# Experimental Bug Flows Enhance Natural Processes That Sustain The Colorado River Ecosystem


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**Ted Kennedy[1], Jeff Muehlbauer[2], Anya Metcalfe[1], Bridget Deemer[1], Morgan Ford[1], Cheyenne Szydlo[1], Kate Behn[1], Charles Yackulic[1]**

1-U.S. Geological Survey, Southwest Biological Science Center, Flagstaff, AZ

2-U.S. Geological Survey, Alaska Cooperative Fish and Wildlife Research Unit, Fairbanks, AK

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

# Outline

- Background
- Lees Ferry fishery
- Grand Canyon

My talk will also cover

From Ellsworth 2023, 3 minutes ago…

## Conclusions

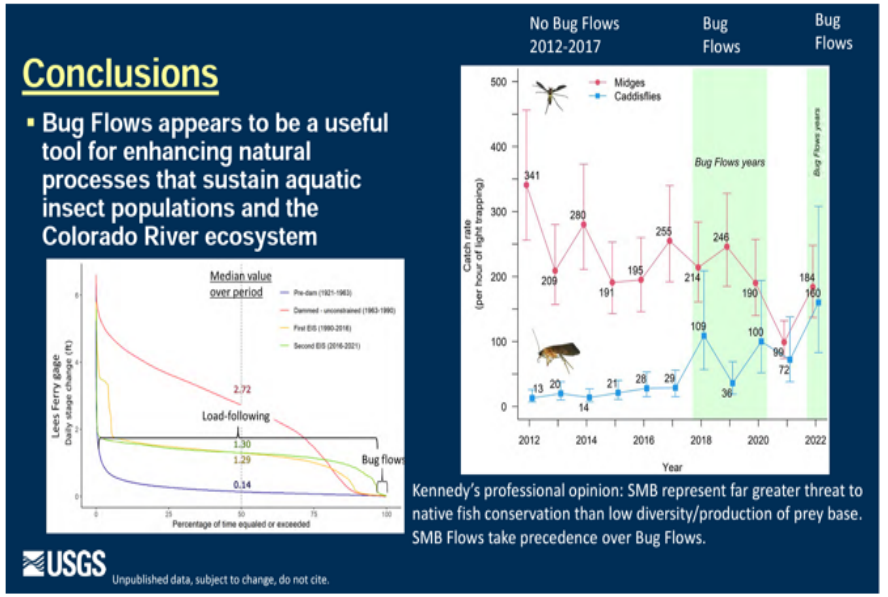
"Enhances natural processes" by reducing flow fluctuations?

But does the data indicate a statistically significant increase in:

- Midge abundance, or
- EPT abundance/diversity

Did we see:

- Smoothing in midge distribution?
- Caddis distribute away from tributaries?




https://www.usbr.gov/uc/progact/amp/twg/2023-01-26-twg-meeting/20230126-AnnualReportingMeeting-BugFlowsFoodBaseUpdate-508-UCRO.pdf

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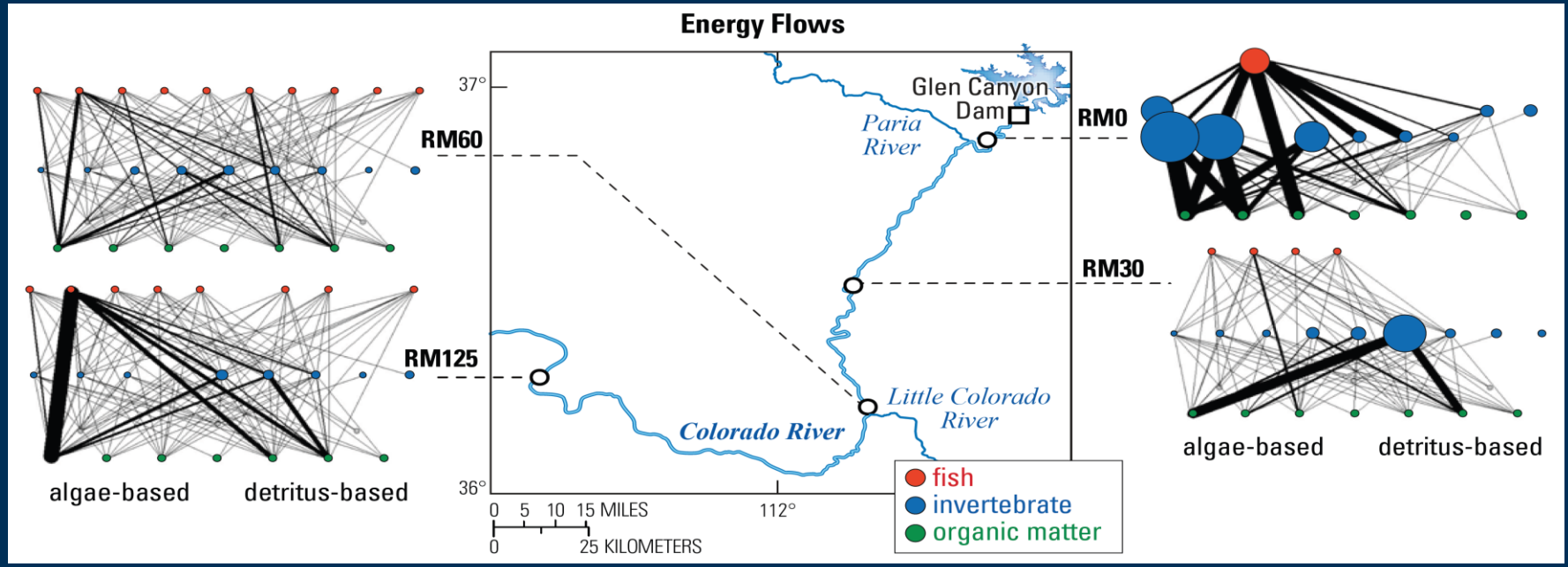
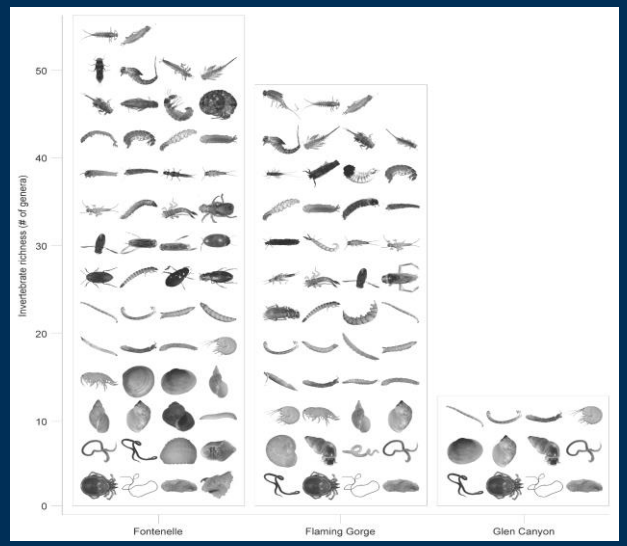
# Why Bug Flows?

- Fish are food limited
- Very few insects
- Food webs built upon algae

Food webs of the Colorado River circa 2006-2009. Modified from Cross and others 2013, Ecological Monographs




From Kennedy and others 2016, Bioscience


Humpback chub

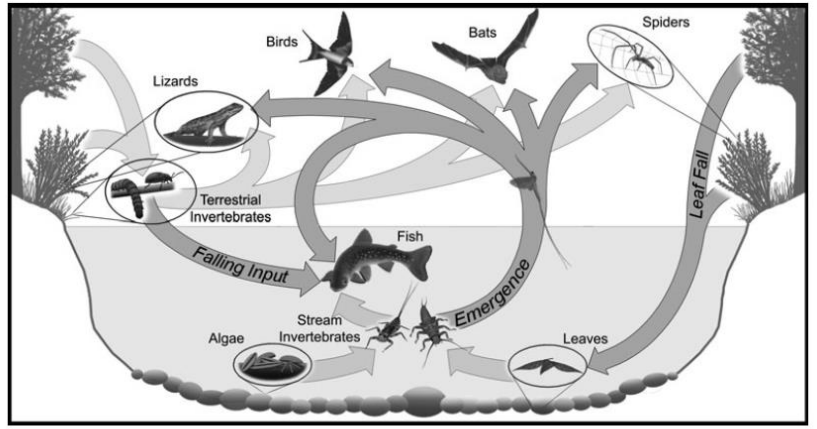



Fig. 1 A generalised diagram showing reciprocal flows of invertebrate prey and inputs of plant material (dark arrows) that have direct and indirect effects in stream and riparian food webs.

Insects play critical role in river food webs; Baxter and others 2005, Freshwater Biology

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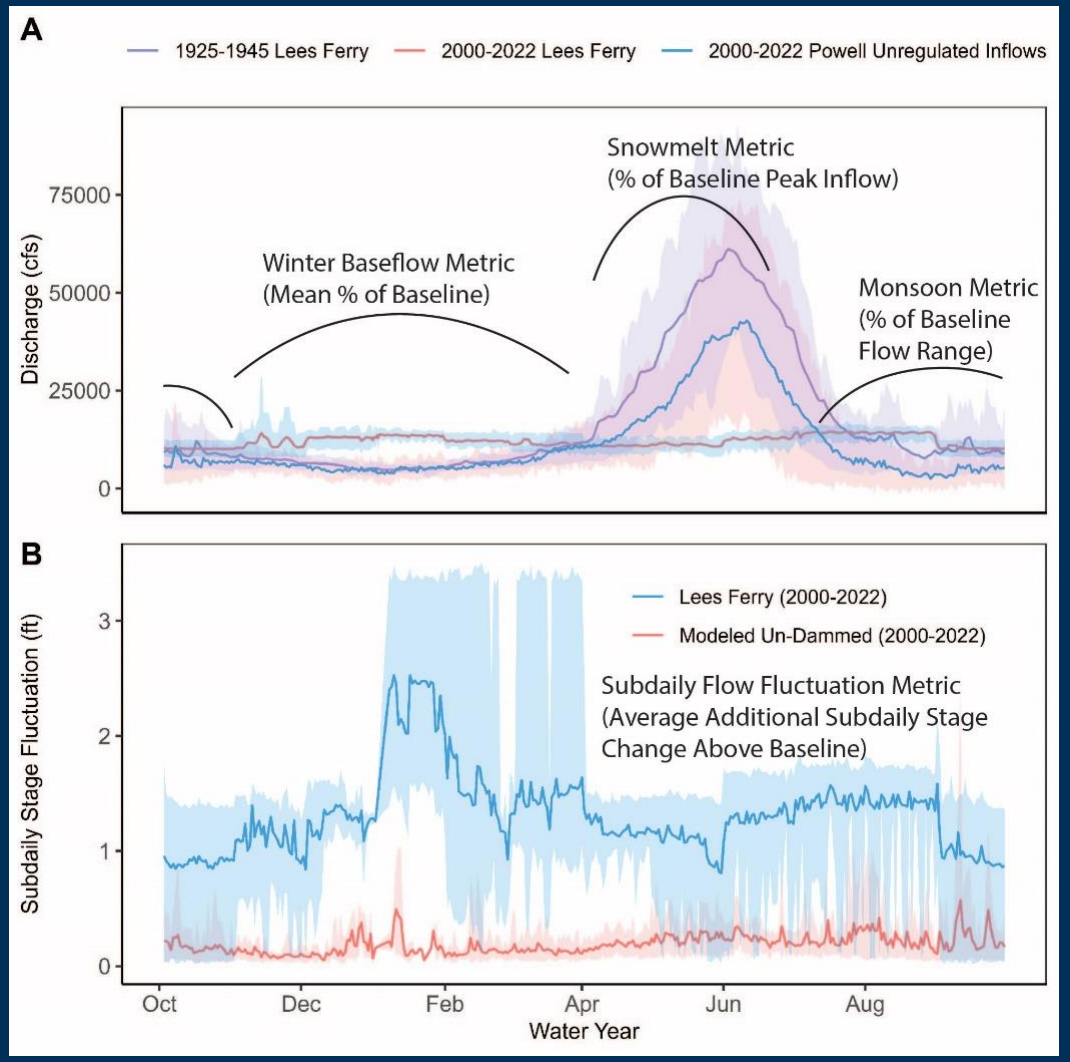
# Why Bug Flows?
# Because load following…

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.

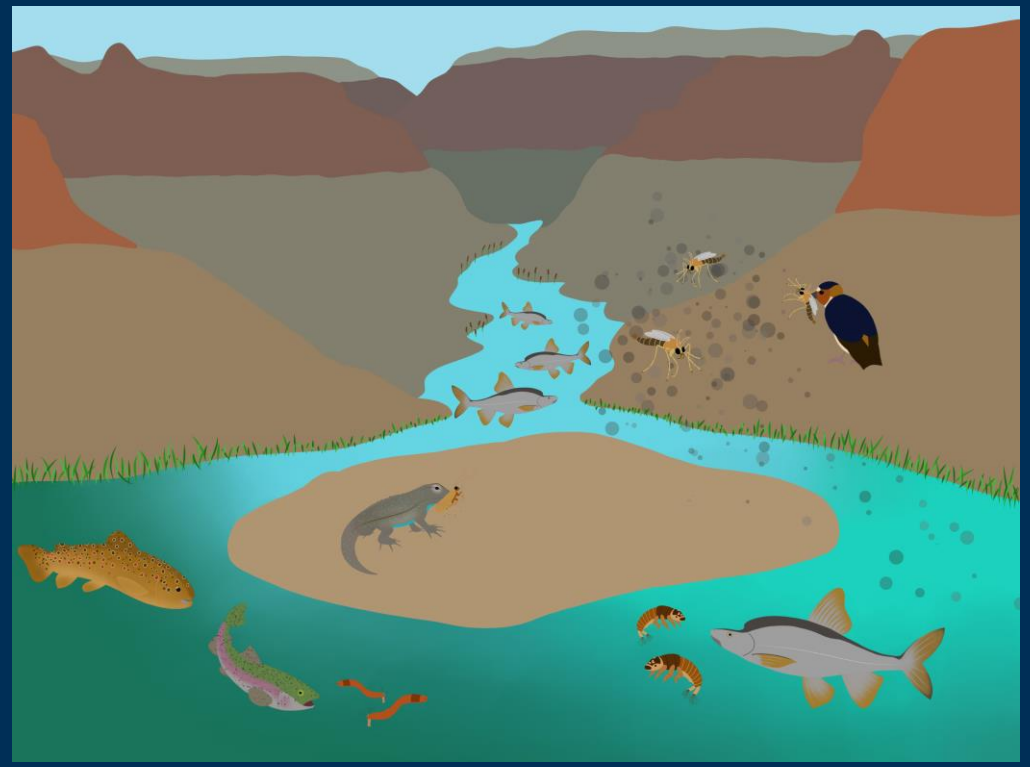
High and low flows eliminated

Load-following causes daily tides




From Fairly and others, Metrics draft dated March 2023,
Figure courtesy Bridget Deemer & Emily Palmquist

Unpublished data, subject to change, do not cite.



Conceptual model of select Natural Processes at the Little Colorado River confluence
Figure courtesy of Diana Valentine

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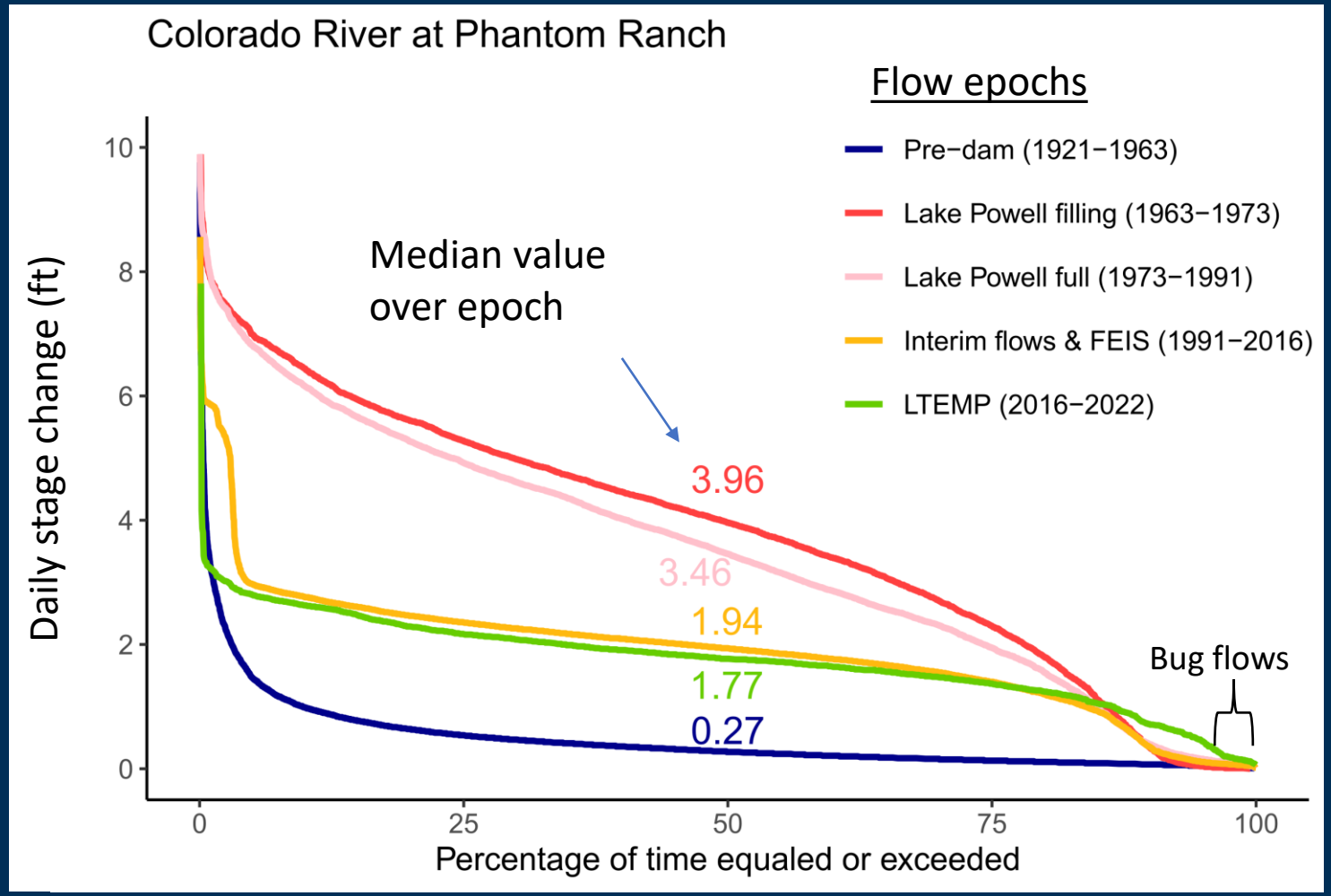
# Why Bug Flows?
# Because Load Following…




From Fairly and others, Metrics draft dated March 2023, figure courtesy of Anya Metcalfe

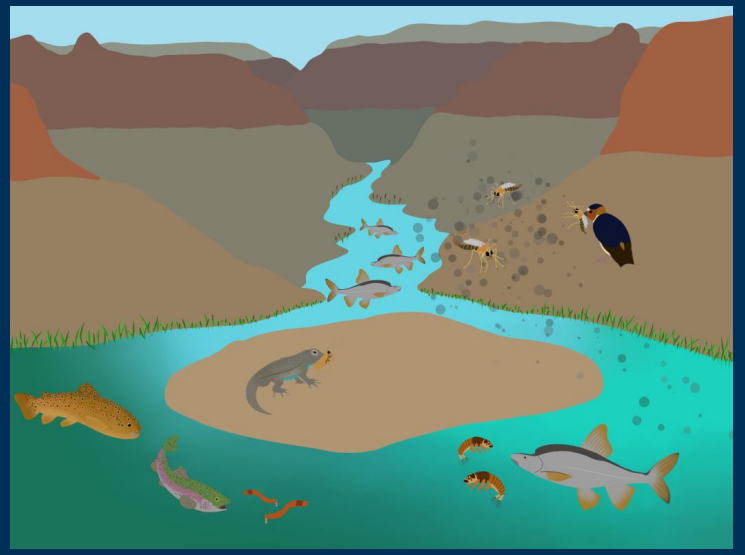


Figure courtesy of Diana Valentine

Bug Flows restores discharge to natural range of variability (i.e., no/minimal tides)

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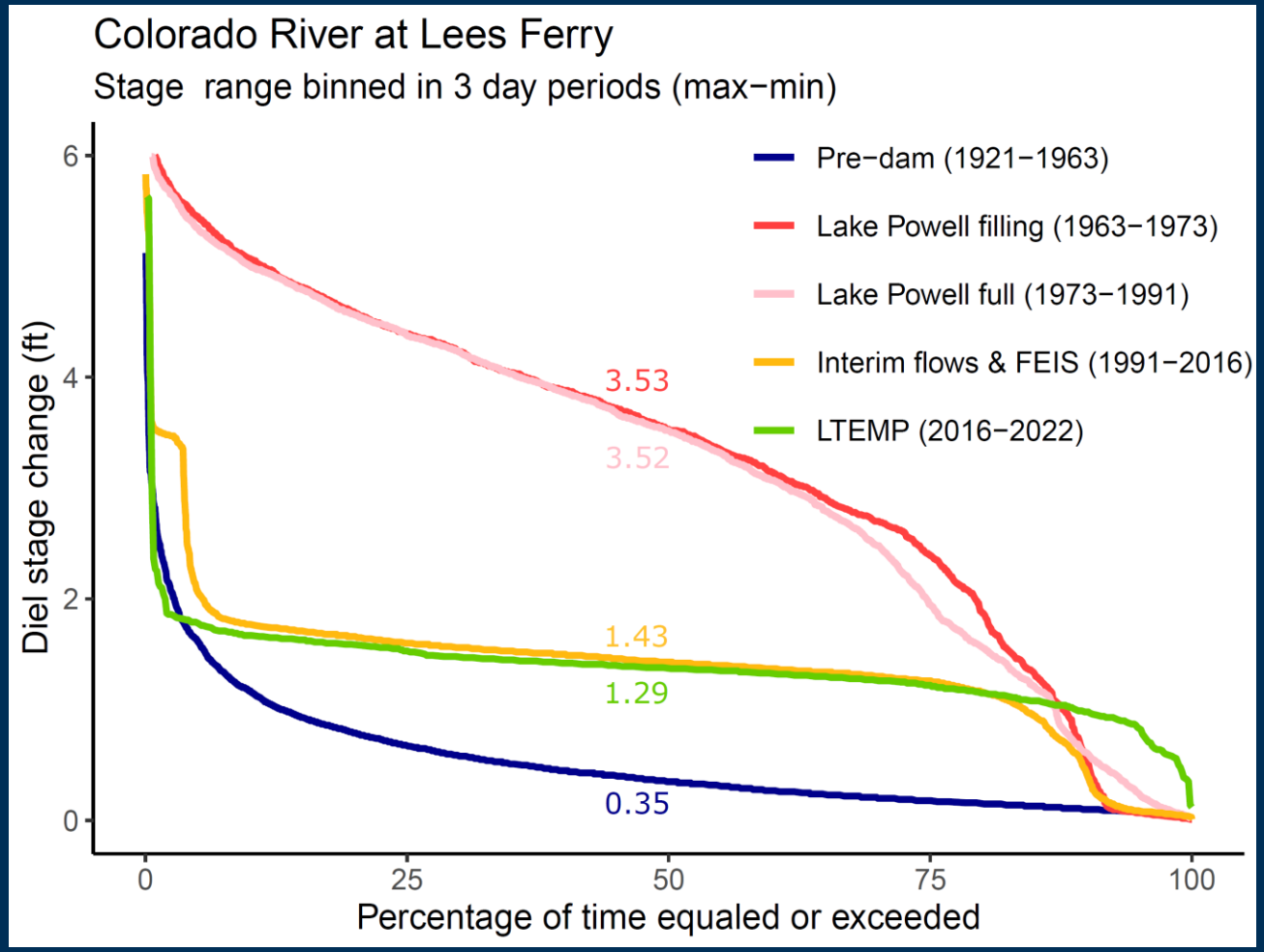
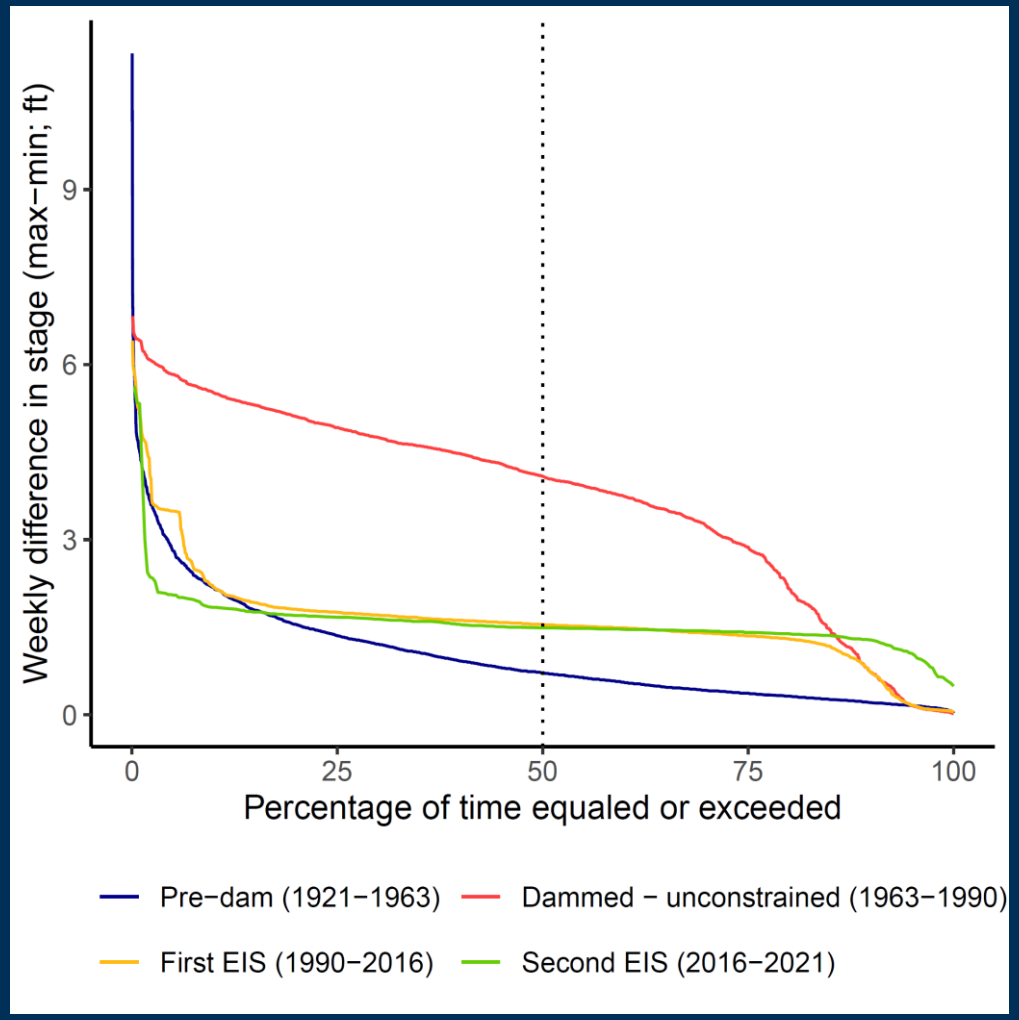
# Why Bug Flows?
# Because Load Following…

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# Why Bug Flows?
# Because Load-Following…

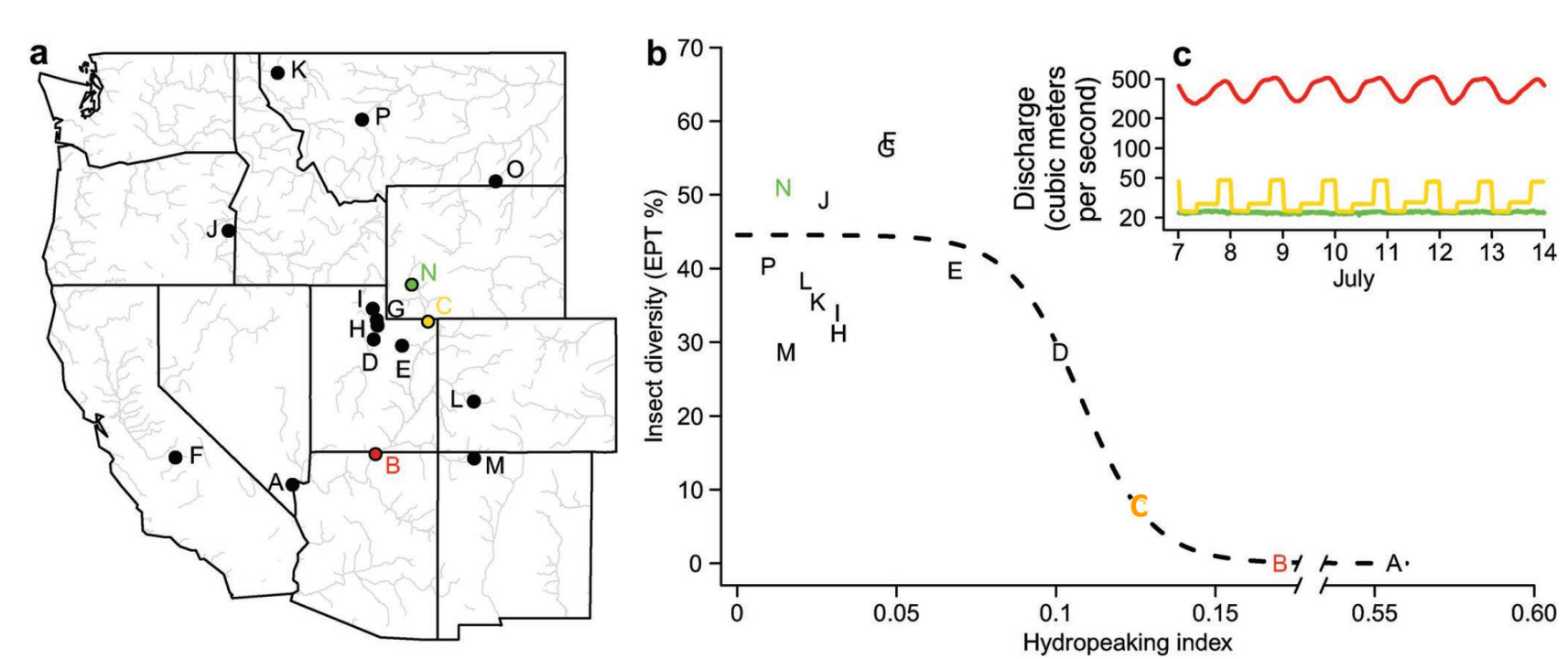


*Figure 6. Hydropeaking is a lever on aquatic-insect diversity. We gathered available invertebrate data from dammed rivers*

- **Insect diversity negatively related to tides across western US**

From Kennedy and others 2016, Bioscience

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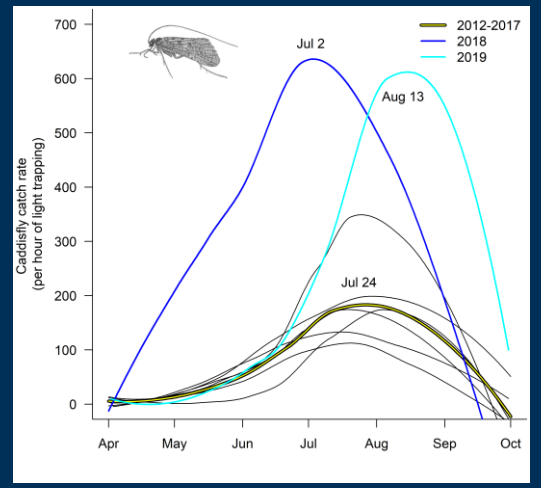
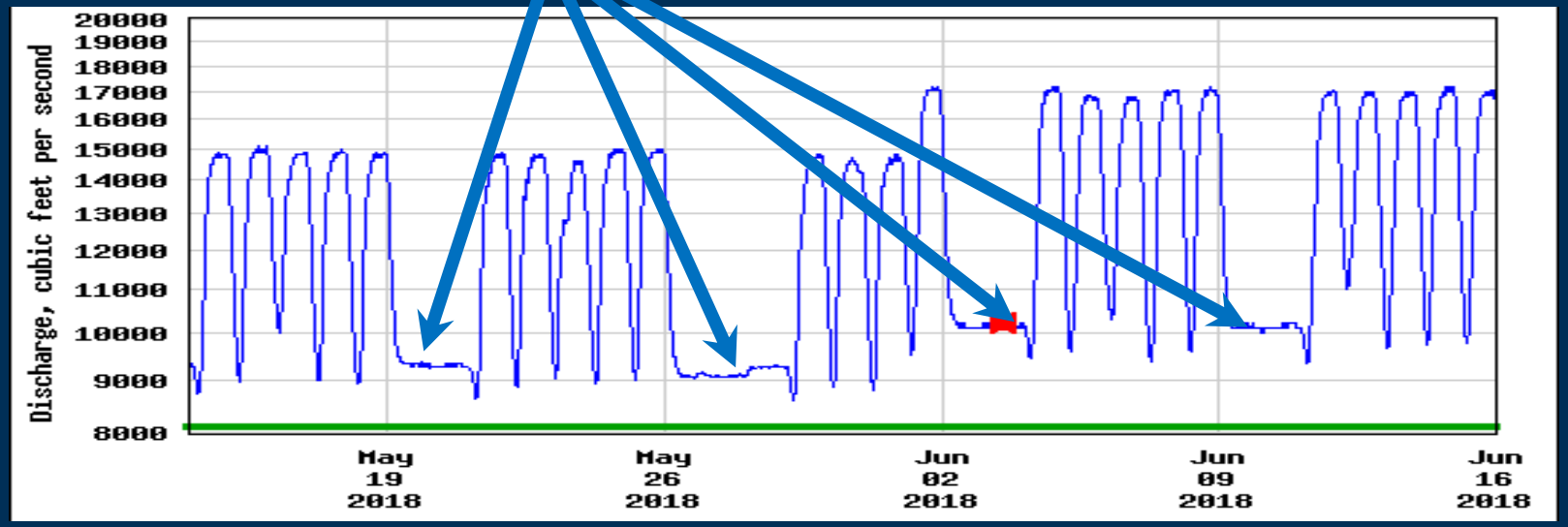
# What Is A Bug Flow?

- Give bugs the weekends off
- Weekend stable low flows from May-August
  - Minimizes impact to hydropower
  - Experiment tested 2018-2020 & 2022
    - paused in 2021 for Science Advisor review
- <u>Restores discharge to natural range of variability (no tide)</u>

Adult caddisfly abundance




May-August




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

# Lees Ferry Fishery

- **Long-term Invertebrate Drift**
  - Monthly since 2008

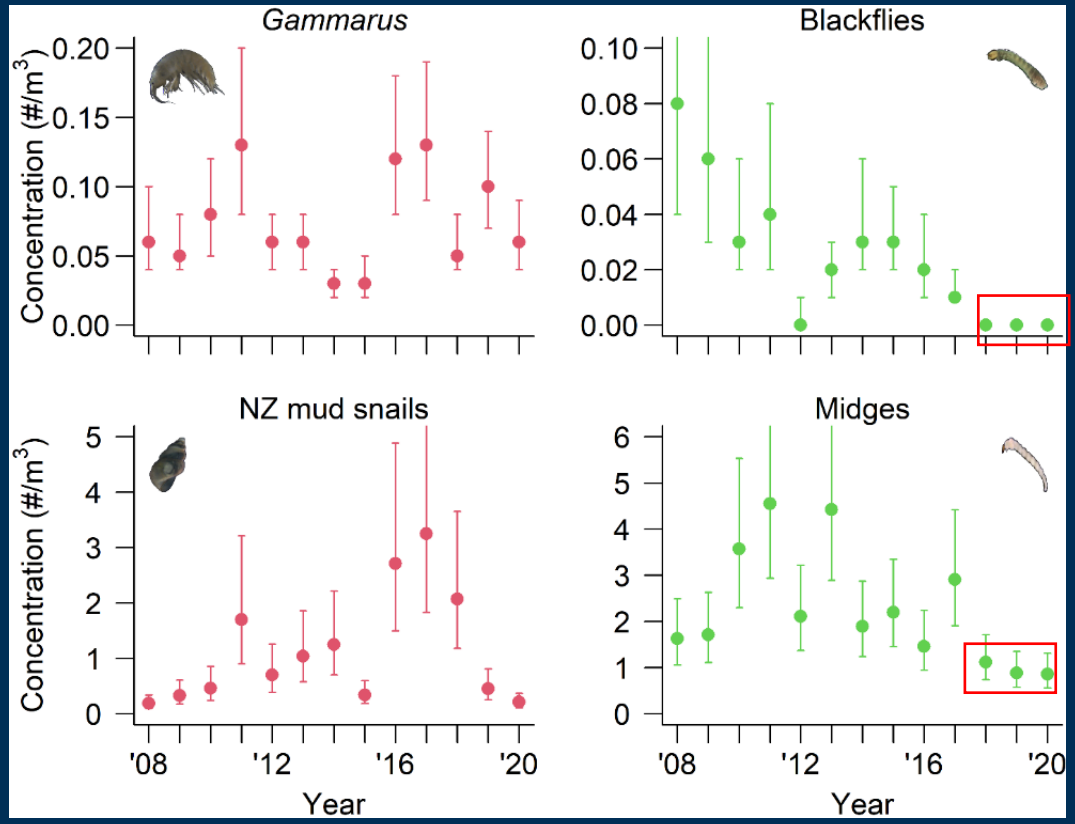
- **Long-term Trout Growth Studies**
  - Seasonal since 2012

Humans collecting invertebrate drift

Rainbow trout collecting invertebrate drift

USGS

# Lees Ferry Fishery




"Annual average drift concentrations for midges aad blackflies during Bug Flows are the three lowest years on record…" From Bug Flow synthesis report (2021)

## Caveats

-No increase in blackflies was predicted

-Drift is imperfect measure of food availability in Lees Ferry (next slide)

-Yard et al. 2022 (next slides) demonstrates trout consumption has huge impact on invertebrate drift concentrations

-Therefore, to evaluate Bug Flows in Lees Ferry focus on trout growth and angling

Humans collecting invertebrate drift

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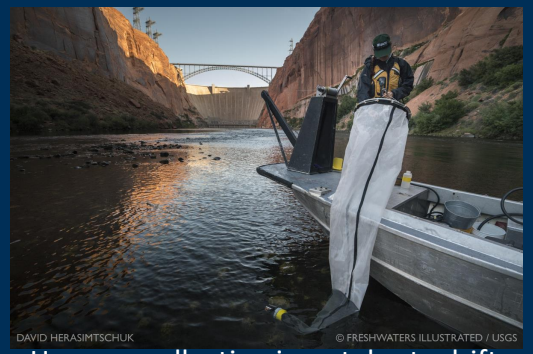
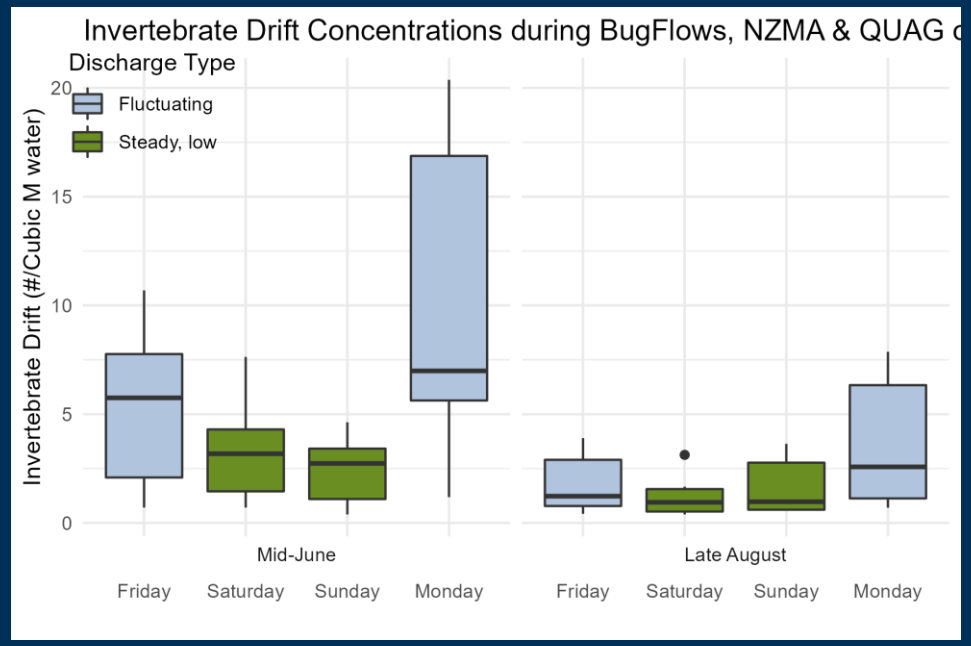
Unpublished data, subject to change, do not cite.

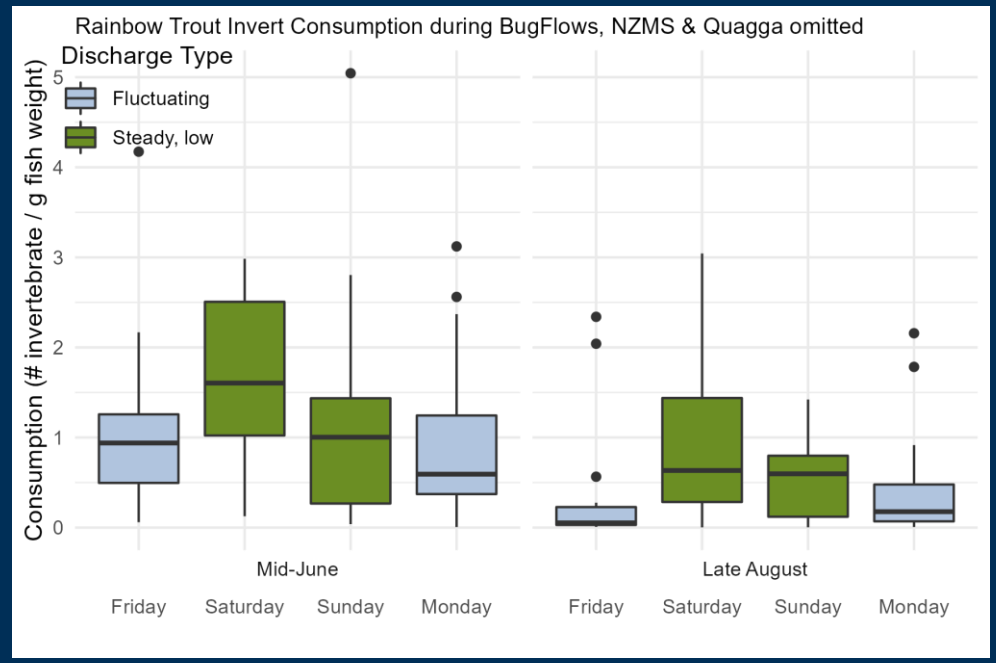
# Drift Nets Are Imperfect Predictor Of Diet



Humans collecting invertebrate drift

Rainbow trout collecting invertebrate drift

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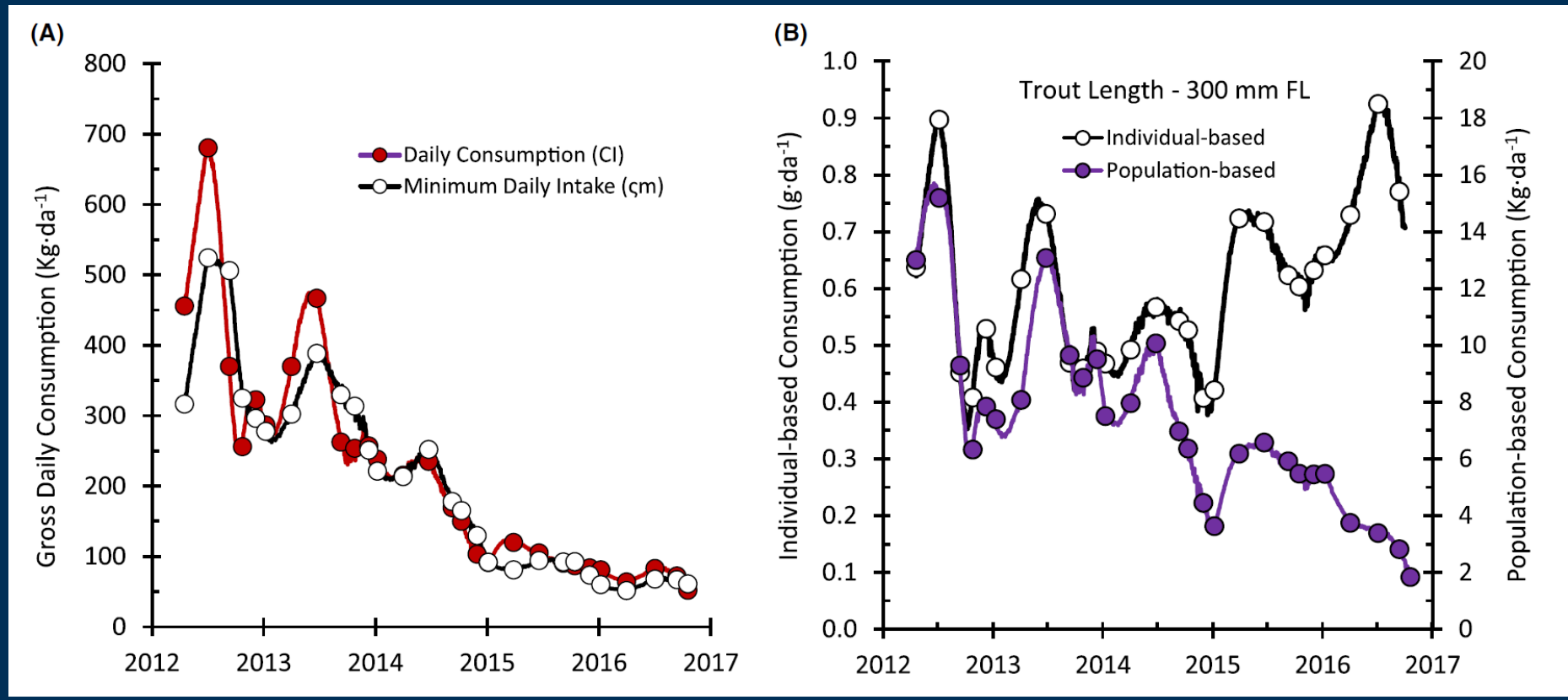
Unpublished data, subject to change, do not cite.

# Trout Consumption Estimates Derived From Growth Measurements


Rainbow trout collecting invertebrate drift




Yard, Michael D., Charles B. Yackulic, Josh Korman, Michael J. Dodrill, and Bridget R. Deemer. "Declines in prey production during the collapse of a tailwater Rainbow Trout population are associated with changing reservoir conditions." *Transactions of the American Fisheries Society* 152, no. 1 (2023): 35-50.

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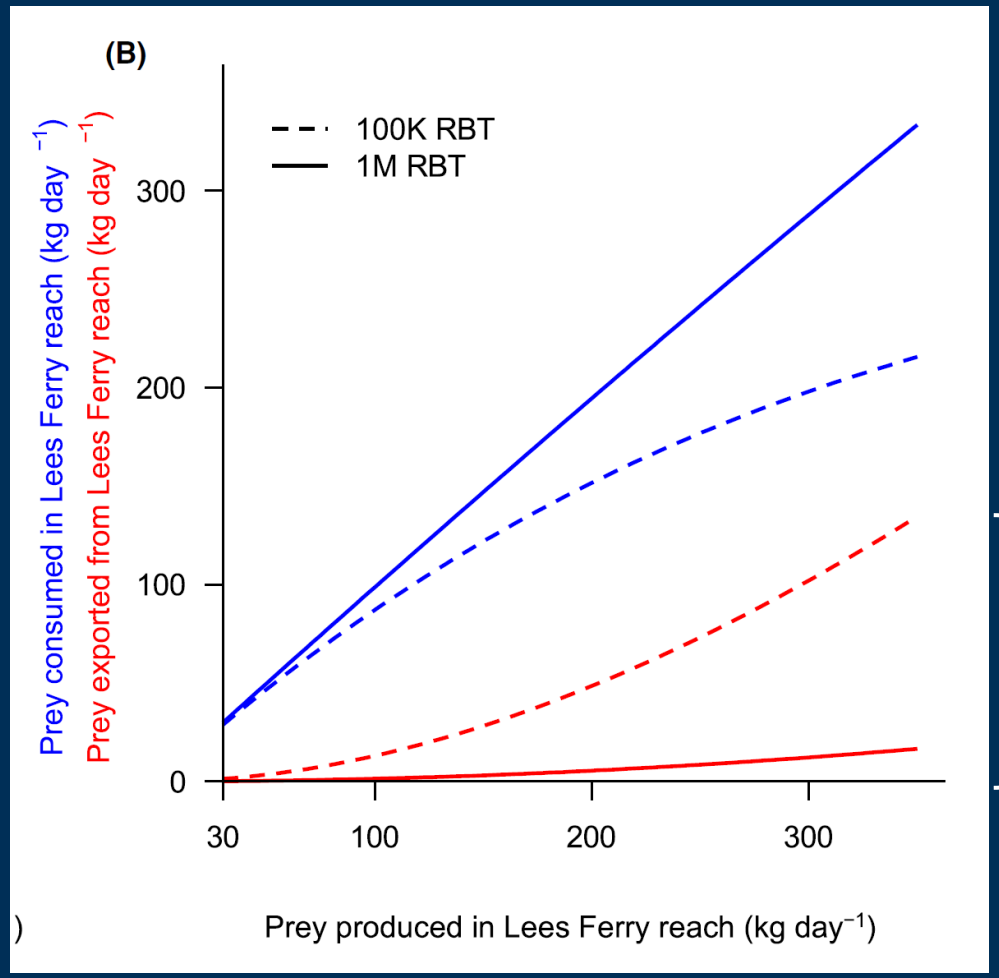
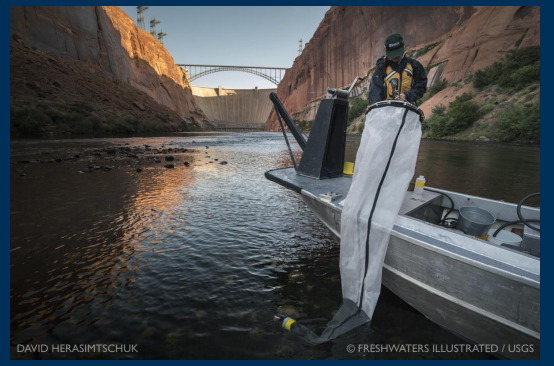
# Trout Are Way Better At Sampling Drift Than Humans




Model estimates of drift that trout might collect in their mouths


Model estimates of drift that we might collect in our nets

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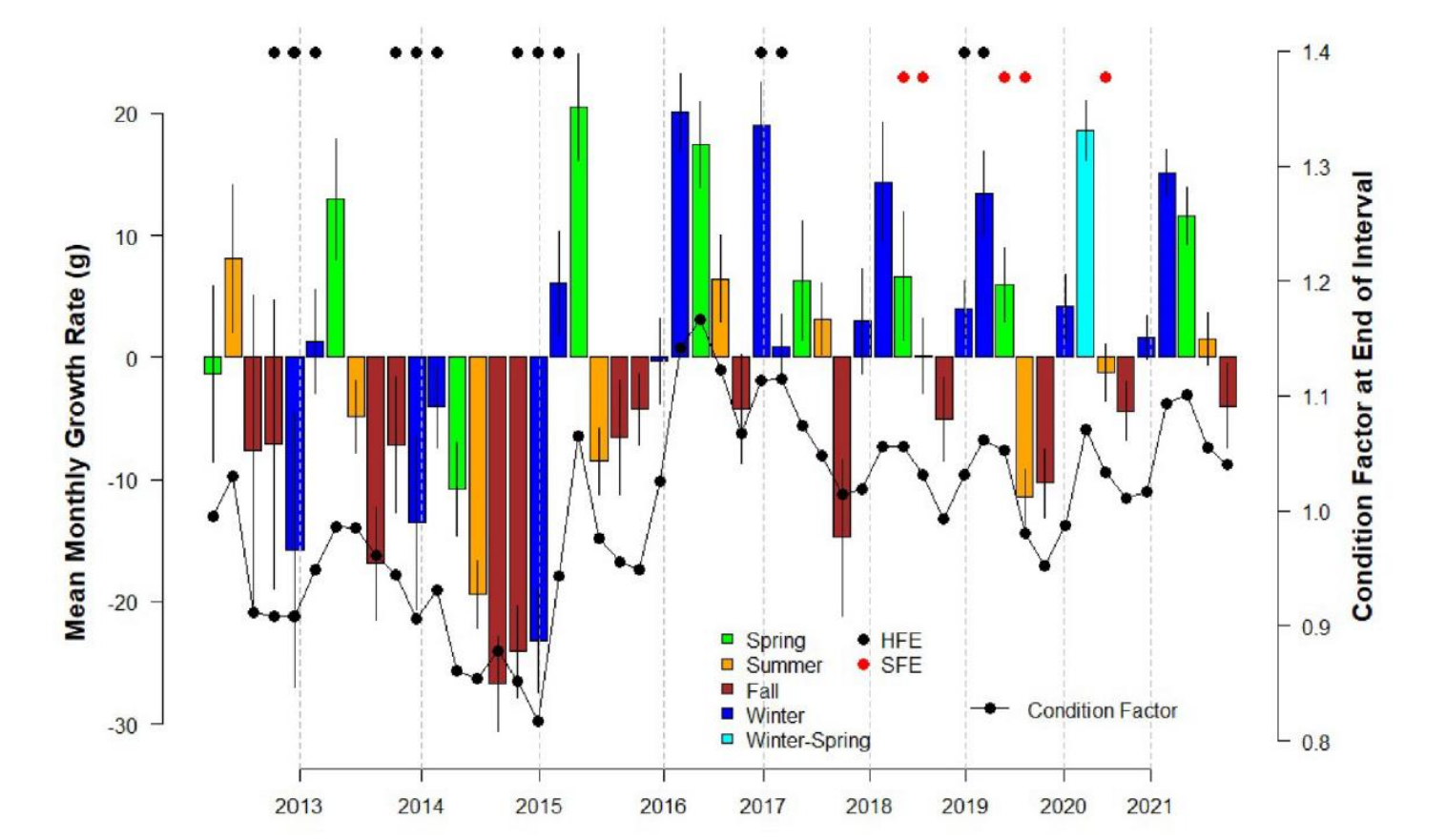
# Bug Flows And Trout Growth




- Based on NO/TRGD mark/recap studies spanning 2012-2022
- 51 seasonal growth intervals, 5 of which include Bug Flows
- Estimate marginal effect of:
  - Bug Flow, fall HFE, competition, discharge, phosphorus, P*light, and temperature

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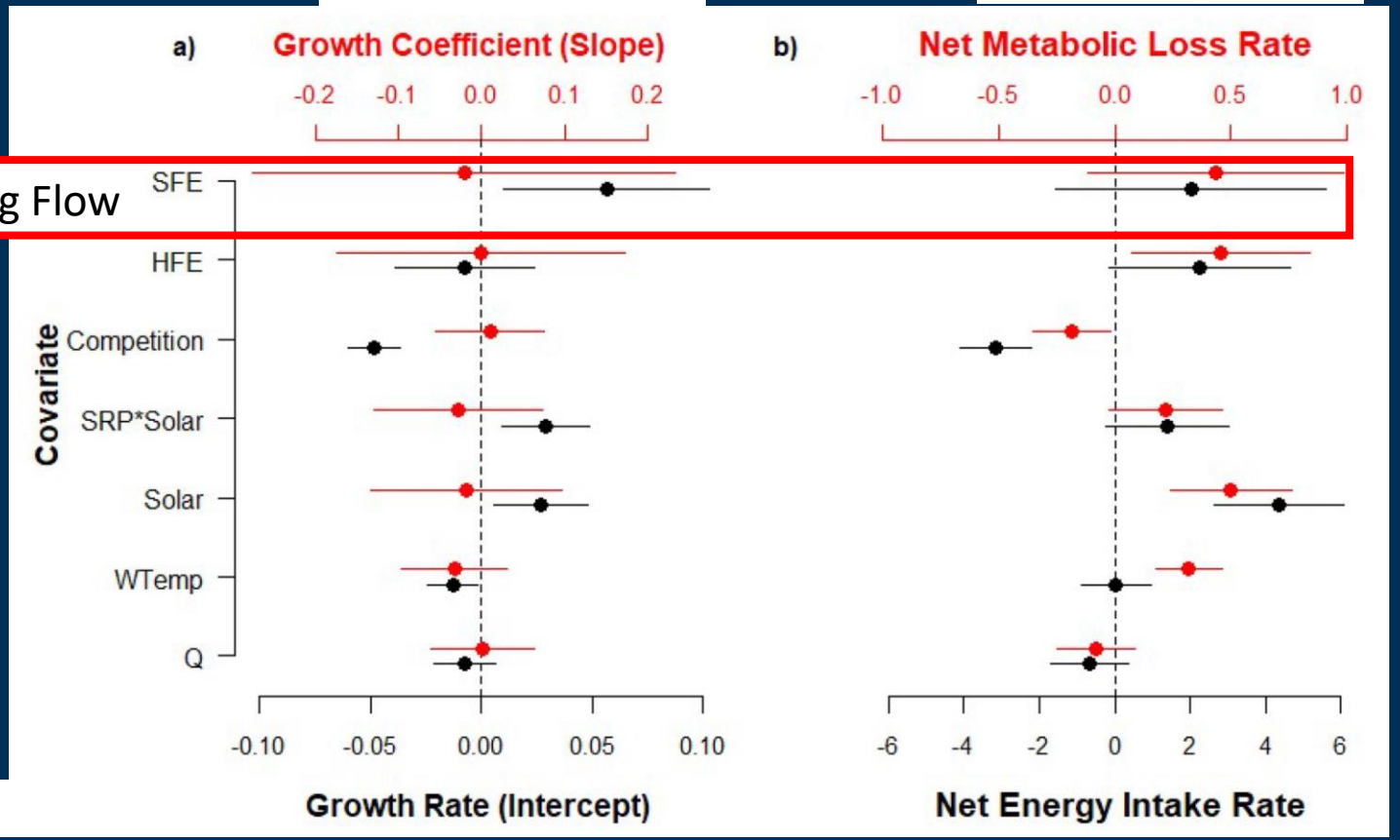
Korman, J., Deemer, B. R., Yackulic, C. B., Kennedy, T. A., & Giardina, M. (2022). Drought related changes in water quality surpass effects of experimental flows on trout growth downstream of Lake Powell reservoir. *Canadian Journal of Fisheries and Aquatic Sciences*, (ja).

# Bug Flows Increased Trout Growth

Growth in length

Growth in weight

Significant positive effect on growth in length




Estimate of growth in weight had positive sign but overlapped zero (not statistically significant)

Korman, J., and others. (2022).

"In our study, [Bug Flows] only had the potential to affect growth rates in 5 of 51 trip intervals clustered near the end of our 10 year study when spring and summer SRP levels were consistently low due to effects of a persistent drought. The resulting unbalanced design matrix led to partial confounding of SRP and SFE effects, which increased uncertainty in the SFE effect size."

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# Conclusions
## Rainbow Trout Fishery


- **Results consistent with LTEMP goal**
  - ***"Achieve a healthy high-quality recreational rainbow trout fishery in GCNRA and reduce or eliminate downstream trout migration consistent with NPS fish management and ESA compliance."***

  **Bug Flows helps achieve fishery goals by:**
    - **Improving angling**
    - **Supporting higher growth in trout length (and possibly weight)**

  - **But over range of variability (~10C!), warm water decreased growth dramatically, and Bug Flows are unlikely to offset negative effects of sustained 20+C water**

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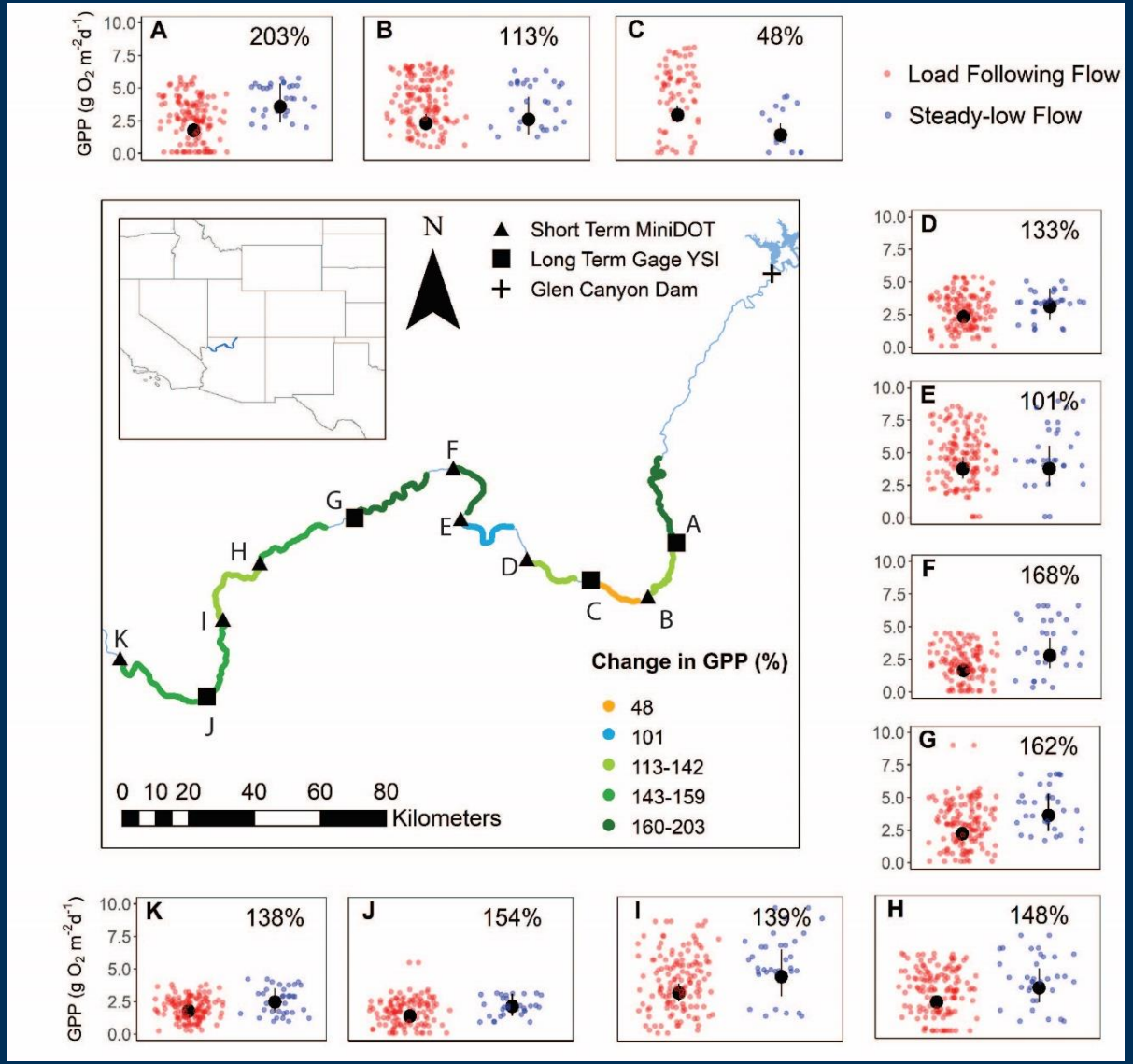
# Part II: Grand Canyon Bug Flows Increased Gross Primary Production

~58% higher GPP on Bug Flow weekends relative to hydropeaking weekday

"If increased native fish production is desired in Marble and Grand Canyons, other management actions could be considered. For example, hydroelectric power generation causes large daily changes to the Colorado River's discharge and lowers algae production relative to more stable discharges (Robert Hall, Jr., and others, unpub. data, 2013). **Thus, stabilizing the discharge regime could lead to increased algae production** at downstream sites, which may in turn have positive effects on invertebrate and fish production"
-From Kennedy and others 2013, Fact-Sheet




Deemer and others, PNAS-Nexus 2022

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# Community Science Insect Monitoring

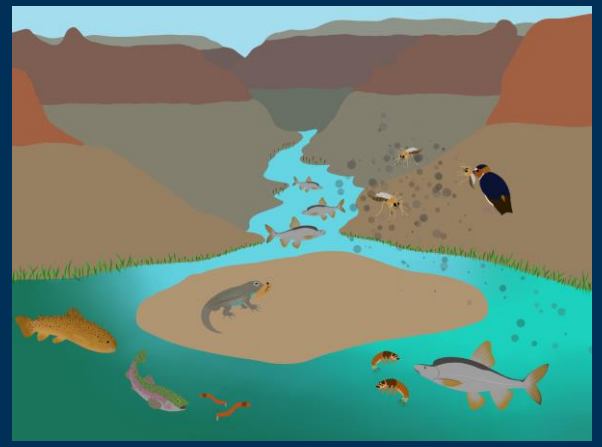
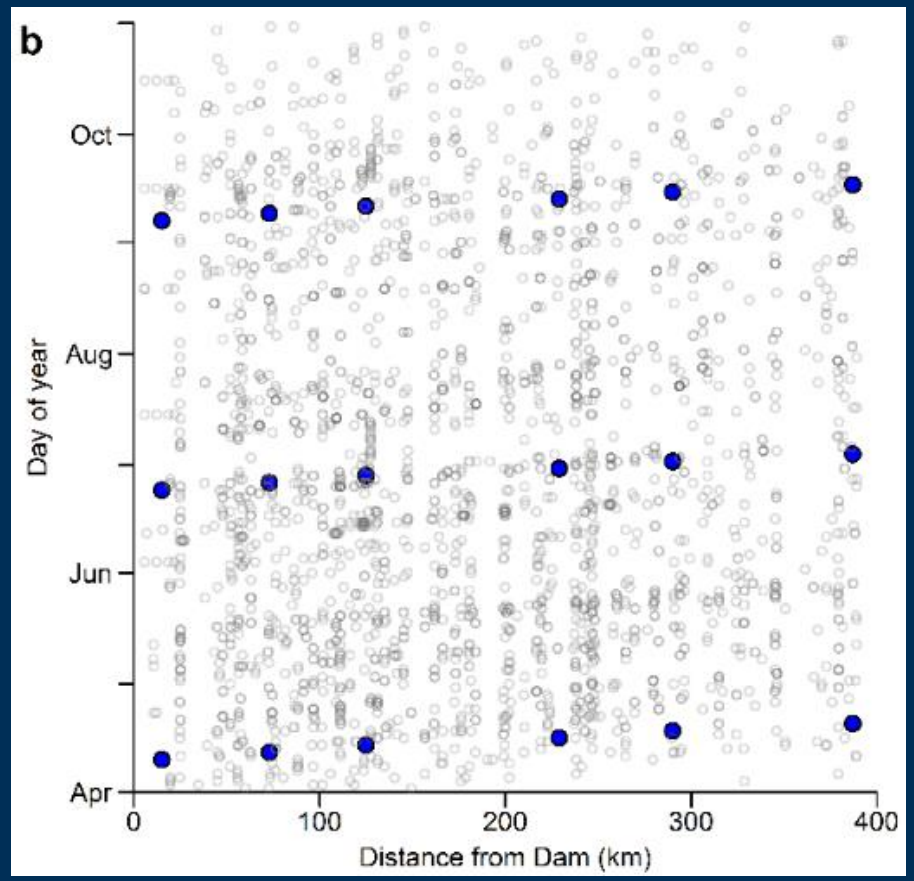


Figure courtesy of Diana Valentine




Kennedy and others 2016, Bioscience

Community science monitoring started in 2012
~750 samples of adult aquatic insects per year
Robust dataset for quantifying insect population response to Bug Flows

| Collector | 2022 samples |
|---|---|
| RoussisO | 52 |
| HanusK | 43 |
| FadeleyB | 39 |
| StalveyA | 39 |
| BurchR | 38 |
| LokeyE | 37 |
| PettyJ | 27 |
| SzydloC | 25 |
| TankersleyG | 25 |
| SiemionG | 23 |
| MacoskoC | 22 |
| PrivateBoater | 21 |
| McIntoshC | 19 |
| SaladinoE | 19 |
| FriendM | 17 |
| BadenS | 16 |
| GCY | 16 |
| KauffmanK | 15 |
| RatayR | 15 |
| GardnerT | 14 |
| WilliamsK | 14 |
| CashelK | 13 |
| KatesB | 11 |
| JenningsM | 8 |
| LouvierM | 8 |
| CatlettJ | 7 |
| MuellerK | 7 |
| ChapmanK | 6 |
| MuehlbauerJ | 5 |
| FordM | 3 |
| GCS/NAU | 3 |
| KennedyT | 3 |
| MetcalfeA | 1 |

Thank you guides and GCRG!!

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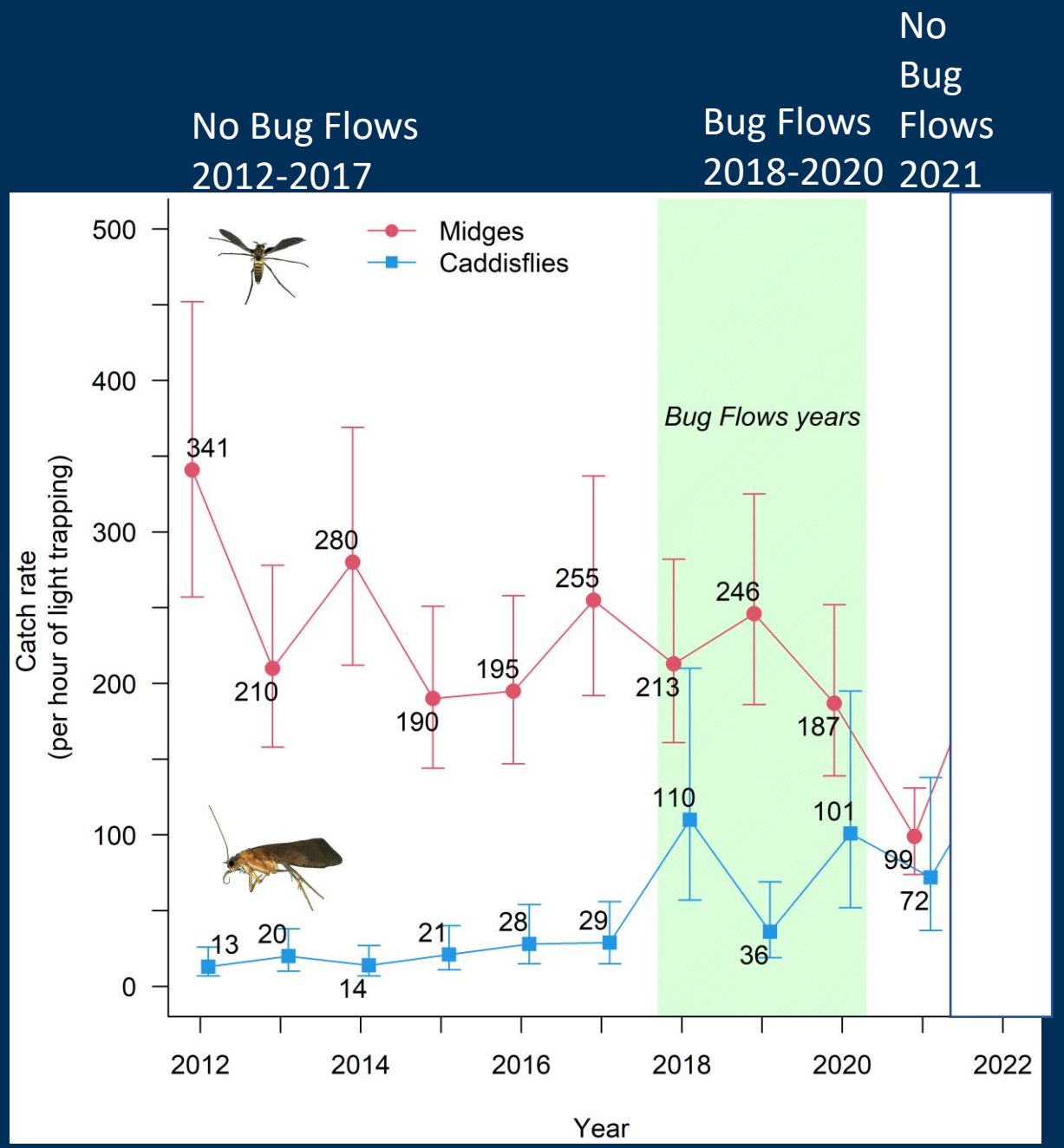
# Insect Response

- 2018-2020 Bug Flows
  - Midges: no change
  - Caddisflies: 400% increase in two of three years
- 2021 cessation of Bug Flows
  - ~50% decline in midges
  - no statistical difference in caddisflies




Estimates of annual average from mixed effects model

# Science Advisor Review, Jan 2022

- Dr. A. Ruhi: “…Bug Flows were successful, overall, in enhancing natural processes…”
- Dr. B. Downes: “Experiment successfully met proximate and ultimate objectives”
- Dr. S. Kroll: “…high likelihood the experiment has worked…”
- Dr. M. Colvin: “The Bug Flows are meeting primary and proximate objectives and the science being conducted is cutting edge.”

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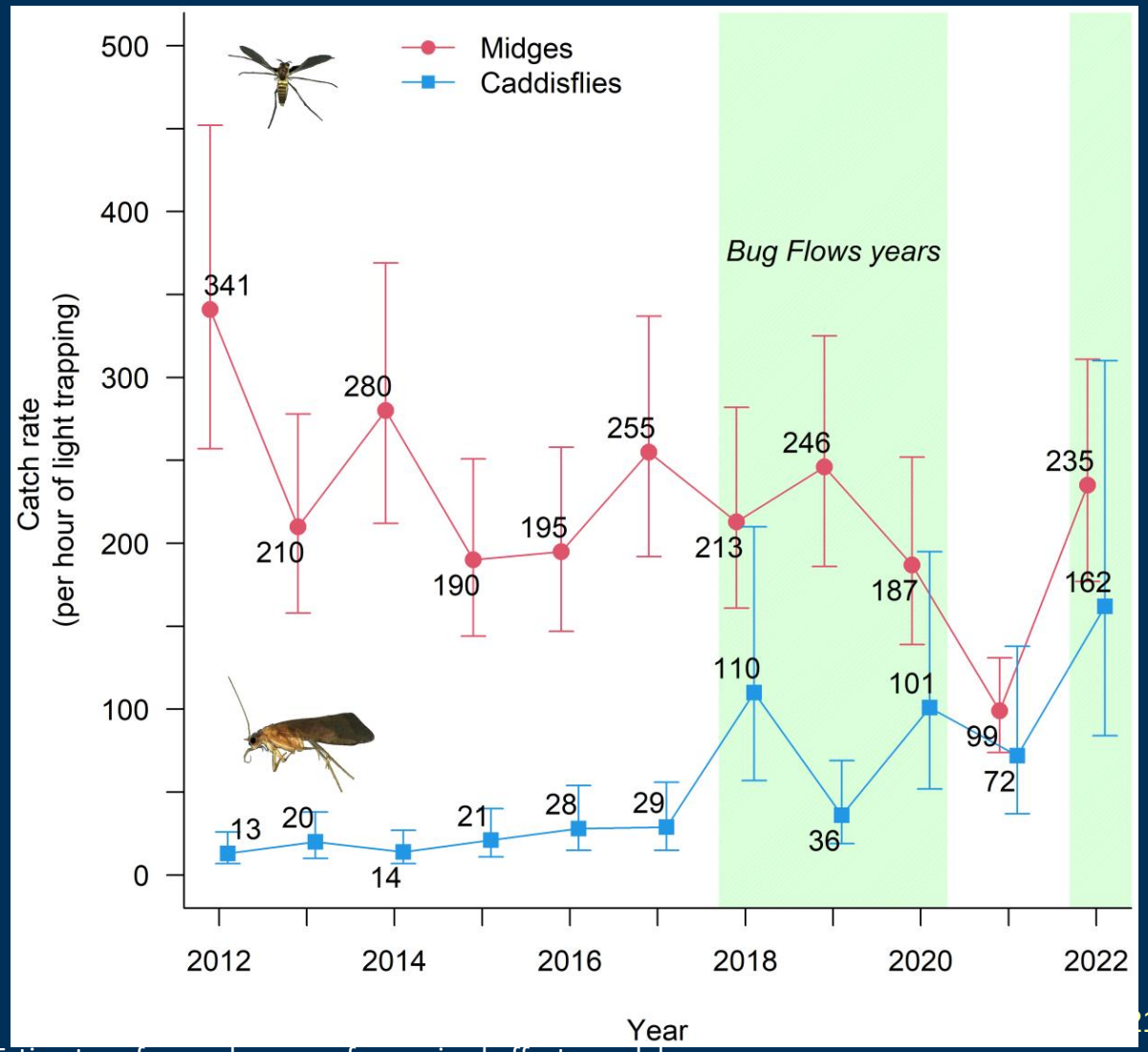
# Insect Response

- **2022 Bug Flows**
  - **137% increase in midges**
  - **125% increase in caddisflies**

**Consistent with hypothesis that Bug Flows supporting aquatic insect populations**

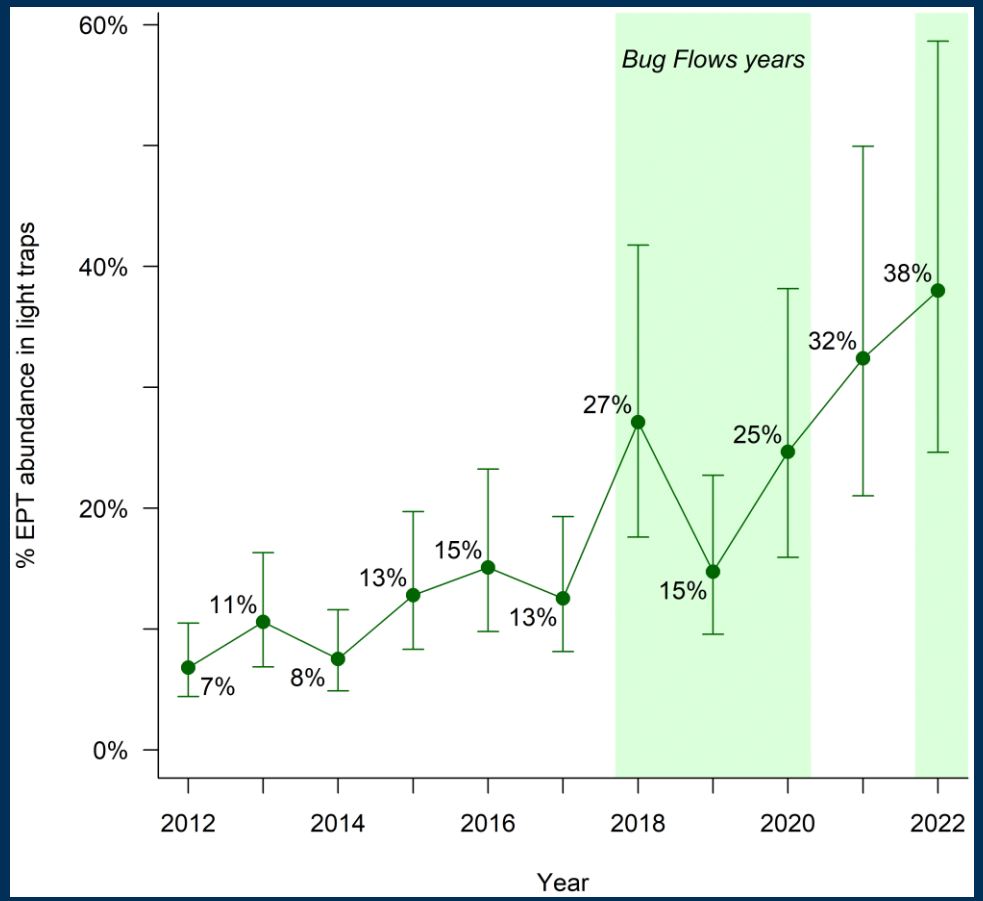
75% of samples processed (n = 457)
Unpublished data, subject to change, do not cite.

Midges significantly more abundant during Bug Flow years
Bug Flows marginal effects: z = 23.85, p < 0.001.
Estimate with Bug Flows = 220 midges/light trap
Estimate without Bug Flows = 211midges/light trap

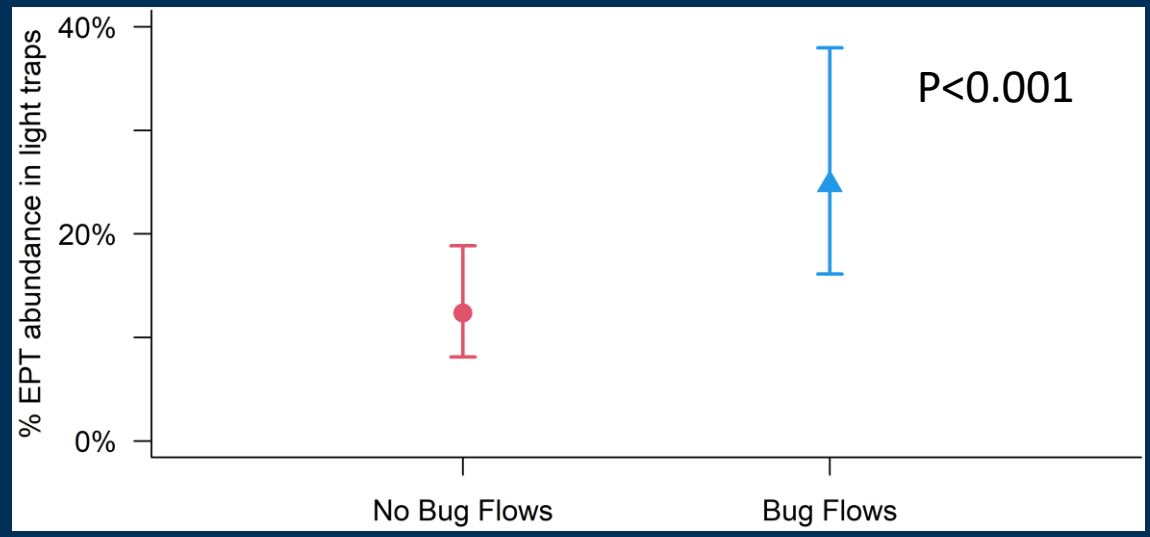



Estimates of annual average from mixed effects model

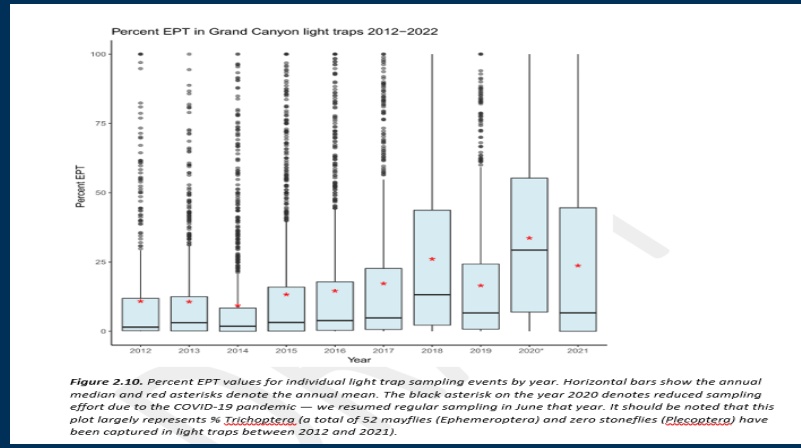
# Bug Flows Increase EPT%




EPT% = EPT in sample/Total aquatic insects in sample




Significantly higher EPT% in Bug Flow years




EPT% graph shown in June 2022 & March 2023 Metrics report

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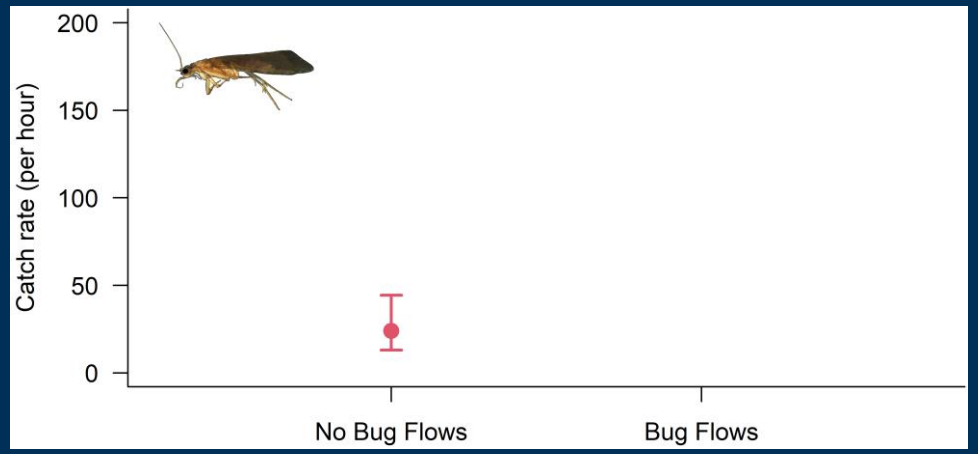
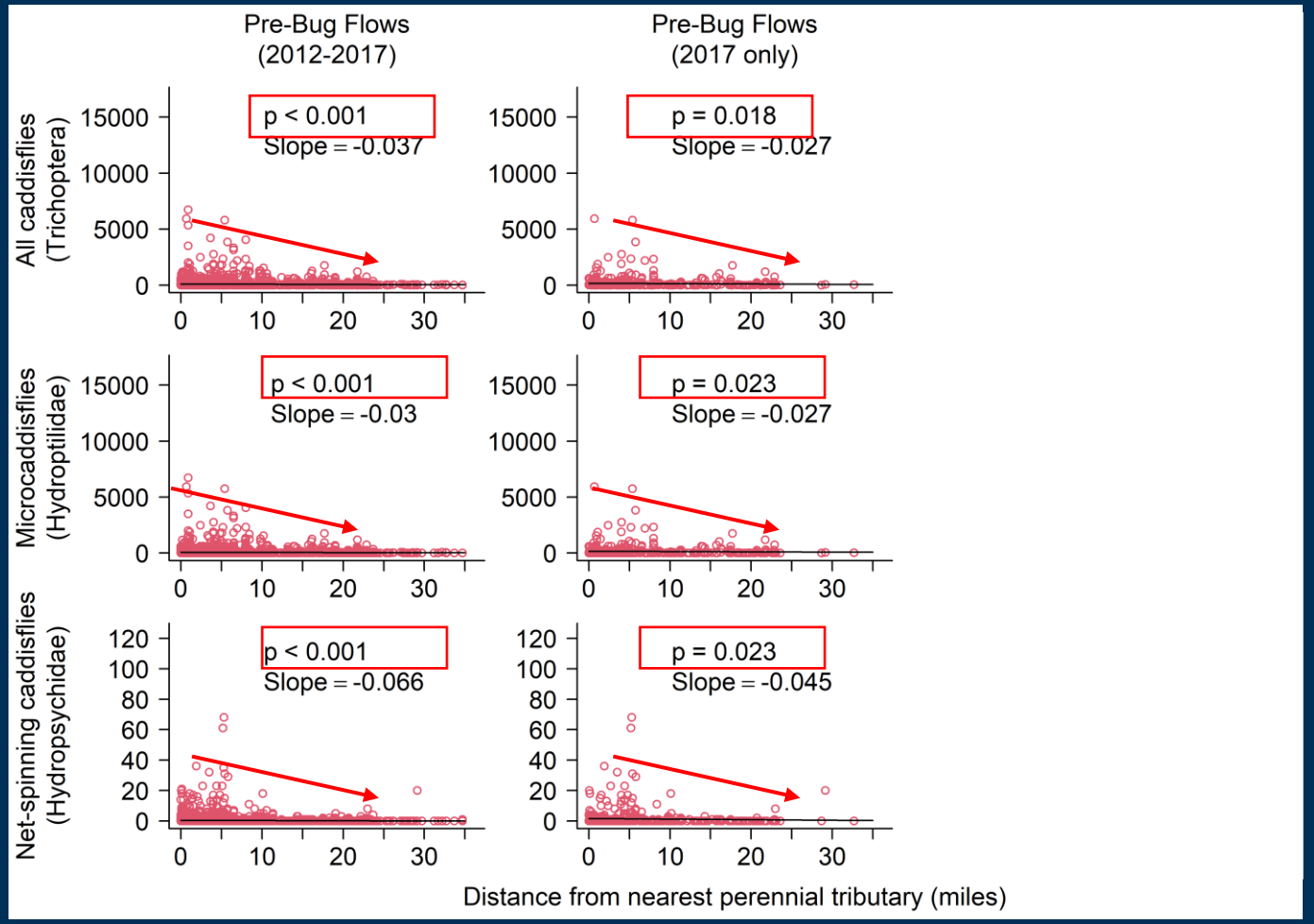
Unpublished data, subject to change,
do not cite.

# Pre-Bug Flows, Caddisflies Tied To Tributaries




"The abundance of microcaddisflies was generally low throughout the Grand Canyon and declined precipitously with distance from tributaries…This suggests that microcaddisflies are not well established in the mainstem Colorado River and that the majority of adult microcaddisflies captured in light traps actually dispersed from tributaries that do support diverse aquatic-insect populations (Oberlin et al. 1999)."
-Kennedy and others 2016, Bioscience

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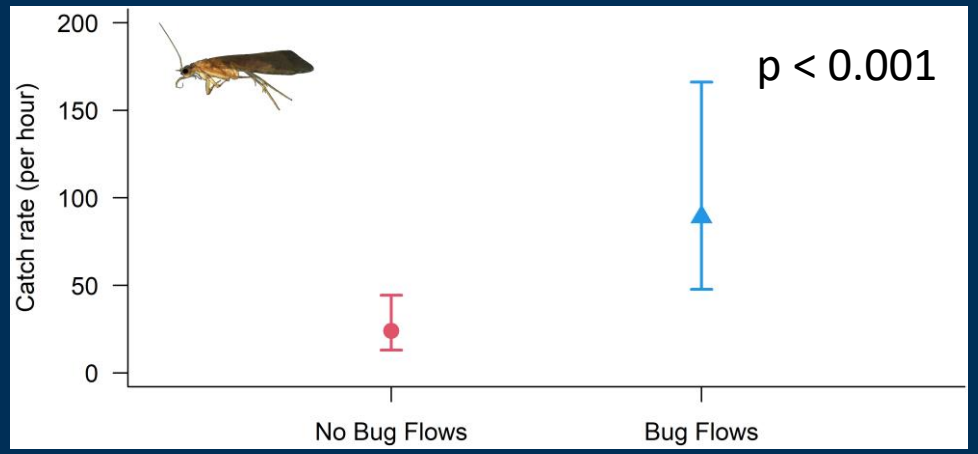
# Caddisflies Increase With Bug Flows, No Longer Tied To Tributaries

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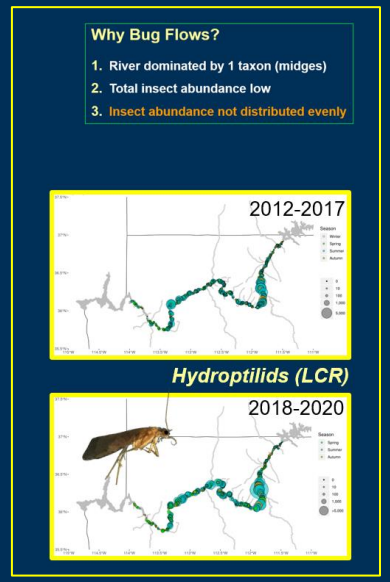
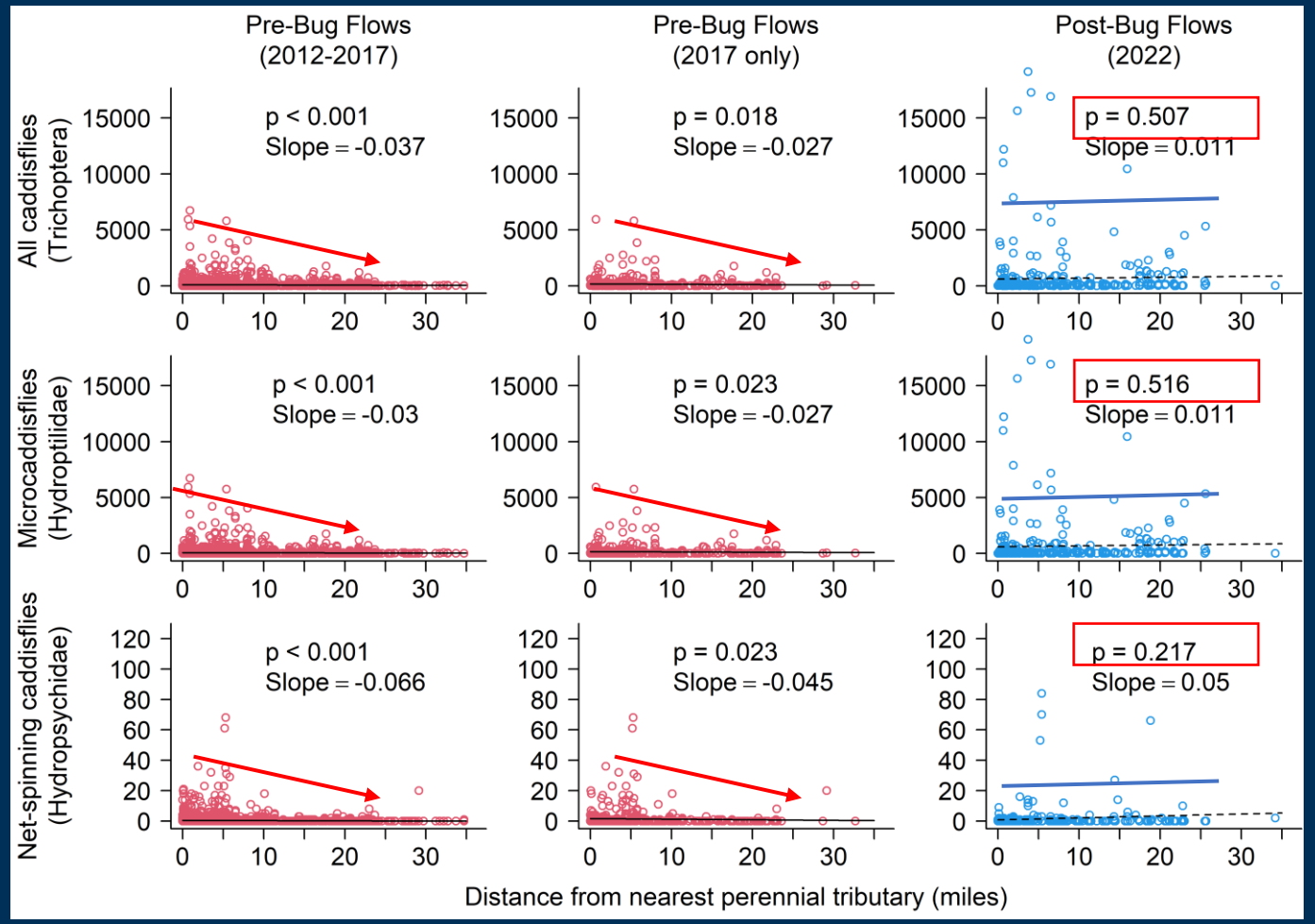
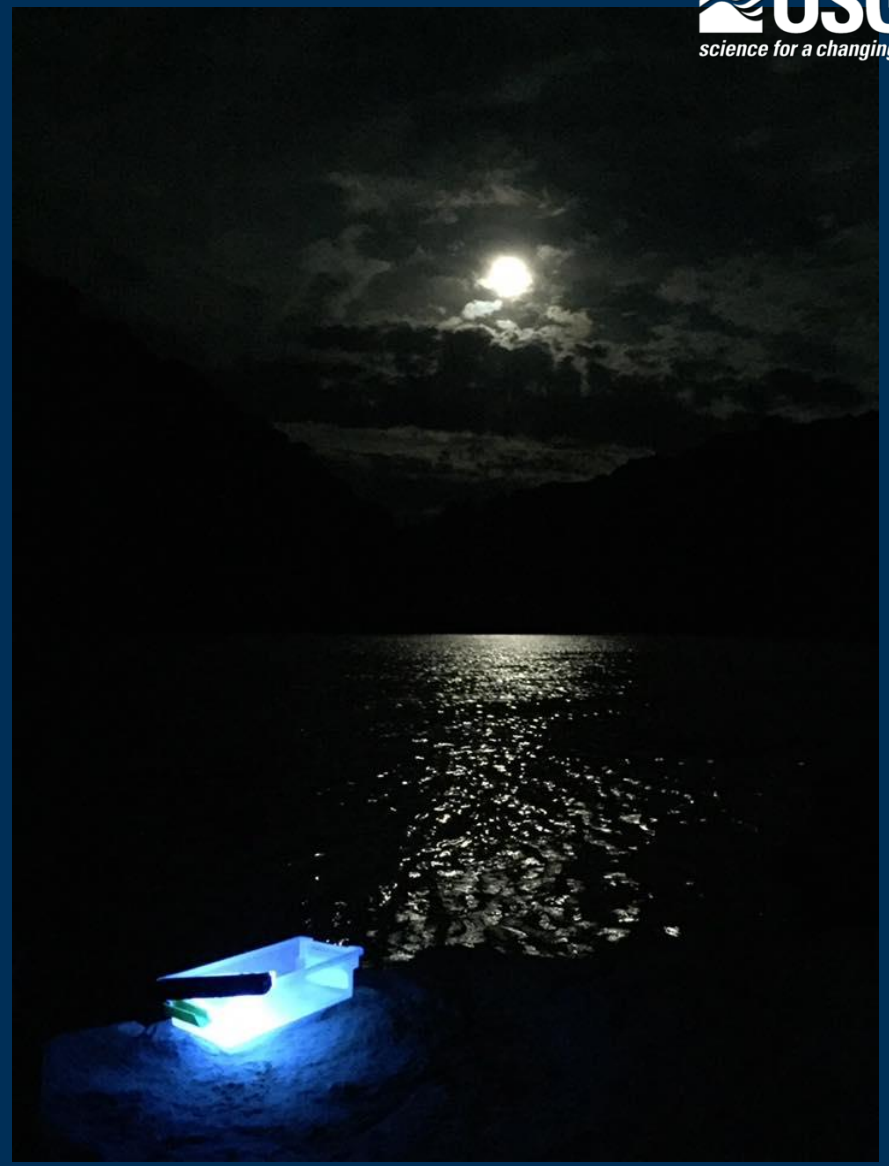



Maps showing caddisfly distribution from Jan 2021 ARM presentation



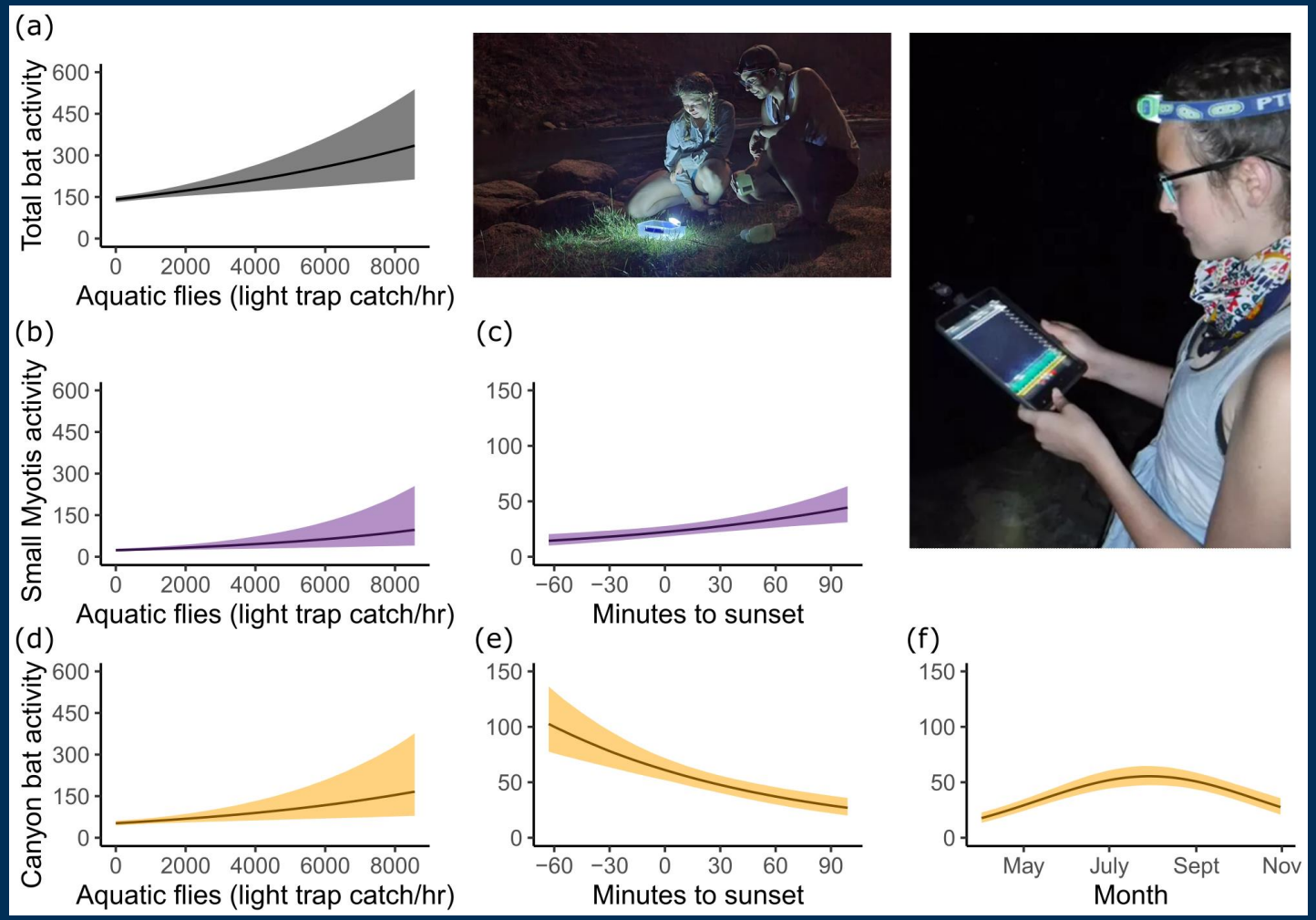
# Bug & Bat sampling 2017-2020

- 1,428 paired bug and bat samples between 2017-2020
- 611 unique sampling dates
- 46+ participants
- modeled 12 different physical and temporal variables
- modeled 7 different prey categories



Metcalfe, Anya N., Carol A. Fritzinger, Theodore J. Weller, Michael J. Dodrill, Jeffrey D. Muehlbauer, Charles B. Yackulic, P. Brandon Holton et al. "Insectivorous bat foraging tracks the availability of aquatic flies (Diptera)." *The Journal of Wildlife Management* (2023): e22414.

# Aquatic Flies (midges) Best Predictor Of Bat Activity







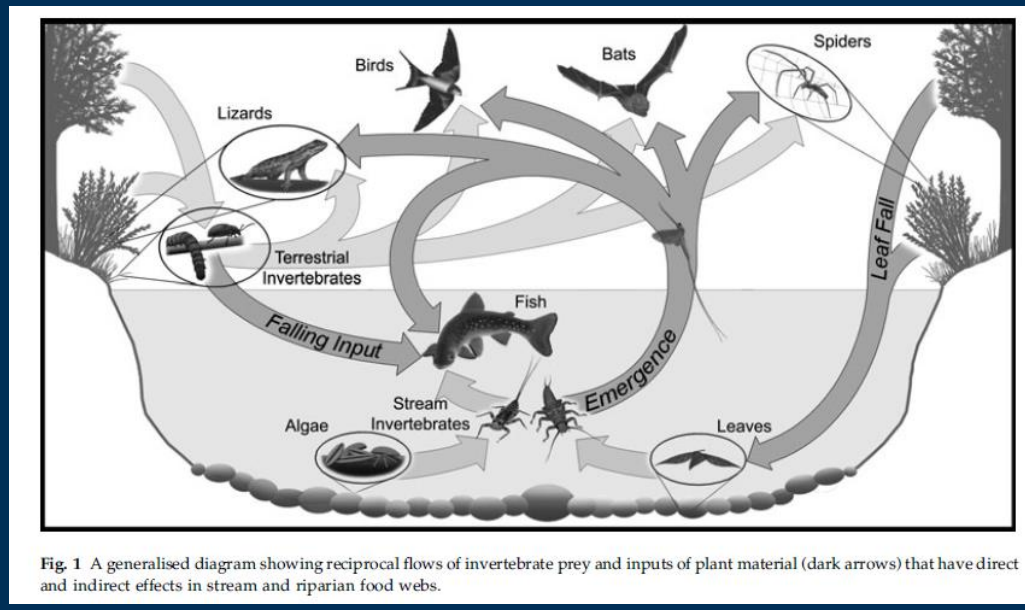




Fig. 1 A generalised diagram showing reciprocal flows of invertebrate prey and inputs of plant material (dark arrows) that have direct and indirect effects in stream and riparian food webs.

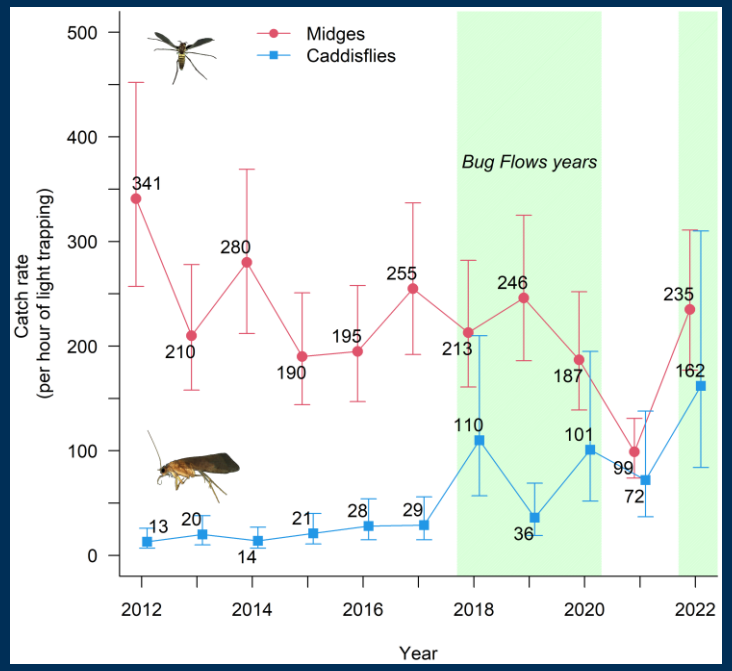
Insects play critical role in river food webs; Baxter and others 2005

USGS

Metcalfe, Anya N., Carol A. Fritzinger, Theodore J. Weller, Michael J. Dodrill, Jeffrey D. Muehlbauer, Charles B. Yackulic, P. Brandon Holton et al. "Insectivorous bat foraging tracks the availability of aquatic flies (Diptera)." *The Journal of Wildlife Management* (2023): e22414.

# Conclusions

- **Bug Flows temporarily restores discharge to natural range of variability (no tides) thereby enhancing natural processes that sustain aquatic insect populations and the Colorado River ecosystem**

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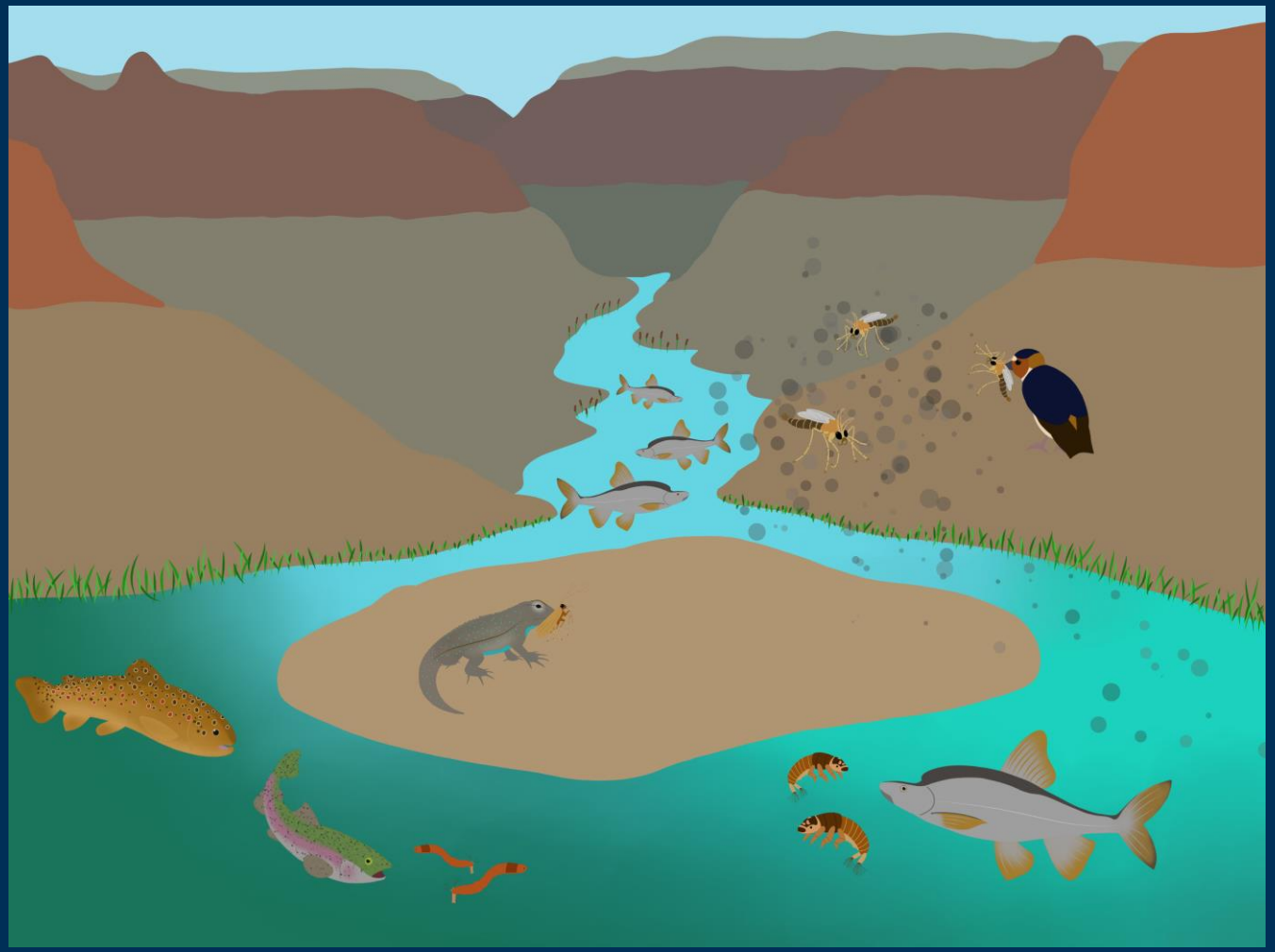

Conceptual model of select Natural Processes
at the Little Colorado River confluence
Figure courtesy of Diana Valentine