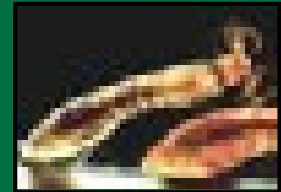




**Big Flood,
Small Flood,
Spring Flood,
Fall Flood:
HFE timing affects food base response?**



**Ted Kennedy
Jeff Muehlbauer**

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



Timeline

Timeframe of this talk

Dam operations
restricted

HFEs

Warmest water
Since 1973

Lake Powell fills

Floods

Glen Canyon Dam
closed

1963

1970

1980

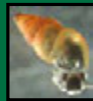
1990

2000

2010

present

Scuds and trout introduced
at Lees Ferry



New Zealand
Mudsnail arrive

Most recent
Spring HFE



Duration of food base monitoring data

1990-2002, 06-09



2007--



2010--



2012--



2013--

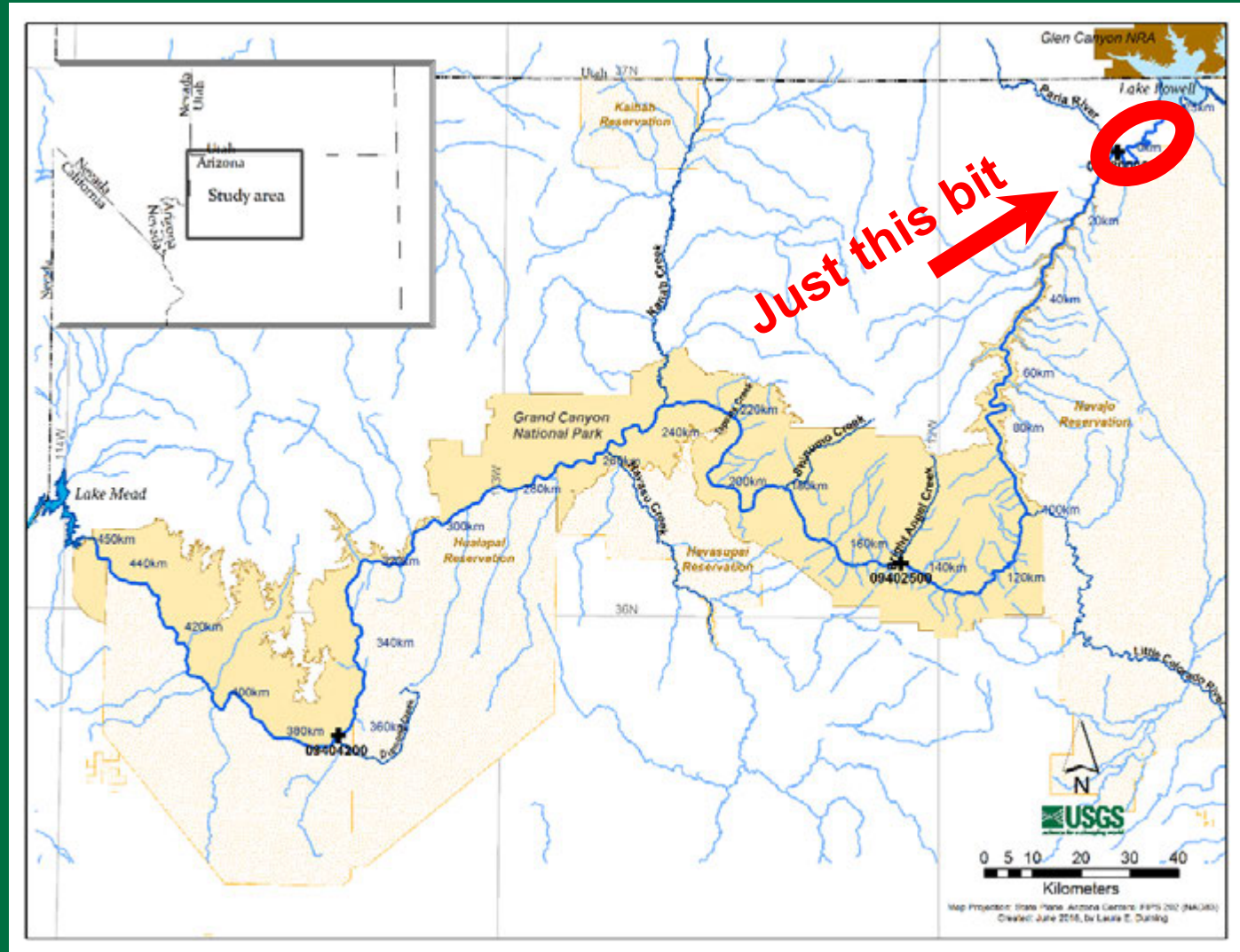


Unpublished data,
subject to change,
do not cite

USGS



HFE Results from Glen Canyon

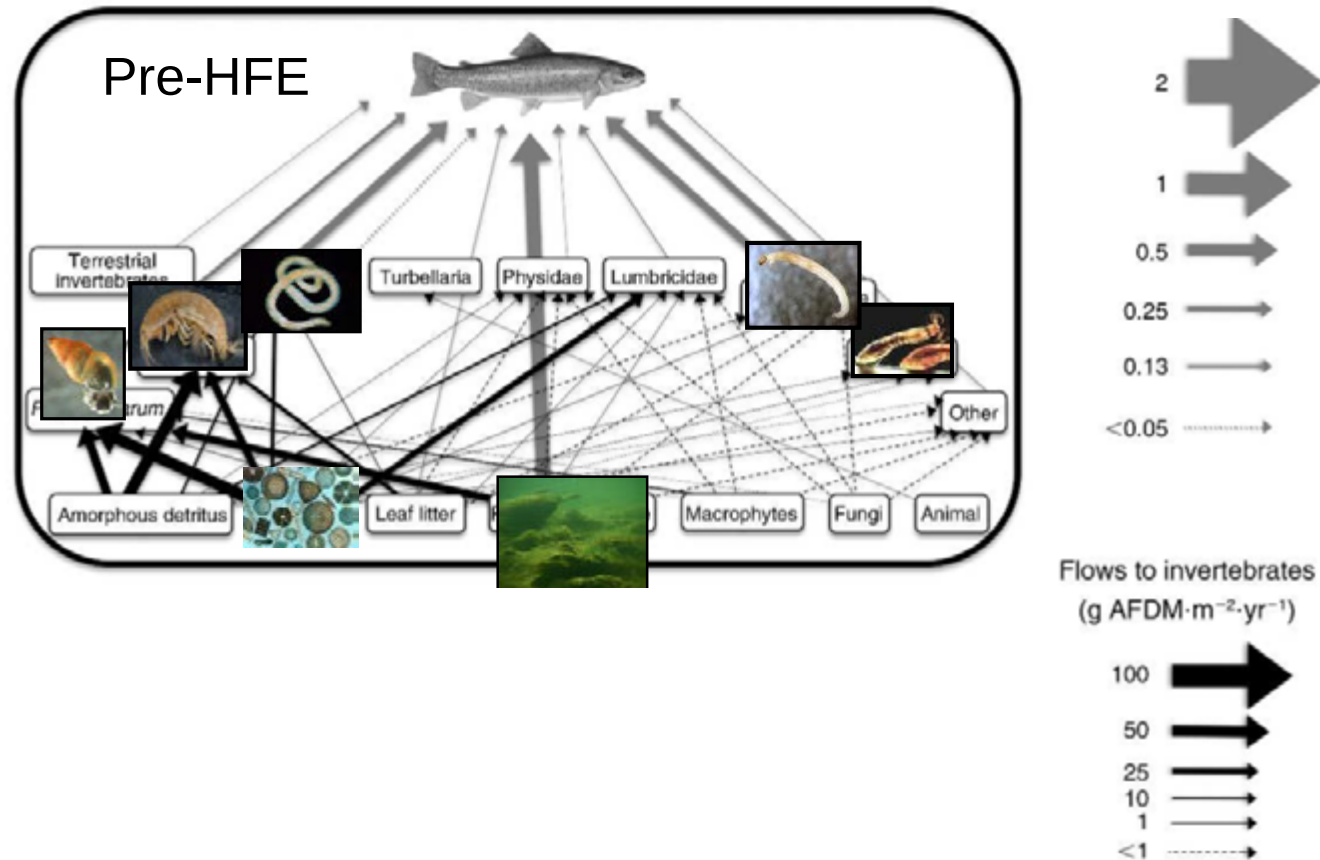


Lees Ferry Food Web

Mudsnails
usurping
lots of energy

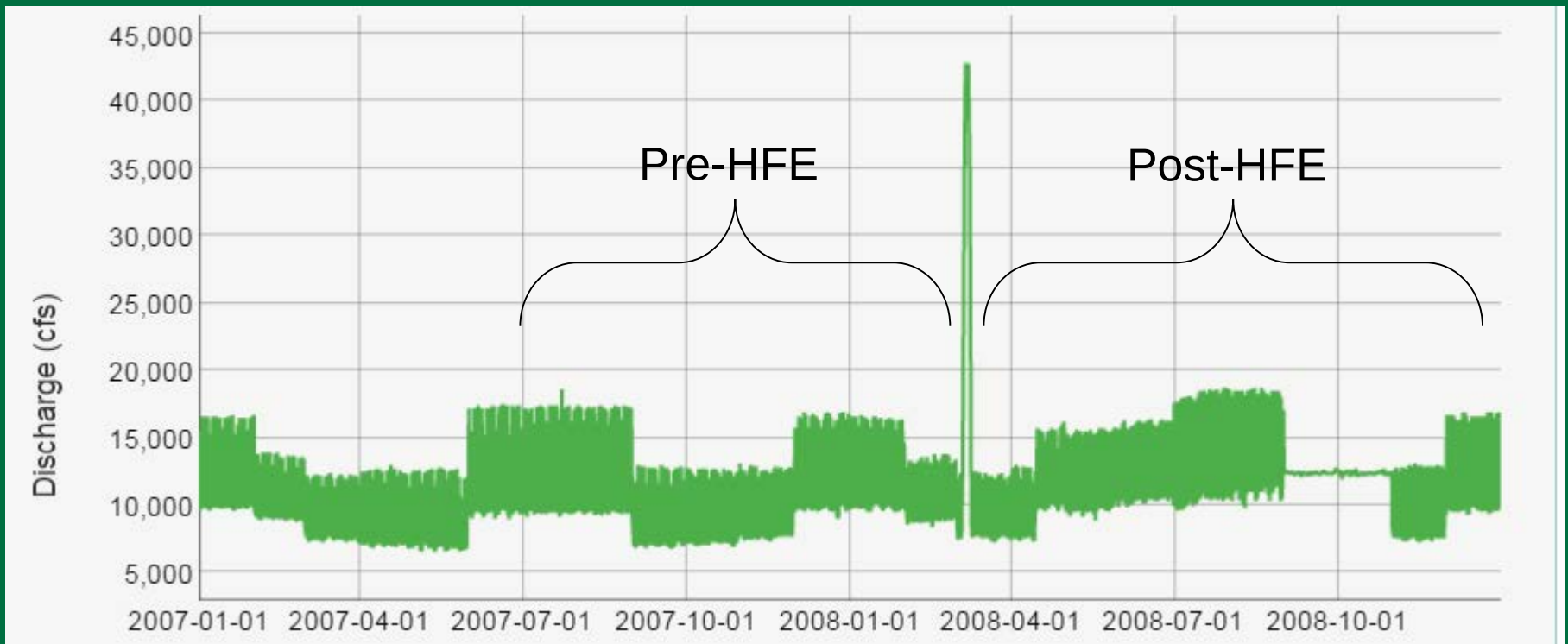
Midges and
blackflies key
prey items for
trout

Midges and
blackflies only
aquatic insects
present



From Cross and others,
2011, Ec. App.

HFE released in March 2008

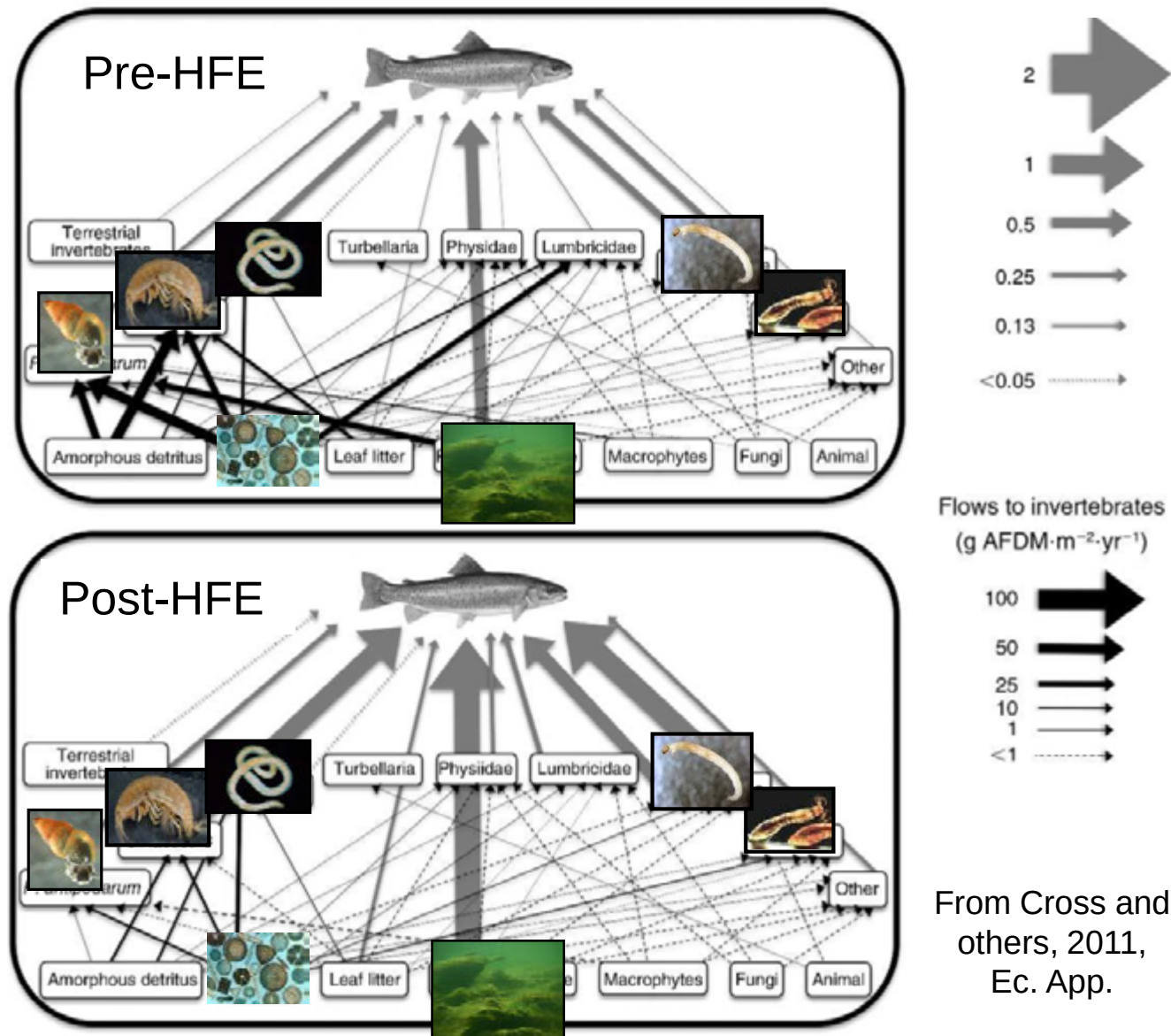


2008 Spring HFE Enhanced the Prey Base

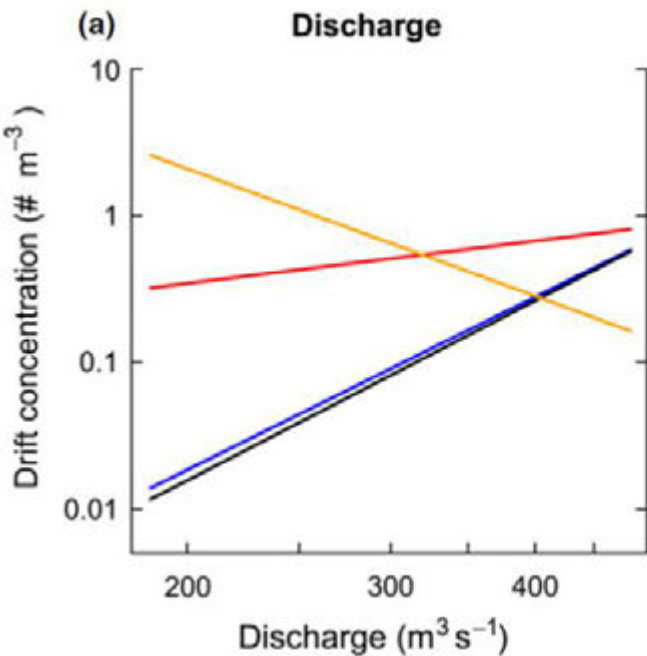
Mudsnails,
worms declined

Midges and
blackflies
increased

Trout growth and
numbers
increased



Drift is proxy for benthic



— Chironomidae



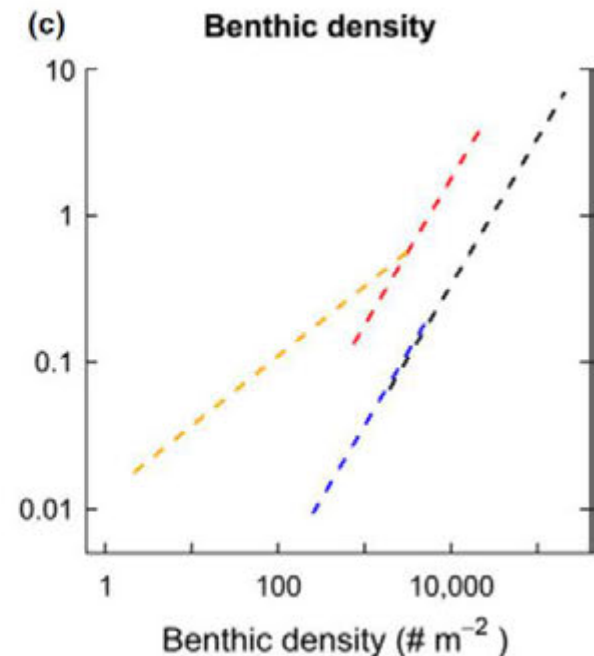
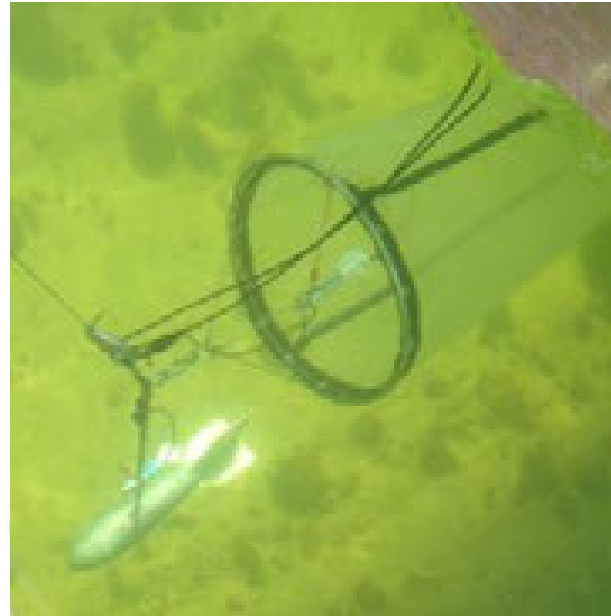
— Simulium



— Gammarus



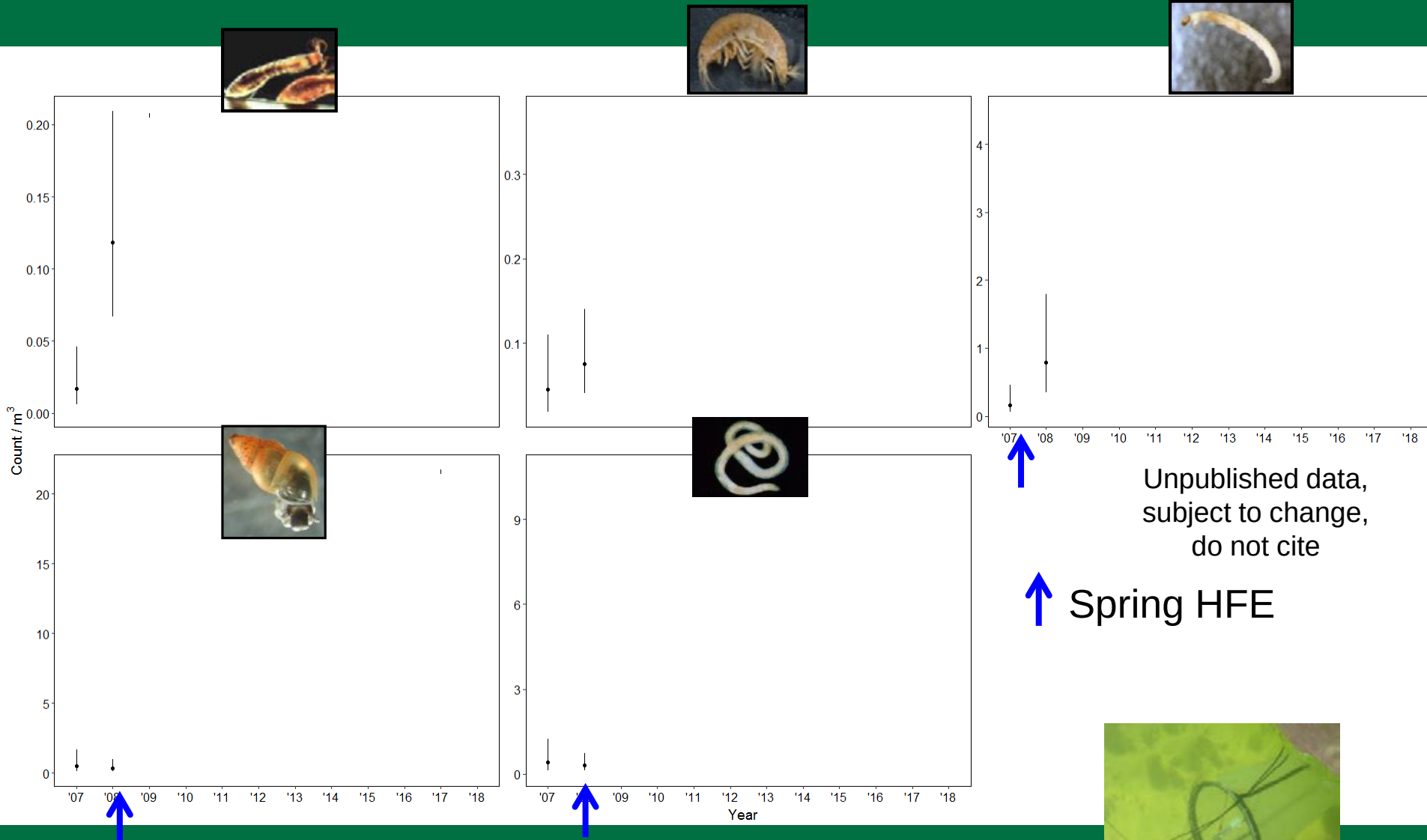
— Potamopyrgus



Kennedy and others, 2014
Freshwater Biology

$$C \propto Q^f B^g$$

Spring HFE enhanced Prey Base



Unpublished data,
subject to change,
do not cite

↑ Spring HFE



Top row: palatable, high quality prey
Bottom row: inedible, low quality prey

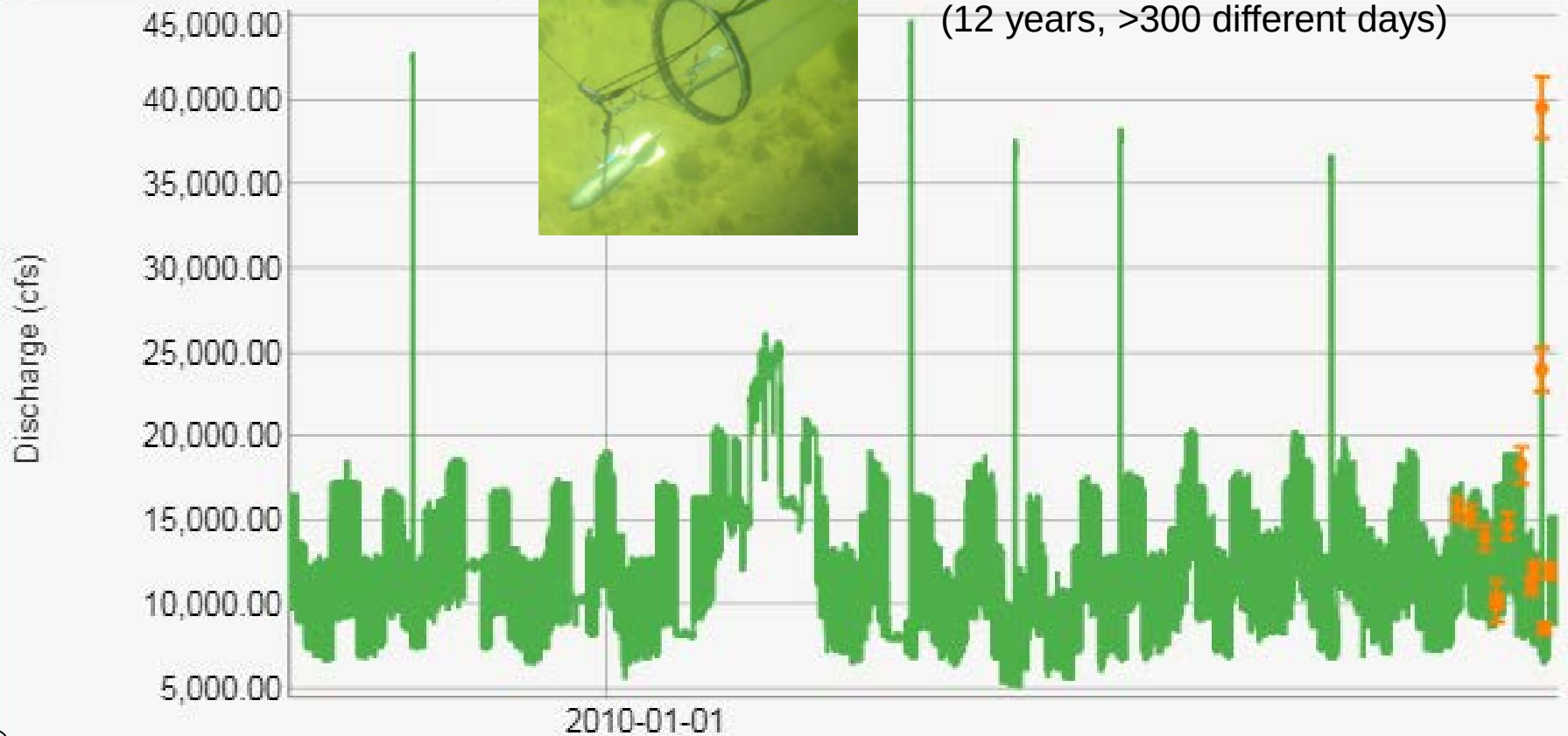


Drift Period of Record

Data

Time Series Plot

Duration Curve Plot

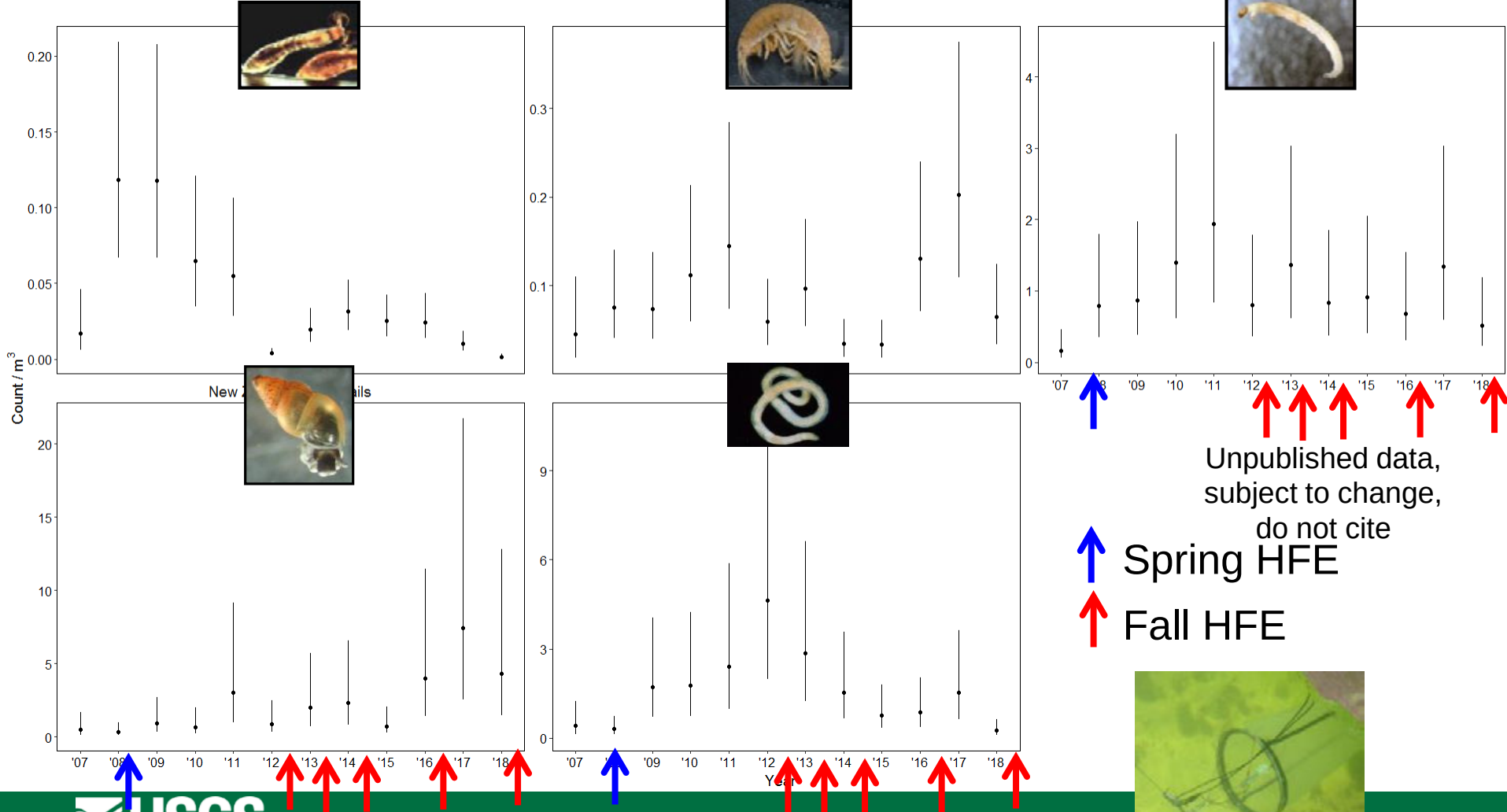


Lees Ferry Drift Monitoring

http://www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09380000

Fall HFEs +/- haven't improved prey base

Long-Term Drift Monitoring



Top row: palatable, high quality prey
Bottom row: inedible, low quality prey

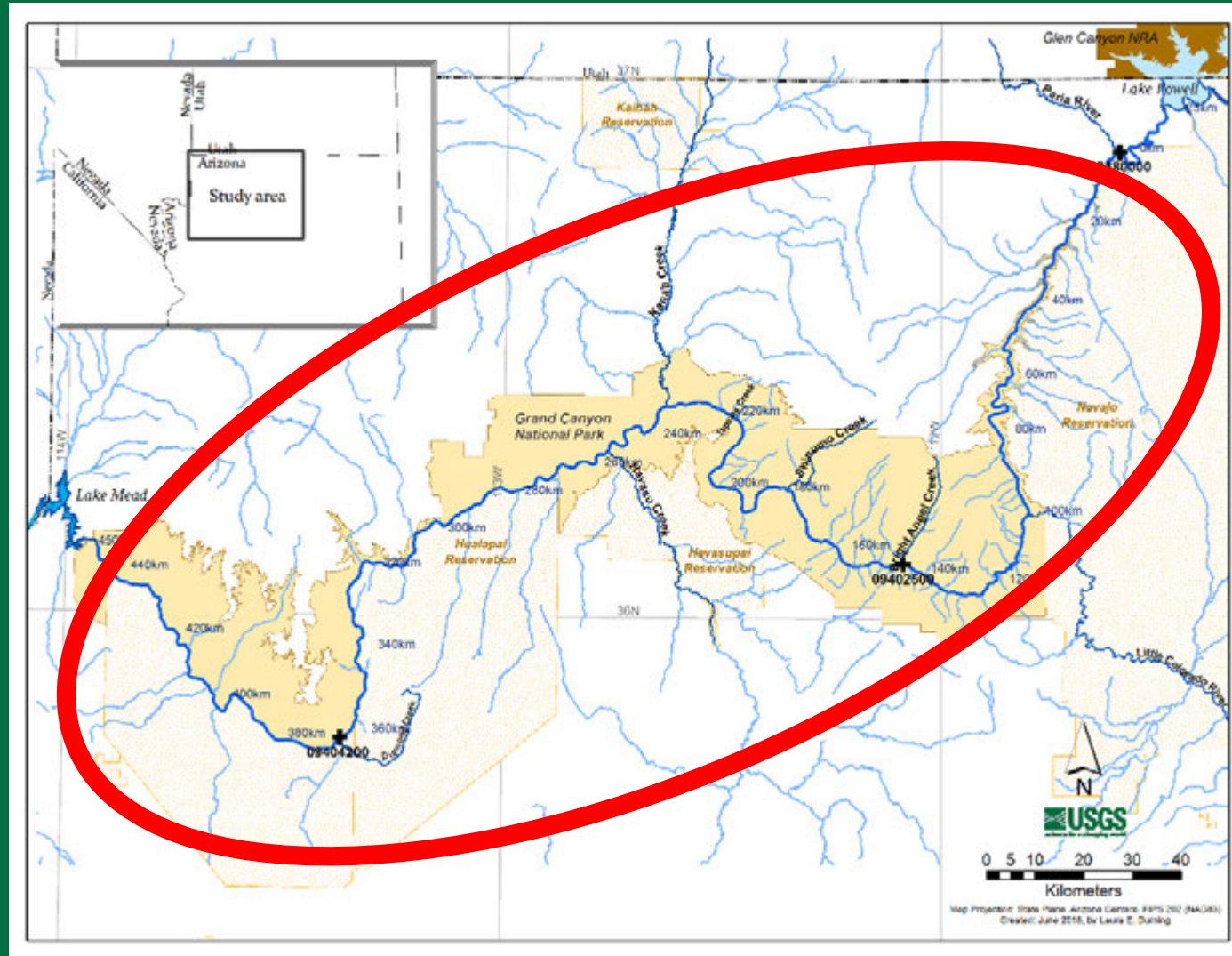


Canyon-wide results

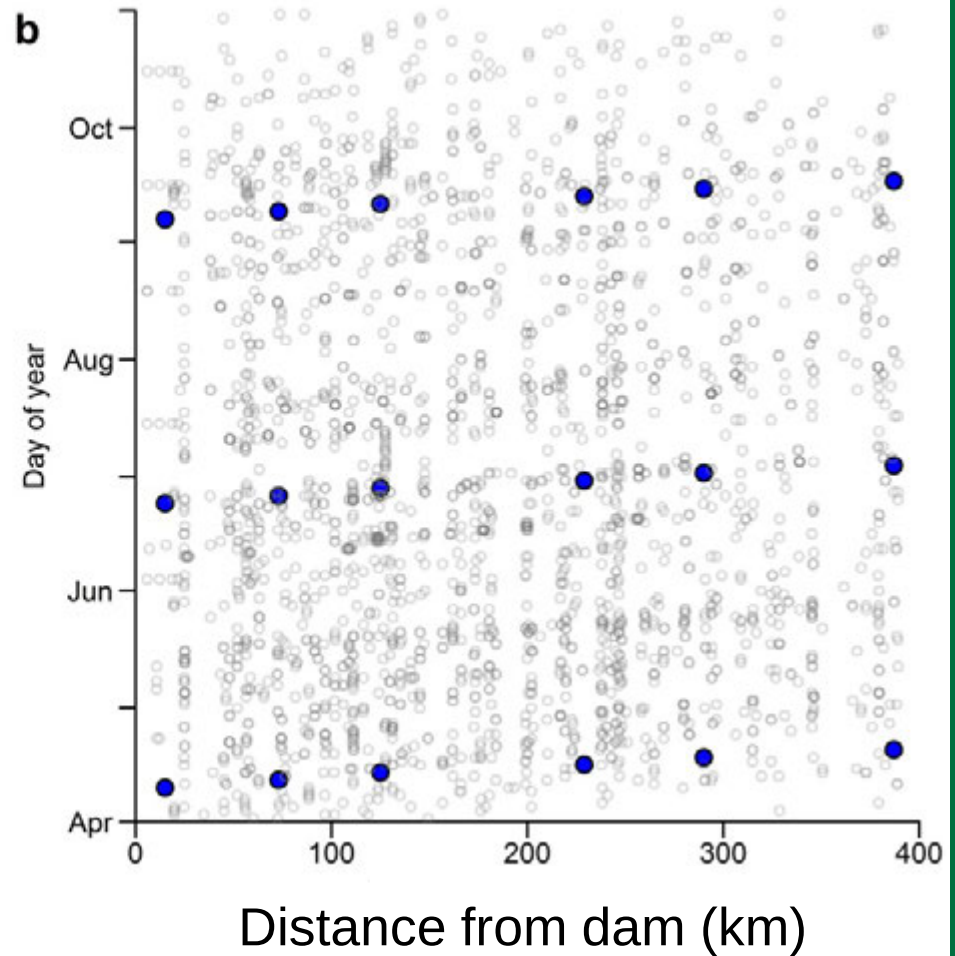
Data only available
Starting in

- 2010(algae)
- 2012 (light traps)

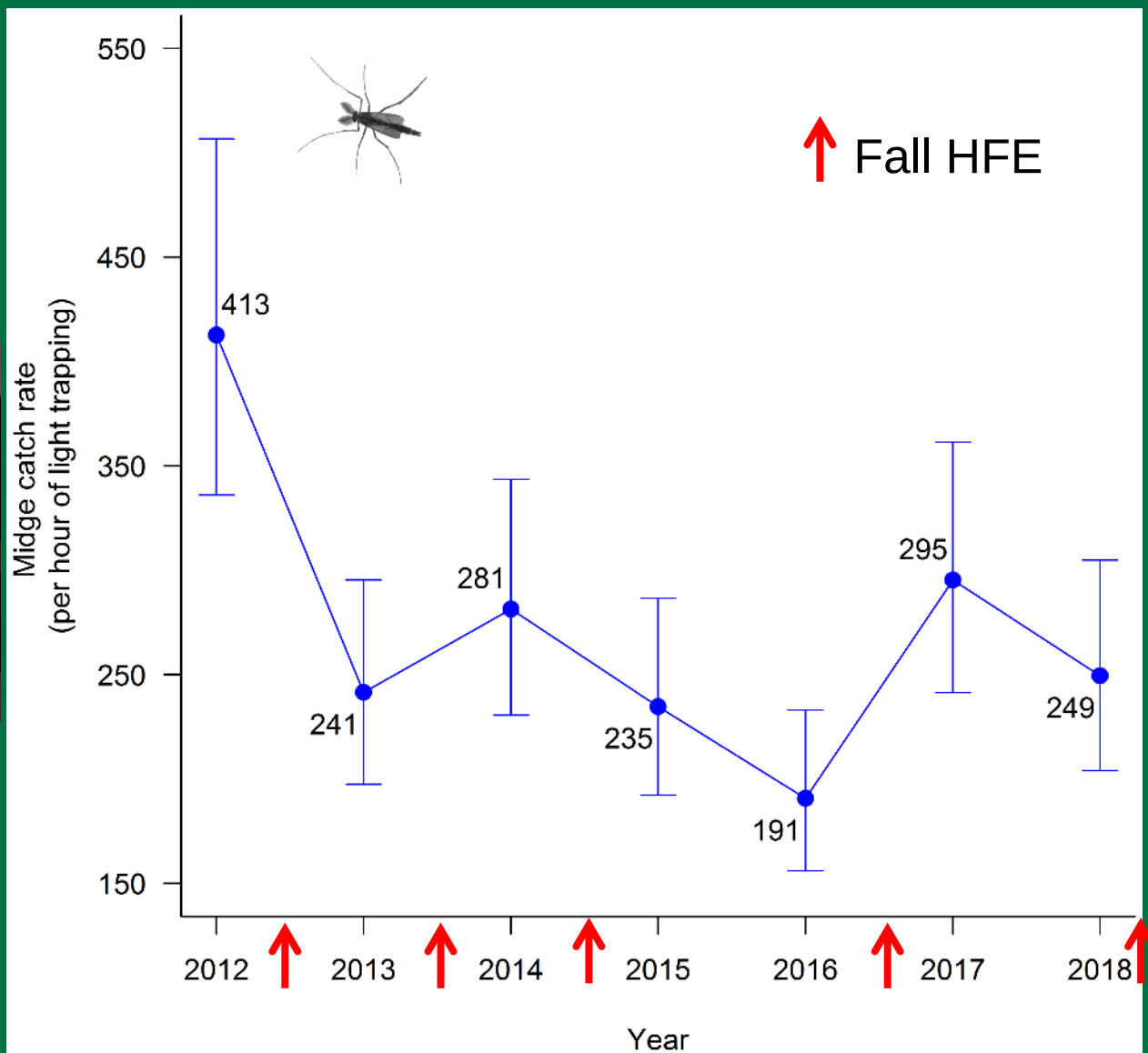
Unpublished data,
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Citizen science emergence monitoring in Grand Canyon (2012-2018)



Fall HFEs +/- haven't improved prey base



HFEs and Algae Production

LIMNOLOGY
and
OCEANOGRAPHY

ASLO

Limnol. Oceanogr. 00, 2015, 00-00
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doi: 10.1002/lno.10001

Turbidity, light, temperature, and hydropeaking control primary productivity in the Colorado River, Grand Canyon

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Emma J. Rosi-Marshall,³ Nicholas Voichick,² Kathrine E. Behn^{2,4}

¹Department of Zoology and Physiology, University of Wyoming, Laramie, Wyoming

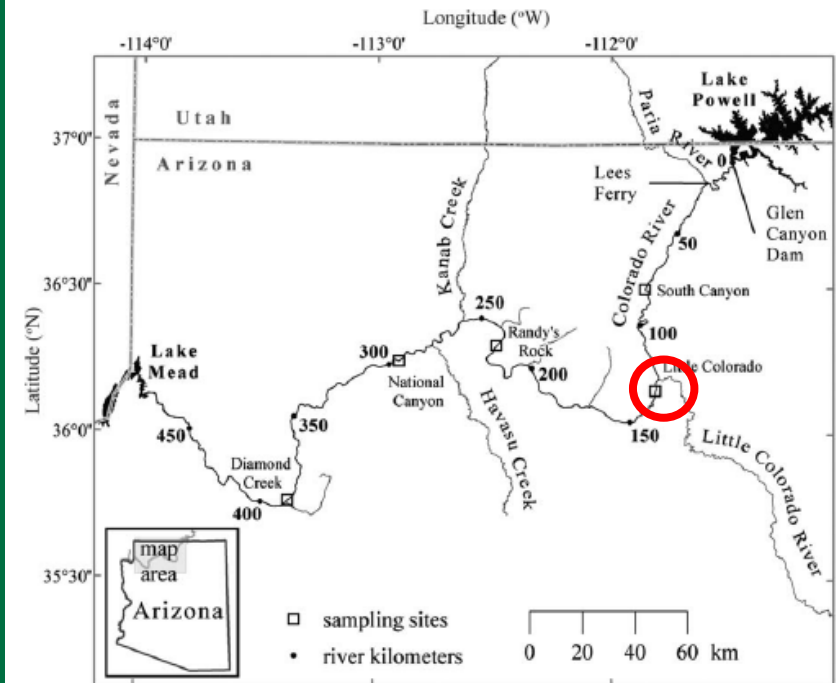
²U.S. Geological Survey, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona

³Cary Institute of Ecosystem Studies, Millbrook, New York

⁴Department of Biological Sciences, Idaho State University, Pocatello, Idaho

Abstract

Dams and river regulation greatly alter the downstream environment for gross primary production (GPP) because of changes in water clarity, flow, and temperature regimes. We estimated reach-scale GPP in five locations of the regulated Colorado River in Grand Canyon using an open channel model of dissolved oxygen. Benthic GPP dominates in Grand Canyon due to fast transport times and low pelagic algal biomass. In one location, we used a 738 days time series of GPP to identify the relative contribution of different physical controls of GPP. We developed both linear and semimechanistic time series models that account for unmeasured temporal covariance due to factors such as algal biomass dynamics. GPP varied from $0 \text{ g O}_2 \text{ m}^{-2} \text{ d}^{-1}$ to $3.0 \text{ g O}_2 \text{ m}^{-2} \text{ d}^{-1}$ with a relatively low annual average of $0.8 \text{ g O}_2 \text{ m}^{-2} \text{ d}^{-1}$. Semimechanistic models fit the data better than linear models and demonstrated that variation in turbidity primarily controlled GPP. Lower solar insolation during winter and from cloud cover lowered GPP much further. Hydropeaking lowered GPP but only during turbid conditions. Using the best model and parameter values, the model accurately predicted seasonal estimates of GPP at 3 of 4 upriver sites and outperformed the linear model at all sites; discrepancies were likely from higher algal biomass at upstream sites. This modeling approach can predict how changes in physical controls will affect relative rates of GPP throughout the 385 km segment of the Colorado River in Grand Canyon and can be easily applied to other streams and rivers.



USGS

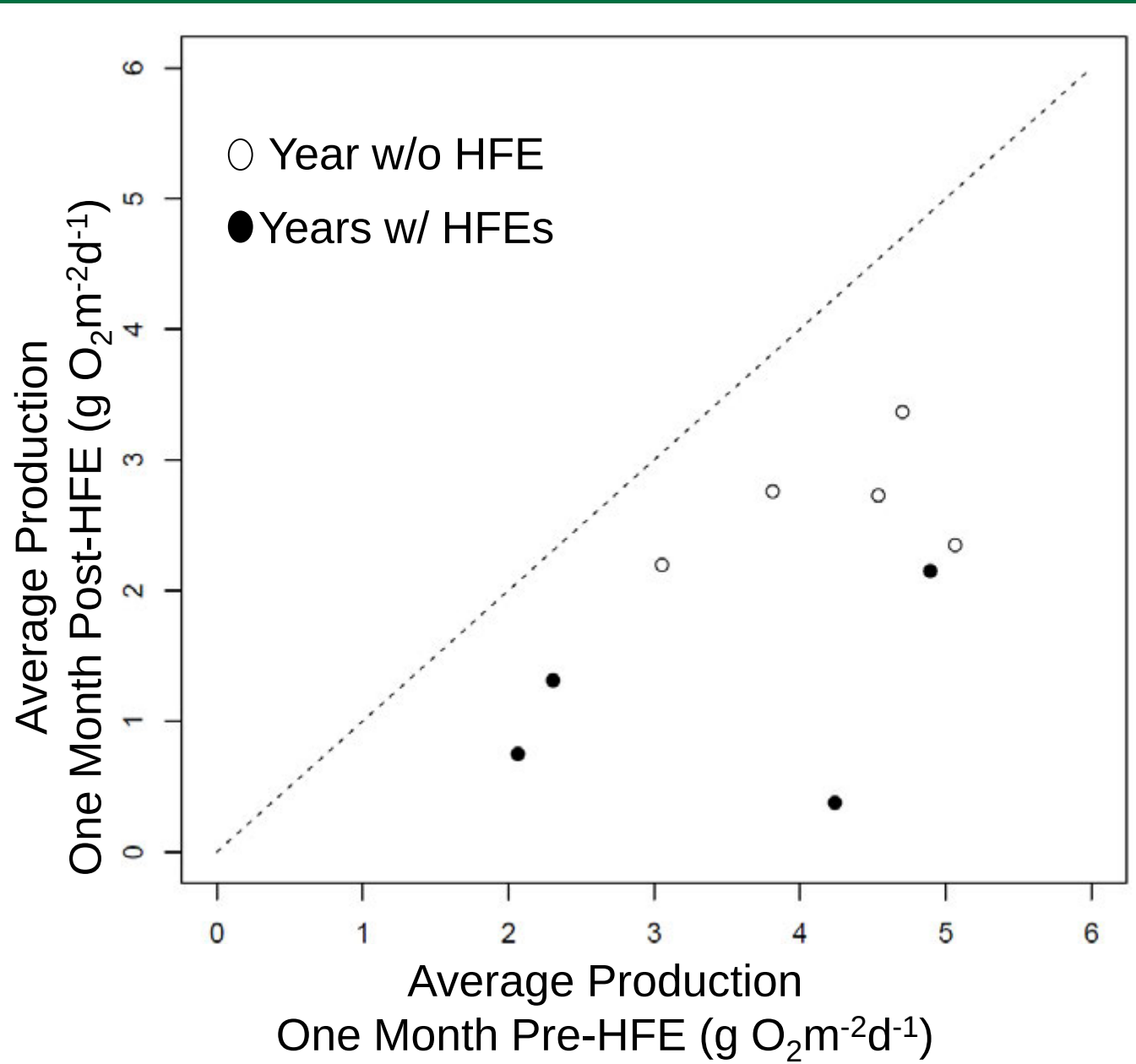


Fall HFEs reduce algae production

- 2010-present

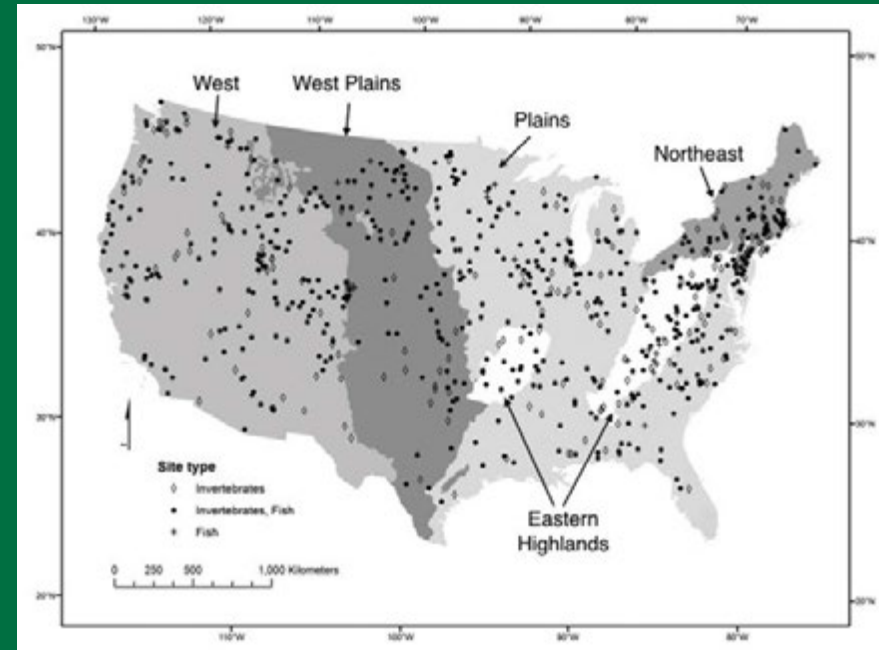
Data courtesy of
Bridget Deemer,
USGS

Unpublished data,
subject to change,
do not cite



Stepping outside of Grand Canyon

- National Synthesis conducted by USGS-NAWQA
- Analyzed link between Flows alteration and Prey Base at 682 sites in US



Carlisle, D. M., Grantham, T. E., Eng, K., & Wolock, D. M. (2017). Biological relevance of streamflow metrics: regional and national perspectives. *Freshwater Science*, 36(4), 927-940.



Spring Floods Improve Prey Base

“Impaired invertebrate communities were associated with depleted high flow magnitude, a result that corroborates theory...and a large body of case studies showing that depleted high flows are detrimental to aquatic species.”

“However, the apparent nationwide importance of high flows in spring (March, April, May) also indicates that the timing (not just magnitude) of high flows is critical.”

From: Carlisle, D. M., Grantham, T. E., Eng, K., & Wolock, D. M. (2017). Biological relevance of streamflow metrics: regional and national perspectives. *Freshwater Science*, 36(4), 927-940.



Floods are Important Life-History Cue

“Swelling stream flow....in the spring is an important life-history cue for most aquatic species in temperate climates.”

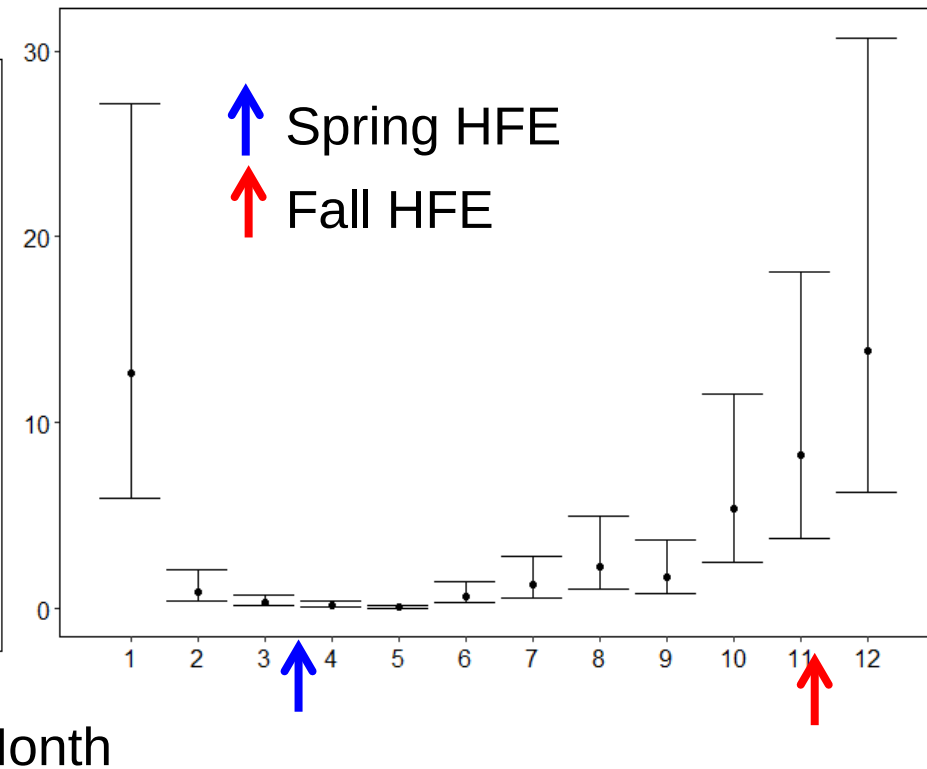
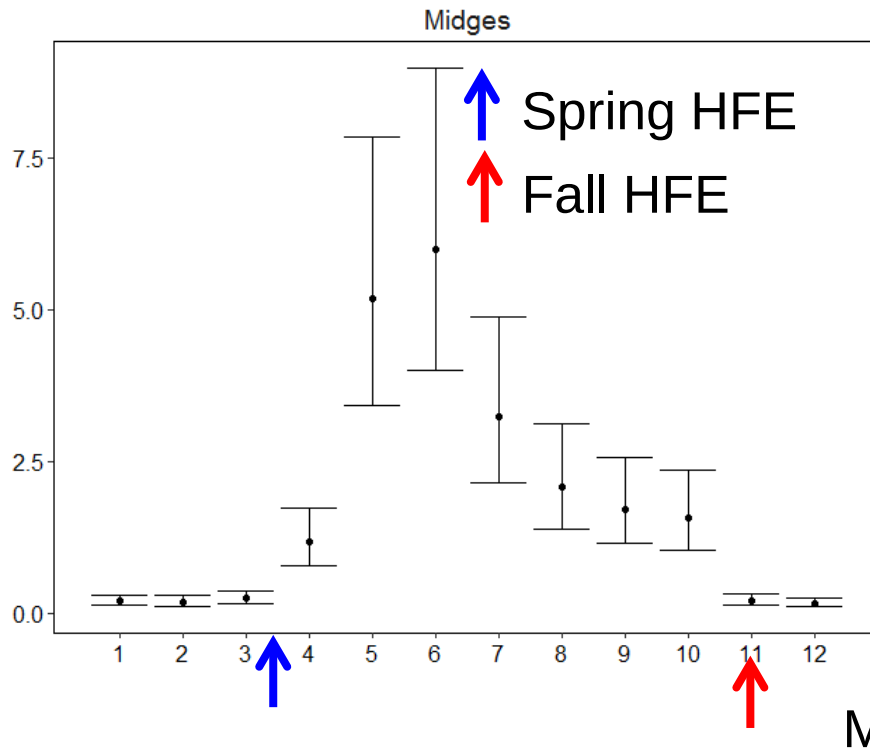
From: Carlisle, D. M., Grantham, T. E., Eng, K., & Wolock, D. M. (2017). Biological relevance of streamflow metrics: regional and national perspectives. *Freshwater Science*, 36(4), 927-940.



Invertebrate life history timing



Drift concentration ($\# \cdot m^{-3}$)



- Data represent average drift concentration by month over period of record (2007-2018)
- HFEs in spring align favorably with life history timing of midges (a palatable, high quality prey item)
- HFEs in fall align favorably with life history timing of mudsnails (an inedible, low quality prey item)

Conclusion

- Spring HFEs (n=2) infrequent compared to Fall HFEs (n = 6).
- Most recent Spring HFE was >10 years ago, which pre-dates most food base datasets
 - Hard to draw inferences about Spring HFEs
- Nevertheless, 2008 Spring HFE appeared to improve food base



Unpublished data,
subject to change,
do not cite

Next steps

- Fall Disturbances (i.e., HFEs) don't improve food base
- Key uncertainty: Will Spring disturbances improve food base in Glen and Grand Canyon?
- Test Benefits of Spring Disturbance
 - Spring HFE and/or
 - Spring Powerplant Flow

