Glen Canyon Dam Adaptive Management Work Group
Agenda Item Form
February 15-16, 2017

Agenda Item

2017 Glen Canyon Dam Adaptive Management Program Annual Reporting Meeting Update

Action Requested

Information item only; we will answer questions but no action is requested.

Presenters

Scott VanderKooi, Chief, Grand Canyon Monitoring and Research Center
Mike Moran, Deputy Chief, Grand Canyon Monitoring and Research Center

Previous Action Taken

N/A

Relevant Science

N/A

Summary of Presentation and Background Information

The January 2017 Annual Reporting meeting was held January 24-25, 2017 in Phoenix, Arizona followed by a one-day Technical Work Group meeting. The two-day meeting included presentations by Grand Canyon Monitoring and Research Center (GCMRC) staff, cooperators and collaborators, staff of sister federal agencies, and Tribal representatives. Speakers presented summaries of findings from work conducted as part of the FY2015-17 Glen Canyon Dam Adaptive Management Program budget and workplan and discussed insights of management significance.

High Flow Experiments

Each of the four high-flow experiments (HFE) implemented under the high-flow protocol since July 2012 resulted in sandbar deposition in Marble and Grand Canyons. Although sandbars have also eroded following each high-flow, the long-term monitoring sites were, on average, larger 10 months following each of the high flows than at any other time between 2009 and 2012. In this period, sandbars were largest in October 2014, 11 months after the 2013 HFE. There was a net decrease in sandbar volume in 2015 and 2016. The November 2016 HFE resulted in deposition similar to that observed in previous HFEs, based on information from a subset of remote cameras. Because Paria River sand inputs have been relatively large and annual release volumes from Lake Powell relatively low, there has been maintenance or accumulation of sand since July 2012 in Marble Canyon and in Grand Canyon between river miles 87 and 166. The segment of Grand Canyon between river mile 61 and river mile 87 has experienced net sand evacuation over this same period, likely owing to much lower than average sand inputs from the Little Colorado River during this period. In addition, there has been likely net sand evacuation from the segment of Grand Canyon between river mile 166 and Diamond Creek during this period for reasons currently under investigation.

Archeological Sites

FY2016 was the second year of a new project (Project 4) with monitoring and research components focused on implementing a long-term monitoring program for archaeological sites and evaluating effects of fluvially-sourced aeolian sediment transport and other geomorphic processes on archaeological site condition. FY2016 was the first year of implementing the monitoring program developed in FY2015 and therefore also the first year of new data collection for the project. Field data were collected during May 2016, and the results of new lidar survey data were analyzed with similar data acquired during previous projects spanning the current HFE protocol and specifically the 2012, 2013, and 2014 HFEs. This work was done using the new automated GIS-based methods that were developed during FY2015. Results of geomorphic changes at the archaeological monitoring sites determined with repeat lidar surveys spanning the 2012, 2013, and 2014 HFEs show that of the monitoring sites ideally situated to receive windblown, river-derived sand, some clearly had sediment resupply from HFE deposits, some clearly did not, and some are very good candidates for experimental vegetation removal to enhance sediment resupply from HFE deposits. In addition, the Project 4 team conducted research in collaboration with scientists and data from projects 3 and 11 to investigate how alterations in flow and vegetation encroachment following construction of Glen Canyon Dam has affected the areal extent of sand available for aeolian transport along a 16-mile study reach in lower Marble Canyon. This work revealed the disproportionate importance of small decreases in low flows (e.g., < 8,000 ft^3/s) in exposing bare sand and emphasized the influence of flow and vegetation in decreasing sand availability in the post-dam era. Importantly, it provides a way forward for (1) quantifying the area of fluvially-sourced aeolian sand using remotely sensed data, (2) identifying the potential for future actions such as targeted vegetation removal and/or flow alteration to expose increased areas of sand for aeolian transport, and (3) refining the conceptual understanding of the transfer of sediment between the modern active river channel and the surrounding river valley.

Riparian Vegetation

Four years of monitoring data (2013–2016) are now available for riparian vegetation at sandbars included in a long-term monitoring program conducted by NAU and GCMRC. Summaries of these data indicate that total foliar cover tends to be highest on sandbars in western Grand Canyon (below river mile 161), but this is largely due to more herbaceous cover rather than woody cover. Woody cover remains fairly constant from Lees Ferry to river mile 224. Vegetation on these sandbars is primarily composed of shrubs and grasses, with a few trees (*Tamarix* spp.). Data for randomly sampled debris fans, channel margins, and sandbars are available for Lees Ferry to river mile 240 in 2014 and 2016, and Glen Canyon for 2015 and 2016. These data indicate that Glen Canyon has higher total foliar cover and woody cover than the rest of the study area. Sandbars in Marble Canyon and channel margins in eastern Grand Canyon (river mile 61 – 161) also have high cover of woody vegetation. While current sampling is documenting typical annual variation, total vegetation cover has remained relatively stable across sampling years. Verifying the utility of the riparian vegetation monitoring protocol continues with a comparison of sampling methods and power analysis. We compared the method we are currently employing to a different, commonly used method. Our method was found to be better in the system than that other approach. A power analysis is underway to determine if our annual sample sizes are large enough to detect vegetation change over a five-year period. While not yet complete, preliminary analyses indicate that our sampling intensity is sufficient to record a 20% change in mostly types of vegetation over five years.

Photo Matching
For Project 12, a summary of results from a recently completed analysis of photographic images from the early 1990s compared with replicates of those images taken in 2010-11 was presented. In addition, numerous examples of panoramic images taken during the 1923 USGS Birdseye expedition were matched with duplicates of those images obtained in May 2016. Both of these Project 12 study components show marked increases the distribution and abundance of woody riparian species, especially *Tamarix* sp. and *Baccharis* sp., throughout the CRE, although some species of cultural importance to tribes, such as *Salix gooddingi* and *Populus fremonti*, have clearly declined in the post-dam era.

Zuni Film, Hualapai Presentation, Hopi Poster
The representative for the Pueblo of Zuni presented a short film on the significance of Grand Canyon to Zuni and representatives for the Hualapai Tribe gave a presentation titled "Kinship to the Canyon: Hualapai Stories of Success." In addition, the Hopi Tribe presented a poster summarizing results from their FY2016 annual monitoring river trip.

Foodbase
Aquatic insects are the primary prey for native and desired non-native fish including humpback chub and rainbow trout. In FY2016, Project 5 completed a major data synthesis demonstrating that daily fluctuations in discharge associated with hydropeaking (load following) from Glen Canyon Dam are constraining the diversity and production of aquatic insect assemblages in Glen, Marble, and Grand Canyon. The results of this synthesis were published in the journal BioScience and represent comprehensive work toward the majority of individual project elements outlined in Projects 5.1.1-8 and 5.2.1 in the workplan. This research was highlighted in a perspectives essay published in Science (http://science.sciencemag.org/content/353/6304/1099), the top scientific journal in the world. One of the outcomes of this research was the suggestion that macroinvertebrate production flows involving stable (non-load following) flows on weekends in summer could improve the food base condition downstream of Glen Canyon Dam by decreasing the mortality of aquatic insect eggs.

Long term monitoring data indicate large year-over-year declines in every foodbase monitoring metric being employed in Glen, Marble and Grand Canyons since 2012. For example, a 10-year set of invertebrate drift data from Glen Canyon shows the abundance of prey items inedible to fish, such as New Zealand mudsnails and sludgeworms (Tubificidae), has been high since ~2012, while the drift of prey items edible to fish, such as midges and blackflies, has been low over this same timeframe. Recent fall HFEs in 2012, 2013, 2014, and 2016 appear to be contributing to the dominance of New Zealand mudsnails in Glen Canyon. In contrast, the Spring-timed HFE in 2008 restructured the food base by causing a 70% reduction in New Zealand mudsnails and stimulating production of prey items edible to fish (midges and blackflies). Monitoring of invertebrate drift at the Little Colorado River confluence shows drift biomass was 50% lower in 2014-2016 than in 2012 and 2013. This decline is likely responsible for recent declines in the relative condition (plumpness) of native fishes, including endangered humpback chub, in this area. Finally, citizen science light trapping of adult aquatic insects throughout Grand Canyon also indicates catches of midges declined by >50% from 2012 to 2015. Collectively, these food base monitoring data demonstrate that prey availability for native and desired non-native fishes has been declining in recent years.

Phosphorous
There is a growing appreciation of the role of phosphorous-limitation as a driver of ecosystem dynamics in the Colorado River. In particular, measurements of phosphorous at penstock depth

within Lake Powell are closely linked to many ecological patterns in the Colorado River. For example, phosphorous is closely linked to seasonal drift concentrations in both Glen Canyon and near the Little Colorado River. Near the Little Colorado River, phosphorous is also highly correlated with estimates of gross primary production (we are working to generate similar estimates in Glen Canyon). Phosphorous is also closely linked to higher trophic levels. Near the Little Colorado River, the condition (i.e., fatness) of adult humpback chub, flannelmouth sucker, and bluehead sucker are all linked to phosphorous over the last five years. In addition, the combination of phosphorous and antecedent conditions (i.e., the relative abundance of rainbow trout over 150 mm in the preceding spring) can explain ~ 70 % of the variation in rainbow trout recruitment over the last 16 years.

Humpback Chub Abundance

Annual estimates of spring abundance of humpback chub in the Little Colorado River for fish >200 mm declined noticeably in 2015, and were again depressed in 2016. Integrated modeling using the multistate model suggests this decline in spawner abundance is most likely because of a reduced number of adults choosing to spawn because of poor body condition among adult chub beginning in September 2014. However, there remains a possibility that there has been an actual decline in adult chub population abundances, in part because capturing adults in the mainstem (when they are not spawning) is difficult. Juvenile humpback chub survival estimates in the mainstem Colorado River near the Little Colorado River confluence for the interval from July 2015 to July 2016 were higher than in prior years. However, the abundance of juvenile chub remains low due to weak recruitment to the mainstem juvenile chub population in recent years.

Rainbow Trout Abundance

The trend in declining abundance of rainbow trout between Glen Canyon Dam and Lees Ferry stabilized in 2015 and reversed in 2016 with substantial numbers of juvenile fish observed. Unlike in recent years (2012-2014), the relative condition of rainbow trout has increased and remained elevated. Brown trout catch continued to increase in Glen Canyon likely due to successful spawning in this reach. This species now comprises from 2-3% of fish captured in Glen Canyon. Abundance estimates for rainbow trout near the Little Colorado River confluence remain below trigger levels identified in the 2011 Biological Opinion for Nonnative Fish Control. New criteria for triggering actions to benefit humpback chub are identified in the Biological Opinion for the LTEMP and will be implemented in 2017. Triggers include adult abundance and recruitment rates of sub-adult fish into the adult population.

Recreational Experience

Colorado River flows through Glen and Grand Canyons impact the quality of world-class angling and whitewater boating. FY2016 was the final year of a project that implemented surveys of Glen Canyon anglers and private Grand Canyon whitewater boaters to estimate how changes in river flows and other resources have impacted recreational experiences and economic values of trips. Results demonstrated that anglers' trip values were dependent on average river flows with values ranging from $87-$432 per trip. Anglers' highest value per trip was for a 10,000 ft^3/s average daily flow scenario. Private whitewater boaters' trip values ranged from $603-$1,237 per trip, depending on average river flow. The whitewater boaters' highest value was for a 22,000 ft^3/s average daily flow scenario. This research demonstrated that angler and private whitewater boater experiences are significantly impacted by river flows.

Bioeconomic Model for Trout Removal

In FY2016, GCMRC and cooperators developed a bioeconomic model to explore whether rainbow trout removal near the Little Colorado River is necessary to maintain a humpback chub adult population greater than 7,000, and, if necessary, to explore the cost-effectiveness of different triggers and removal intensities. The model integrates an abridged version of the Long-Term Expermental and Management Plan Environmental Impact Statement humpback chub and rainbow trout population models with a management model that aimed to minimize the number of rainbow trout removals over a 20-year period. Results indicate that, based on our best estimates of humpback chub population parameters, the least-cost management strategy to achieve an adult humpback chub population greater than 7,000 adults entails rainbow trout removal over moderate intensity (~3 trips) when their abundance is at moderate levels. Removing rainbow trout at low or high abundances proved less cost-effective. However, current levels of uncertainty in humpback chub population model parameters precluded identification of a specific rainbow trout removal strategy.

GCMRC Annual Reporting Meeting Update

Adaptive Management Work Group Meeting
February 15-16, 2017

Scott VanderKooi

Southwest Biological Science Center

Grand Canyon Monitoring and Research Center

Outline

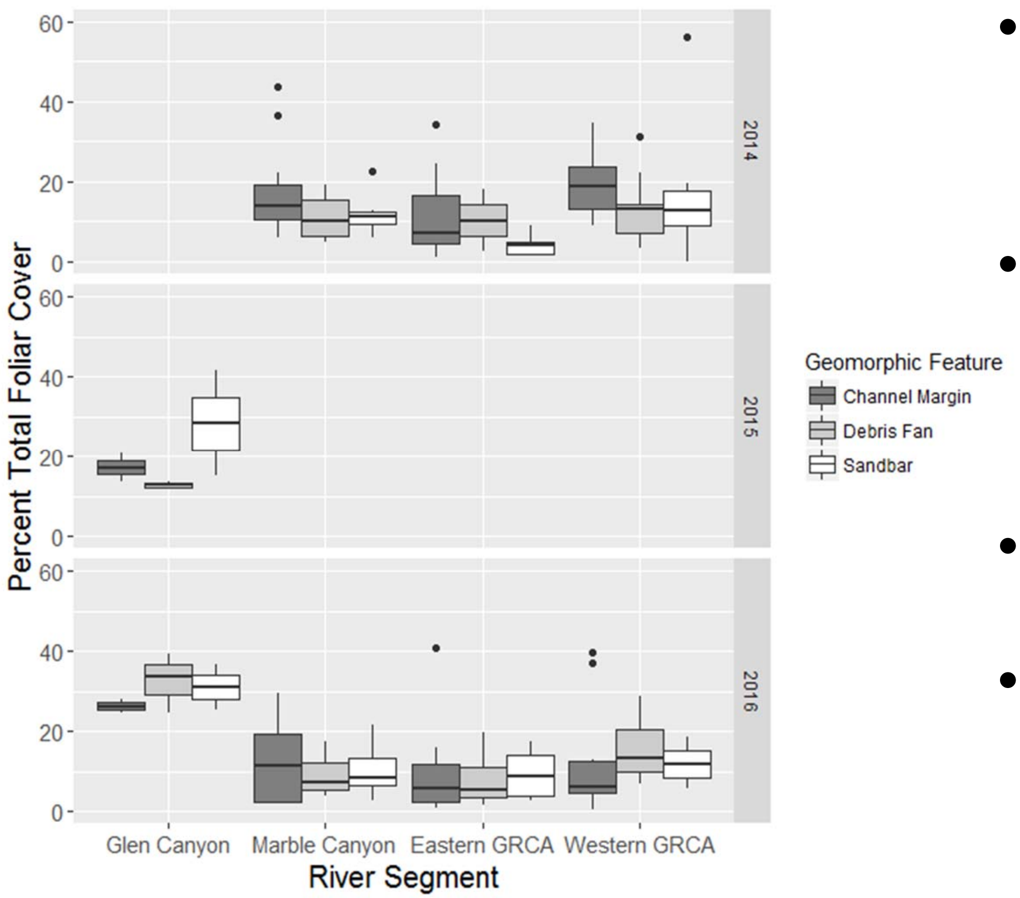
- Riparian Vegetation Monitoring
- Project 12
- Aquatic Foodbase
- Humpback Chub and Rainbow Trout Updates
- Brown Trout

USGS

Project Element 11.1
Ground-based Vegetation Monitoring

USGS

Riparian Vegetation – annual monitoring



Data from random sample sites: total foliar cover in each river segment by year and by geomorphic feature.

(Preliminary data from Palmquist 2016. Do Not Cite.)

- Repeat sample sites (NAU sandbars)
  - Four years of data are available (2013 – 2016)
- Random sample sites (channel margins, debris fans, sandbars)
  - 2 years of data available for Lees Ferry to river mile 240 (2014, 2016) and Glen Canyon (2015, 2016)
- Glen Canyon has highest total foliar cover and woody cover
- Woody cover is notably high in Glen Canyon, on sandbars in Marble Canyon, and channel margins in Eastern GRCA
- Foliar cover remains relatively stable in this short time frame

USGS

Riparian Vegetation – Methods Comparison

- Two common methods of collecting vegetation data
  - Ocular cover estimates
  - Line-point intercept
- Ocular cover estimates (what we have been using) found to be sufficiently reliable and useful
- Methods were equally variable among observers
  - Neither significantly different among observers
- Ocular cover estimates recorded more species

(Preliminary data from Palmquist 2016. Do Not Cite.)

USGS

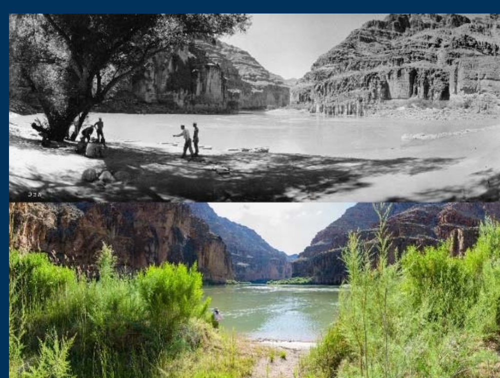
Project 12: Analysis of Changes to Culturally Valued Riparian Vegetation

Two main accomplishments in 2016-17:

1) Photo matching and 2) Analysis of Change

- **Part 1: matched 35 panoramas from 1923 Birdseye Expedition**



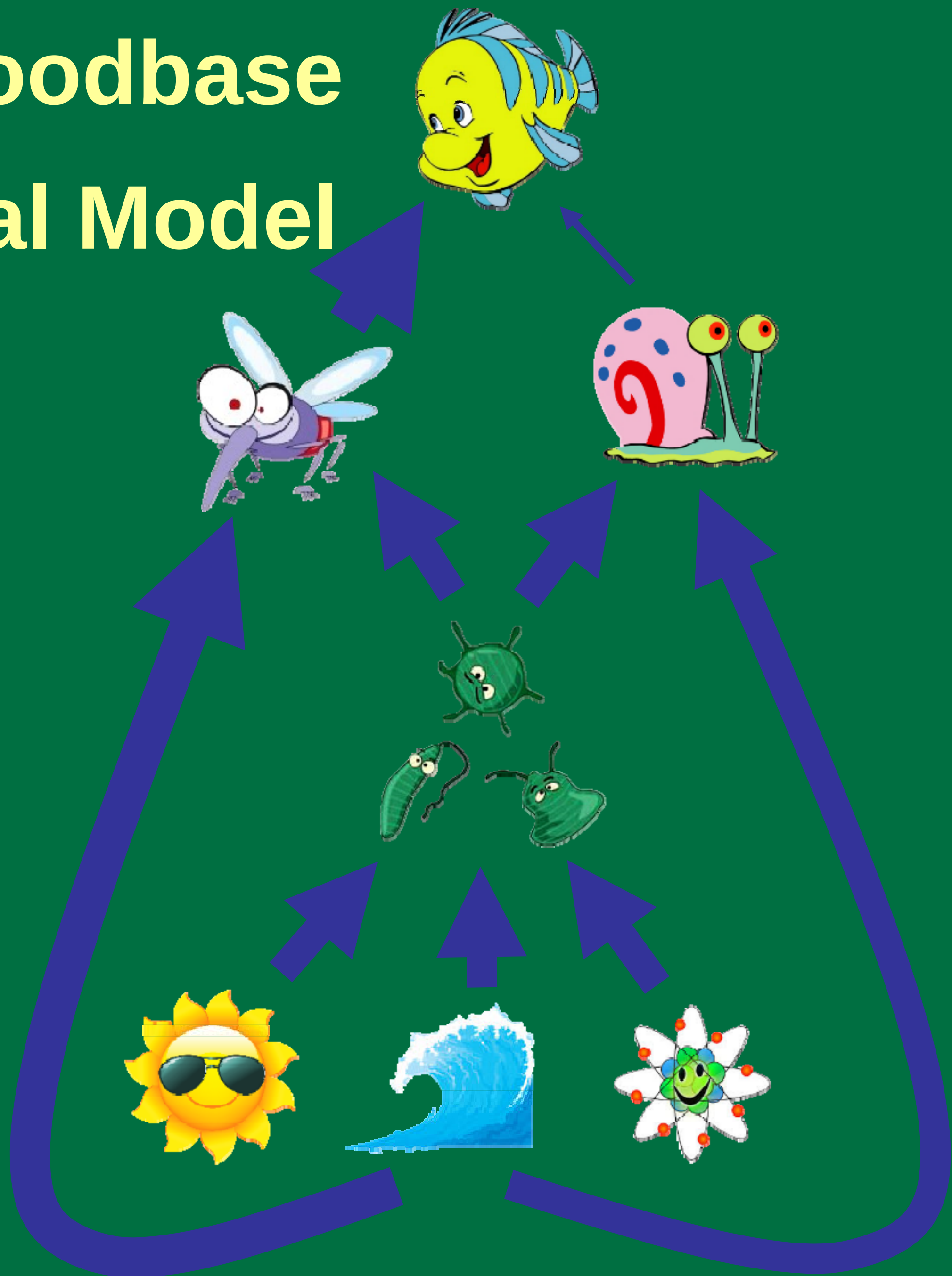




Part 2: Results of photo analysis, 1990-2012

(analysis of R. Webb photo matches from 1990-91 & 2010-11)

- **Woody vegetation (.e.g., tamarisk, baccharis) increased throughout river corridor, 1990-2012**
- **89% of analyzed photo matches showed increases in tamarisk; 53% showed increases in *Baccharis sp.;* 2% showed clear increases in *Salix exigua***
- **9% showed no significant change; <2% showed decrease**
- **Most change occurred above 45,000 cfs; some vegetation changes are due to encroachment of desert species (e.g., mesquite, acacia, cactus) into Old High Water Zone**
- **More change in wider reaches; less in narrow reaches**
- **Future Publication: Scott M.L., Webb R.H., Johnson R.R., Turner R.M., Friedman J.M., Fairley H.C. In review. *Evaluating Riparian Vegetation Change in Canyon-bound Reaches of the Colorado River Using Spatially Extensive Matched Photo Sets*. Chapter 18. In: Johnson R.R., Carothers S.W., Finch, D.M., and Kingsley, K.J., 20XX. Riparian Ecology: Past, Present, Future. USDA Gen. Tech. Report, Rocky Mountain Research Station, Fort Collins, CO**

Aquatic Foodbase Conceptual Model



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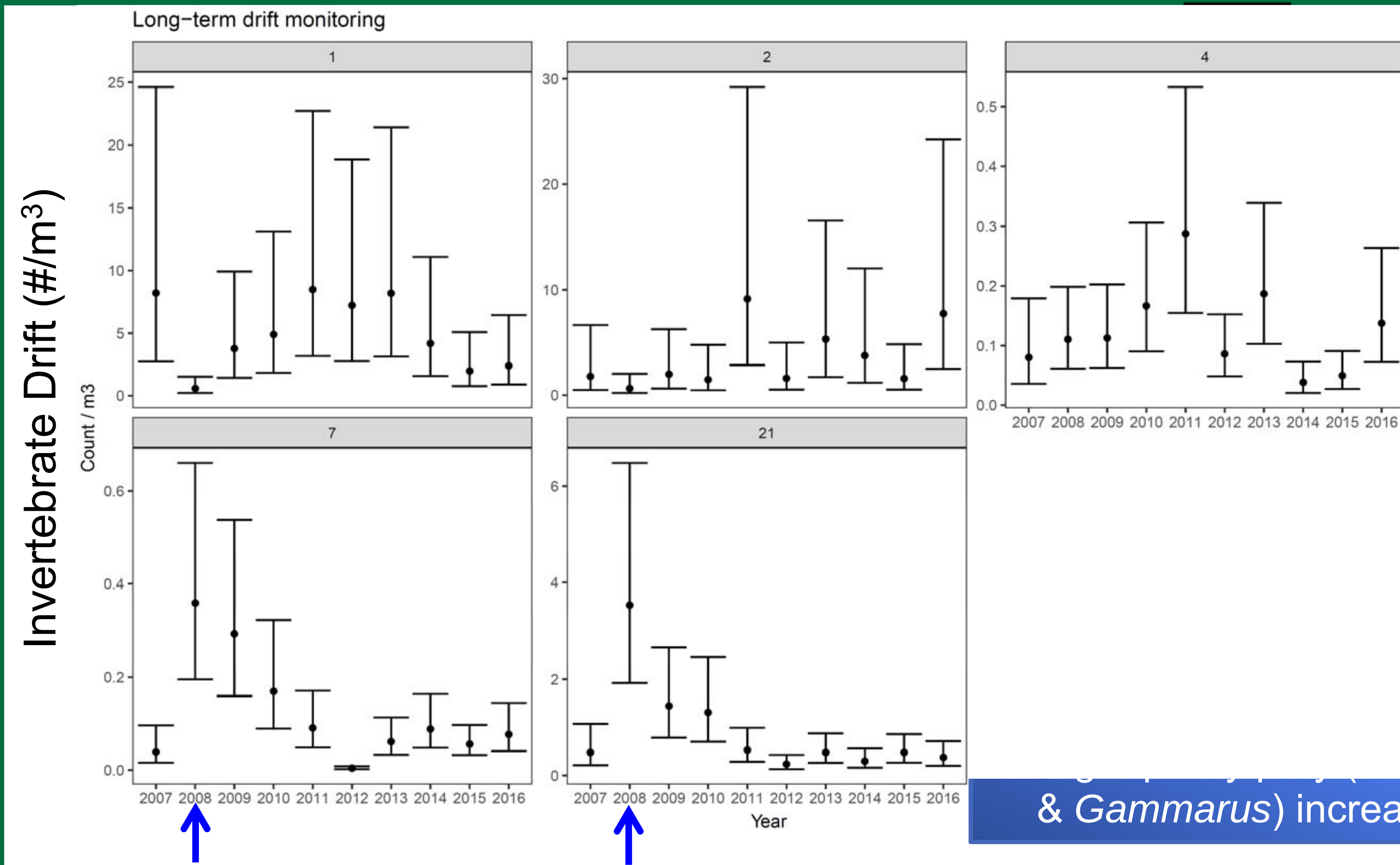
Unpublished data, subject to change, do not cite

Food Base in Glen Canyon – HFE Effects



rms
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ects
& *Gammarus*) increased.

Unpublished data,
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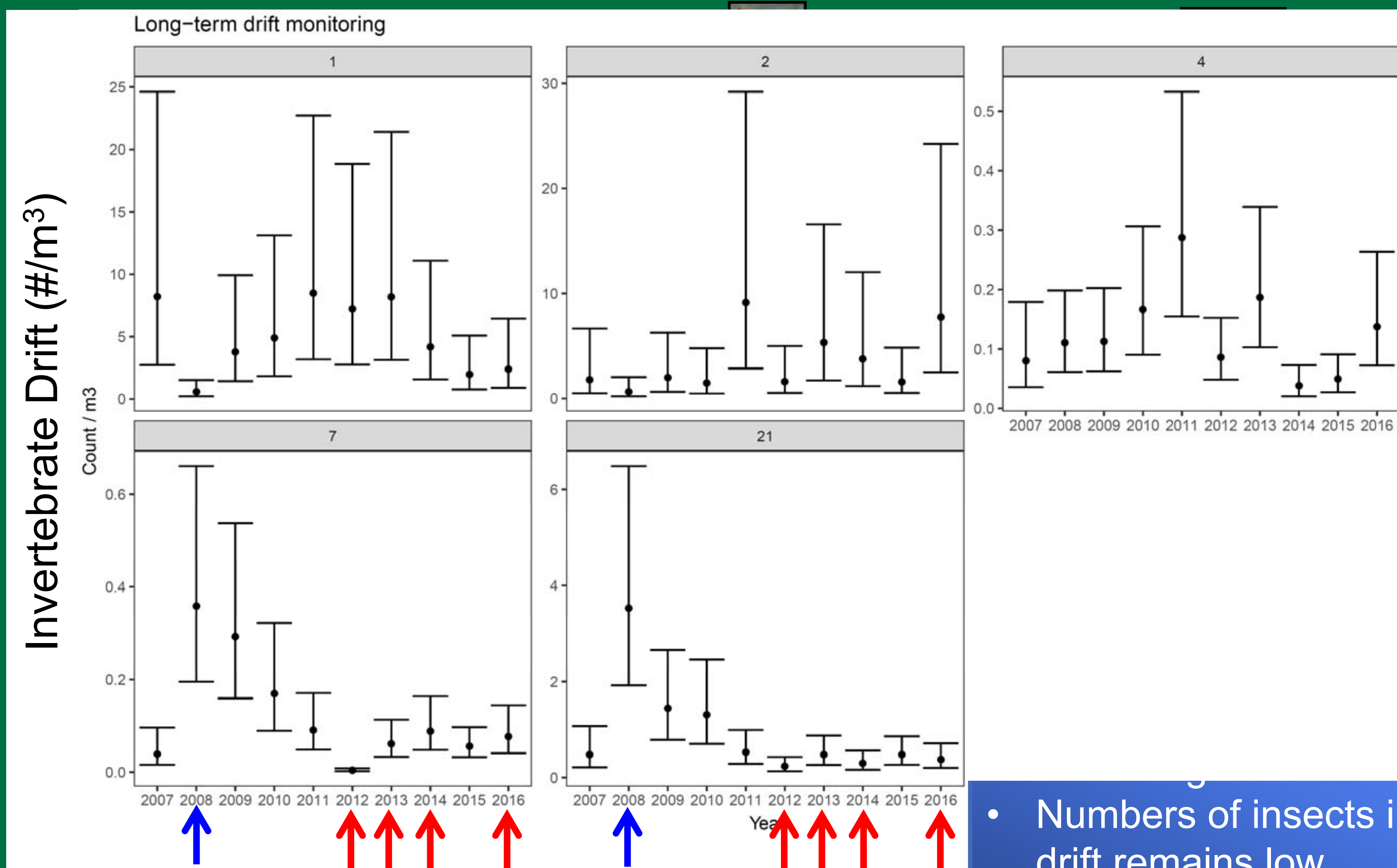
Food Base in Glen Canyon – HFE Effects

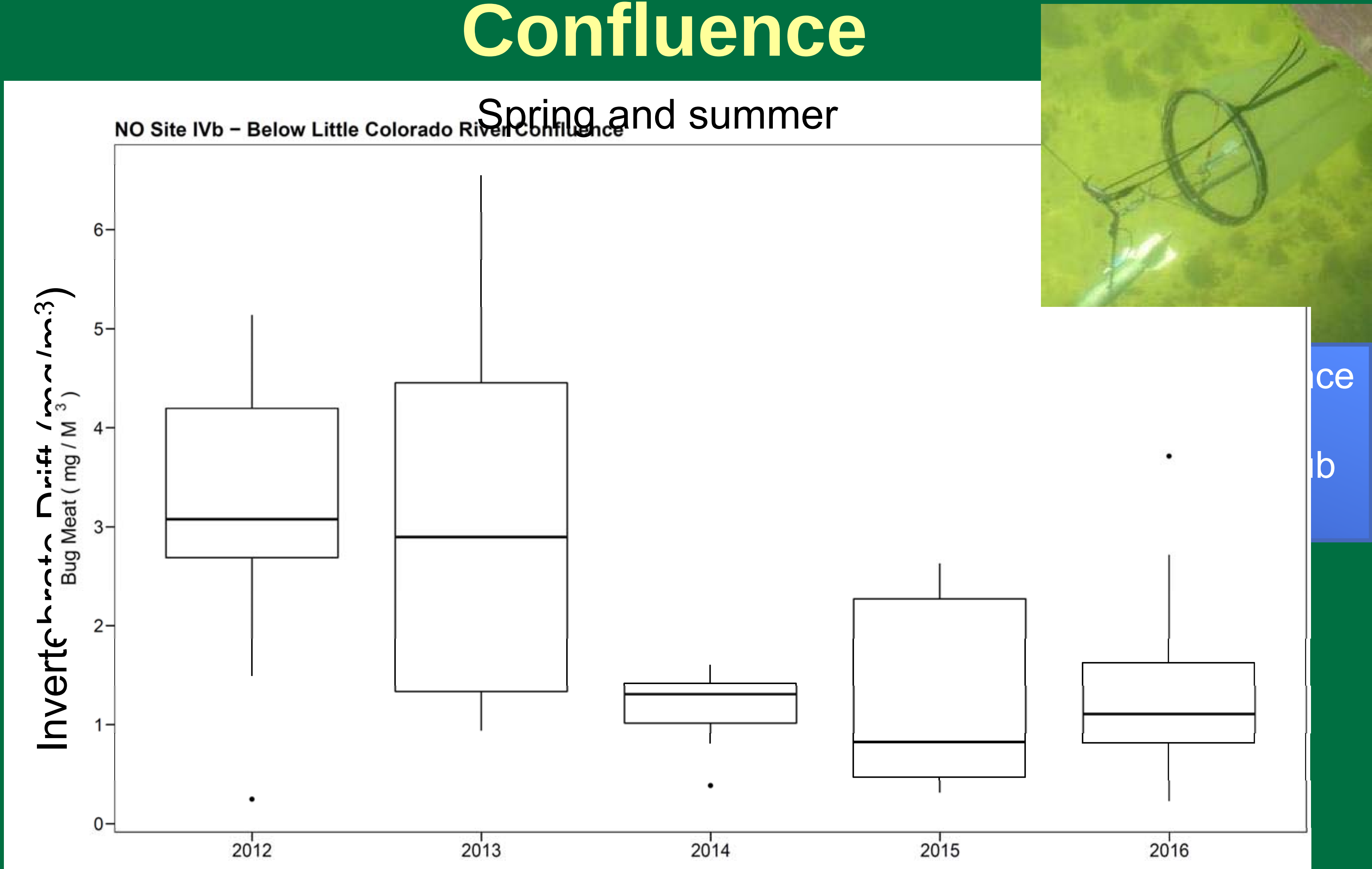


FEs:

- Numbers of insects in drift remains low.

Unpublished data, subject to change, do not cite

Food Base at Little Colorado River Confluence



Unpublished data, subject to change, do not cite

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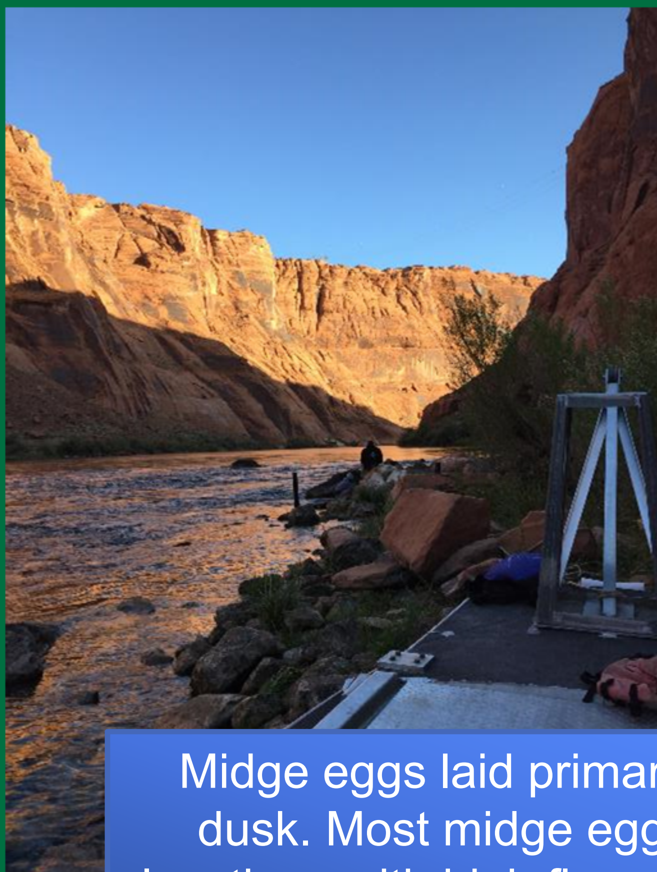
Effects of Daily Flow Variation on Insects - Timing Midge Egg Laying



Midge eggs laid primarily at dusk. Most midge eggs at locations with high flow at dusk will be exposed at low flows.

Dusk
>1,000,000 eggs

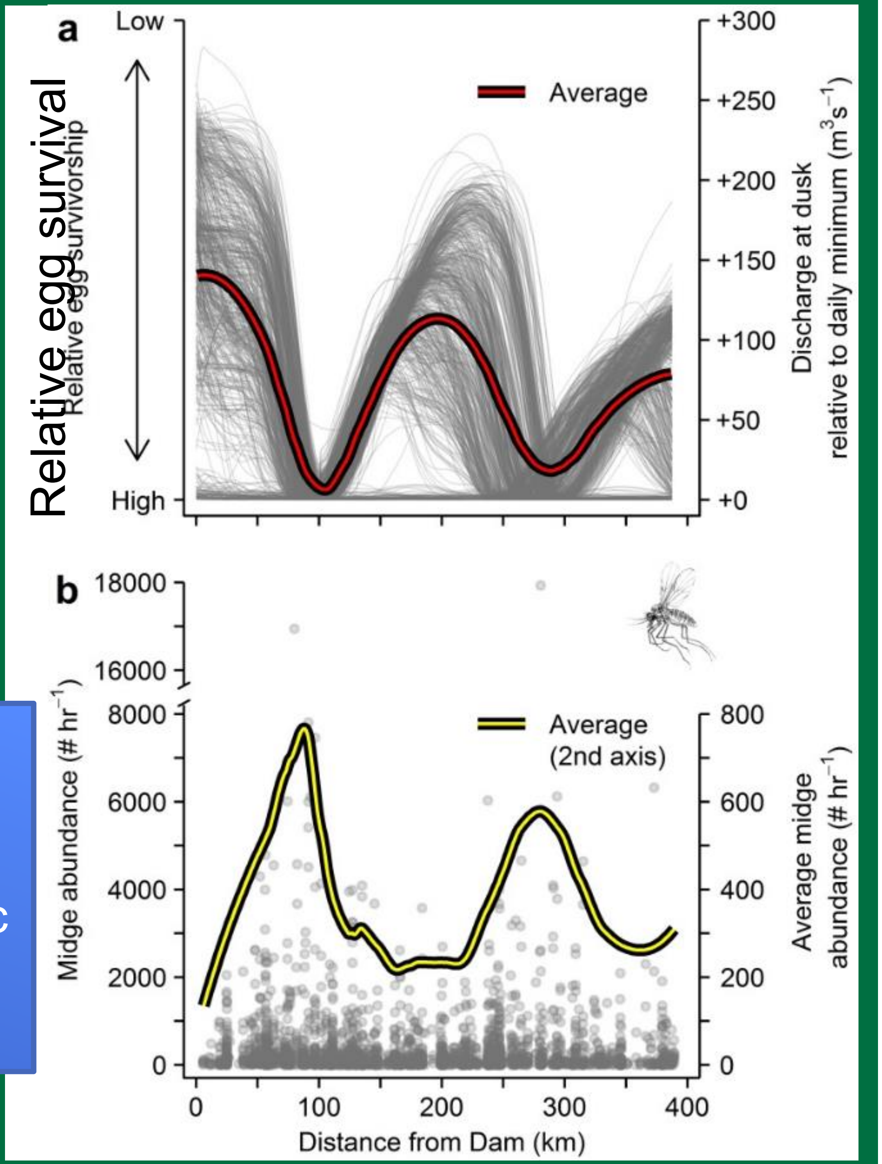
Dawn
>10,000 eggs

Unpublished data, subject to change, do not cite

Spatial Periodicity in Midge Abundance

Midges: 3X greater at nodes

Timing of midge egg laying consistent with observations of greatest midge abundance at sites where flows are low at dusk. Supports hypothesis that daily flow variation limits aquatic insects that lay eggs along river margins. Supports rationale for testing bug flows.

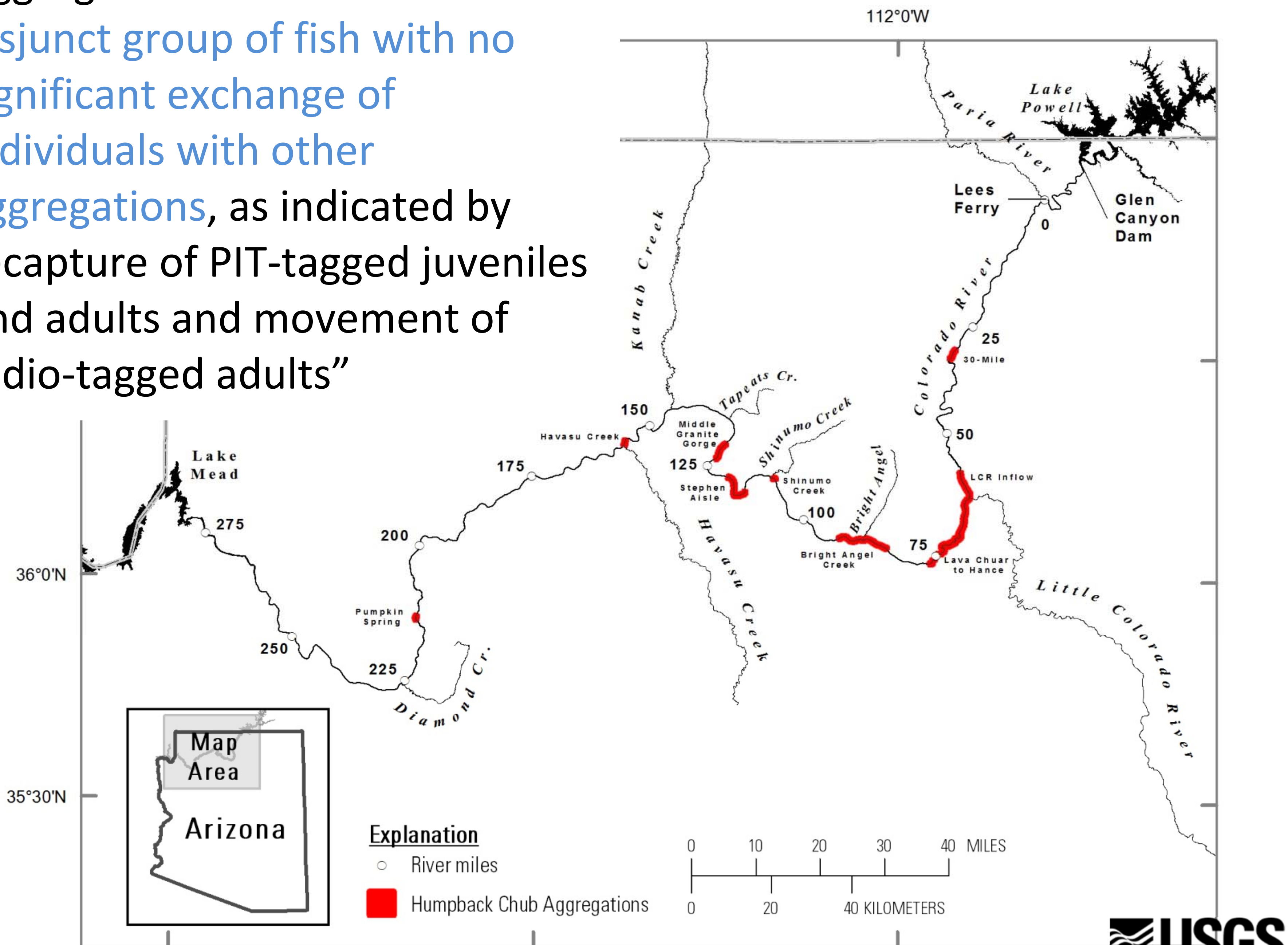


USGS

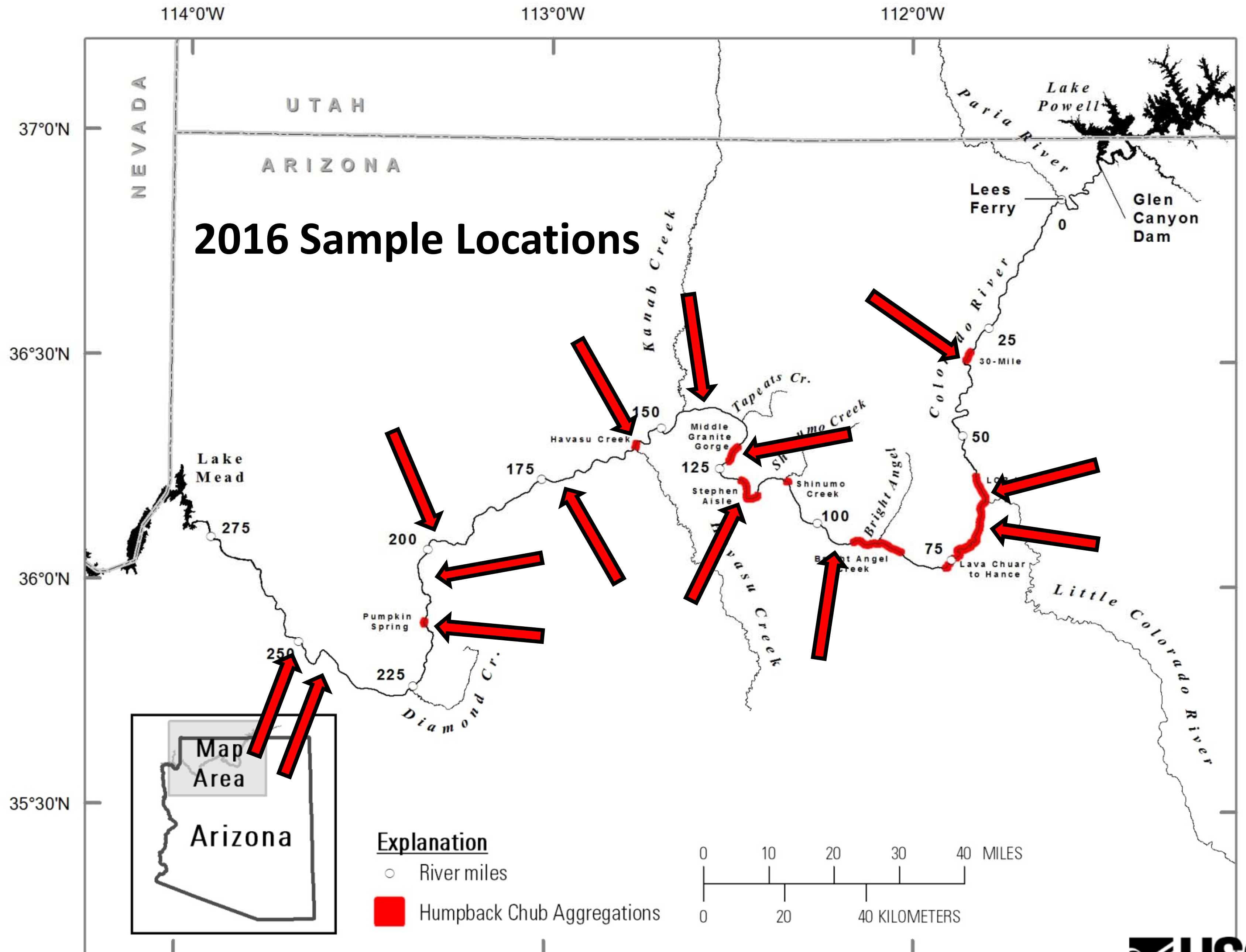
Kennedy et al. 2016
BioScience

USGS

Aggregation: "a consistent and disjunct group of fish with no significant exchange of individuals with other aggregations, as indicated by recapture of PIT-tagged juveniles and adults and movement of radio-tagged adults"



(Slide courtesy Kirk Young USFWS)

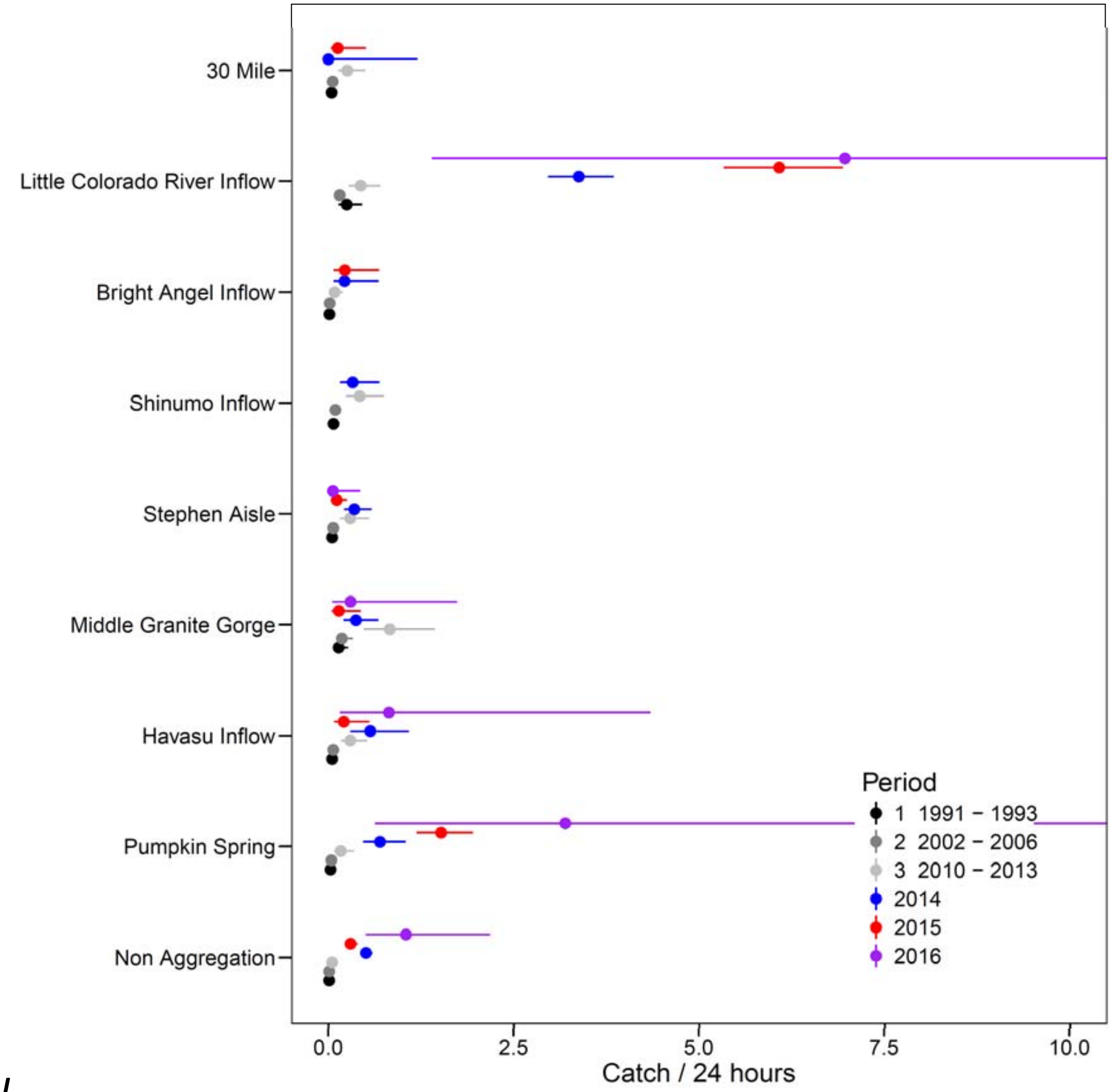


(Slide courtesy Kirk Young USFWS)

Humpback Chub Catch Per Unit Effort

High Catch Rates at:

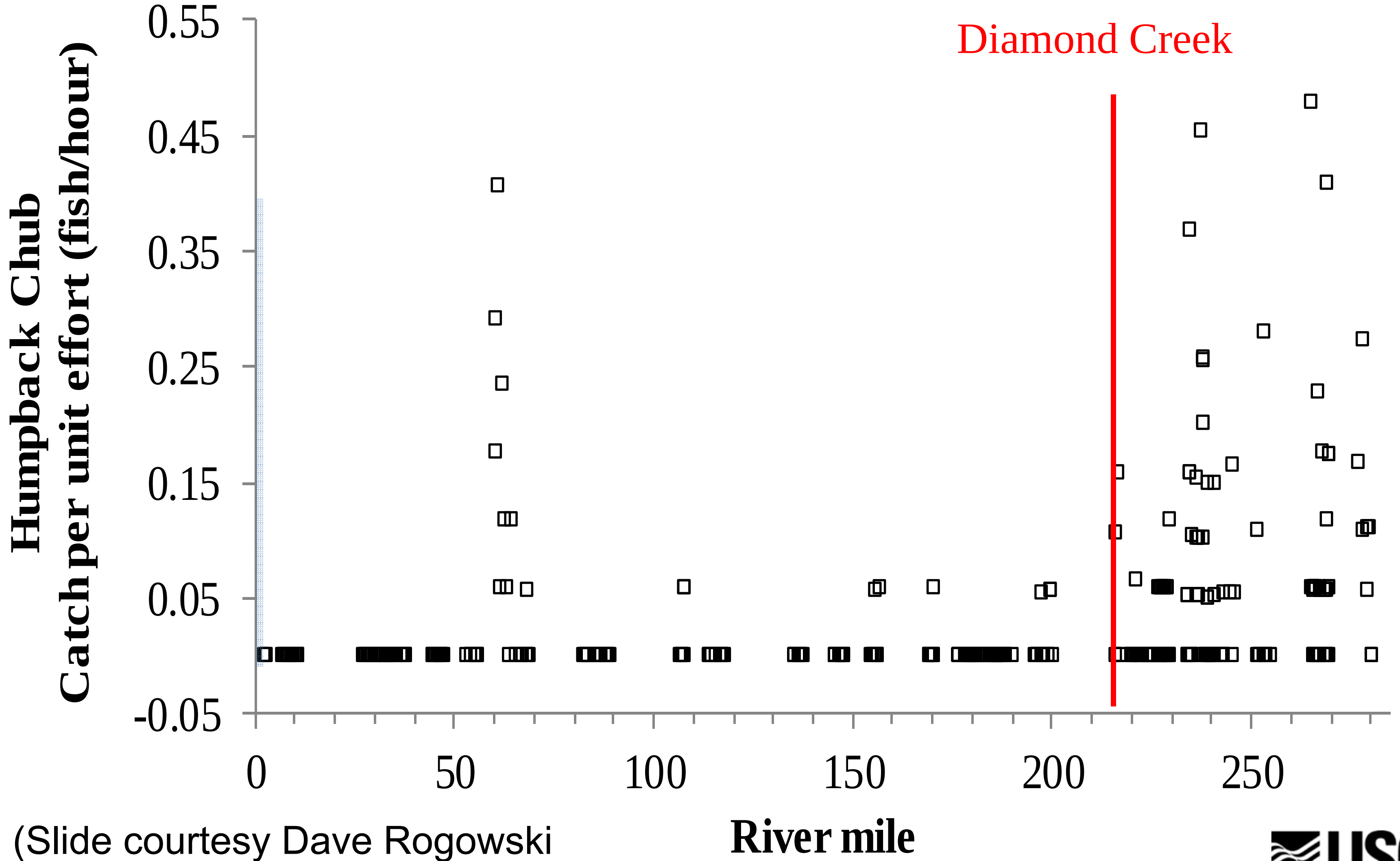
- Little Colorado River
- Pumpkin Spring
- Non Aggregation Sites



Preliminary data from Young et al. USFWS. 2017. Do not cite.

USGS

2016 Humpback Chub CPUE via hoop nets (n = 319)

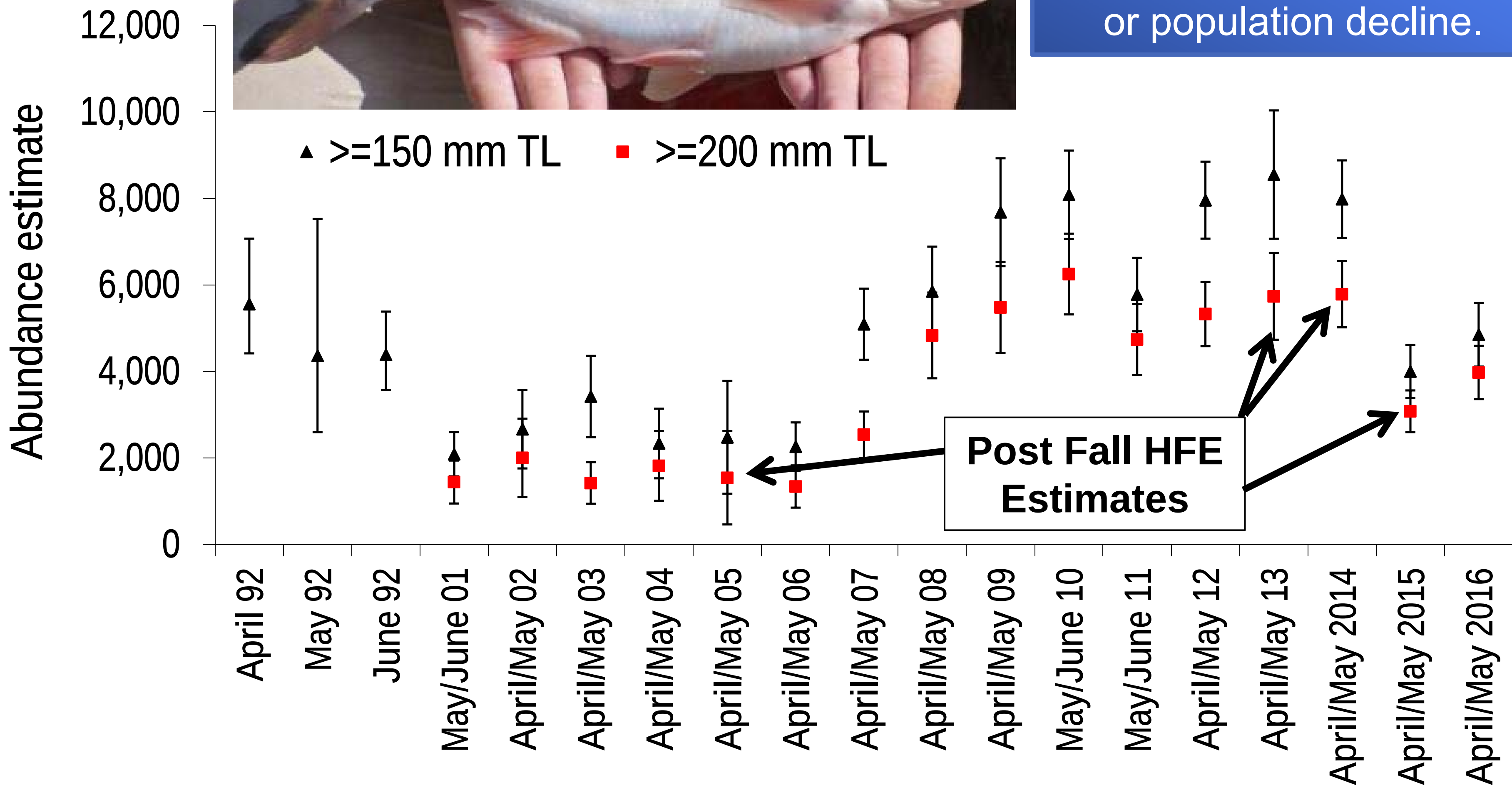


(Slide courtesy Dave Rogowski AG&FD. Preliminary data, do not cite)

USGS

Annual spring abundances of Humpback Chub in lower Little Colorado River

2015 & 16 spring estimates considerably lower than recent years. Potentially due to skipped spawning, or population decline.



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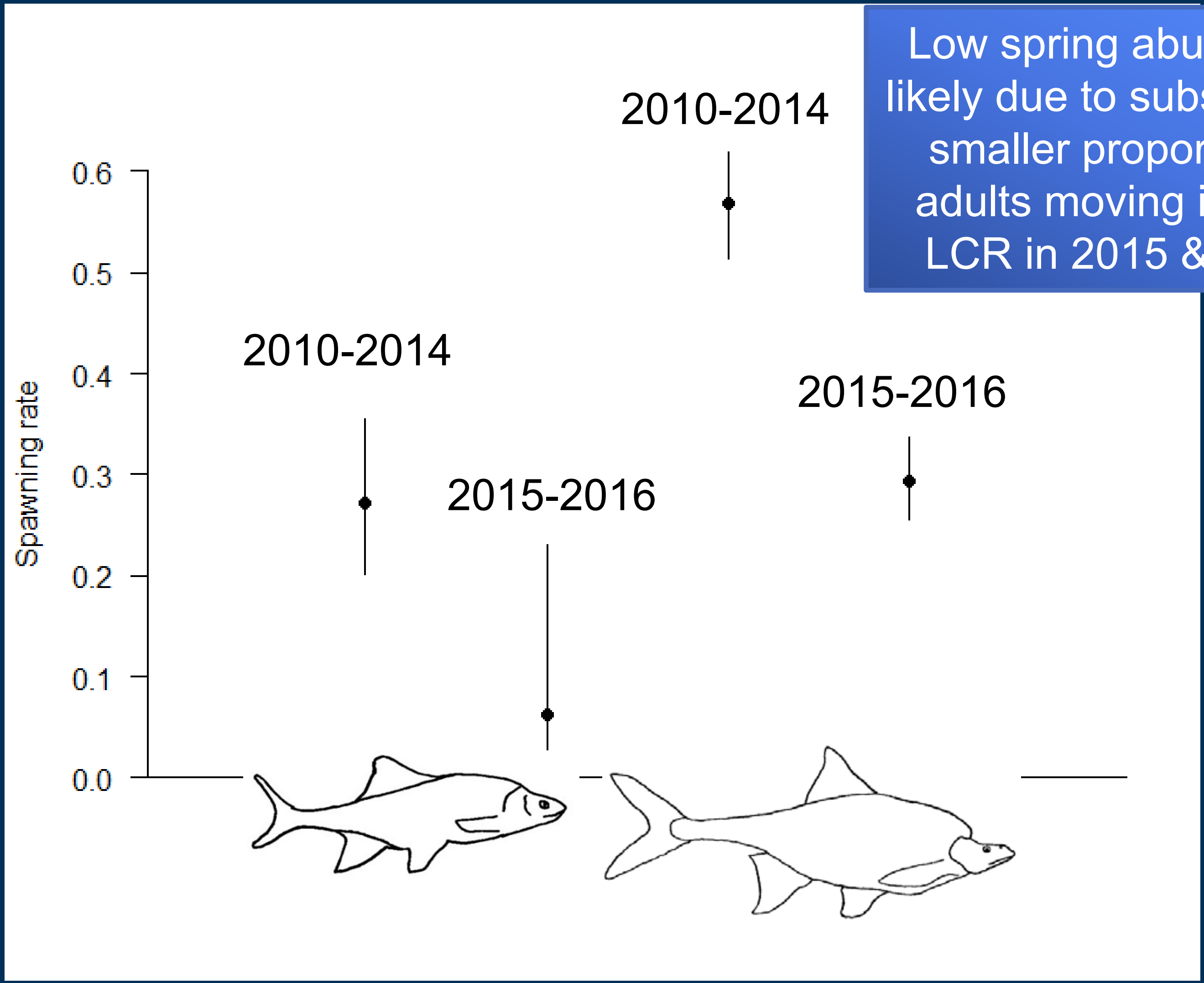
(Preliminary Data from VanHaverbeke et al. USFWS. 2016. Do Not Cite.)

Proportion of Colorado River fish moving into Little Colorado River during spring



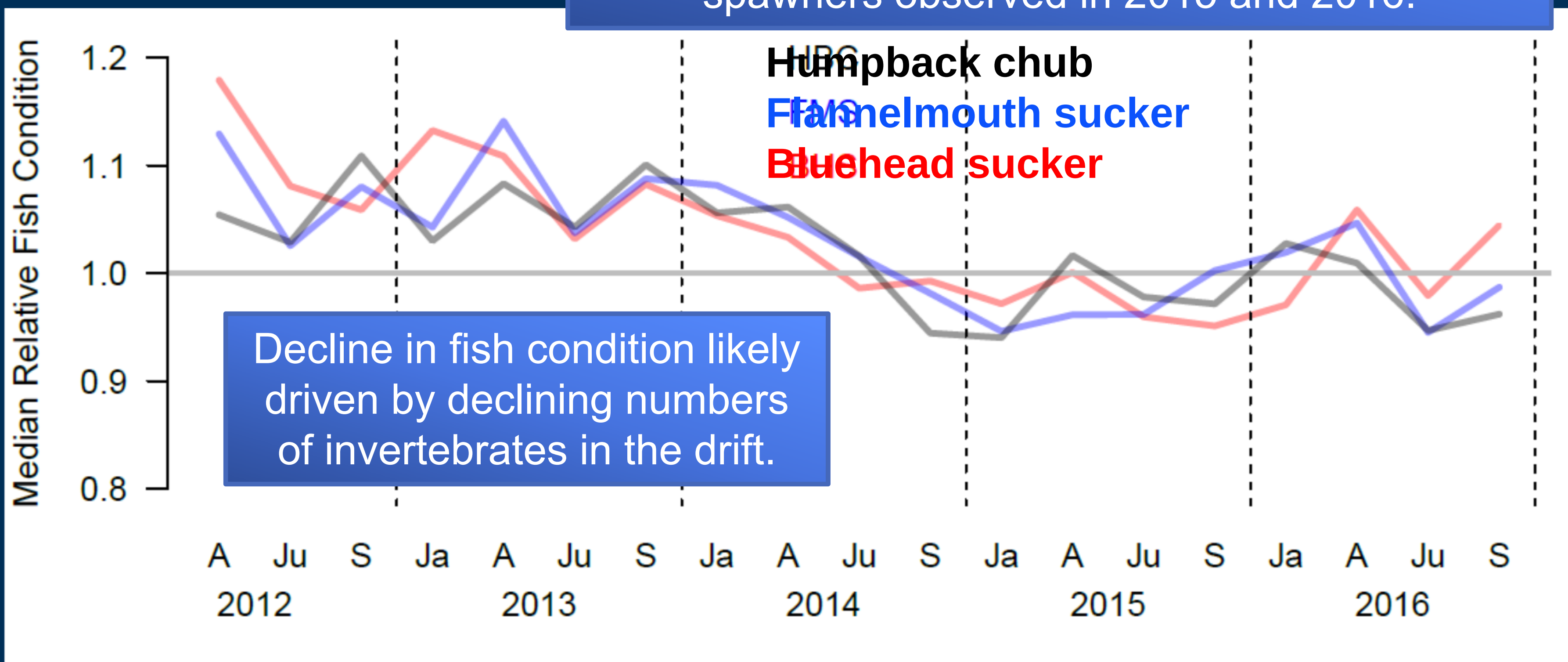
Low spring abundance likely due to substantially smaller proportion of adults moving into the LCR in 2015 & 2016.

USGS

Preliminary data. Do not cite.

Adult large bodied native fish got skinny at the same time rainbow trout populations declined

Lower condition observed since 2014 supports hypothesis of skipped spawning due to less energy available to devote to reproduction. Fewer spawners observed in 2015 and 2016.

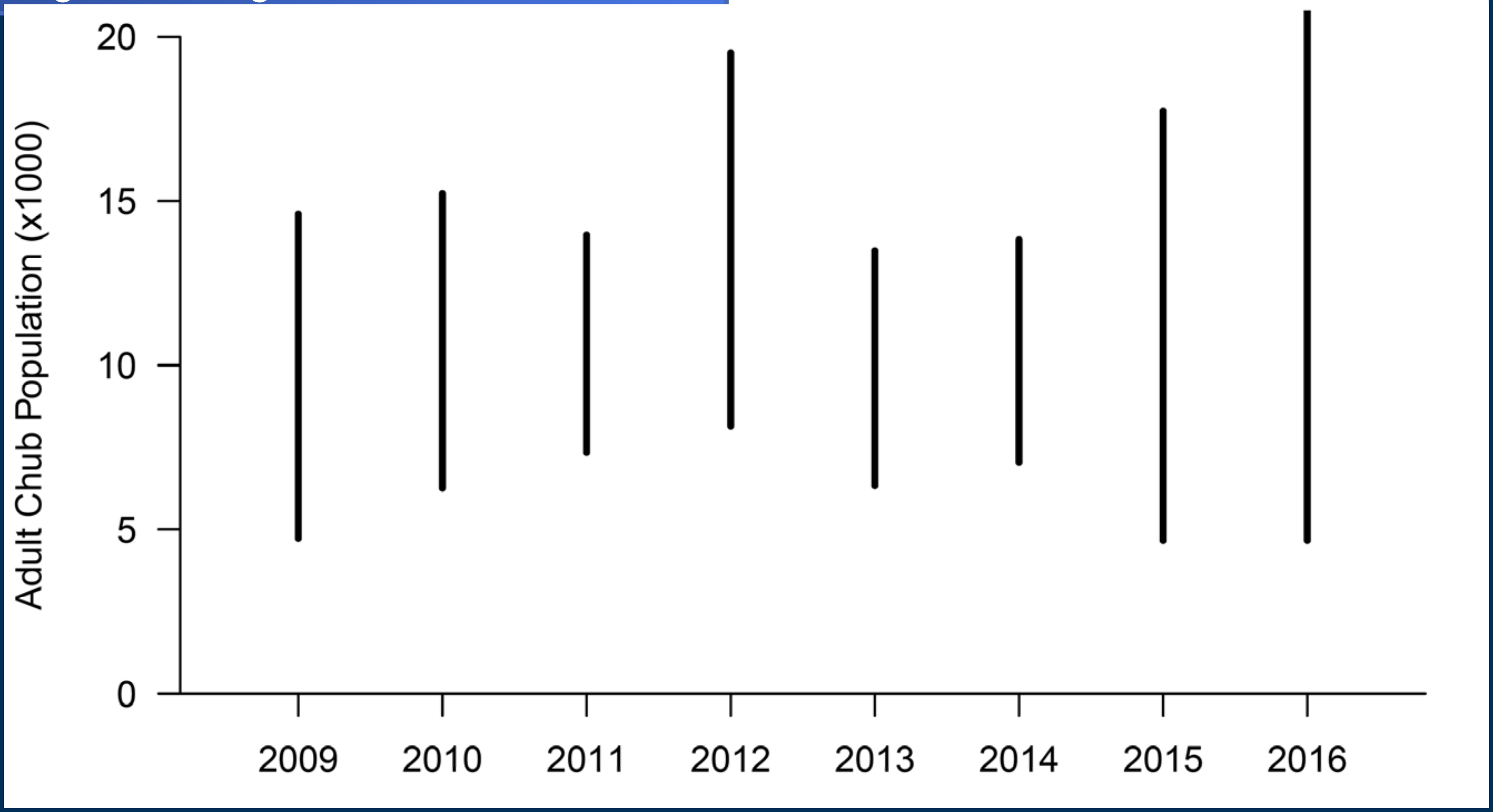


Decline in fish condition likely driven by declining numbers of invertebrates in the drift.

Preliminary data. Do not cite.

Adult Humpback Chub Abundance Estimates: Multistate Population Model

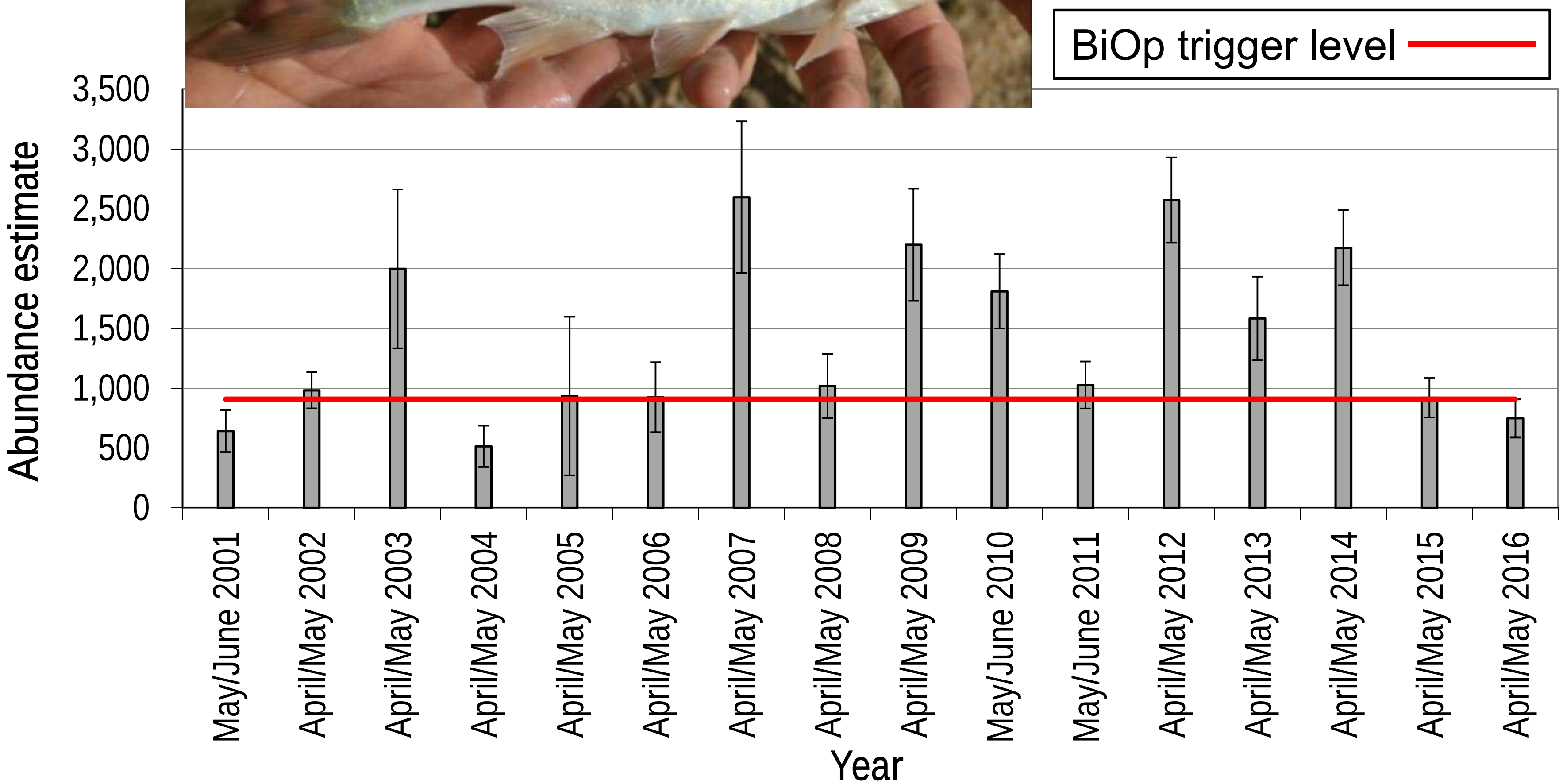
Adult humpback chub abundance appears stable from 2009 – 2016, no change following 2012 – 2014 fall HFEs.



Preliminary data. Do not cite.

Spring LCR 150-199 mm Humpback Chub abundance estimates

2016 spring abundance estimate for sub-adults below 2011 BiOp trigger level



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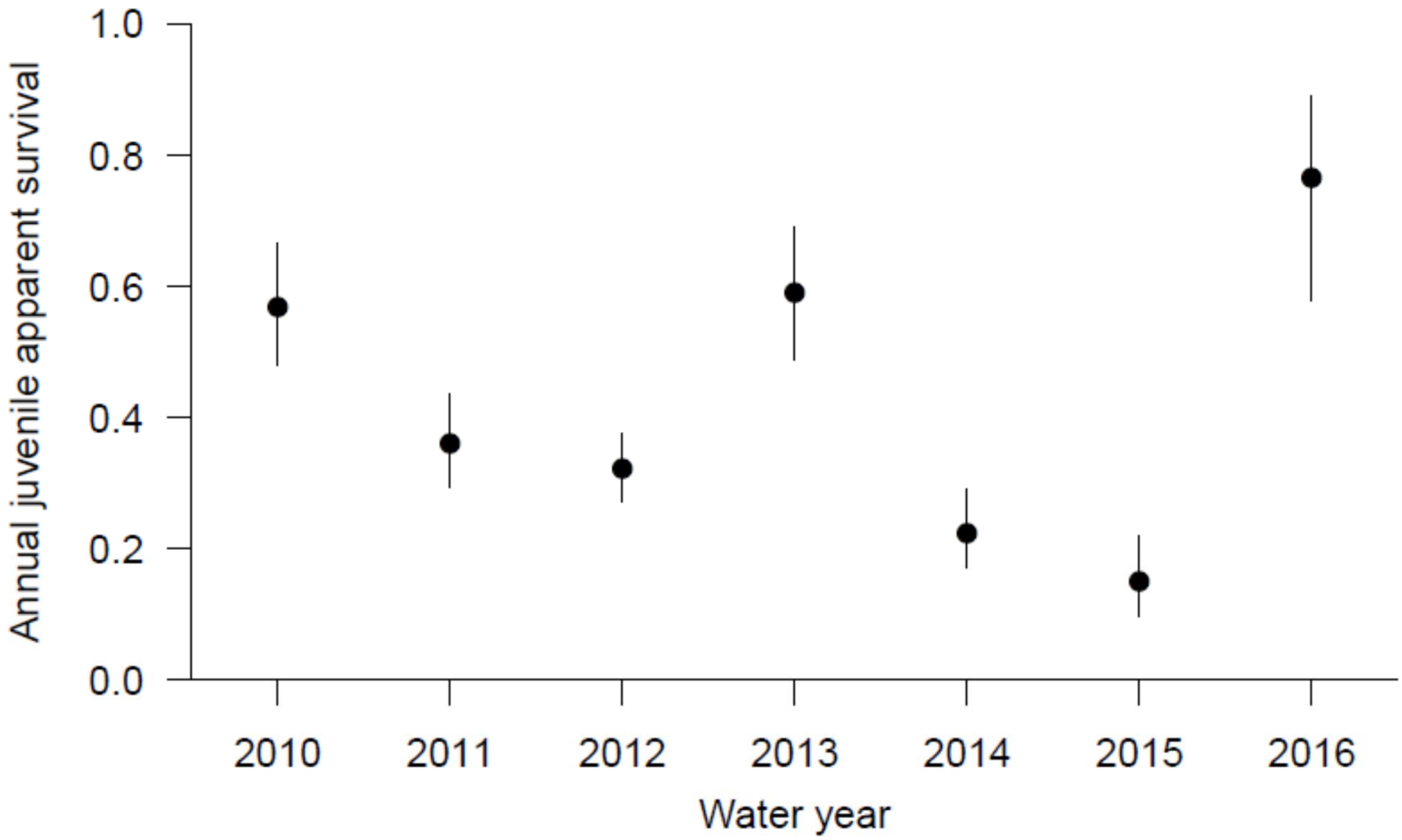
(Preliminary Data from VanHaverbeke et al. USFWS. 2016. Do Not Cite.)

Juvenile Humback Chub Survival Rates



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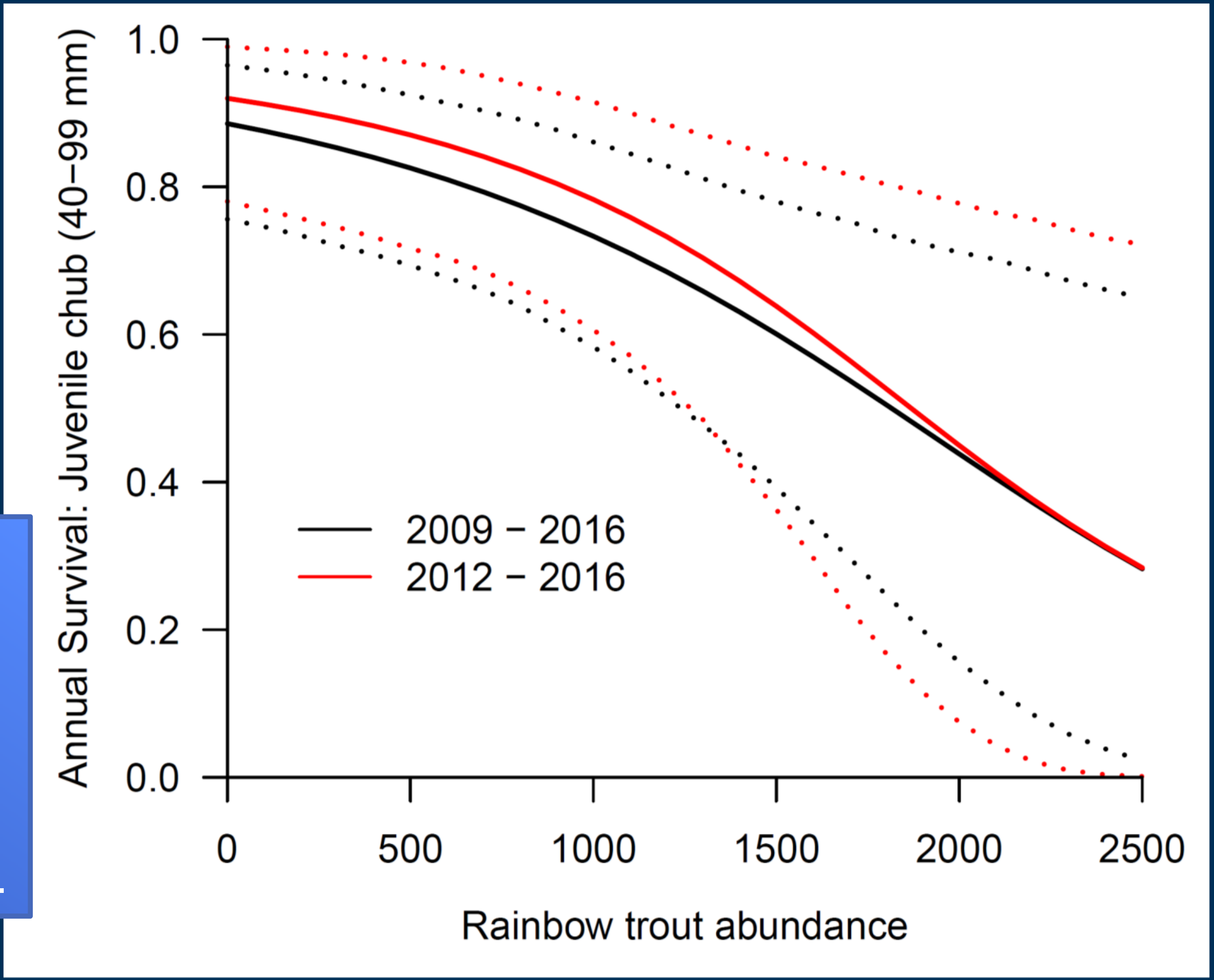
(Preliminary Data from Yackulic 2016. Do Not Cite.)

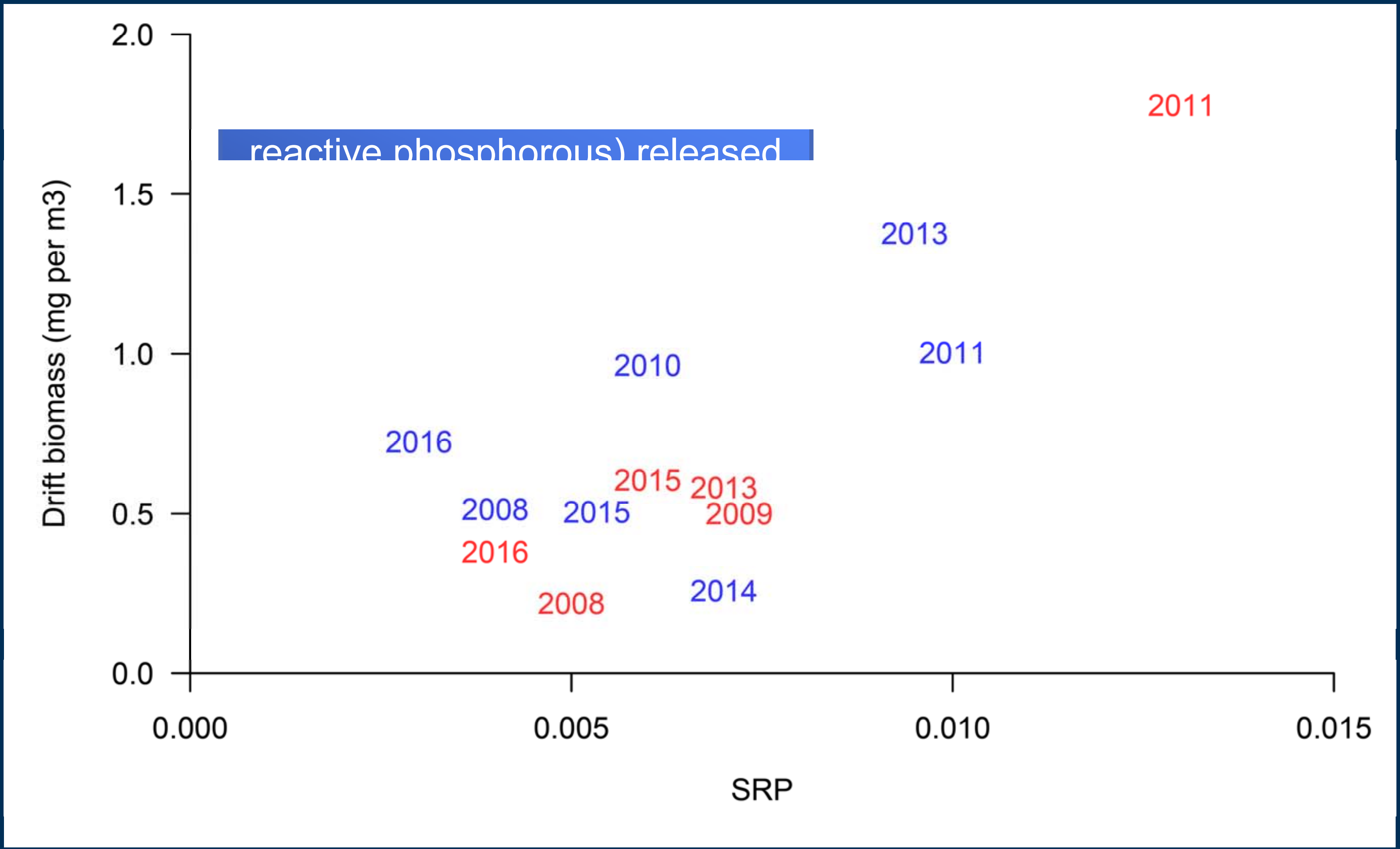
Juvenile Humback Chub Survival vs. Rainbow Trout Abundance

Juvenile humpback chub survival is negatively related to increased rainbow trout abundances. This is the most consistent relationship across years.



Preliminary data. Do not cite.

Drift Biomass vs. Soluble Reactive Phosphorus (SRP)



Preliminary data. Do not cite.

Take home messages

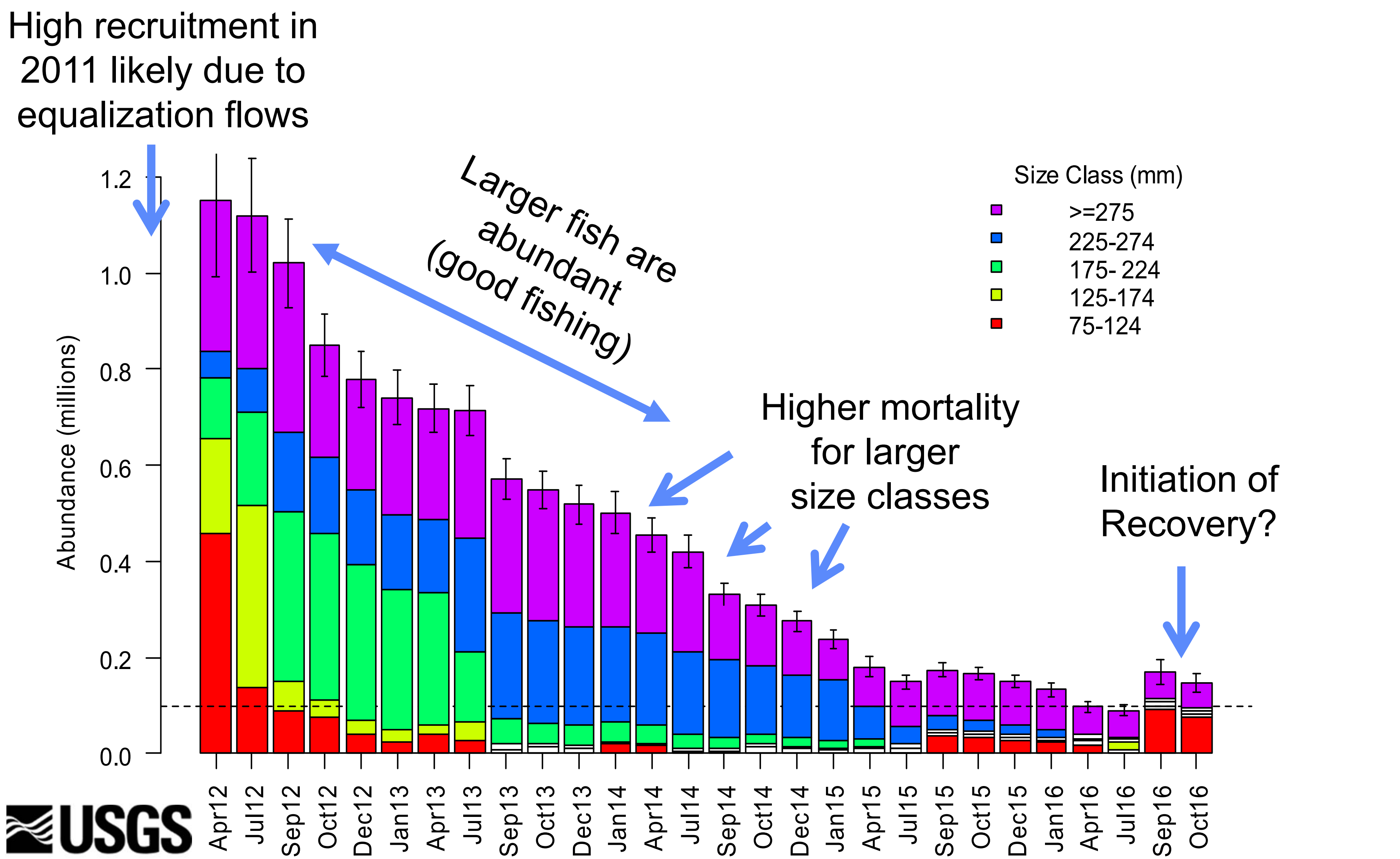
- While many factors likely drive ecosystem responses, the role of nutrients has been understudied in our system, and phosphorous is the most likely nutrient to be limiting.
- Recent declines in gross primary production, invertebrate drift biomass and native fish condition near the LCR all line up with trends in P.
- Invertebrate drift at two sites in Lees Ferry also line up with trends in P since 2008.
- The combination of existing rainbow trout populations and P can explain much of the observed variation in recruitment since 2000.

USGS

Preliminary data. Do not cite.

USGS

Rainbow Trout Abundance Estimates in Glen Canyon



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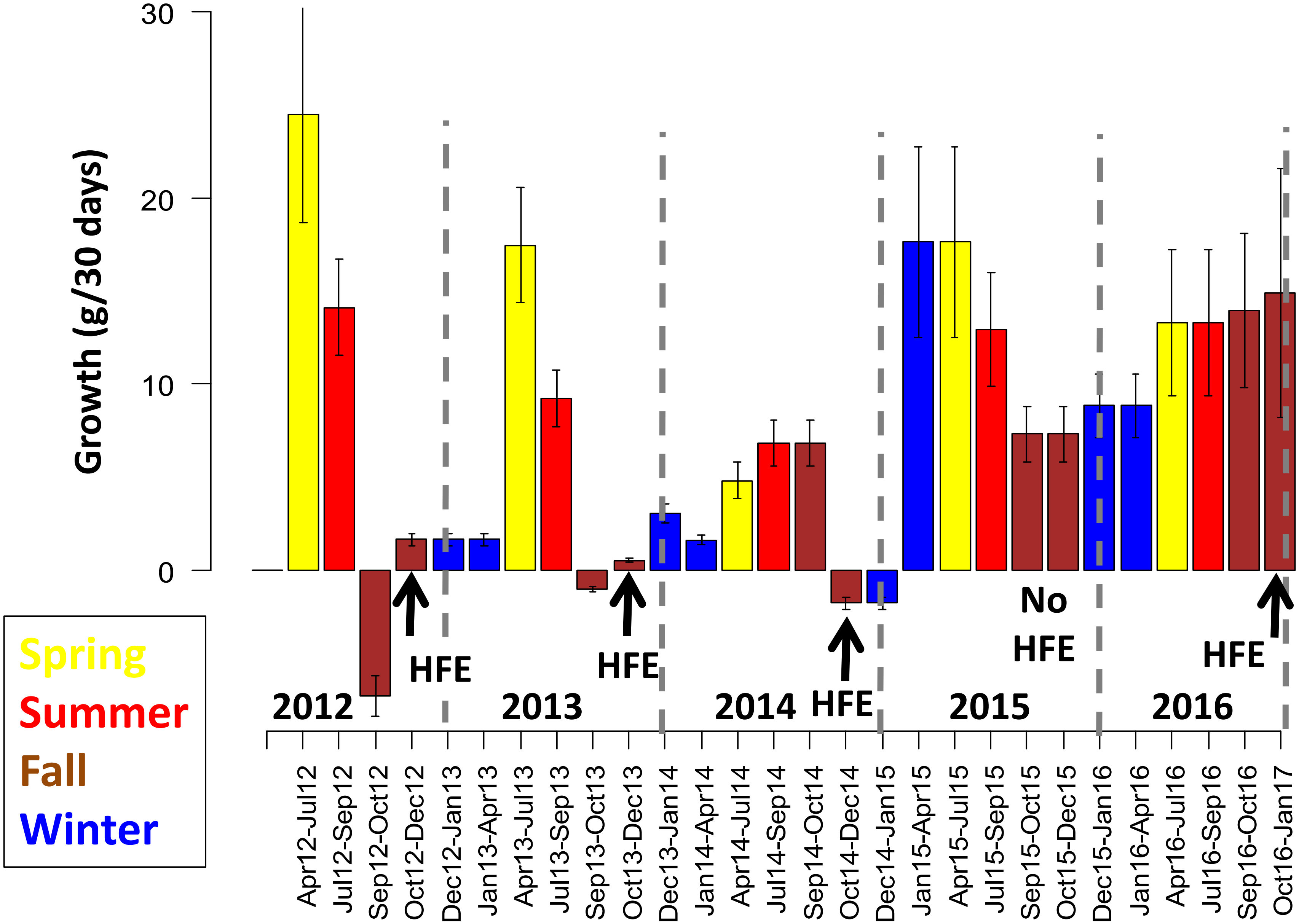
(Preliminary data from Korman and Yard 2017. Do Not Cite.)

Effect of Fall HFEs on Rainbow Trout Growth in Glen Canyon



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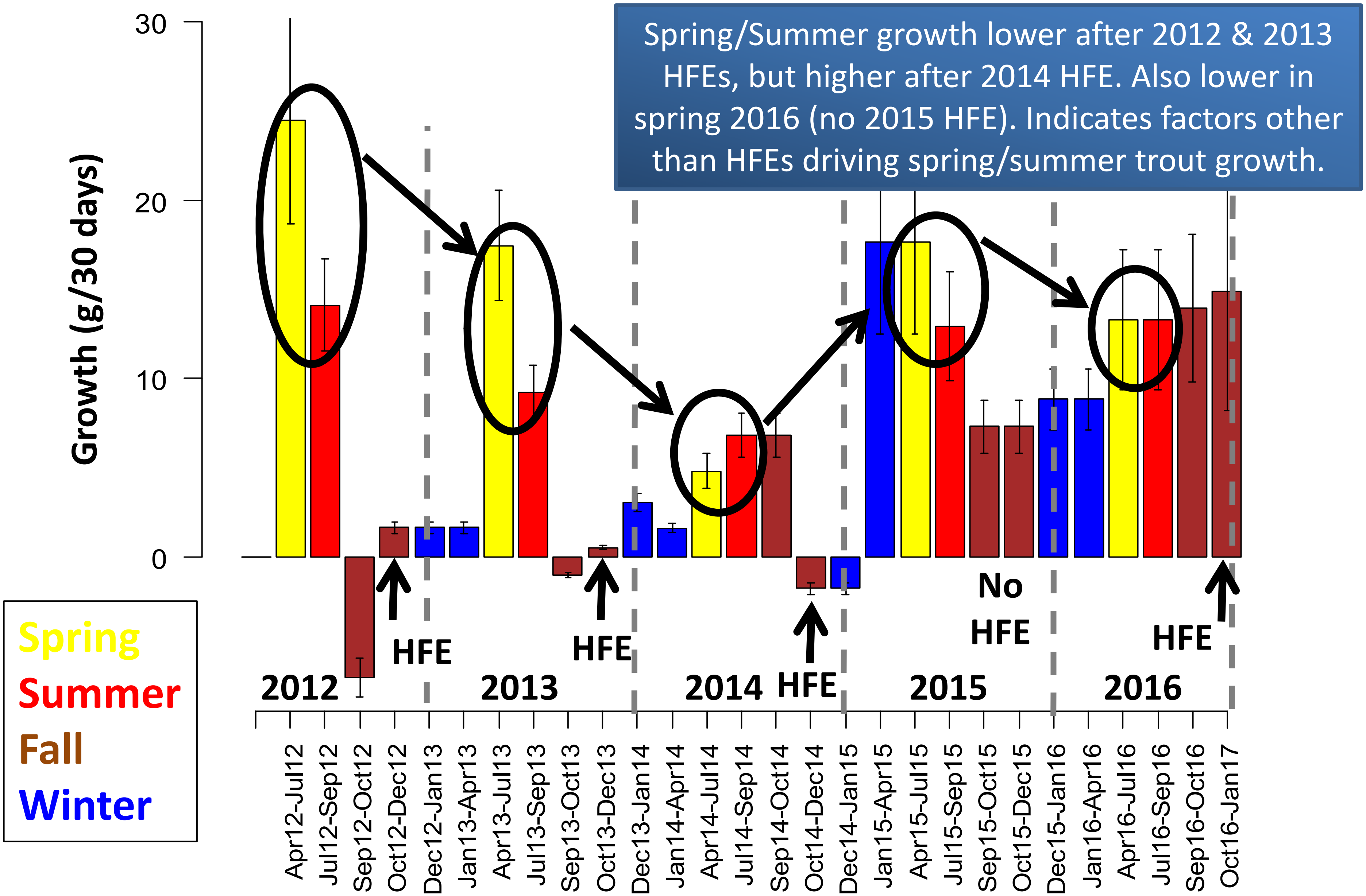

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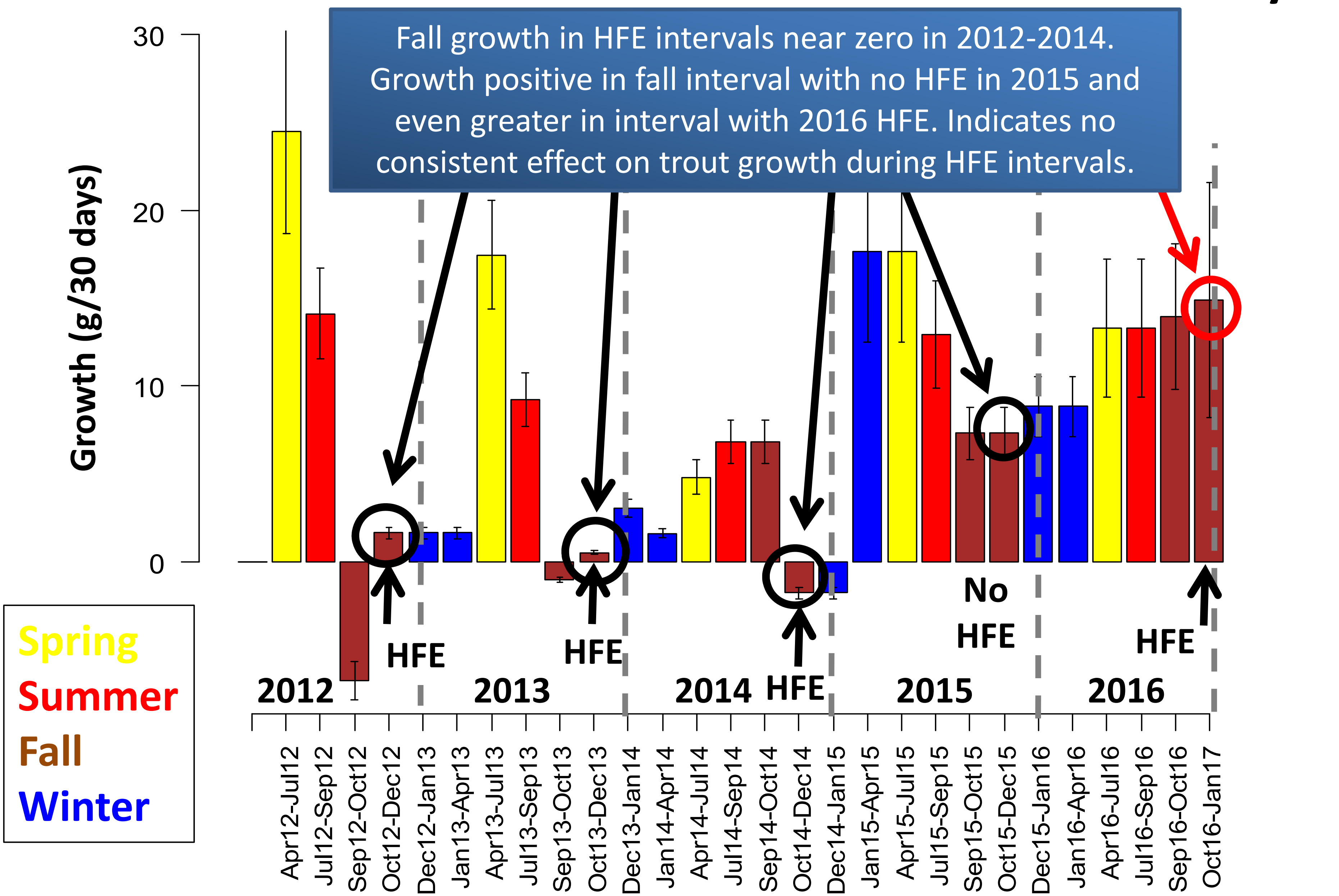
Effect of Fall HFEs on Rainbow Trout Growth in Glen Canyon



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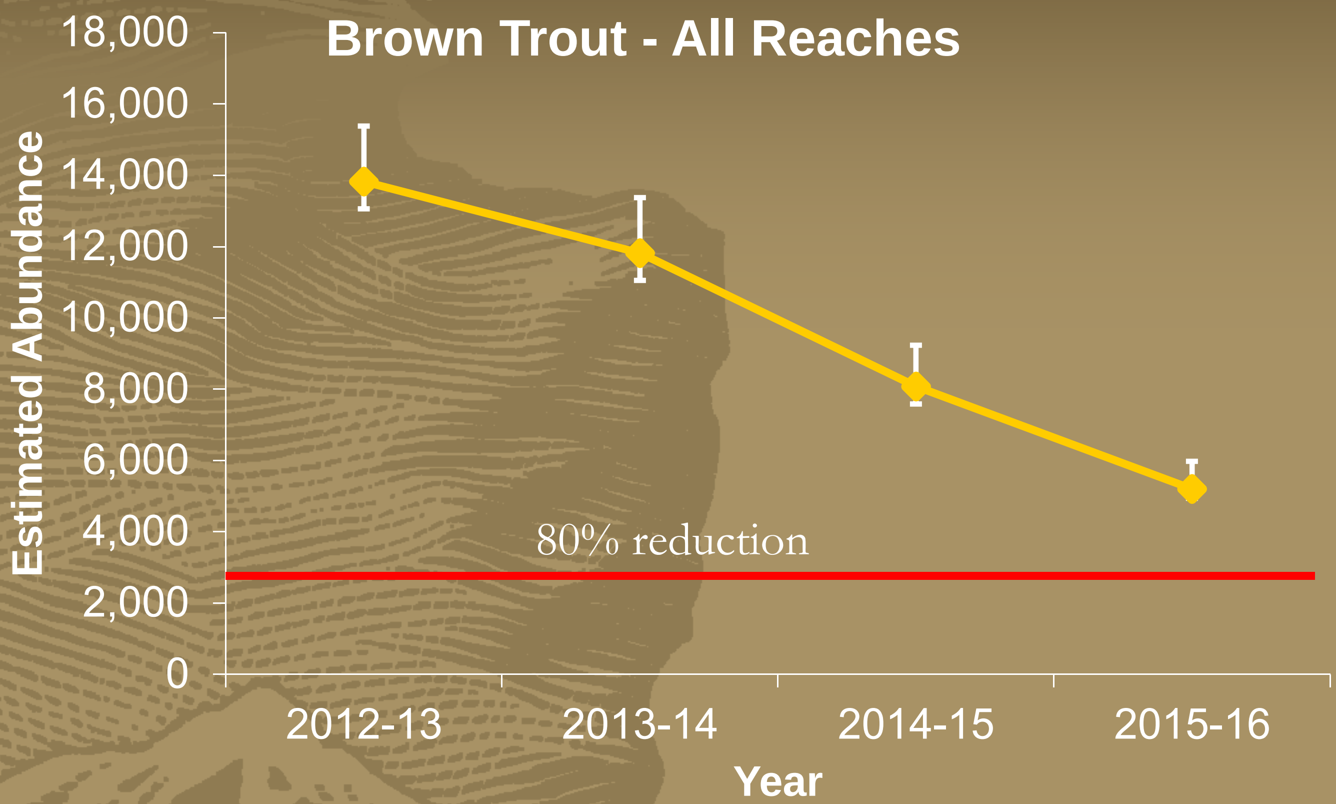
(Preliminary data from Korman and Yard 2017. Do Not Cite.)

Bright Angel Creek Annual Electrofishing Effort

- Electrofishing conducted over ≈ 12 miles of creek
  - Excluding Ribbon Falls Creek confluence
- 2012-2017 (2016-17 in progress)
- Multiple monitoring metrics: Abundance, survival, recruitment

(Slide courtesy Brian Healy NPS)

Electrofishing- Results: Brown Trout



- **62% Overall reduction through the beginning of 2015**
- **Based on trend, objective could be met in 2016 (In progress)**

(Slide courtesy Brian Healy NPS)

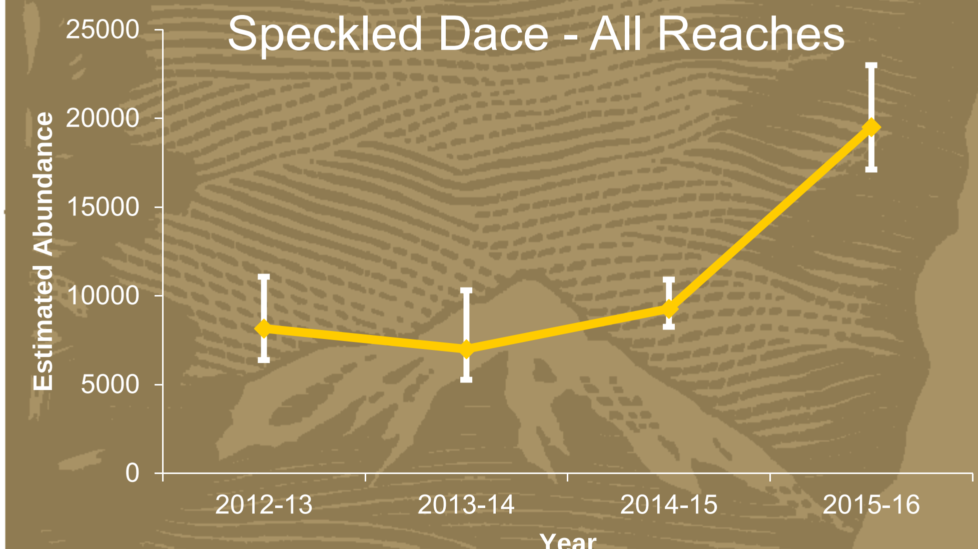
USGS (Preliminary data, do not cite)

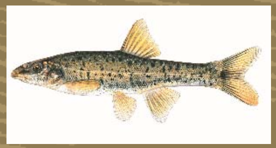
EXPERIENCE YOUR AMERICA

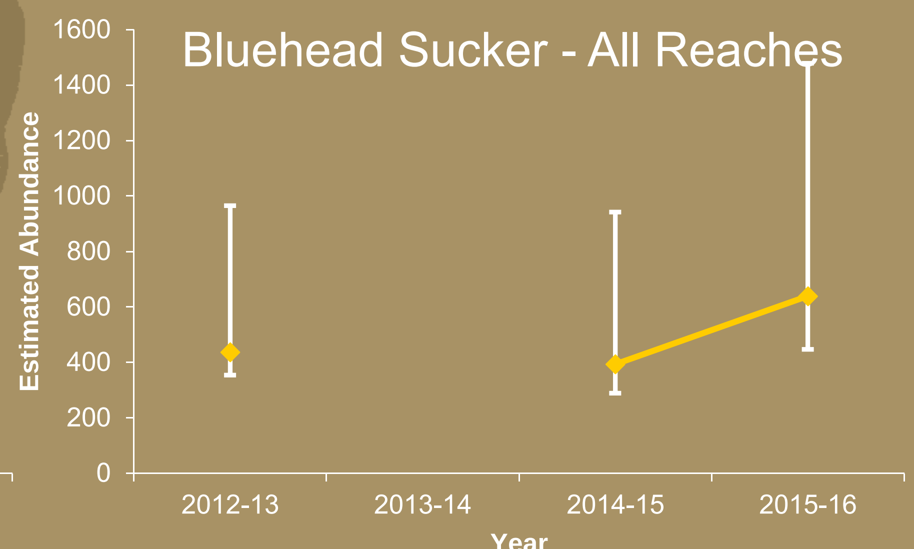
Electrofishing- Results: Native Fish

- Objective: Maintain stable/increasing populations
- Metrics: Abundance, Survival, and Recruitment

- Abundance: Meeting Objective (Speckled Dace)

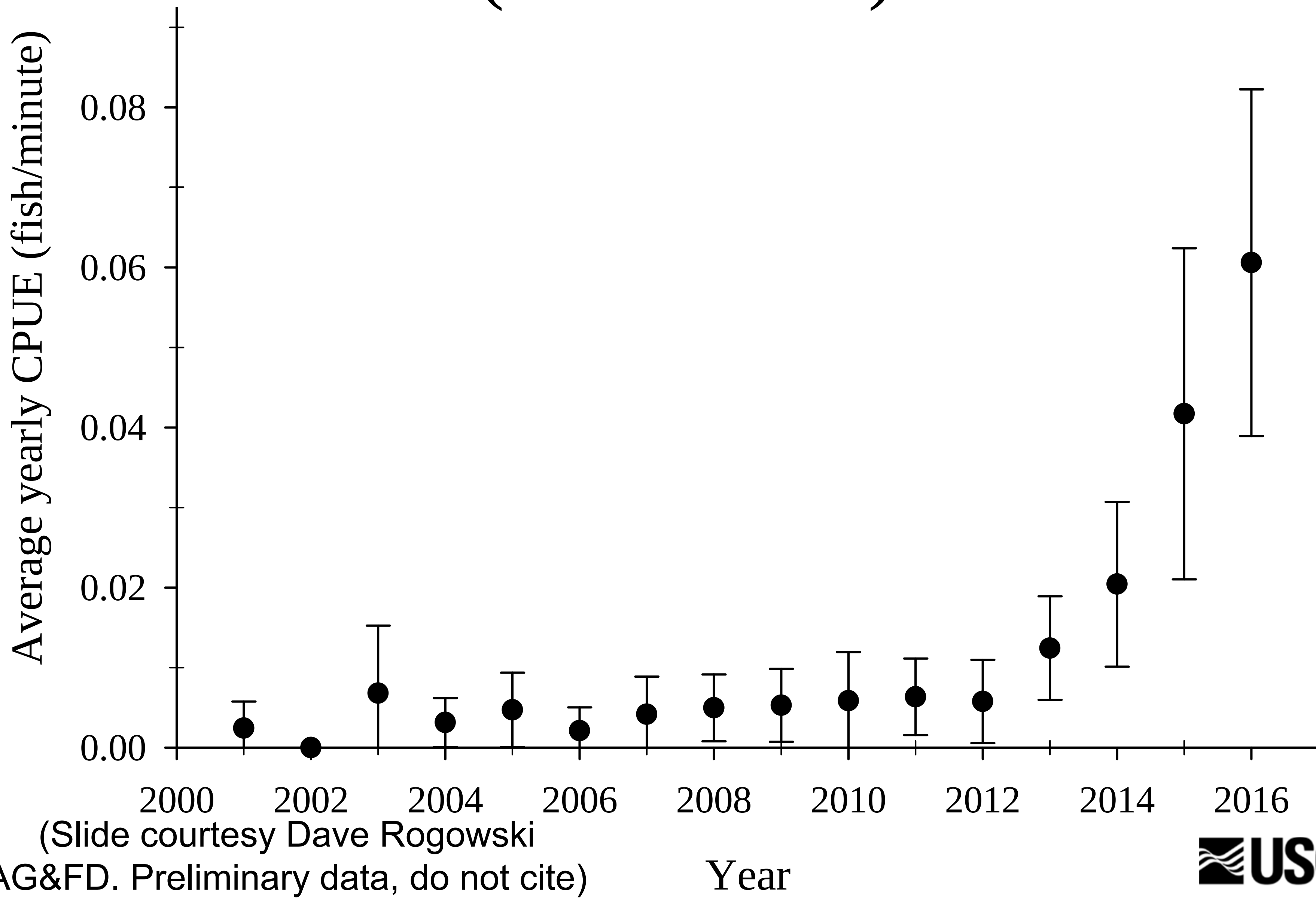






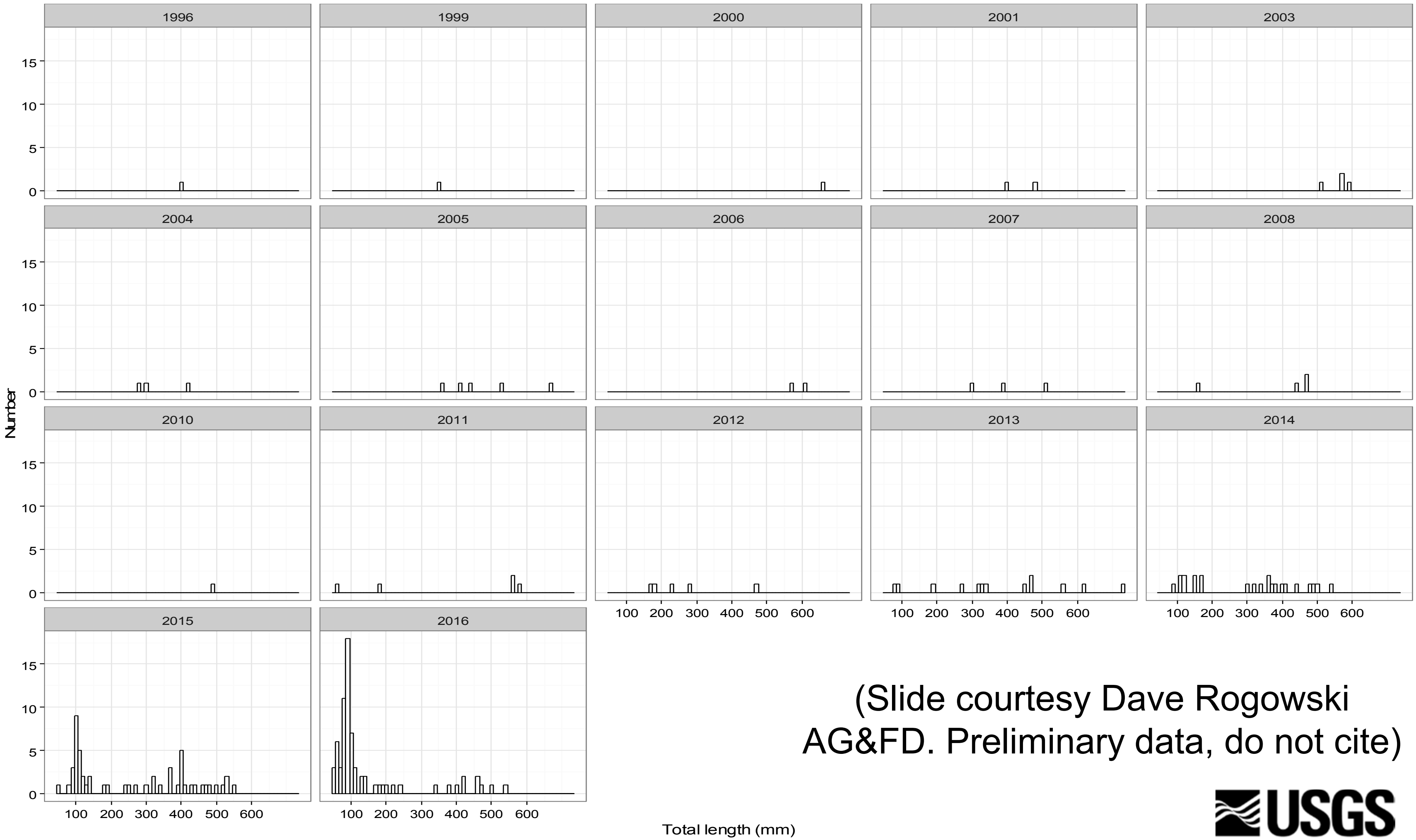
(Slide courtesy Brian Healy NPS. Preliminary data, do not cite)

Brown Trout average electrofishing CPUE (fish/minute)



(Slide courtesy Dave Rogowski
AG&FD. Preliminary data, do not cite)

Brown Trout in Glen Canyon: length frequency histograms



(Slide courtesy Dave Rogowski AG&FD. Preliminary data, do not cite)

USGS

Brown Trout Expert Elicitation Surveys

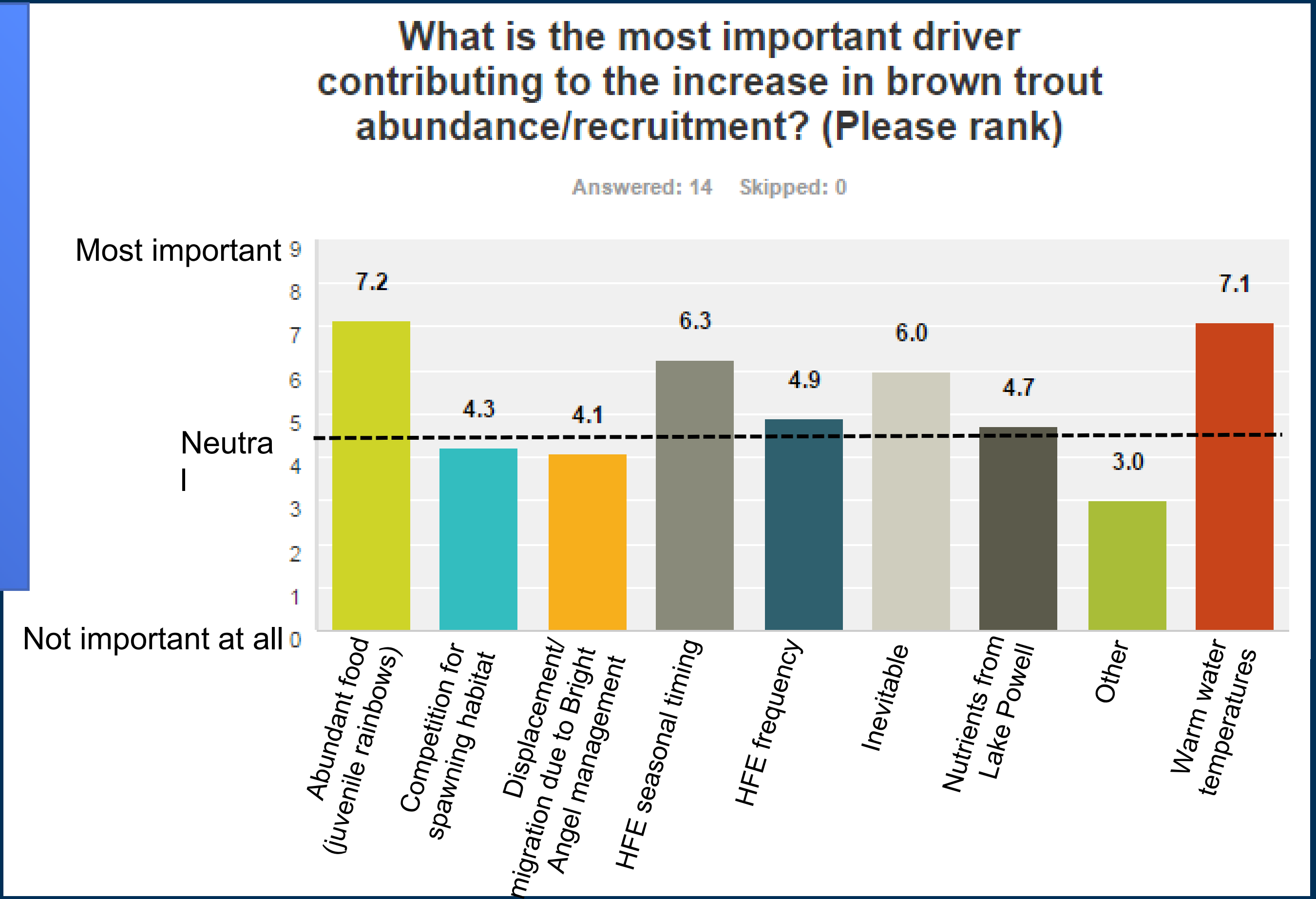
- Why a survey?
- Lots of talk about brown trout
- Little data so look to expert opinion

- Identify broad patterns of consensus?
- Inform management priorities?

- Actually 2 surveys:
  - Initial questions, then focused follow-up

USGS

Survey 1: How did brown trout become a problem? Many comments highlighting confluence of factors (warm water, fall HFEs, RBT numbers…). No consensus on single cause.



Representative comments:

- "I think the list of potential influences is a good one."
- "The only two plausible answers in my opinion are seasonal timing of HFEs and warm water temperatures."
- "It was inevitable (i.e., there is no root cause that we can target for mitigation) is more plausible than these other drivers in my opinion."
- "There is no one important driver, it is a combination of factors that has resulted in an increased recruitment of Brown Trout."

USGS

Unpublished data, subject to change, do not cite

Survey 2 summary

- Skepticism that mechanical removal will be effective, especially without flows.
- Consensus that some flows (alone or in combination) are best option.
- Any action needs study, planning, and goals.
- Need to be prepared for the long-term.

USGS

Acknowledgements

- Bureau of Reclamation and the Glen Canyon Dam Adaptive Management Program
- Arizona Game and Fish Department
- National Park Service
- US Fish and Wildlife Service
- Ecometric Inc.
- USGS-GCMRC


Questions?

2016 USFWS Biological Opinion

- **Tier 1 – Adult humpback chub in the Colorado River mainstem aggregation and Little Colorado River < 9,000 OR if recruitment of sub-adult humpback chub 150-199 mm does not equal or exceed estimated adult mortality.**
  - **Triggers conservation actions such as expansion of translocation actions in the Little Colorado River, head-starting larval chub to later translocate.**
- **Tier 2 – Adult humpback chub decline to < 7,000 fish and the prescribed conservation measures and remedial actions under each trigger do not mitigate a decline in the humpback chub population.**
  - **Triggers threat reduction in the form of mechanical nonnative predator removal. Ends if over two years predator index < equivalent of 60 RBT/km or HBC > 7,500 adults and sub-adult recruitment > adult mortality.**

USGS

2011 USFWS Biological Opinion Non-native Fish Control Trigger

- Adult humpback chub <7000 fish? **No**
- OR
- ALL THREE? **No**
  - 3 of 5 years 150-199 mm humpback chub in the LCR drops below 910? **Yes**
  - Temperature <12° C for 2 consecutive years at LCR? **No**
  - Annual survival of 40-99 mm humpback chub in JCM drops 25% from preceding year? **No**

USGS

2011 USFWS Biological Opinion Non-native Fish Control Trigger

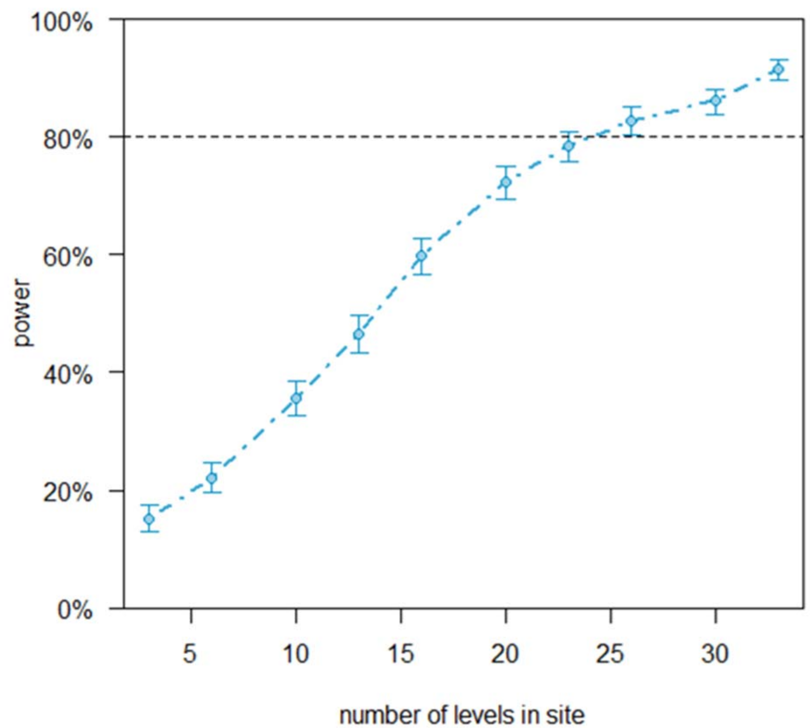
- AND
- Rainbow trout abundance over 760? **No**

  Open model estimates below threshold for all trips in 2016 (Korman and Yard, preliminary data)
- AND
- Brown trout abundance over 50? **Unknown**

  Only 1 caught in 2016 (four trips) – catch too low to generate abundance estimate (Yard and Korman, preliminary data)

USGS

Riparian Vegetation – Power Analysis



Example of how statistical power increases with increasing sample size. In this example, we need at least 25 sample sites per year to be 80% confident that we could detect a 10% change in frequency over 5 years.

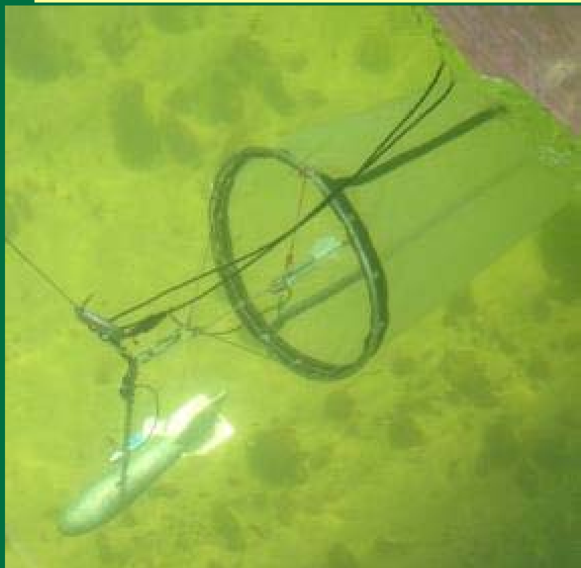
(Preliminary data from Palmquist 2016. Do Not Cite.)

- Statistically determining how many samples are needed to record vegetation change over time
- Over 5 years, we want to be able to reliably detect
  - 10% change in frequency for each functional group by river segment and hydrologic zone
  - 20% change in cover for each functional group by river segment and hydrologic zone
- We will have more power to detect change in species with intermediate frequencies/covers
  - Very rare species and ubiquitous species require special sampling to detect change

USGS

Monitoring the Aquatic Foodbase

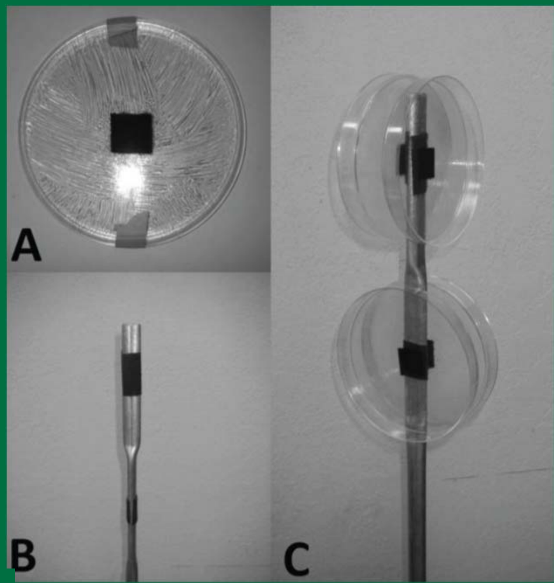
Invertebrate Drift



Plankton nets

Direct measure of prey availability for drift feeding fishes

Insect emergence



Sticky traps

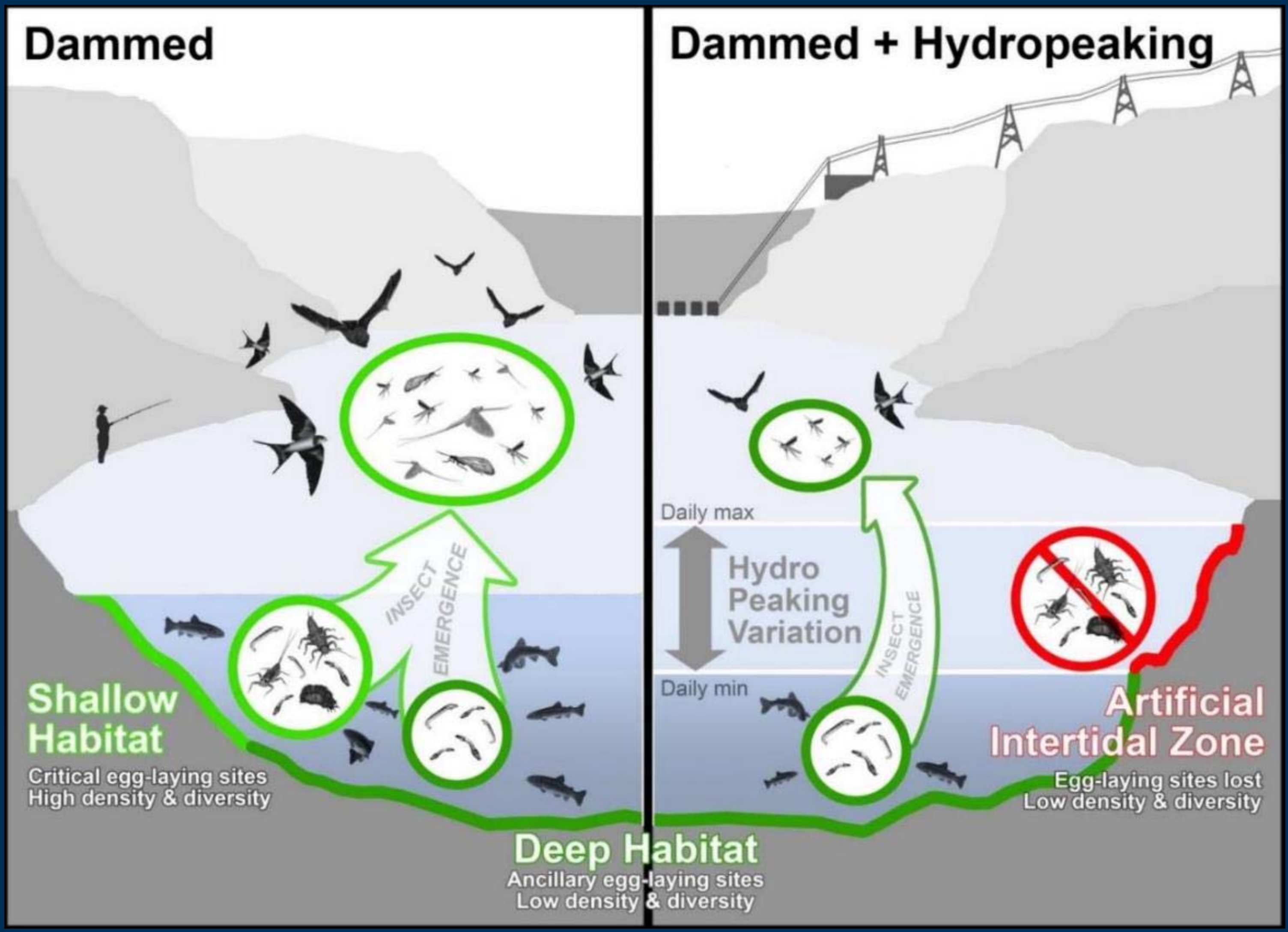
Citizen science

Captures adult aquatic insects, a key prey item for fishes

USGS

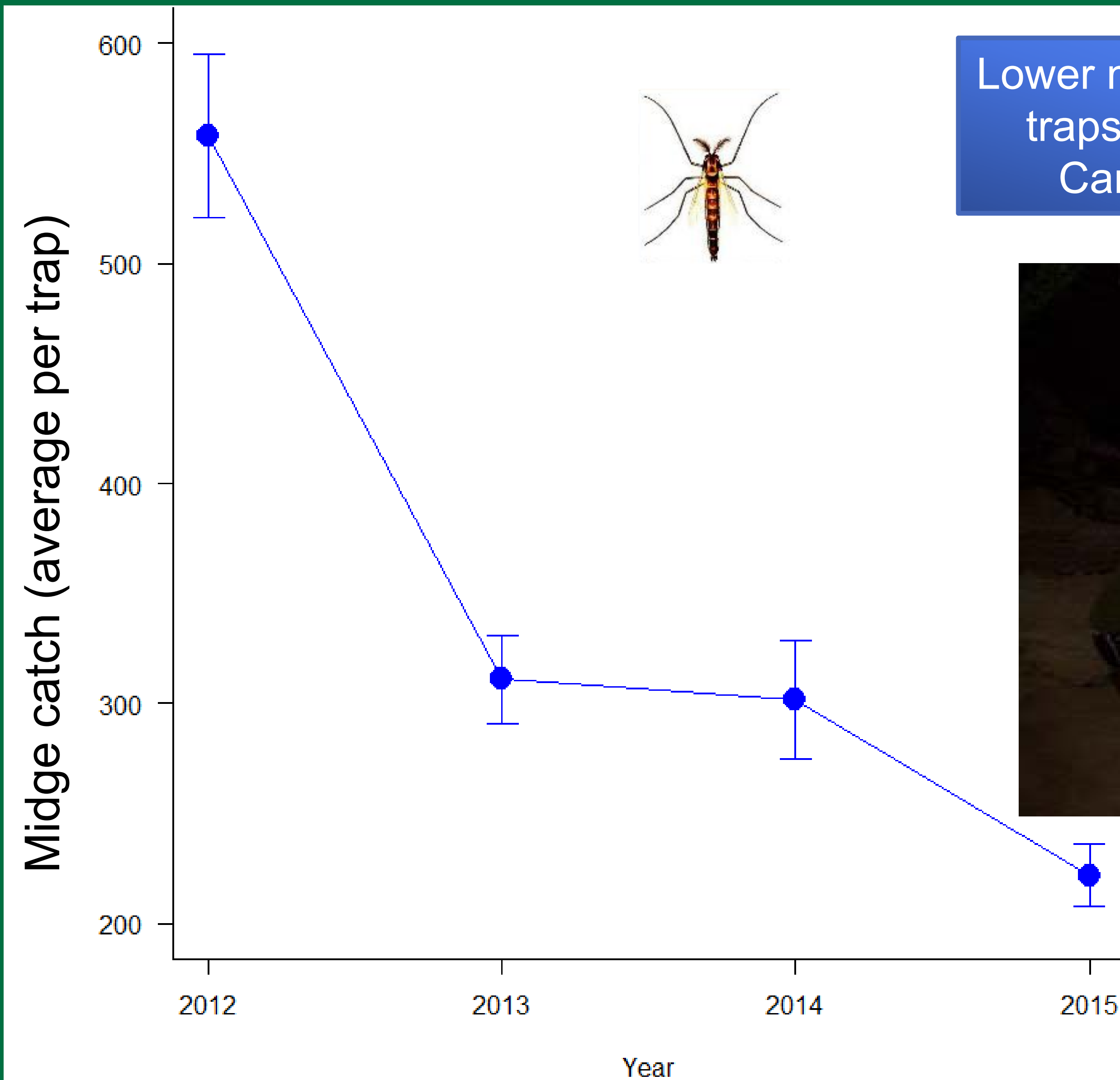
Unpublished data, subject to change, do not cite

Bug flows may enhance the food base



From Kennedy and others (2016) BioScience

Food Base in Grand Canyon



Lower midge catches in light traps throughout Grand Canyon since 2013.

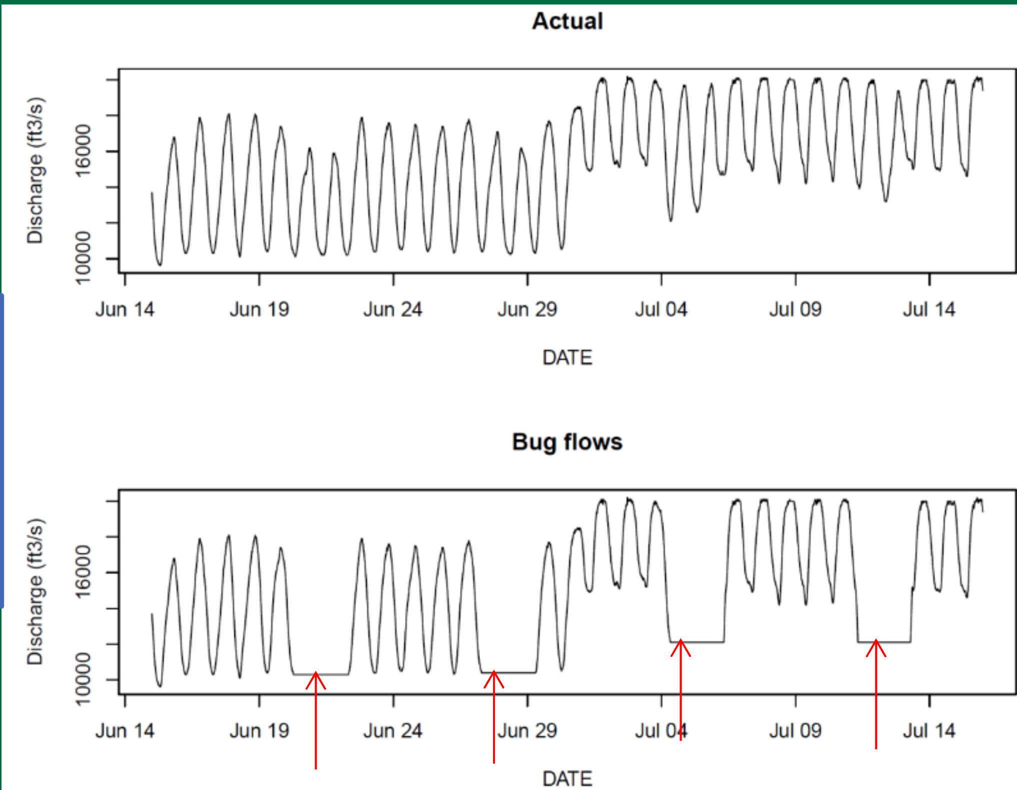
Unpublished data, subject to change, do not cite

USGS

Give bugs the weekend off!!

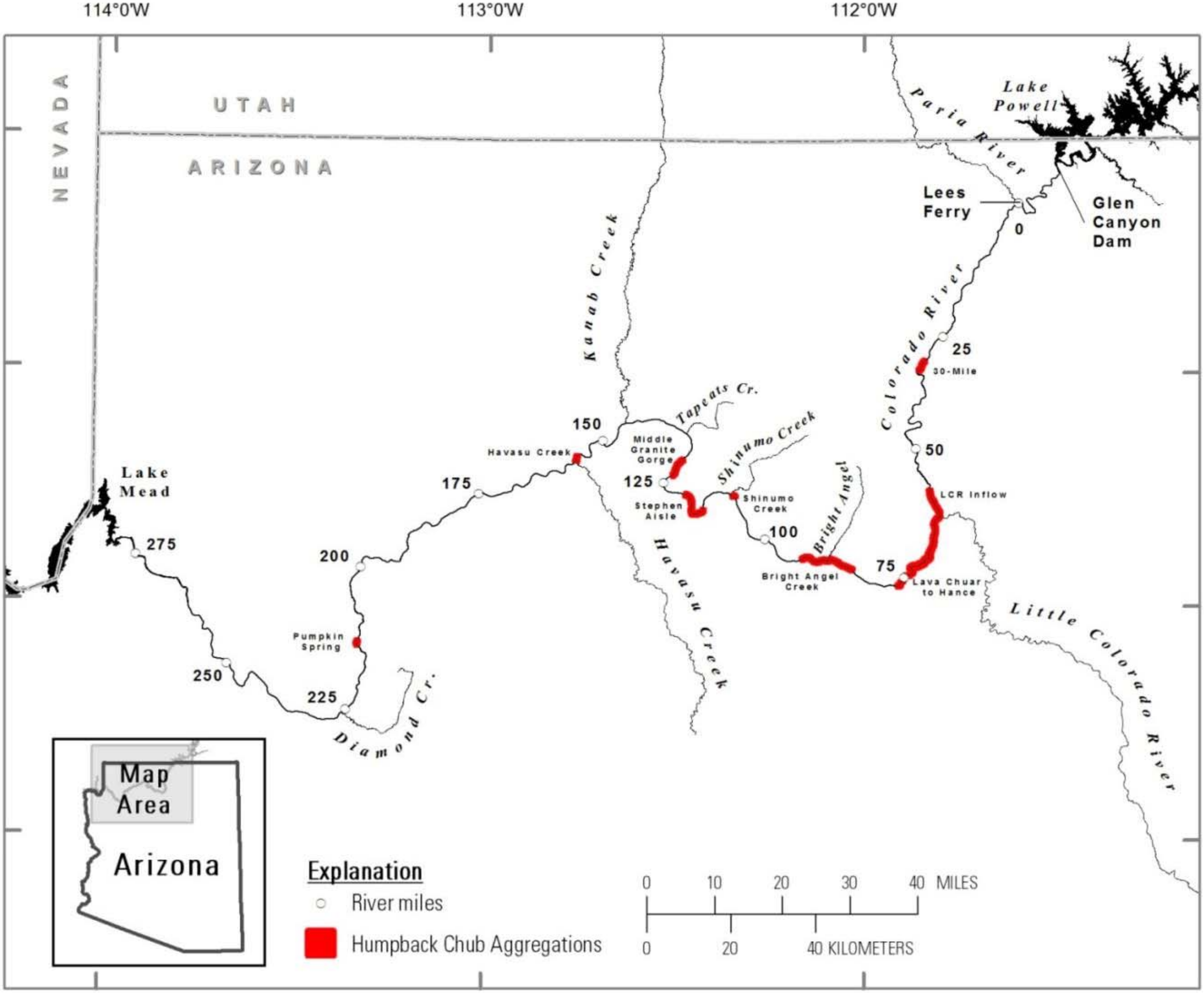
- Steady/low flows weekends May-Aug (36-38d/yr)
- Periodically create ideal egg-laying conditions

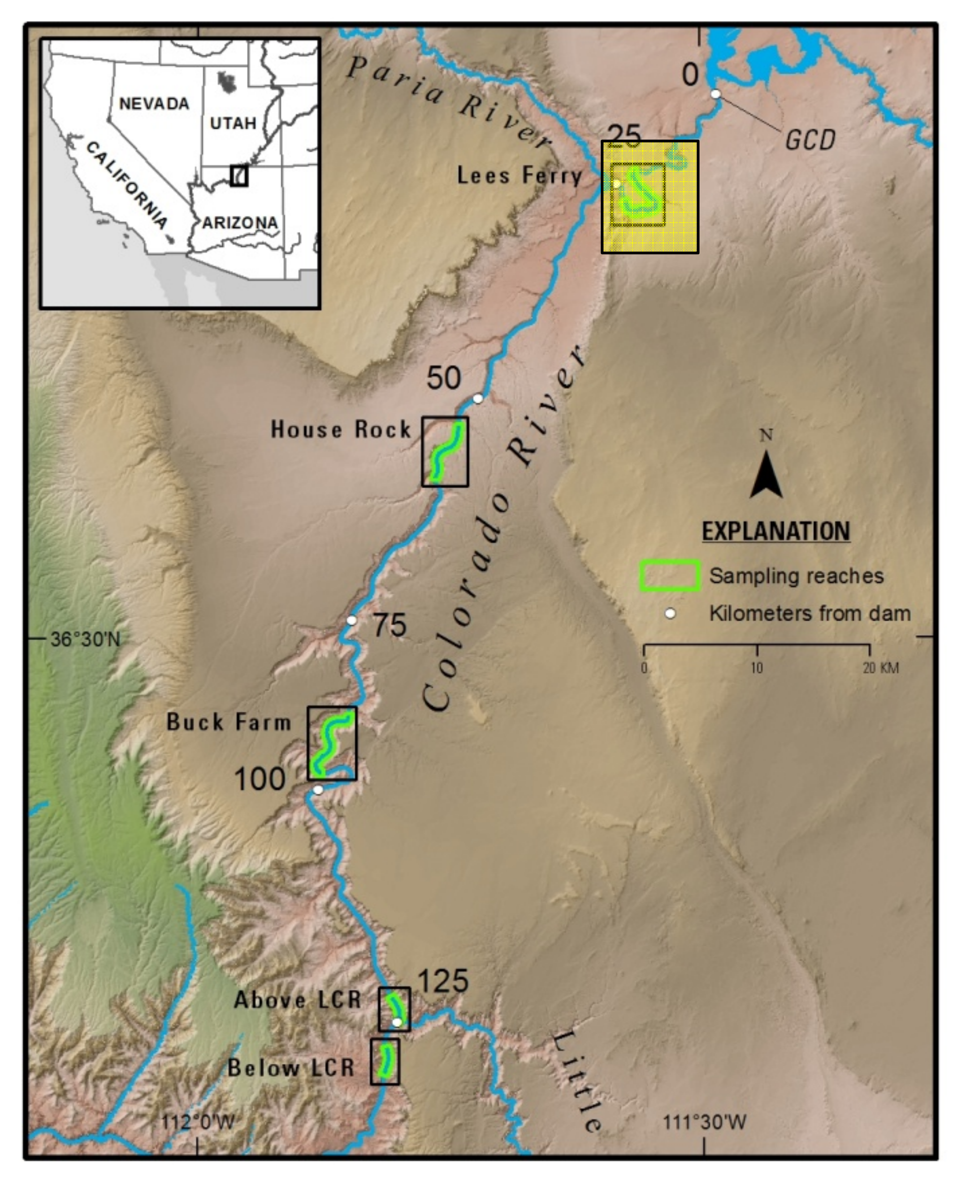
Timing of midge egg laying and spatial distribution supports rationale for testing bug flows.



Eggs laid here will never be desiccated

USGS


114°0'W
113°0'W
112°0'W
37°0'N
36°30'N
36°0'N
35°30'N
NEVADA
UTAH
ARIZONA
Lake Powell
Paria River
Lees Ferry
0
Glen Canyon Dam
Colorado River
25
30-Mile
50
LCR Inflow
75
Lava Chuar to Hance
Little Colorado River
Bright Angel
Bright Angel Creek
100
Shinumo Creek
Shinumo Creek
Tapeats Cr.
Middle Granite Gorge
125
Stephen Aisle
Kanab Creek
150
Havasu Creek
Havasu Creek
175
200
Pumpkin Spring
Diamond Cr.
225
250
275
Lake Mead
Map Area
Arizona
Explanation
River miles
Humpback Chub Aggregations
0 10 20 30 40 MILES
0 20 40 KILOMETERS



USGS

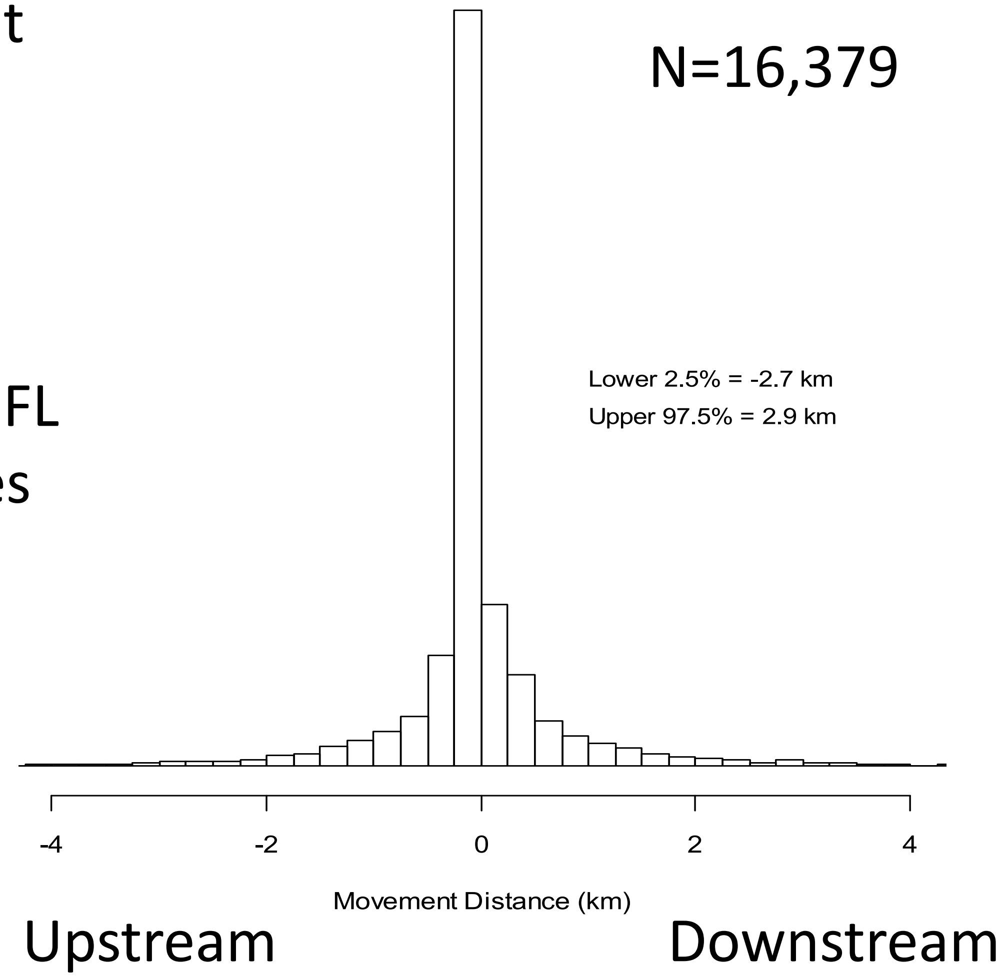
Rainbow Trout Natal Origins Study Sampling Design

- **Annual age-0 marking trips from dam to Lees Ferry**
  - **Length >75 mm**
  - **~ 10,000 marked/yr**
  - **Nov. 2011, Oct & Dec 2012, 2013, and 2014**

- **Quarterly trips for marking and tag recovery by reach**
  - **Jan, Apr, Jul, and Sept**
  - **LEES FERRY (I, -5.5 to -2.1 RM)**
  - **HOUSE ROCK (II, 17.2-20.6 RM)**
  - **BUCK FARM (III, 38.2 to 41.6 RM)**
  - **ABOVE LCR (IVa, 60.2 to 61.2 RM)**
  - **BELOW LCR (IVb, 63.4 to 64.9 RM)**

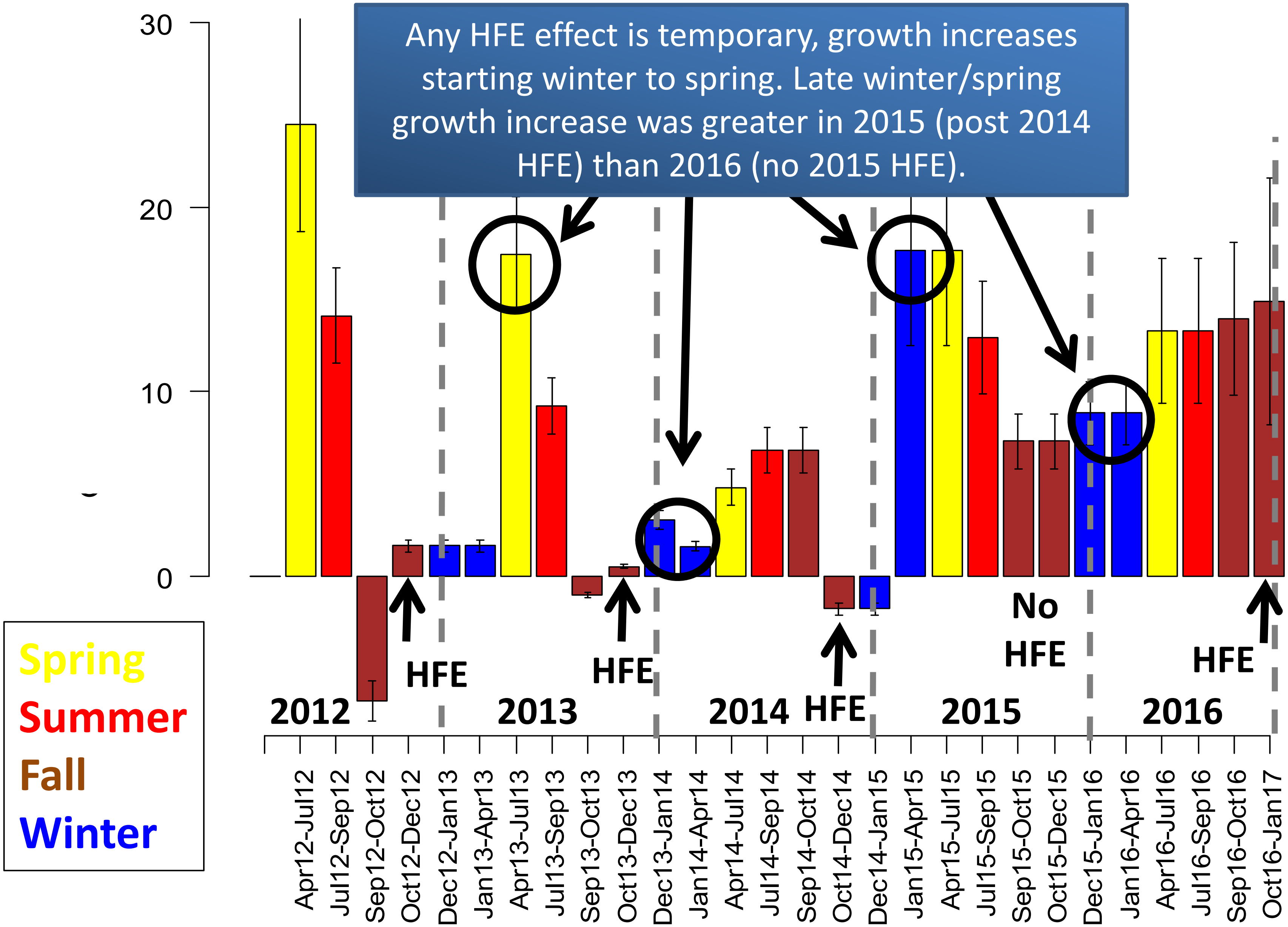
Movement Based on Tag Recoveries

- Majority of rainbow trout exhibit limited movement based on differences between release and recapture locations.
- Taggable size is ≥ 75 mm FL
  - Moderate to large sizes
- 95% of recaps moved no more than
  - -2.7 km upstream
  - 2.9 km downstream



Korman et al. 2016 & and
Yard and Korman, preliminary
data, do not cite

Effect of Fall HFEs on Rainbow Trout Growth in Glen Canyon



USGS

(Preliminary data from Korman and Yard 2017. Do Not Cite.)

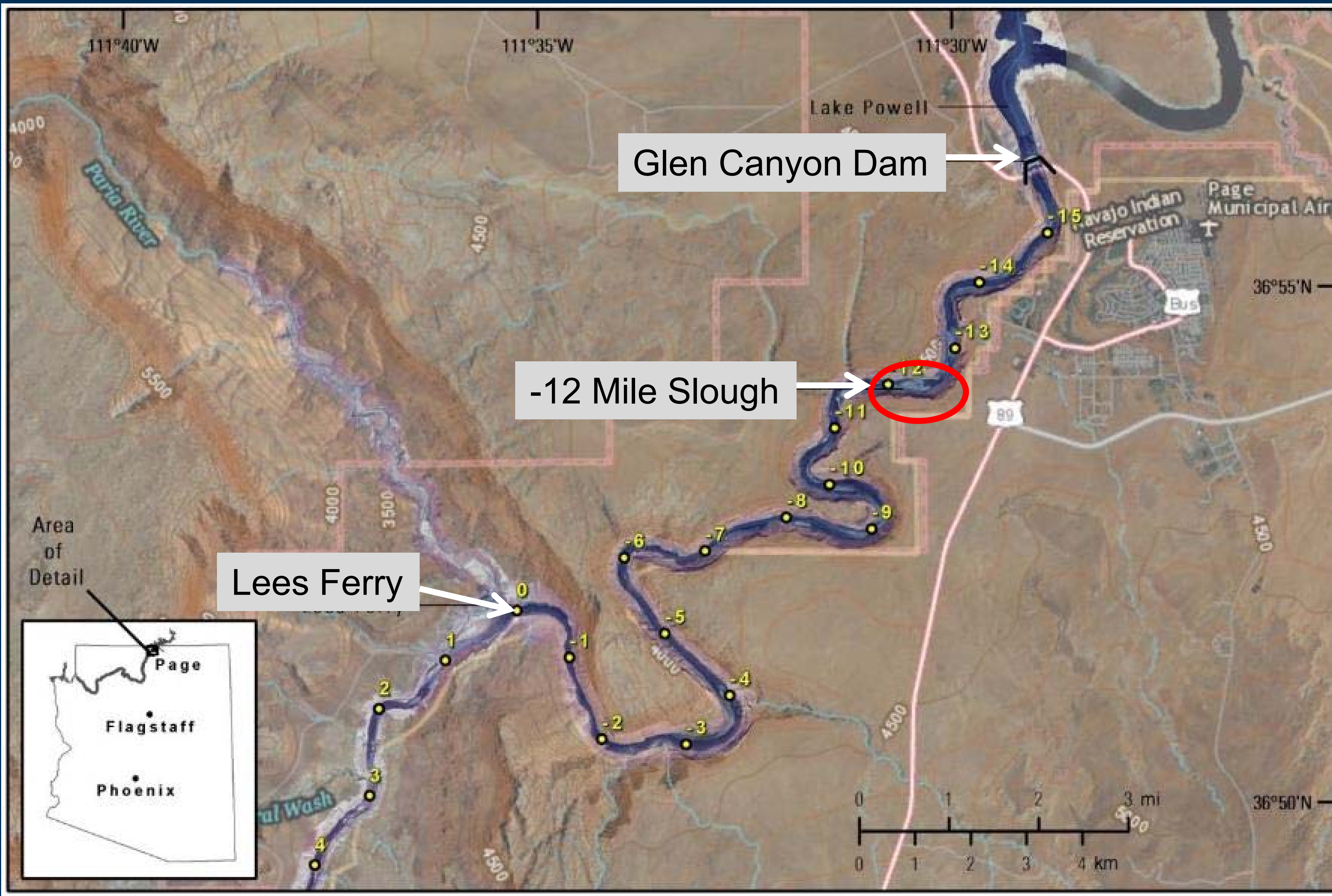
Green Sunfish in Glen Canyon (Again)




USGS

Photos courtesy Lisa Winters, AG&FD

Green Sunfish in Glen Canyon



USGS

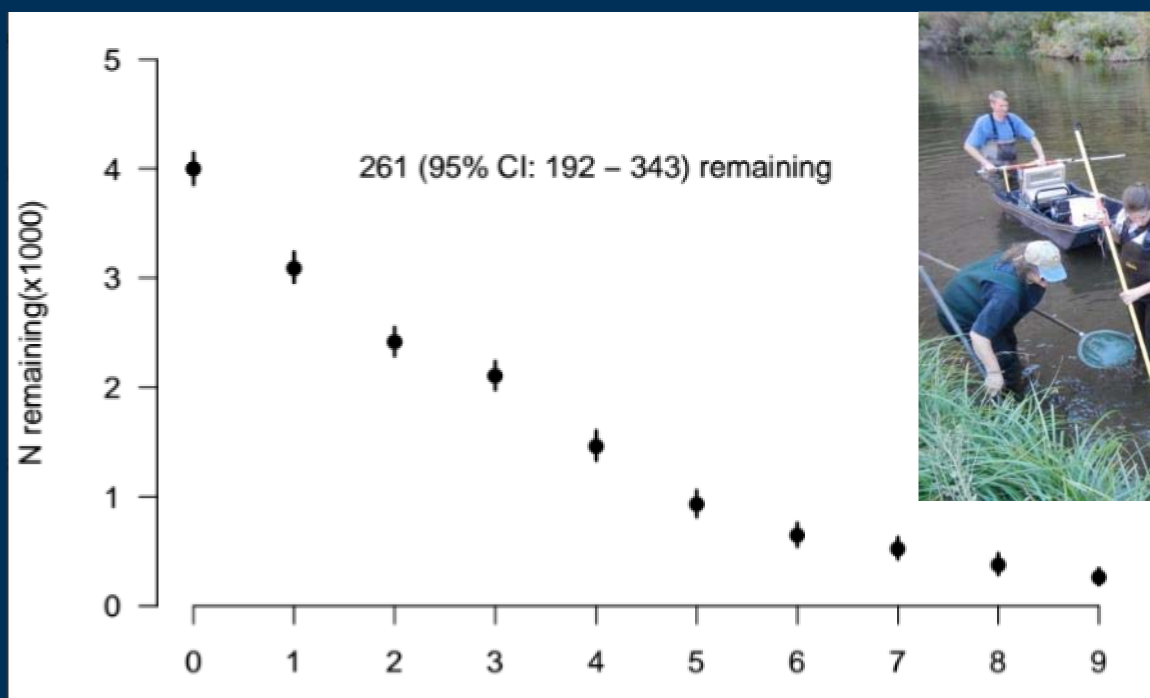
Green Sunfish in Glen Canyon

Almost all green sunfish collected in 2016 found in this pond

USGS

2016 Green Sunfish Rapid Response

- Two detection trips in July 2016 = no GSF
- August 2016 – GSF detected
- 10 removal trips from August – October captured and removed over 4600 GSF
  - Trips conducted by GCMRC, AGFD, and NPS



Preliminary results provided by Charles Yackulic (GCMRC)

2016 Green Sunfish Rapid Response

- **GSF numbers reduced by mechanical removal but could not be eliminated**
  - **GSF removed by mechanical means were provided to the Tribes for beneficial use**
- **NPS received a permit from ADEQ to apply ammonia as an experimental piscicide**

Experimental Ammonia Treatment

- Noon Oct 20, 20 gal ammonium hydroxide 2
- Dying fish 90 min
- Ammonia 8+ ppm
- Sentinel fish all dead next morning
- A few live fish along bank where some inflow
- Treated with one more gallon
- Next week electrofishing survey, no fish
- Slight levels of ammonia in first 3 yards of lower slough, no dead fish
- HFE Nov 7 to 12 (96 hours at 36,000 cfs)
- Success