Hotter Temperatures Change Plant Response to River Regulation

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Plant communities are shaped by hierarchical drivers

Climate: Temperature, precipitation, humidity

River Hydrology: High flow experiments, daily fluctuations, seasonality

Geomorphology: Channel shape, landforms

Biotic Interactions: Competition, herbivory

Riparian Plant Community: Cover, composition, diversity

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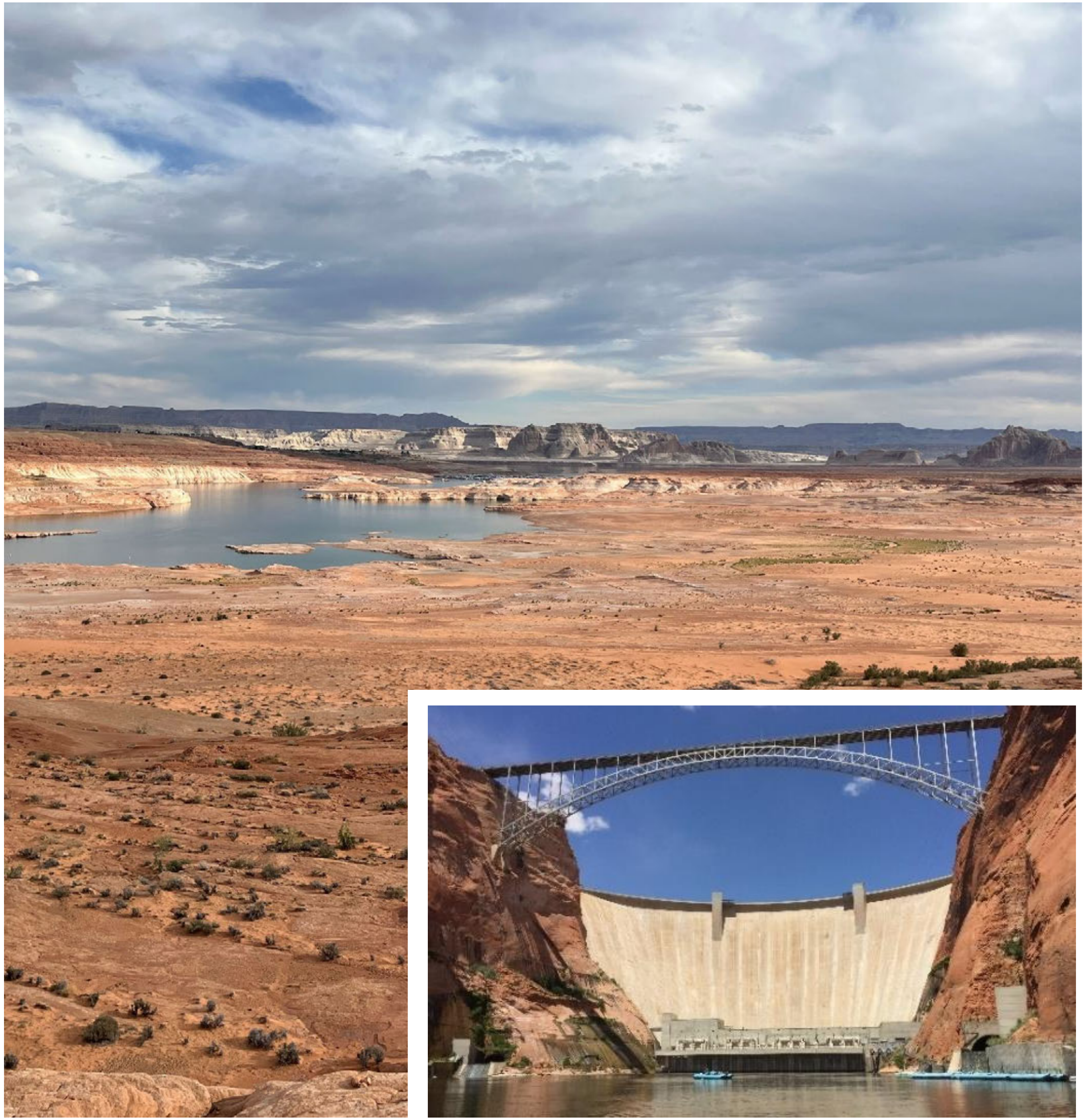
But both climate and river flows are changing…

- Increasing temperatures, precipitation changes
- Dam regulation creates novel riparian ecosystems
- Changing power needs and flood/drought patterns
- Could change responses to hydrology, substrate, topography, and other plants



Photos: E. Palmquist

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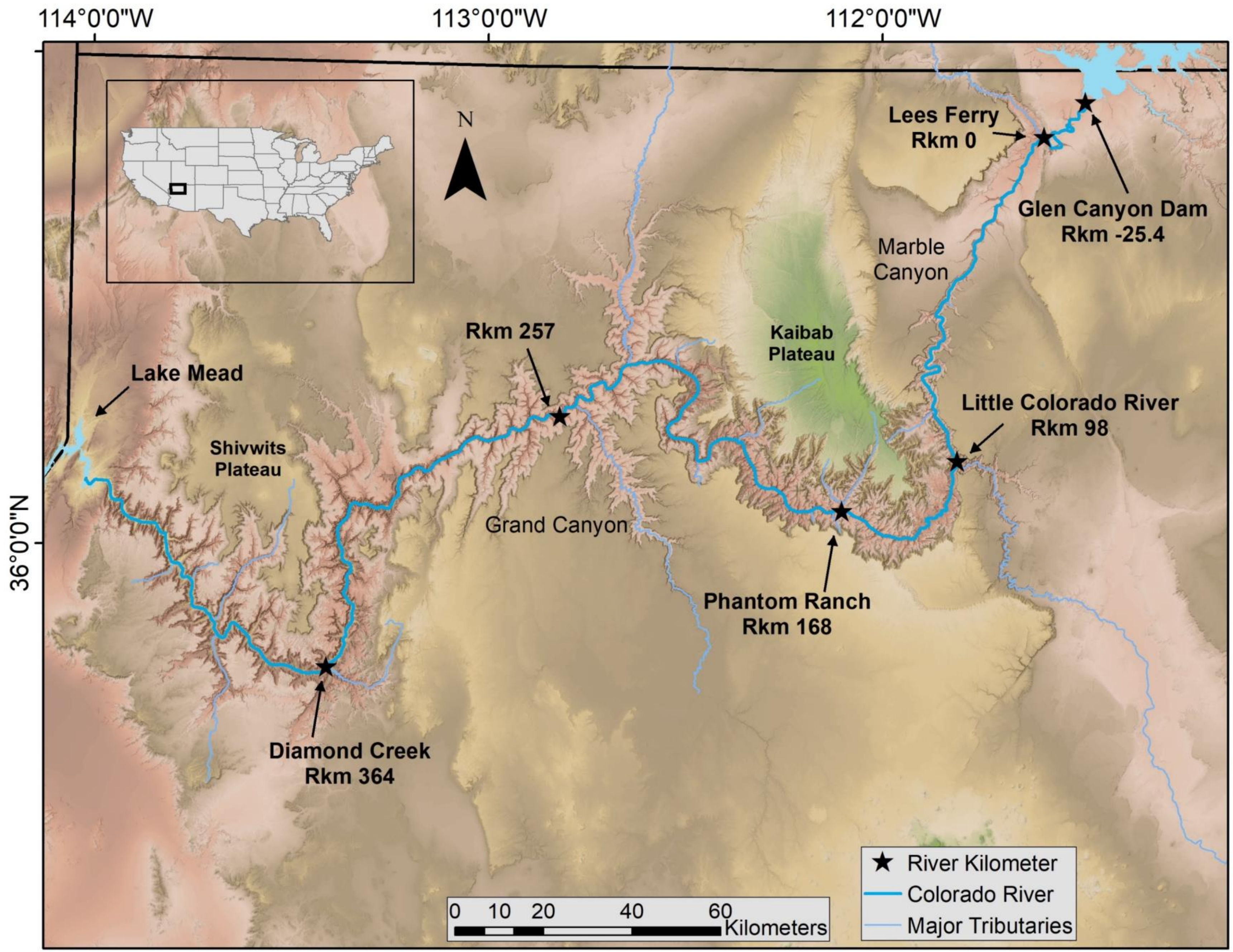
Study area

- Colorado River riparian area
  - ~370 river kilometers
- Semi-arid
- Mean annual temperature gradient ~5.6°C
- Geographically complex
- Hydropower-derived flows



Basemap credit: T. Gushue

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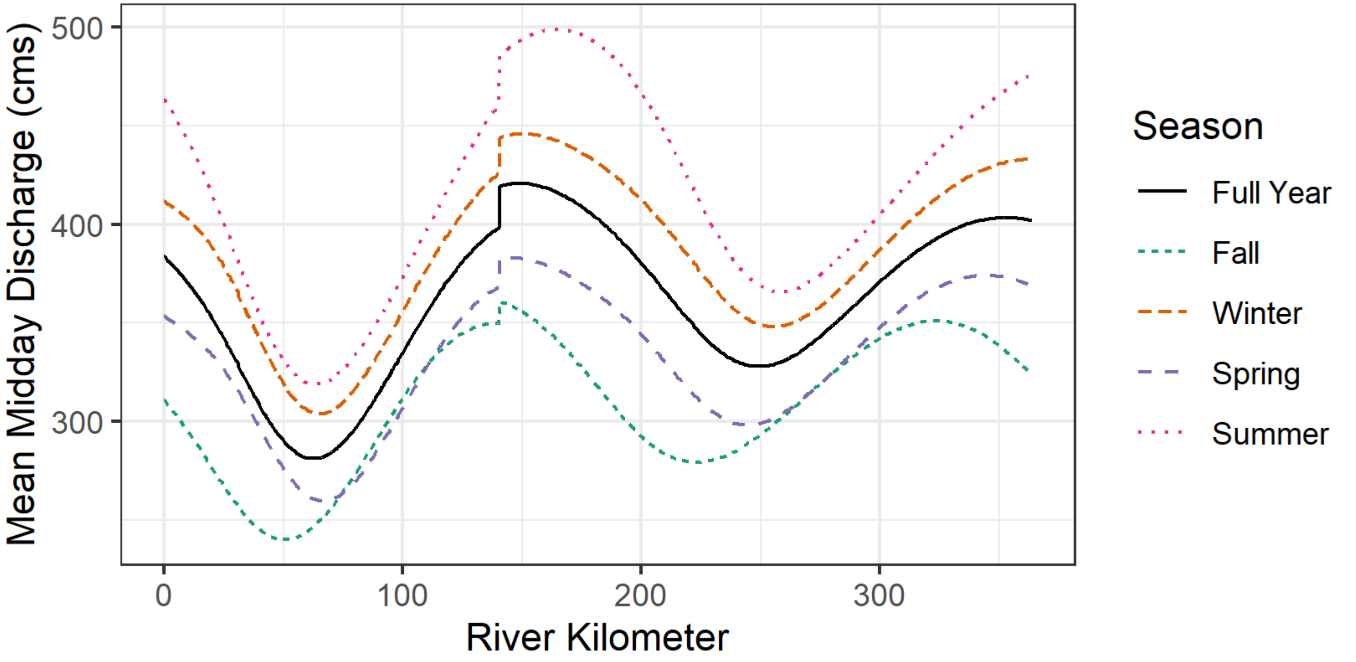
Environmental setting

- Lateral gradient of flood frequency
- Rocky to sandy substrates
- Variable solar insolation
- Load-following flows
  - Tributaries are dry or comparatively low-flow

Photos: USGS GCMRC



Modeled discharge data: Wiele and Smith, 1996

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Understanding complex relationships

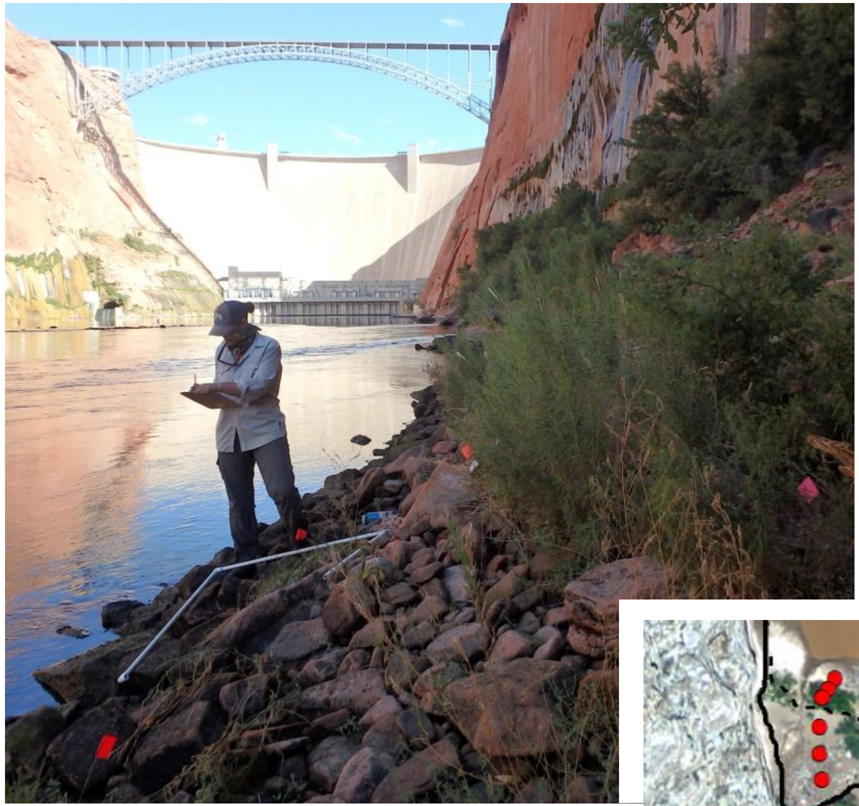
Questions:

1. Do hotter conditions change how riparian plants respond to other environmental factors?
2. Does the timing of hydropower tides benefit some species over others?
3. Does erosion of sand hinder riparian species more than upland species?

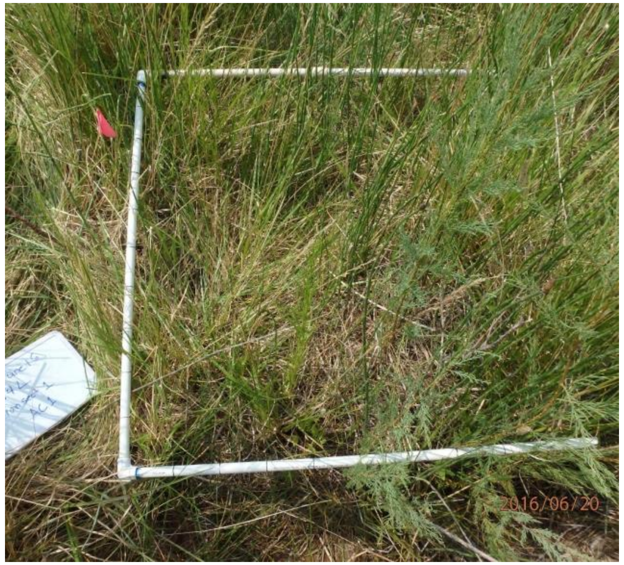
Photo: Durning and others, 2016

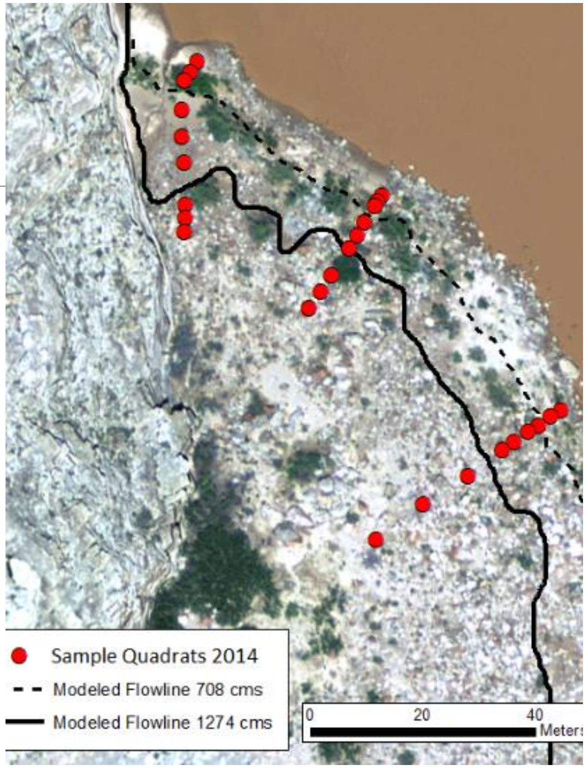
Plant data

- Individual species cover
- 418 sites
  - 10,762 quadrats
- 2016 – 2020
  - Annual survey in August/September
- Cover classes
  - 0, Trace, 1%, 5%, 10%, 15%, etc.



Photos: USGS GCMRC





36 species

- Grasses, forbs, shrubs, tree
- Wetland to upland gradient
- Native and nonnative species

Photos: E. Palmquist

Environmental data

- Quadrat level
  - Meters to baseflows
  - Mean midday discharge
  - Stage change between base and high flows
  - % sand
  - % silt/clay
  - Dead, rooted plant material
  - Overhanging plant cover
- Site level
  - Mean annual temperature (MAT)
  - Precipitation of warmest quarter
  - Insolation
  - Channel width
  - Slope
- Interactions with all variables and MAT

Photo credit: A. Washuta

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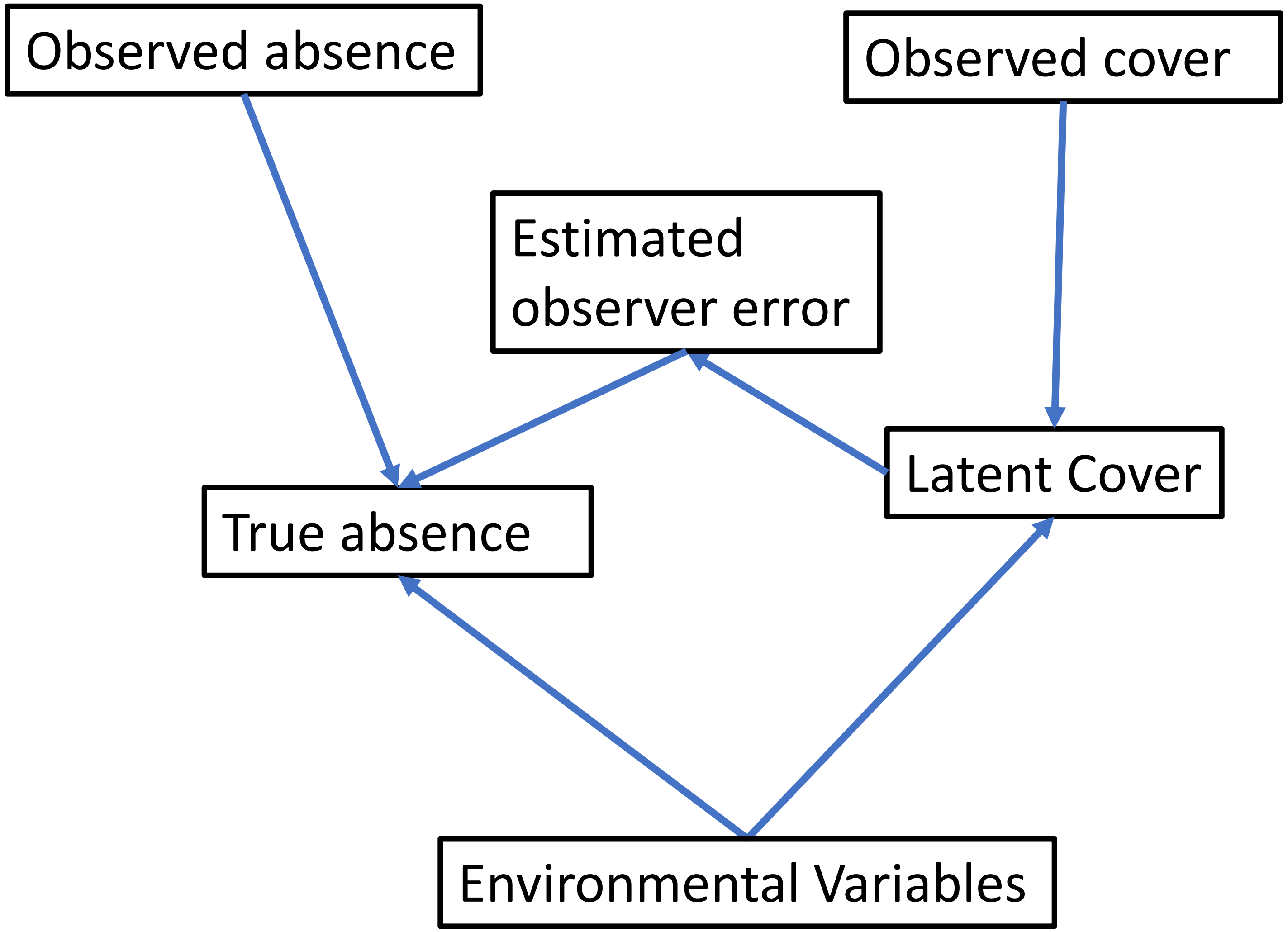
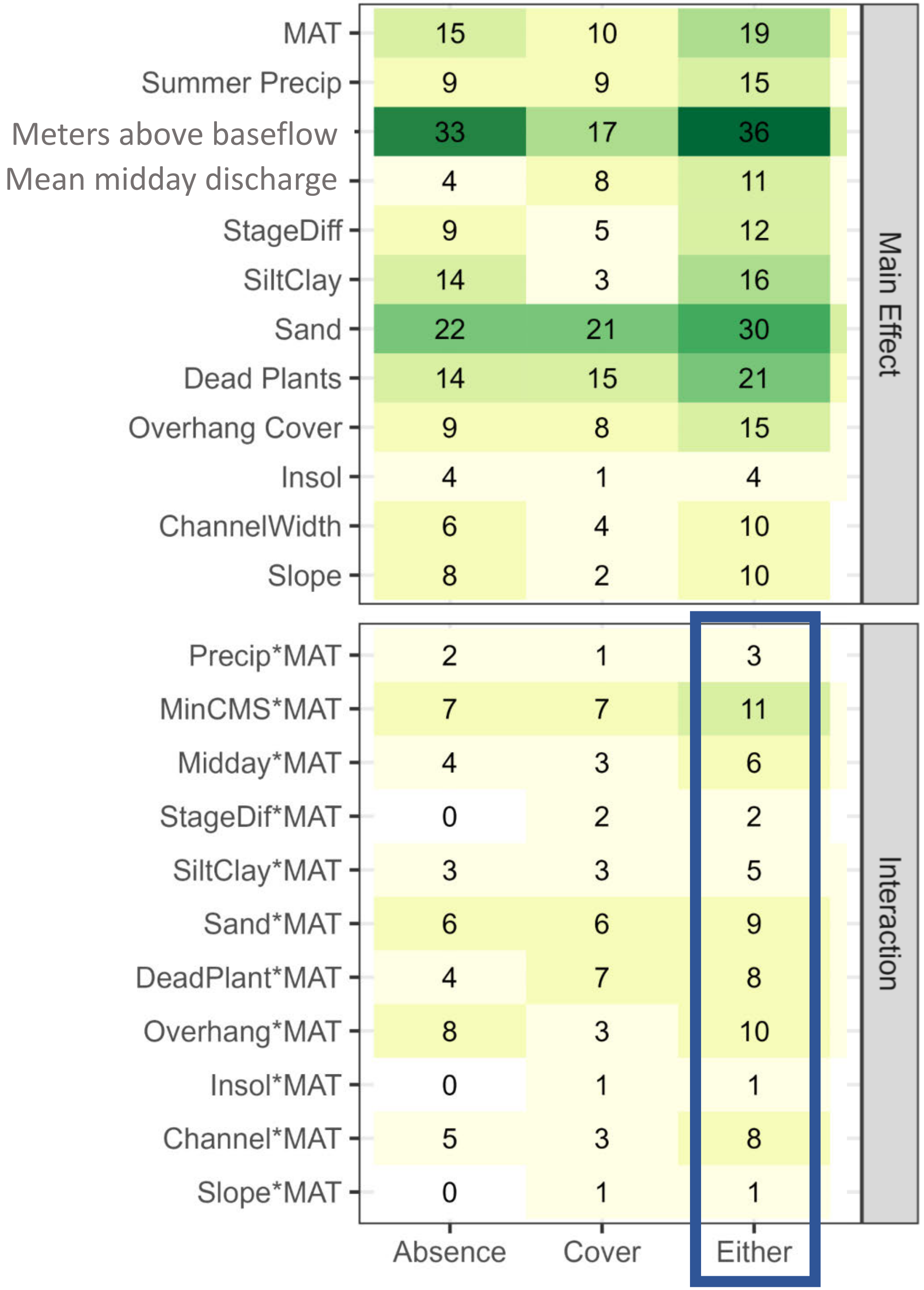
Bayesian analysis

- Each species modeled independently
- Absence & cover integrated in same model, but with own responses
- Observer errors estimated



Increasing MAT changes plant responses to other environmental variables

- Greater dependence on stable water supply
  - Seepwillow, mule-fat (*Baccharis salicifolia*)
  - Common reed (*Phragmites australis*)
  - Arrowweed (*Pluchea sericea*)
  - Tamarisk (*Tamarix ramosissima* and hybrids)
  - Also true for cottonwoods (Hultine et al., 2020; Moran et al., 2023; Zhou et al., 2020)
- Likely favor species tolerant of higher temps and more variable minimum flows, like
  - Alkali goldenbush (*Isocoma acradenia*)
  - Mesa dropseed (*Sporobolus flexuosus*)



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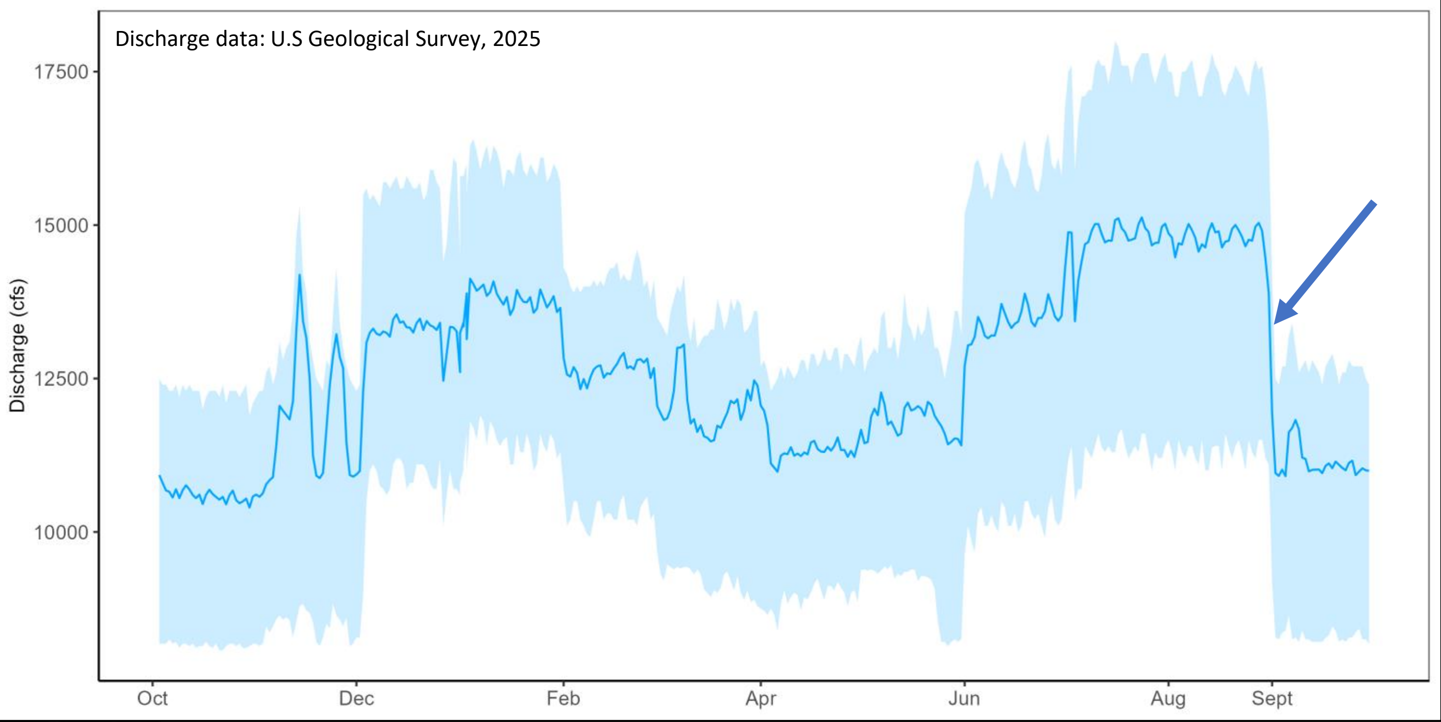
What this means

Photos: E. Palmquist



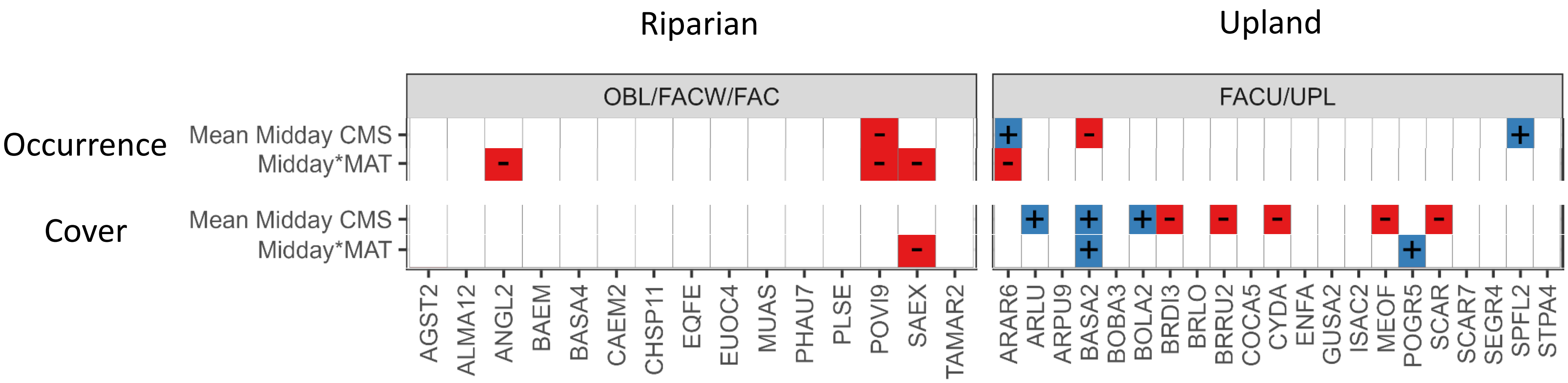
Summary of WY 1996-2022, solid blue line indicates daily mean discharge, blue color band indicates the 25 and 75th percentile.

- Big sudden drops in discharge during hot periods could stress plants
- High flow variability and high temps = possible loss of a suite of riparian species, more heat/drought tolerant species
- May already be limiting some riparian species

Palmquist and others, 2025

Timing of hydropower tides shapes plant community composition

- More significant responses for upland species
- Only neutral or negative for riparian species
- Both positive and negative responses for upland species



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Photos: E. Palmquist

What this means

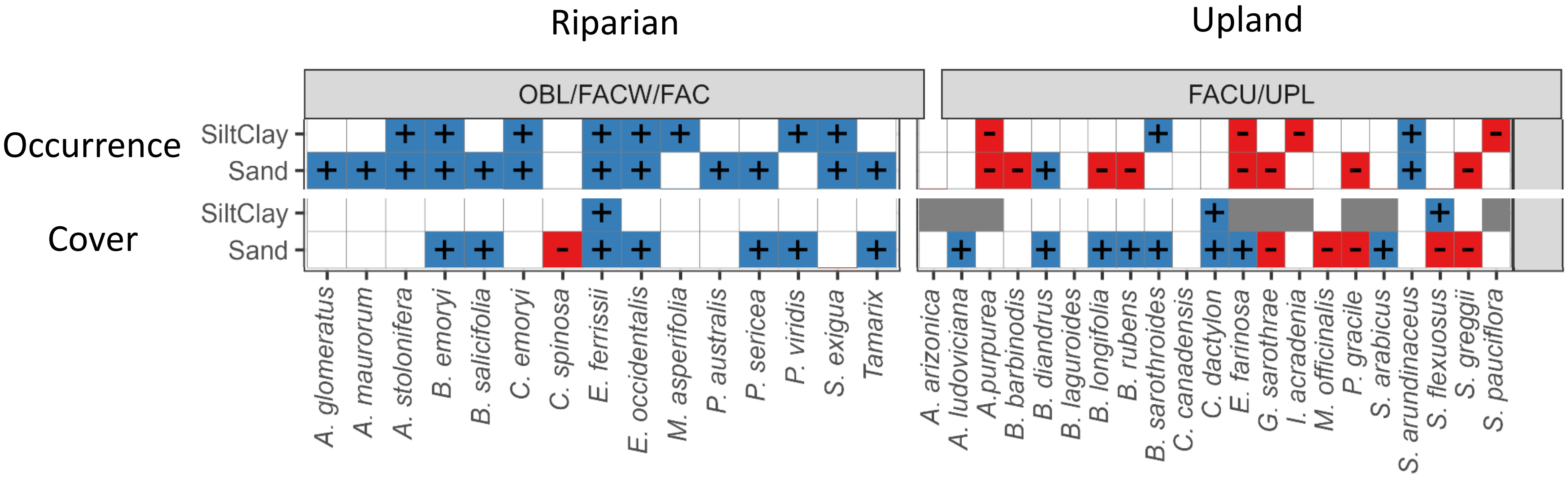
Photos: E. Palmquist

- May be supporting native upland plant communities
- Preventing nonnative grasses in some areas
- Likely preventing the establishment of species very sensitive to daily fluctuations (Baladrón and others, 2022; Bejarano and others, 2018)
- With increasing temps and continued hydropower, could expect
  - Overall declines in coyote willow (*Salix exigua*), bushy beardgrass (*Andropogon glomeratus*)
  - Increase in desert broom (*Baccharis sarothroides*) and slender poreleaf (*Porophyllum gracile*)

Palmquist and others, 2025

Sand supply has an outsized effect on riparian species

- Riparian species occurrence and cover strongly related to fine sediments
- Upland species more often hindered by fine sediments, but mixed



What this means


Photo: USGS GCMRC



Photos: E. Palmquist

- High flow experiments (HFEs) support riparian plant habitat by building sandbars
- Loss of HFEs and associated sediment loss could lead to a loss of regionally unique plant species = decline in species richness

Palmquist and others, 2025

Conclusions

- Higher mean annual temperatures can change how plants respond to water availability
- Timing of daily inundation is affecting species absence and cover, and thus community composition
- Changes to sediment erosion and deposition will have large impacts on riparian plant species

Photo: E. Palmquist

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Many colleagues, collaborators, boat operators, students, and volunteers assisted with this project -

Thank you!

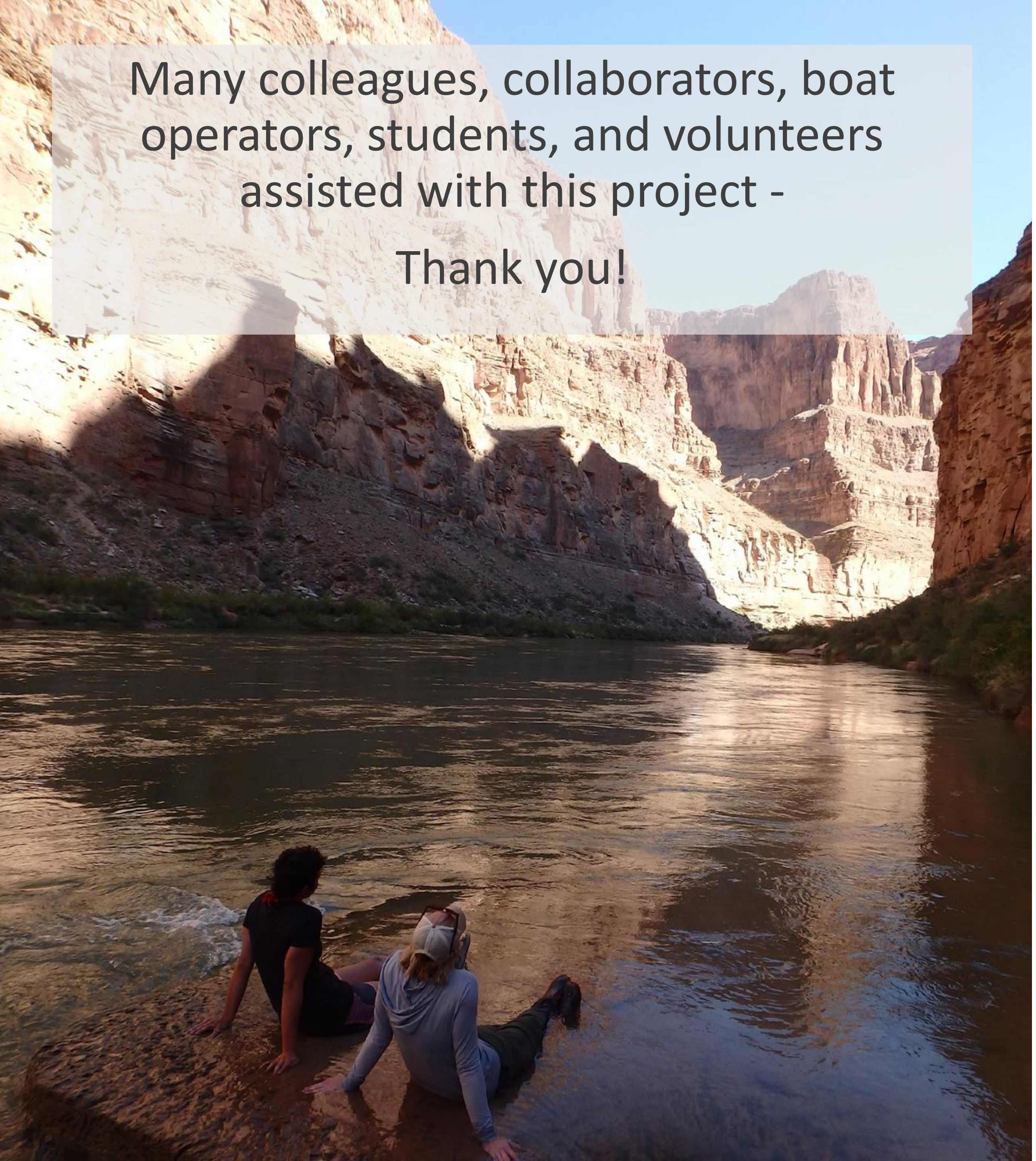

Photo: USGS GCMRC

Further questions?

Contact me:

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or search "Emily Palmquist USGS"

Interested in our program?

Check out our websites:

https://www.usgs.gov/centers/southwest-biological-science-center/science/overview-riparian-vegetation-grand-canyon

https://www.usgs.gov/centers/southwest-biological-science-center/science/terrestrial-riparian-vegetation-monitoring-how

or Search "GCMRC riparian vegetation"

Interested in Bayesian models?

Check out the Ogle Lab website:

Ecological Synthesis Lab –

https://ogle-lab.nau.edu/

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Scientific Name	Family	Growth Form	Native Status	Wetland Indicator Status	Site (Quadrat)
Agrostis stolonifera	Poaceae	Graminoid	Nonnative	FACW	96 (229)
Alhagi maurorum	Fabaceae	Shrub	Nonnative	FAC	108 (560)
Andropogon glomeratus	Poaceae	Graminoid	Native	FACW	47 (115)
Aristida arizonica	Poaceae	Graminoid	Native	UPL	84 (237)
Aristida purpurea	Poaceae	Graminoid	Native	UPL	222 (768)
Artemisia ludoviciana	Asteraceae	Forb	Native	FACU	126 (389)
Baccharis emoryi	Asteraceae	Shrub	Native	FACW	282 (1188)
Baccharis salicifolia	Asteraceae	Shrub	Native	FAC	117 (269)
Baccharis sarothroides	Asteraceae	Shrub	Native	FACU	145 (464)
Bothriochloa barbinodis	Poaceae	Graminoid	Native	UPL	167 (442)
Bothriochloa laguroides	Poaceae	Graminoid	Native	UPL	74 (172)
Brickellia longifolia	Asteraceae	Shrub	Native	UPL	146 (366)
Bromus diandrus	Poaceae	Graminoid	Nonnative	UPL	184 (934)
Bromus rubens	Poaceae	Graminoid	Nonnative	UPL	324 (2057)
Carex emoryi	Cyperaceae	Graminoid	Native	OBL	38 (120)
Chloracantha spinosa	Asteraceae	Forb	Native	FAC	117 (487)
Conyza canadensis	Asteraceae	Forb	Nonnative	UPL	109 (253)
Cynodon dactylon	Poaceae	Graminoid	Nonnative	FACU	213 (1876)
Encelia farinosa	Asteraceae	Shrub	Native	UPL	114 (219)

Scientific Name	Family	Growth Form	Native Status	Wetland Indicator Status	Site (Quadrat)
Equisetum xferrissii	Equisetaceae	Forb	Native	FACW	234 (1623)
Euthamia occidentalis	Asteraceae	Forb	Native	FACW	150 (455)
Gutierrezia sarothrae	Asteraceae	Shrub	Native	UPL	86 (214)
Isocoma acradenia	Asteraceae	Shrub	Native	FACU	126 (528)
Melilotus officinalis	Fabaceae	Forb	Nonnative	FACU	95 (195)
Muhlenbergia asperifolia	Poaceae	Graminoid	Native	FACW	81 (234)
Phragmites australis	Poaceae	Graminoid	Native	FACW	58 (227)
Pluchea sericea	Asteraceae	Shrub	Native	FACW	125 (876)
Polypogon viridis	Poaceae	Graminoid	Nonnative	FACW	97 (193)
Porophyllum gracile	Asteraceae	Shrub	Native	UPL	74 (128)
Salix exigua	Salicaceae	Shrub	Native	FACW	87 (310)
Schedonorus arundinaceus	Poaceae	Graminoid	Nonnative	FACU	149 (707)
Schismus arabicus	Poaceae	Graminoid	Nonnative	UPL	50 (110)
Senegalia greggii	Fabaceae	Tree	Native	FACU	138 (287)
Sporobolus flexuosus	Poaceae	Graminoid	Native	FACU	170 (562)
Stephanomeria pauciflora	Asteraceae	Shrub	Native	UPL	96 (147)
Tamarix ramosissima x chinensis	Tamaricaceae	Tree	Nonnative	FAC	246 (560)