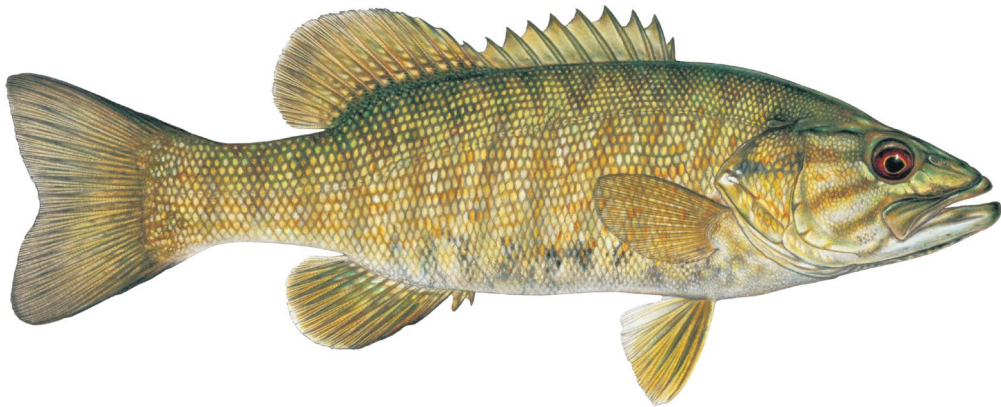


Smallmouth Bass Population Modeling and Implications

Drew Eppehimer¹, Charles B. Yackulic¹, Kate Behn¹, Maria Dzul¹,
Pilar Rinker², Brian Healy¹, and Laura Tennant³



¹ US Geological Survey, Southwest Biological Science Center,
Grand Canyon Monitoring and Research Center

² US Fish and Wildlife Service

³ Grand Canyon National Park

Annual Reporting Meeting

Jan 23, 2024

Phoenix, AZ



Preliminary data, subject to change, do not cite

Acknowledgements

Interagency Smallmouth Bass Taskforce

Glen Canyon Dam Adaptive Management Program

L. Bruckerhoff, J. Wang, K. Young, B. Mihalevich, K. Bestgen, & J. Schmidt

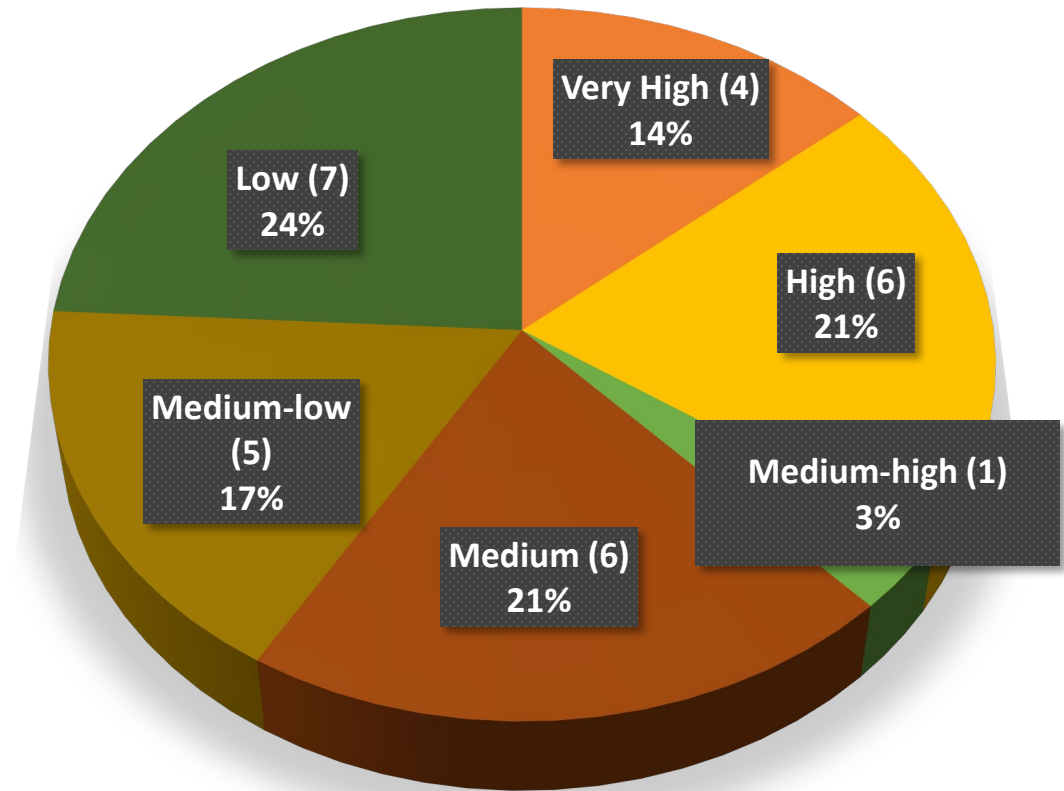
P. Budy, B. Friesen, D. Ward, B. Healy, W. Pine, R. Valdez, A. Schultz, G. Anderson, G. Chong, & E. Rumpf

Southwest Climate Adaptation Science Center

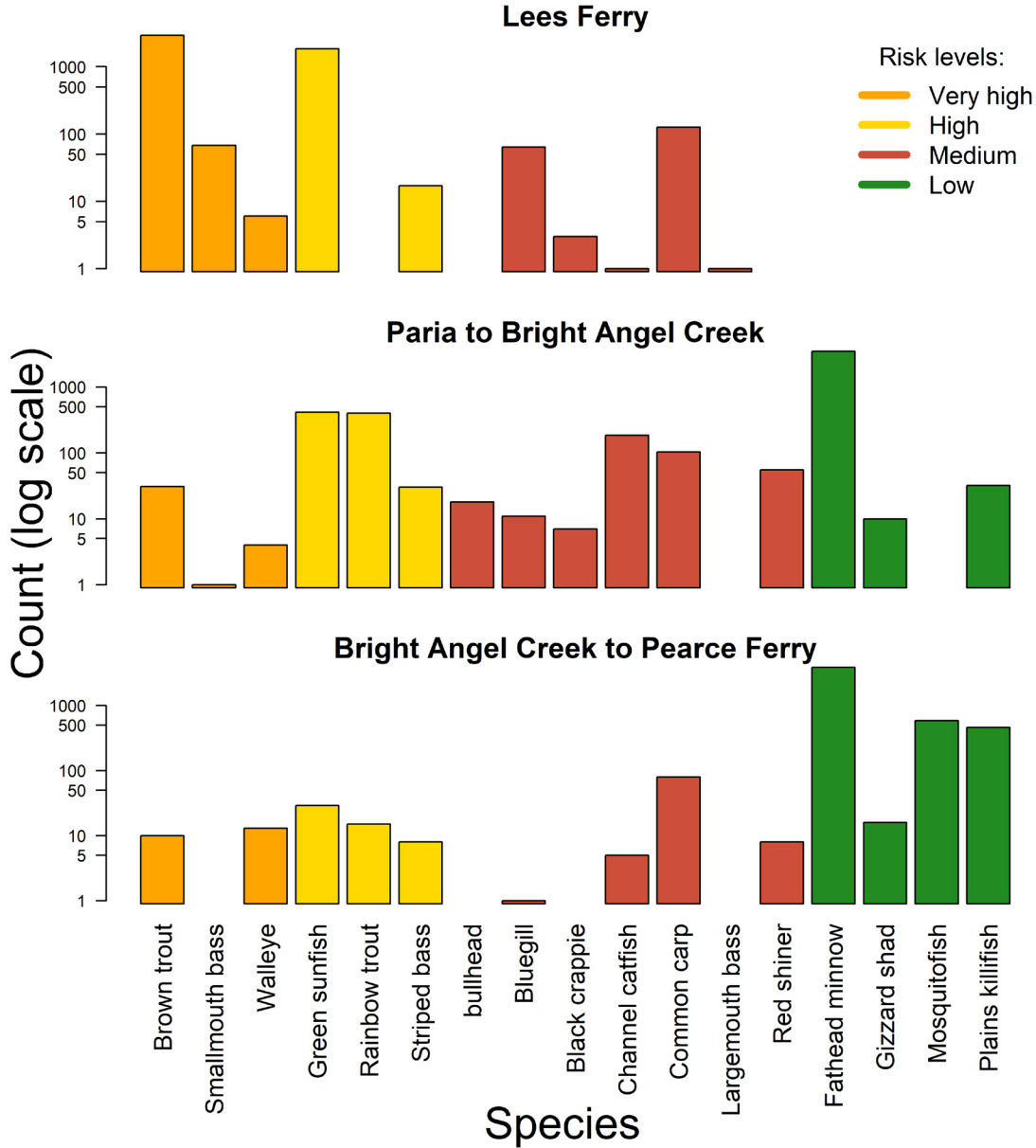


Introduced fishes do not pose equal risks

- NPS Risk Levels (2021 update):
 - Smallmouth Bass (Very High)
 - Walleye (Very High)
 - Brown Trout (Very High)
 - Green Sunfish (High)
 - Rainbow Trout (High)
 - Common Carp (Med.-low)
 - Fathead Minnow (Low)



2023 Grand Canyon Nonnative Fishes



*Does not include NPS targeted SMB removals

Grand Canyon Nonnative Fishes

Nonnative species that have increased in catch more than 100% in last 3 years compared to 2000-2019:



Channel Catfish



Smallmouth Bass



Green Sunfish



Black Crappie



Striped Bass



Bluegill



Fathead Minnow



Threadfin Shad



Walleye



Bullhead Catfish



Mosquitofish



Plains Killifish

Grand Canyon Nonnative Fishes

Nonnative species that have increased in catch more than 100% in last 3 years compared to 2000-2019:

Potential for self-sustaining population and high piscivory



Smallmouth Bass



Channel Catfish



Green Sunfish



Black Crappie



Striped Bass



Bluegill



Fathead Minnow



Threadfin Shad



Walleye



Bullhead Catfish

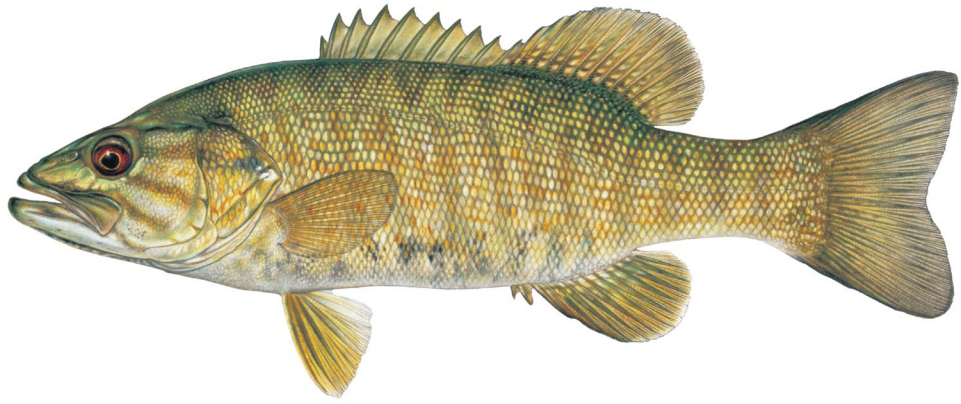


Mosquitofish



Plains Killifish

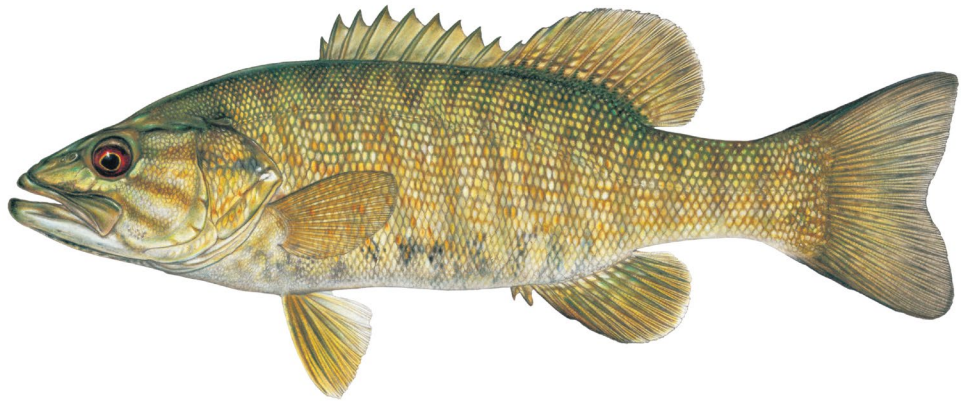
Lake Powell



Lake Mead

Colorado River



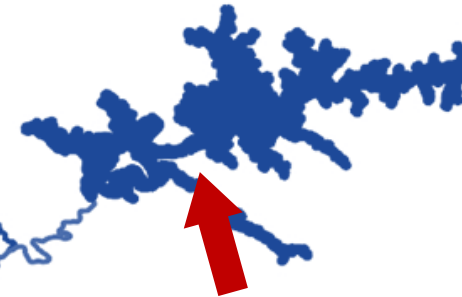


Lake Mead



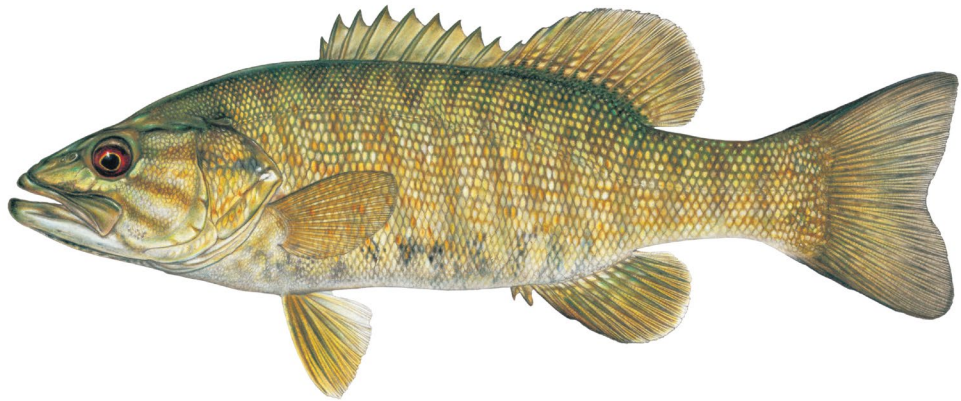
Colorado River

Lake Powell

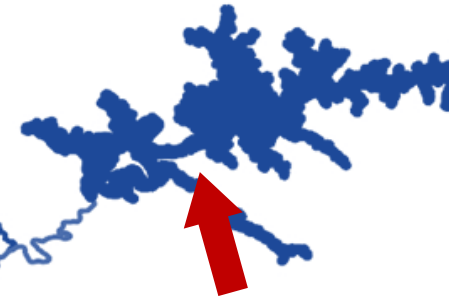


**1982-1989
stocked**



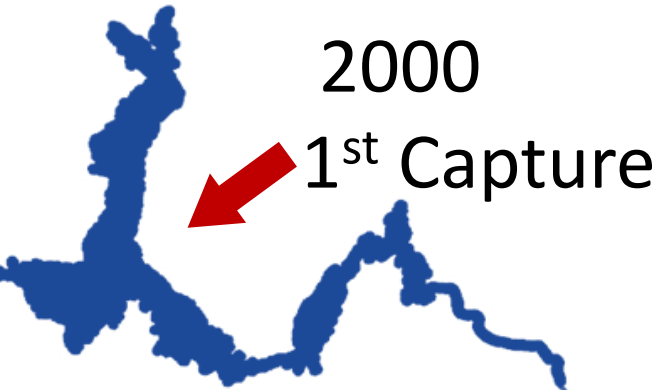


Lake Powell



1982-1989
stocked

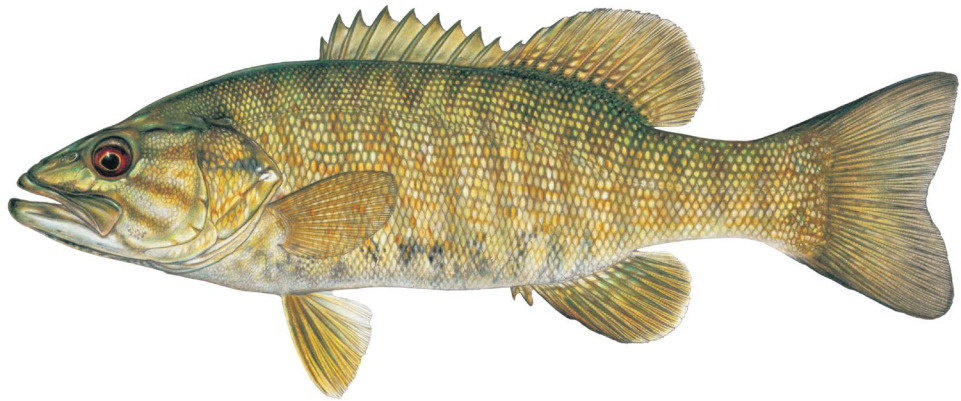
Lake Mead



2000
1st Capture

Colorado River





Lake Mead

2000

1st Capture



Lake Powell

2003

1st Capture



1982-1989

stocked



Colorado River



10

30

70

miles

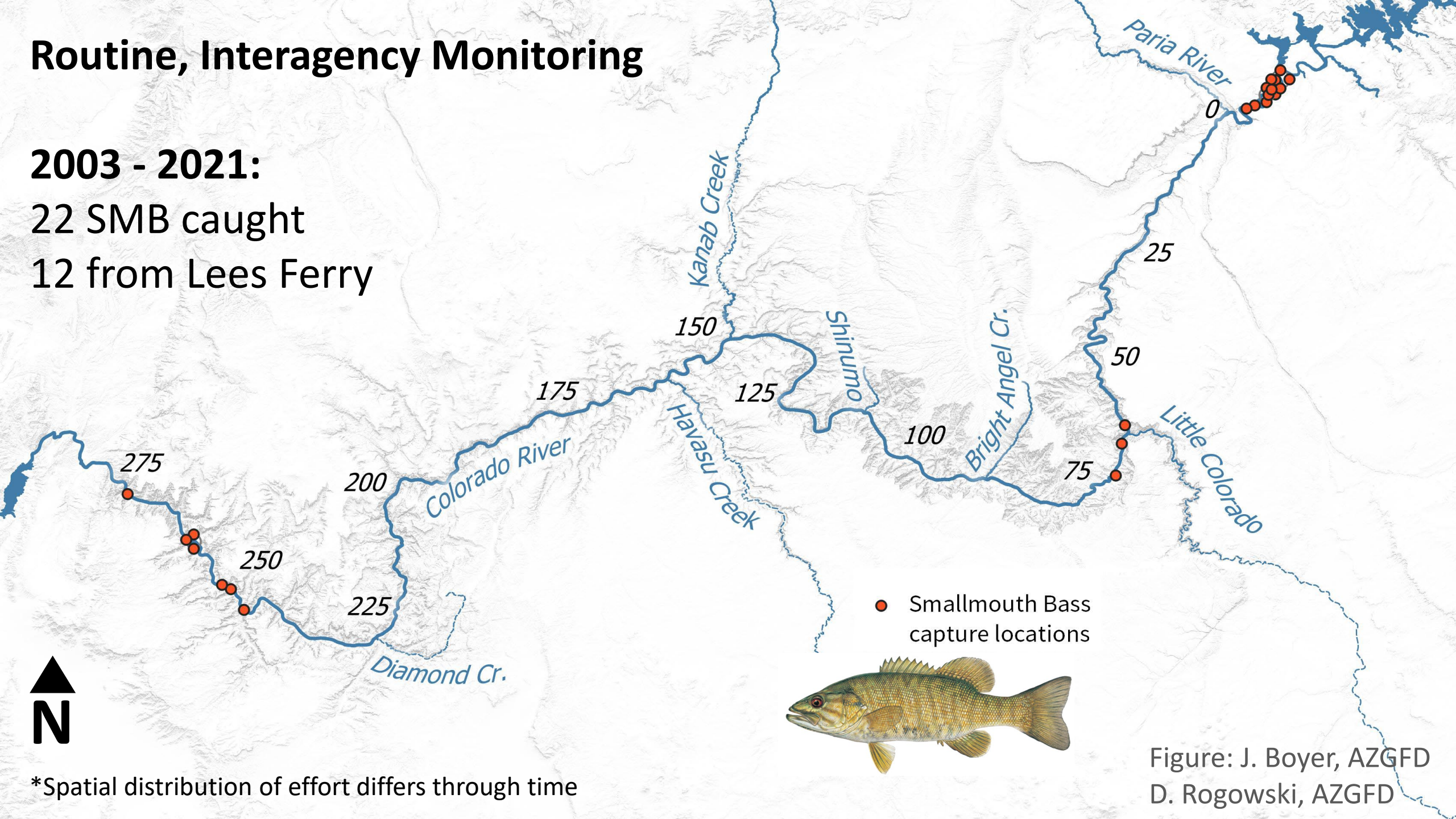


Routine, Interagency Monitoring

2003 - 2021:

22 SMB caught

12 from Lees Ferry

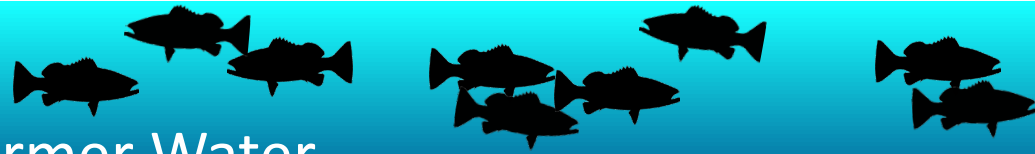


*Spatial distribution of effort differs through time

Figure: J. Boyer, AZGFD
D. Rogowski, AZGFD

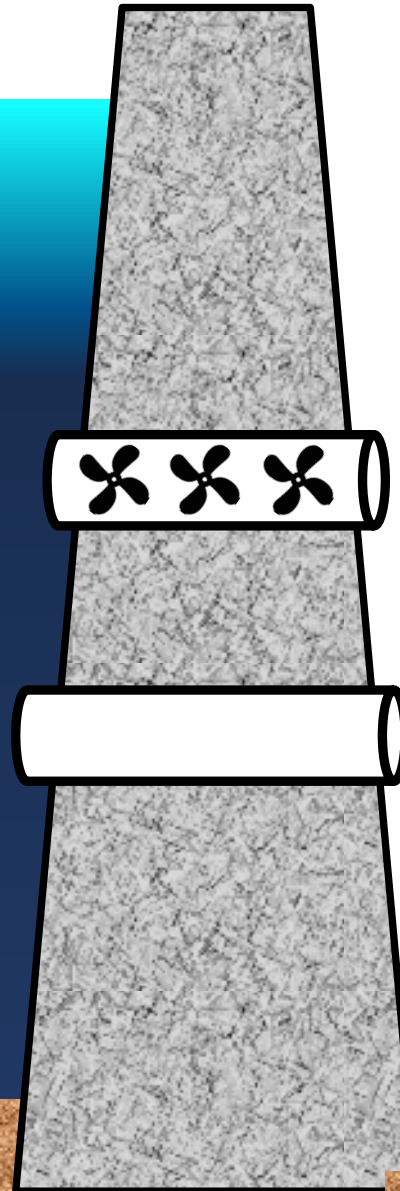
Glen Canyon Dam

Lake Powell



Warmer Water

Colder Water



Lees Ferry

3470 ft: Penstocks

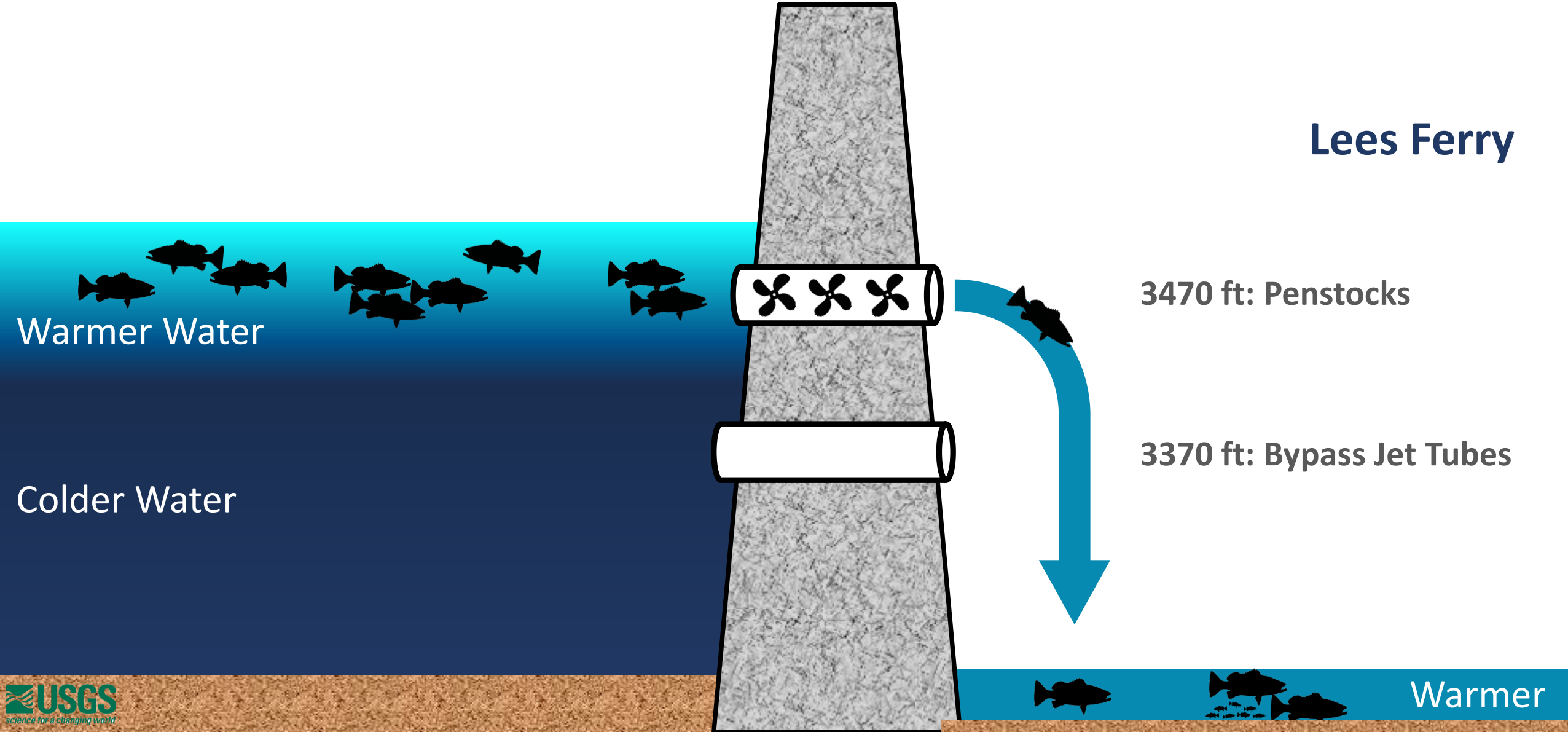
3370 ft: Bypass Jet Tubes

Colder

Glen Canyon Dam

Lake Powell

Lees Ferry



3470 ft: Penstocks

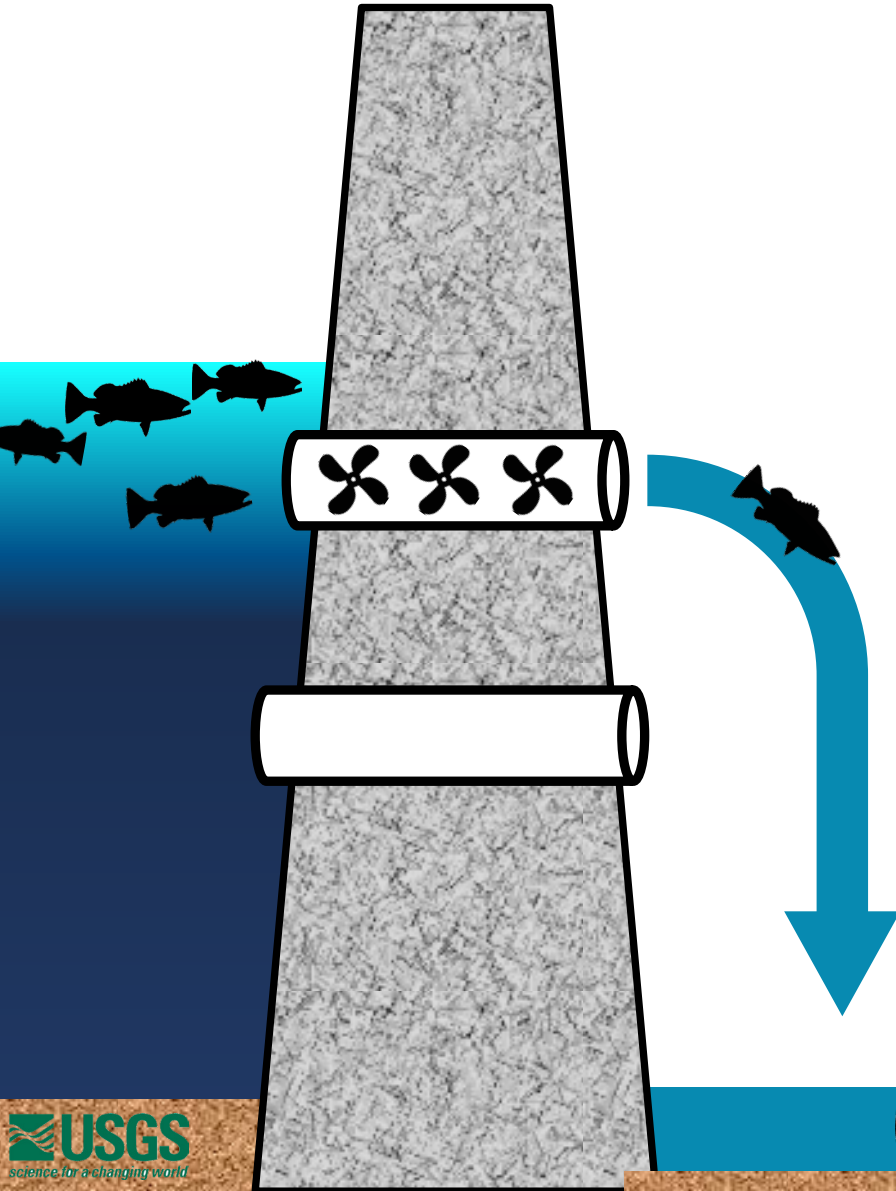
3370 ft: Bypass Jet Tubes

Warmer Water

Colder Water

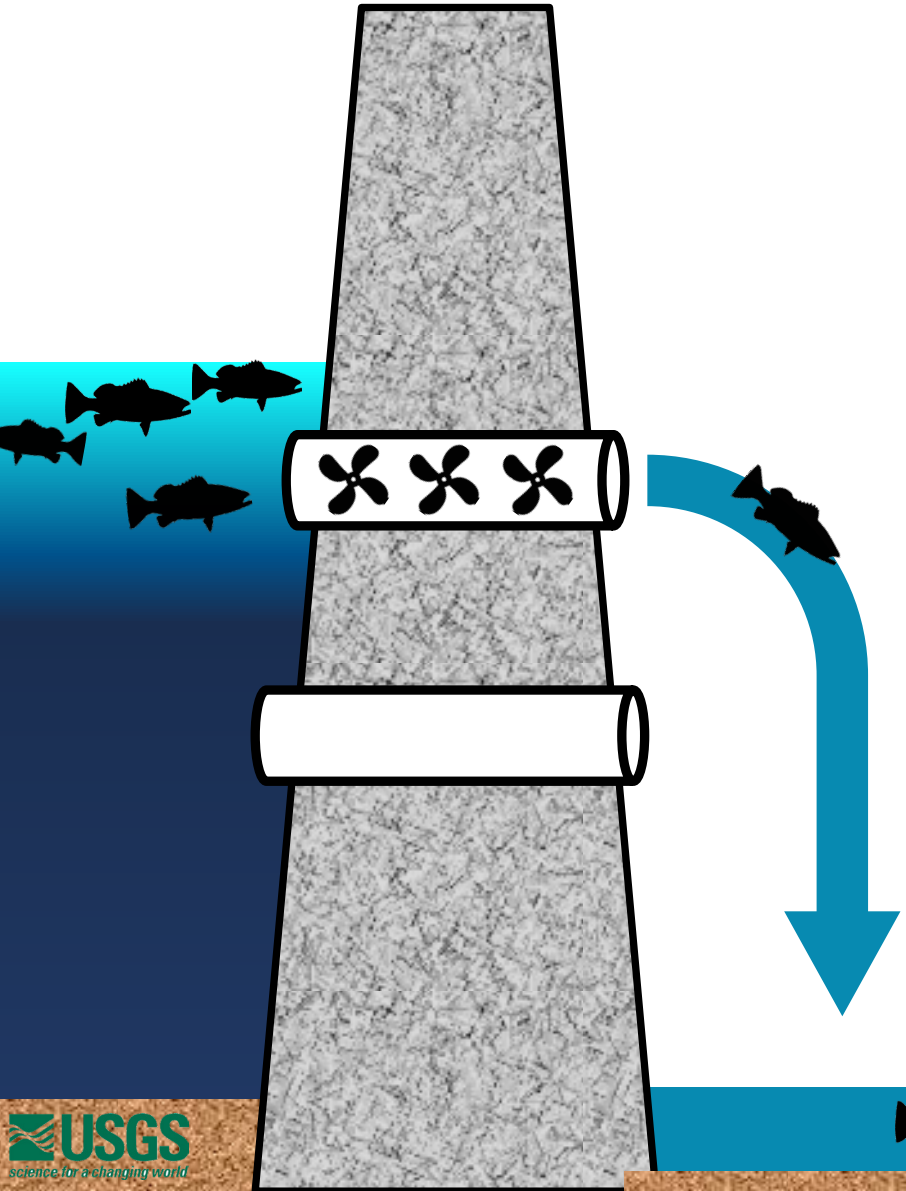
Warmer

Smallmouth bass modeling



- 1. Propagule Pressure from Lake Powell**
 - Entrainment (fish passage through dam)
 - Elevation dependent
- 2. Population Growth**
 - Reproduction, survival, recruitment
 - Thermal suitability
 - Elevation dependent

Smallmouth bass modeling

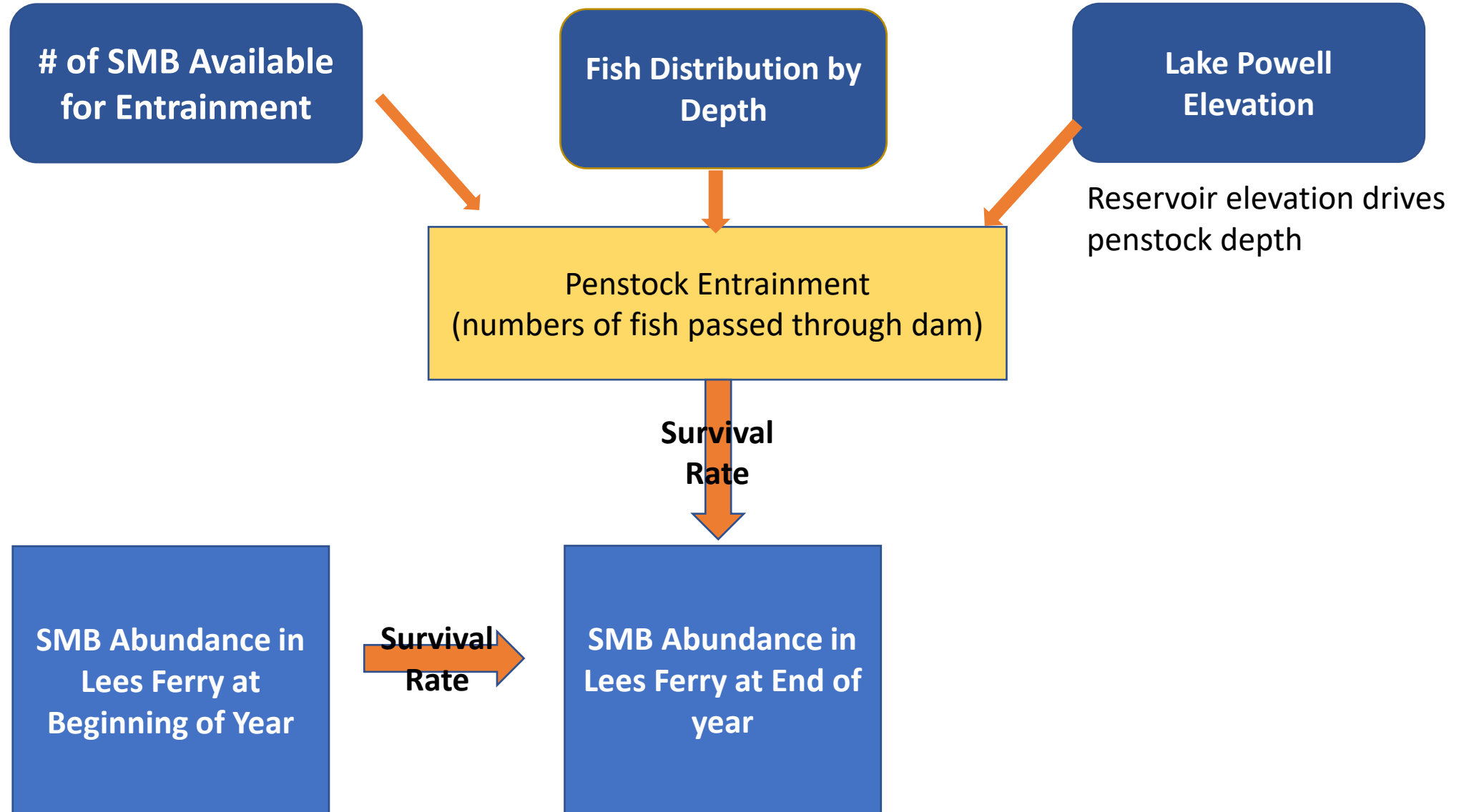


1. Propagule Pressure from Lake Powell
-Entrainment (fish passage through dam)
Elevation dependent

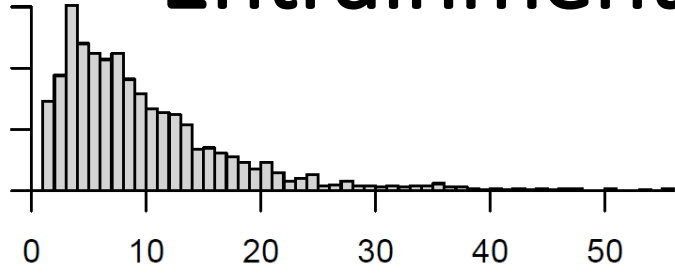
2. Population Growth
-Reproduction, survival, recruitment
Thermal suitability
Elevation dependent

Modeling: Smallmouth Bass Propagule Pressure

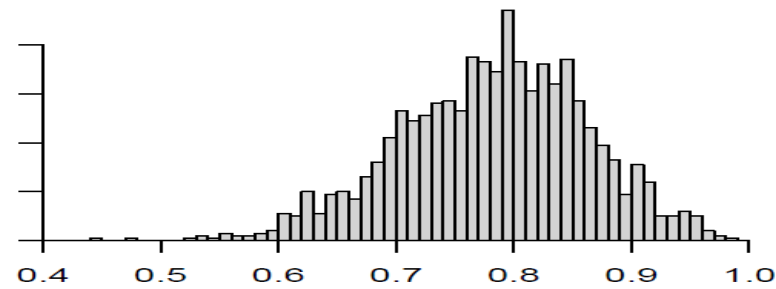
Conceptual Model of Entrainment Risk



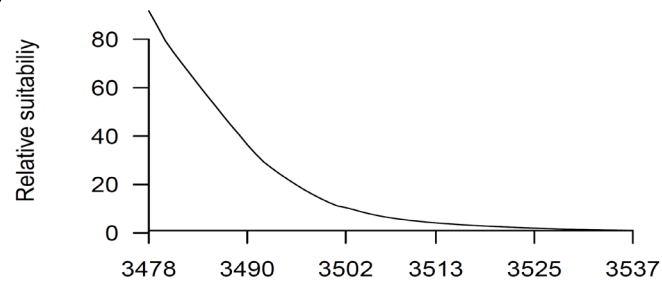
Statistical Model of Entrainment Risk



Size of entrainable population (x 1,000)

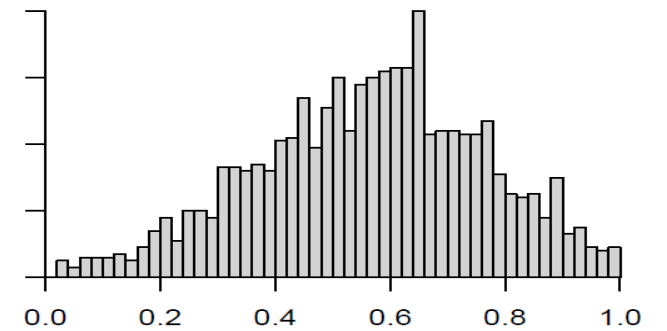


Annual adult survival



**Inflows
Outflows
(Bank Storage,
Evaporation)**

**Penstock Entrainment
(numbers of fish passed through dam)**



Survival through penstocks

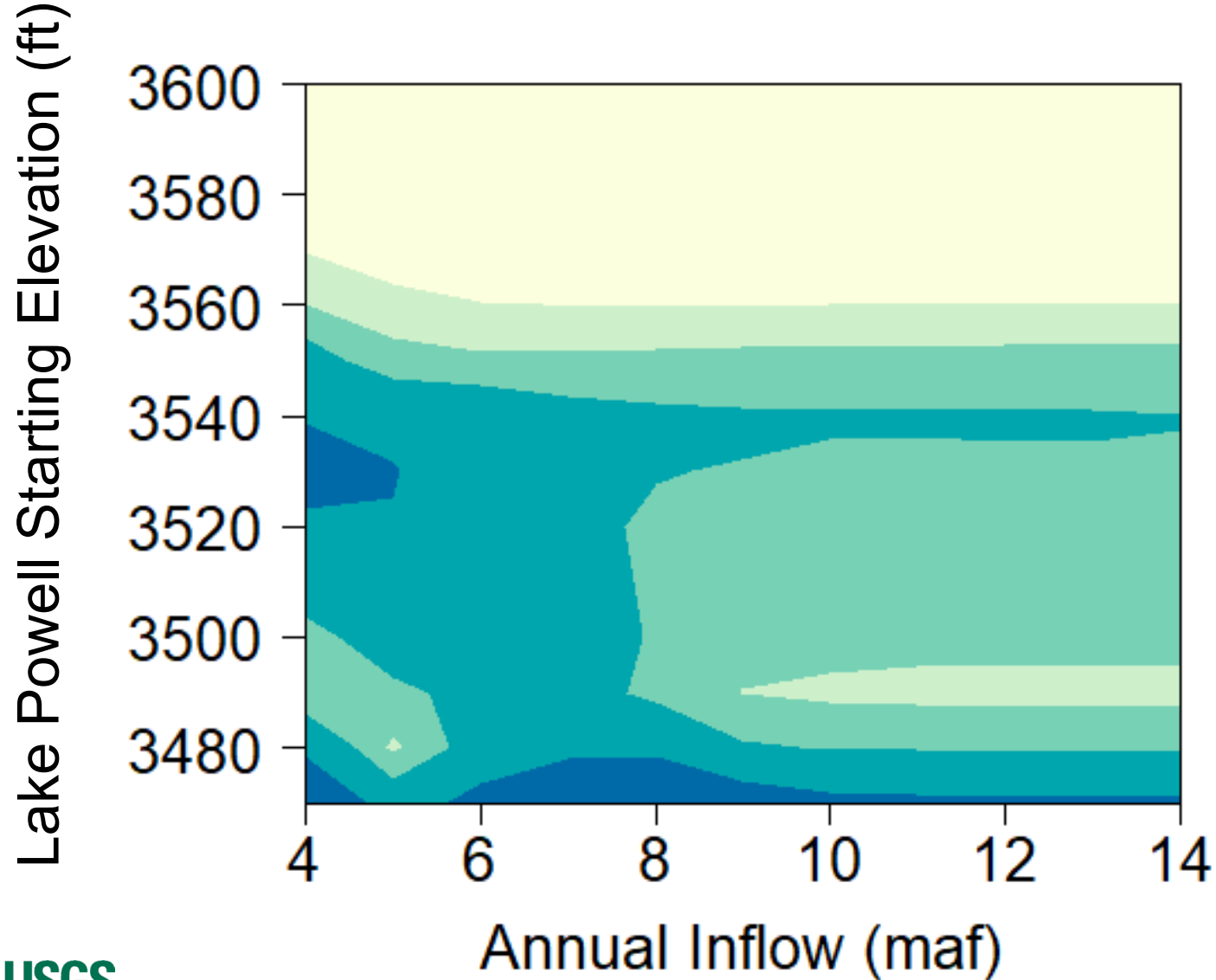
**Survival
Rate**

**SMB abundance in
Lees Ferry at
beginning of year**

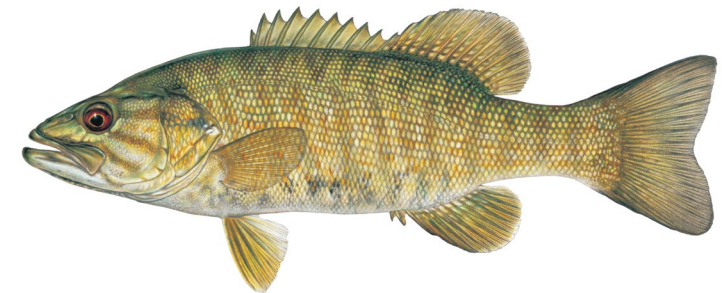
**Survival
Rate**

**SMB abundance in
Lees Ferry at end of
year**

Modeling: Smallmouth Bass Propagule Pressure

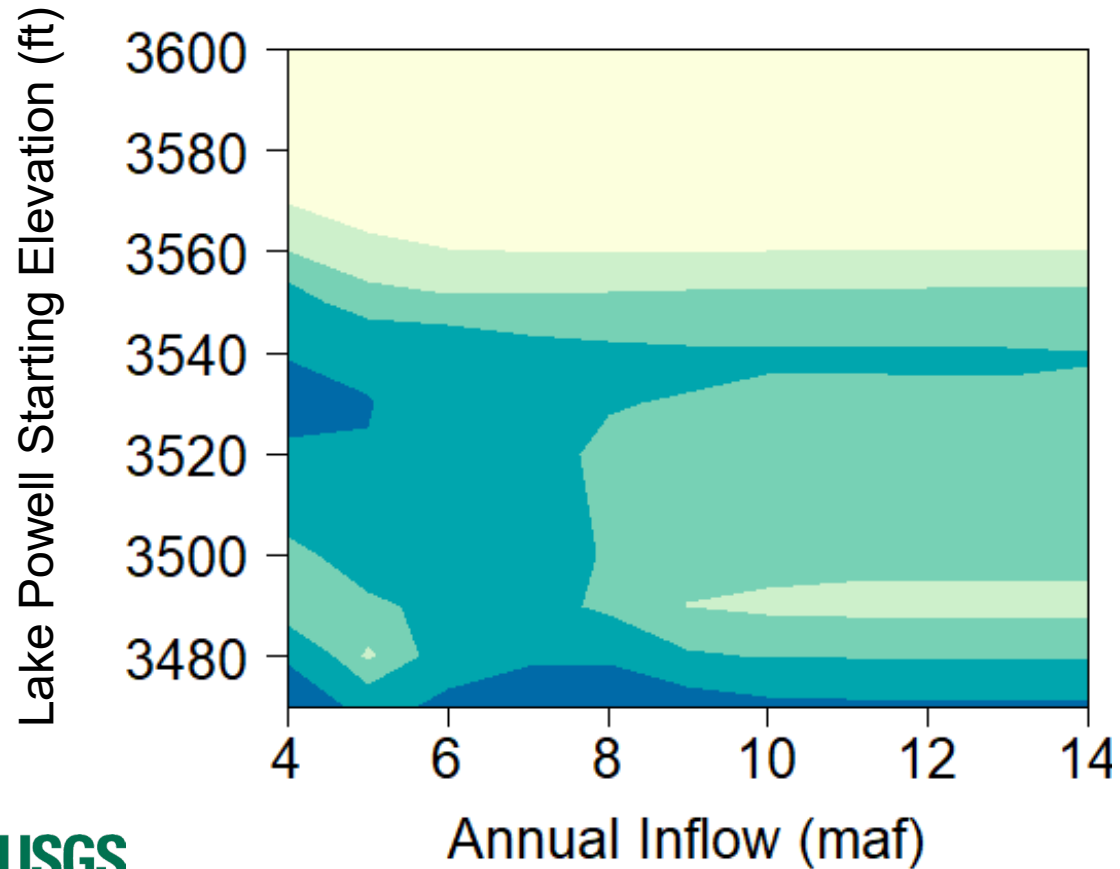


Assumes
7.48 maf outflows

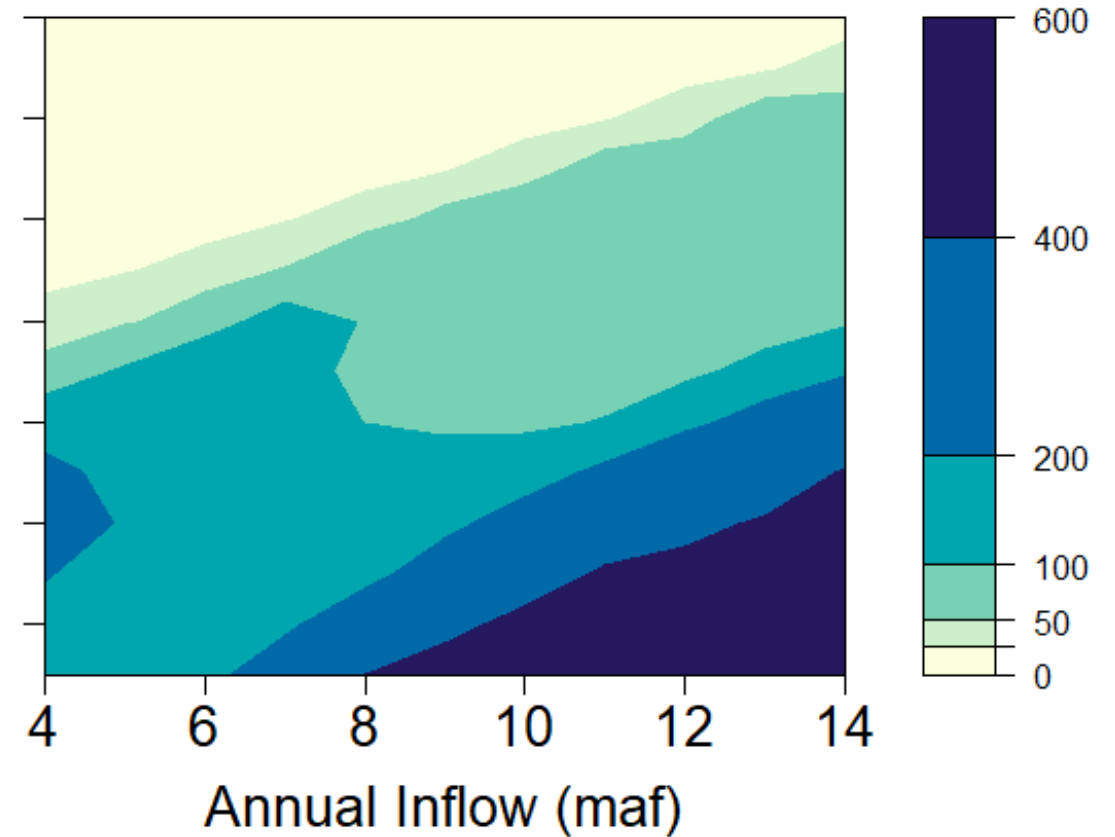


Modeling: Smallmouth Bass Propagule Pressure

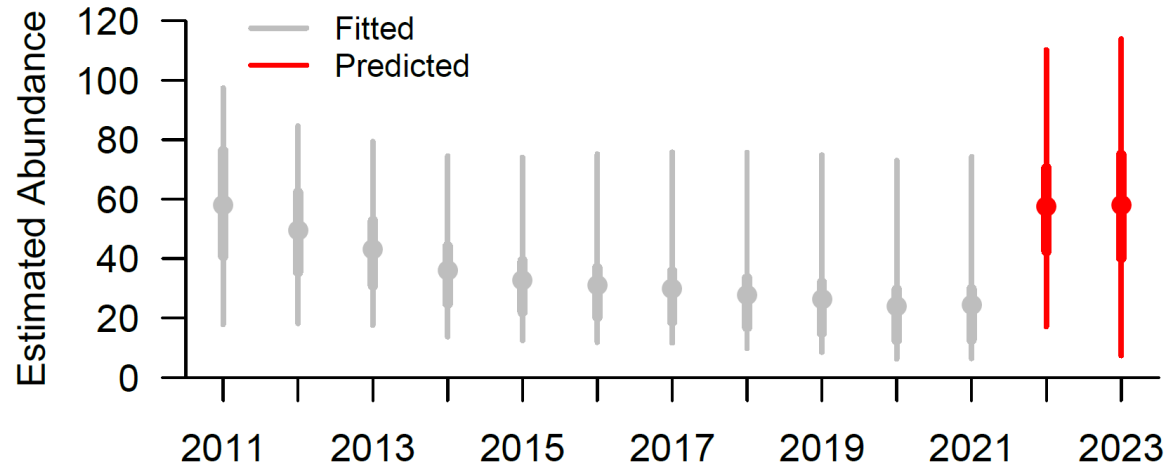
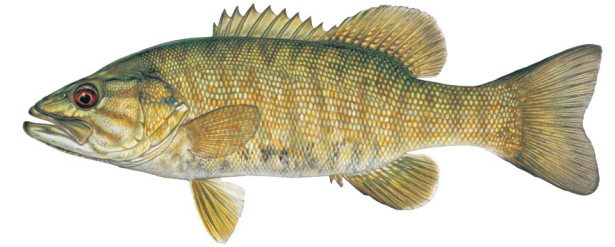
7.48 maf outflows



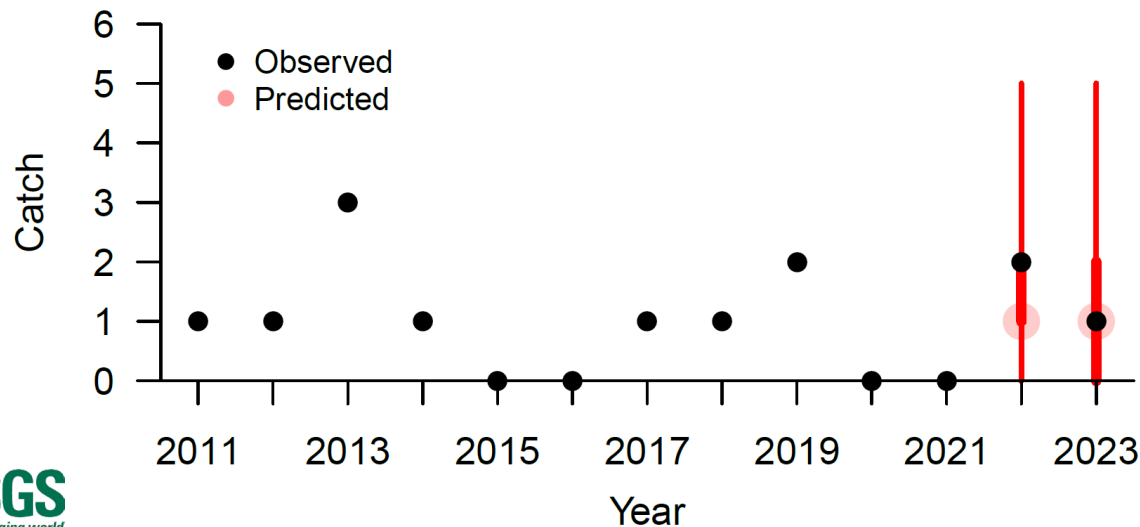
Match inflows and outflows



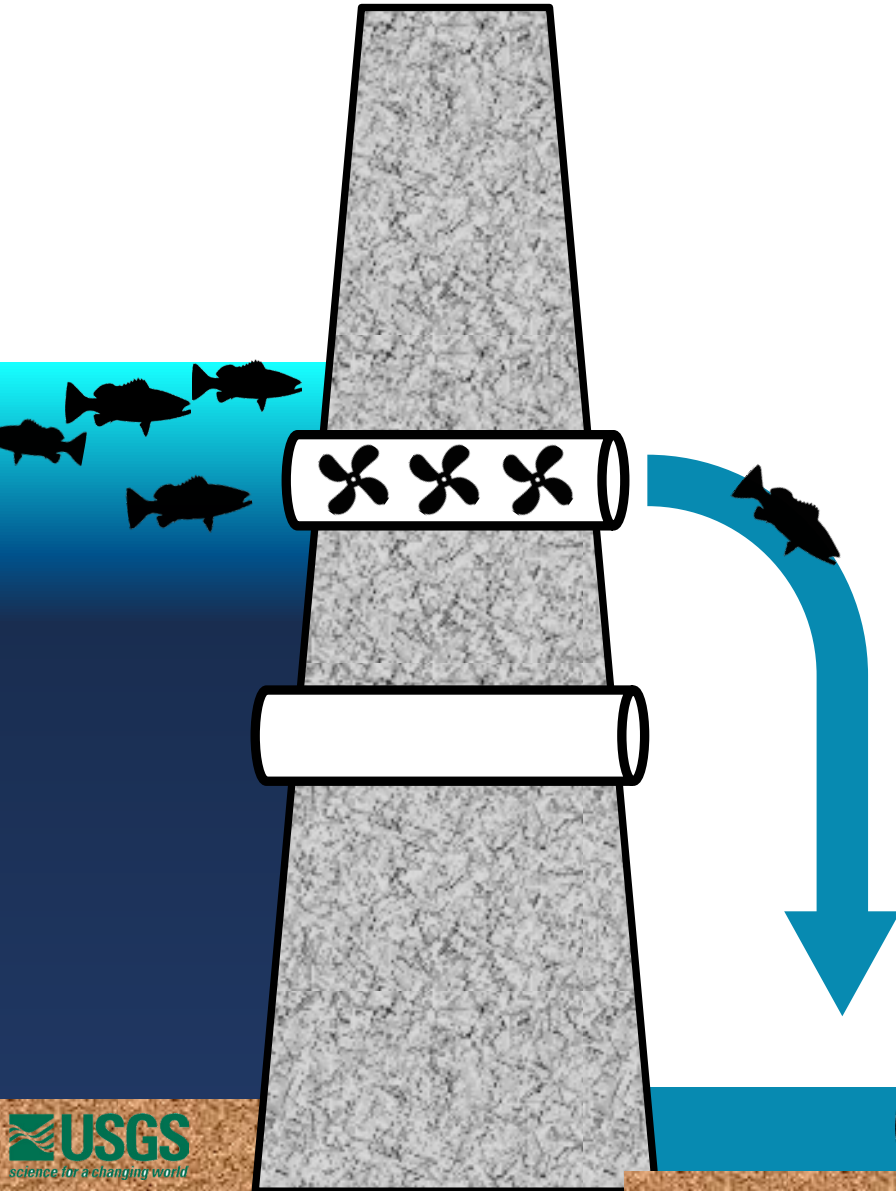
Modeling: Smallmouth Bass Propagule Pressure



Out of sample prediction for 2022 and 2023 entrainment



Smallmouth bass modeling



- 1. Propagule Pressure from Lake Powell**
 - Entrainment (fish passage through dam)
 - Elevation dependent

- 2. Population Growth**
 - Reproduction, survival, recruitment
 - Thermal suitability
 - Elevation dependent

Modeling: Smallmouth Bass Population Growth

(Assumes Allee Effect threshold is surpassed)

Population Growth Rate (λ)

Based on thermal suitability

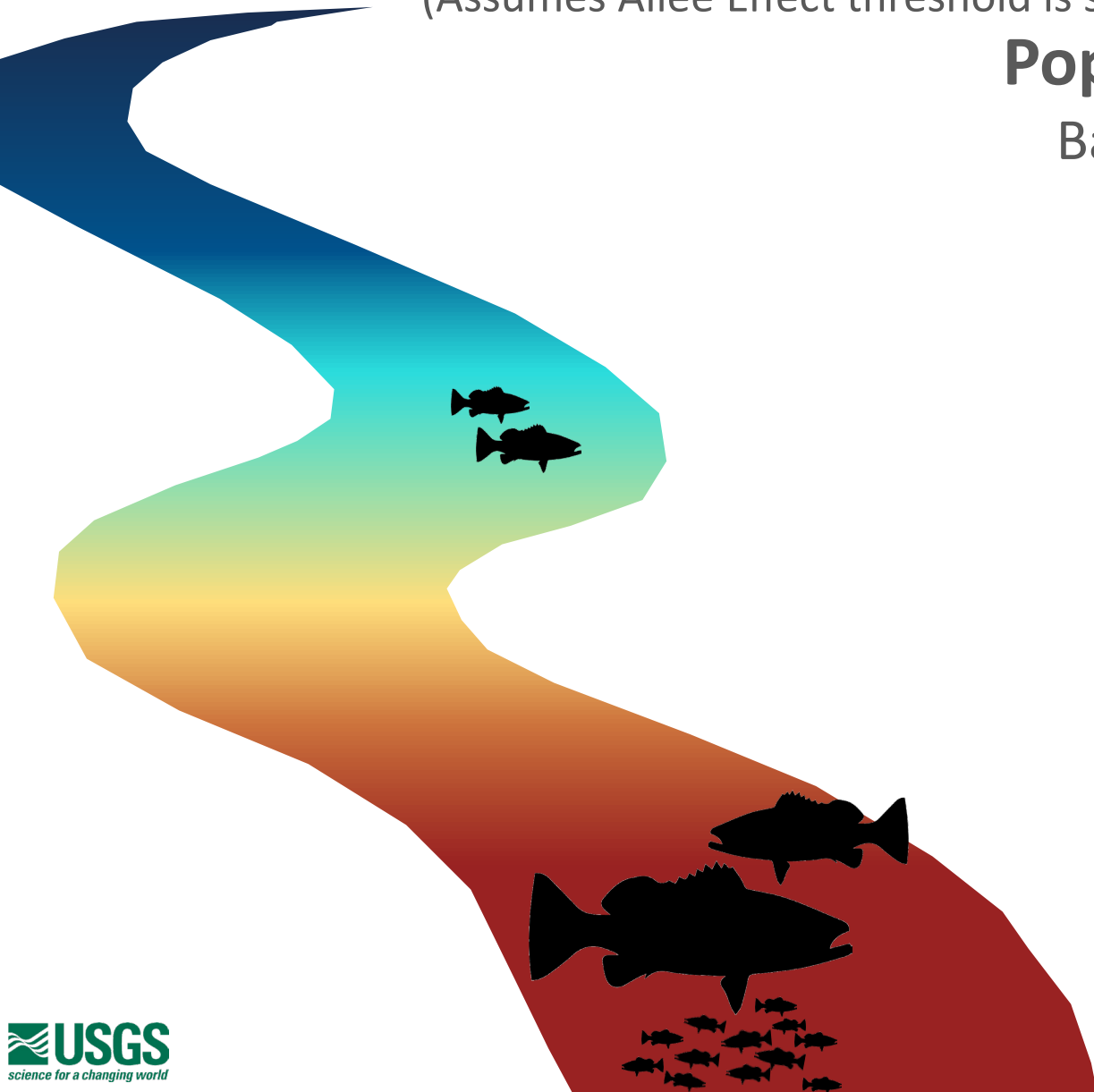
Daily River Temperature (mainstem only)

- Lake Powell depth profiles
- Lake Powell elevation
- Downriver temp model (Dibble et al. 2021)

Smallmouth Bass and Temperature

- Spawn/hatch (16C spawning threshold)
- Age 0 growth
- Age 0 overwinter survival

Parameters were derived from Breton et al. (2015) and Bruckerhoff et al. (in prep)



Modeling: Smallmouth Bass Population Growth

(Assumes Allee Effect threshold is surpassed)

Population Growth Rate (λ)

Based on thermal suitability

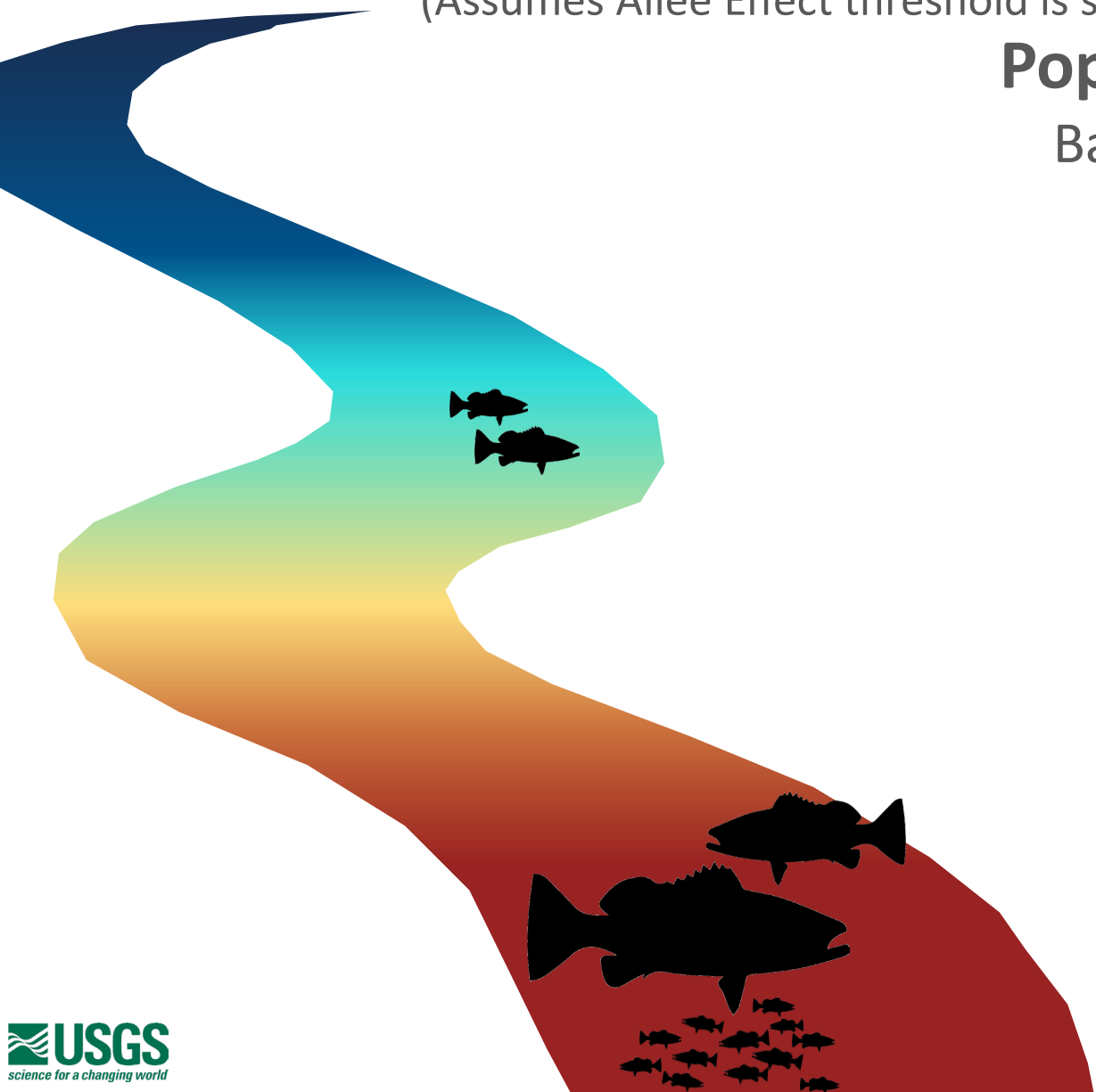
Daily River Temperature (mainstem only)

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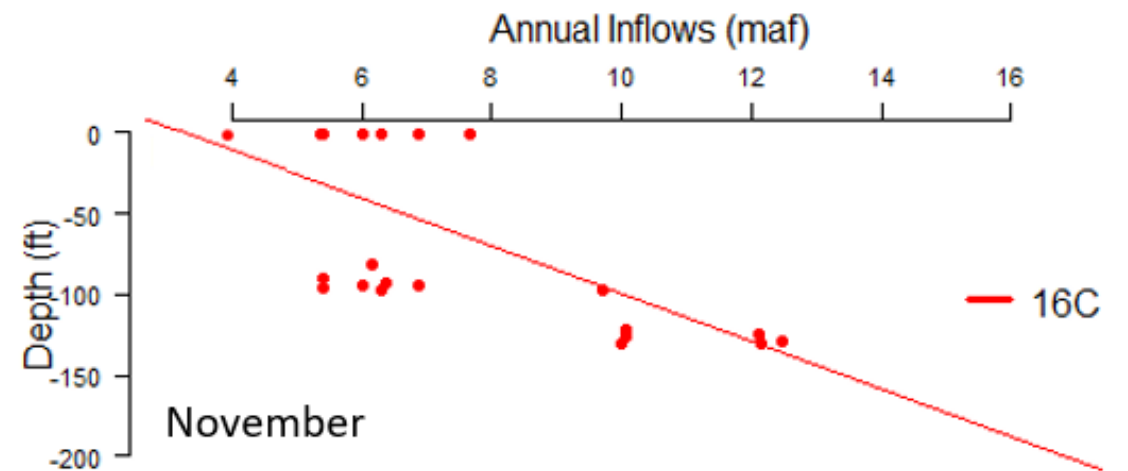
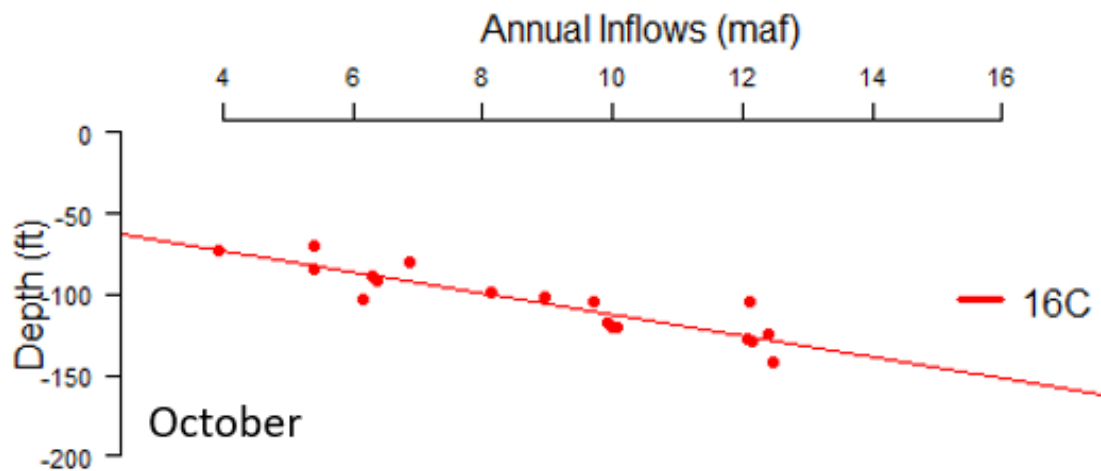
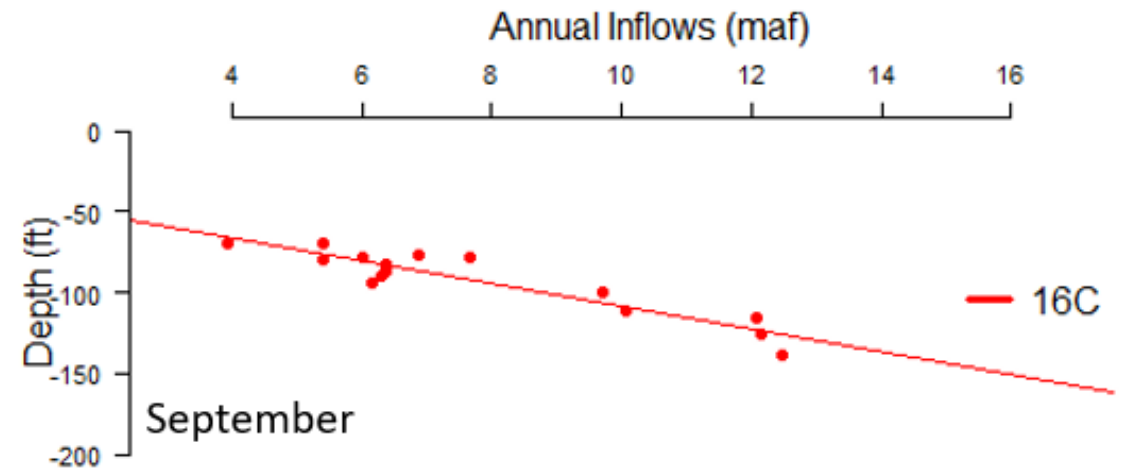
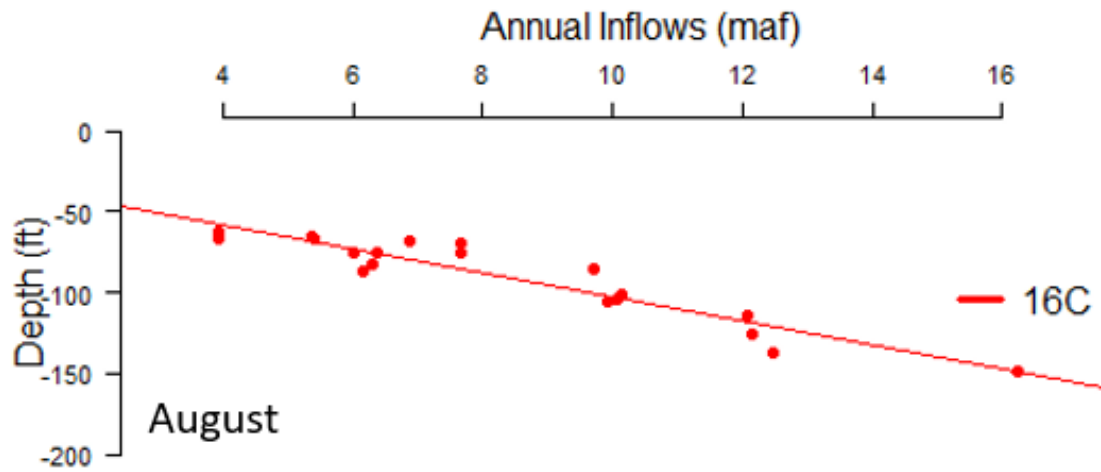
Parameters were derived from Breton et al. (2015) and Bruckerhoff et al. (in prep)



Inflow strength changes thermal profile

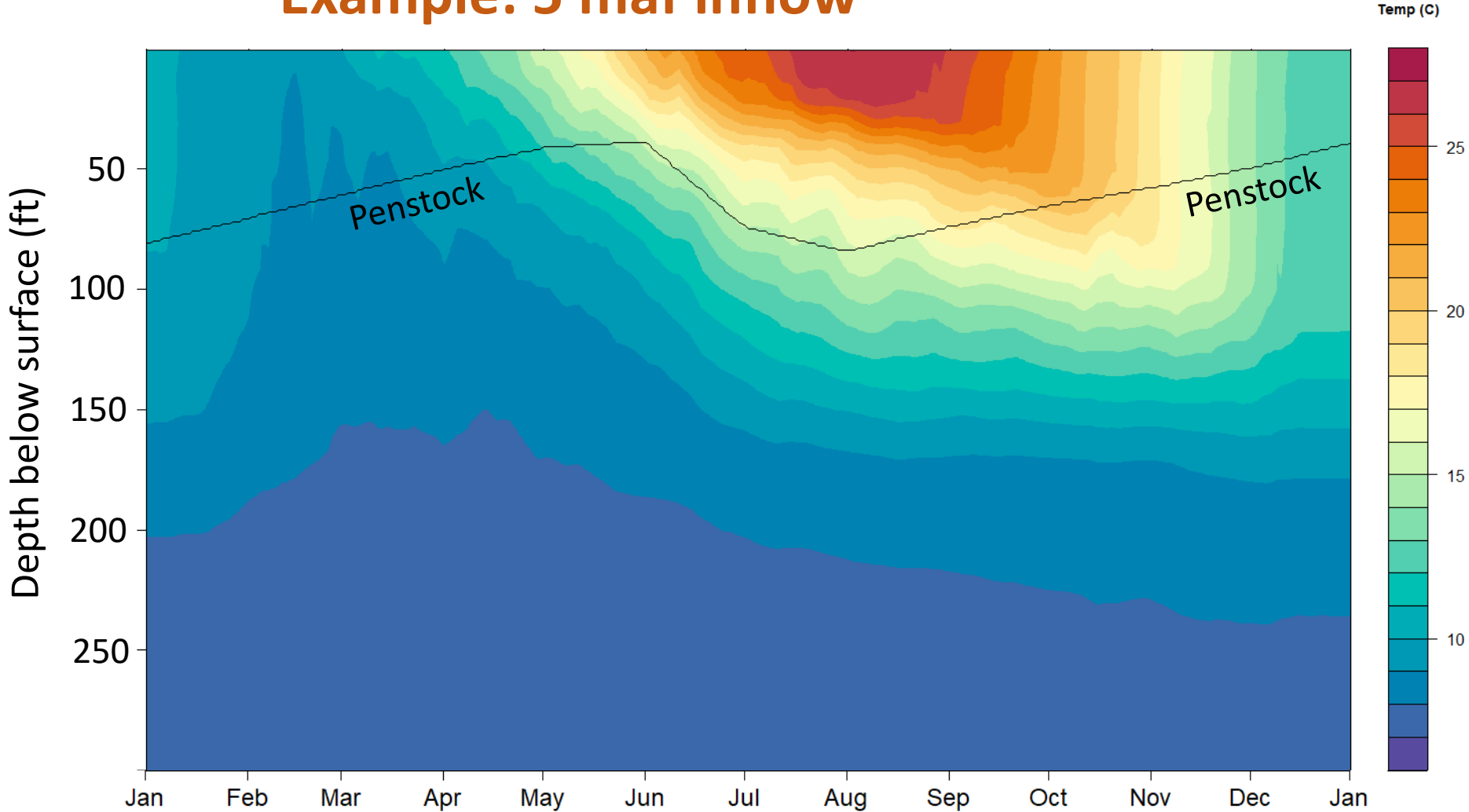
Bigger inflows = warmer water deeper

Depth to 16C can change by >100ft!



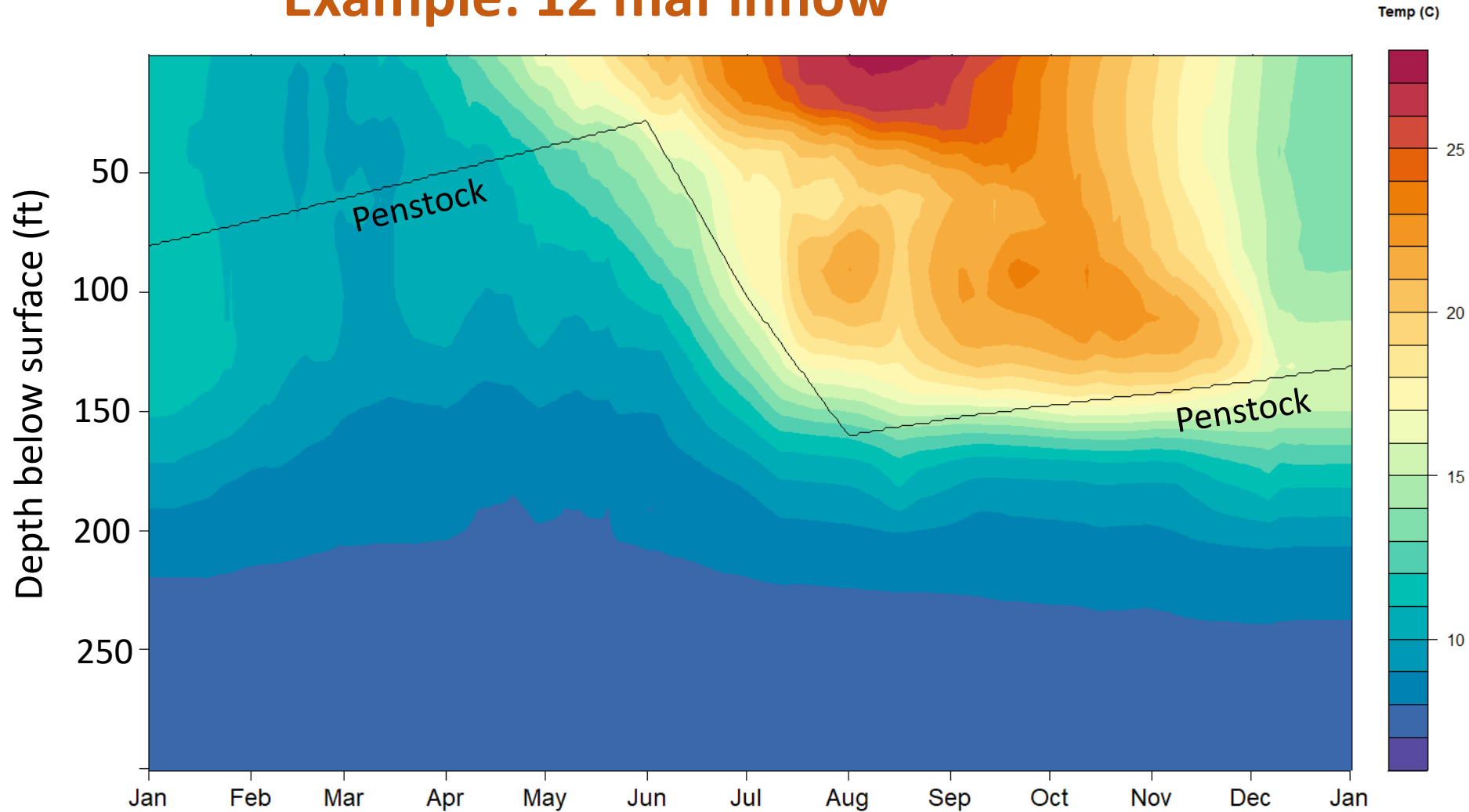
Lake Powell temperature model

Example: 5 maf inflow



Lake Powell temperature model

Example: 12 maf inflow

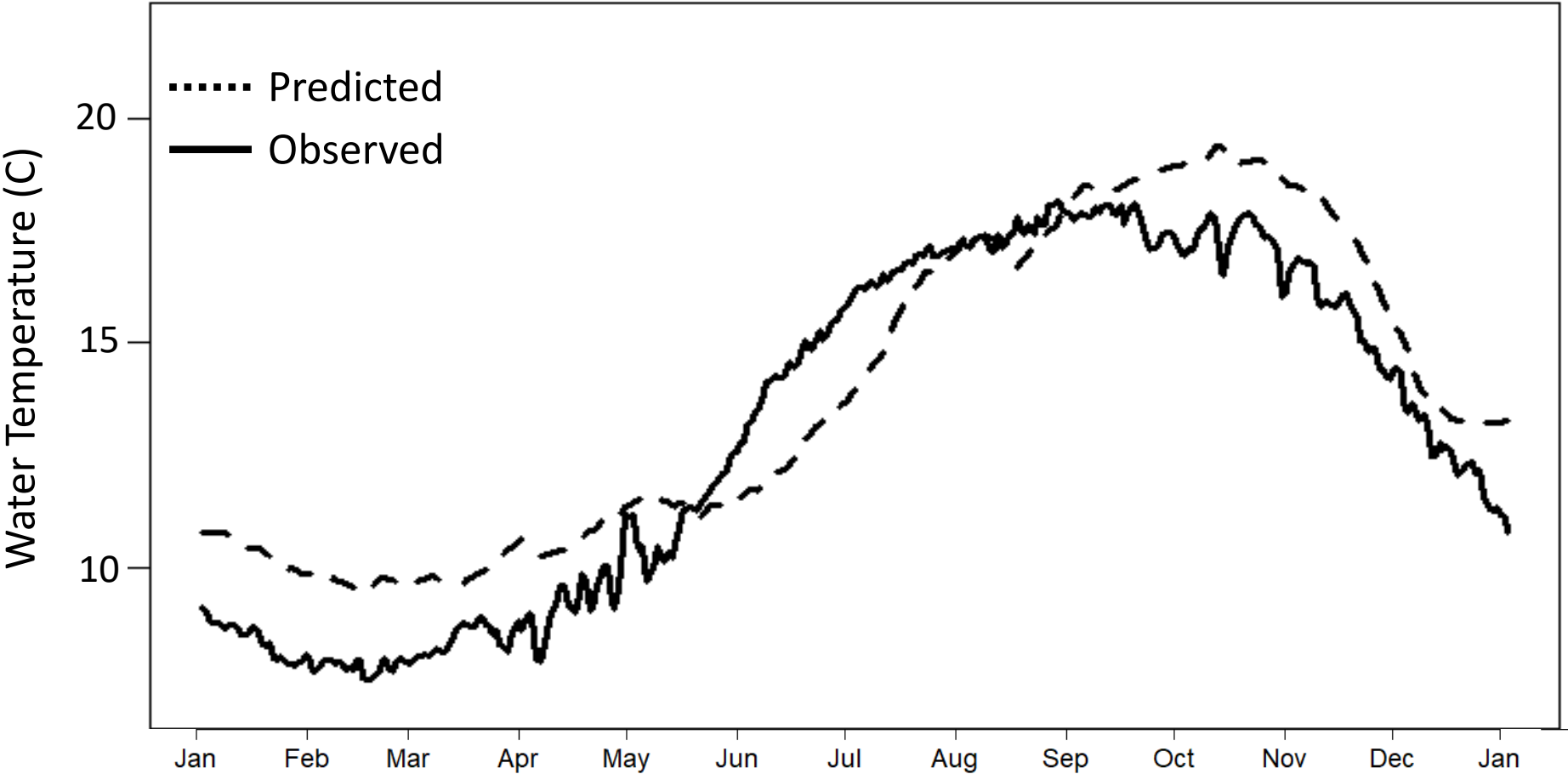


7.48 maf
outflows

3,550 ft starting
elevation

Predicted vs observed water temperature

Out of sample prediction for Lees Ferry 2023



Error
RMSE= 1.28

Modeling: Smallmouth Bass Population Growth

(Assumes Allee Effect threshold is surpassed)

Population Growth Rate (λ)

Based on thermal suitability

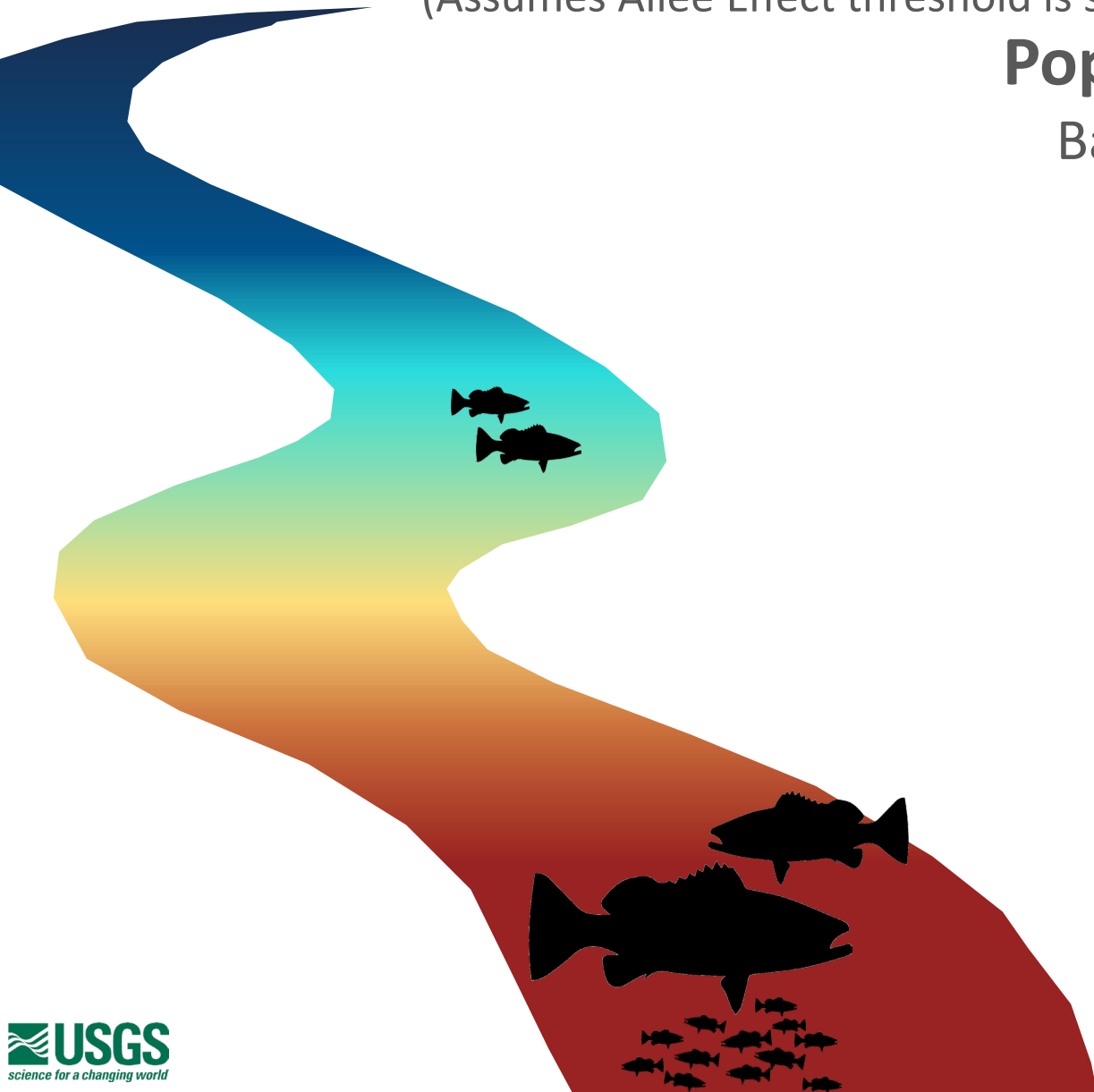
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- Age 0 overwinter survival

Parameters were derived from Breton et al. (2015) and Bruckerhoff et al. (in prep)



Smallmouth Bass and temperature

Yampa River Data: Smallmouth Bass Hatch

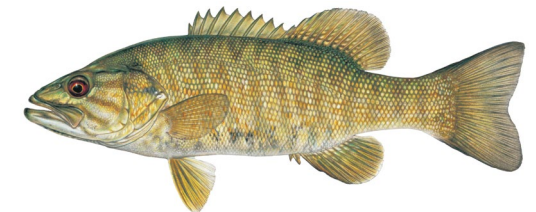
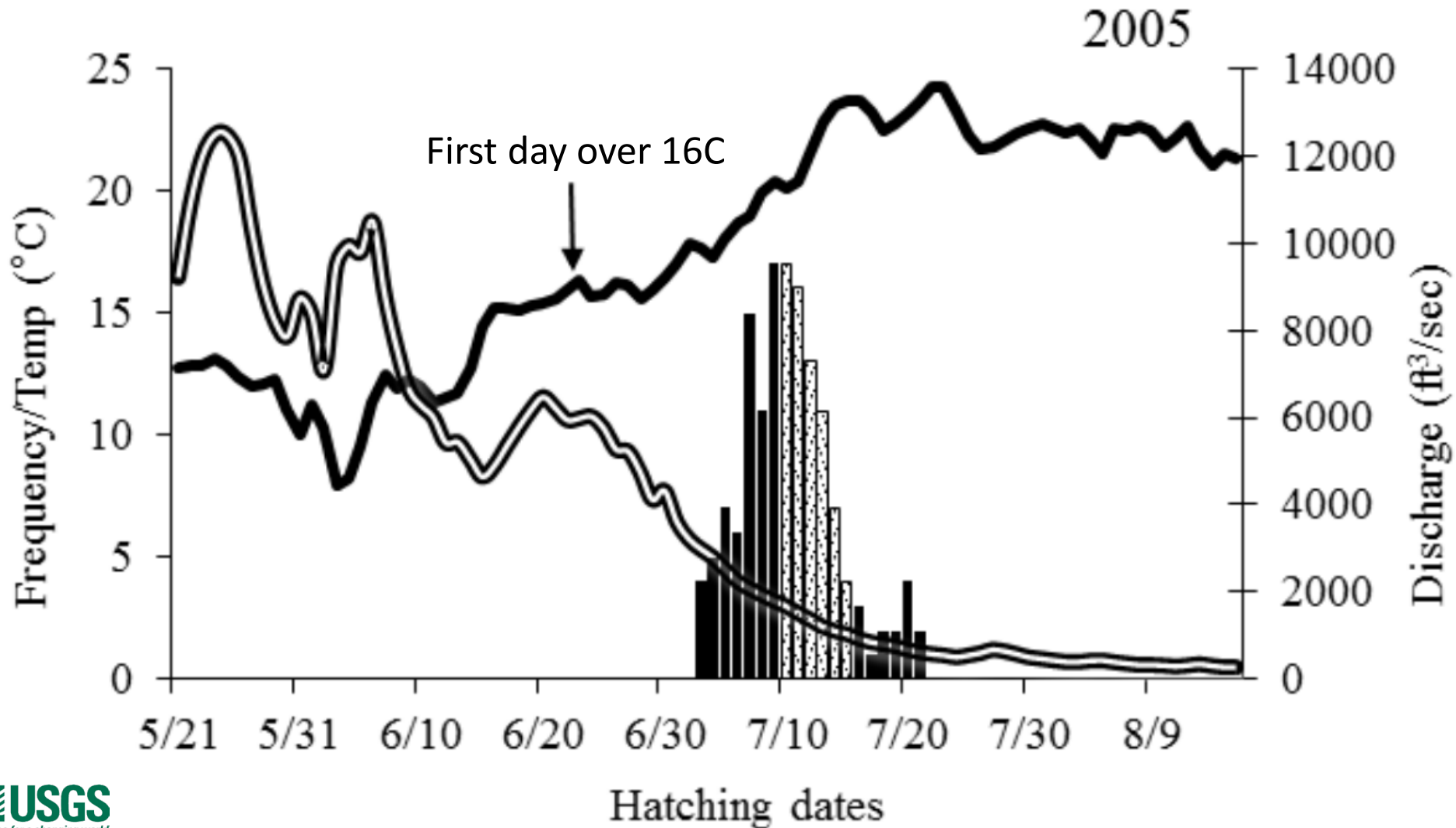
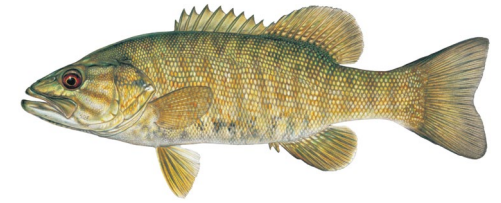
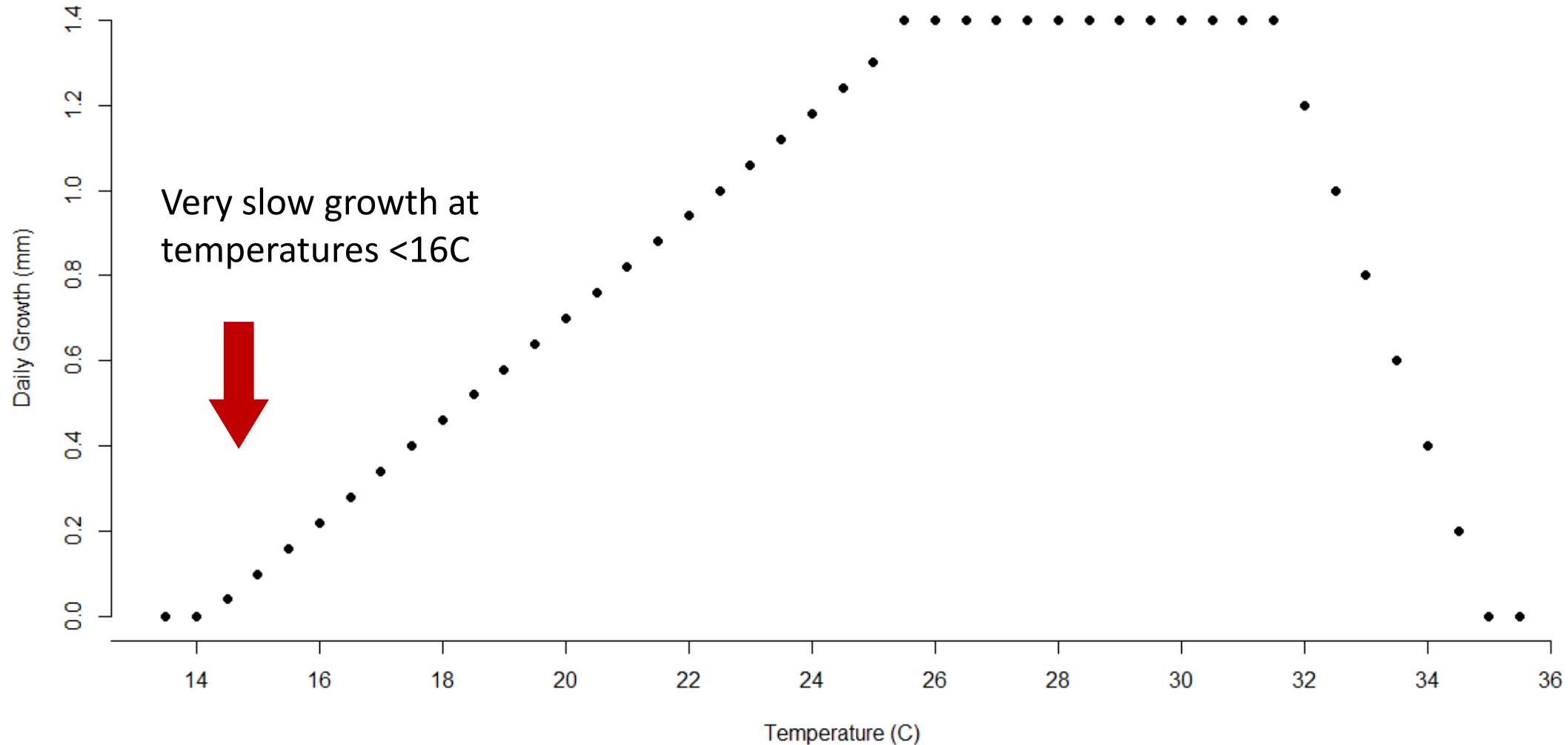


Figure: Bestgen & Hill, 2016

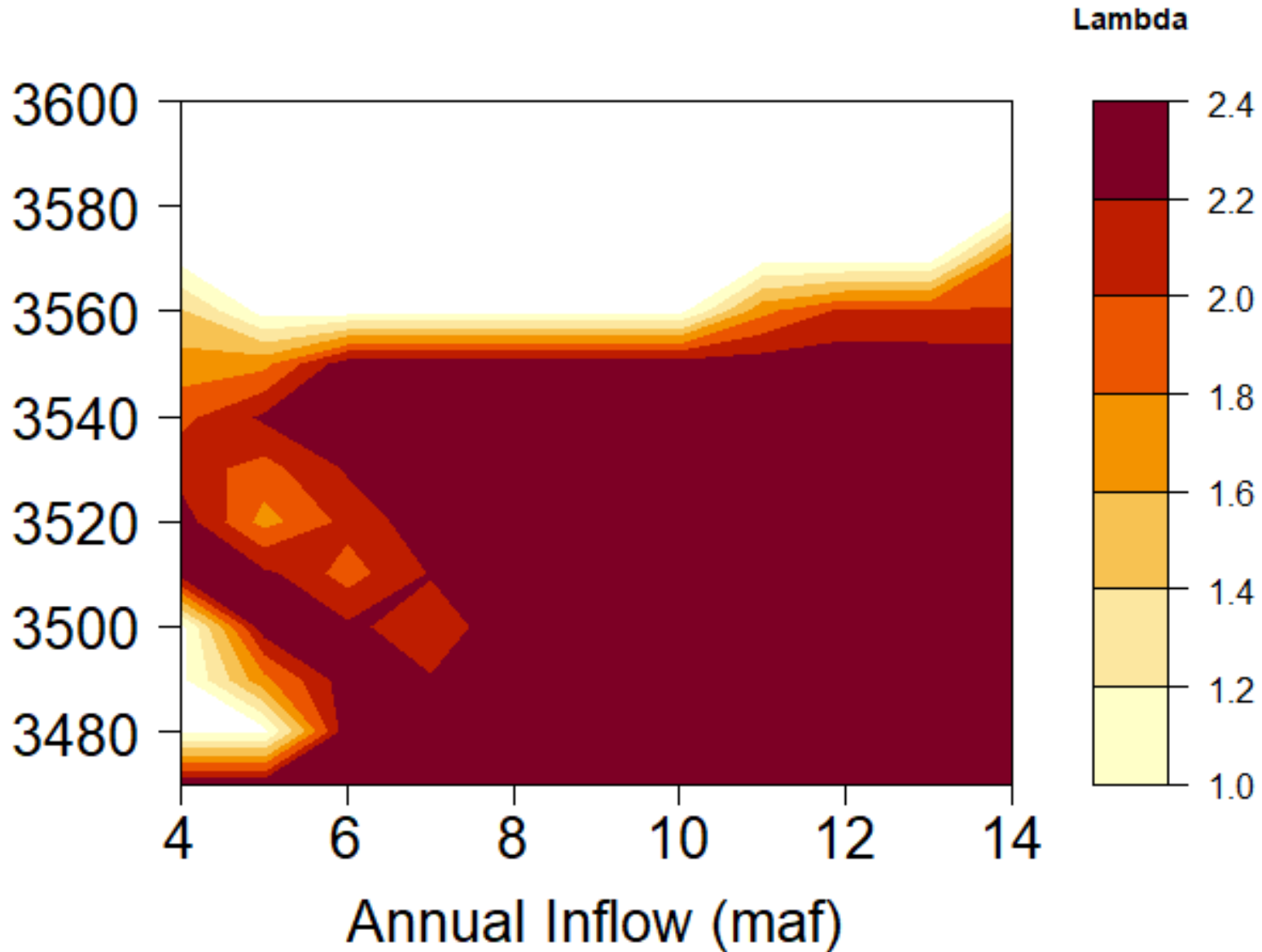
Smallmouth Bass and temperature



Age-0 Smallmouth Bass Growth

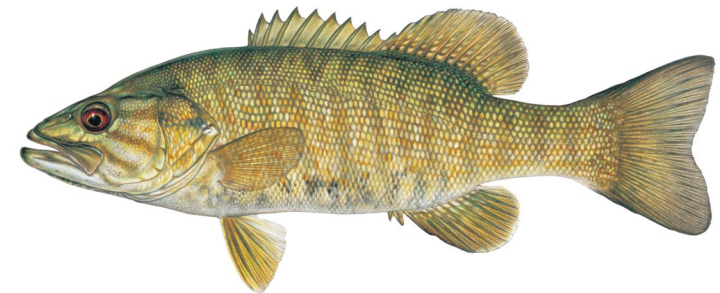


Modeling: Smallmouth Bass Population Growth



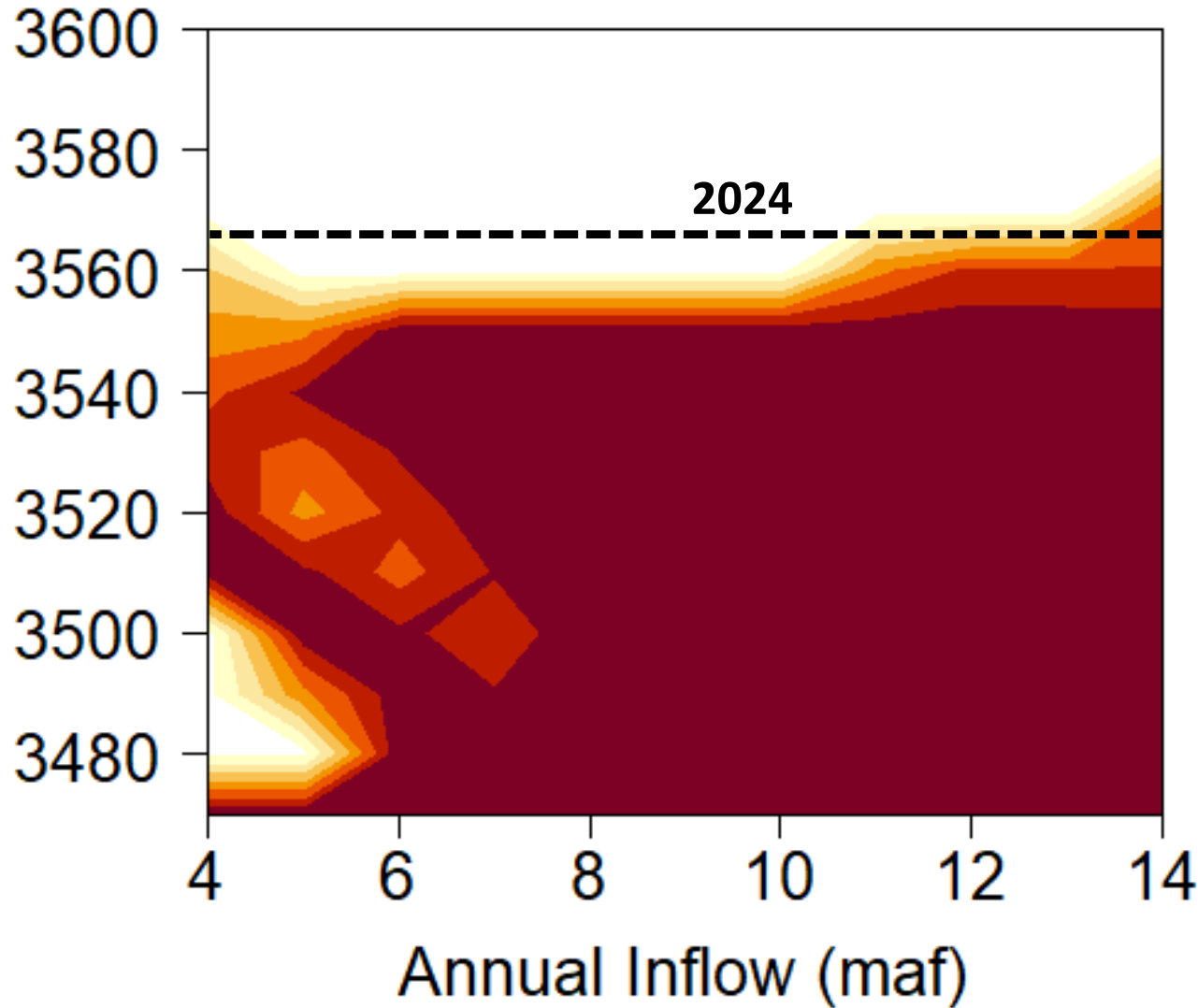
Lees Ferry

Assumes 7.48 maf outflows



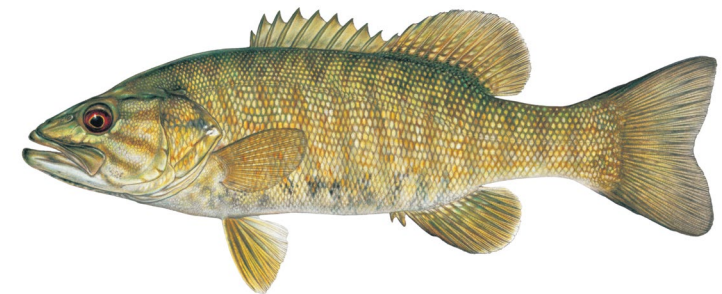
Modeling: Smallmouth Bass Population Growth

Lake Powell Starting Elevation (ft)



Lees Ferry

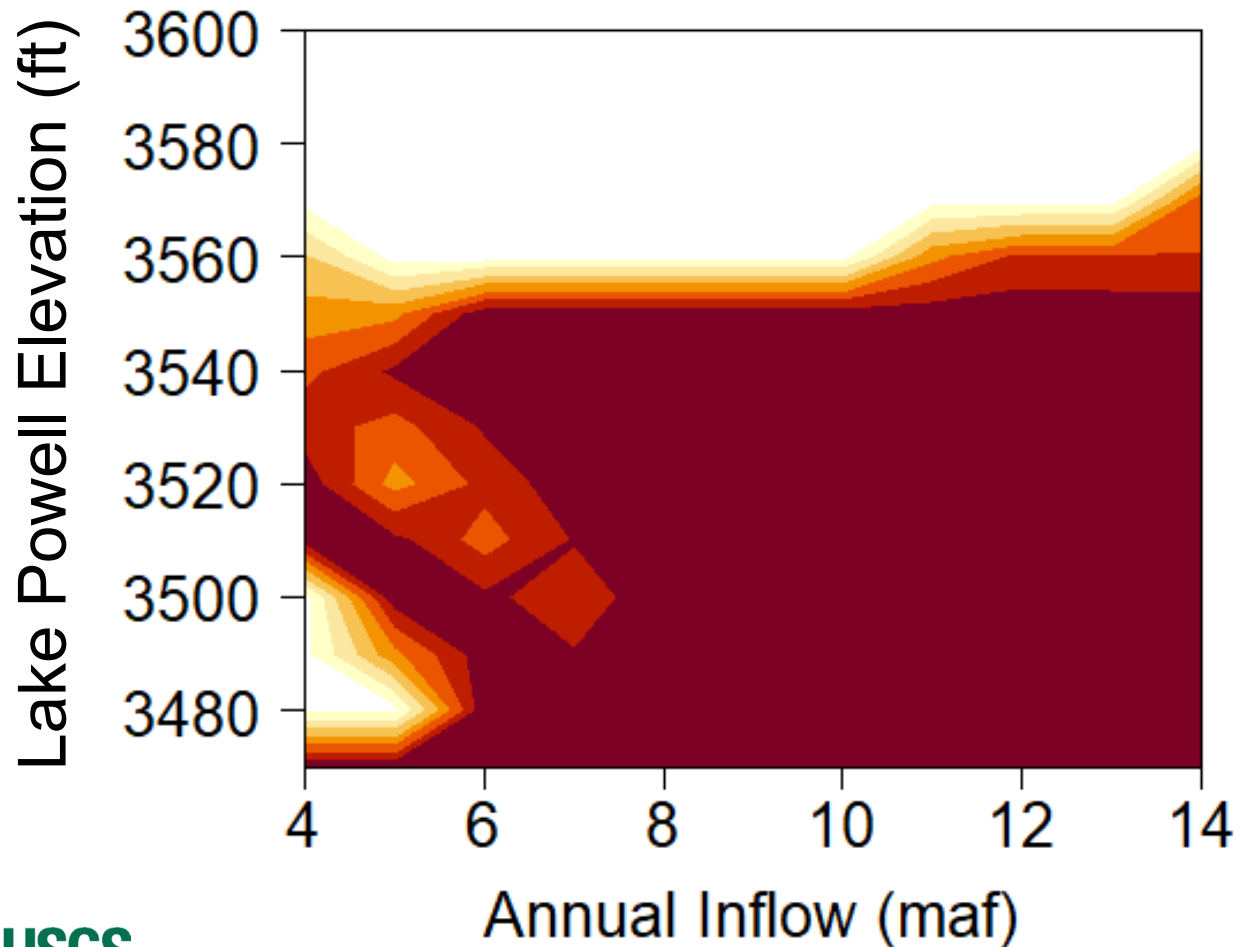
Assumes 7.48 maf outflows



Modeling: Smallmouth Bass Population Growth

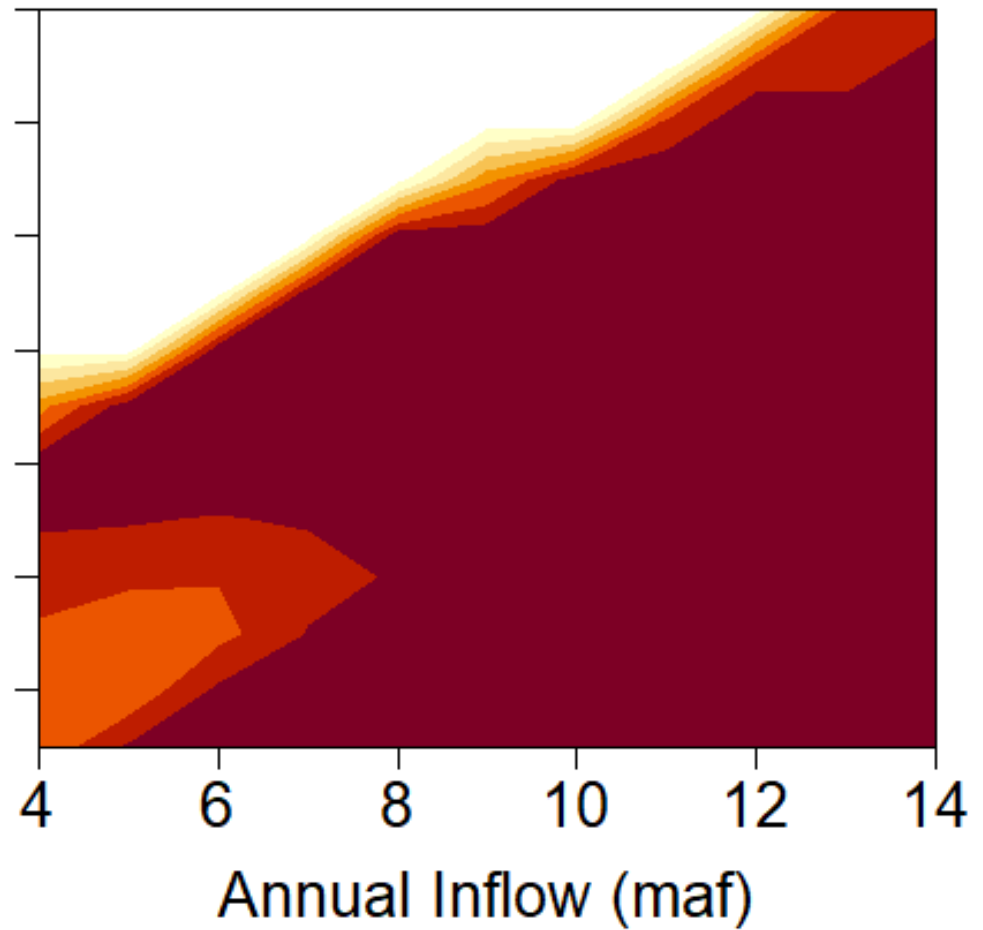
Lees Ferry

7.48 maf outflows

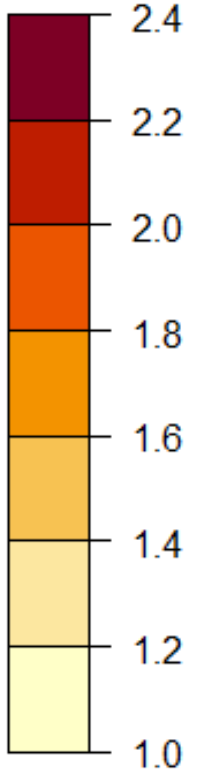


Lees Ferry

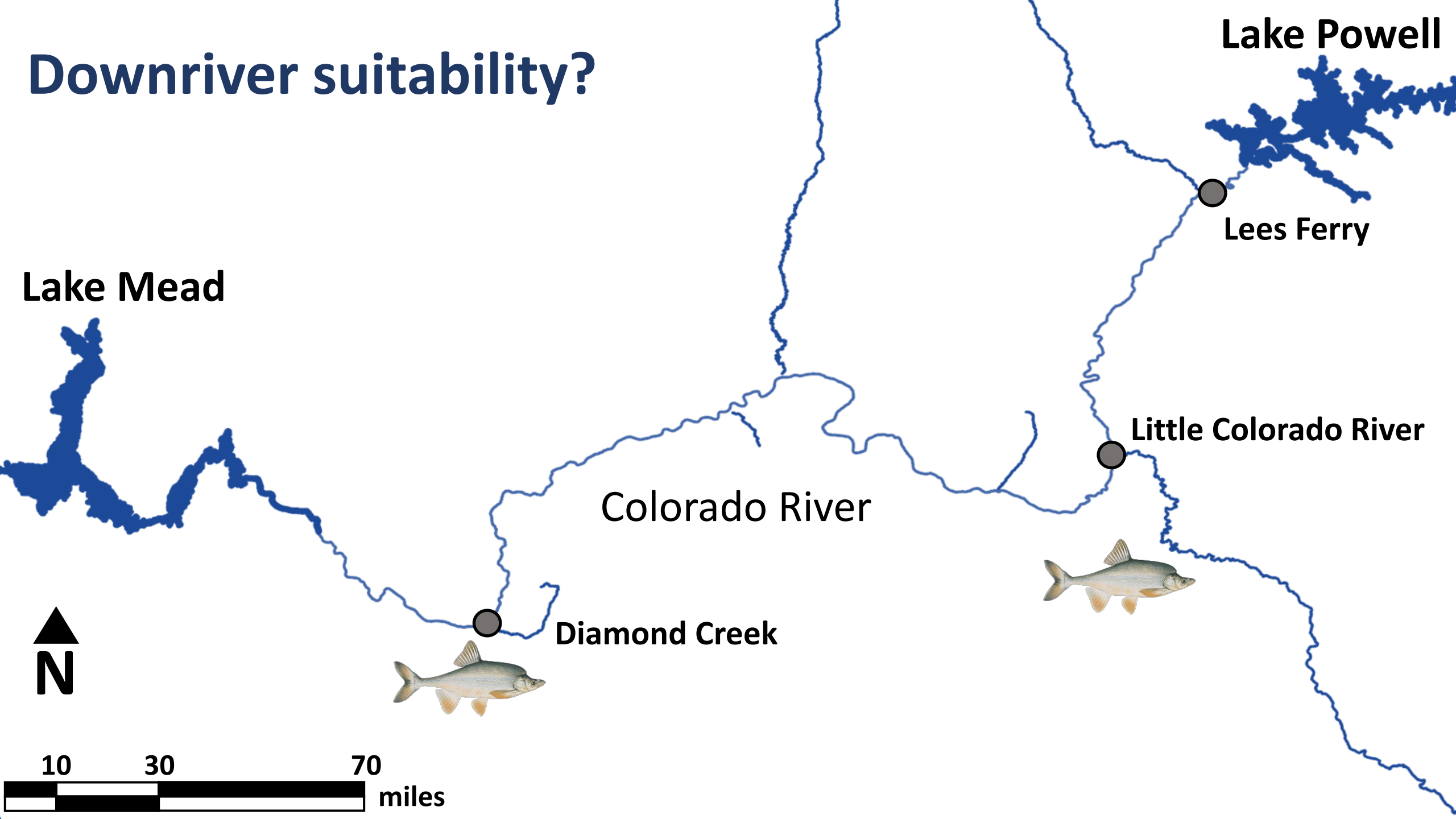
Match inflows and outflows



Lambda



Downriver suitability?



Lake Powell

Lees Ferry

Lake Mead

Little Colorado River

Colorado River

Diamond Creek



10 30 70

miles

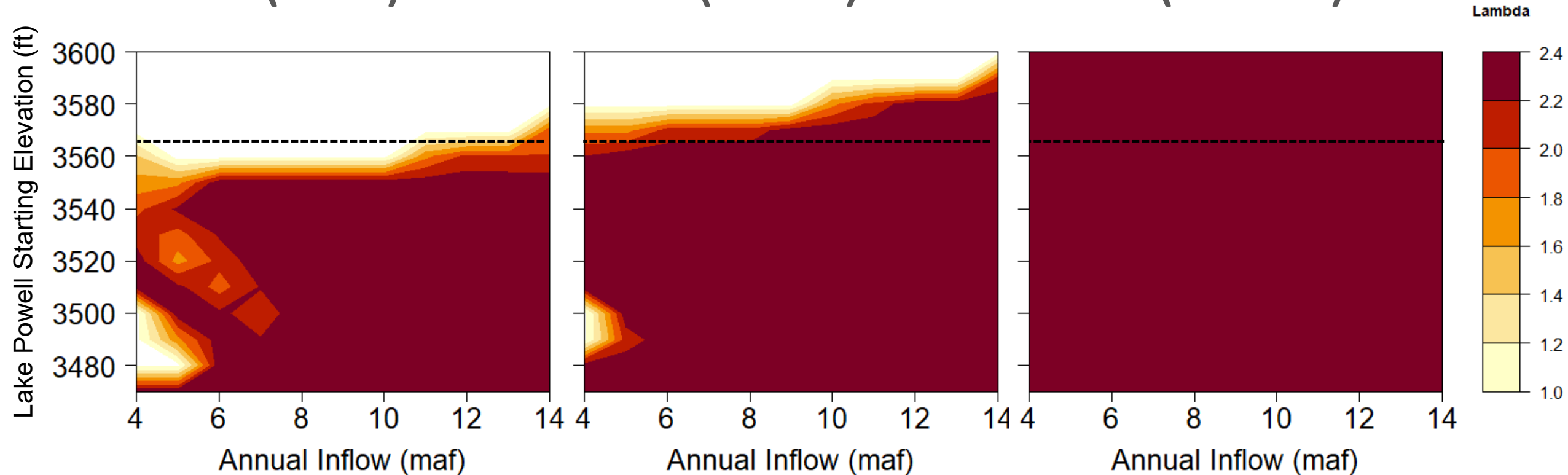
Modeling: Smallmouth Bass Population Growth

Downriver warming

Lees Ferry
(RM 0)

LCR Confluence
(RM 61)

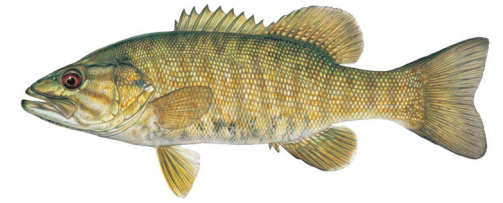
DC Confluence
(RM 225)



Testing assumptions and learning from two years of data collection

- **Suitable water temperatures**
- Sufficient food
- Sufficient spawning habitat
- Suitable water turbidity

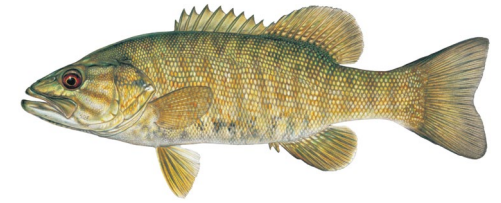
Smallmouth Bass and temperature



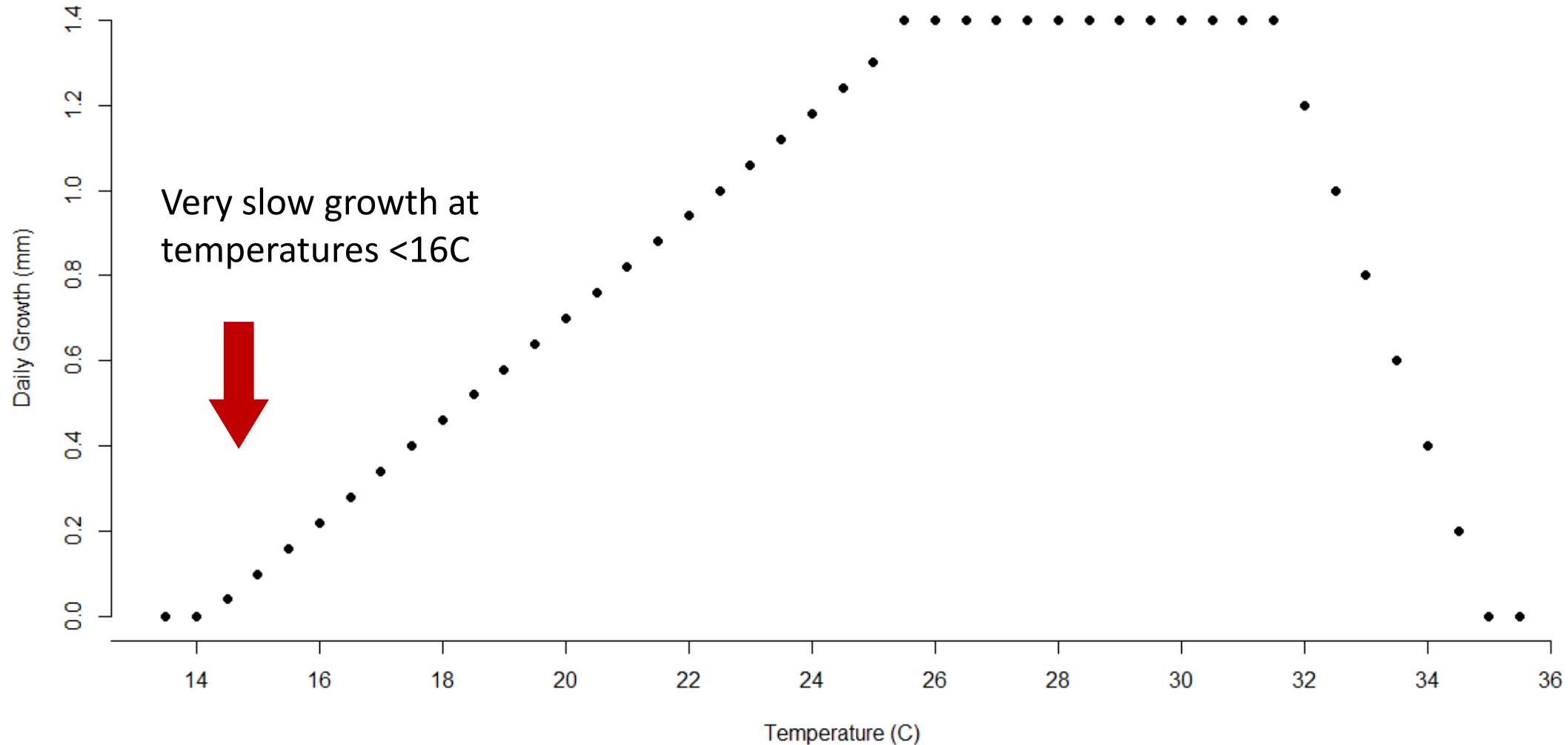
Spawning initiation (observed eggs in nest)

Temperature (°C)	Location	Type	Citation
15	Nagano, Japan	Lake	Peterson & Kitano, 2022
15	Oregon, USA	River	Rubenson & Olden, 2019
15.2	Ontario, CA	Lake	Turner & MacCrimmon, 1970
15.5	Saskatchewan, CA	Lake	Rawson, 1938
16.2	Oklahoma, USA	River	Dauwalter & Fisher, 2007

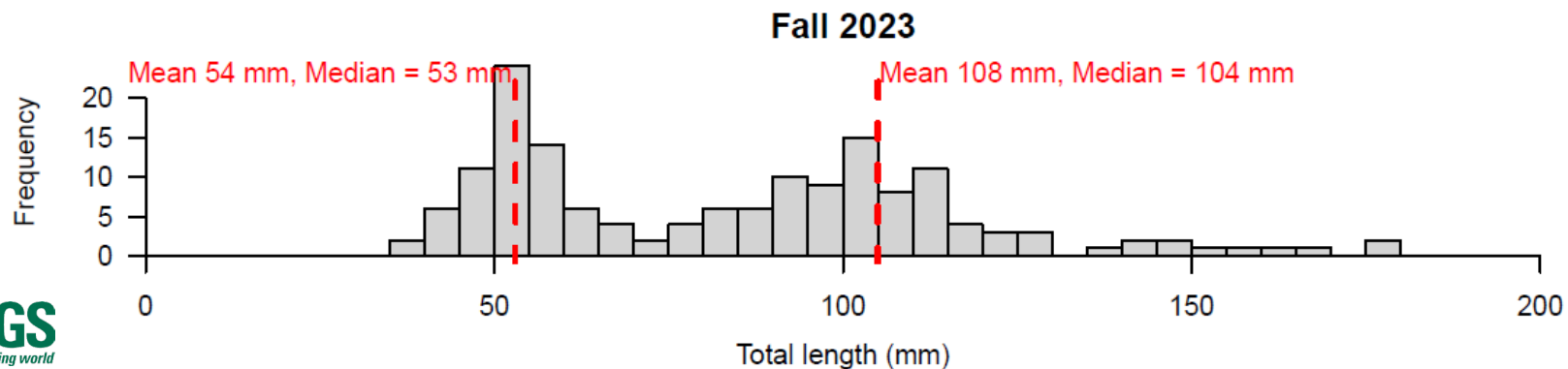
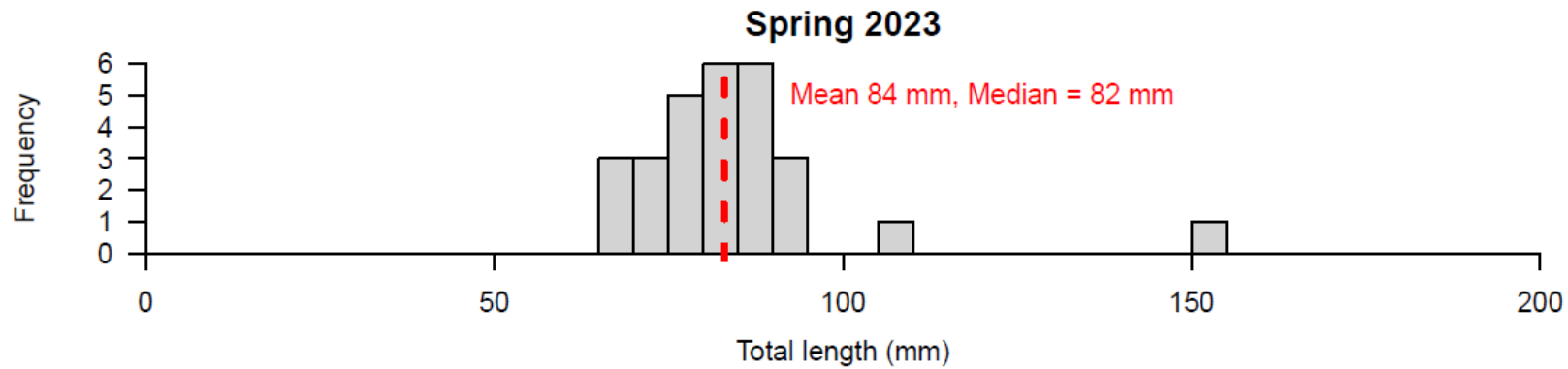
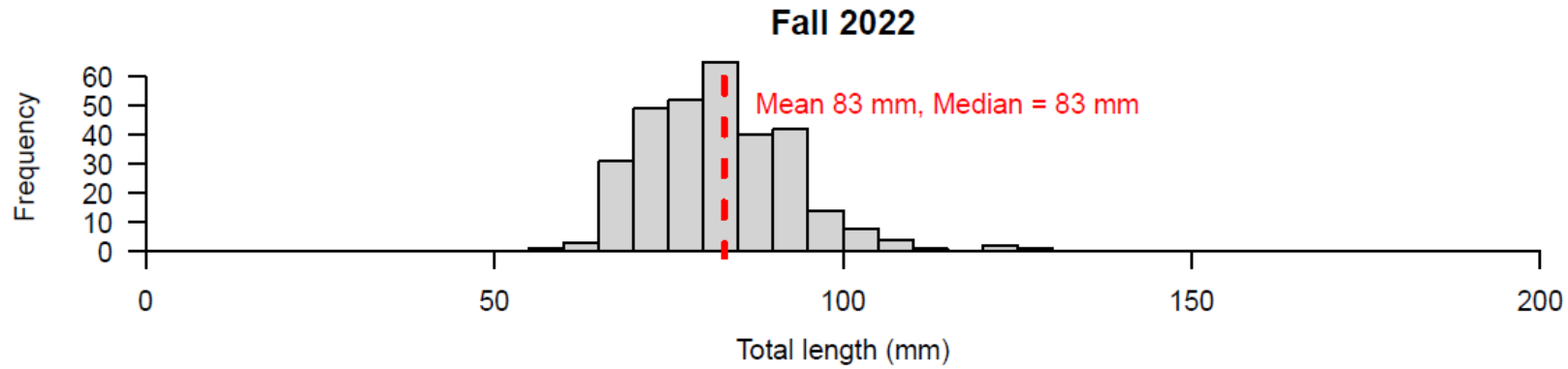
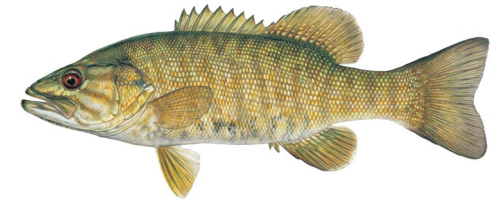
Smallmouth Bass and temperature



Age-0 Smallmouth Bass Growth



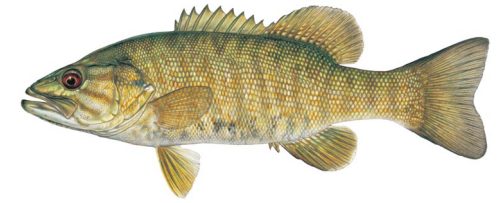
Smallmouth Bass and temperature



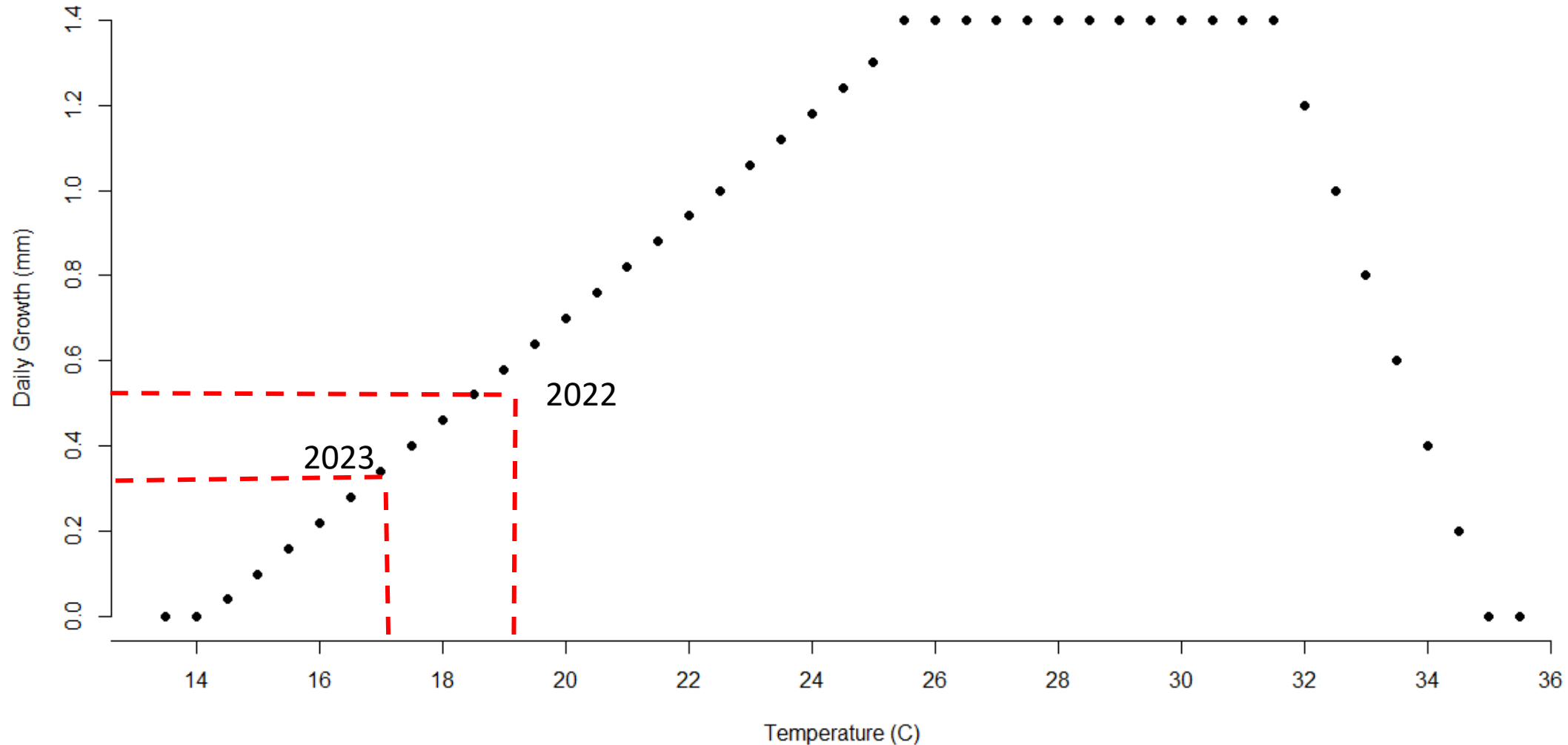
Data: Nonnative fish database

Preliminary data, subject to change, do not cite

Smallmouth Bass and temperature



Age-0 Smallmouth Bass Growth



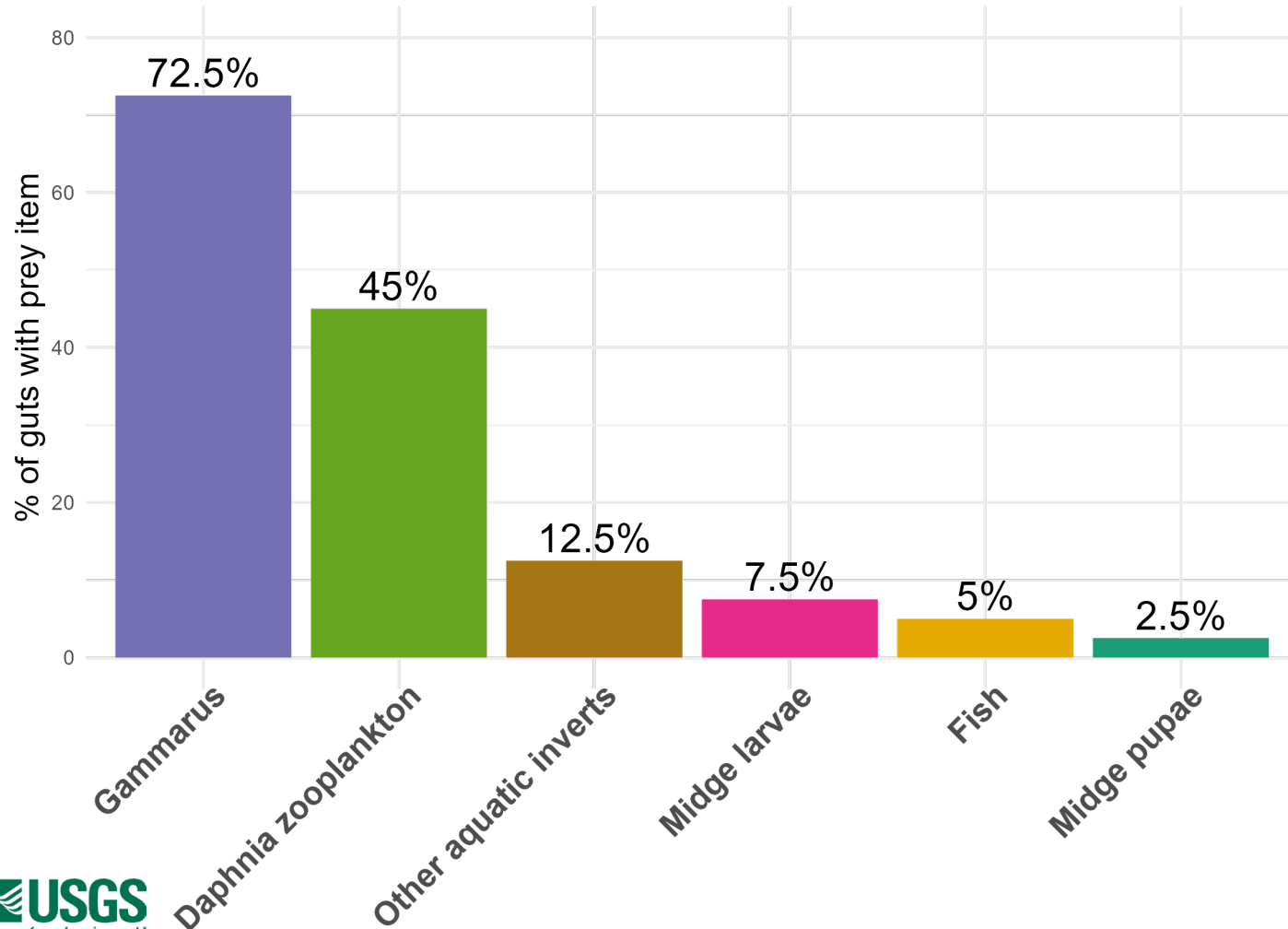
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- Suitable water turbidity

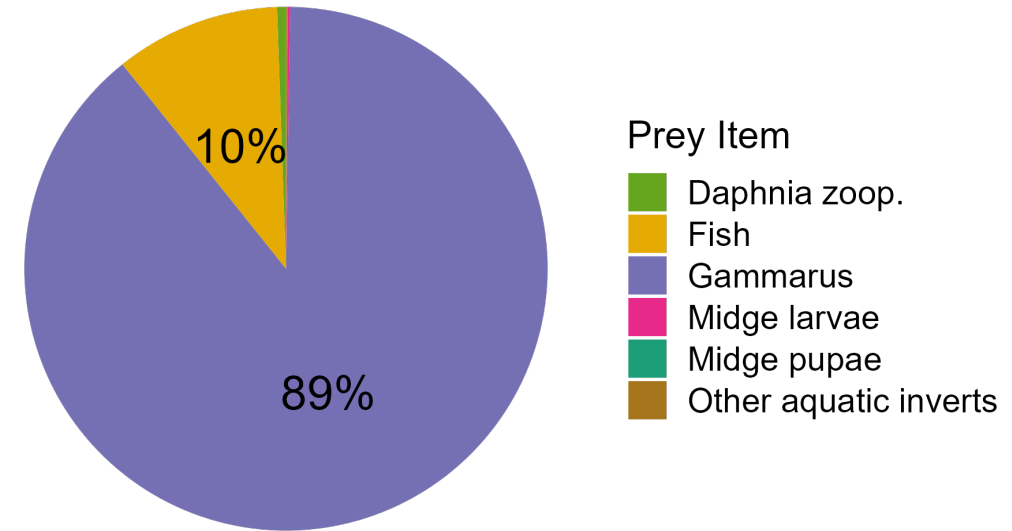
Smallmouth Bass Diets

2022 Fall Juvenile SMB from the mainstem
Total n=53, non-empty n= 40

Frequency of occurrence



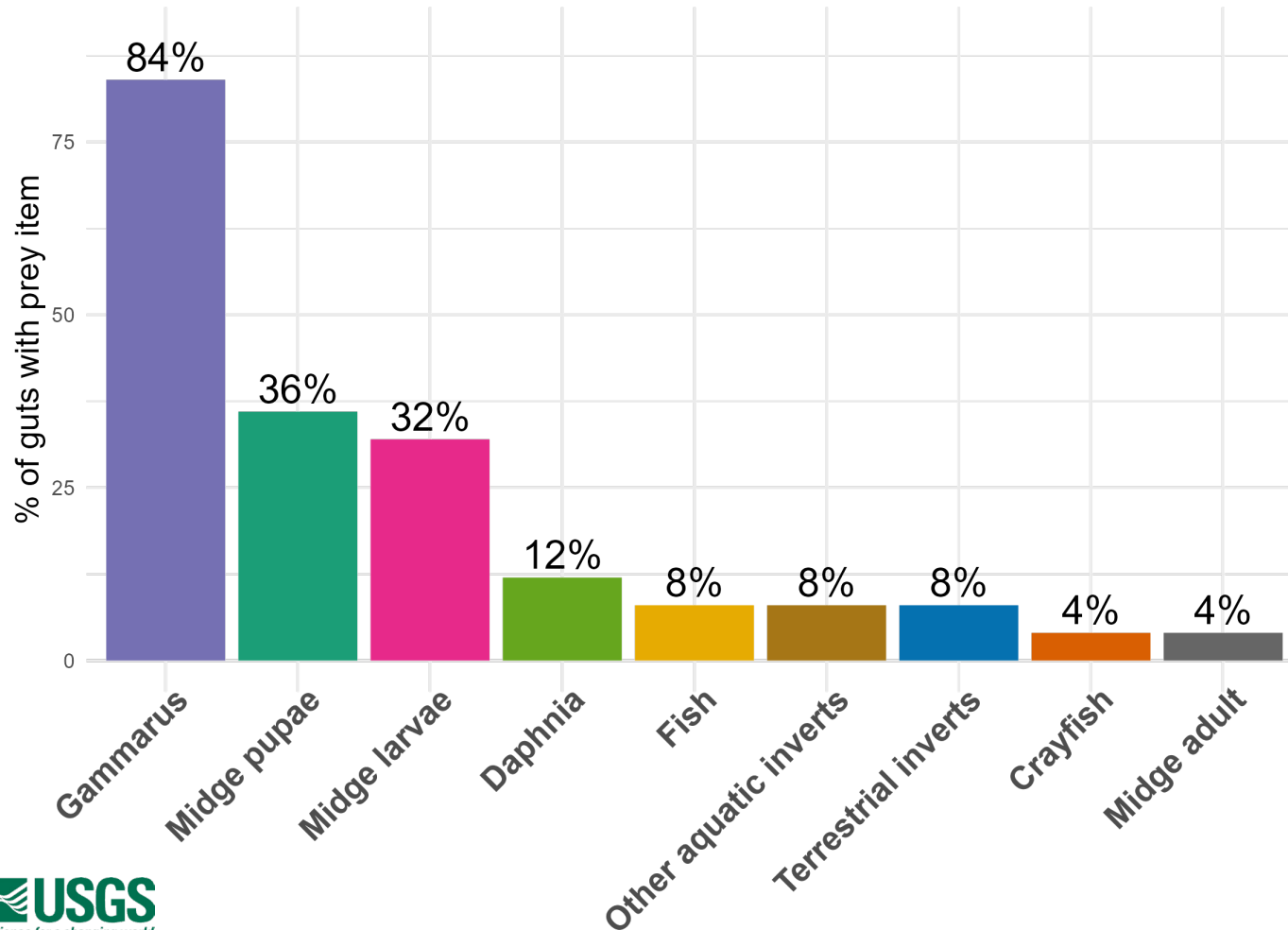
Prey by % biomass



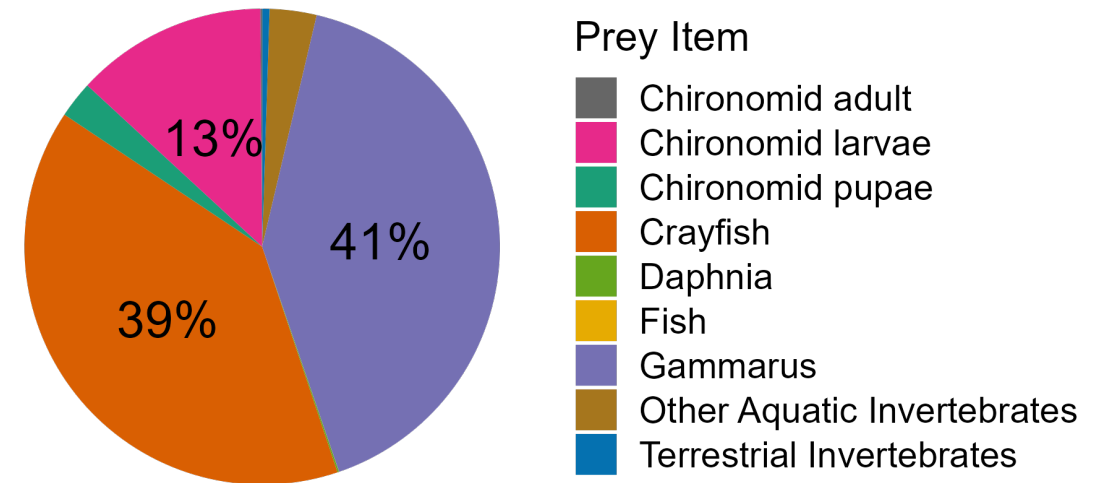
Smallmouth Bass Diets

2023 Summer Juvenile SMB from the mainstem
Total n=42, non-empty n= 25

Frequency of occurrence



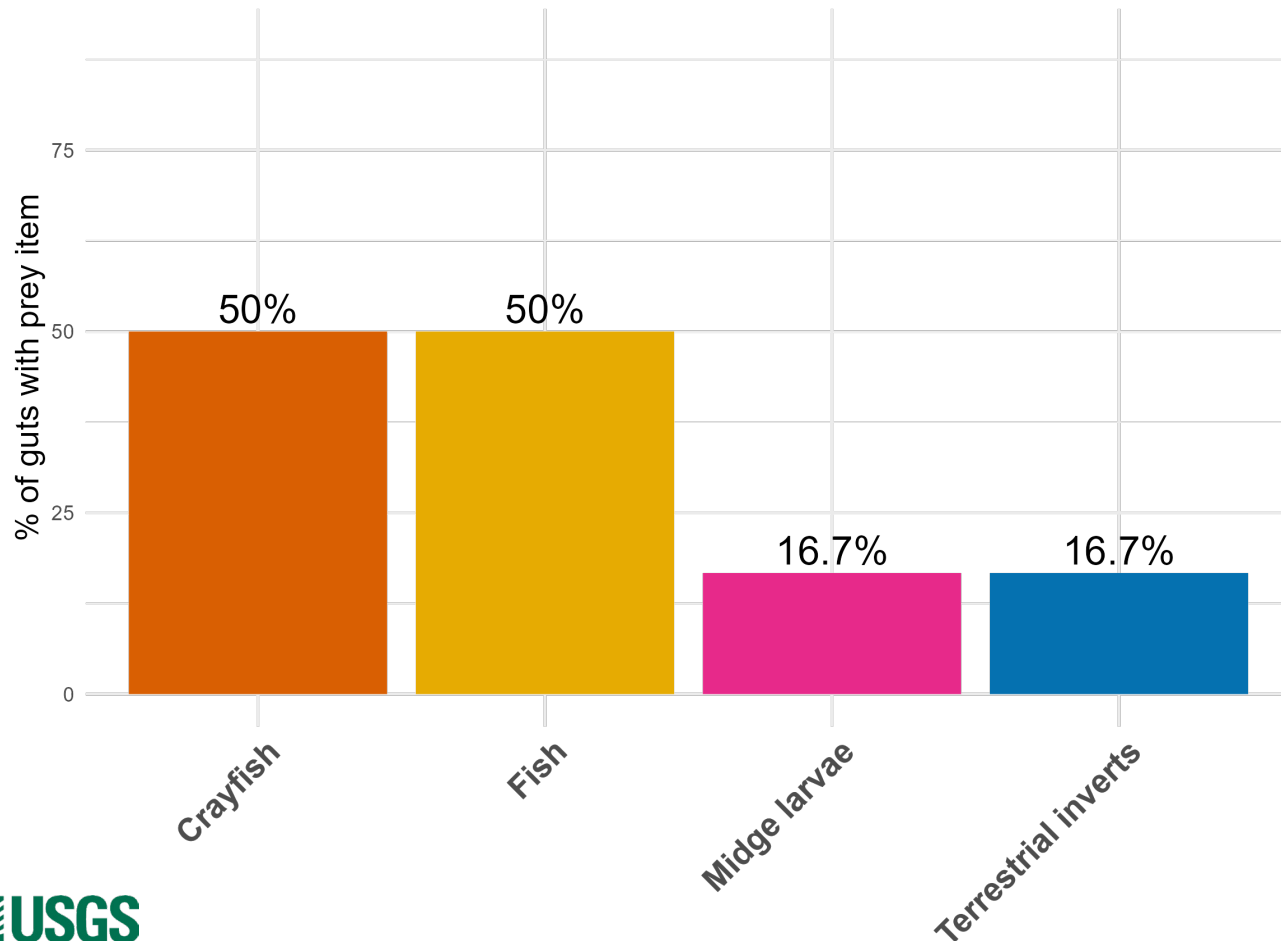
Prey by % biomass



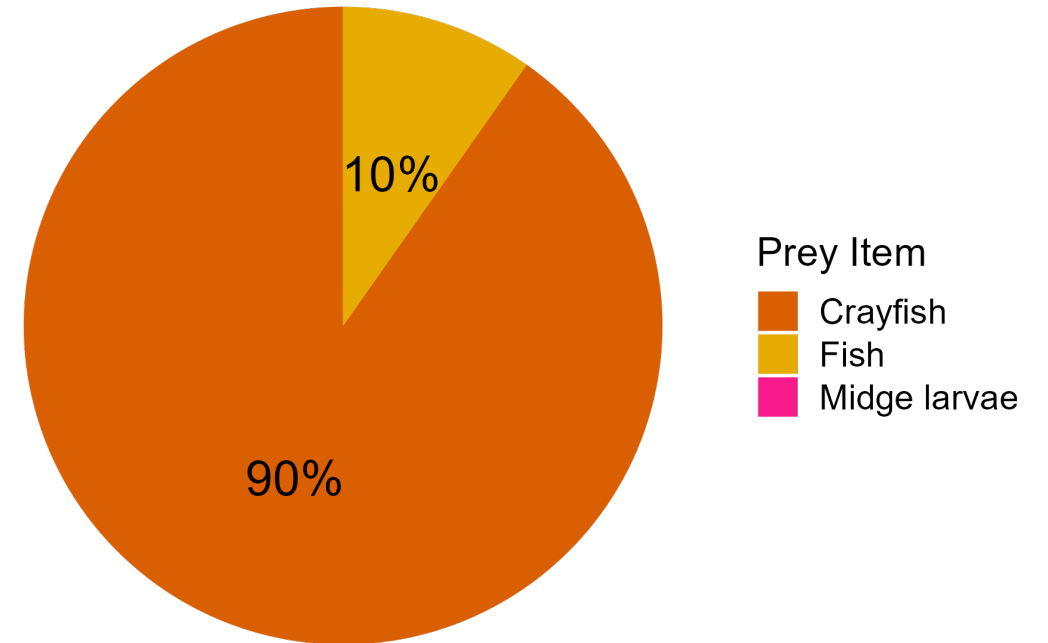
Smallmouth Bass Diets

2023 Summer Adult SMB (mainstem and slough)
Total n=10, non-empty n= 6

Frequency of occurrence

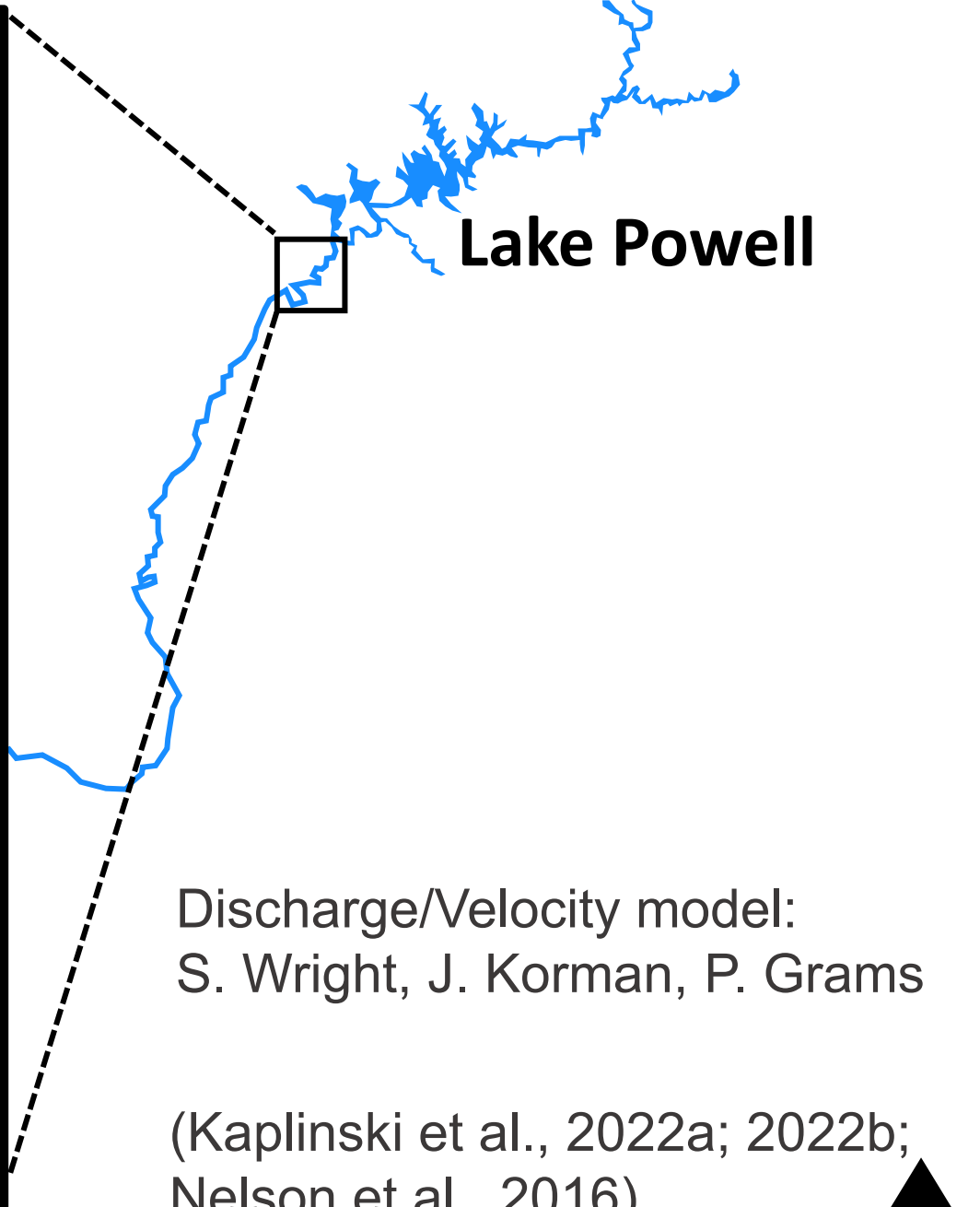
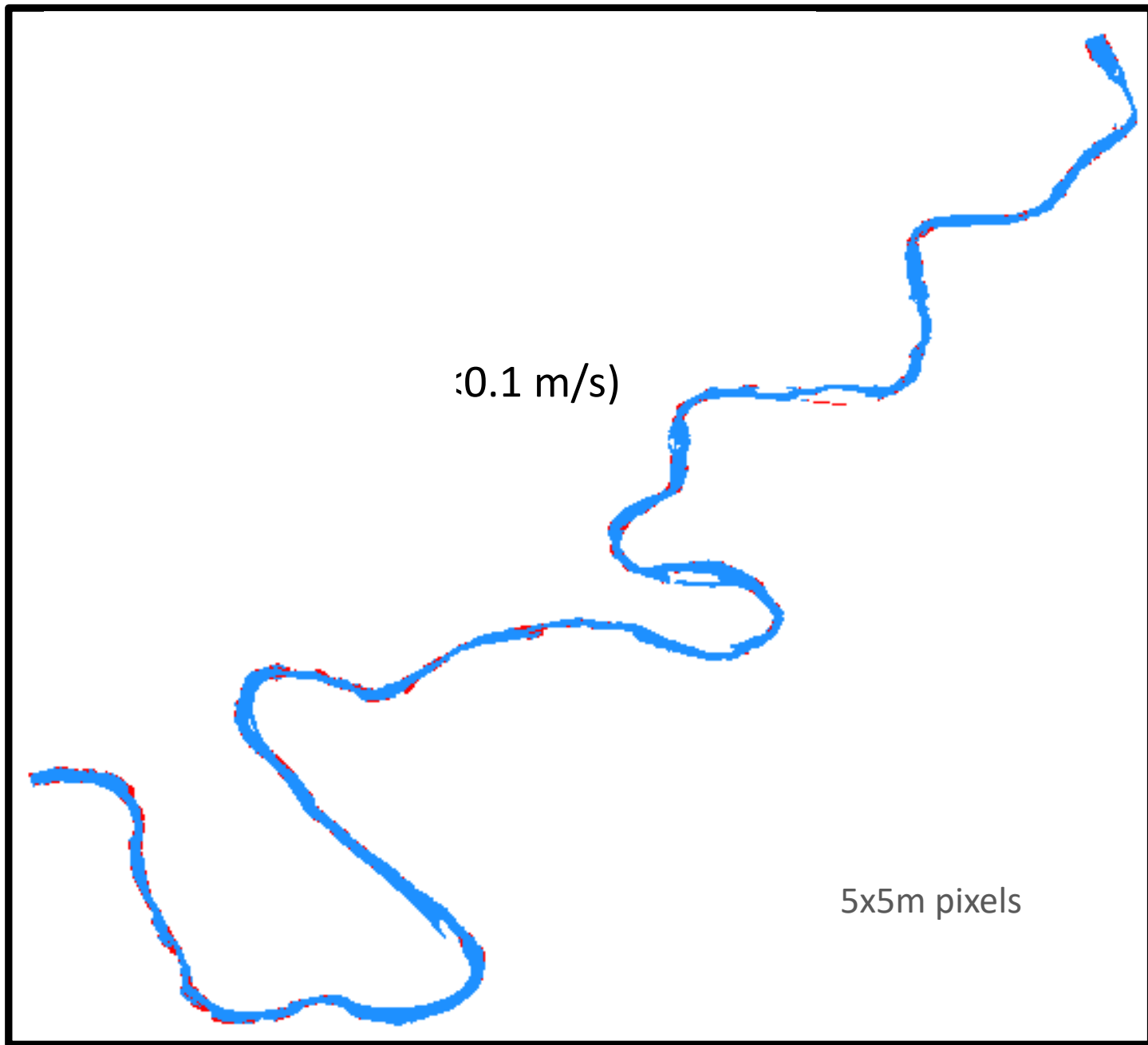


Prey by % biomass



Testing assumptions and learning from two years of data collection

- Suitable water temperatures
- Sufficient food
- **Sufficient spawning habitat**
- Suitable water turbidity



Preliminary data, subject to change, do not cite



Lees Ferry Velocity Map

Baseline operations (6-12k CFS)

19.63 ha (0.2 km²)

■ Spawning Habitat (<0.1 m/s)

-12 mile Slough

5x5m pixels

10 30 70

miles

Lake Powell

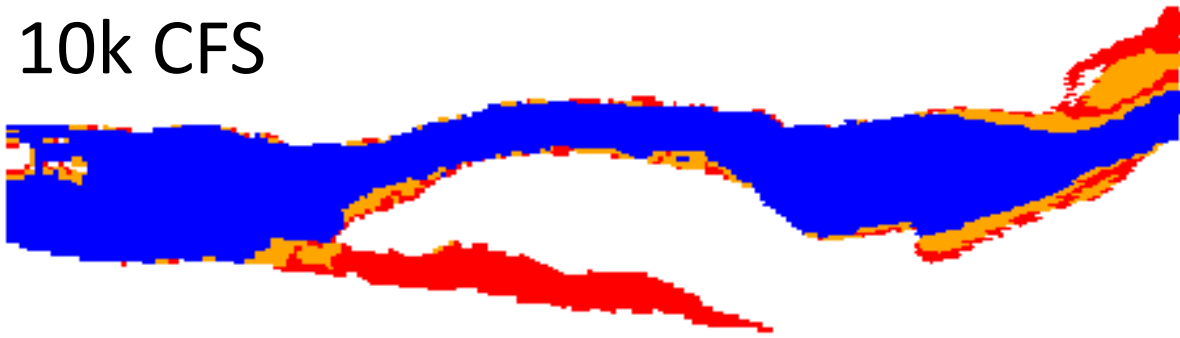
Discharge/Velocity model:
S. Wright, J. Korman, P. Grams

(Kaplinski et al., 2022a; 2022b;
Nelson et al., 2016)

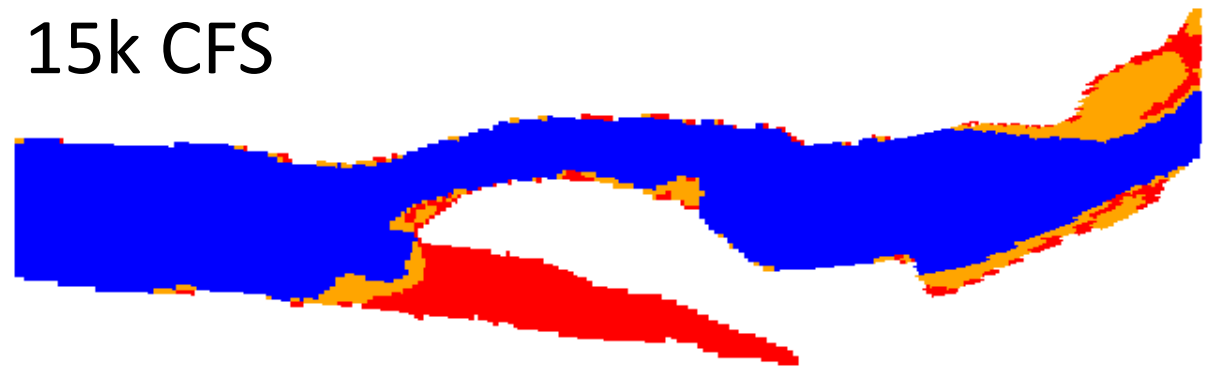
Preliminary data, subject to change, do not cite



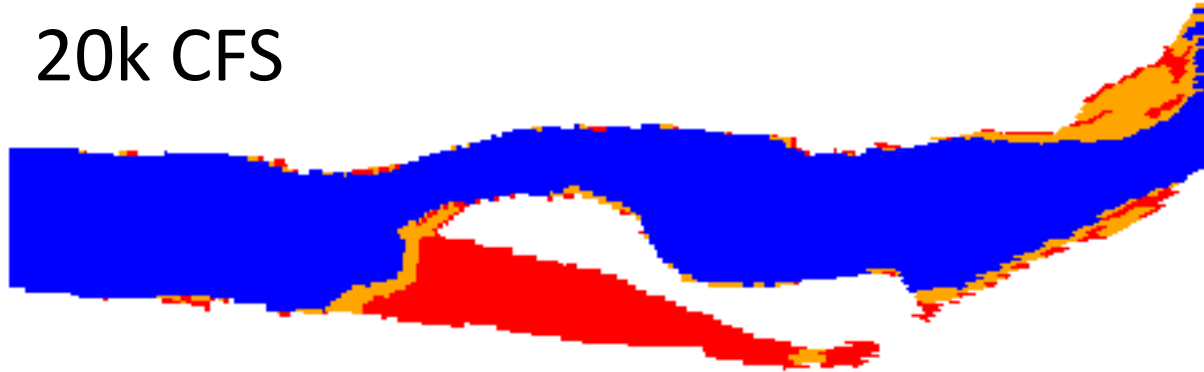
10k CFS



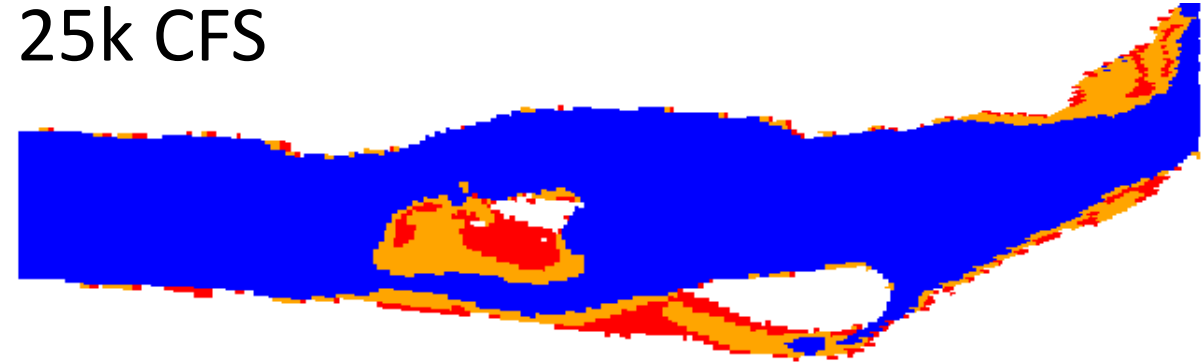
15k CFS



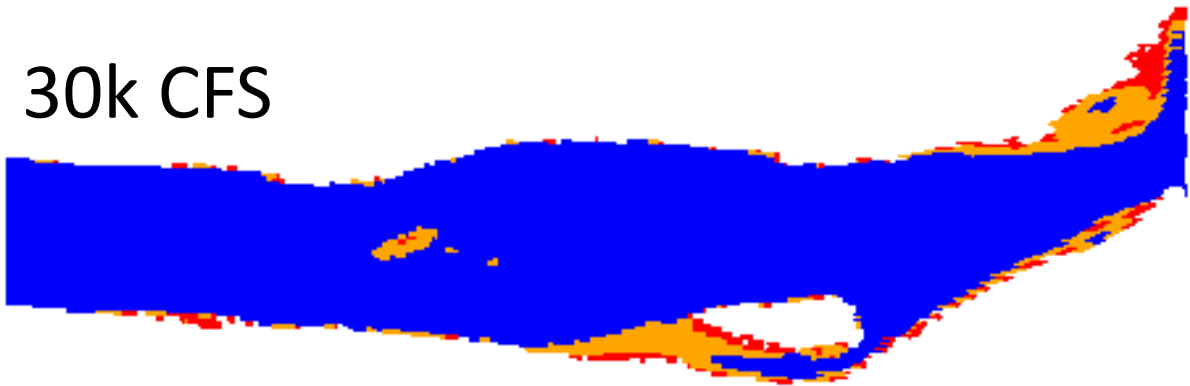
20k CFS



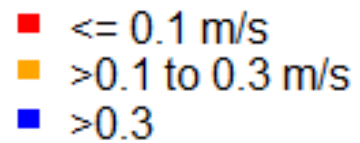
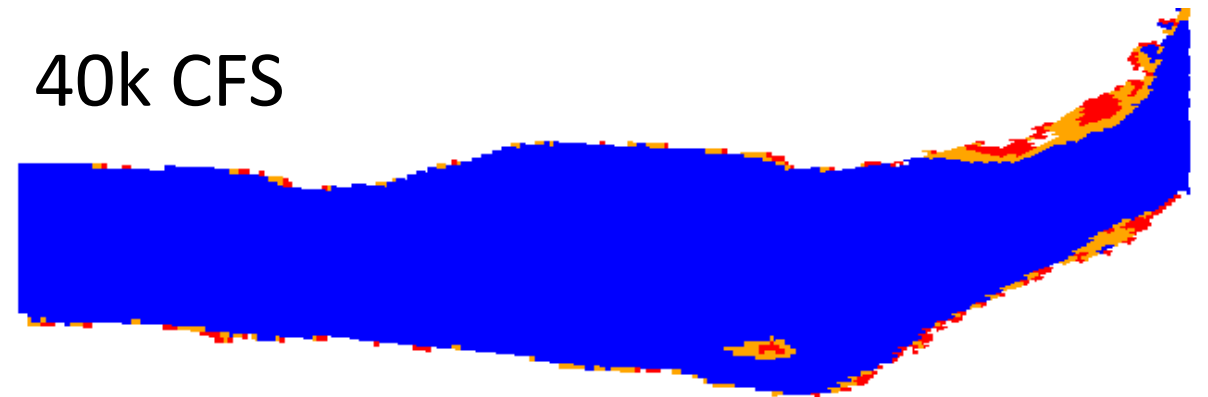
25k CFS



30k CFS



40k CFS



What about downriver spawning habitat?

No discharge-velocity model exists

Potential surrogate:
cobble, gravel, talus, or debris fan adjacent to an eddy

Analysis currently underway

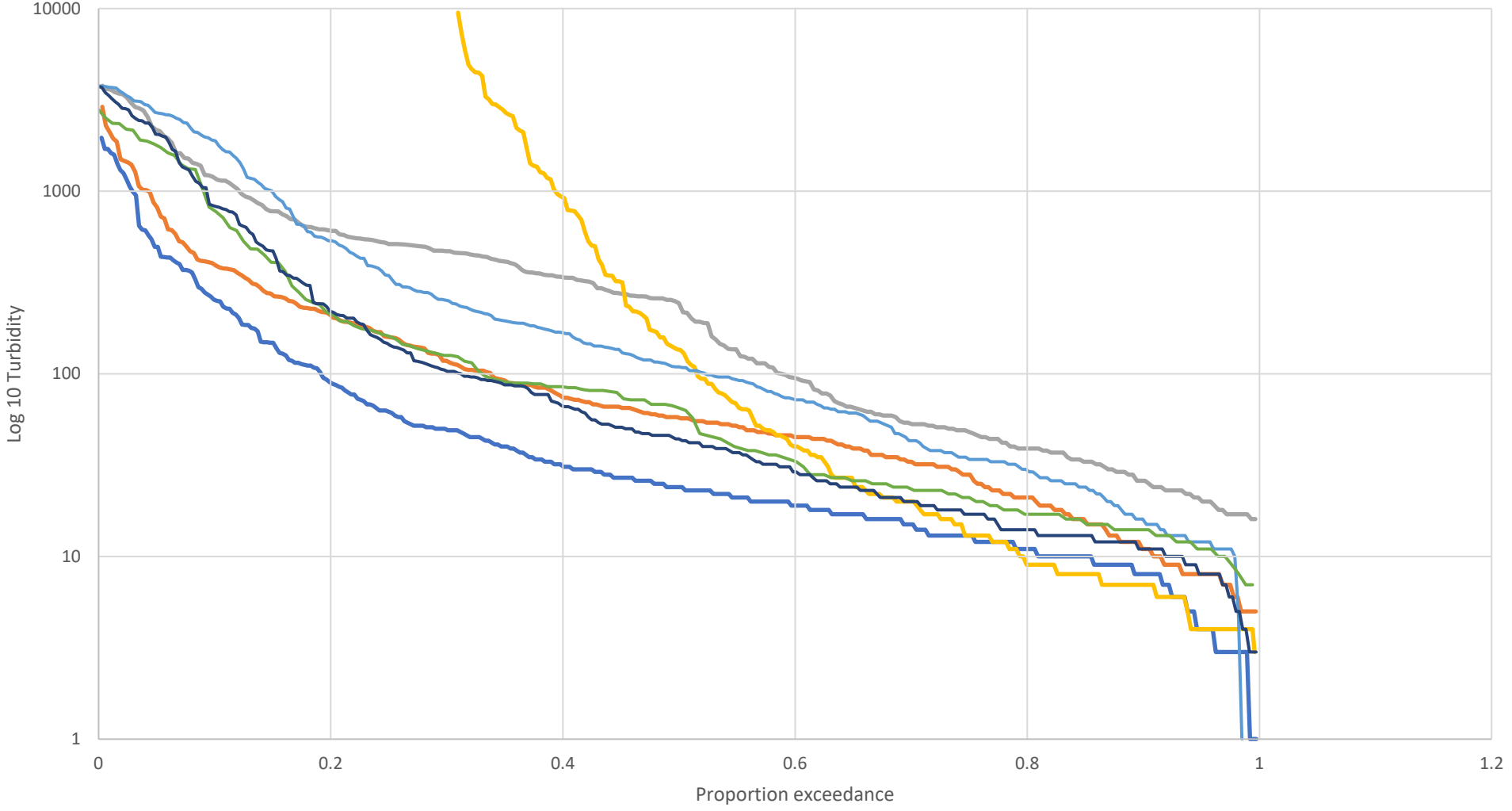


Testing assumptions and learning from two years of data collection

- Suitable water temperatures
- Sufficient food
- Sufficient spawning habitat
- Suitable water turbidity

Colorado River Turbidity

Ex: 2021-2022



- Colorado River at Diamond Creek (09404200)
- Colorado River at Cameo (09095500)
- Colorado River at Stateline (09163500)
- Green River at Green River (09315000)
- San Juan River at Bluff (09379500)
- San Juan River at Farmington (09365000)
- San Juan River at Four Corners (09371010)

CR at cameo Cr at stateline GR at GR Diamond SJ bluff SJ farmington SJ four corners



Preliminary data, subject to change, do not cite

Conclusions

- Smallmouth Bass entrainment model predicted catch of adults in 2022 and 2023 and suggests entrainment was only modestly elevated.
- Smallmouth Bass lambda model predicted reproduction in 2022 and 2023, and growth was consistent with model assumptions.
- Smallmouth bass diet are consistent with literature but have provided some system specific surprises.
- Studies to address uncertainties are ongoing.

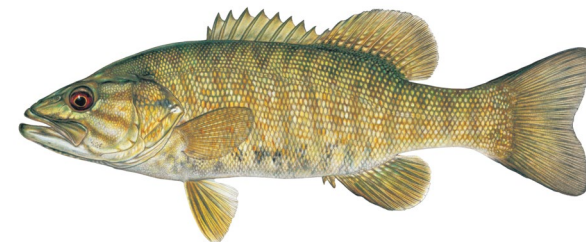


Photo Credit: Richard McLeish

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