Riparian Plant Responses to Flow Regulation: A Preliminary Synthesis

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Image credit: Brad Butterfield

Dimensions of Flow Regulation in the CRe

- HFEs
  - Habitat creation via sediment deposition
  - Adding moisture to soils
- High vs. low monthly volumes
  - High flows → anoxia → root asphyxiation
  - Low flows → drought → dehydration
- Seasonality of monthly volumes
  - Exacerbate or alleviate other stressors (e.g. extreme temperatures)
- Daily fluctuations
  - Tolerance of both dry and wet conditions

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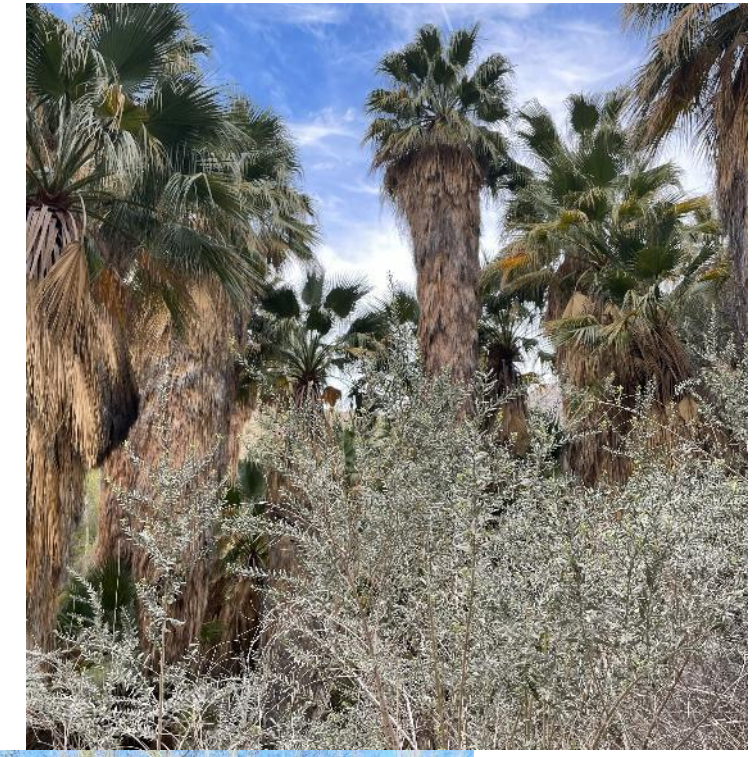
Case Study: Arrowweed (*Pluchea sericea*)

- Highly clonal, kinda shrubby thing
- Sunflower family
- Tall, straight stems
- Many species of *Pluchea* in South and Central America, as well as Africa, Australia, and tropical parts of Asia
- Many traditional uses:
  - Arrows
  - Thatching
  - Edible roots
  - Medicinal properties



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Desert Botanical Garden
Tohono O'odham Exhibit

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Case Study: Arrowweed

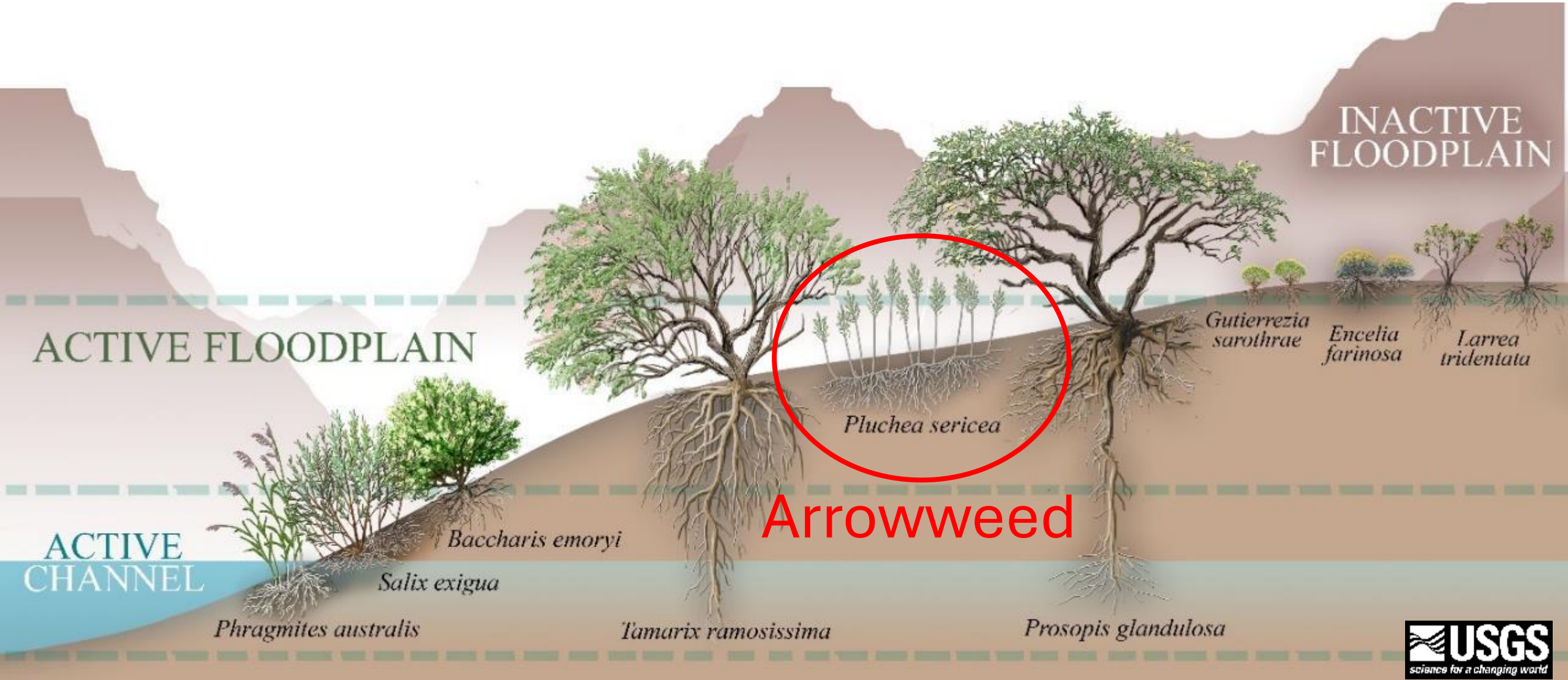
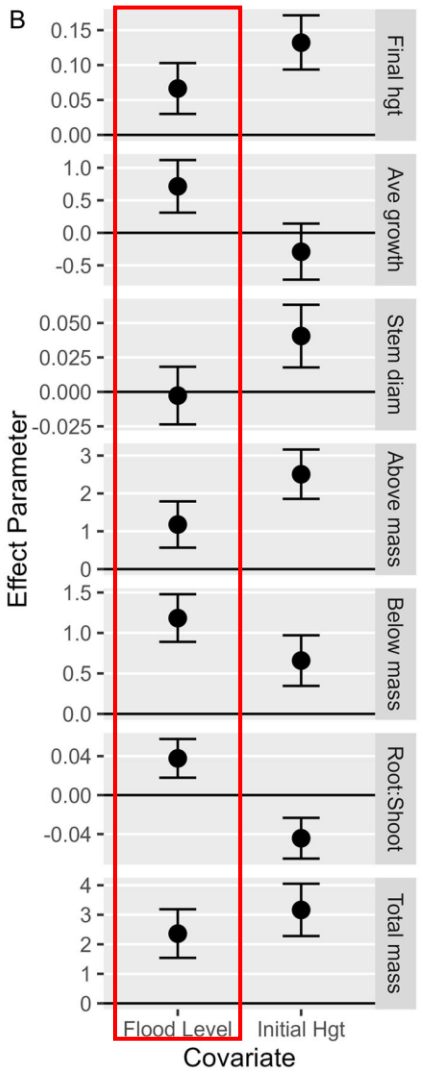


Image credit: Victor Leshyk

Negative Effects of Inundation (Consistent High Flows)

- Negative effects of inundation depth on multiple aspects of plant growth
- Suggests that lack of inundation tolerance keeps arrowweed from spreading aggressively in near channel habitats



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Palmquist and others (2023) *American Journal of Botany*

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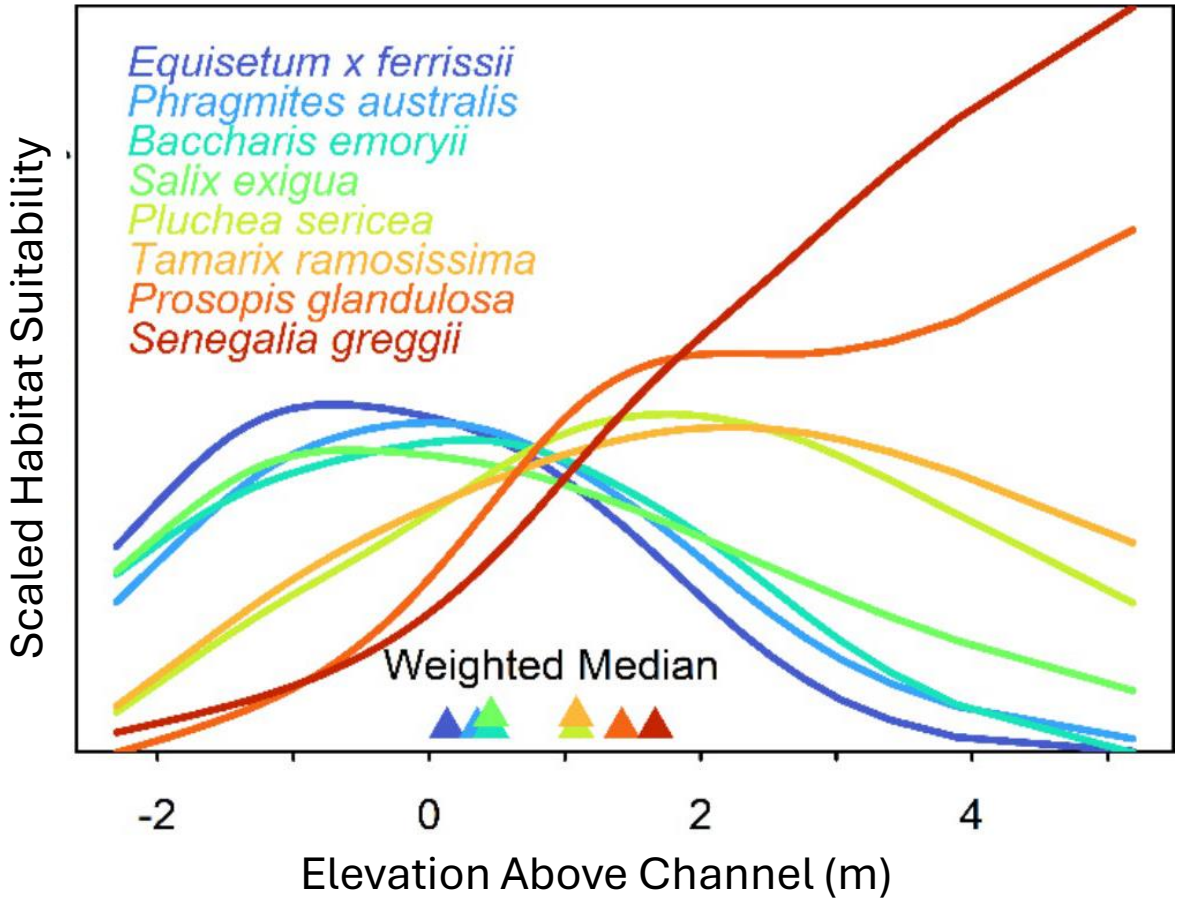
Responses to Inundation and Drought



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Butterfield and Palmquist (2024) *Wetlands*

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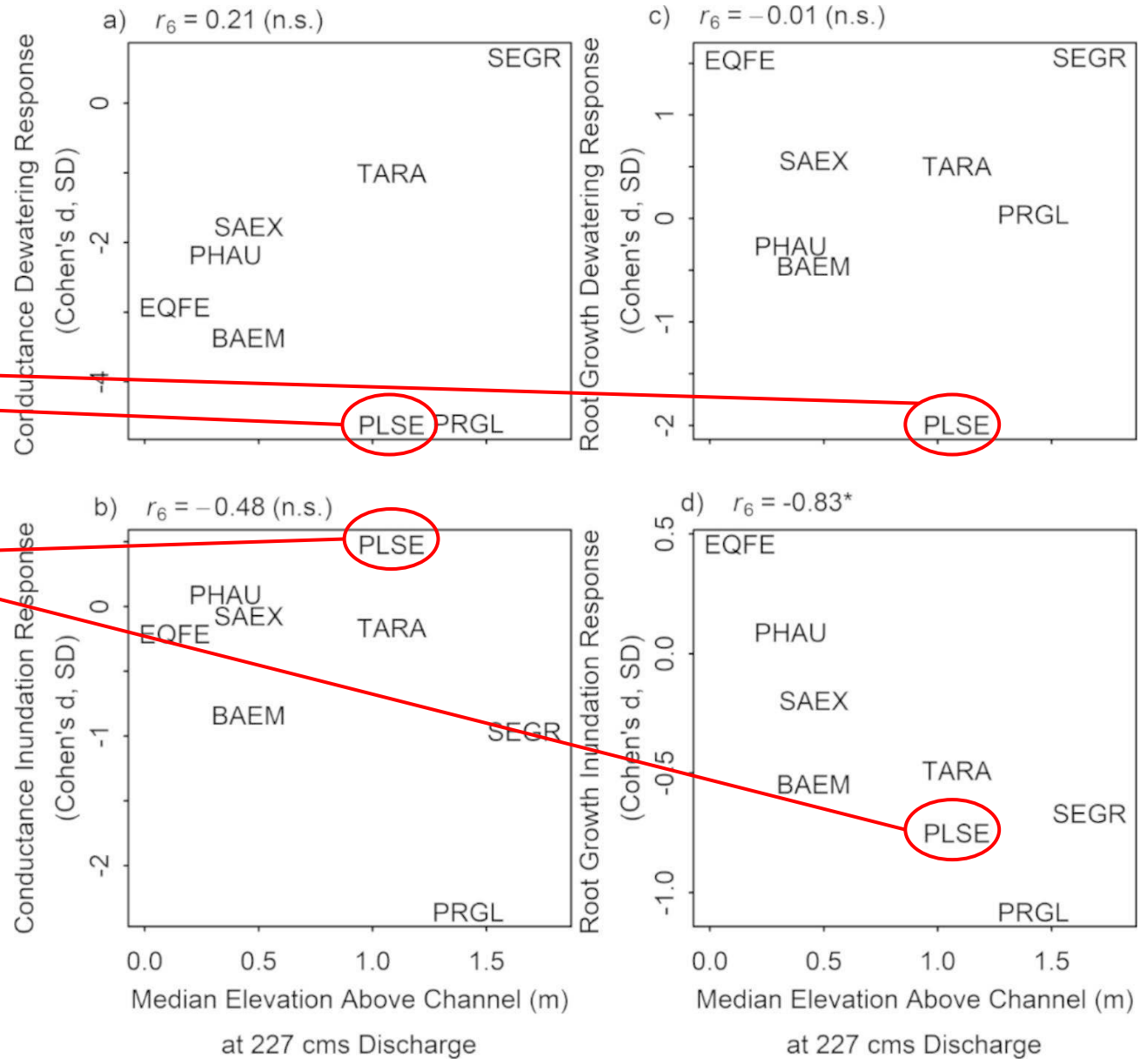
Goldilocks: Not too Wet, not too Dry

- Strong negative responses to drought
- Moderate negative responses to inundation
- May explain why arrowweed is most abundant at intermediate elevations above the channel



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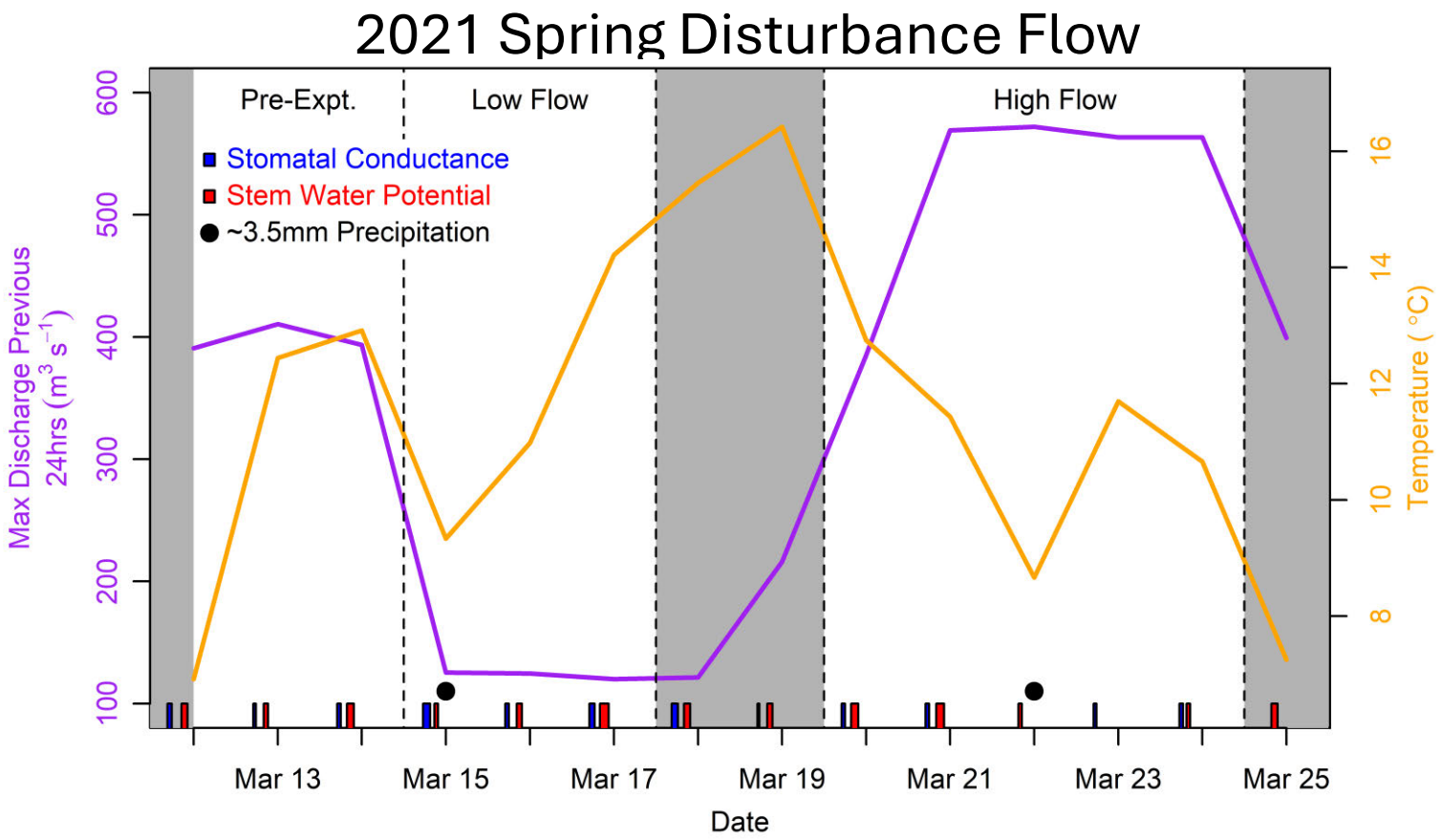
Do We See These Patterns in the Field?



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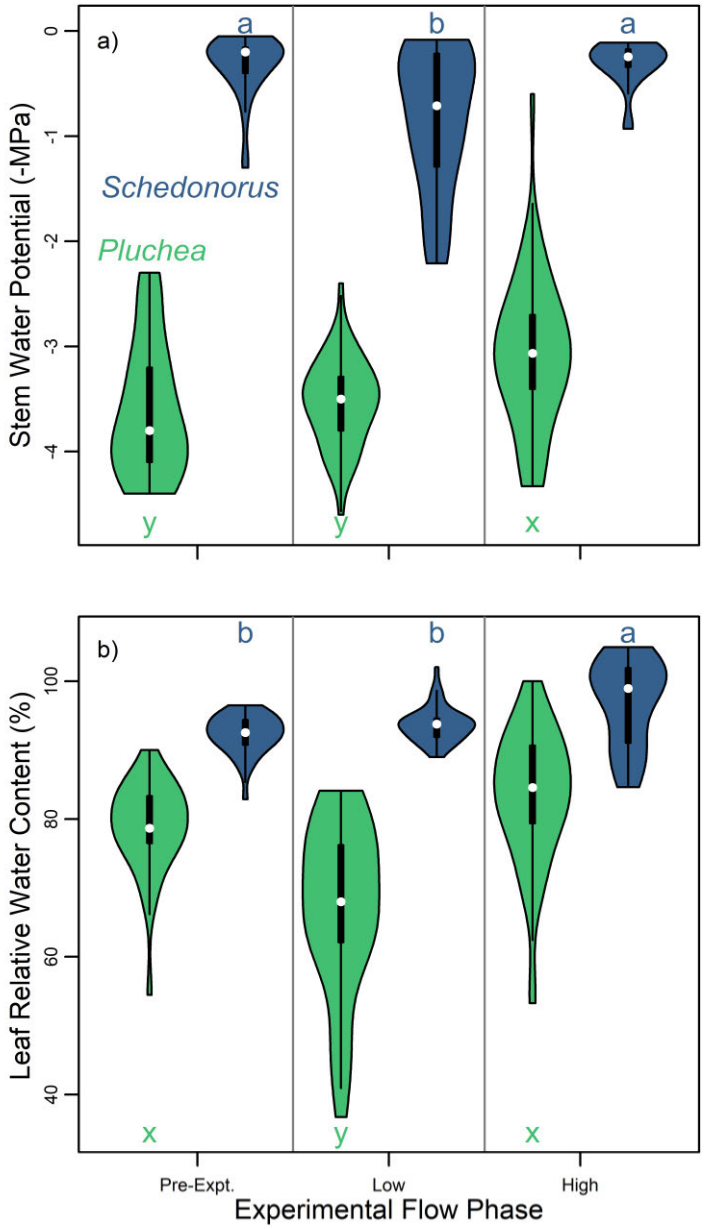
Arrowweed Responds to Both Low and High Flows

- Stems hydrate in response to high flow phase
  - Increase water transport for photosynthesis
- Leaves dehydrate in response to low flow phase
  - Protecting stems from cavitation
- These plants were as much as 10 feet above the channel, responding to changes in the water table driven by streamflow



Butterfield and Palmquist (2024) *Plant Ecology*

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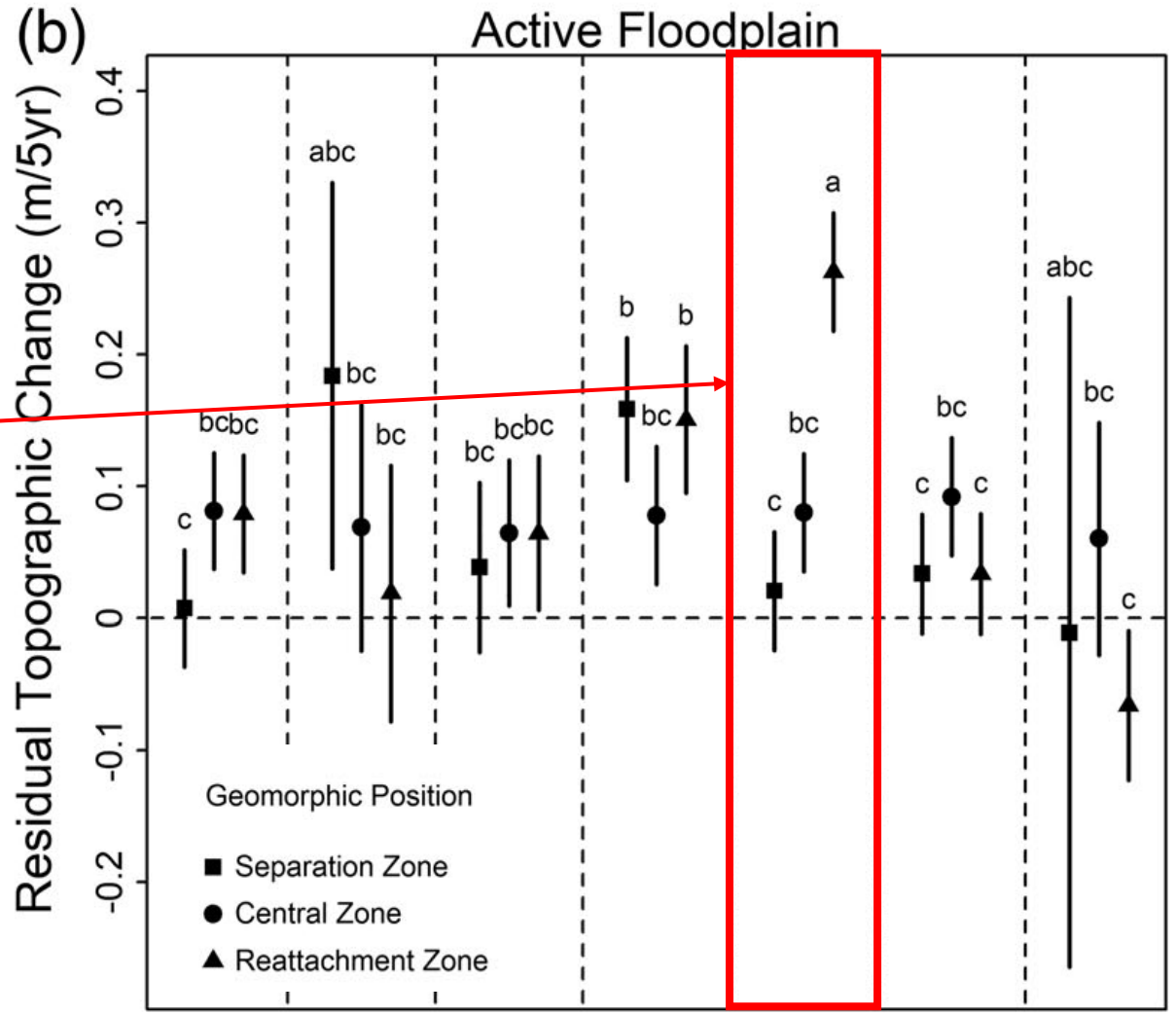
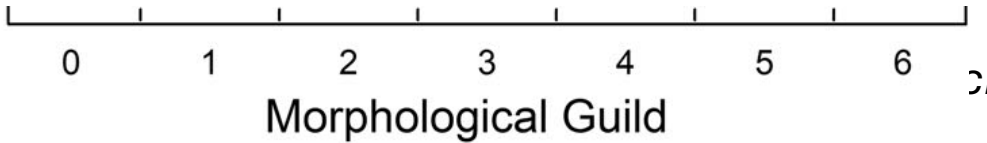
What About HFEs?

- Strong positive effect via sediment deposition
  - Arrowweed enhances deposition, helping to engineer its own habitat
- Watering effect could be minimal
  - May not matter in the fall if plants are dormant, but could be active in lower, hotter reaches
  - Spring HFEs could provide moisture at beginning of growing season (Spring Disturbance Flow was in March)
  - Insights into seasonality?





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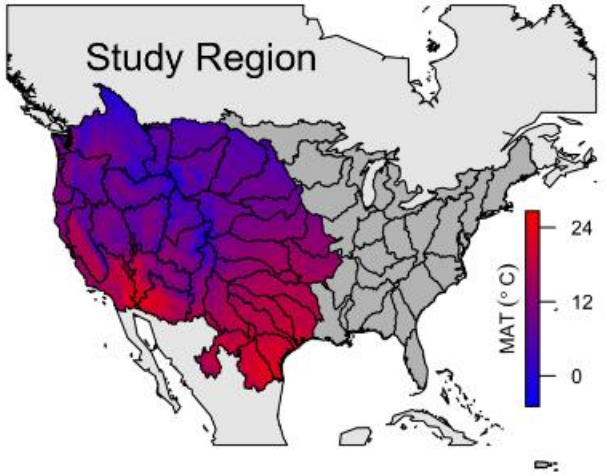
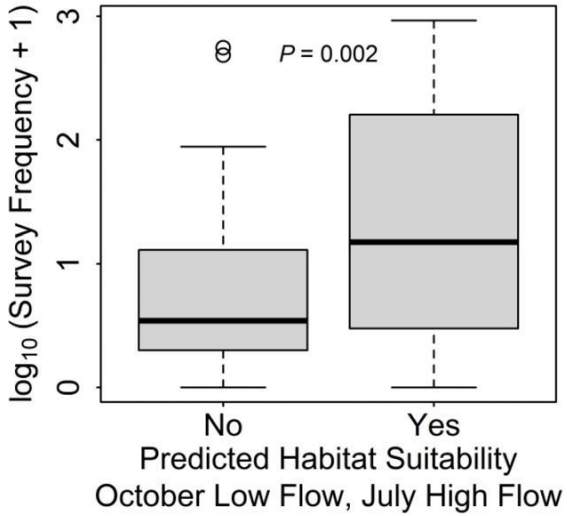
Seasonal Timing of Low and High Monthly Totals Affects Habitat Suitability

- Identify suitable combinations of monthly flow totals and climate for many species across the West
- Models predict species prevalence within the CRe (good check on model relevance)





Butterfield and others (2023) *River Research and Applications*

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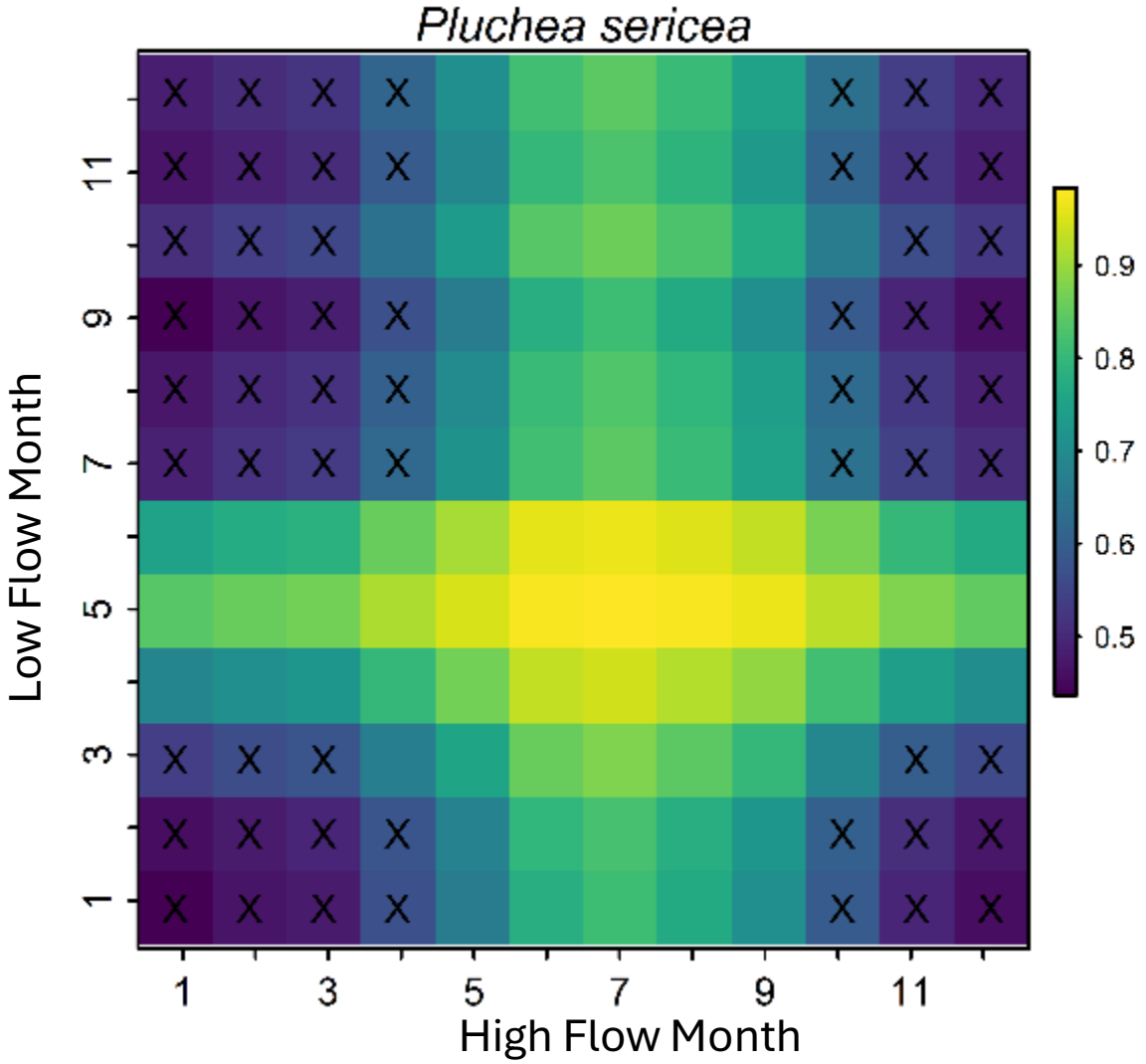
Arrowweed Likes Summer High Flows and Late Spring Low Flows



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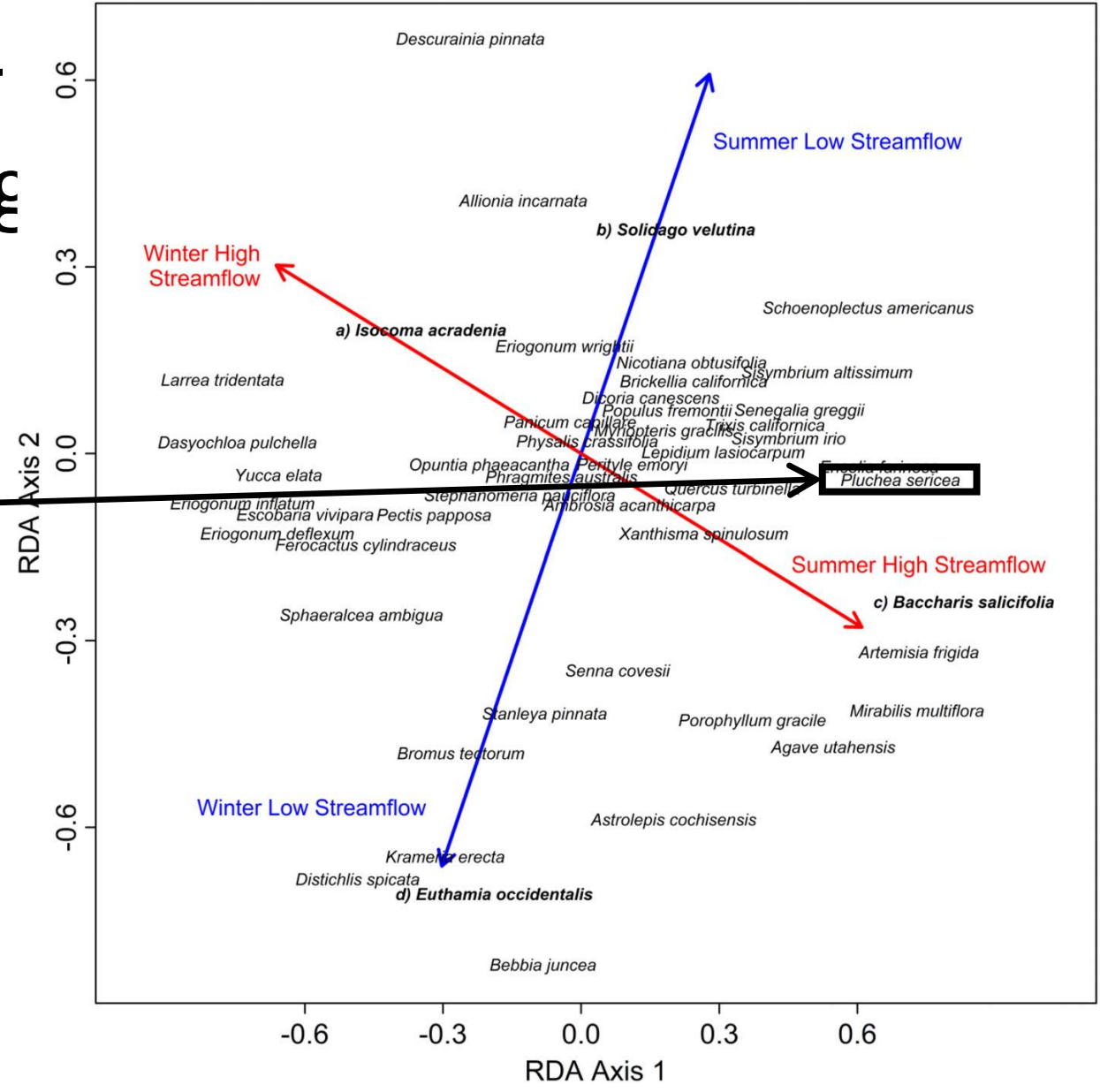
Arrowweed Likes Summer High Flows and Late Spring Low Flows

- Particularly responsive to high summer flows
  - Water table is higher and more accessible during the hottest months when arrowweed is physiologically active



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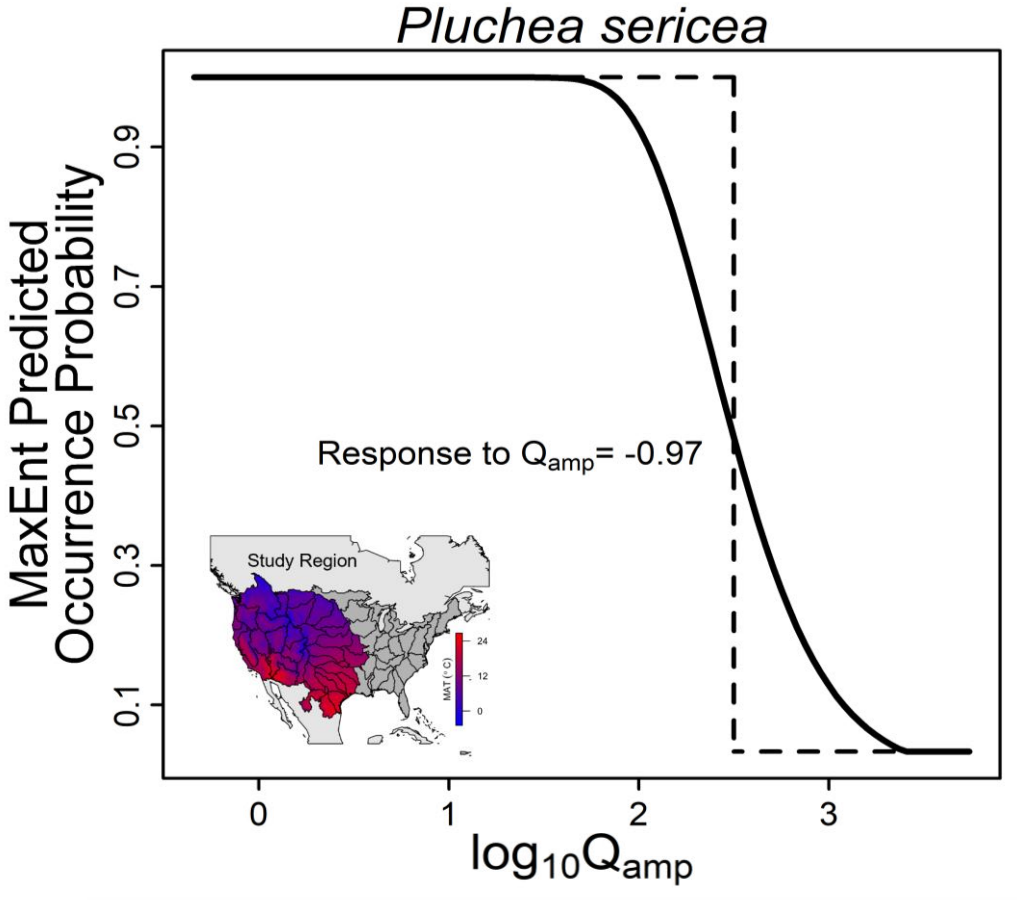
Arrowweed Is Less Likely to Occur on Rivers with High Amplitude Daily Fluctuations

- Suggests that daily saturation of soils is detrimental to growth
- Consistent with greenhouse experiments
- Consistent with other species that are prevalent in the Active Floodplain (data not shown)



Butterfield and Palmquist (2025) *Applied Vegetation Science*

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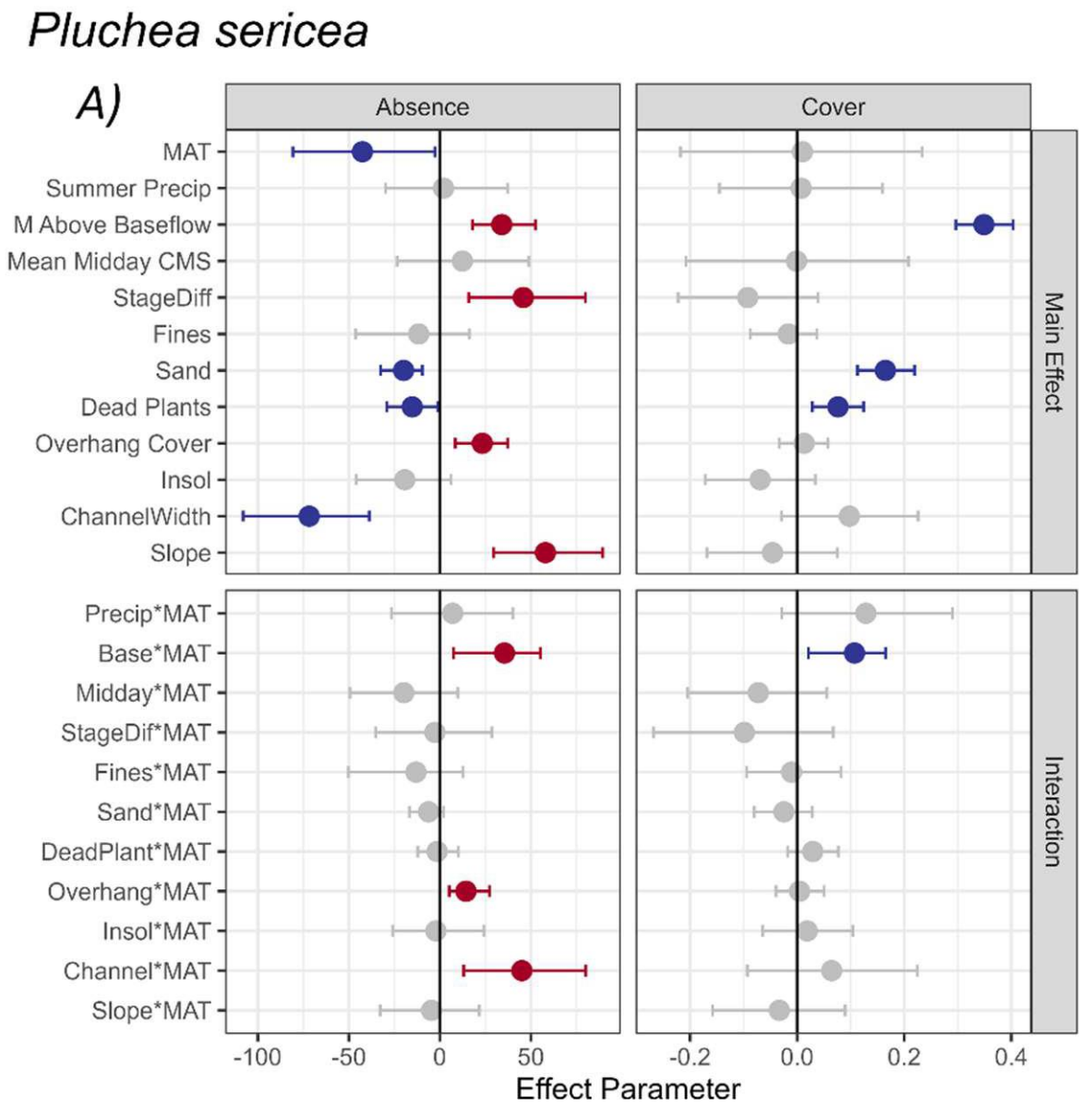
Synthesis of Arrowweed Results

- Likes it not too wet, not too dry
- High monthly totals in summer improve habitat suitability
- Daily fluctuations exclude arrowweed from near channel habitat
- HFEs enhance arrowweed habitat through sediment deposition, but probably not through water addition or disturbance
- We can provide quantitative estimates of changes in habitat suitability to specific changes in each of these dimensions of streamflow

Monitoring Allows Us to Extend These Insights

- Arrowweed
  - Likes it hot
  - Likes it sandy
  - Likes wider parts of the channel
- Have similar information for many other species



Palmquist and others (2025) *Ecological Monographs*

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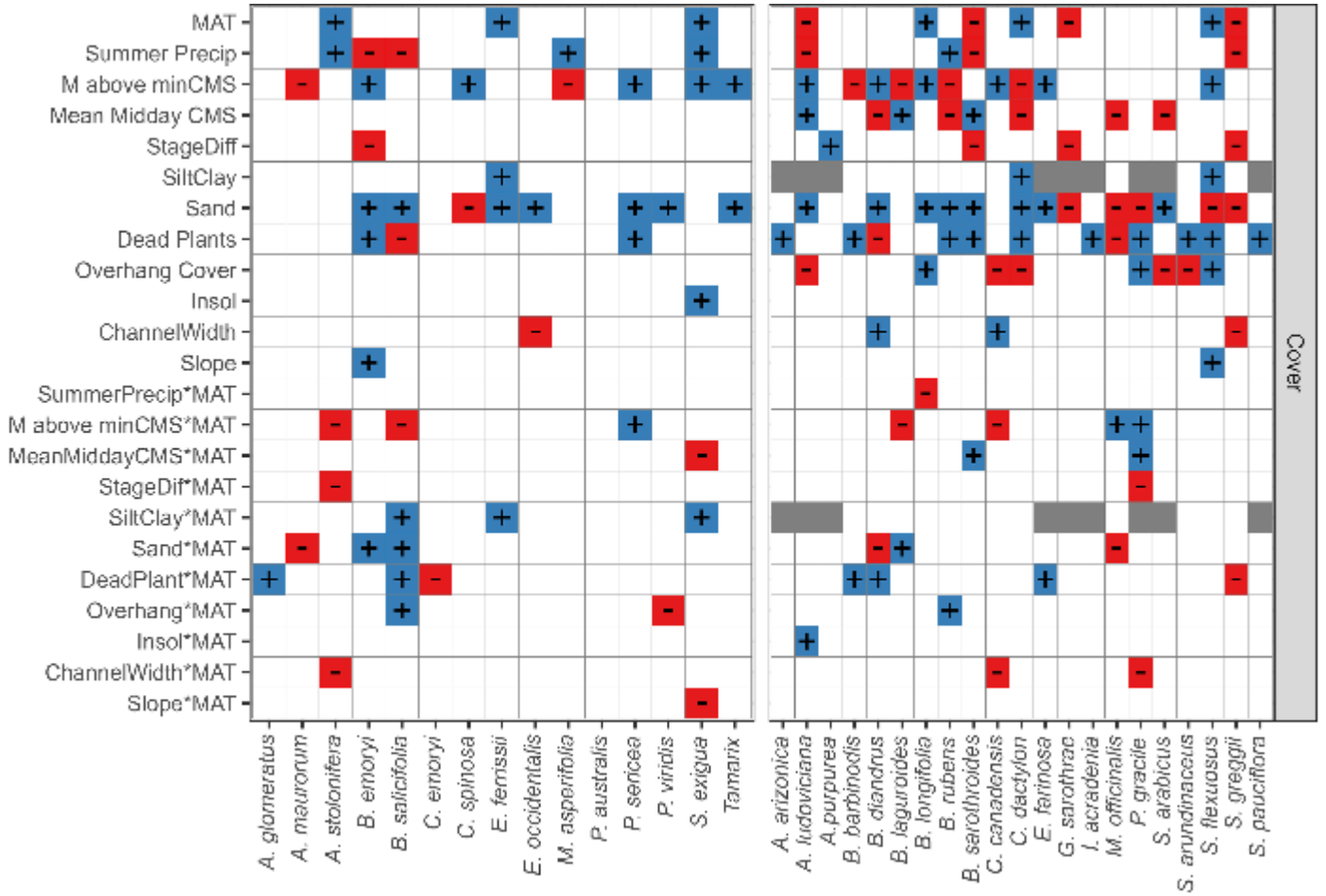
Linkages to Other Species

- Varying levels of information from one species to the next
  - Survey data for many species
  - Detailed responses to flows and other aspects of the environment

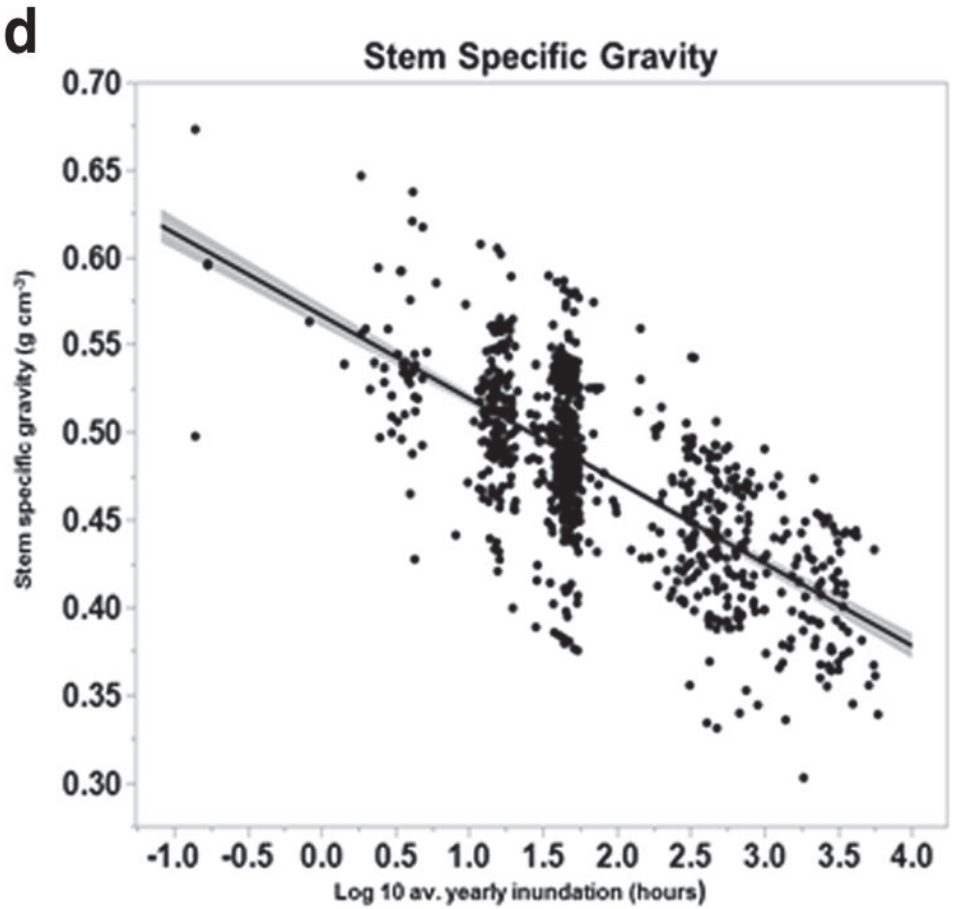


Palmquist and others (2025) *Ecological Monographs*

What About the Other Plant Species?

- Trait data for many species can help to infer flow responses for species with less information
  - “Sharing of strength”
  - Identify generality of responses

20 traits/affinities for 179 species
Palmquist and others (2017) *USGS Data Release*



McCoy-Sullentic and others (2017) *Wetlands*

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Summary

- We have conducted research on multiple dimensions of river regulation/streamflow for many species
- We can attribute effects of specific dimensions of streamflow to habitat suitability for some of these species
- Each species exhibits individualistic responses to streamflow variation
- But, we can make some inferences based on ecological similarities/differences among species

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References

- Butterfield, B. J., P. E. Grams, L. E. Durning, J. Hazel, E. C. Palmquist, B. E. Ralston, and J. B. Sankey. 2020. Associations between riparian plant morphological guilds and fluvial sediment dynamics along the regulated Colorado River in Grand Canyon. *River Research and Applications* 36:410–421
- Butterfield, B. J., and E. C. Palmquist. 2024. Inundation Tolerance, Rather than Drought Tolerance, Predicts Riparian Plant Distributions Along a Local Hydrologic Gradient. *Wetlands* 44:6
- Butterfield, B. J., E. C. Palmquist, and C. B. Yackulic. 2023. The hydroclimate niche: A tool for predicting and managing riparian plant community responses to streamflow seasonality. *River Research and Applications* 39:84–94.
- Butterfield, B. J., and E. C. Palmquist. 2024. Divergent physiological responses of hydric and mesic riparian plant species to a Colorado River experimental flow. *Plant Ecology* 225:125–133
- Butterfield, B. J., and E. C. Palmquist. 2025. Daily Fluctuating Flows Affect Riparian Plant Species Distributions From Local to Regional Scales. *Applied Vegetation Science* 28:e70033
- McCoy-Sulentic, M. E., T. E. Kolb, D. M. Merritt, E. Palmquist, B. E. Ralston, D. A. Sarr, and P. B. Shafroth. 2017. Changes in Community-Level Riparian Plant Traits over Inundation Gradients, Colorado River, Grand Canyon. Wetlands 37:635–646
- Palmquist, E. C., B. E. Ralston, D. A. Sarr, D. M. Merritt, P. B. Shafroth, and J. A. Scott. 2017. Southwestern Riparian Plant Trait Matrix, Colorado River, Grand Canyon, Arizona (ver. 2.0, January 2022)
- Palmquist, E. C., K. Ogle, T. G. Whitham, G. J. Allan, P. B. Shafroth, and B. J. Butterfield. 2023. Provenance, genotype, and flooding influence growth and resource acquisition characteristics in a clonal, riparian shrub. American Journal of Botany 110:e16115
- Palmquist, E. C., K. Ogle, B. J. Butterfield, T. G. Whitham, G. J. Allan, and P. B. Shafroth. 2025. Hotter temperatures alter riparian plant outcomes under regulated river conditions. Ecological Monographs 95:e1645

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