Dissolved Oxygen Dynamics in Lake Powell and Glen Canyon

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Glen Canyon Dam Adaptive Management Program
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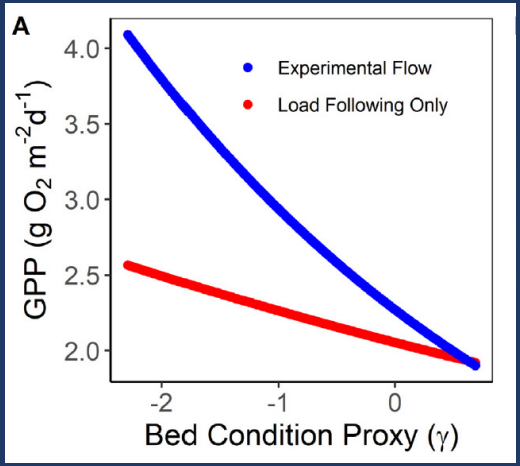
Photo Credit. David Herasimtschuk, ©Freshwaters Illustrated

Escalante arm of Lake Powell
Campsite for Lake Powell quarterly trip- March 9, 2022

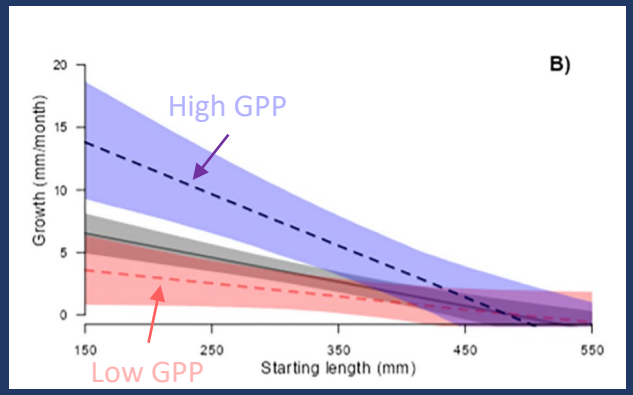
Project E TWP Accomplishments

Bug flows increase canyon-wide gross primary production (GPP) especially when bed grain size distribution is coarse



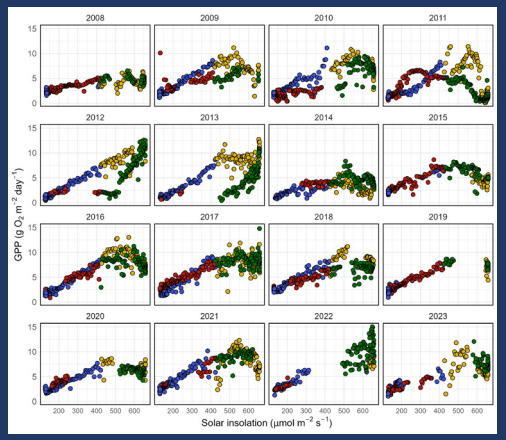
Modified from *Deemer et al. 2022 PNAS Nexus*

GPP positively influences Flannelmouth Sucker growth & modeling efforts are underway to explore the role of GPP in Humpback Chub growth (see Lindsay Hansens' poster!)



Modified from *Hansen et al. 2023 CJFAS*

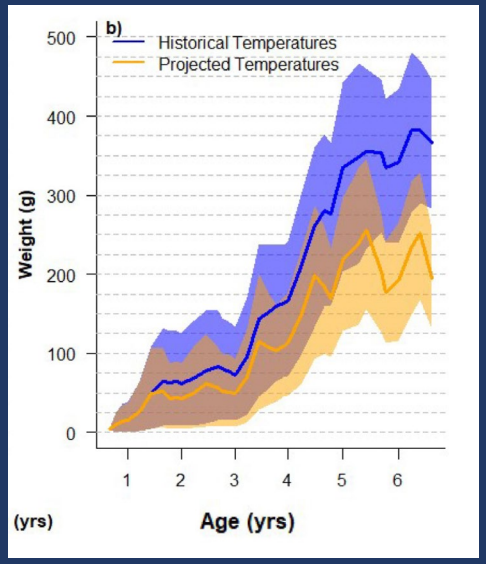
Method improvement for estimating tailwater metabolism will support food web inferences in Glen Canyon (see Ian Bishop's poster!)



Preliminary Data, Do Not Cite

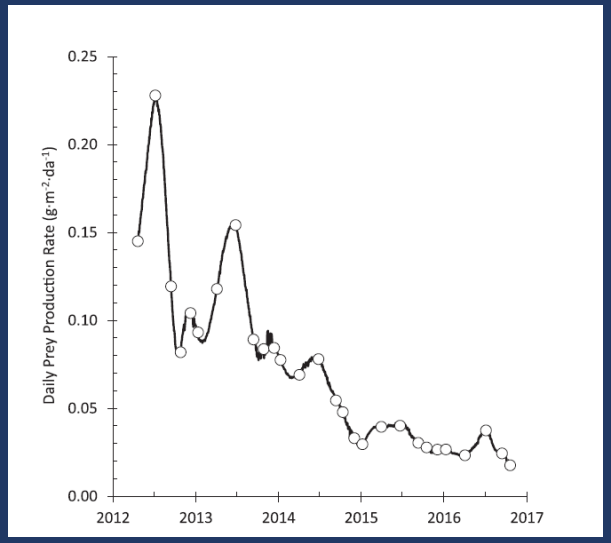
Project E TWP Accomplishments

High Flow Events (HFEs) and Bug Flows do not affect Rainbow Trout growth as much as water quality from reservoir releases



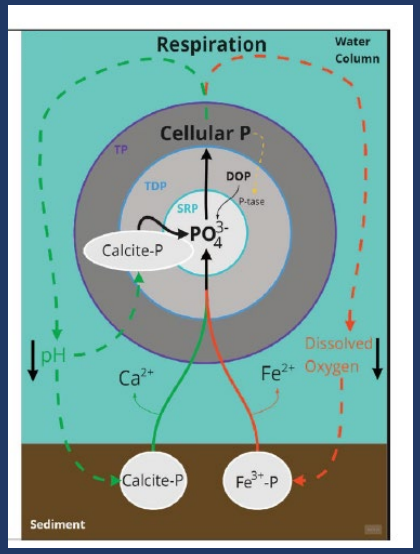
Modified from *Korman et al. 2022 CJFAS*

Reservoir phosphorus release drove declines in prey production and collapse of Rainbow Trout fishery in Glen Canyon (*Yard et al. 2023 TAFS*)



Modified from *Yard et al. 2023 TAFS*

Declining pH from both storms and reservoir elevation can elevate bioavailable phosphorus in the Colorado River below Glen Canyon Dam



Modified from *Deemer et al. 2023 Biogeochemistry*

Why Do We Care About Low Dissolved Oxygen (DO)?

- Generally considered a key metric of water quality
  - In the River: Biodiversity
    - Some species are more sensitive to low DO than others
    - In lakes and reservoirs, fish habitat can be “pinched” where fish will intentionally avoid low oxygen regions

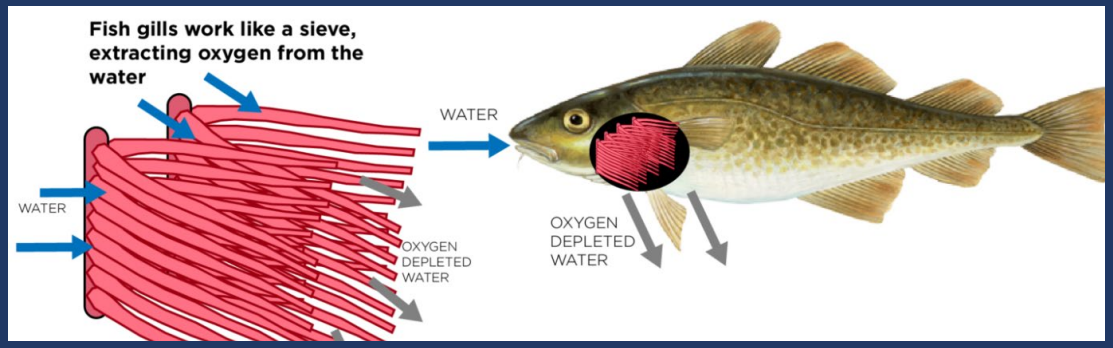
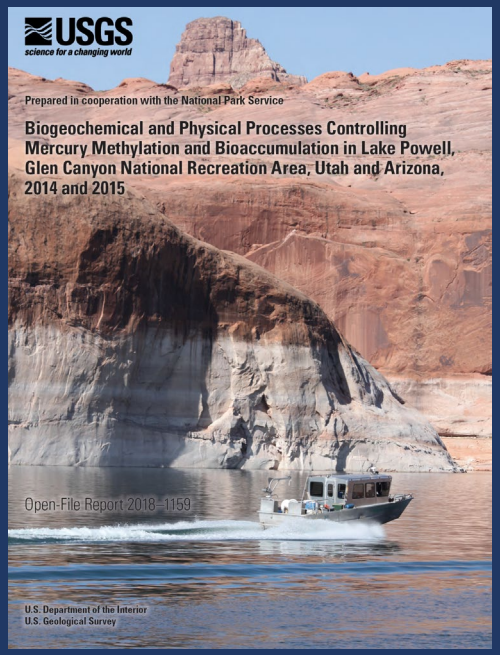


Diagram demonstrating how fish breathe dissolved oxygen
Modified from schematic by Lindsay Lafreniere

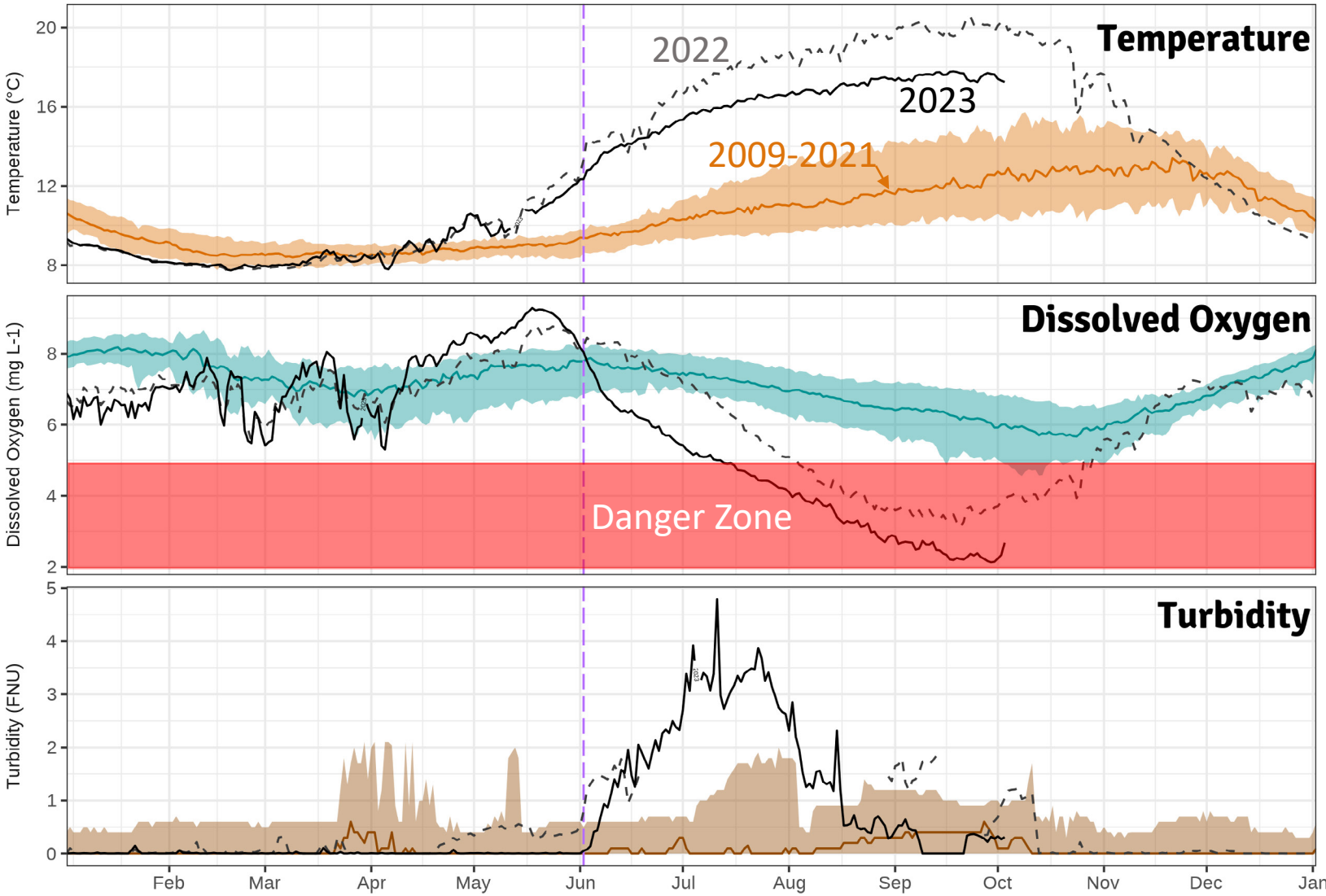
Carp gasping for oxygen:
Photo by Laszlo Balogh

Why Do We Care About Low DO?

- Generally considered a key metric of water quality
  - In Reservoirs:
    - Drinking water quality and mercury dynamics
    - Can enhance nutrient availability and shift nutrient limitation leading to algal blooms
    - Fish habitat can be “pinched” where fish will intentionally avoid low oxygen regions



Water Quality Conditions Immediately Below Glen Canyon Dam

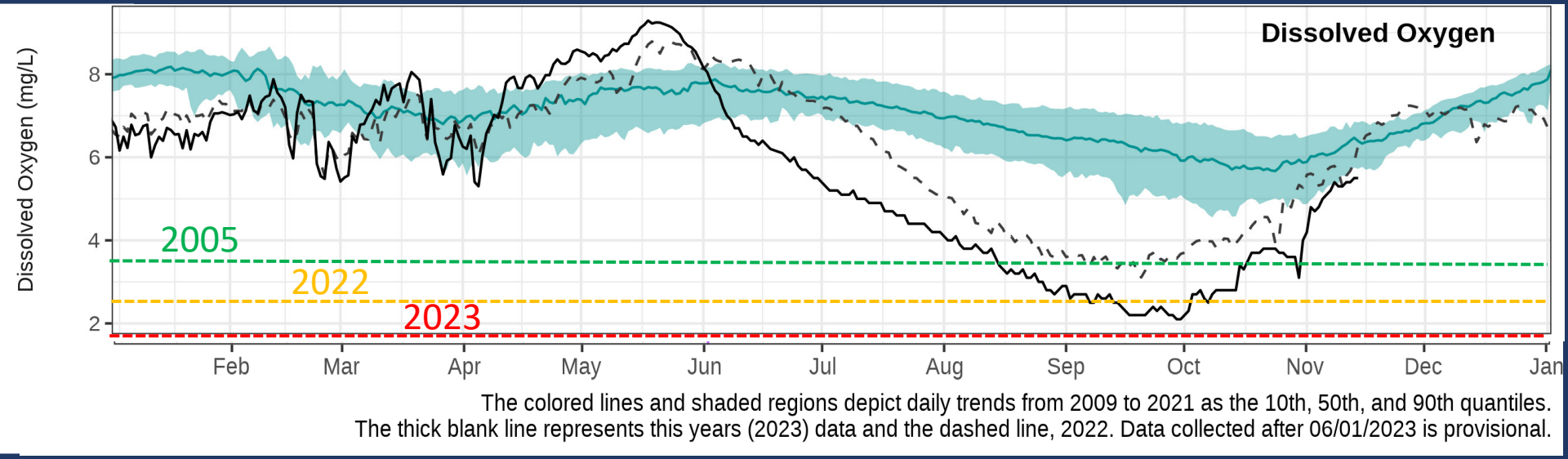


The colored lines and shaded regions depict daily trends from 2009 to 2021 as the 10th, 50th, and 90th quantiles. The thick blank line represents this years (2023) data and the dashed line, 2022. Data collected after 06/01/2023 is provisional.

Preliminary Information Subject to Revision. Not for Citation or Distribution

How Low is Low?

The low oxygen in dam releases this year was unprecedented in both magnitude and duration



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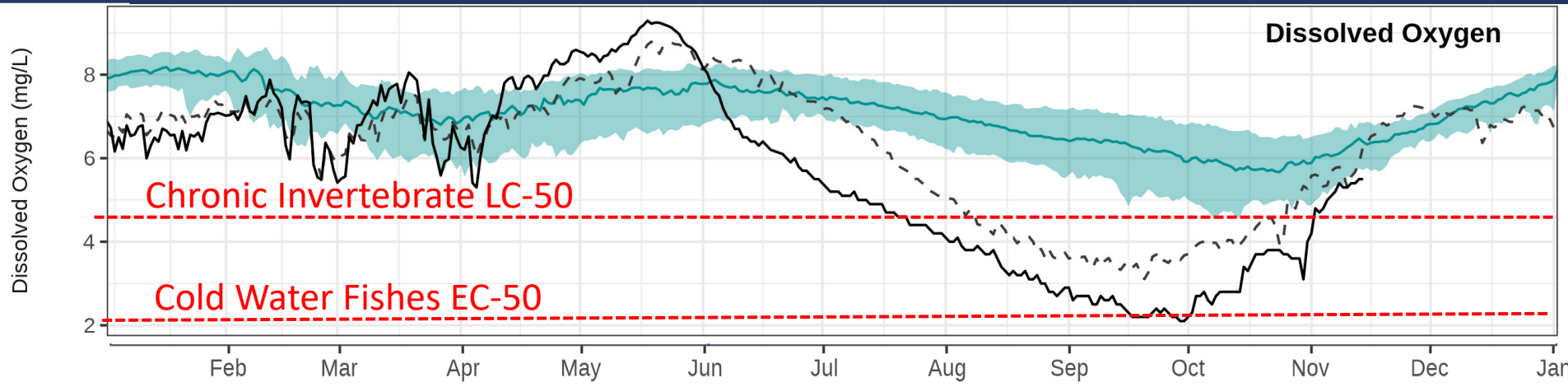
Red lines show the median:

1. LC-50 for invertebrates: concentration that is lethal to 50% of test population w/ 96+ hr acute exposure (Saari et al. 2018)
2. EC-50 for cold water fishes: concentration that has a 50% effect on growth or reproductive effect w/ 96+ hr chronic exposure (Saari et al. 2018)



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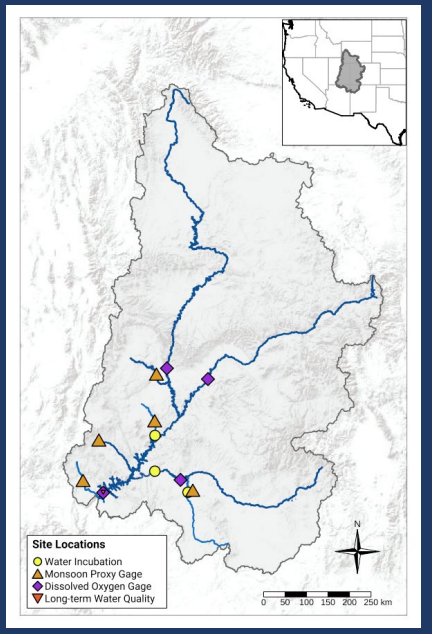
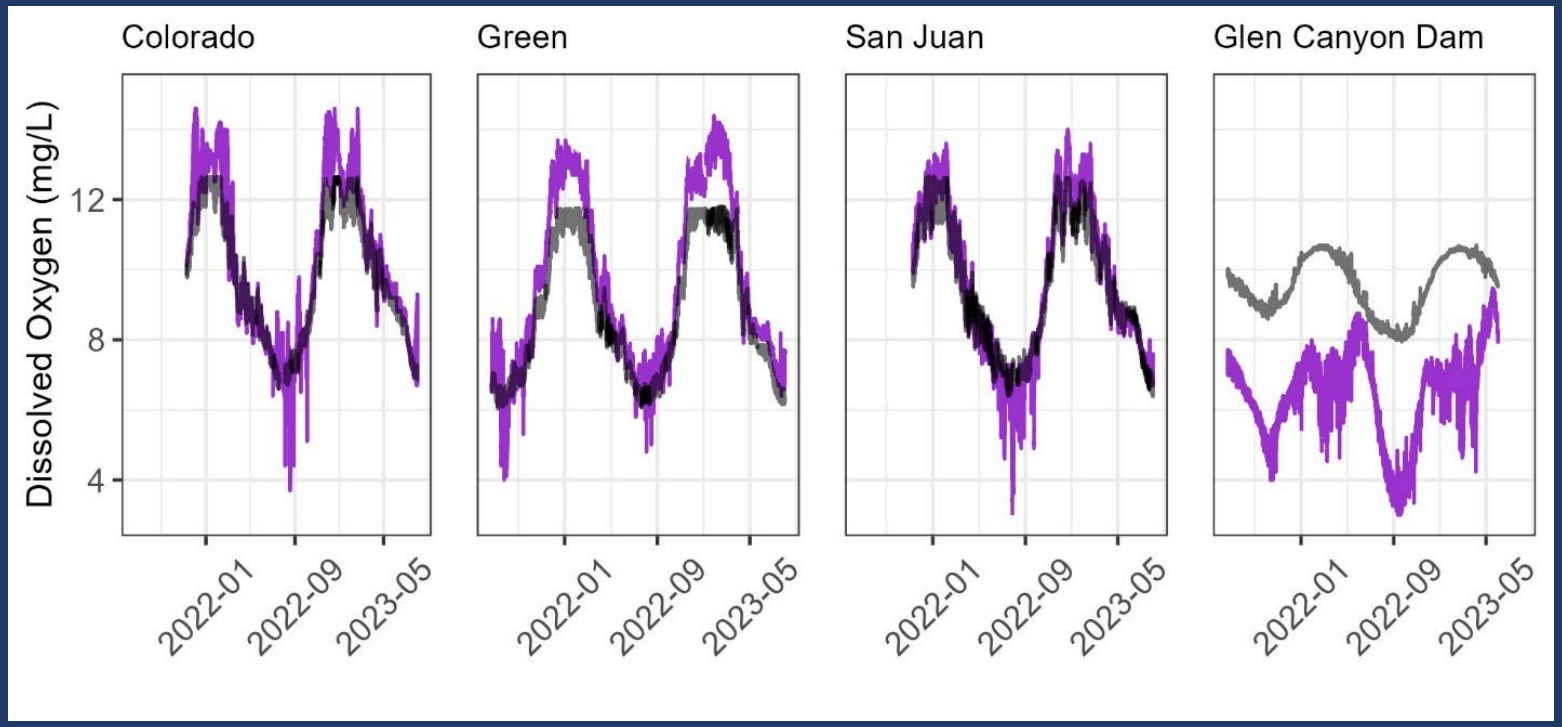
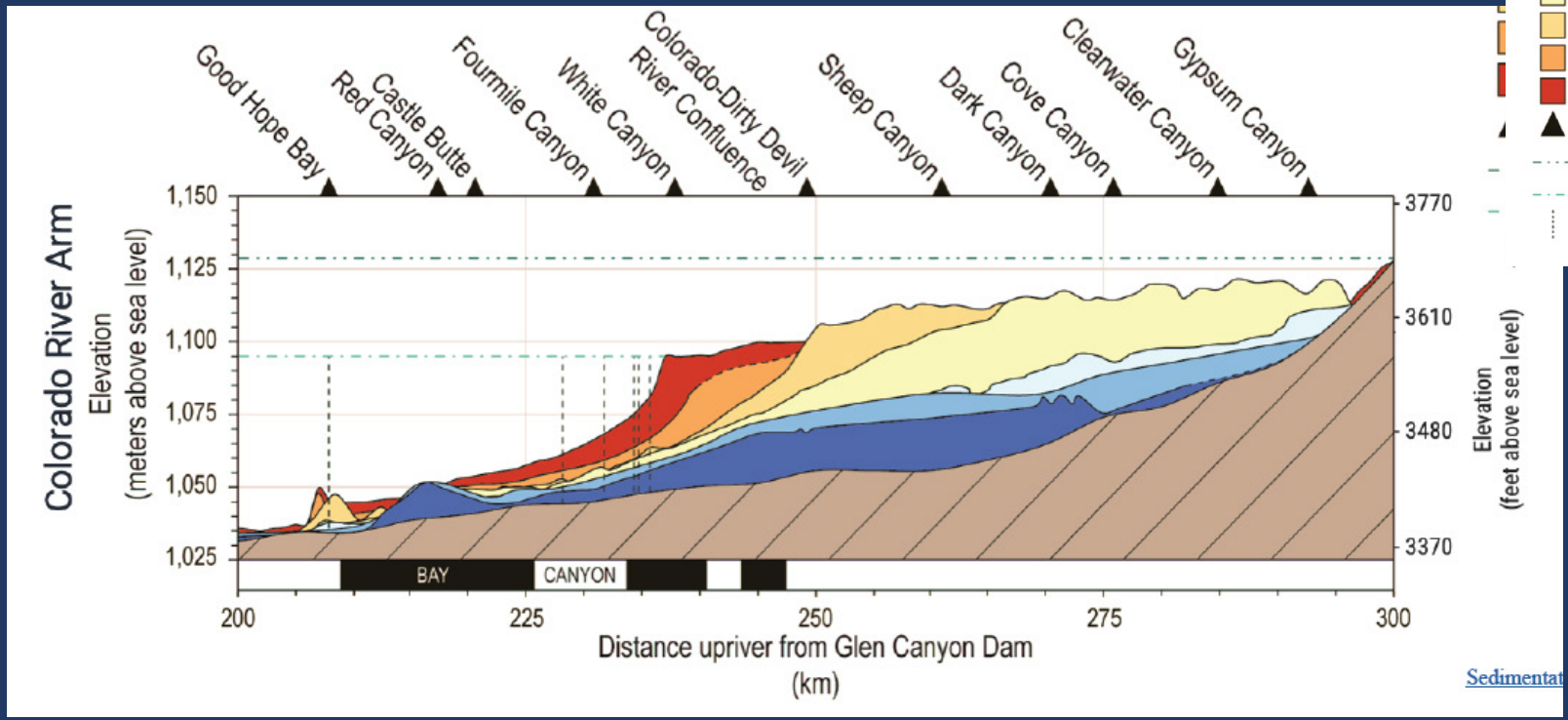
More Persistent Low DO Events Below Glen Canyon Dam





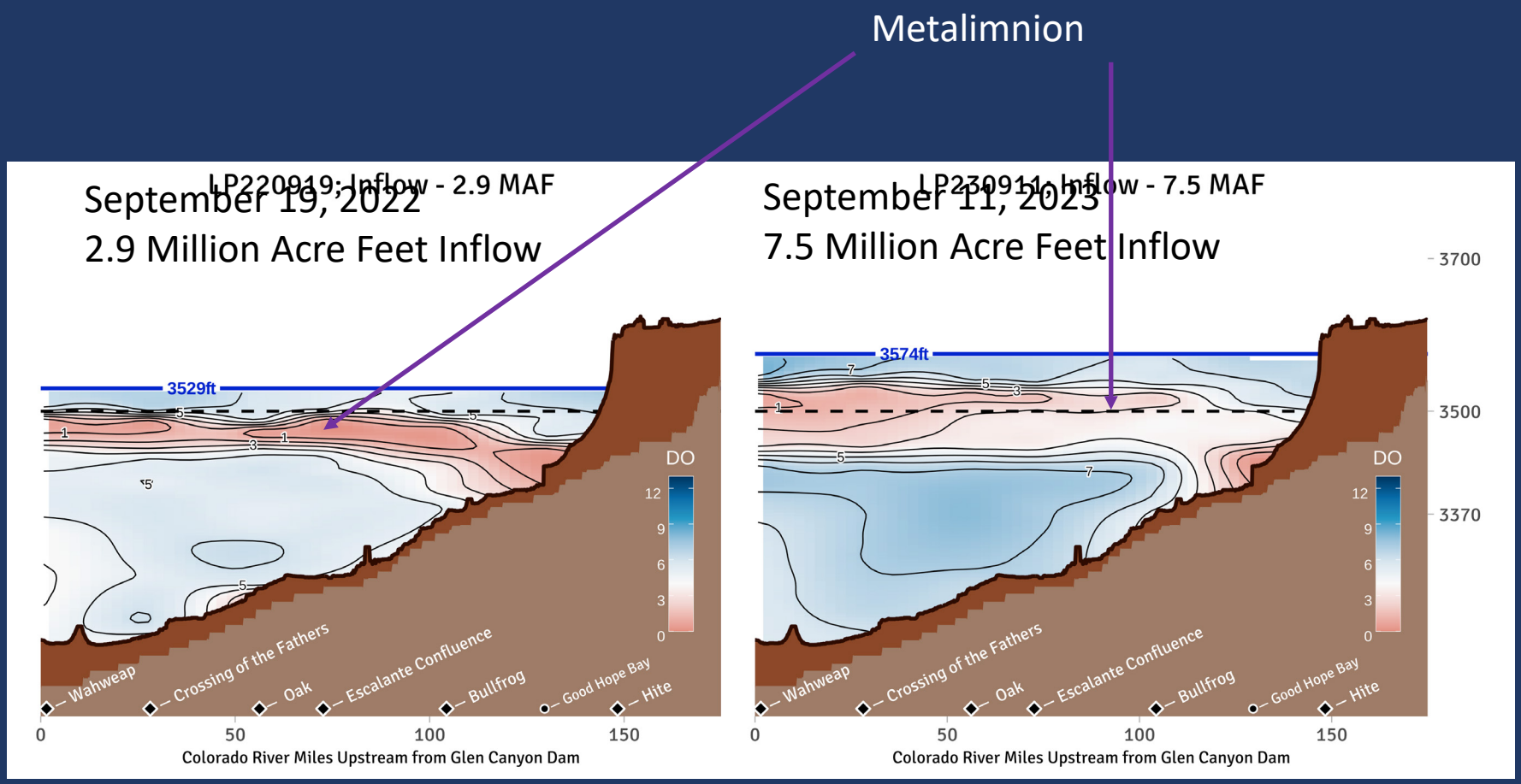
Dynamic Deltas in Powell's Inflows Have Impacts Far Downstream

- ~7% loss in reservoir storage capacity



Krolczyk and Schmidt 2023- Sediment Delivery to Lake Powell and Lake Mead Factsheet

Spring Inflows Remobilize Sediment and Create DO Demand



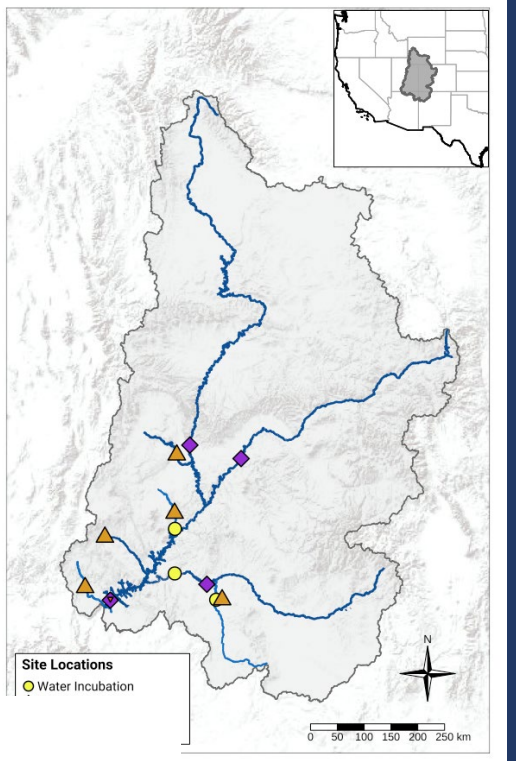
Incubation Experiment

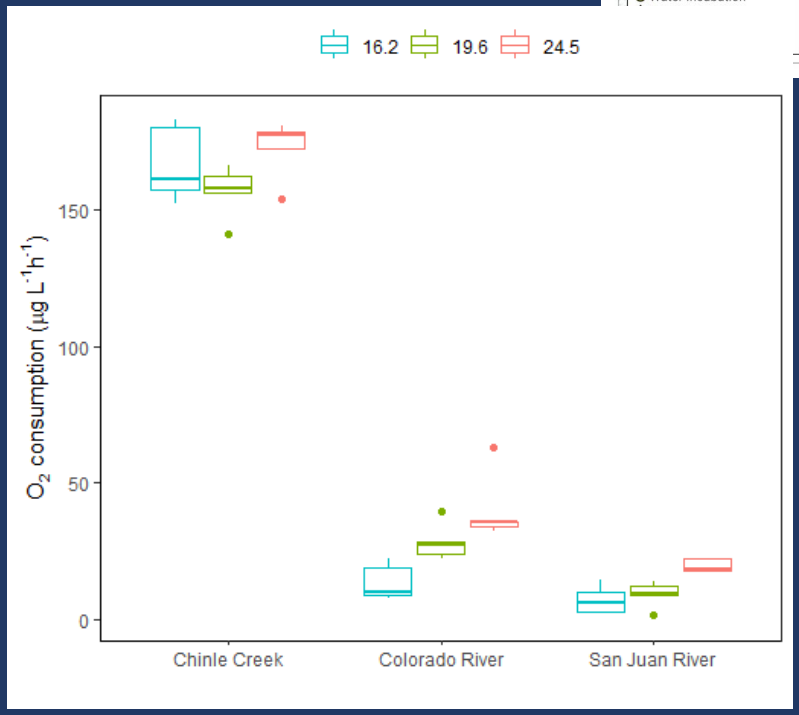
(funded by Ecosystems Mission Area)

Oxygen consumption rate depends on water temperature and sediment source

Larger temperature response in the Colorado than the San Juan

Highest rates of consumption in the monsoonal Chinle Creek sediments, but no temperature dependence (likely because rate is saturated)





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Incubation Experiment

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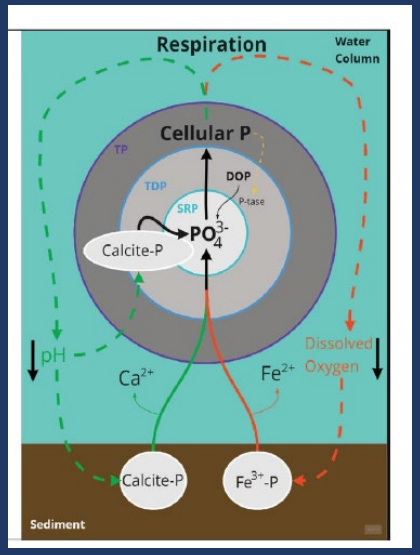
Phosphorus release measured in all incubations



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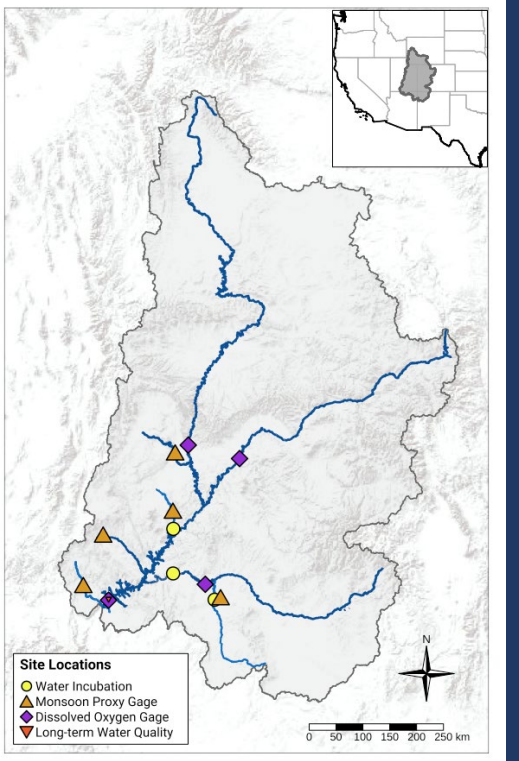

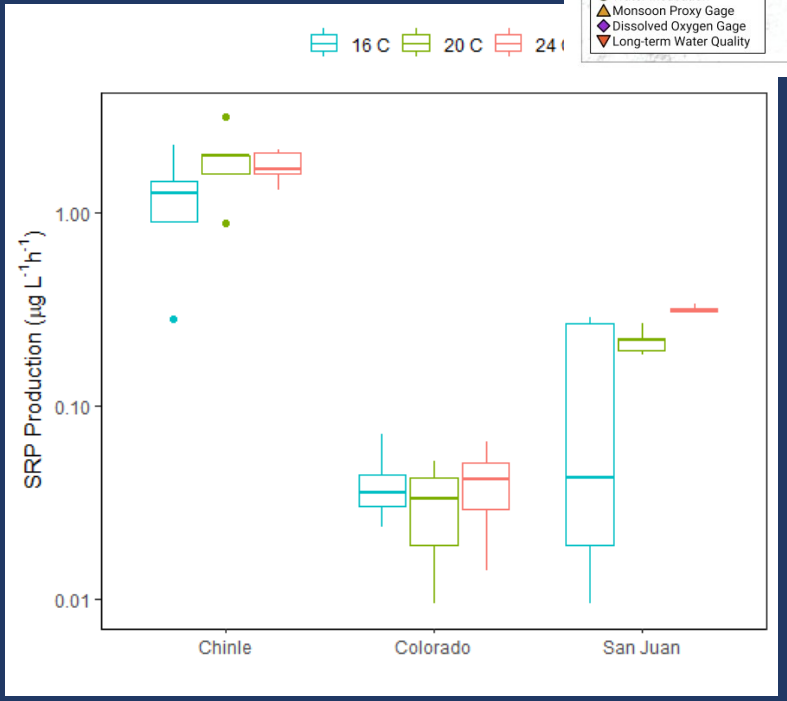

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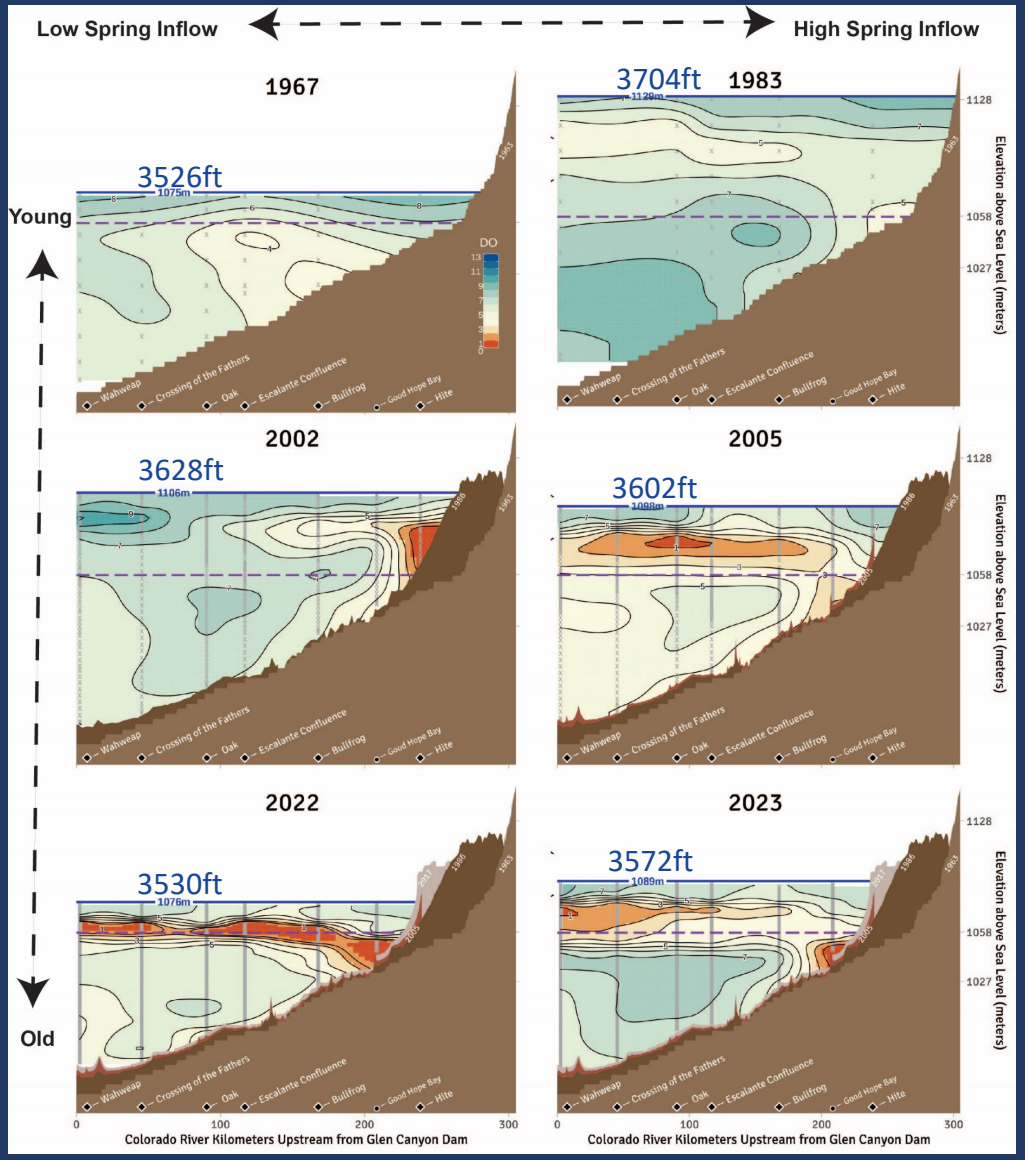
What Can The Historical Dataset Tell Us?

Lower average late summer/fall dissolved oxygen in the metalimnion when:

1. Reservoir spring elevation is low
2. Spring inflow is large
3. Age/elevation interaction

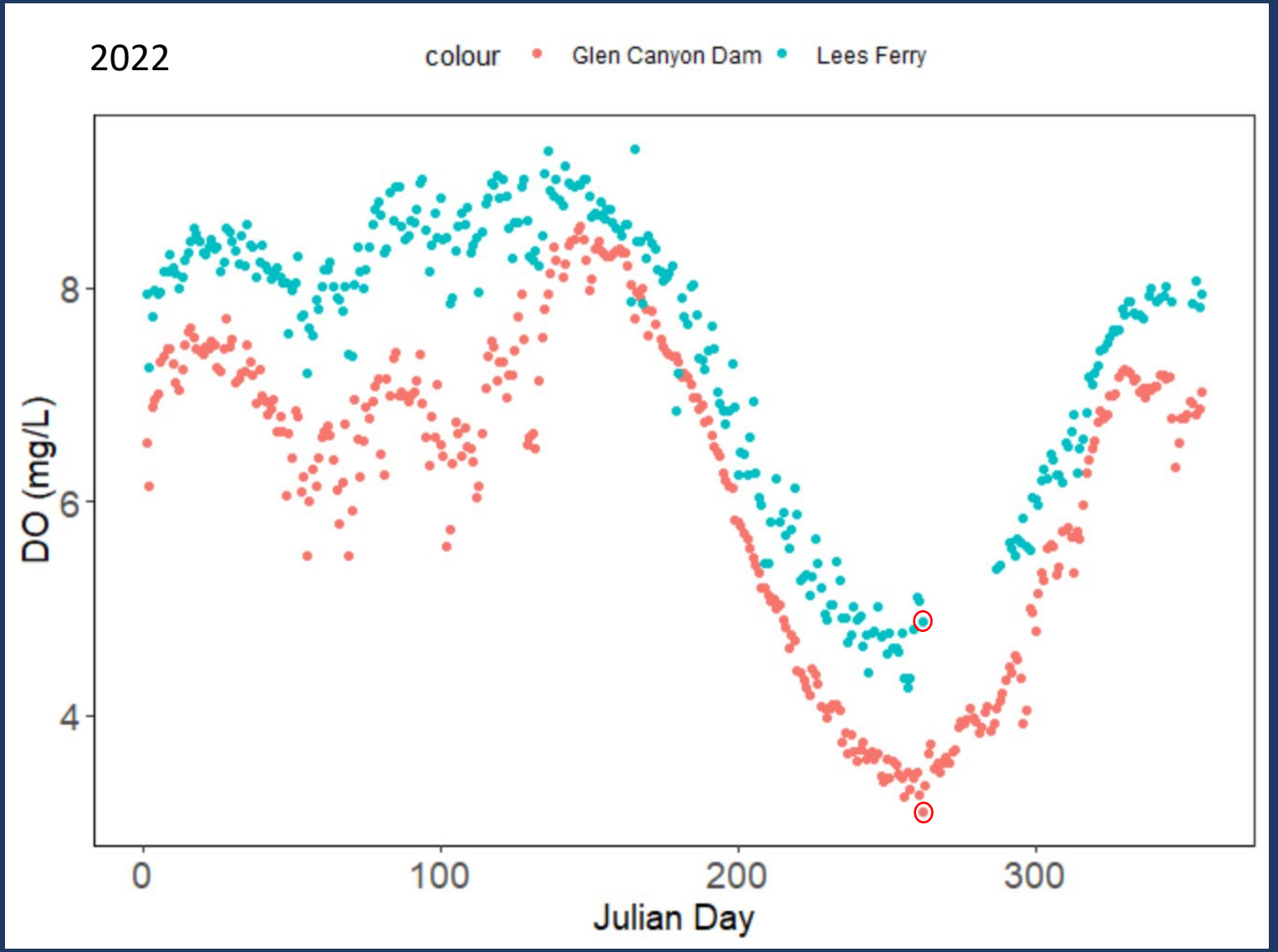
Lake-wide low dissolved oxygen events will be increasingly common when lake elevation is below ~3620 ft.



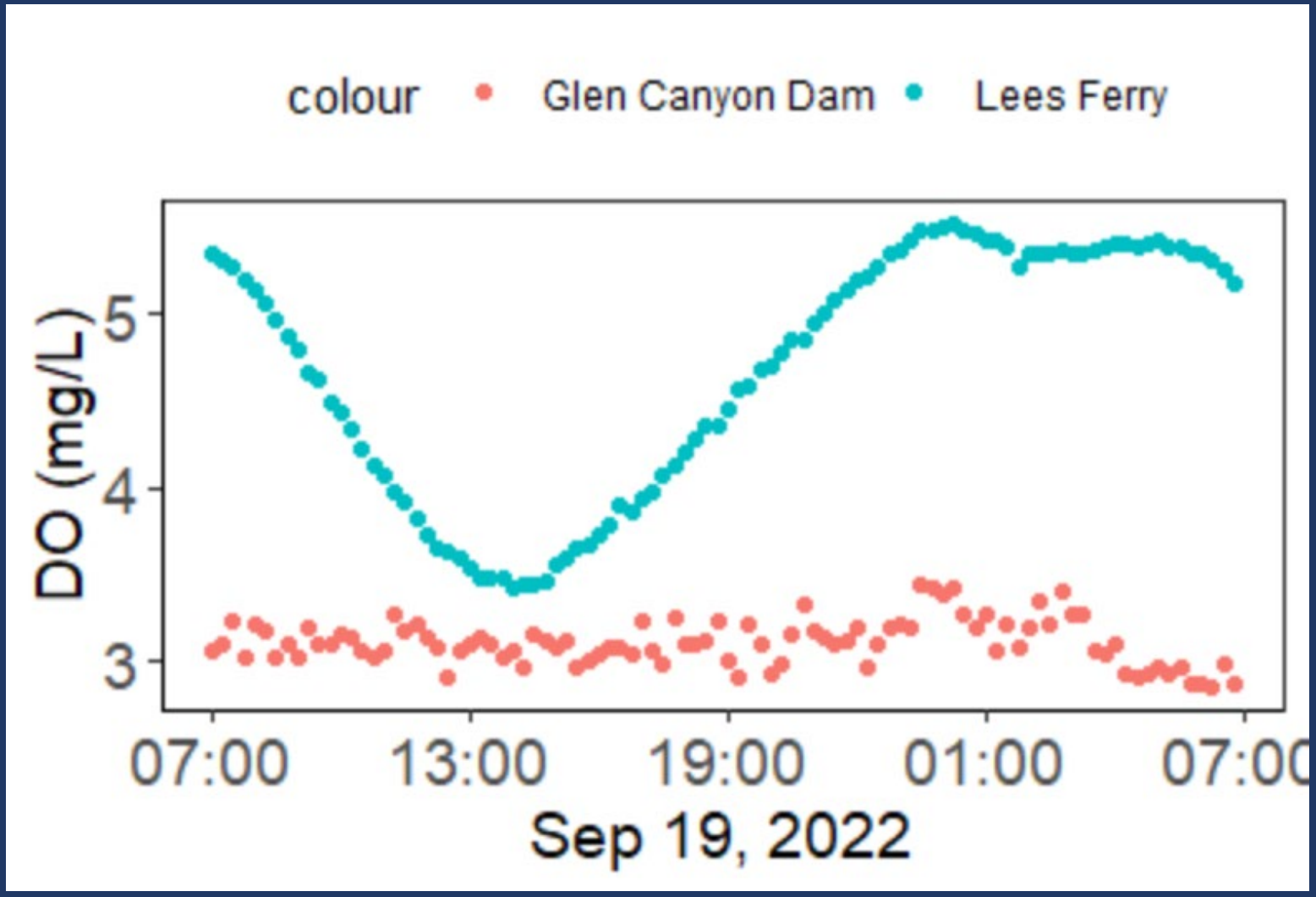
Low Dissolved Oxygen Will Have Largest Impact on Trout Near Dam

Daily average DO ~1 mg/L higher at Lees Ferry than at Dam

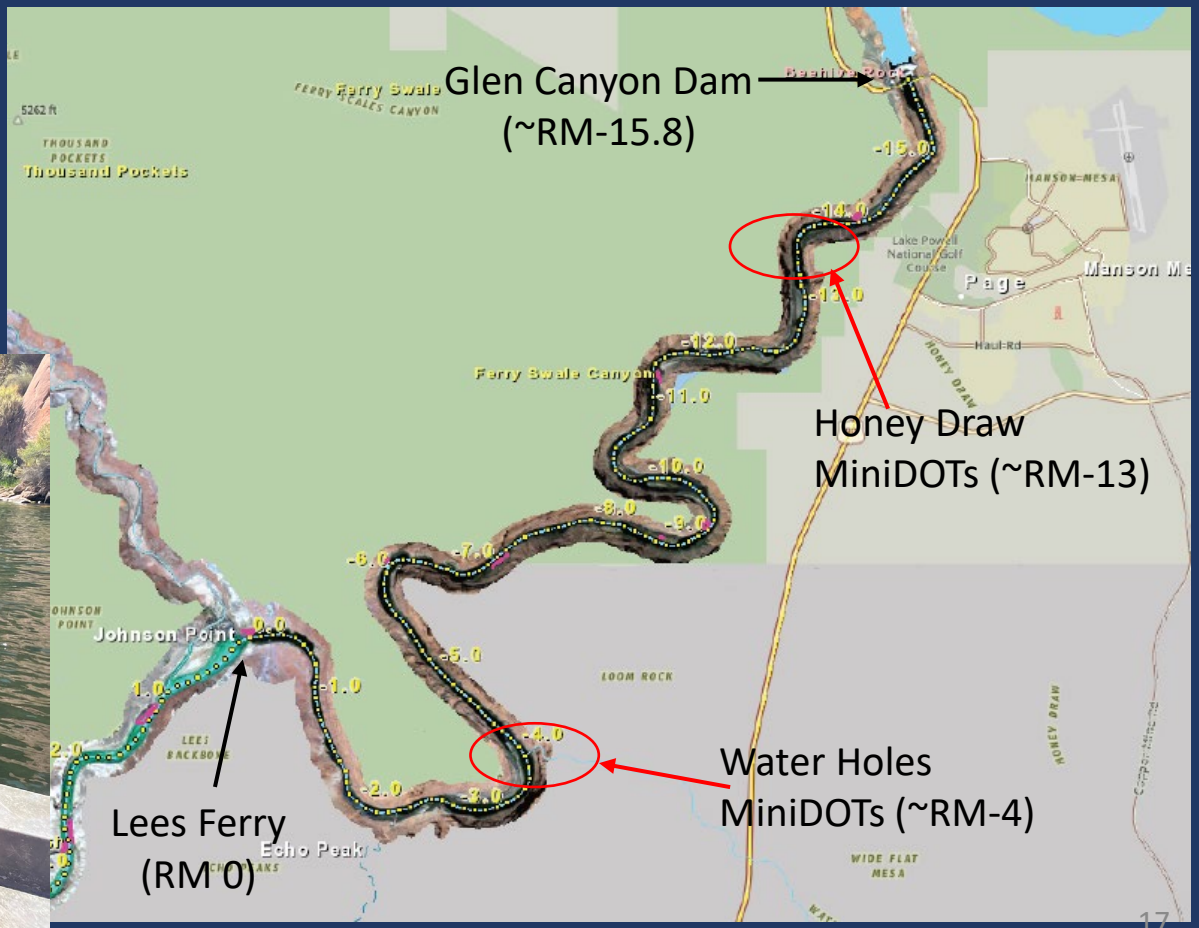
Oxygen fully mixed by rapids downstream



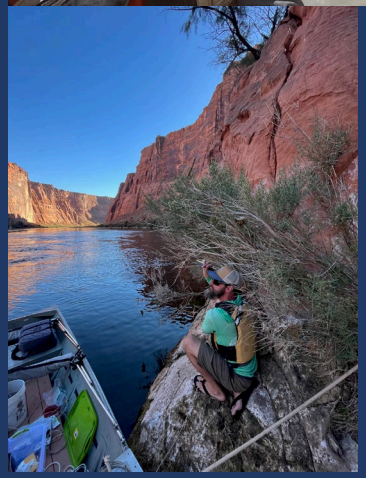
DO Departure Largest During Day



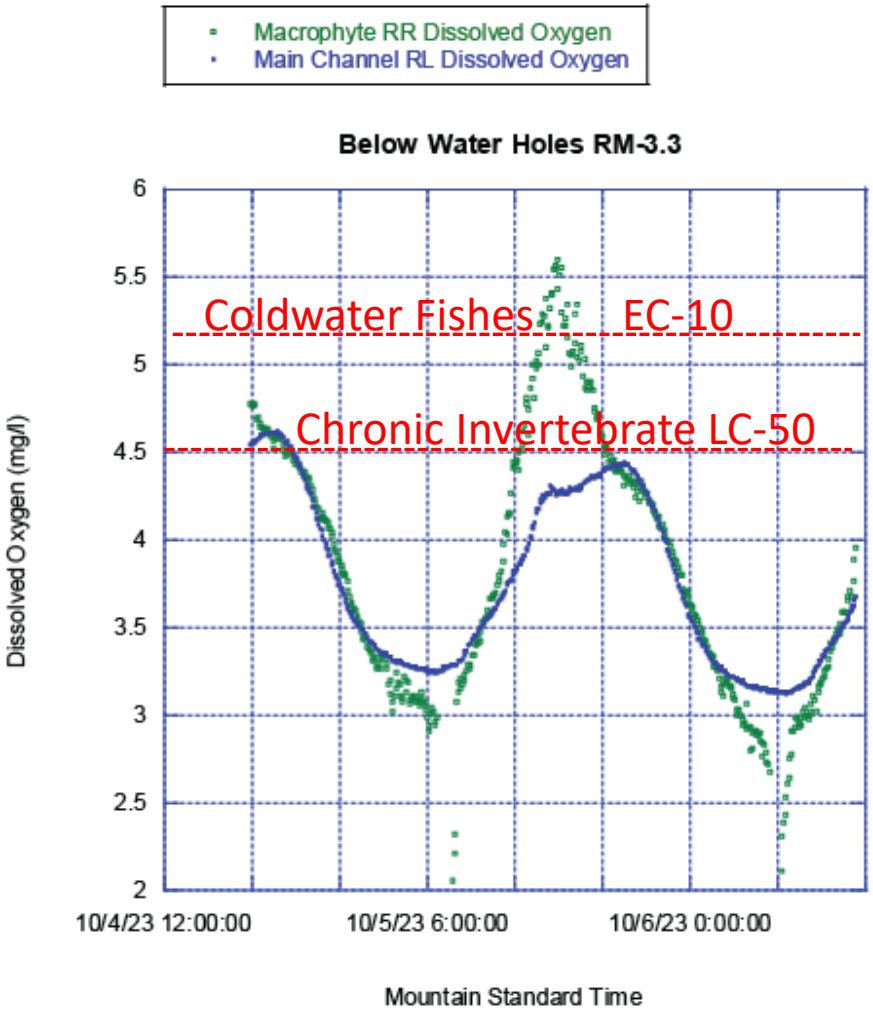
How spatially variable is DO?



Side Channel Habitats vs. Main Channel



>1 mg/L departures in DO between main channel and macrophyte beds



Acknowledgements

- Eric Frye
- Morgan Ford
- Bryce Mihalevich
- Josh Korman
- Sasha Reed
- Funding from the GCDAMP, the Bureau of Reclamation and the USGS Ecosystems Mission Area

Questions?

What does this mean for the Glen Canyon Tailwater?

Distributions	*n*	*Sp*	Median toxicity value
Lotic invertebrates	27	17	2.40
Lentic invertebrates	8	4	2.06
Lotic and lentic invertebrates	48	31	1.53
All acute invertebrates	83	52	1.99
Post-1986 invertebrates	8	6	0.93
Pre-1986 invertebrates	75	47	2.20
Chronic invertebrate LC_{50}	5	5	4.5
Warm water fish EC_{10}	5	4	5.00
Cold water fish EC_{10}	16	7	5.20
Warm water fish EC_{50}	5	4	1.38
Cold water fish EC_{50}	16	7	2.26
Warm and cold water fish LC_{50}	13	9	1.59
EPT taxa	62	38	2.66
None EPT taxa	21	14	0.96
All fish and invertebrate LC_{50}	96	61	1.82

Red box shows where we are already below published literature median toxicity values

LC50- concentration that is lethal to 50% of test population w/ 96 hr acute exposure

EC10- concentration that has a 10% effect on growth or reproductive effect w/ 96+ hours chronic exposure

Adapted from Saari et al. 2018