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science for a changing world

Science Update: Lake Powell, Riparian Vegetation, and Bug Flows

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US Geological Survey, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center

***-presenting**

Glen Canyon Dam Adaptive Management Work Group

February 15, 2023, Phoenix, AZ

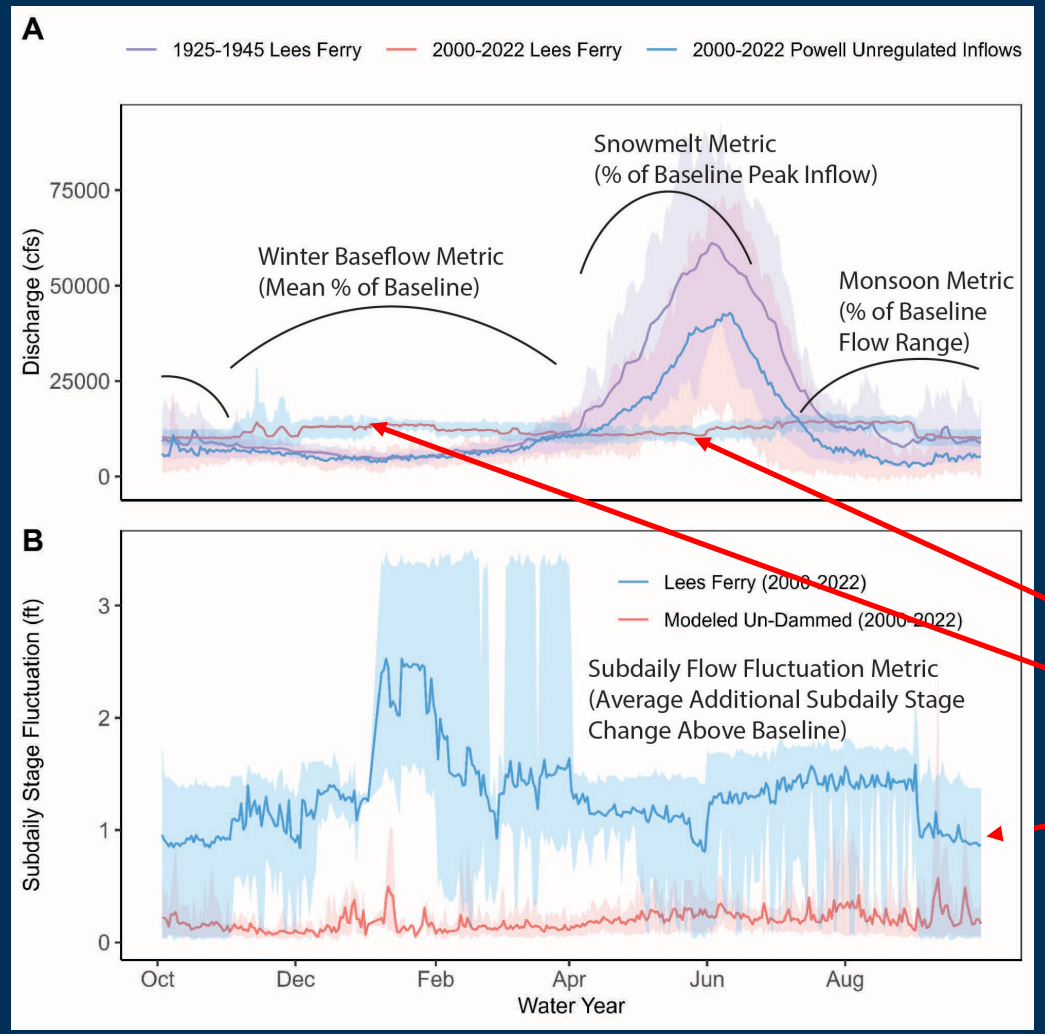
**This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government shall be held liablefor any damages resulting from the authorized or unauthorized use of the information.*

U.S. Department of the Interior
U.S. Geological Survey

Goal 2. Natural Processes

Restore, to the extent practicable, ecological patterns and processes within their range of natural variability, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems.

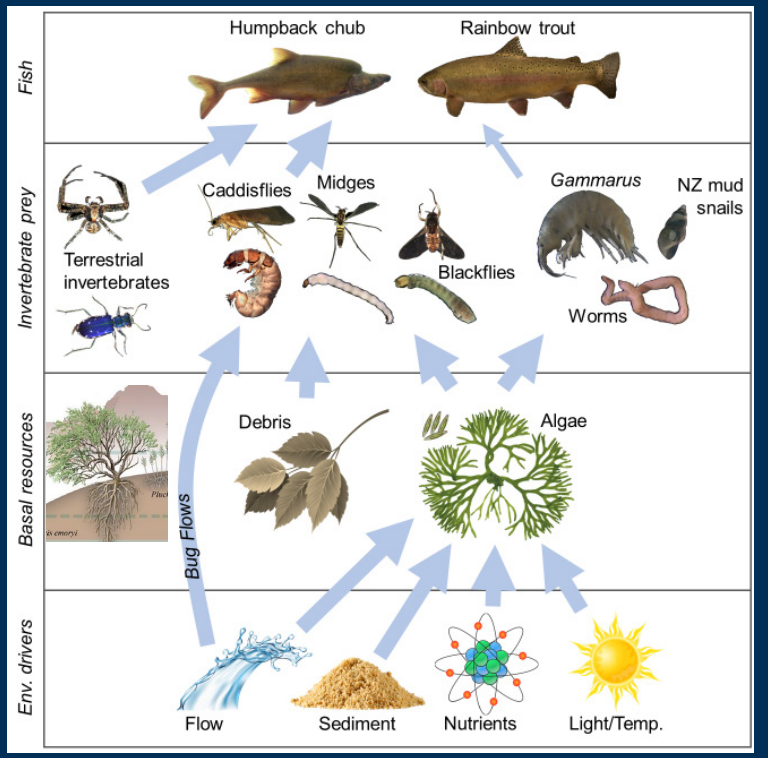
Flow regimes are a major driver of Natural Processes



Natural Processes?

Annual
Seasonal
Daily pattern
all different

Colorado River Food Webs



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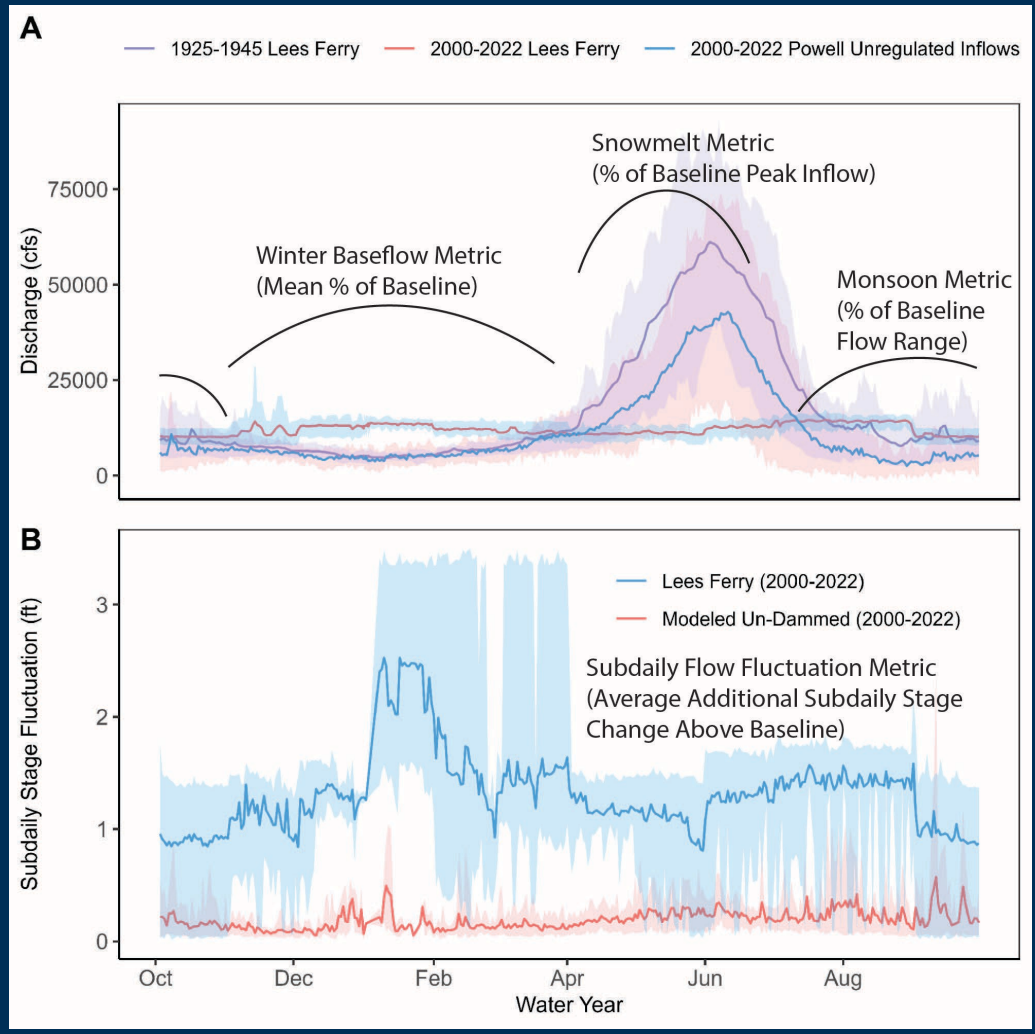
From Natural Processes-metrics draft, courtesy of Bridget Deemer & Emily Palmquist

Preliminary data, subject to change, do not cite

Outline

- **Lake Powell-mechanistic model (4 slides)**
- **Dissolved oxygen (4 slides)**
- **Riparian vegetation (4 slides)**
- **Bug Flows (4 slides)**



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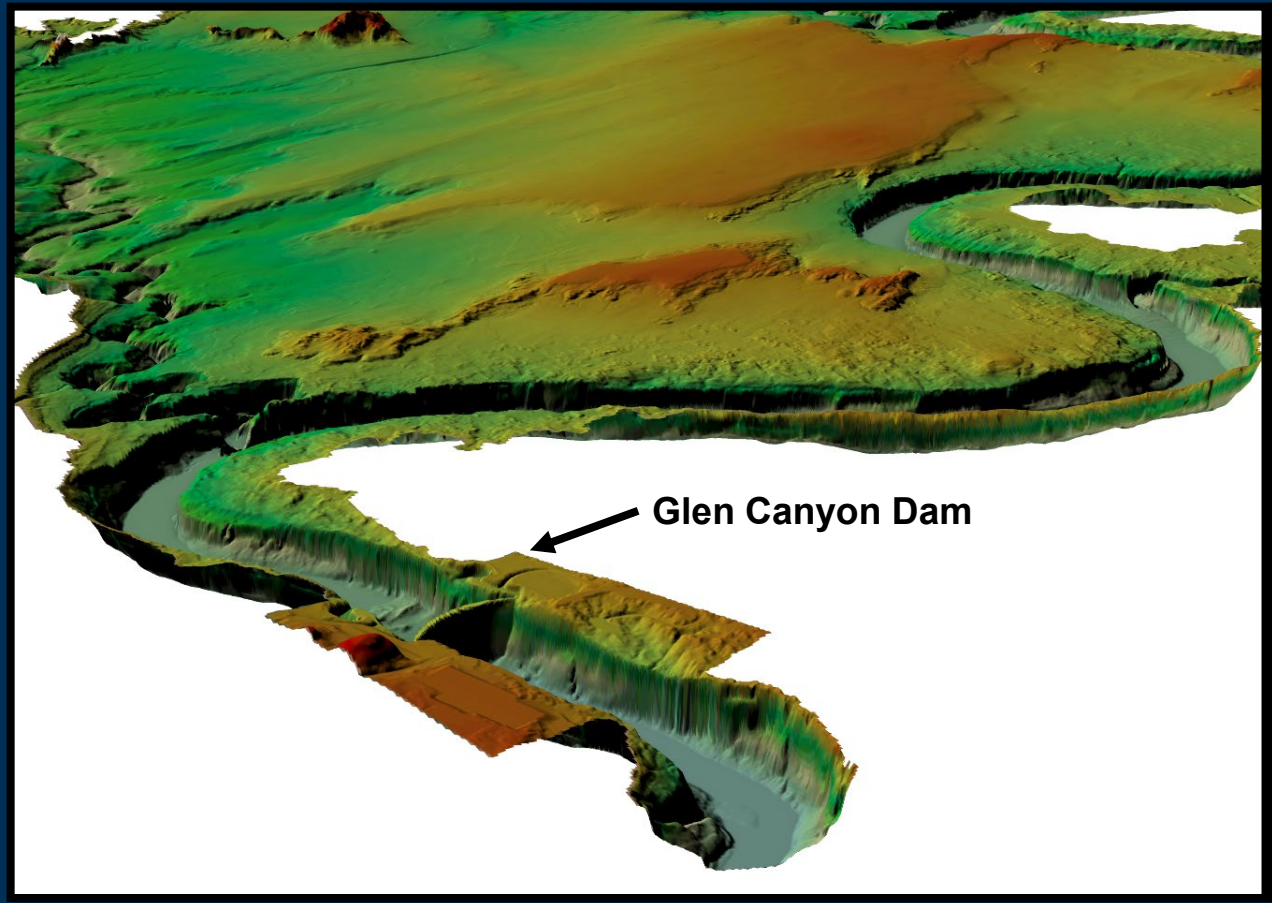
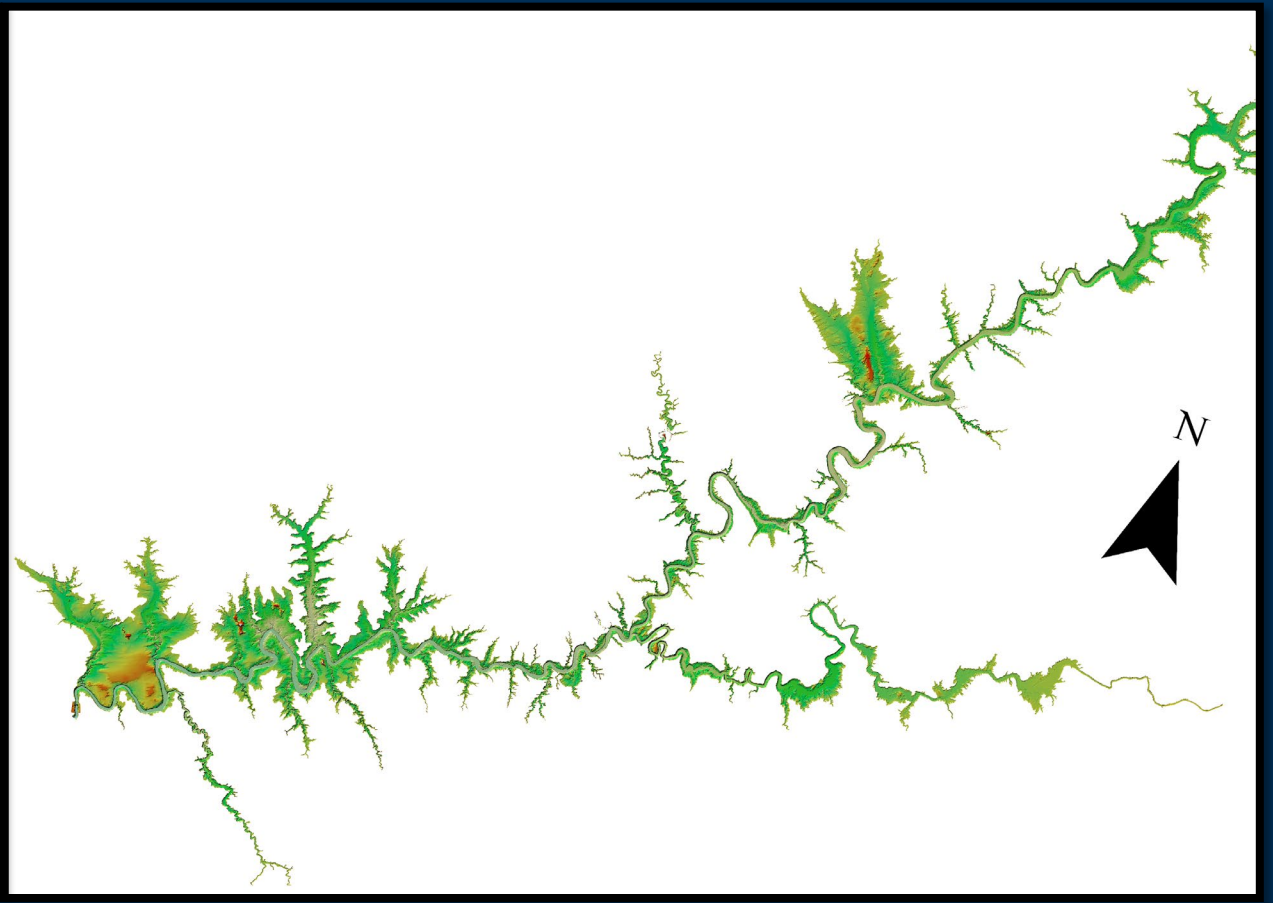
Model Updates

- 1. Incorporate new bathymetry data
  - Match the volume-elevation curve used by BOR's CRSS
  - Represents ~7% loss in storage from last bathymetry dataset





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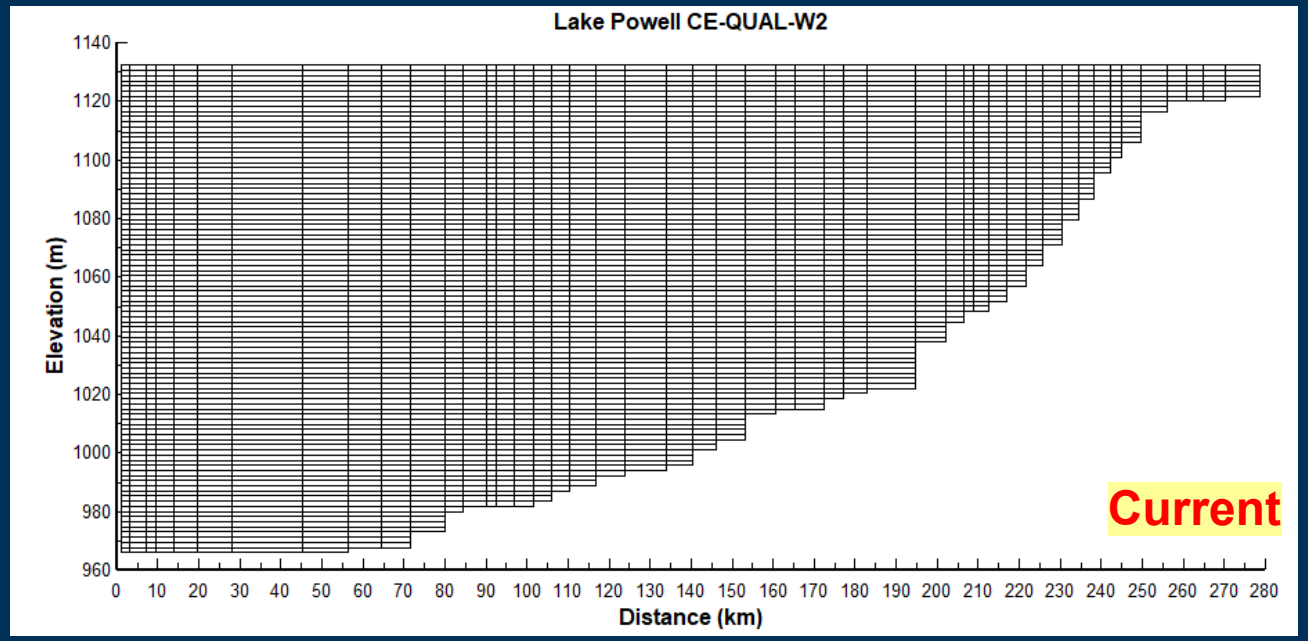
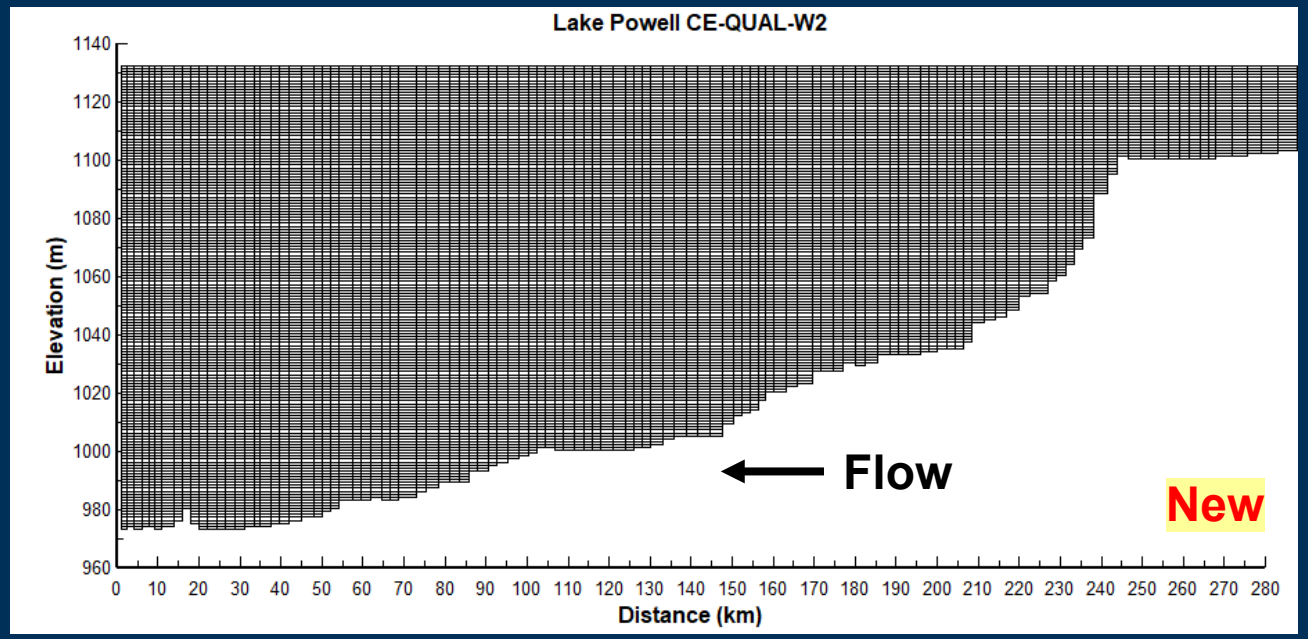
Jones and Root, 2021

Model Updates

- 2. Increased vertical and longitudinal resolutions (mainly in mainstem)
  - Improves numerical stability
  - Better represents physical features

	Current	New
Cell Depth (m)	1.75	1.00
Avg Cell Length (km)	~ 5.8	~ 2.5
Min Cell (km)	2	1.5
Max Cell Length (km)	17.4	4.75





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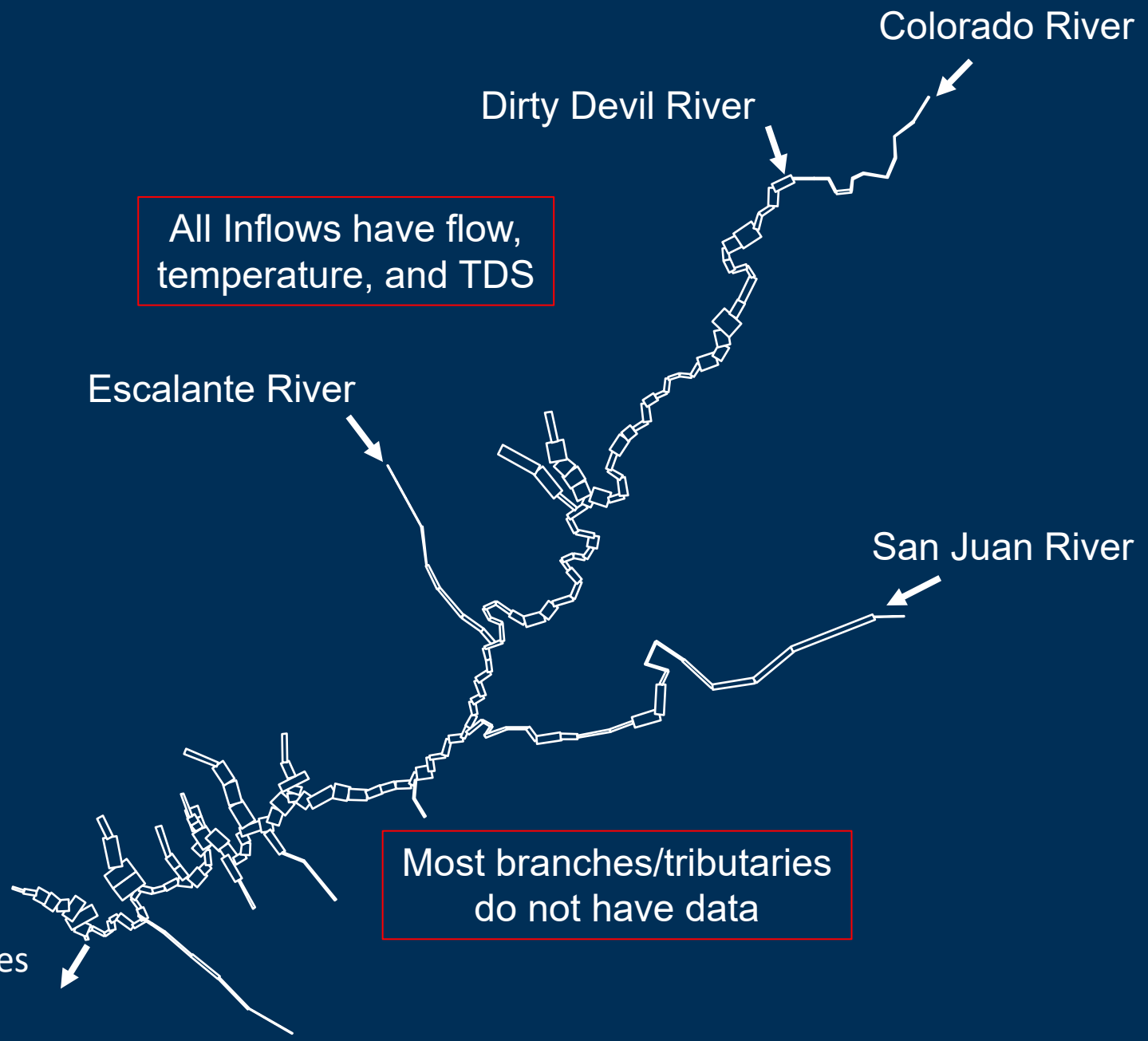
Model Inputs

- **Inflows**
  - **Discharge**
  - **Temperature**
  - **Constituents (TDS)**
- **Outflows**
  - **Penstock and Bypass Release**
- **Weather**
  - **Air Temperature**
  - **Dew Point Temperature**
  - **Solar Radiation**
  - **Wind Speed/Direction**
  - **Cloud Cover**



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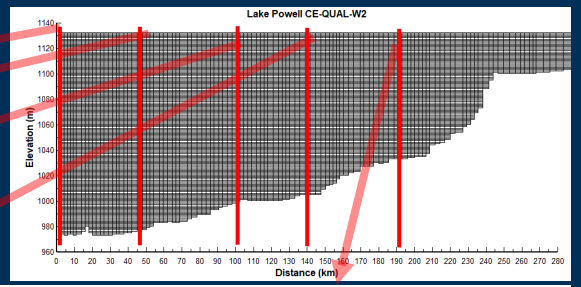
Preliminary Results Cont'd

Model started in 2010

5 different stations



LPCR0024 | LPCR0453 | LPCR1001 | LPCR1395 | LPCR1933

Depth [m]

Observed

Model

Temperature

Conductance

Improved LP model more accurately predicts temperature and conductivity

Wahweap | Gooseneck Point | San Juan River | Iceberg Canyon | Knowles Canyon

September 19-21, 2022

Temperature [°C]

Conductance [µS/cm]

Observed | Model | Penstock | Bypass

Forebay ⟷ Inflow Area

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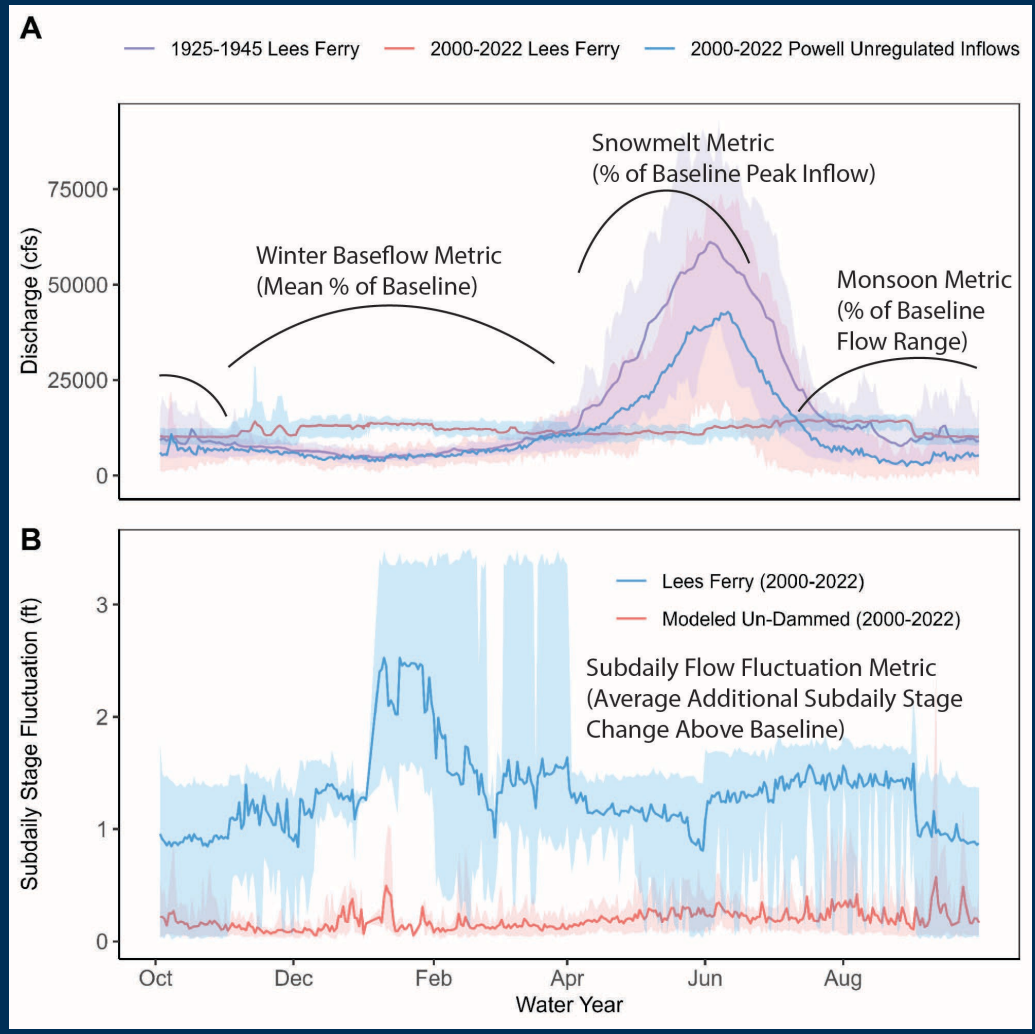

From Natural Processes-metrics draft, courtesy of Bridget Deemer & Emily Palmquist

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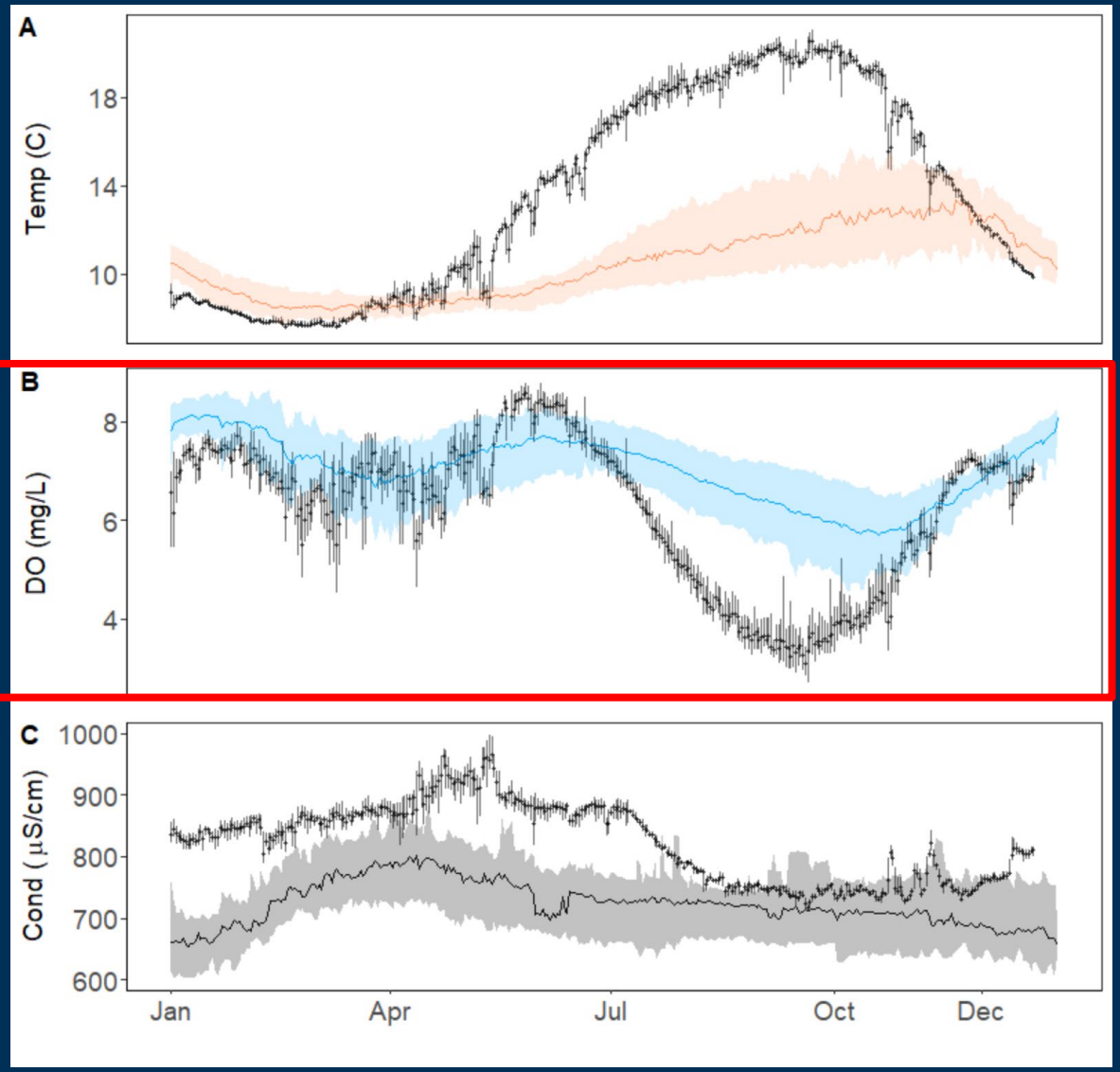
Low Reservoir Water Levels= New Era of Water Quality

Maximum temp of ~21 C in Sep 2022
Warmest in over 50 years

Physiology Note:
DO <5mg/L is chronic stressor for trout, and <3mg/L is acute stressor

Minimum dissolved oxygen (DO) of 2.5 mg/L in Sep 2022

Higher than average winter and spring conductivity– indicative of lake turnover



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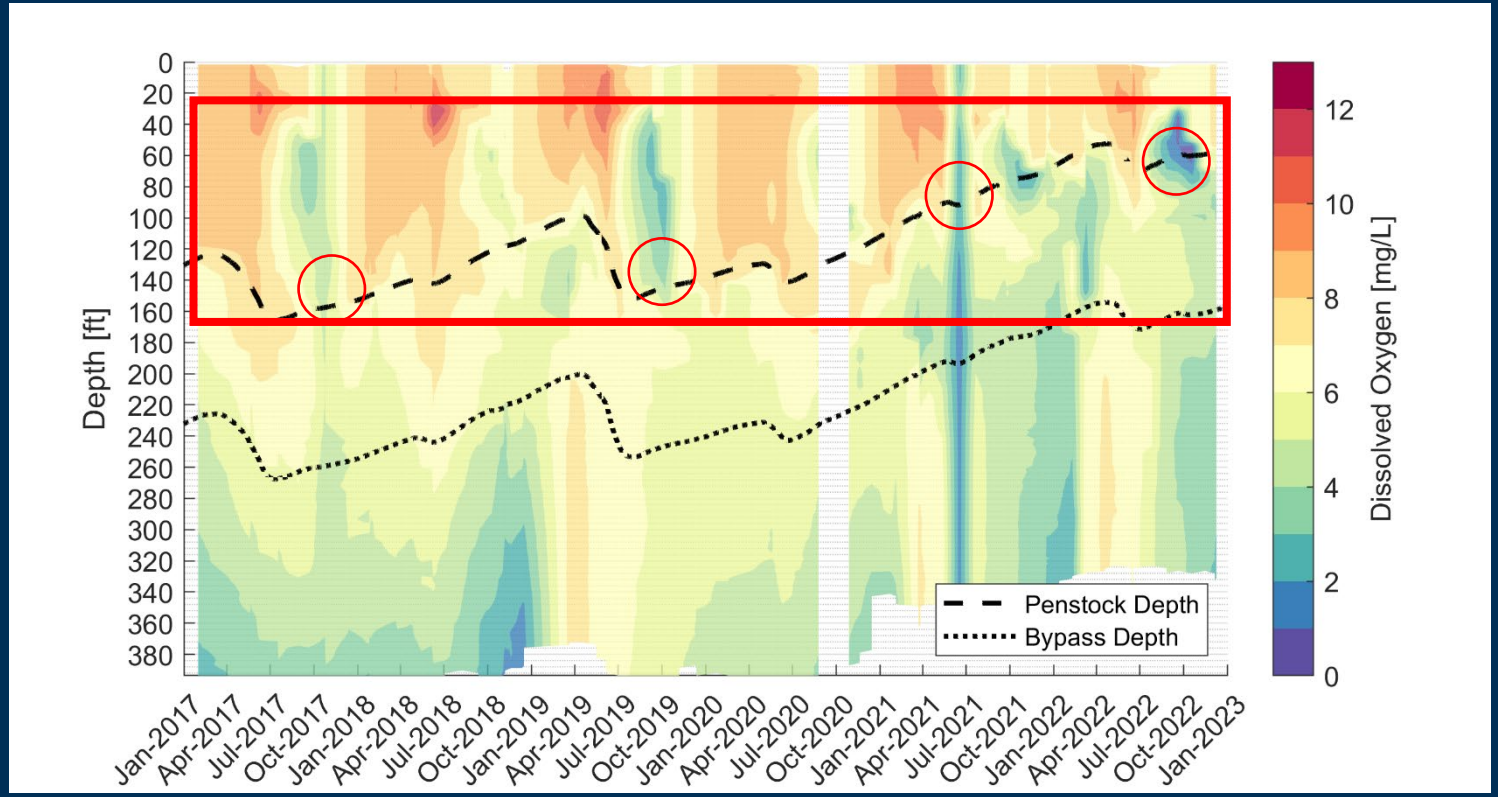
Metalimnion Low Dissolved Oxygen Events



Plot courtesy of Bryce Mihalevich

Quantified the mean DO concentration In metalimnion (between 23 and 164 feet deep)

Focused on the summer and fall (July-October)

Did not use 2020 given limited data

Periods of low DO at penstocks

Recent Elevation vs. DO Relationship

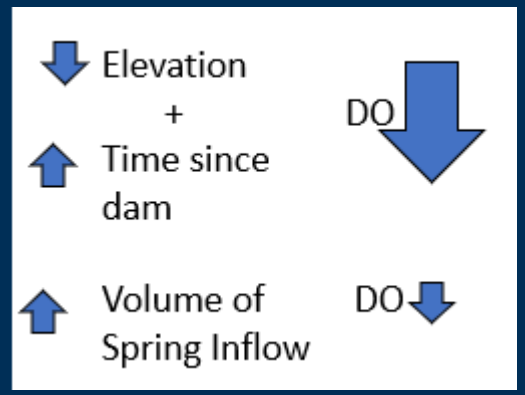
General linear model of 50 years of dissolved oxygen data:

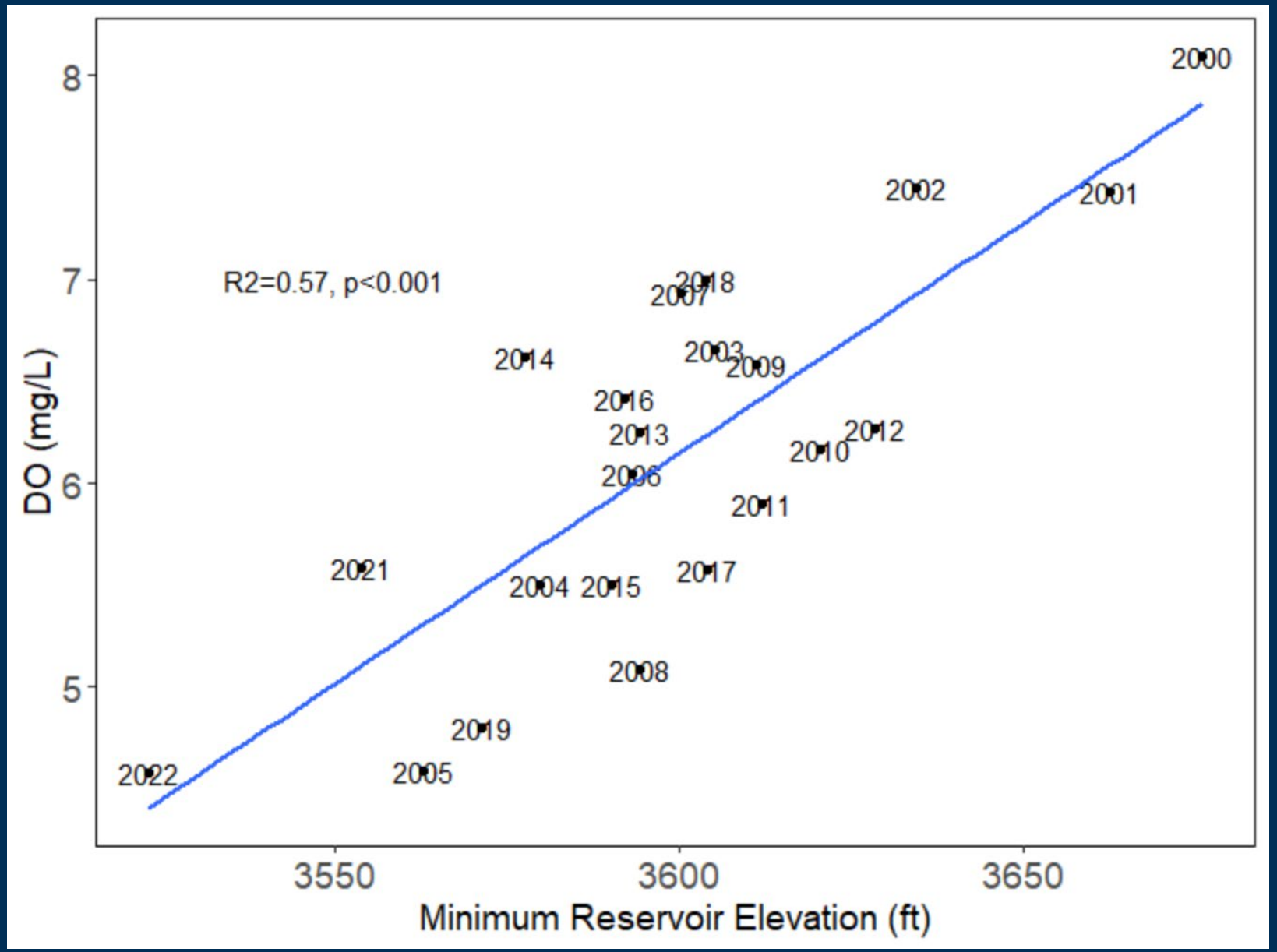
<u>Best model</u>

DO ~ Spring Inflow + Years Since Filling + Elevation * Years Since Filling.

Largest effect:

Elevation*Years Since Filling





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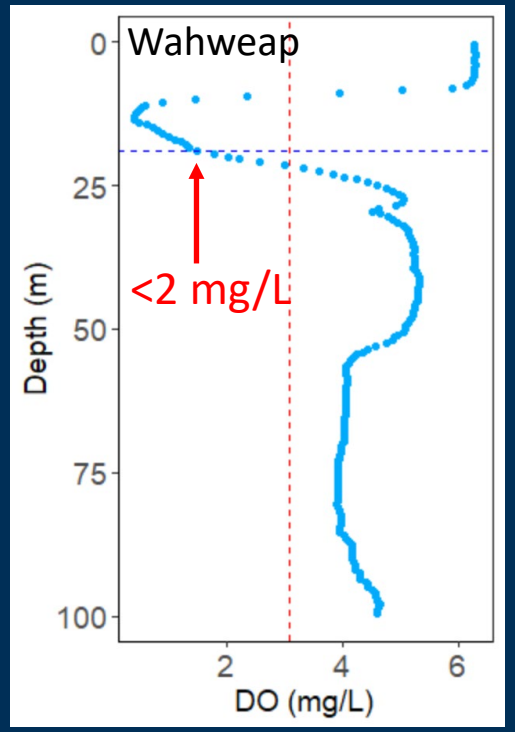
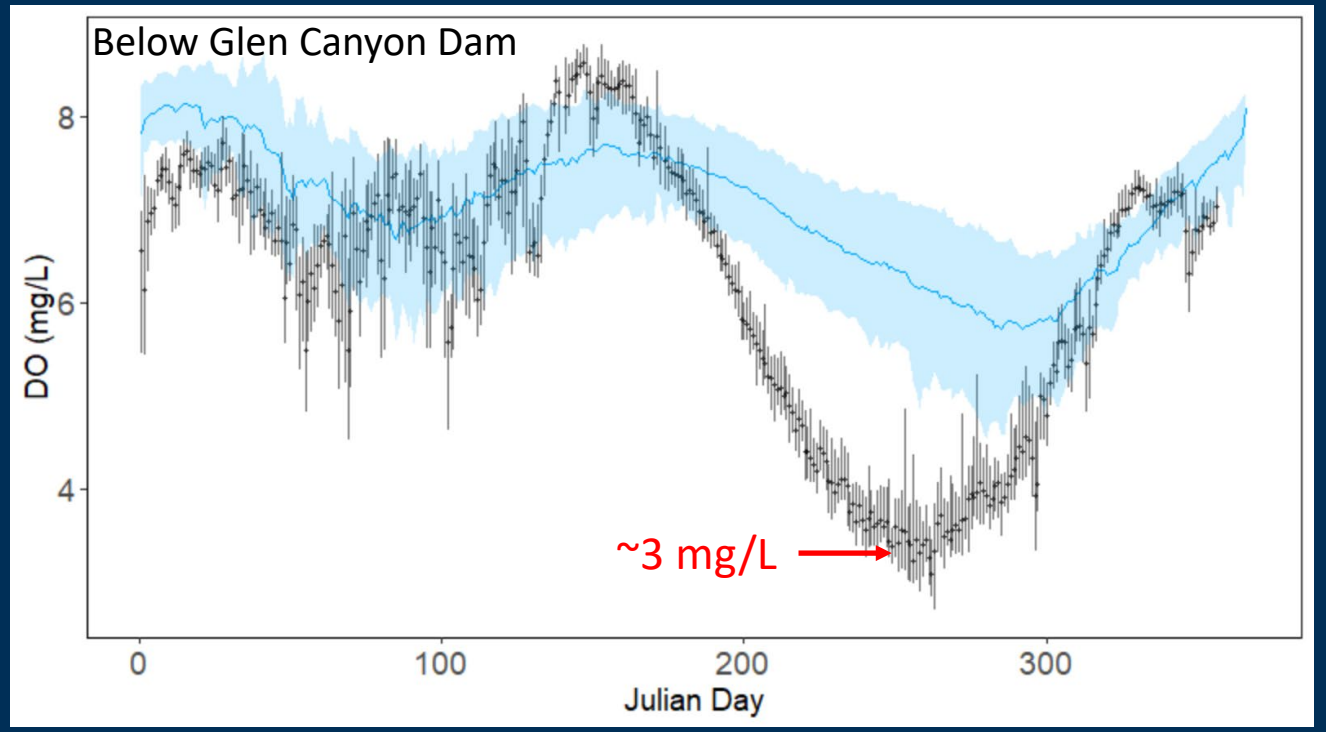
What does this mean for the Glen Canyon Tailwater?

- ~1 mg/L increase in DO between forebay and tailrace
- Dam is in "rough zone" at low elevations
  - "rough zone" operations add oxygen to release waters, somewhat mitigating low DO

Conclusion is corroborated by observations of bubbles in draft tubes





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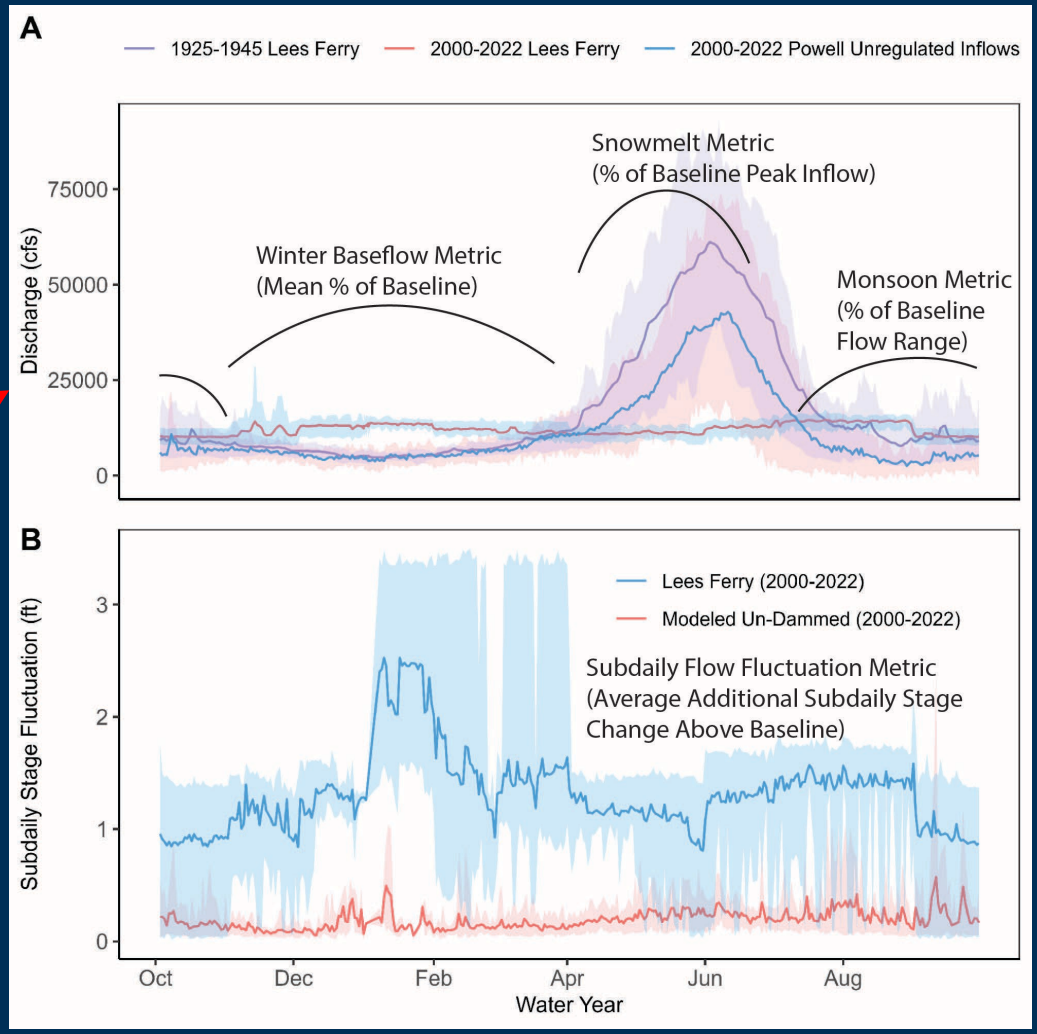

From Natural Processes-metrics draft, courtesy of Bridget Deemer & Emily Palmquist

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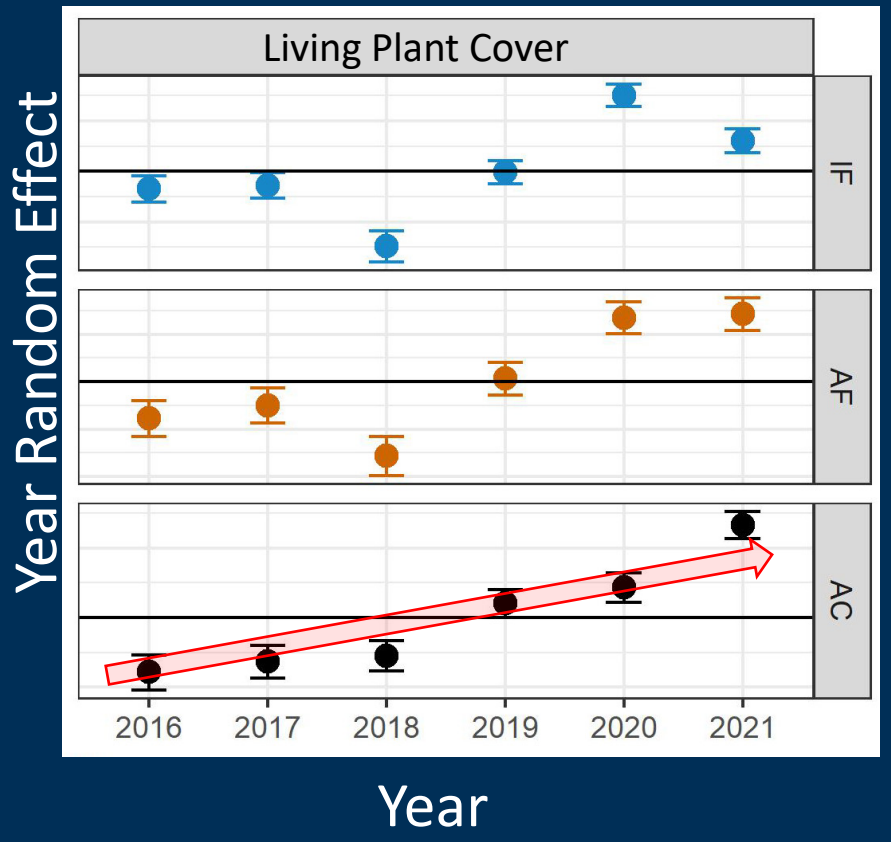
We're Good at Tracking Current Vegetation

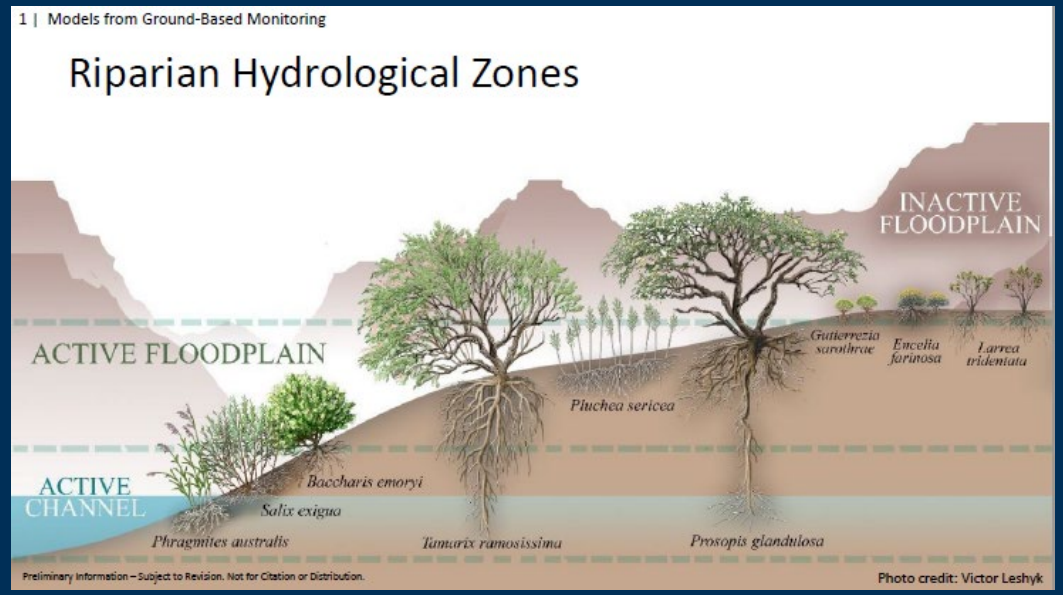
- **Annual monitoring program supports LTEMP proposed metrics**

Inactive floodplain (elevations >45kcfs)

Active floodplain (elevations >25kcfs & <45kcfs)

Active channel (elevations >8kcfs & <25kcfs)



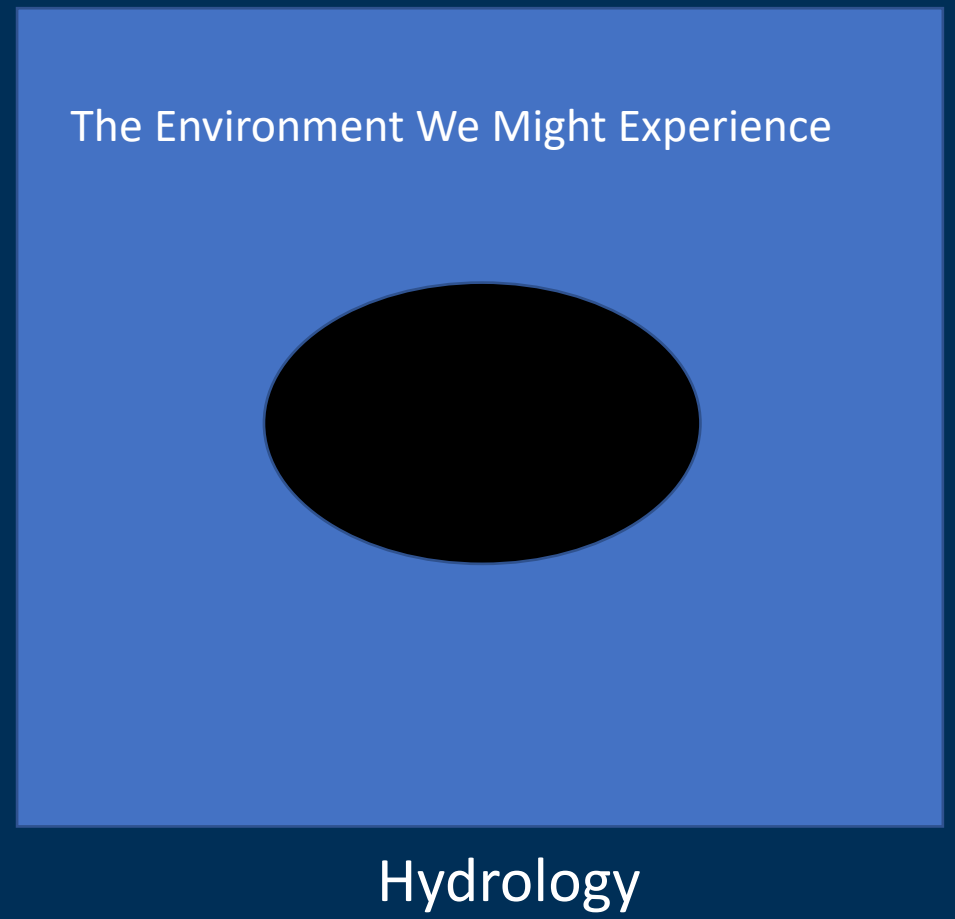


We're Good at Predicting Vegetation Under Current Conditions

Strong effects of:

- Elevation above river stage
- Minimum temperature

But predicting how departures from current conditions (i.e., aridification) requires extrapolation



Vegetation Modeling: Challenges and Solutions

	Challenge	Solution
Current Work	▪ Altered hydrograph	▪ Use data from other river systems with similar species, but different hydrographs
	▪ Correlation ≠ causation	▪ Conduct experiments that control for multiple correlated factors
Future work	▪ Vegetation interacts with other resources (e.g. sand)	▪ Develop dynamic, integrative models across systems

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Breaking the Correlation between Drought and Inundation with Controlled Experiments

Received: 1 July 2022 | Accepted: 23 November 2022

DOI: 10.1002/ajb2.16115

Botany

RESEARCH ARTICLE

Provenance, genotype, and flooding influence growth and resource acquisition characteristics in a clonal, riparian shrub

Emily C. Palmquist[1,2] | Kiona Ogle[3] | Thomas G. Whitham[2,4] | Gerard J. Allan[2,4] | Patrick B. Shafroth[5] | Bradley J. Butterfield[2]

-Arrow weed thrives with inundation, drying, you name it
-Quantifying environment effects on shrubs separately from trees improves models.
Upshot: experiments identify mechanisms underlying prolific arrow weed growth, inform predictions of future conditions (aridification)

Photo credit: Grand Canyon Monitoring and Research Center

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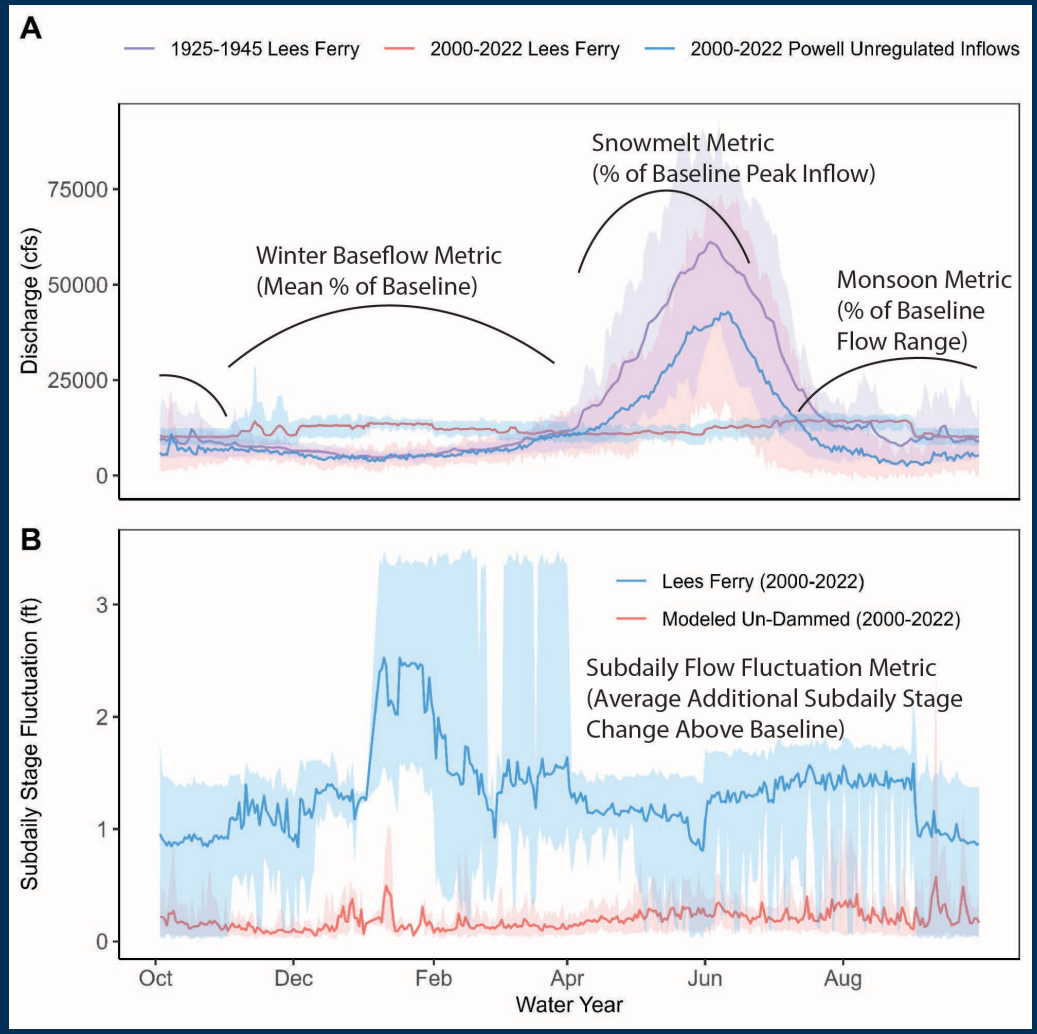

From Natural Processes-metrics draft, courtesy of Bridget Deemer & Emily Palmquist

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Why Bug Flows?

- Daily hydropower flows create “tides”
- Insects lay eggs at water line
- When tide drops, eggs dry, die

Bug Flows tested
2018-2020 & 2022
Weekends, May-Aug.

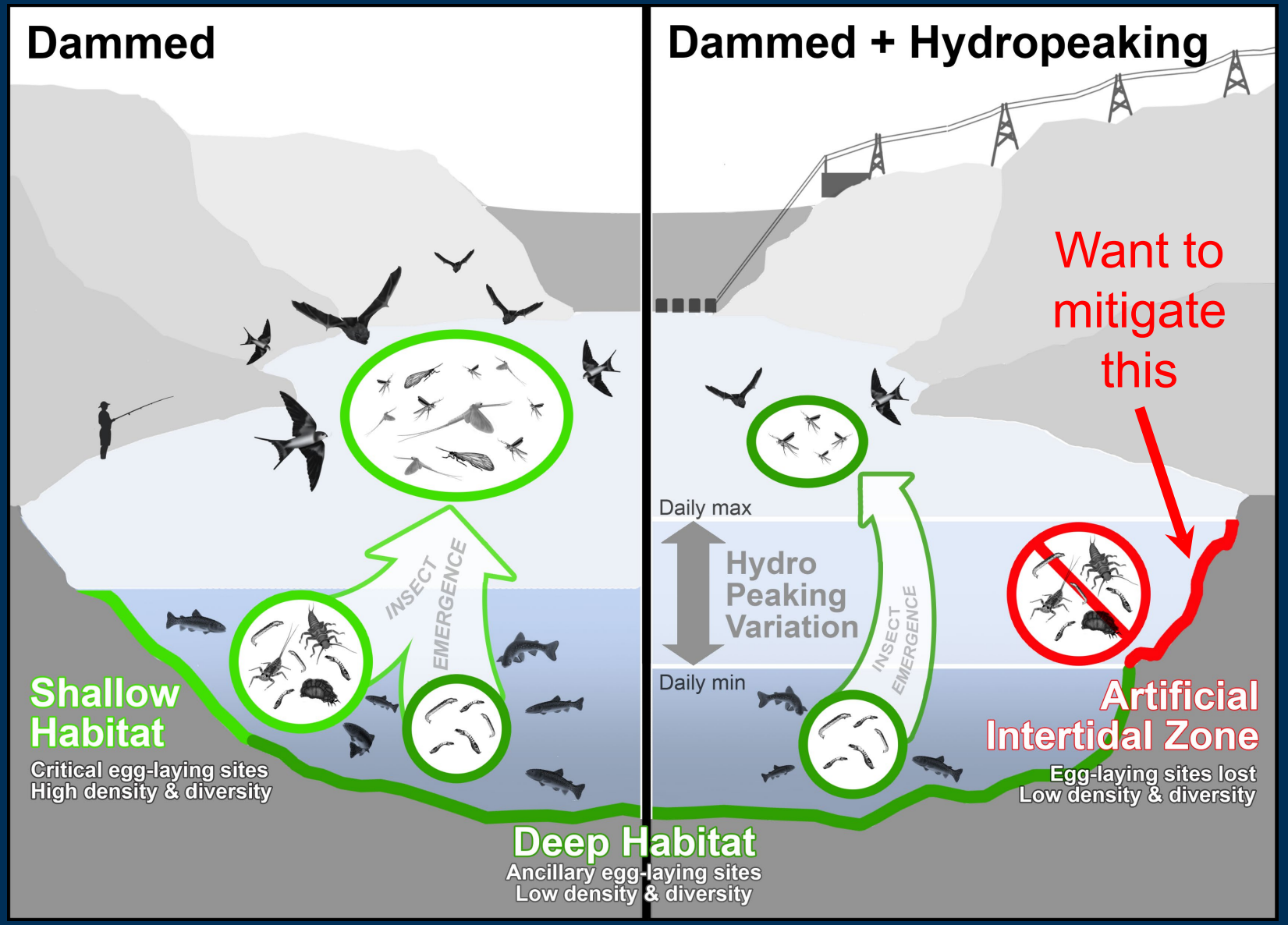

Illustration by Jeremy Monroe Freshwaters Illustrated, from Kennedy and others 2016, Bioscience

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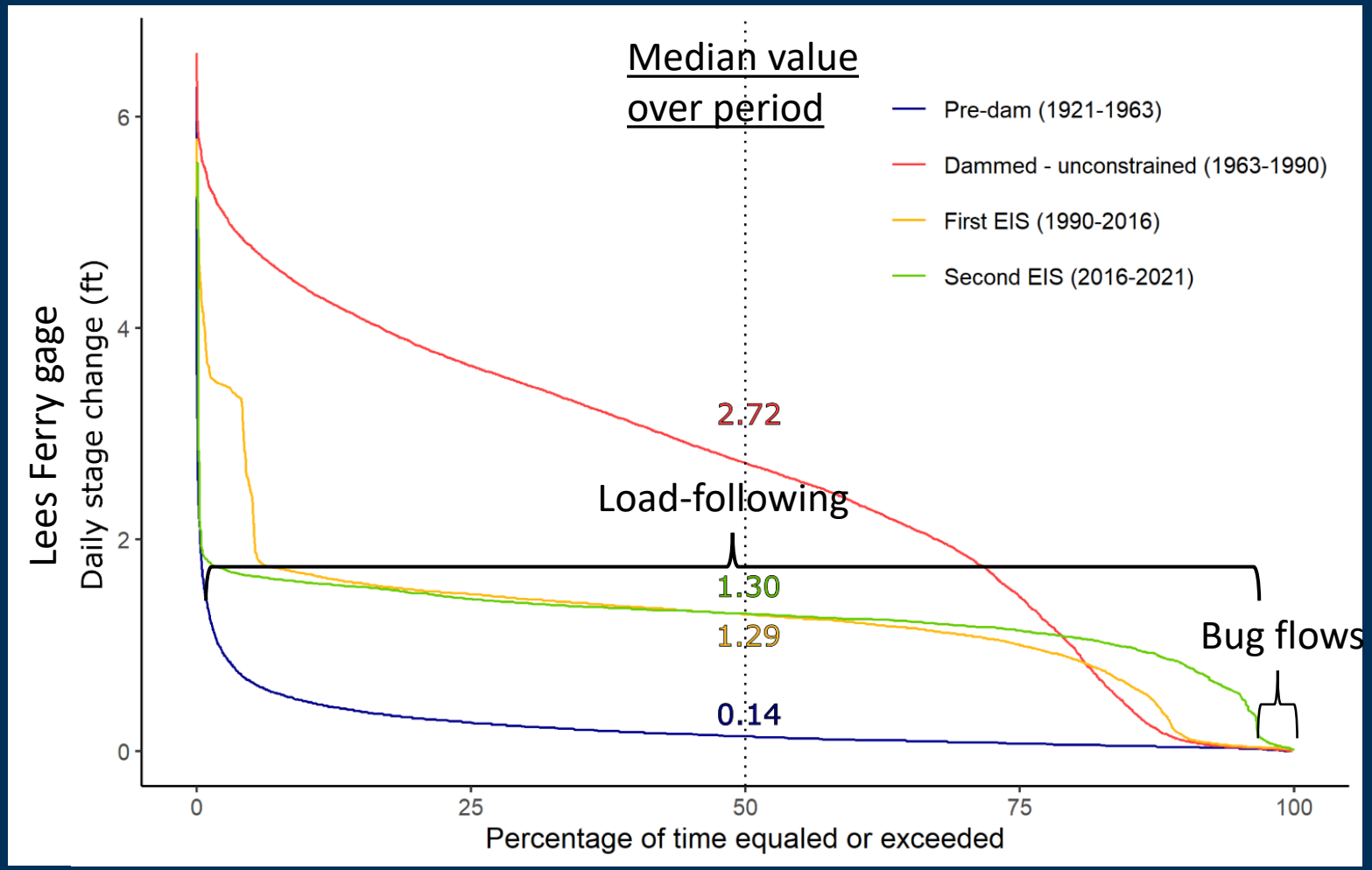
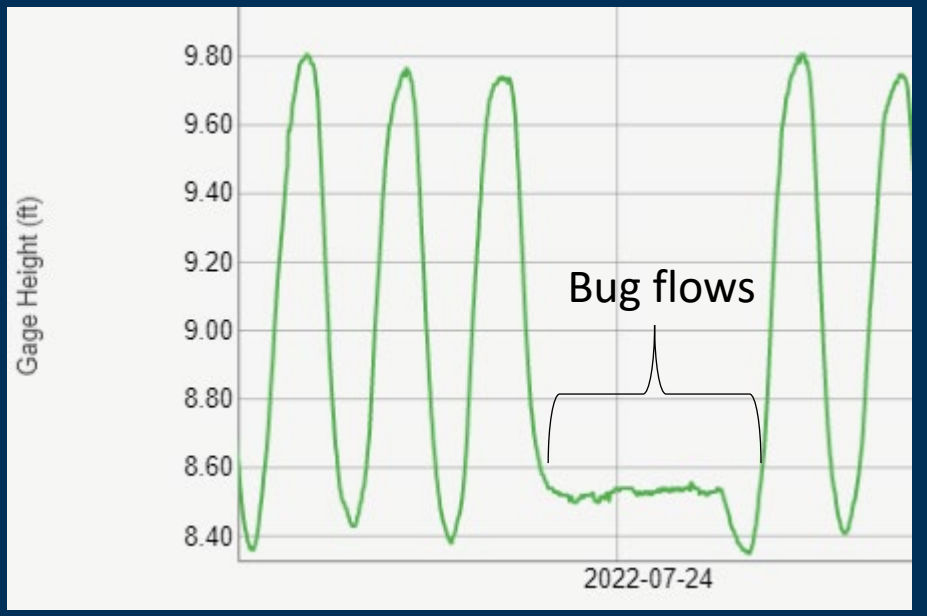
Why Bug Flows?

Daily Tides



Lees Ferry-discharge



https://www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09380000

Why?

Stabilize near-shore habitats that are critical to insect egg laying.

Eggs laid on weekends will never dry

From Natural Processes-metrics draft, courtesy Anya Metcalfe

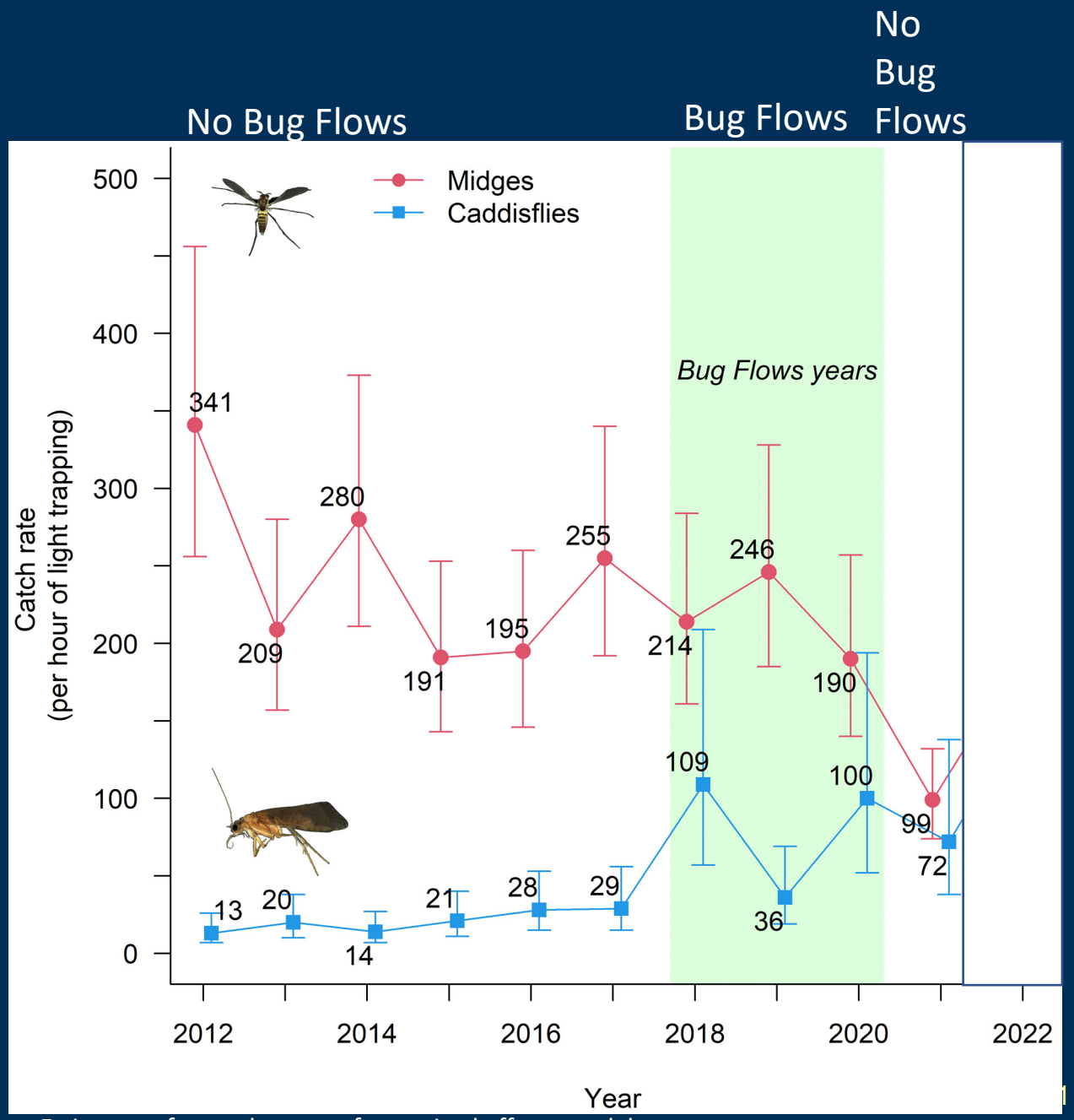
Preliminary data, subject to change, do not cite

Insect response

- 2018-2020 Bug Flows
  - 400% increase in caddisflies
- 2021 paused
  - ~50% decline in midges

Consistent with hypothesis that Bug Flows enhancing insects

Community scientists collecting a light trap sample



Estimates of annual average from mixed effects model

Preliminary data, subject to change

Insect response

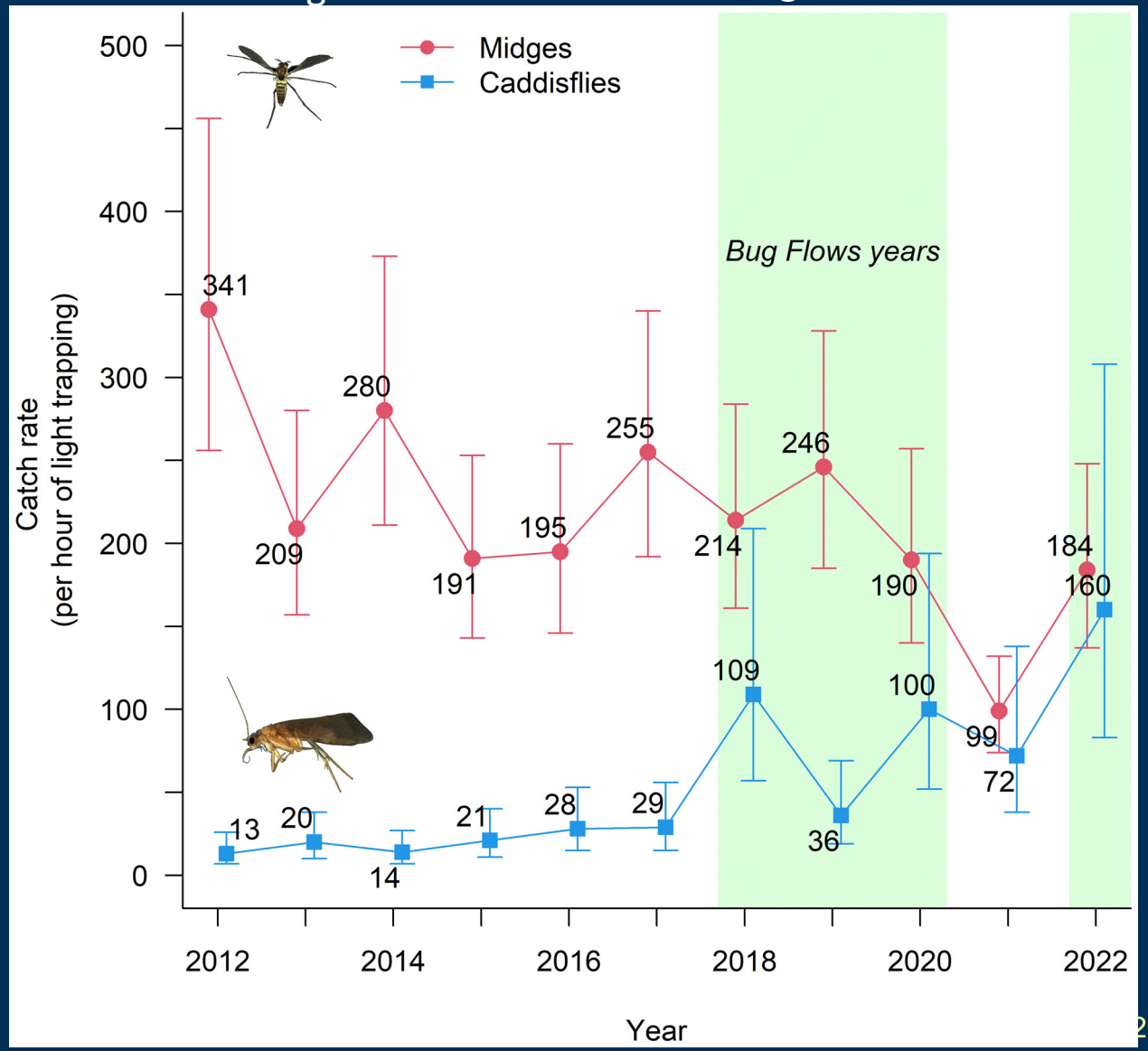
- 2022 Bug Flows
  - 80% increase in midges*
  - 120% increase in caddisflies*

Consistent with hypothesis that Bug Flows supporting aquatic insect populations

Note that 2021 & 2022 had similar environmental conditions

Kennedy's professional opinion: SMB represent far greater threat to native fish conservation than low diversity/production of prey base.
SMB Flows take precedence over Bug Flows.

*330 samples (50% of total) processed, final numbers will change somewhat



Estimates of annual average from mixed effects model

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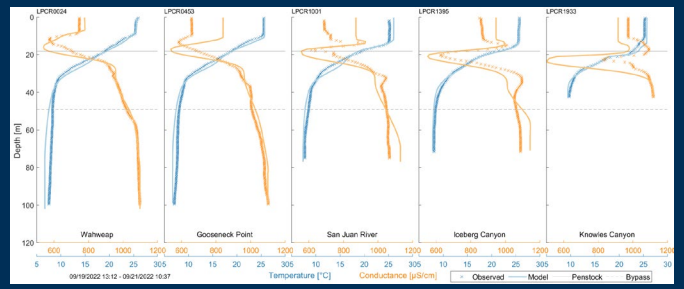
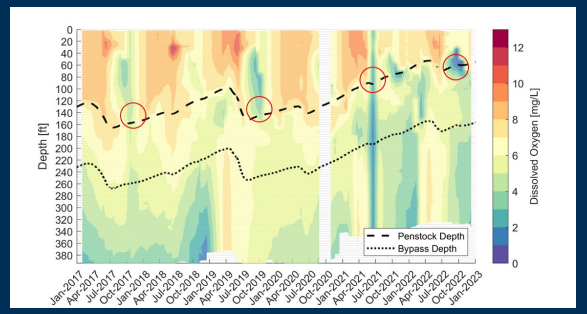
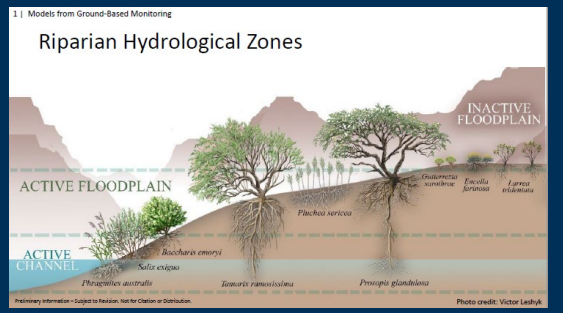
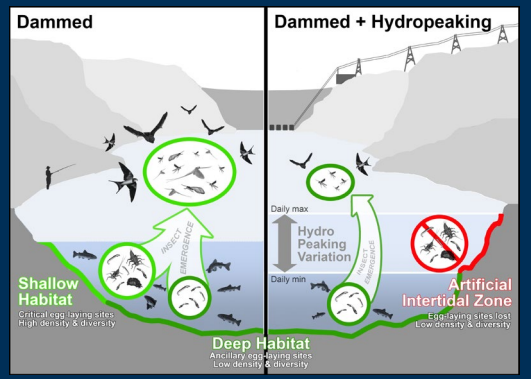
Conclusions

- Improvements to Lake Powell model greatly improve accuracy of predictions
- Low (stressful) dissolved oxygen more likely with:
  - low reservoir elevations, high inflows, older reservoir
- Riparian models predict current vegetation
  - Experiments, other advancements help predict future conditions
- Bug Flows useful tool for improving natural processes and health of aquatic insect assemblages









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