

A Synthesis of Nonnative Aquatic Species Monitoring, Research, and Modeling in the Colorado River

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(with data and help from many others)

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RECLAMATION



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Presentation Outline

- Background on nonnative species and projects
- LTEMP metrics results - very high-risk species
- Addressing uncertainties in the current status of nonnative species in the GCe
 - Environmental DNA – Seining trip and autosampler
 - Genetic kinship analysis
- Developing tools to forecast impacts of management decisions on the future status of nonnative species



Photo: Freshwaters Illustrated



Nonnative Aquatic Species Monitoring and Research

- Project Elements and Objectives
 - I.1: System-wide Native Fishes and Nonnative Aquatic Species Monitoring (AZGFD)
 - I.2: Estimating Kinship and Spawner Abundance of Warm-Water Nonnatives
 - I.3: Identifying Emerging Threats to the Colorado River using eDNA; Parasite Monitoring - BiOp
 - I.4: Modeling Population Dynamics and Improving Forecasting Tools for SMB and Nonnative Fishes
- LTEMP Resource Goals
 - Nonnative Invasive Species - *Minimize or reduce the presence and expansion of nonnative species*
 - Other Native Fish Species
 - Humpback Chub
- Cooperators
 - AZGFD, NPS, USFWS, USBR, USFS, Ohio State University
- Fish Data Collection
 - FY25-27 TWP Projects: G (Humpback Chub), H (Rainbow Trout), I (Nonnative Species)
 - Glen Canyon National Recreation Area, Grand Canyon National Park, Bureau of Reclamation, ASIR/BioWest



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Nonnative Aquatic Species

Very-High Risk



Smallmouth Bass



Walleye



Flathead Catfish



Brown Trout

High-Risk



Northern Pike



Green Sunfish



Striped Bass



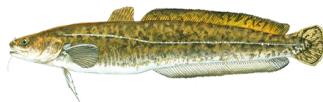
Rainbow Trout (GCNP)



White Sucker



Rusty Crayfish



Burbot

Medium to Medium-High Risk



Largemouth Bass (MH)



Black Bullhead



Yellow Bullhead



Channel Catfish



Blue tilapia (and other cichlids)



Grass Carp (and Asian carps)

Medium-Low Risk



Black Crappie



Redear Sunfish



Bluegill



Common Carp



Red Shiner

Low-Risk



Mosquitofish



Fathead Minnow



Plains Killifish



Golden Shiner



Gizzard Shad



Threadfin Shad



Rainbow Trout (GLCA)



Brook Trout (or other salmonids)



Northern/
Virile Crayfish



Zebra and Quagga Mussels
(in the river)

Invasive Species Risk Levels

- Species assigned to risk levels in the NPS *Expanded Non-Native Aquatic Species Management Plan* (2018, as amended in 2021)
- Risk level based on potential for predation, competition, or adverse effects on:
 - Native and/or federally listed species
 - Recreational rainbow trout fishery
- Accounts for current population status, likelihood of entrainment or expansion, and environmental factors



LTEMP Goal 10: Nonnative Invasive Species

“Minimize or reduce the presence and expansion of aquatic nonnative invasive species.”

- Measures progress in minimizing the presence and expansion of aquatic nonnative species in the Colorado River and its tributaries over the period of the LTEMP.
- Eight metrics defined for LTEMP Goal 10:
 - *10.1-10.4: Average number of invasive aquatic species present per habitat segment within each risk level (low, medium, high, very-high).*
 - *10.5-10.8: Average number of invasive aquatic species present per habitat segment within each risk level that exhibit evidence of reproduction (early life history stages).*

2025 Trips: Lees Ferry Tailwater

Gear

Electrofishing

Netting

Fisheries- Lees Ferry 2025

GCMRC AZGFD TRGD
(RM -13, RM -4)

GLCA Monitoring
(RM -15.7 to RM 0)

~16% Reduction in Effort

Shutdown

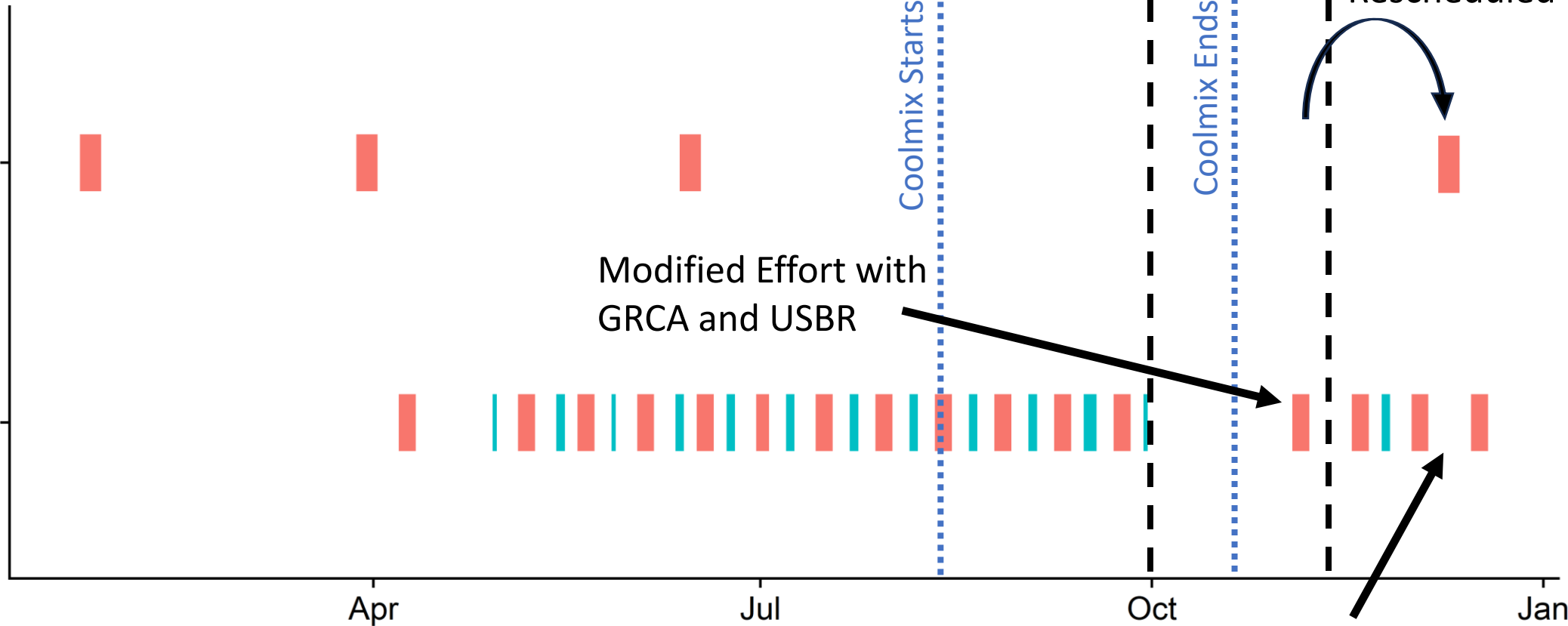
Coolmix Starts

Coolmix Ends

Rescheduled

Modified Effort with
GRCA and USBR

Cancelled due to TRGD Overlap

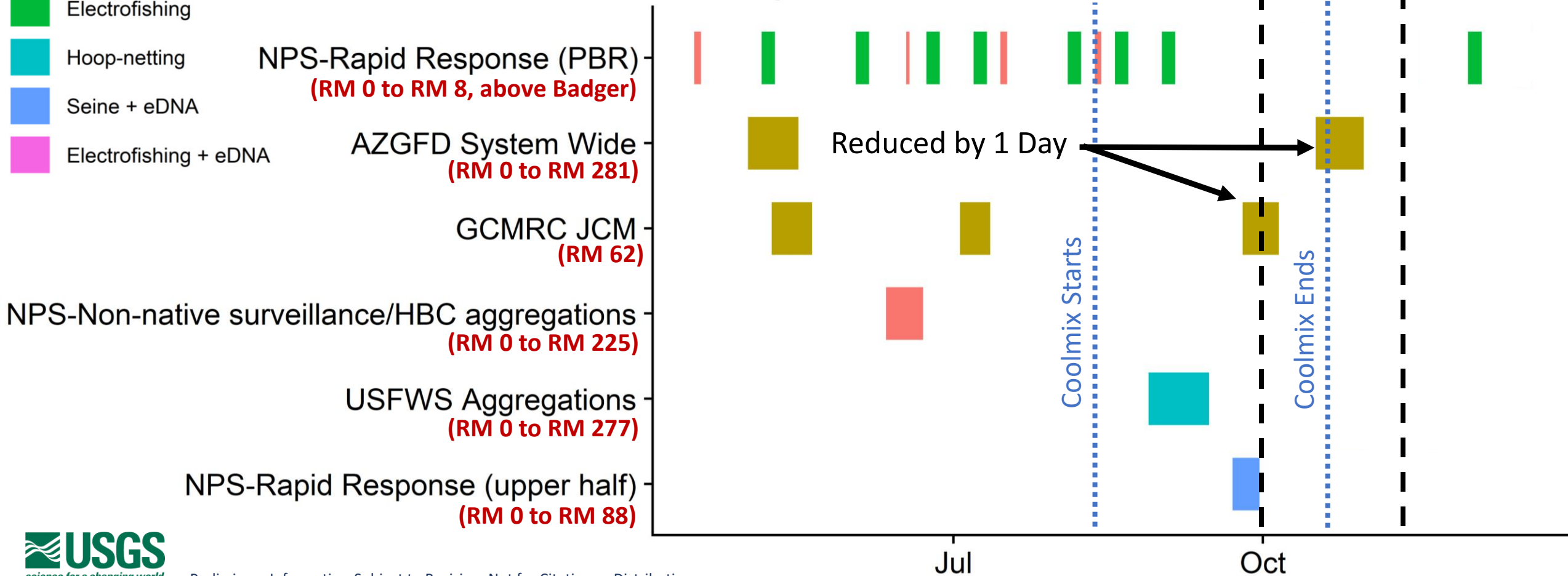


2025 Trips: Downstream

Gear

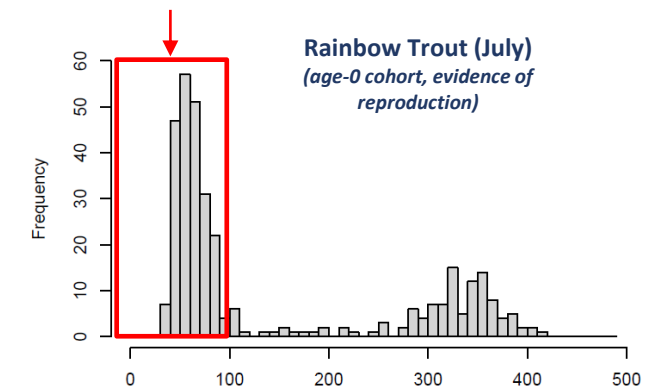
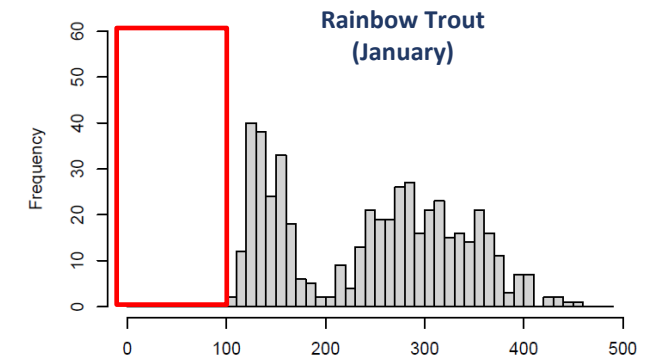
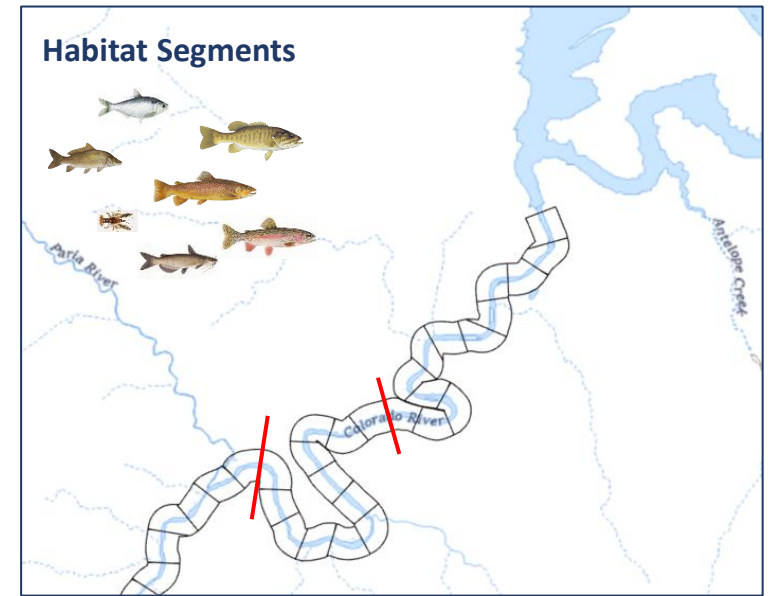
- Seine + Hoop-netting
- Electrofishing + Hoop-netting + Angling
- Electrofishing
- Hoop-netting
- Seine + eDNA
- Electrofishing + eDNA

Fisheries- Grand Canyon Mainstem 2025



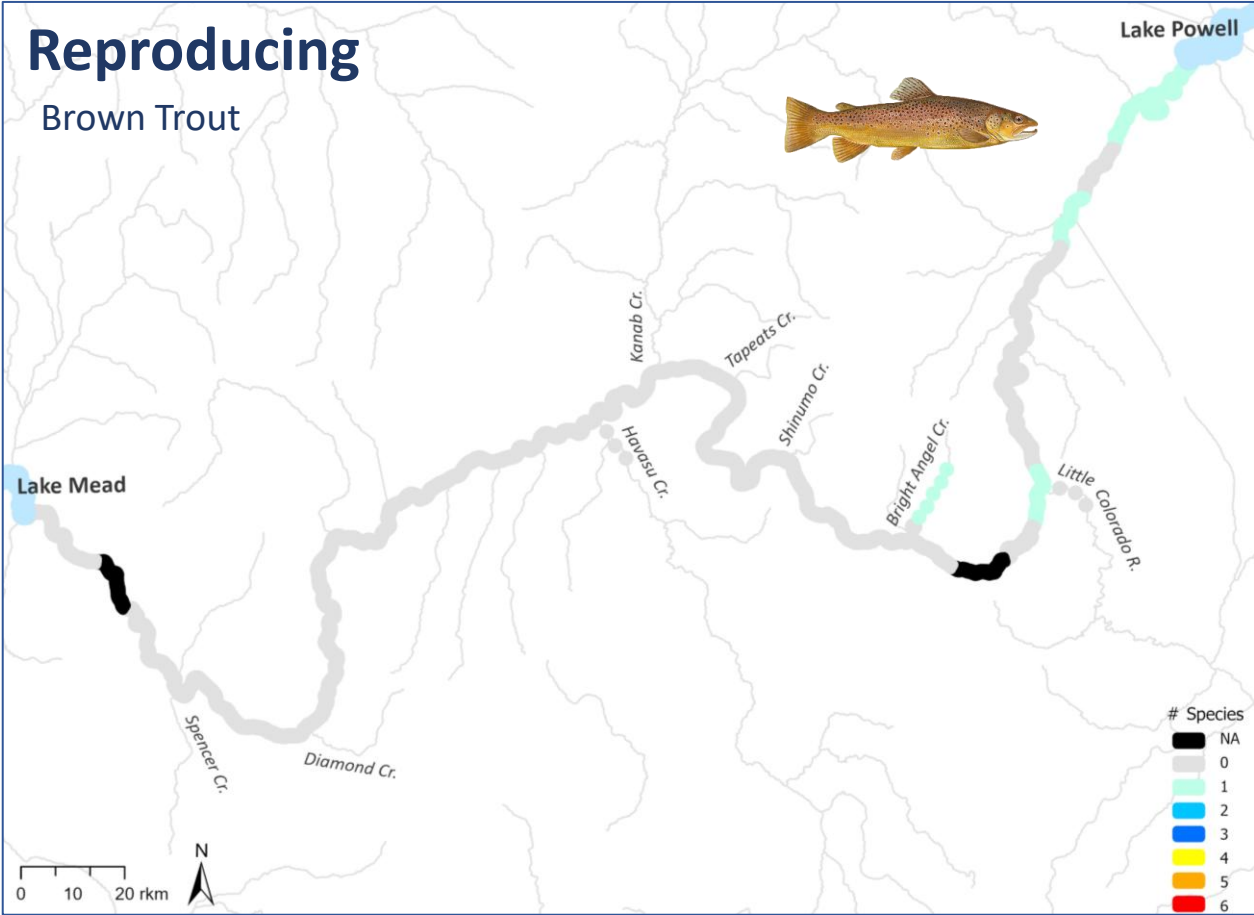
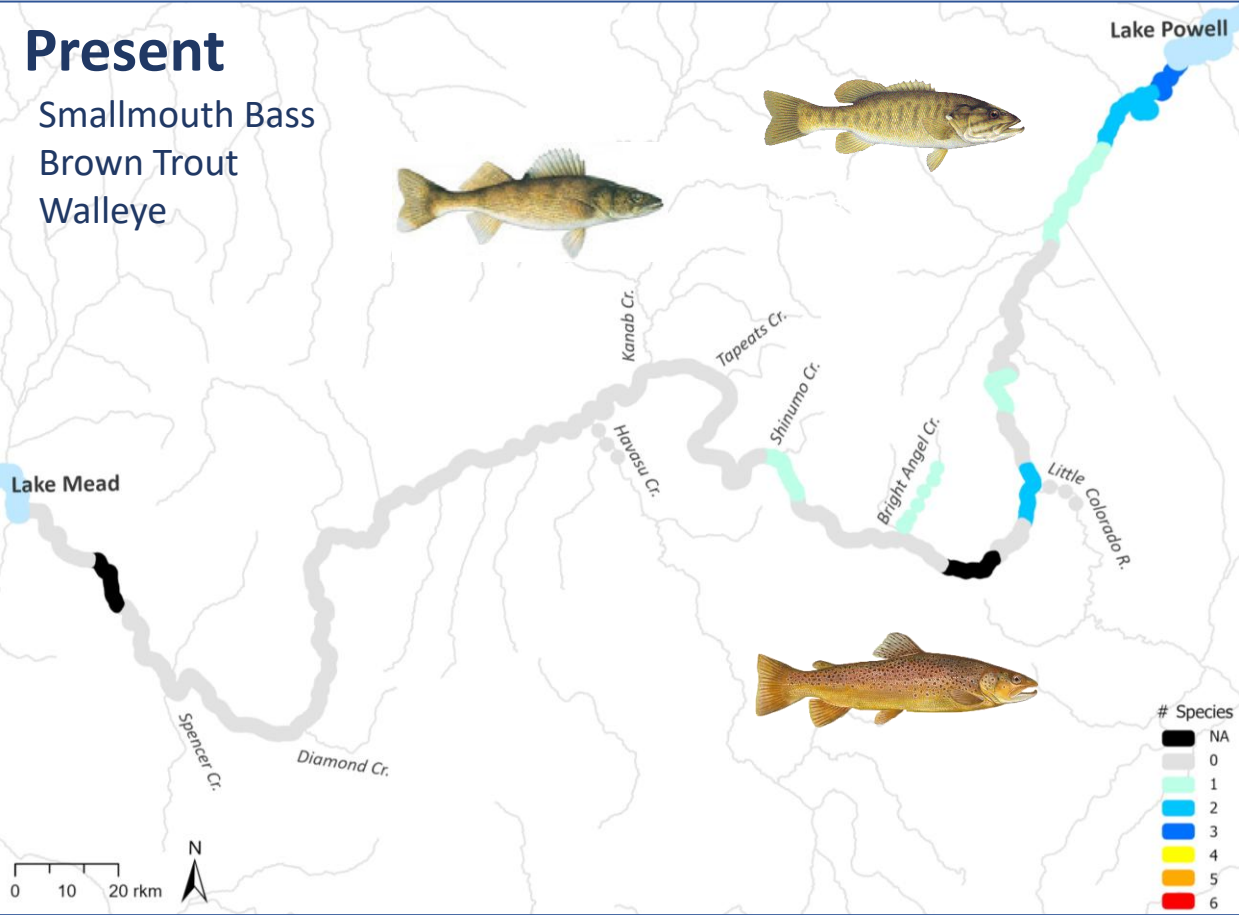
Fish Metric Methods

- Compiled 2025 data from partners and collaborators
- Defined habitat segments at meaningful scale (11-13 river kilometers)
- Calculated average # species present in any life stage
- Created length-frequency plots and identified age-0 fish cohorts
- Calculated average # species with evidence of reproduction



Very High-Risk Species

River/Tributary	Present	Reproducing
Colorado River	0.4	0.1
Little Colorado River	0	0
Havasu Creek	0	0
Bright Angel Creek	1.0	0.8



Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Illustrations: Joe Tomelleri and Duane Raver
Shapefile layer for defining habitat segments provided by Tom Gushue (GCMRC, Project K)

Detecting Nonnative Species in Backwaters & Isolated Pools

- Purpose of project is to compare eDNA methods to traditional sampling gear to detect sources and dispersal of nonnative species
 - Determine whether relative abundance (eDNA copies/L) is comparable to catch rates
 - Develop occupancy model based on physical captures and eDNA detections
- USFWS Aggregations trip, Sept. 2025 – seining boat added for nonnative species surveillance
 - Sampled 3 locations in subset of backwaters and isolated pools seined for nonnative species
 - eDNA Samples currently being extracted at the USFS National Genomics Center; they will be analyzed using their aquatic invasive species ht-qPCR biochip

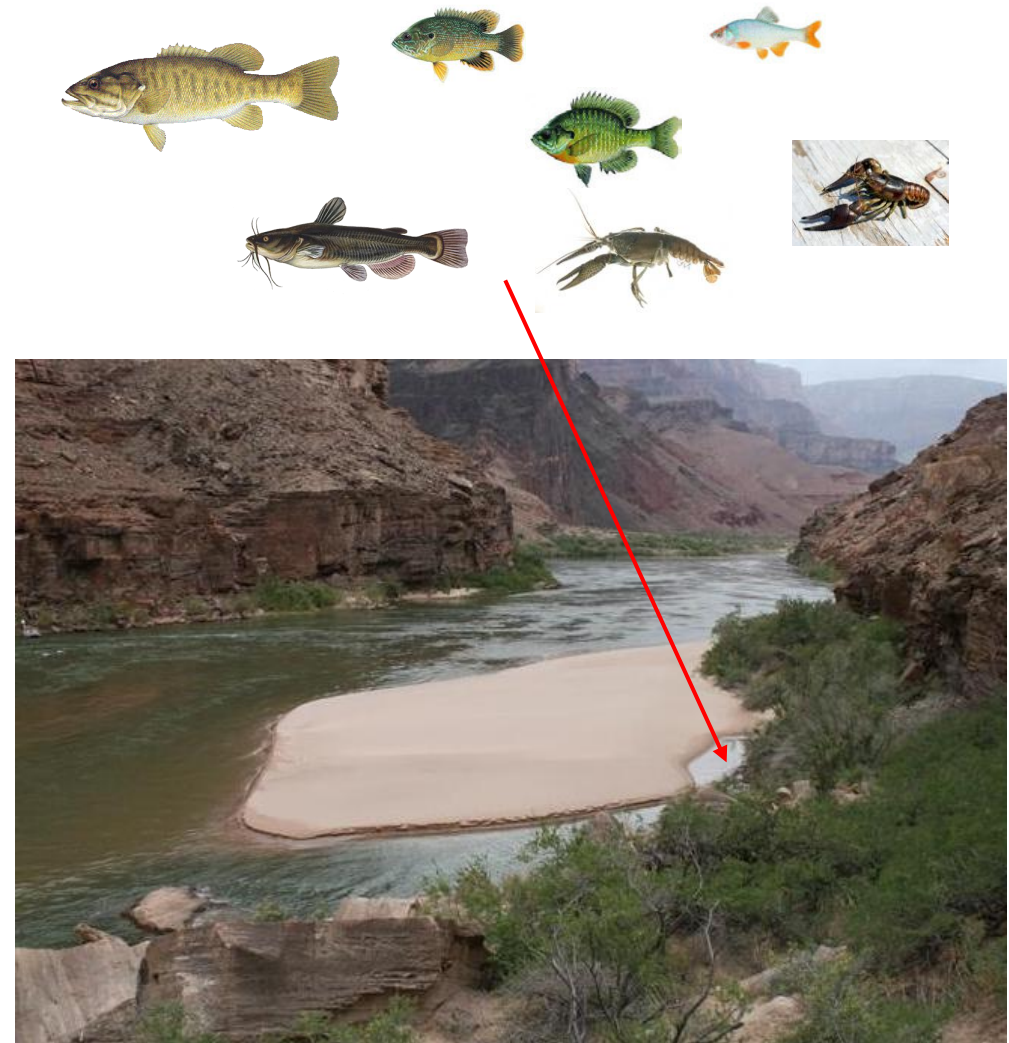
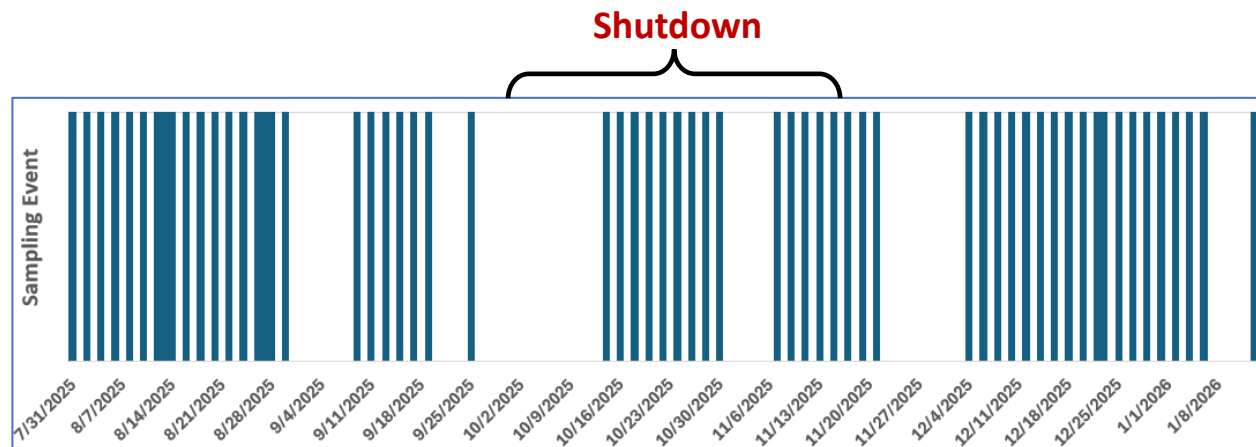
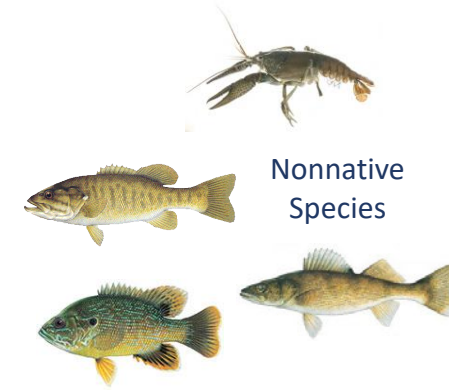


Photo: USGS, M. Kaplinski

Automated eDNA Sampling in Slough

- Detection of nonnative species using eDNA autosampling technology (Smith-Root)*
- Sampler deployed in re-designed slough in July 2025
 - Sampled every 2 days during warmest time of day
 - Sampler broken during first part of shutdown, but sampled when fish monitoring trips not on the water
- Filters shipped to USFS National Genomics Center
 - Samples will be run using high-throughput qPCR biochip to detect up to 46 aquatic invasive species
- Technology could be utilized to sample remote areas in Grand Canyon across multiple seasons – biodiversity assessments



*Project not funded by GCDAMP



Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Photos: USGS, K. Dibble, K. Allen

Smallmouth Bass: Research and Monitoring

Determining the effectiveness of removals & flow experiments

Abundance/
Catch

Distribution/
Dispersal

Growth

Diet

Kinship

Reproduction?

No evidence of
Age-0

Evidence of
Age-0

Age-0 Growth
Rate

Recruitment?

Entrained
from Lake?

Reproduced
locally?

When?
(relative to
experimental
actions)

Pop Growth?

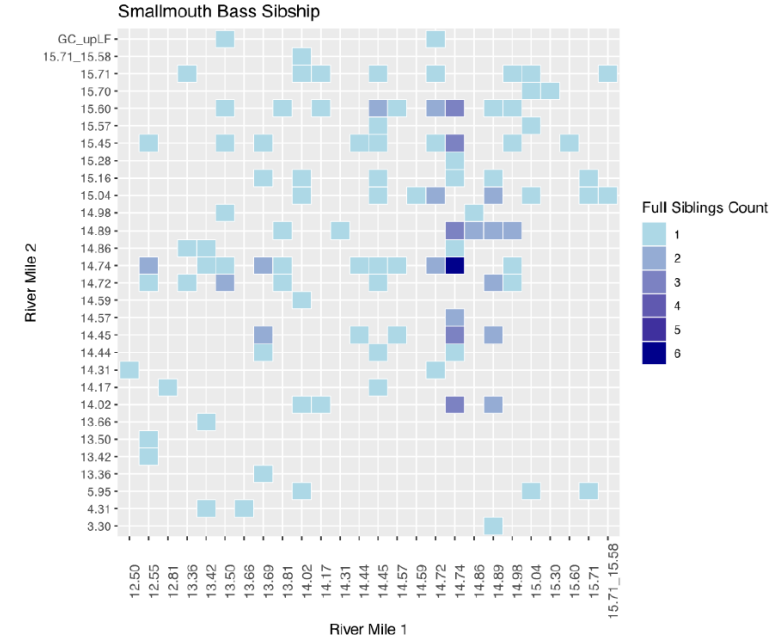
Where?
(mainstem or
backwater)

Entrainment?

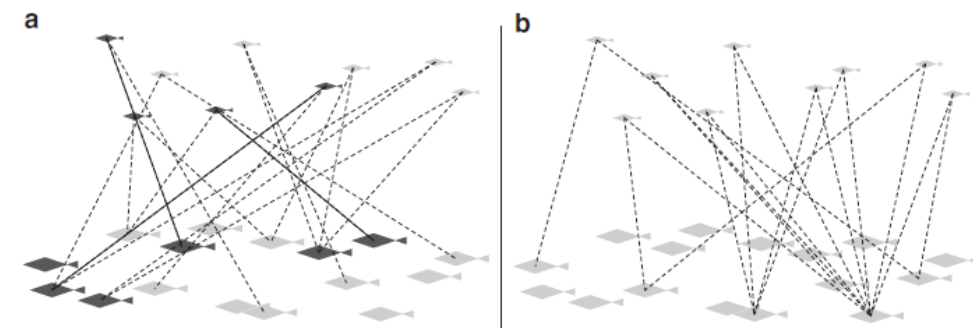
Smallmouth Bass Kinship Analysis



- This project uses genetic data from fin clips to estimate kinship (relatedness) across fish in the Colorado River and in Lake Powell. Results can be used to understand the following:
 - Effective population size/number of breeders (N_e/N_b)
 - Breeding hot spots, diversity
 - Repeated parents, mating strategy
 - Entrainment vs. local production
- Close-kin mark recapture may be used on a surrogate species to estimate adult abundance and survival
 - Application to SMB would provide a population estimate without having to mark and release fish
- Current Status
 - Fin clips: ~1,600 in Lake Powell and the Colorado River
 - Working with a geneticist at the USGS/New Mexico State University Coop Unit to develop a GT-seq panel, which will be used to genotype other fish samples
 - Timeline for initial results: Spring-Summer 2027



Osborne et al. 2024, Project Report to the USBR, # R18AC00015



Bravington et al. 2016, Nature Communications

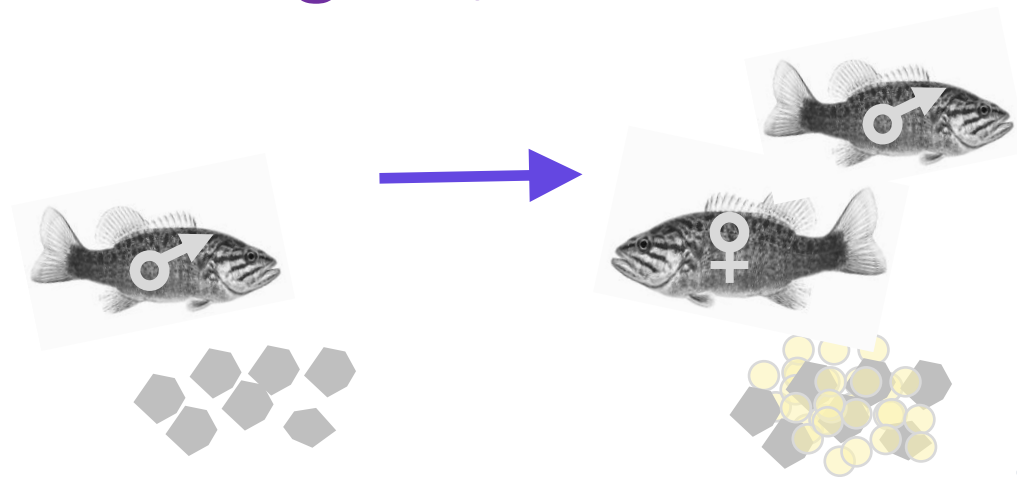
Forecasting Smallmouth bass population dynamics: recent modeling and lab studies

- Improving understanding of Smallmouth Bass early life history
 - Testing of hypotheses regarding drivers
 - More efficient application of management actions
- Inferring turbidity regimes from satellite observations

Smallmouth bass early life history: prior modeling

Spawning

- Timing: T_e , F

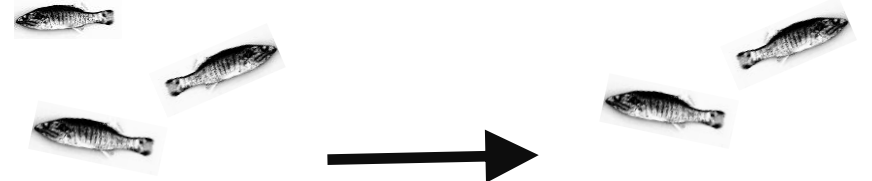


Winter starvation period

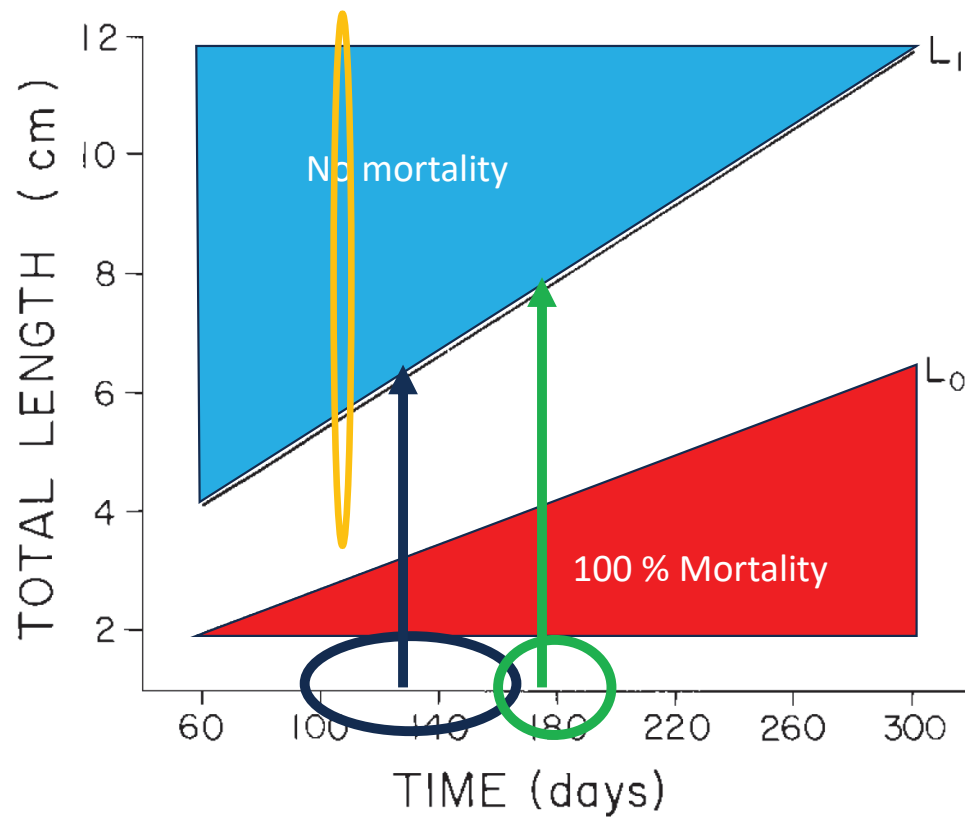
- Survival: Size, Duration

End of growing season

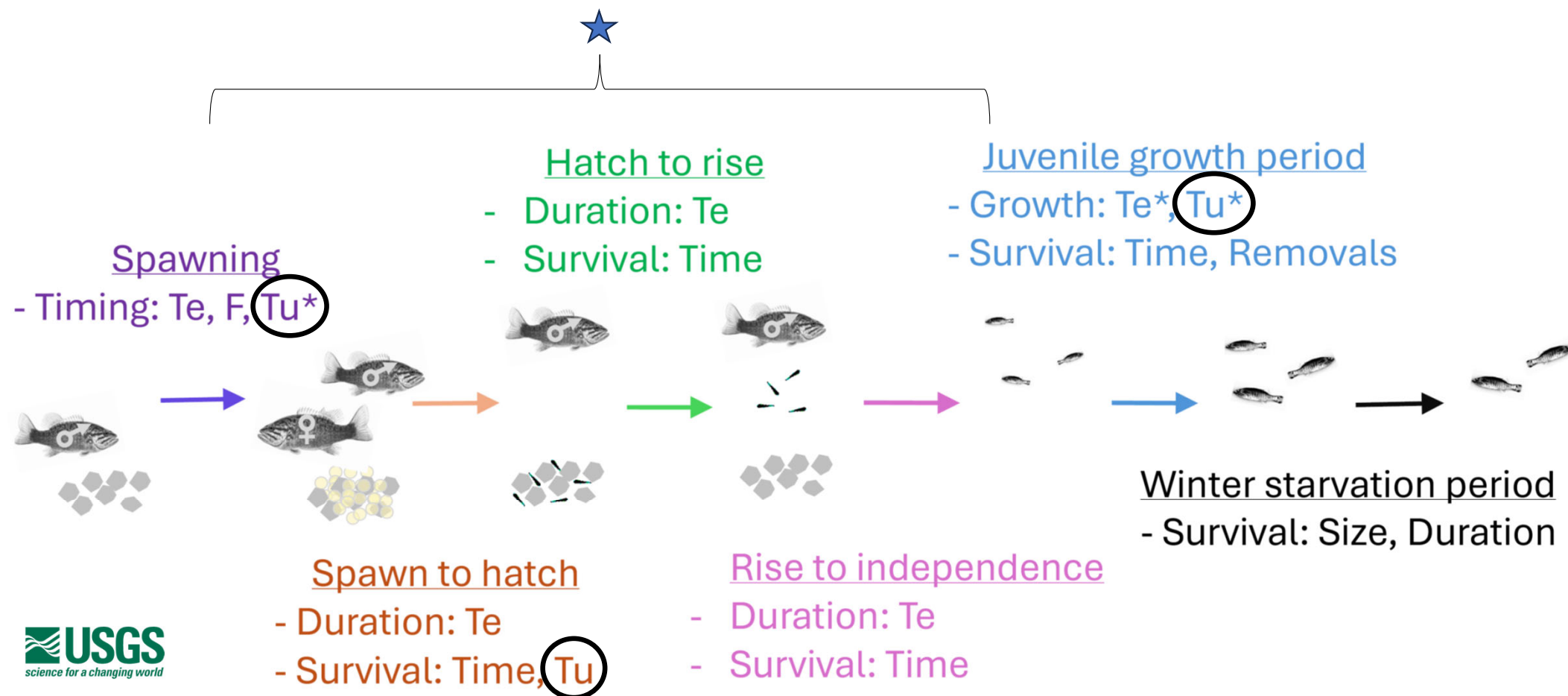
- Size: spawn dates, T_e



Overwinter mortality



Smallmouth bass early life history: new framework



Impacts of Total suspended sediment (TSS) on early life history of SMB

Parameter	Sediment	
	Grand Haven Harbor	Fairport Harbor
CEC (meq/100 g)	3.8	3.8
Moisture (%)	47.86	42.85
OM (%)	2.4	2.7
Soil pH	7.9	7.7
TOC (%)	1.69	1.57
Clay (%)	6	20
Silt (%)	20	60
Sand (%)	74	20
Textural classification	Sandy loam	Silt loam

The primary difference between sediments is the silt versus sand fractions

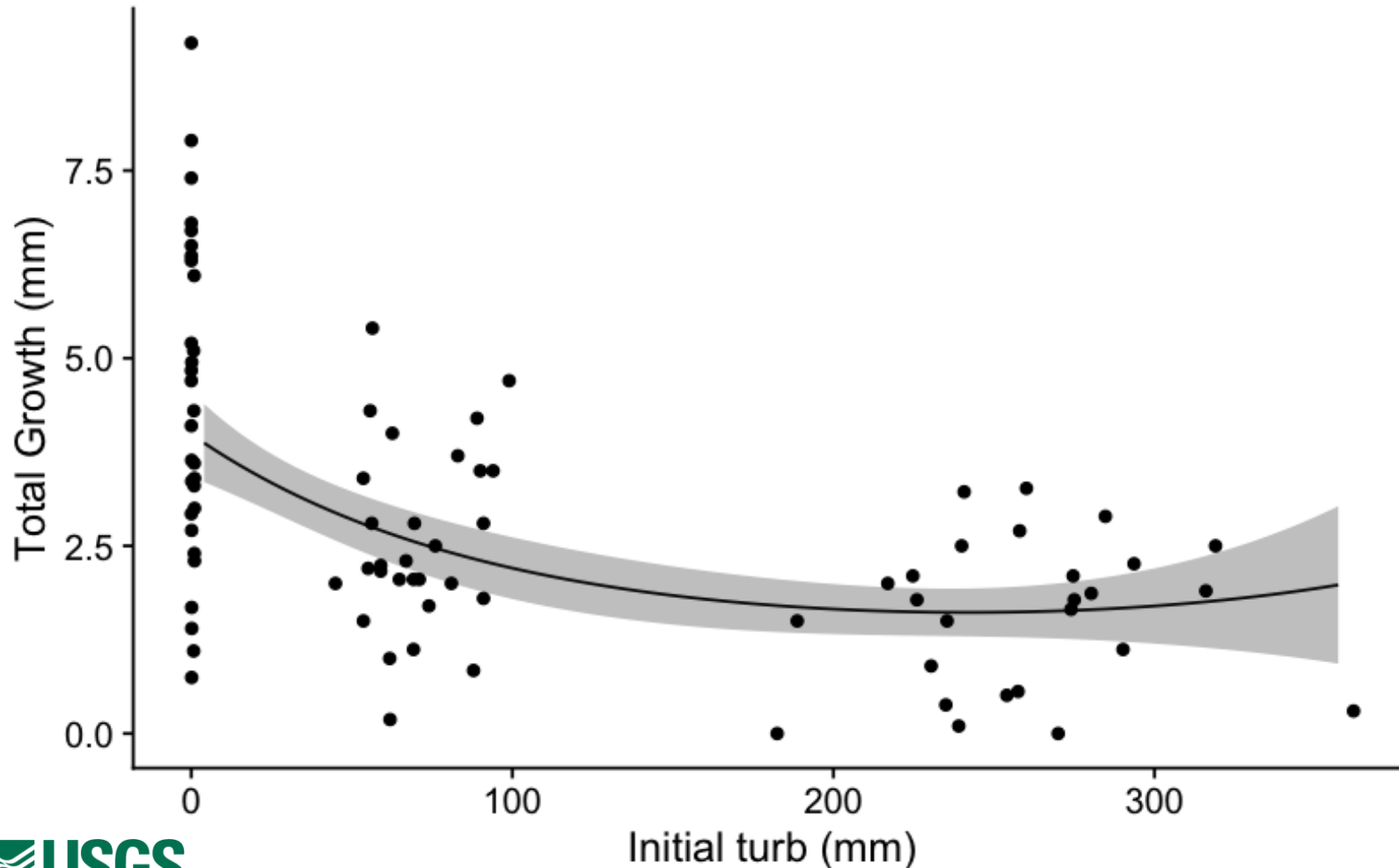
- TSS of 250 mg/L using siltier sediment and 100 mg/L using sandier sediment led to low survival of smallmouth bass eggs.
- Big Caveat – no adult SMB present and in the wild, male SMB fan nest removing sediment so these represent lower end estimates.
- Minimal impacts of TSS up to 500 mg/L on survival/growth of fry.

Smallmouth Bass Turbidity Experiment

- Laboratory experiment
 - Gradient of turbidity ranging from 0 – 370 NTU
 - 10 tanks in each of low, medium, and high range
 - Four 2-week trials
 - 1 fish per tank to avoid interactions
 - Fed consistent ration of zooplankton twice daily
 - Measured via images (to minimize handling) at beginning and end of experiment.



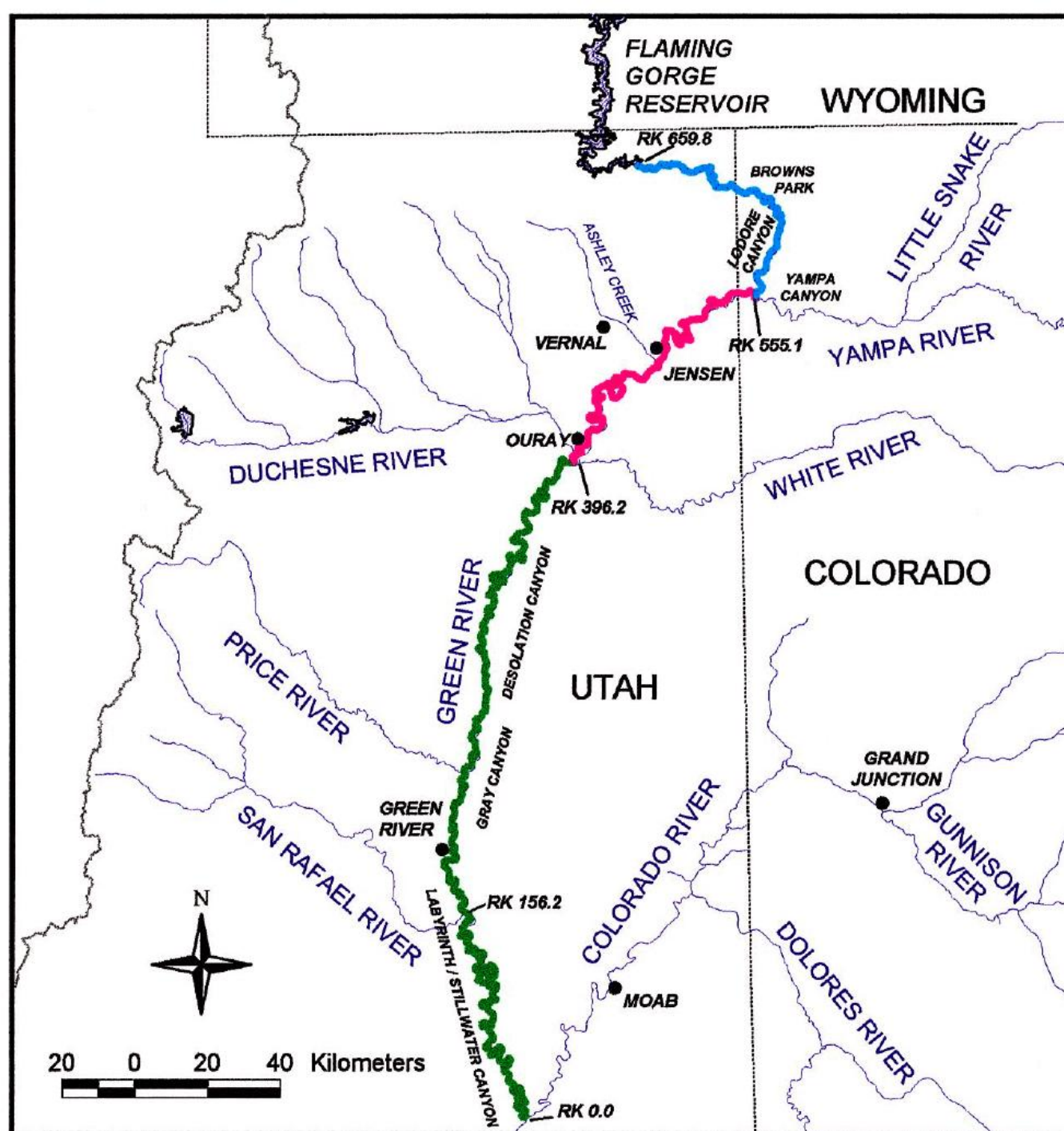
Smallmouth Bass Turbidity Experiment - Growth



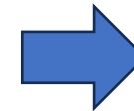
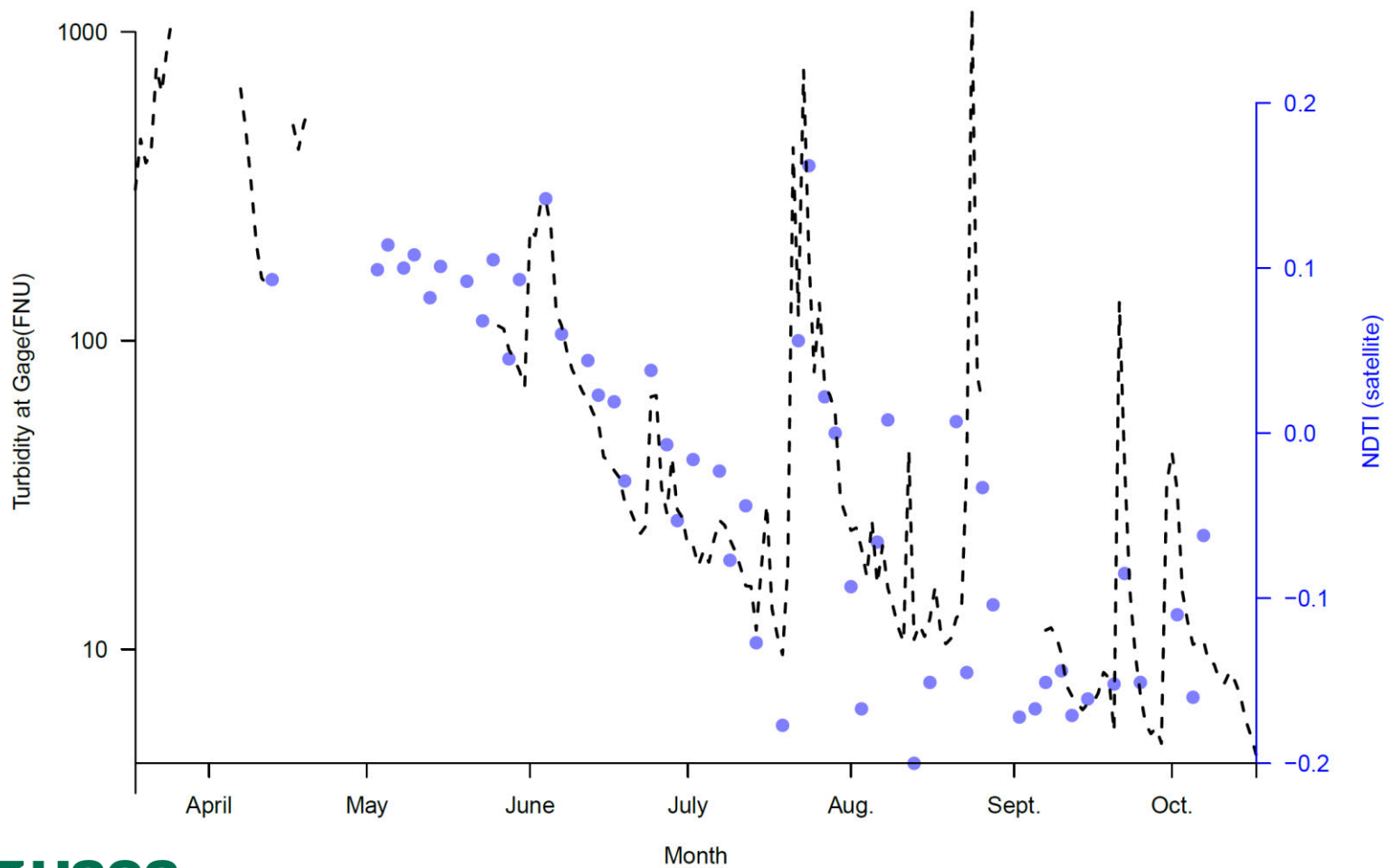
- Decline in growth with turbidity, especially max growth
- Substantial variation in growth, even when turbidity was zero.
- Average temperature during experiment was not important (ranged from 21.1-24.5) relative to turbidity and length

Looking for evidence in field observations

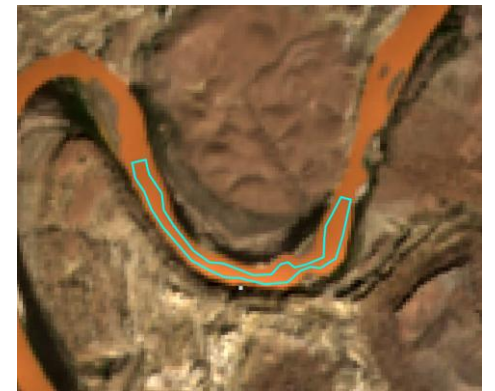
- Turbidity and warm season temperatures generally increase as you travel downriver.
- Studies of SMB hatch dates focused on Lodore, Yampa and Whirlpool.
- Chub functionally extirpated from upper population and declining in lower population over last half-decade.



Filling in gaps in the turbidity record – NDTI + state-space modeling

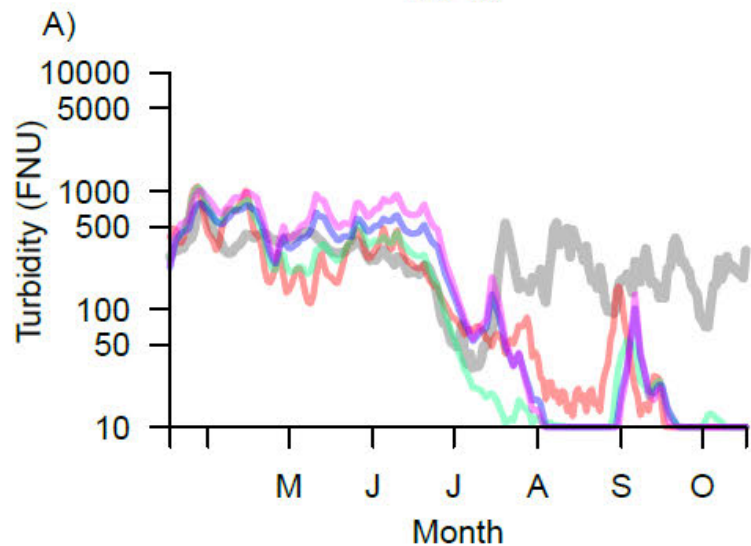


<10 FNU

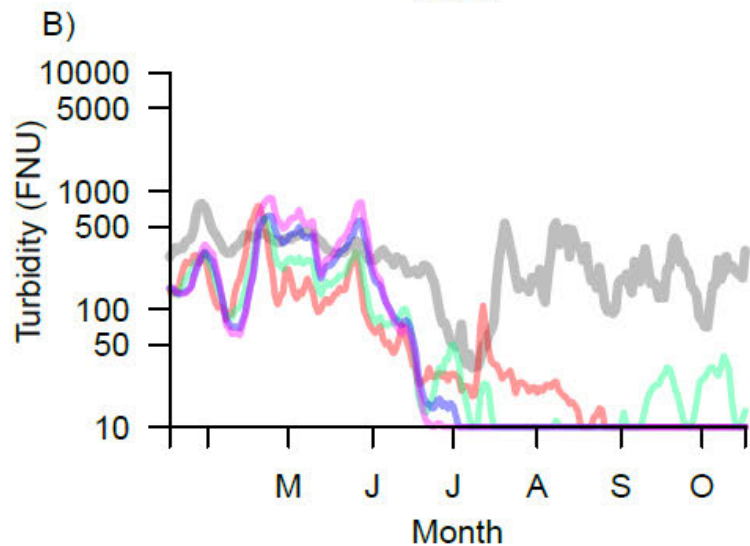


~ 525 FNU

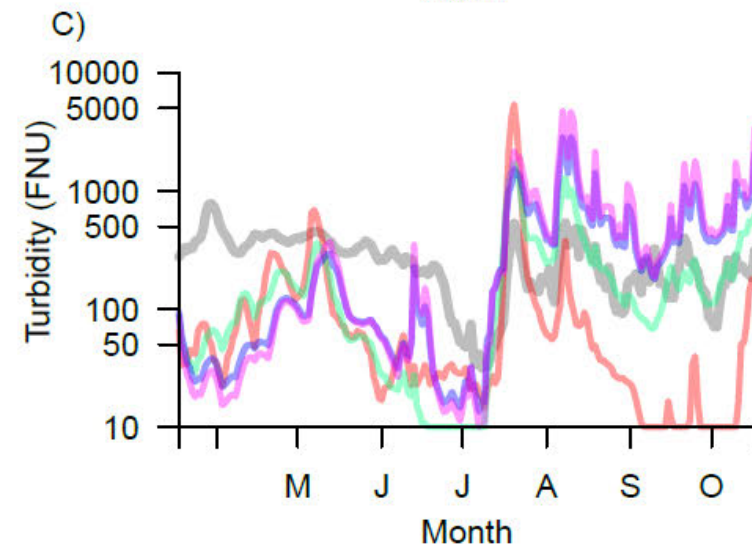
2019



2020



2021



Jensen

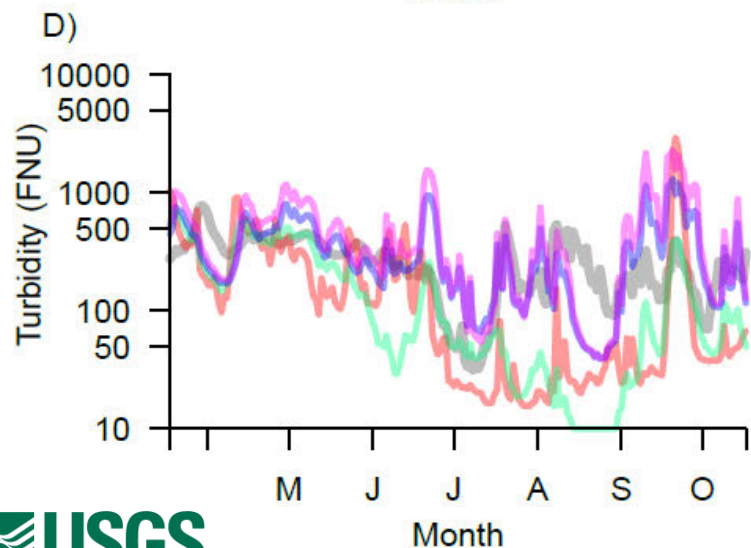
Ouray

Desolation

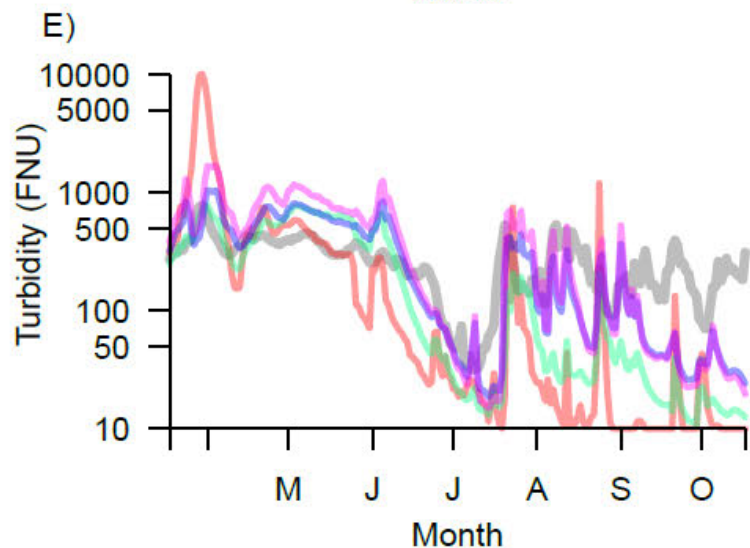
Gray

Average

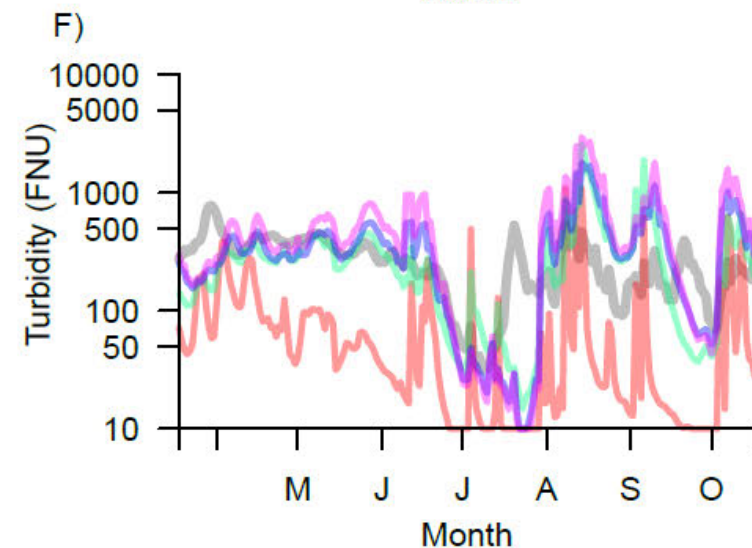
2022



2023

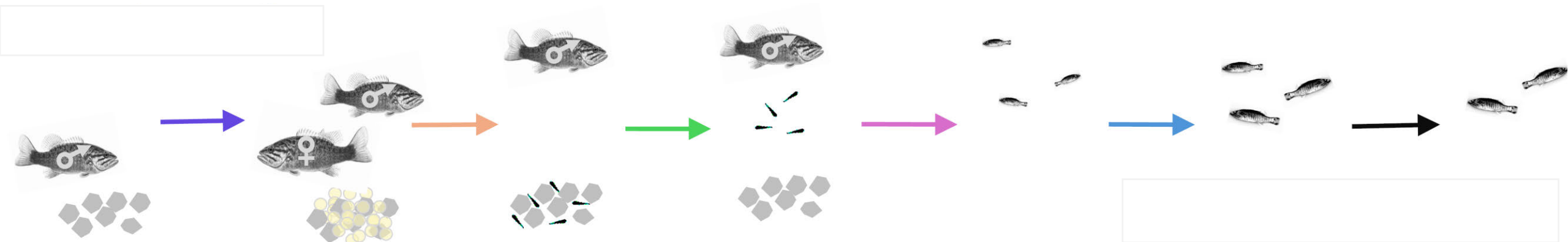


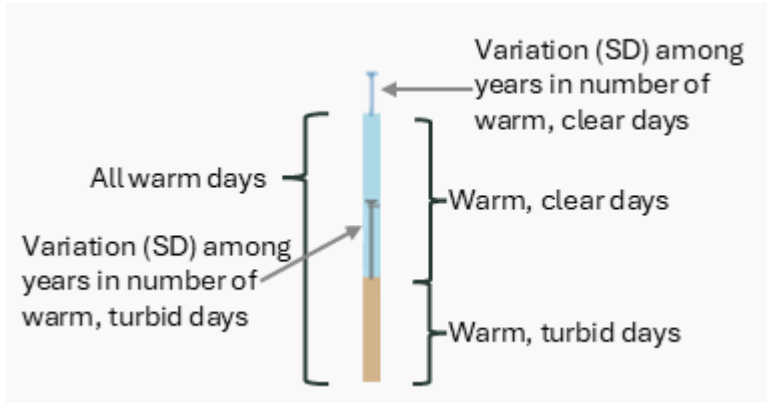
2024



Applications of these data

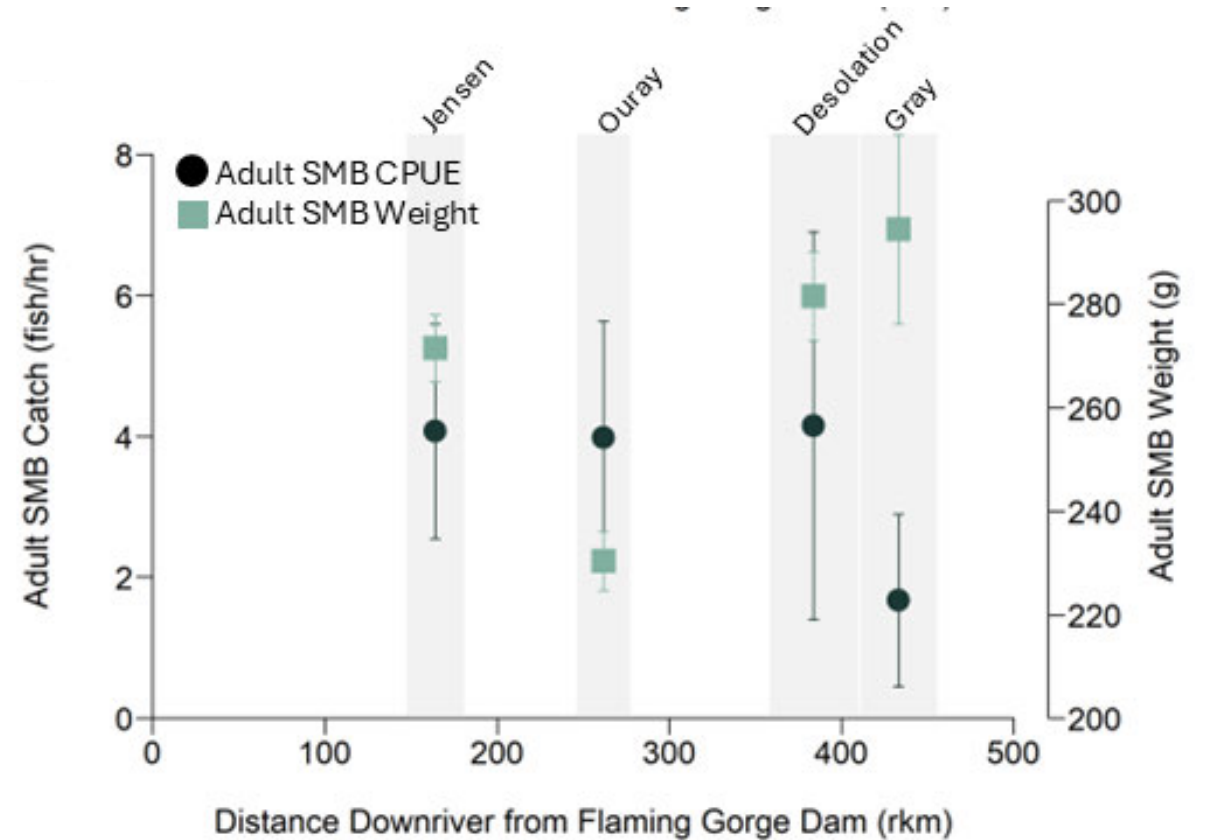
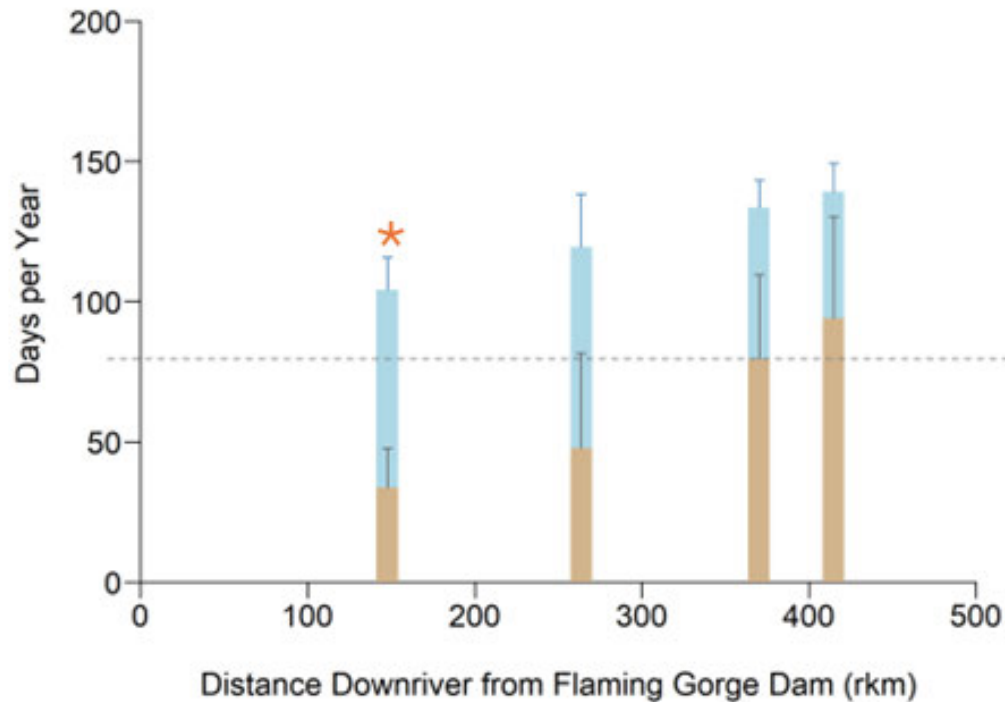
- Broad comparisons between river segments throughout basin.
- Combine with discharge data and hatch data from earlier period to estimate potential sediment conditions when spawning occurred.
- Estimate impacts of temperature and turbidity on growth of smallmouth bass in different river segments.

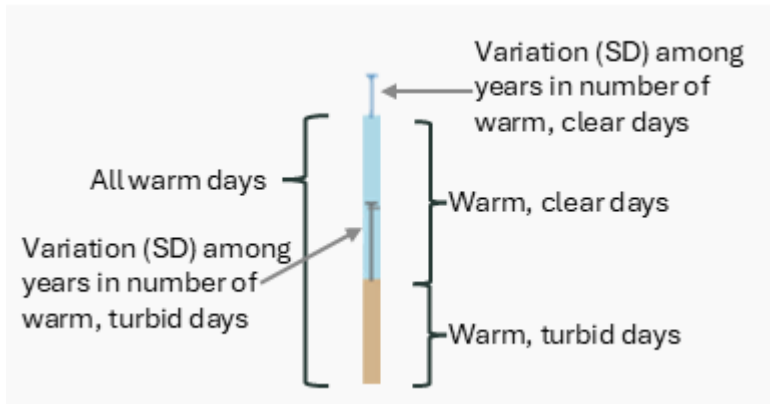




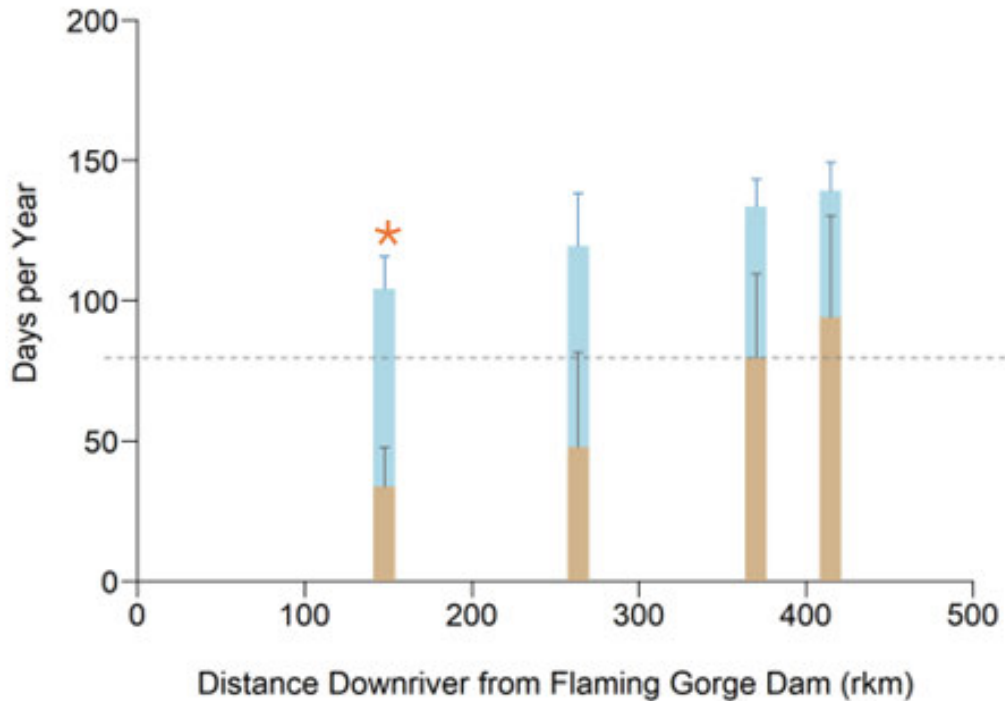
Synthesize turbidity information into metrics like number of warm days that are clear (<50 FNU) or turbid (>50 FNU) and compare to catch data.

Green River

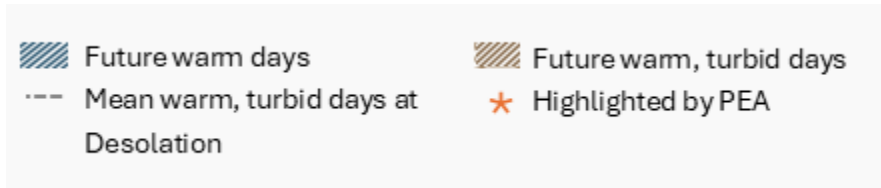




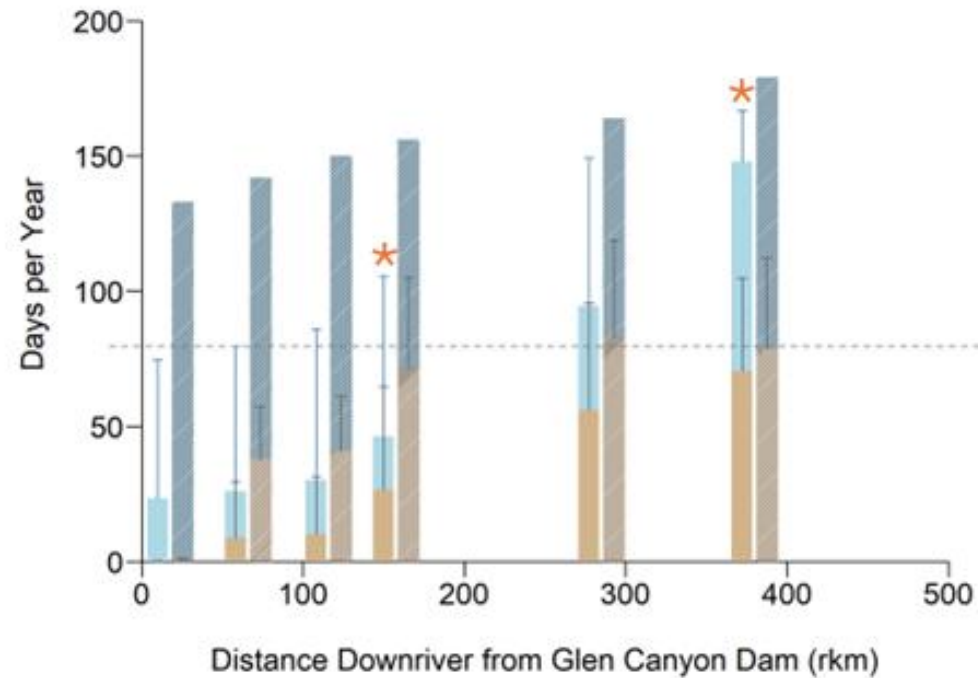
Green River



Then compare to Grand Canyon and consider different temperature scenarios.

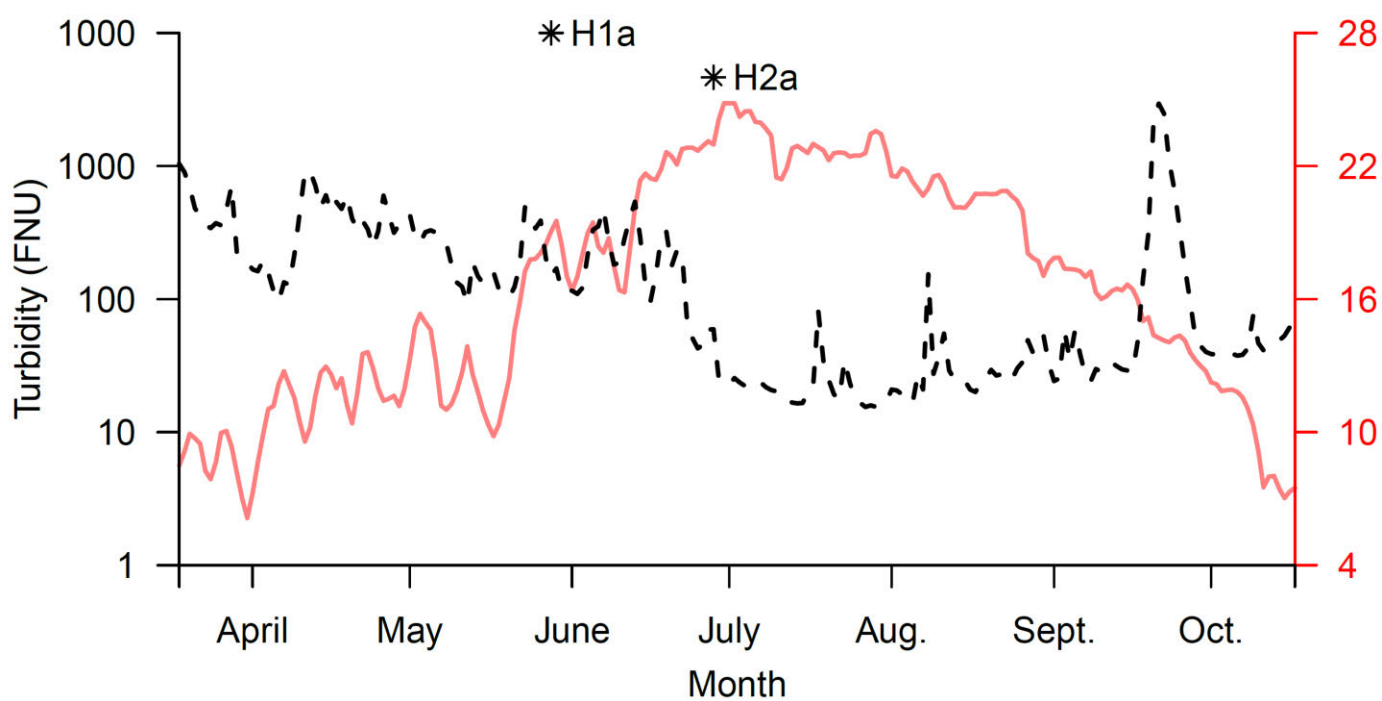


Grand Canyon



Spawning – what role for turbidity?

- Based on literature review & back-calculations from Bestgen and Hill (2016), we identified two potential thresholds.
- Complicated because discharge (which primarily affects velocity in potential spawning habitat) and turbidity are highly confounded.
- Temperature relationships are much more well understood.
- Hypothesis 1a – Spawning initiates after 5 consecutive days with temperatures greater than 16° C and turbidity less than 599 FNU.
- Hypothesis 1b – Spawning initiates after 5 consecutive days with temperatures greater than 16° C and turbidity less than 113 FNU.



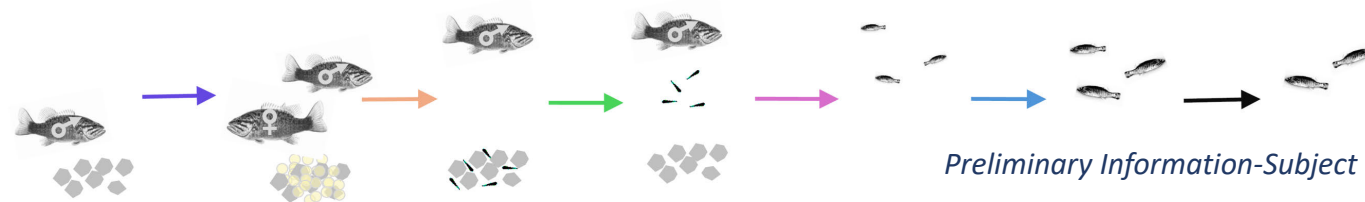
Implications for how much time is spent in vulnerable early stages and the length of juvenile growth period

- Spawning
- Hatching
- Rising
- Growing to independence
- Juvenile growth
- Winter starvation period

H1a: T_e and $T_u < 599$ FNU



H1b: T_e and $T_u < 113$ FNU

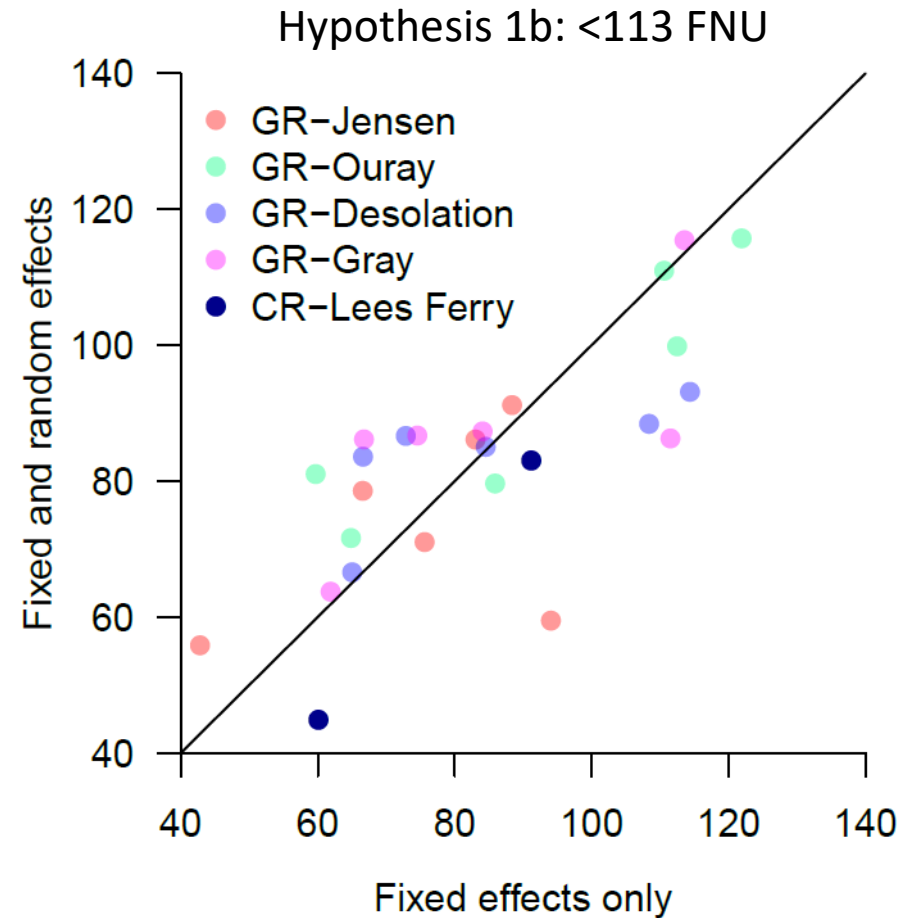
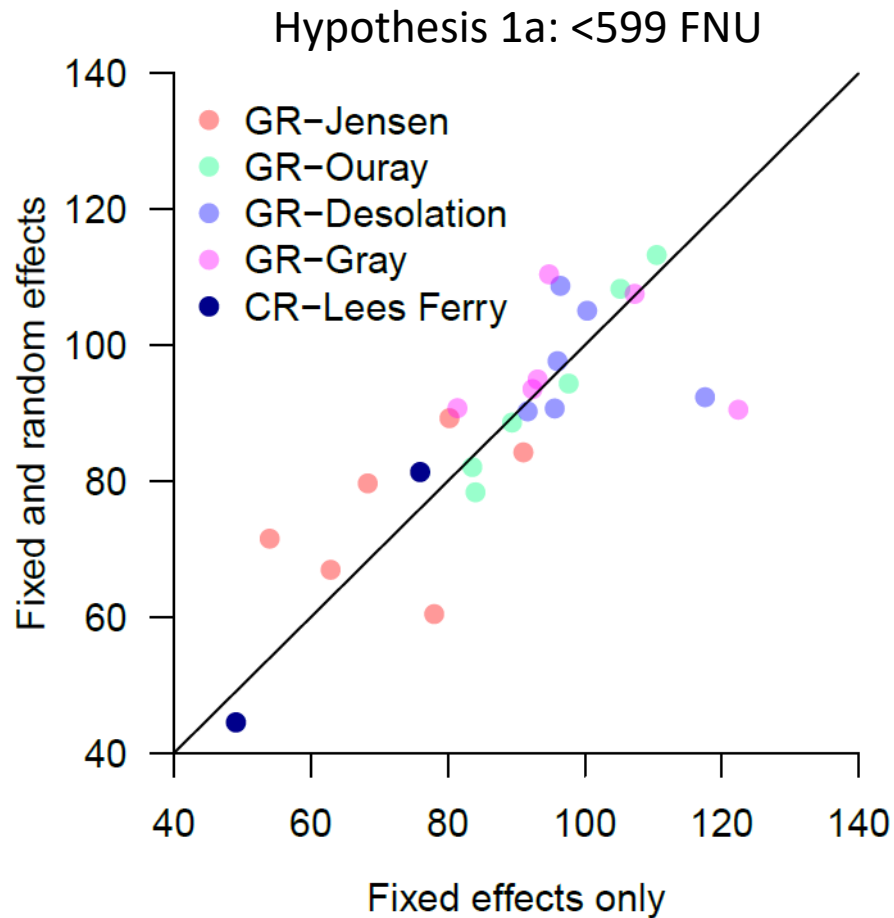


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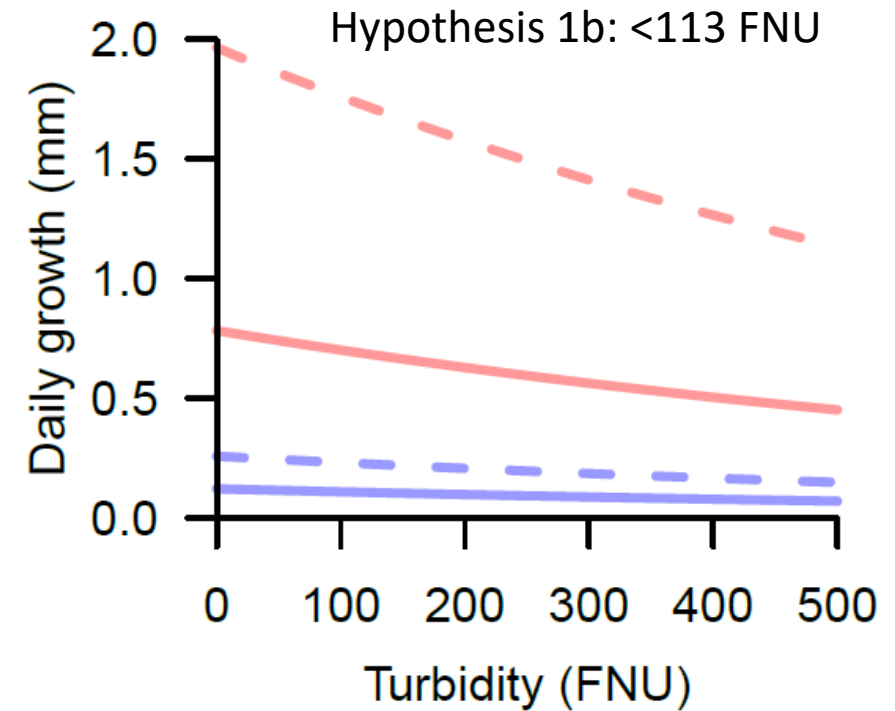
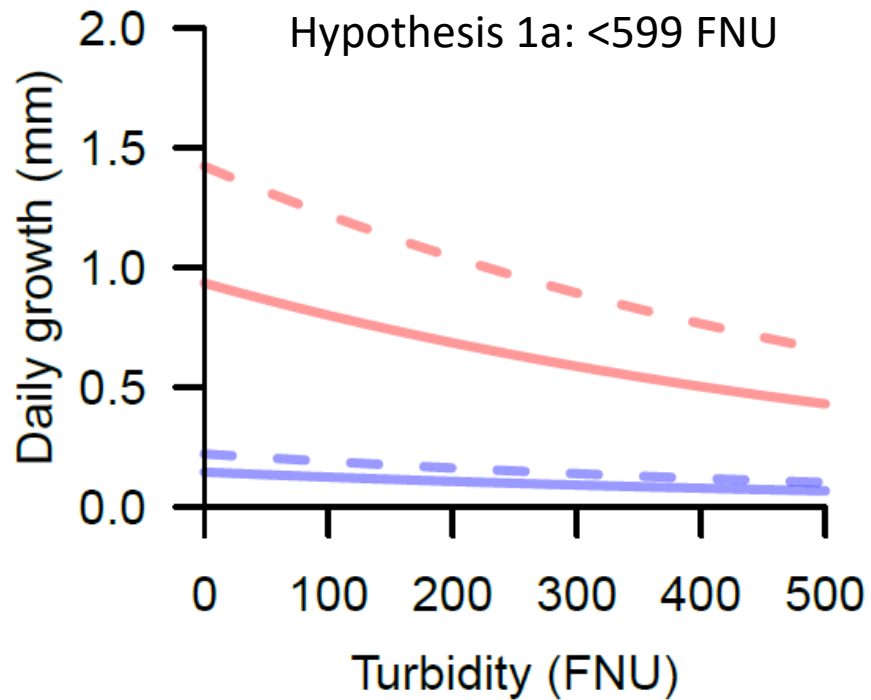
Growth analysis conditional on spawning hypotheses

- Fit to six years of data from 4 river segments in Green River (Jensen, Ouray, Desolation, and Gray) as well as two years of Lees Ferry data.
- Track growth of age-0 and age-1 smallmouth bass
- Include temperature, turbidity and length in a state space model of daily growth.

Compare expected sizes under different hypotheses



Can also examine daily growth predictions under both hypotheses



Next steps in smallmouth bass modeling

- Fitting population models using removal data from four river segments in Green River to estimate population level impacts.
- Planning out of sample forecasting using data from the upper portions of the Colorado River.
- Parameterize already developed simulation model for Grand Canyon.
- Working on smallmouth bioenergetics model to link SMB population abundances to forecasts of humpback chub population dynamics.

Take home messages

- Simple metrics (e.g., # of warm days with turbidity greater than 50 FNU) suggest Western Grand Canyon will be more favorable for Smallmouth Bass than Desolation Canyon so long as river temperatures are warm.
- Catch per hour of electrofishing of adult smallmouth bass in Desolation Canyon is comparable to clearer river segments like Jensen, and humpback chub catch per effort in Desolation-Gray river segments has declined by 22% per year during 2019-2024.
- Nonetheless, negative impacts of turbidity on smallmouth bass growth can be inferred from both laboratory and field measurements and future works will explore whether differences in sediment regimes in the Grand Canyon matter for forecasts of potential invasion dynamics.
- Focusing on early life history has helped identify opportunities to fine tune management actions like cool mix.

Acknowledgements

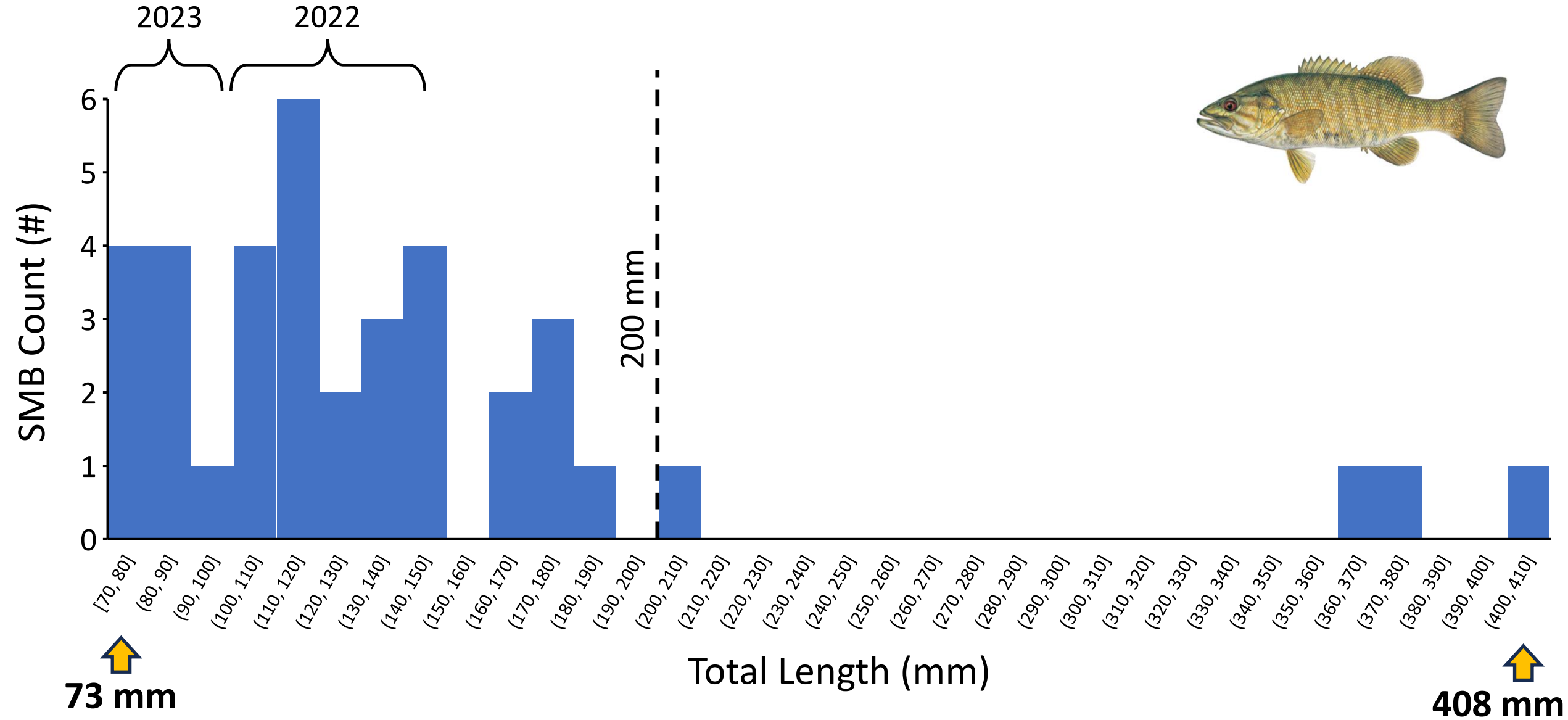
Many thanks to the biologists, boatmen, support staff, and others who contribute to our understanding of nonnative fish population dynamics in Grand Canyon, and to the Glen Canyon Dam Adaptive Management Program for making data collection possible.

Maria Dzul, Brian Healy, Lindsay Hansen, Ben Miller, Kate Behn, Kiona Allen, Shonie Hardeen, Svea Conrad, Tom Gushue, Ann-Marie Bringhurst, Lucien Bucci, Daniela Tirado, Tommy Franklin, Emily Omana Smith, Jeff Arnold, Conor Clancy, Kurt Shollenberger, Laura Tennant, Sue Wood, Matt O’Neill, Clarence Fullard, Alex Walker, Bryce Mihalevich, Brian Hines, David Ward, Pilar Rinker, Mike Pillow, Tiffany Love-Chezem, David Rogowski, Dale Fonken, John Fennell, Trenton Schipper, and many others.

Modeling of Green River data relied on extensive input from Nathaniel Bransky, Kevin R. Bestgen, M. Tildon Jones, Chris Michaud, and Anna Amidon.



2025 Smallmouth Bass Captures: Total Length



73 mm

408 mm

Parasite Monitoring

- Incidence of parasitic infection monitored in native fish per the 2016 Biological Opinion
 - Asian tapeworm (*Bothriocephalus acheilognathi*)
 - Praziquantel treatment (n=40 humpback chub) – May 2025 mainstem, LCR
 - Mainstem: 22% incidence of infestation, with 1-3 tapeworms per individual
 - Little Colorado River: 2005-2007: 40% infected; 2015-2019: 20% infected
 - Anchor worm (*Lernaea*)
 - Visual screening on all fish trips
 - n=37 infected individuals across trips in 2025
- Disease/wound monitoring – October JCM trip
 - Opportunistically sampled fish with visible wounds and healthy-appearing individuals
 - Swabs, skin scrapes, gill biopsy
 - Lernaea on humpback chub (n=4)
 - Leeches on bullhead catfish (n=3)
 - Wounds – no infection identified



Asian Tapeworm Trends in the LCR and Mainstem

