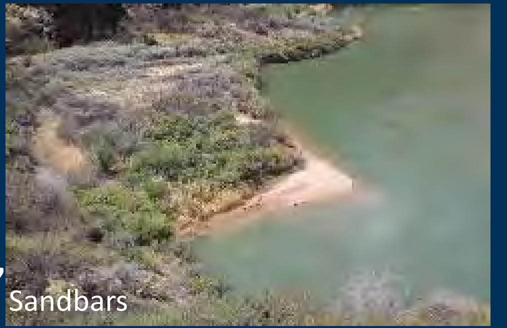
Spring Disturbance Flow Update 2022 Annual Reporting Meeting

Ted Kennedy[1], Bridget Deemer[1], Dave Lytle[2], Paul Grams[1], Joel Sankey[1], Brad Butterfield[3], Kim Dibble[1], Bob Tusso[1], Lucas Bair[1]

1-US Geological Survey, Southwest Biological Science Center-Grand Canyon Monitoring and Research Center, 2-Oregon State University, 3-Northern Arizona University



USGS science for a changing world

NORTHERN ARIZONA UNIVERSITY

OUTLINE

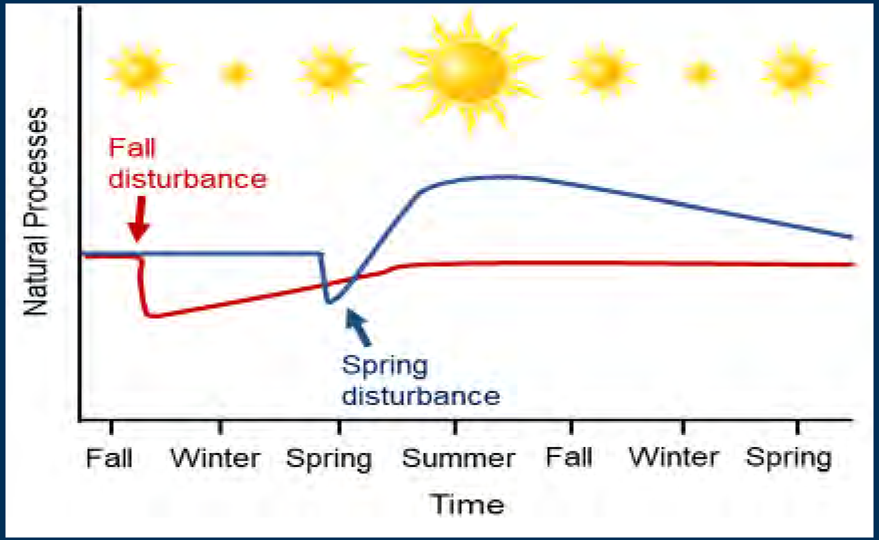
- Introduction-me (4 slides)
- Nutrients-Deemer (11 slides)
- Invertebrates-Lytle (5 slides)
- Sediment-Grams (13 slides)
- Aeolian-Sankey (11 slides)
- Terrestrial Vegetation-Butterfield (9 slides)
- Aquatic Vegetation-Dibble (8 slides)
- Trout-Dibble (9 slides)
- Angling surveys-Bair (6 slides)
- Sandbars-Tusso (11 slides)
- Wrap up and next steps (4 slides)

Problem Statement

- Disturbance is essential natural process in rivers
  - maintains biological diversity
  - native species life cycles often tuned to disturbance
  - high flows only tool for rebuilding sandbars
- Disturbance was historically most common in spring/early summer

Lees Ferry

Natural Flows-1937



Conceptual Model

Preliminary results subject to review and revision

Problem Statement

- HFE Protocol favors fall HFEs
  - Good for sandbars
  - But role of spring HFE in achieving LTEMP goals remains unclear
- Most recent spring HFE was 2008
  - Many biology projects didn't exist in 2008

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
2020	2021	2022	2023	2024	2025	2026	2027	2028	2029

LEGEND

Spring HFE

Spring Disturbance Flow

Fall HFE

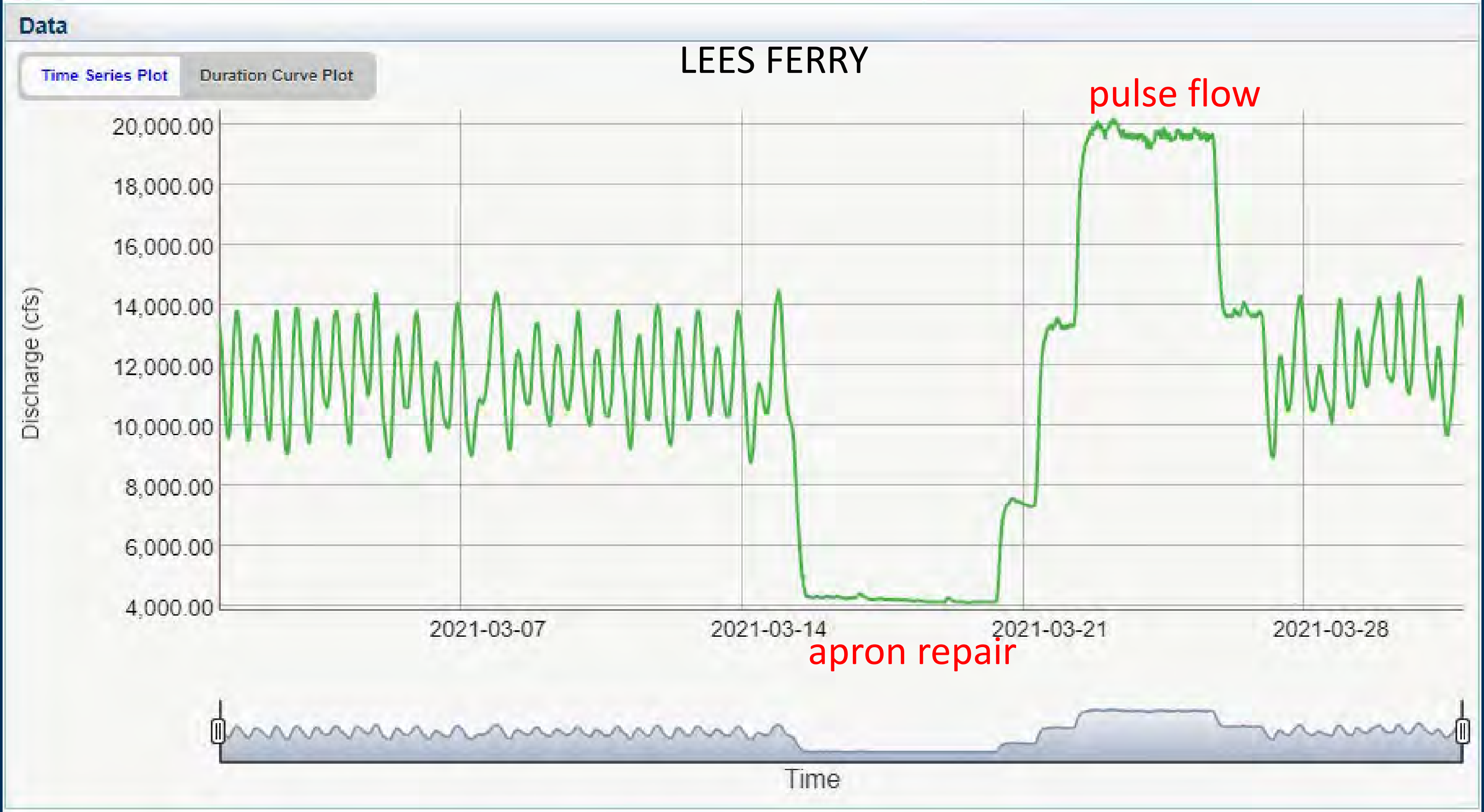
Sediment trigger, but no fall HFE

Preliminary results
subject to review and revision

March 2021-Spring Disturbance Flow

- Apron repair is unique opportunity
  - 5 days of 4,000 cfs needed for dam maintenance
  - low flow = disturbance
- Combine with pulse flow
  - potential synergistic effect
  - low + pulse >>

  low or pulse alone



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

Nutrient Dynamics During the Spring Disturbance Flow

GCDAMP Annual Reporting Meeting

January 12, 2022

Bridget Deemer- bdeemer@usgs.gov

People

Ted Kennedy- funding support from Project O
Bob Hall & Adam Baumann- laboratory analysis
Freshwaters Illustrated- photography
Ann-Marie Bringhurst & Clay Nelson- logistics

Tom Sabol

Charles Yackulic

Hypothesis

- A high flow immediately following a low flow will result in a large pulse of nutrients to the water column.
- Three mechanisms:
  - elevated sediment nutrient mineralization in dessicated zone
  - scouring of benthic algae and associated macroinvertebrates
  - elevated suspended sediment and associated nutrients

Methods

Two Sites:

Glen Canyon (RM -2)

Grand Canyon (RM 225)

Three sediment subsites:

Temporarily exposed (mainstem)

Temporarily exposed (backwater)

Temporarily inundated

5 time points:

pre-experiment

day 2 low

day 5 low

high water

return to base

March 16, 2021- Low Flow- Glen Canyon

March 22, 2021- High Flow- Glen Canyon

March 21, 2021- Low Flow- Grand Canyon

March 24, 2021- High Flow

Sampling Design

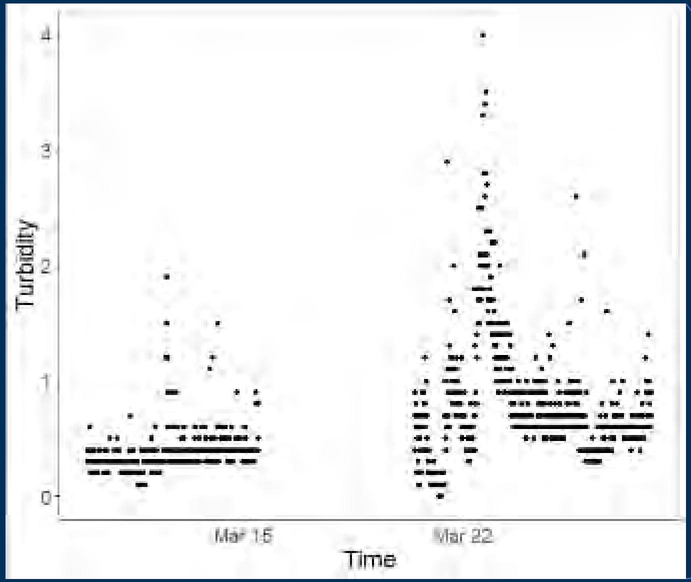
Triplicate water sampling

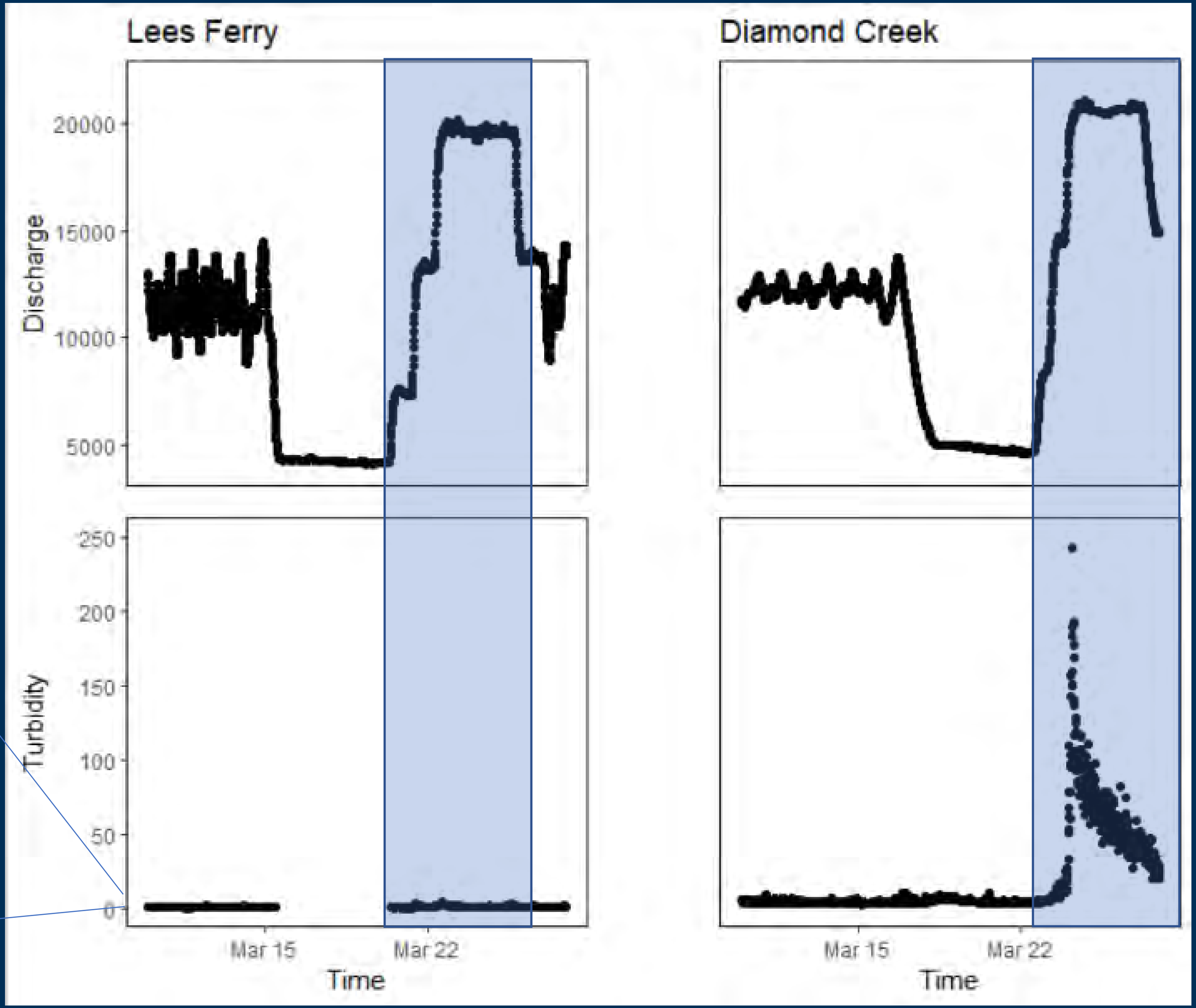
Rhizon porewater samples

Sediment Cores

Results: Turbidity

Increased turbidity during high flow

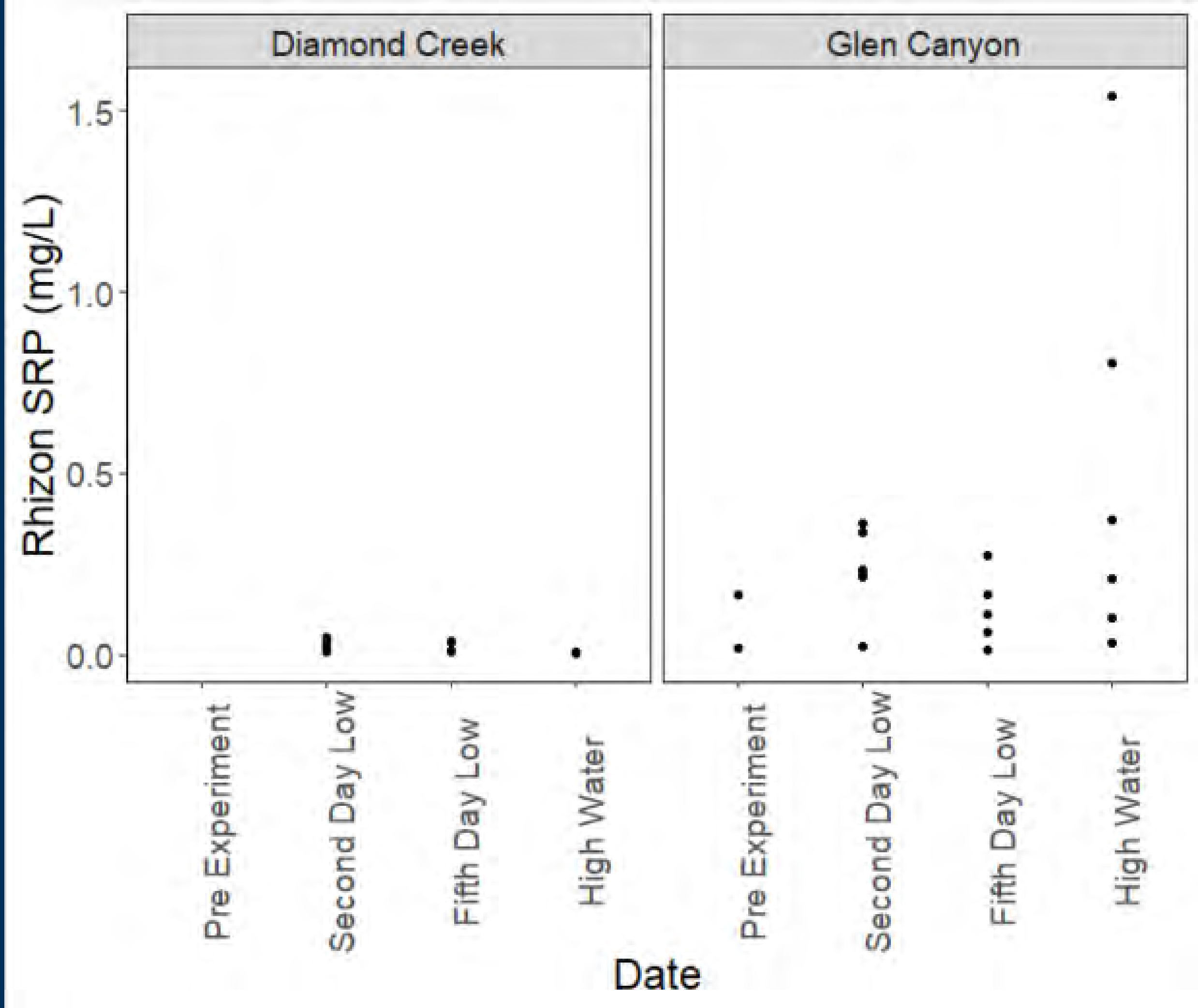




Preliminary results
subject to review and revision

Results: Porewater

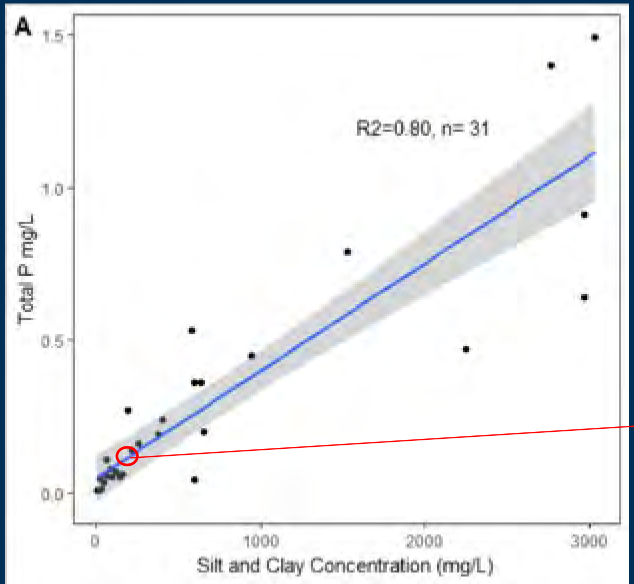
No evidence for mineralization in sediment porewater matrix (so far)



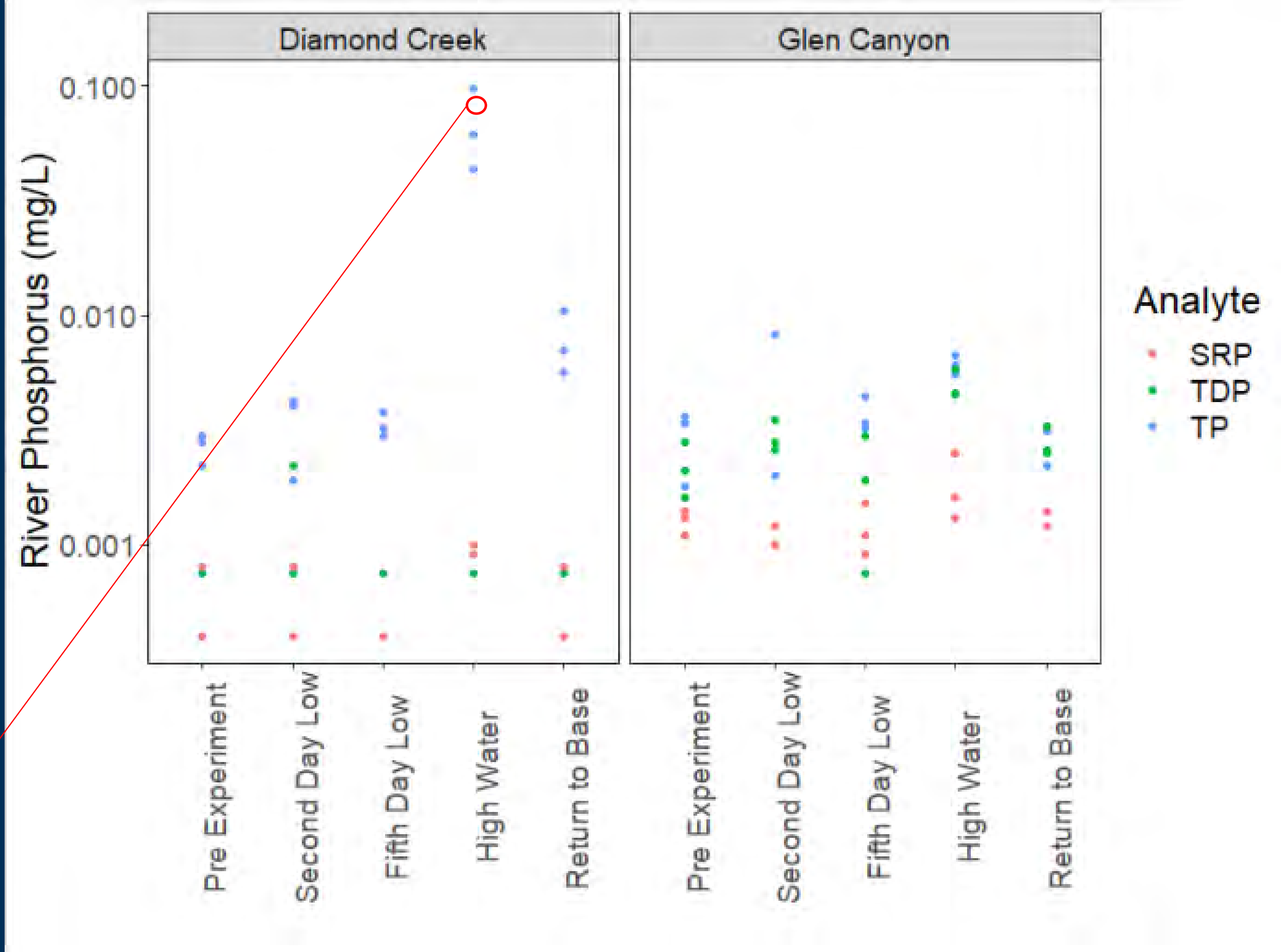
Preliminary results
subject to review and revision

Results: River Chemistry

Huge bump in total phosphorus at Diamond Creek can be explained by silt and clay concentrations



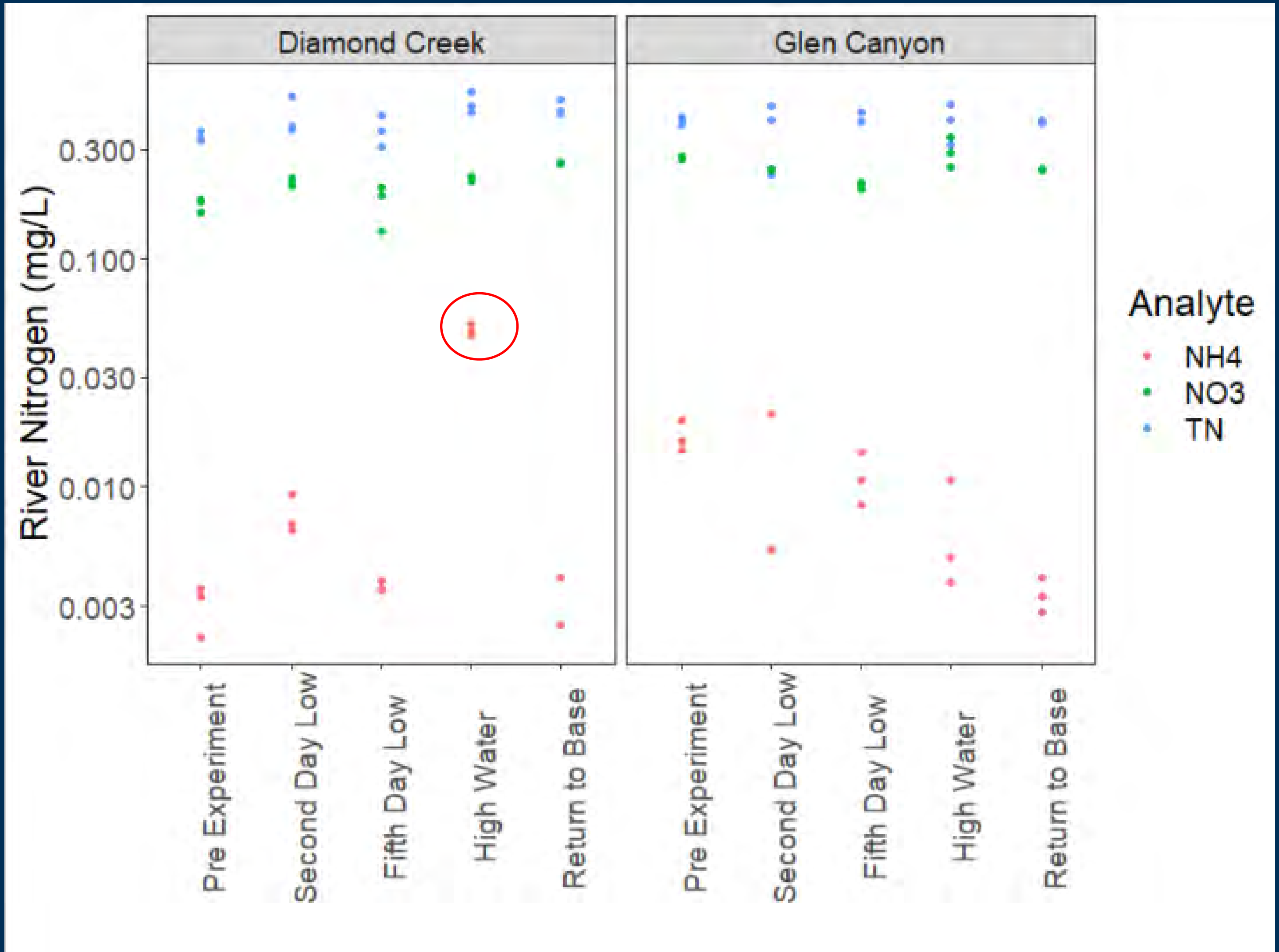
0.08 TP
@ 100
mg/L Fines



Preliminary results
subject to review and revision

Results: River Chemistry

Elevated ammonium levels in the river suggest that in-stream mineralization is releasing nutrients



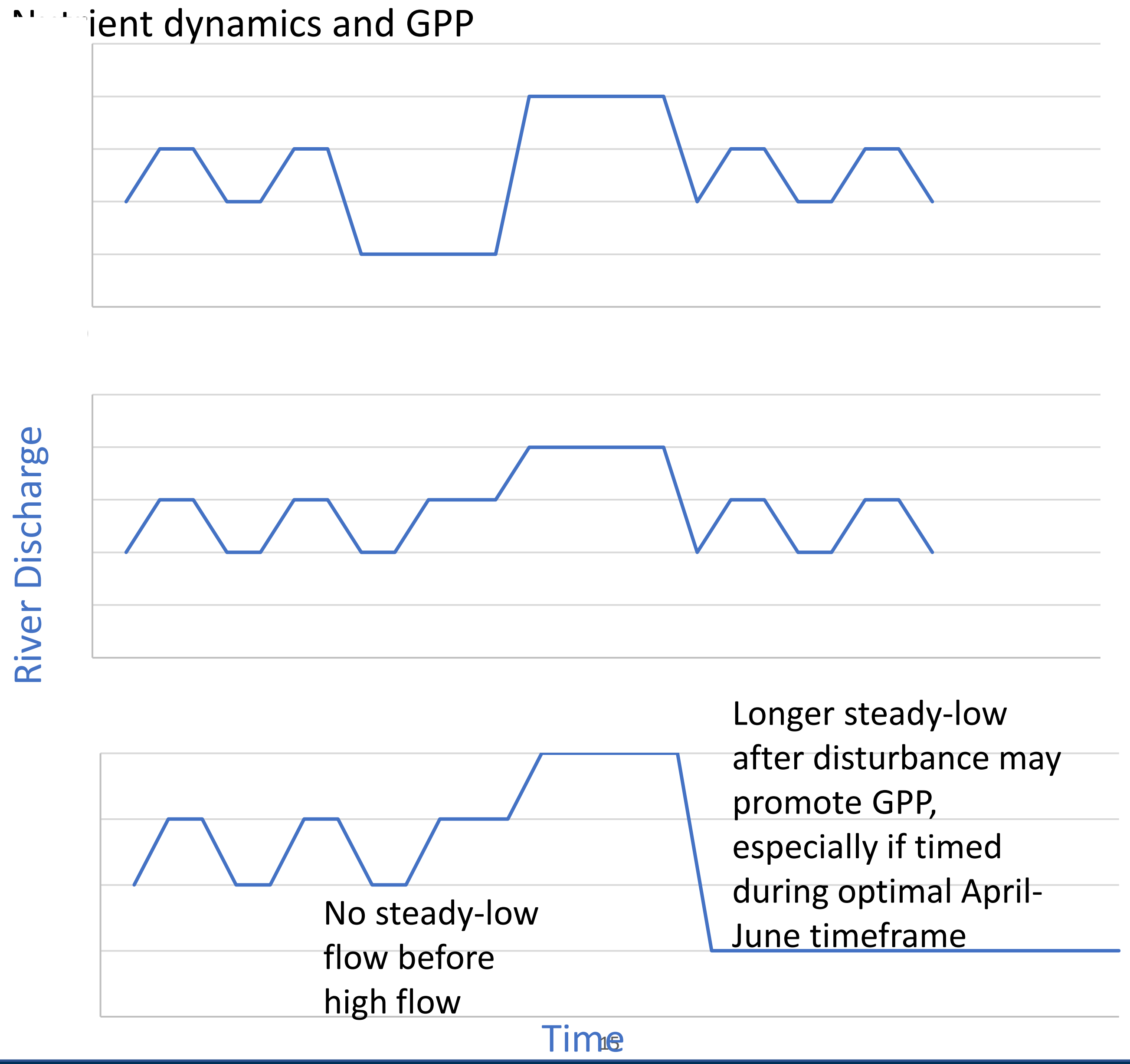
Preliminary results
subject to review and revision

Hypotheses Regarding Future Disturbance Flows

2021 Spring disturbance flow

Similar disturbance effect. Results thus far suggest similar nutrient mobilization would occur even without the 4000 cfs steady-low

Best disturbance flow for nutrients/gpp could be a high flow followed by a longer steady-low flow



Preliminary results subject to review and revision

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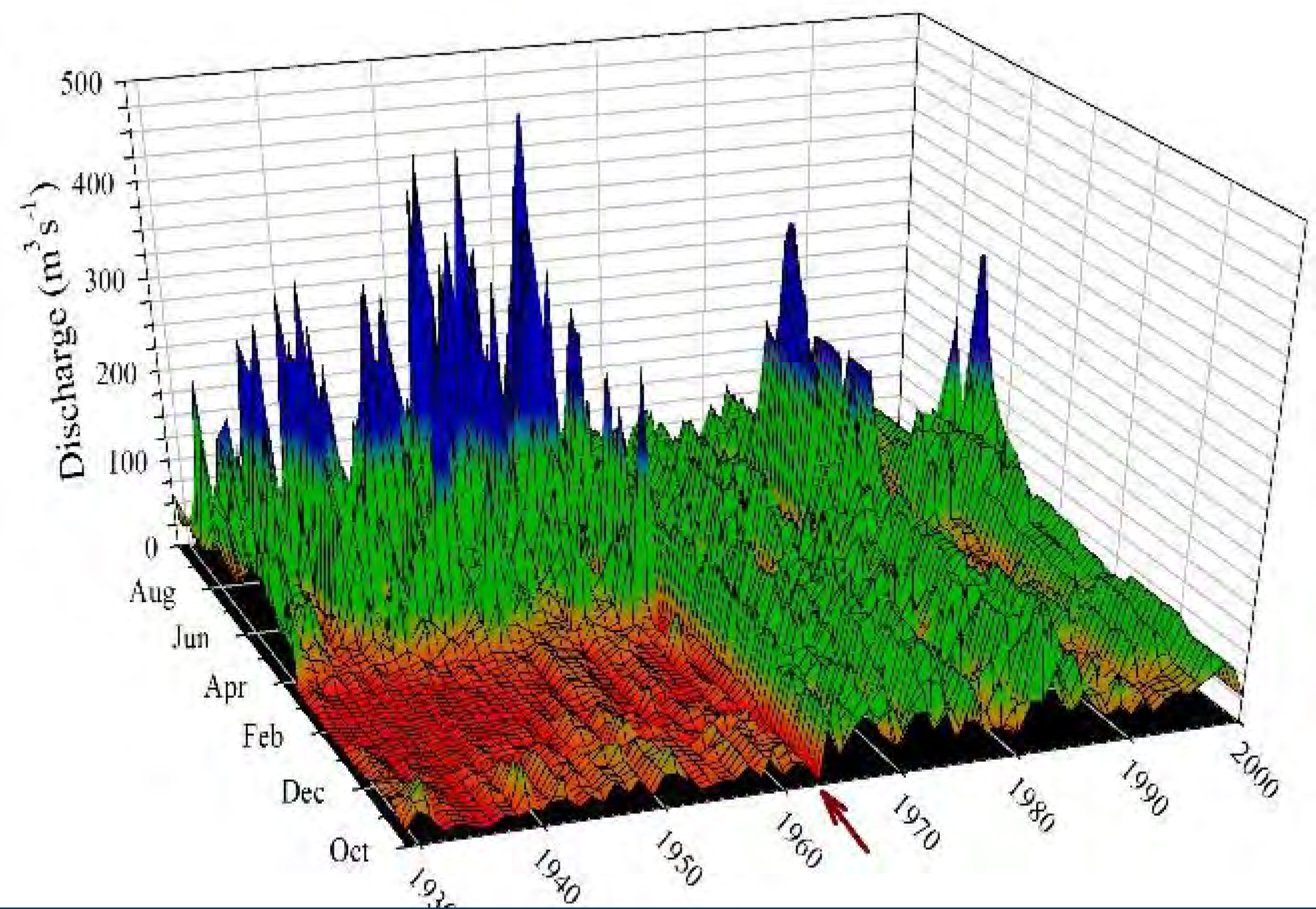
Aquatic invertebrate community models - low flow parameters

David A. Lytle and Angelika Kurthen
Oregon State University

Goals:

- Develop population models for Grand Canyon food base species (amphipods, NZMS, midges, blackfies, mayflies, etc.)
- Link population dynamics to flow event types (high, **low**, hydropeaking) and environmental conditions (seasonal temperatures, food availability)



Green River, Utah. Low flow events and spring floods were once a major characteristic of the Colorado River ecosystem (Lytle & Poff, *Trends in Ecol. & Evol.*)

Natural flow regime paradigm:

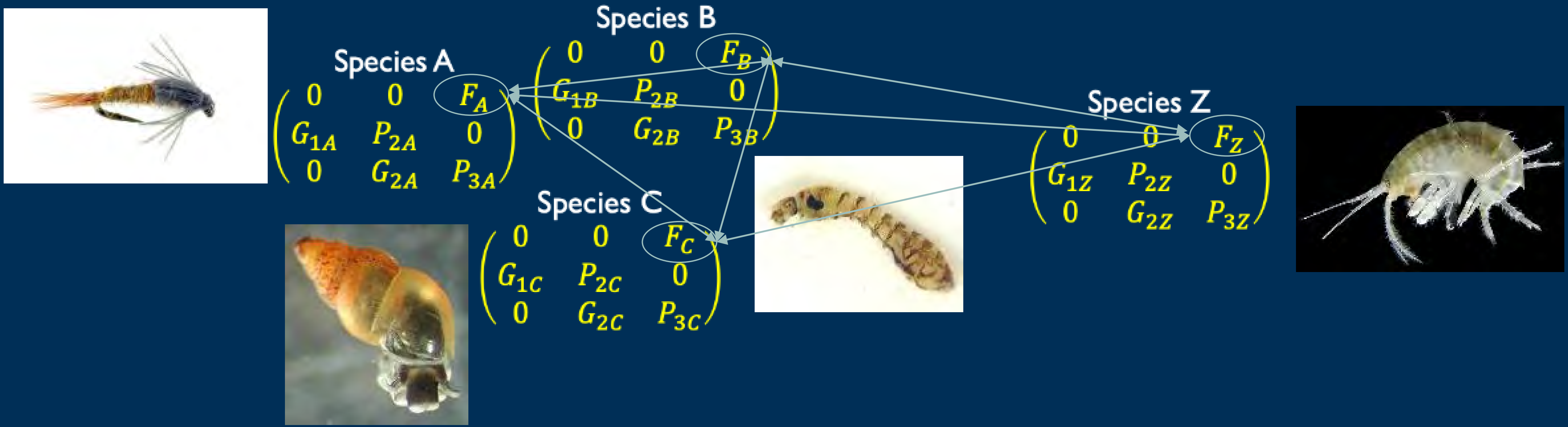
Organisms evolved in the context of seasonal floods and low flows

Spring floods and fall low flow events nearly absent from system for 50+ years

Question: what role do flow events play in supporting food base species? (blackflies, chironomid midges, mayflies, caddisflies; also *Gammarus*, NZ mudsnails, quagga mussels)

Population models for food base communities

1. Construct matrix population models for each relevant species



2. Parameterize with vital rates according to major event types: mortality and growth rates in response to floods, low flows, hydropeaking, etc.

3. Use model to ask “what if” questions about future flow scenarios

Quagga Mussels in exposed algal mats at RM -14

March 2021 Low flow sampling

Goal: Estimate **maximum loss rate** (LR_{max})of individuals due to stranding

Paired Design: Sample stranded and still-submerged cobble beds

Three locations:

RM -14 (Below Glen Canyon dam), n=10

RM -3.5 (Above Lees Ferry), n=20

RM 226 (Diamond Creek), n=10

Methods:

1. Benthic core sampler
2. Sediments and algal mats removed and washed 3x by hand
3. Sediments collected to 5 cm deep, elutriated 10x
4. Preserved in 95% ethanol in field
5. Physiochemical data: Temp, pH, substrate (Wolman walk), dissolved O_2

Expected outcomes

Samples: In process (URSA Engage student Connor Eck), will finish by mid-May.

Dominant taxa:

RM -14 and RM -3.5: Mostly quagga, NZMS, *Gammarus*

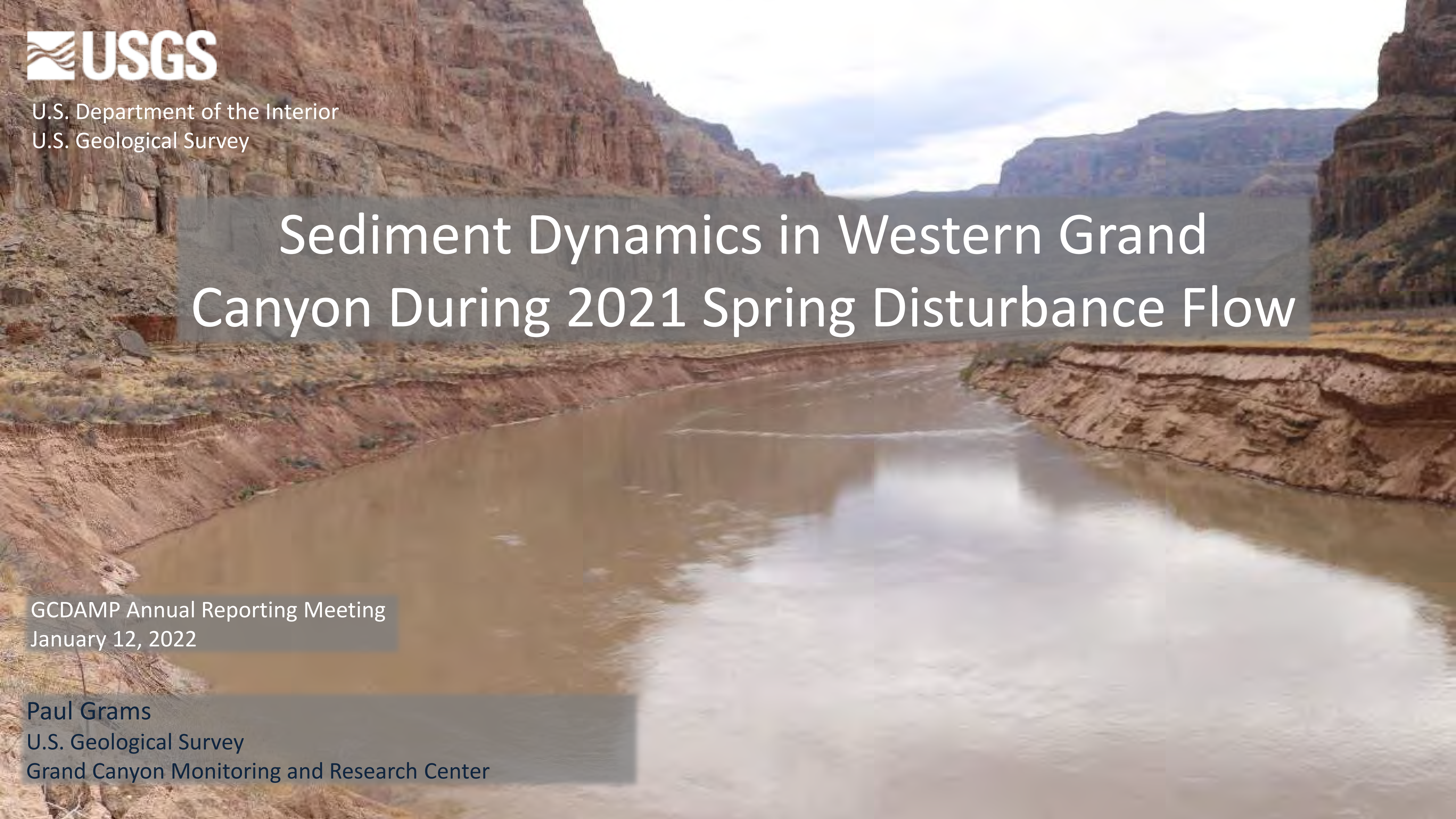
RM 226: caddisflies (*Hydropsyche*)

Hypotheses:

- Higher LR_{max} for *Gammarus*, quagga, caddisflies
- Likely an overestimate for NZMS (operculum)

Next steps:

- Add parameters to population models
- In a future low flow experiment, measure actual loss rates over time



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Sediment Dynamics in Western Grand Canyon During 2021 Spring Disturbance Flow

GCDAMP Annual Reporting Meeting
January 12, 2022

Paul Grams
U.S. Geological Survey
Grand Canyon Monitoring and Research Center

Acknowledgements

Project O.2 personnel:

Matt Kaplinski, Katie Chapman, and Vincent Diaz
Northern Arizona University

Paul Grams, Keith Kohl, and Robert Tusso
U.S. Geological Survey
Grand Canyon Monitoring and Research Center

Corey Sannes
U.S. Geological Survey
Arizona Water Science Center

Project O.2 in the Columbine Study Reach in Western Grand Canyon

- Objective: Understand and quantify relation between changes in bed configuration in Western Grand Canyon and dam releases. *Do certain dam operations reduce, exacerbate or mitigate sediment accumulation in this reach?*
- Measurements conducted during 2021 pulse flow: Mapping of bed and banks in 2-mile study reach before during and after pulse flow (will map again in August).

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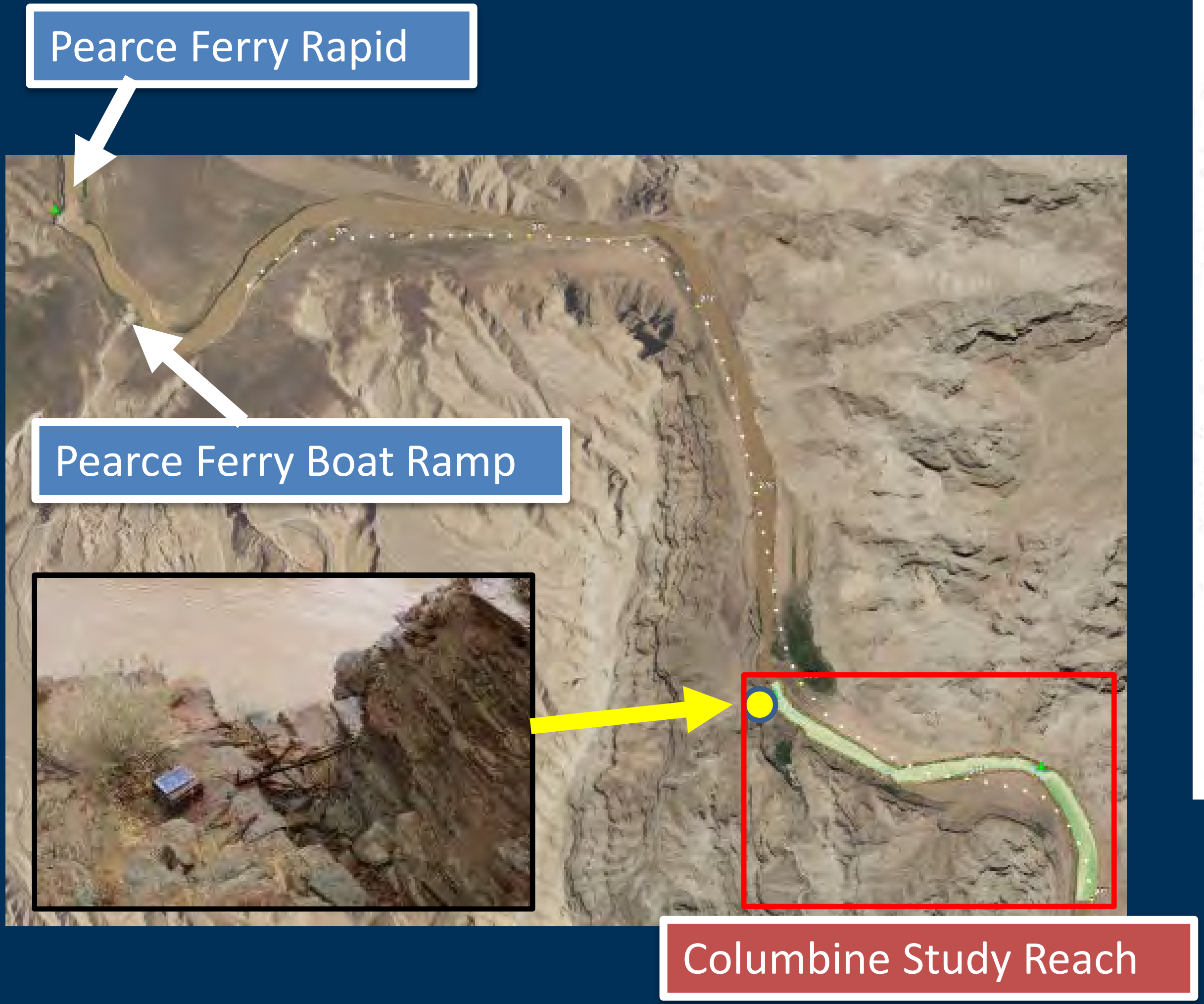
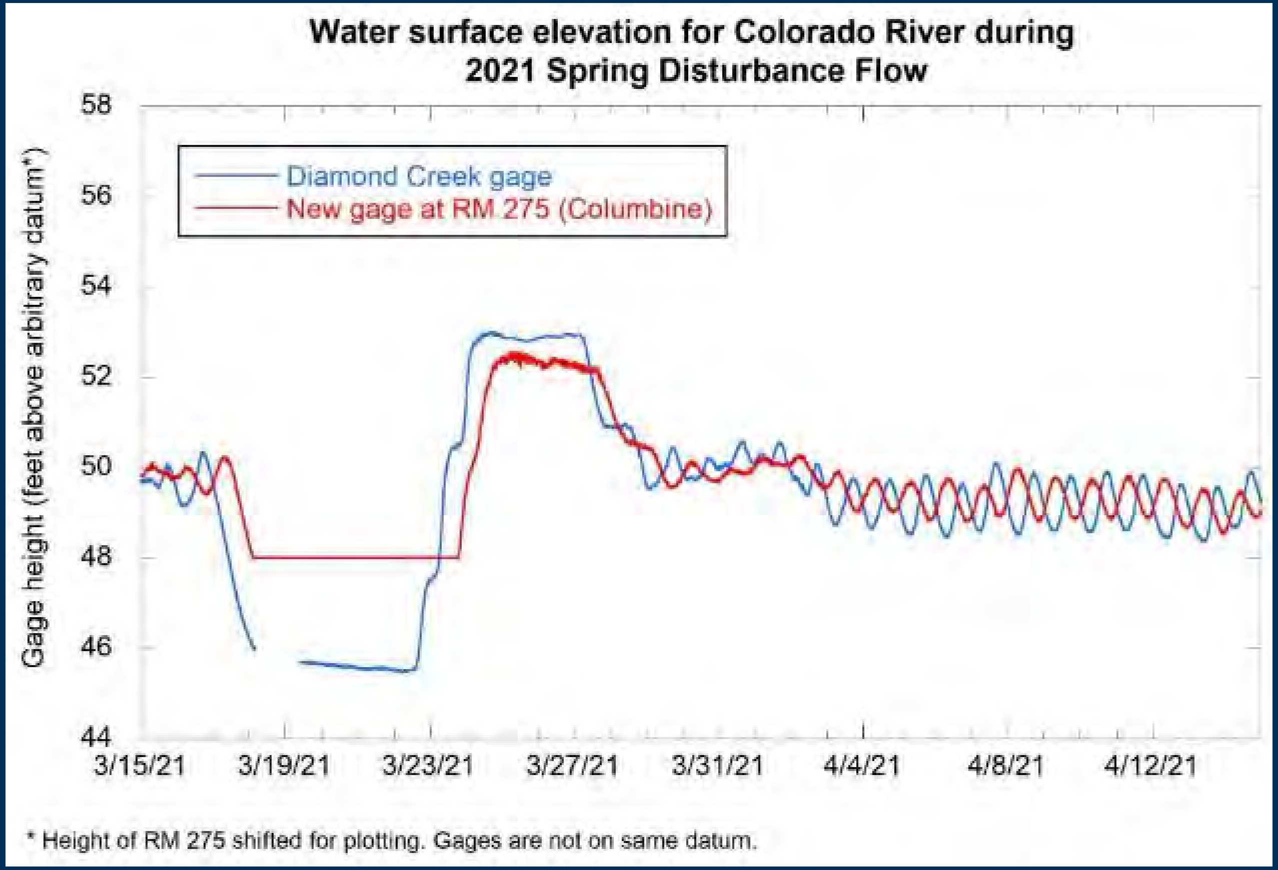
Columbine Study Reach in Western Grand Canyon

View of study reach from outside of bend at RM 273.6R

Temporary gage to measure water-surface elevation and travel-time between Diamond Creek and study reach





Preliminary results, subject to review, do not cite

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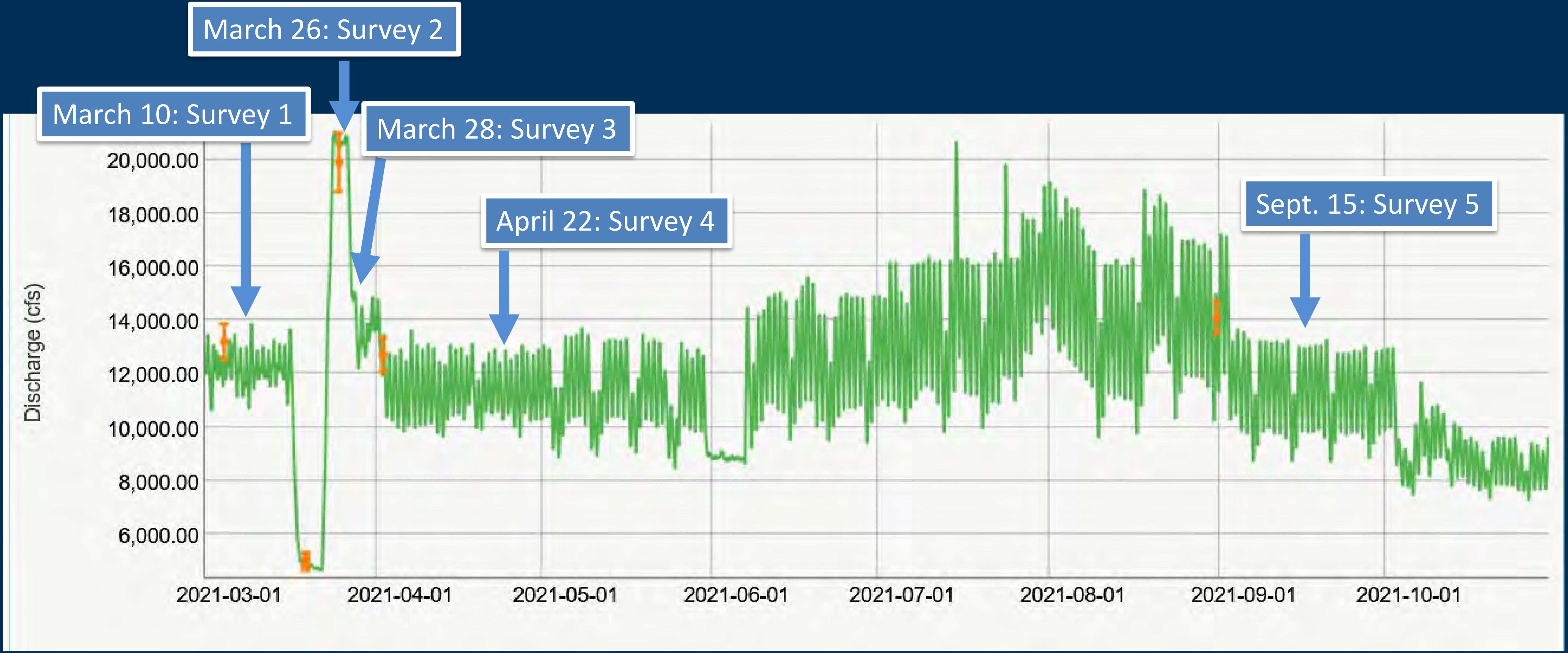
Project O.2: Field surveys around 2021 Spring Pulse Flow

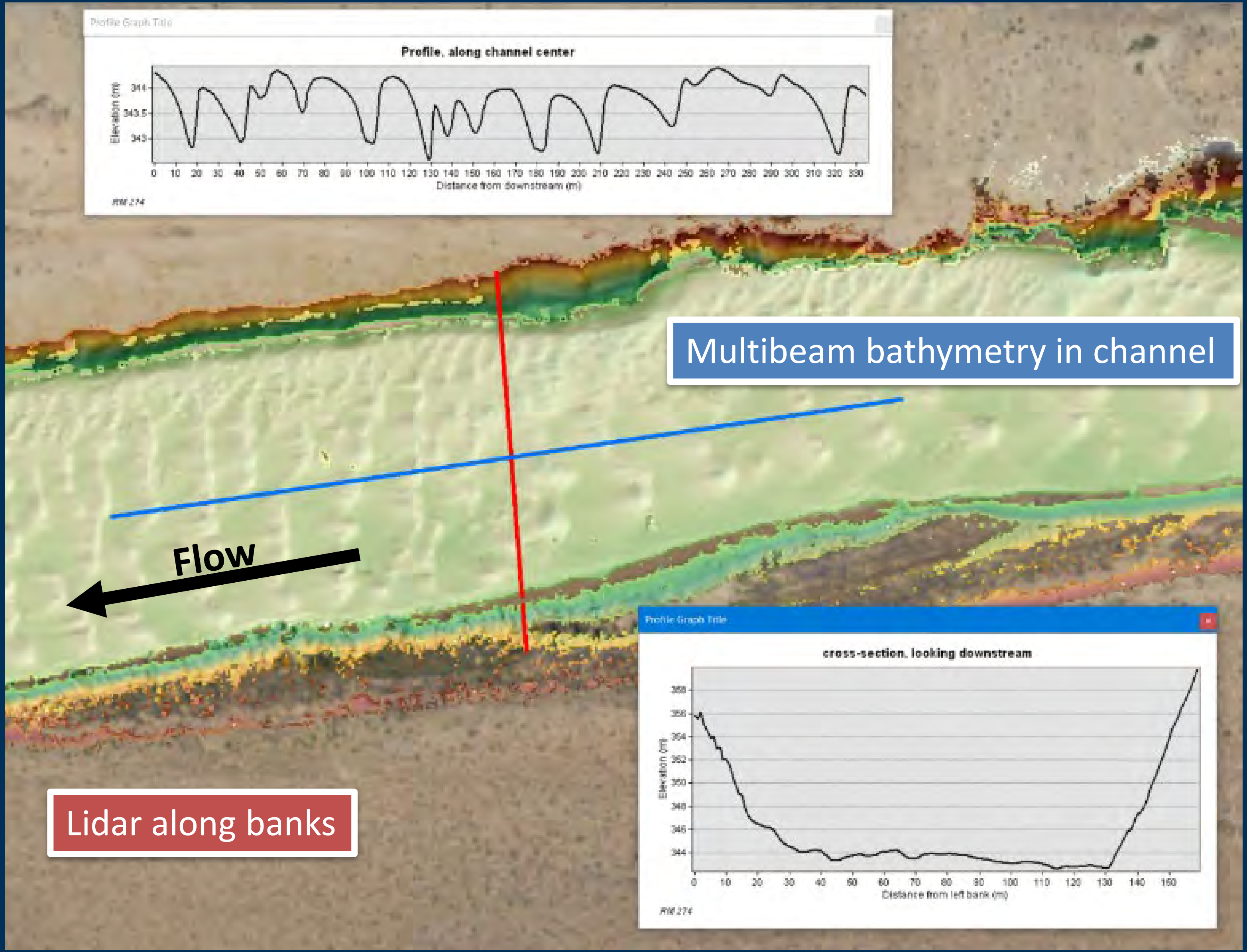


https://www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09380000

USGS

Field Surveys

- Sonar survey of riverbed
- Boat-based lidar survey of banks
- Ground-based RTK-GPS survey of water surface and check points
- Time-lapse cameras to show bars during low-flow and bank erosion



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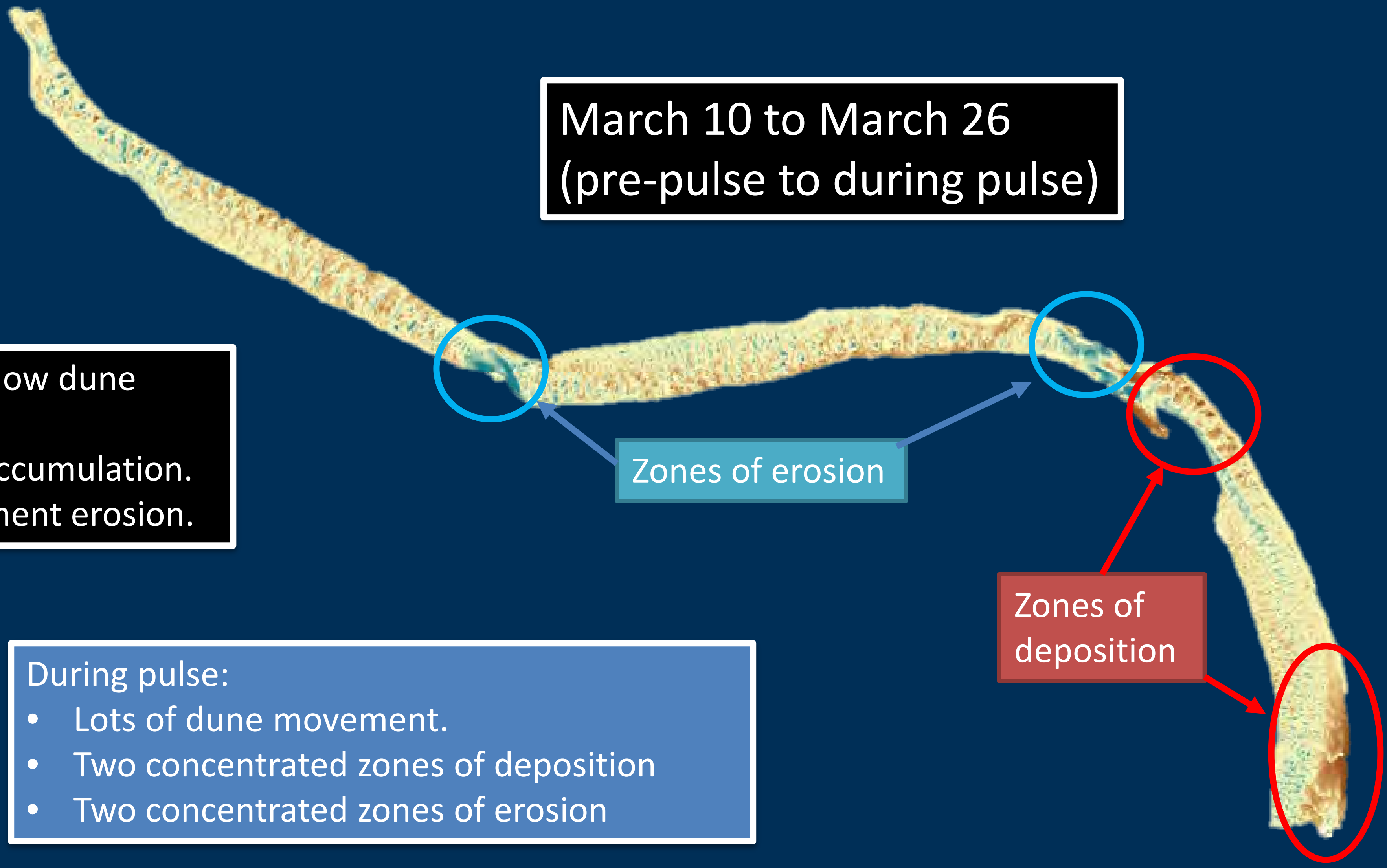
Columbine Reach Bed erosion and deposition

March 10 to March 26
(pre-pulse to during pulse)

- Alternating red and yellow show dune movement.
- Dark red areas of sediment accumulation.
- Blue-green are areas of sediment erosion.



During pulse:
- Lots of dune movement.
- Two concentrated zones of deposition
- Two concentrated zones of erosion

Preliminary results, subject to review, do not cite

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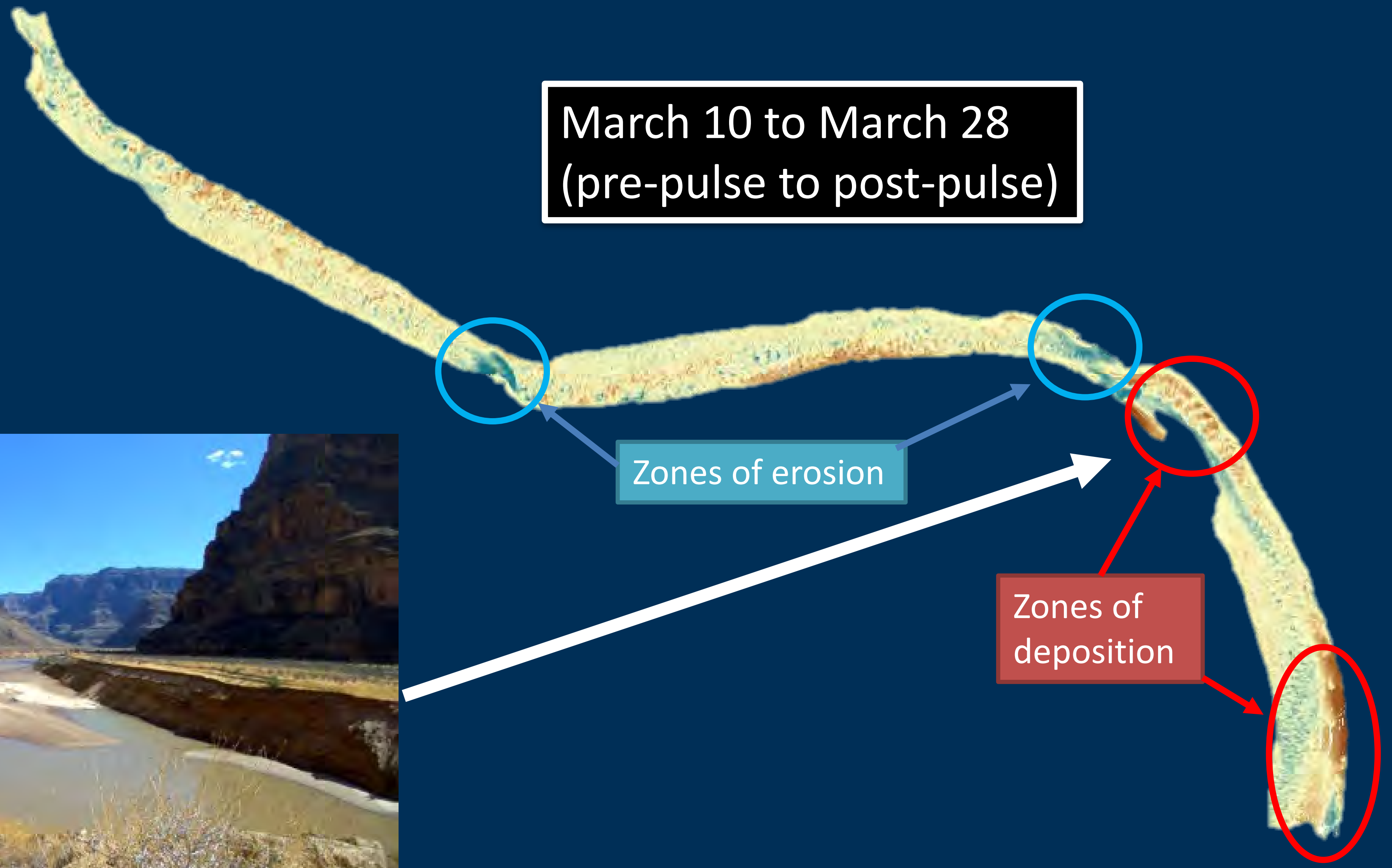
Columbine Reach Bed erosion and deposition



Preliminary results, subject to review, do not cite

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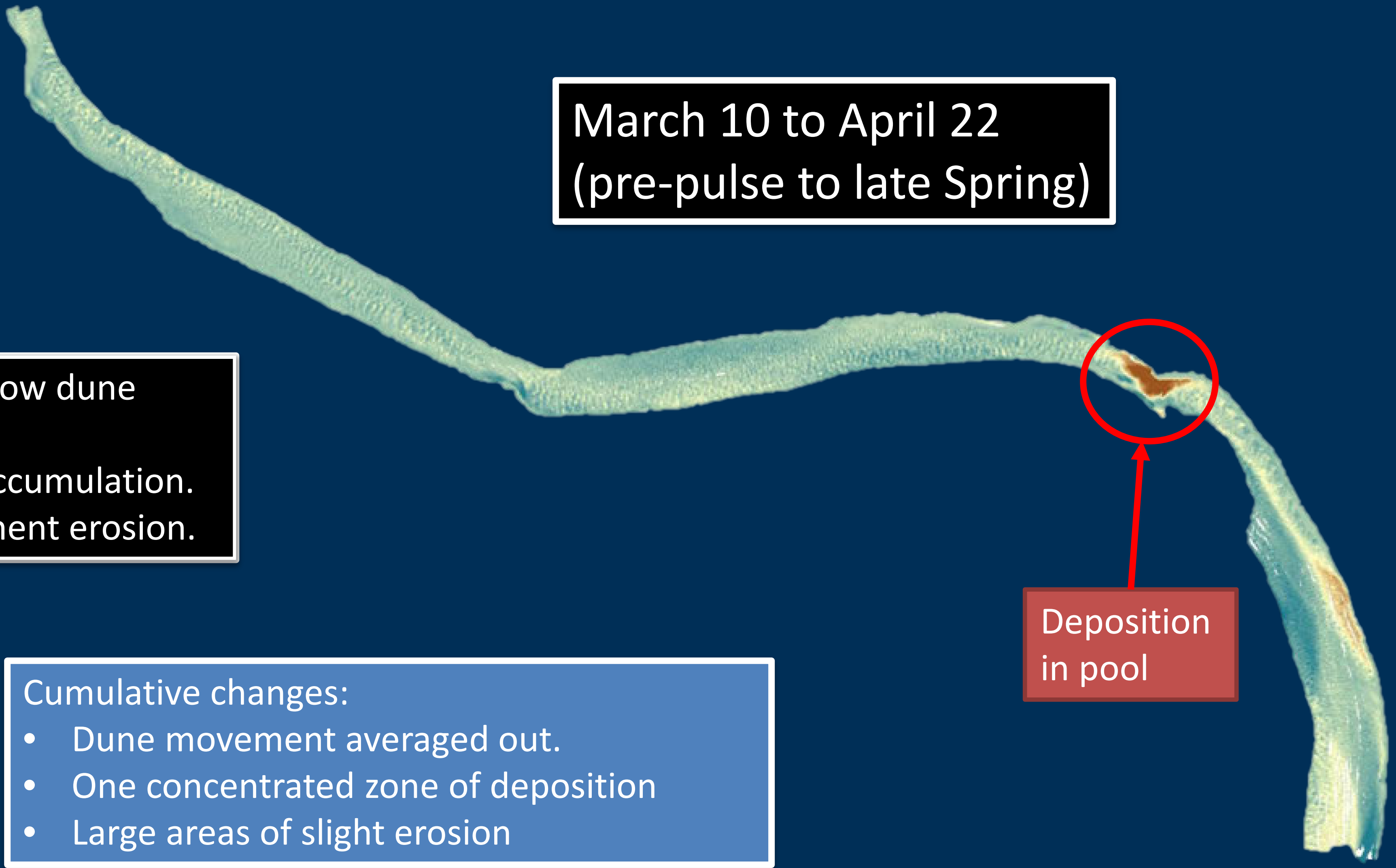
Columbine Reach Bed erosion and deposition

March 10 to April 22
(pre-pulse to late Spring)

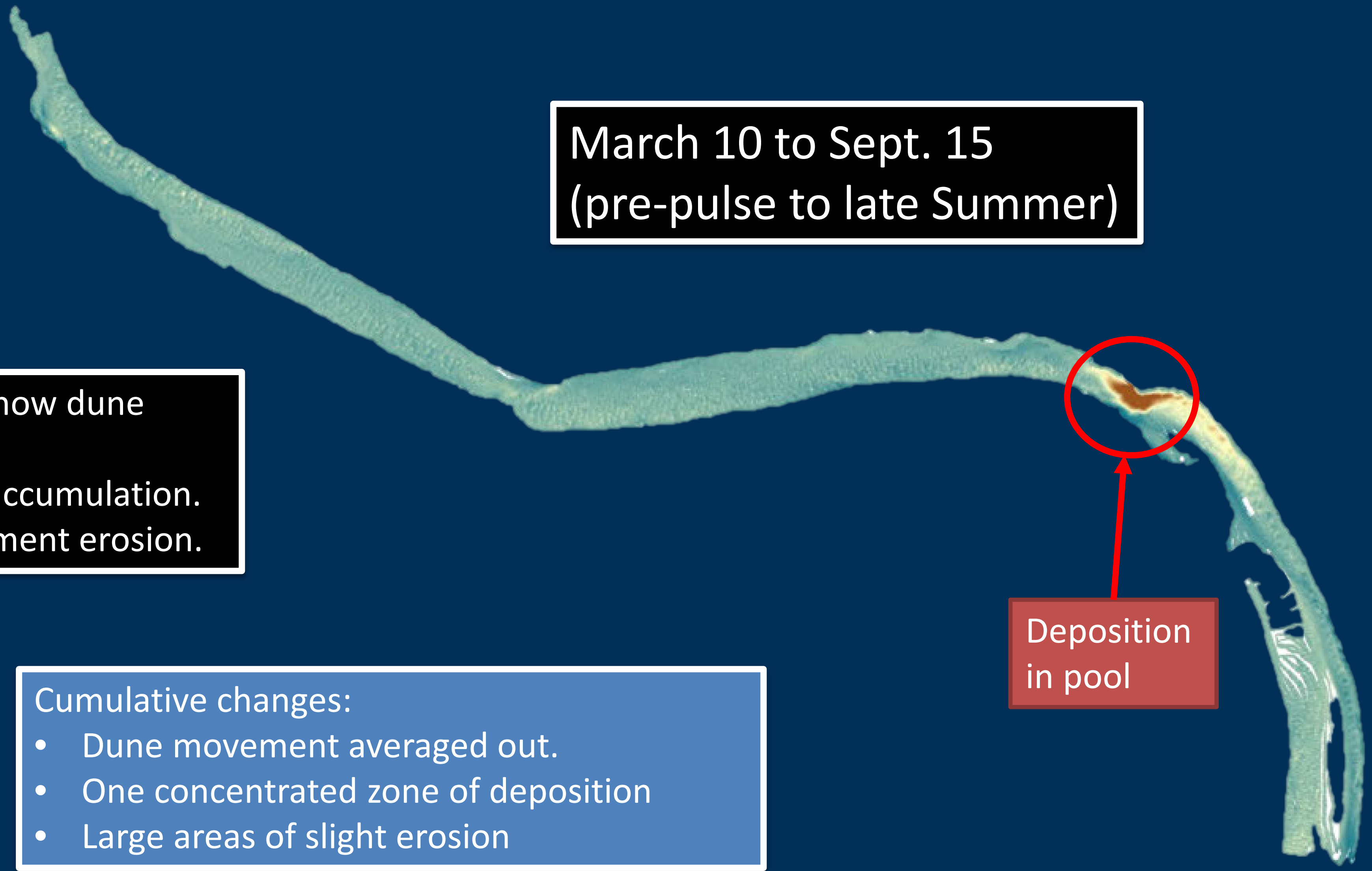
- Alternating red and yellow show dune movement.
- Dark red areas of sediment accumulation.
- Blue-green are areas of sediment erosion.



Cumulative changes:
- Dune movement averaged out.
- One concentrated zone of deposition
- Large areas of slight erosion

Columbine Reach Bed erosion and deposition

March 10 to Sept. 15
(pre-pulse to late Summer)



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Cumulative changes:
- Dune movement averaged out.
- One concentrated zone of deposition
- Large areas of slight erosion

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USGS

Conclusions

- As expected, the reach is dynamic
- Preliminary analysis of the repeat surveys:
  - Bars in the reach were active and aggraded slightly during the disturbance flow
  - Pools in the reach scoured during the disturbance flow
  - Following summer operations, bars eroded slightly and pools filled
- Repeat with different/higher flow pulse would be informative

Proposed FY2022/23 Activities

- Complete analysis of changes in Columbine study reach.
- Develop sediment budget for Western Grand Canyon based on transport measurements (CR at Diamond Creek) and estimates of sediment input from banks.
- Develop and calibrate numerical flow model for study reach.
- Use model to predict response to different dam operations.
- Prepare draft report to be finalized in FY2023.

Project Element O.3. Aeolian Response to a Spring Pulse Flow

Annual Reporting Meeting, January 12, 2022

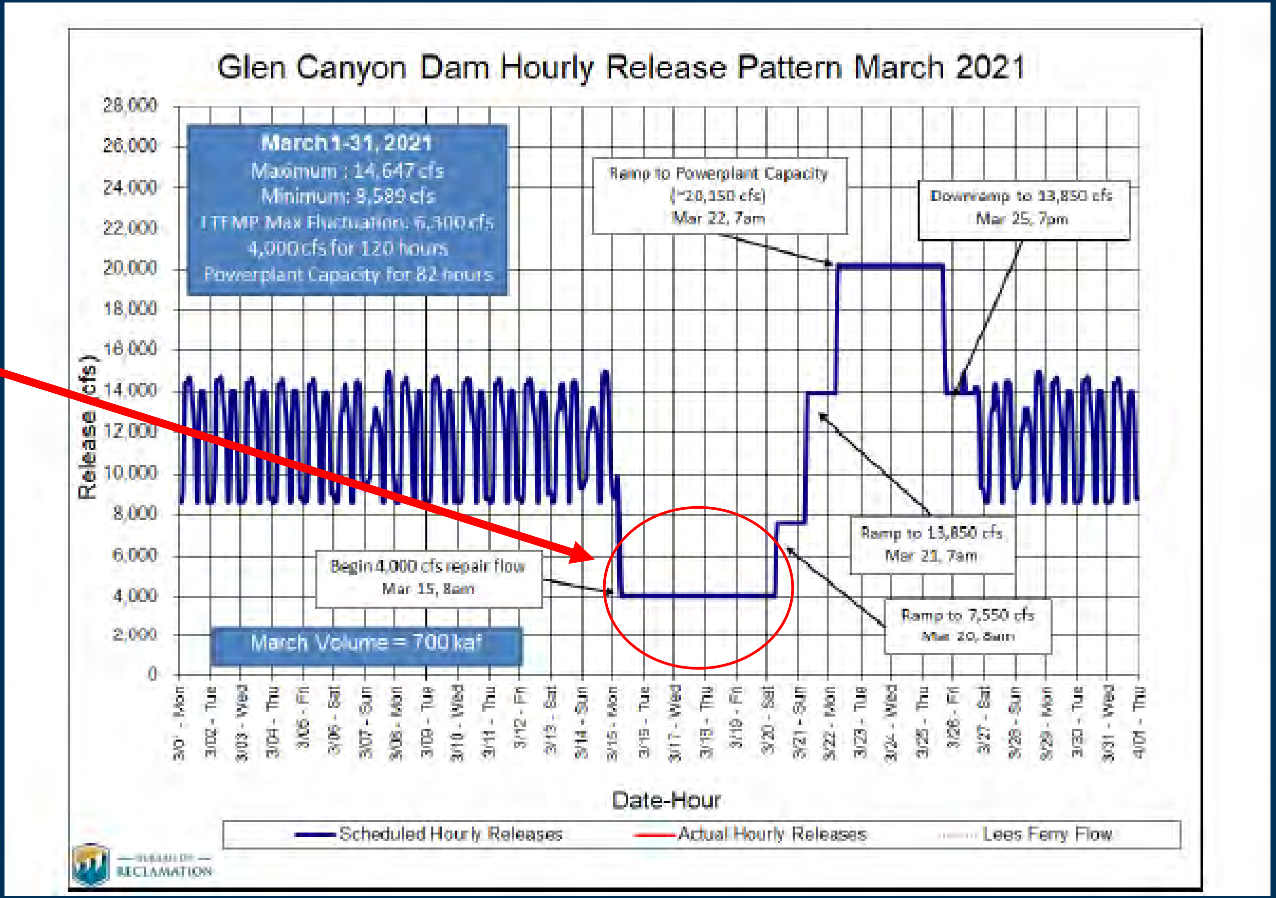
Joel B. Sankey, Joshua Caster, Helen Fairley

U.S. Geological Survey, GCMRC

Project Element O.3. Aeolian Response to a Spring Pulse Flow

- Focused on the five-day drop in river flow (“low steady flow”) during the 2021 SDF

- Discharge from the upstream Glen Canyon Dam dropped to 122 m^3/s (4,300 cfs), approximately 104 m^3/s (3,700 cfs) lower than the regularly occurring contemporary base-flow discharge of the river



https://www.usgs.gov/centers/sbsc/science/timing-really-everything-evaluating-resource-response-spring-disturbance-flows?

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O.3 Fluvial-aeolian experiment in the Colorado River in Grand Canyon

- **Experimental five-day drop in river flow exposed ~ 26,154 m^2 of sand per kilometer of Colorado River in Grand Canyon (Kasprak et al., 2021)**
- **>100% increase in source area of potential windblown sediment supply for 57 aeolian dunefields and 60 additional areas of unvegetated high-elevation sand that contain archaeological sites along Colorado River in Grand Canyon National Park (Sankey et al., 2018)**

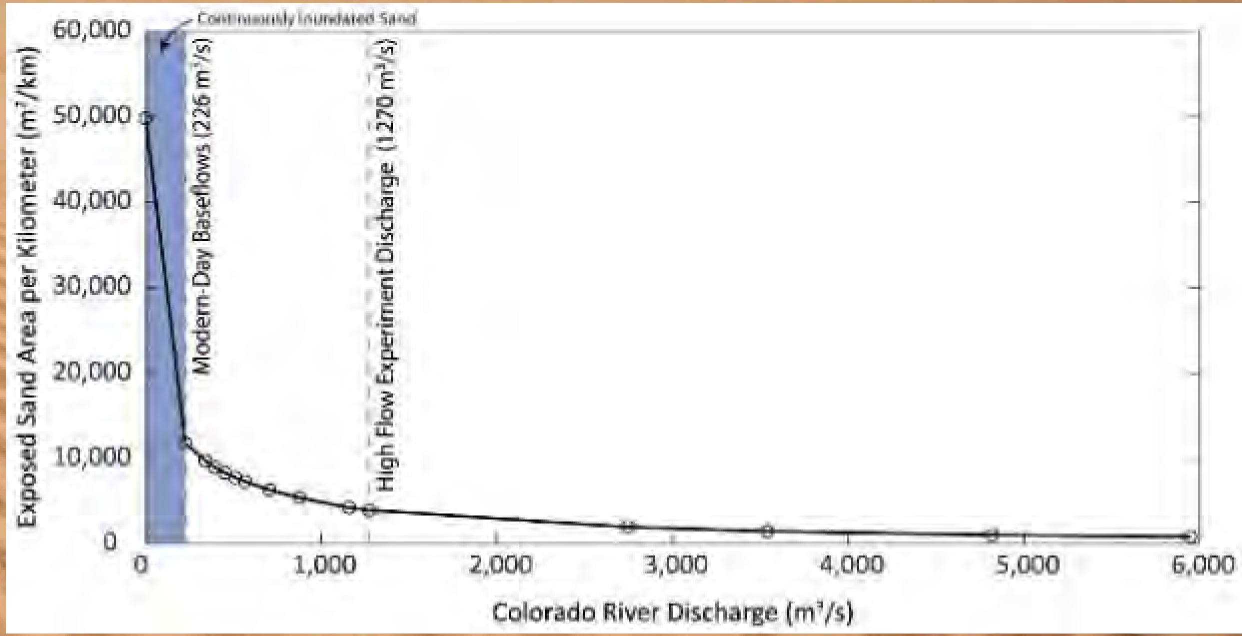
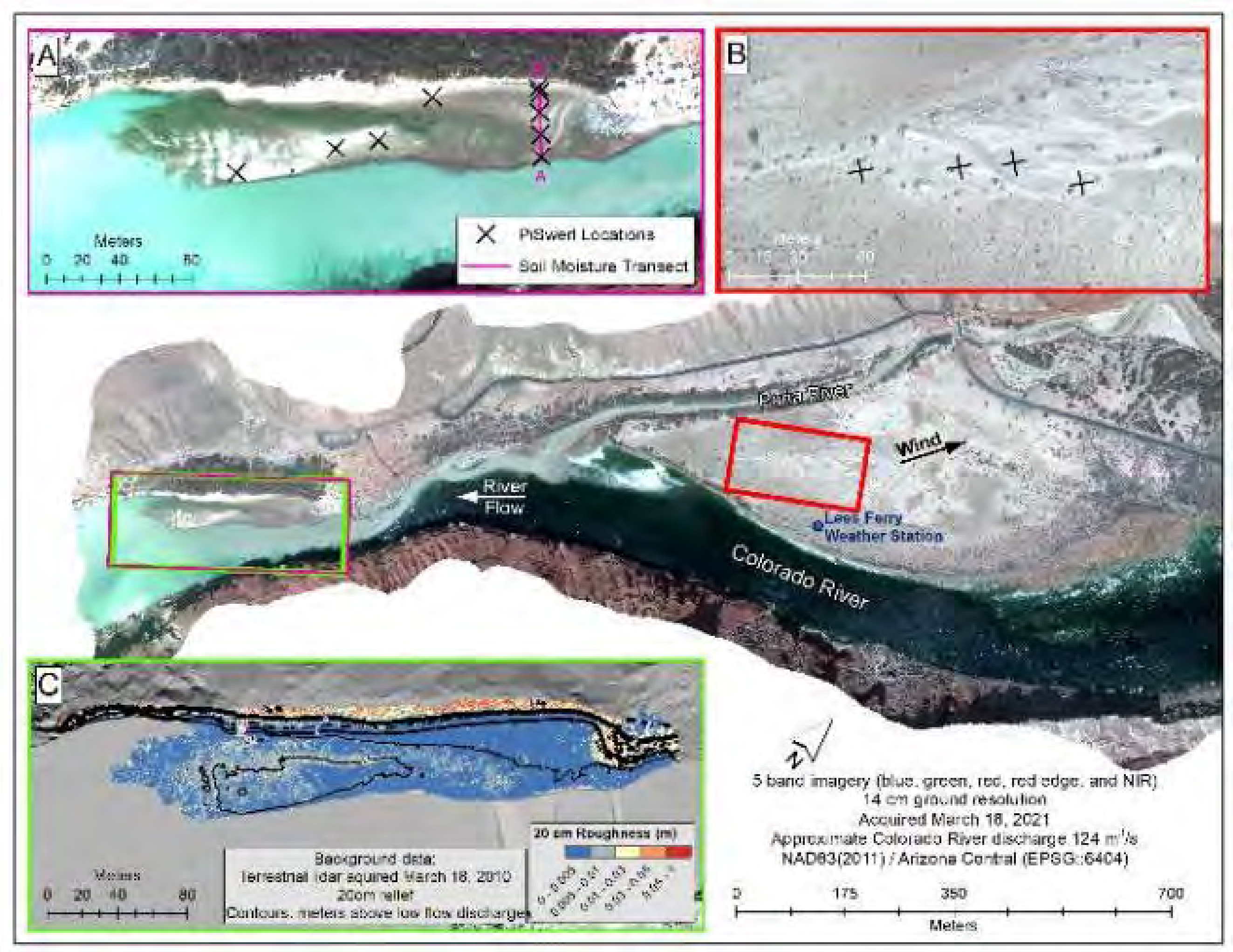


Figure from: Kasprak et al., 2021, "Future regulated flows of the Colorado River in Grand Canyon foretell decreased areal extent of sediment and increases in riparian vegetation." Environmental Research Letters 16.1 (2021): 014029.

O.3 Fluvial-aeolian experiment: Methods

- Study area was a 18,000 m^2 sandbar and adjacent dunefield at Lees Ferry on the Colorado River
- Used portable in-situ wind erosion lab (PI-SWERL) to measure the threshold friction velocities (U*t) for sand saltation. U*t is the *wind velocity required to initiate aeolian sediment transport*
- Collected measurements on the sandbar during each day of the low river flow experiment.

PI-SWERL



O.3 Fluvial-aeolian experiment: Methods

- Measured particle size distribution, gravimetric and volumetric water content at the sample locations.
- Surveyed the elevation, topography, and surface roughness of the sample locations using ground-based lidar remote sensing.
- Modelled instantaneous aeolian sediment fluxes (q; kg/m/s) using measured u*t, wind data, following Bagnold (1941)

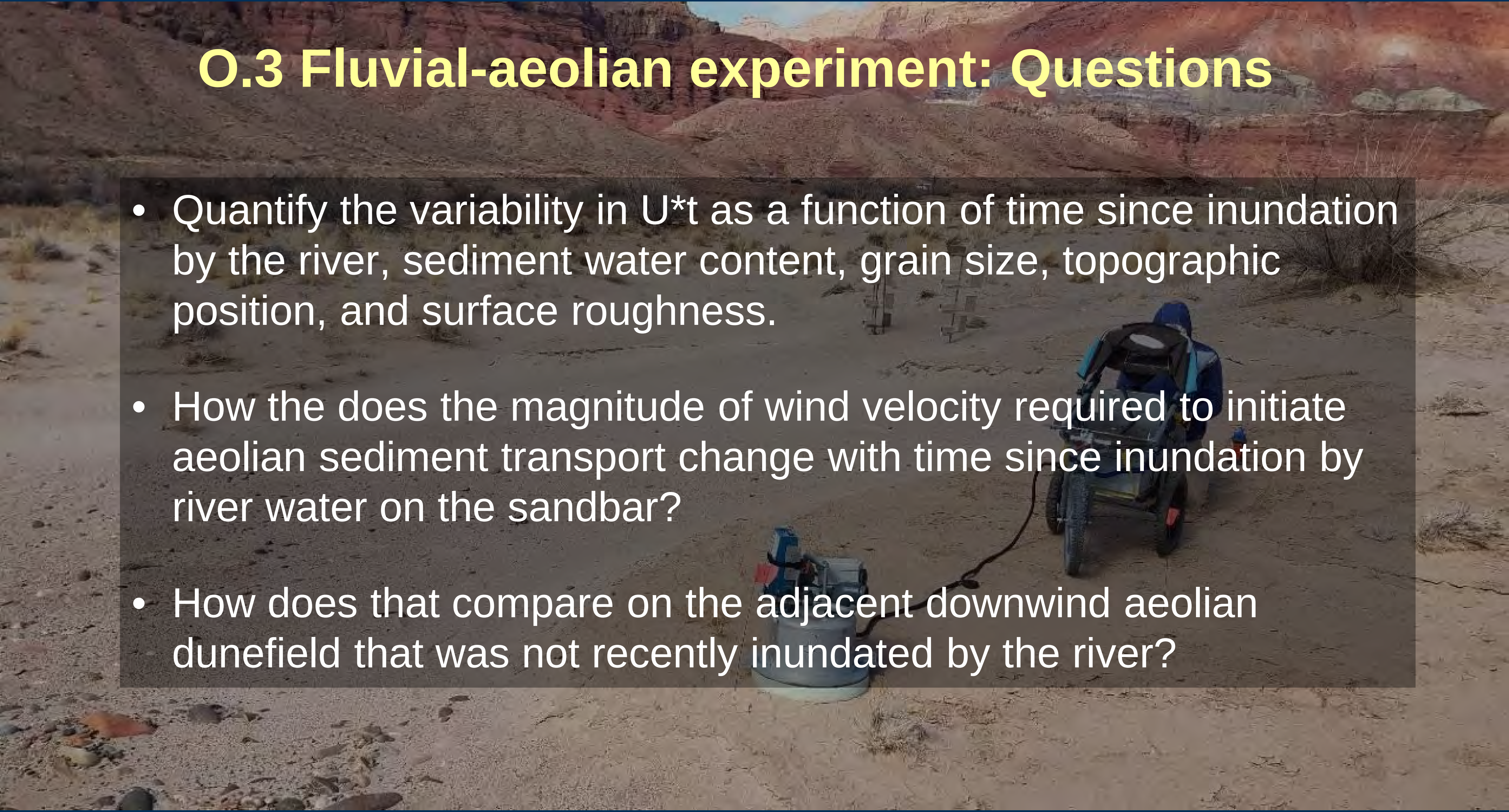
USGS on-site weather station

Caster and others, 2014

Reigl vz 1000 Terrestrial Lidar

Near surface sediment sample collection

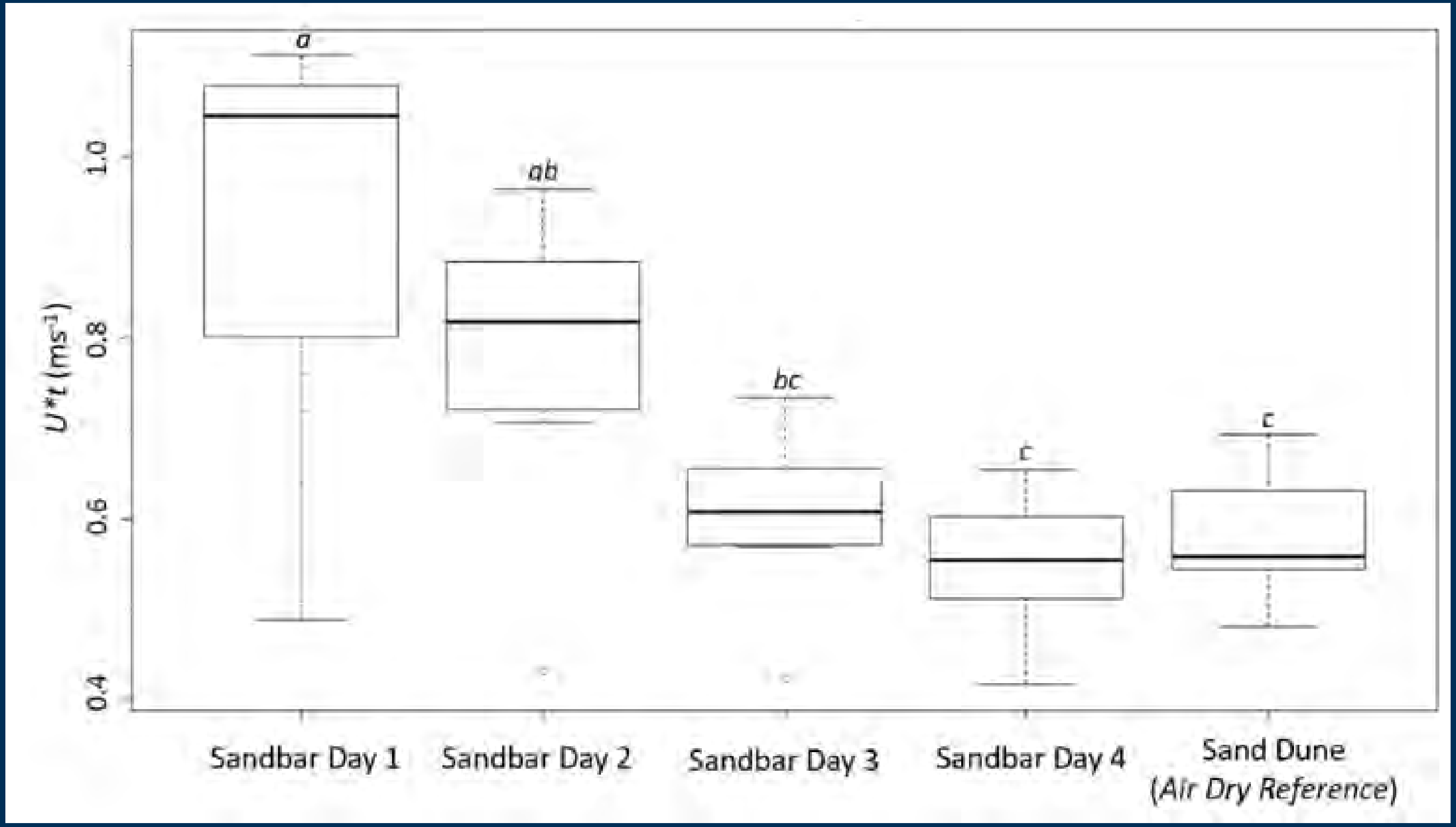
O.3 Fluvial-aeolian experiment: Questions



- Quantify the variability in U*t as a function of time since inundation by the river, sediment water content, grain size, topographic position, and surface roughness.
- How the does the magnitude of wind velocity required to initiate aeolian sediment transport change with time since inundation by river water on the sandbar?
- How does that compare on the adjacent downwind aeolian dunefield that was not recently inundated by the river?

O.3 Fluvial-aeolian experiment: Results

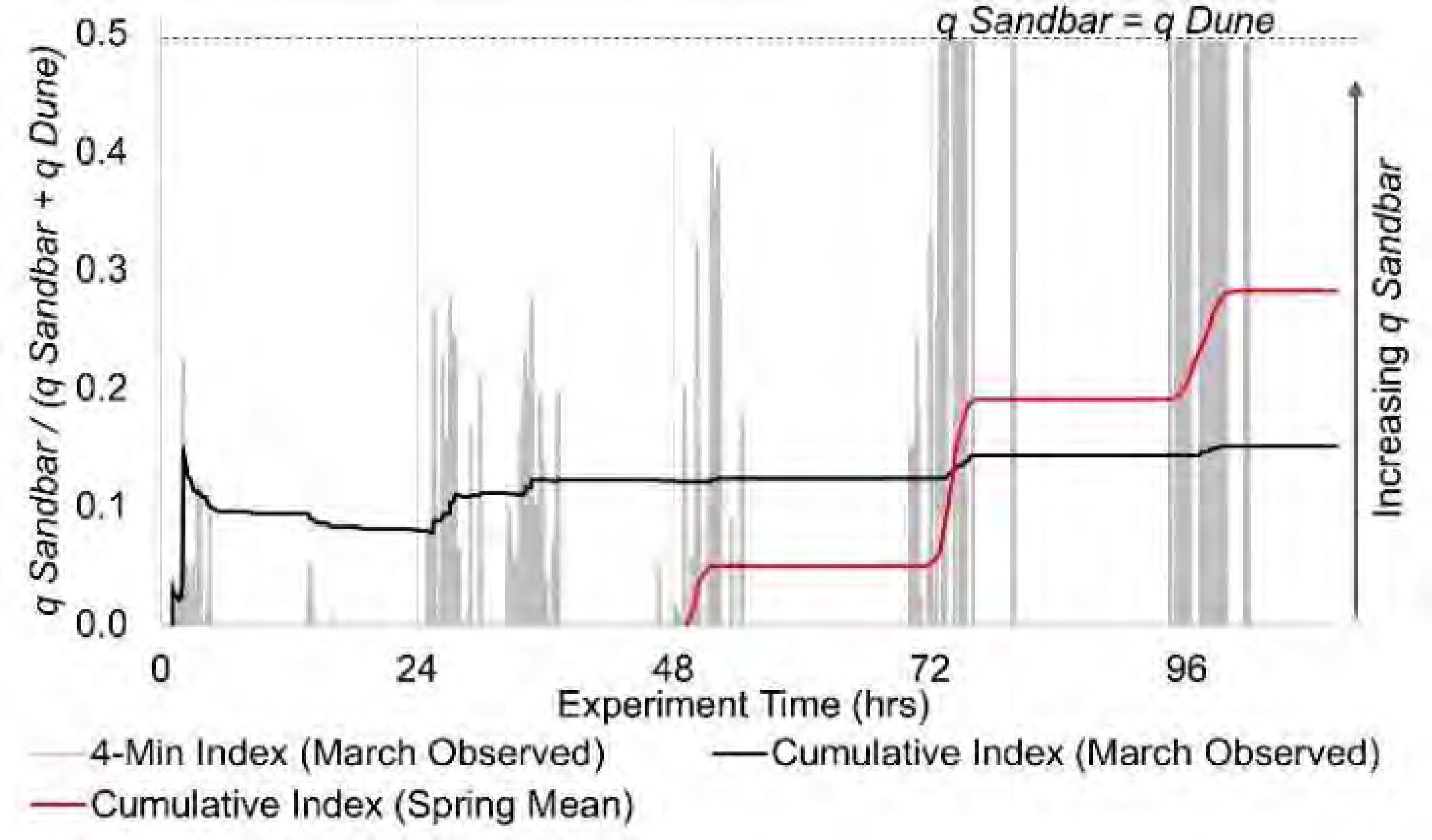
- Wind velocity required to initiate aeolian sediment transport (U*t) decreased as time since inundation increased
- By third day of steady low river flow, U*t on the river sandbar was statistically similar to adjacent sand dune that hadn't been previously inundated by river



Preliminary results, subject to review, do not cite

O.3 Fluvial-aeolian experiment: Results

- Modelled aeolian sediment flux was significantly greater on the dry sand dune on Days 1 and 2, but differences with modelled sandbar flux decreased with exposure time.
- 3 days after river flow dropped, modeled sandbar flux ≈ modeled sand dune flux.
- Under typical spring wind conditions, the cumulative sandbar flux could be greater than half that of weekly cumulative flux for the dry sand dune.



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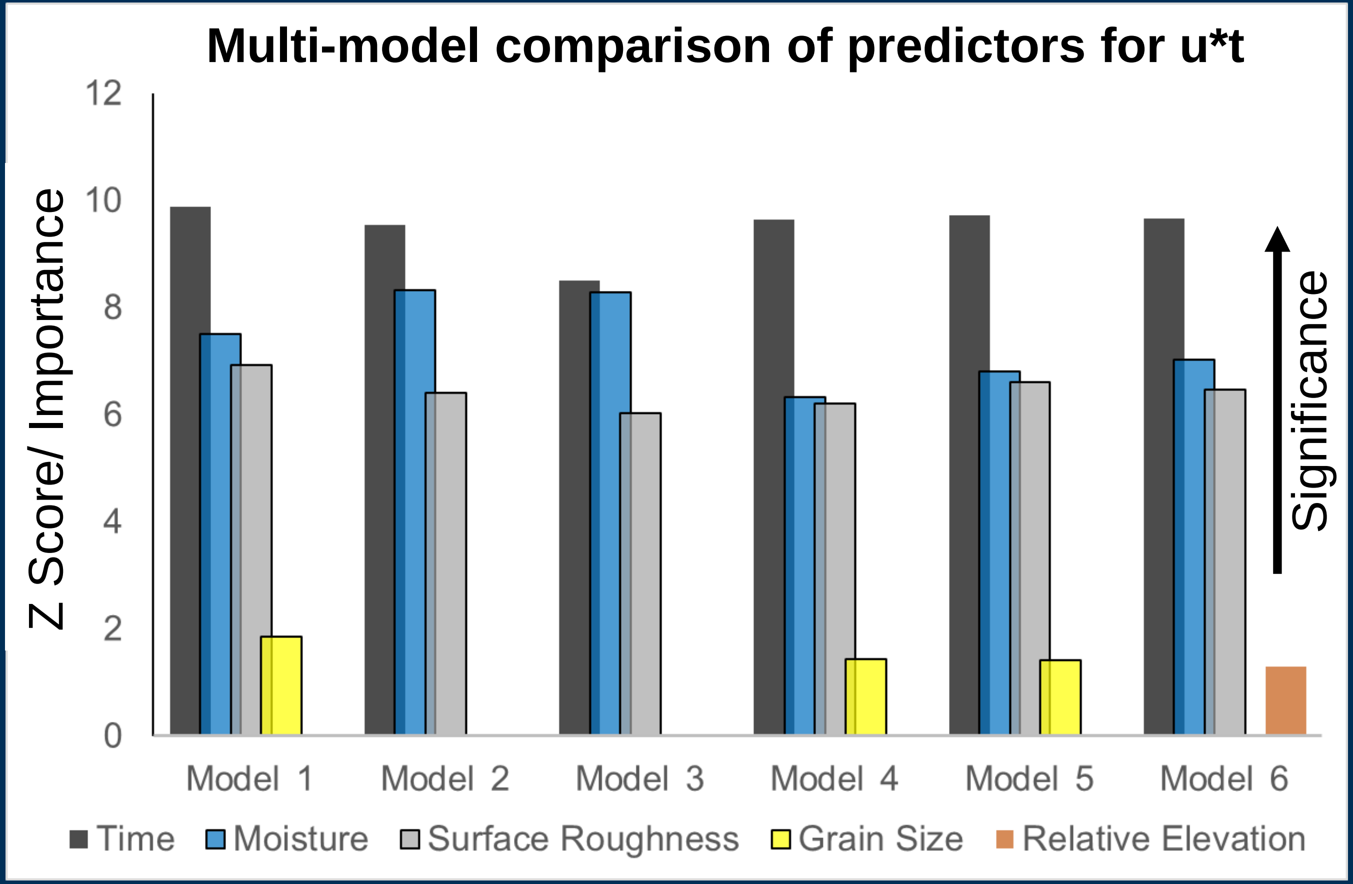
O.3 Fluvial-aeolian experiment: Results

- Changes in measured U*t over the experiment were significantly influenced by **subaerial exposure time**, **moisture**, and **surface roughness**



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O.3 Fluvial-aeolian experiment: Conclusions

- Confirmed that by drastically lowering flows and allowing sand to dry out, can potentially greatly increase the amount of sand transported to inland to dunes and archeological sites
  - Low-steady flow of SDF exposed ~ 26,154 m^2 of sand per kilometer of the river; >100% increase source area of aeolian sediment supply
  - When river flow dropped and river sand was exposed to the wind, some damp sand could be blown out of the river sandbar towards dunefield during the first 48 hours of drying, but was fully susceptible to the wind's energy after 72 hours of drying
- Predicted u*t (wind velocity required to initiate aeolian sediment transport) on river sandbar as a function of subaerial exposure time, moisture, surface roughness, grain size, elevation above water surface
- Modelled aeolian sediment transport on river sandbar as a function of wind and changes in u*t owing to subaerial drying time
- Can model aeolian sediment transport on river sandbars for different hydrograph scenarios
  - Manage river flows to promote aeolian landscape habitat and support in-situ preservation of archaeological sites in Grand Canyon by optimizing the timing and duration of periods of low flows (that might become increasingly relevant in light of drought-mitigation needs).

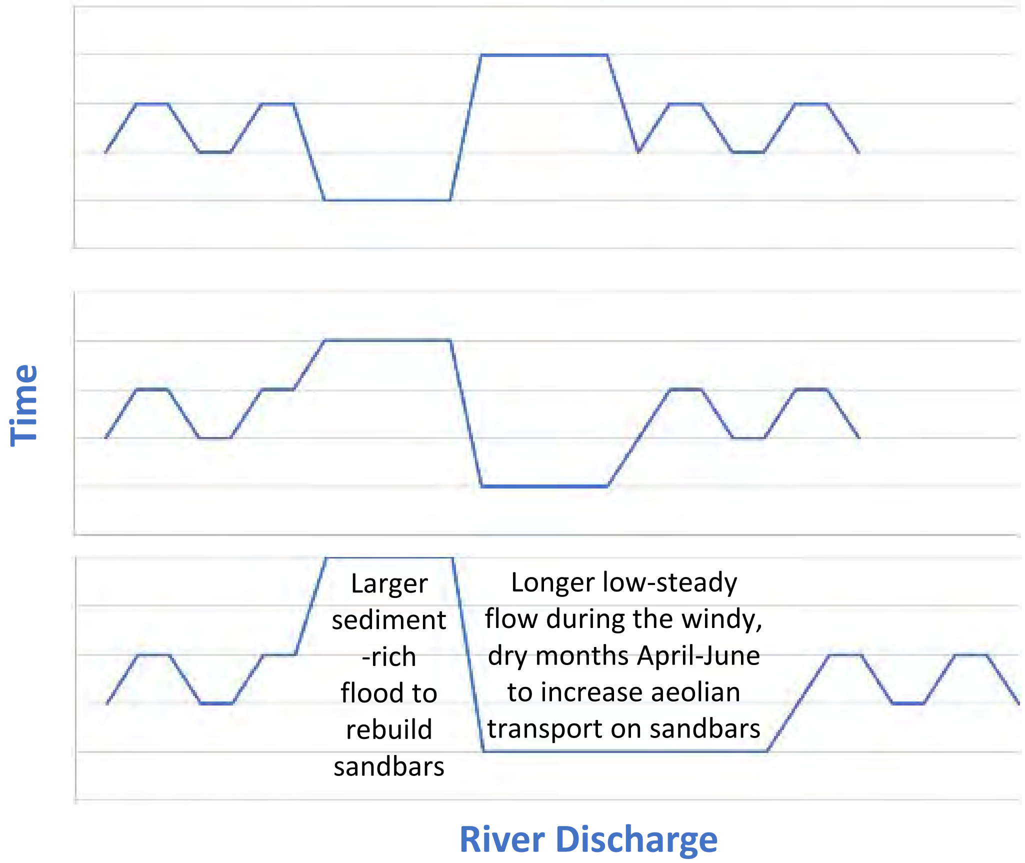
Preliminary results, subject to review, do not cite

O.3 Hypotheses Regarding Future Disturbance Flows

2021 Spring Disturbance Flow

Better disturbance flow to increase aeolian sand transport from sandbars to dunefields for preservation of archaeological sites and cultural resources?

Best disturbance flow to increase aeolian sand transport from sandbars to dunefields for preservation of archaeological sites and cultural resources?



Preliminary results, subject to review, do not cite

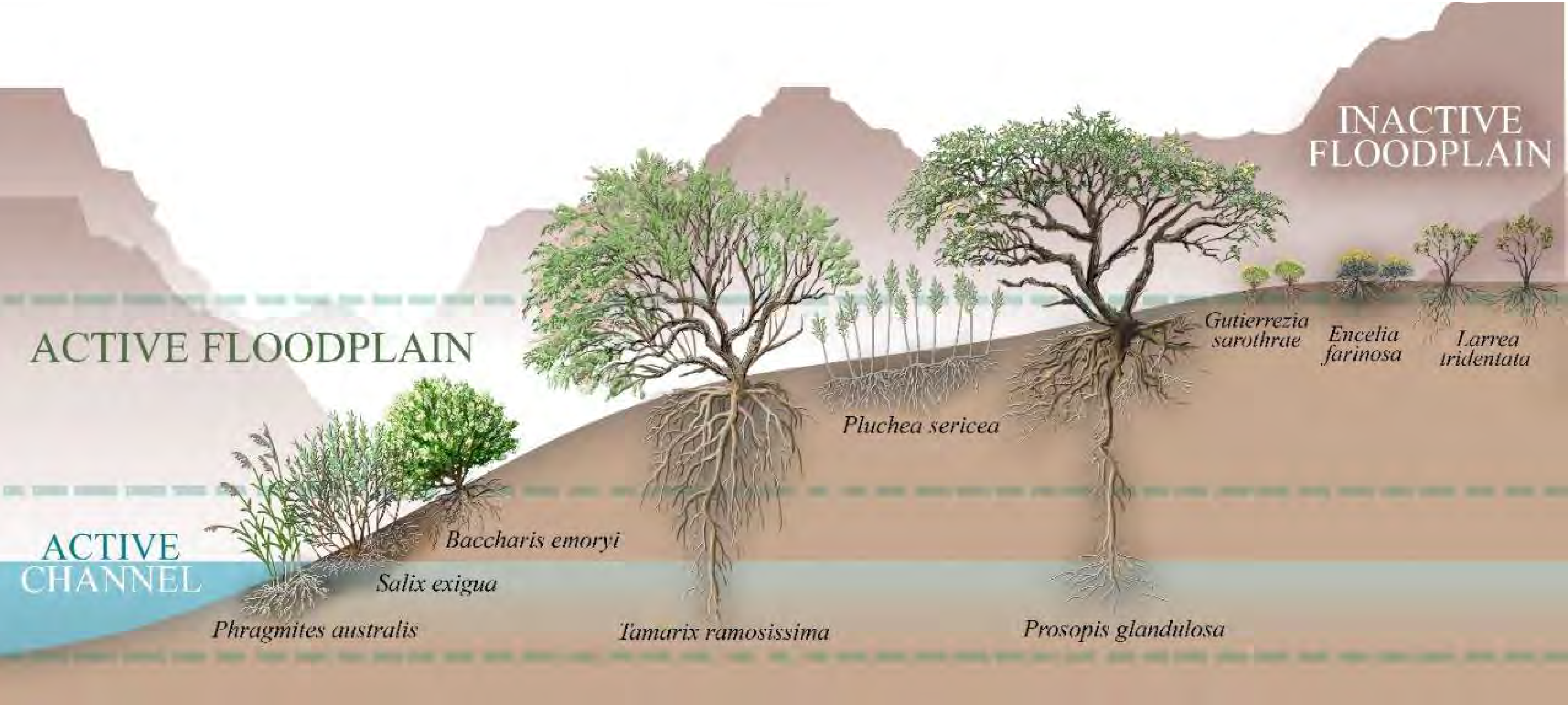
Short-term Physiological Responses of Two Plant Species to the 2021 SDF

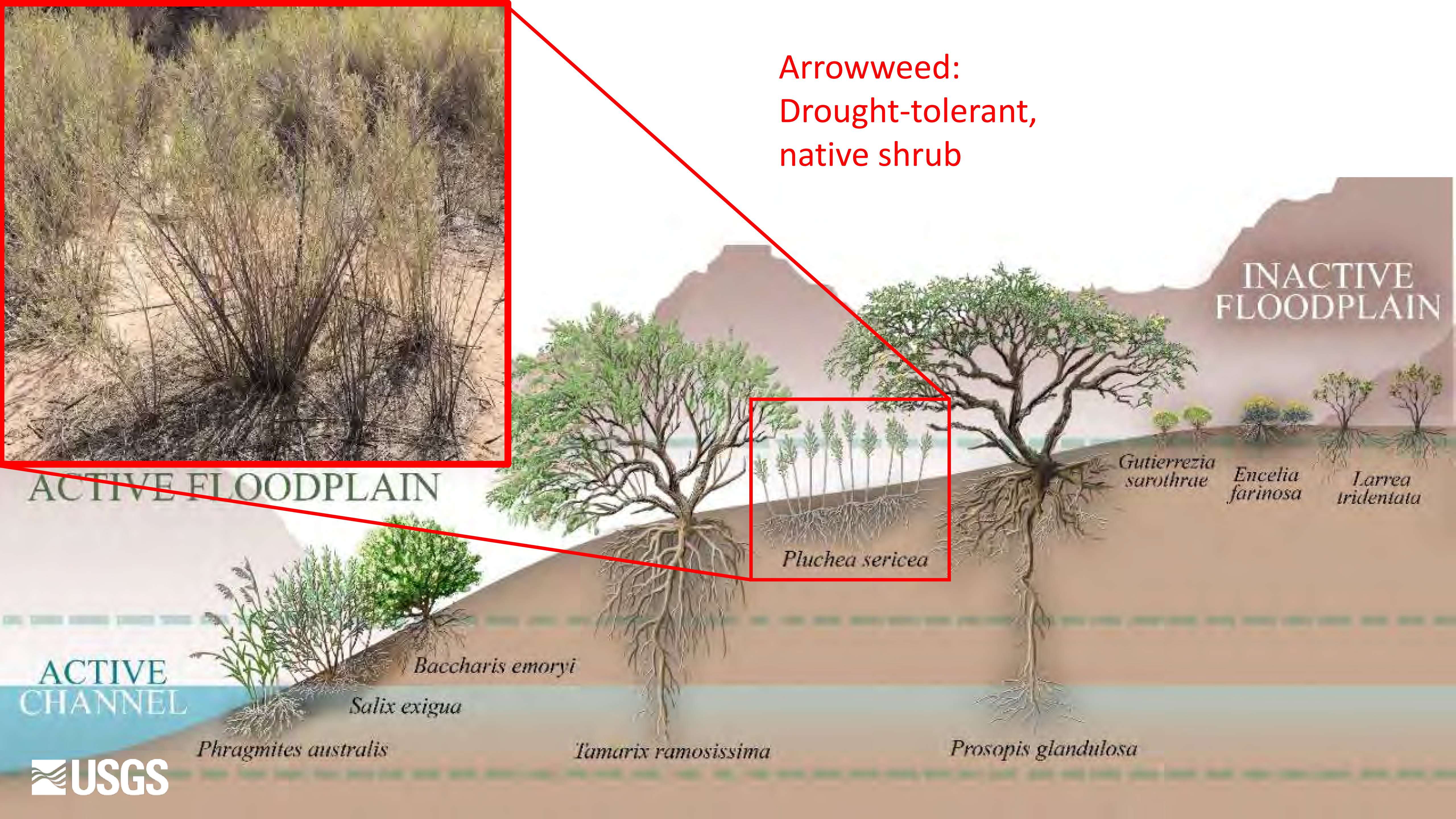
Brad Butterfield[1] and Emily Palmquist[2]

1 Department of Biological Sciences, Northern Arizona University

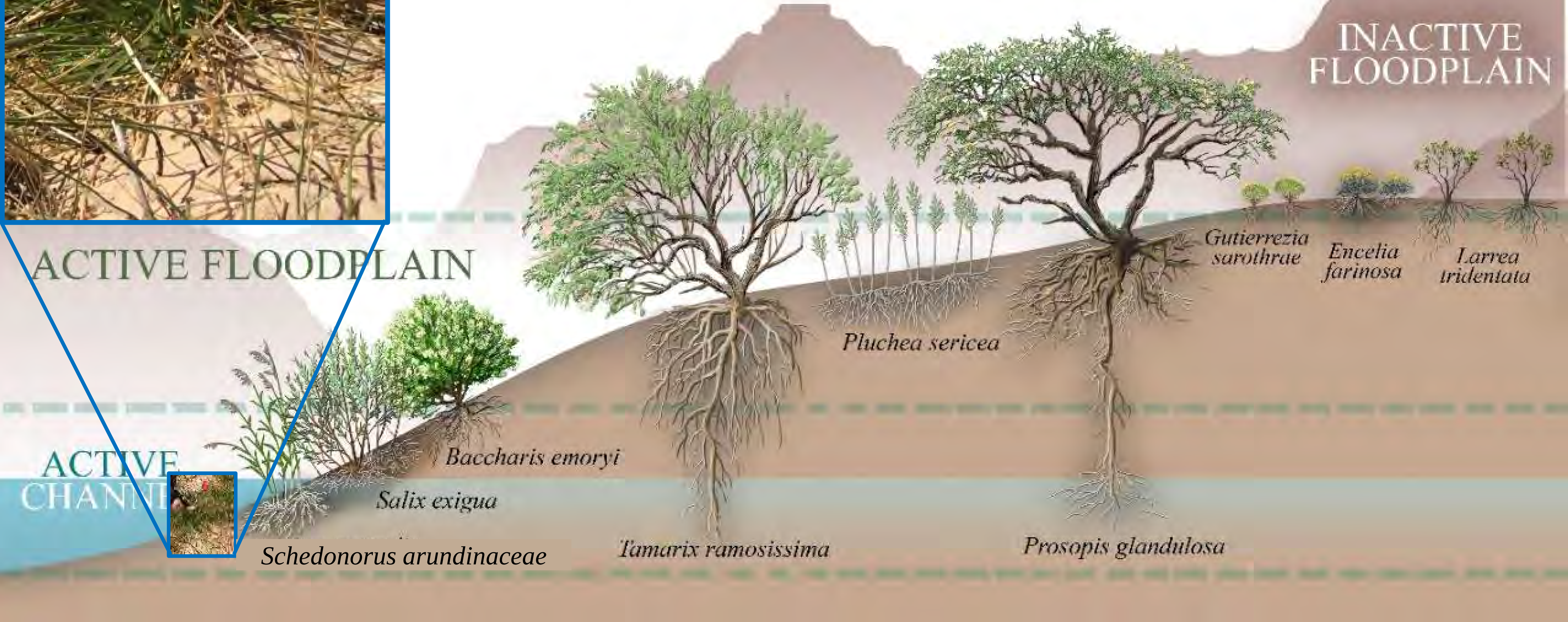
2 Grand Canyon Monitoring and Research Center, Southwest Biological Science Center, USGS, Flagstaff

Did Plants Respond to the SDF?




Arrowweed:
Drought-tolerant,
native shrub
INACTIVE
FLOODPLAIN
ACTIVE FLOODPLAIN
Pluchea sericea
Gutierrezia
sarothrae
Encelia
farinosa
Larrea
tridentata
Baccharis emoryi
ACTIVE
CHANNEL
Salix exigua
Phragmites australis
Tamarix ramosissima
Prosopis glandulosa
USGS

Tall fescue:
Water-loving,
non-native grass



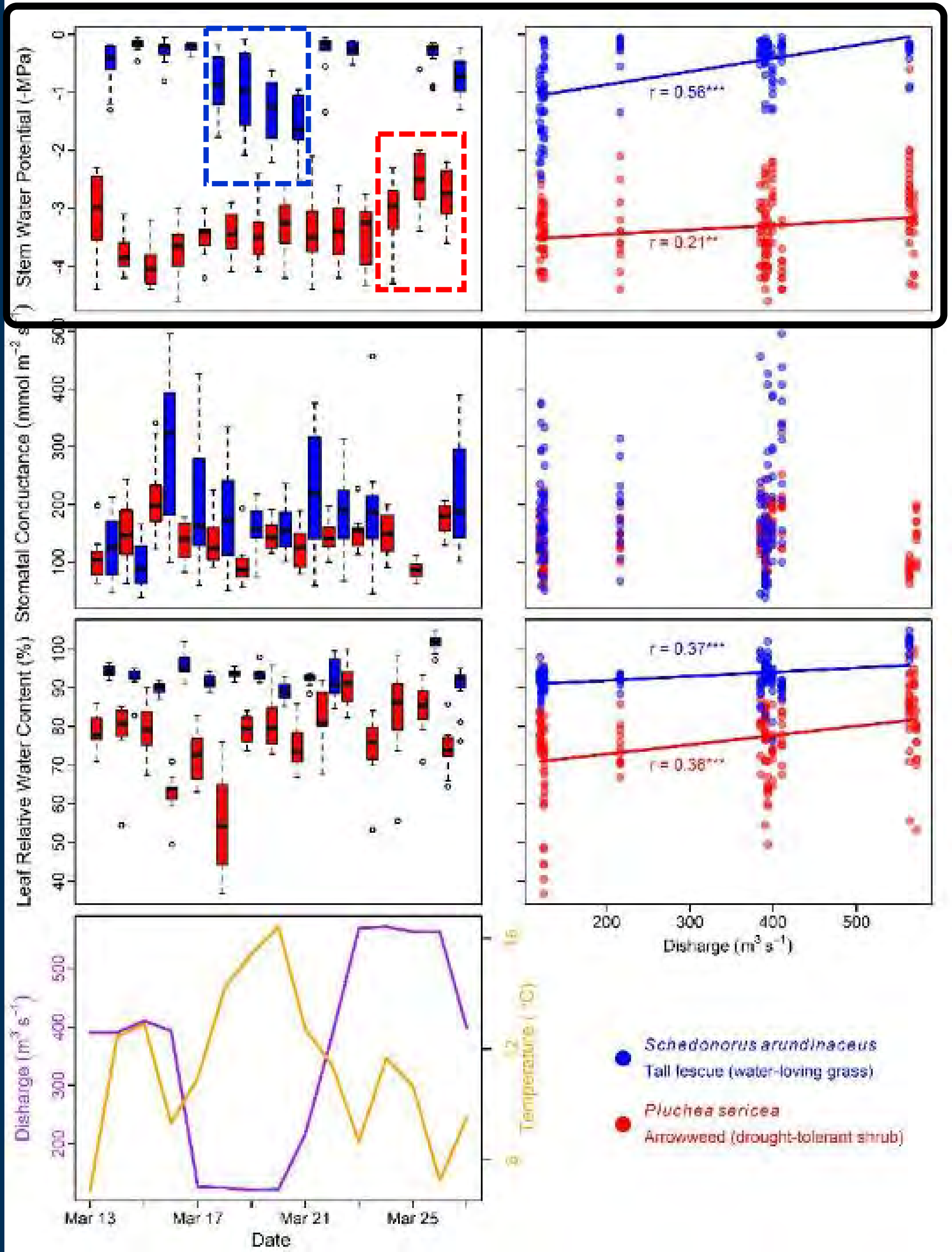
Daily Physiological Measurements

- Stem water potential
  - Tension of the water column within a plant stem (more negative = more stressed)
- Stomatal conductance to water vapor
  - Gas exchange with the atmosphere (lower = more stressed)
- Leaf relative water content
  - Leaf hydration (lower = more stressed)

USGS

Results: Both Species Responded to SDF

- Stem water potential responded positively to discharge
  - Tall fescue responded stronger to dry-down
  - Arrowweed responded stronger to the wet-up



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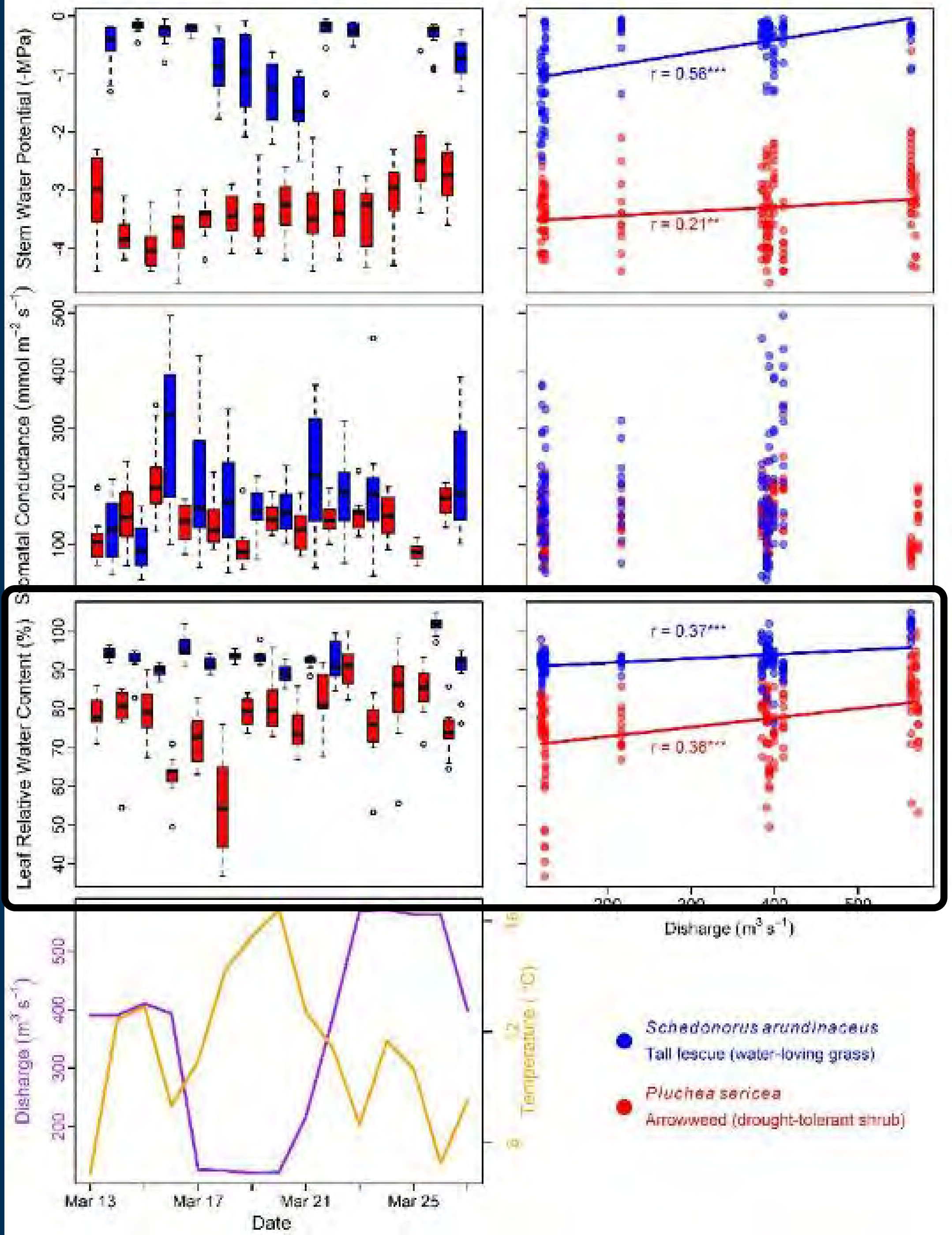
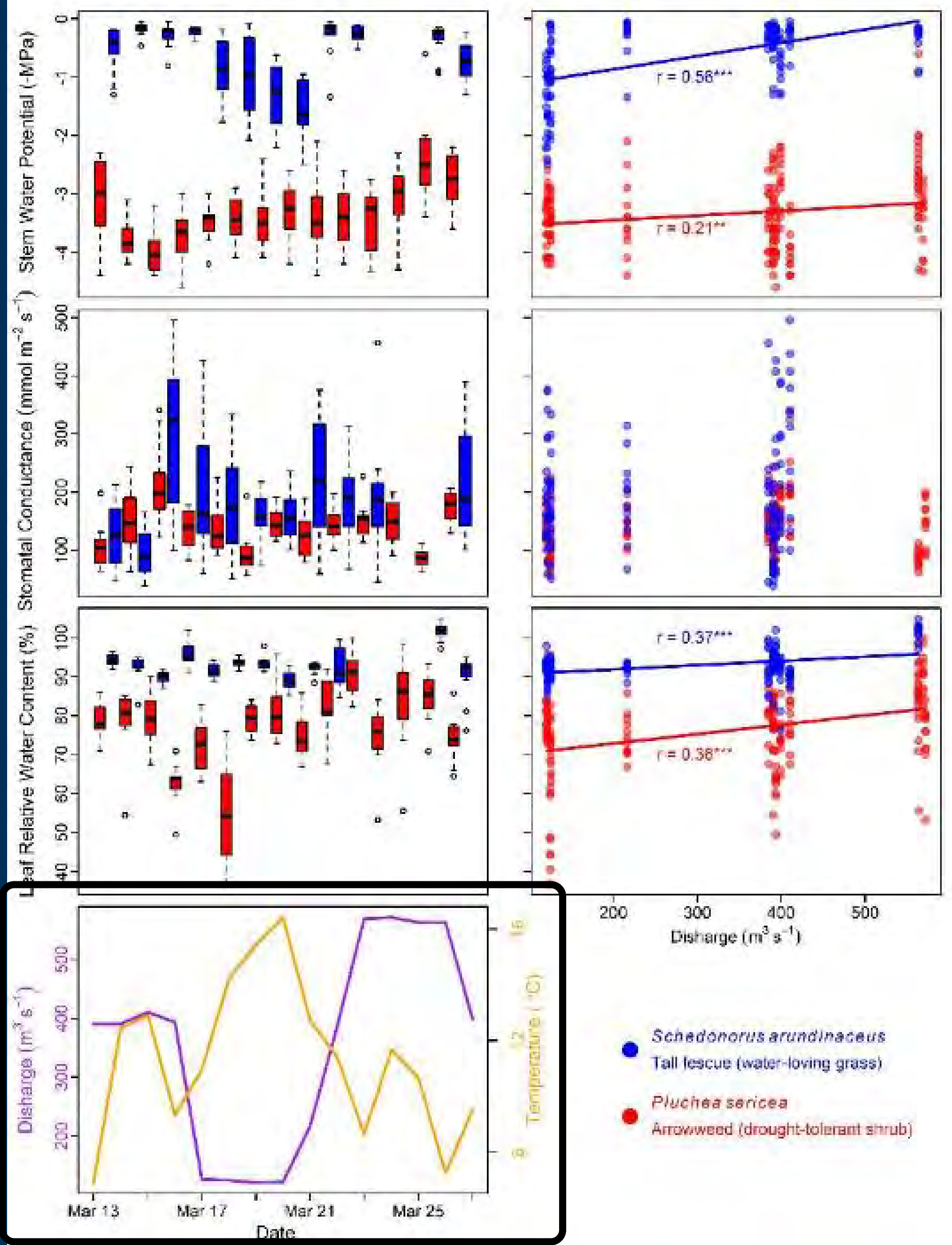
  - Arrowweed responded stronger to the wet-up
- Leaf relative water content responded positively to discharge



Preliminary results, subject to review, do not cite

Results: Both Species Responded to SDF

- **Stem water potential responded positively to discharge**
  - **Tall fescue responded stronger to dry-down**
  - **Arrowweed responded stronger to the wet-up**
- **Leaf relative water content responded positively to discharge**
- **Caveat: Weather did not cooperate**
  - **Though in multiple regression models, discharge remained significant while temperature was not**



USGS

Preliminary results, subject to review, do not cite

Conclusions

- Stem water potential appeared to be the most sensitive response to flow variation
- The water-loving grass (tall fescue) appeared to respond most strongly to the dry-down, reflecting its dependence on consistent soil moisture
- The drought-tolerant shrub (arrowweed) appeared to respond most strongly to the wet-up, reflecting its ability to capitalize on enhanced soil moisture that feeds up the soil profile through capillary action
- Not entirely capable of teasing apart flow and weather effects
- Most species were not photosynthetically active at this time of year, so were unlikely to be affected by the SDF

Aquatic vegetation in Glen Canyon: Observations following a Spring Disturbance Flow

Kimberly Dibble, Mike Yard, Bob Tusso, Dan Buscombe

(with contributions from Ted Kennedy and Jeff Muehlbauer)

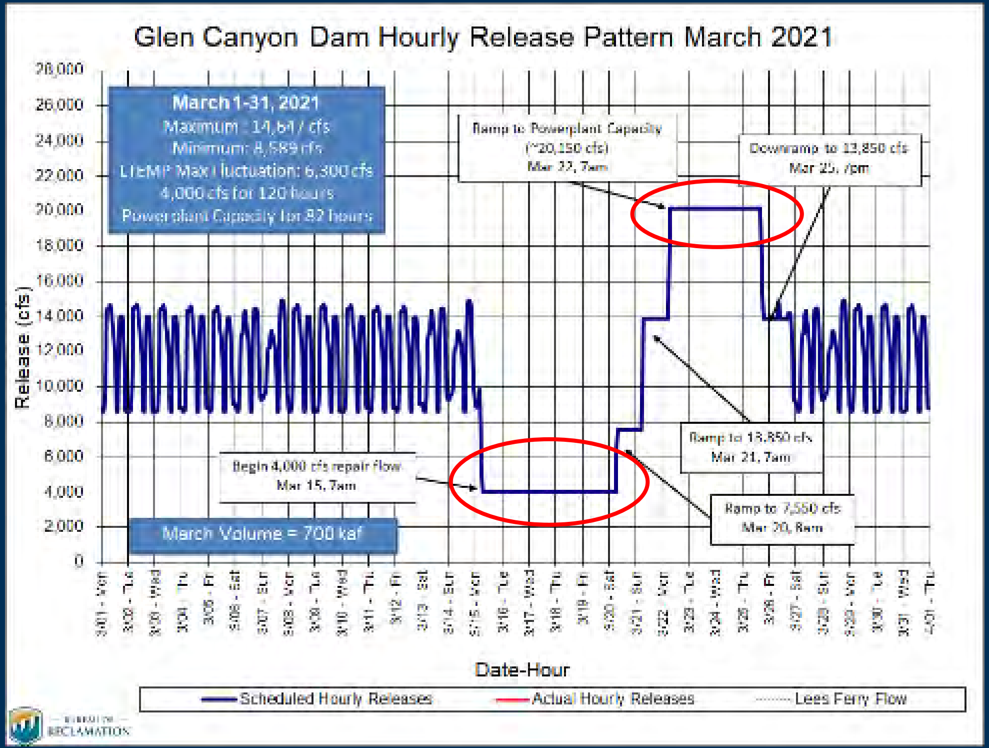
GCDAMP Annual Reporting Meeting

January 12, 2022

Freshwaters Illustrated, 2021

Project O.5: How will the pulse flow affect aquatic vegetation?

Background



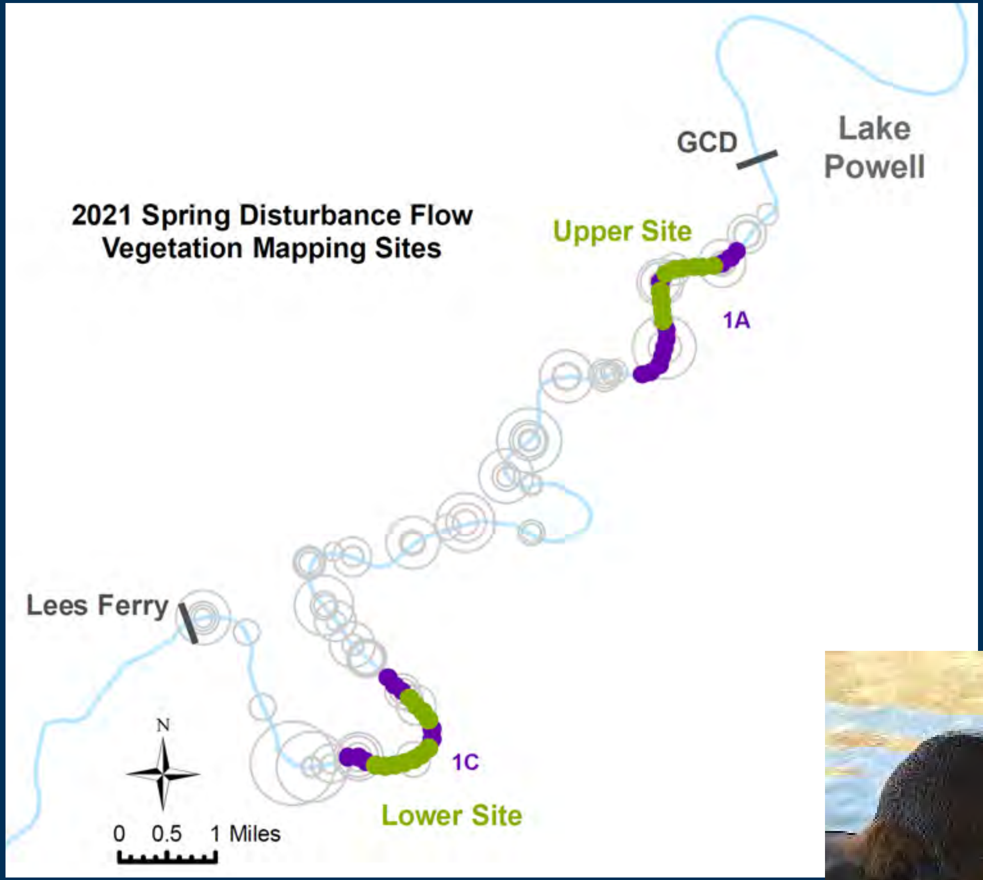
https://www.usgs.gov/centers/sbsc/science/timing-really-everything-evaluating-resource-response-spring-disturbance-flows?

- Prolonged desiccation followed by an increase in sheer stress will export organic matter and aquatic vegetation from LF
- Scour and cleaning of cobble will facilitate re-growth of diatom assemblages that are more palatable to invertebrate consumers, which may stimulate higher trophic levels

- Hypothesis: The SDF will have a greater effect on macroalgal species at the littoral edge such as Chara, Cladophora, and Ulothrix, while rooted macrophytes (Potamogeton) and bryophytes (Fontinalis spp.) located deeper in the water column will be less affected by the flow.

Project O.5: Methods

- Field surveys
  - Photos taken in August 2016 and June 2019 (Element E.2)
  - 2021 SDF trips
    - Pre-flow: March 9-11
    - Post-Flow: March 29-31, July 21-22
  - 48,084 total images
  - Upper site (RM -13.2 to -14.2) and lower site (RM-3.0 to -4.2)
  - Overlaps with TRGD 1A & 1C
- Model development
  - Label images to train model (Dibble & Yard)
  - Create a machine learning model for image segmentation of vegetation and substrate types (Buscombe)
  - Use model to create vegetation maps

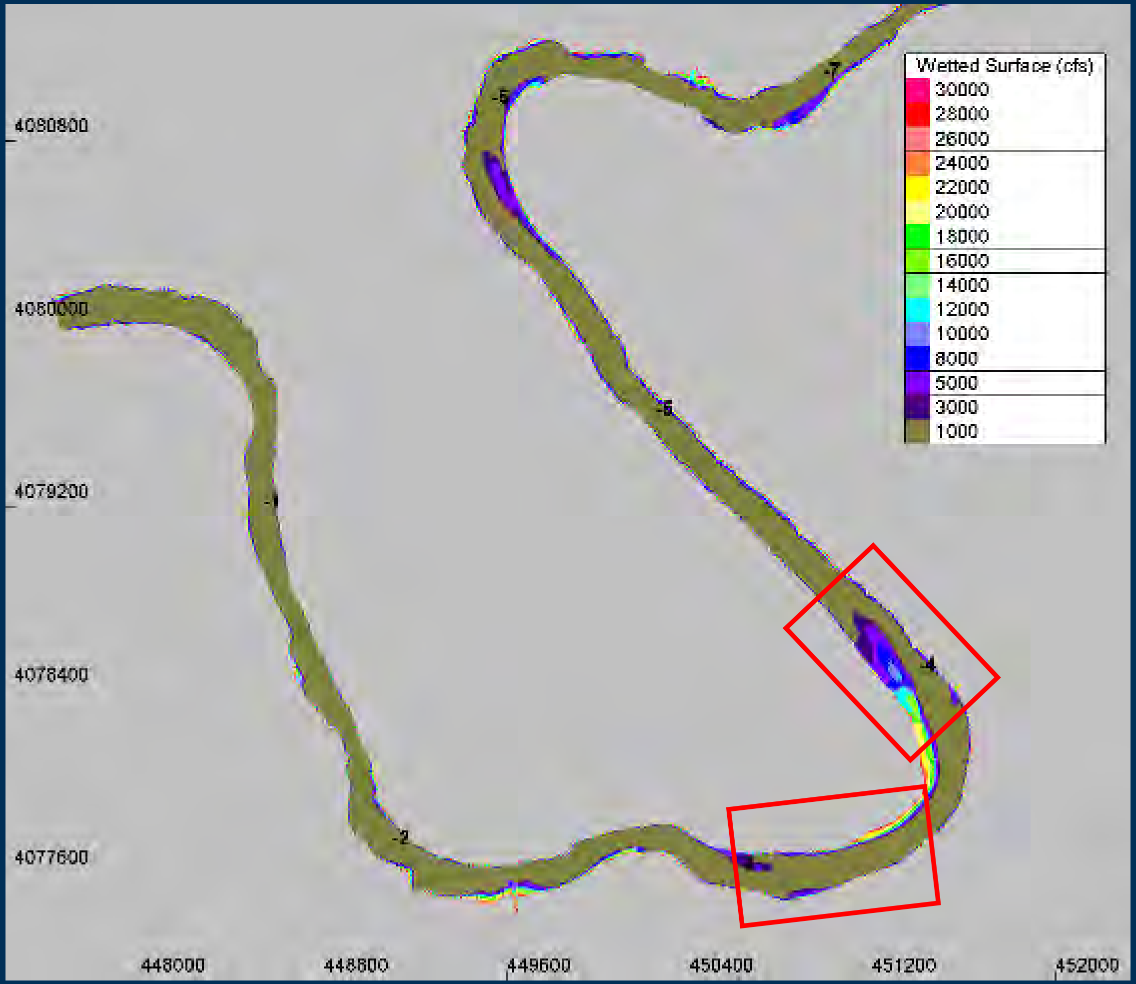


USGS

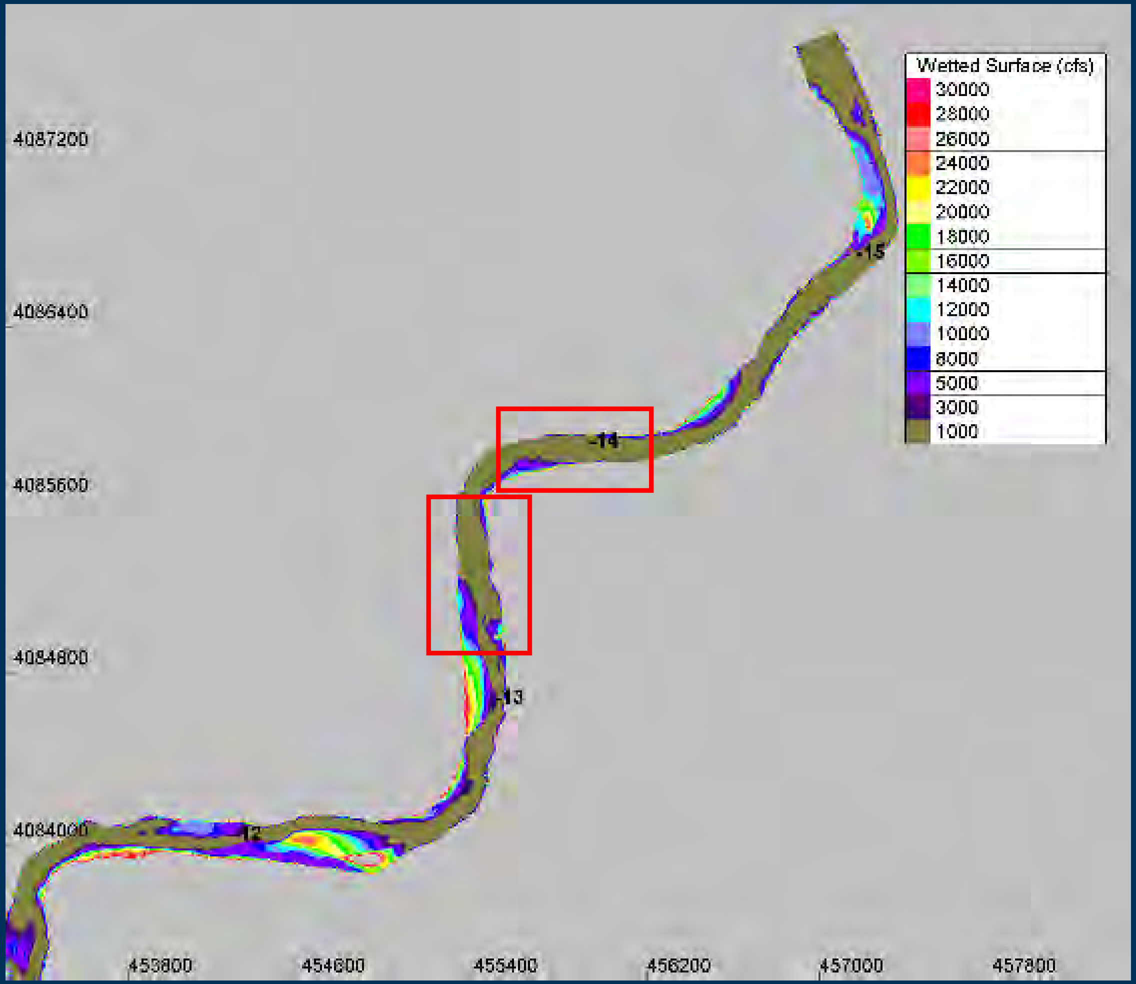
Preliminary results, subject to review, do not cite

Project O.5: Predicted desiccation at various flows

Lower Site



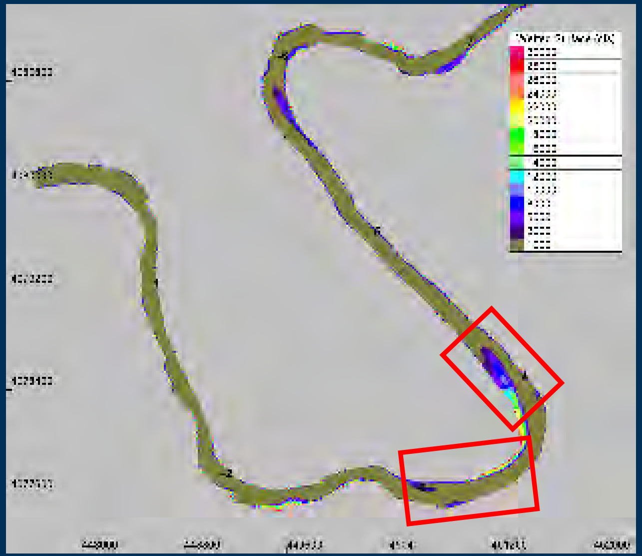
Upper Site



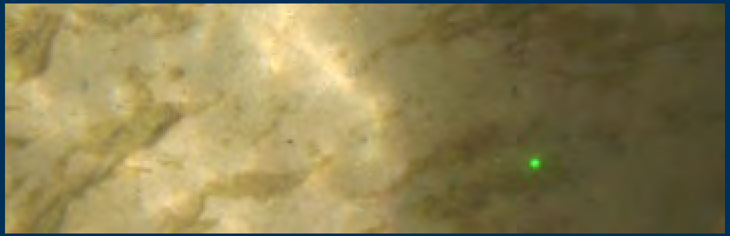
J. Korman, unpub. maps

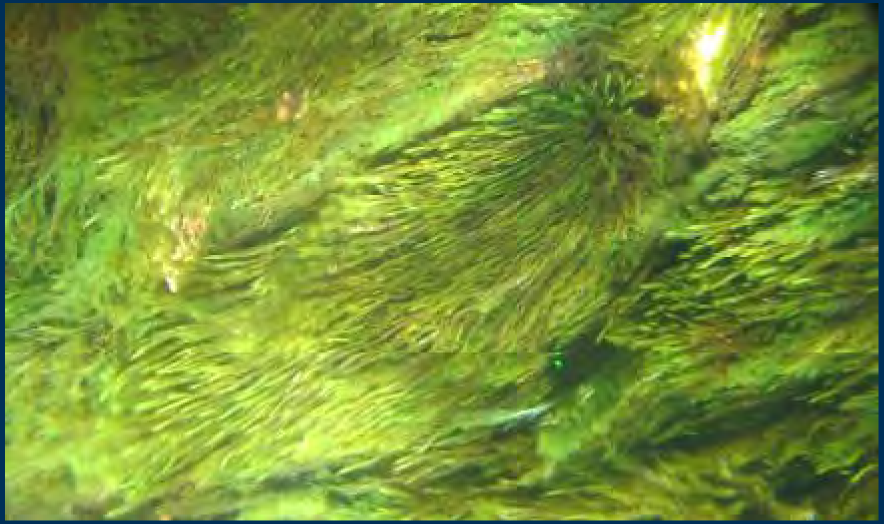
Preliminary results, subject to review, do not cite

Project O.5: Observations at lower site



J. Korman, unpub. maps

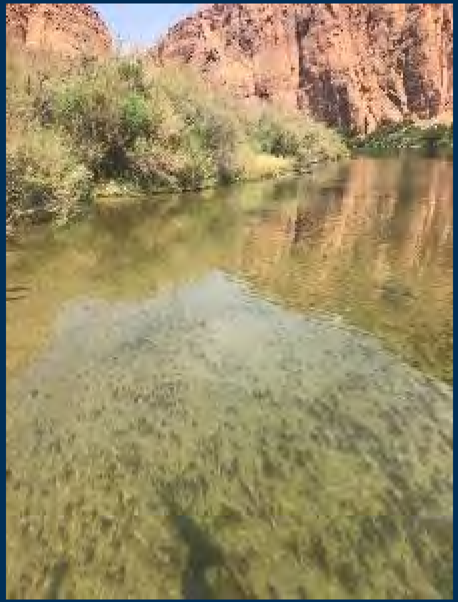


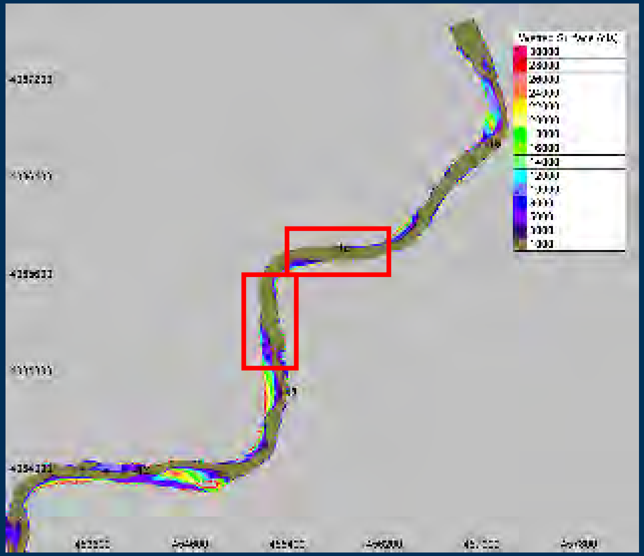


USGS

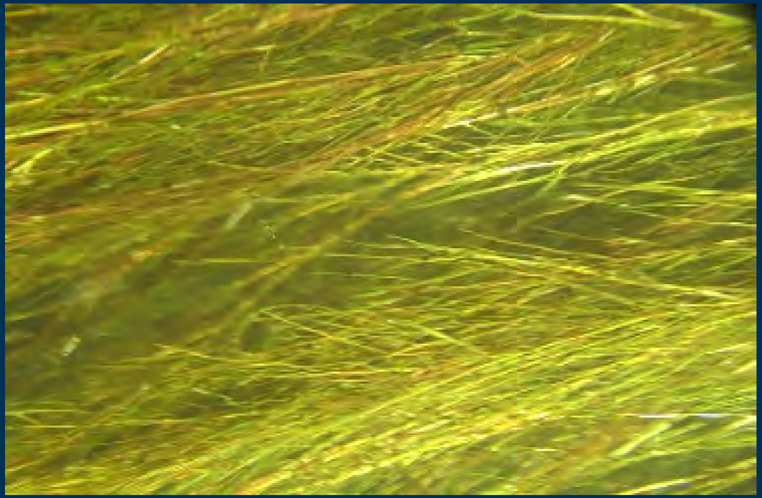
Preliminary results, subject to review, do not cite

Project O.5: Observations at upper site





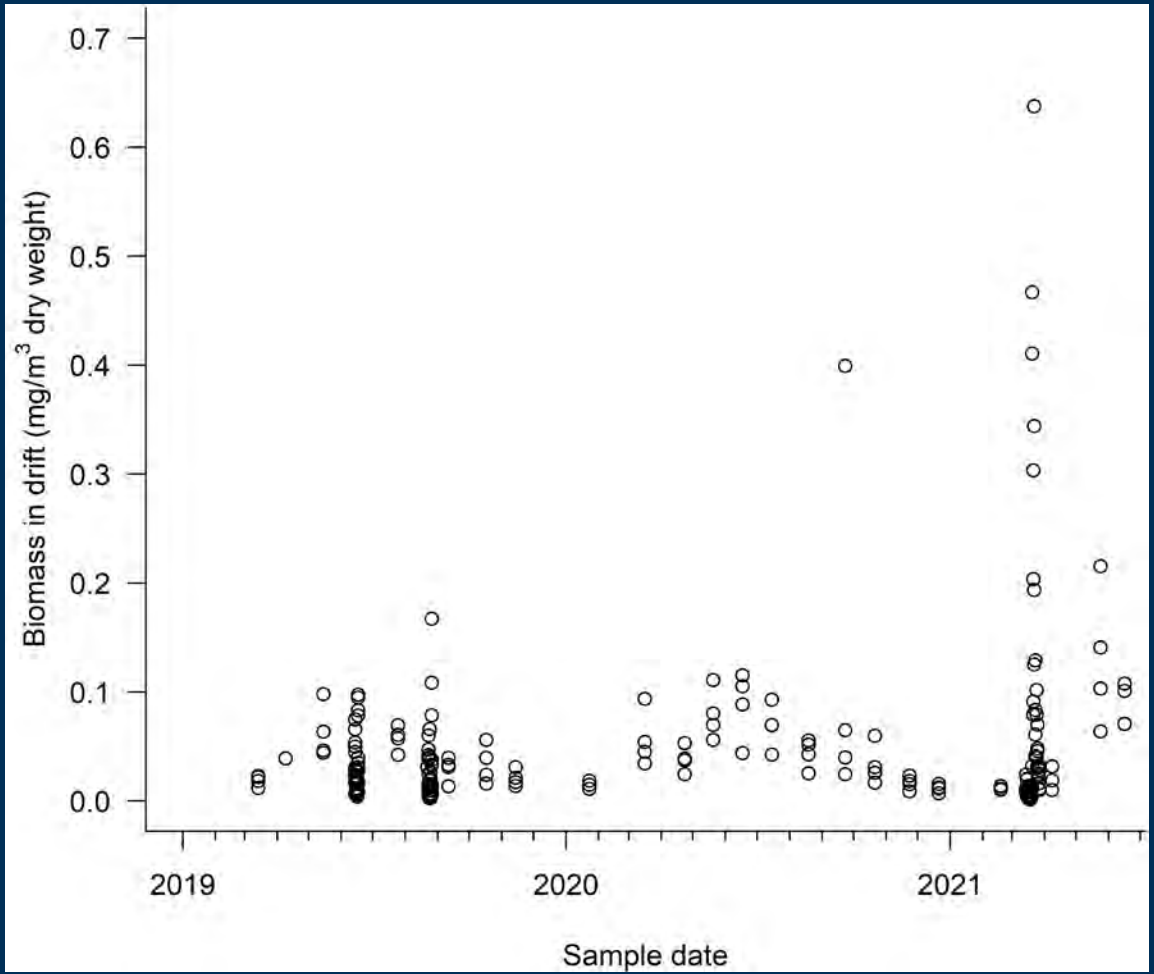
J. Korman, unpub. maps

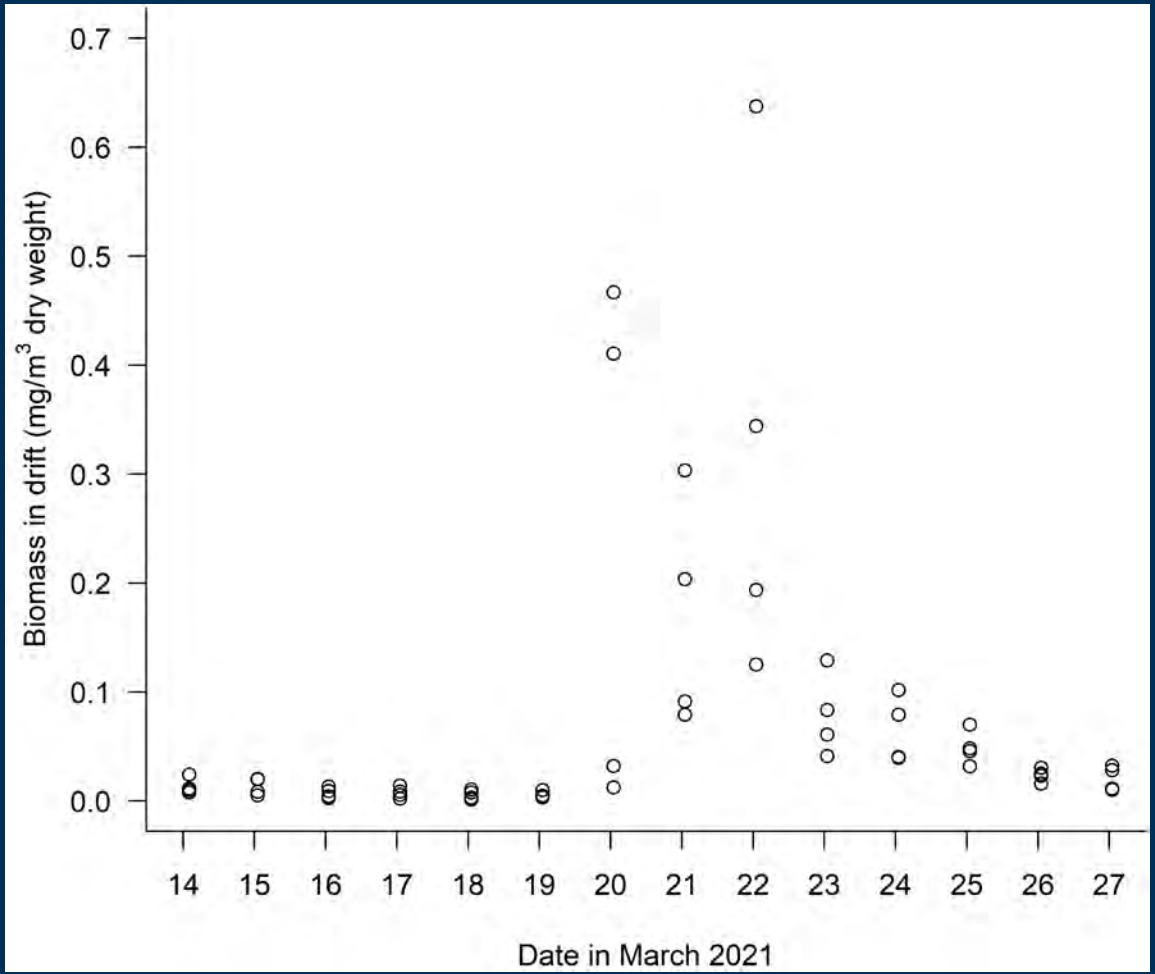


USGS

Preliminary results, subject to review, do not cite

Project O.1: Organic matter transport resulting from SDF





Kennedy and Muehlbauer, unpub. data, do not cite

USGS

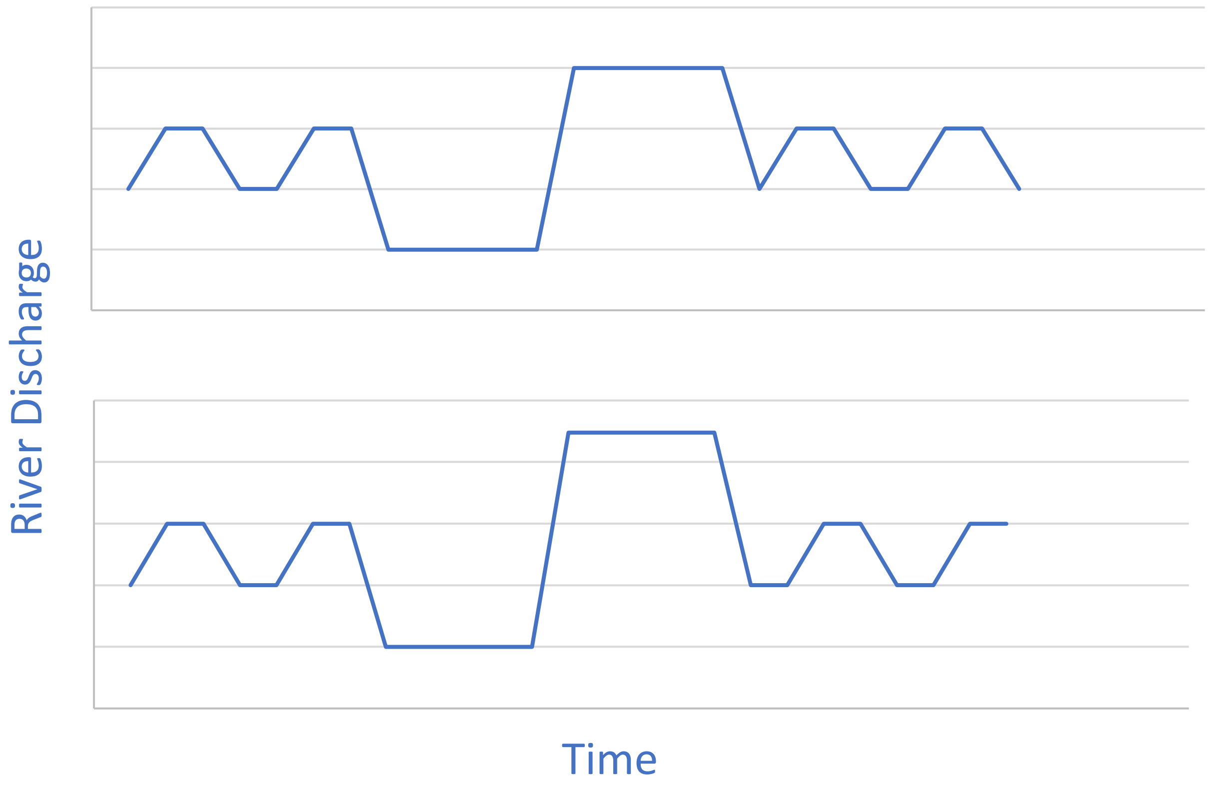
Preliminary results, subject to review, do not cite

Future Disturbance Flows

Macrophytes

2021 Spring disturbance flow

Potential future disturbance: low flow remains the same to desiccate nearshore habitat, but high flow is higher to disturb rooted macrophytes



Preliminary results, subject to review, do not cite

Nearshore habitat use and distribution of age-0 trout in Spring 2021

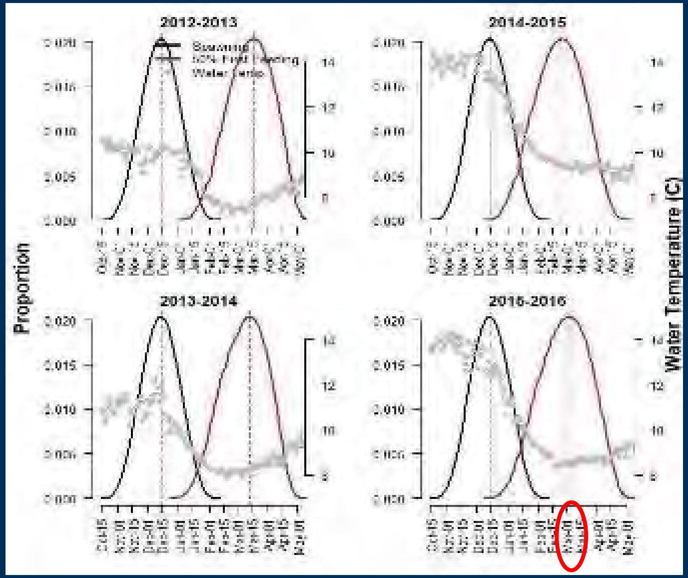
Kimberly Dibble, Laura Tennant, and Clay Nelson
(with collaborators Mike Yard and Josh Korman)

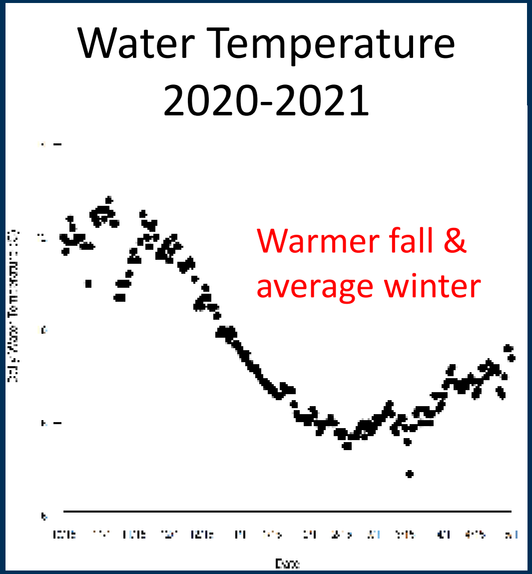
GCDAMP Annual Reporting Meeting
January 12, 2022

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

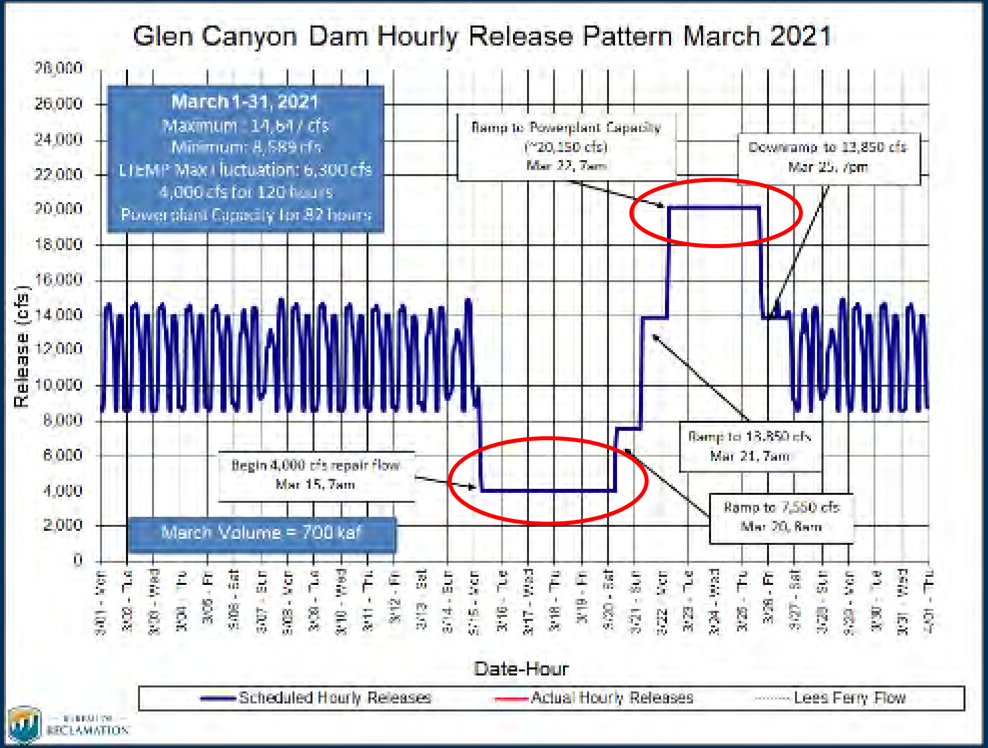
Project O.6: How will the pulse flow affect juvenile brown trout?

Background





Korman and Yard, unpublished data, do not cite



- Peak brown trout emergence occurs in March
  - Warmer temperatures= ~March 1
  - Cooler temperatures= ~March 15
- SDF timing will likely affect the vulnerability of recently hatched or newly emerged brown trout

- Hypothesis: A low steady flow during peak emergence may temporarily improve swim-up and growth conditions for YOY trout, but the pulse will decrease survival due to energetic costs or displacement from nearshore habitats
- Objective: Determine the effect of the SDF on hatch date, emergence timing, habitat use, survival, and relative abundance

USGS

Preliminary results, subject to review, do not cite

Project O.6: Methods

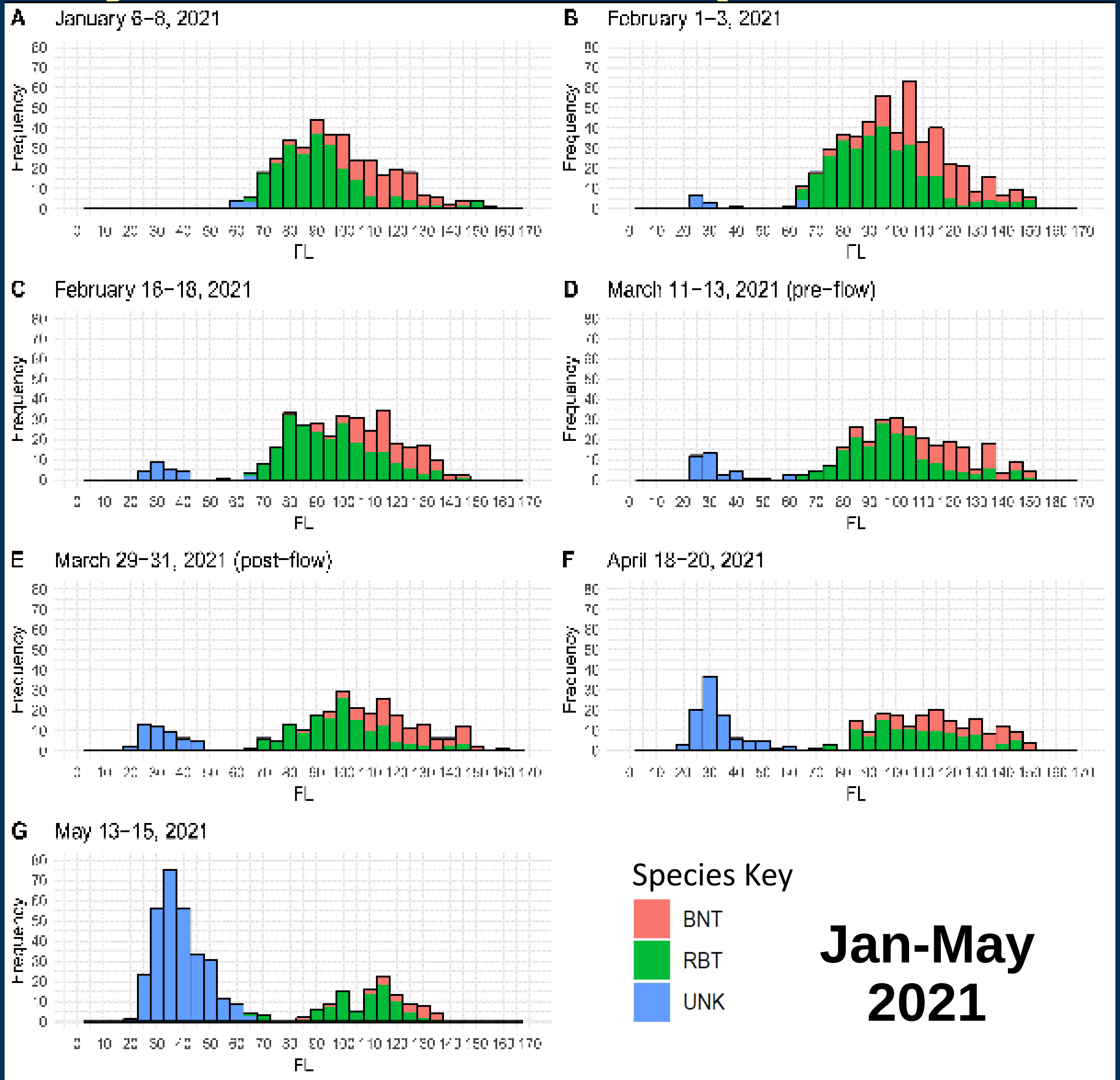
- **Brown Trout Early Life Stage Survey (BTELSS, Element H.3)**
- **Field surveys**
  - **RTELSS design (comparable data)**
  - **January-May (7 trips, 2021 & 2022)**
  - **40 sites, spatially distributed**
  - **Talus (high angle); cobble bars, sand bars, debris fans (low angle)**
- **Laboratory work**
  - **Hatch & emergence dates (otoliths)**
  - **Growth rates**
- **Compare data to year lacking Spring Disturbance Flow (2022)**

Field Surveys

Laboratory Work

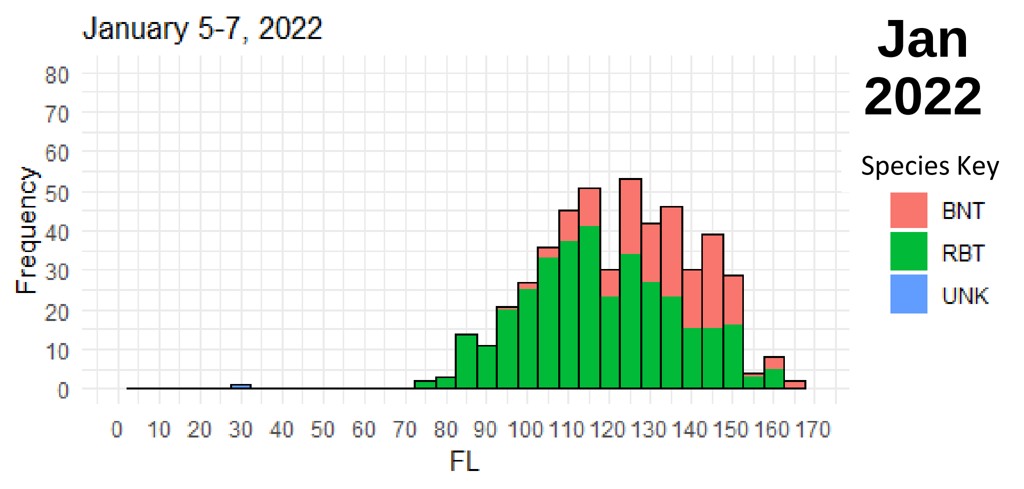
Daily Growth Increments on Otolith

Project O.6: Results (size structure)



Field Identification Challenges

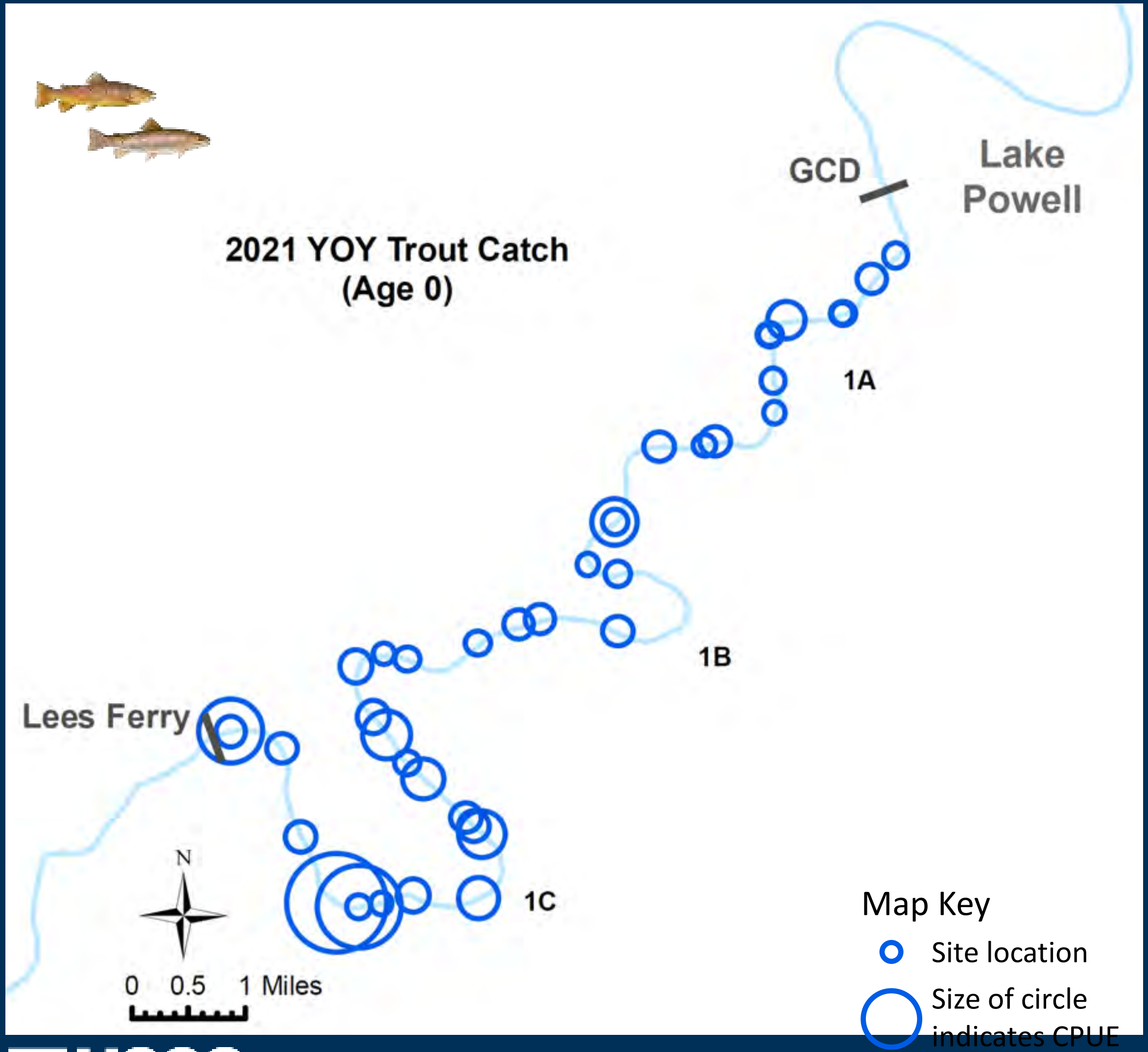
- Spawning periods overlap for brown and rainbow trout
- Larval fish difficult to identify in field
- Adipose fins may have characteristics of both species
- Issue will resolve in spring 2022
- ‘Unknown’ is YOY brown or rainbow trout (for now…)



Preliminary results, subject to review, do not cite

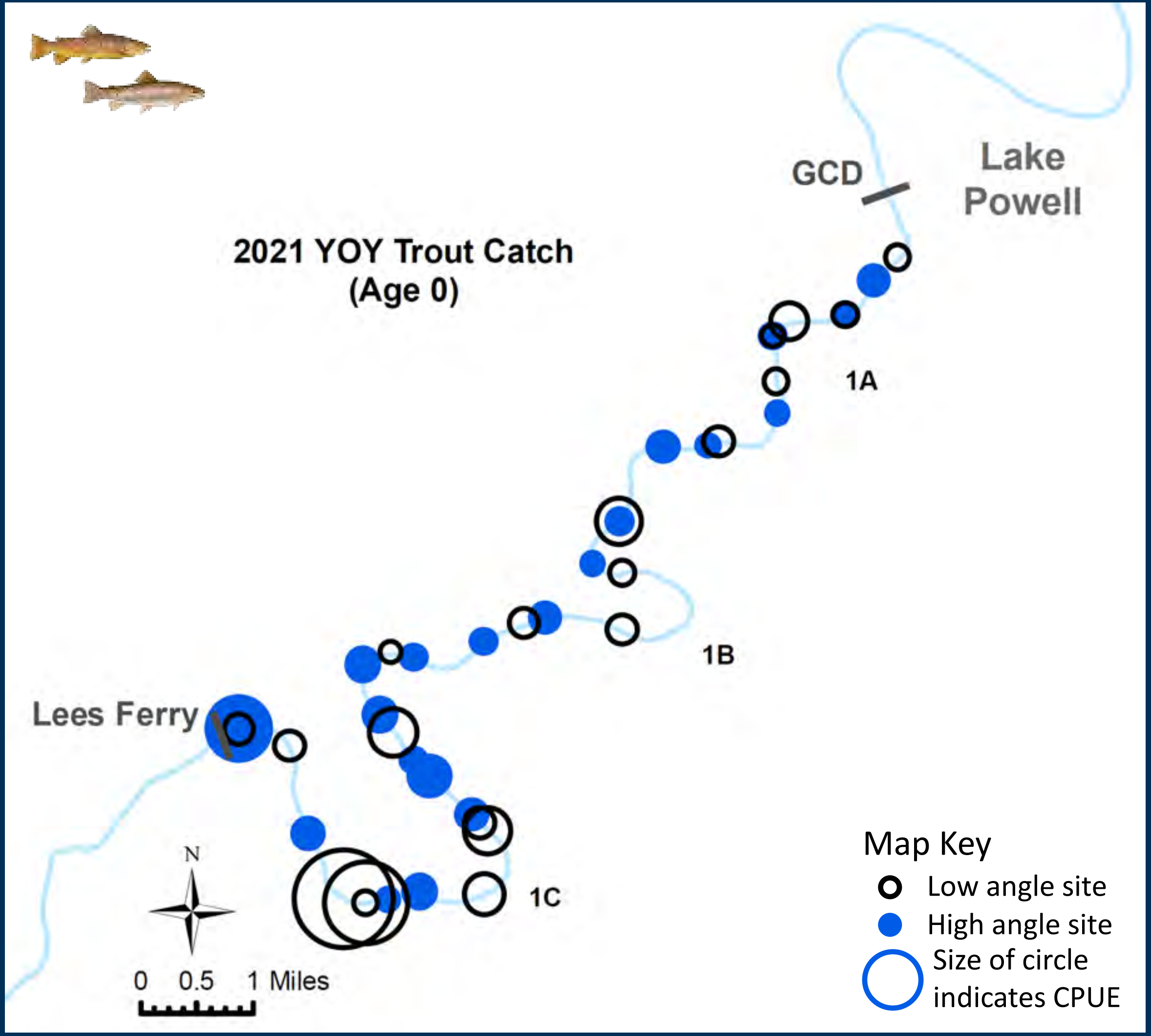
Project O.6: Results

Age-0 trout distribution and catch rates



YOY trout utilize low and high angle habitats throughout Lees Ferry

Relatively consistent catch rates except downstream from -4 mile bar

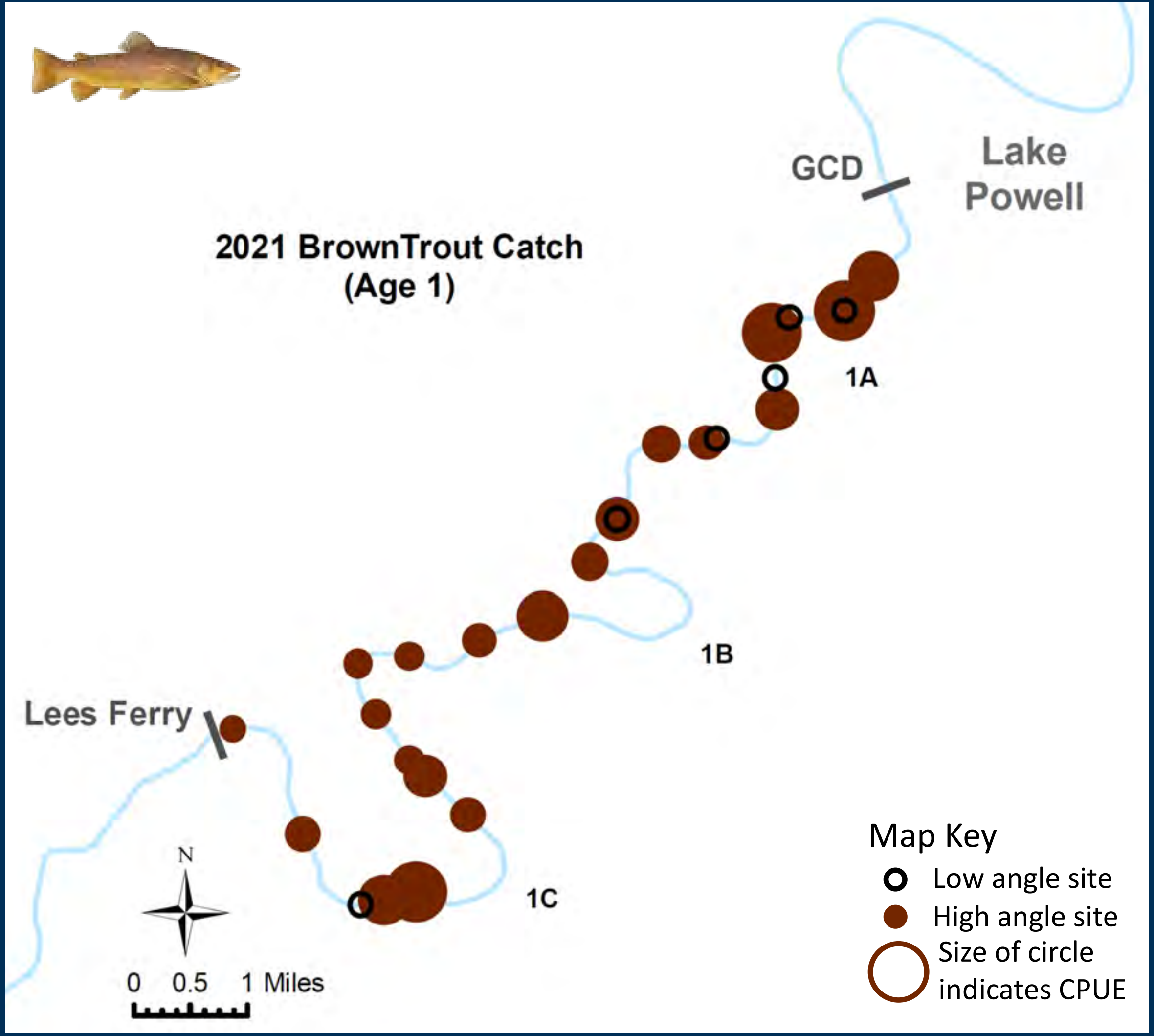


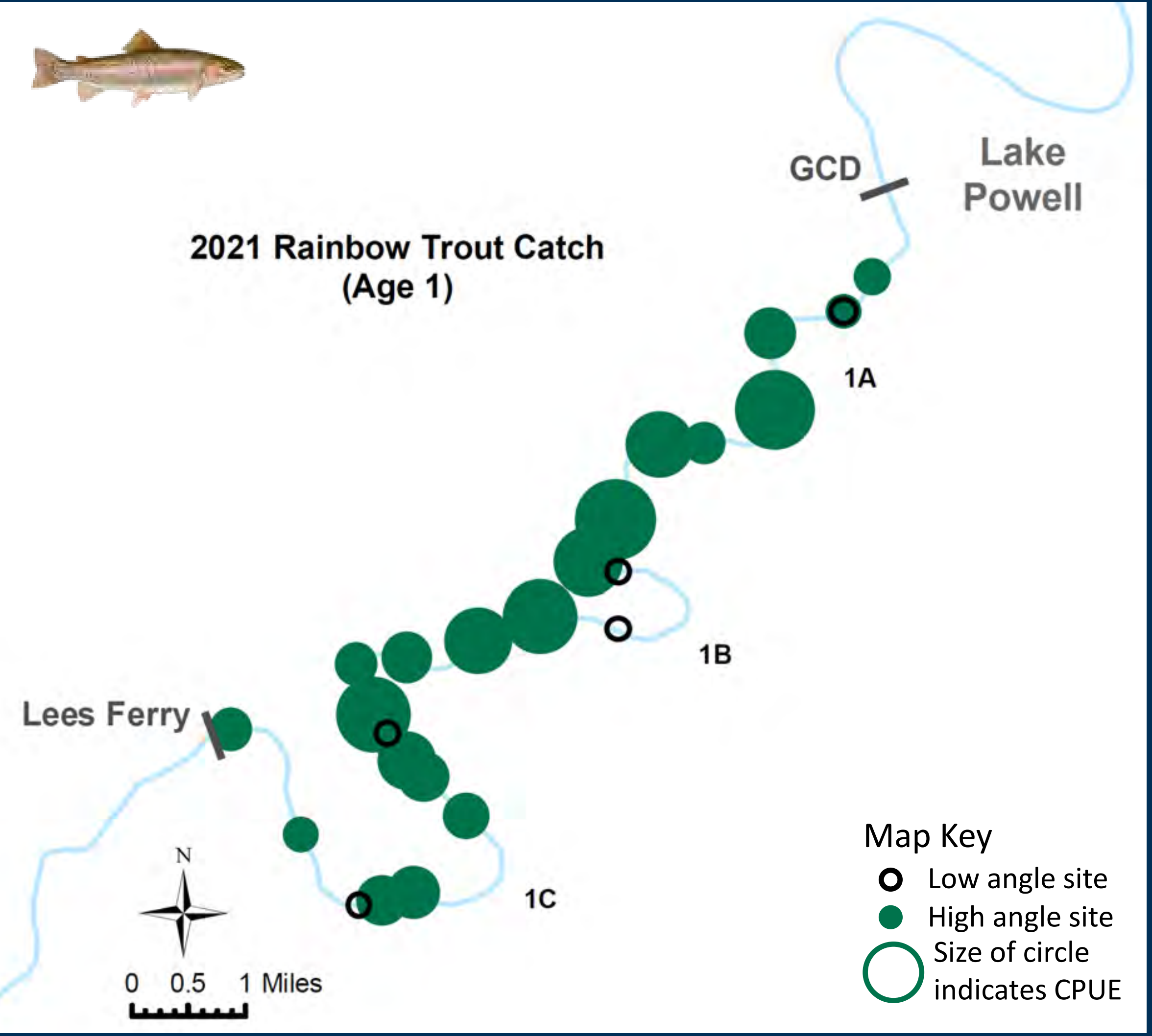
Preliminary results, subject to review, do not cite

Project O.6: Results
Age-1 trout distribution and catch rates

Brown trout primarily use high angle (talus) habitats and are spatially distributed throughout Lees Ferry. Catch is higher near TRGD reaches 1A and 1C.

Rainbow trout have higher catch rates than brown trout and are mostly captured in talus habitats.





USGS

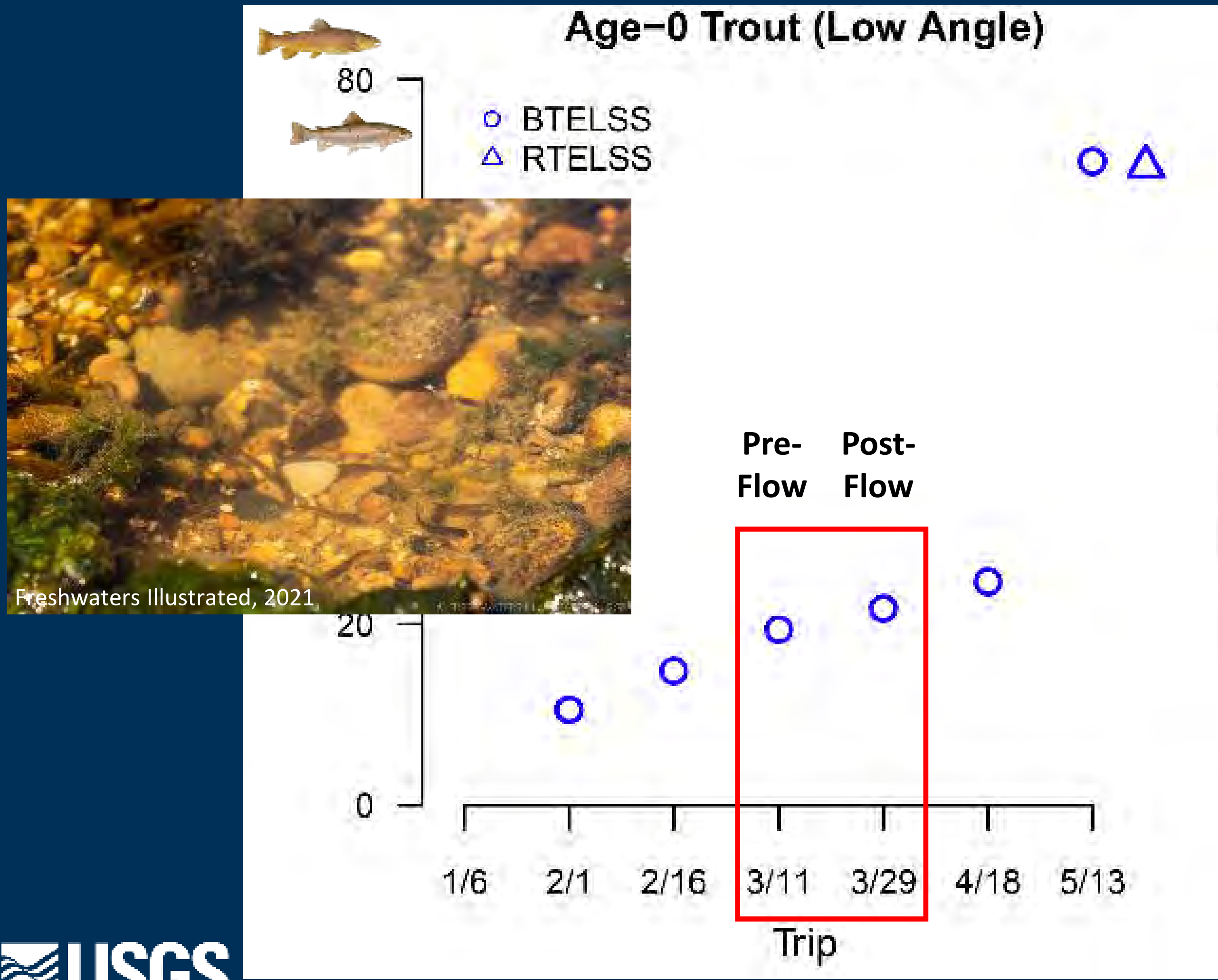
Preliminary results, subject to review, do not cite

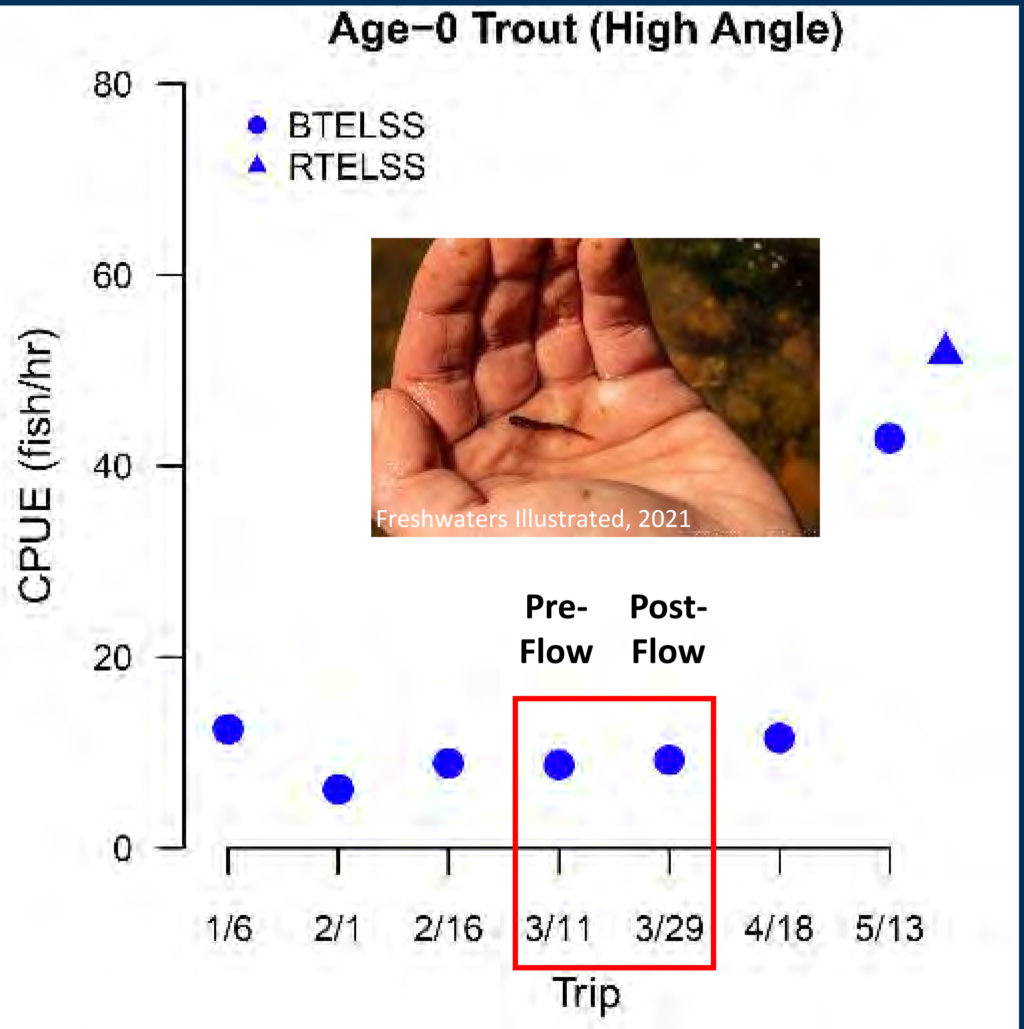
Project O.6: Results

Age-0 trout catch by trip and habitat use

YOY catch in low angle sites steadily increases from Feb-April. Large increase in YOY in May in both low/high angle sites could be RBT, consistent with RTELSS data.

The SDF does not appear to have affected YOY trout catch, but more analysis and clarity is needed on species identification.





USGS

Preliminary results, subject to review, do not cite

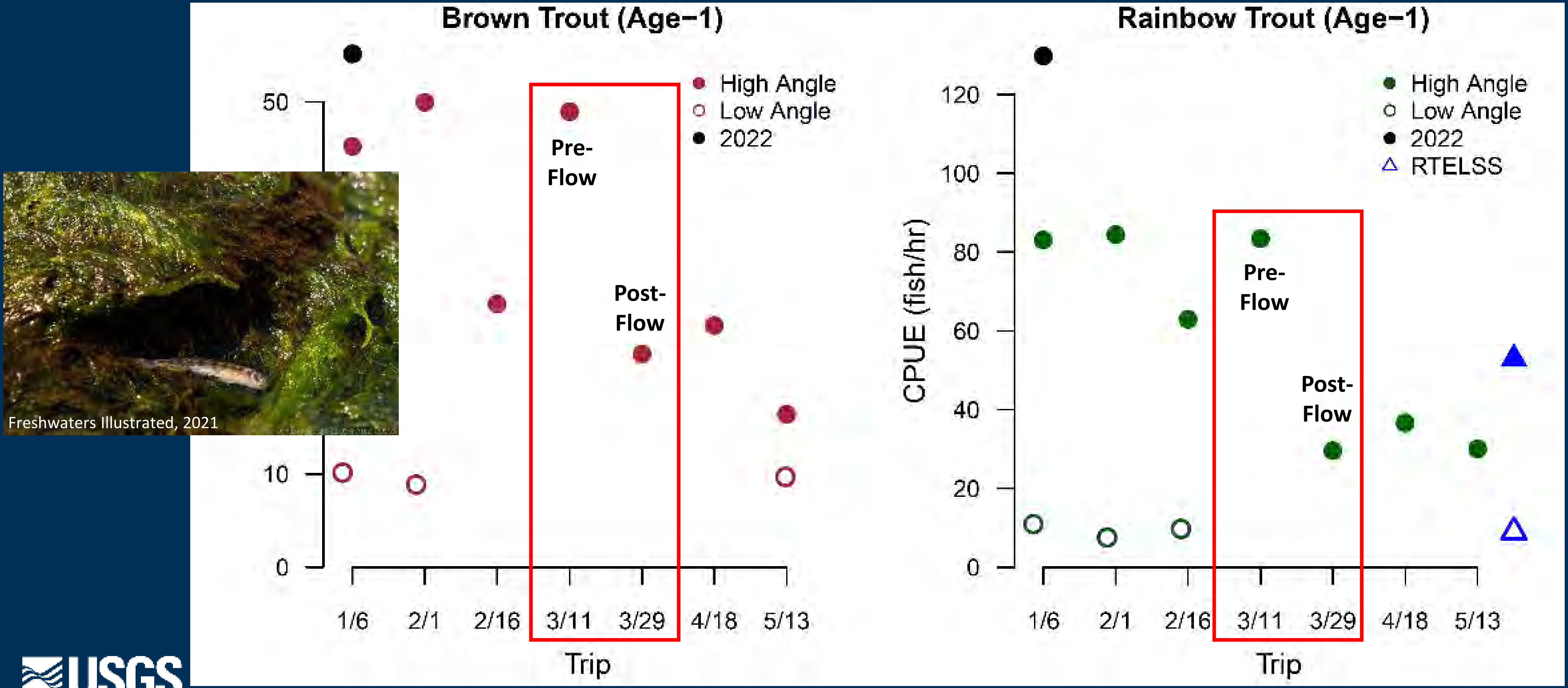
Project O.6: Results

Age-1 trout catch by trip and habitat use

Brown & rainbow trout catch is consistent in low angle habitats.

Brown & rainbow trout catch declines in talus from January-May. This may indicate movement offshore into deeper habitats or mortality.

The pre- and post-flow difference may be part of a natural declining trend in talus habitat use, but data from a non-SDF year is needed.



Freshwaters Illustrated, 2021

USGS

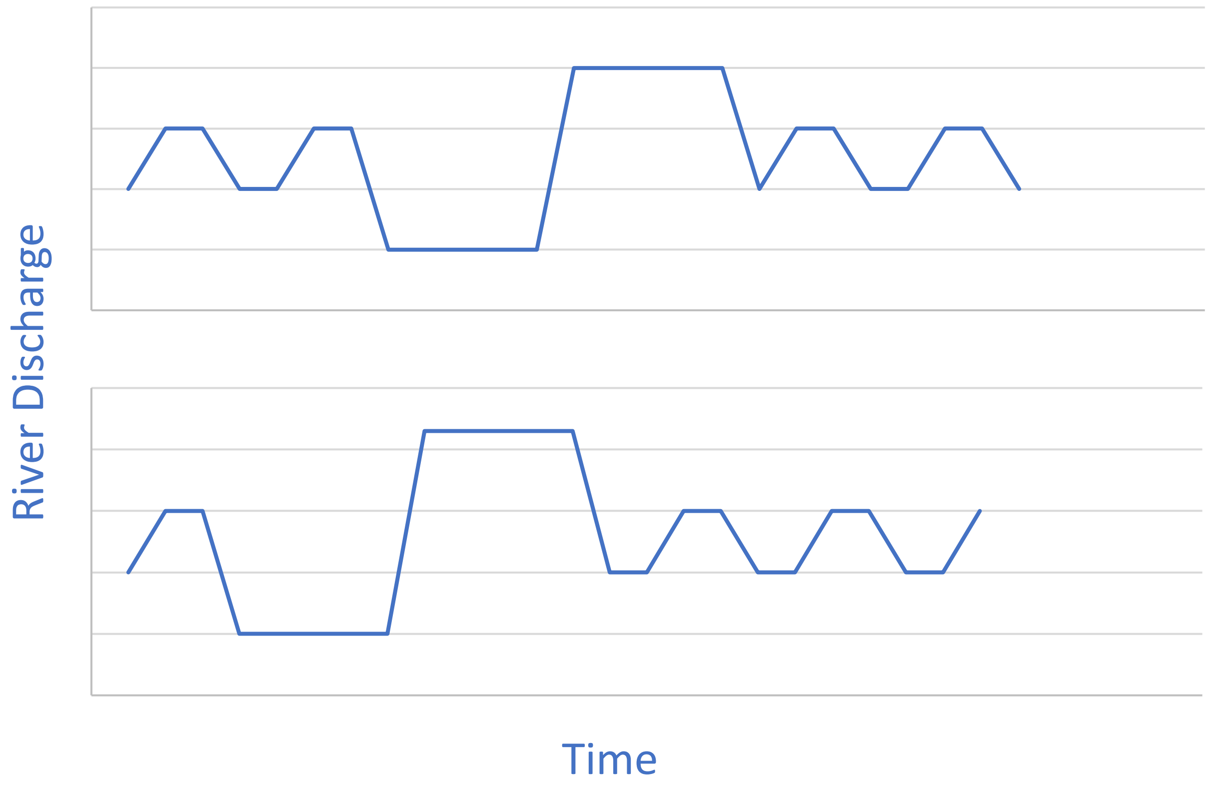
Preliminary results, subject to review, do not cite

Future Disturbance Flows

Trout

2021 Spring disturbance flow

Potential future disturbance: low flow is earlier and high flow is slightly higher, timed during peak emergence



Preliminary results, subject to review, do not cite

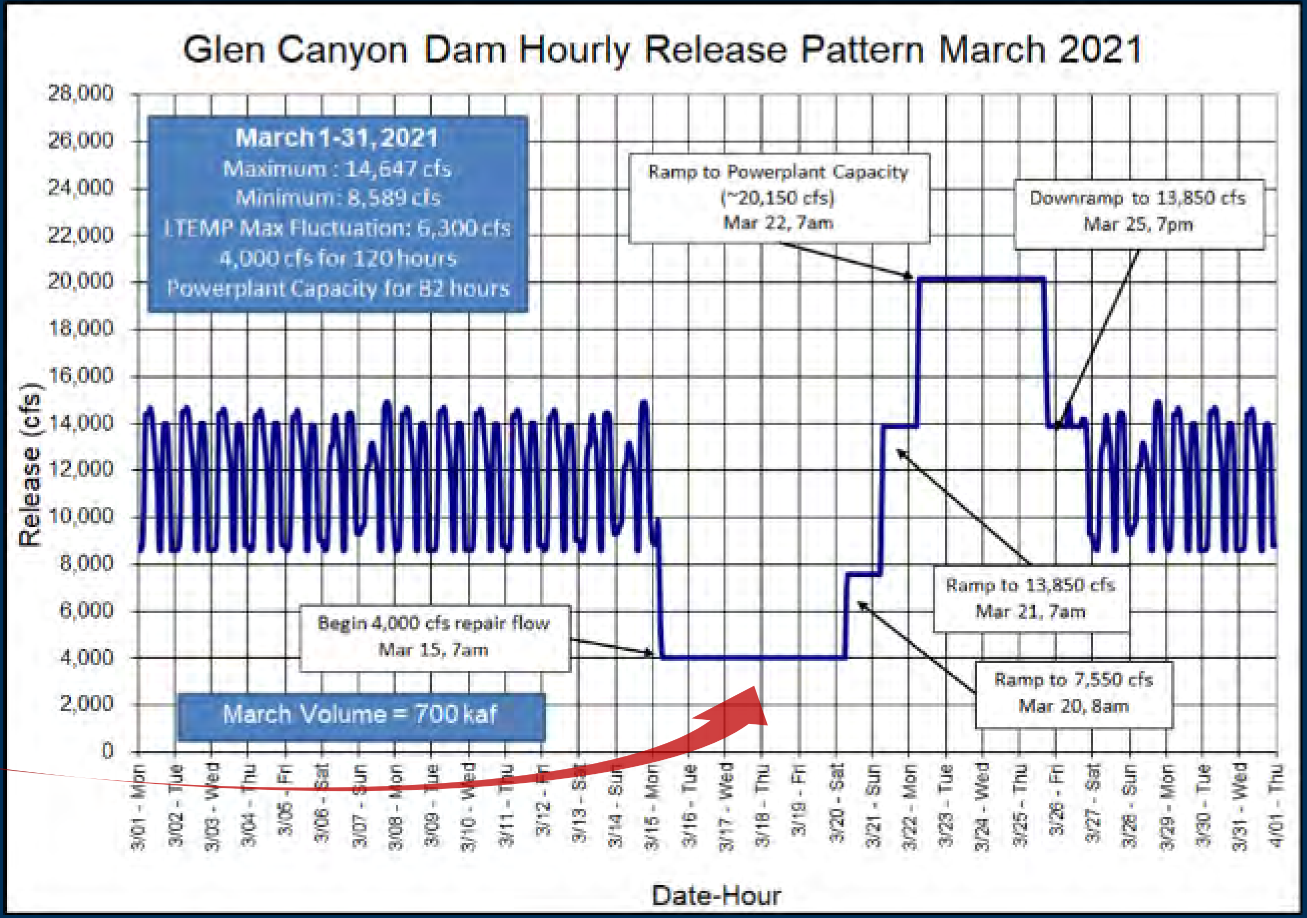
Lees Ferry angler's expectations and response to the Spring Disturbance Flow

Lucas Bair, U.S. Geological Survey
Chris Neher, University of Montana

GCDAMP Annual Reporting Meeting
January 12, 2022

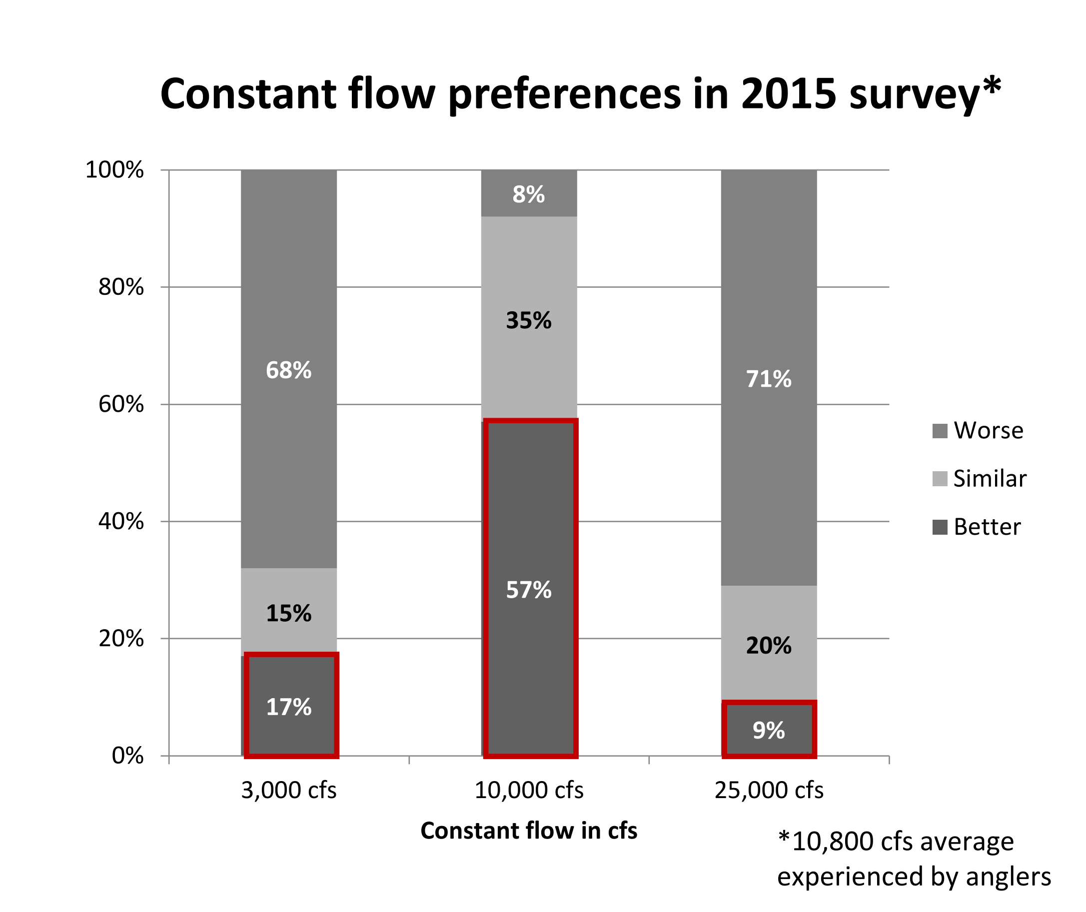
Project Element O.8. Do Disturbance Flows Significantly Impact Recreational Experience?

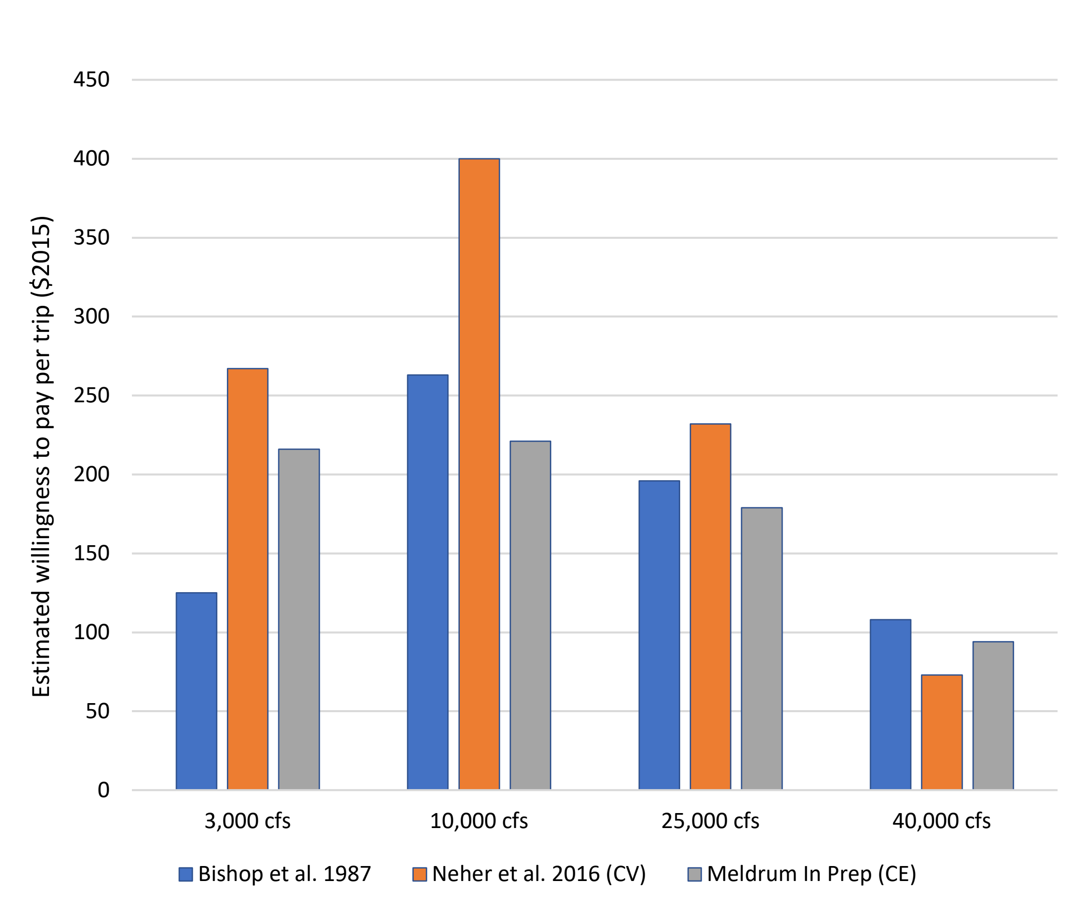
- The objective of this project element is to refine our understanding of recreational preferences for flow attributes specific to spring disturbance flows.
- Focused on the five-day steady low flow (4,000 cfs) during the disturbance event.



USGS

Project Element O.8: Background

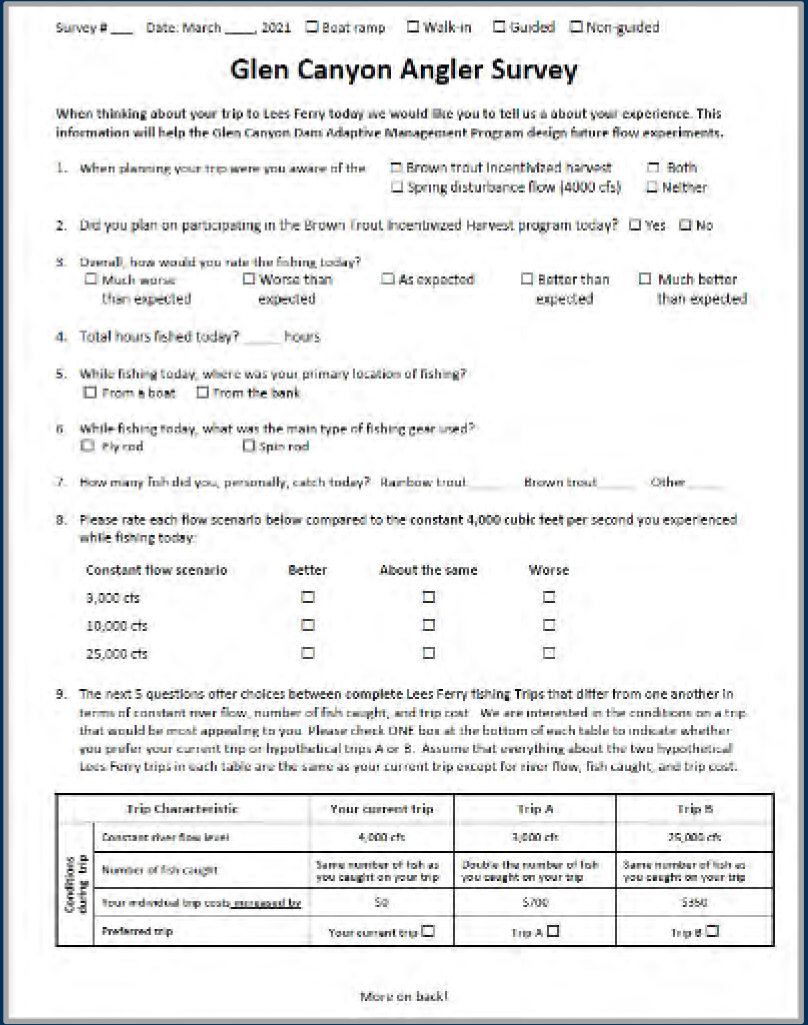




Preliminary results, subject to review, do not cite

Project Element O.8: Methods

- Angler choice experiment survey
- Modified creel survey that respondents completed and returned by mail
- 150 survey forms were distributed
- 79 completed for an overall response rate of 52.7%



Survey # ___ Date: March ____, 2021 ☐ Boat ramp ☐ Walk-in ☐ Guided ☐ Non-guided

Glen Canyon Angler Survey

When thinking about your trip to Lees Ferry today we would like you to tell us a about your experience. This information will help the Glen Canyon Dam Adaptive Management Program design future flow experiments.

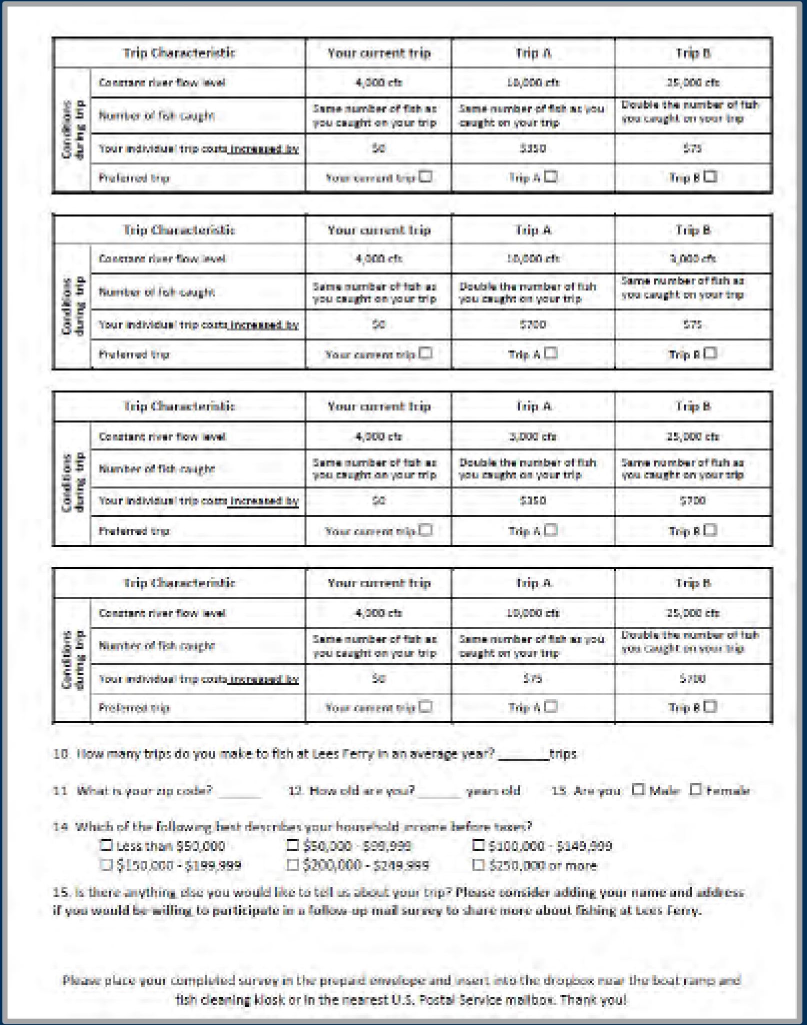
1. When planning your trip were you aware of the ☐ Brown trout Incentivized harvest ☐ Spring disturbance flow (4000 cfs) ☐ Both ☐ Neither
2. Did you plan on participating in the Brown Trout Incentivized Harvest program today? ☐ Yes ☐ No
3. Overall, how would you rate the fishing today? ☐ Much worse than expected ☐ Worse than expected ☐ As expected ☐ Better than expected ☐ Much better than expected
4. Total hours fished today? ____ hours
5. While fishing today, where was your primary location of fishing? ☐ From a boat ☐ From the bank
6. While fishing today, what was the main type of fishing gear used? ☐ Fly rod ☐ Spin rod
7. How many fish did you, personally, catch today? Rainbow trout____ Brown trout____ Other____
8. Please rate each flow scenario below compared to the constant 4,000 cubic feet per second you experienced while fishing today:

Constant flow scenario	Better	About the same	Worse
3,000 cfs	☐	☐	☐
10,000 cfs	☐	☐	☐
25,000 cfs	☐	☐	☐

9. The next 5 questions offer choices between complete Lees Ferry fishing Trips that differ from one another in terms of constant river flow, number of fish caught, and trip cost. We are interested in the conditions on a trip that would be most appealing to you. Please check ONE box at the bottom of each table to indicate whether you prefer your current trip or hypothetical trips A or B. Assume that everything about the two hypothetical Lees Ferry trips in each table are the same as your current trip except for river flow, fish caught, and trip cost.

	Trip Characteristic	Your current trip	Trip A	Trip B
Conditions during trip	Constant river flow level	4,000 cfs	3,000 cfs	25,000 cfs
	Number of fish caught	Same number of fish as you caught on your trip	Double the number of fish you caught on your trip	Same number of fish as you caught on your trip
	Your individual trip costs increased by	$0	$700	$350
	Preferred trip	Your current trip ☐	Trip A ☐	Trip B ☐

More on back!



	Trip Characteristic	Your current trip	Trip A	Trip B
Conditions during trip	Constant river flow level	4,000 cfs	10,000 cfs	25,000 cfs
	Number of fish caught	Same number of fish as you caught on your trip	Same number of fish as you caught on your trip	Double the number of fish you caught on your trip
	Your individual trip costs increased by	$0	$350	$75
	Preferred trip	Your current trip ☐	Trip A ☐	Trip B ☐

	Trip Characteristic	Your current trip	Trip A	Trip B
Conditions during trip	Constant river flow level	4,000 cfs	10,000 cfs	3,000 cfs
	Number of fish caught	Same number of fish as you caught on your trip	Double the number of fish you caught on your trip	Same number of fish as you caught on your trip
	Your individual trip costs increased by	$0	$700	$75
	Preferred trip	Your current trip ☐	Trip A ☐	Trip B ☐

	Trip Characteristic	Your current trip	Trip A	Trip B
Conditions during trip	Constant river flow level	4,000 cfs	3,000 cfs	25,000 cfs
	Number of fish caught	Same number of fish as you caught on your trip	Double the number of fish you caught on your trip	Same number of fish as you caught on your trip
	Your individual trip costs increased by	$0	$350	$700
	Preferred trip	Your current trip ☐	Trip A ☐	Trip B ☐

	Trip Characteristic	Your current trip	Trip A	Trip B
Conditions during trip	Constant river flow level	4,000 cfs	10,000 cfs	25,000 cfs
	Number of fish caught	Same number of fish as you caught on your trip	Same number of fish as you caught on your trip	Double the number of fish you caught on your trip
	Your individual trip costs increased by	$0	$75	$700
	Preferred trip	Your current trip ☐	Trip A ☐	Trip B ☐

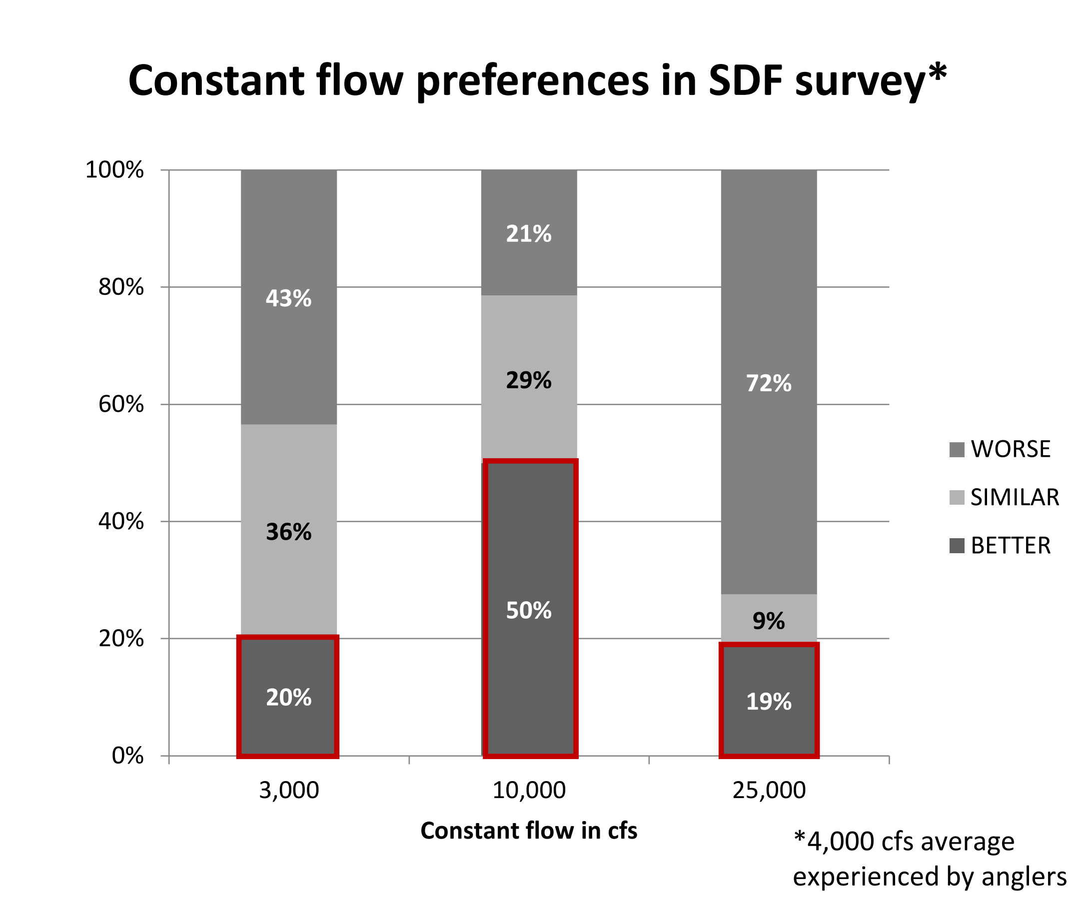
10. How many trips do you make to fish at Lees Ferry in an average year? ______trips
11. What is your zip code? ______ 12. How old are you? ______ years old 13. Are you ☐ Male ☐ Female
14. Which of the following best describes your household income before taxes? ☐ Less than $50,000 ☐ $50,000 - $99,999 ☐ $100,000 - $149,999 ☐ $150,000 - $199,999 ☐ $200,000 - $249,999 ☐ $250,000 or more
15. Is there anything else you would like to tell us about your trip? Please consider adding your name and address if you would be willing to participate in a follow-up mail survey to share more about fishing at Lees Ferry.

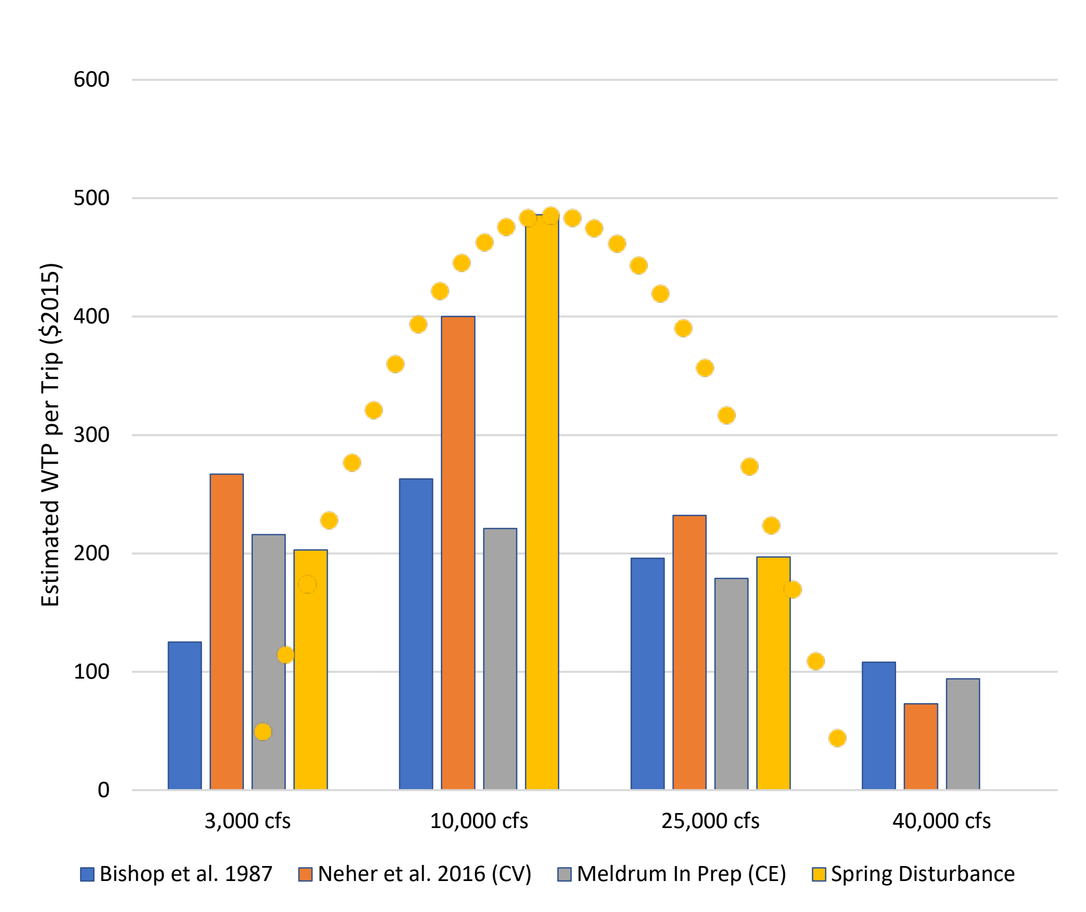
Please place your completed survey in the prepaid envelope and insert into the dropbox near the boat ramp and fish cleaning kiosk or in the nearest U.S. Postal Service mailbox. Thank you!

Preliminary results, subject to review, do not cite

USGS

Project Element O.8: Results





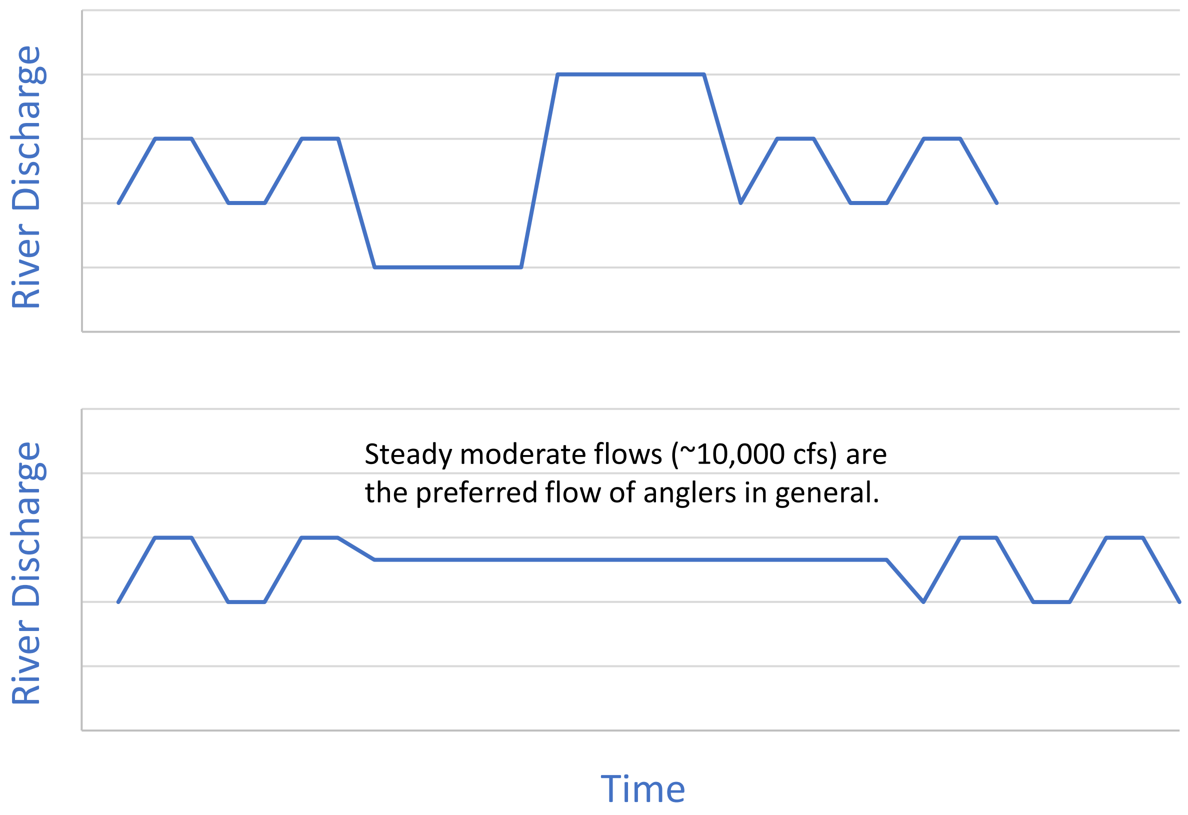
Preliminary results, subject to review, do not cite

Hypotheses Regarding Future Disturbance Flows

Recreational angling

2021 Spring
Disturbance Flow

The best disturbance flow for recreational angling (in the short run) is no disturbance at all.



Preliminary results, subject to review, do not cite

Effects of the March 2021 Disturbance Flow on subaerial sandbars

GCDAMP

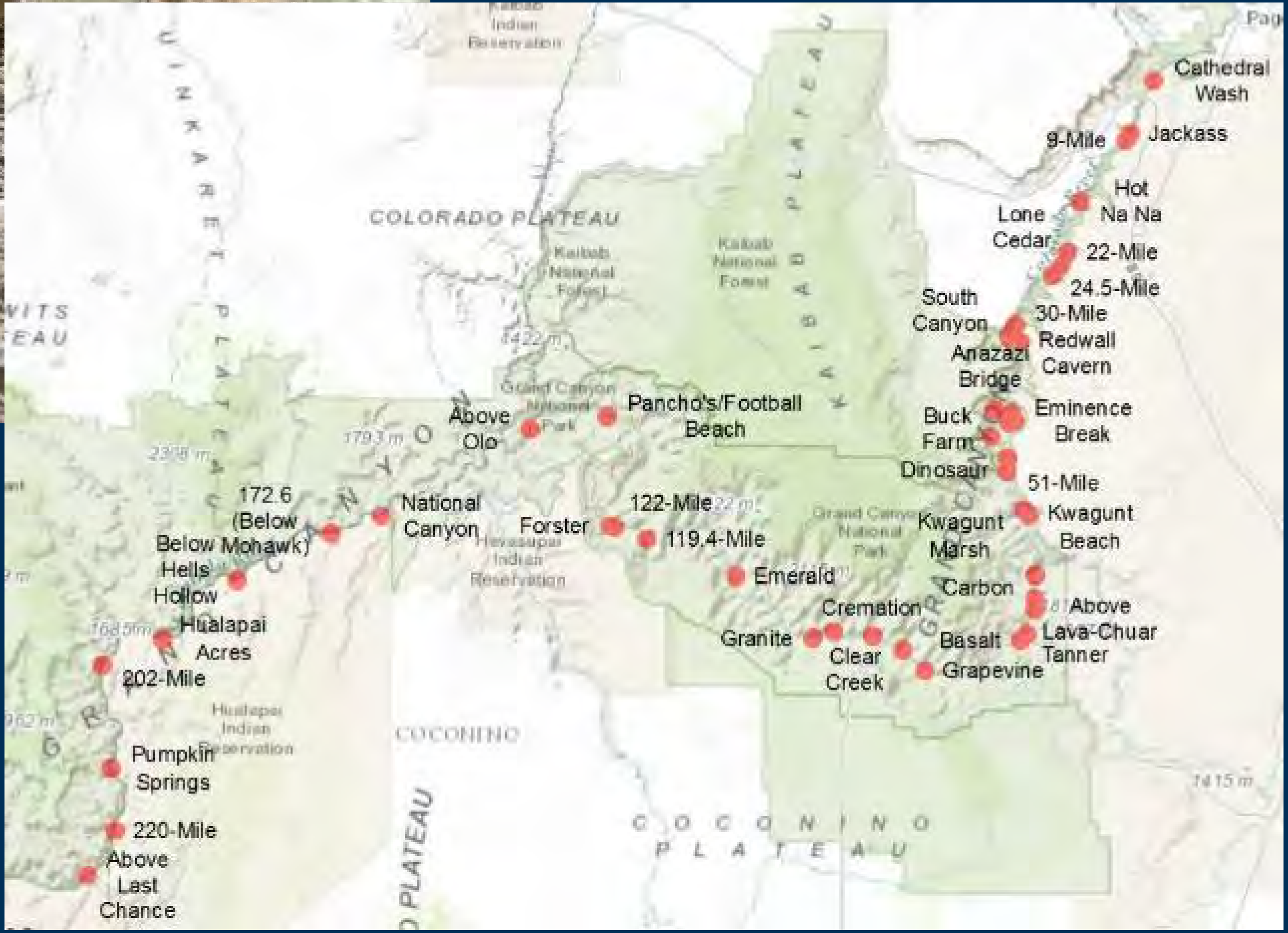
Annual Reporting Meeting

January 12, 2022

Robert Tusso

GCMRC

GCMRC Remote Camera Project



- 44 cameras

- 5 images daily

- Lower quantitative precision than terrestrial surveys

- Better temporal precision/resolution

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

2018 High Flow Experiment

Major Gain

2018 High Flow Experiment

Major Loss

USGS
science for a changing world

2018 High Flow Experiment Sandbar Metrics

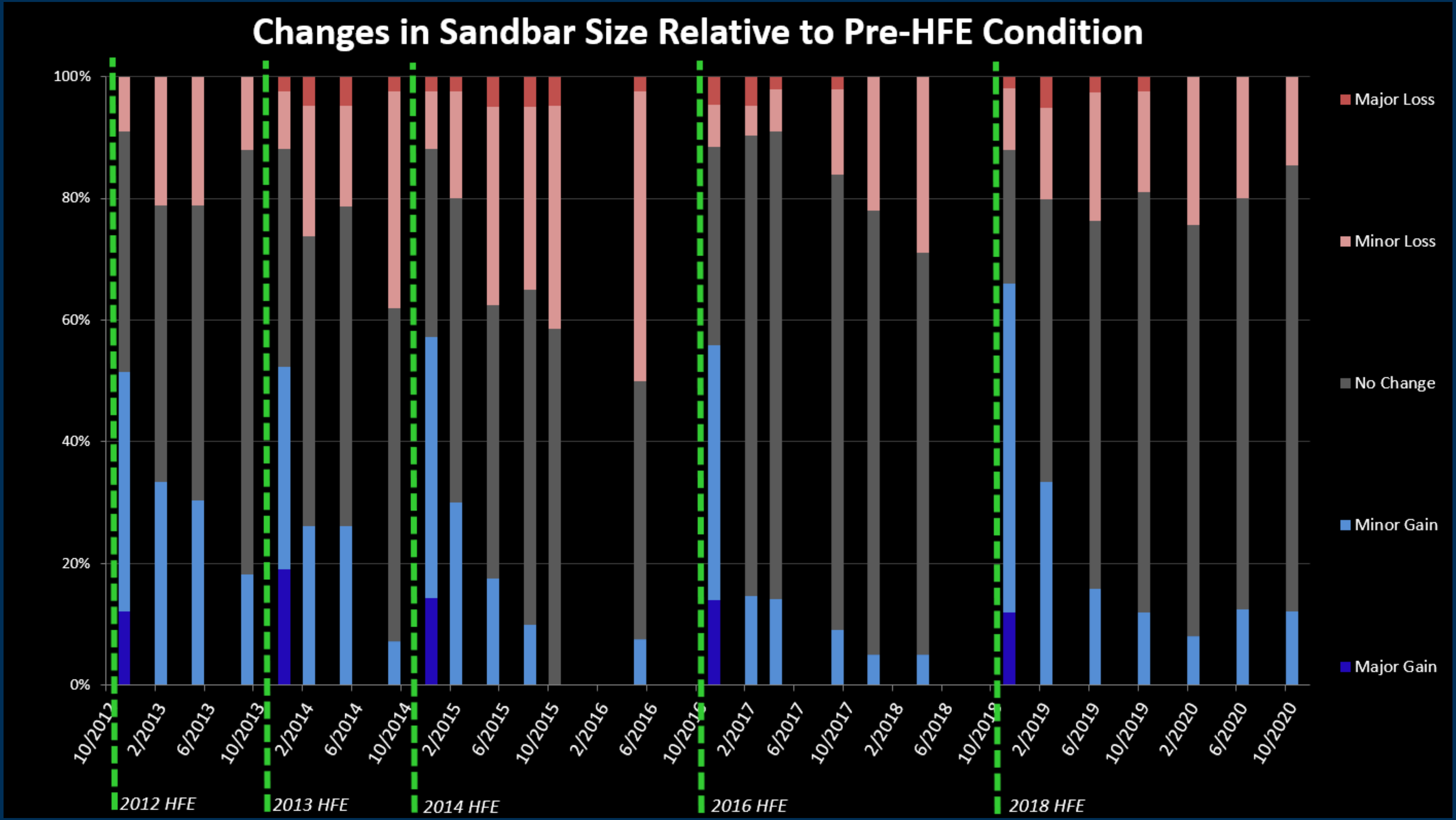
Change Classification	Number of Sites	Percentage of Sites
Large Loss	1	2%
Small Loss	4	10%
Negligible Change	9	22%
Small Gain	22	54%
Large Gain	5	12%

66% of sites increased in size

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

Preliminary results, subject to review, do not cite.

2012-2018 High Flow Experiments Sandbar Metrics



Preliminary results, subject to review, do not cite.

2021 Disturbance Flow

Minor Gain

2021 Disturbance Flow

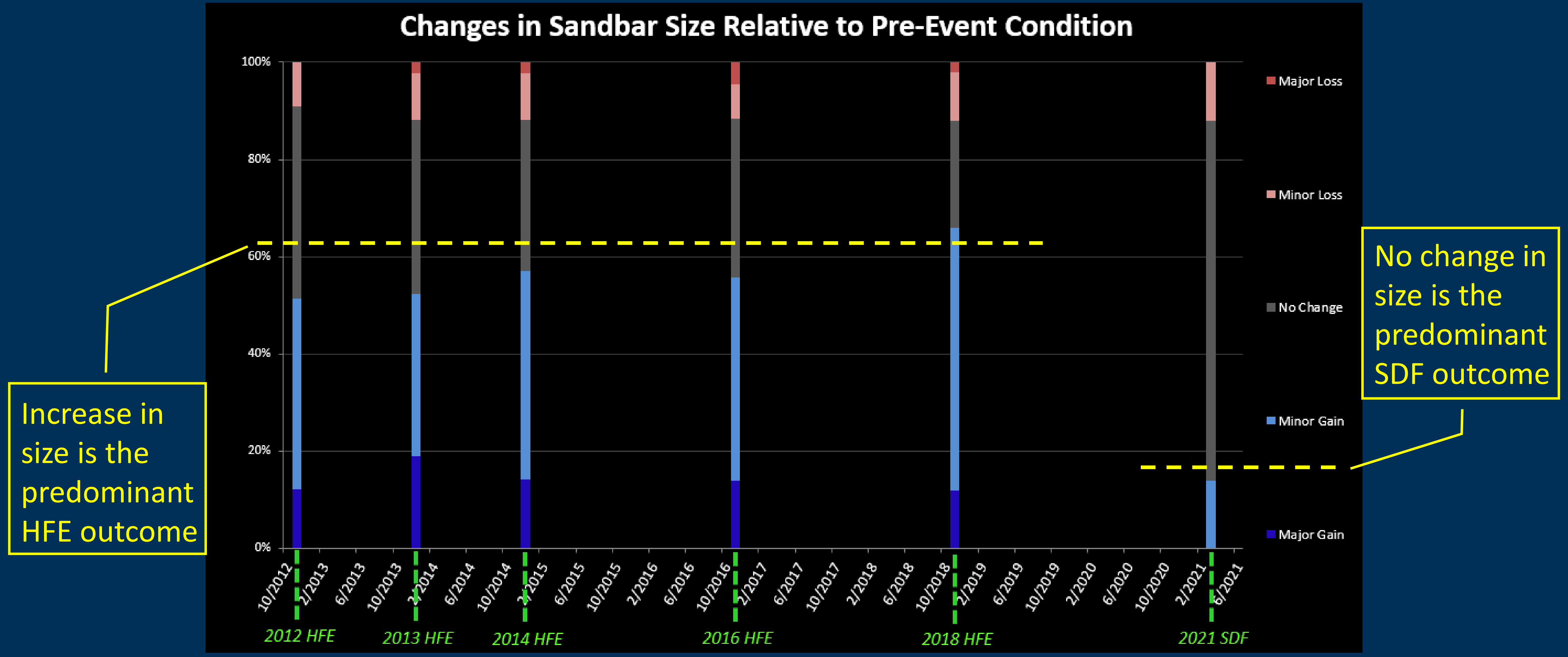
Minor Loss

2021 Disturbance Flow Sandbar Metrics

Change Classification	Number of Sites	Percentage of Sites
Large Loss	0	0%
Small Loss	5	12%
Negligible Change	31	74%
Small Gain	6	14%
Large Gain	0	0%

74% of sites remained the same size

Preliminary results, subject to review, do not cite.



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

Preliminary results, subject to review, do not cite.

Conclusions

- 74% of sites underwent “Negligible Change” vs 20-40% in typical HFE
- 0% of sites underwent “Major Change” vs 15-20% in typical HFE
- Magnitude of beach change was minimal compared to typical HFE’s
- Of changed beaches, 14% underwent “Gain” and 12% underwent “Loss”
- A Typical HFE has 51-66% undergo “Gain” and 9-12% undergo “Loss”
- Sign of beach change was neither overwhelmingly positive or negative

Synthesis of the Spring Disturbance Flow
Where do we go from here?

GCDAMP

Annual Reporting Meeting

January 12, 2022

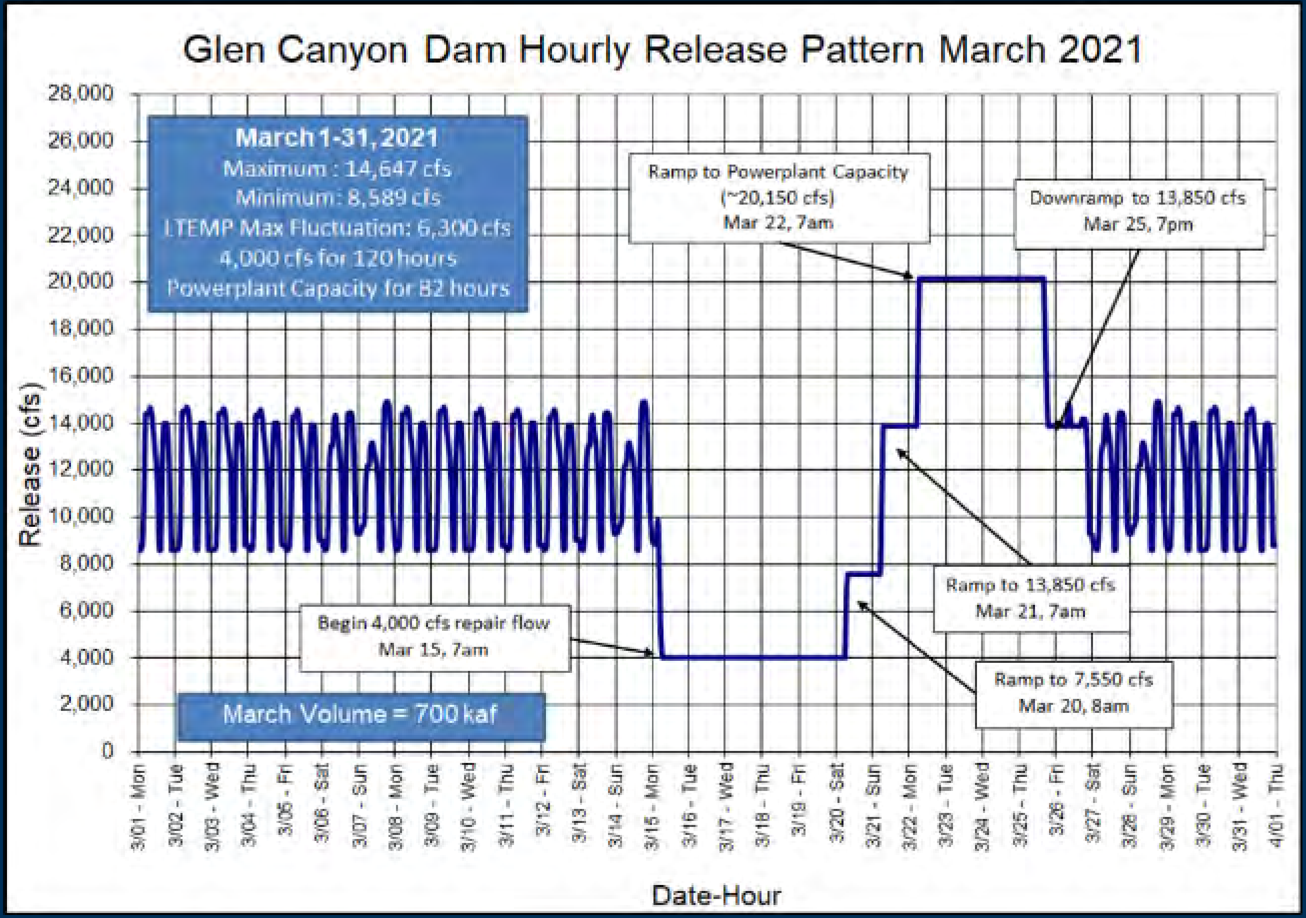
Lucas Bair

GCMRC

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

Synthesis of the Spring Disturbance Flow

- The purpose of Project O is to evaluate whether a spring-timed disturbance flow will improve resources in the Colorado River Ecosystem.
- Project O will test the hypothesis that disturbance of benthic (river bottom) habitats in spring enhances the LTEMP resources goals such as the goal of Natural Processes (i.e., food base) of the Colorado River.



USGS

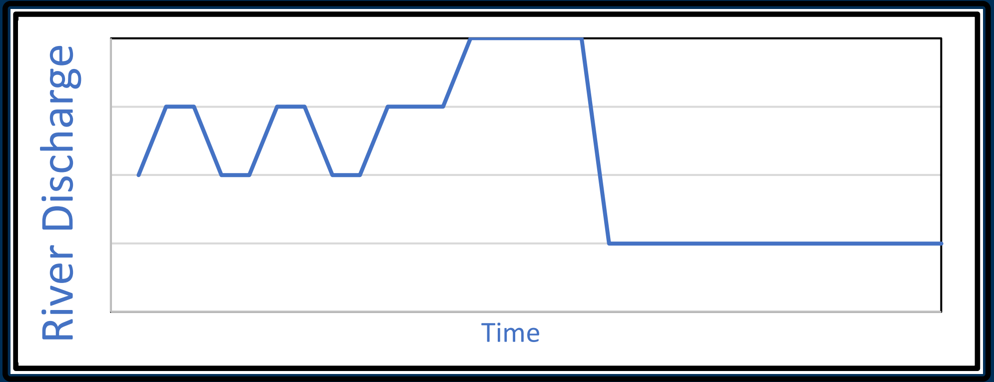
Synthesis of the SDF: preliminary results

- Nutrients
- Invertebrates
- Sediment
- Aeolian
- Terrestrial Vegetation
- Aquatic Vegetation
- Trout
- Angling surveys
- Sandbars

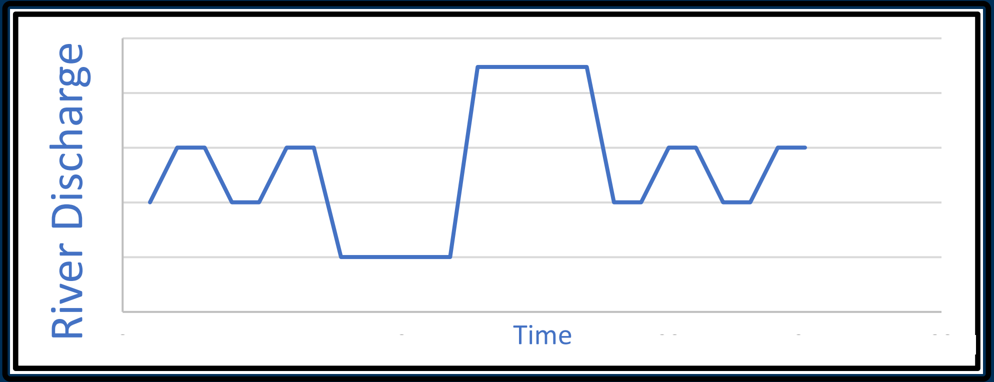
USGS

Synthesis of the SDF: hydrograph results

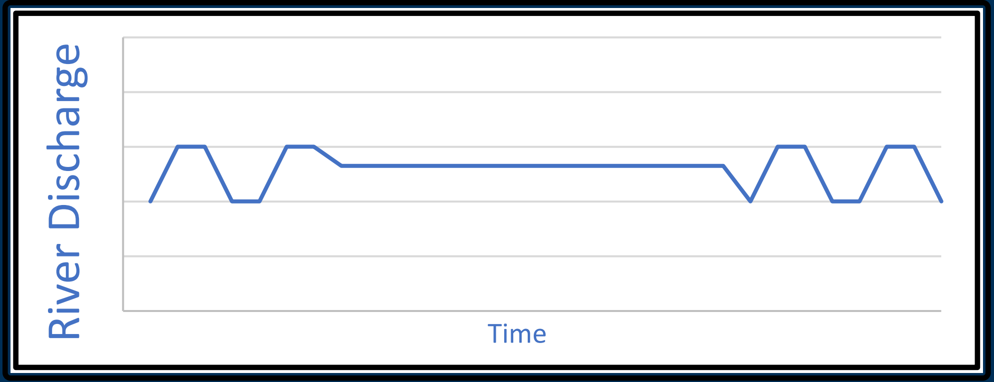
- Nutrients and Aeolian



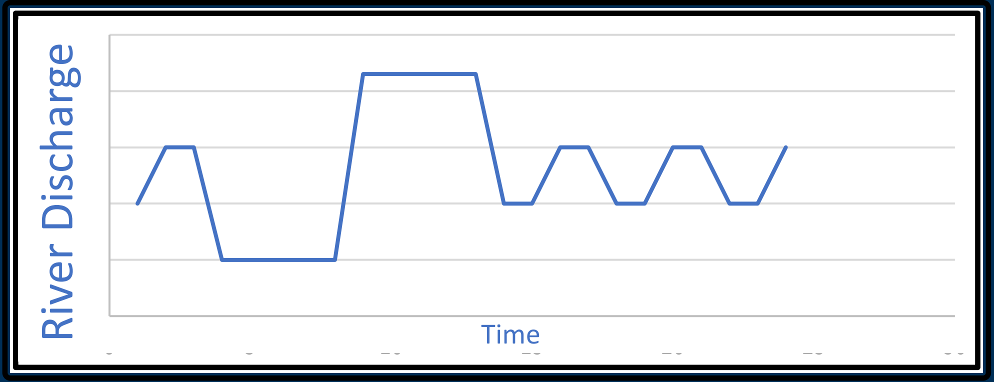
- Aquatic vegetation



- Recreational angling



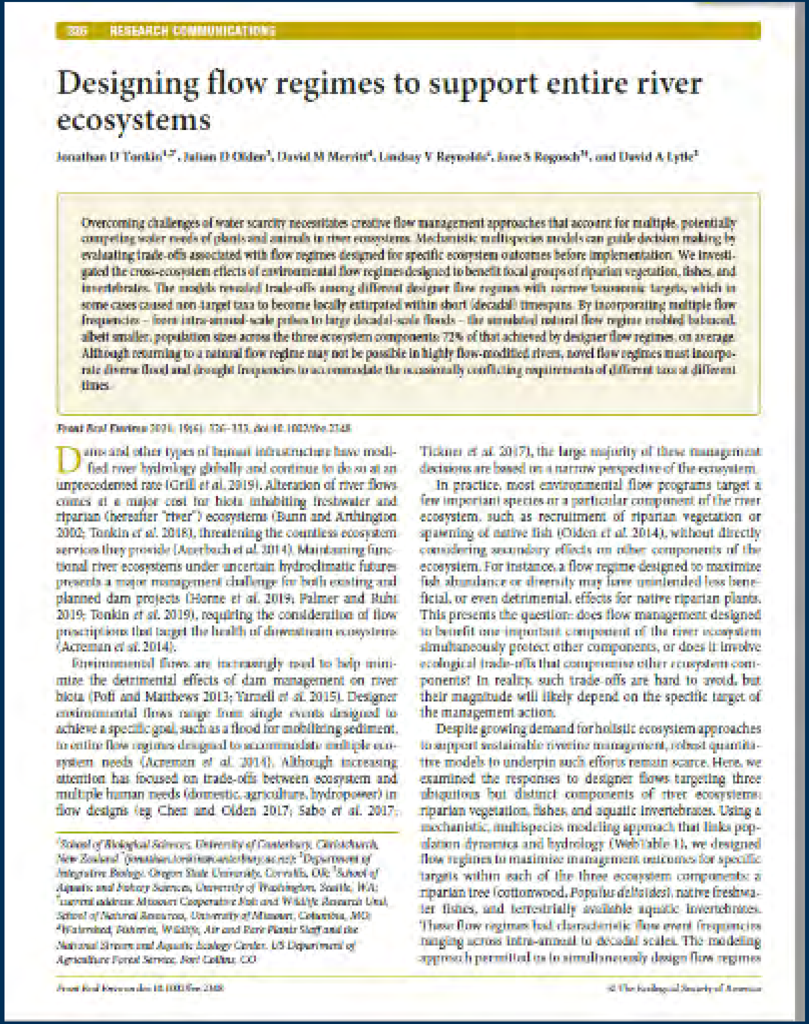
- Trout



Preliminary results, subject to review, do not cite.

Synthesis of the SDF: looking forward

- Objective: what do we want to accomplish and why?
  - Hydrograph design
  - Hypothesized resource response
    - Direction and magnitude
  - Tradeoff analysis: is there an opportunity to achieve multiple objectives?
- Uncertainties that impede management
- Multiple future scenarios


RESEARCH COMMUNICATIONS

Designing flow regimes to support entire river ecosystems

Jonathan D Tonkin, Julian D Olden, David M Merritt, Lindsay V Reynolds, Jane S Rogosch, and David A Lytle

Overcoming challenges of water scarcity necessitates creative flow management approaches that account for multiple, potentially competing water needs of plants and animals in river ecosystems. Mechanistic multispecies models can guide decision making by evaluating trade-offs associated with flow regimes designed for specific ecosystem outcomes before implementation. We investigated the cross-ecosystem effects of environmental flow regimes designed to benefit focal groups of riparian vegetation, fishes, and invertebrates. The models revealed trade-offs among different designer flow regimes with narrow taxonomic targets, which in some cases caused non-target taxa to become locally extirpated within short (decadal) timespans. By incorporating multiple flow frequencies – from intra-annual-scale pulses to large decadal-scale floods – the simulated natural flow regime enabled balanced, albeit smaller, population sizes across the three ecosystem components: 72% of that achieved by designer flow regimes, on average. Although returning to a natural flow regime may not be possible in highly flow-modified rivers, novel flow regimes must incorporate diverse flood and drought frequencies to accommodate the occasionally conflicting requirements of different taxa at different times.

Tonkin, Jonathan D., Julian D. Olden, David M. Merritt, Lindsay V. Reynolds, Jane S. Rogosch, and David A. Lytle. "Designing flow regimes to support entire river ecosystems." Frontiers in Ecology and the Environment 19, no. 6 (2021): 326-333.


Food base (invertebrates, macrophytes)


Sediment dynamics


Vegetation

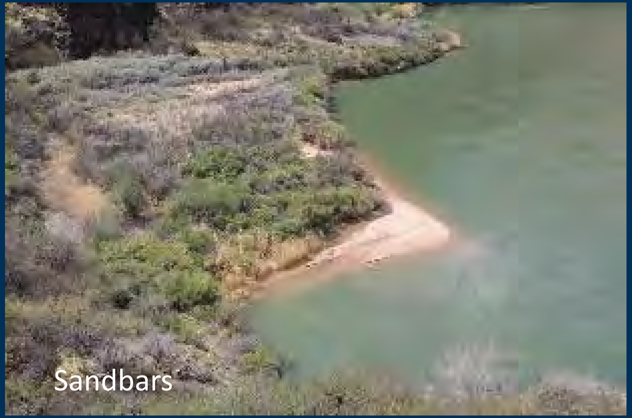

Nutrient dynamics


Angler surveys


Aeolian studies


Trout habitat use


Freshwaters Illustrated, 2021


Sandbars