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Bug Flows Implementation and Resource Response

Ted Kennedy and Jeff Muehlbauer

Annual Reporting Meeting, Phoenix, AZ

12 March 2019

Grand Canyon Monitoring and Research Center
Southwest Biological Science Center
U.S. Department of the Interior
U.S. Geological Survey

Workplan Project Summary

- Project F: Aquatic Invertebrate Ecology
  - F.1: Influence of dam operations on the food base
  - F.2: Aquatic food base status at humpback chub monitoring locations
  - F.4: Glen Canyon aquatic food base monitoring and research
- Project Objectives: “To determine how the aquatic food base responds to LTEMP flow experiments such as macroinvertebrate production flows”
- Funding Amount and Source: GCDAMP $811,000 (for all of F)
- Cooperators: None for this presentation
- Products: Next slide

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Products/Reports

Type	Title	Due Date	Date Delivered	Date Expected	Citations/Comments
Presentation	Hydropower and the aquatic-terrestrial dynamic downstream of Glen Canyon Dam		Mar 2018	Mar 2018	Lupoli, C.A., Kennedy, T.A., Muehlbauer, J.D., Sabo, J.L. & Yackulic, C.B., 2018, Hydropower and the aquatic-terrestrial dynamic downstream of Glen Canyon Dam—poster: Glen Canyon Dam Adaptive Management Program, Annual Reporting Meeting, Flagstaff, Ariz., March 2018.
Presentation	Possible LTEMP experiment in 2018: macroinvertebrate production flows (bug flows)		Mar 2018	Mar 2018	Grantz, K., VanderKooi, S. & Muehlbauer, J.D., 2018, Possible LTEMP experiment in 2018—Macroinvertebrate production flows (bug flows): WebEx presentation to Glen Canyon Dam Adaptive Management Working Group Experimental Technical Team Meeting, Webinar, March 2018.
Presentation	Invertebrate drift throughout Colorado River Basin tailwaters		Mar 2018	Mar 2018	Muehlbauer, J.D. & Kennedy, T.A., 2018, Invertebrate drift throughout Colorado River Basin tailwaters: Lower Colorado River Science Symposium, Laughlin, Nev., March 2018.
Presentation	Update on proposed 'Bug Flow' Experiment		Apr 2018	Apr 2018	Kennedy, T.A., Metcalfe, A.N., and Muehlbauer, J.D., 2018, Update on proposed Bug Flow Experiment: Grand Canyon River Guides Association, Annual Guides Training Seminar: Marble Canyon, Ariz., April 2018.
Presentation	Update on proposed 'Bug Flow' Experiment		Apr 2018	Apr 2018	Kennedy, T.A., and Muehlbauer, J., 2018, Update on proposed Bug Flow Experiment—Presentation to Pueblo of Zuni Tribal President, Tribal Council, and Tribal Elders: Pueblo of Zuni, New Mex., April 2018.
Presentation	Update on the progress of the Bug Flow experiment		Aug 2018	Aug 2018	Kennedy, T.A., and Muehlbauer, J.D., 2018, Update on the progress of the Bug Flow experiment: Glen Canyon Dam Adaptive Management Program, Adaptive Management Working Group, Flagstaff, Ariz., August 2018.

Type	Title	Due Date	Date Delivered	Date Expected	Citations/Comments
USGS Report	Brown trout in the Lees Ferry reach of the Colorado River: Evaluation of causal hypotheses and potential interventions		Apr 2018	Apr 2018	Runge, M.C., Yackulic, C.B., Bair, L.S., Kennedy, T.A., Valdez, R.A., Ellsworth, C., Kershner, J.L., Rogers, R.S., Trammell, M., and Young, K.L., 2018, Brown trout in the Lees Ferry reach of the Colorado River—Evaluation of causal hypotheses and potential interventions: U.S. Geological Survey Open-File Report 2018-1069, 83 p., https://doi.org/10.3133/ofr20181069.
Presentation	Longitudinal drift recovery patterns downstream of large dams		May 2018	May 2018	Muehlbauer, J. and Kennedy, T., 2018, Longitudinal drift recovery patterns downstream of large dams—presentation: Society for Freshwater Science Annual Meeting: Detroit, Mich., May 20-24, 2018.
Presentation	Implementation of macroinvertebrate production flows: Preliminary observations		May 2018	May 2018	Vanderkooi, S. and Kennedy, T.A., 2018, Implementation of macroinvertebrate production flows—Preliminary observations: Webex briefing to Glen Canyon Dam Adaptive Management Program, May 2018.
Journal article	Warm water temperatures and shifts in seasonality increase trout recruitment but only moderately decrease adult size in western North American tailwaters		May 2018	May 2018	Dibble, K.L., Yackulic, C.B., and Kennedy, T.A., 2018, Warm water temperatures and shifts in seasonality increase trout recruitment but only moderately decrease adult size in western North American tailwaters: Environmental Biology of Fishes, v. 101, no. 8, p. 1269-1283, https://doi.org/10.1007/s10641-018-0774-7.
Presentation	Hydropeaking dams facilitate ecological dominance		May 2018	May 2018	Abernethy, E.F., Muehlbauer, J.D., Kennedy, T.A., Van Driesche, R.P., and Lytle, D.A., 2018, Hydropeaking dams facilitate ecological dominance—presentation: Society for Freshwater Science Annual Meeting, Detroit, Mich., May 20-24, 2018.
Presentation	Update on the progress of the bug flow experiment		Jun 2018	Jun 2018	Kennedy, T.A., and Muehlbauer, J.D., 2018, Update on the progress of the Bug Flow experiment—presentation: Glen Canyon Dam Adaptive Management Program, Technical Work Group: Phoenix, Ariz., June 2018.
Presentation	Does hydropower affect food web connectivity in an arid large-river system?		Aug 2018	Aug 2018	Lupoli, C.A., Kennedy, T.A., Muehlbauer, J.D., Sabo, J.L. & Yackulic, C.B., 2018, Does hydropower affect food web connectivity in an arid large-river system?—presentation: Ecological Society of America Annual Meeting: New Orleans, LA, August 5-10, 2018.

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Groundwork for Bug Flows

- **Cross, et al. 2013 *Ecological Monographs***
  - **Fish in River are food limited**
  - **Not enough "bug meat"**
  - **Unstable, low-diversity food base**

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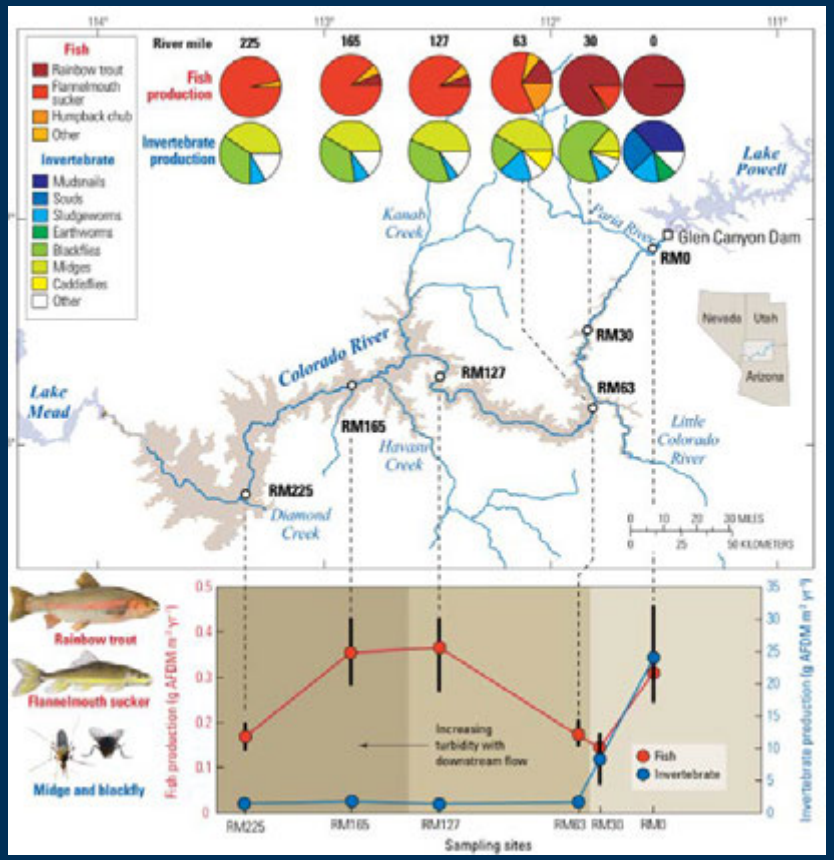
Native and Nonnative Fish Populations of the Colorado River are Food Limited—Evidence from New Food Web Analyses

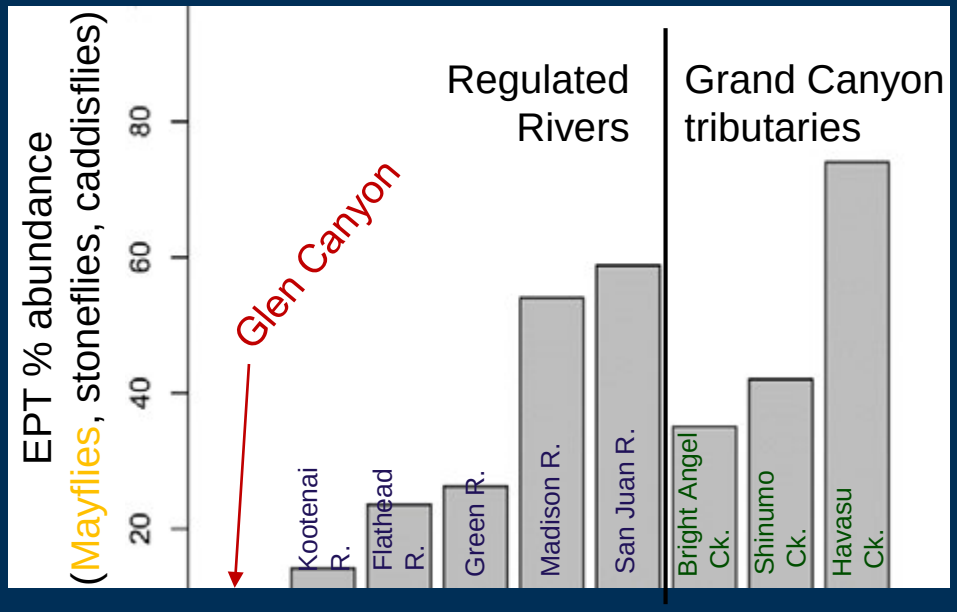
Summarized by Kennedy, et al 2013
http://pubs.usgs.gov/fs/2013/3039



Should the River have so few insects?

- **Likely not!**

Evidence elsewhere in West



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Evidence pre-dam

Barry Goldwater

Camp 30, August 8, 1940. 69 ½ Mile:
"I am seated on a rock ledge above the river in the Grand Canyon with dozens of the most pestiferous of all insects, the **May fly**, hovering around my head…"

From Goldwater 1970,
Delightful Journey down the Green and Colorado Rivers

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Does it matter to have so few insects?

Resource Category	Upper Basin					Lower Basin
	Black Rocks	Westwater Canyon	Desolation/ Gray canyons	Cataract Canyon	Dinosaur National Monument	Grand Canyon
	Extant				Extirpated	Extant
1. Diverse rocky canyon river habitat						
2a. Suitable flow						
2b. Suitable temperature						
3. Adequate and reliable food supply						
4. Habitat with few nonnative predators and competitors						
5. Suitable water quality						
6. Unimpeded range and connectivity						
7. Persistent populations						
8. High genetic diversity						

- **The main issue for Humpback Chub in Grand Canyon**

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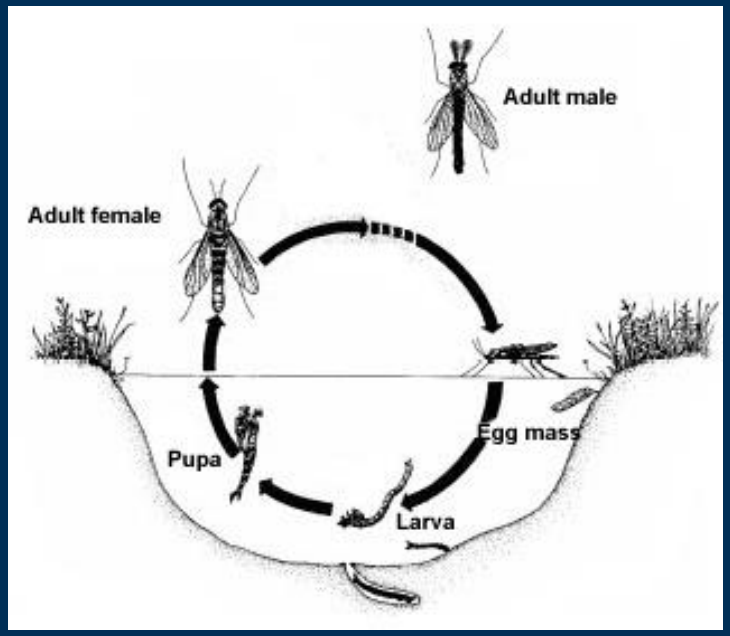
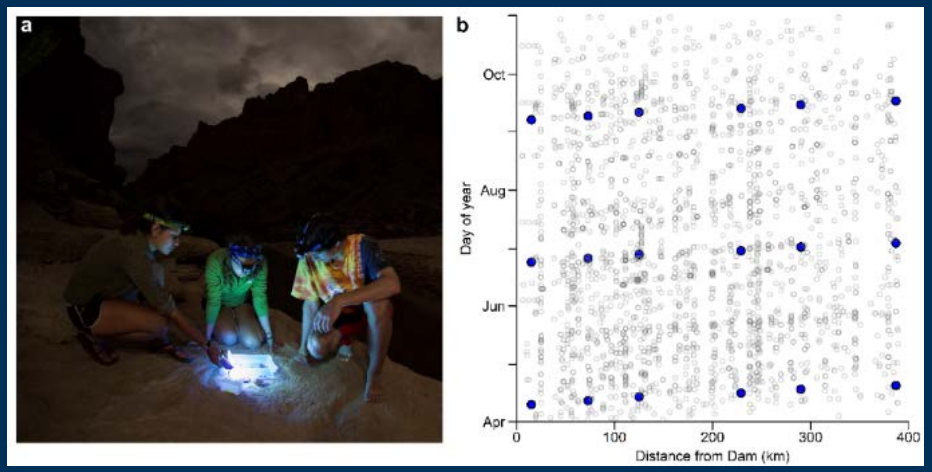
From USFWS 5-year review
SSA on Humpback Chub

But WHY so few aquatic insects?

- Typical insect life cycle
- Studying multiple life stages yields insight



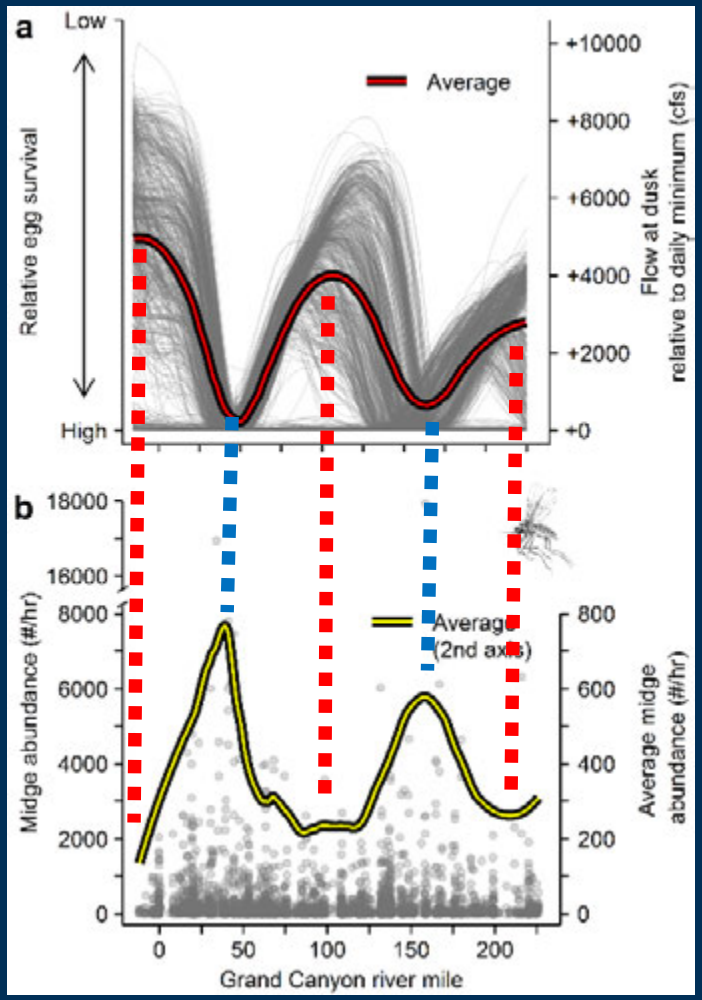
- Citizen science program:
  - Light traps for adult insects



From Kennedy, Muehlbauer, and others, 2016, *BioScience*

Groundwork for Bug Flows

- Kennedy, et al. 2016 *BioScience*
  - Light trap data
  - Throughout Canyon:
    Spatial pattern in midges
  - High midge counts:
    low water at dusk
  - Low midge counts:
    high water at dusk



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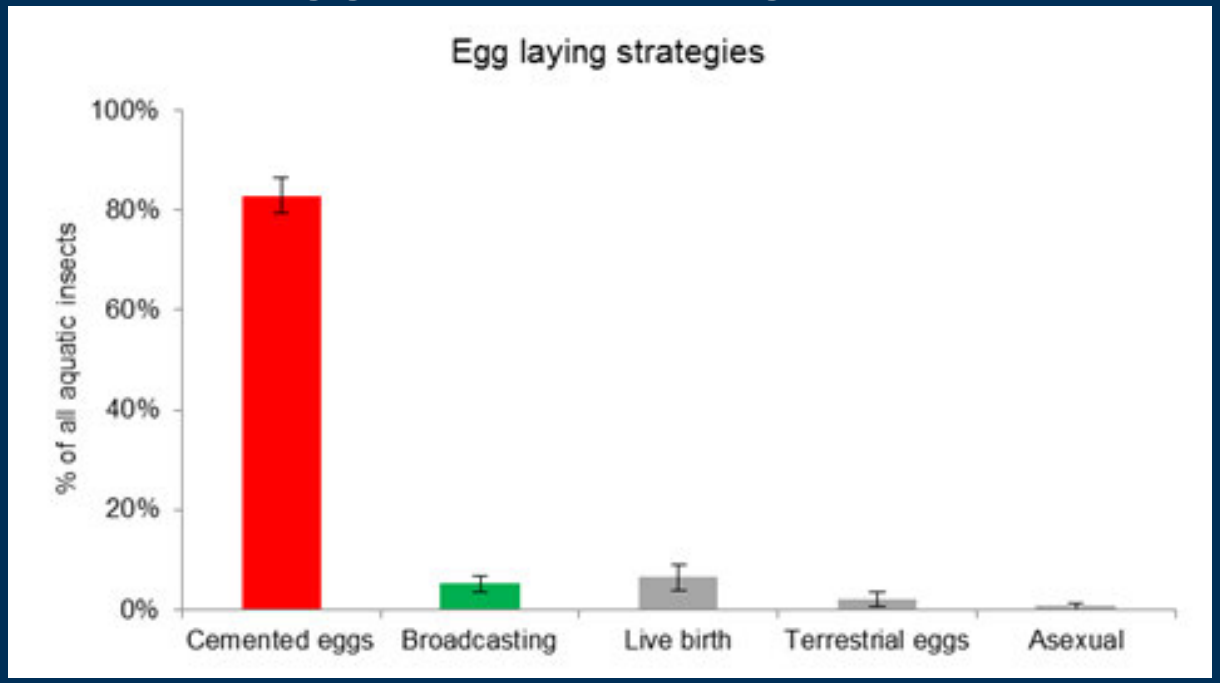
Groundwork for Bug Flows

- **Kennedy, et al. 2016 *BioScience***
  - **Midges (and most other aquatic insects):**

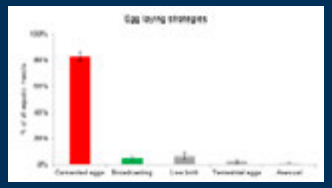
    ‘Cement’ eggs on river edges



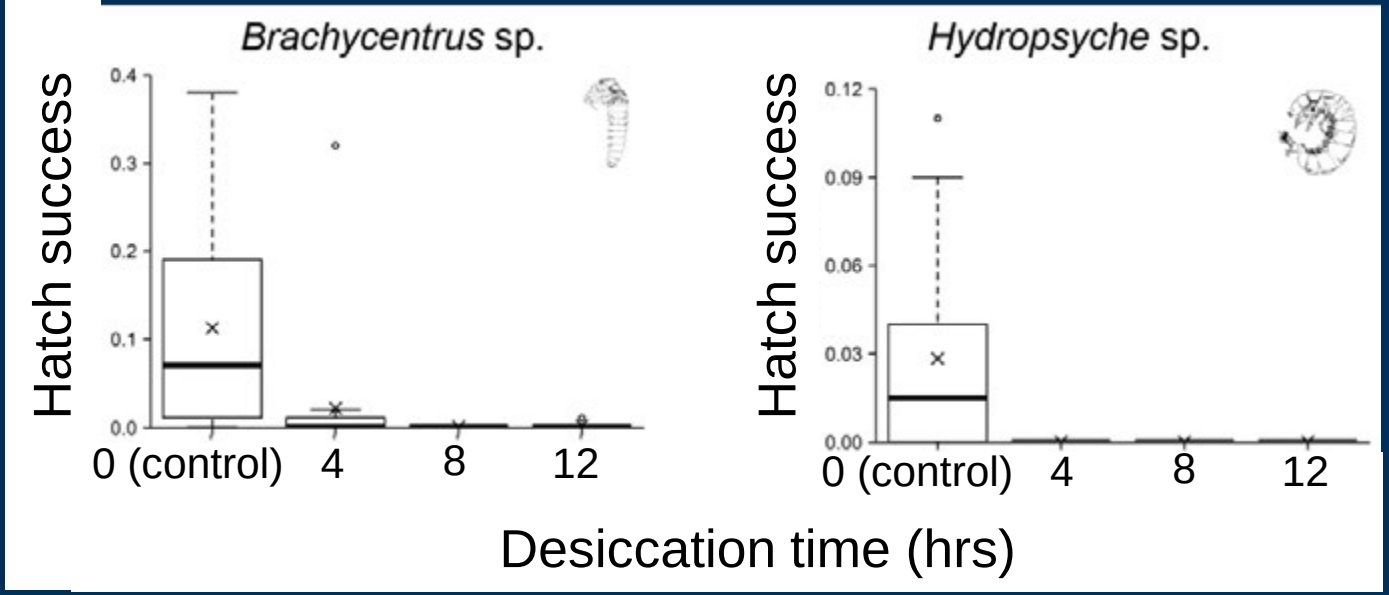
Data synthesized from Statzner & Beche 2010, *Freshwater Biology*

Groundwork for Bug Flows

- **Kennedy, et al. 2016 *BioScience***
  - **Midges (and most other groups):**
    Lay eggs on river edges



  - **Eggs dry out, die after ~ 1 hour**



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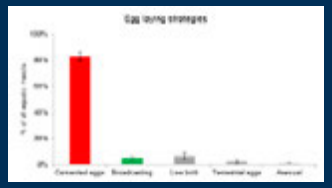
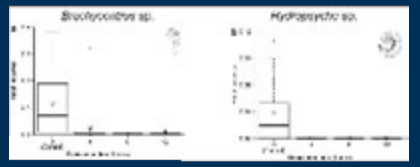
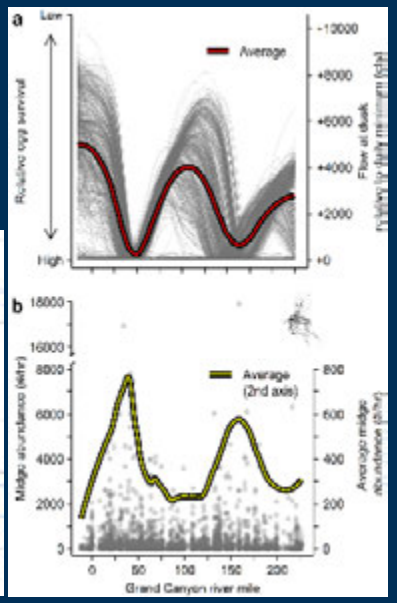
Data from Scott Miller, BLM/USU BugLab

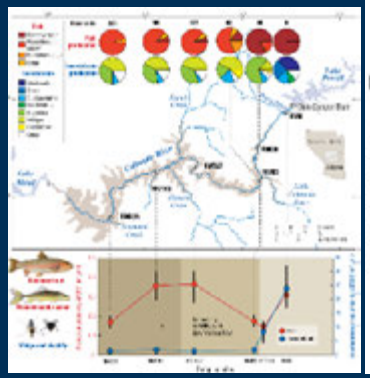
Groundwork for Bug Flows

- **Kennedy, et al. 2016 *BioScience***
  - **Midges (and most other groups):**
    Lay eggs on river edges
  - **Eggs dry out and die after ~1 hour**
  - **Eggs laid at high water die**
    - **Explains spatial pattern**
    - **Explains low production/diversity**









Poor egg-laying conditions in Grand Canyon (flow-related)

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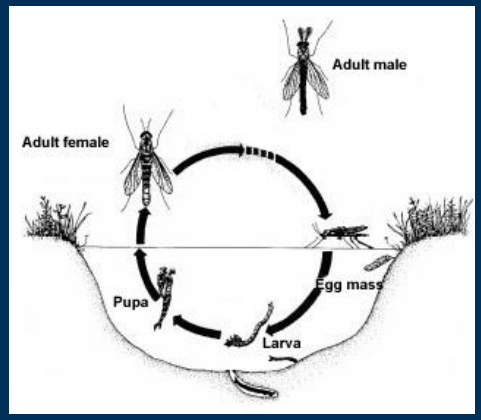
Purpose of Bug Flows Experiment

- Improve egg-laying conditions for insects!



- Therefore:
  - Increase midge abundance

  - Increase sensitive EPT abundance/diversity (longer term?)

- Ultimately:
  - Improve fish food base

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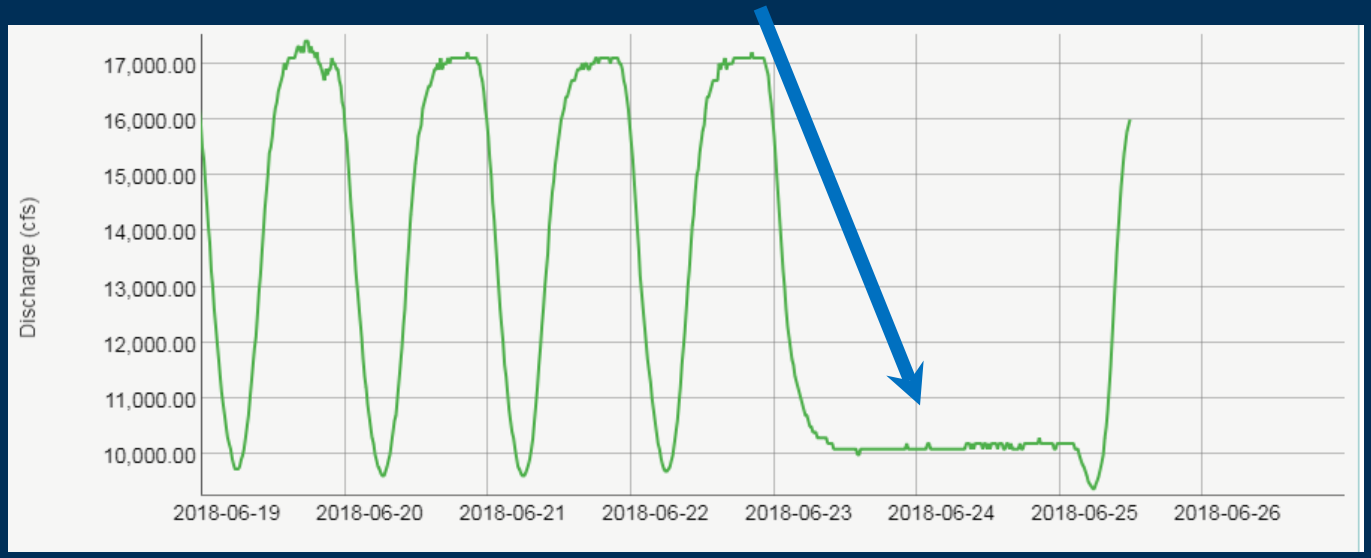
Design of Bug Flows

- "Give bugs the weekends off!"
- May – August 2018
- Stable, low flows on summer weekends
  - Eggs laid on weekends won't dry/die



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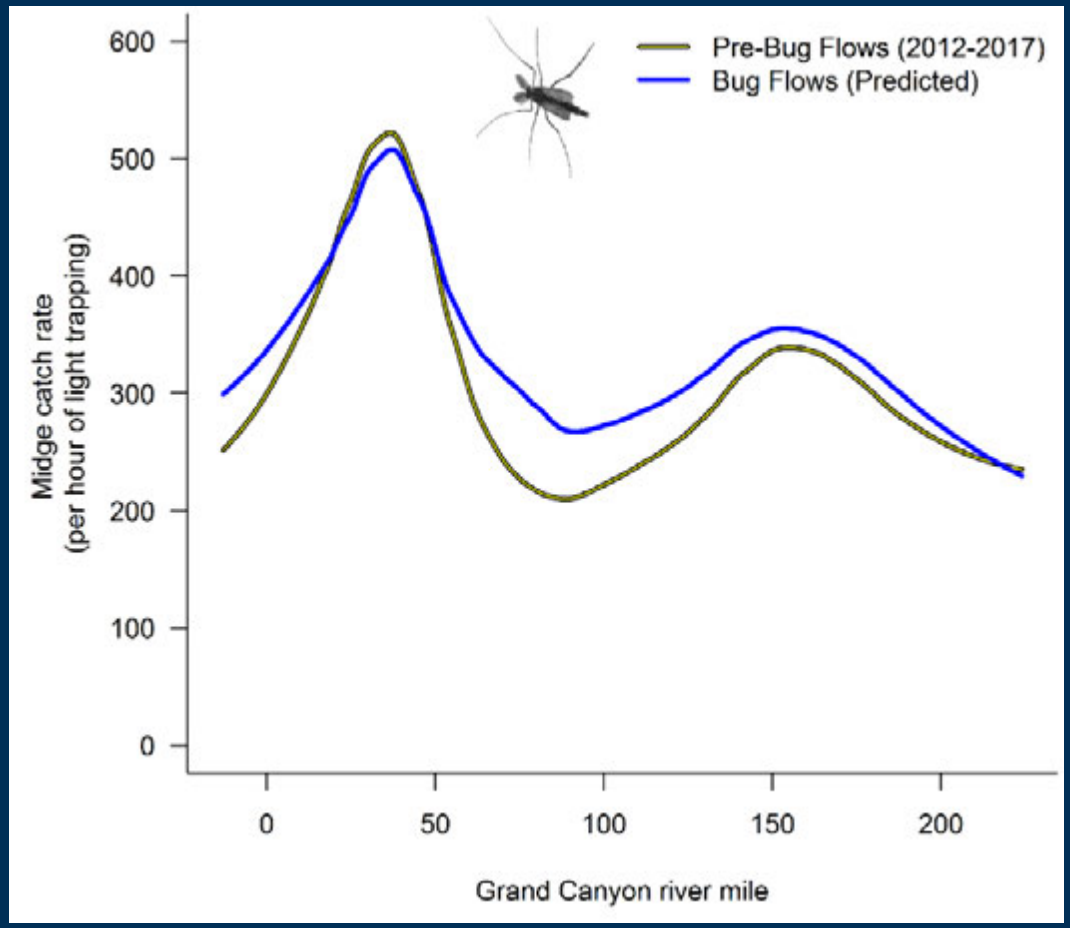
Predicted Responses (long-term)

- **Smoothing**

of spatial pattern

- **More midges**

throughout Canyon



When?
Starting 2019

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Predicted Responses (long-term)

- **Smoothing**

of spatial pattern

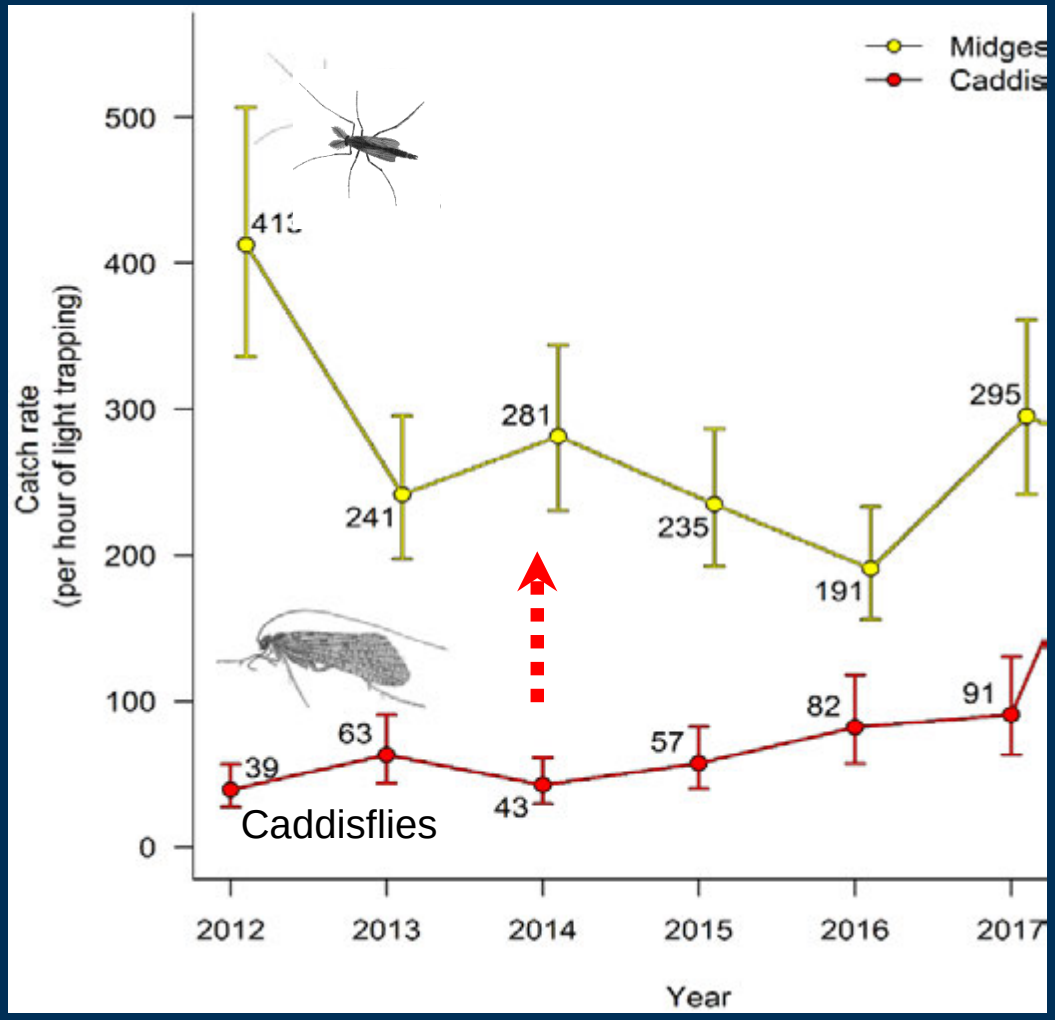
- **More midges**

throughout Canyon

- **More caddisflies**

(EPT)

When? Starting 2019



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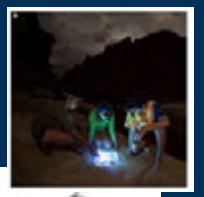
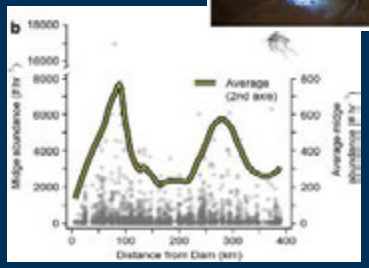
Bug Flows Monitoring Program

- Light traps

  - ~ 1000 samples per year, throughout Canyon
  - Data were the basis for Bug Flows

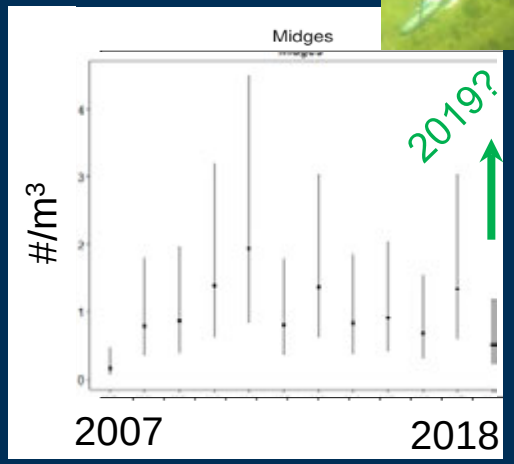




- Invertebrate Drift

  - 10+ year dataset at Lees Ferry
  - Correlated w/ light traps throughout Canyon
  - Food directly available to fish

- Sticky traps
- Egg surveys



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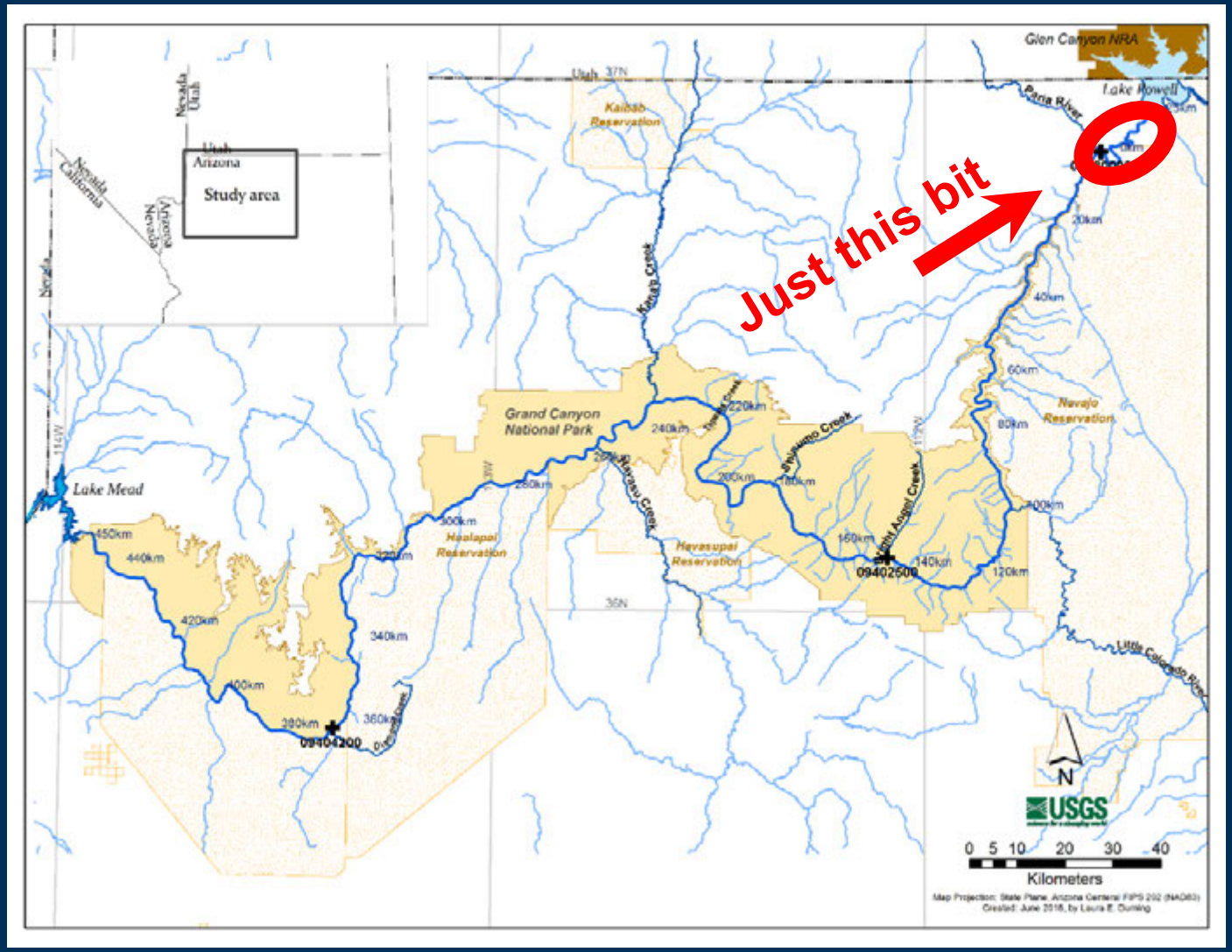
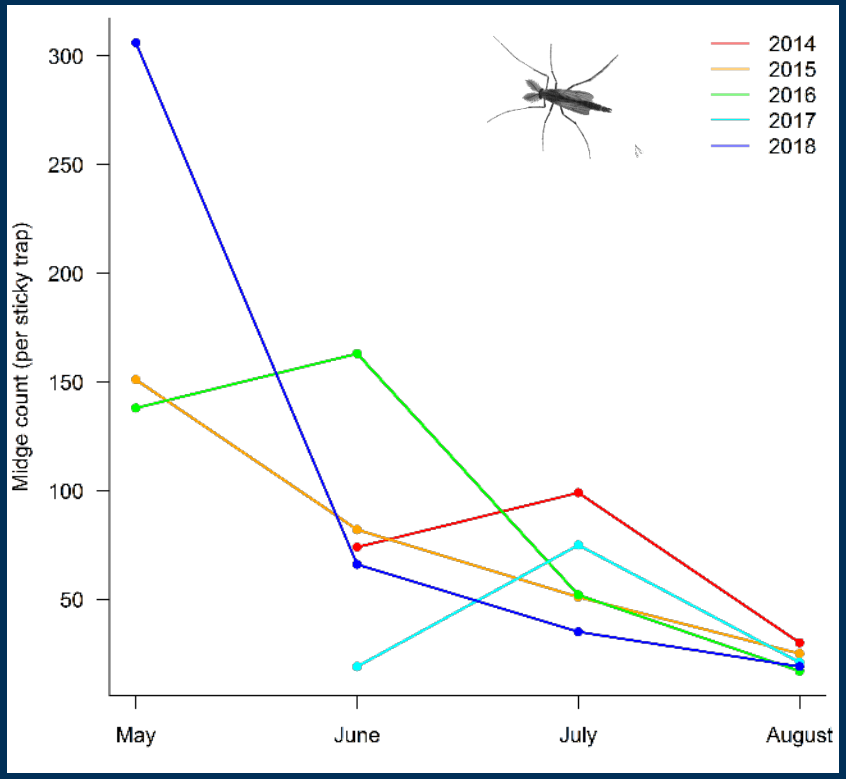
Early results from Glen Canyon



Early results from Glen Canyon (other monitoring)

- May 2018: “It’s buggy out there!”
- Sticky traps: massive emergence event

- Summer 2018: Overall more midges than any other year



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Early results from Glen Canyon (other monitoring)

Eggs

Sunday May 6, River Mile -6

May weekends: High egg-laying

Female midges

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Early results from Glen Canyon (other monitoring)

Eggs

Sunday May 6, River Mile -6

May weekends: High egg-laying

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Early results from Glen Canyon (other monitoring)

Eggs

Sunday May 6, River Mile -13

May weekends: High egg-laying

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Early results from Glen Canyon (other monitoring)

Eggs

Bug Flows

Many emergent rocks

Load-Following

One emergent rock

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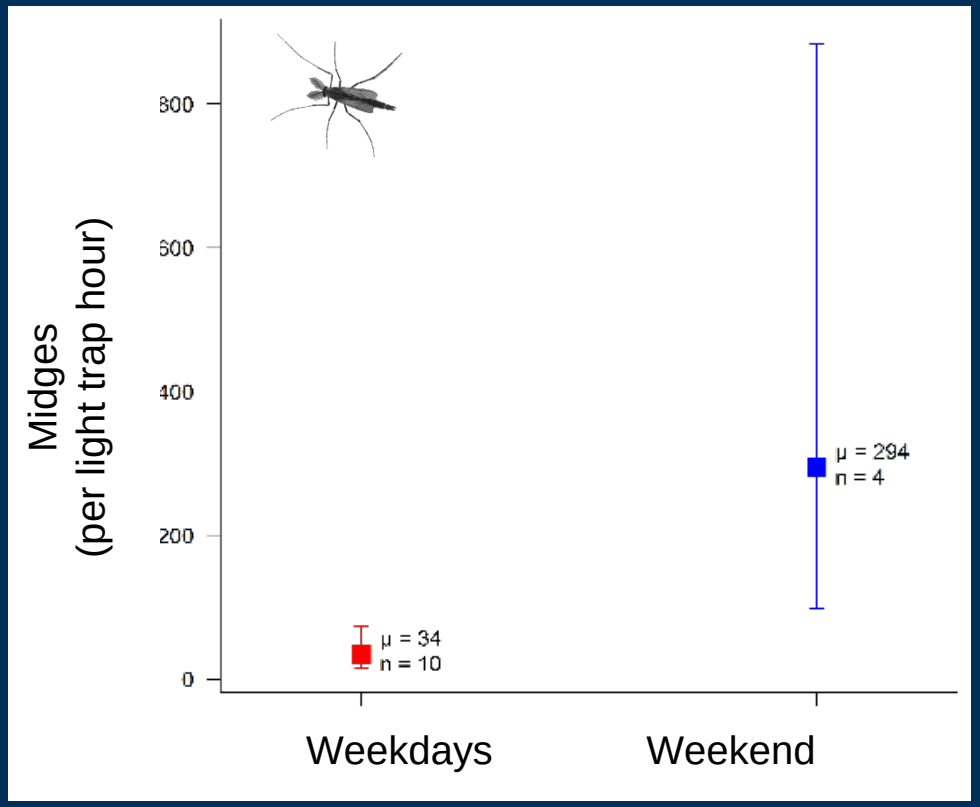
Early results from Glen Canyon (other monitoring)

- August 2018: Weekday vs. weekend study
  - More emergence on weekends:

    Unexpected egg-laying benefit of Bug Flows
  - More eggs to hatch
  - Better fishing on weekends (AZGFD Creel)



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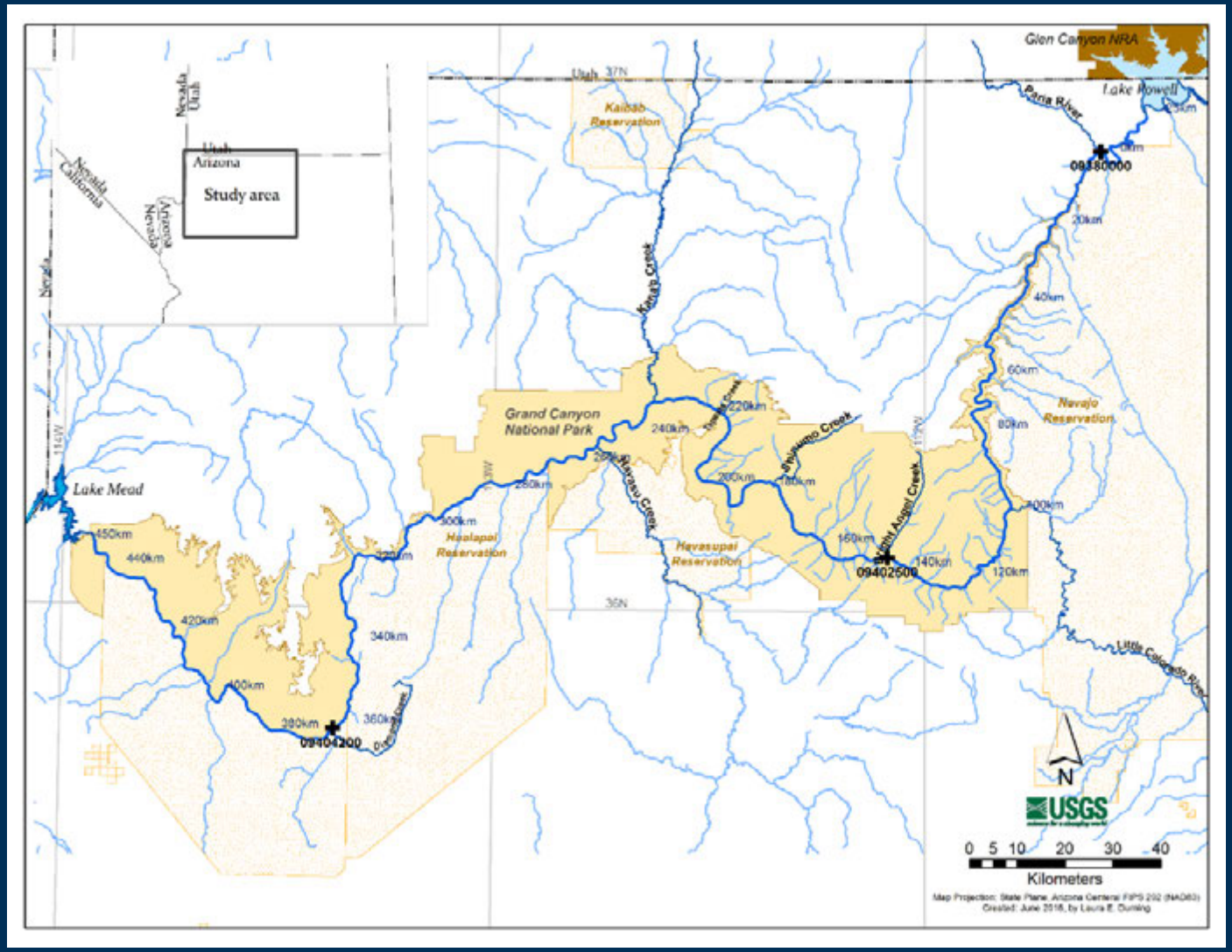
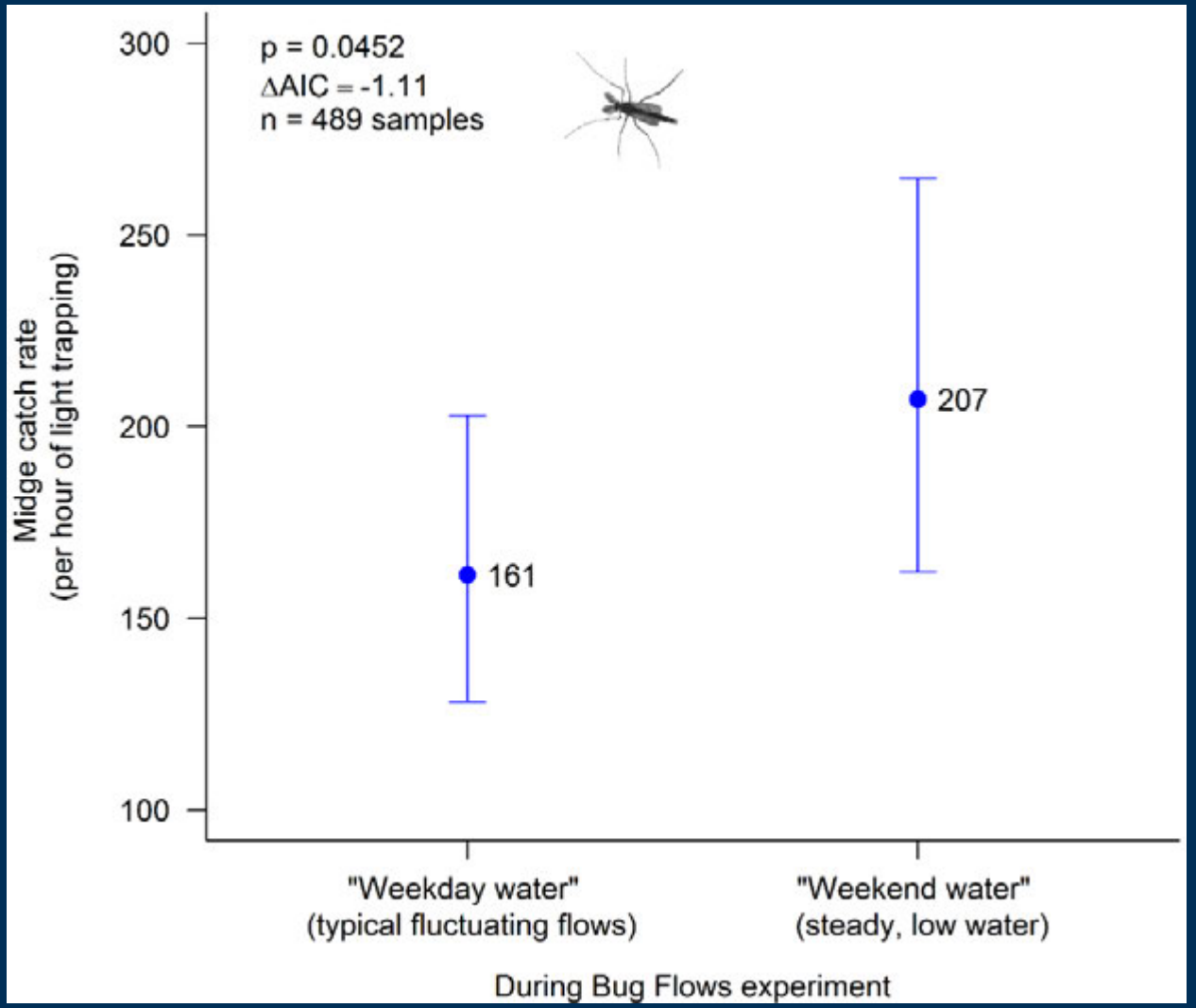
Canyon-wide results



Canyon-wide results

- Weekdays vs. weekends:
  - More midges emerging on “weekend water”



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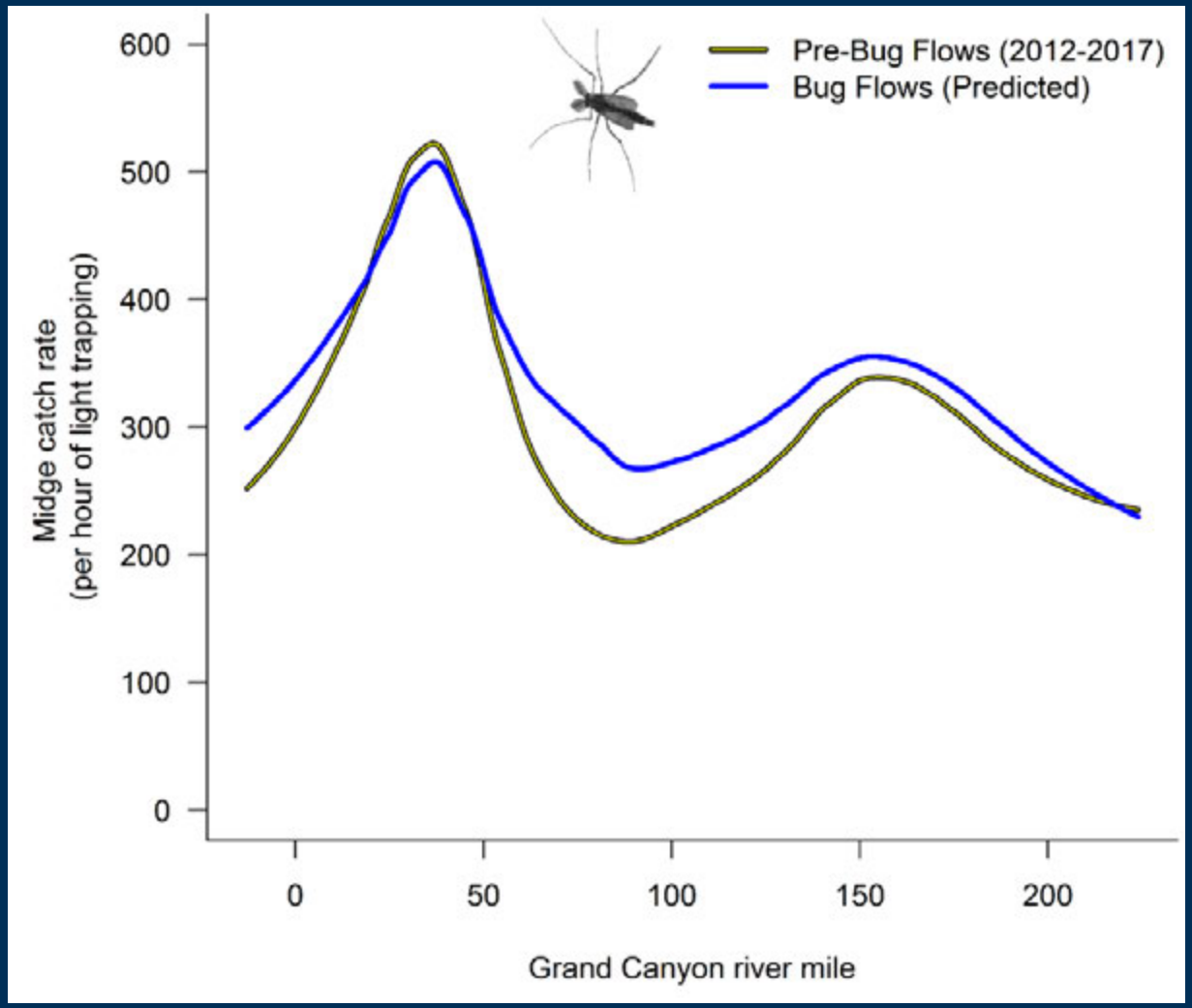
Canyon-wide results

- **Prediction:** Sine wave flattens
- **Result:** Yes, but different than expected



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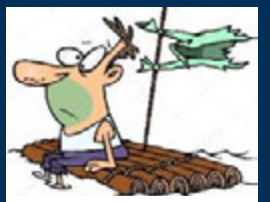
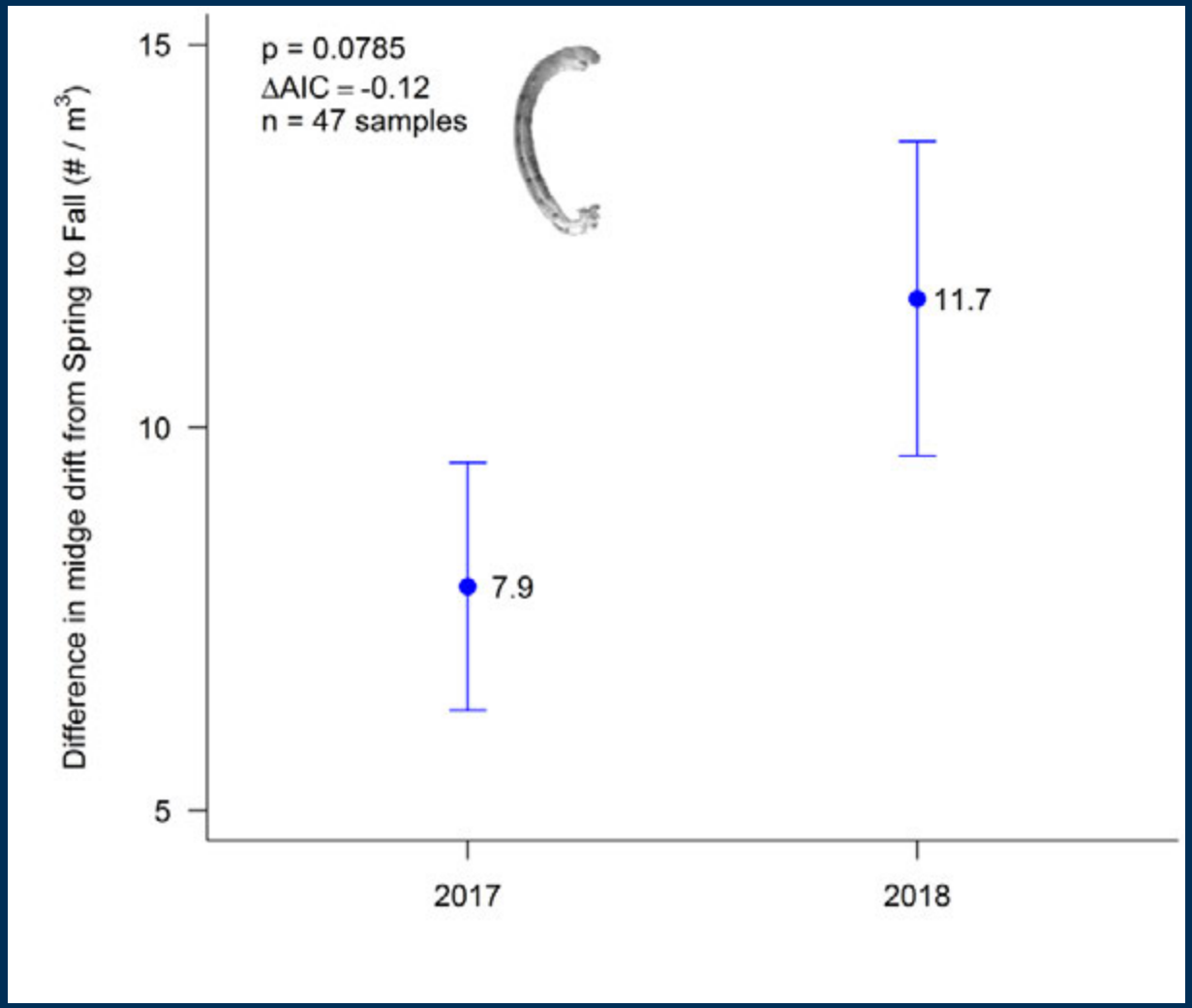
Canyon-wide results


Drift

- **Prediction**: More midges canyon-wide (>1 years)
- **Result**: Encouraging initial signs (more drift after Bug Flows)



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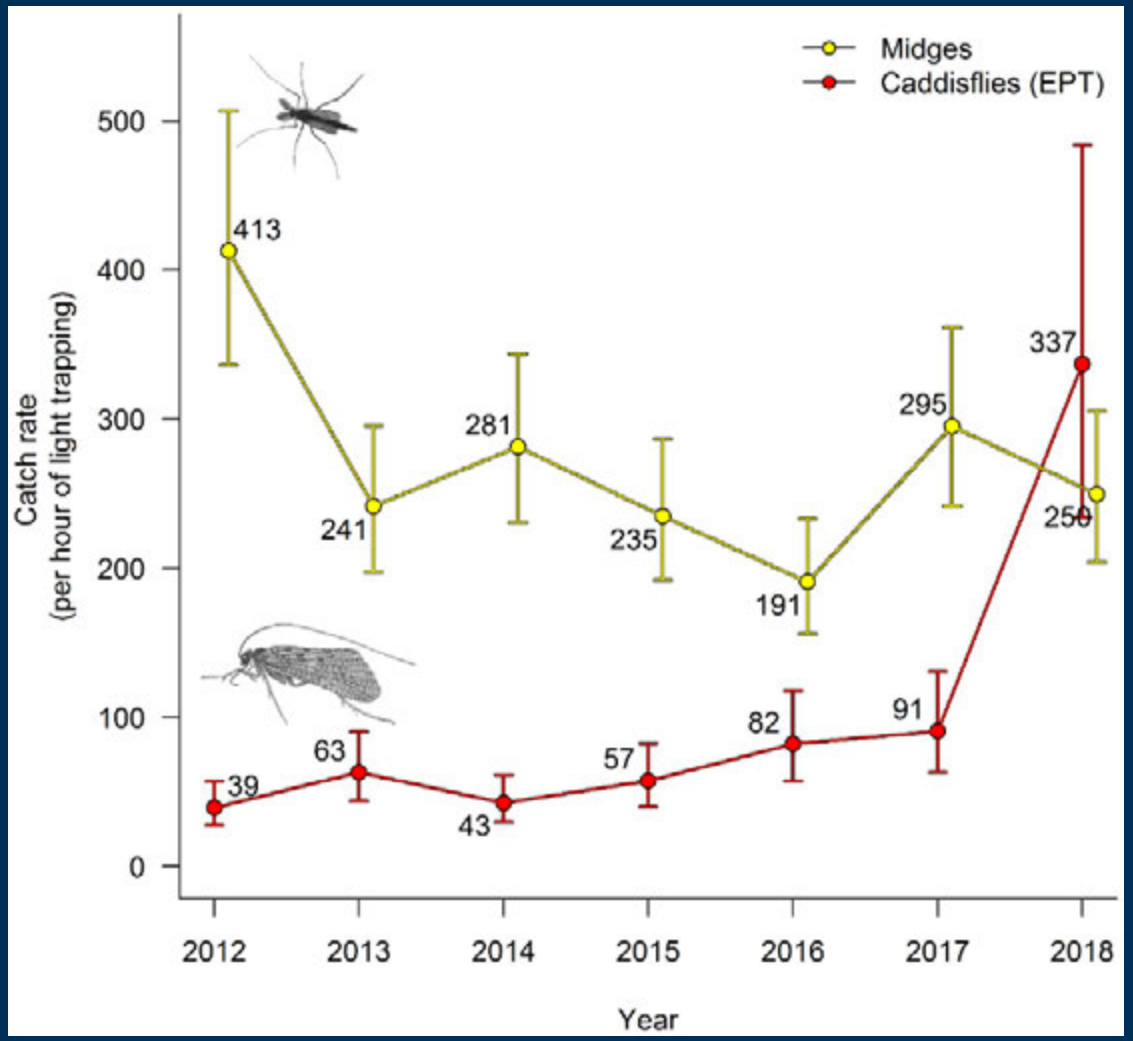
Canyon-wide results

- **Prediction:** More caddisflies (>1 years)
- **Result:** Caddisfly population boom in 2018



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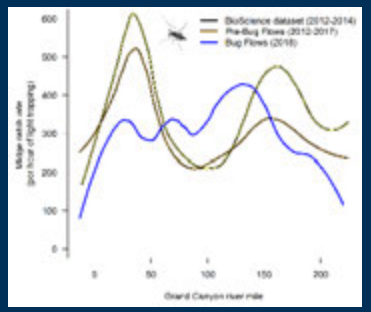
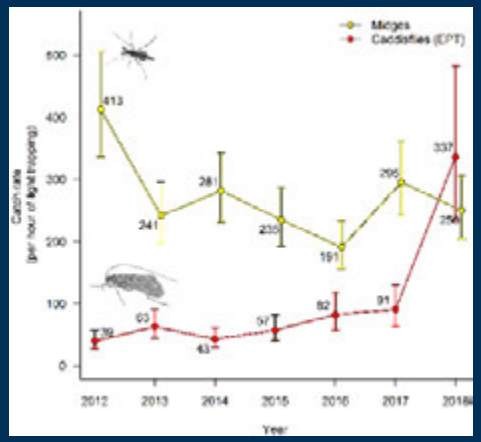
Conclusions

- Bug Flows in 2018 had ecosystem-wide effect
  - Flow matters!
- More egg-laying, weekend activity
- Less canyon-wide variability (↓ sine)
- More midges (maybe)
- Caddisfly explosion (definitely)





Hard to say all of this is *definitely* due to Bug Flows.

2019 will be telling!

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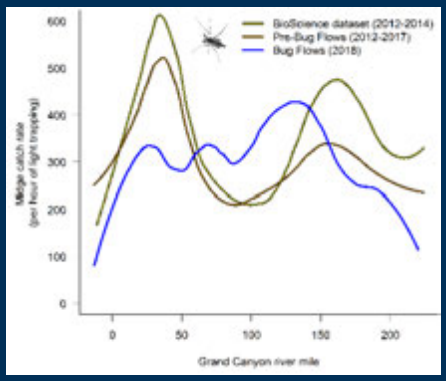
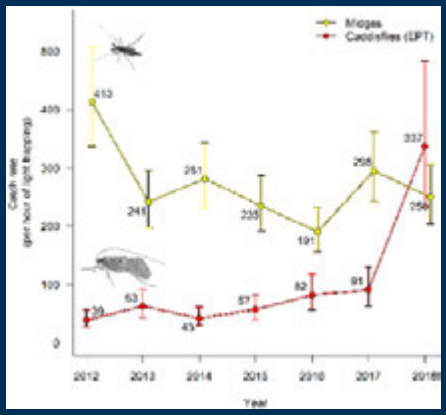
Potential Next Steps



- **Robust, 3-year test**
  - **Conduct Bug Flows again: 2019, 2020**

- **Expand experiment into other months?**
  - **Earlier (spring): Natural life history timing?**
  - **Later (fall): Food when critical for fish?**

- **Continuous monitoring regardless**
  - **Effect of 2018 Bug Flows propagates**



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