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Update on the Bug Flow Experiment: Background, Monitoring, and New Analyses

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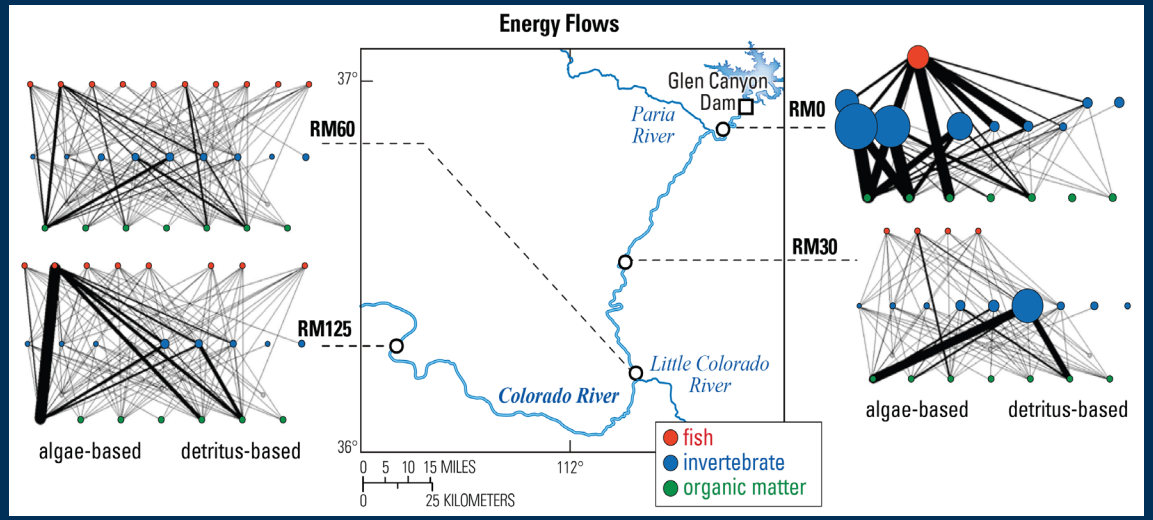
U.S. Department of the Interior
U.S. Geological Survey

Why Bug Flows?

- Not enough insect prey for fish
- Low diversity, inherently unstable
- Food webs built on algae

"The post-dam aquatic macroinvertebrate fauna in the Grand Canyon portion of the Colorado River is remarkably depauperate compared with other rivers. Virtually no Ephemeroptera [mayflies], Plecoptera [stoneflies] or Trichoptera [caddisflies] were collected..."

Excerpt from:
Stevens, Lawrence E., Joseph P. Shannon, and Dean W. Blinn. "Colorado River benthic ecology in Grand Canyon, Arizona, USA: dam, tributary and geomorphological influences." Regulated Rivers: Research & Management v.13, no. 2 (1997): 129-149.



Simplified food webs of the Colorado River circa 2006-2009.

Figure from:
Kennedy, Theodore A. and others. "Native and non-native fish populations of the Colorado River are food limited—evidence from new food web studies. USGS Fact-Sheet 2013-3039

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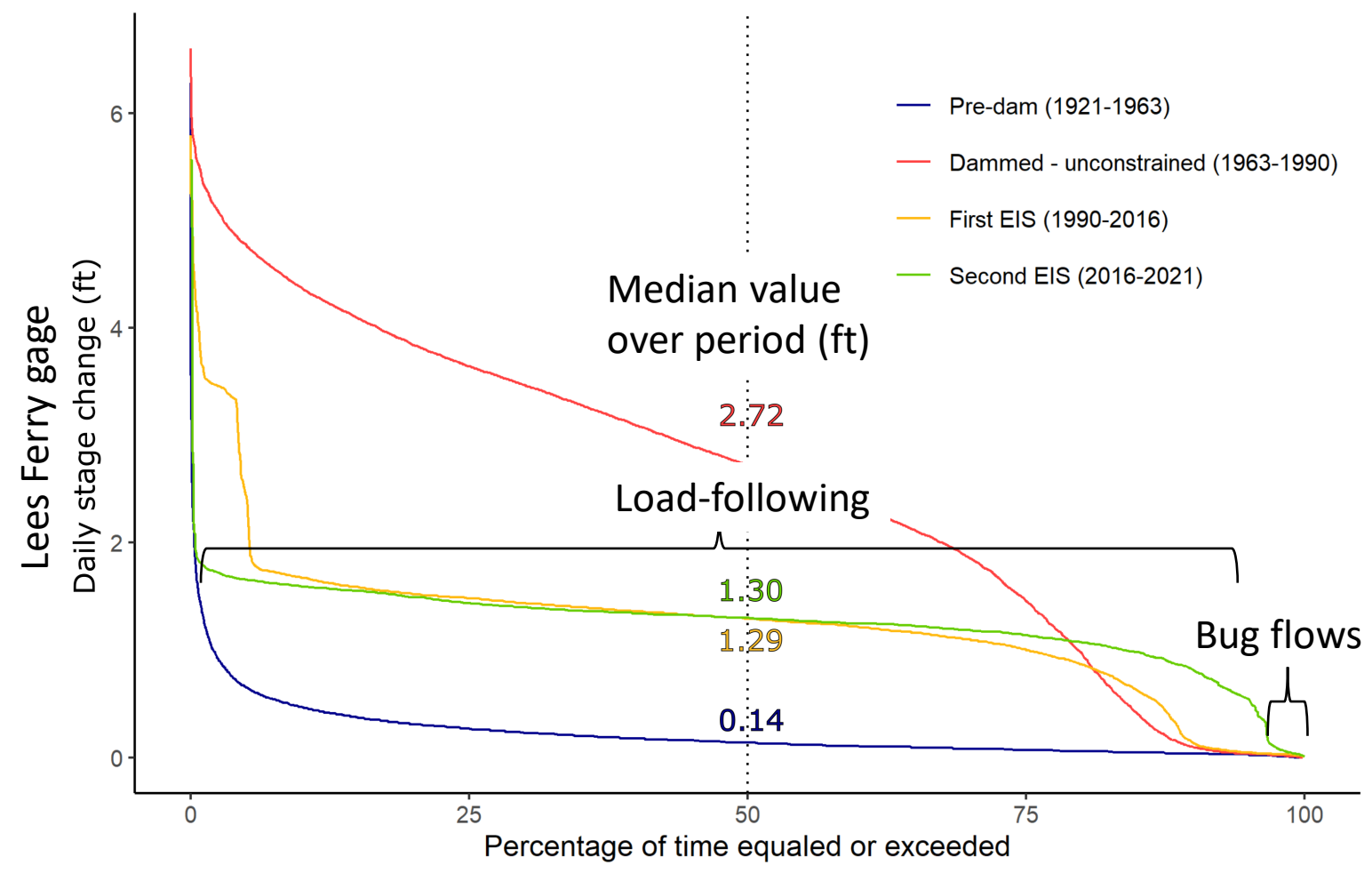
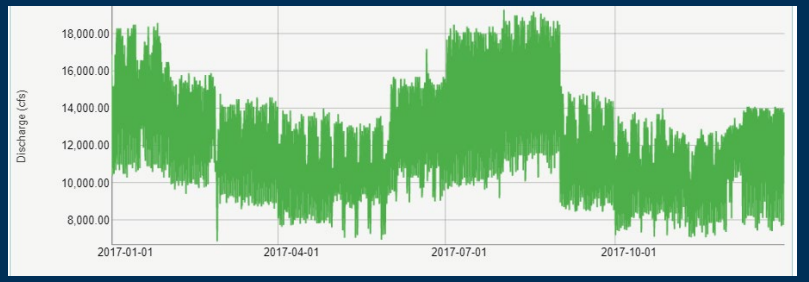
Why Bug Flows?

Daily Tides



https://www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09402500#

Regulated Flows



Since start of LTEMP, median daily change in river height at Lees Ferry is 1.30 ft (15.6 inches)

Natural Flows

In pre-dam river, median daily change in river height at Lees Ferry gage was 0.14 ft (1.7 inches)

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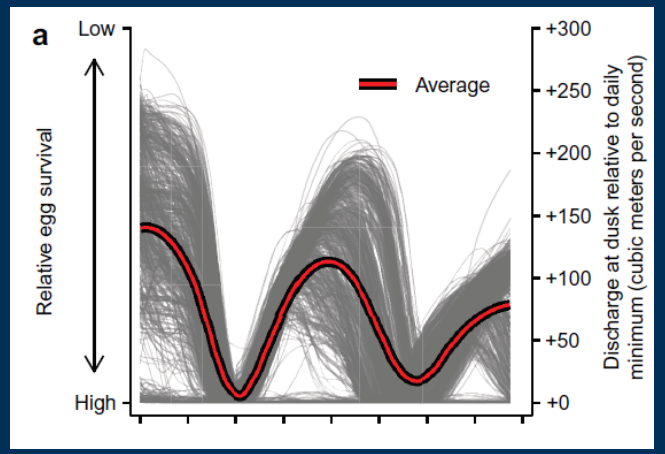
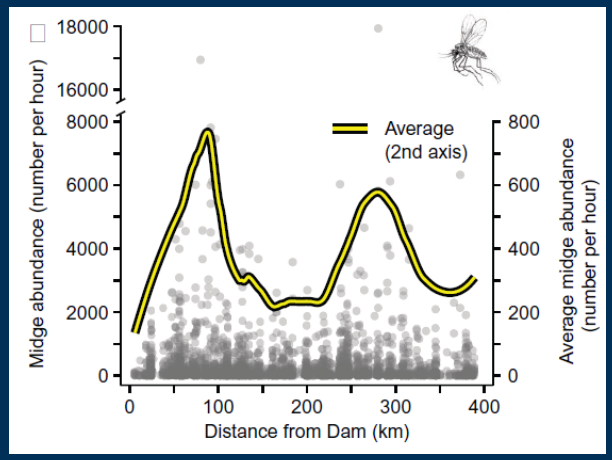
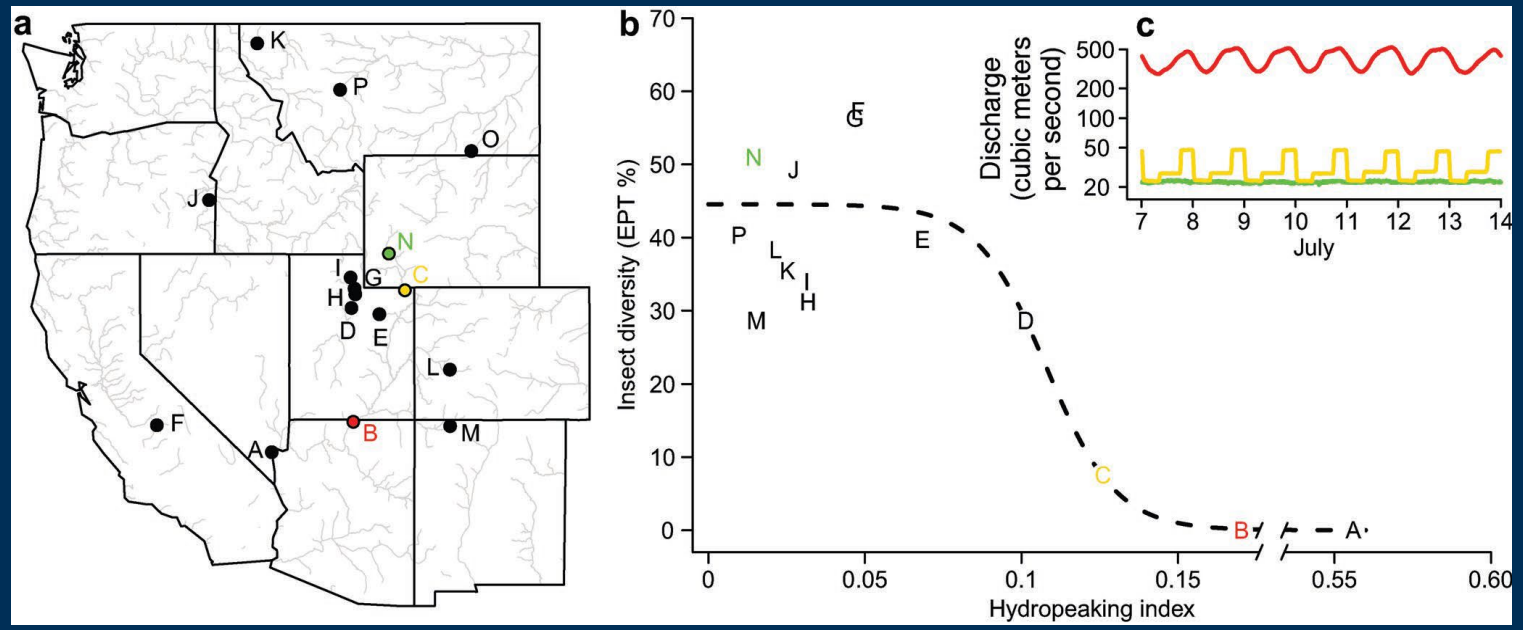
Why Bug Flows?

- Midge abundance negatively related to tides in GC
- Insect diversity negatively related to tides across West





Abundance of midges in Grand Canyon is predicted by timing of tides.
If timing aligns with egg laying (dusk) relatively high egg survival.



Insect diversity across 18 tailwaters in US West. Tailwaters with large tides have low insect diversity (EPT)

From Kennedy and others 2016

Why Bug Flows?

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

Conceptual Model

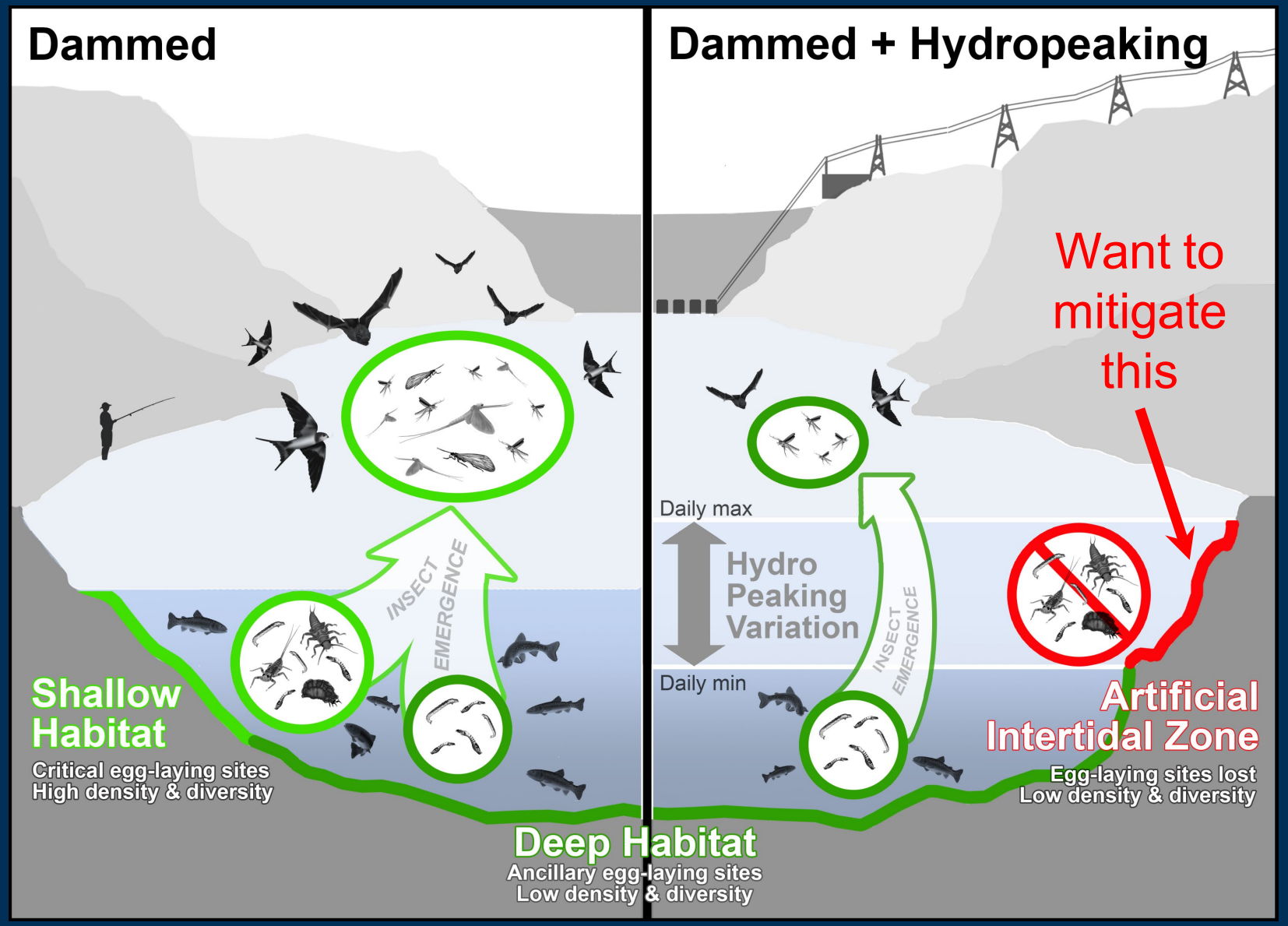


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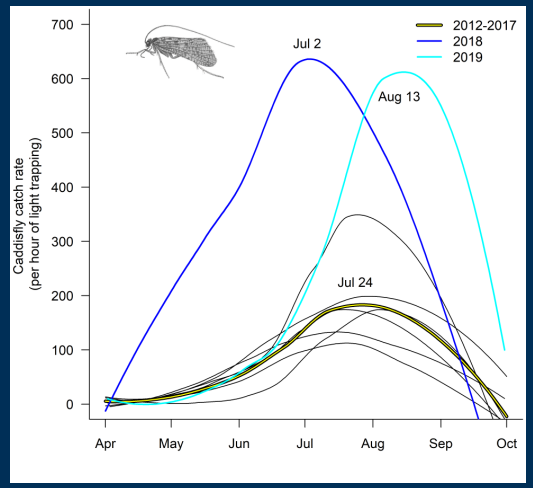
Illustration by Jeremy Monroe-Freshwaters Illustrated, from Kennedy and others 2016, Bioscience

What is a Bug Flow?

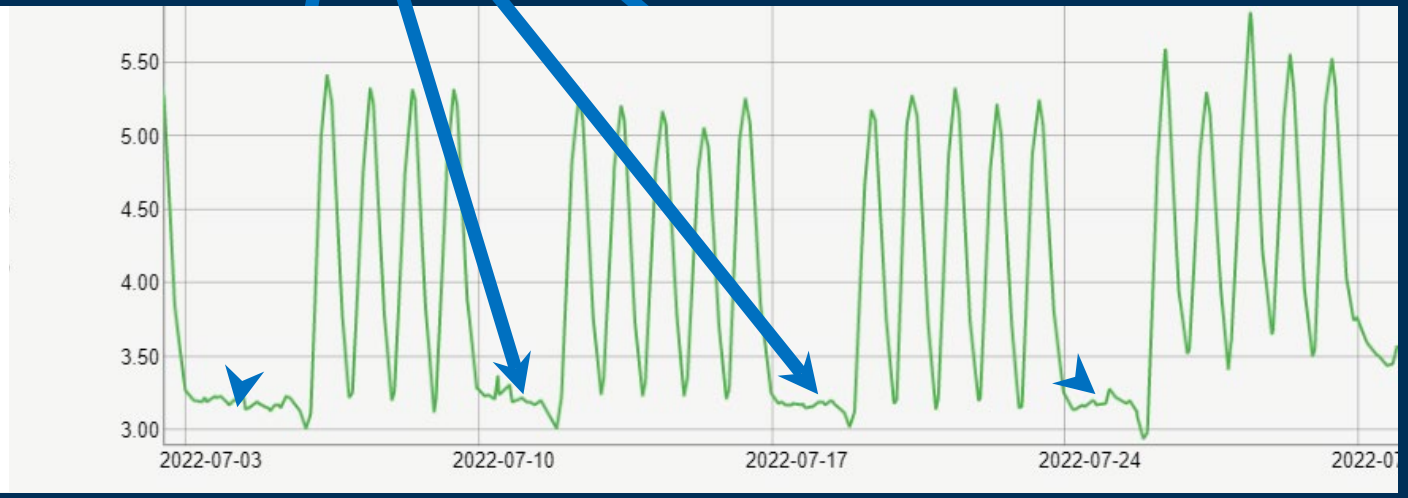
- Give bugs the weekends off
  - Support natural processes essential to aquatic insects
- Weekend stable low flows from May-August
  - Reduces impact to hydropower
  - Experiment tested 2018-2020 & 2022
- Eggs laid on weekends never dry

Peak egg laying activity occurs May-August



Preliminary data, subject to change, do not cite

RM 61 Colorado River upstream of LCR confluence



https://www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09383100

"Objectives of Bug Flow Experiment: Improve food base productivity and abundance or diversity of mayflies, stoneflies, and caddisflies"
From 2016 Glen Canyon Dam EIS, Table 4.

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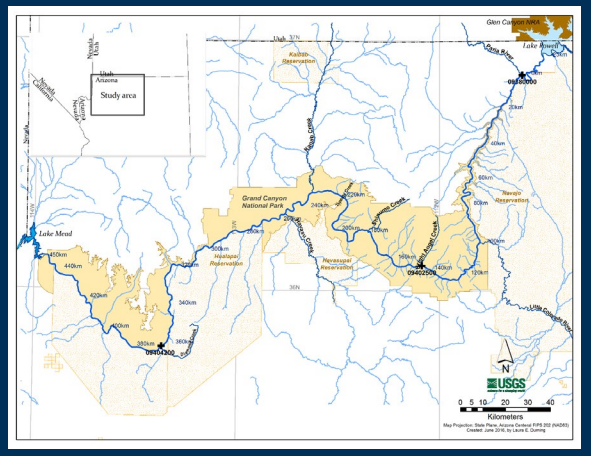
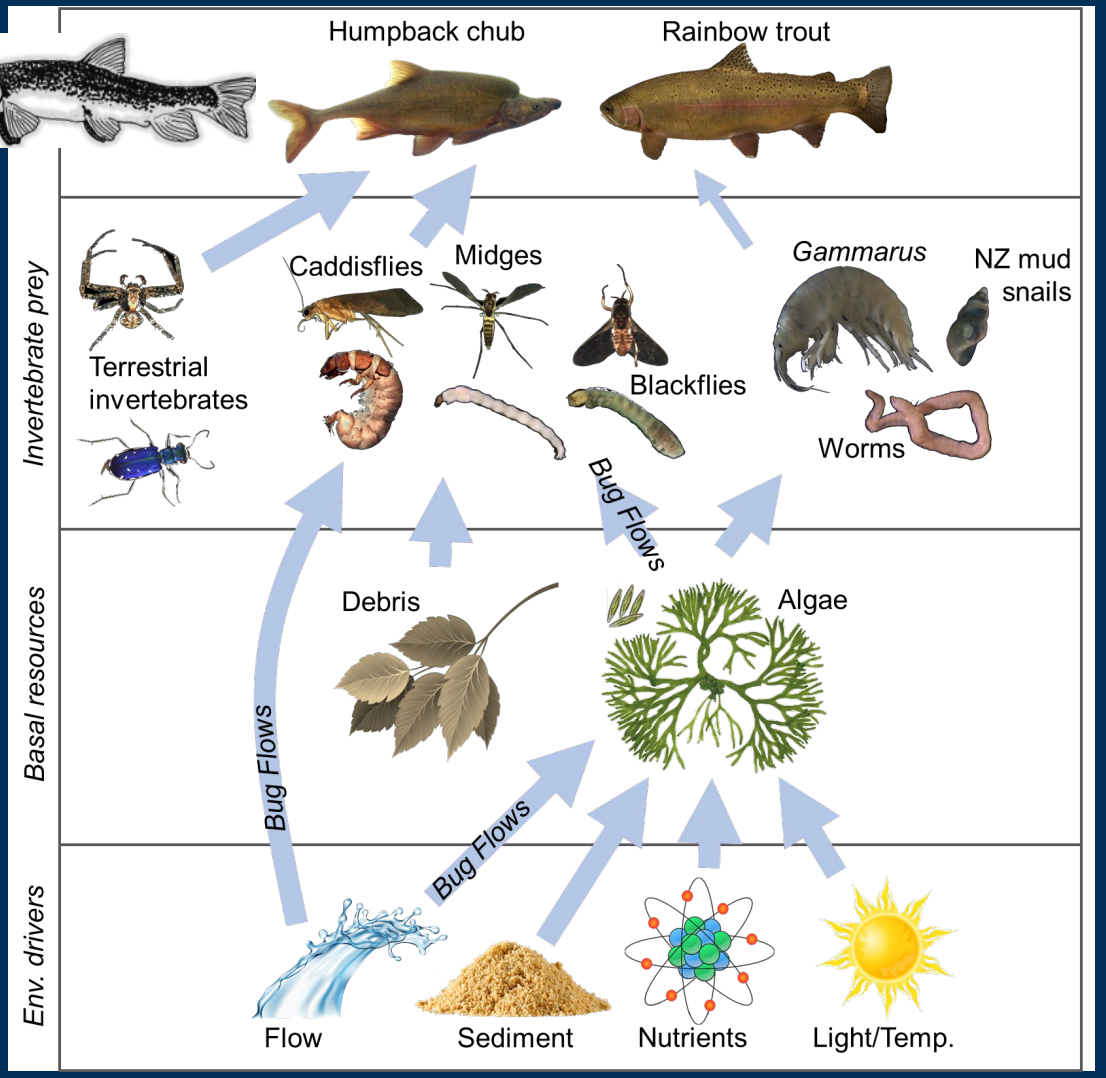
Monitoring Bug Flows in 2022

How to monitor ecosystem response over 400 river kilometers in remote canyon?



August 2022 Update: Monitoring going as planned



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Mark-Recapture studies

- Estimate growth rates at seasonal intervals
- Estimate marginal effect of Bug Flow
- New: Diet studies in 2022

Night fish sampling

Network of community scientists

- Light trap monitoring of aquatic insects
- Key life stage
- Robust scope

Night bug sampling

Network of dissolved oxygen sensors

- Model gross primary production in entire river
- Key ecosystem process
- Daily time step

Dissolved oxygen sensor

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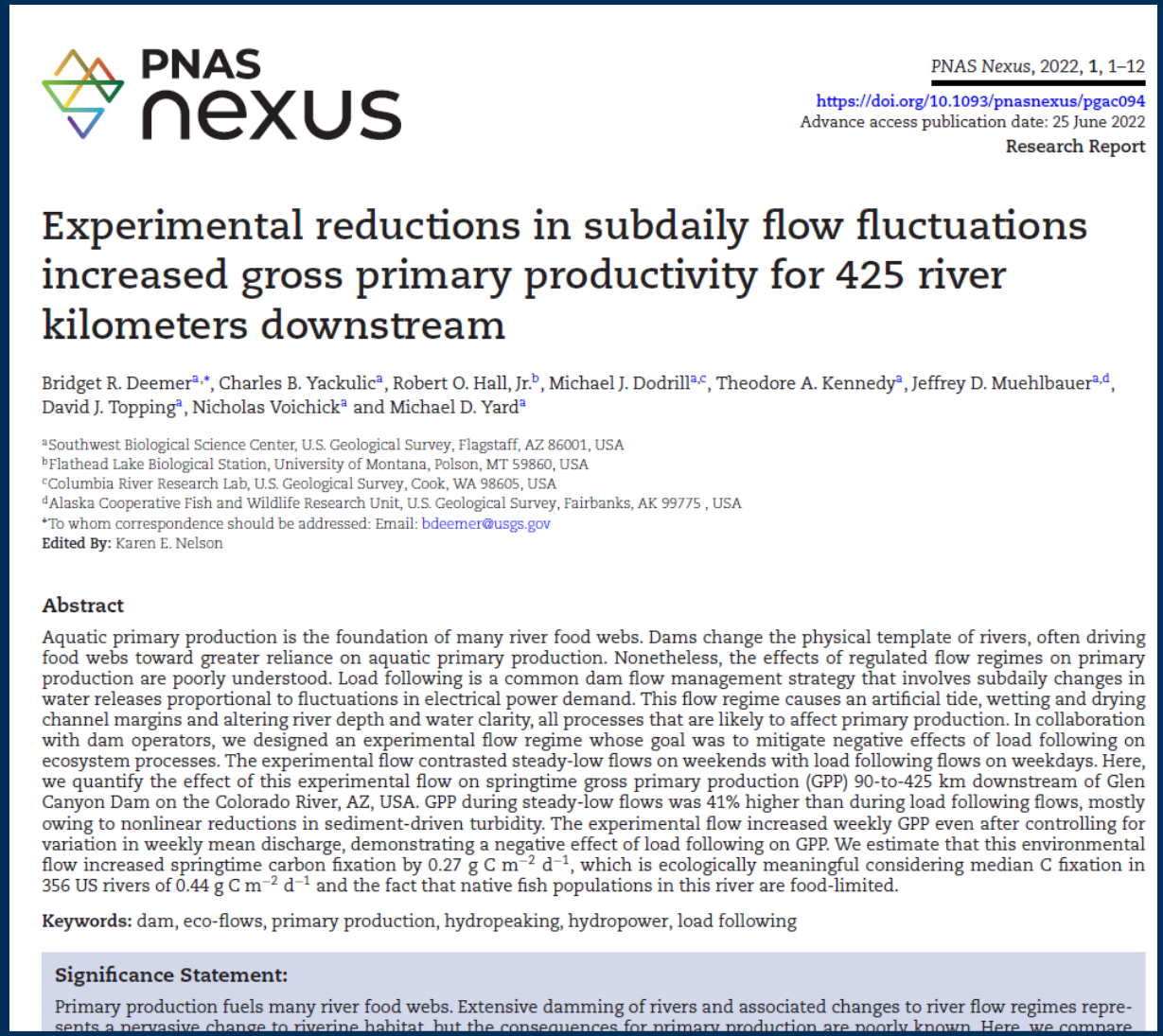
Bug Flows and GPP—New Publication

- **"These findings show that dam management can affect photosynthetic rates, thus affecting carbon supply to food webs over large spatial extents."**

Citation:
Deemer, B. R., Yackulic, C. B., Hall Jr, R. O., Dodrill, M. J., Kennedy, T. A., Muehlbauer, J. D., ... & Yard, M. D. (2022). Experimental reductions in subdaily flow fluctuations increased gross primary productivity for 425 river kilometers downstream. PNAS Nexus, 1(3), pgac094.



PNAS nexus

PNAS Nexus, 2022, 1, 1–12
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Advance access publication date: 25 June 2022
Research Report

Experimental reductions in subdaily flow fluctuations increased gross primary productivity for 425 river kilometers downstream

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Abstract

Aquatic primary production is the foundation of many river food webs. Dams change the physical template of rivers, often driving food webs toward greater reliance on aquatic primary production. Nonetheless, the effects of regulated flow regimes on primary production are poorly understood. Load following is a common dam flow management strategy that involves subdaily changes in water releases proportional to fluctuations in electrical power demand. This flow regime causes an artificial tide, wetting and drying channel margins and altering river depth and water clarity, all processes that are likely to affect primary production. In collaboration with dam operators, we designed an experimental flow regime whose goal was to mitigate negative effects of load following on ecosystem processes. The experimental flow contrasted steady-low flows on weekends with load following flows on weekdays. Here, we quantify the effect of this experimental flow on springtime gross primary production (GPP) 90-to-425 km downstream of Glen Canyon Dam on the Colorado River, AZ, USA. GPP during steady-low flows was 41% higher than during load following flows, mostly owing to nonlinear reductions in sediment-driven turbidity. The experimental flow increased weekly GPP even after controlling for variation in weekly mean discharge, demonstrating a negative effect of load following on GPP. We estimate that this environmental flow increased springtime carbon fixation by 0.27 g C m^{-2} d^{-1}, which is ecologically meaningful considering median C fixation in 356 US rivers of 0.44 g C m^{-2} d^{-1} and the fact that native fish populations in this river are food-limited.

Keywords: dam, eco-flows, primary production, hydropeaking, hydropower, load following

Significance Statement:

Primary production fuels many river food webs. Extensive damming of rivers and associated changes to river flow regimes repre-
sents a pervasive change to riverine habitat, but the consequences for primary production are poorly known. Here, we compare

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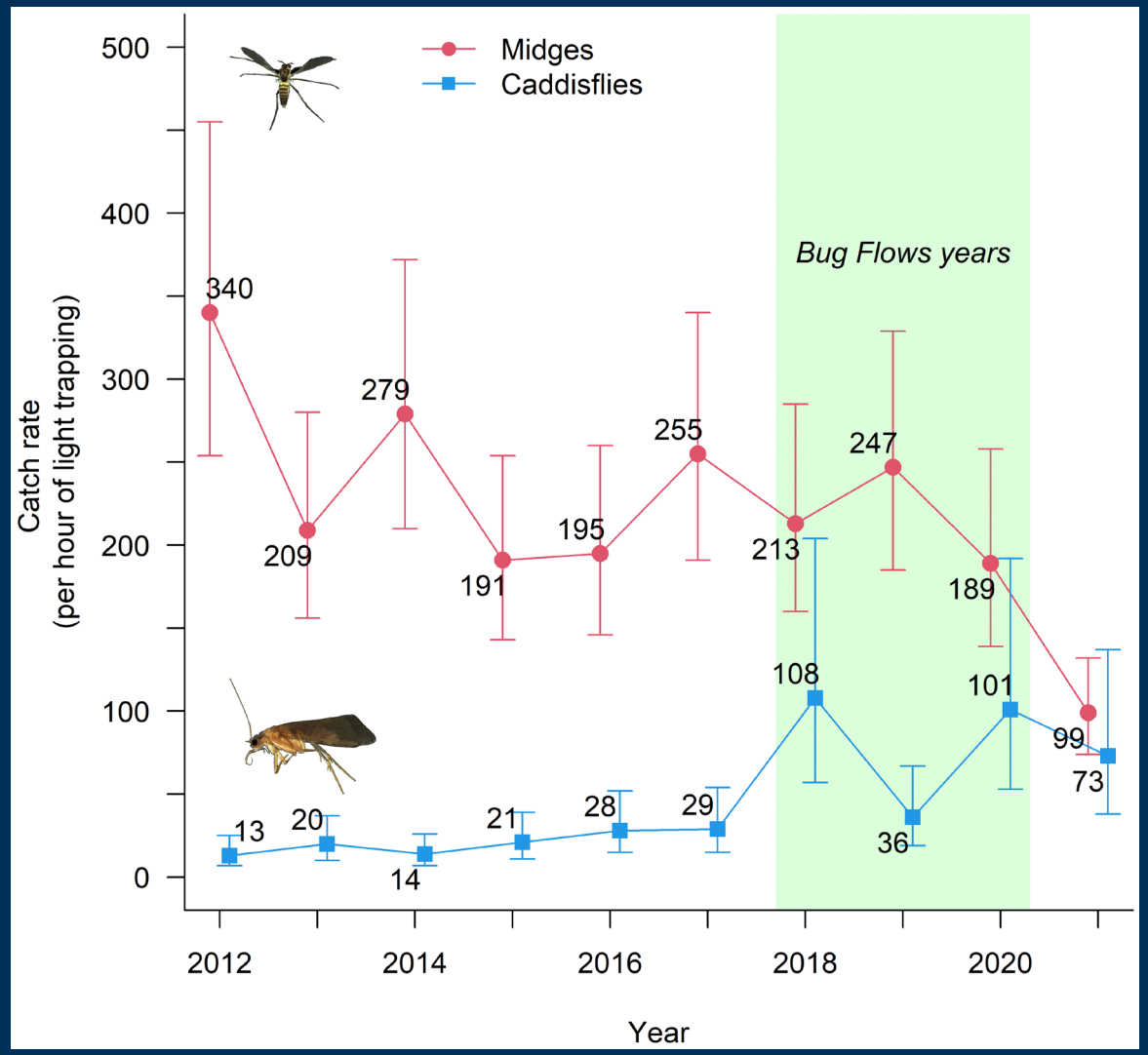
Monitoring Insect Response

Tough to untangle what 2021 means
-no direct benefits to GPP, larvae or emergence
-But multiple years of good egg laying & very clear water (low sediment turbidity)

- **Cessation of Bug Flows in 2021 associated with:**
  - **Midges: ~50% decline**
  - **Caddisflies: no change from year prior**

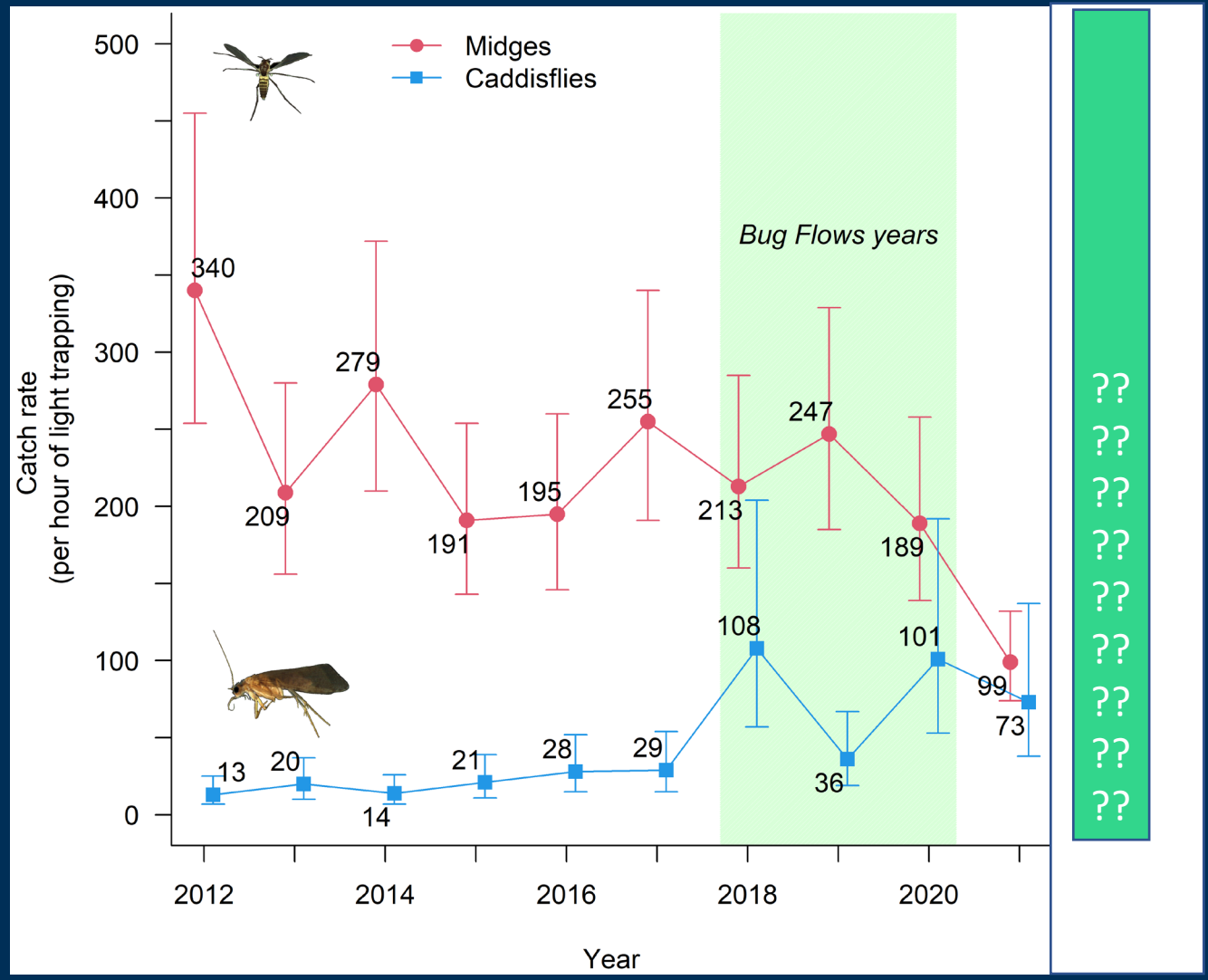


Estimates of annual average from mixed effects model

Monitoring Insect Response

- **Community science light trap monitoring of aquatic insects in 2022 going as planned…**

Community Science light trap collection during June 2022 Grand Canyon Youth river trip



Estimates of annual average from mixed effects model

USGS Unpublished data, subject to change, do not cite.

Analyzing Insect Monitoring Data—New Population Models

1. Construct matrix population models for each relevant species

Species A

$$\begin{pmatrix} 0 & 0 & F_A \\ G_{1A} & P_{2A} & 0 \\ 0 & G_{2A} & P_{3A} \end{pmatrix}$$

Species B

$$\begin{pmatrix} 0 & 0 & F_B \\ G_{1B} & P_{2B} & 0 \\ 0 & G_{2B} & P_{3B} \end{pmatrix}$$

Species C

$$\begin{pmatrix} 0 & 0 & F_C \\ G_{1C} & P_{2C} & 0 \\ 0 & G_{2C} & P_{3C} \end{pmatrix}$$

Species Z

$$\begin{pmatrix} 0 & 0 & F_Z \\ G_{1Z} & P_{2Z} & 0 \\ 0 & G_{2Z} & P_{3Z} \end{pmatrix}$$

2. Parameterize with vital rates according to major event types: mortality and growth rates in response to floods, low flows, steady flows, hydropeaking, etc.

3. Use models to ask “what if” questions about flow experiment and scenarios

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Preliminary data, subject to change, do not cite

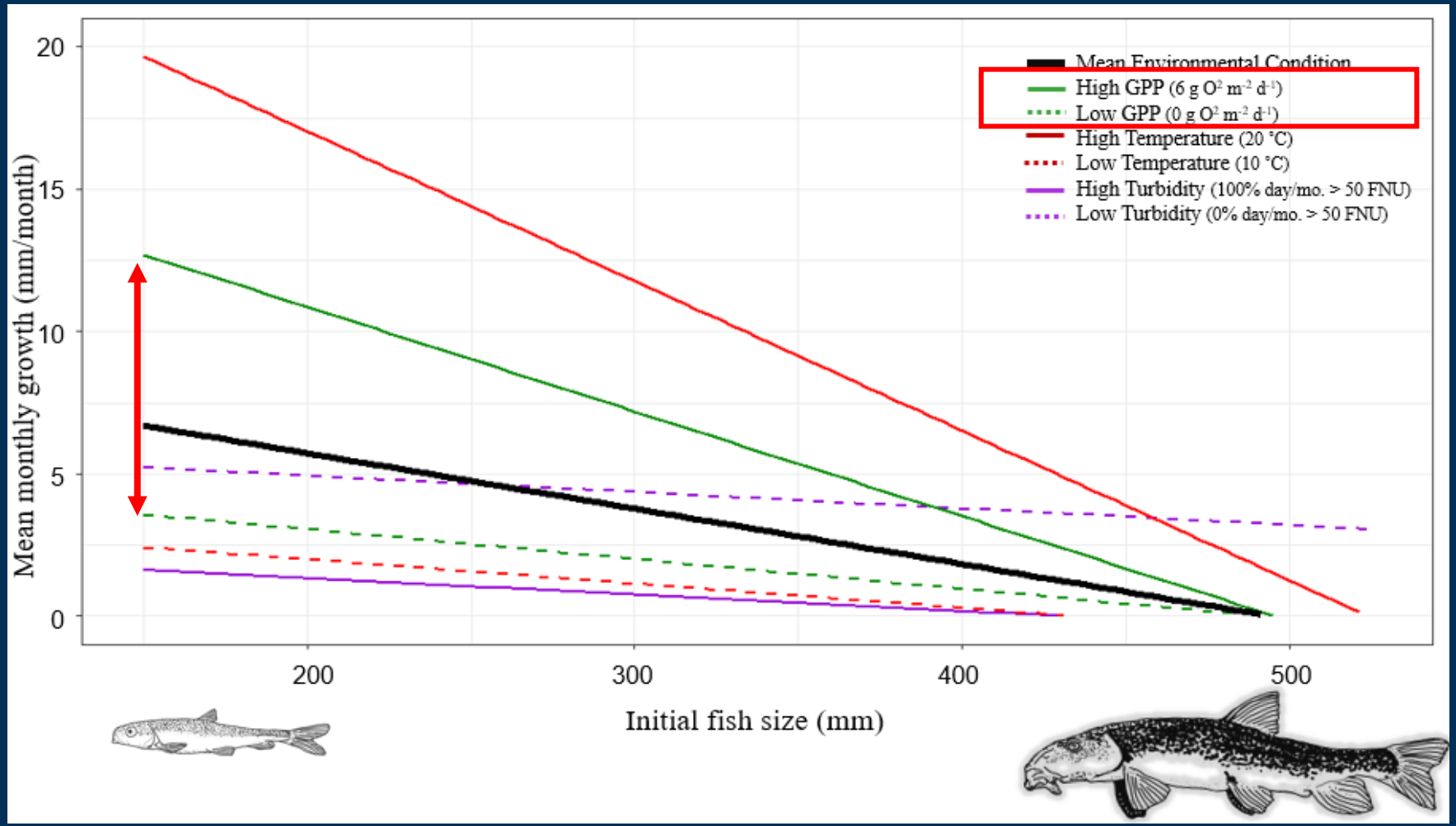
David A. Lytle and Angelika Kurthen, Oregon State University

GPP and Fish—New Analyses

Increase in GPP arising from Bug Flows increases flannelmouth sucker growth by ~1.5mm/month.

The increase in flannelmouth growth arising from Bug Flows→GPP is equivalent to growth increase associated with a 1C temperature increase.

Next Steps: develop similar models for Humpback chub



Unpublished data, subject to change, do not cite.

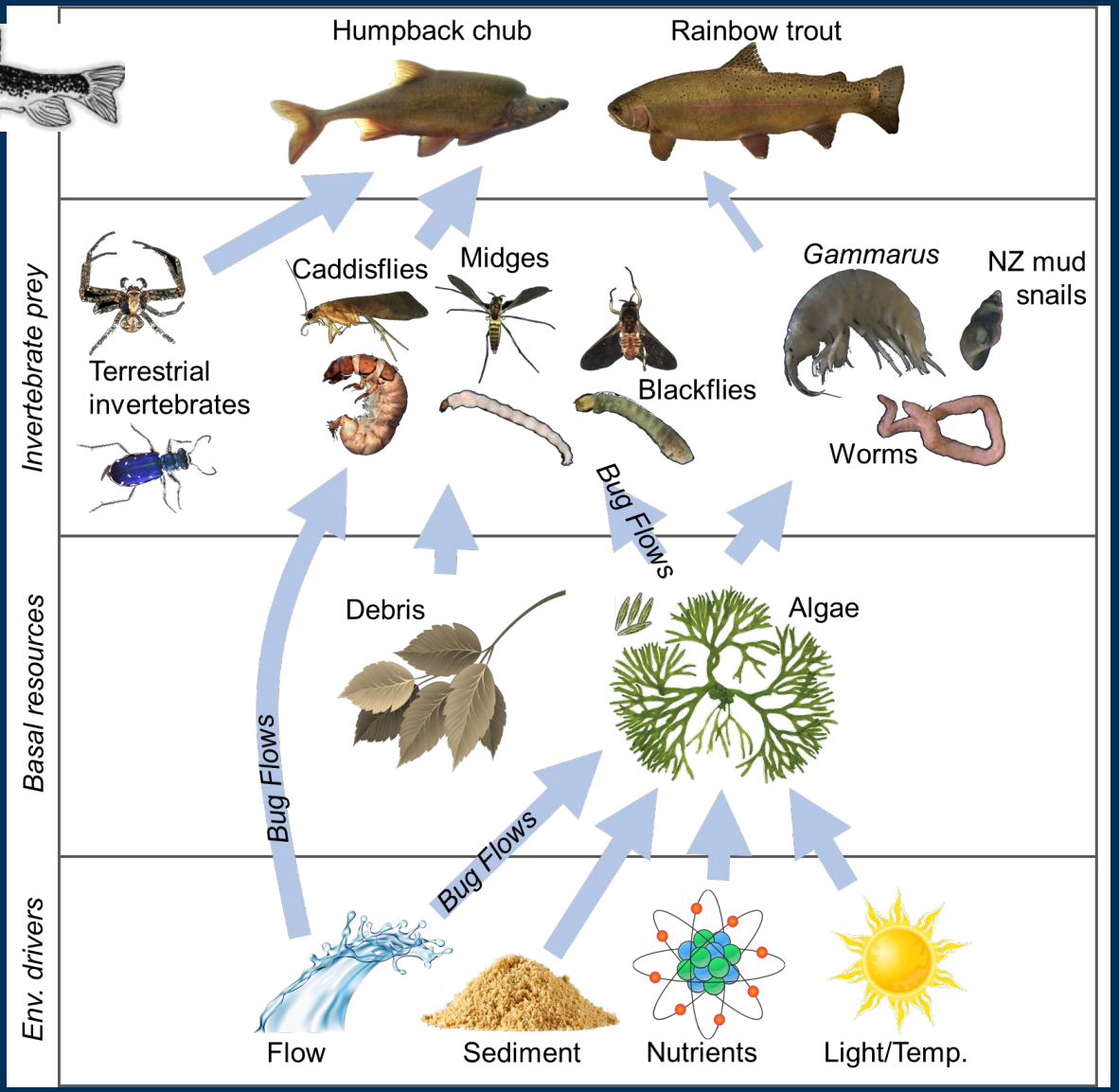
New results from mark-recapture studies. Hansen, L. and others, manuscript in review

Conclusions

- **Natural Processes from LTEMP:**

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.

- **Bug Flows appears to be a useful tool for enhancing natural processes that sustain the Colorado River ecosystem**



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