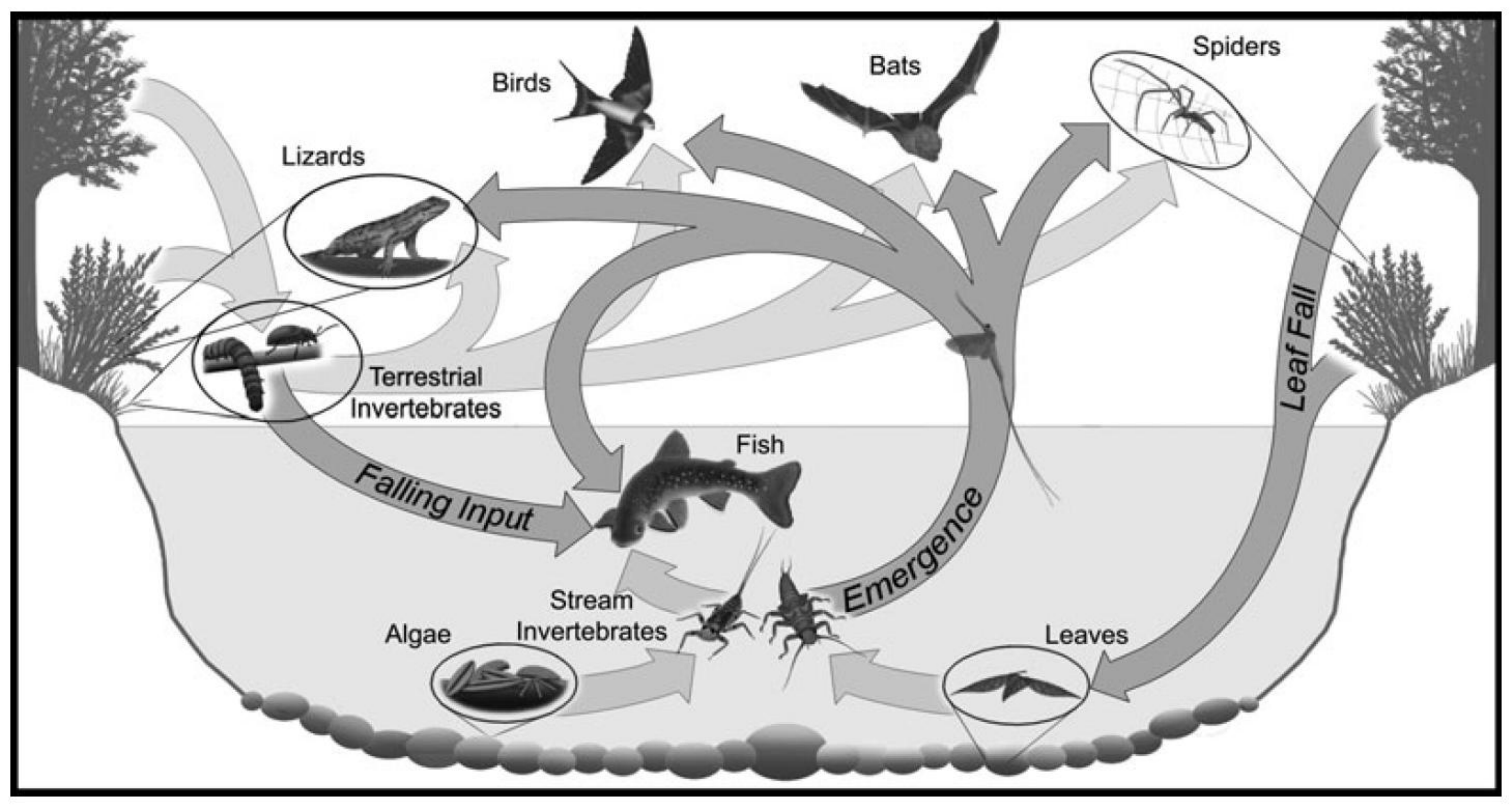
Drivers of food base diversity and productivity

LTEMP 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.



From: Baxter, C. V., Fausch, K. D., & Carl Saunders, W. (2005). Tangled webs: reciprocal flows of invertebrate prey link streams and riparian zones. Freshwater biology, 50(2), 201-220.

Ted Kennedy, Eric Scholl, Kate Behn, Anya Metcalfe,

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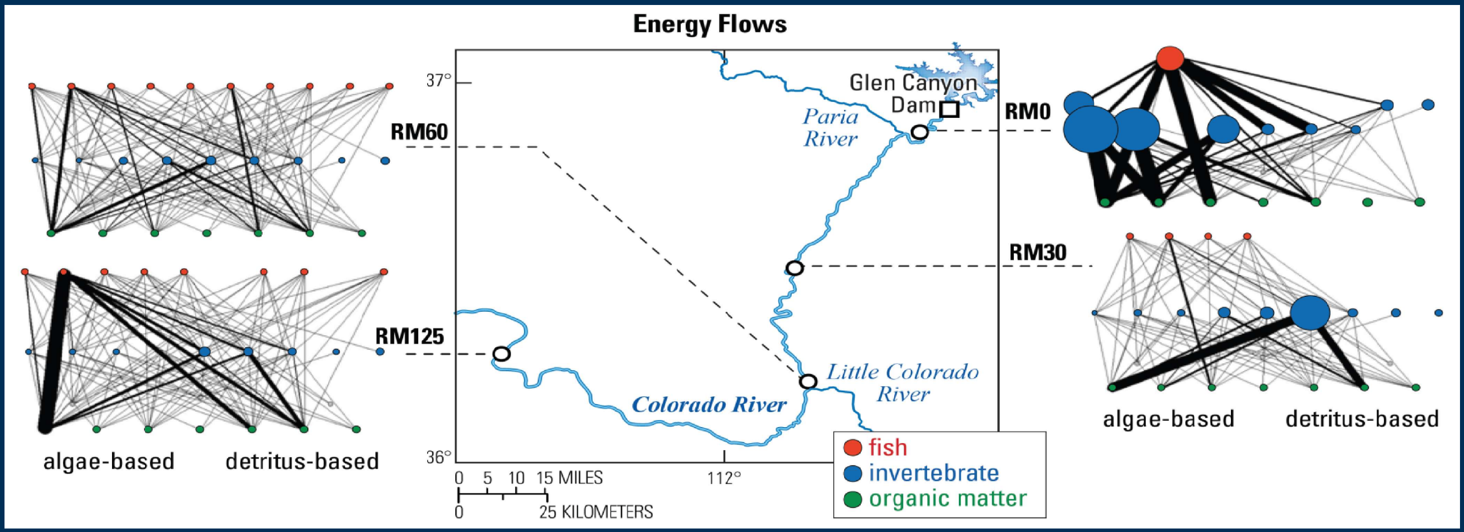
Outline

- Background--Food web studies (2 slides)
- Constraints on insect diversity & production (2 slides)
- Monitoring insects in a massive ecosystem (1 slide)
- Bug Flow Experiment
  - Annual abundance (3 slides)
  - Spatial patterns (5 slides)
  - Phenology & Body size (4 slides)
- Conclusions (1 slide)

Food web studies (2006-2009)

From: Kennedy, T. A., and others (2013). Native and nonnative fish populations of the Colorado River are food limited--evidence from new food web analyses (No. 2013-3039). US Geological Survey.

- Primary prey–aquatic insects
- Simplified food webs, unstable
- Food webs built upon algae



Rainbow Trout

Humpback Chub


Flannelmouth Sucker

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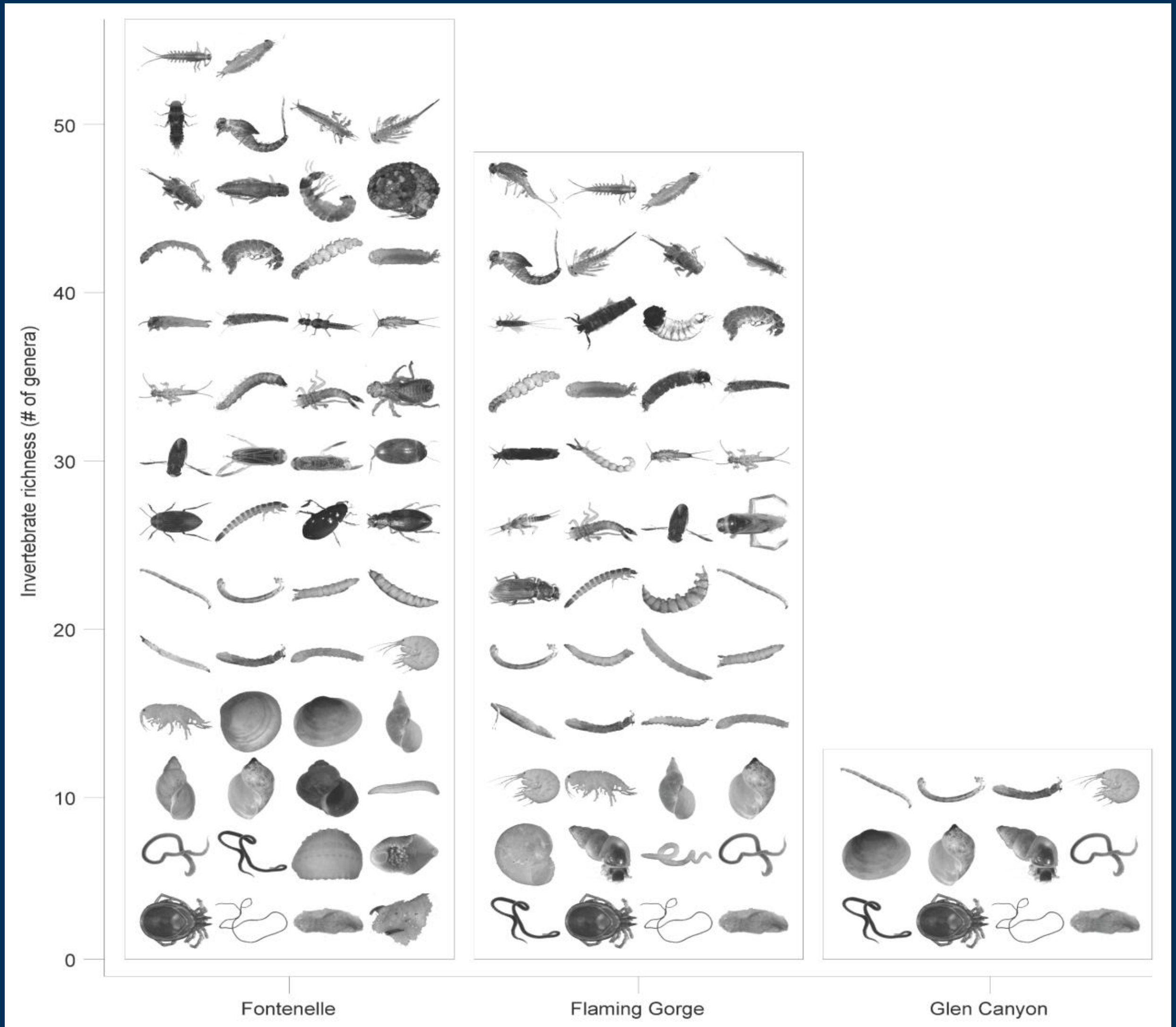
Insect diversity & river health

- Virtually no sensitive insect species (mayflies, stoneflies, caddisflies = EPT)
  - EPT species are ubiquitous in “reference” or analogs including:
    - Cataract Canyon
    - San Juan River
    - Flaming Gorge tailwater
    - Grand Canyon tributaries



From: Kennedy, Theodore A., et al. "Flow management for hydropower extirpates aquatic insects, undermining river food webs." BioScience 66.7 (2016): 561-575.

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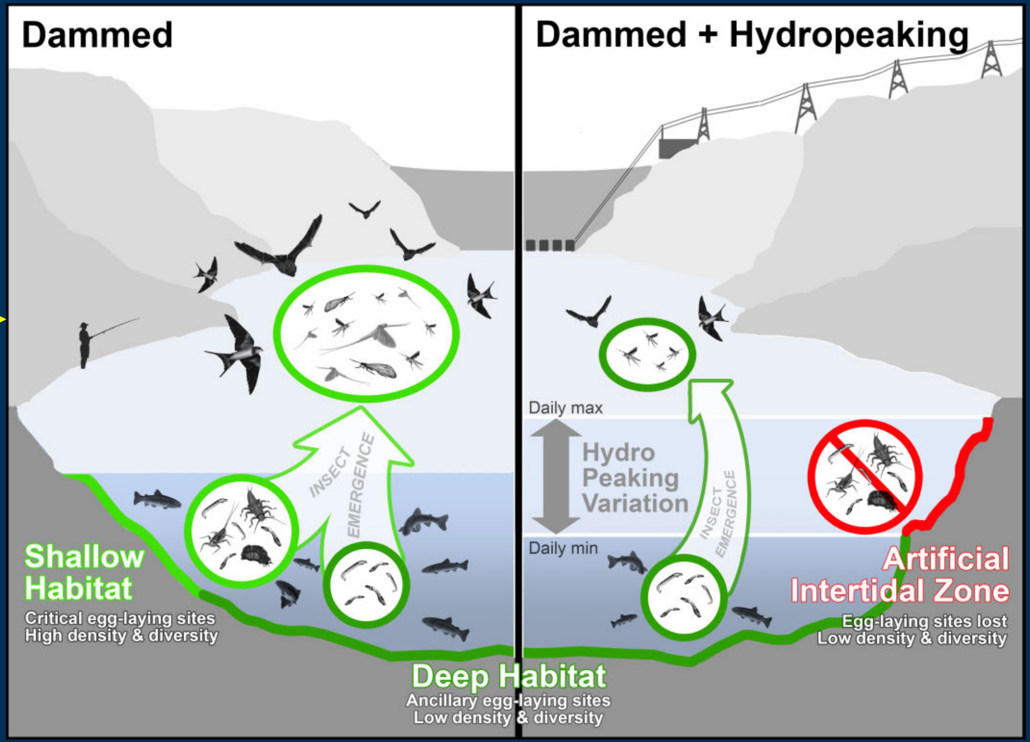
What constrains insect diversity downstream of Glen Canyon Dam?

- Dam closure and operations creates new physical template → extirpates species
  - Flow regimes
    - Tides will disproportionately affect EPT species, greatly limiting their recruitment
      - 2016 Bioscience paper showed this
    - Spring flooding eliminated
      - See Natural Processes Poster
  - Colder temperature regimes
  - Sediment regimes
    - Changing habitat conditions
    - See posters by Larry Stevens

- Dispersal limitation prevents, or slows, colonization by species that are tolerant of current conditions
  - UPSTREAM colonization rates for aquatic insects are glacial compared to fish



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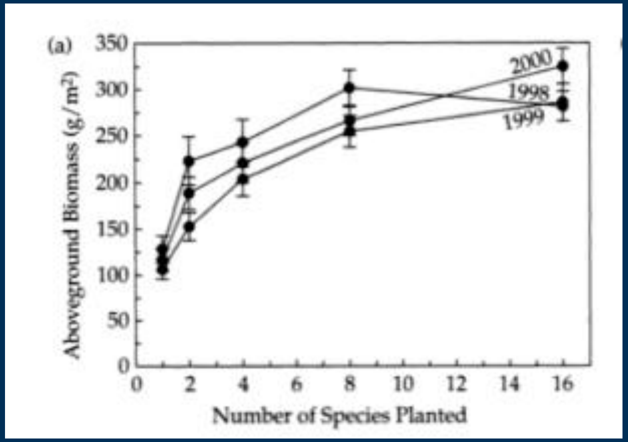
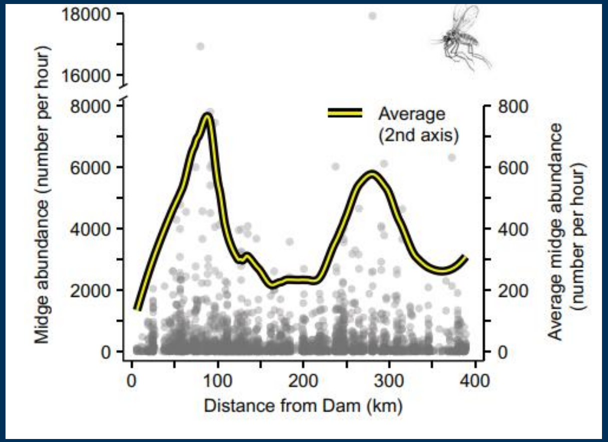
What constrains insect production downstream of Glen Canyon Dam?

- Low diversity
  - Species richness drives productivity
- Low phosphorus/nutrients
  - See papers by Deemer; Korman; Yard
- Flow regimes
  - Tides→ abundance
    - 2016 Bioscience paper showed this
- Habitat quality
- Turbidity
- Etc, etc
- This list is much longer in my opinion…

Experimental gardens



From: Tilman, D. J. D. P. M., et al. "Plant diversity and composition: effects on productivity and nutrient dynamics of experimental grasslands." Biodiversity and ecosystem functioning: synthesis and perspectives. Oxford University Press, Oxford, UK (2002): 21-35.



From: Kennedy, Theodore A., et al. "Flow management for hydropower extirpates aquatic insects, undermining river food webs." BioScience 66.7 (2016): 561-575.

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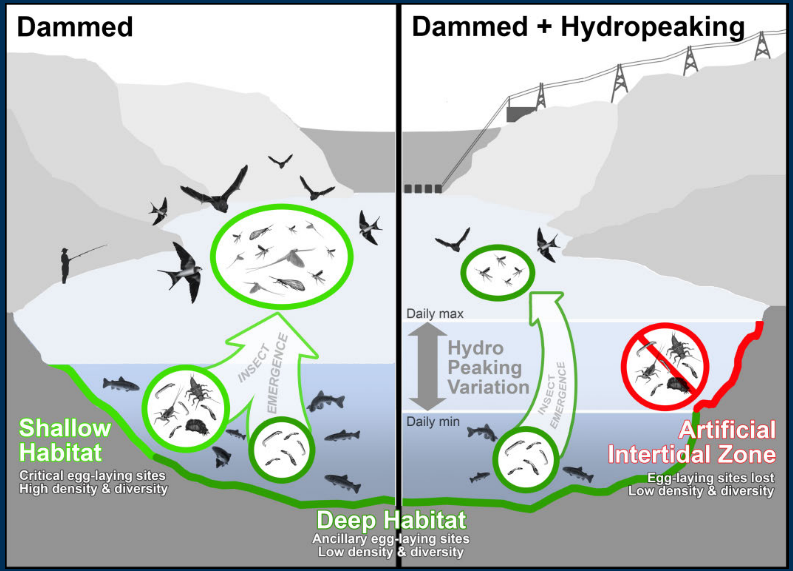
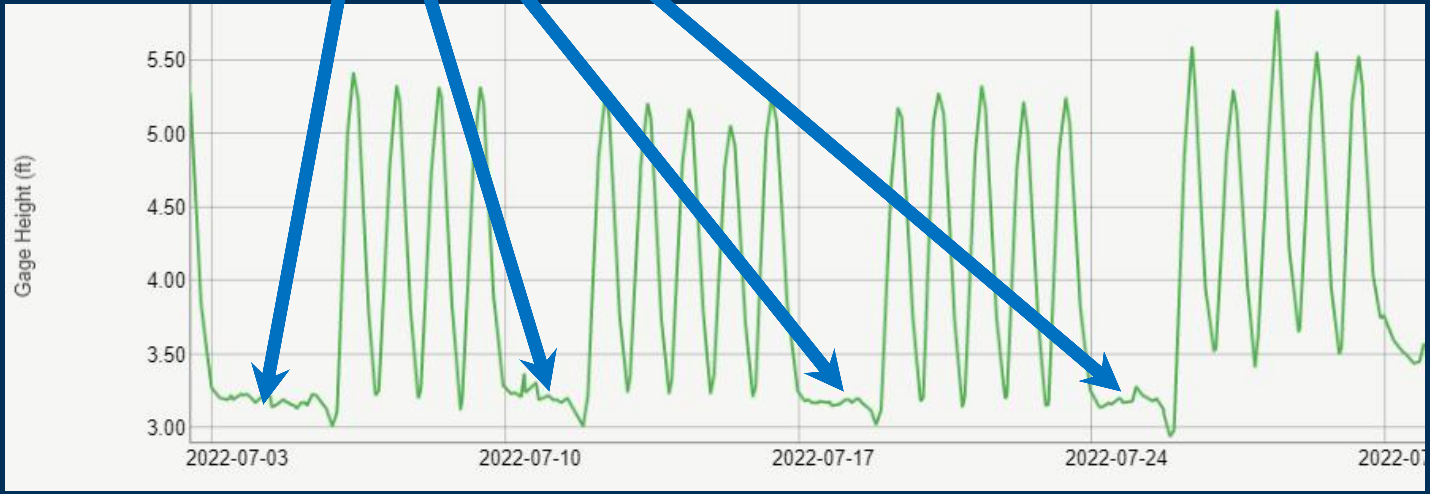
Bug Flows

- Give bugs the weekends off
- Weekend stable low flows from May-August
  - Experiment tested 2018-2020 & 2022



From: Kennedy, Theodore A., et al. "Flow management for hydropower extirpates aquatic insects, undermining river food webs." BioScience 66.7 (2016): 561-575.

- Eggs laid on weekends never dry



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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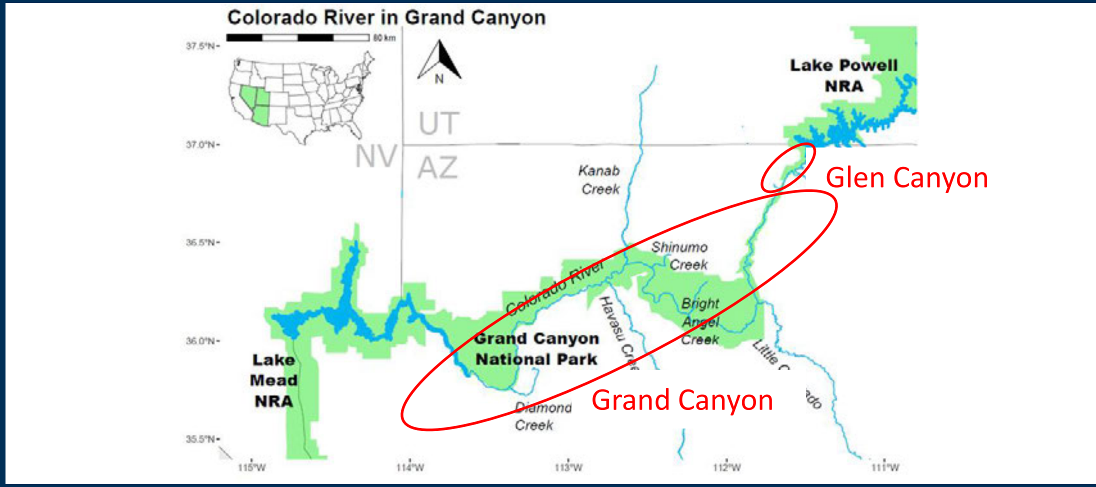
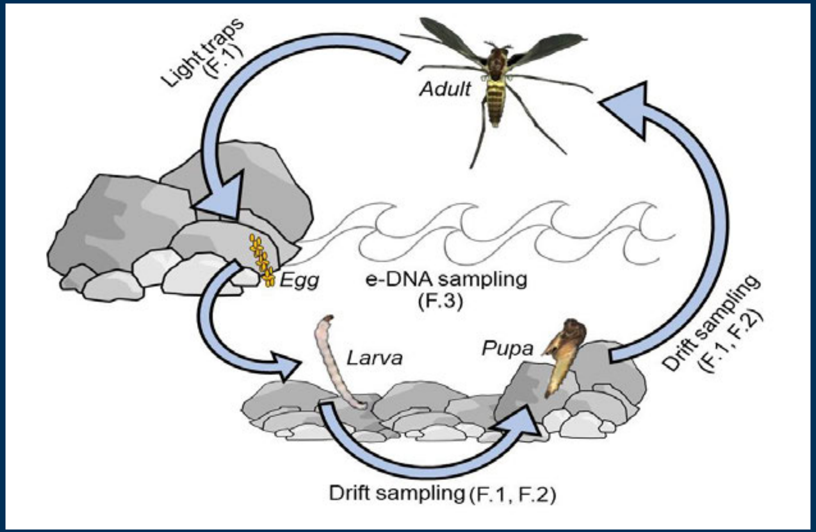
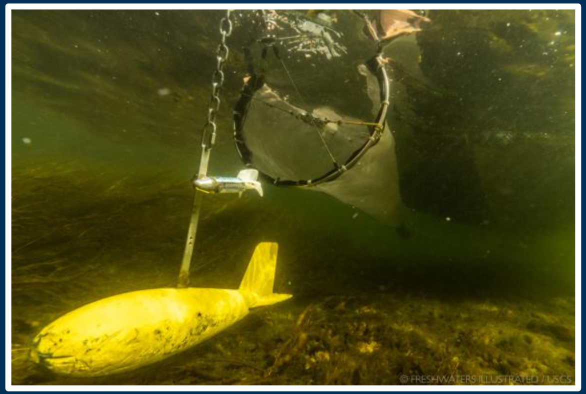
Monitoring the invertebrate prey base in a massive ecosystem



Aquatic insects have complex lifecycles



Approaches we use to monitor invertebrate populations

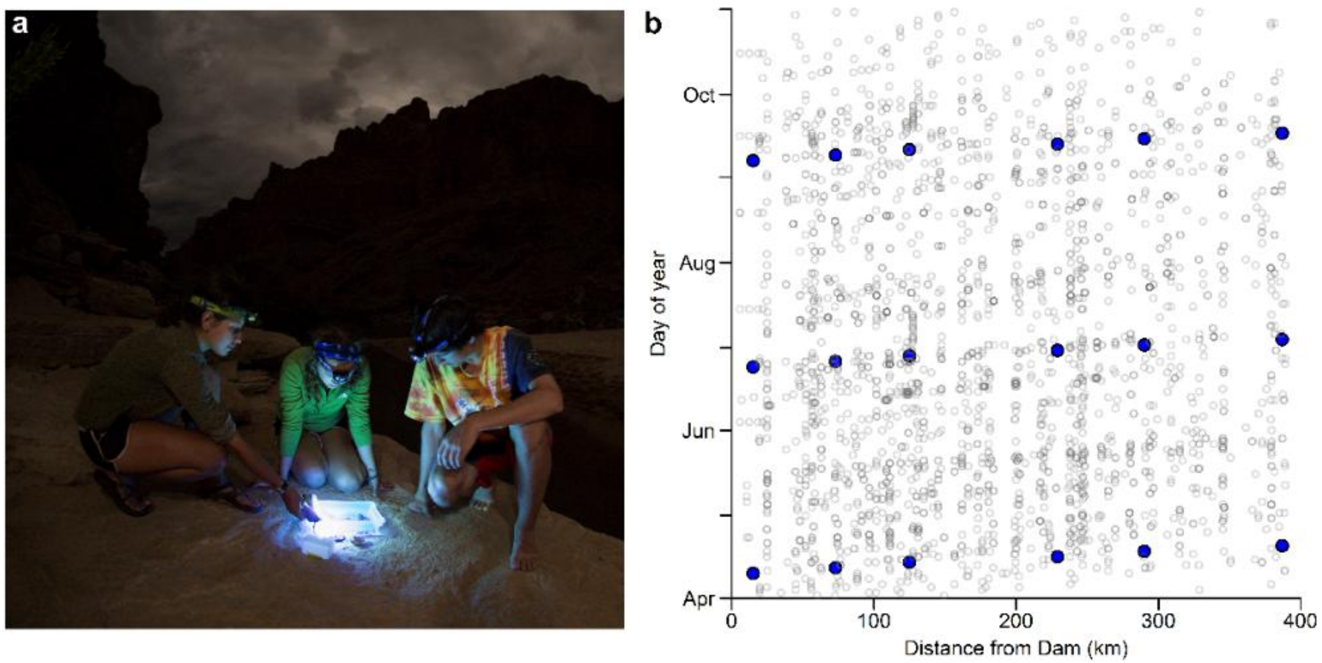


Drift sampling of larvae and adults
Glen Canyon only: 2008- present

Citizen science light trapping of adults
Grand Canyon only: 2012-present

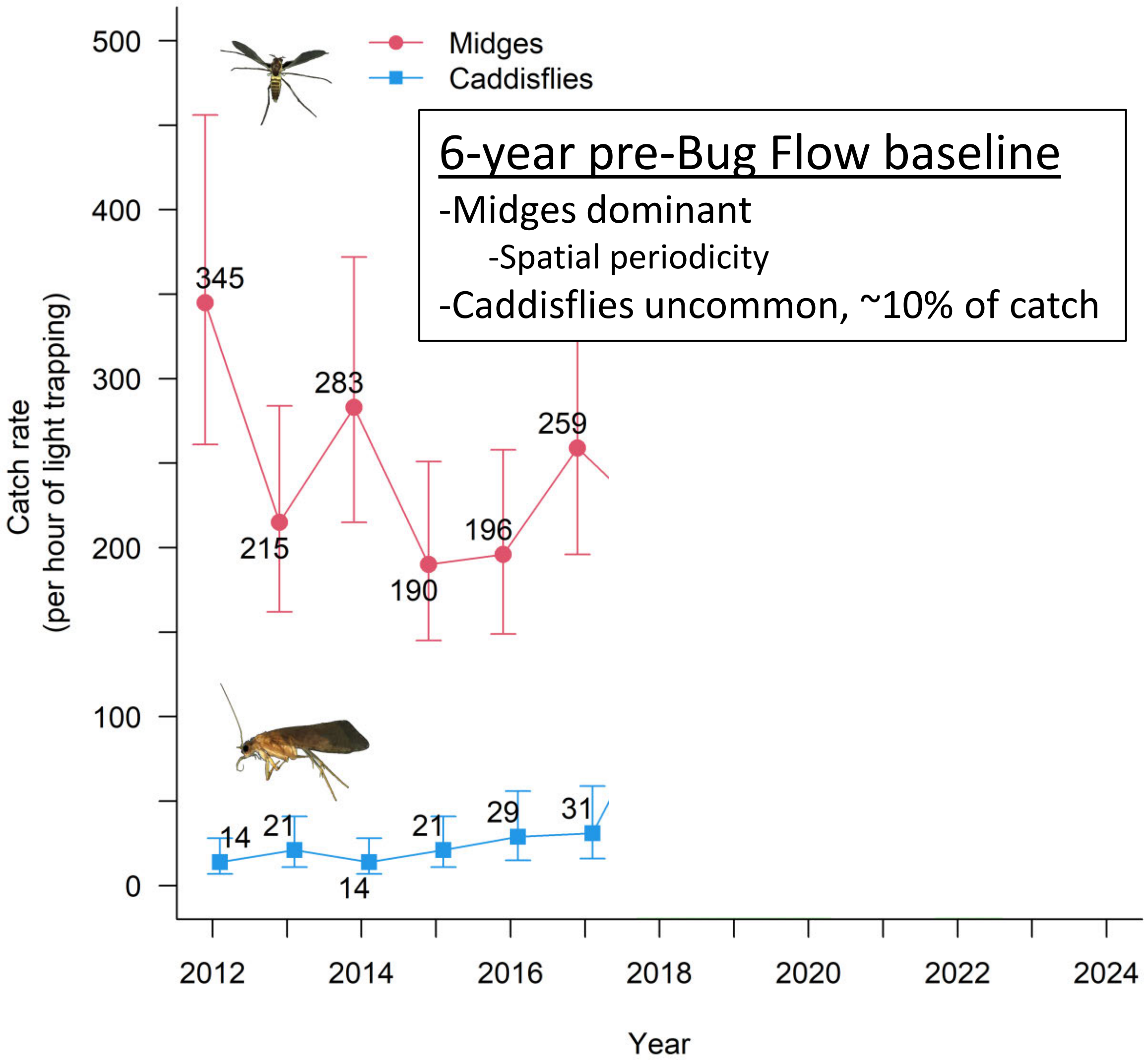
eDNA sampling
Glen and Grand Canyon: 2021-present
(see next talk)

Citizen Science Insect Monitoring



From: Kennedy, T. A., Muehlbauer, J. D., Yackulic, C. B., Lytle, D. A., Miller, S. W., Dibble, K. L., ... & Baxter, C. V. (2016). Flow management for hydropower extirpates aquatic insects, undermining river food webs. BioScience, 66(7), 561-575.

	Count	Percent of total
Total Catch		
Glen & Grand Canyon, Aquatic + Terrestrial	5,648,420	100%
Aquatic	4,548,272	81%
Chironomidae (midges)	2,546,253	45%
Trichoptera (caddisflies)	1,886,086	33%
Hydroptilidae (micro-caddisfly)	1,797,484	32%
Hydropsychidae (net-spinning caddisfly)	14,962	0.3%



Preliminary Information-Subject to Revision.
Not for Citation or Distribution.

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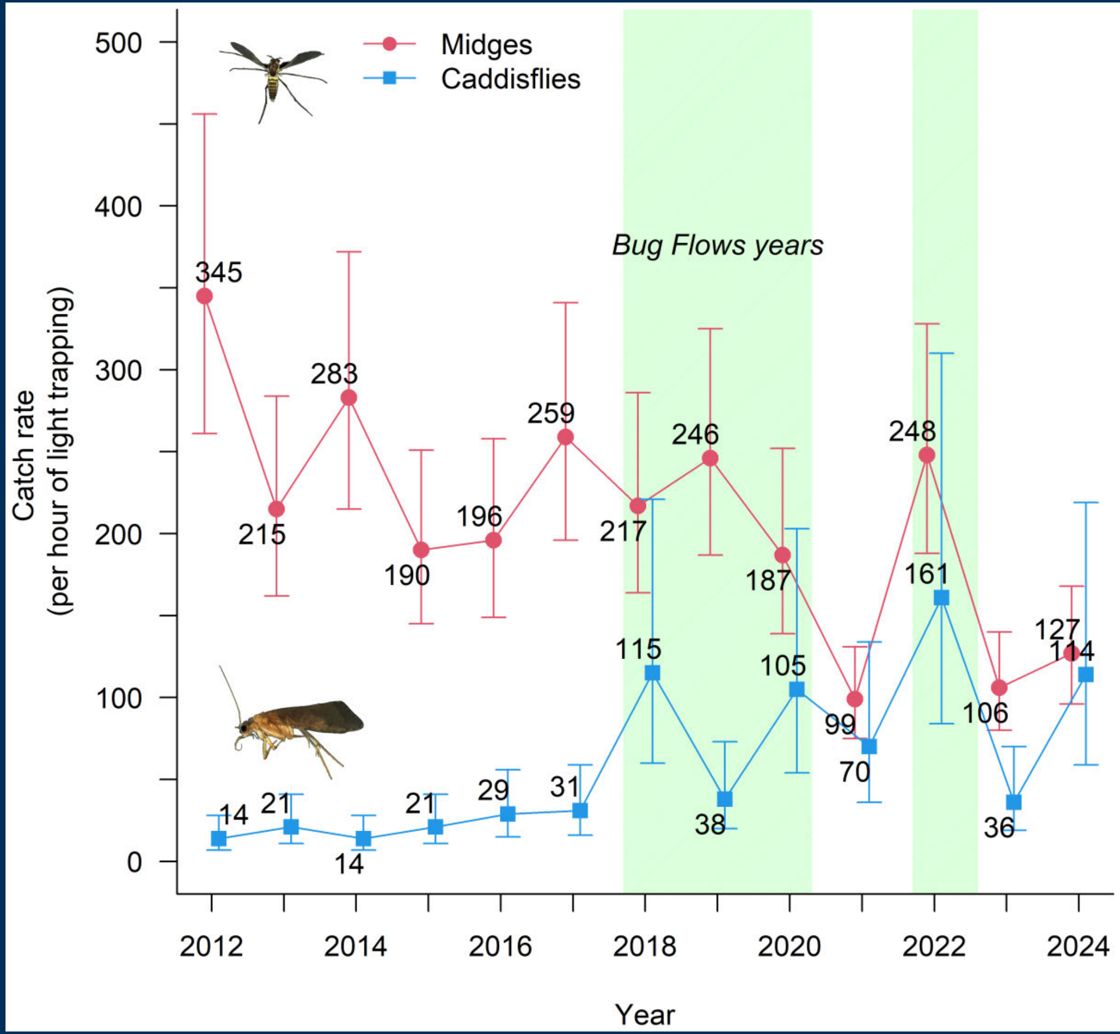
As of 2024…
Higher adult aquatic insect abundance with Bug Flows



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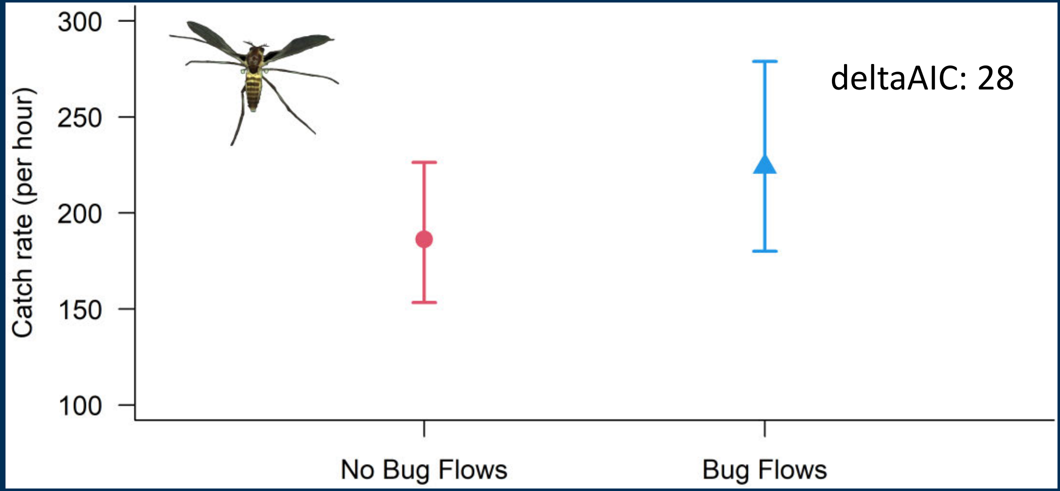
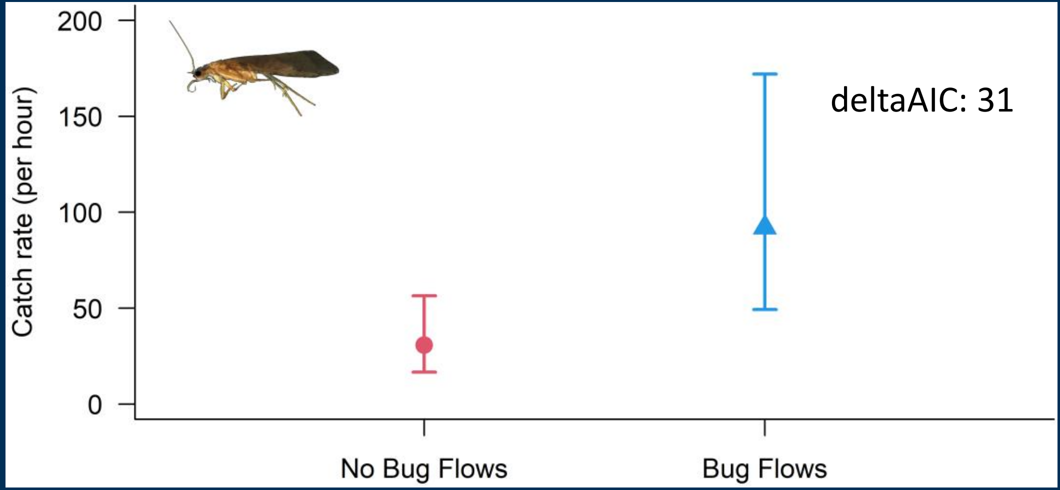
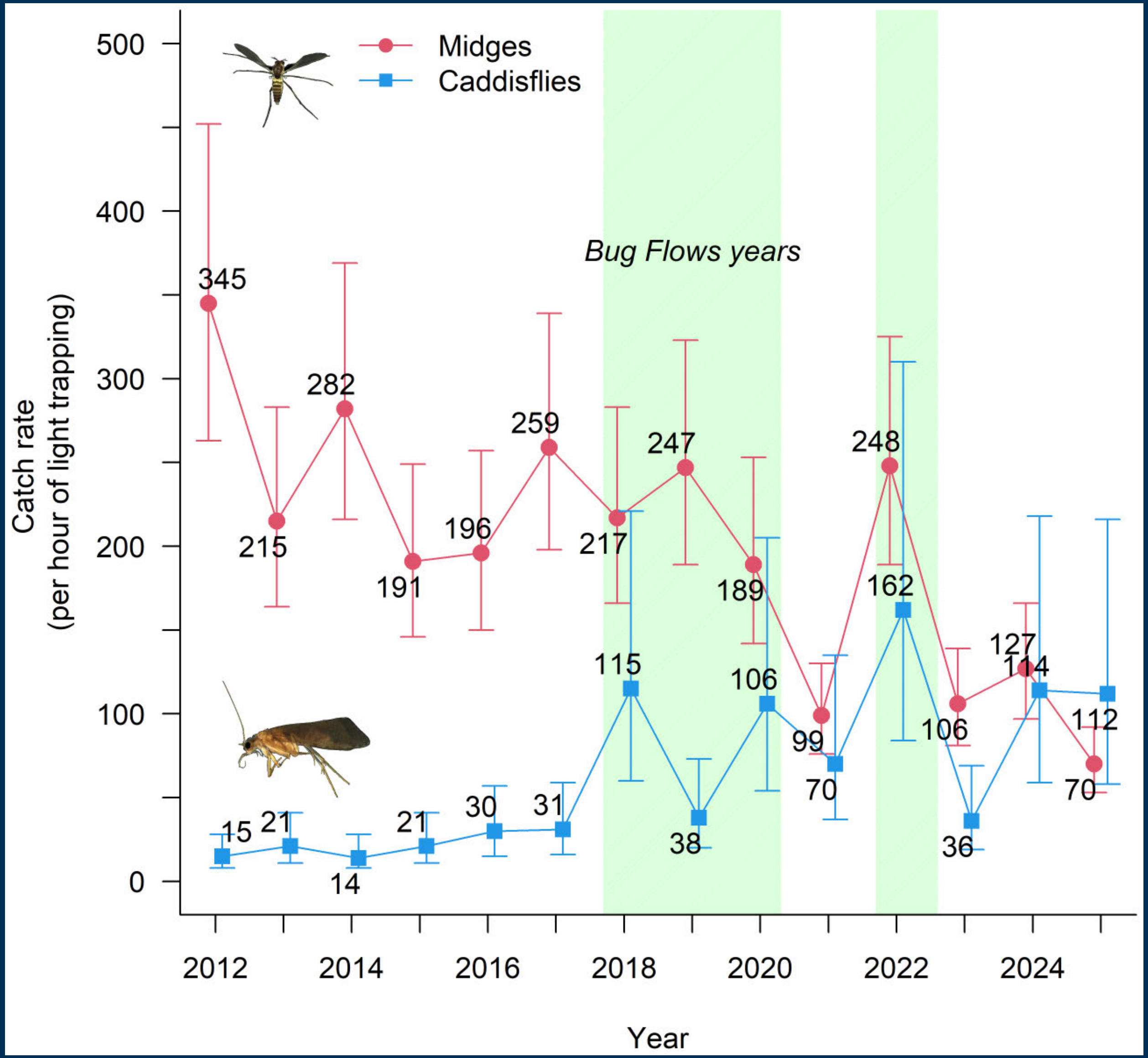




Statistical notes:
DeltaAIC > 8 considered very strong model support
Alternative hypotheses/variables considered:
HFE, temperature, GPP, sediment…

2025…



- **Caddisflies > midges**
- **Lowest midge catch**
- **~240 of 480 samples processed (50%)**
  - **Estimates will change**
- **New family of statistical models now possible**
  - **Long-term post-treatment data (3 yr)**
  - **Intervention analysis and other causal inference tools**
- **New insect population models coming soon**
  - **Forthcoming papers by Angelika Kurthen, OSU PhD**
  - **Will help disentangle temperature, flow, and other drivers**
  - **Thanks to BOR for modeling support funds**

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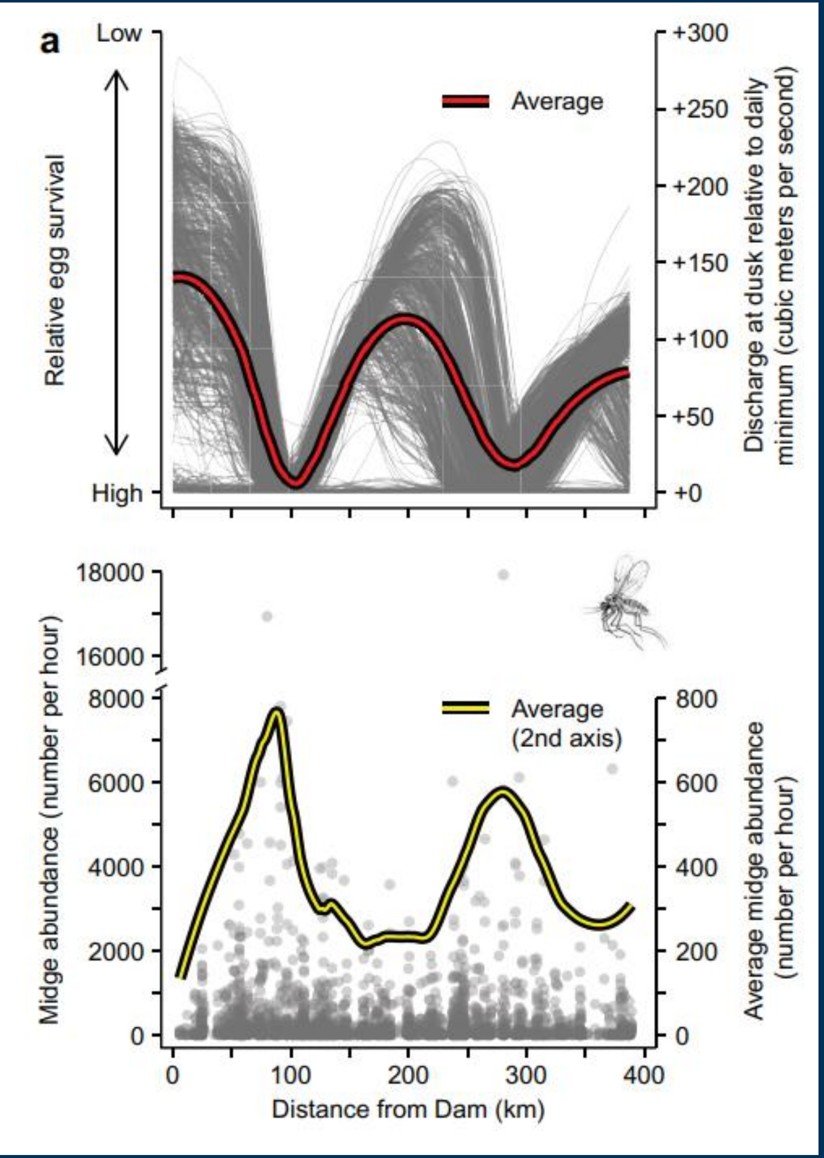
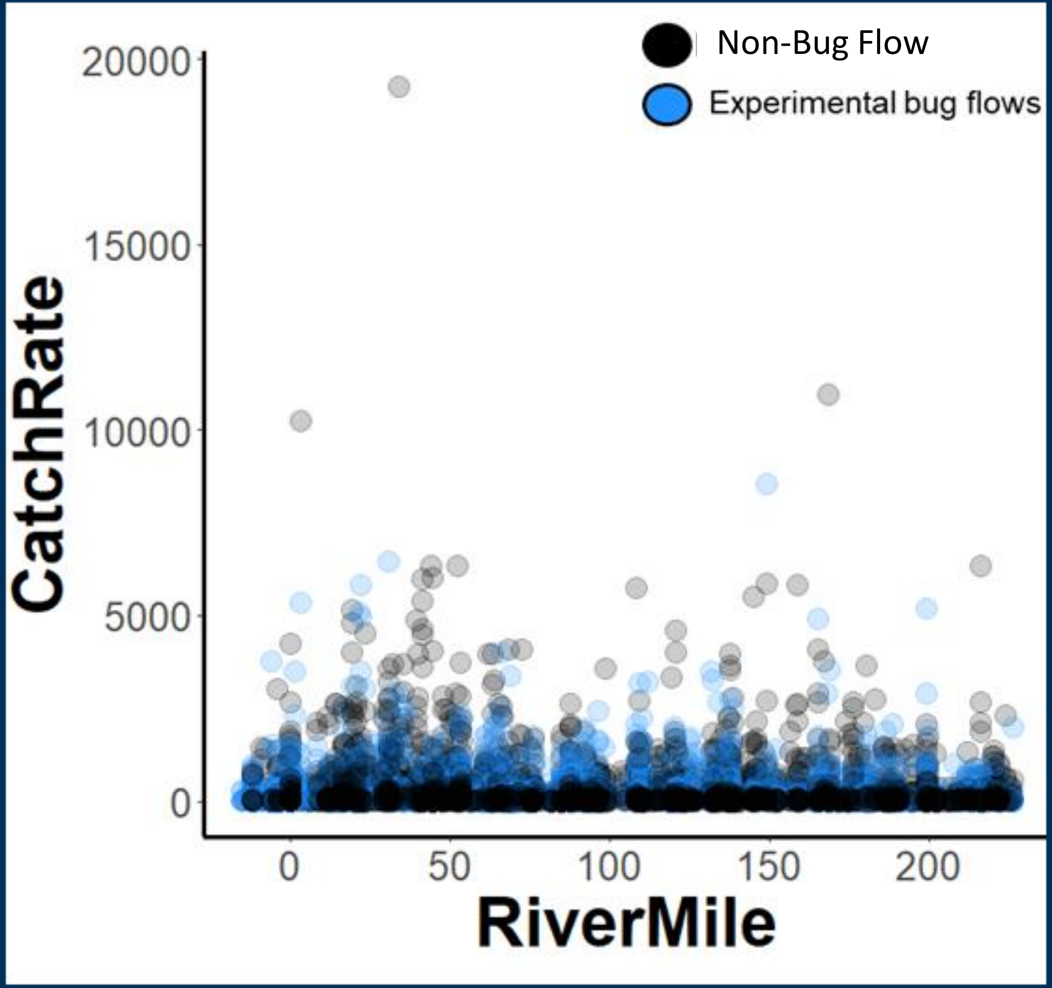
Midge spatial patterns: did they change with experiment?

Midge spatial patterns 2012-2014



Midge spatial patterns 2012-2024



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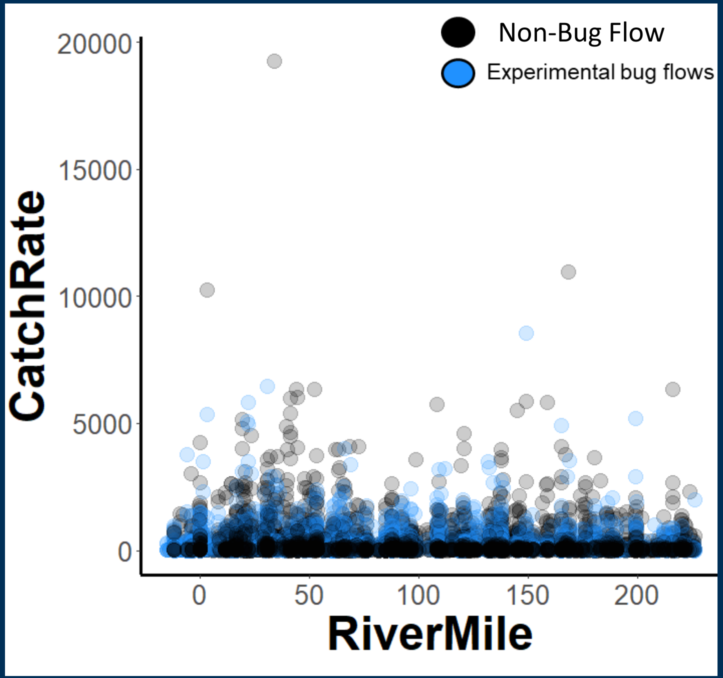
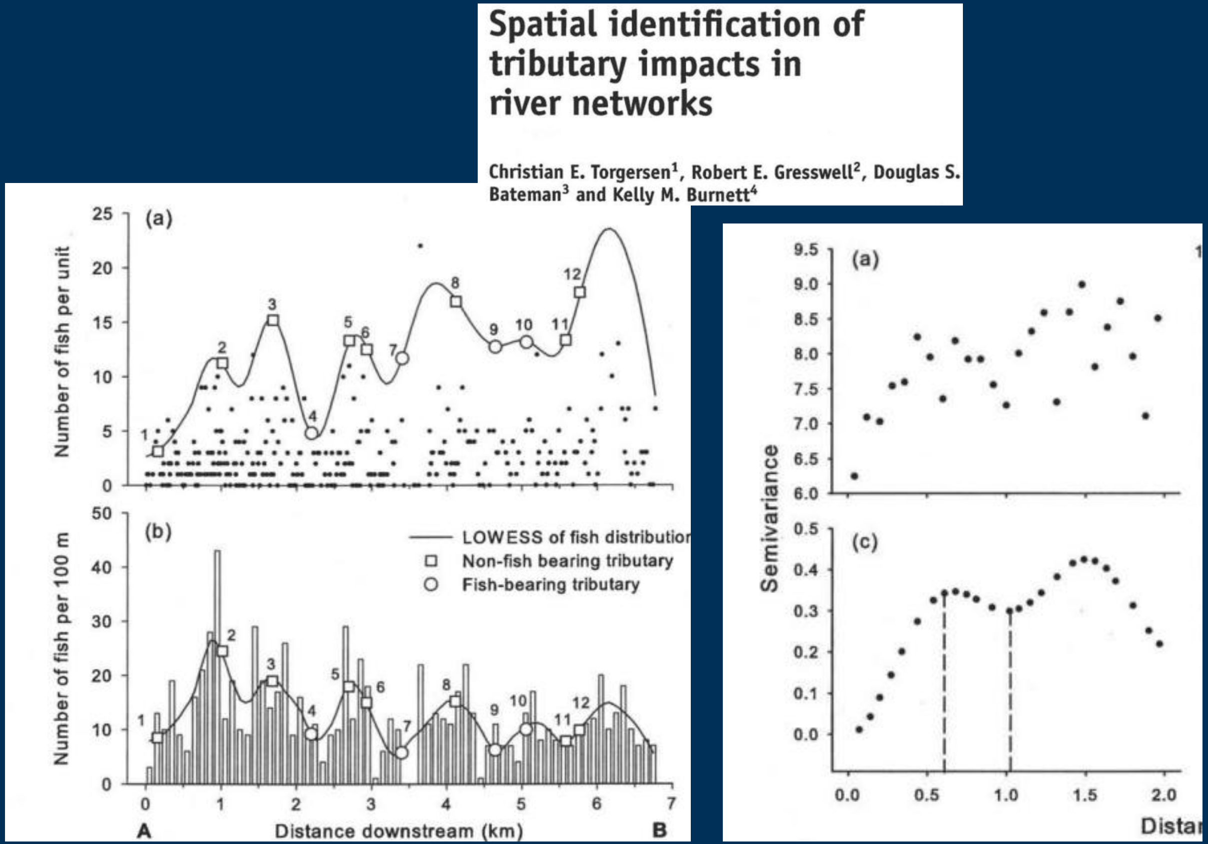
Midge spatial patterns: did they change with experiment?

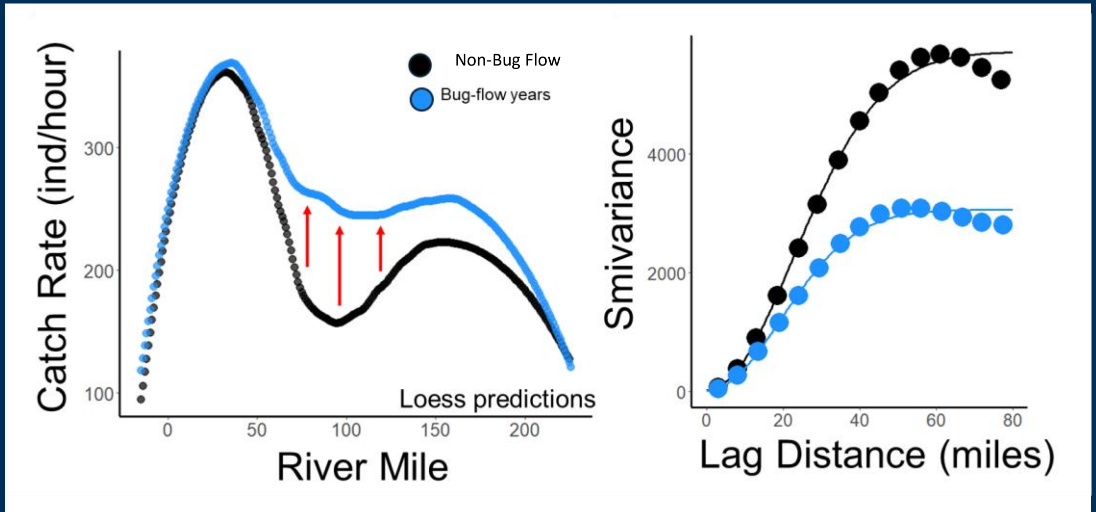
To find a spatial signal in ‘noisy’ catch data…
loess smoother → semivariogram

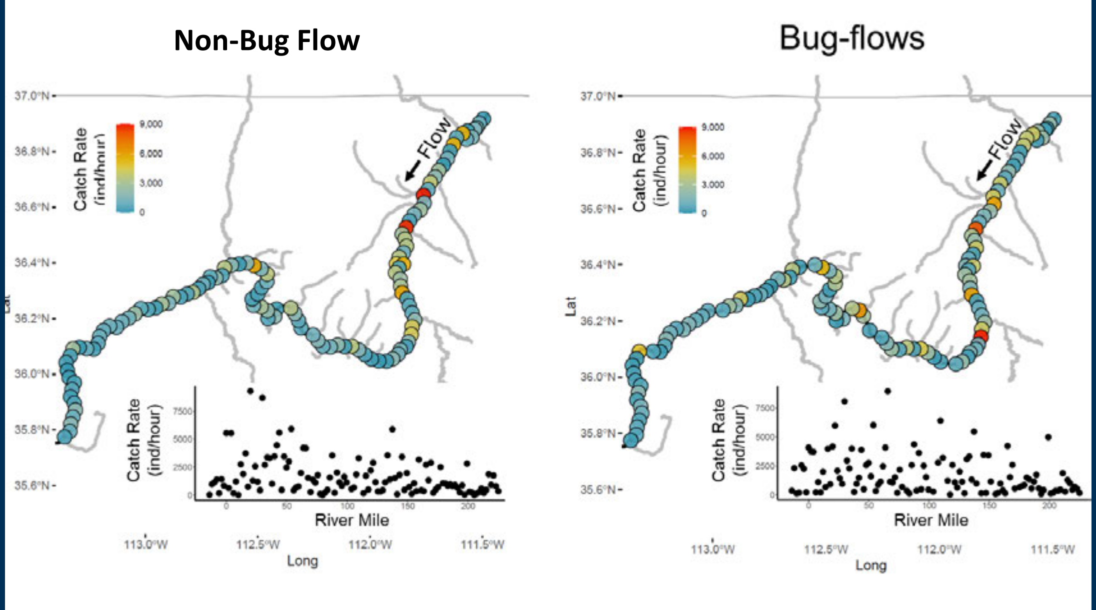




From: Torgersen, Christian E., et al. "Spatial identification of tributary impacts in river networks." River Confluences, Tributaries and the Fluvial Network. Chichester, UK: John Wiley & Sons Ltd (2008): 159-181.

Midge spatial patterns: did they change with experiment?...YES

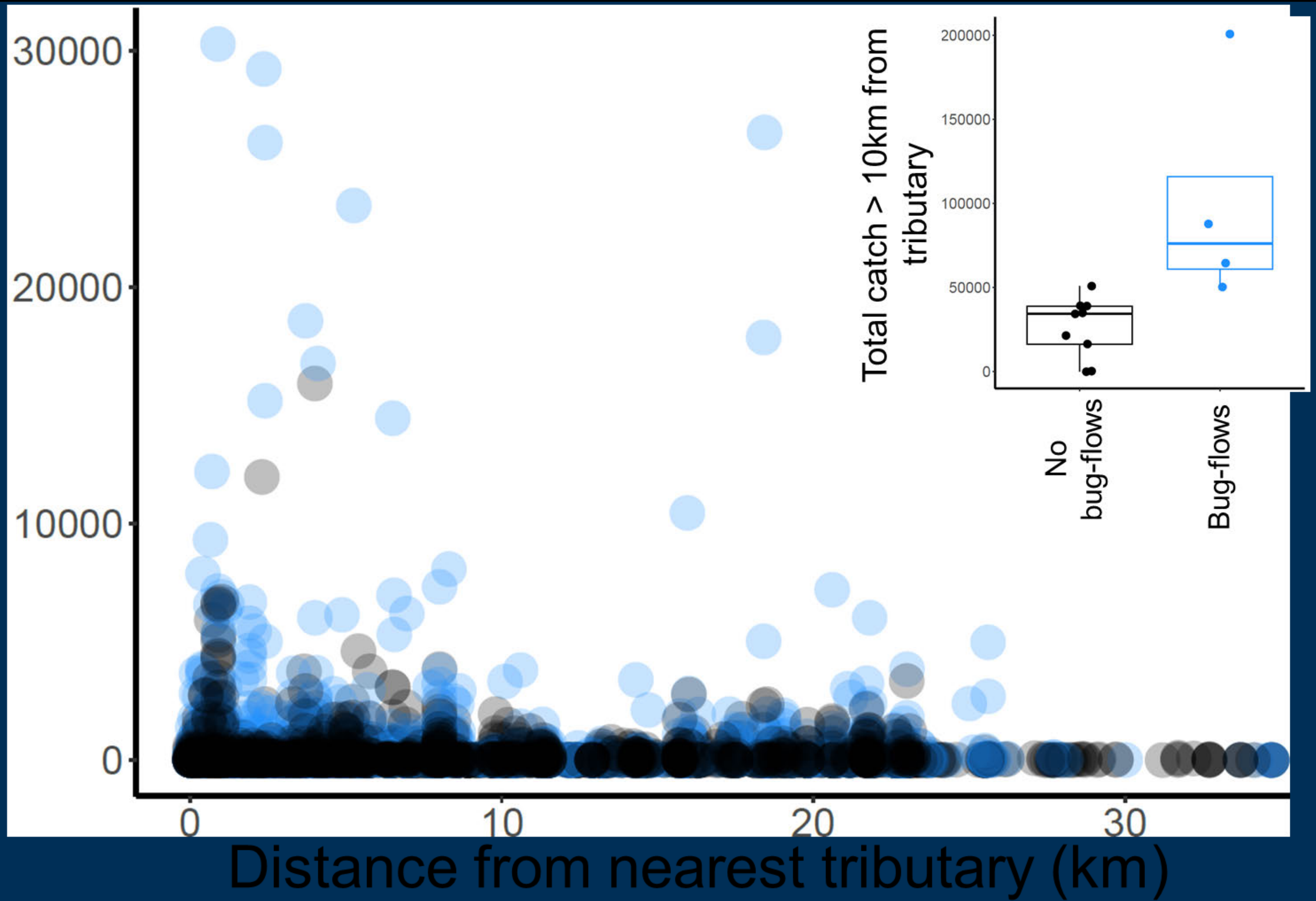




Take homes

- Midge catch rates in “trough” are bolstered in Bug Flow years
- Increase in trough leads to:
  - <u>higher</u> overall abundance
  - <u>lower</u> overall spatial variability
  - <u>lower</u> semivariogram sill

Caddisfly (Hydroptilidae) spatial patterns also changed: High catch rates away from tributaries in Bug Flow years



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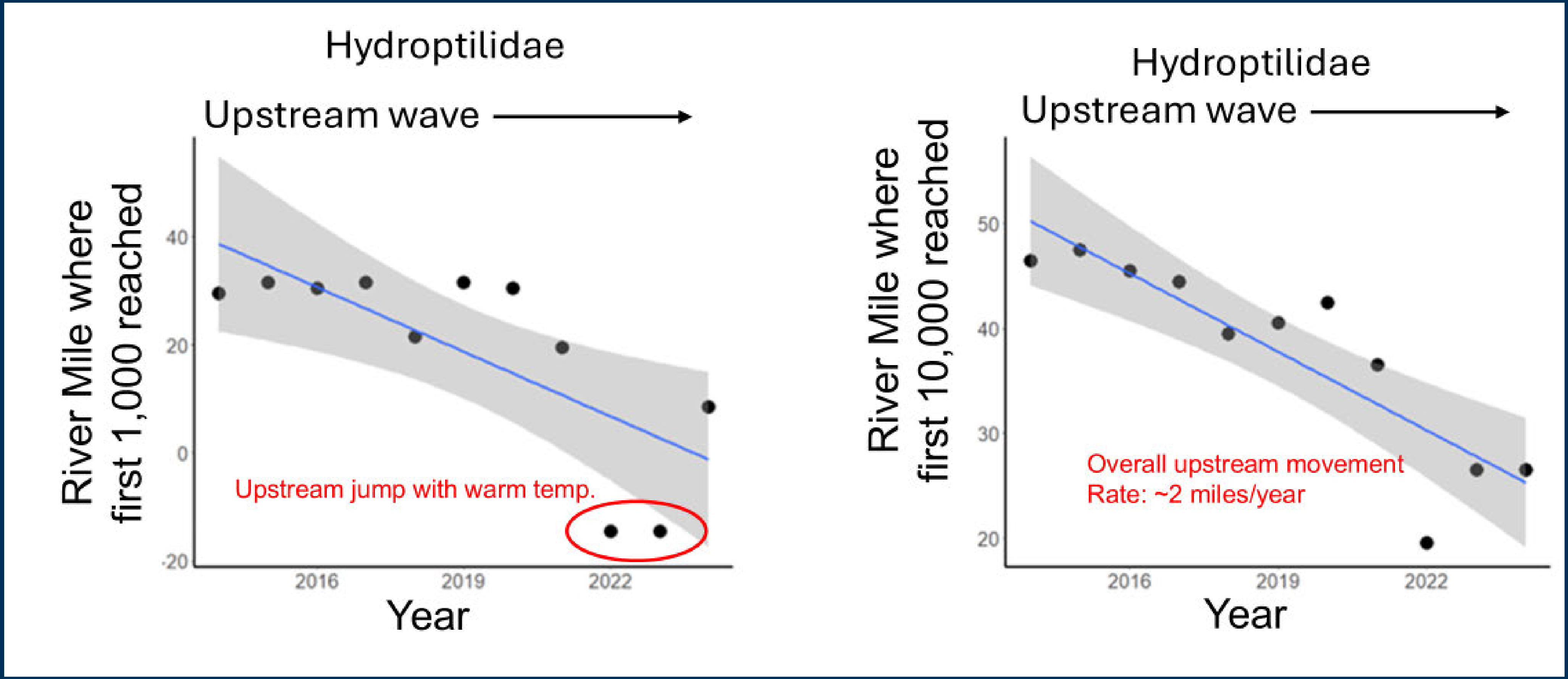
Caddisflies (Hydroptilidae) also show overall upstream movement and population expansion



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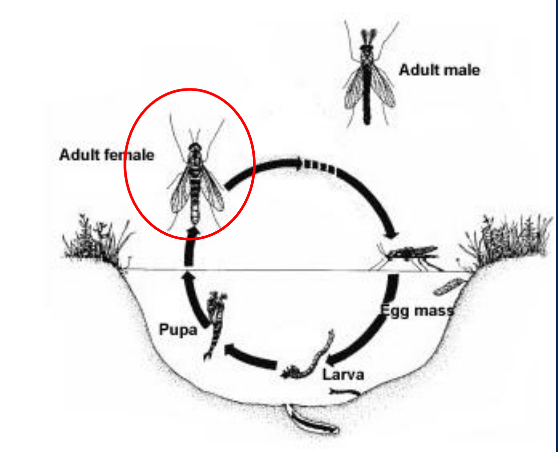
Phenology

- ***The study of cyclic and seasonal natural phenomena, especially in relation to climate and plant and animal life*. –Wikipedia**
- **Phenology is a strong predictor of yield in crops**
  - **Earlier development (e.g., germination, flowering) → higher yields**

Examples of phenology

Timing of migration

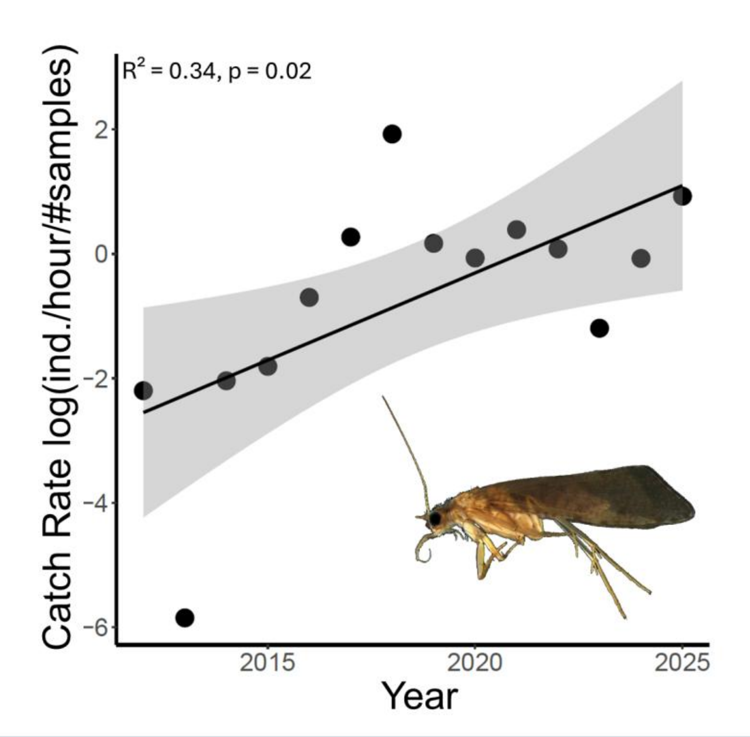
Timing of sprouting

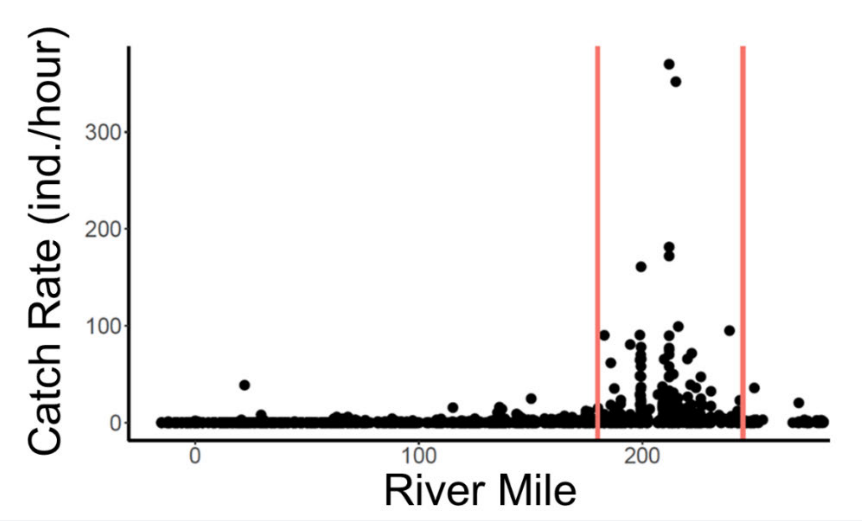


Timing of insect emergence

Hydropsyche oslari

- **Net-spinning caddisfly**
  - **Known as “spotted sedge”**
  - **Readily identified to species**
  - **Can detect population-level response**
    - **Not obscured by aggregate response of a community**
- **Large bodied**
  - **10-50x bigger than a midge**
- **Common in Western Grand Canyon**





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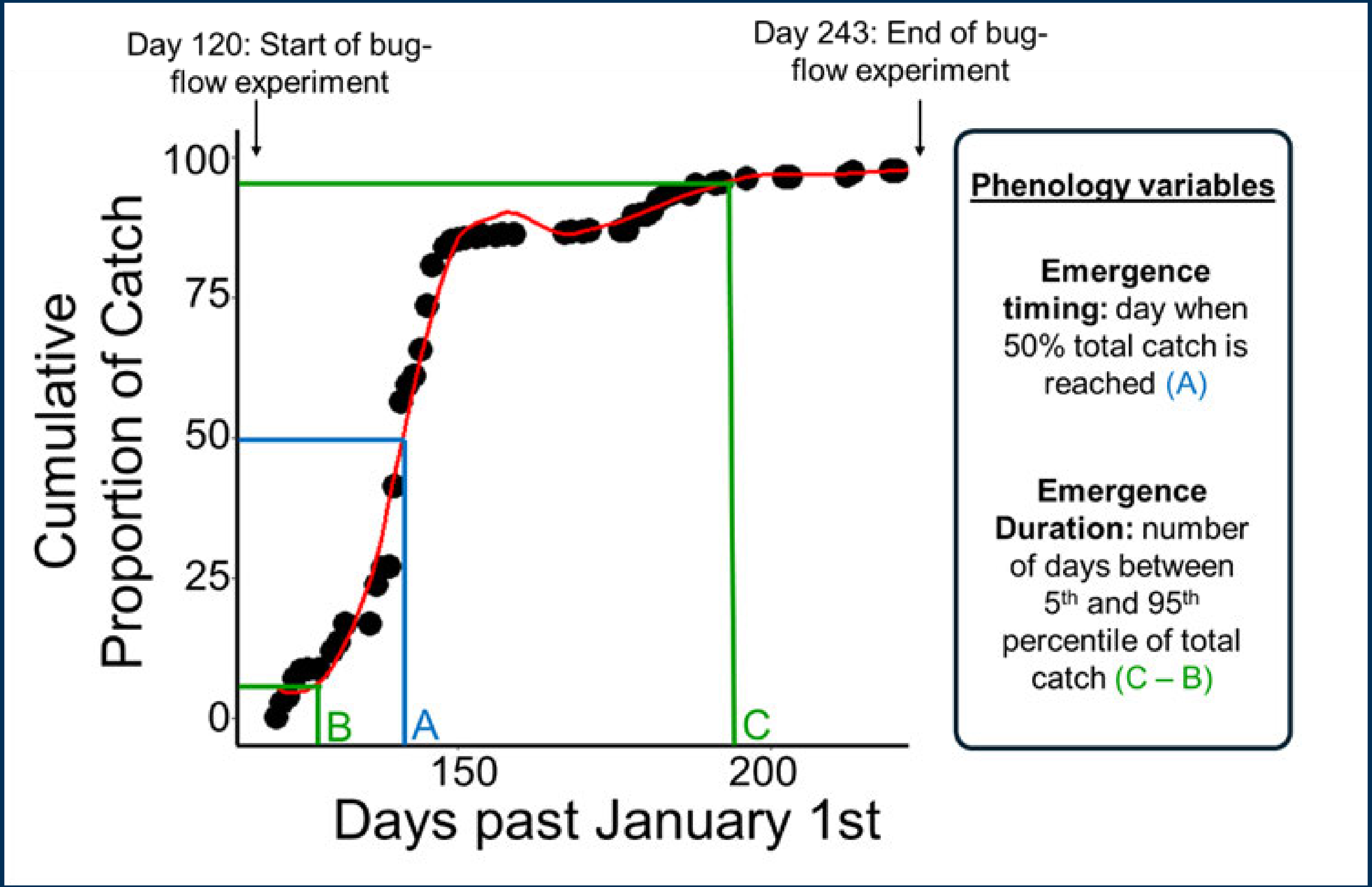
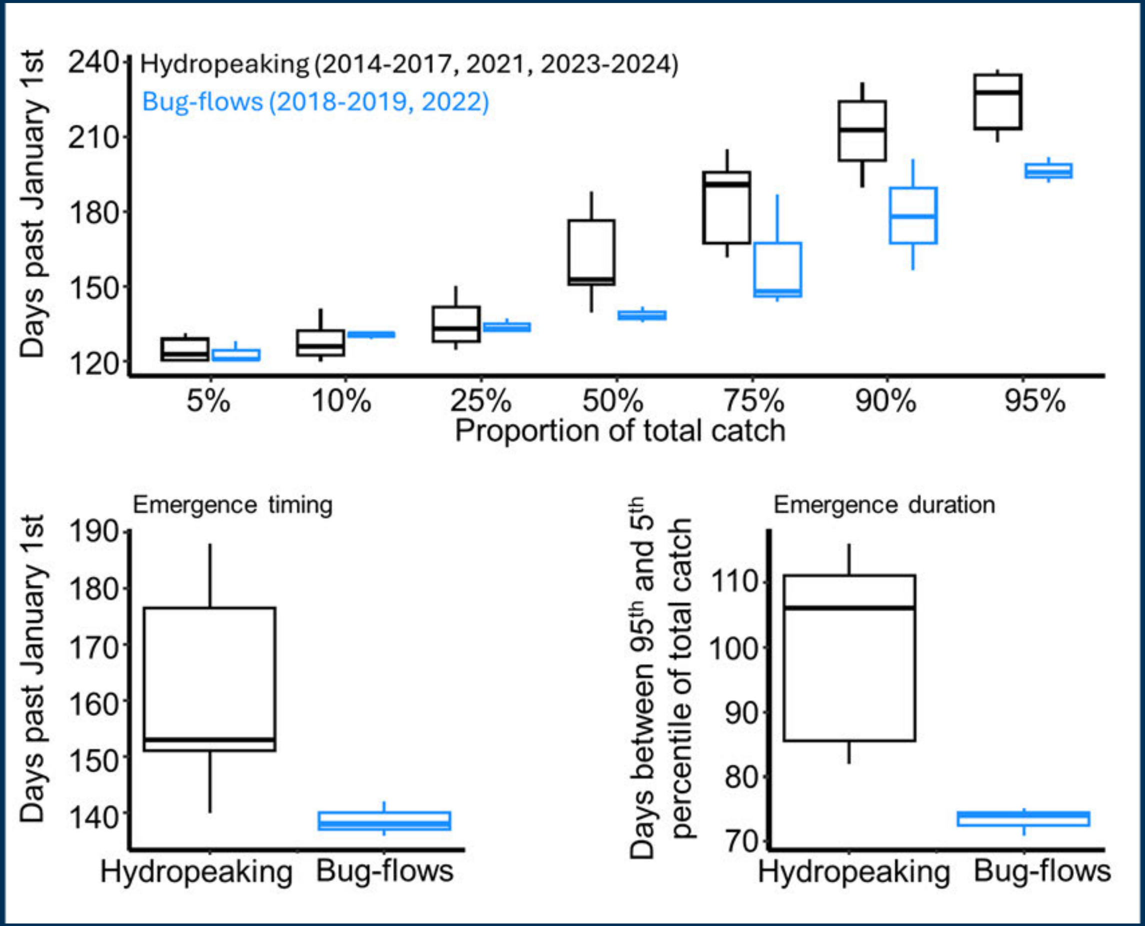
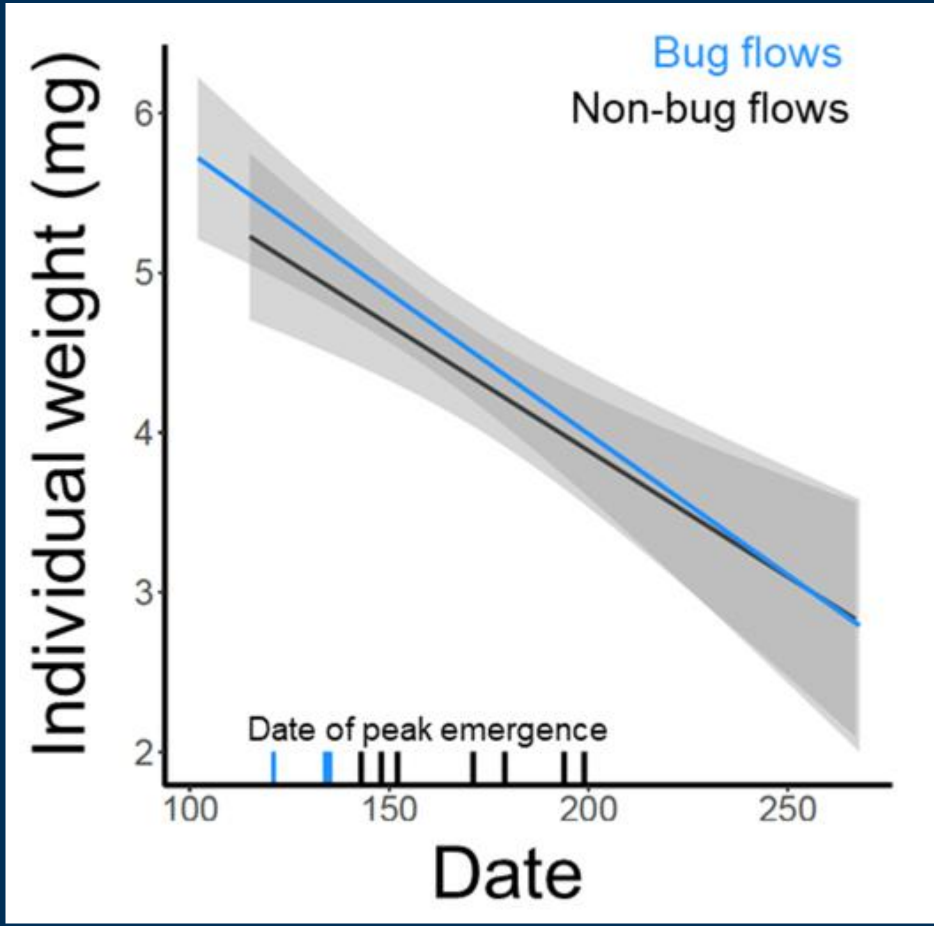
Phenology statistics



H. oslari emerged earlier, more synchronously, and at larger body size in Bug Flow Years





- Peak emergence (date of 50%) > 1 month earlier in Bug Flow years
  - Best model—Peak Emergence ~ Bug Flow + AprilGPP ($R2 = 0.57$, $p = 0.03$).
  - Best model—Duration (synchronicity) ~Bug Flow + SpringQ ($R2 = 0.58$, $p = 0.02$).

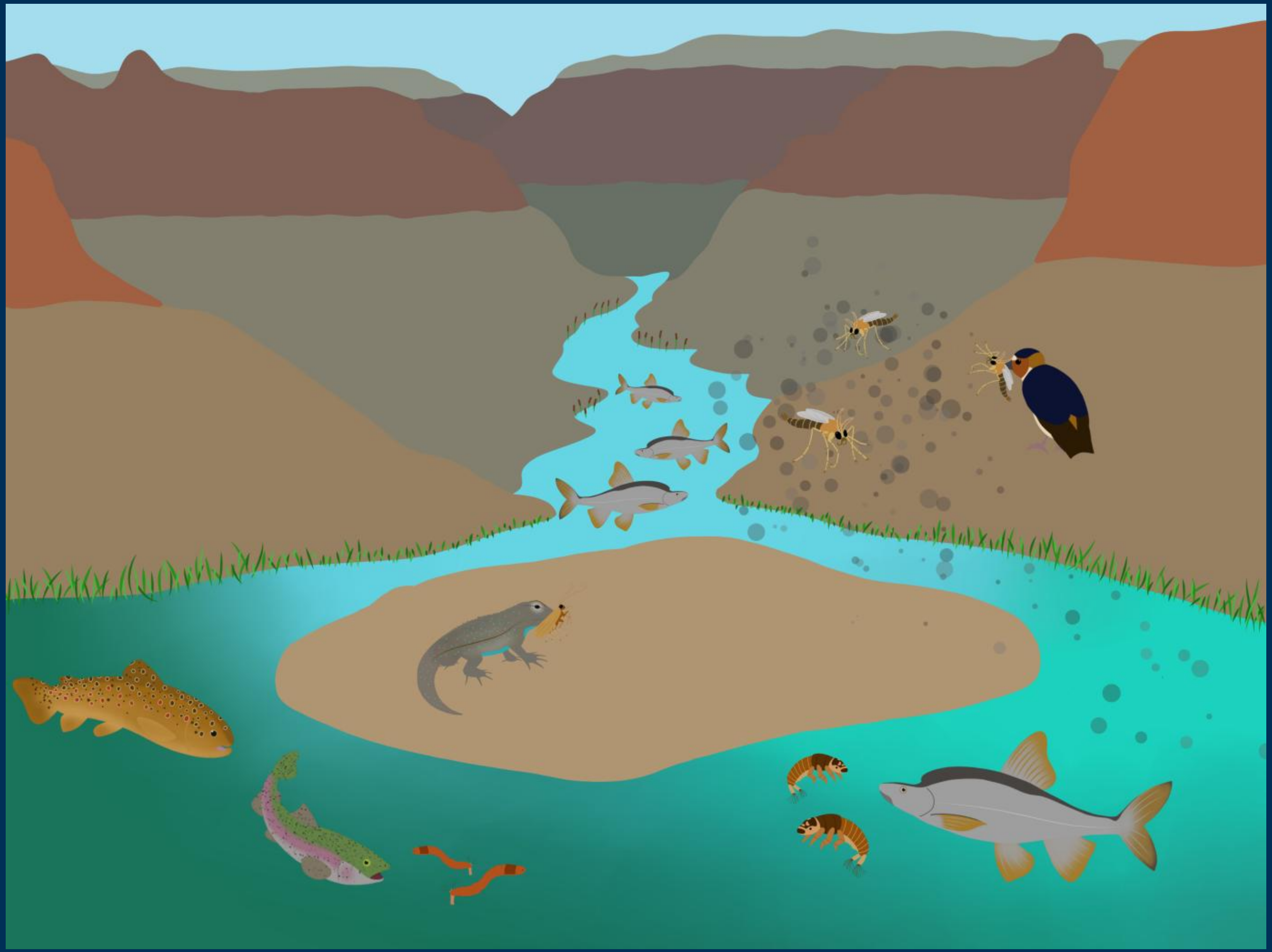
Conclusions

- **Bug Flows is a tool for increasing food base diversity and production**

During Bug Flow years…

  - **Higher catches of midges and caddisflies**
  - **Spatial patterns changed and align with predictions**
  - **Population level effects on caddisfly phenology and body size**

- **THANKS to River Guides, Grand Canyon Youth, and other citizen scientists that have made this work possible**



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