Distribution and Impacts of Benthic and Hyporheic Anoxia on the Colorado River Ecosystem Downstream from Glen Canyon Dam, Arizona

Courtney McDaniel
Larry Stevens
Joseph Holway
Craig Ellsworth

Springs Stewardship Institute

- Museum of Northern Arizona: 50 years of preserving the heritage of the Colorado Plateau
- Springs Stewardship Institute: focus on spring ecosystem ecology & conservation
  - Director: Dr. Larry Stevens

Glen Canyon Dam & Tailwaters

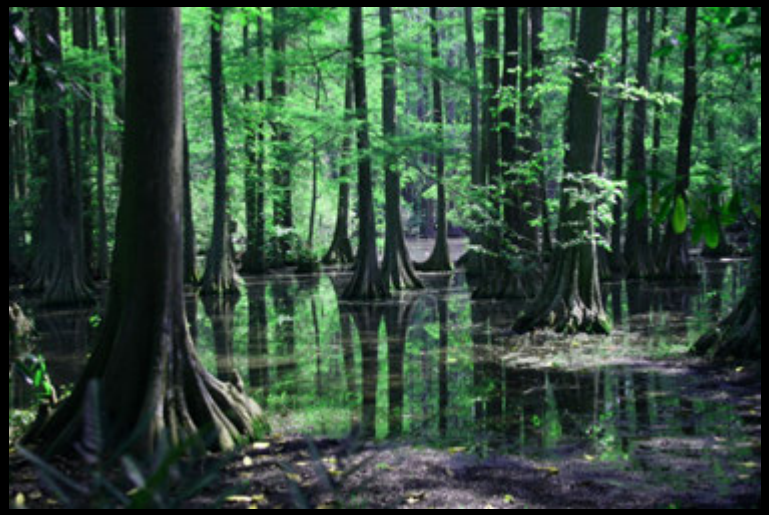
- Hypolimnetic flow – cold, low oxygen
- Very little sediment
- Highly controlled releases – predictable river stages

Benthic & Hyporheic Anoxia (BHA)

- **Hyporheic zone** = river sediments where surface and groundwater are exchanged
- **Benthic zone** = shallowest portion of hyporheic zone
- **Anoxia** = lacking oxygen
- Characteristics:
  - Stinky!
  - Fine sand/organic particles
  - Just below the surface sediments
  - AKA “maenke”

Benthic & Hyporheic Anoxia

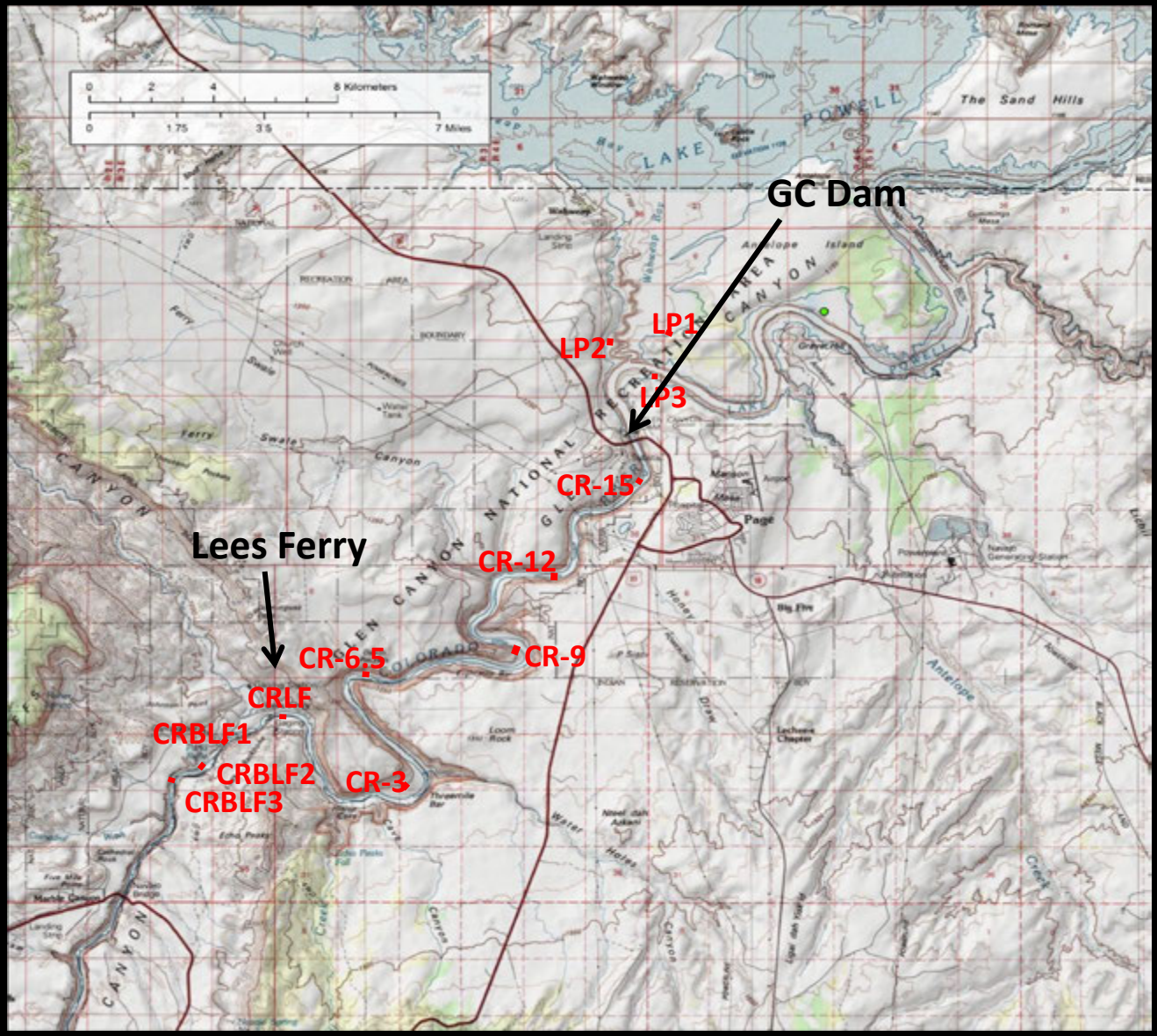
- Common in many stagnant-water habitats
  - Swamps
  - Floodplains
  - Bogs
- Due to decomposition
  - Bacteria decompose leaf litter → uses up oxygen
  - With little water flow, no new oxygen introduced → ANOXIA
- BUT, not documented in flowing rivers or below dams… until now



Study Objectives

1. Determine distribution of BHA
   - Lower Lake Powell
   - GC Dam to Lees Ferry
   - Below Lees Ferry
2. Explore what may be causing BHA to form
3. Determine if BHA has negative effects on aquatic insects

1. Distribution of BHA



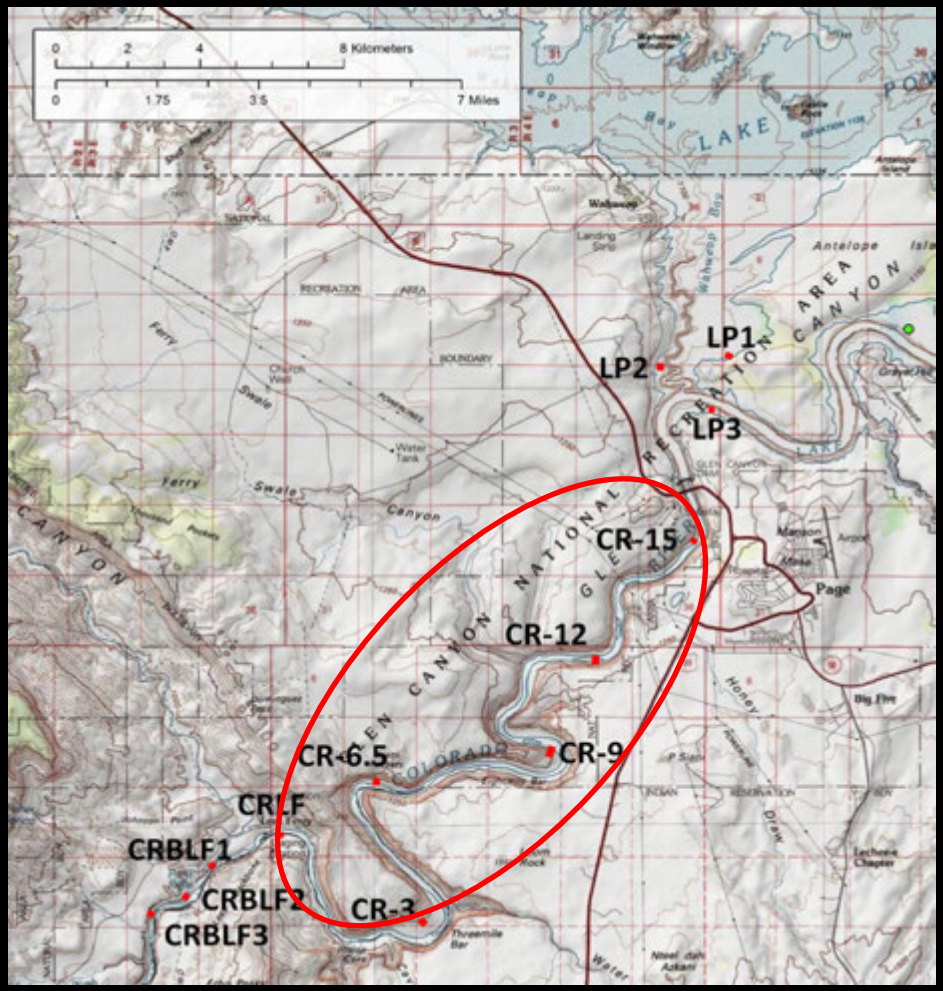
1. Distribution of BHA

Site transects:

- Transects extended from highest elevation point on bank to 1.5 m below low water stage
- Elevation profiles
- Soil excavated at each abrupt change in elevation or substrate
  - Presence/depth of BHA measured

1. Distribution of BHA

- Most prevalent:
  - between GC dam and Lees Ferry
  - in slow-moving waters
  - in the presence of dense submerged vegetation



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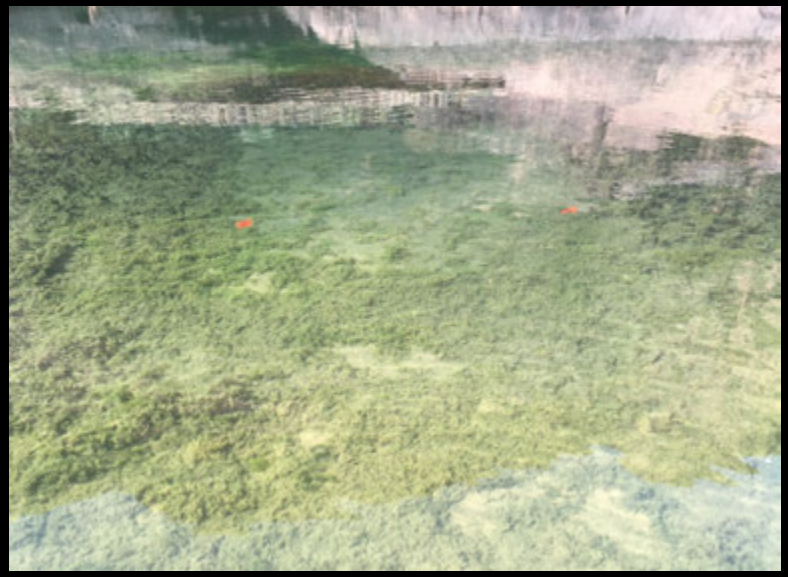


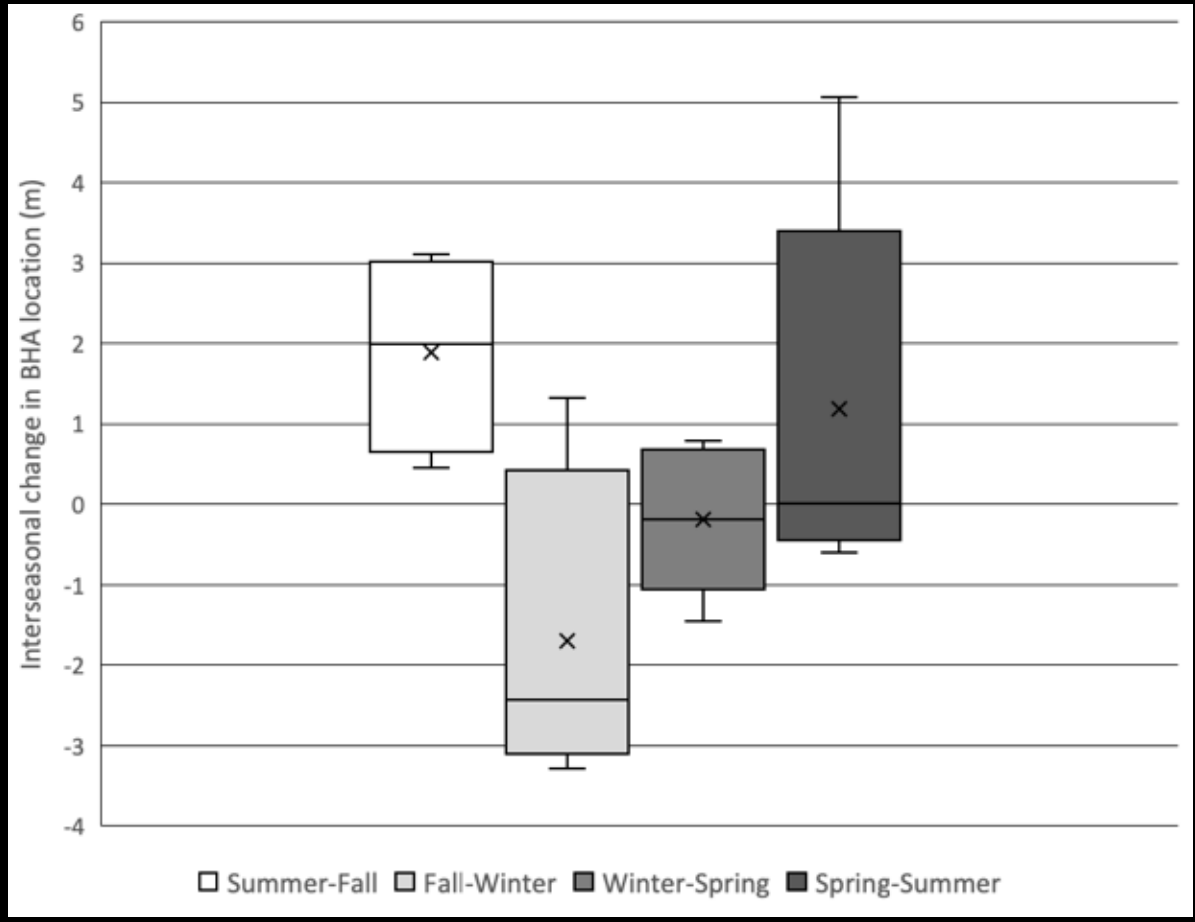
1. Distribution of BHA

Below Paria River mouth

Lake Powell

1. Distribution of BHA

- Seasonality
  - Greatest extent in early fall
  - Decrease in colder months
  - Appears to track water stage along shoreline



2. BHA Development

Floating

Submerged

- Field experiment
  - 20 L chambers with non-BHA river sediment + river water
  - 6 floating, 6 submerged
  - In each treatment: 3 with *Chara* algae added, 3 without *Chara*
  - 38 days
  - Measured depth of BHA, water chemistry (temp, DO, pH)

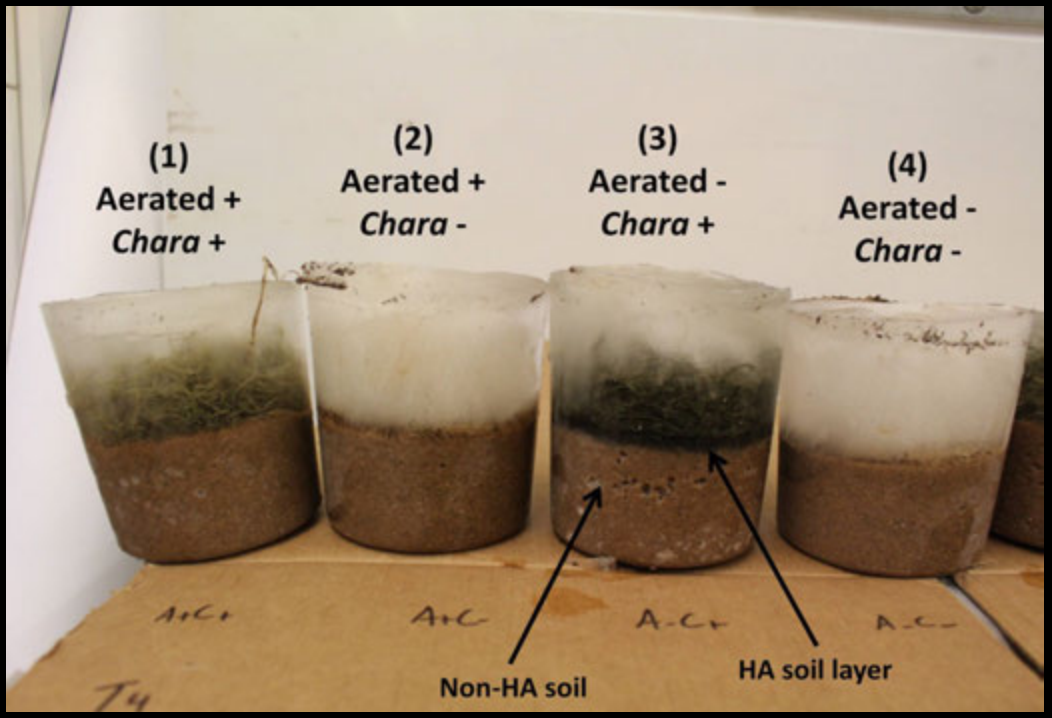
2. BHA Development

- Results – field experiment
  - BHA only in buckets with vegetation
  - Significant BHA development in 38 days
  - Developed in both submerged and floating buckets
  - Significantly lower DO in treatments with *Chara* ($p<0.001$)
    - Without *Chara*: mean = 7.36 mg/L
    - With *Chara*: mean = 5.71 mg/L

2. BHA Development

- Lab experiment
  - How do temperature, aeration, & vegetation interact to affect BHA development?
  - Treatments:
    - 3 temperatures (5°C, 12°C, 20°C)
      - With *Chara*
      - With *Chara* & aeration
      - With aeration
      - Neither *Chara* nor aeration
  - 10 days
  - Measured depth of BHA, water chemistry (DO, pH)

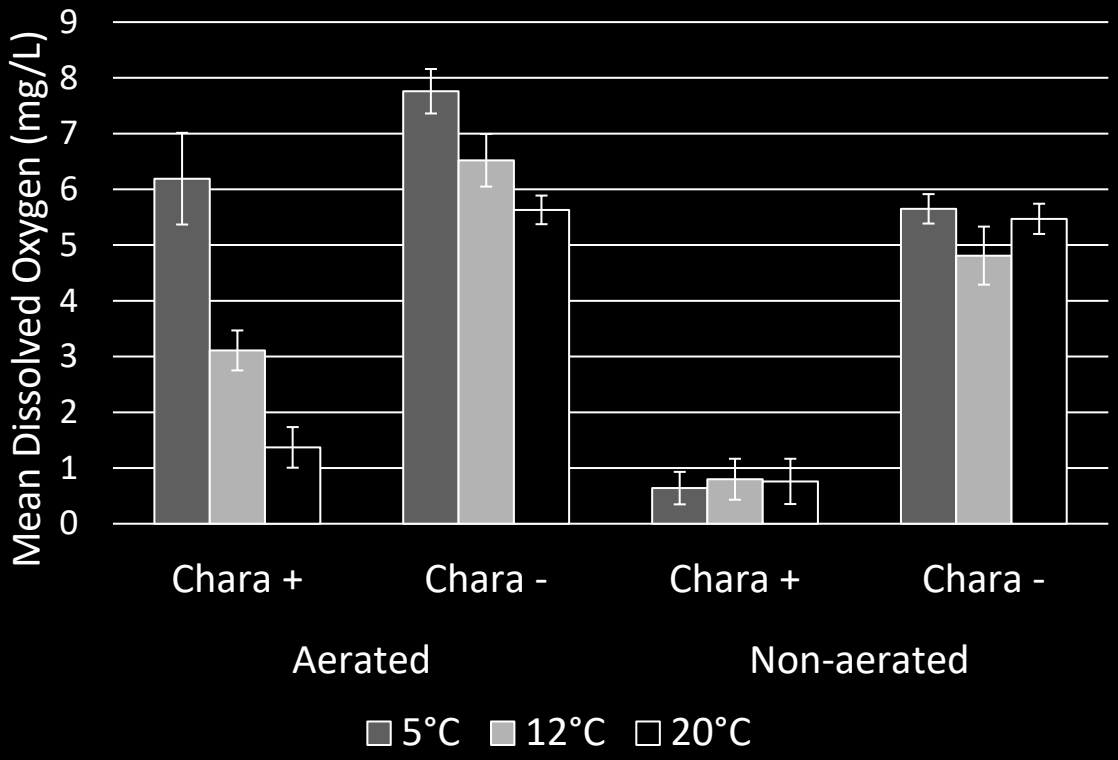
2. BHA Development



- Results – lab experiment
  - All +*Chara* treatments developed BHA
  - BHA development increased with each increase in temperature
  - Non-aerated treatments developed more BHA than aerated treatments
  - Even at elevated temp and with *Chara* present, aeration led to decreased BHA development

2. BHA Development

- Results – lab experiment
  - Dissolved oxygen results similar to field experiment
  - Presence of *Chara* led to lower DO
  - Aeration + low temperature lessened effect of *Chara* presence



3. Effects on aquatic insects

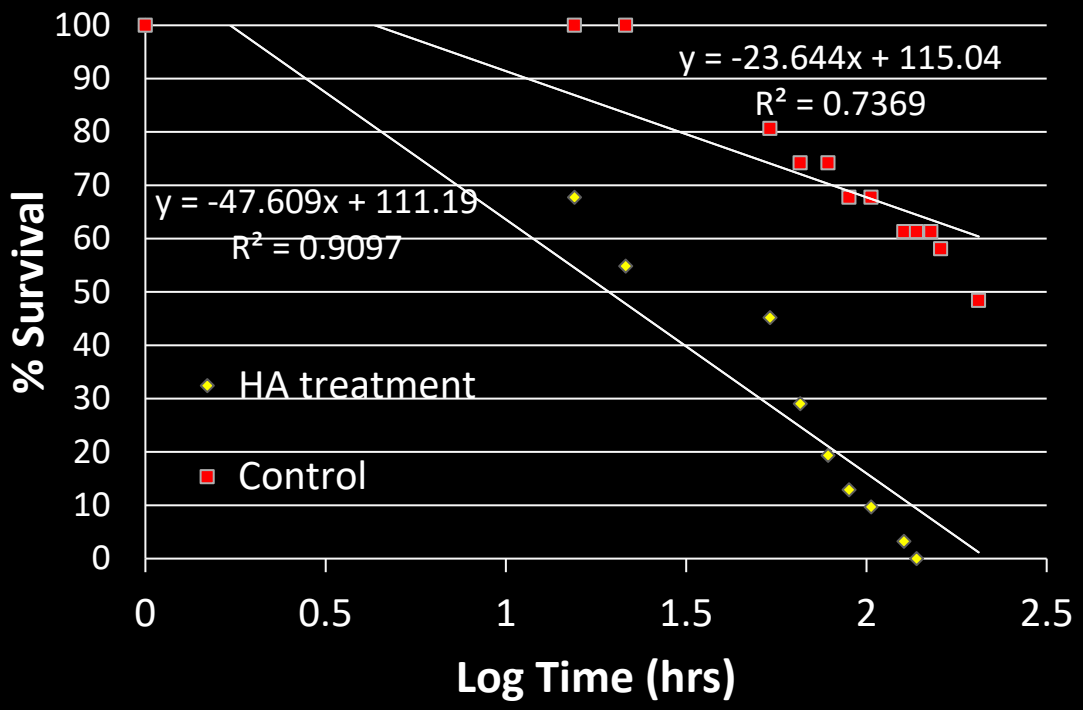
Dragonflies

Damselflies

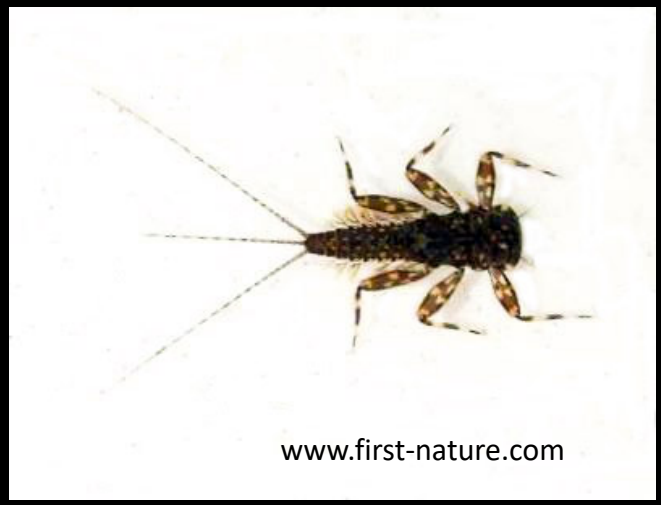
Mayflies

3. Effects on aquatic insects

High mortality in mayflies



n = 31 per treatment



Conclusions

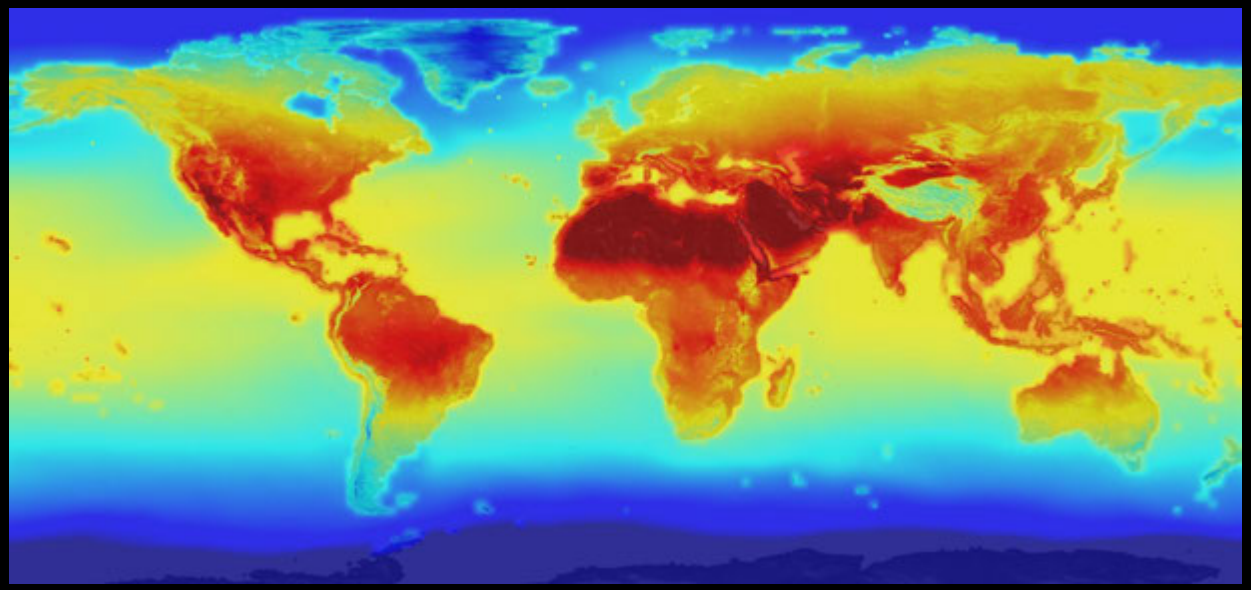
- BHA most prevalent in dam tailwaters
- BHA development limited by:
  - Aeration
  - Turbidity
  - Lower temperature
  - Decreased aquatic vegetation
- Some aquatic invertebrates may be impaired by BHA

Potential Solutions

- Increase oxygenation of the tailwaters → aeration of benthic sediment
  - Fairly unrealistic
- Increase turbidity → less light for vegetation to grow → less decomposition
  - BUT negative effects on trout fishery
  - Expensive
- Decrease water temperature → less microbial activity
  - BUT may harm native fish survivorship
- **Increase flow variability** → increase scour → expose sediments to air → decrease growth of aquatic vegetation (via exposure & turbidity)

Downstream

- Currently, mostly limited to Glen Canyon reach
- Potential in Grand Canyon
  - Climate change: drier climate in SW U.S. → less tributary input → less turbidity → more vegetation → **more BHA**



Thank you!

Thanks to:

Glen Canyon National Recreation Area

Glen Canyon Adaptive Management Program

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Argonne NATIONAL LABORATORY

Western AREA POWER ADMINISTRATION