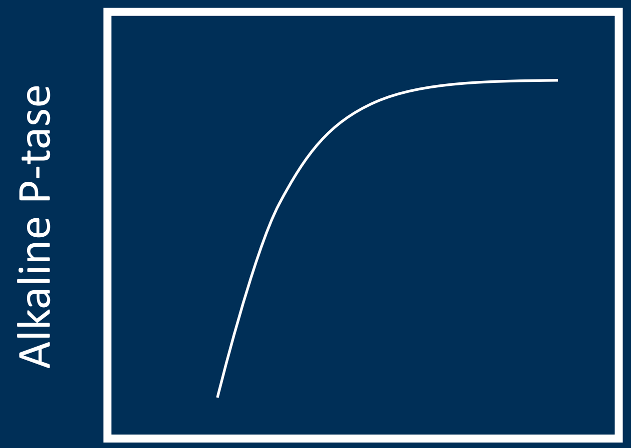
Higher total protein in the bottles with lower pH

Less indicator of phosphorus limitation (alkaline phosphatase) in the bottles with lower pH









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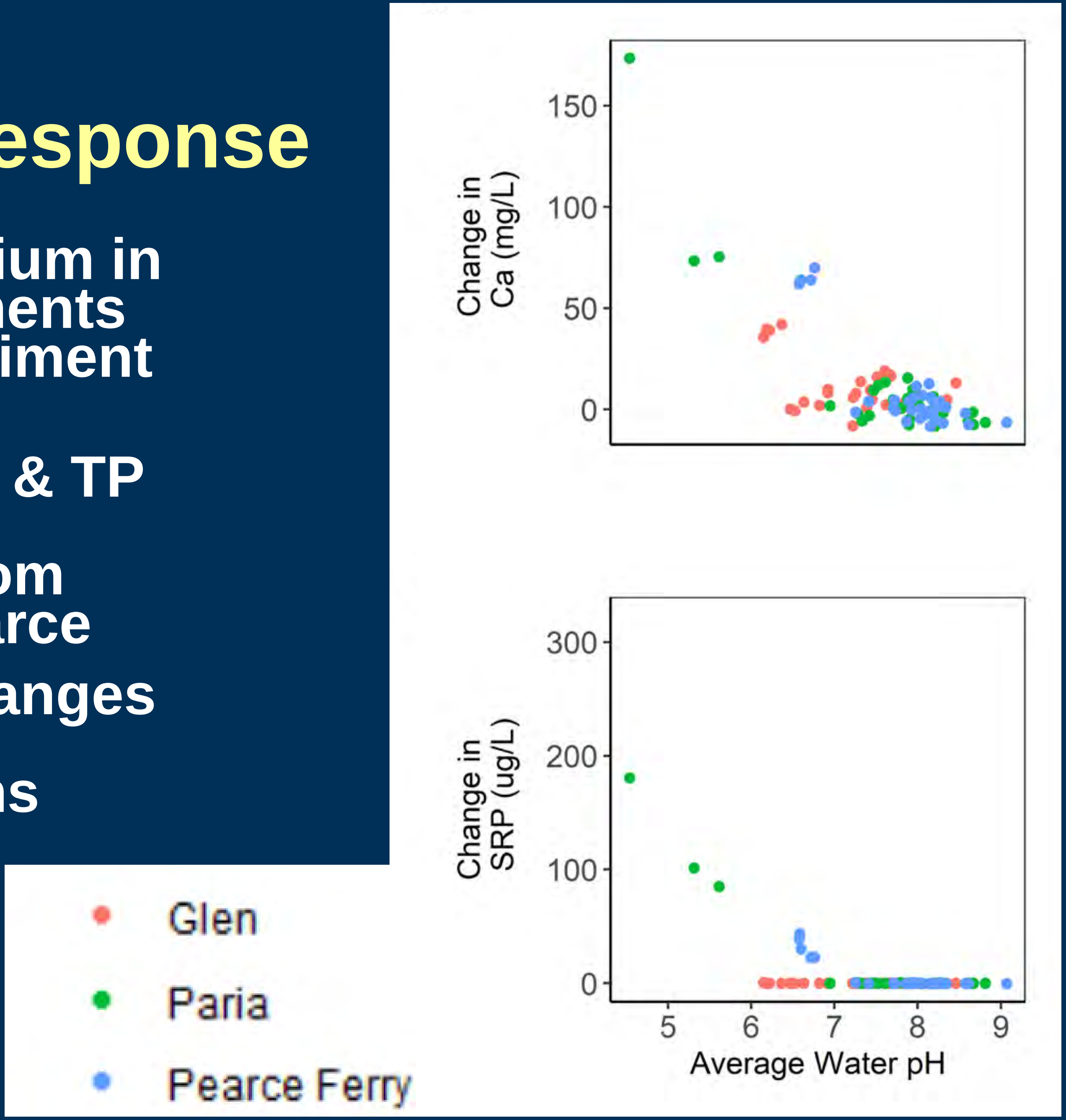
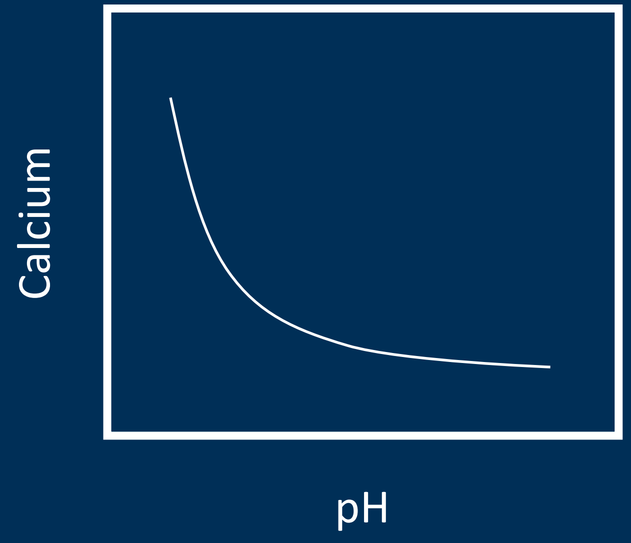
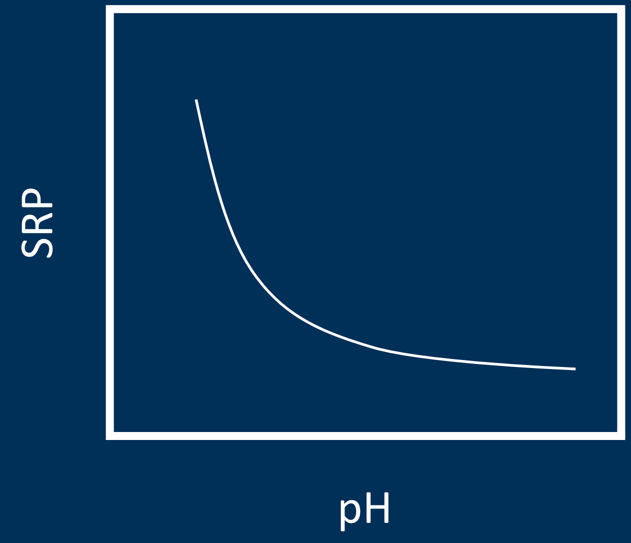
Chemical Response

- Elevated calcium in low pH treatments from all 3 sediment types
- Elevated SRP & TP in low pH treatments from Paria and Pearce
- No similar changes in nitrogen concentrations across pH







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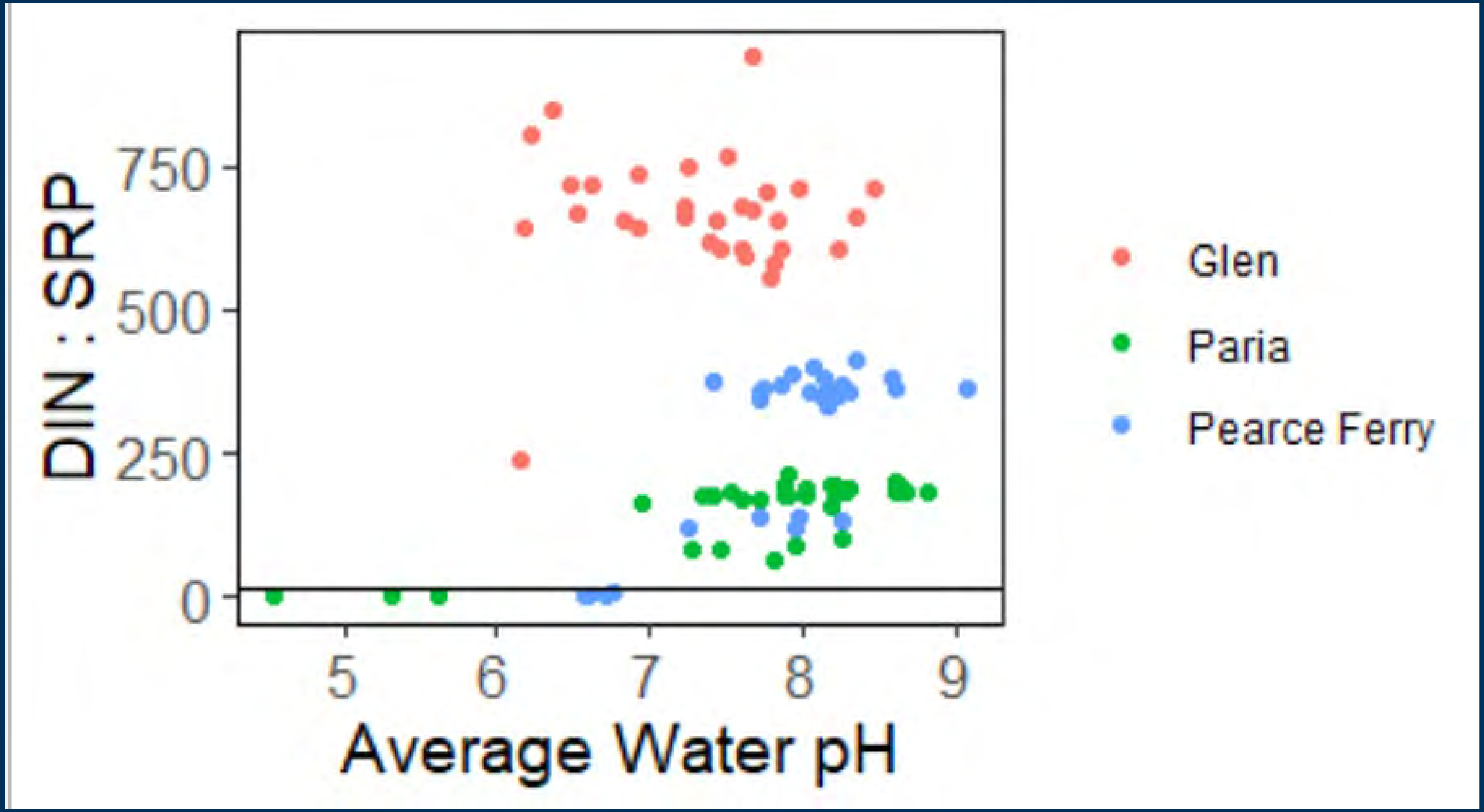
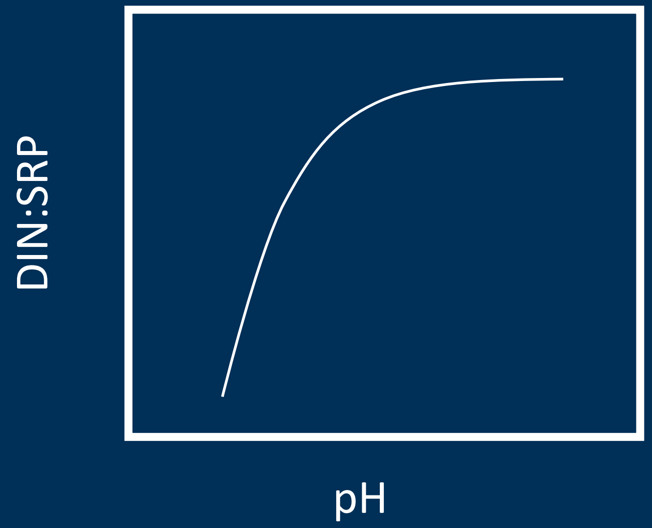
P limitation is alleviated in Paria and Pearce Ferry Incubations under low pH





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Estimating the Potential Effect on the P Budget

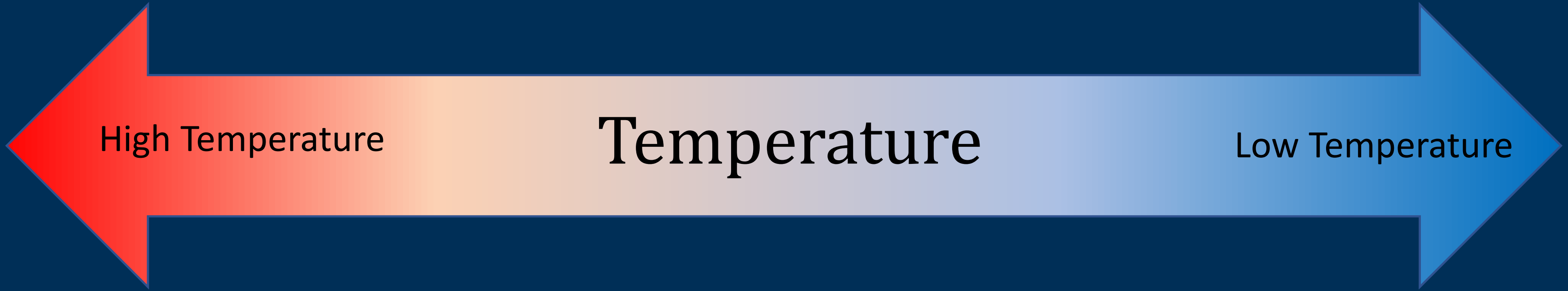
- Average loading from dam is ~65 kg SRP d-1
- SRP loading from Pearce under pH 6 treatment is ~31 kg d-1

Study Questions

Q1: Is P bioavailability in the Colorado River pH-driven?
Data thus far seems to support pH-driven P release.

Q2: Can sediments override dam loading in terms of a P source under certain conditions?– Downstream on an event-based/daily timescale, yes

Future Directions



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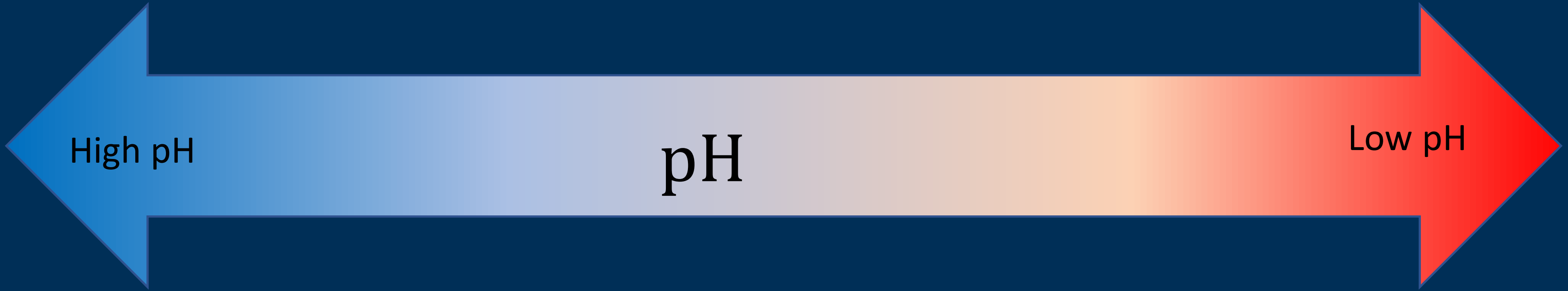

Acknowledgements

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Questions?