Effects of Daily Fluctuating Flows on Riparian Plant Distributions

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Photo credit: Brad Butterfield

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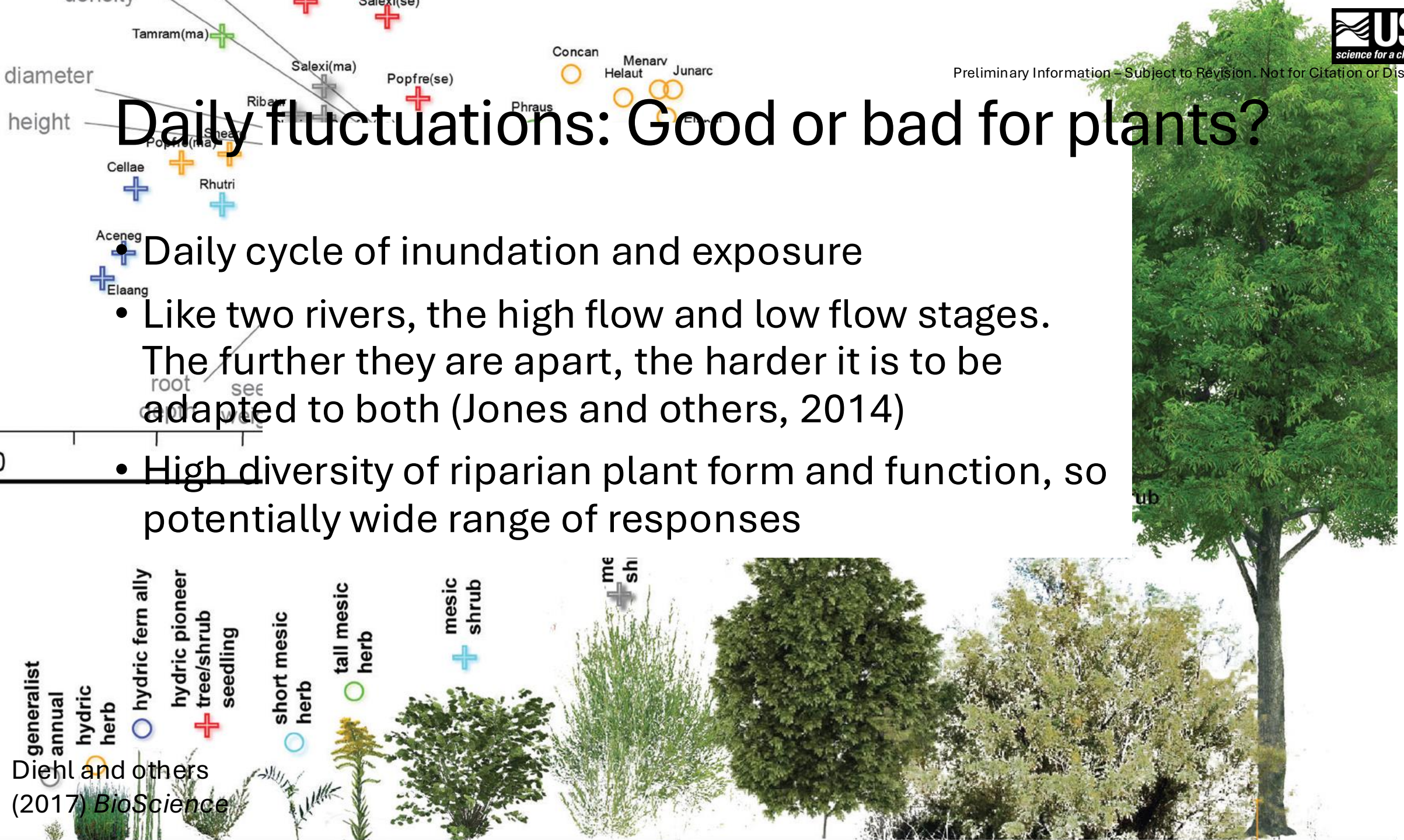
Daily fluctuations: Good or bad for plants?

- Daily cycle of inundation and exposure
- Like two rivers, the high flow and low flow stages. The further they are apart, the harder it is to be adapted to both (Jones and others, 2014)
- High diversity of riparian plant form and function, so potentially wide range of responses



Diehl and others (2017) *BioScience*

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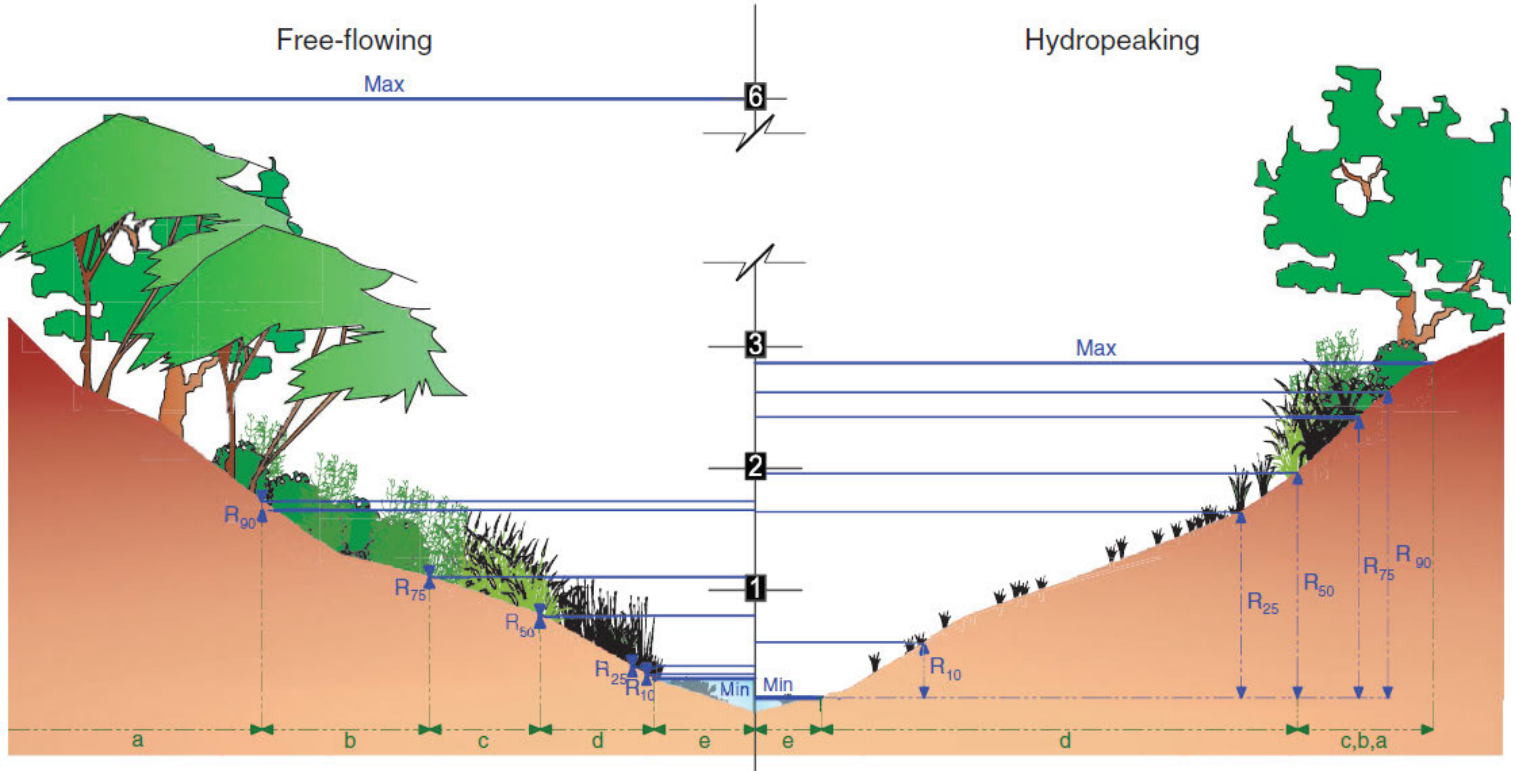
Some Benefit, Most Suffer



Bejarano and others (2018a) *Biol. Reviews*

Current Ideas

- Obligate riparian species suffer, some facultative riparian species benefit
- Irrigation hypothesis (Gill and others, 2018): Plants just above the zone of daily peak flows benefit from moisture provided by daily fluctuations
- Exclusion hypothesis: Plants just above daily peak flows are being excluded from otherwise suitable habitat nearer the channel

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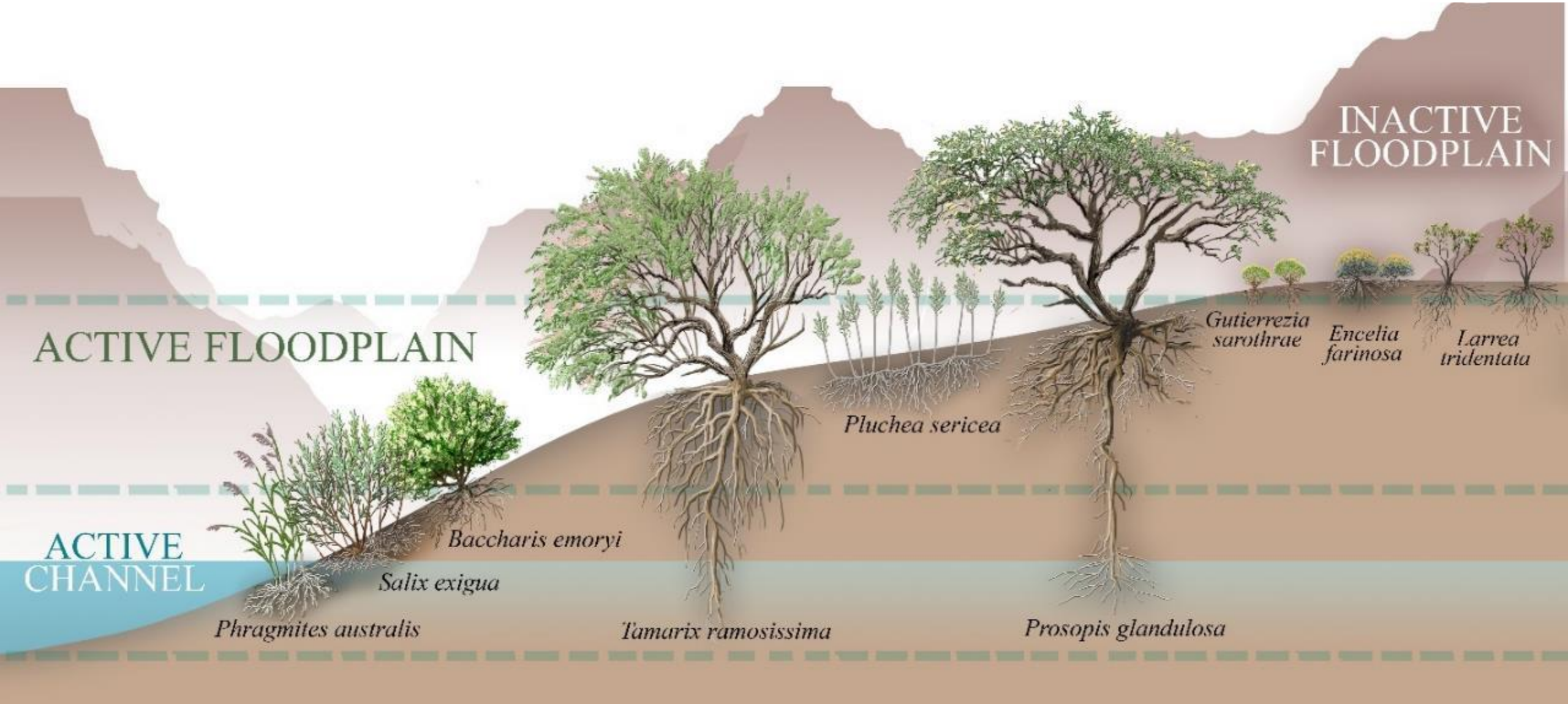
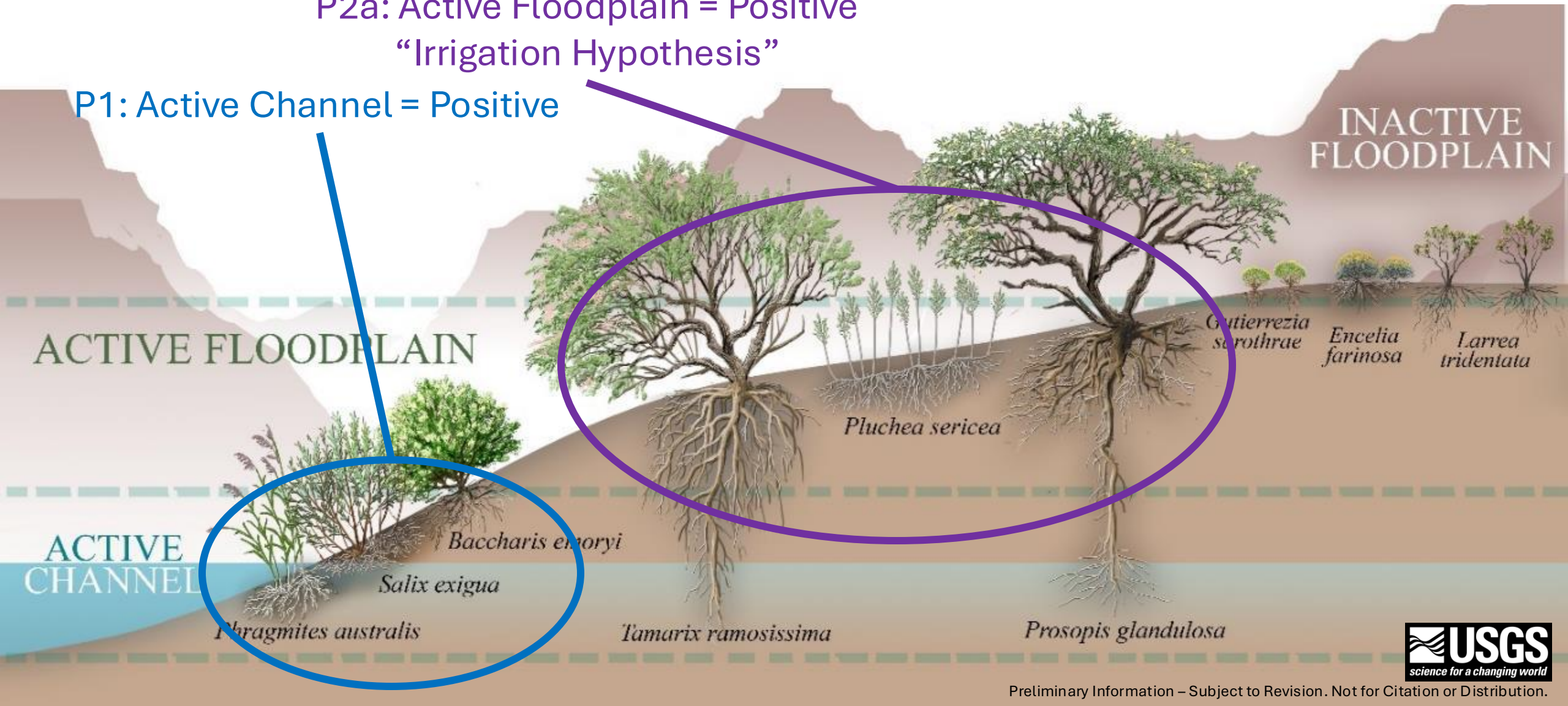
Predicted Responses to Daily Fluctuations



Predicted Responses to Daily Fluctuations

P2a: Active Floodplain = Positive
"Irrigation Hypothesis"

P1: Active Channel = Positive



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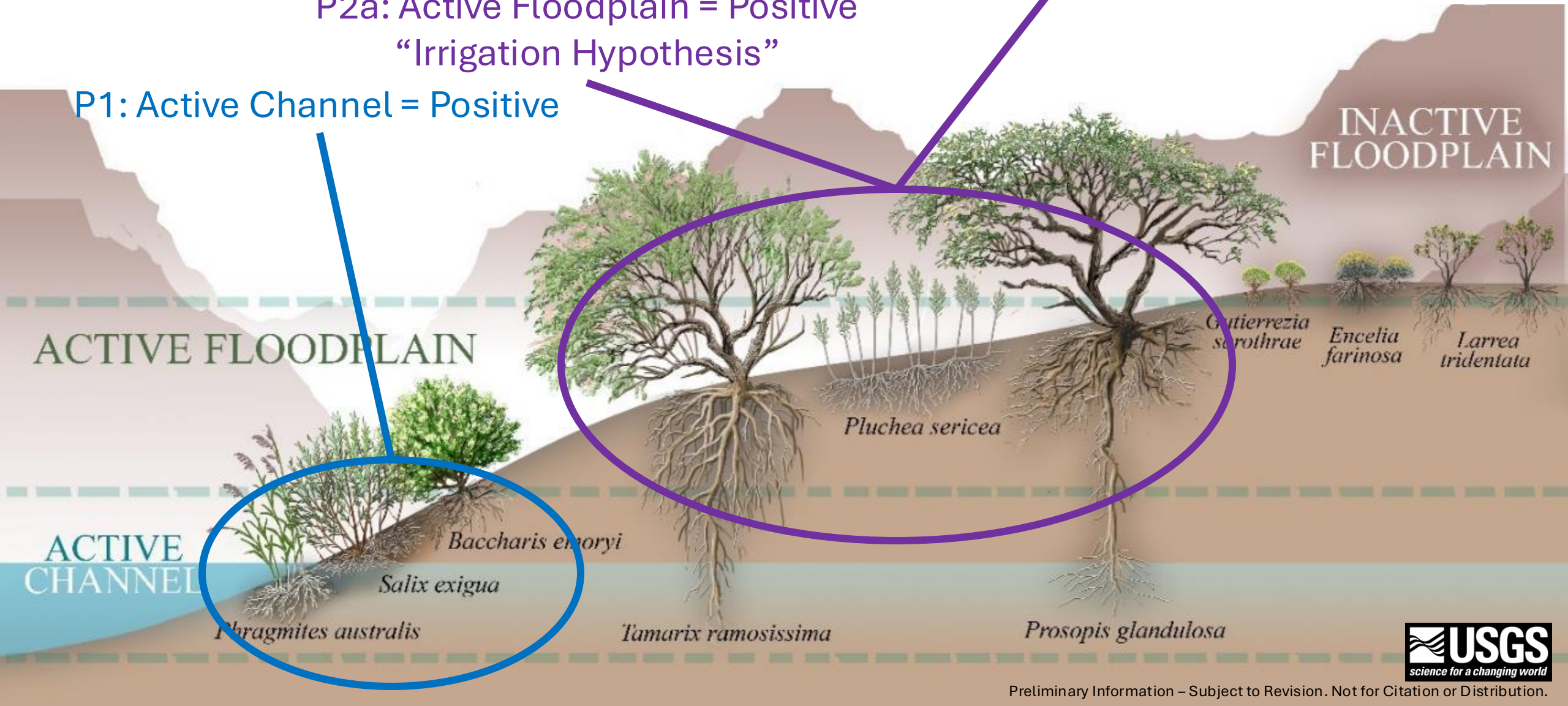
Predicted Responses to Daily Fluctuations

P2b: Active Floodplain = Negative
"Exclusion Hypothesis"

P2a: Active Floodplain = Positive
"Irrigation Hypothesis"

P1: Active Channel = Positive



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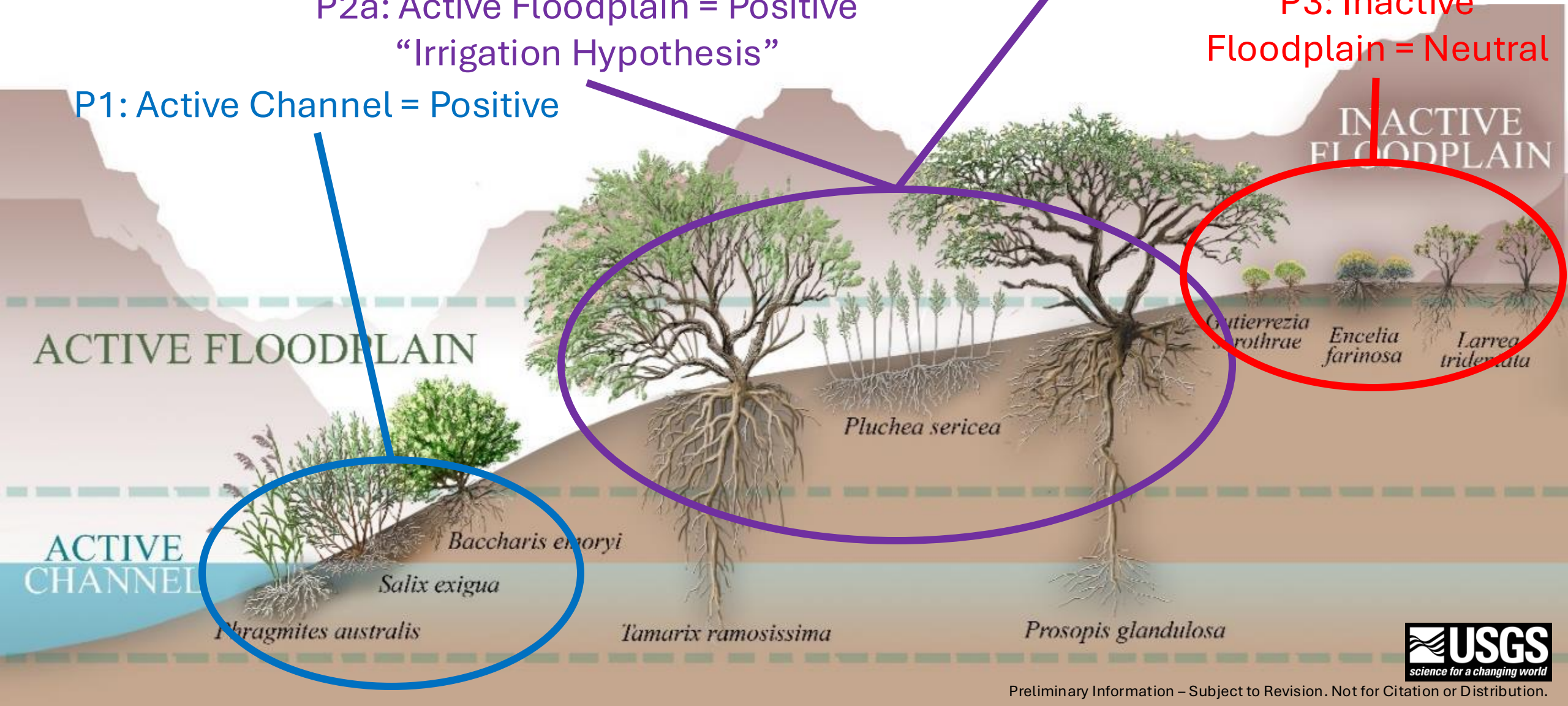
Predicted Responses to Fluctuations

P2b: Active Floodplain = Negative
"Exclusion Hypothesis"

P2a: Active Floodplain = Positive
"Irrigation Hypothesis"

P3: Inactive Floodplain = Neutral

P1: Active Channel = Positive



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How to Isolate Effects of Daily Fluctuations?

Photo credit: Brad Butterfield

Experiments in controlled environments

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How to Isolate Effects of Daily Fluctuations?

Sweden

Photo credit: Brad Butterfield

Paired un/regulated rivers

Bejarano and others (2018b) *J. Appl. Ecol.*

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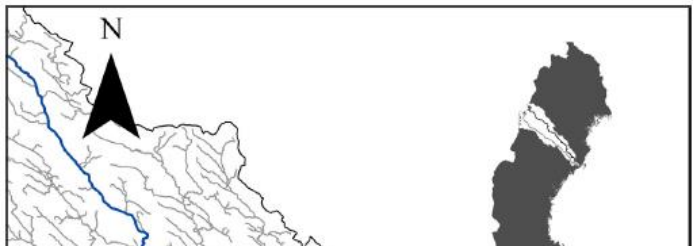
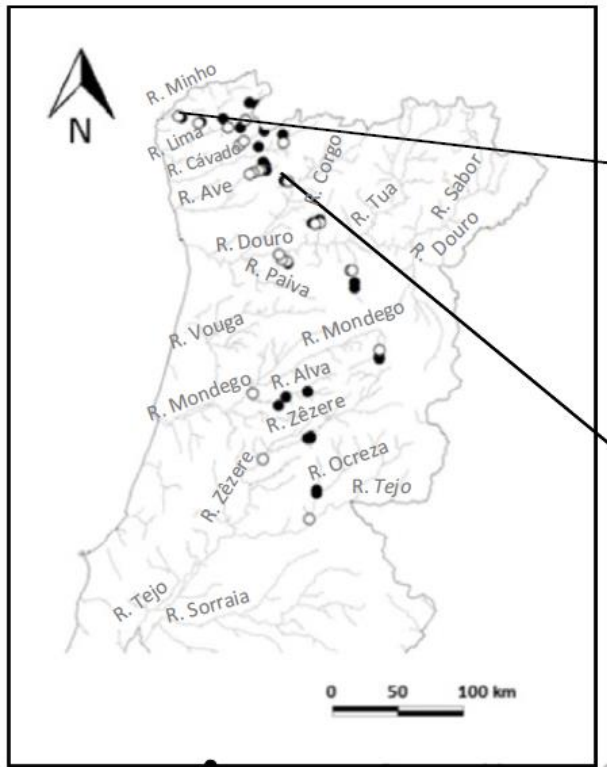
How to Isolate Effects of Daily Fluctuations?

Many un/regulated rivers within a region

N. Portugal





Aguiar and others (2018) *J. Appl. Ecol.*

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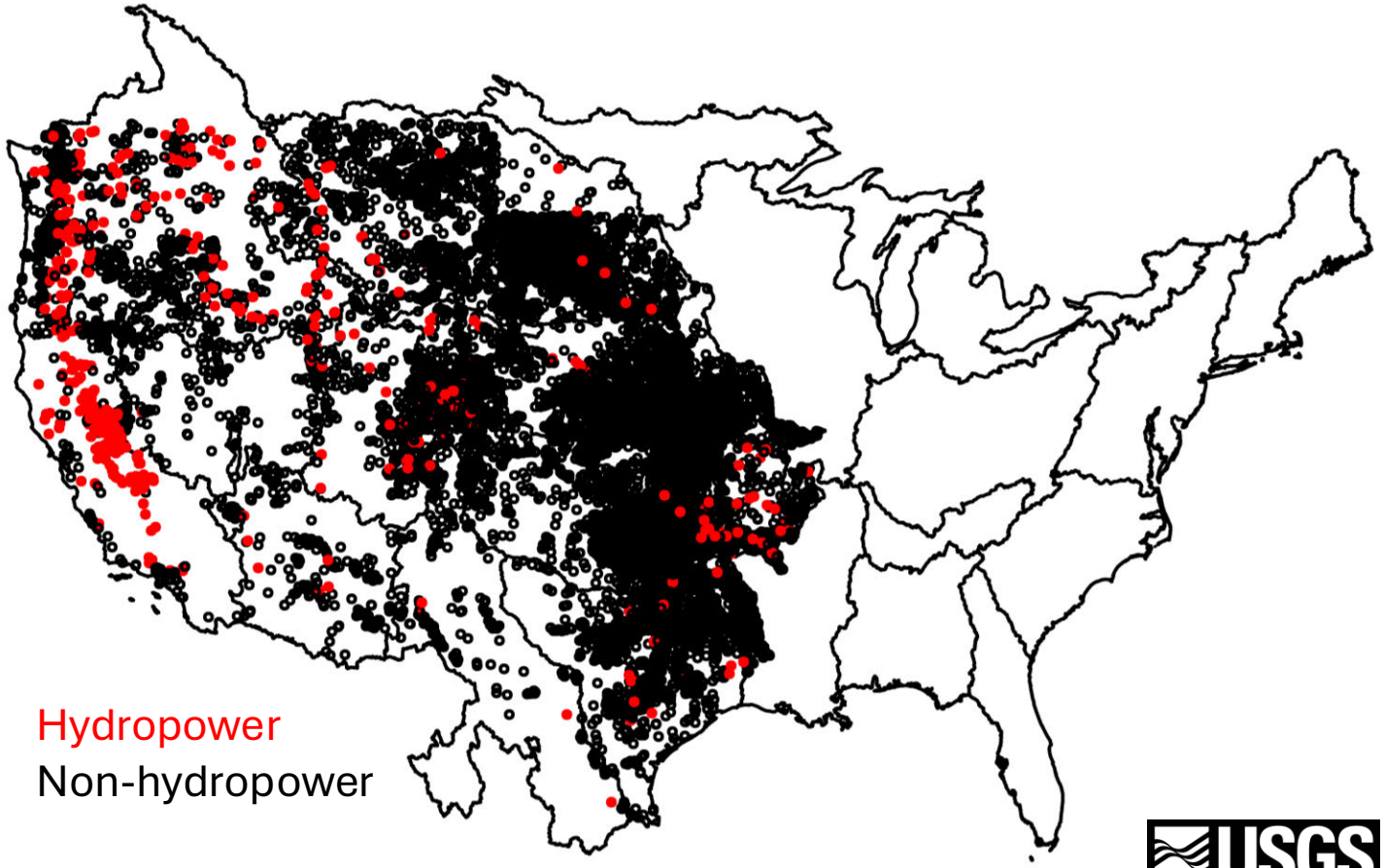
Study Region: Western US

- National Inventory of Dams
  - >21,000 dams
  - 572 hydropower dams
- National Hydrography Database
  - Identify stream segment associated with each dam
- USGS Streamgaging Network
  - Extract sub-daily flow data where available



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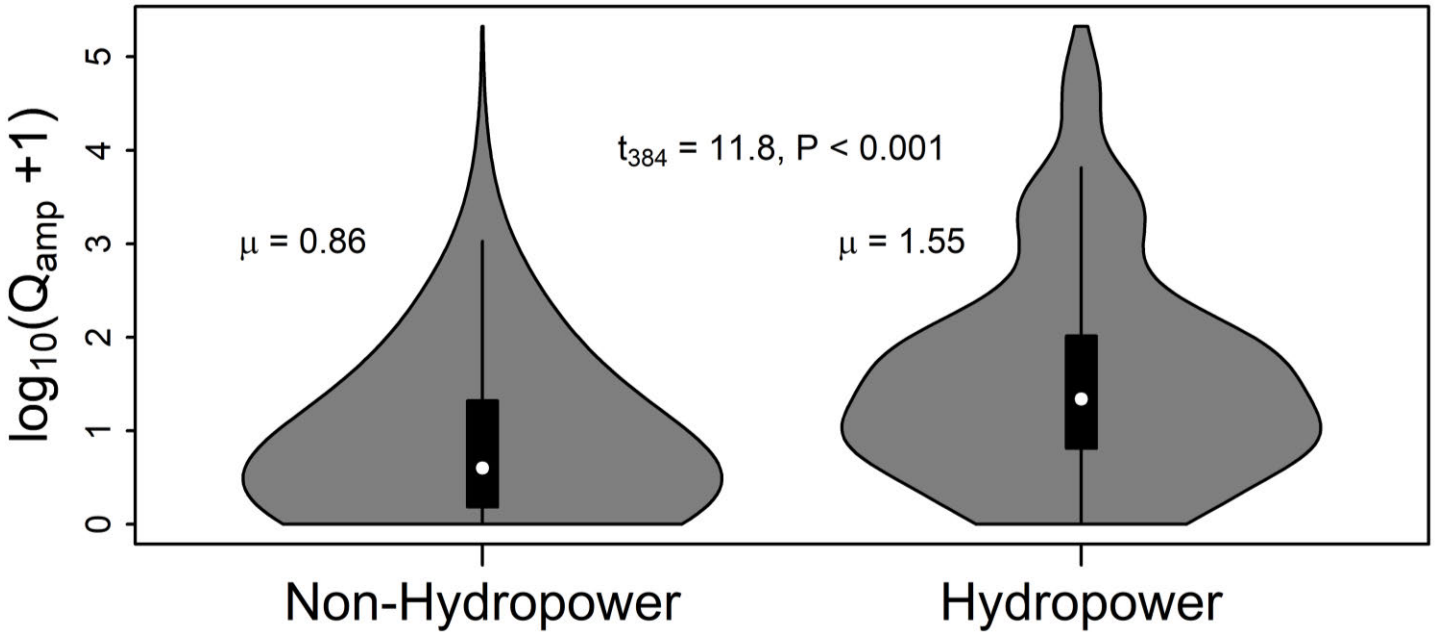
Daily Fluctuation Index: Amplitude of Daily Flow Fluctuations

- Gages downstream of hydropower dams have nearly an order of magnitude greater magnitude of daily fluctuations than downstream of non-hydropower dams
- Included daily mean flow in models too



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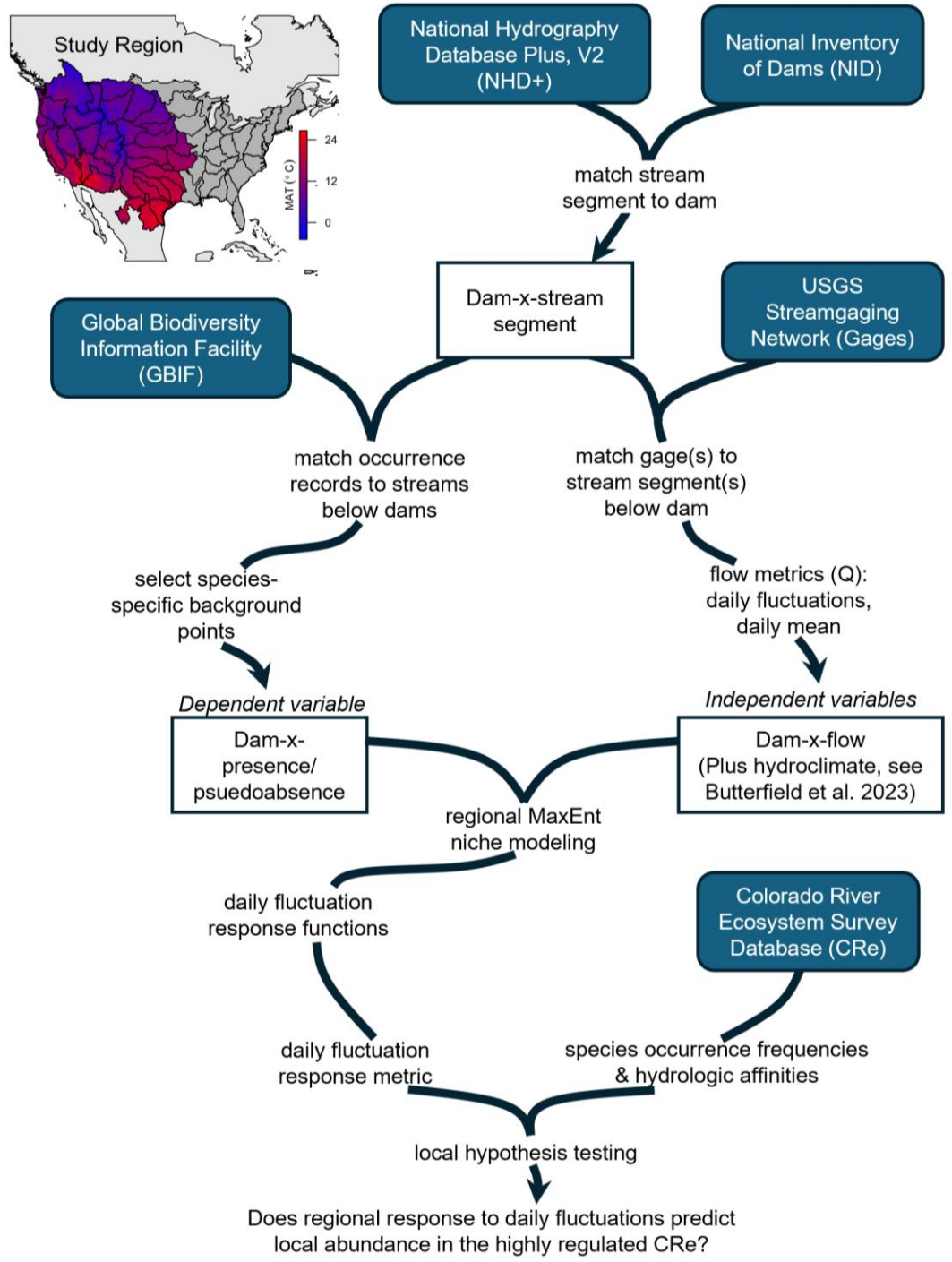
Analytical Pipeline

- Climate and streamflow data (Q_{amp} and Q_{mean}) for each river segment wit sub-daily gage data
- Match to plant occurrence records associated with stream segments (Butterfield and others, 2023 *RRA*)
- Quantify relationships between species occurrences and daily fluctuations (while accounting for other variables)



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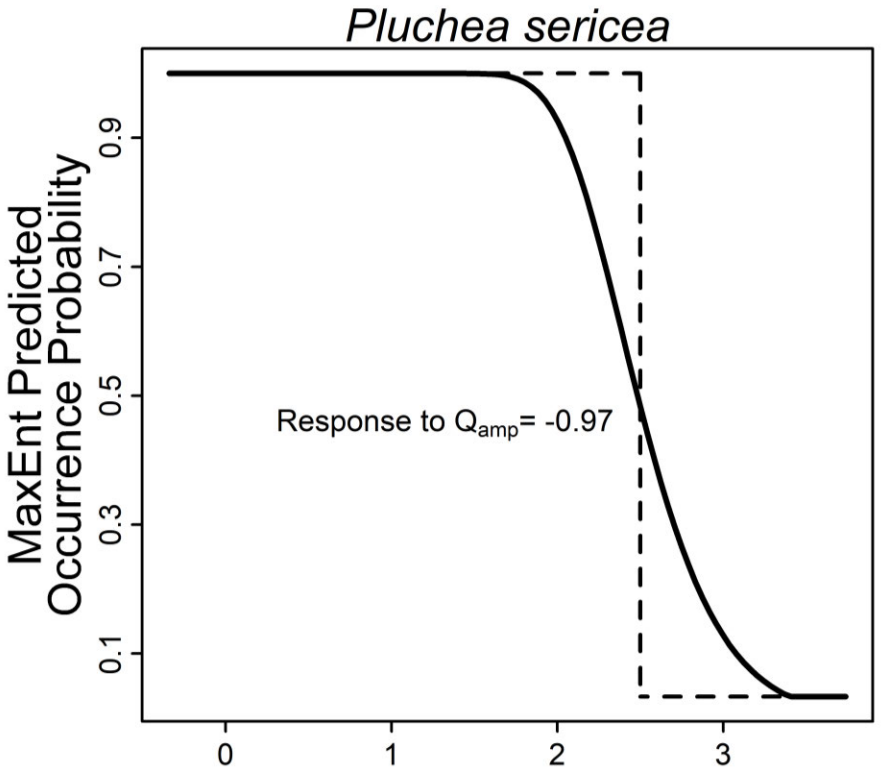
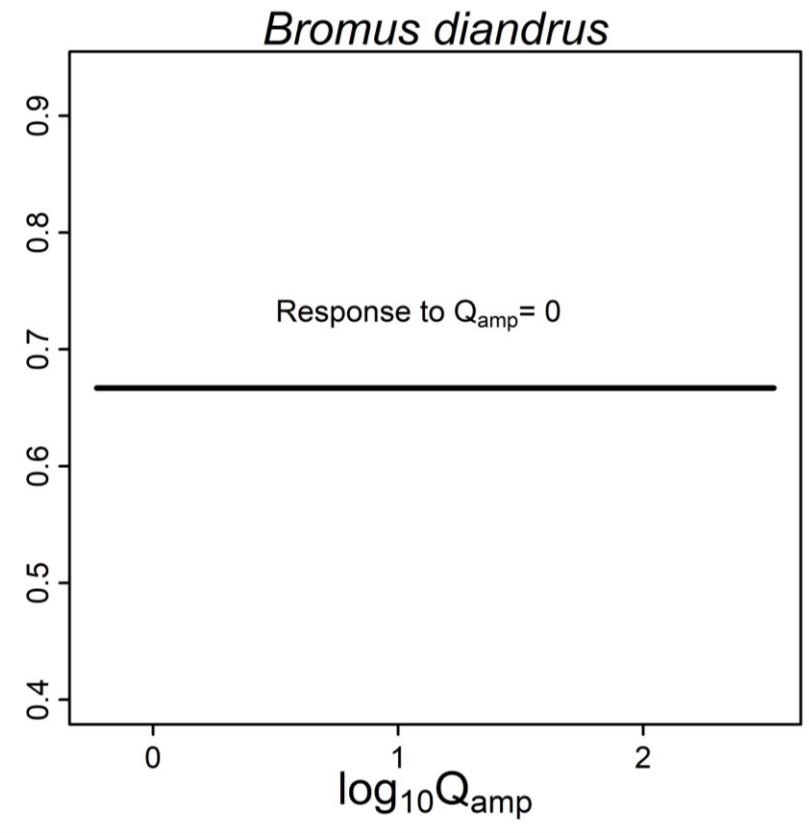
Example Modeled Responses to Daily Fluctuations

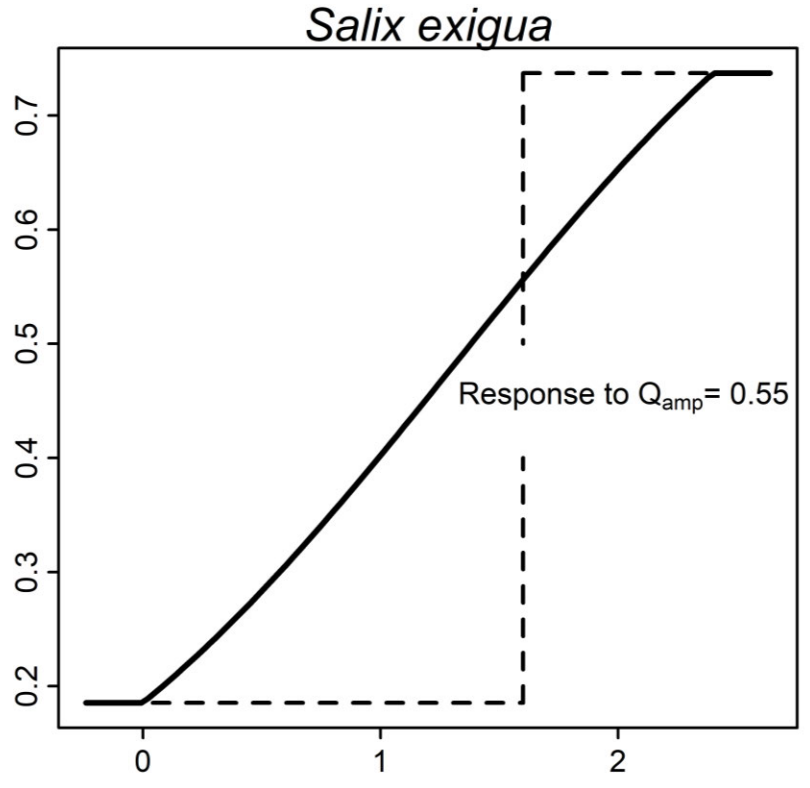
Negative



Neutral



Positive



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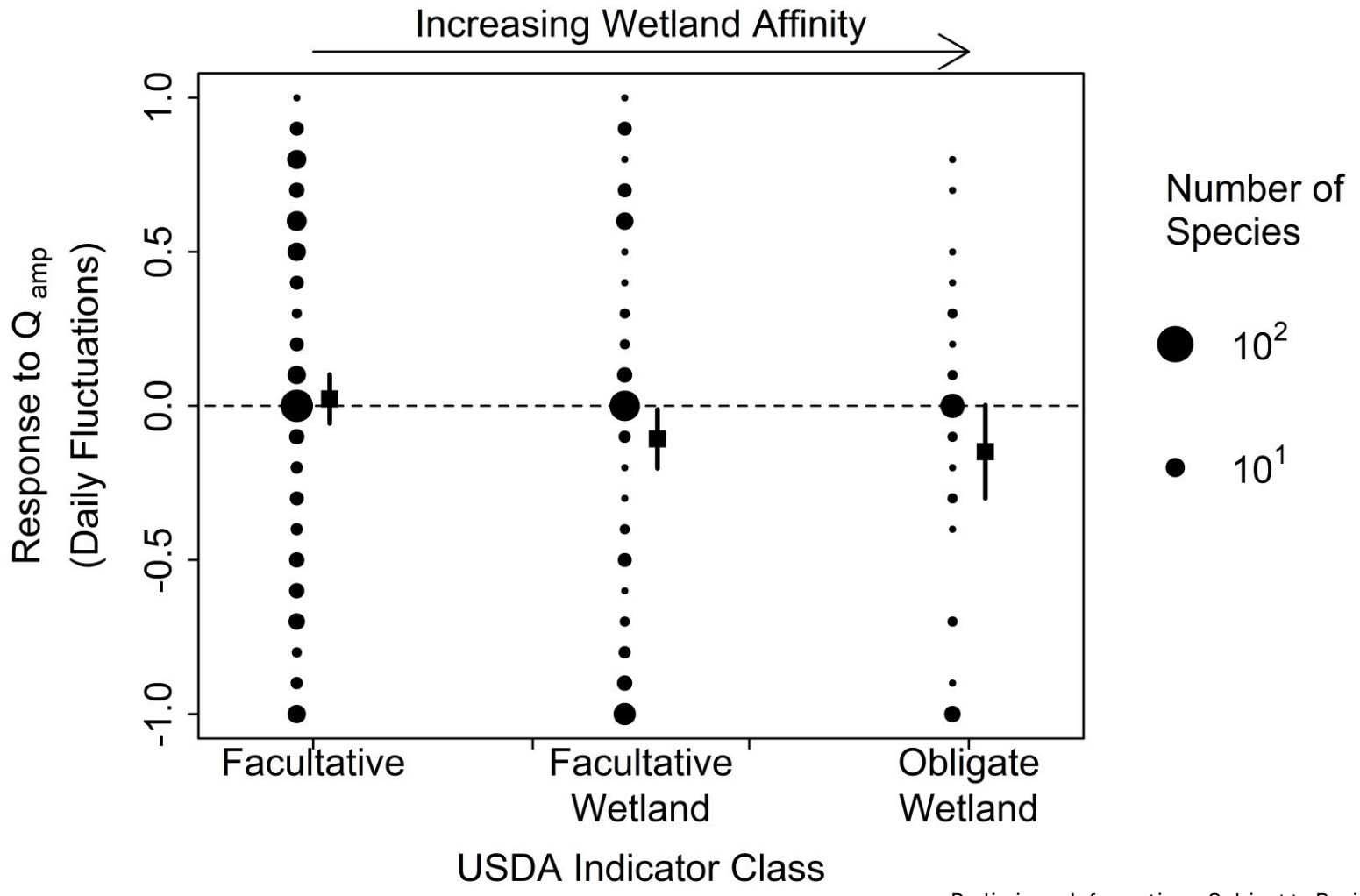
Response to Daily Fluctuations is Negatively Correlated with Wetland Affinity at Regional Level



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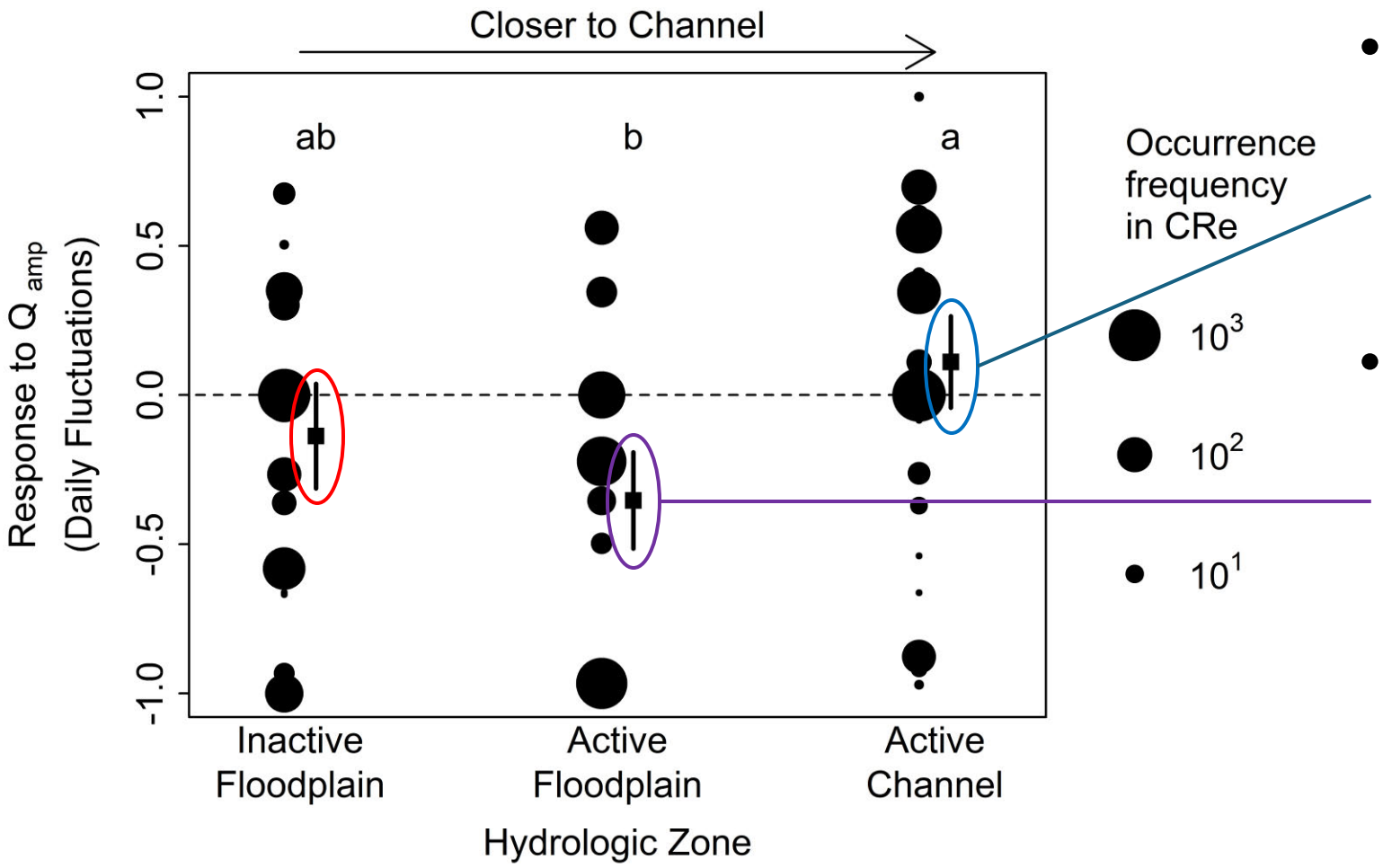
Response to Daily Fluctuations Varies among Hydrologic Zones in CRe



- Most species in daily inundation zone have positive responses to daily fluctuations
- Species immediately above daily inundation zone have negative responses to daily fluctuations
  - Supports “exclusion” hypothesis, refutes “irrigation” hypothesis

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Results Recap

- On average, species across the West have negative responses to daily fluctuations, and it increases with wetland affiliation, though there is SUBSTANTIAL variation
- In the CRe, prevalent species in the Active Channel tend to respond positively to daily fluctuations
  - The long history of daily fluctuations in the CRe has likely selected for these species that can tolerate daily inundation
- In the CRe, prevalent species in the Inactive Channel respond negatively to daily fluctuations
  - Suggests that they may be excluded from otherwise suitable habitat near the channel

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Species of Interest: Active Channel

- Coyote willow, horsetail and mule fat all had strong positive responses to daily fluctuations and are abundant in the Active Channel
- Criteria for daily fluctuation tolerance (Bejarano and others, 2018a)
  - Clonality, easy dispersal, flood tolerance, flexibility
- Common reed, Emory's baccharis and Western goldenrod had neutral daily fluctuation responses
  - Other aspects of river regulation may be promoting their prevalence in the Active Channel of the CRe

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Species of Interest: Inactive Channel

- Negative daily fluctuation responses of two dominant species: Arrowweed and salt cedar
- Salt cedar: negative effects of daily fluctuations on recruitment?
  - Mature plants are highly tolerant of both drought and inundation
  - Reproduce from seeds, which germinate following floods, but are not tolerant of flooding for several years after (Cooper and others, 2003)
- Arrowweed: physiology maladapted to daily fluctuations?
  - Root growth inhibited by inundation (Butterfield and Palmquist, 2023)
  - Conservative growth strategy (Sala and others, 1996) typically results in negative response to daily fluctuations (Aguiar and others, 2018)
  - Prevalence in CRe may be due to sand availability, rather than flow per se

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Species of Interest: Uncommon Trees

- Cottonwood, Goodding's willow and hackberry all had neutral responses to daily fluctuations
- Other aspects of river regulation, particularly the seasonal timing and ramping of floods (Stromberg and others, 1993; Salzer and others, 1996; Mahoney and Rood, 1998), are implicated in the low numbers of these species in the CRe

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Conclusions

- Daily fluctuations may be promoting the expansion of some species like coyote willow and mule fat near the channel
- Conversely, daily fluctuations may be excluding arrowweed and salt cedar from near channel habitat
- This study, as well as previous research on impacts of flow seasonality (Butterfield, Palmquist and Yackulic, 2023), are helping us to isolate impacts of different dimensions of river regulation on riparian plant communities
- Upcoming greenhouse experiments will help us dig deeper into impacts of daily fluctuations on plant establishment and survival

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