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A life history bottleneck for aquatic insects arising from load following

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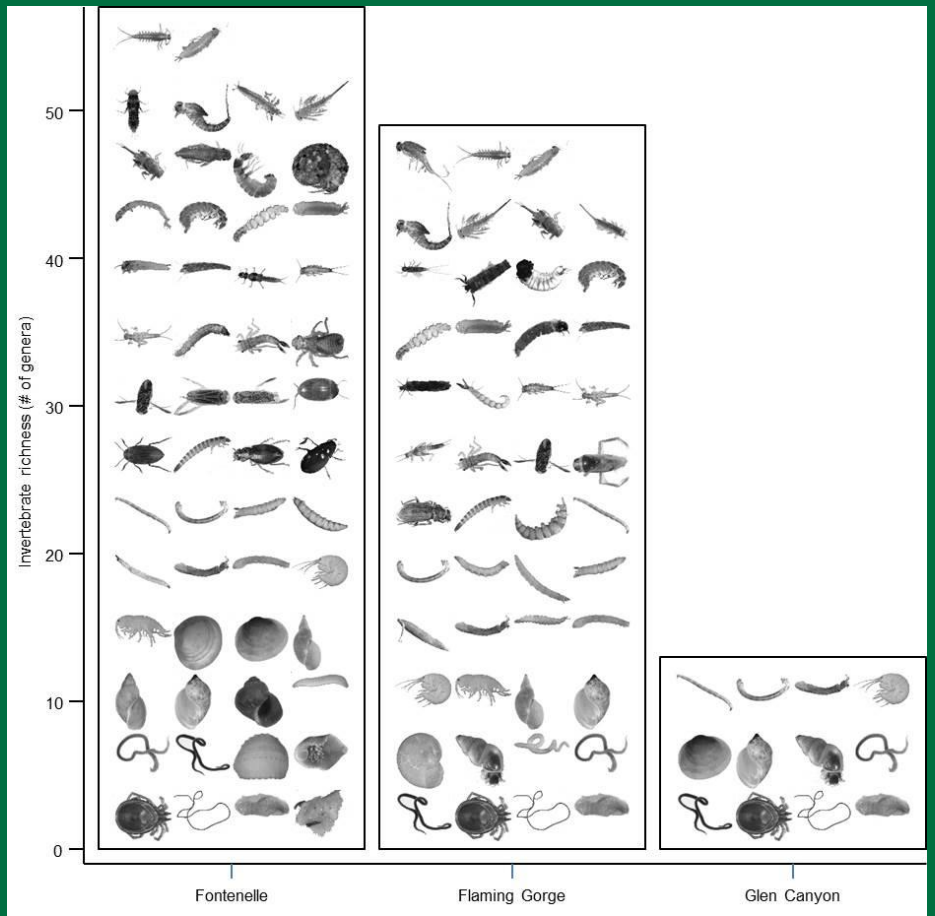
U.S. Department of the Interior
U.S. Geological Survey

Key Question in FY15-17 workplan Project 5

- Why are mayflies, stoneflies, and caddisflies (EPT) absent/rare?
- Why is midge and blackfly production low?



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These are actually long standing questions

- The aquatic insects occurring in the Colorado River consist of but a few species *Blinn and Cole 1991*
- The post-dam aquatic macroinvertebrate fauna in Grand Canyon is remarkably depauperate compared with other rivers…virtually no EPT are present *Stevens et al. 1997*





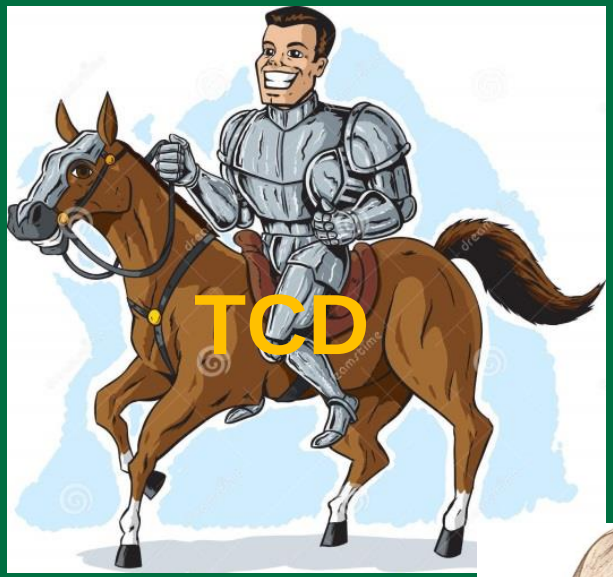
For 25 years, answer has been:

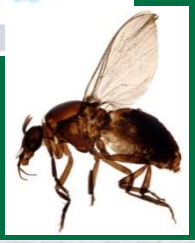
It's the TEMPERATURE!

- Cold and constant temperatures below Glen Canyon Dam may disrupt thermal signals essential for the completion of aquatic insect life cycles. *Blinn and Cole, 1991*
- Mayflies and other taxa should be abundant in the clear water segment, but are apparently excluded by the stenothermic temperatures (Hauer and Stanford 1982, 1991). *Stevens et al. 1997*

For 25 years this answer was a no-brainer

- Temperature is a <u>HUGE</u> lever
- Temperature control device (TCD) was coming
- Didn't require tinkering with Dam operations





But temperate can't be the *only* explanation

- **Tapeats Creek:**

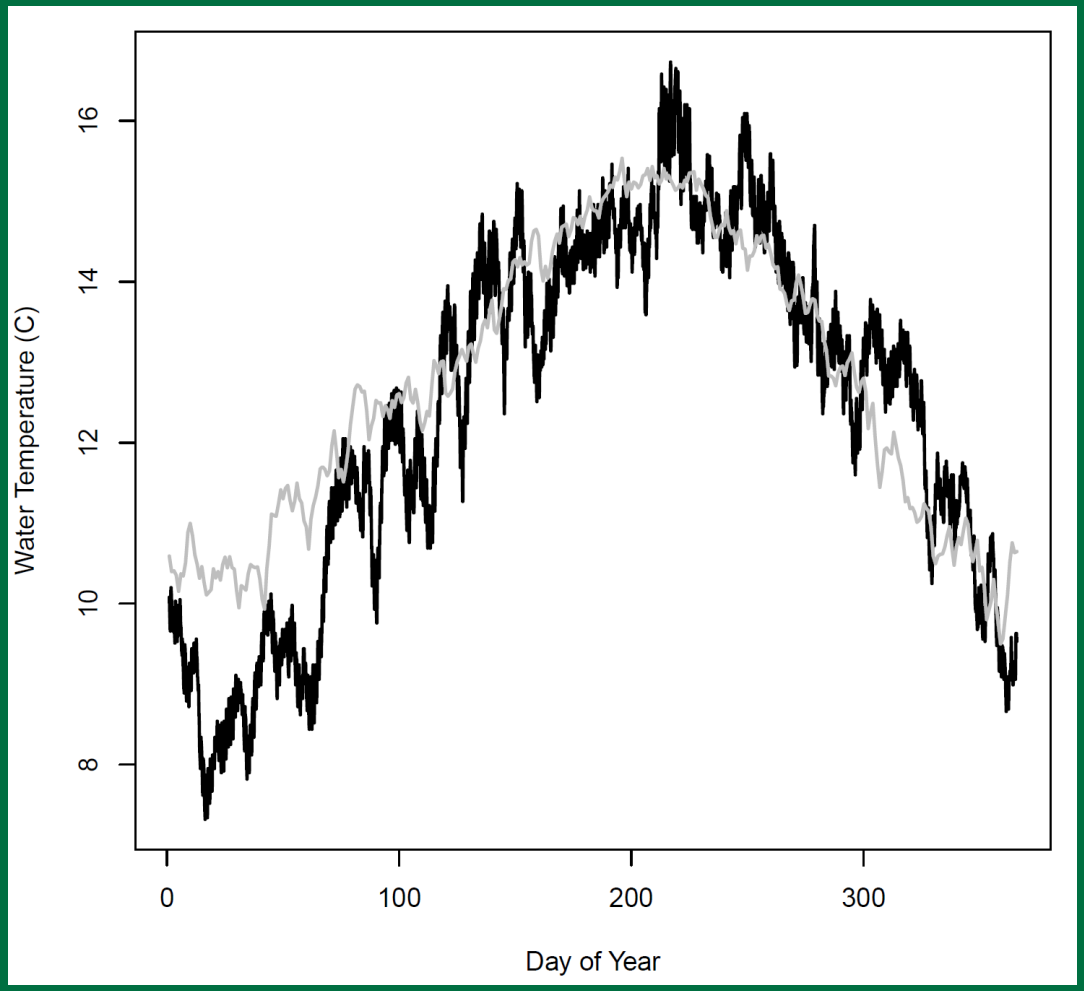
7 genera caddisfly

3 genera mayfly

1 genera stonefly

Why haven't these species colonized the mainstem??

Temperature can't be the only bottleneck



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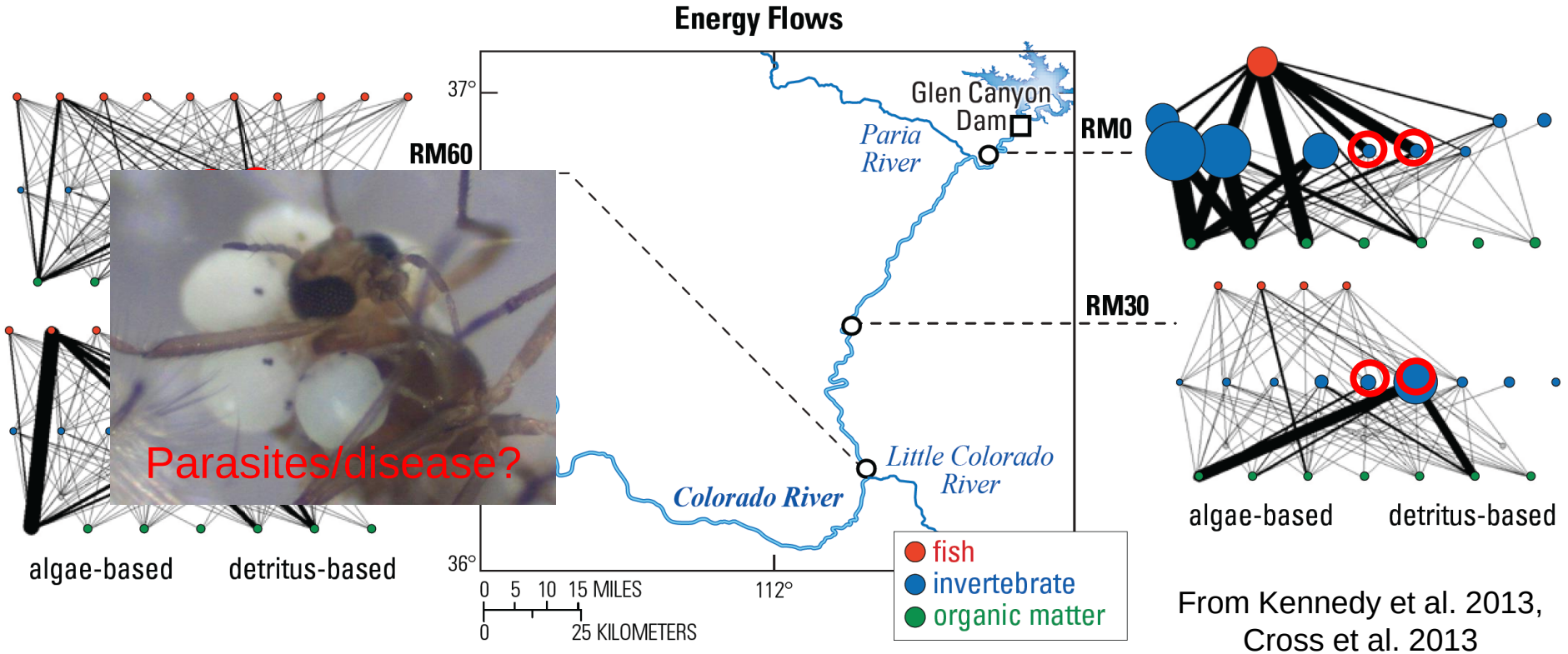
Temperature Control Device no longer feasible

- High cost: >$100,000,000
- High risk: warm water non-natives
  - Non-native bass are <u>decimating</u> Colorado River native fish populations in the Upper Basin

- Carl Walters: “Maybe the bugs don’t matter, Kennedy?”

S

Low insect diversity: tangible negative impacts



From Kennedy et al. 2013, Cross et al. 2013

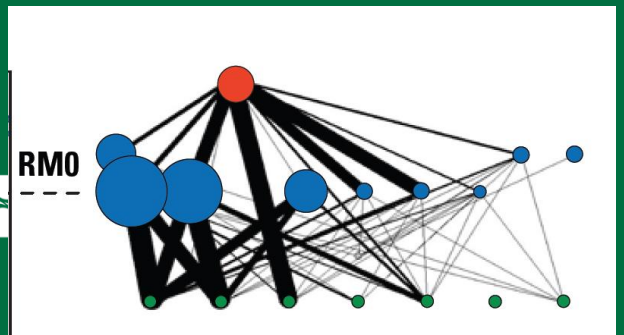
Fish populations limited by insect prey
Insect prey vital to fishes in Grand Canyon
Trout populations inherently unstable
Very little redundancy: what if something goes wrong?

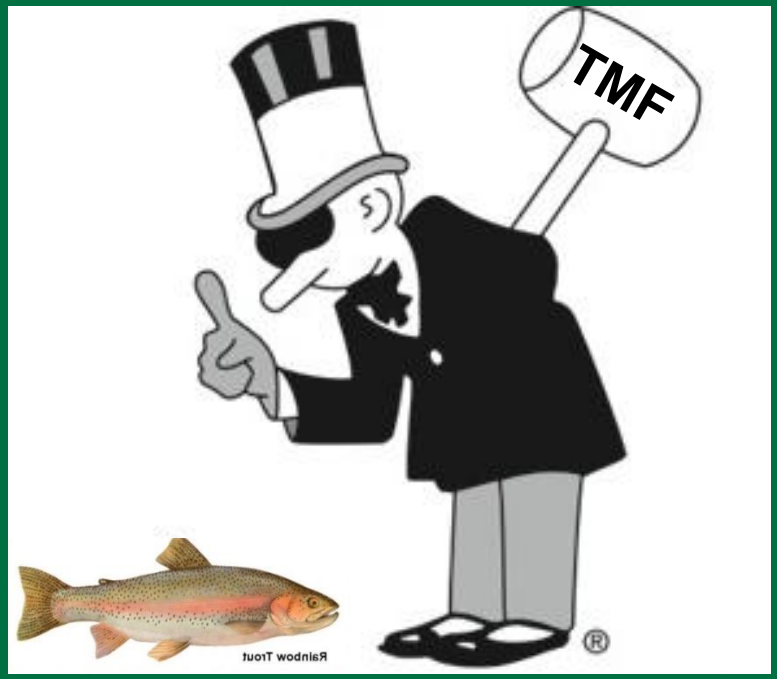
A path forward for LTEMP EIS: June 2011 Knowledge Assessment

- **Unable to rehabilitate food webs with temperature**
- **But native fish are limited by insect prey**
- **Solution: kill off the competition**
  - **This was the only topic Carl Walters allowed us to discuss**

I wanted to also discuss approaches that dealt with root cause of problem

-But the food webs are inherently unstable?
-Maybe there are ways to rehabilitate food food webs so both trout and chub benefit?





What to do when you suffer a public beating at the hands of Carl Walters?

A. Lick your wounds

B. Soul searching

C. Talk to colleagues

D. Write a paper

E. All of the above

-Surveys developed using GCDAMP SSQs

-Converted to multiple choice or categorical to facilitate quantitative analysis

Surveys sent to 40 biologists familiar with the program and key issues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Identification and Evaluation of Scientific Uncertainties Related to Fish and Aquatic Resources in the Colorado River, Grand Canyon—Summary and Interpretation of an Expert-Elicitation Questionnaire

Scientific Investigations Report 2013–5027

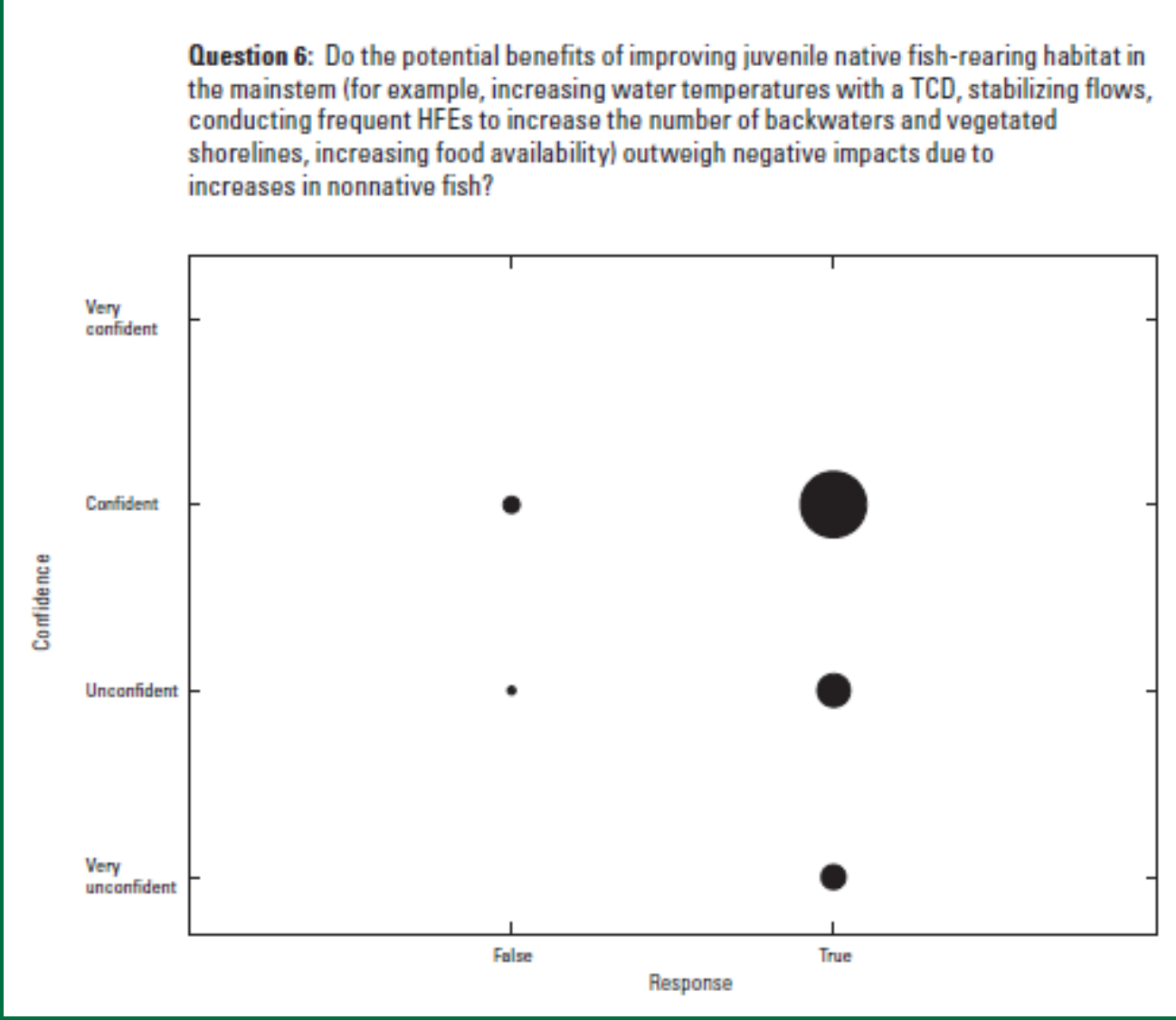
U.S. Department of the Interior
U.S. Geological Survey

Kennedy, 2013

Surprising what folks will say when they can talk freely

20 Respondents:

John Beeman, USGS
Aaron Bunch, AZGFD
Lew Coggins, FWS
Wyatt Cross, UMontana
Kevin Donner, ISU
Colton Finch, UF
Bob Hall, UWyo
Brian Healy, NPS
Ted Kennedy, USGS
Josh Korman, Ecometric
Ted Melis, USGS
Bill Persons, USGS
Bill Pine, UF
Barb Ralston, USGS
Emma Rosi-Marshall, Cary
Dennis Stone, FWS
Scott Vanderkooi, USGS
Randy VanHaverbeke, FWS
David Ward, USGS
Mike Yard, USGS

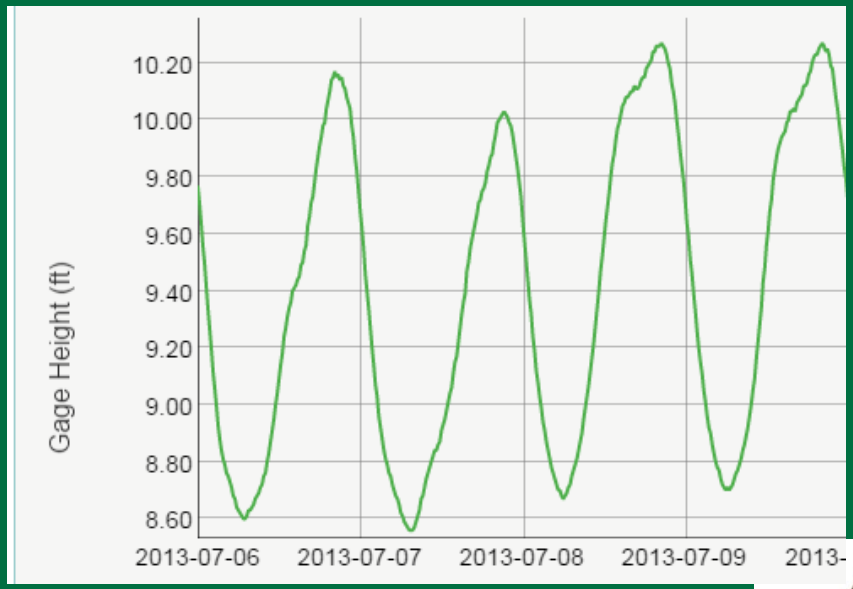


Kennedy, 2013

Not everyone has given up hope

Back to the drawing board: the other 800lb gorilla

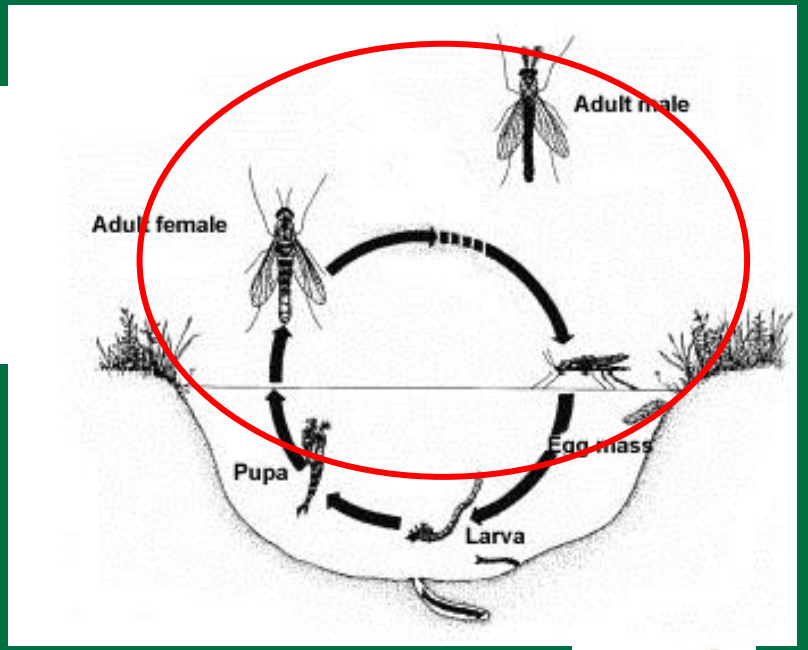
- Load following: obvious variable to consider
- Prior studies investigated load following
  - But focus was on larval life stages



Need new study approaches

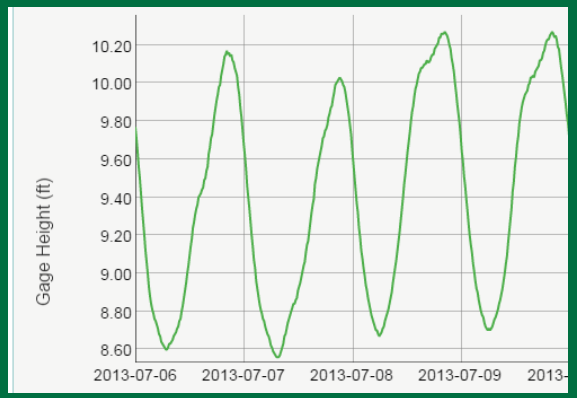
- Larval studies limit learning
- 30 years of larval studies failed to f
bottlenec
- Maybe bottleneck occurs at other life stages?

A bottleneck at any of these life stages will limit aquatic insects



Hypothesis: Aquatic insects are recruitment limited, because load following causes high egg mortality

"Mated females of the mayfly genus *Baetis* alight on rocks protruding from streams, crawl under water and deposit a single egg mass under a rock."
Encalada and Peckarsky 2012



No Mayflies?

Why this hypothesis is so appealing

- TK wants to put an end to load following?

  FALSE

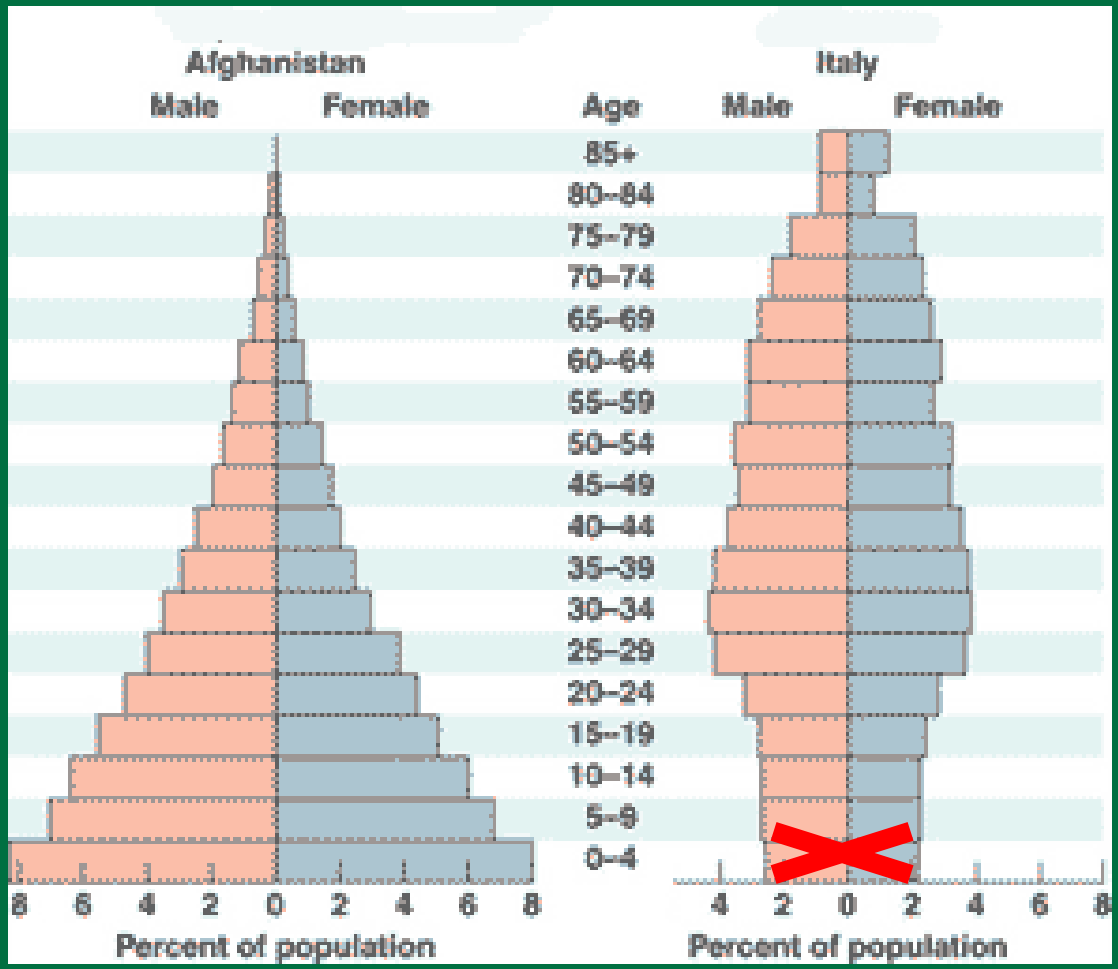
- **Answer:**
  - **It is potentially really easy to FIX**

Hypothesis: Egg mortality limits aquatic insects

Population

Growing

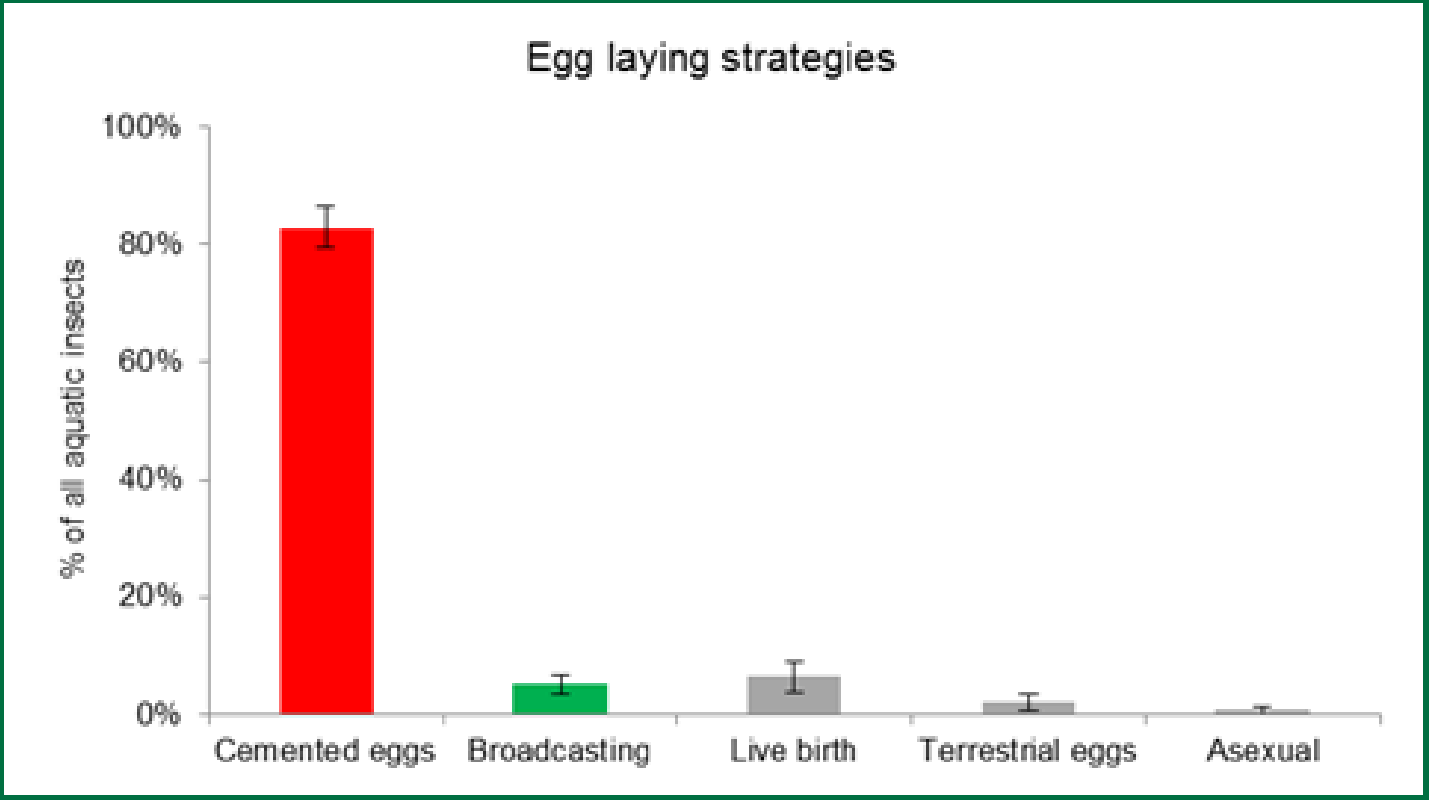
Shrinking



Mitigating egg mortality is easy, because insects are prolific and spend very little time at this life stage

Assumption 1: Many aquatic insects lay eggs along shorelines

TRUE: The majority of aquatic insects lay eggs along shorelines



Statzner and Beche 2010:

Analyzed biological traits across:

1200 North American genera
+
600 European species

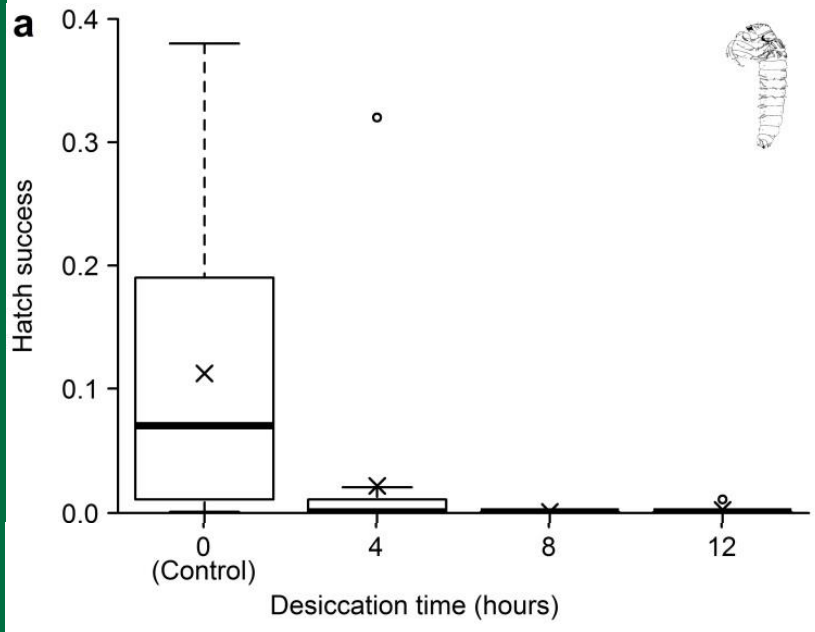
Statzner B. and Beche LA, 2010. Can biological invertebrate traits resolve effects of multiple stressors on running water ecosystems? *Freshwater Biology* **55**: 80-119.

Assumption 2: Insect eggs subject to drying suffer high mortality

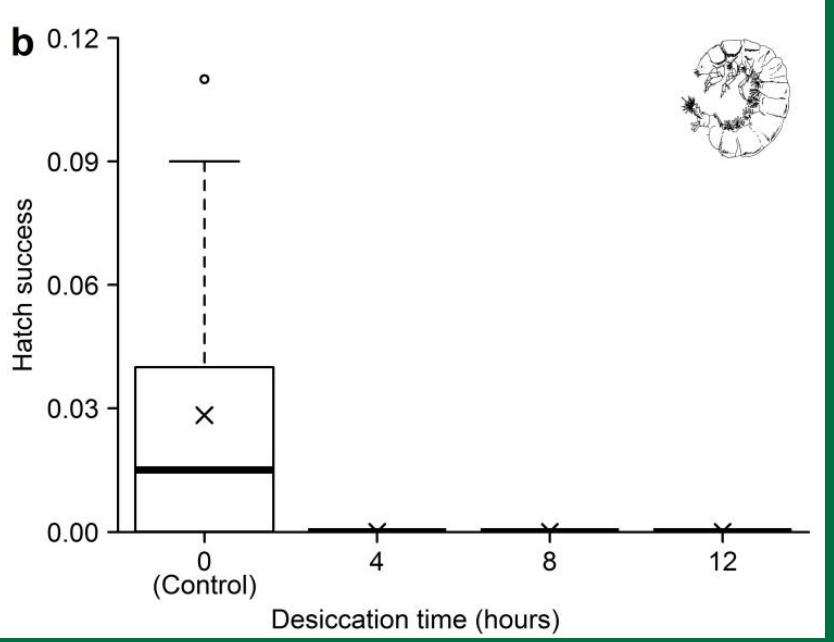
TRUE: Brief exposure to air renders caddisfly eggs unviable

New experiments show drop in mayfly egg survival at 30 minutes, and 99% mortality at ≥1hr

Brachycentrus sp.

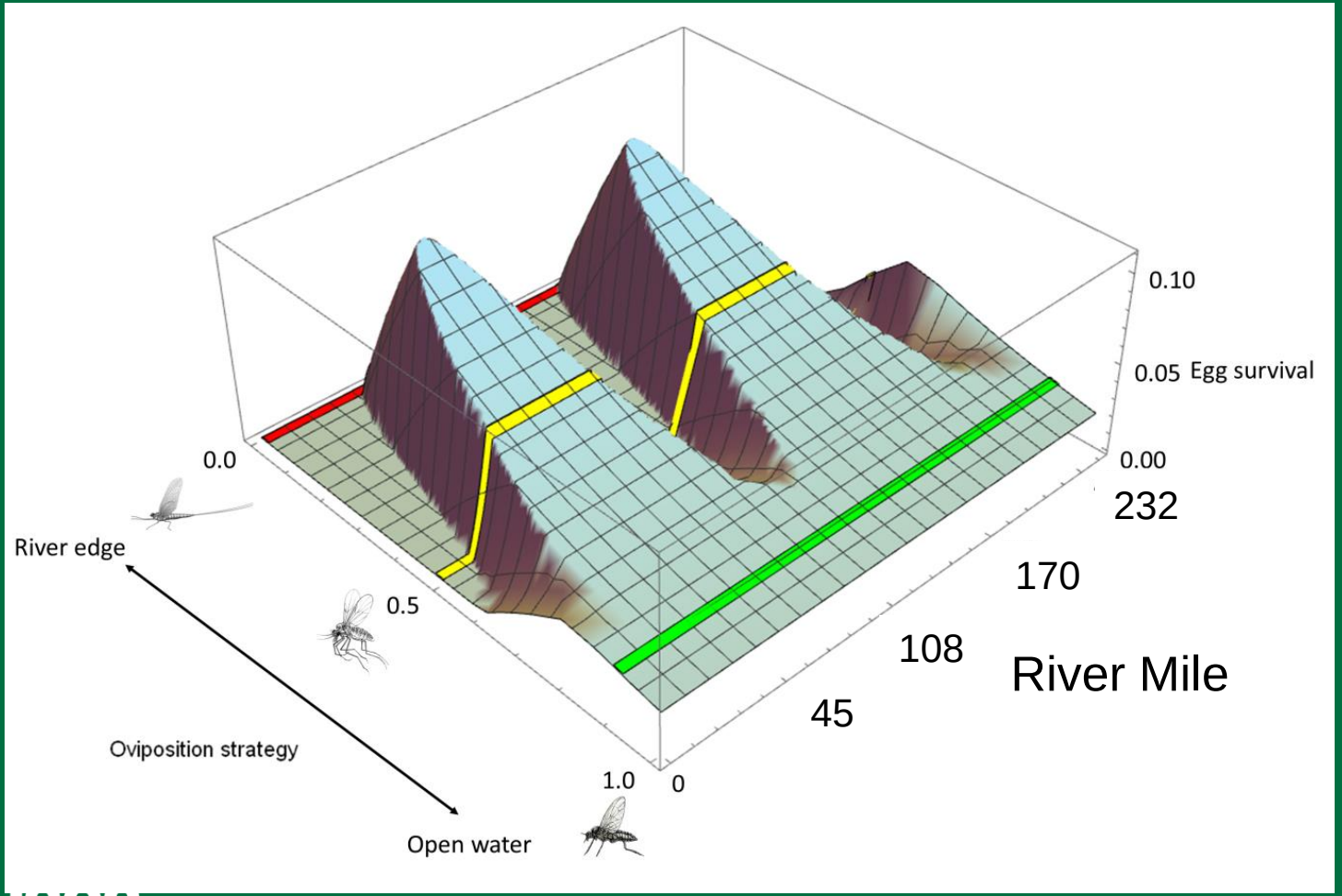


Hydropsyche sp.



Scott Miller, USU, unpublished data

Egg-laying behavior determines population response



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David A. Lytle OSU, unpublished data

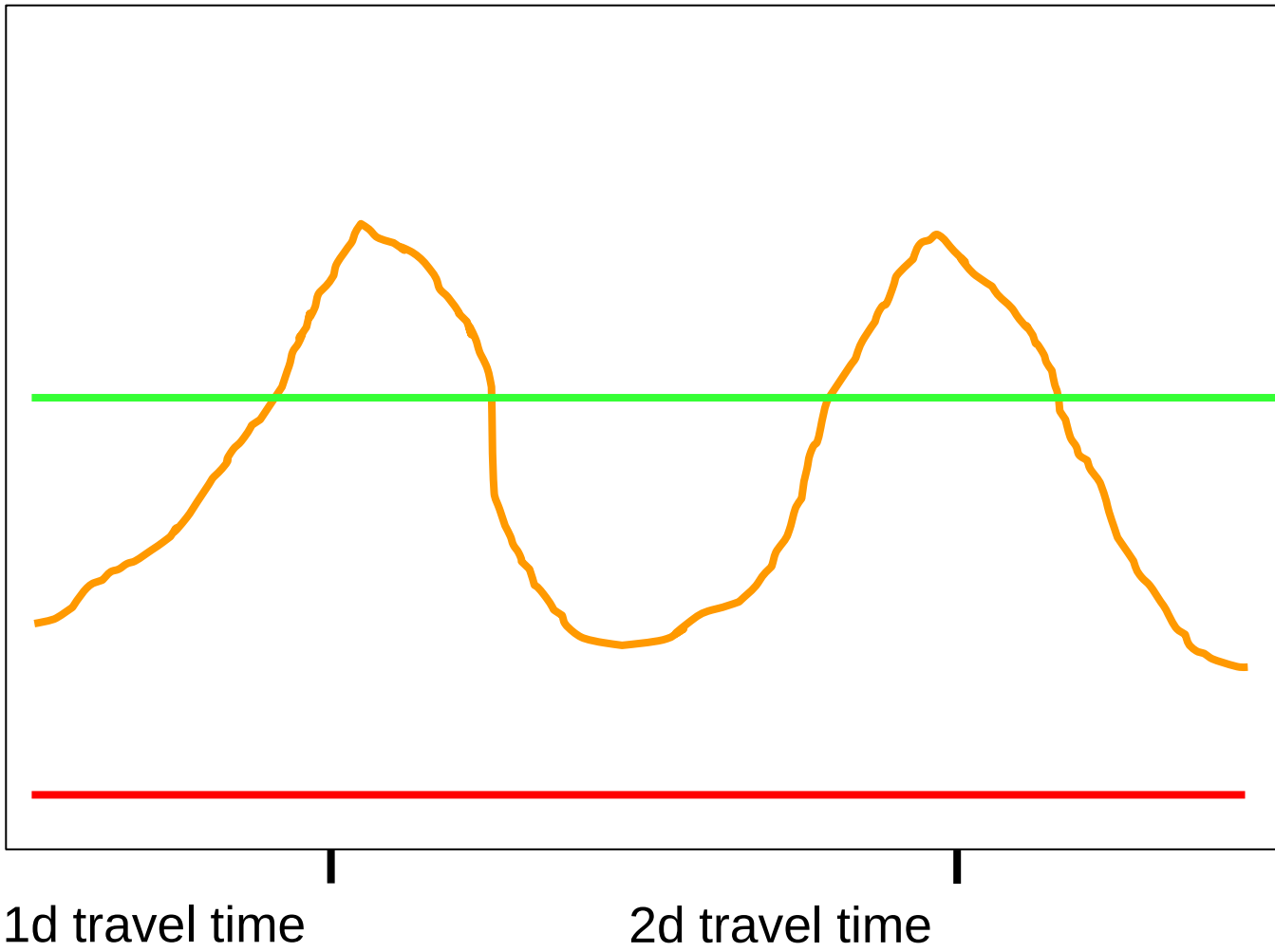
Model predictions

Predictions

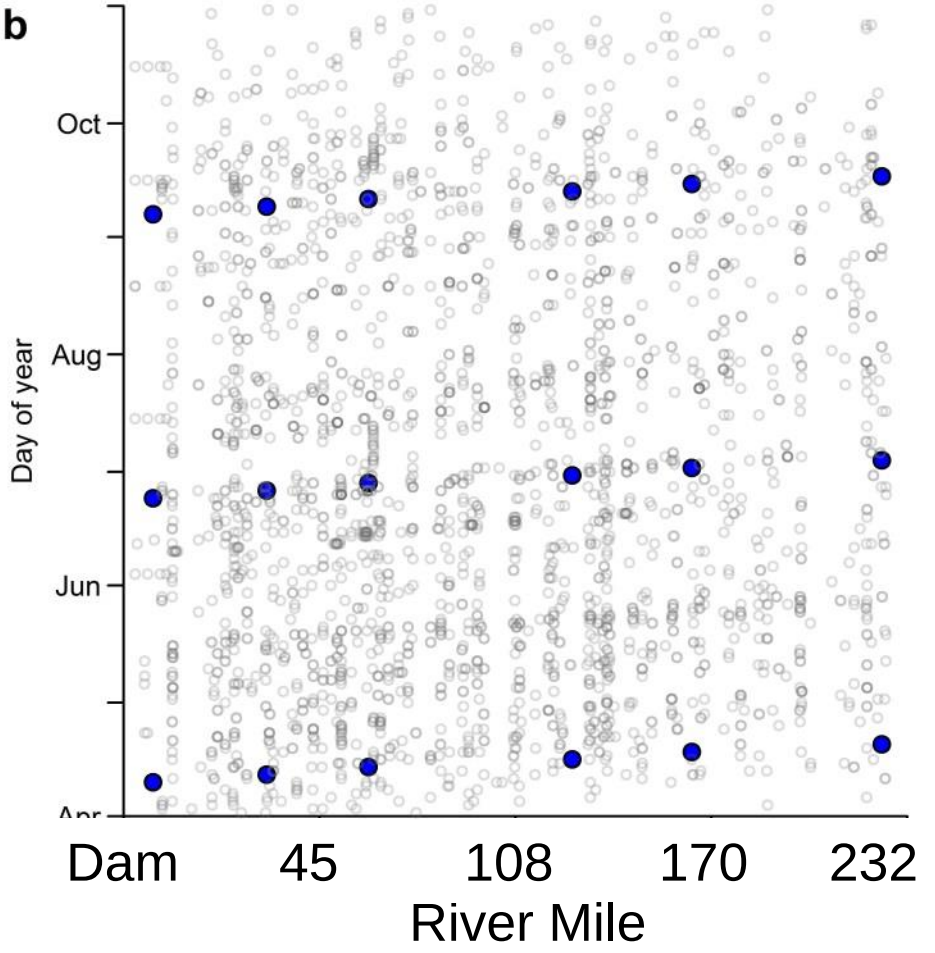
Constant

Spatial periodicity

Extinct



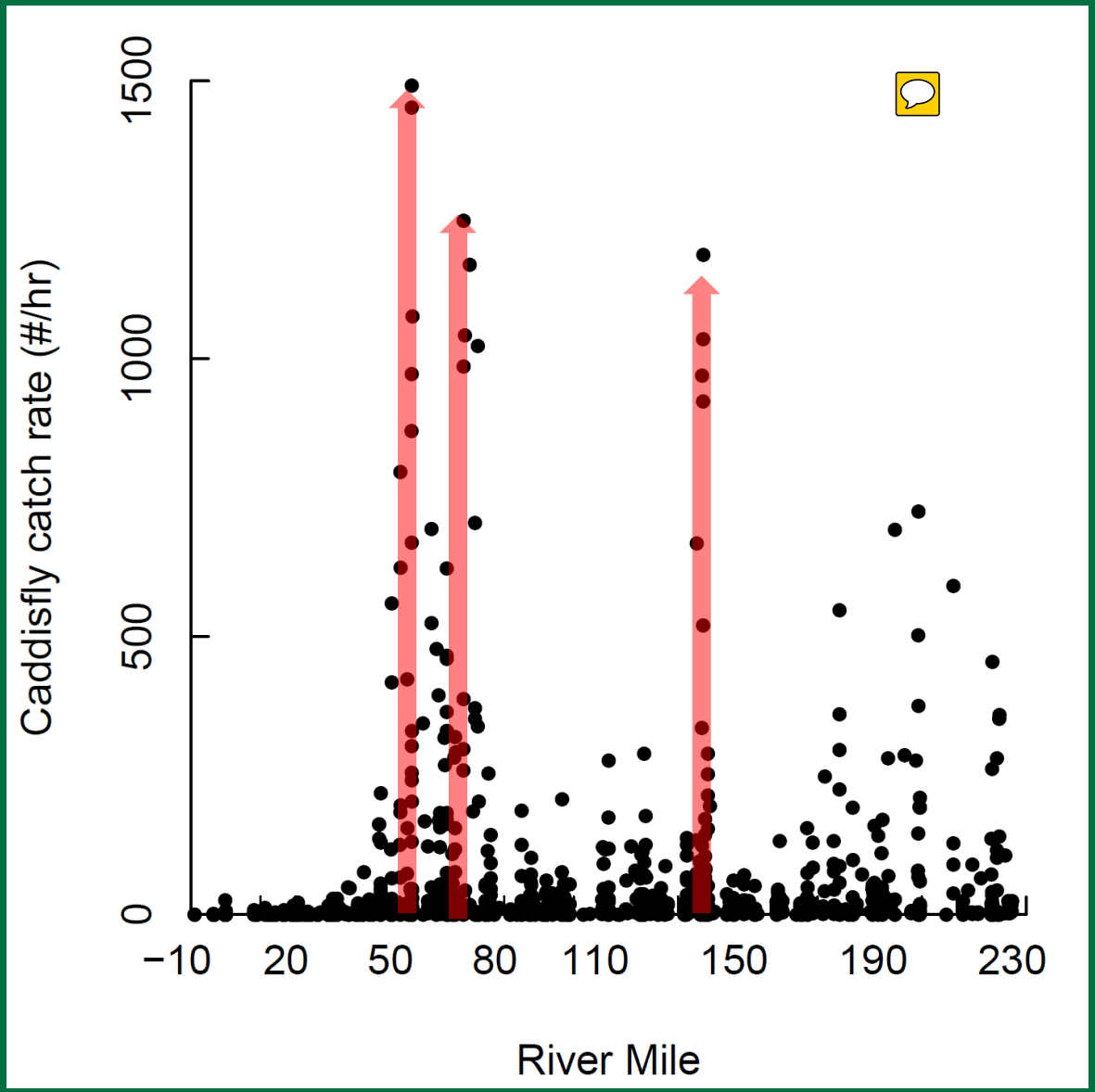
Testing predictions: citizen science in Grand Canyon 2012-2014



River edge egg layers: Microcaddisflies

Prediction:
Extinct

Observation:
Present, but originating from tributaries



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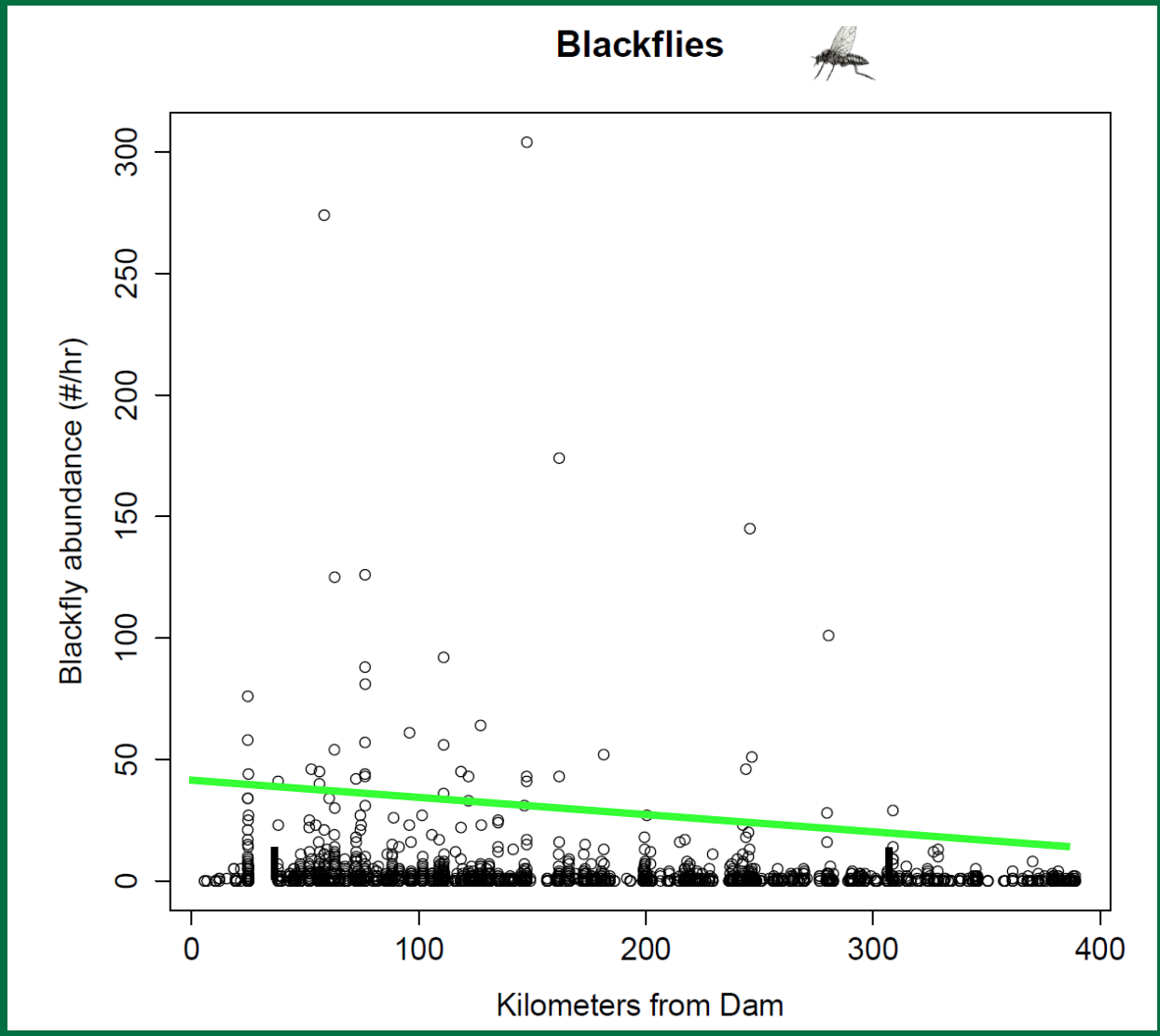
Broadcast egg layer: blackflies

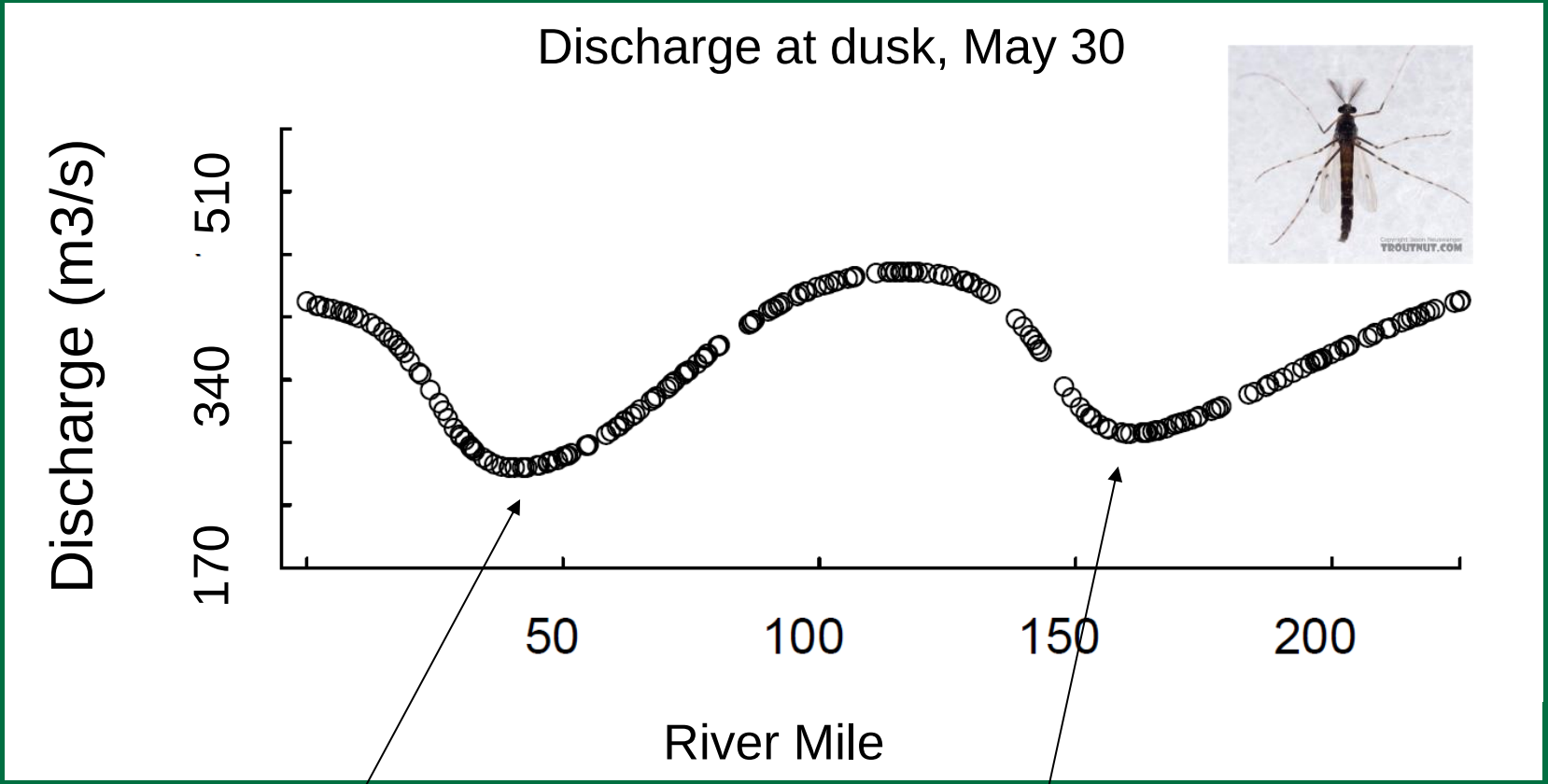
Prediction:
Constant

Observation:
Downstream
Decline

-Likely caused by declining food quality



Intersection of daily tides and timing of egg laying



Midges emerge and oviposit at dusk

Prediction: Midge abundance higher at these nodes

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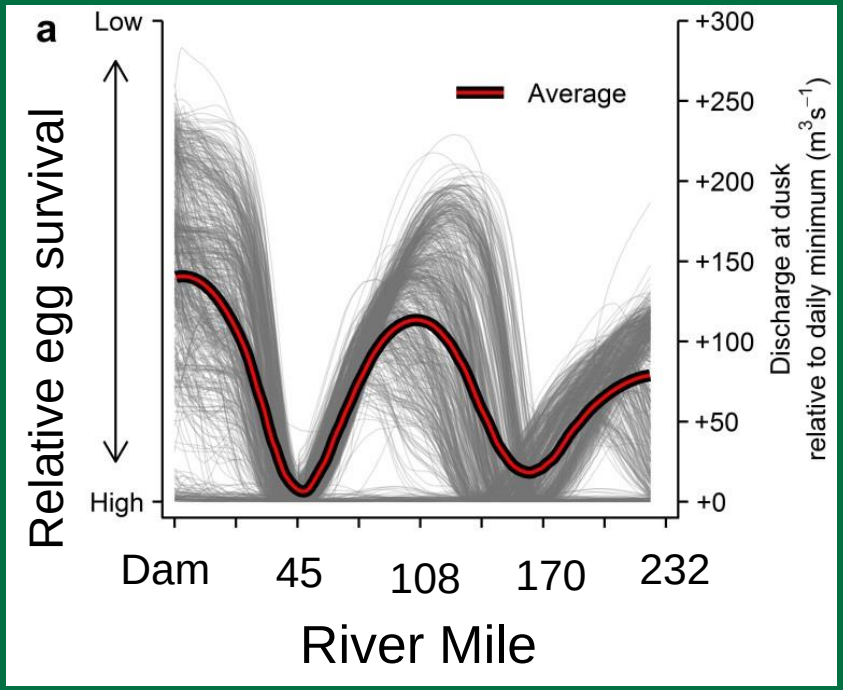
Consistent timing of daily tides



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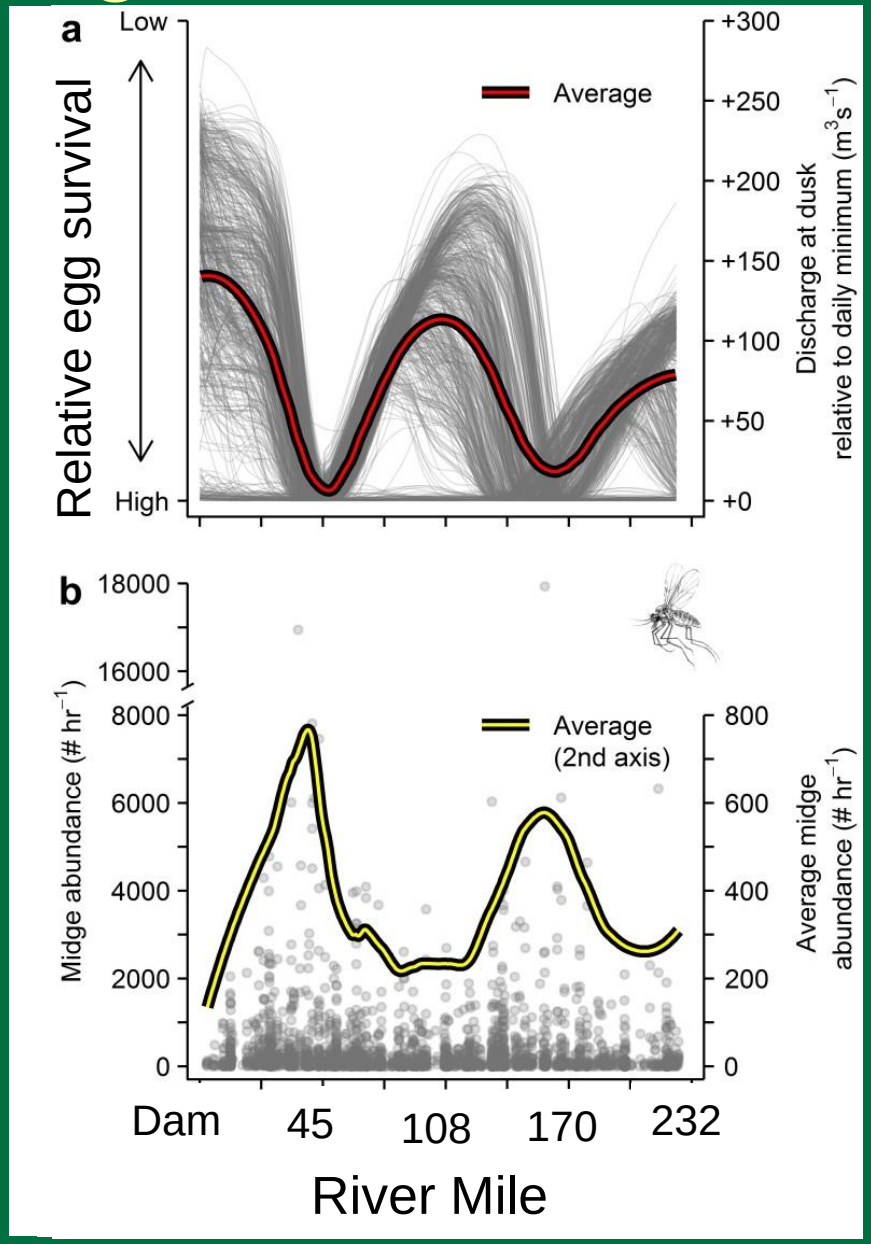
Spatial periodicity in midge abundance

Midges: 3X greater at nodes



Stepping outside of Grand Canyon

- **Build on Dibble's tailwater synthesis**
- **Compare insect diversity across range of load following intensity**

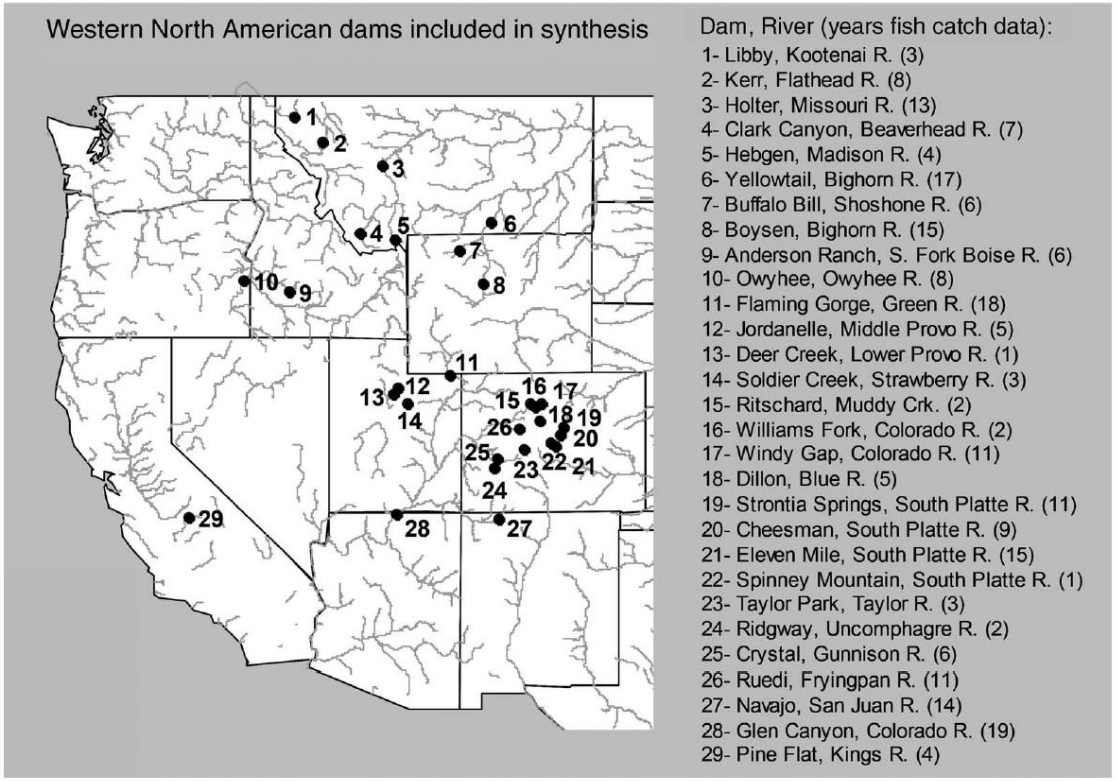


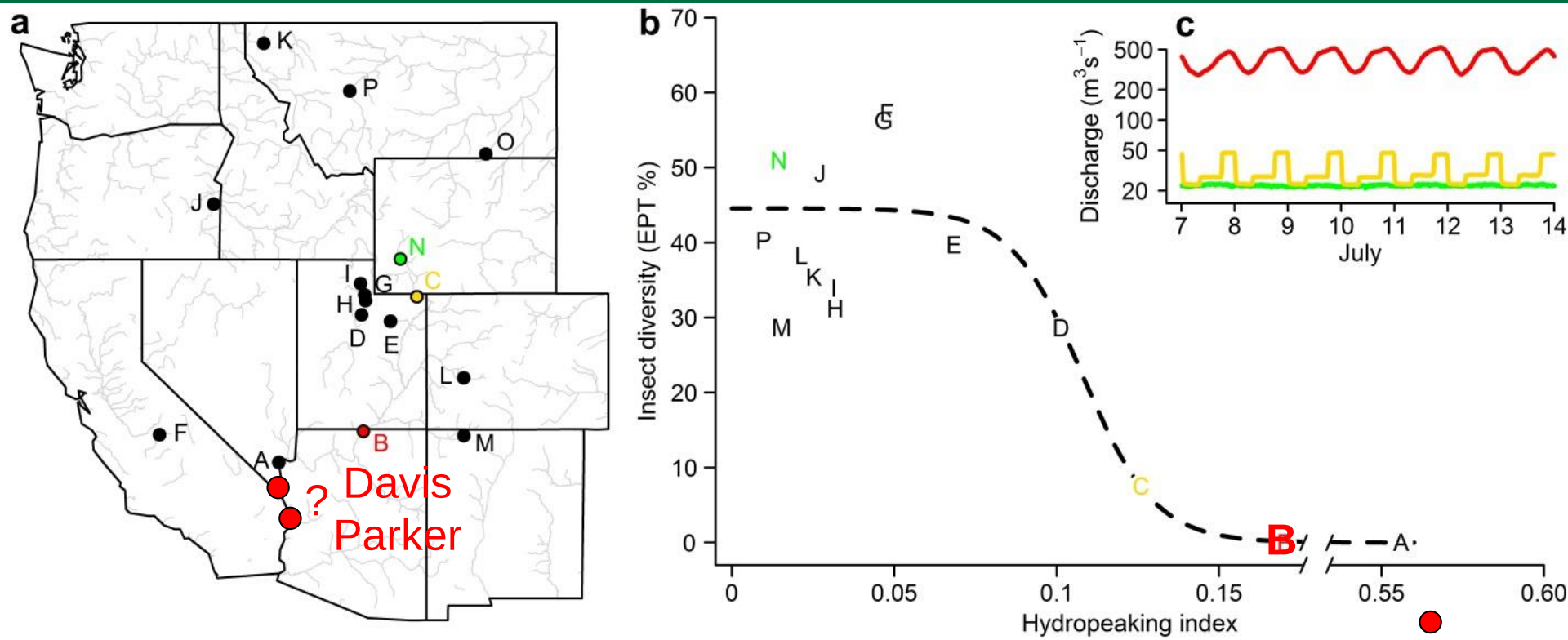
FIG. 2. Map showing location of western North American tailwaters included in synthesis.

<u>Filtered invertebrate data</u>:

-Only sites with 3+ bug samples

-Only samples <30 km from dam

Insect diversity negatively related to load following intensity



EPT = $\frac{\#\ of\ E,P,T}{total\ \#\ of\ invertebrates}$ =

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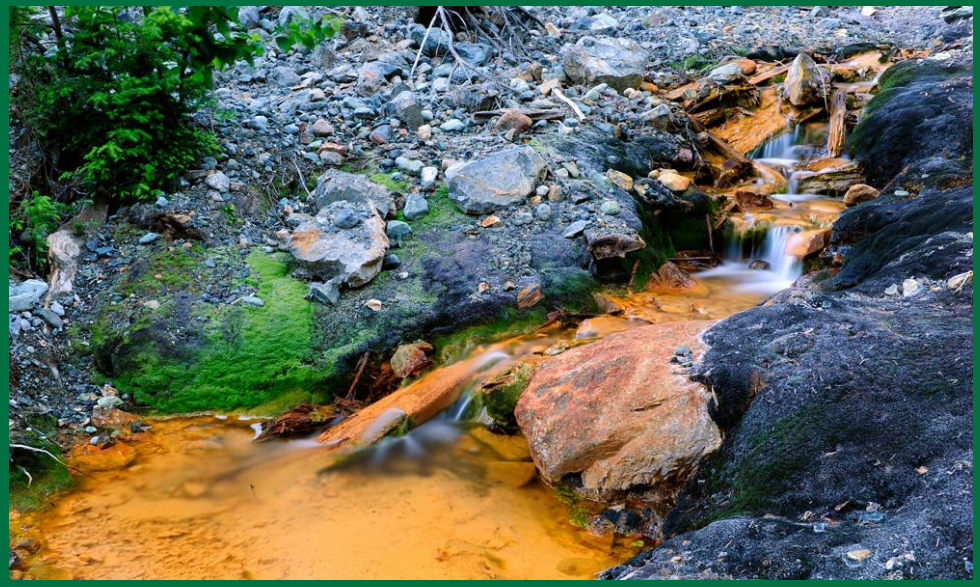
A Path Forward

- Load following is a significant filter
  - Imposes bottleneck at critical life stage
- But insects are prolific
  - Just need a foothold

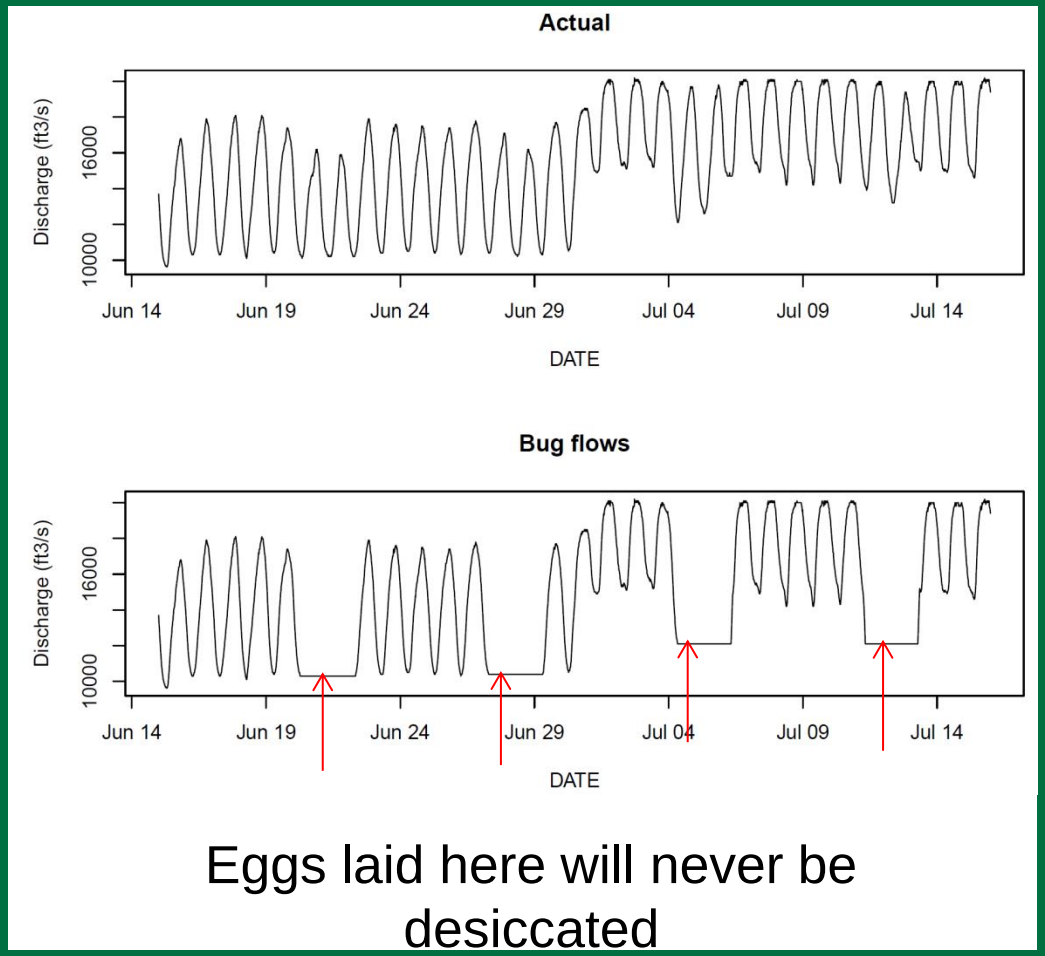
Mayfly egg laying in San Juan



EPT even found in contaminated sites

Give bugs the weekend off!!

- Steady and low flows every weekend May-Aug
- Periodically create ideal egg-laying conditions
- Minimizes impacts to hydropower



Eggs laid here will never be desiccated

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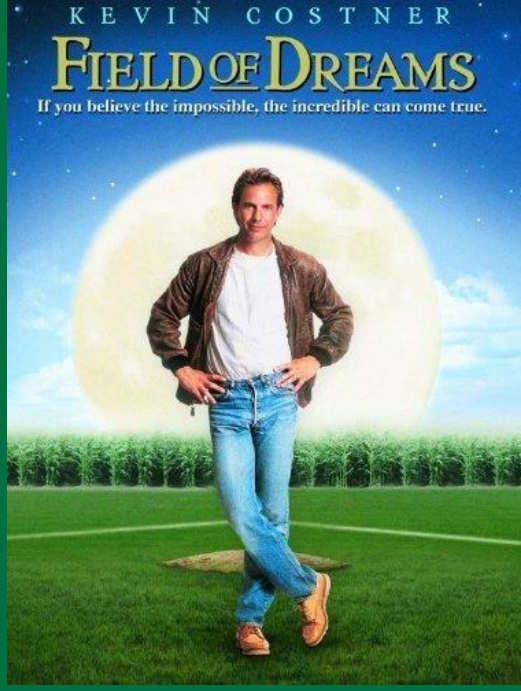
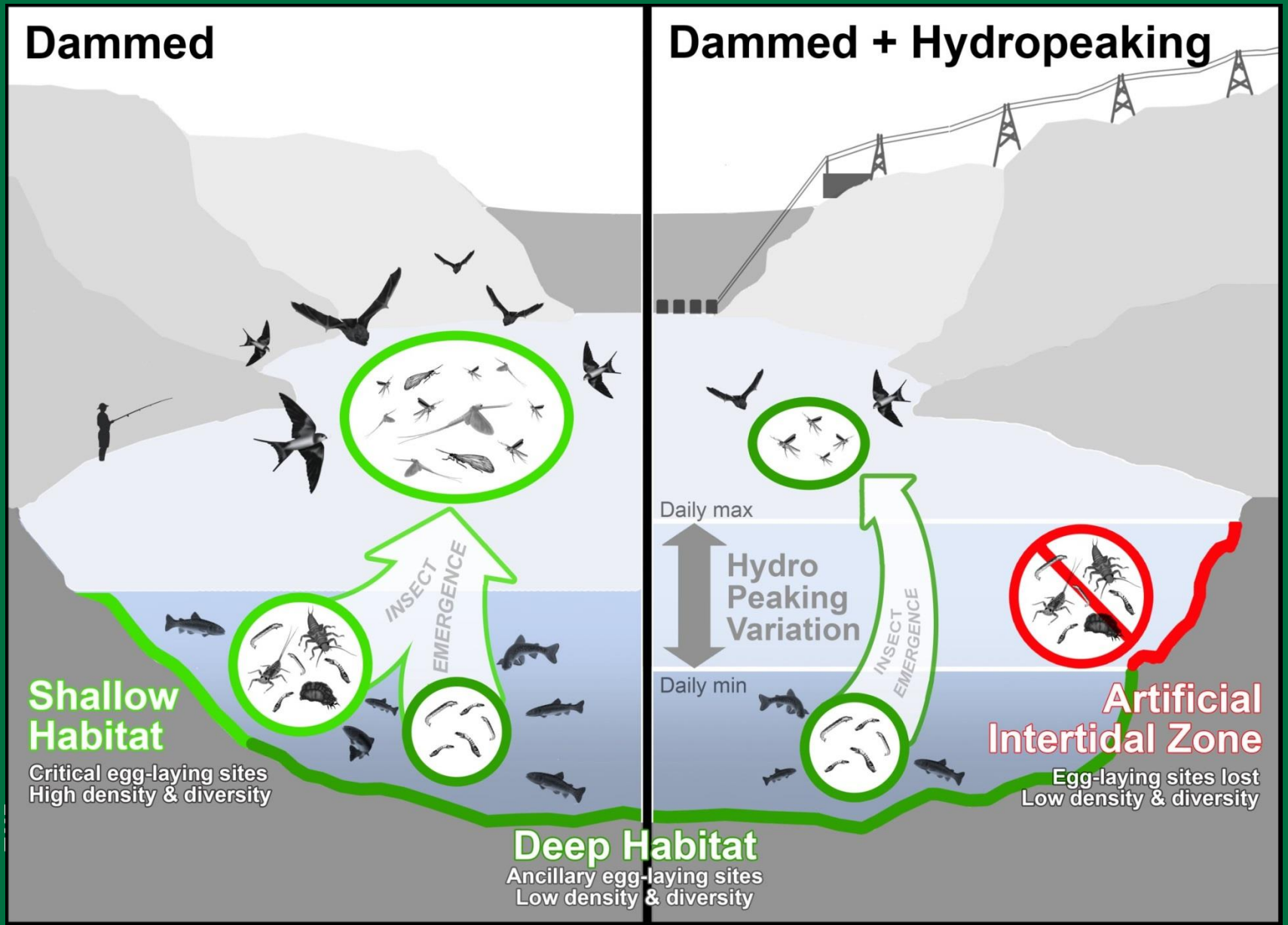
Repatriation

- Bug flows = Field of Dreams?
  - If you build it, will EPT really come?
  - How far to nearest big river mayfly populations?

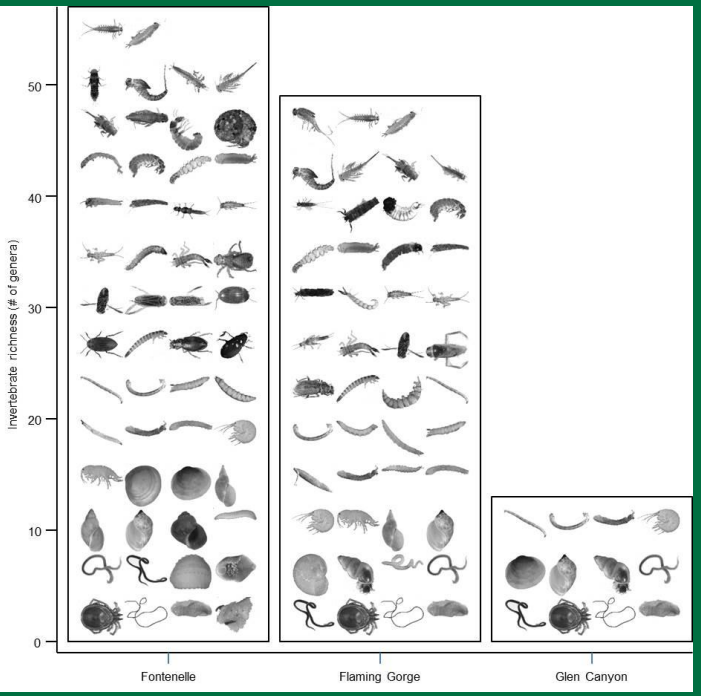


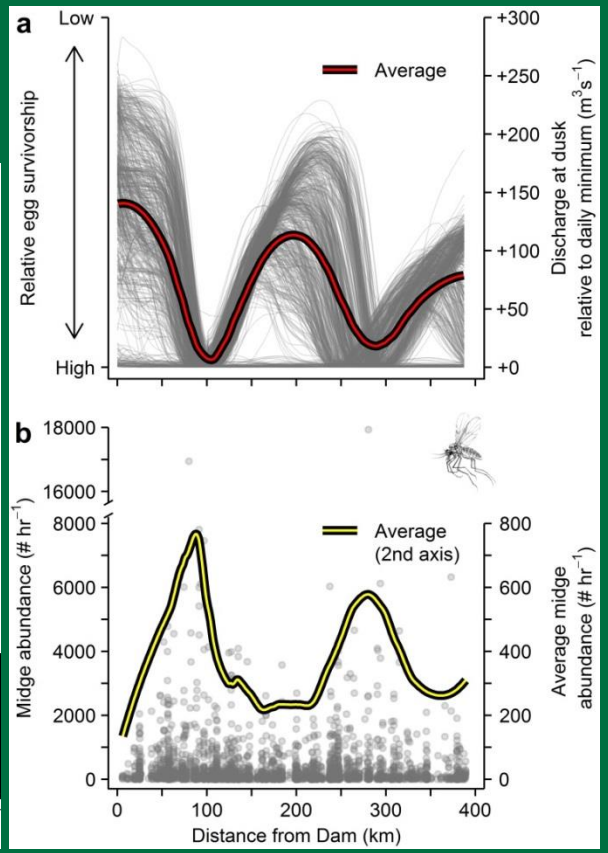
- Repatriation + bug flows would be a powerful experiment

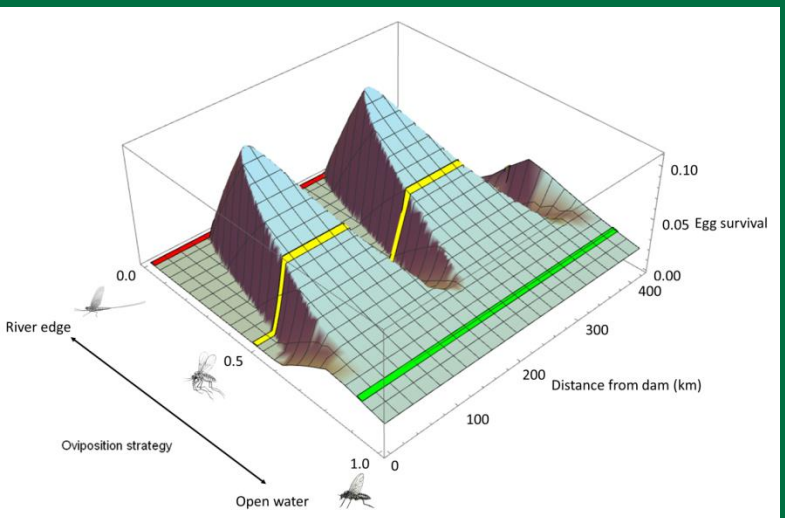
Questions?

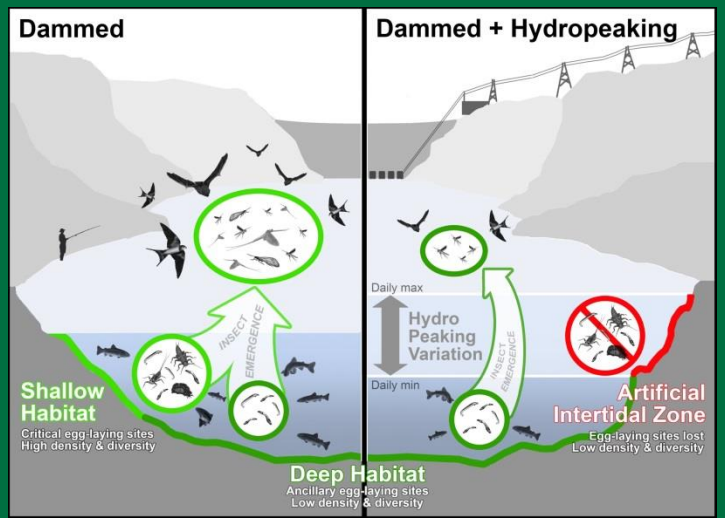

Dammed
Dammed + Hydropeaking
INSECT EMERGENCE
Daily max
Hydro Peaking Variation
Daily min
INSECT EMERGENCE
Shallow Habitat
Critical egg-laying sites
High density & diversity
Artificial Intertidal Zone
Egg-laying sites lost
Low density & diversity
Deep Habitat
Ancillary egg-laying sites
Low density & diversity

Questions


Invertebrate richness (# of genera)
0
10
20
30
40
50
Fontenelle
Flaming Gorge
Glen Canyon


a
Low
High
Relative egg survivorship
Average
+300
+250
+200
+150
+100
+50
+0
Discharge at dusk relative to daily minimum ($m^3 s^{-1}$)
b
18000
16000
8000
6000
4000
2000
0
Midge abundance (# hr^{-1})
Average (2nd axis)
800
600
400
200
0
Average midge abundance (# hr^{-1})
0
100
200
300
400
Distance from Dam (km)


0.10
0.05
0.00
Egg survival
0.0
0.5
1.0
River edge
Oviposition strategy
Open water
0
100
200
300
400
Distance from dam (km)


Dammed
Dammed + Hydropeaking
Daily max
Hydro Peaking Variation
Daily min
INSECT EMERGENCE
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Shallow Habitat
Critical egg-laying sites
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