Predictive Vegetation Modeling: Progress and Opportunities for Growth

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Project C: Riparian Vegetation Monitoring and Research

- Project Elements and Objectives
  - C.1 Ground-based Riparian Vegetation Monitoring
  - C.2 Determining Hydrological Tolerances and Management Tools for Plant Species of Interest
  - C.3 Predictive Models and Synthesis
  - C.4 Vegetation Management Decision Support
- Funding amount and source: $267,602 (AMP)
- Cooperators: Northern Arizona University
- LTEMP Resource goals: "Maintain native vegetation and wildlife habitat, in various stages of maturity, such that they are diverse, healthy, productive, self-sustaining, and ecologically appropriate."

Riparian Vegetation: Interface Between Aquatic and Terrestrial Systems

Vegetation interacts with multiple resources

- Sand
- Recreation
- Archaeological and Tribal

Photo credit: Brad Butterfield

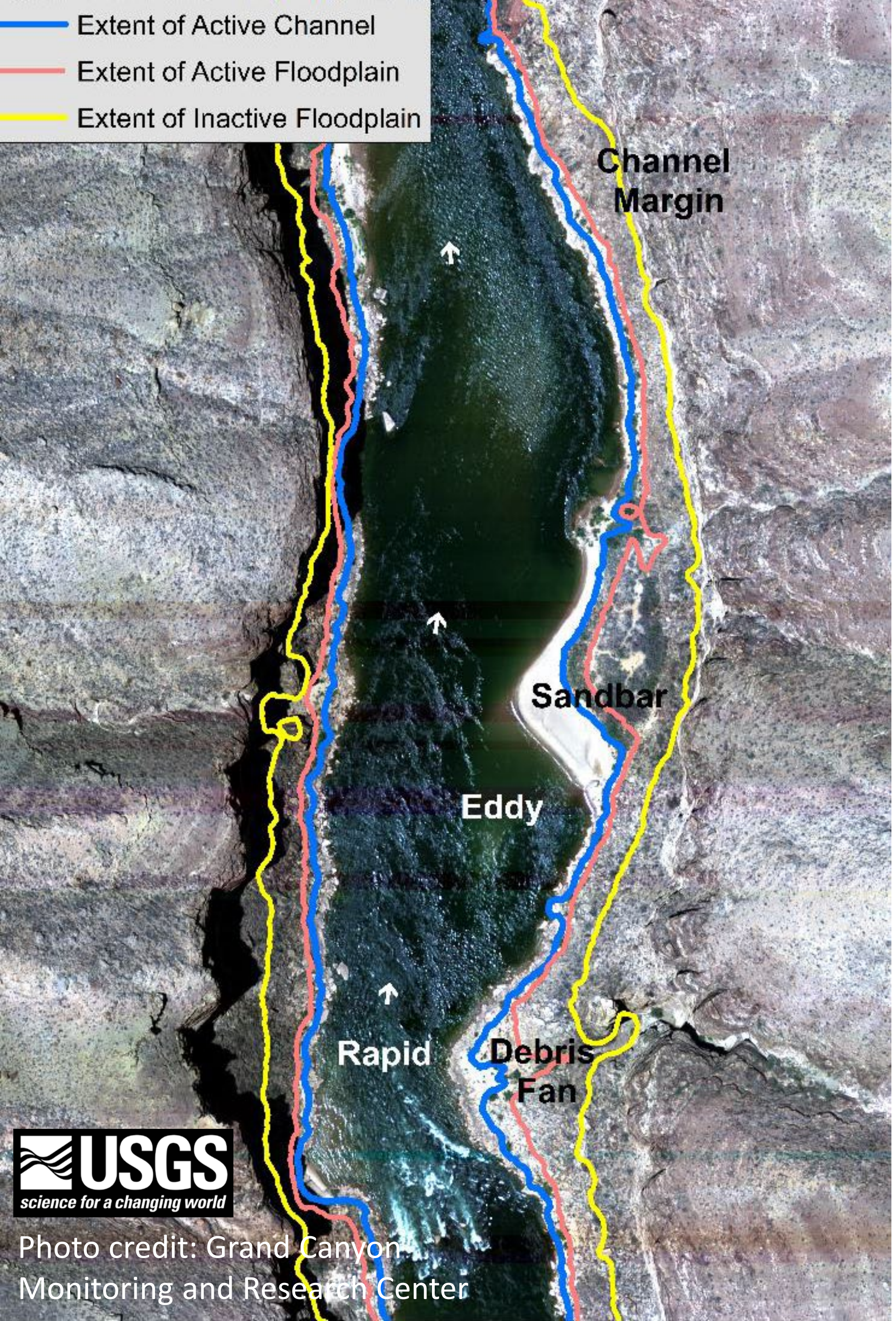

Photo credit: Grand Canyon Monitoring and Research Center

Ground-Based Monitoring

- Backbone of our modeling
- More than 17000 plots surveyed since 2014
  - From near channel to pre-dam floodplain habitats
  - Sandbars, debris fans, and channel margins
  - NAU sandbars and throughout the Canyon

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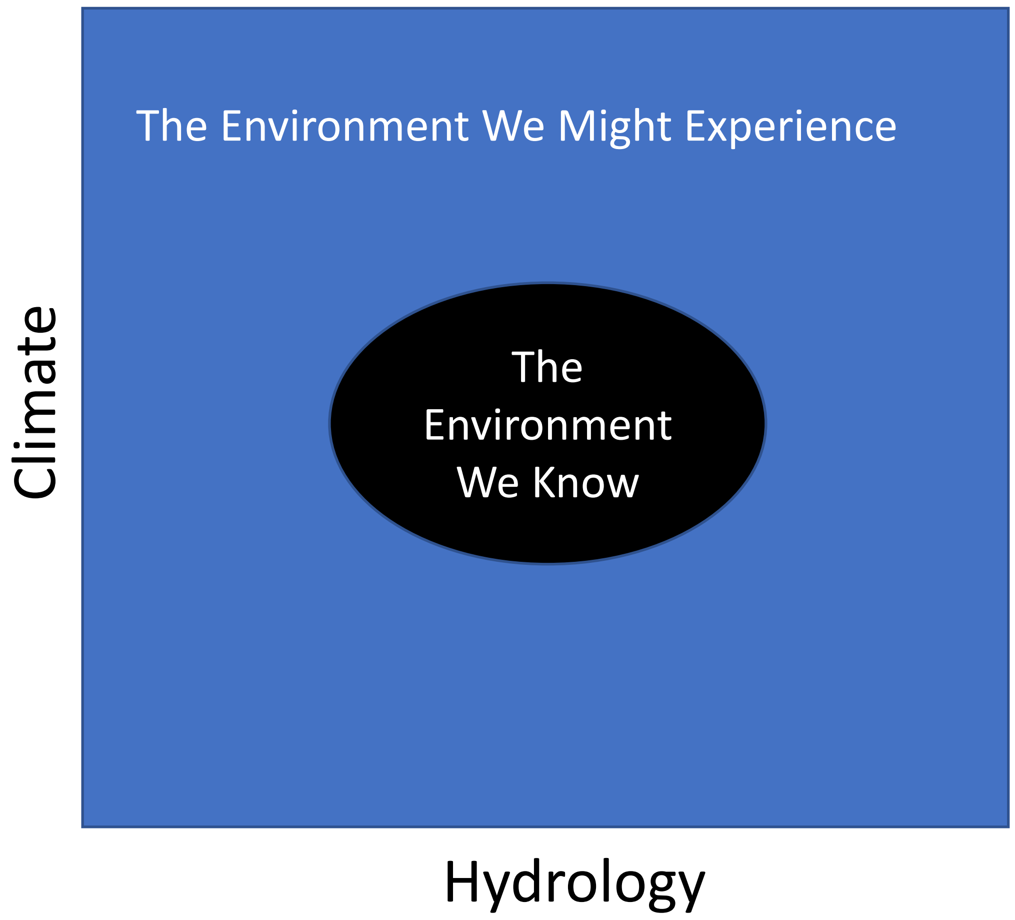
We're Good at Predicting Current Vegetation

- Vegetation composition is highly predictable based on current hydrology and climate in the Colorado River ecosystem (CRe)
- But large departures from the current conditions will require extrapolation



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Veg Modeling Challenges and Solutions

Challenge

- Altered hydrograph
- Correlation ≠ causation
- Vegetation interacts with other resources (e.g. sand)

Solution

- Use data from other river systems with similar species, but different hydrographs
- Conduct experiments that control for multiple correlated factors
- Develop dynamic, integrative models across systems

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1 | Models from Ground-Based Monitoring

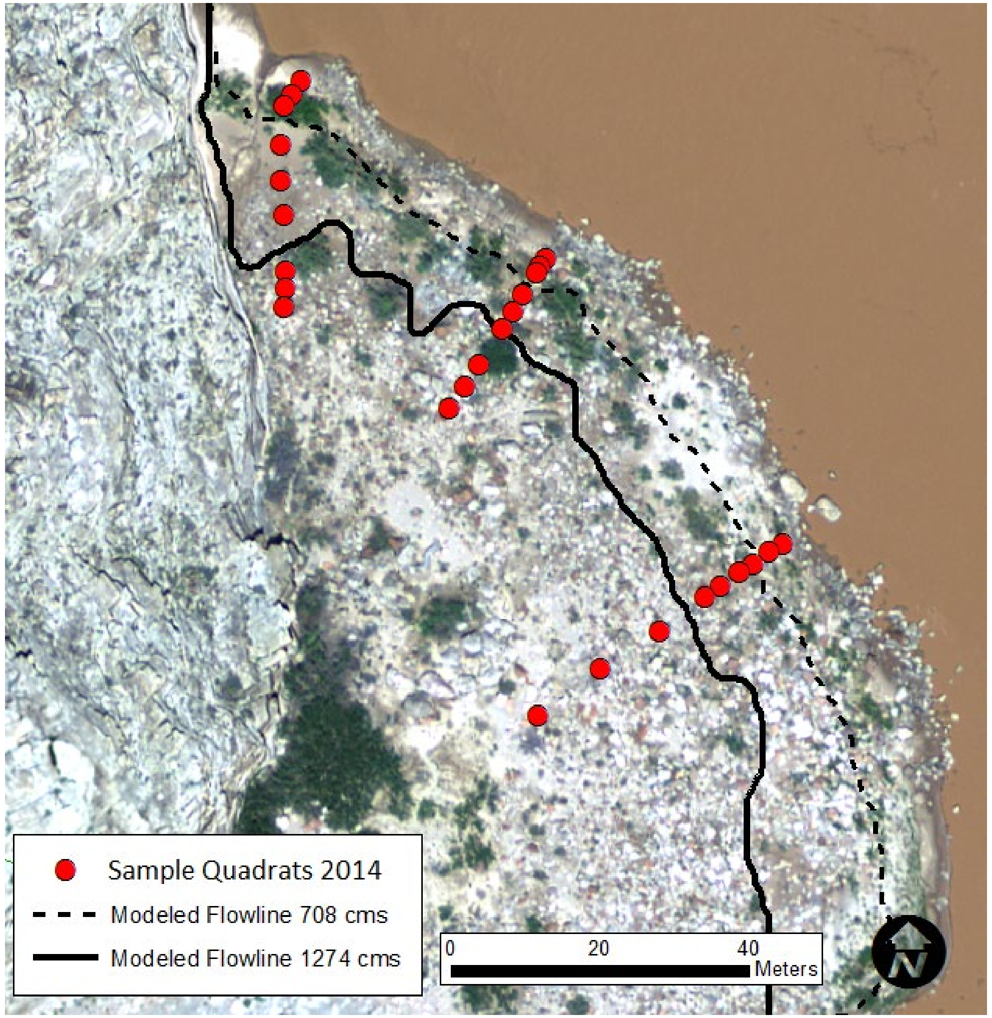

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Photo credit: Grand Canyon Monitoring and Research Center

Riparian Hydrological Zones

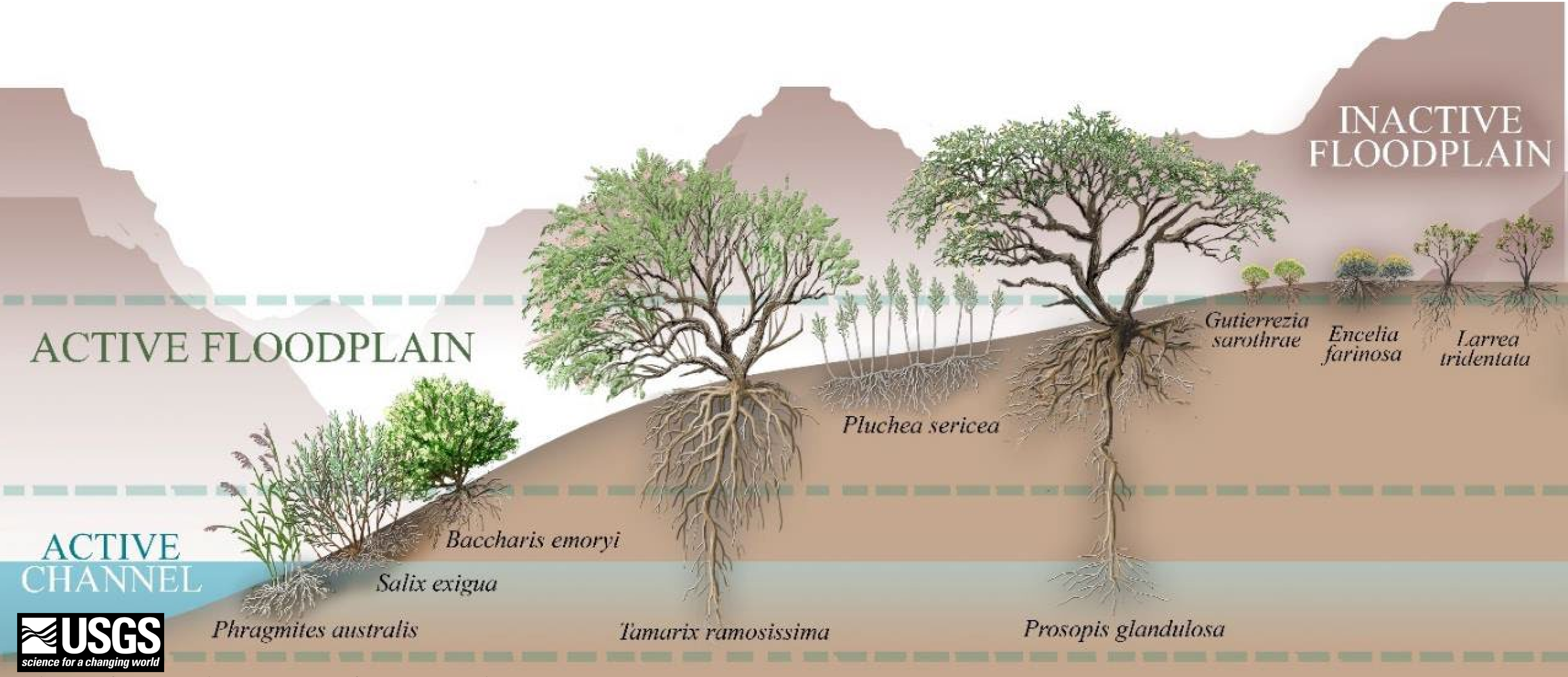

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Photo credit: Victor Leshyk

Received: 12 February 2018 | Revised: 2 May 2018 | Accepted: 28 May 2018
DOI: 10.1111/avsc.12390

Applied Vegetation Science IAVS

RESEARCH ARTICLE

Hydrological regime and climate interactively shape riparian vegetation composition along the Colorado River, Grand Canyon

Bradley J. Butterfield[1] | Emily Palmquist[1,2] | Barbara Ralston[3]

Strong effects of:
- Elevation above river stage
- Minimum temperature

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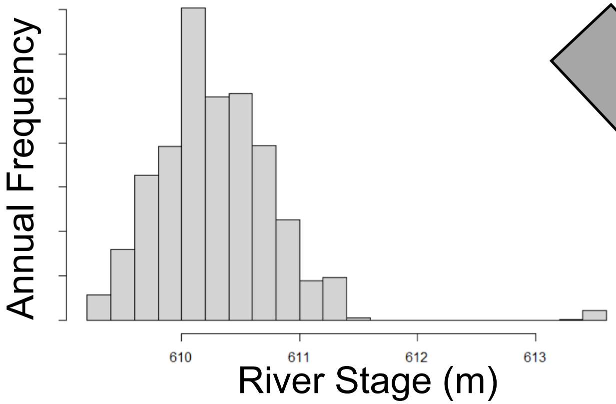
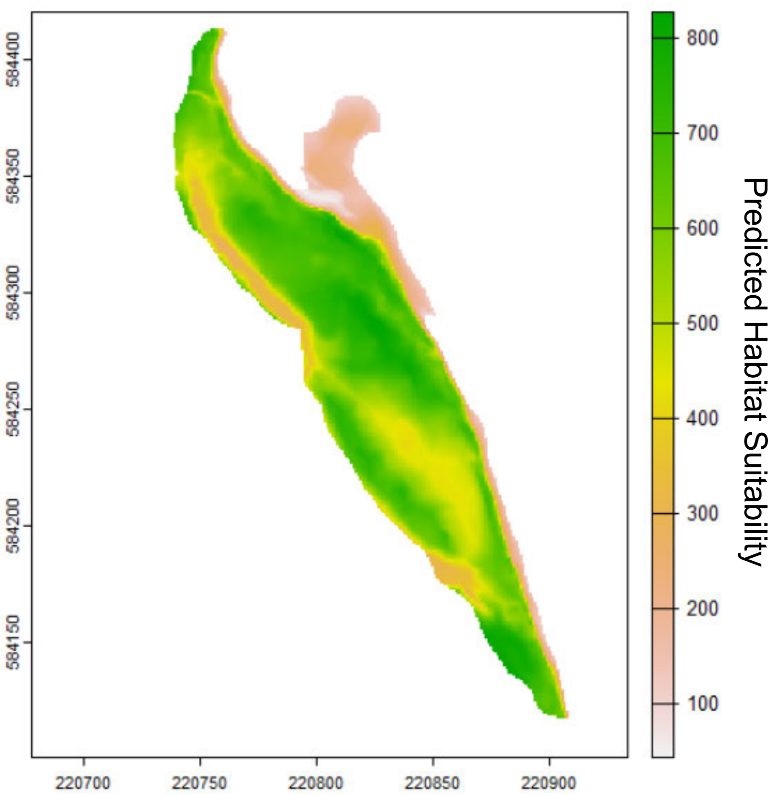
How Much Suitable Habitat?

Veg Monitoring + Environmental Data

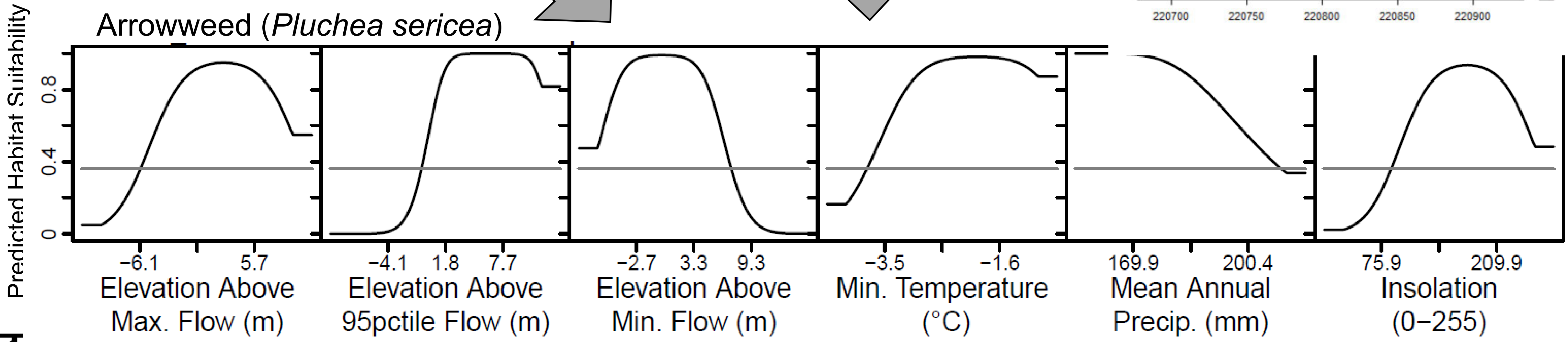


Model Training

Model Projection



Arrowweed (*Pluchea sericea*)



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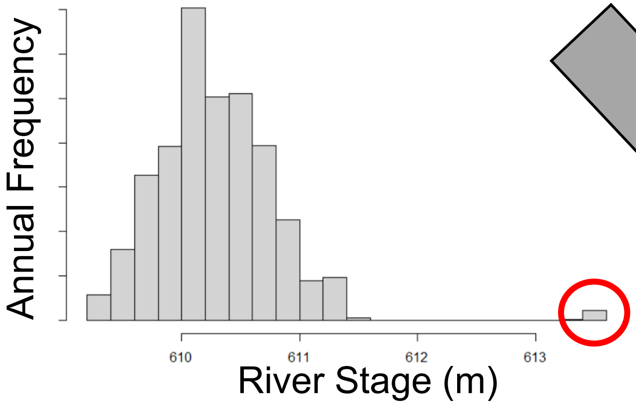
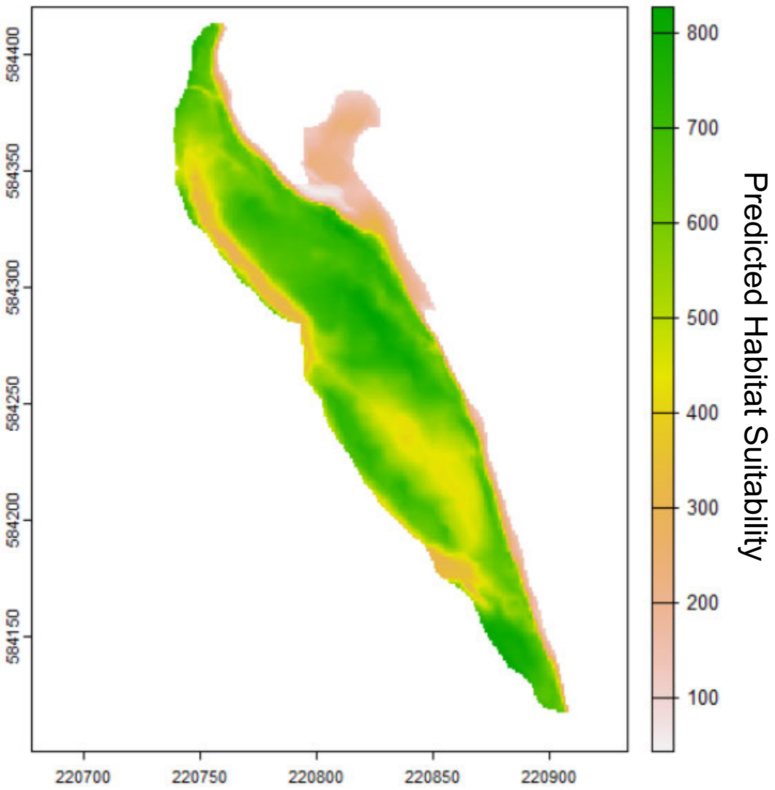


Arrowweed at Kwagunt Marsh



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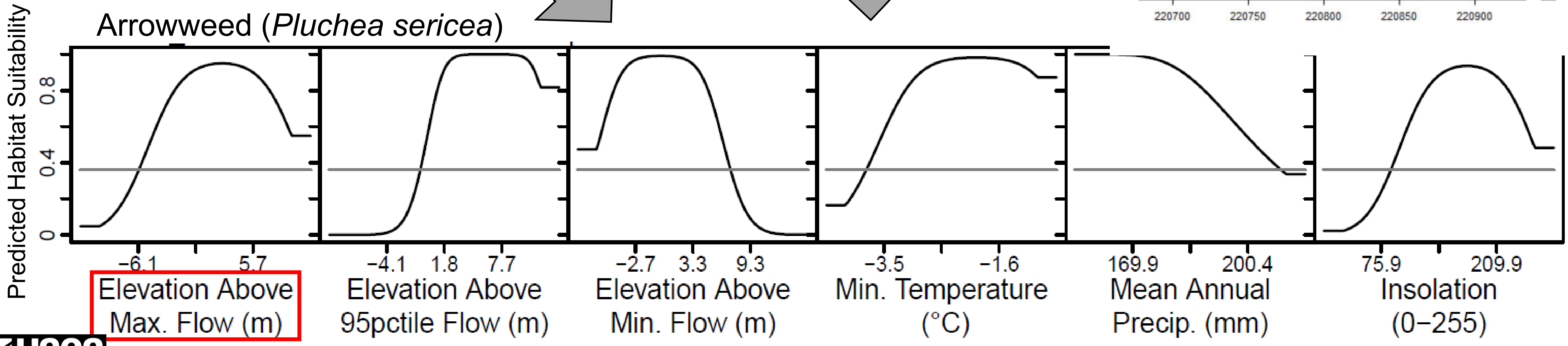

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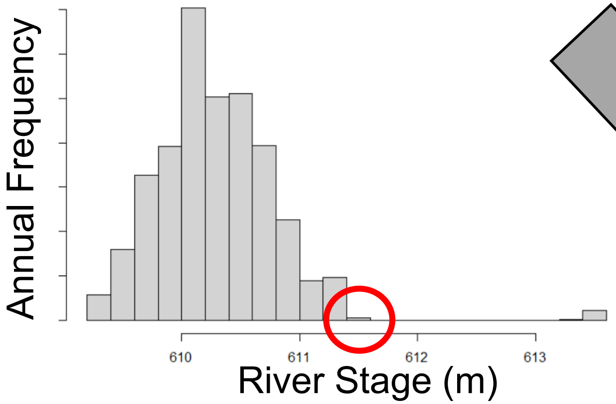

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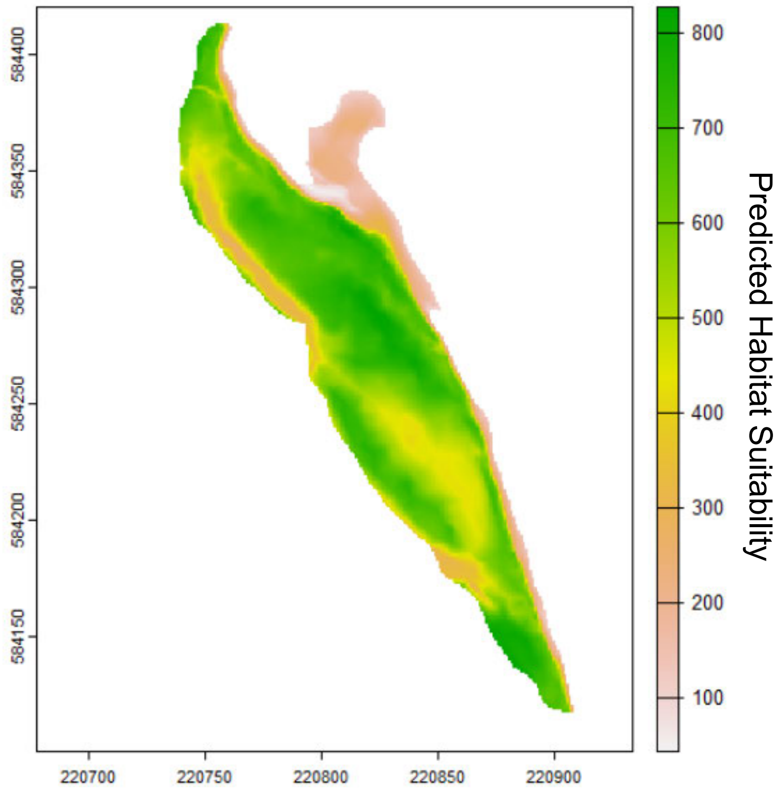

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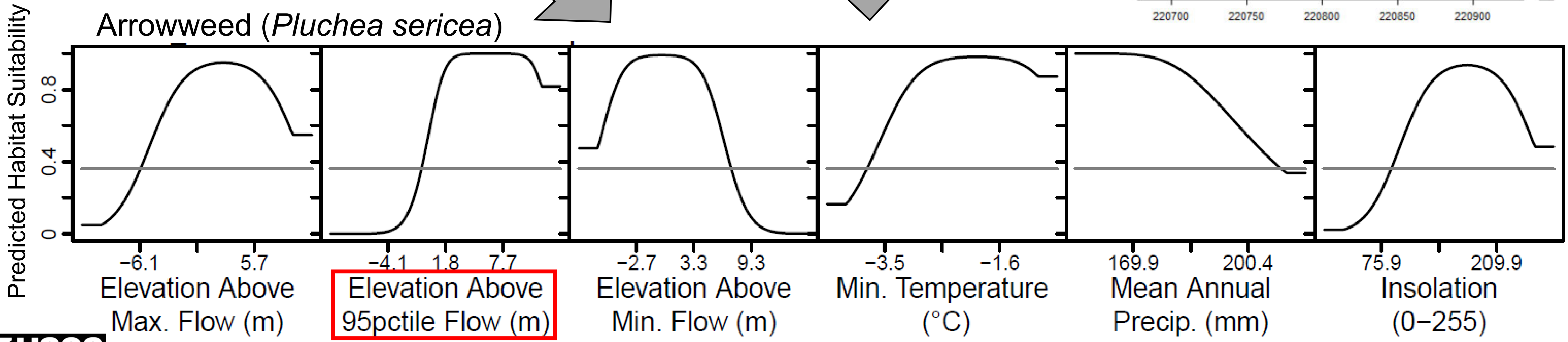

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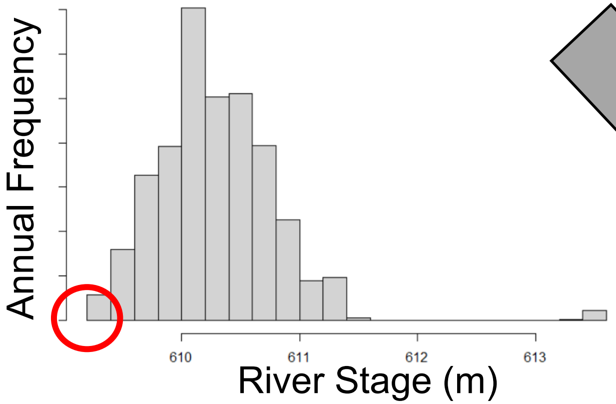

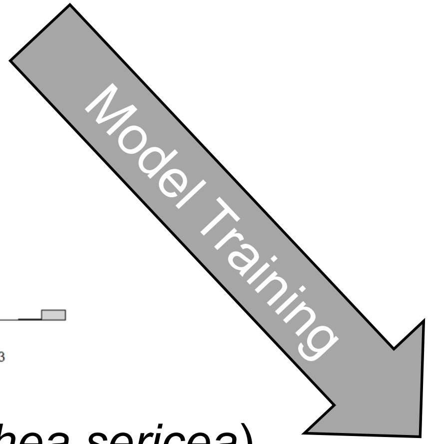

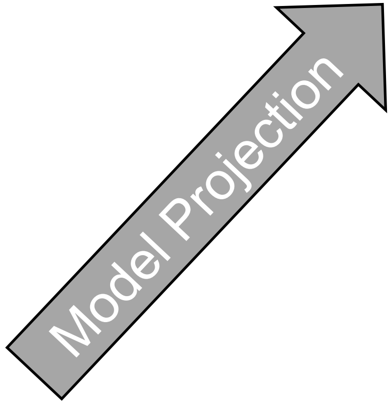

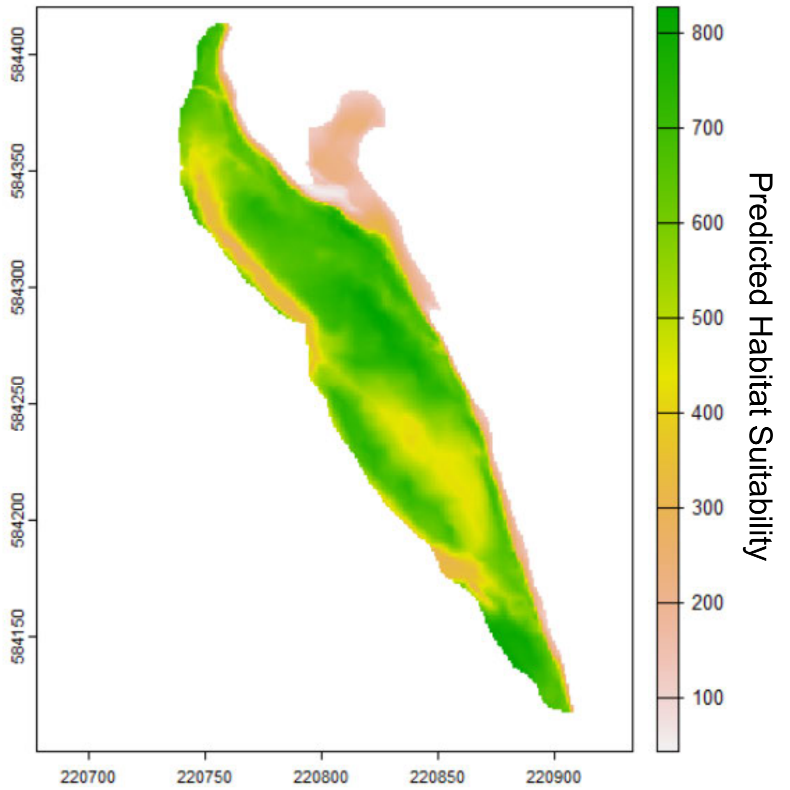

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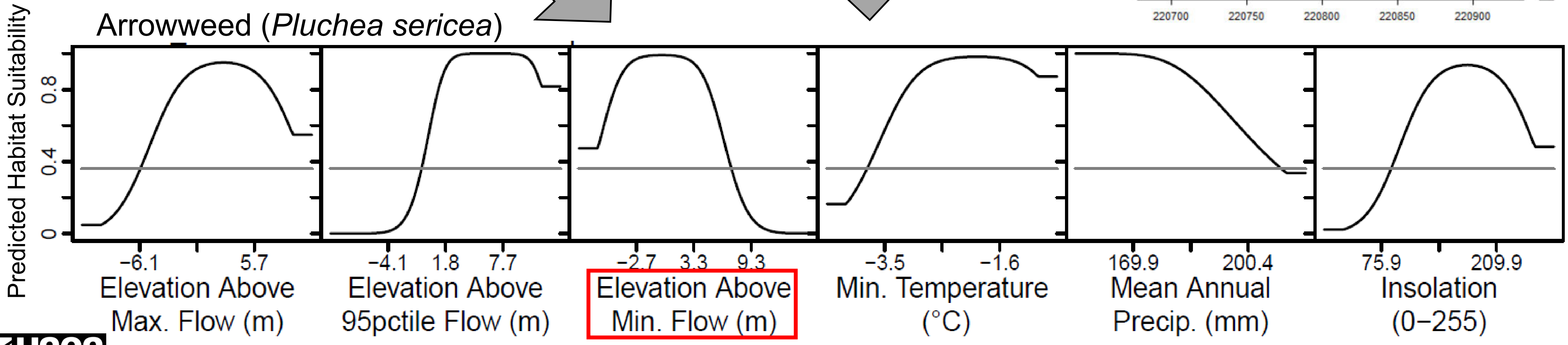

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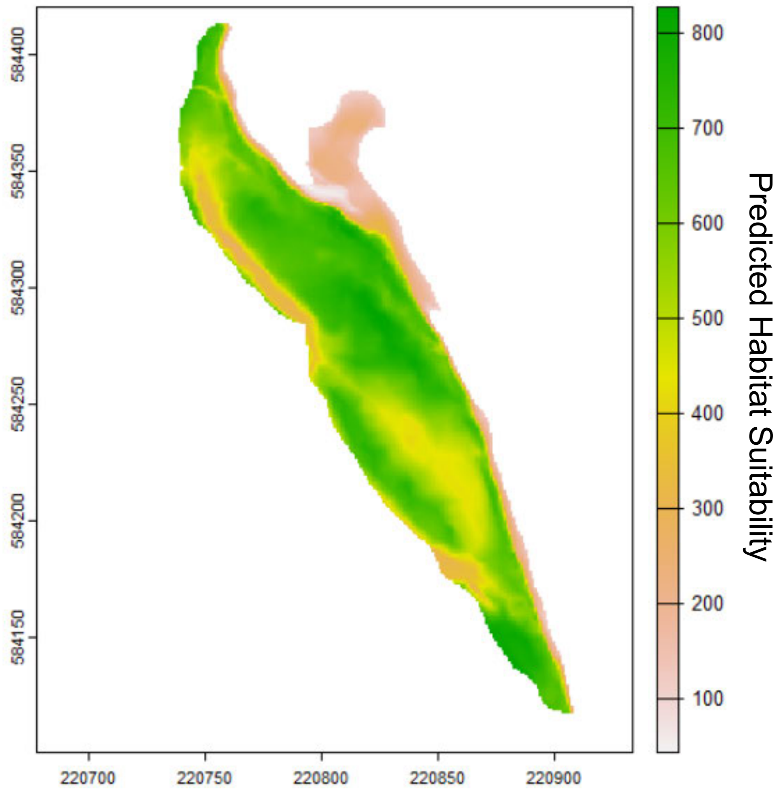

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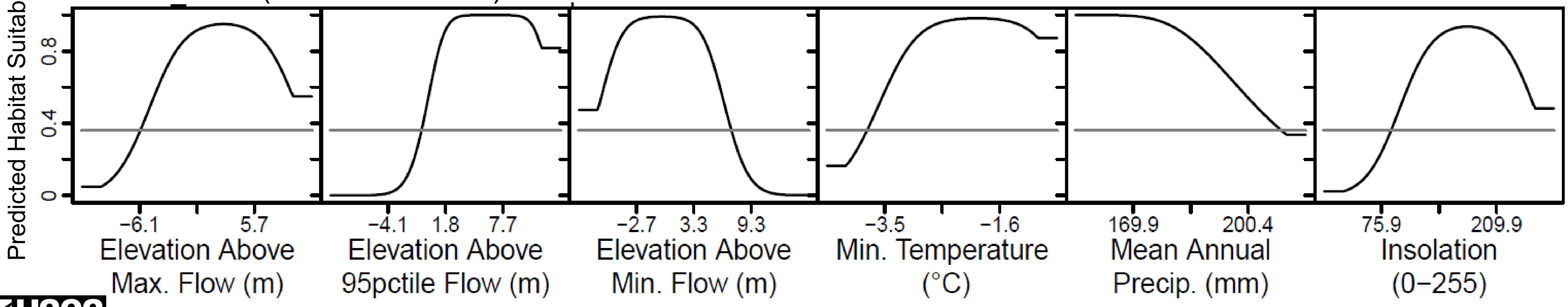

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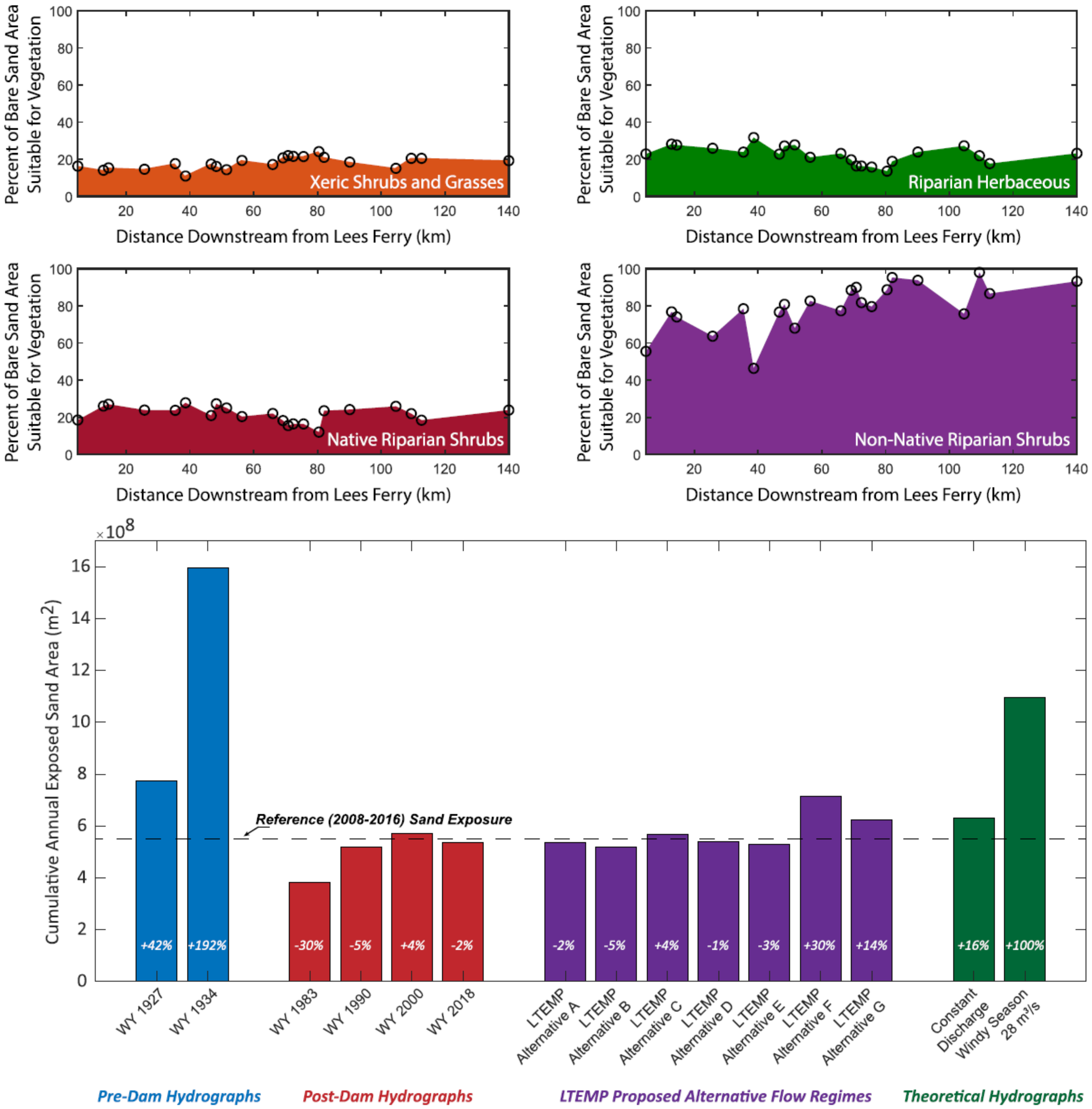
Flow Scenarios

- Can generate composite metrics (e.g. native riparian shrubs, species richness, etc.)
- Project under different flow scenarios
  - E.g. Kasprak, Sankey and Butterfield. 2021. *Environmental Research Letters*



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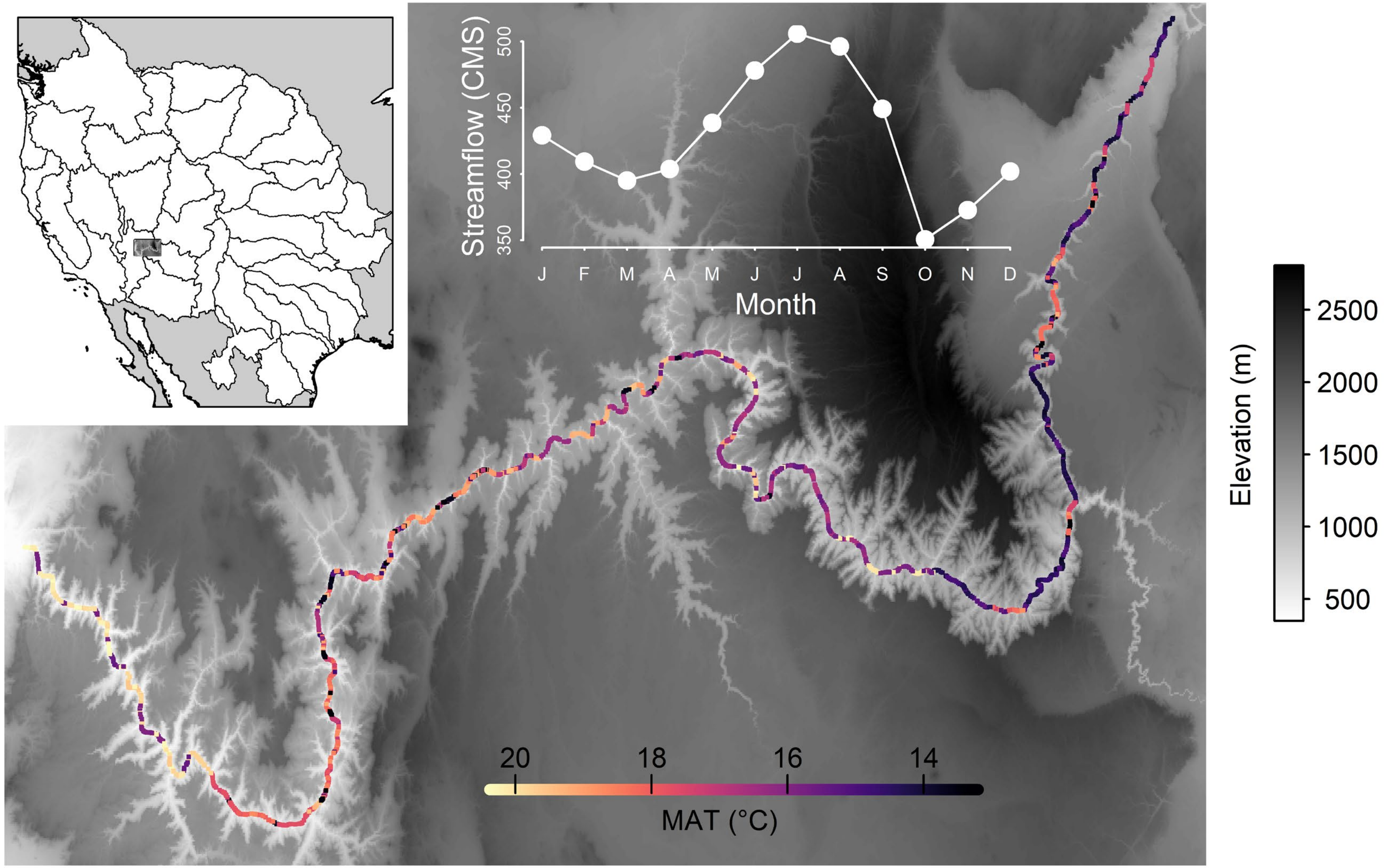
2 | Expanding Predictive Ability



Butterfield, Palmquist and Yackulic. 2022. *River Research and Applications*

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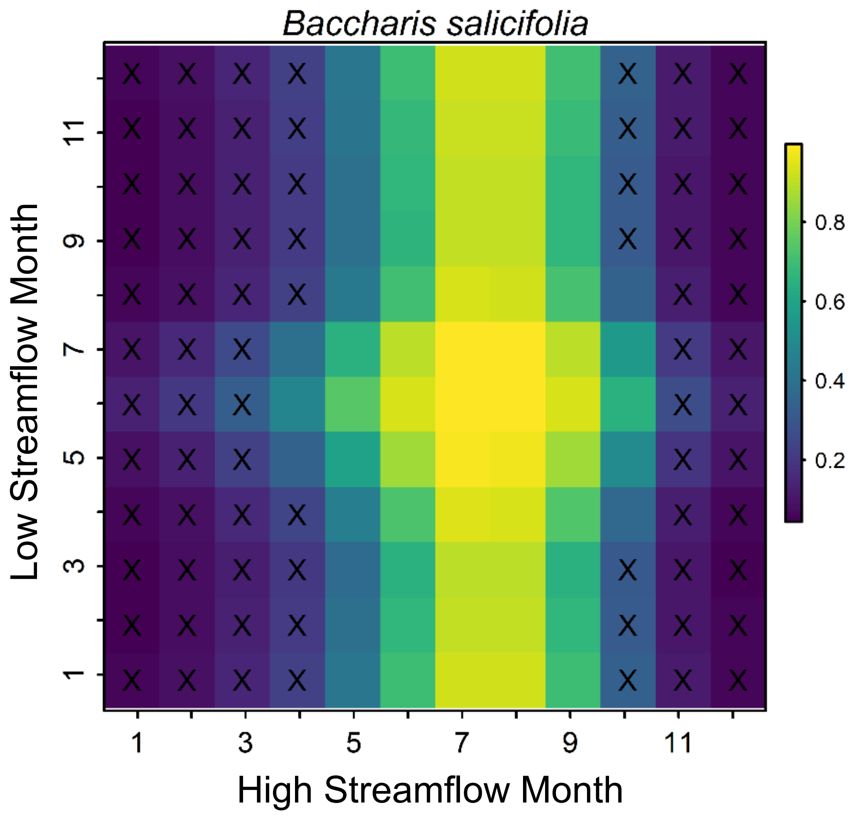
Flow Seasonality has Shaped the CRe Species Pool

- Models predict which species occur most frequently in the CRe
- Predicted species richness is greatest with high summer flows
- Species that have expanded in recent decades (e.g. *Baccharis*, arrowweed) are predicted to respond positively to high summer flows

Predicted Habitat Suitability under Different Flow Scenarios



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Drought or Inundation: Which Determines Species Distributions?

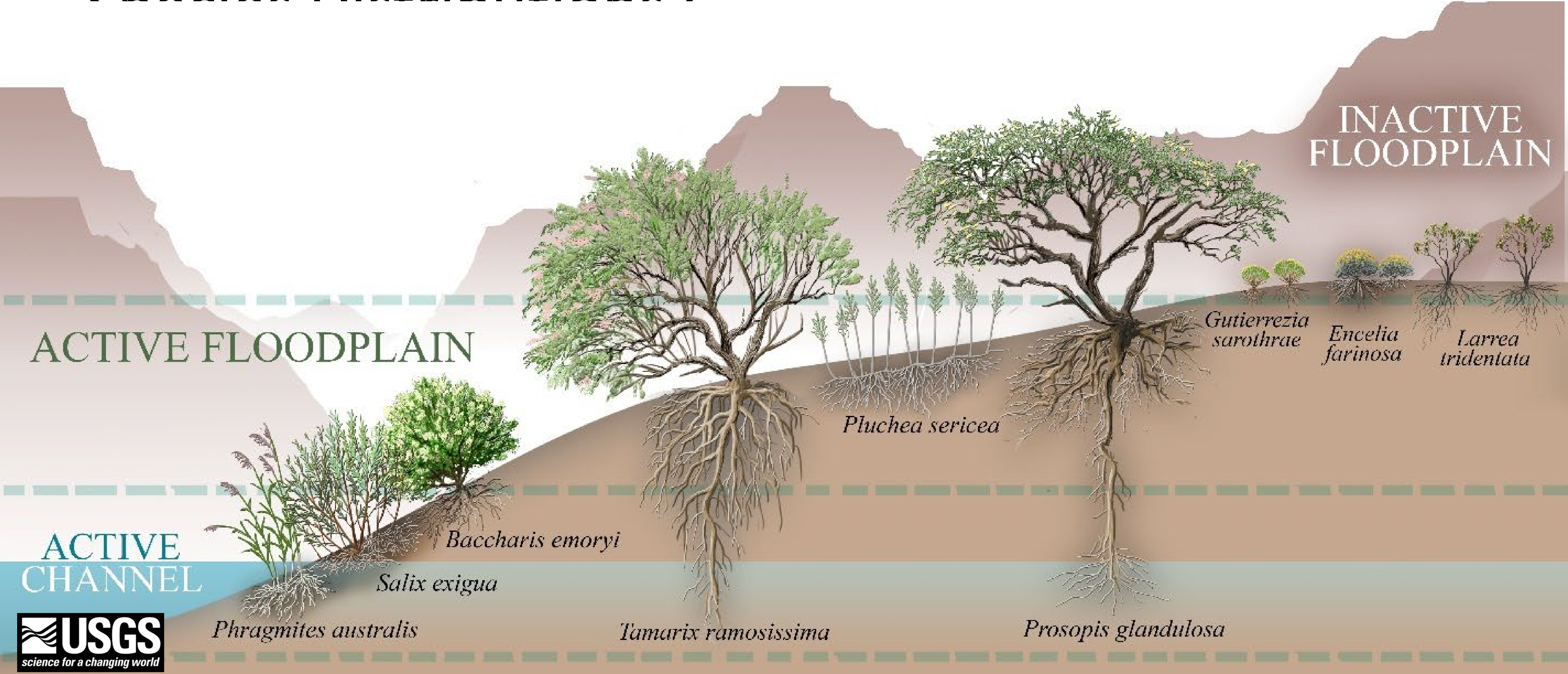

Image credit: Victor Leshyk

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Breaking the Correlation between Drought and Inundation with Controlled Experiments

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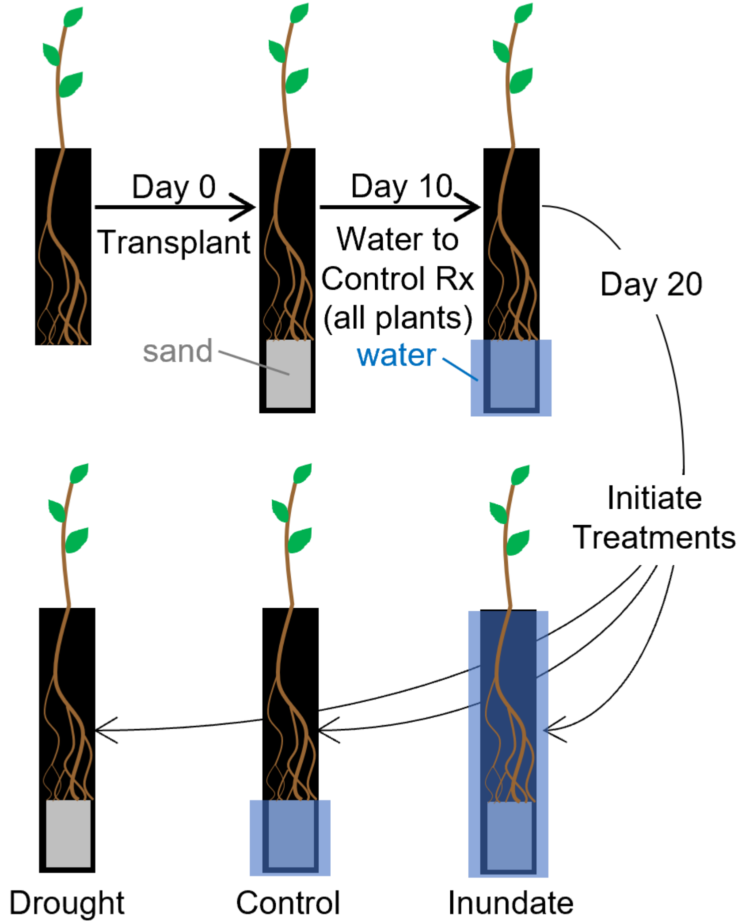
Photo credit: Grand Canyon Monitoring and Research Center



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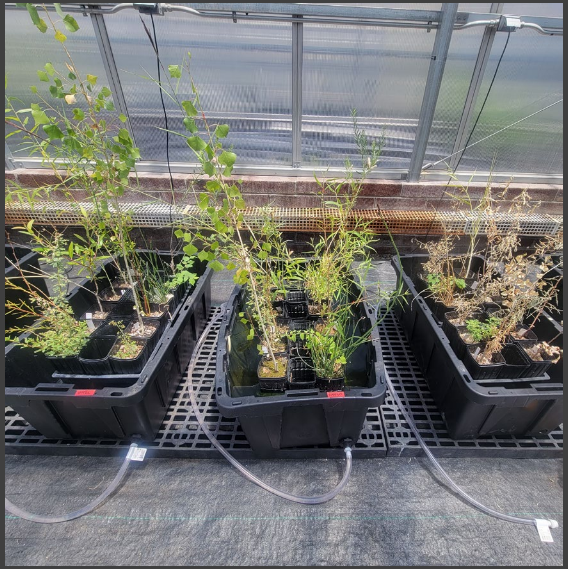

Measurements

- Stomatal conductance to water vapor
- New root growth

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Photo credit: Grand Canyon Monitoring and Research Center

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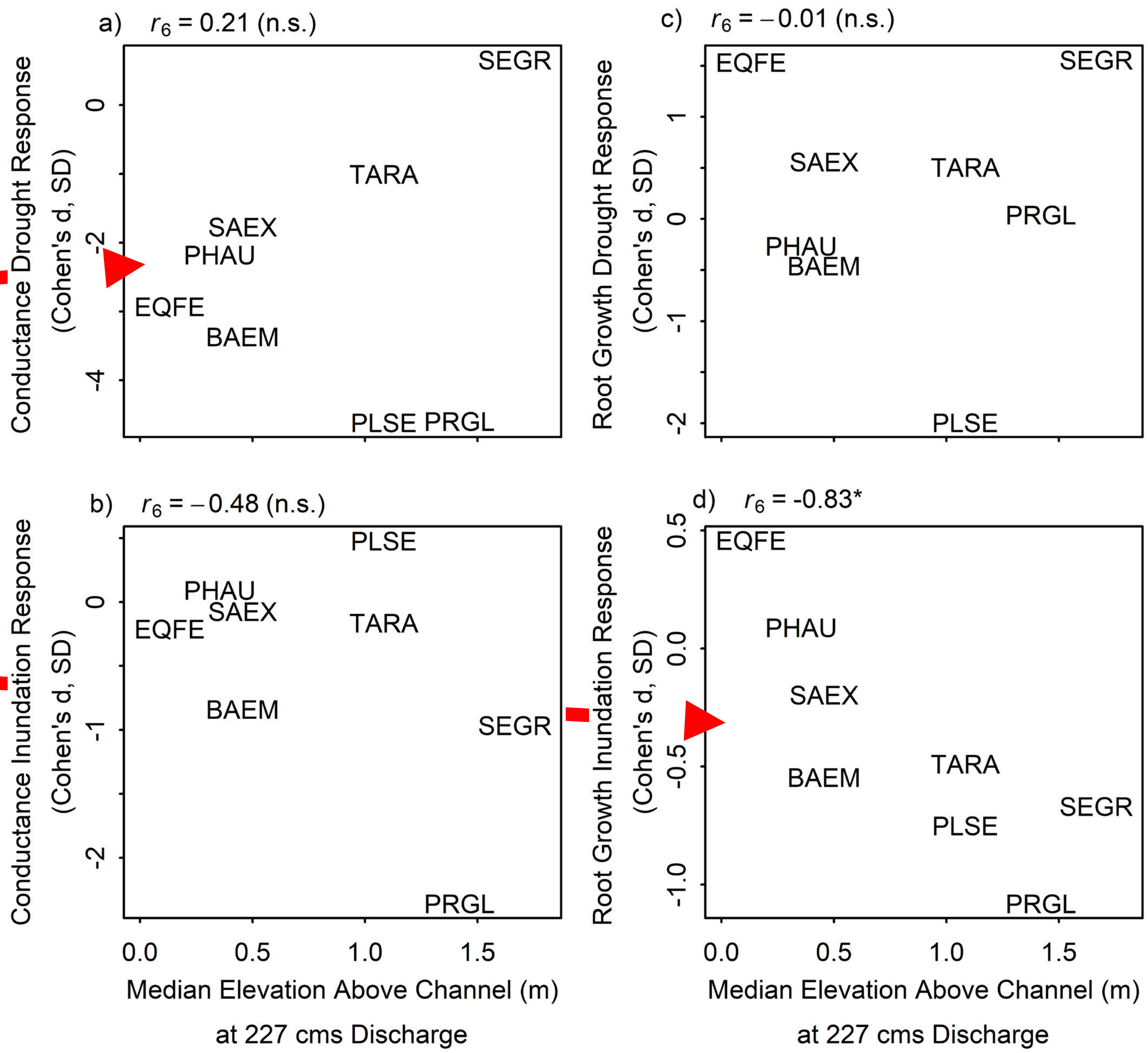
BAEM = *Baccharis emoryii*, EQFE = *Equisetum x ferrissii*, PHAU = *Phragmites australis*, PLSE = *Pluchea sericea*, PRGL = *Prosopis glandulosa*, SAEX = *Salix exigua*, SEGR = *Senegalia greggii*, TARA = *Tamarix*

Shaped by Inundation, Vulnerable to Drought?

- Divergent responses to drought
  - Predict idiosyncratic responses to low flows
- More systematic responses to inundation
  - Inundation has shaped the current vegetation, but perhaps less relevant in the future



Preliminary data, do not cite

3 | Integration: Complementary Approaches

Tool	Strengths	Weaknesses
Hydrological Niche Modeling (from ground-based monitoring data)	Fine-resolution prediction of species responses to dam operations	Limits to extrapolation under new environmental conditions
Hydrograph Seasonality (from rivers across the western US)	Extrapolate to new climate conditions and dam operations based on extensive data	Coarse resolution
Mechanistic Modeling (from controlled experiments)	Differentiate among drivers that may exhibit different collinearity or range in the future (i.e. low-flow vs. high-flow anomalies)	Connecting controlled experiments to real-world predictions

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Additional Vegetation Models and Data Types

- Other models I did not touch on today
  - Emily's Bayesian models differentiate habitat suitability from abundance
  - Models that incorporate traits to improve predictions for uncommon species
  - Models that allow us to infer interactions (competition and facilitation) among species
- Experiments
  - Spring disturbance flows (manuscript in review)
  - Hydropeaking greenhouse experiment coming summer of '23

Photo credit: Freshwaters Illustrated

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Biological-Physical Linkages

- Aeolian and alluvial processes have strong feedbacks with the biological system
  - Plants trap both wind- and waterborne sediment
  - Changes in sediment affect plant growth and survival
- Having all three components interacting in a dynamic model would be a big step forward in predictive ability and mechanistic understanding

Photo credit: Brad Butterfield

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