


Movement, habitat use, and early life history of fishes in novel river-reservoir complexes

Biodiversity crisis

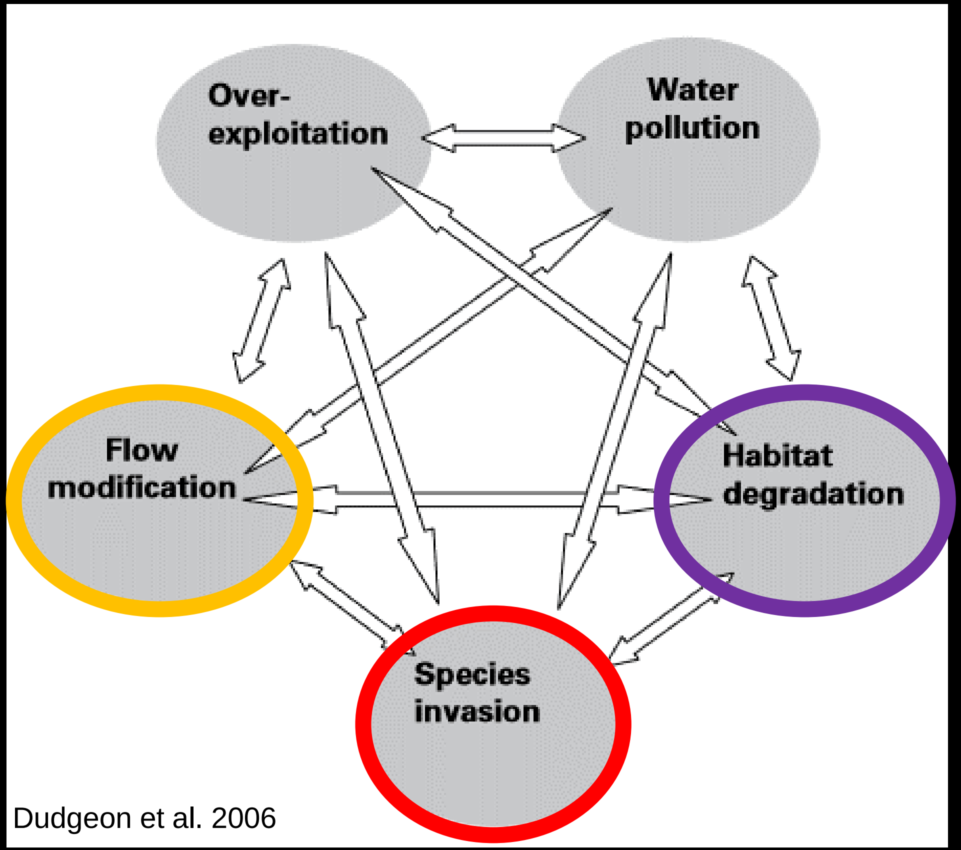
- Freshwater vertebrate populations declining 2x as fast as terrestrial or marine

- Freshwater fishes have highest extinction rate among vertebrates worldwide

- Higher for North America
  - (877x greater)

Group	Extinction rate relative to background
Reptiles	27
Amphibians	44
Mammals	109
Birds	113
Freshwater fishes	203

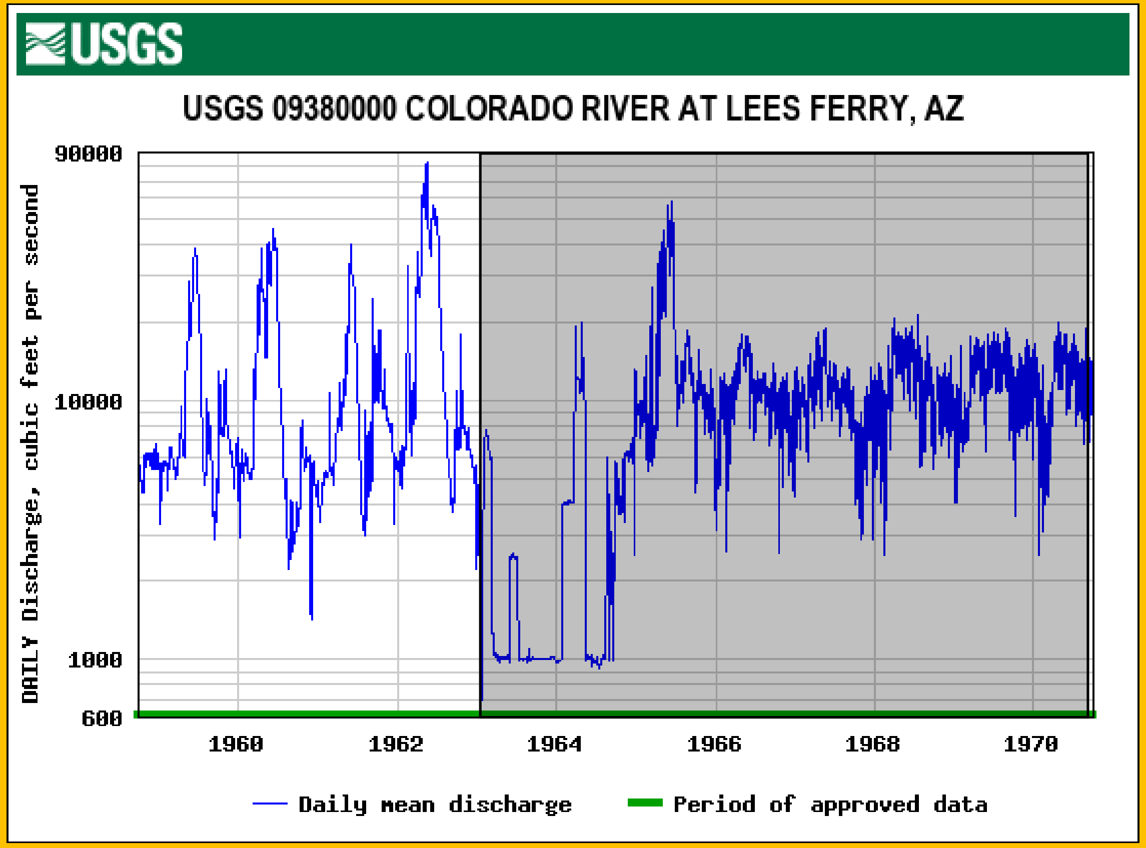
Burkhead 2012, *BioScience*
McRae et al. 2017, *PLOS One*


Over-
exploitation
Water
pollution
Flow
modification
Habitat
degradation
Species
invasion
Dudgeon et al. 2006


Grill et al. 2015

Colorado River Basin

- Flow modification
  - Large dams, diversions



Colorado River Basin

- Flow modification
  - Large dams, diversions

- Divert water for agricultural and industrial purposes

Colorado River Basin

- Habitat degradation-

Colorado River Basin

- Species invasions-

Highly imperiled fish fauna

- Depauperate fish community
- Several endemic species
- As a result, many federally listed

- Razorback Sucker

Highly imperiled fish fauna

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- Several endemic species
- As a result, many federally listed

- Razorback Sucker

Outline

Chapter 1
Feeding ecology

Recruitment (Larvae-Juvenile)

Feeding/Refuge (Adult)

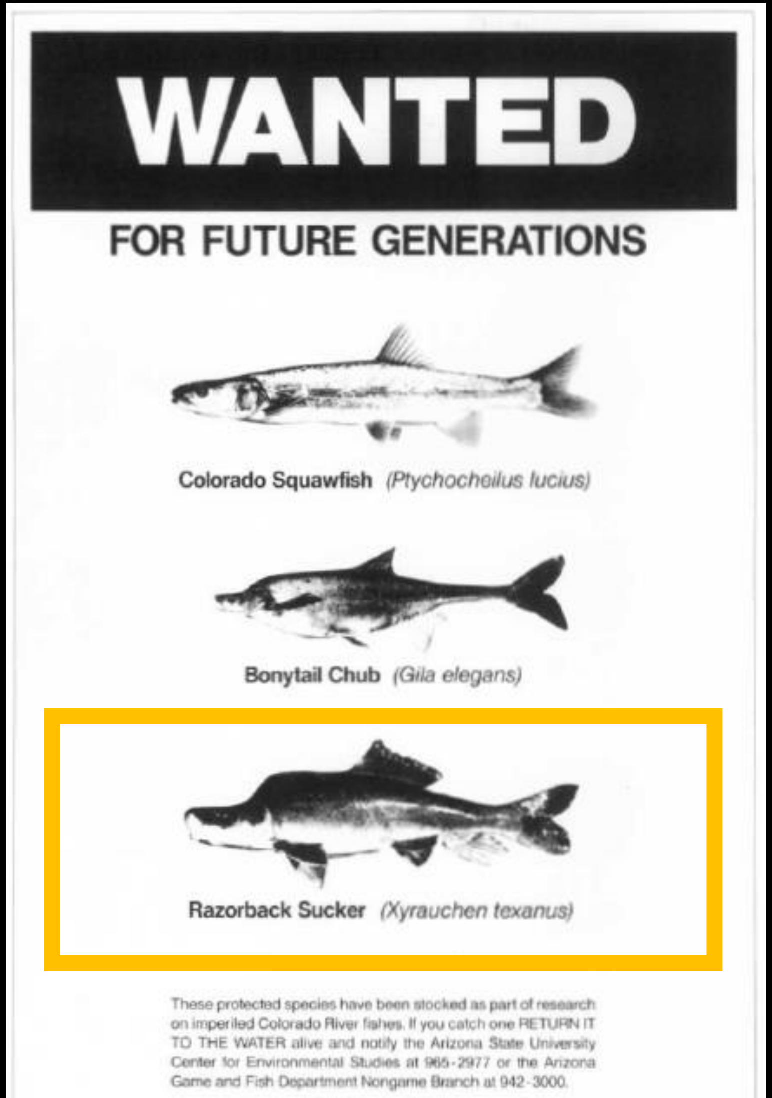
Chapter 2
River-reservoir inflow

Spawning (Adult)

Chapter 3
Basin-wide movements

Plight of the razorback

- Long lived (~40 years), large bodied (~90 cm)
- Evolved in highly connected and diverse floodplain river system
- Wyoming to Colorado River delta
- Maintained in wild by intense stocking efforts



In Minckley et al. (1991)

Why are razorbacks not recruiting?

- *Alternatively, why are other sucker species successful?*

✓Basin-wide declines

○ No self-sustaining populations

>560,000 adults stocked from 2002-2018

✓Basin-wide declines

✓Self-sustaining populations

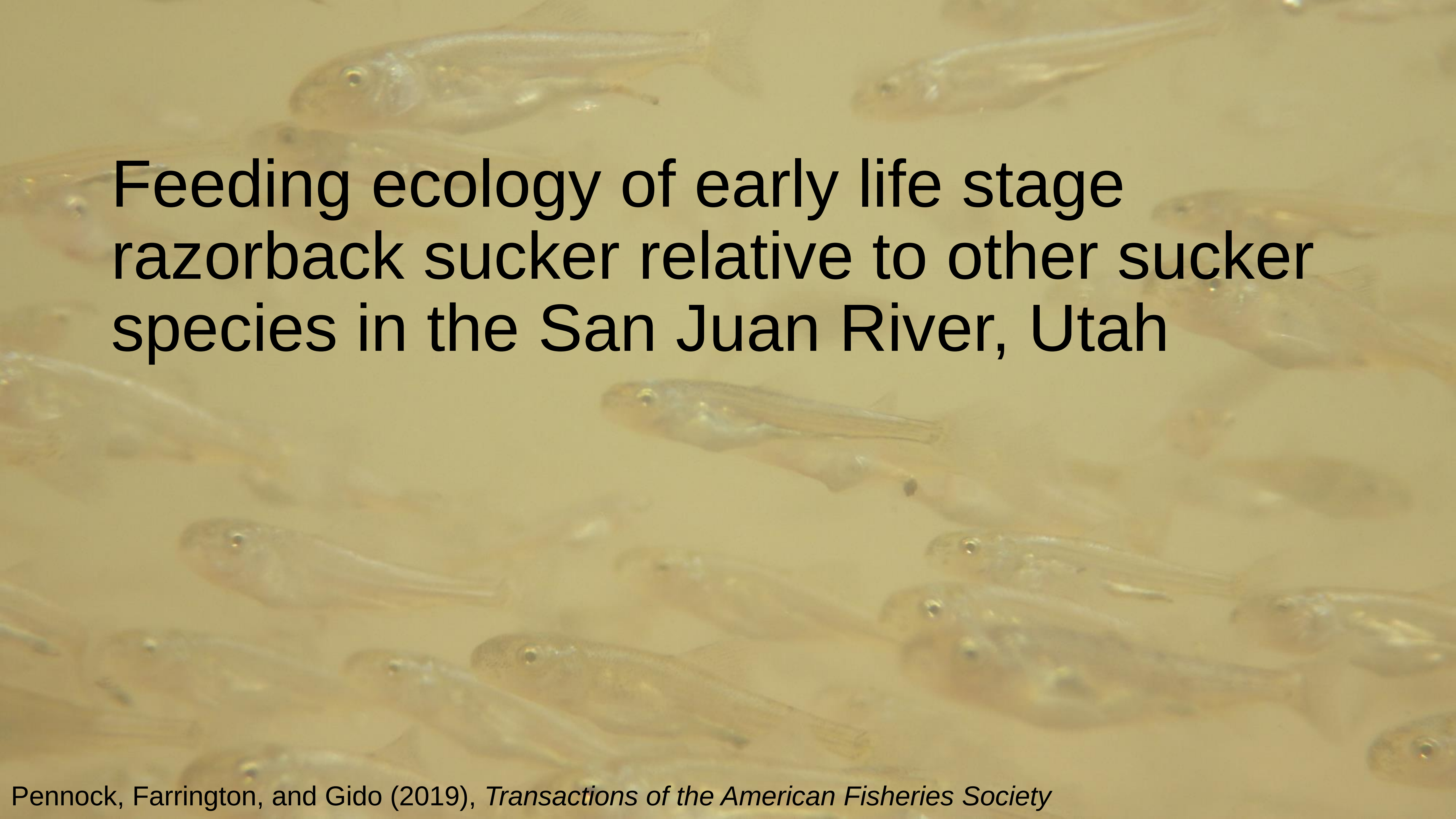
Single stocking of 600 adults to Lower CR

(Mueller & Wydoski 2004)

Recruitment bottleneck

Factors limiting razorback sucker recruitment

- Non-native species introductions
  - (Minckley et al. 1991; Minckley et al. 2003)
- Habitat degradation
  - (Horn 1996; Minckley et al. 2003)
- Food limitation/quality
  - (Papoulias and Minckley 1990; Horn 1996)

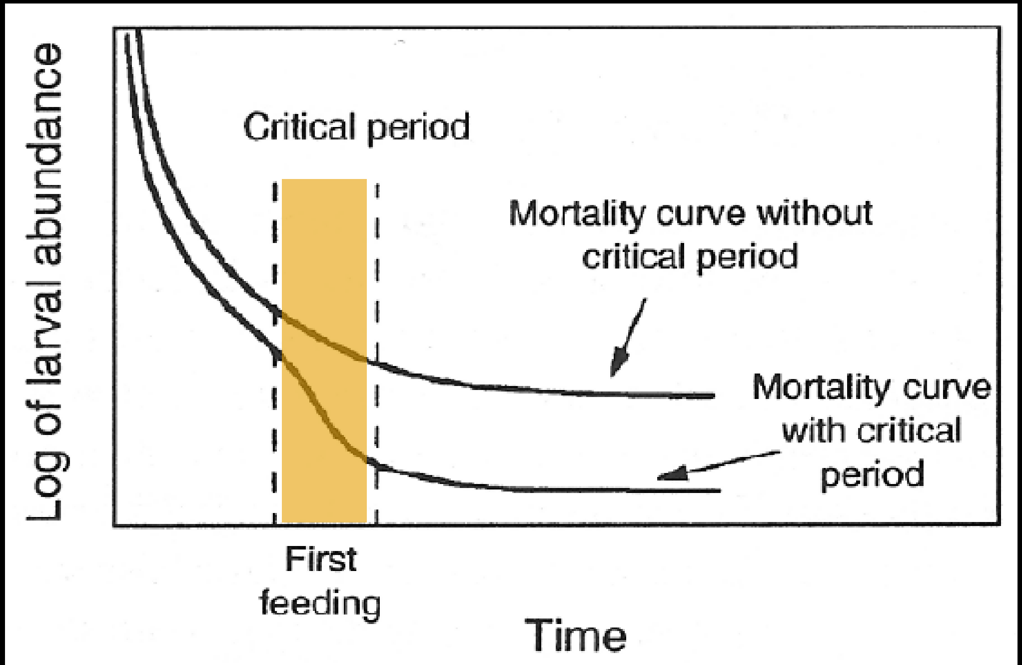


Feeding ecology of early life stage razorback sucker relative to other sucker species in the San Juan River, Utah

Pennock, Farrington, and Gido (2019), *Transactions of the American Fisheries Society*

Feeding ecology of early life stage fish

- "Critical period" (Hjort 1914)
- Gape limited
- Potentially high overlap in trophic resource use



Legget and Deblois (1994)

- High diet overlap between flannelmouth and bluehead sucker in LCR

(Schoener's Index = 0.91 Childs et al. 1998)

Celebration of suckers

- Scraping ridge

- Most general feeder

- More terminal mouth
- More gill rakers (filtering food)

Feeding ecology of early life stage suckers

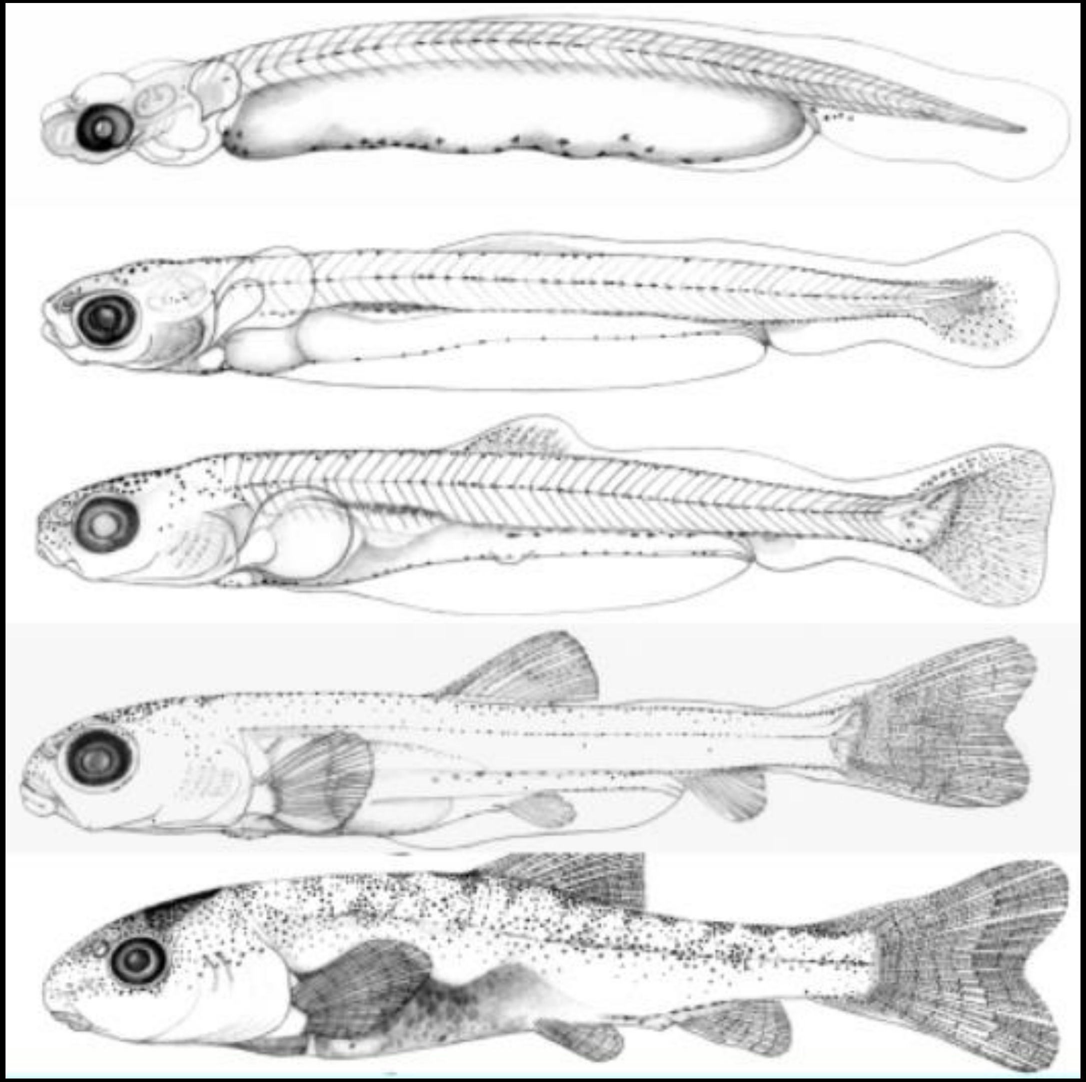
Yolk-sac larvae

Protolarvae

Mesolarvae

Metalarvae

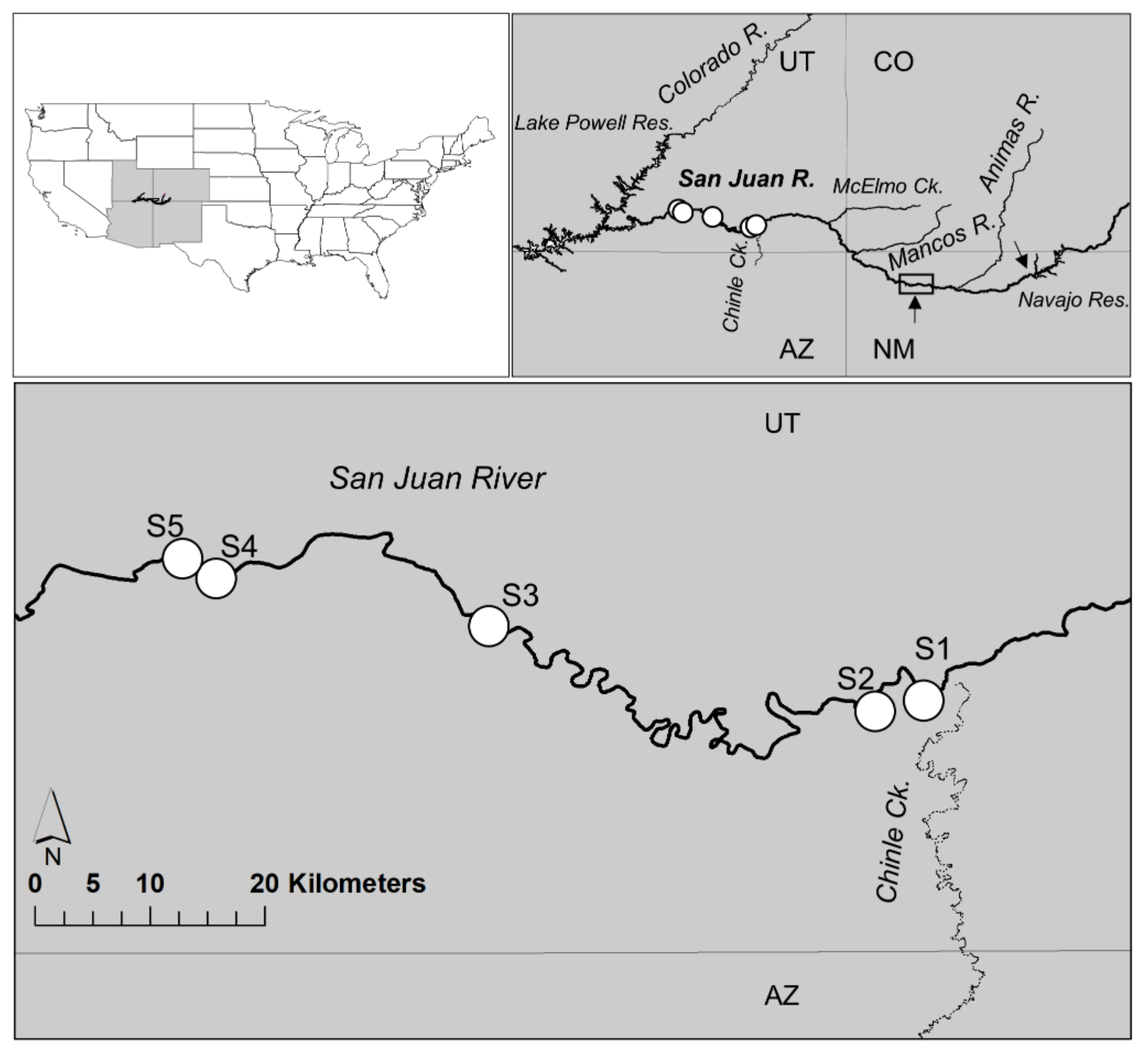
Juvenile



Razorback Sucker, protolarvae

Methods

- Museum-vouchered specimens
- Five sites
- 10 fish/species/site
- N = 150



Pennock et al. 2019

Methods

- Gut content analysis
  - Frequency of occurrence
  - 12 categories
  - 40-250x, light microscope

- Stable isotopes
  - $\delta^{13}C$
  - $\delta\ ^{15}N$

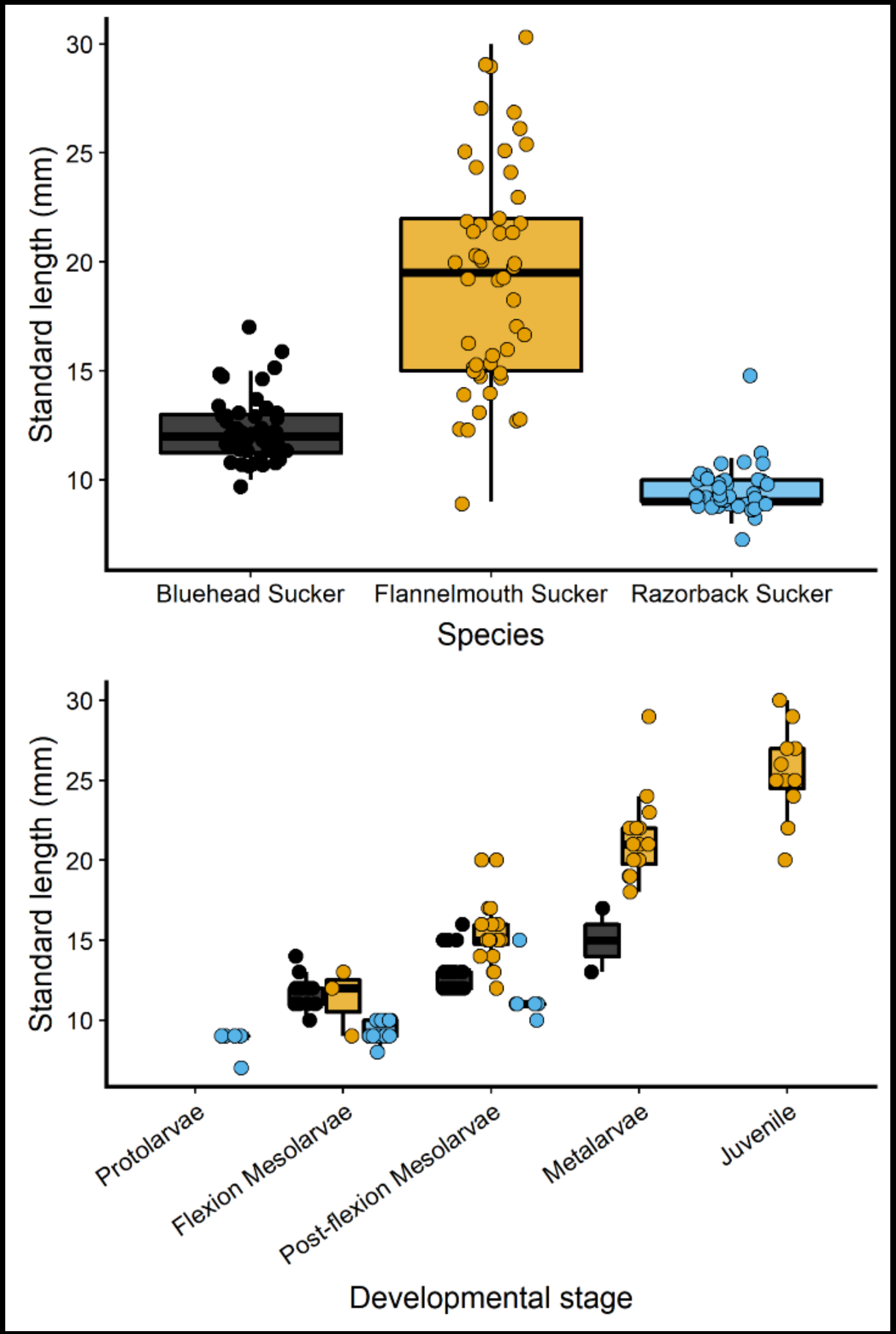
$$\delta^{13}C \text{ or } \delta^{15}N = [(R_{sample}/R_{standard}) - 1] \times 1,000,$$

Pennock et al. 2019

Gut content analysis

- Species differed in size and developmental stage

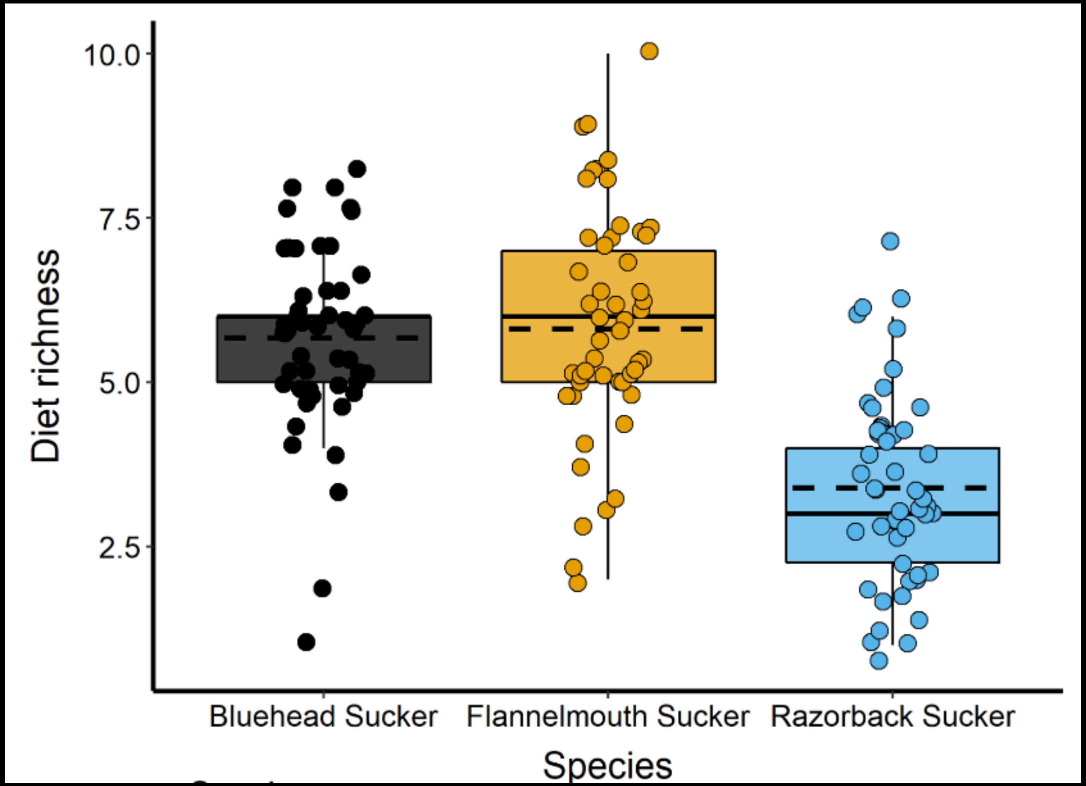
- Kruskal-Wallis ANOVA
  - H =115.8, df = 2, $P < 0.001$



Pennock et al. 2019

Gut content analysis

- Mean diet richness 1.7x higher in Bluehead and Flannelmouth Sucker

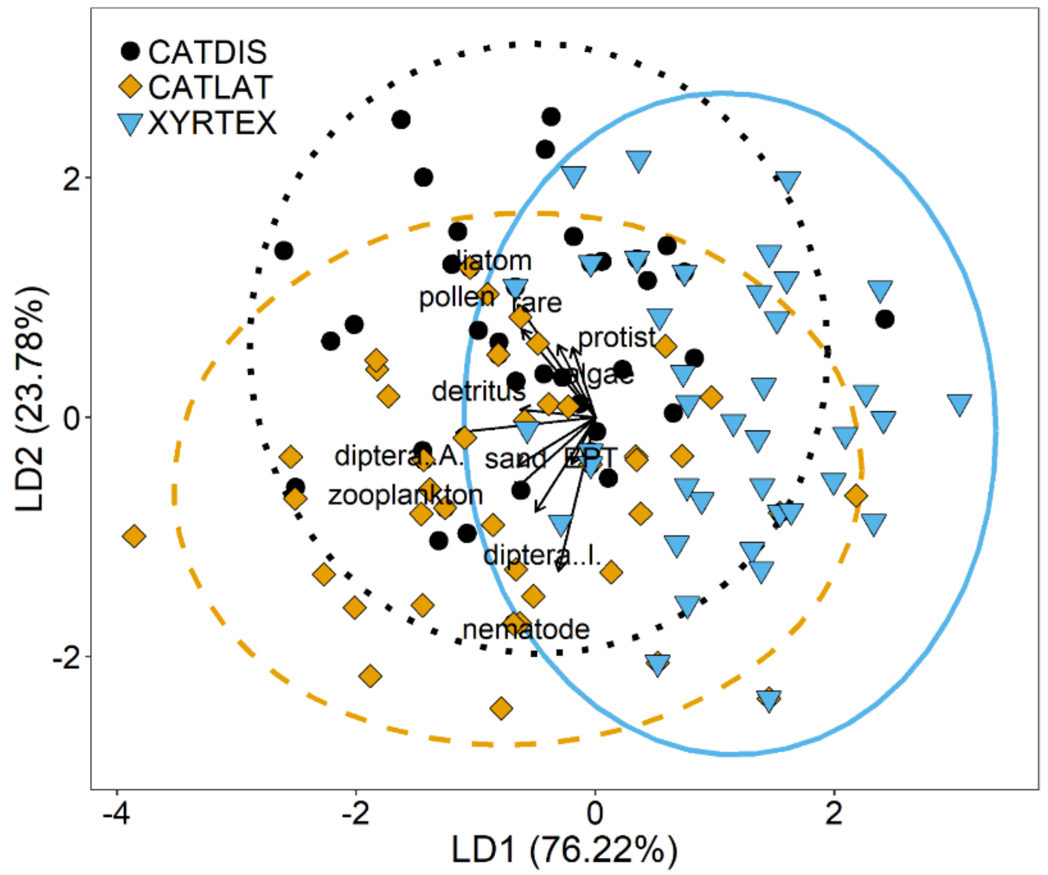


<u>Generalized linear mixed model (Poisson)</u>

- *LR* = 39.65, *P* < 0.001
  - Diet richness ~ Species + (1|Site)

Pennock et al. 2019

Gut content analysis



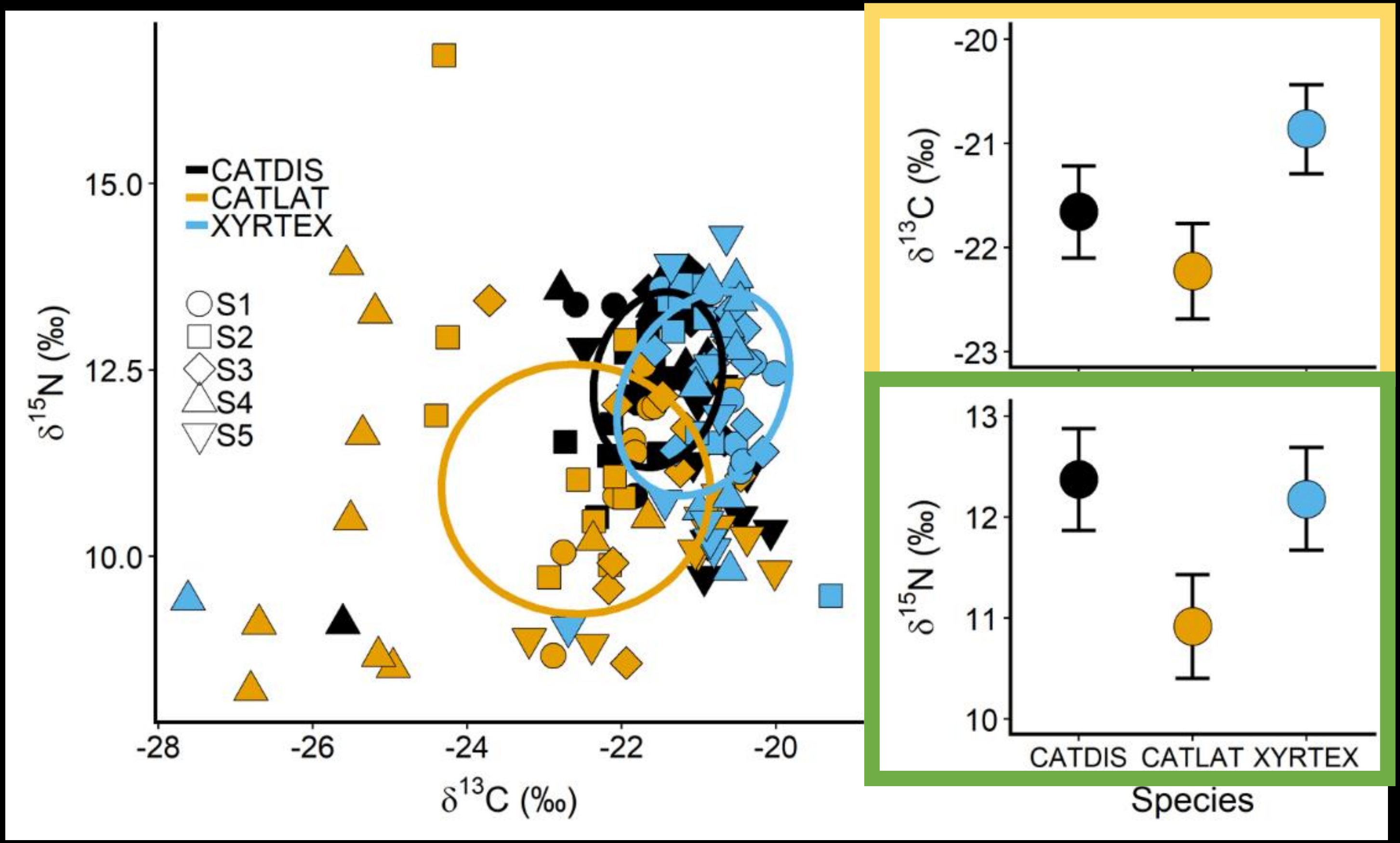
Pennock et al. 2019

Diet item category	Bluehead Sucker	Flannelmouth Sucker	Razorback Sucker	*P*
Algae	0.80	0.78	0.58	**0.019**
Detritus	0.90	0.94	0.68	**<0.001**
Diatom	0.80	0.58	0.46	**0.002**
Diptera (a)	0.20	0.32	0.00	**<0.001**
Diptera (i)	0.62	0.84	0.42	**<0.001**
EPT	0.02	0.12	0.12	0.114
Nematode	0.14	0.24	0.06	0.061
Pollen	0.60	0.44	0.20	**<0.001**
Protist	0.42	0.28	0.20	0.065
Sand	0.22	0.24	0.00	**<0.001**
Zooplankton	0.72	0.84	0.62	0.076
Rare	0.24	0.20	0.06	**0.037**

Stable isotope analysis

- Differences among species in mean $\delta^{13}C$ and $\delta\ ^{15}N$

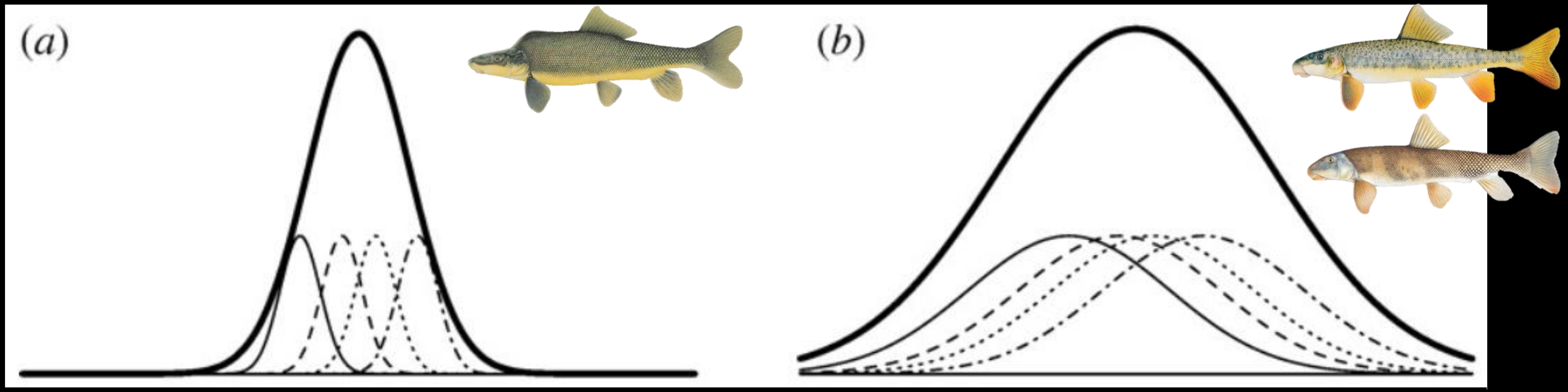
- $\delta^{13}C$
  - LR = 57.88; *P* < 0.001
  - Marginal $R^2 = 0.45$
  - Conditional $R^2 = 0.71$
- $\delta\ ^{15}N$
  - LR = 30.06; *P* < 0.001
  - Marginal $R^2 = 0.18$
  - Conditional $R^2 = 0.24$



Pennock et al. 2019

Conclusions

- Differences in diet richness and composition among species
  - Low intraspecific versus high intraspecific overlap



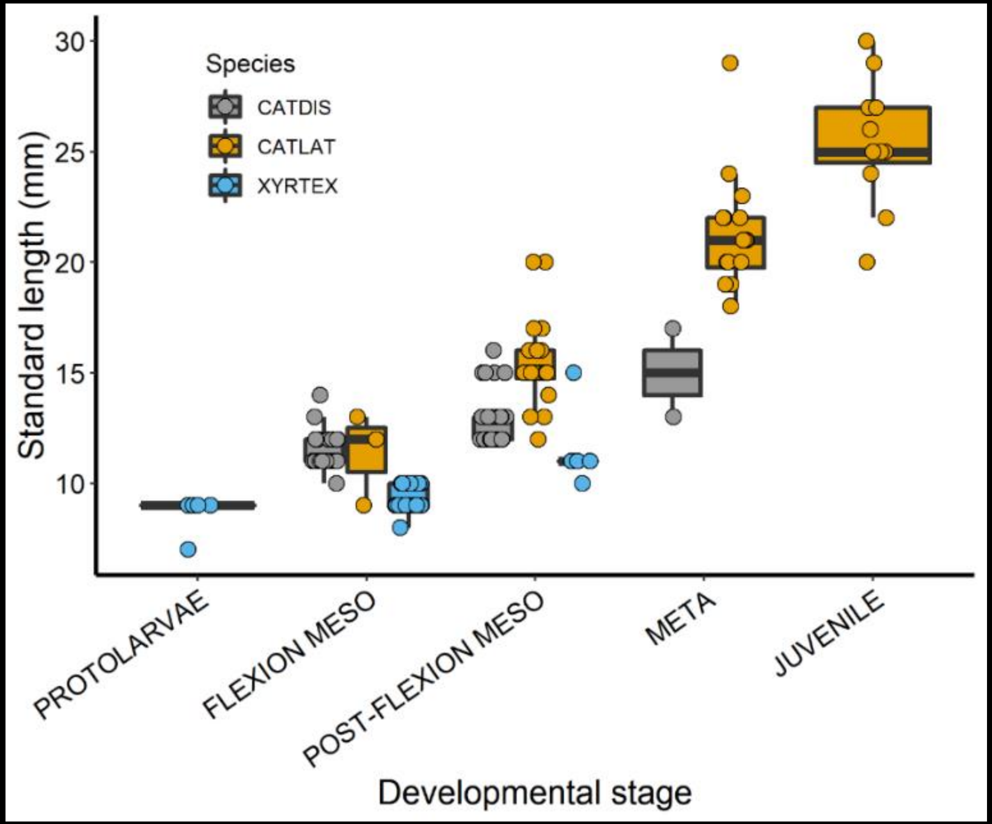
Total niche width

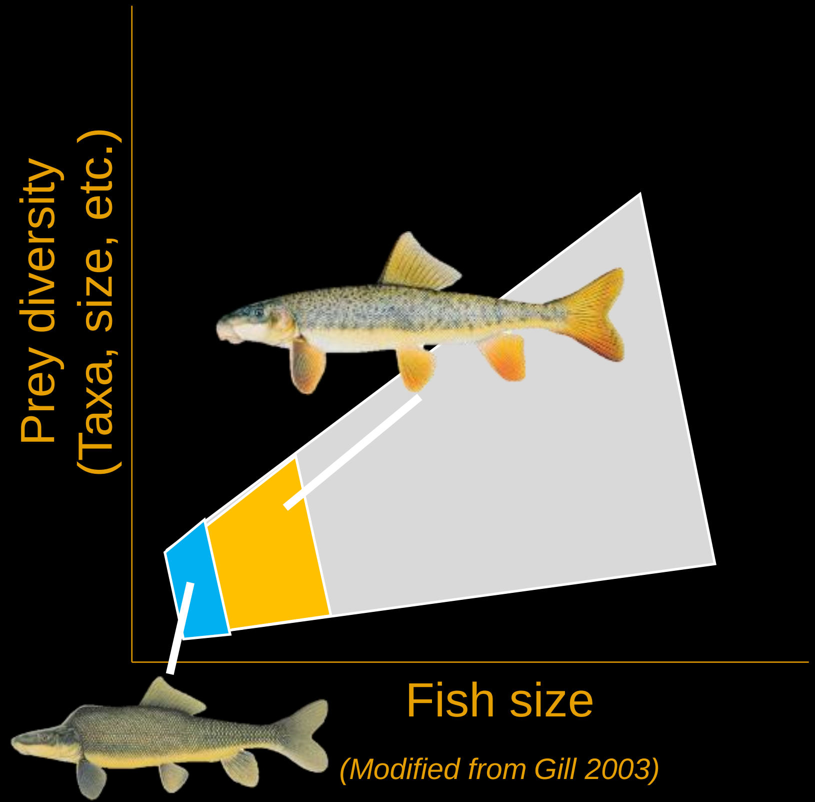
Modified from Bolnick et al. 2010

Pennock et al. 2019

Conclusions

- Differences in size among species and individuals





(Modified from Gill 2003)

Pennock et al. 2019

Outline

Chapter 1
Feeding ecology

Recruitment
(Larvae-Juvenile)

Chapter 3
Basin-wide
movements

Spawning
(Adult)

Feeding/Refuge
(Adult)

Chapter 2
River-reservoir
inflow

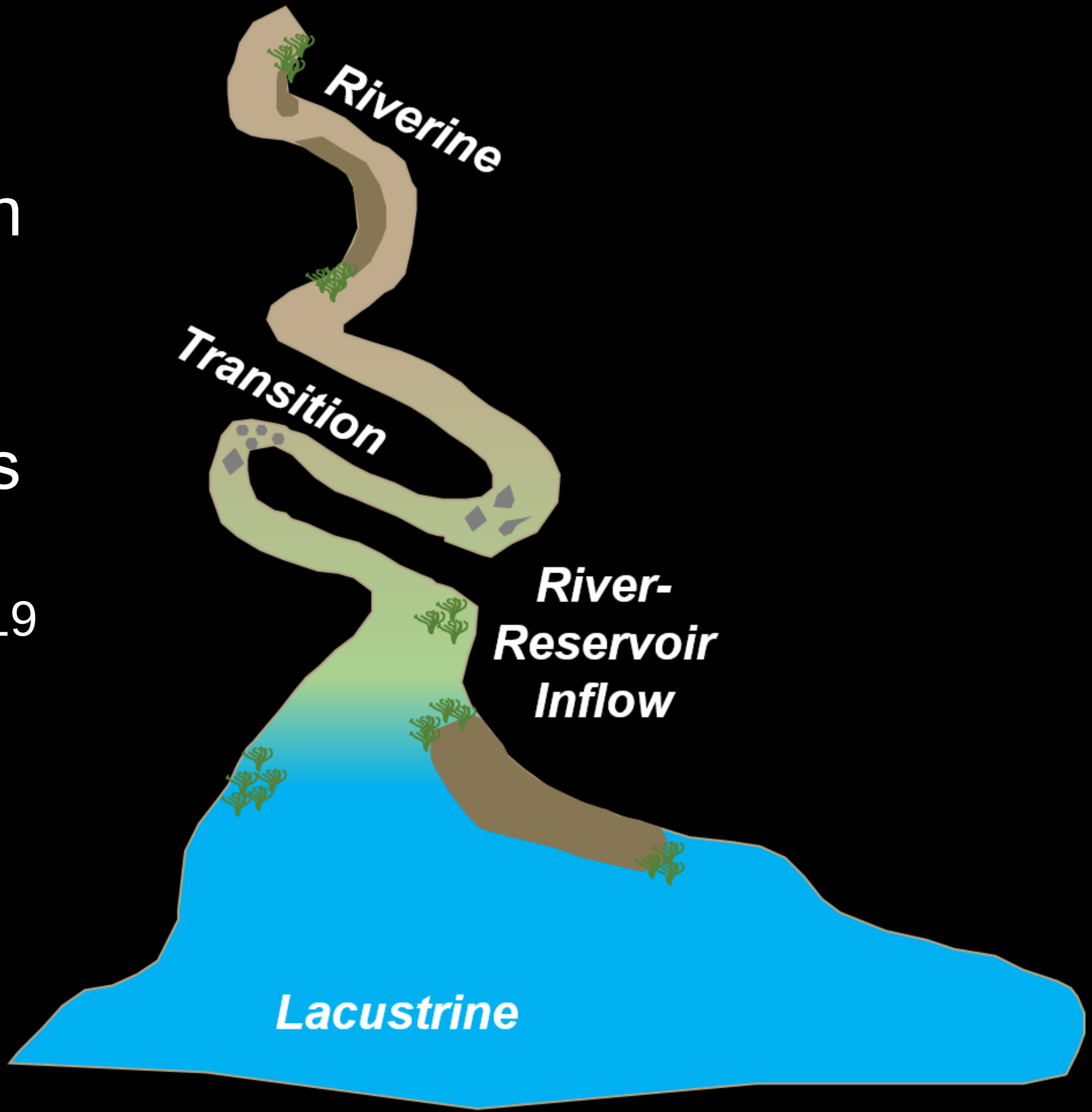
Fish in Novel Ecosystems

- Ubiquitous
- Altered habitat
- Non-native species

Reservoir inflow areas as hotspots for fish conservation: shifts in arid-land fish assemblage structure across an aquatic ecotone

River-reservoir inflows

- Reservoirs exhibit spatial zonation
  - Riverine, transition, lacustrine
- RRI’s high in fish species richness
  - Blends of lotic and lentic habitat
    - Buckmeier et al. 2014; Nobile et al. 2019



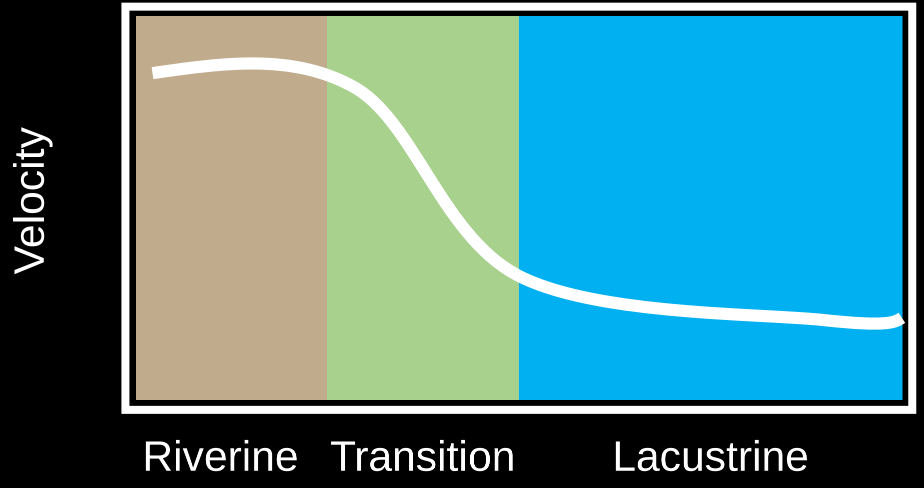
Thornton et al. (1990)

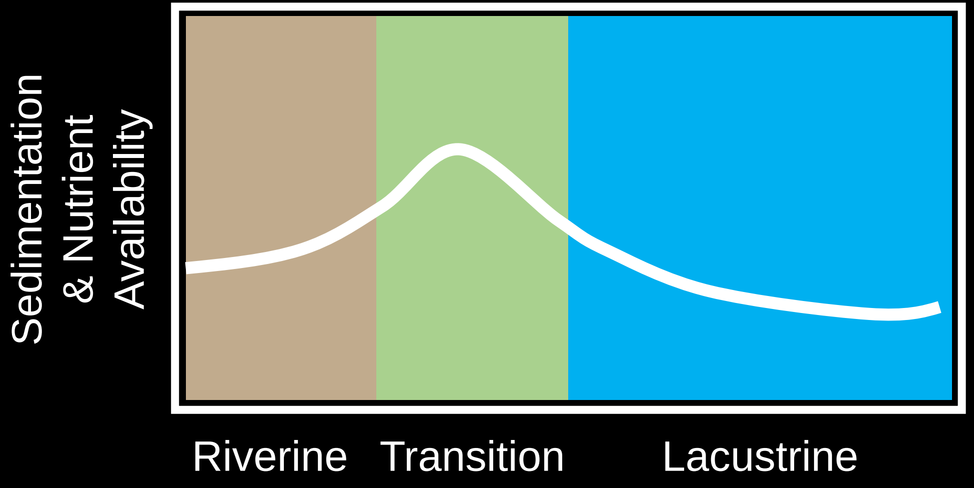

Western Grebe

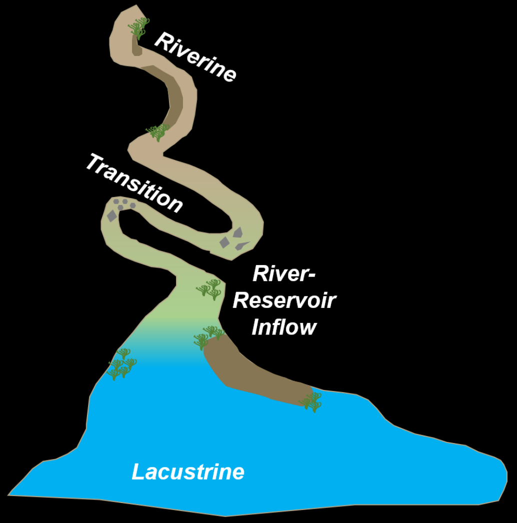
River Otter

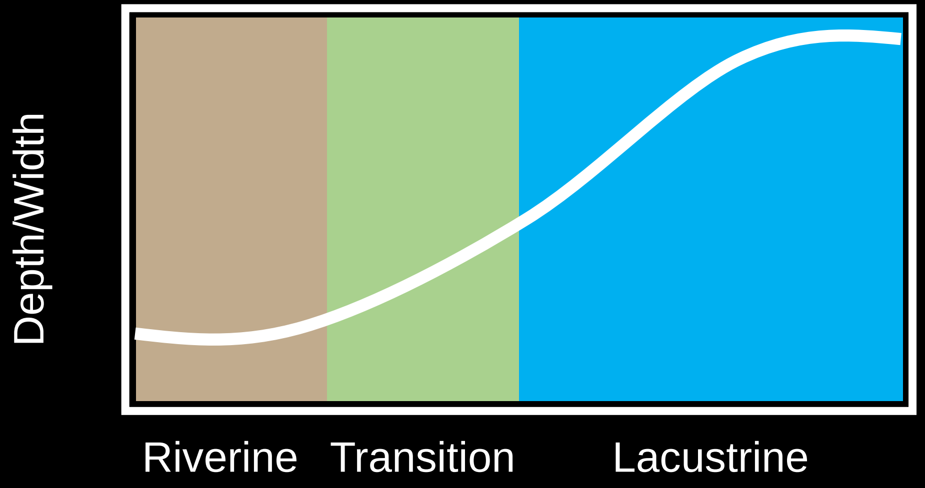

Volke et al. (2015), *BioScience*
Volke et al. (2019), *Ecological Monographs*
Photo from *Bulletin of the Ecological Society of America*

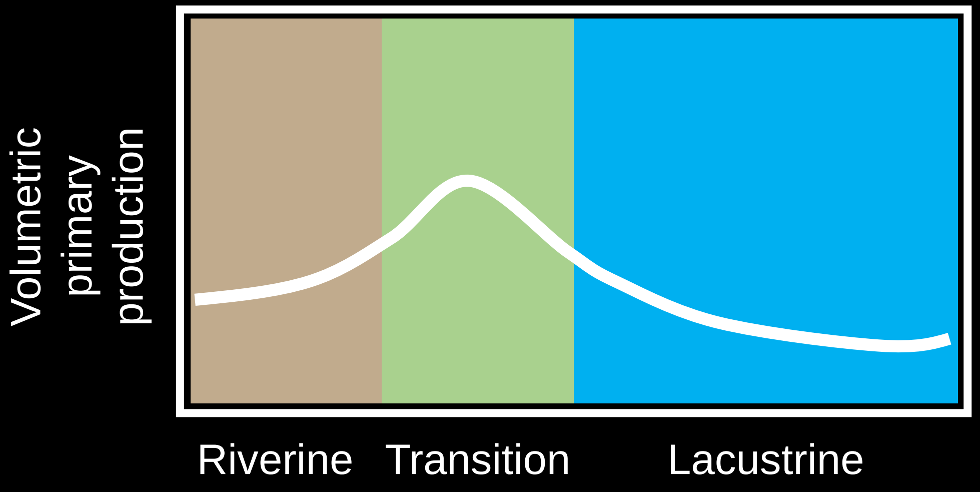
River-reservoir inflows











Thornton et al. (1990)

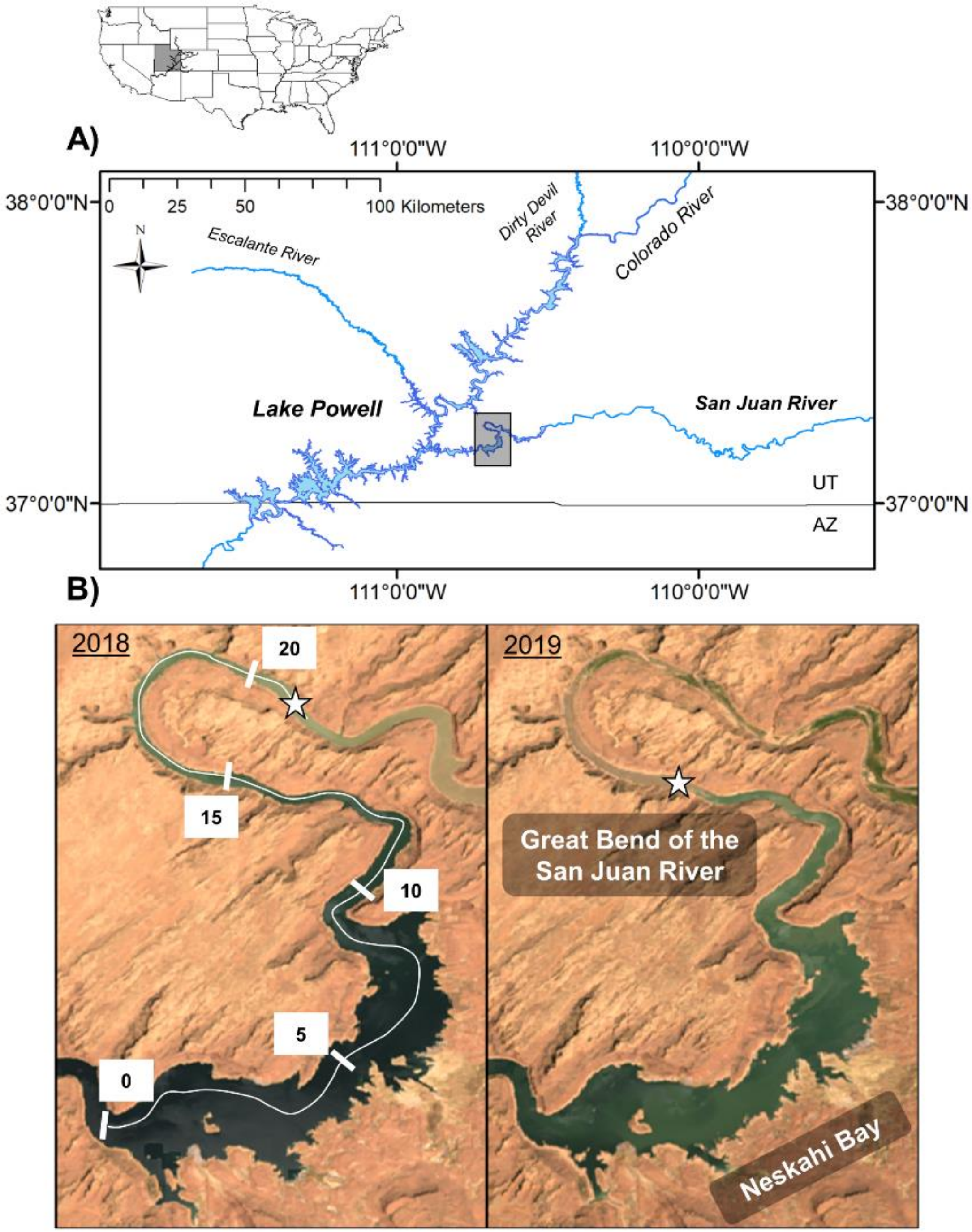
Questions

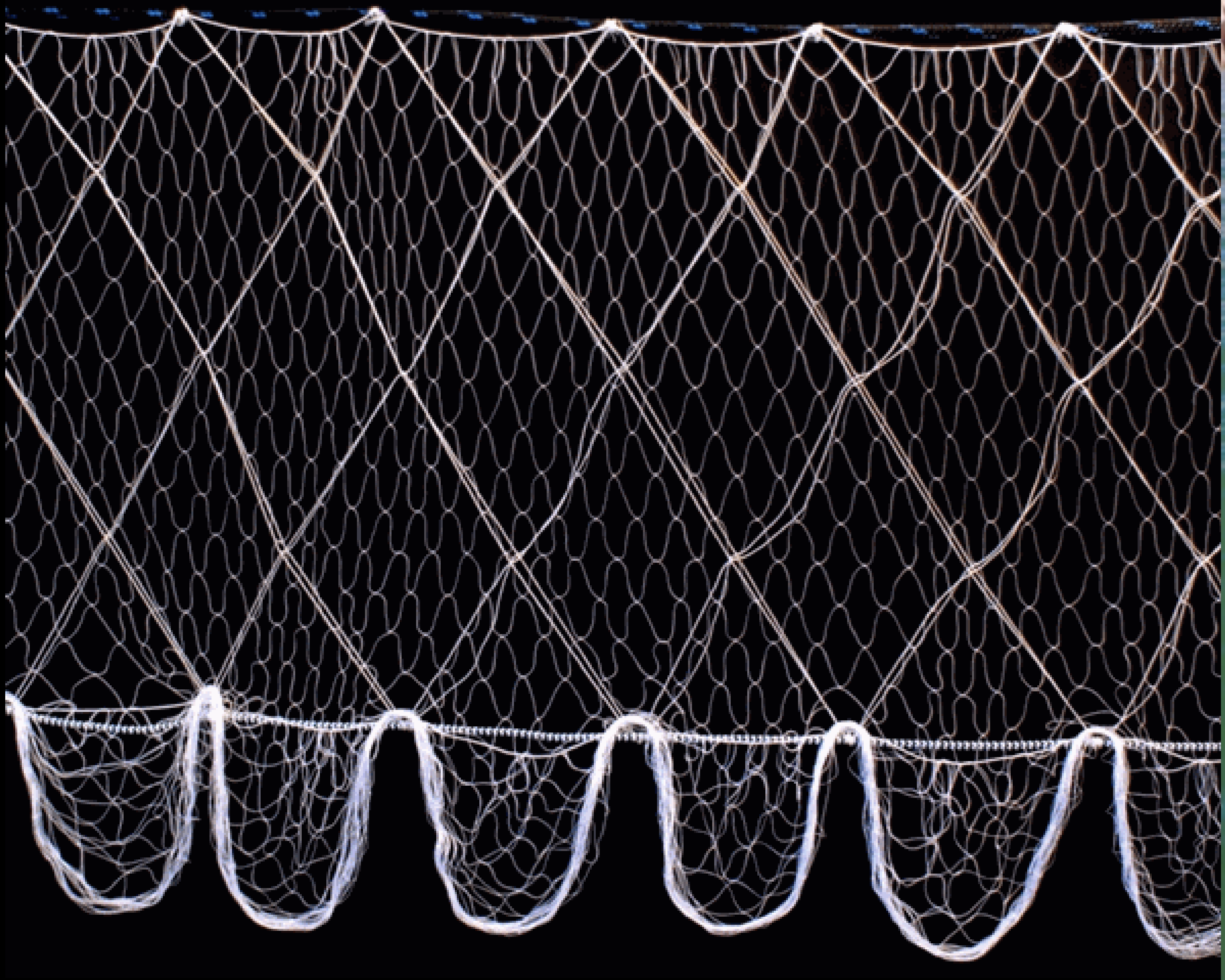
- How does fish assemblage structure change along the San Juan River-Lake Powell inflow area?
  - Predictions: Higher numbers of species and individuals towards the river inflow

- Is there synchrony in distributions of different feeding groups?
  - Predictions: Species with similar habitat and trophic resource use would overlap in distribution

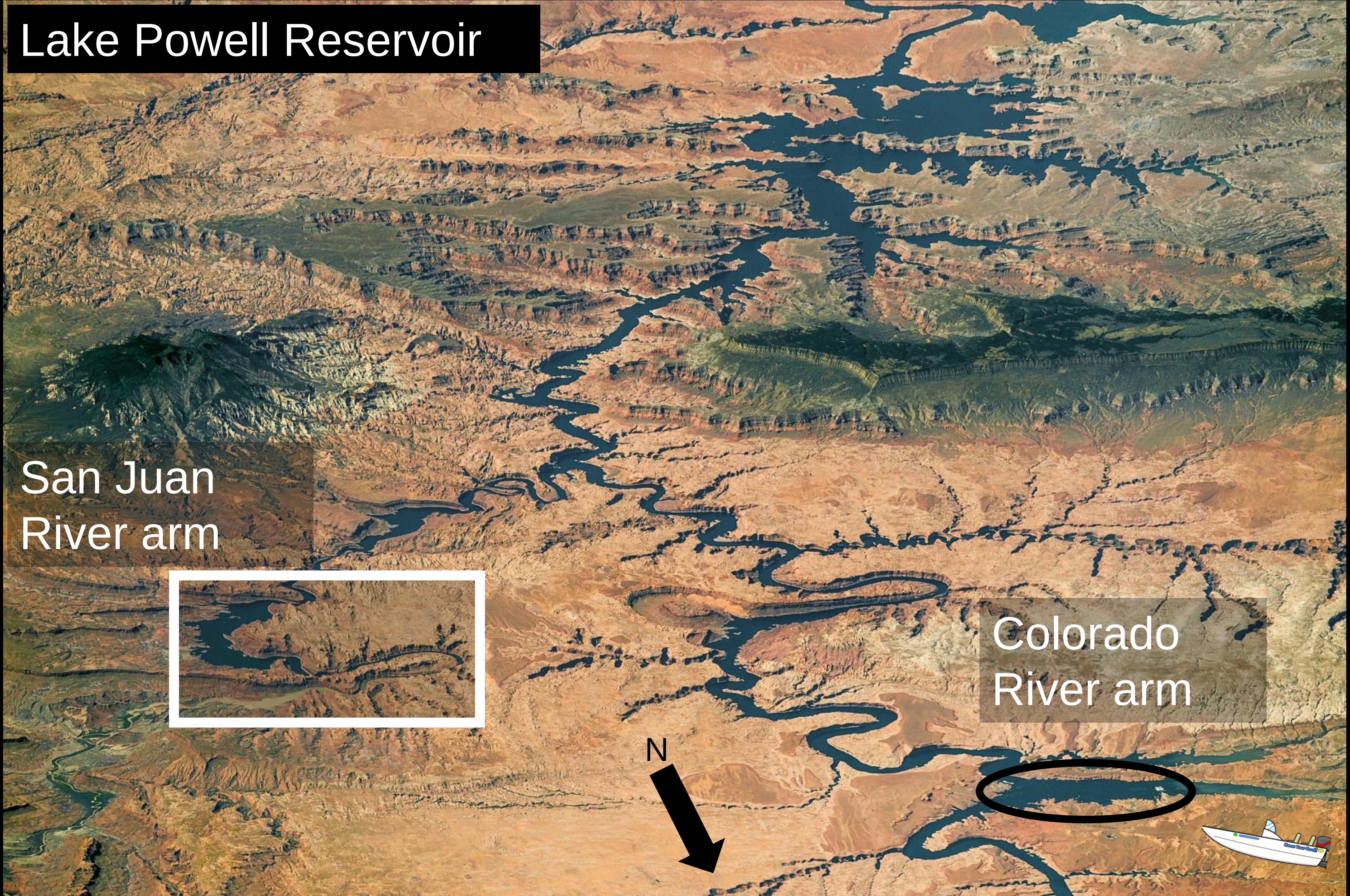
Methods

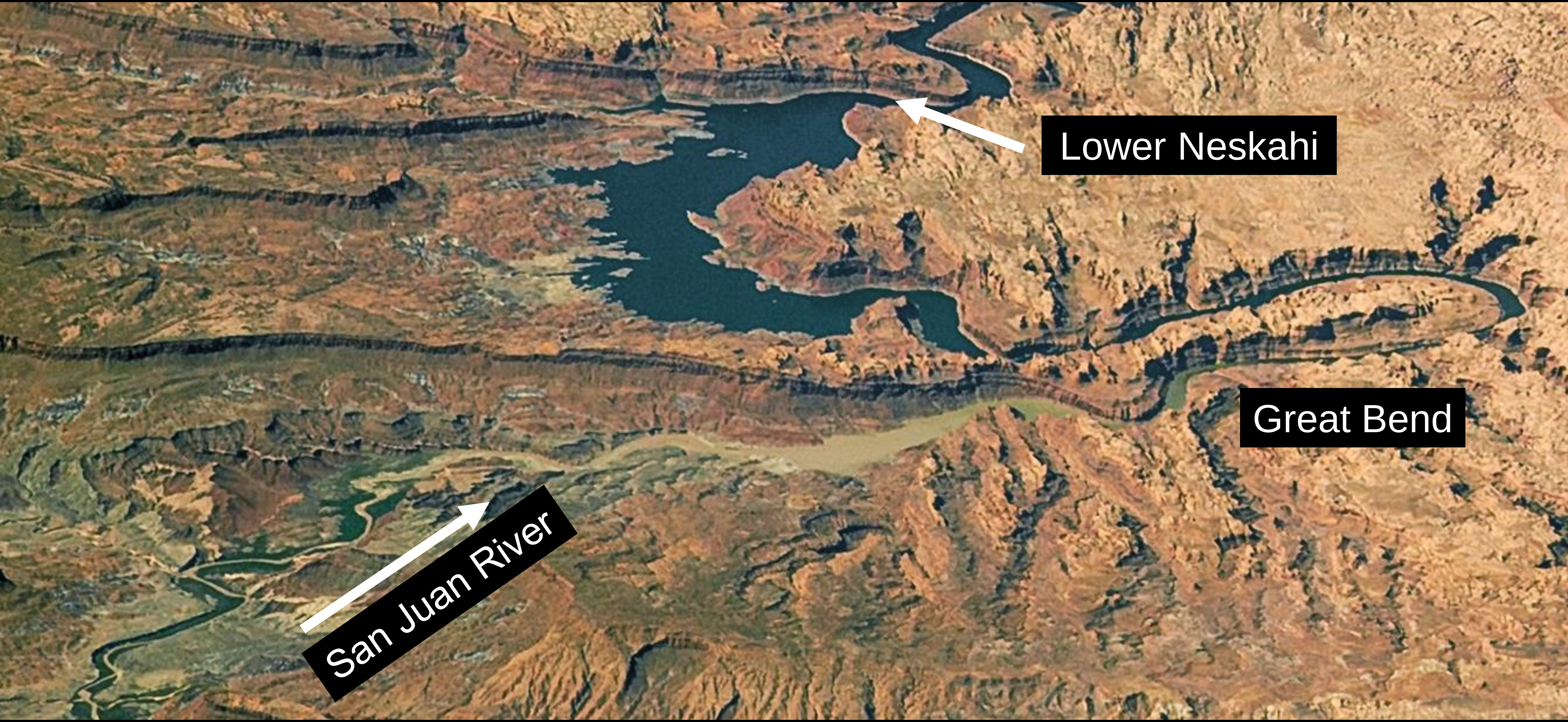
- Sampled fish along the inflow area
  - Trammel nets
  - 3 weeks (April-June)
  - 2018 & 2019



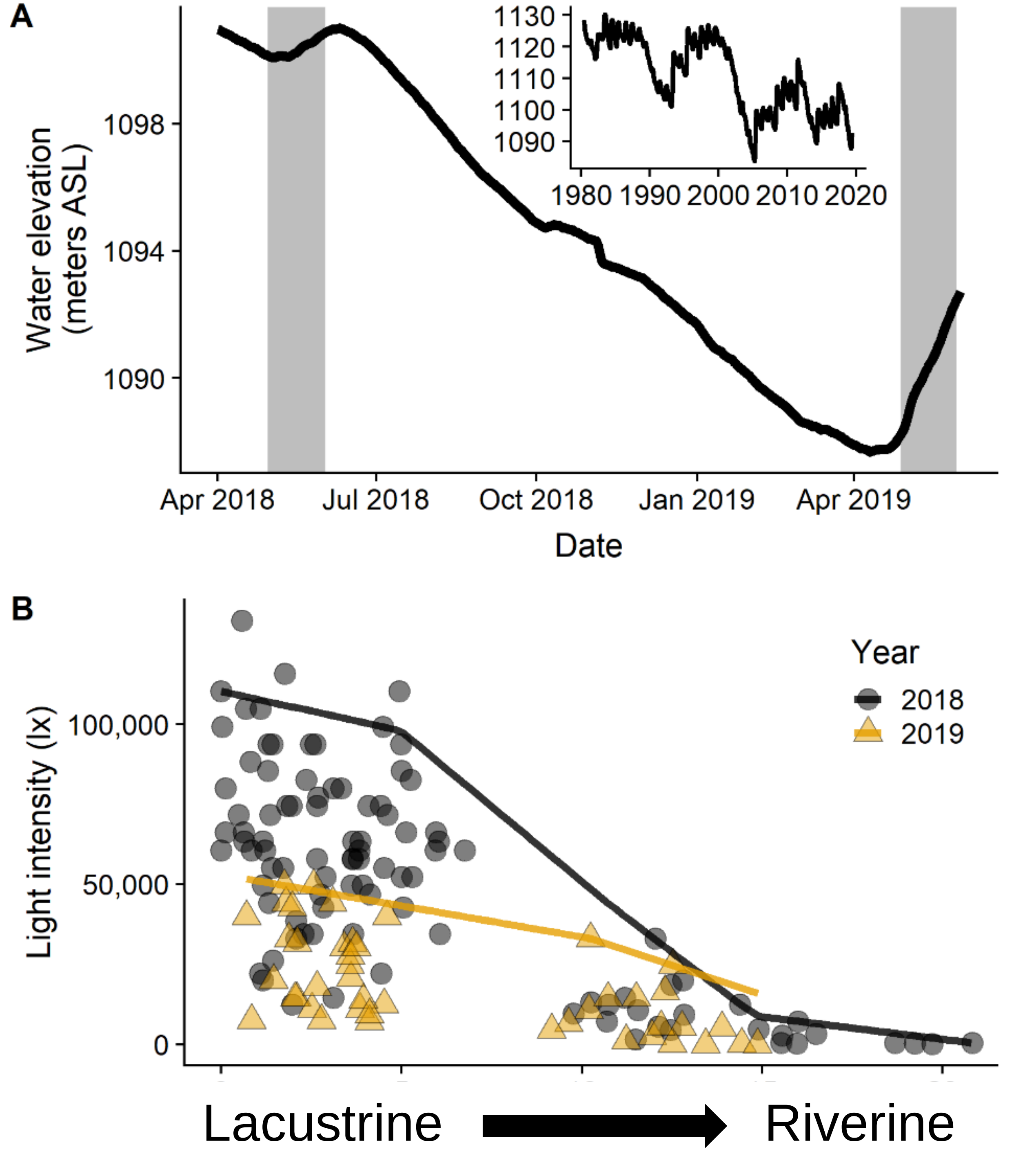
Lake Powell Reservoir




Lower Neskahi
Great Bend
San Juan River

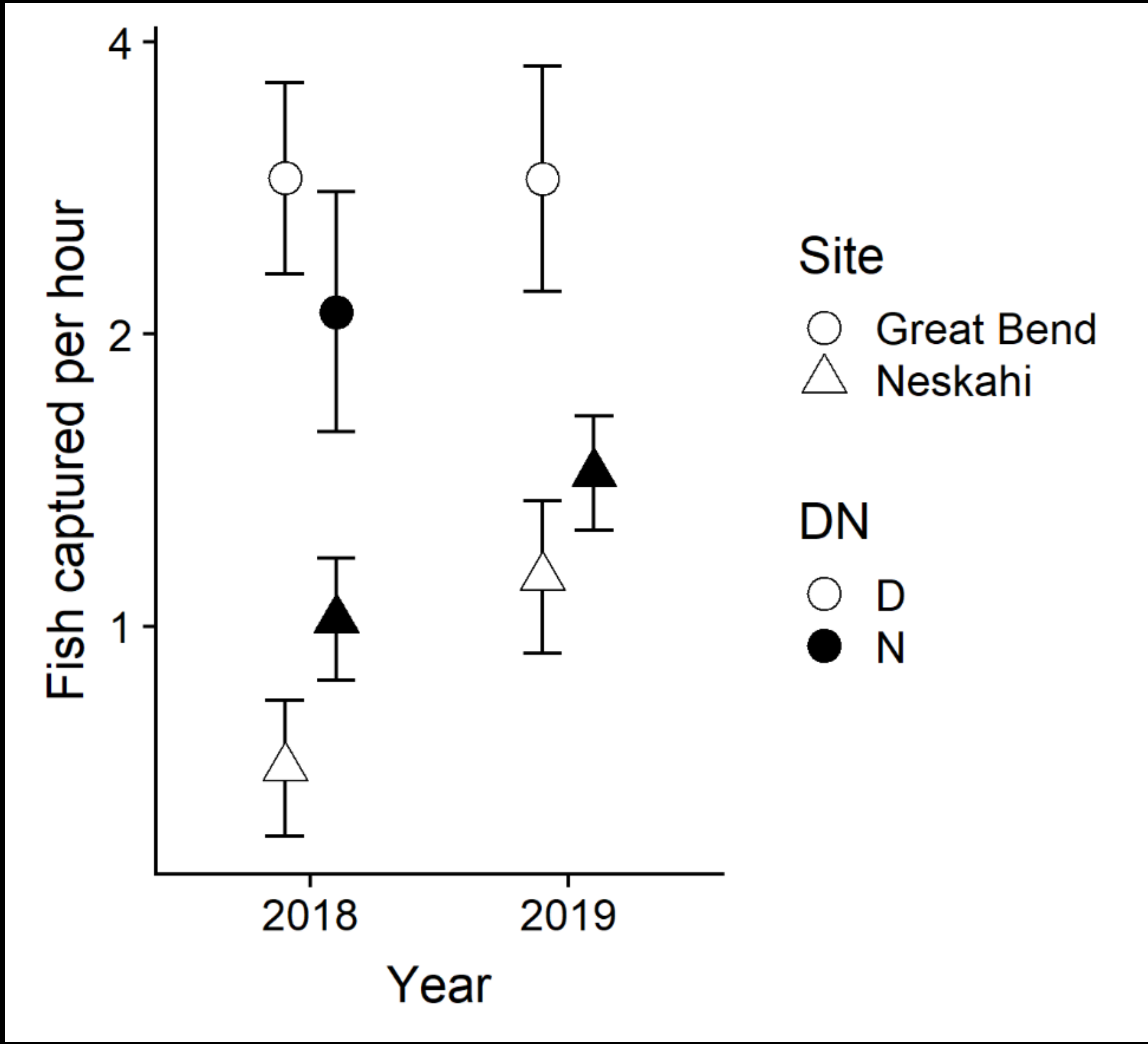
Methods

- Analyzed years separately
  - Variable water level
- Used distance along river channel as latent variable
  - Gradients of depth, turbidity, and trophic resources



Results

- 7,218 fish captured
  - 403 net deployments
- 18 species, one hybrid
  - Only 4 native species
- Caught more fish per hour in Great Bend (*P* < 0.01)



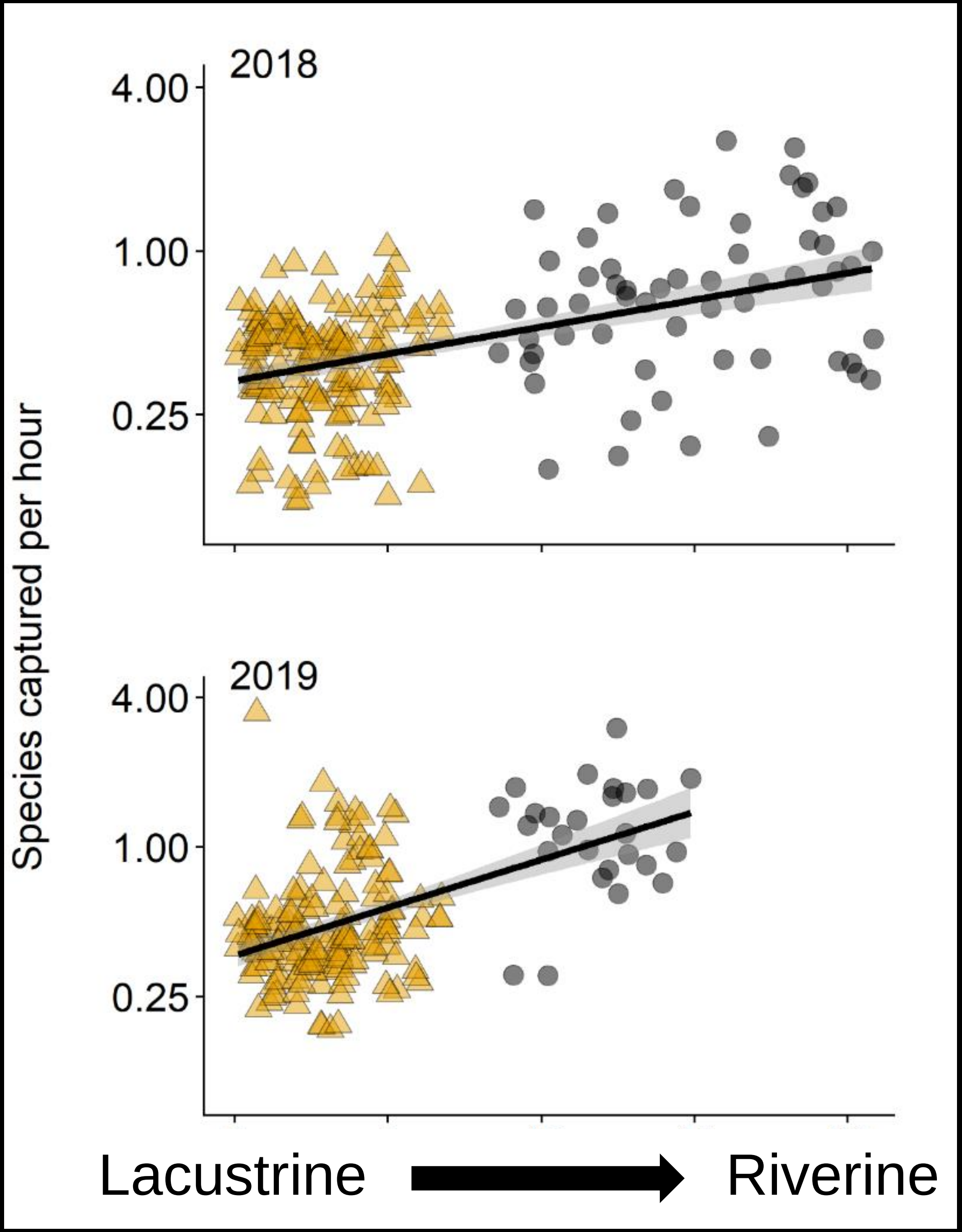
*Y-axis on a log-scale

Results

- More species per hour towards river inflow

- 2018: $F_{1,217} = 60.7$, $P < 0.001$

- 2019: $F_{1,182} = 72.9$, $P < 0.001$



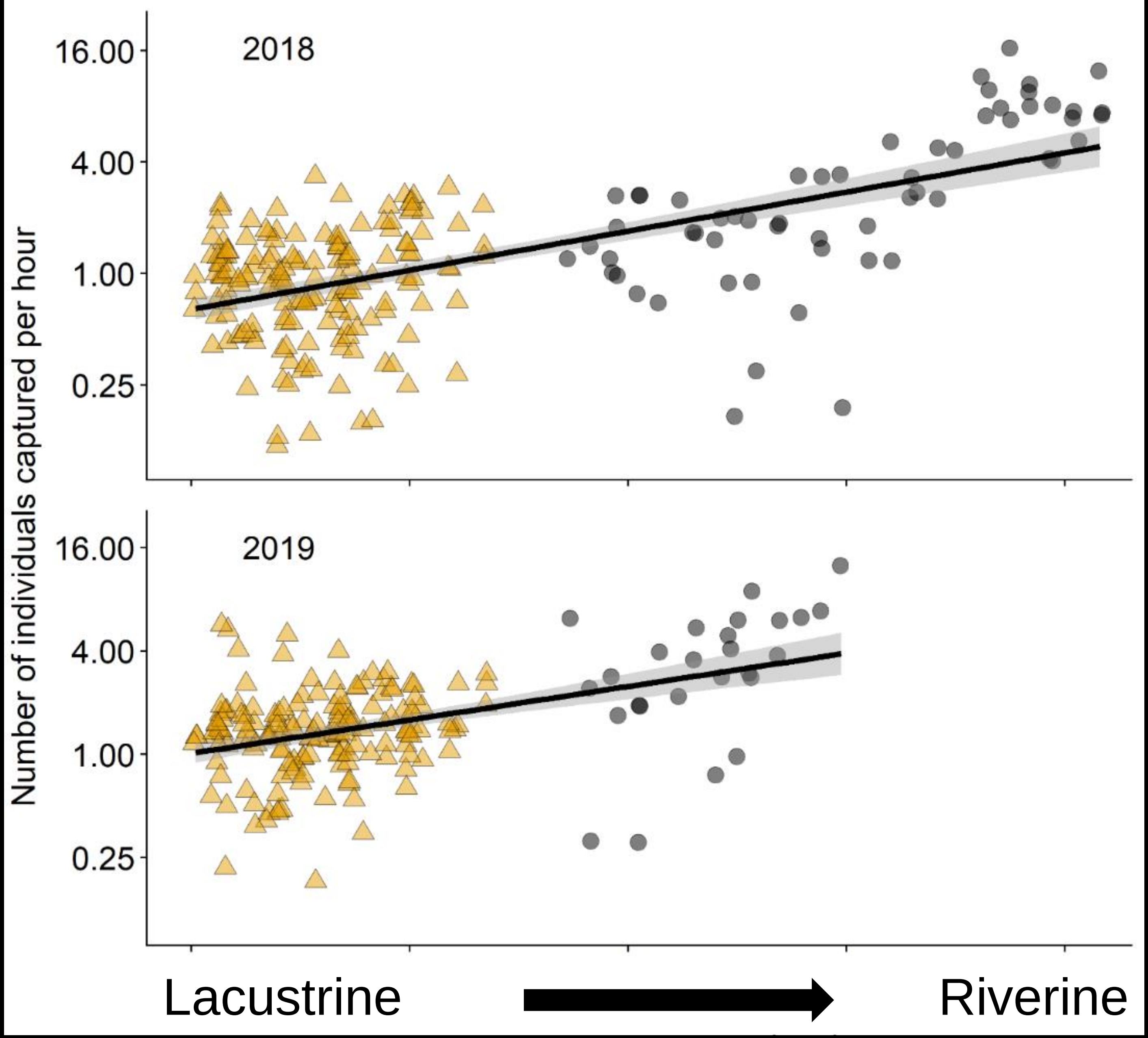
*Y-axis on a log-scale

Results

- More individuals per hour towards river inflow

- 2018: $F_{1,217} = 144.9$, $P < 0.001$

- 2019: $F_{1,182} = 49.8$, $P < 0.001$



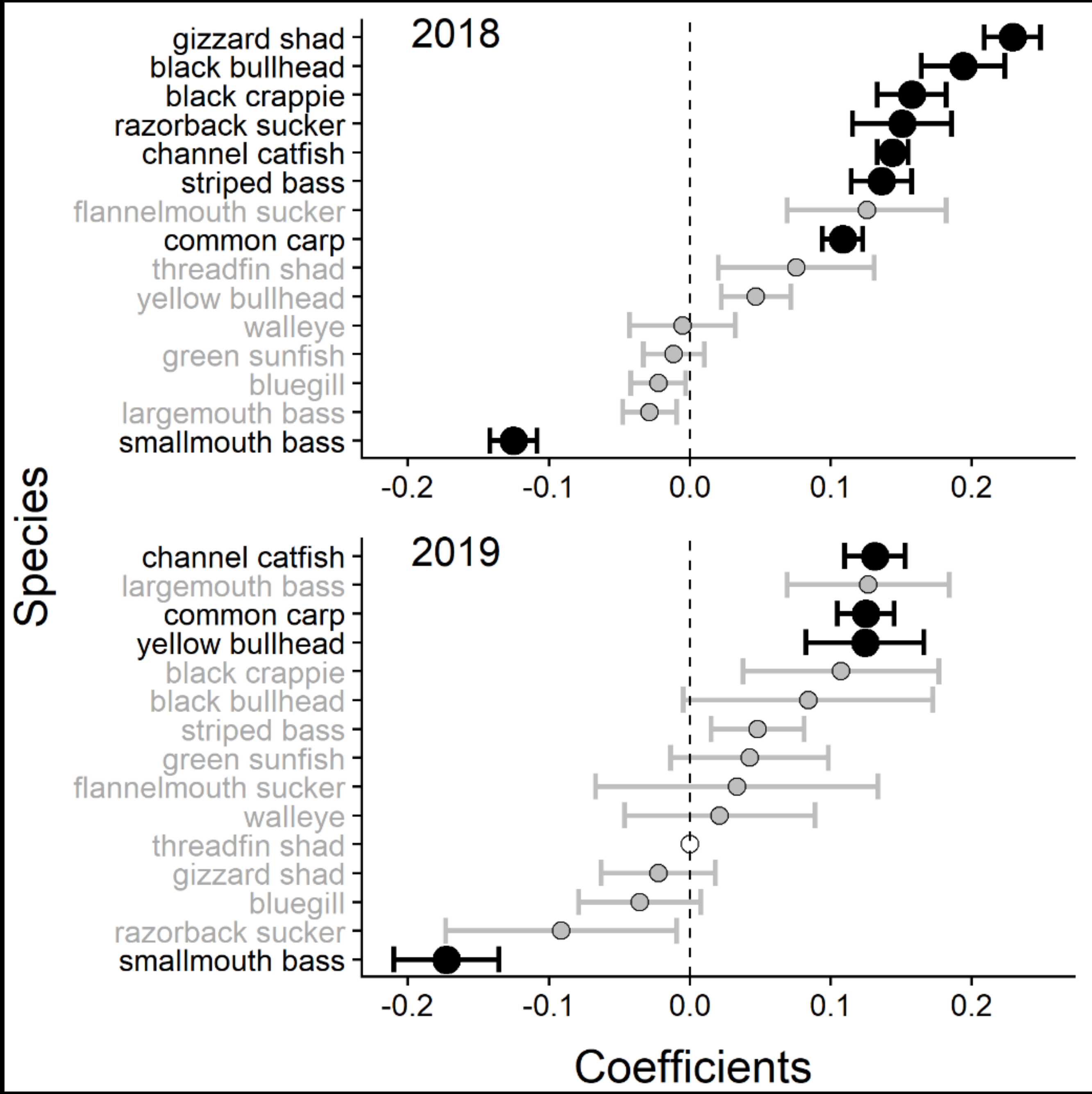
*Y-axis on a log-scale

Results

- Species-specific patterns differed among years

- manyGLM (Negative binomial, link=log)
  - 2018: *Sum-of-LR* = 529.4, *P* = 0.001
  - 2019: *Sum-of-LR* = 129.2, *P* = 0.001

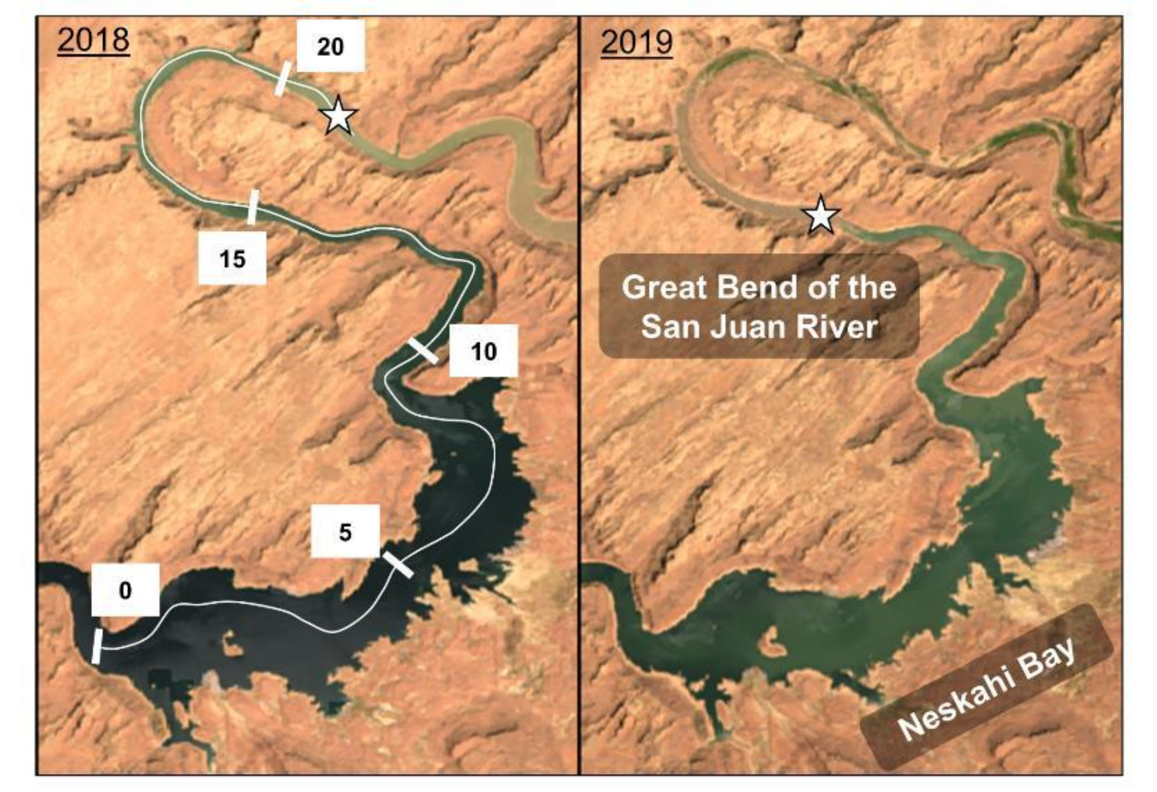
*Hours nets deployed included as a covariate



Conclusions

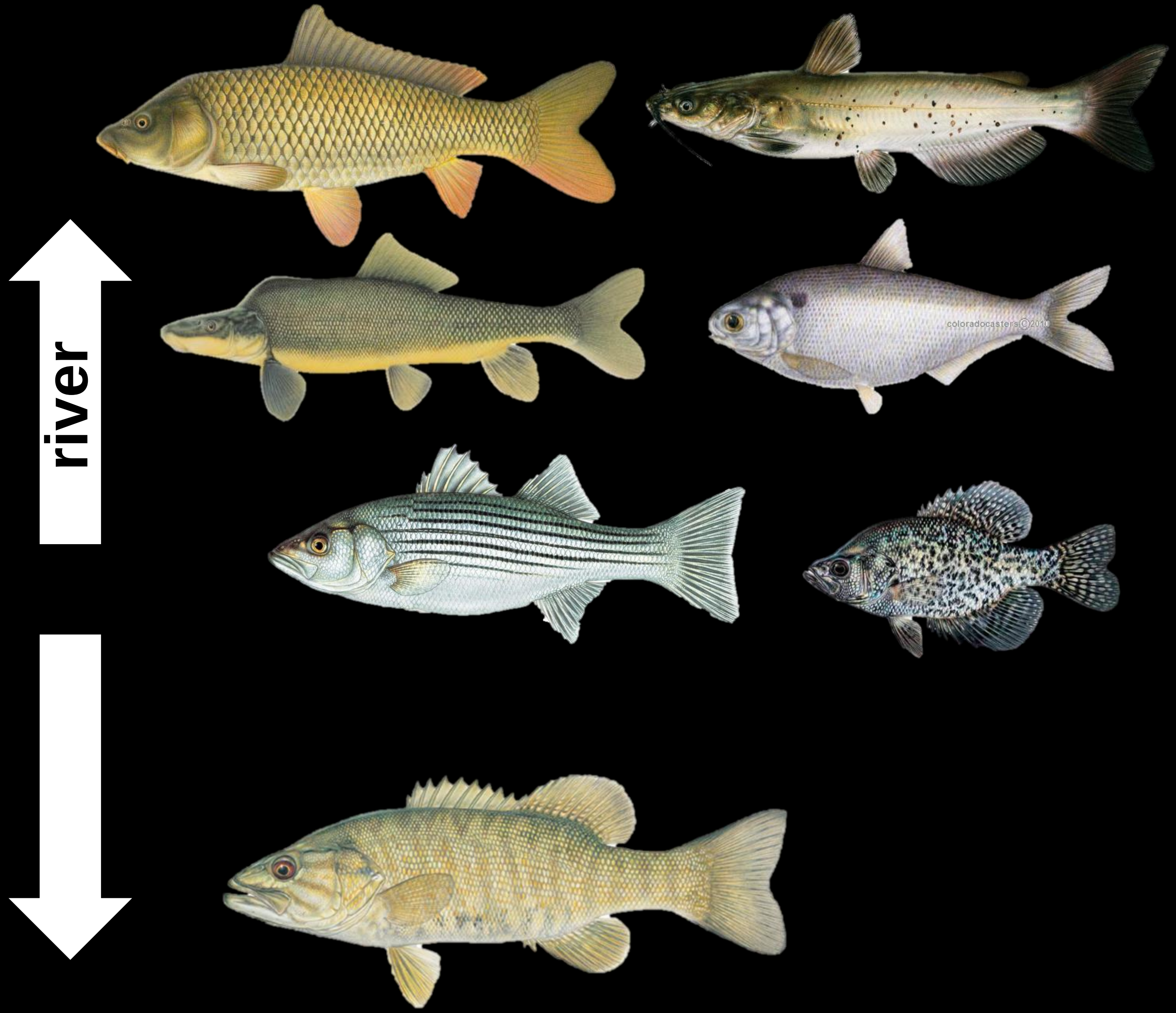
- Strong patterns in both richness and total catch towards river inflow
  - (e.g., Matthews et al. 2004; Buckmeier et al. 2014)

- Water level likely influenced species-specific patterns



Conclusions

- Benthic omnivores increased in relative abundance toward river inflow
- Some predatory species also showed increases
- What allows fish to be successful in reservoirs?
  - Turbidity?, Food?, Temperature?
- Are fish moving between reservoir and riverine habitat?



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Recruitment (Larvae-Juvenile)

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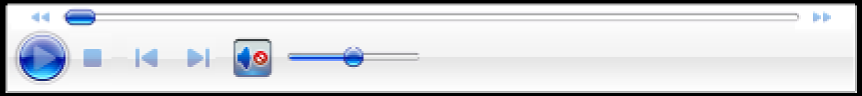
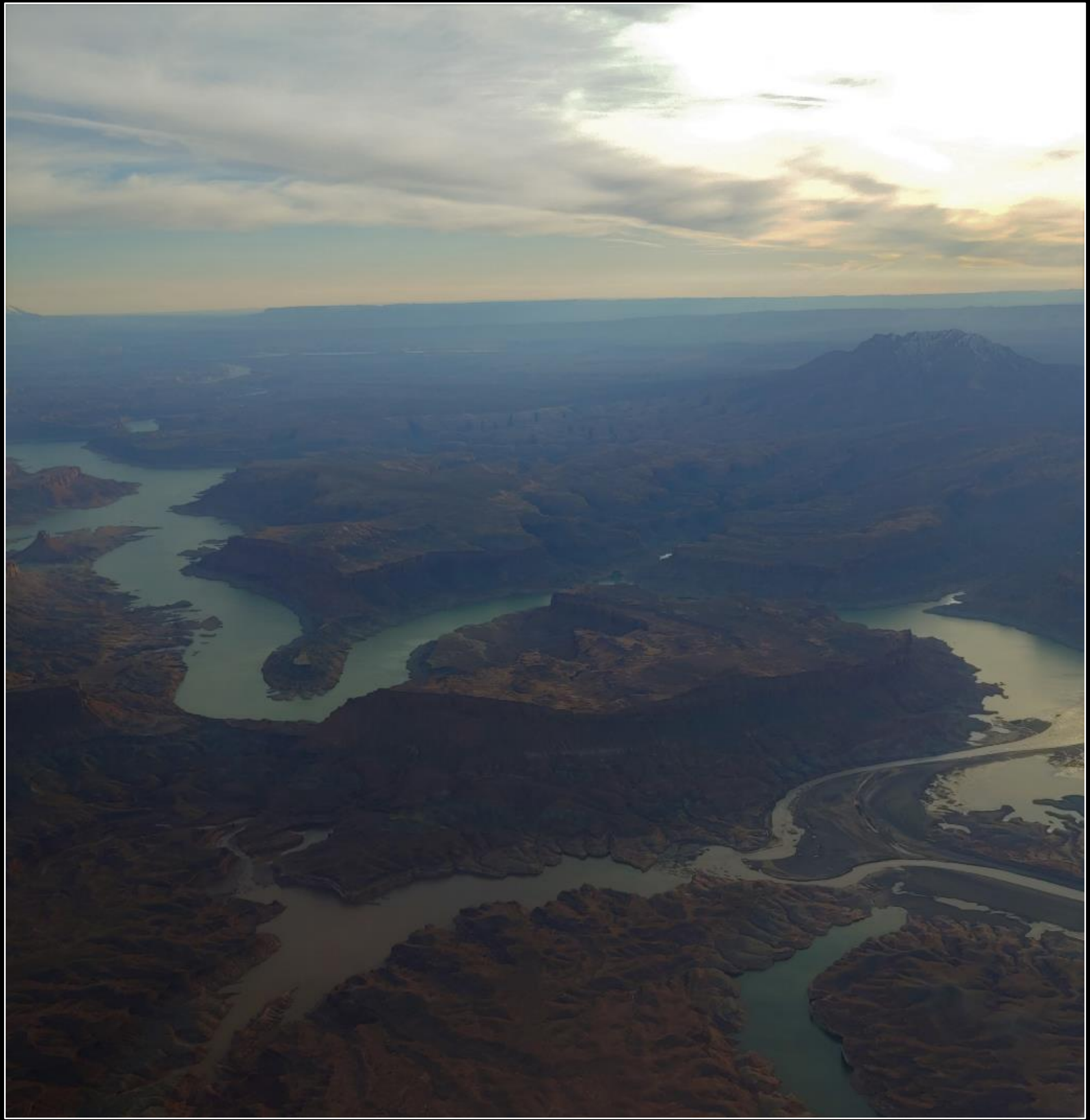
Spawning (Adult)

Feeding/Refuge (Adult)

Chapter 2
River-reservoir inflow

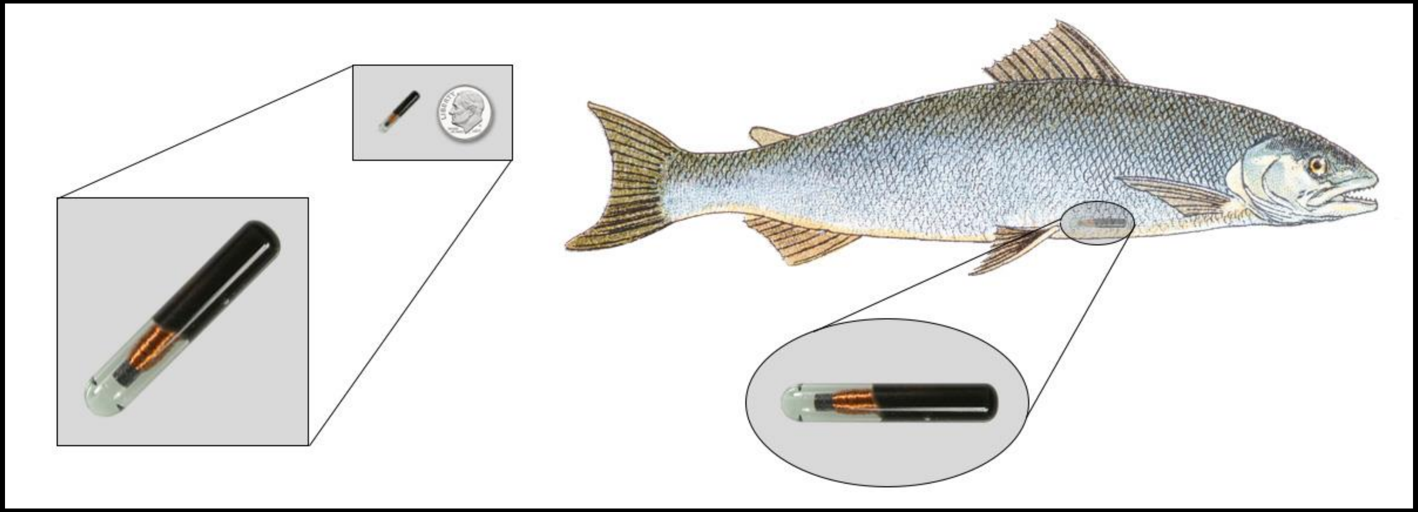


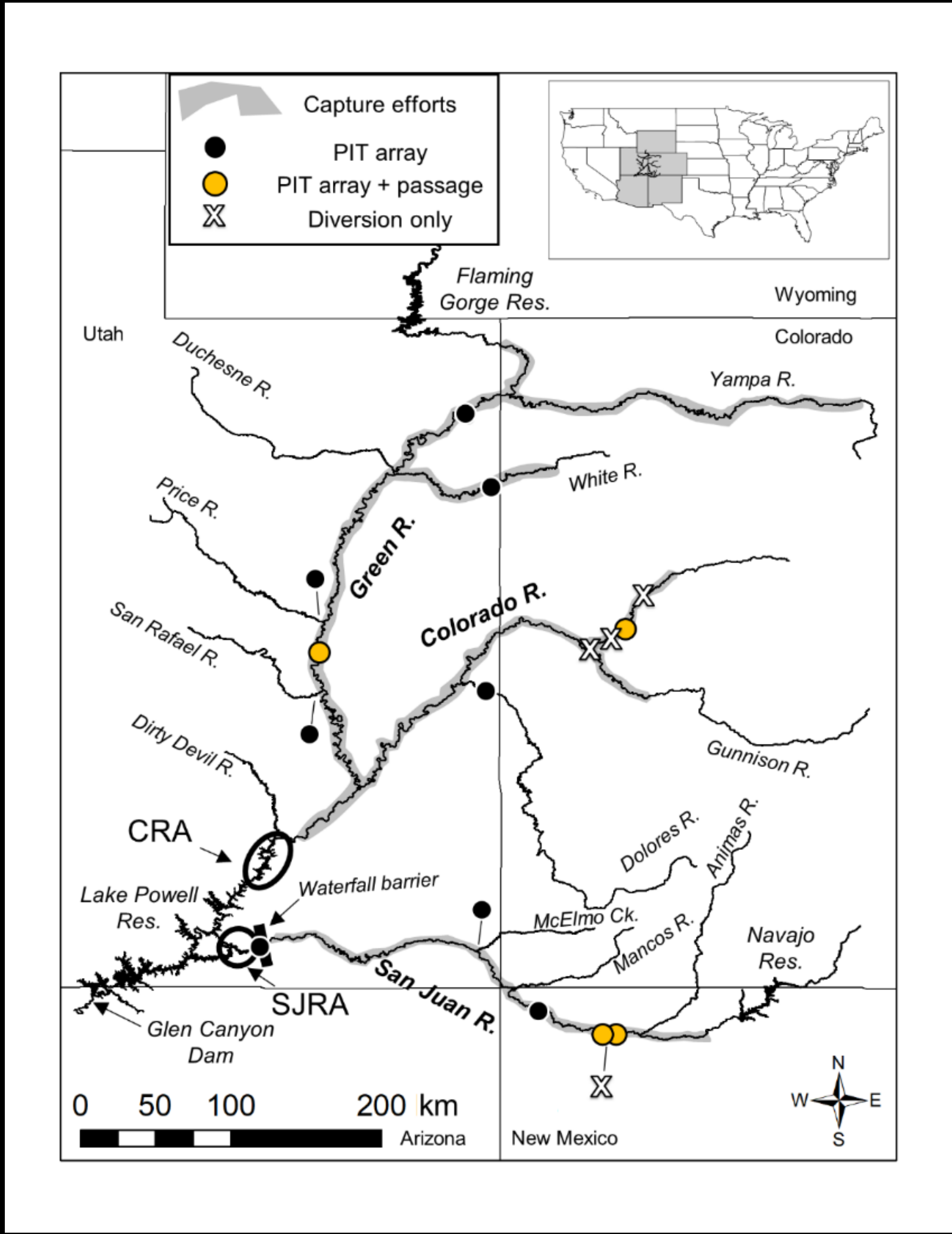
Movement ecology of imperiled fish in a novel ecosystem



A dammed river basin

- Colorado River Basin heavily fragmented
- Many smaller diversion weirs





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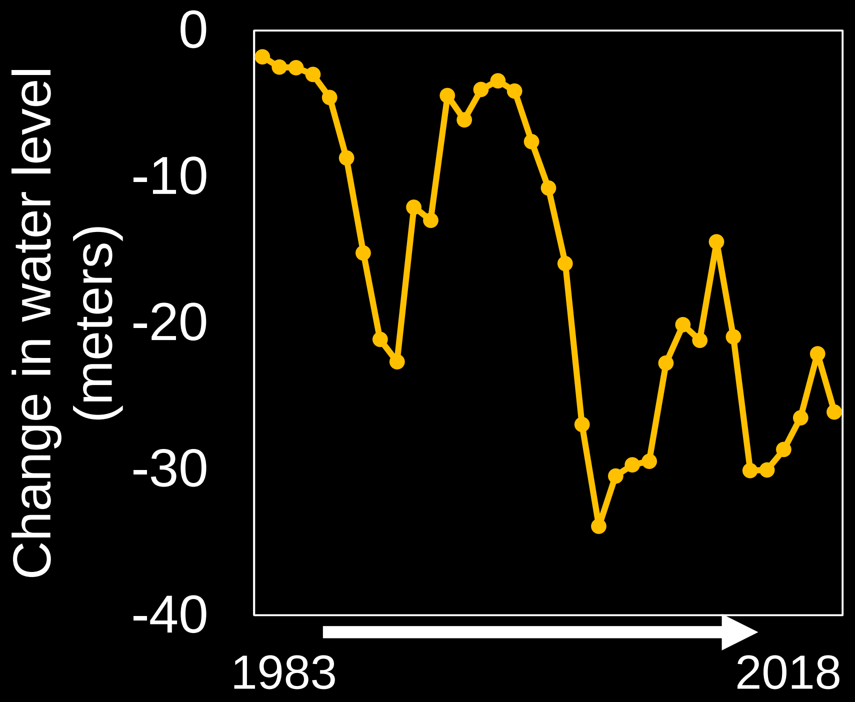


Broad scale animal movements

- Limited by number of marked individuals and spatial extent of observing

Broad scale animal movements

- Monitoring fish movement is difficult
- Direct observation often impossible

Figure 2

STReaMS database

- STReaMS
  - Species Tagging, Research and Monitoring System: A Centralized Database for the Upper Colorado and San Juan River Endangered Fish Recovery Programs. USFWS.

- Over 2.2 million encounter records of 1.2 million fish (as of 4/8/2019)
  - Stockings, Recaptures, PIT tag detections

Questions

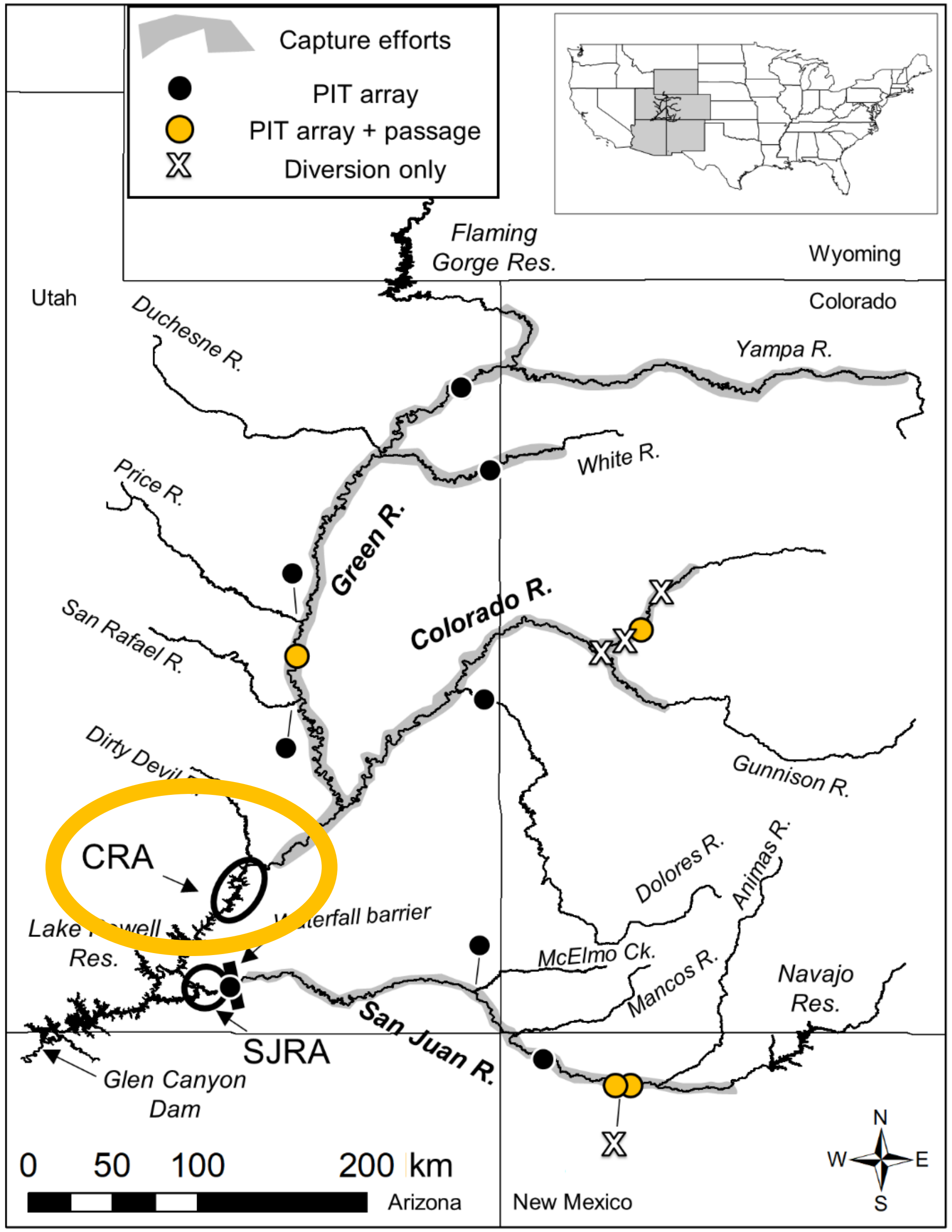
1. Where do Razorback Sucker captured in the Colorado River arm of Lake Powell redistribute?

2. What is the proportion of fish in the San Juan River arm of Lake Powell moving into the river below the waterfall?

3. How do fish behave that are captured below the waterfall and translocated upstream into the San Juan River?

Dispersal from Colorado River arm of Lake Powell

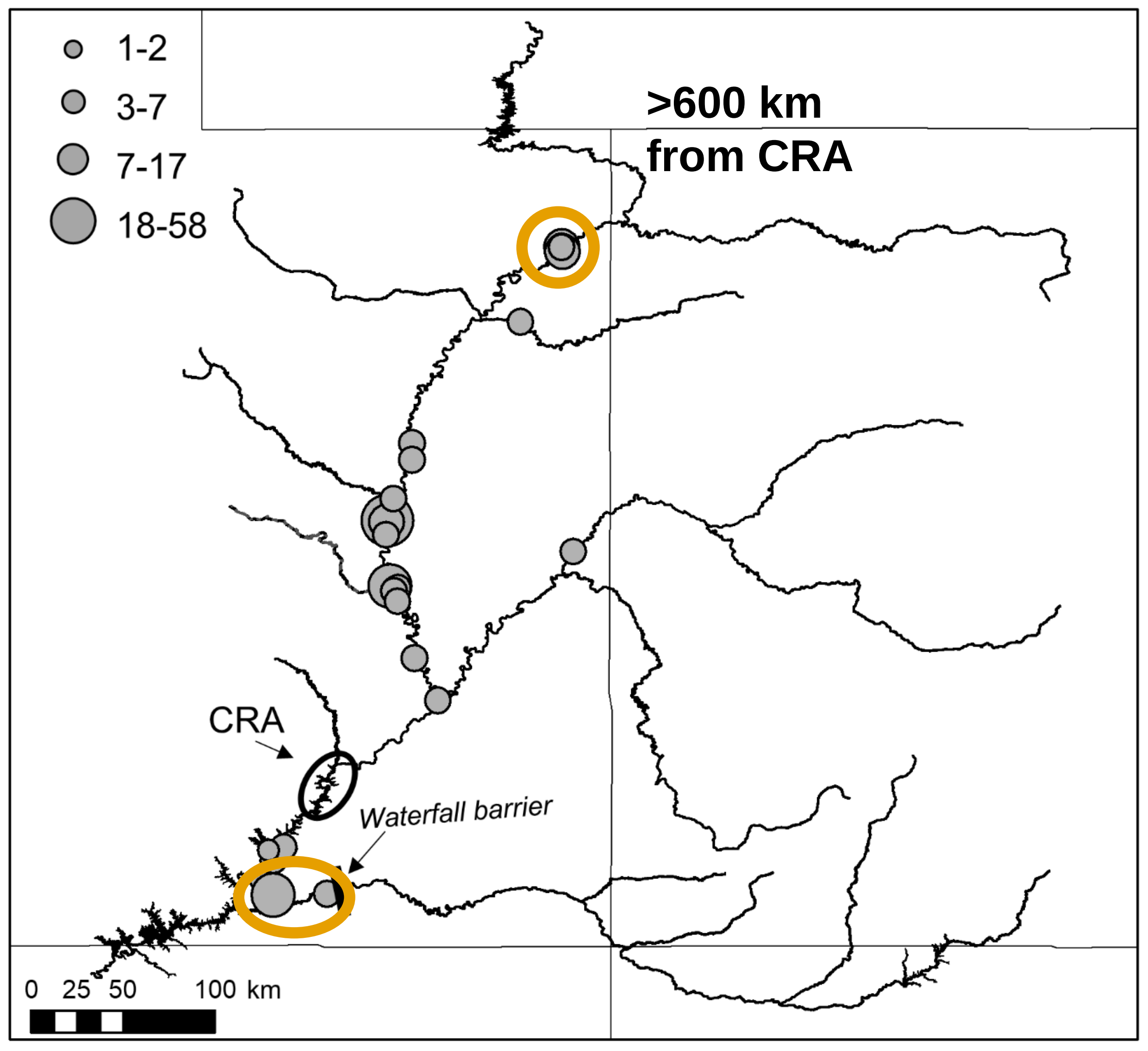
- USFWS captured razorbacks in 2014-2016
- 722 individuals captured
- All fish PIT tagged, 44 fish acoustic tagged



All encounters in STReaMS as of December 2018

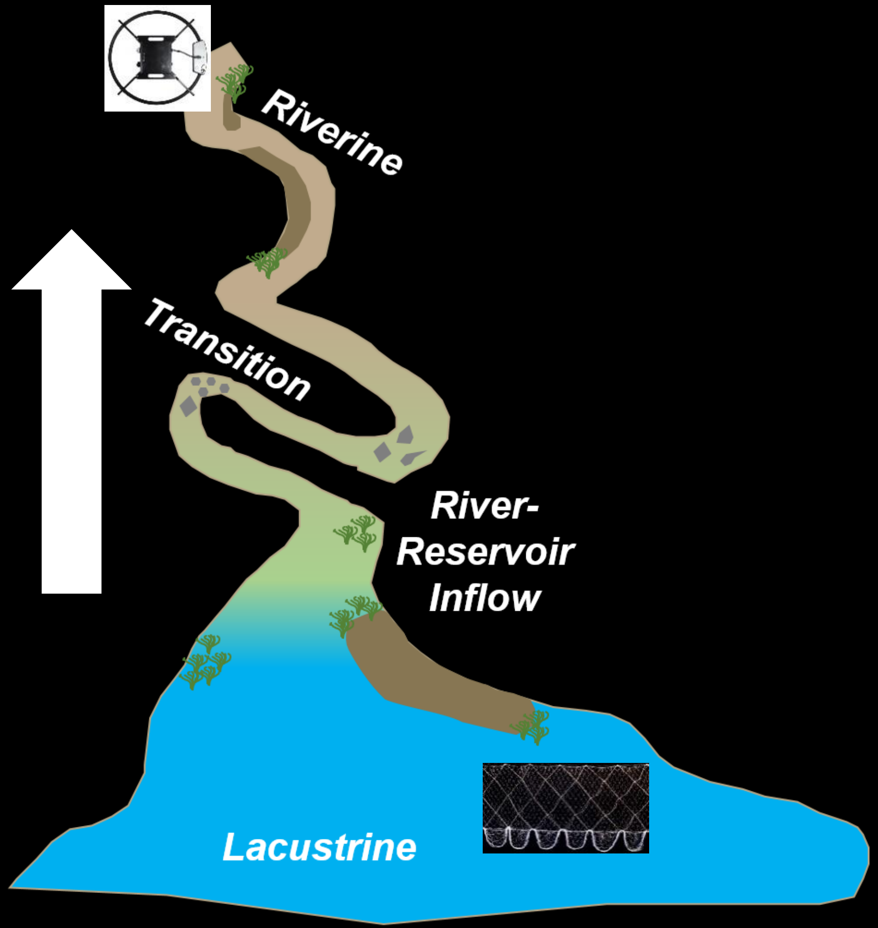
Dispersal from Colorado River arm of Lake Powell

- 461 never re-encountered
- 154 (59%) only re-encountered back in CRA
- 107 (41%) re-encountered outside CRA
- 39% of acoustic tagged fish detected in SJRA



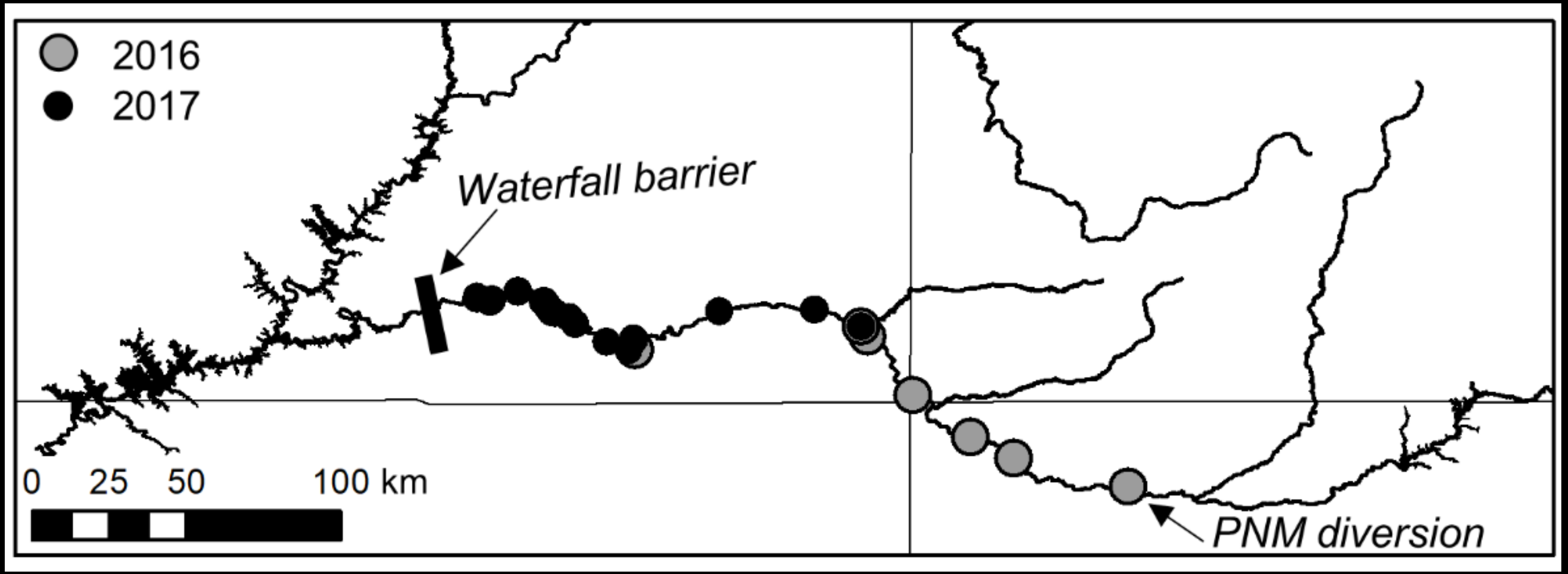
Proportion moving between Lake Powell and river tributaries?

- 147 & 74 fish captured in SJRA
  - April-June 2017 & 2018
- 2017: 29% CI = [21-36%] detected at waterfall post-capture (365 d)
- 2018: 20% [12-30%]
- Similar to Colorado arm [29-42%]



Translocation of Razorbacks

- Feb-Mar 2016 & 2017
- 303 fish translocated
- 80% encountered back below waterfall within 365 days



*PIT detections, recaptures, and active telemetry

Conclusions

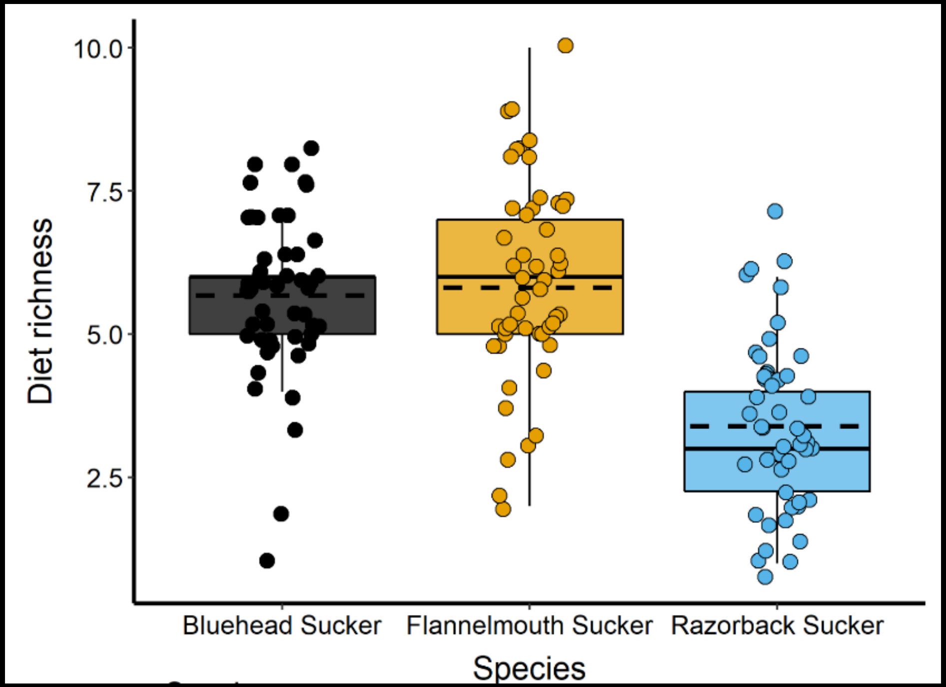
- Moving throughout altered habitat, including large reservoir
  - Not limited to just a few individuals, ~30% of population
  - Observed movement distances were large even among catostomids

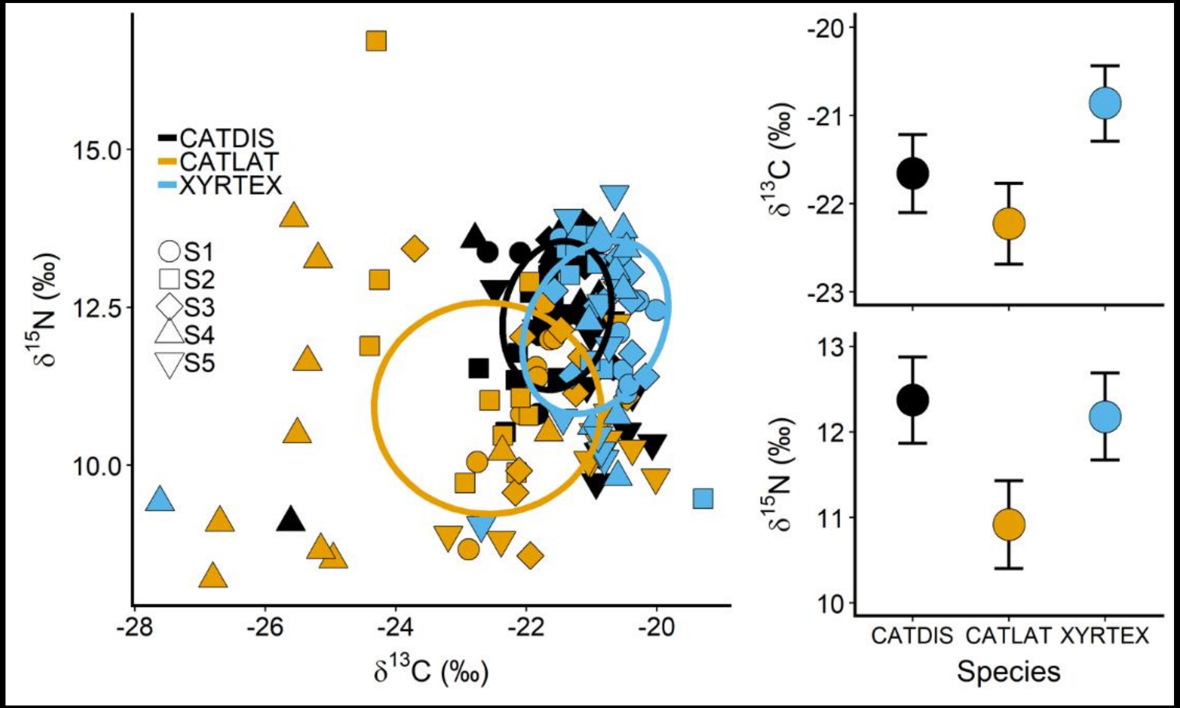
- Access to multi-agency database covering multiple states and river systems
  - PTAGIS-Columbia River Basin (Marvin 2012)
  - North American Bird Banding Program

Conclusions overall

- Differences in feeding ecology among sizes and species might explain low survival at critical life stages

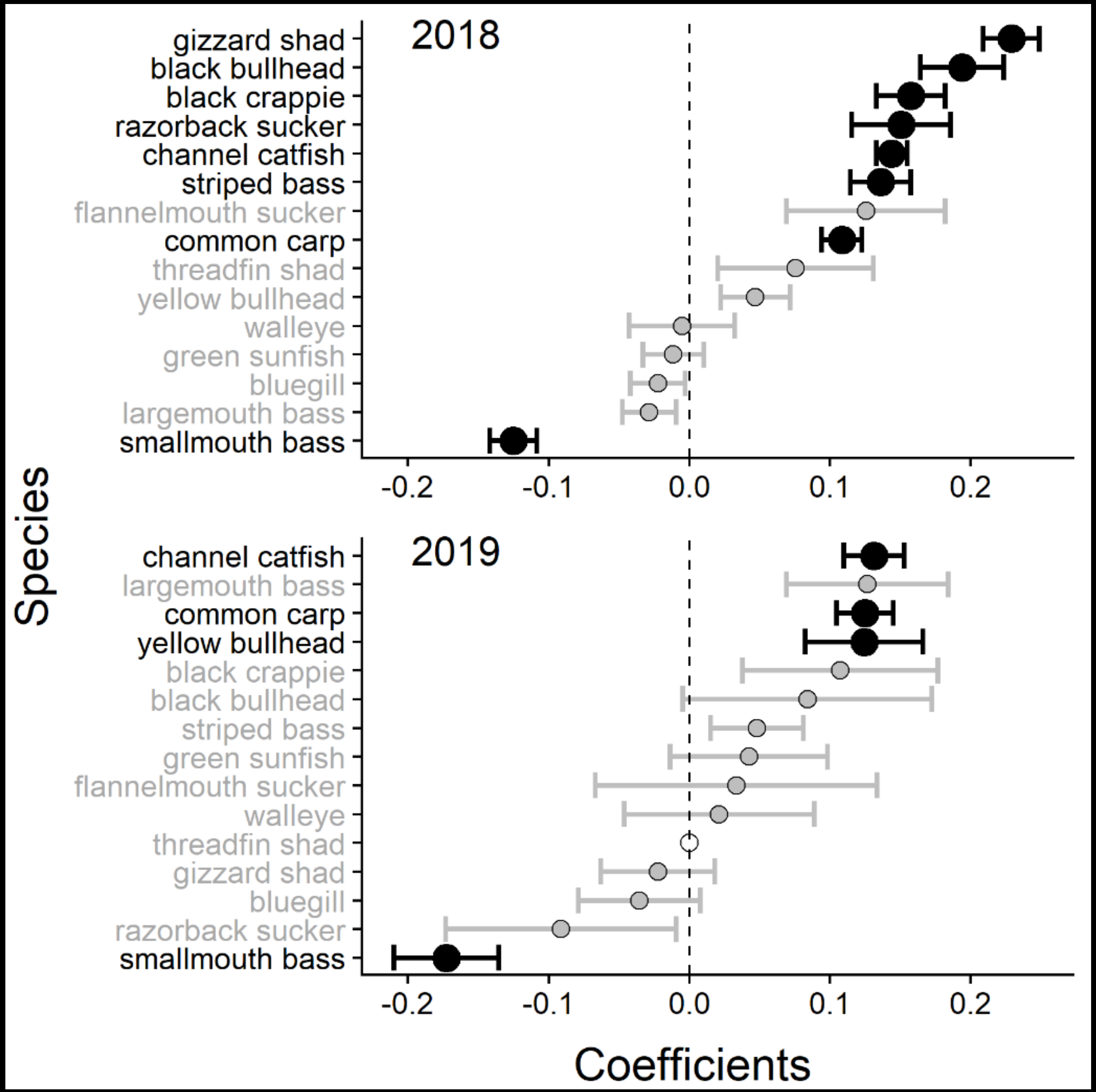
- Data is limited on early life stages for many species





Conclusions overall

- Assemblage structure changes along river-reservoir inflows
- What allows species to be successful in artificial habitats?
    - Temperature
    - Food
    - Habitat complexity
    - Turbidity (cover)
- How can we manage inflow areas?

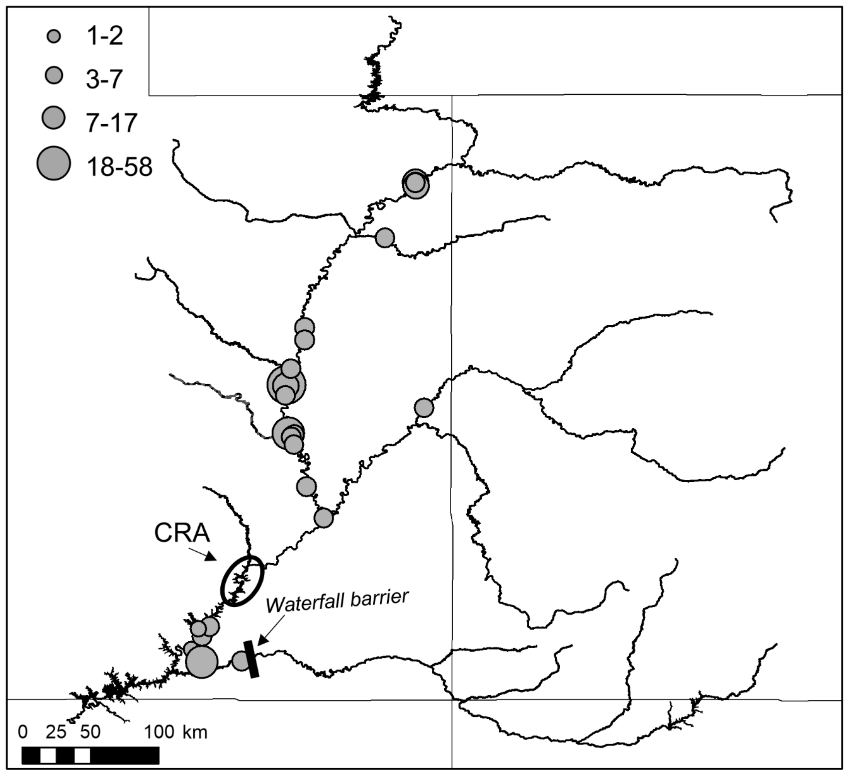


Conclusions overall

- Large-bodied fishes are moving throughout altered habitats and among river systems
  - Ensuring connectivity is maintained is important for fish to access critical habitats

- Large reservoirs can pose barriers to fish movement

  (Hudman & Gido 2013; Pelicice et al. 2015)



Other efforts and questions

- Translocations in 2018 & 2019

- Fine-scale movement and habitat use in river-reservoir inflow?

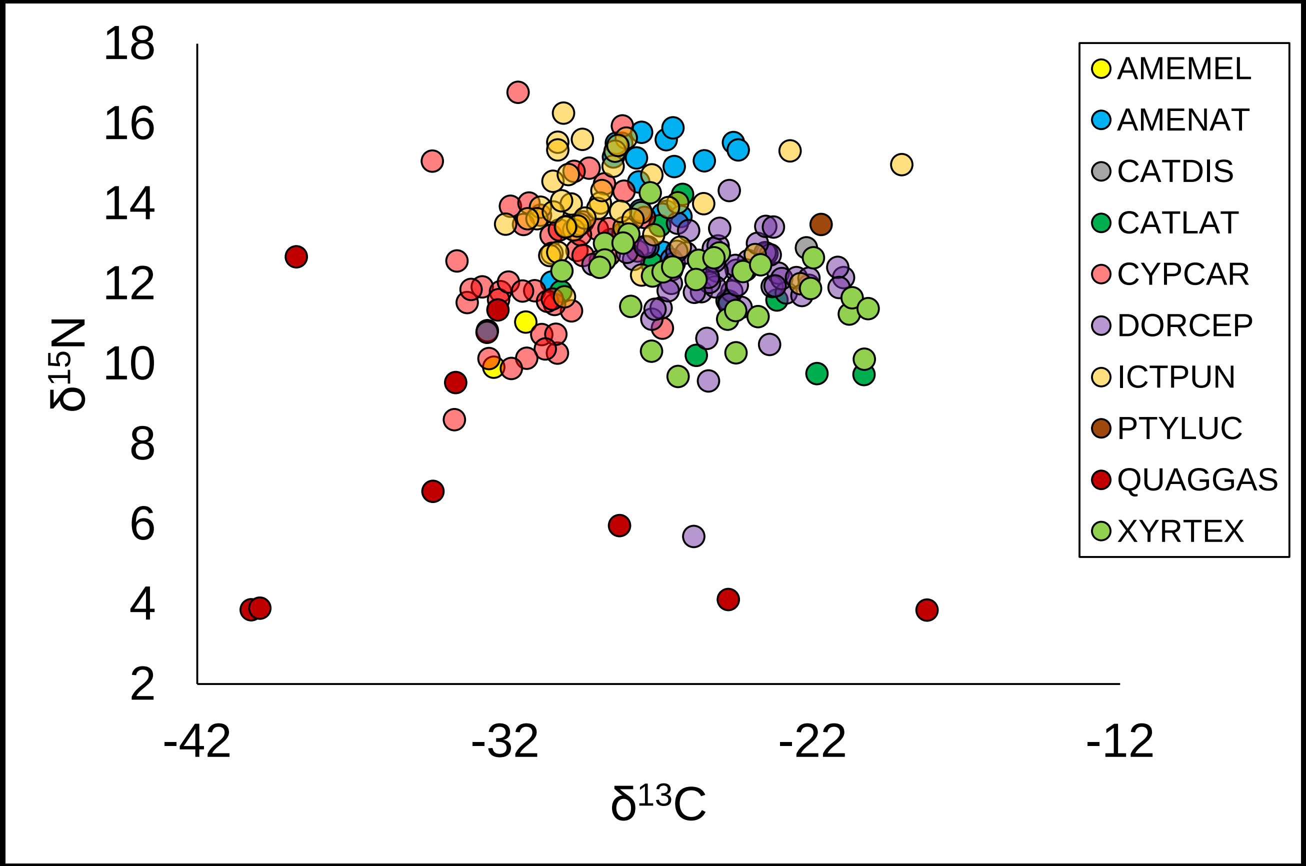
Other efforts and questions

- Translocations in 2018 & 2019
-

Other efforts and questions

- Translocations in 2018 & 2019
-

Other efforts and questions



- Trophic resource use of native and nonnative fishes?

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- Tari Philips
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Keith Gido
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BOR


Questions?