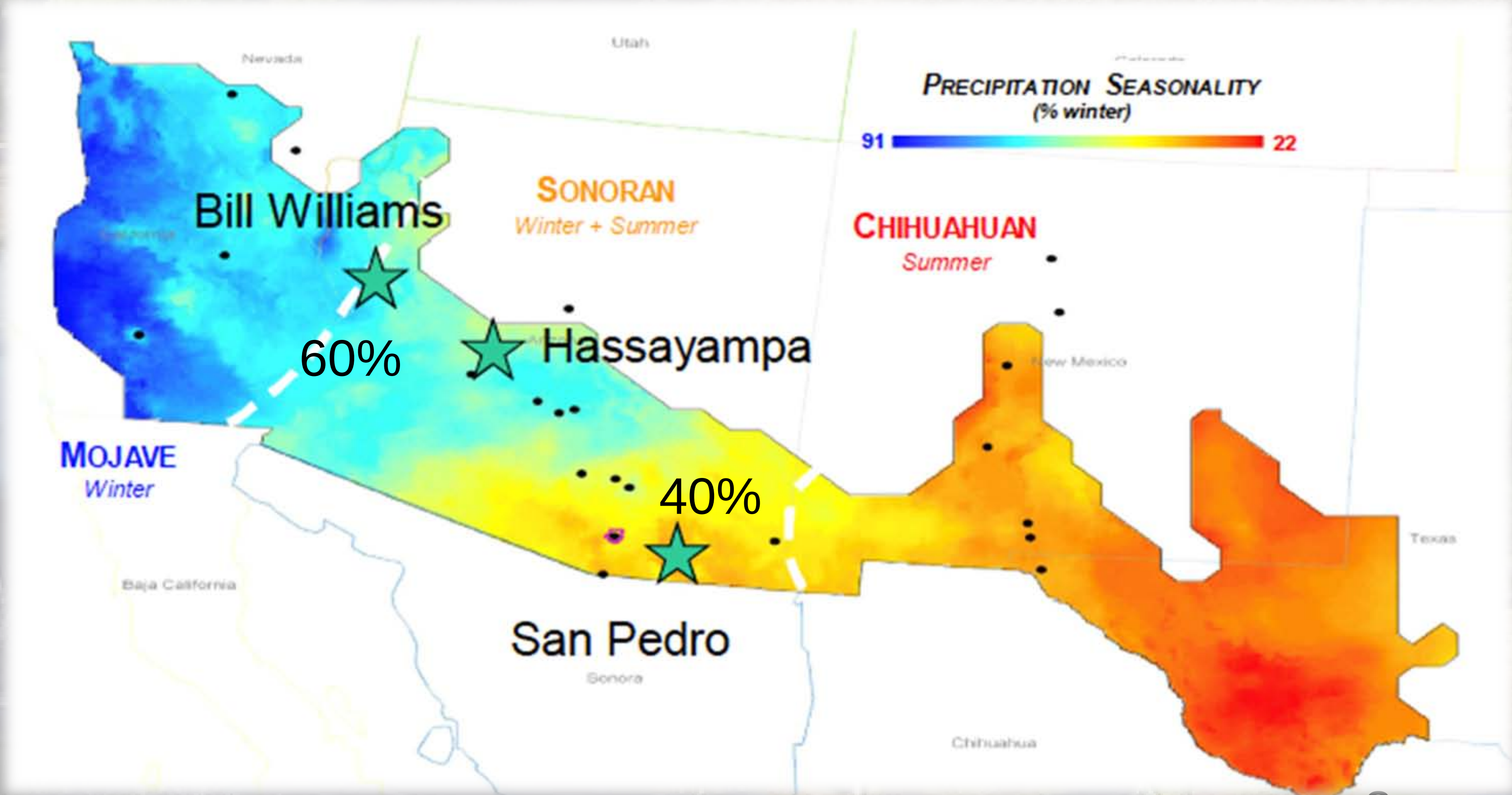
Hydrologic Thresholds for Biodiversity in Arid and Semiarid Riparian Ecosystems: Importance of Climate Change and Variability

Tom Meixner and James Hogan,
University of Arizona
Julie Stromberg,
Arizona State University

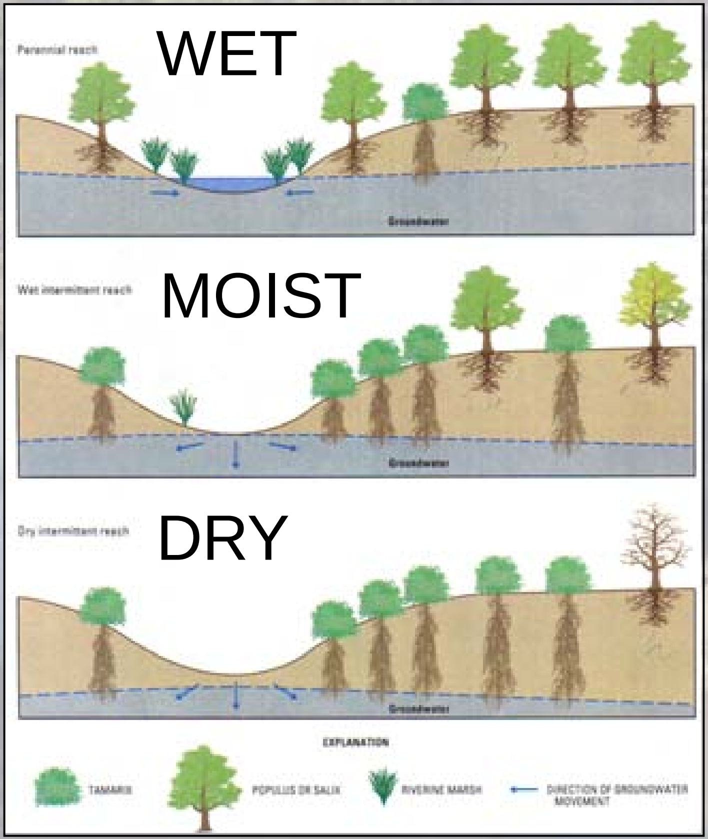
Project Goals - Hypotheses

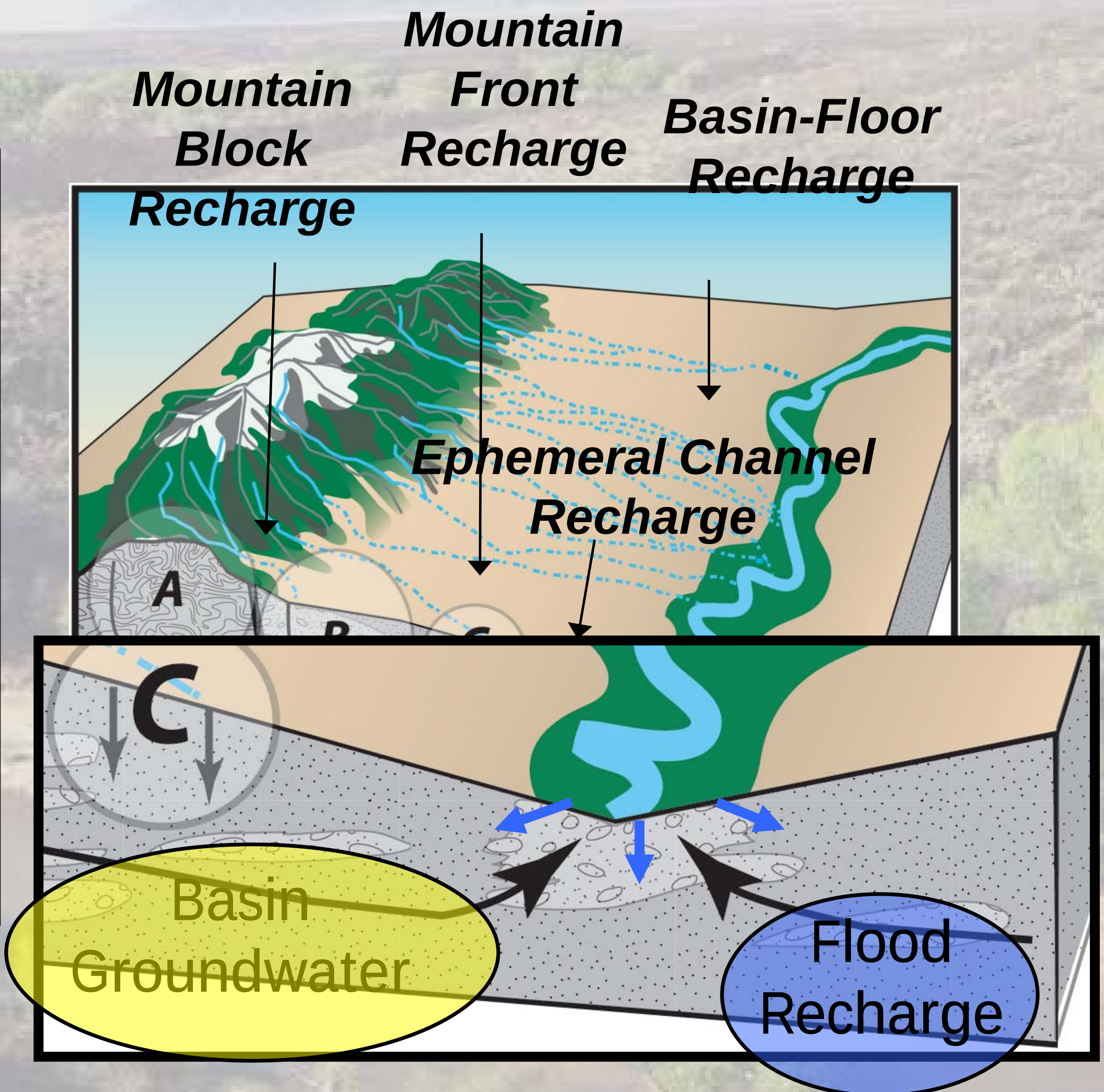
1) *Decadal scale climate change and variability alter riparian aquifer recharge through mechanisms that depend on the magnitude, frequency and seasonality of flooding, and exert the greatest change in reaches that receive minimal groundwater inflow from the regional aquifer.*
2) *Riparian vegetation structure responds non-linearly as riparian aquifers are dewatered and as key hydrologic thresholds for survivorship of plant species are exceeded.*
3) *Decadal scale climate variability and change alters riparian ecosystem water budgets that in turn change vegetation structure and function and the ecosystem services provided to society.*

Precipitation Seasonality has important implications for hydrology of riparian systems

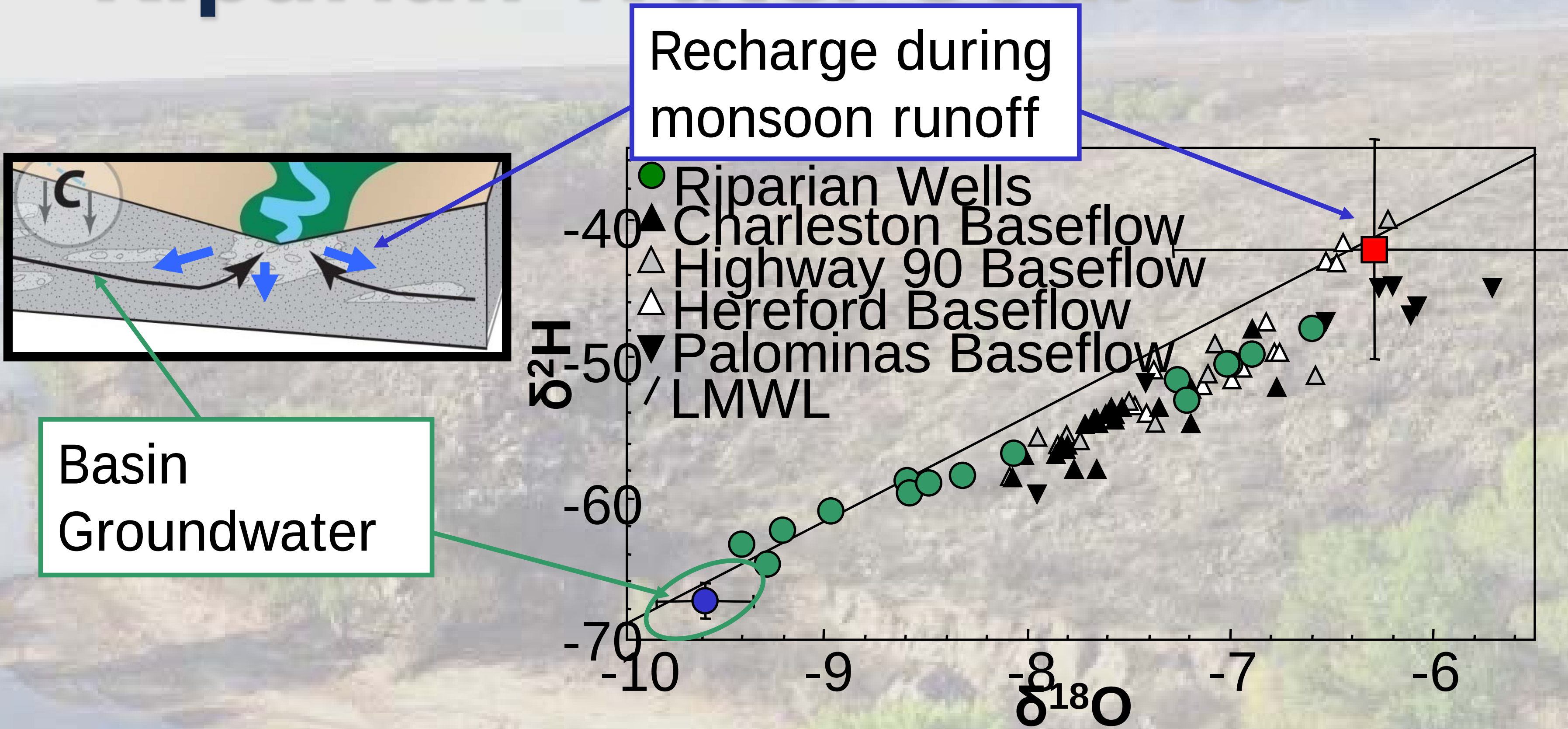


Water availability controls biological conditions in riparian zone





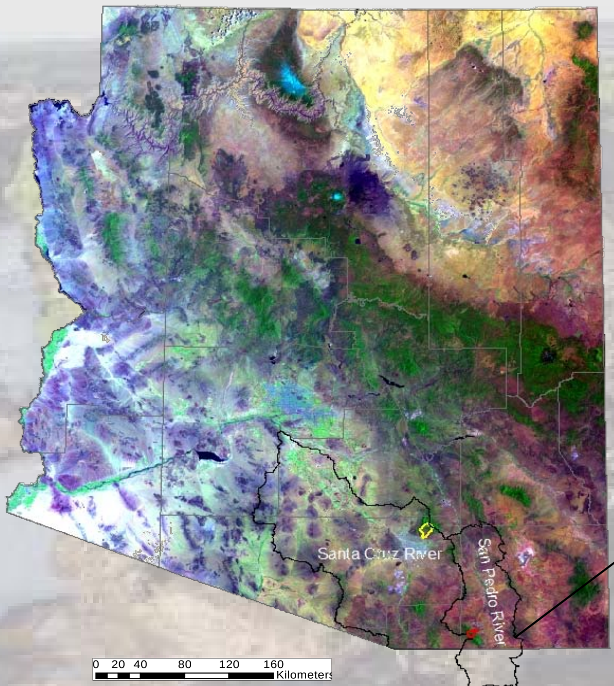
Riparian Water Sources

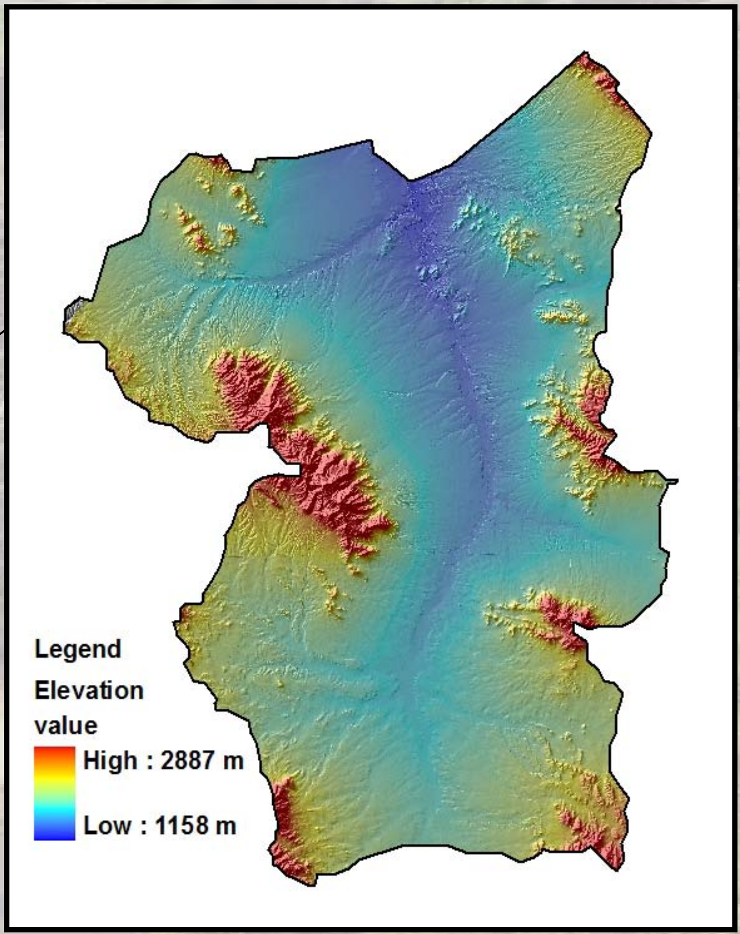


- Isotopes of water – natural tracer of source
- Riparian wells span range between end members
- Roughly 50% of San Pedro river water is flood recharge
- Mountain system recharge has very long travel times
- Flood recharge is much more variable (susceptible)

Baillie et al., 2007 JGR

Study site: Upper San Pedro Basin, AZ

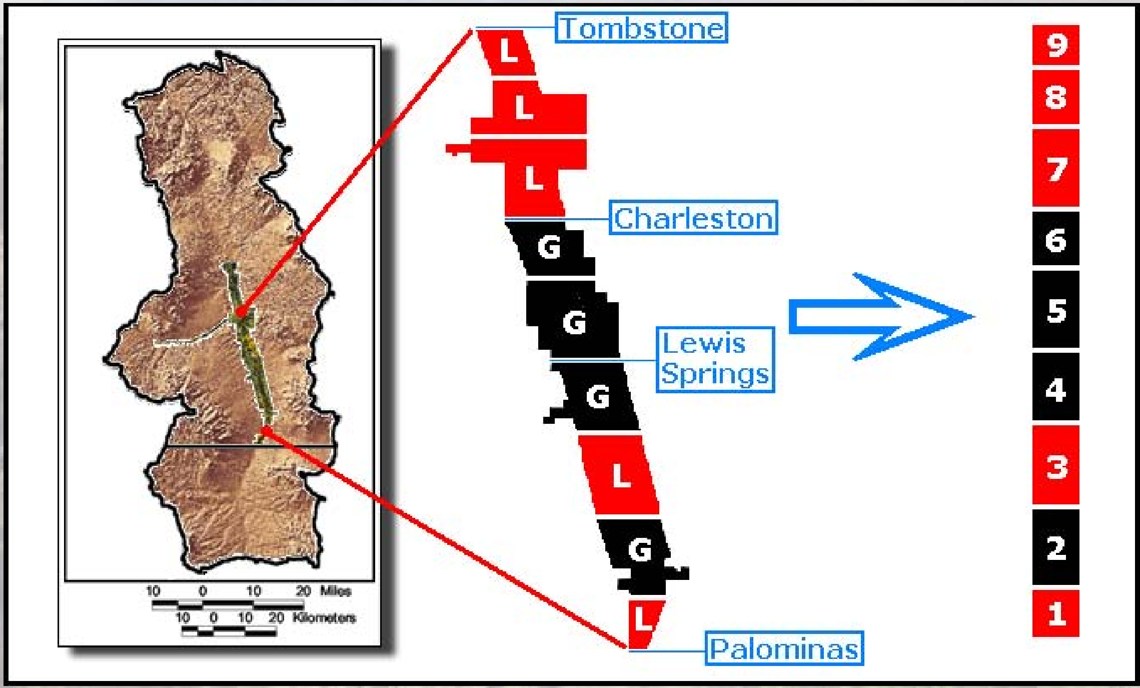




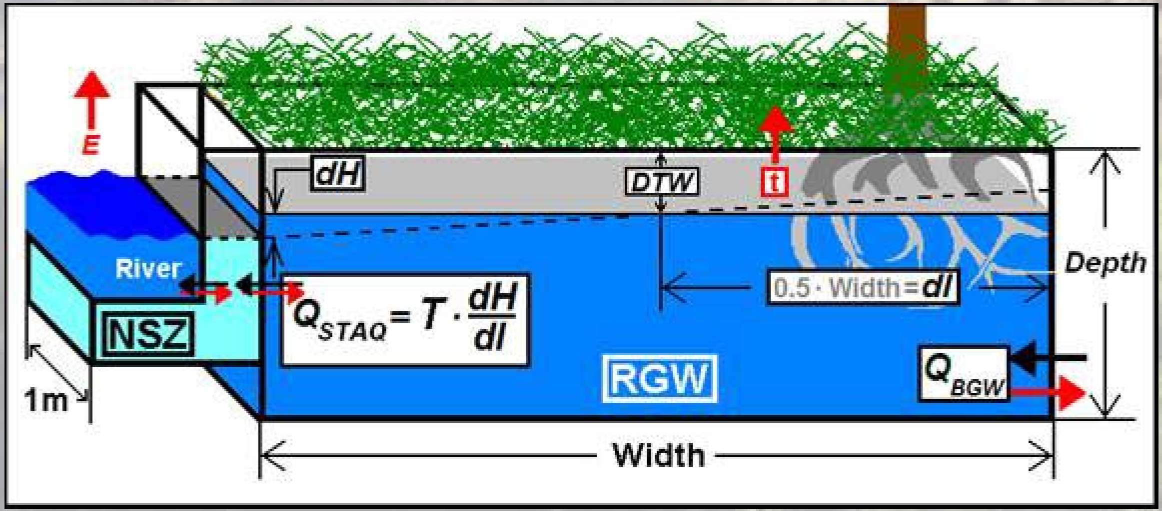
http://abell.as.arizona.edu/~hill/4x4/espiritu/

The Upper San Pedro basin is about 4500 km^2 with mean annual precipitation of 41 cm. Historically, July through September are the wettest months.

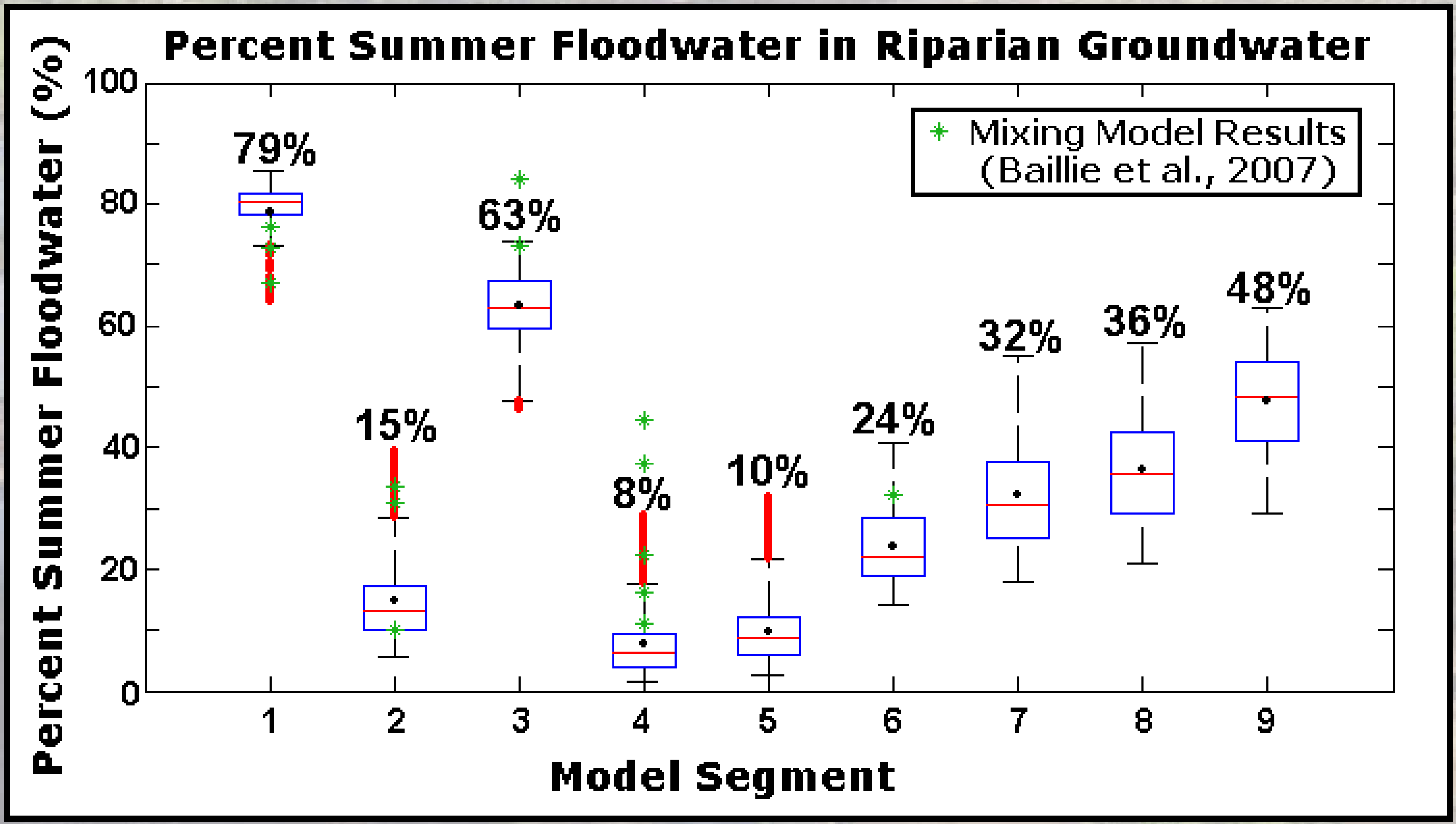
Flood recharge model simulates gaining and loosing reaches



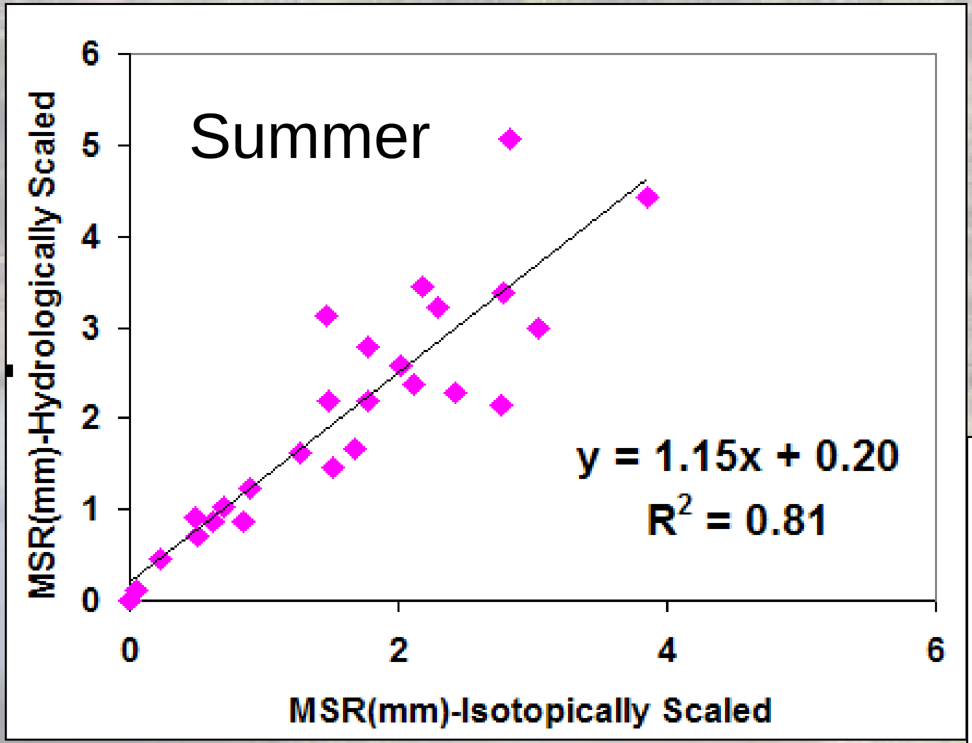
Gradient driven exchange



Flood recharge model reproduced earlier results for 10 yr. sim. period



Comparison between hydrologically & isotopically scaled recharge (MSR)



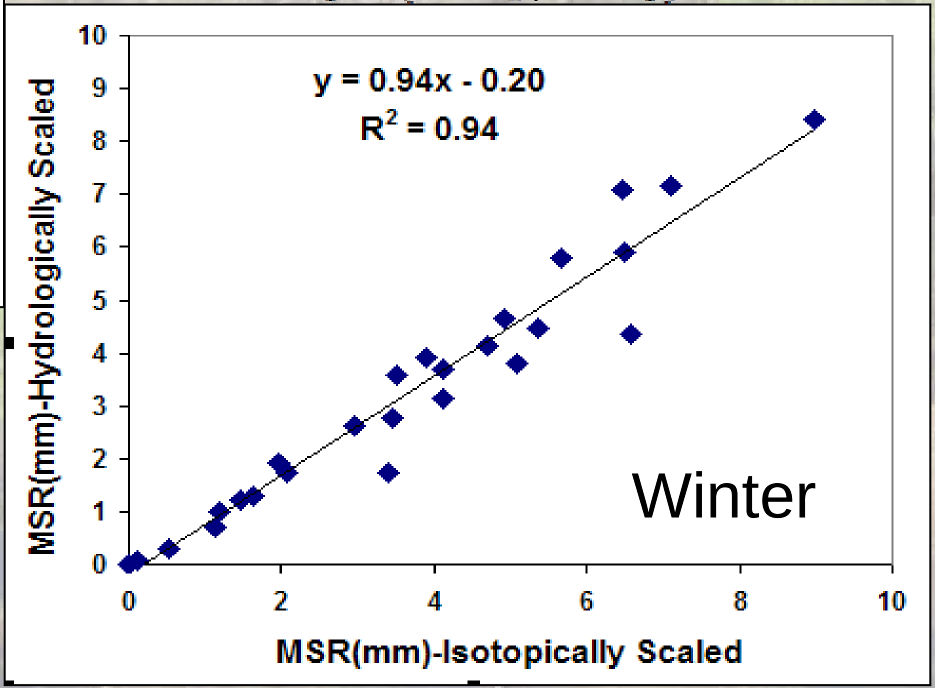
Annual Recharge - Empirical

$$\mathrm{Log}(MSR_a) = -1.4 + 0.98\log(P_a)$$

Normalized Seasonal Wetness Index - to Seasonalize

$$\frac{MSR_w}{MSR_s} = \left(\frac{P_w / P_s}{AET_w / AET_s} \right)$$

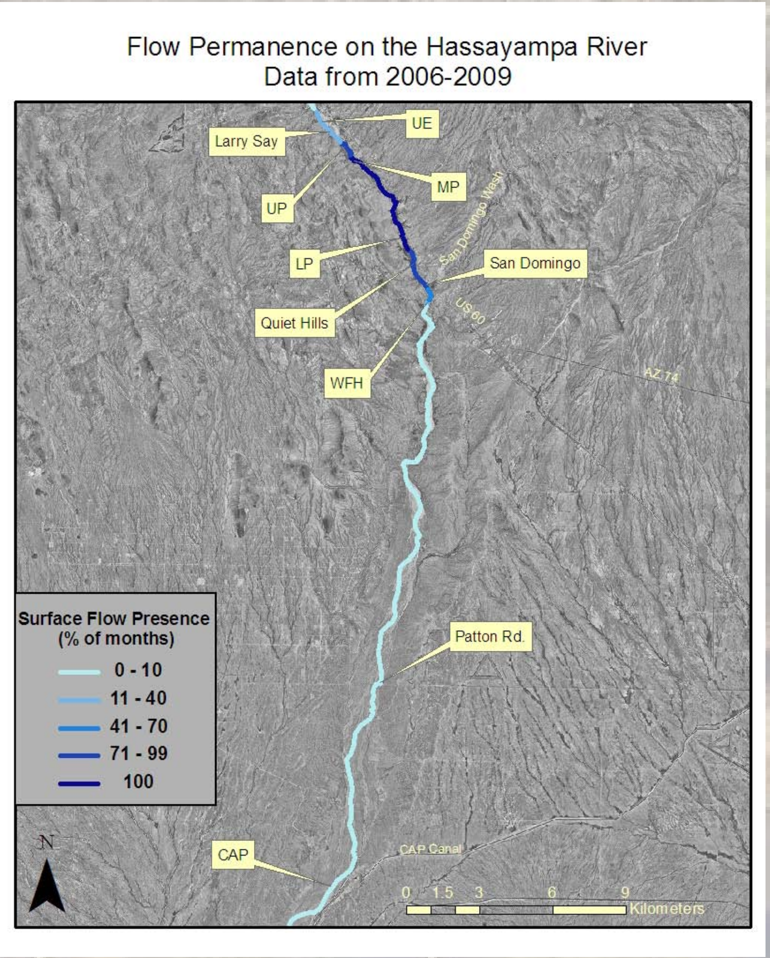
Incorporating ET values enhanced MSR predictions especially for summer season.



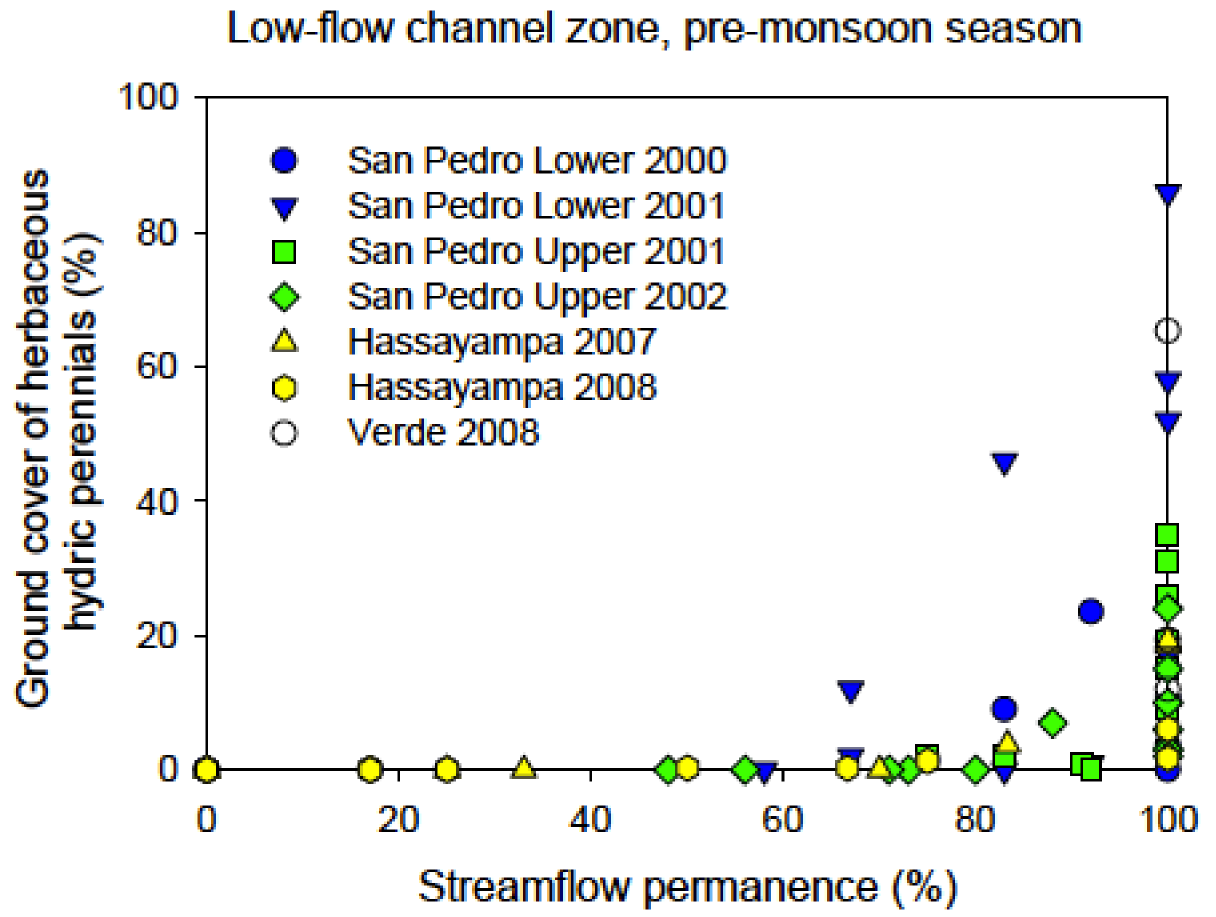
Threshold #1: Flow permanence and decline of hydric herbaceous plants

Problem statement: The regional uniformity of the response of riparian vegetation to declines in stream flow permanence is unknown.

Methods:
Surface flow monitored monthly for presence/ absence at ephemeral to perennial sites at multiple rivers;
Vegetation sampled along active channel.



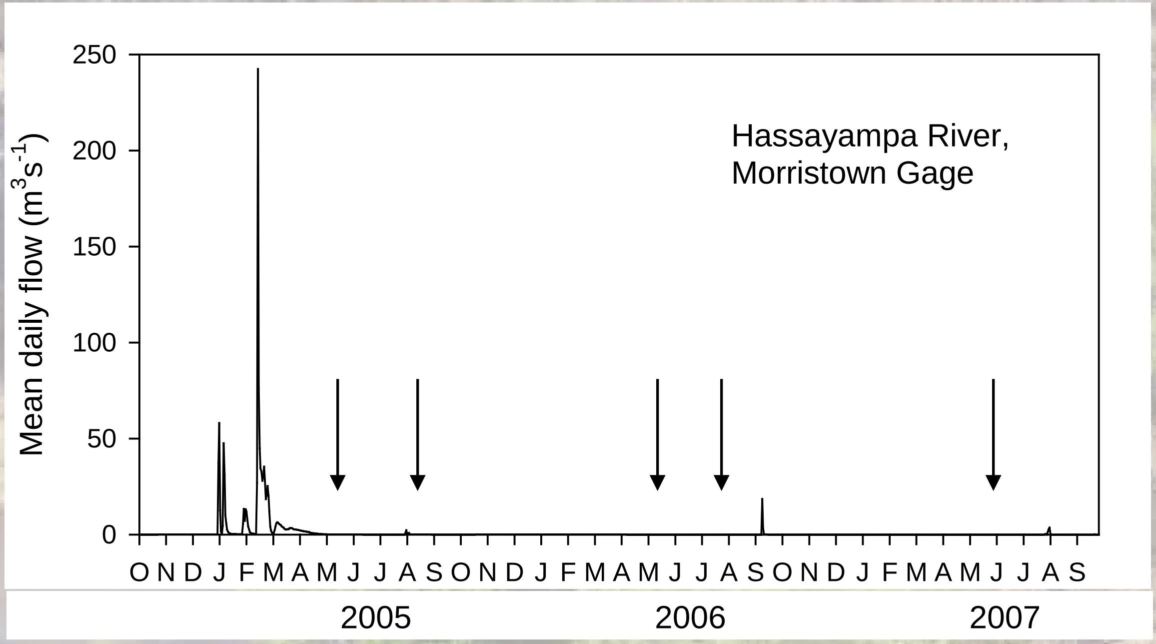
Results: Wetland perennial herbaceous plants show consistent pattern of sharp decline in abundance as stream flow becomes non-perennial



Conclusion: Abundance of a key stream community type (riverine marshland) will decline with increasing aridity

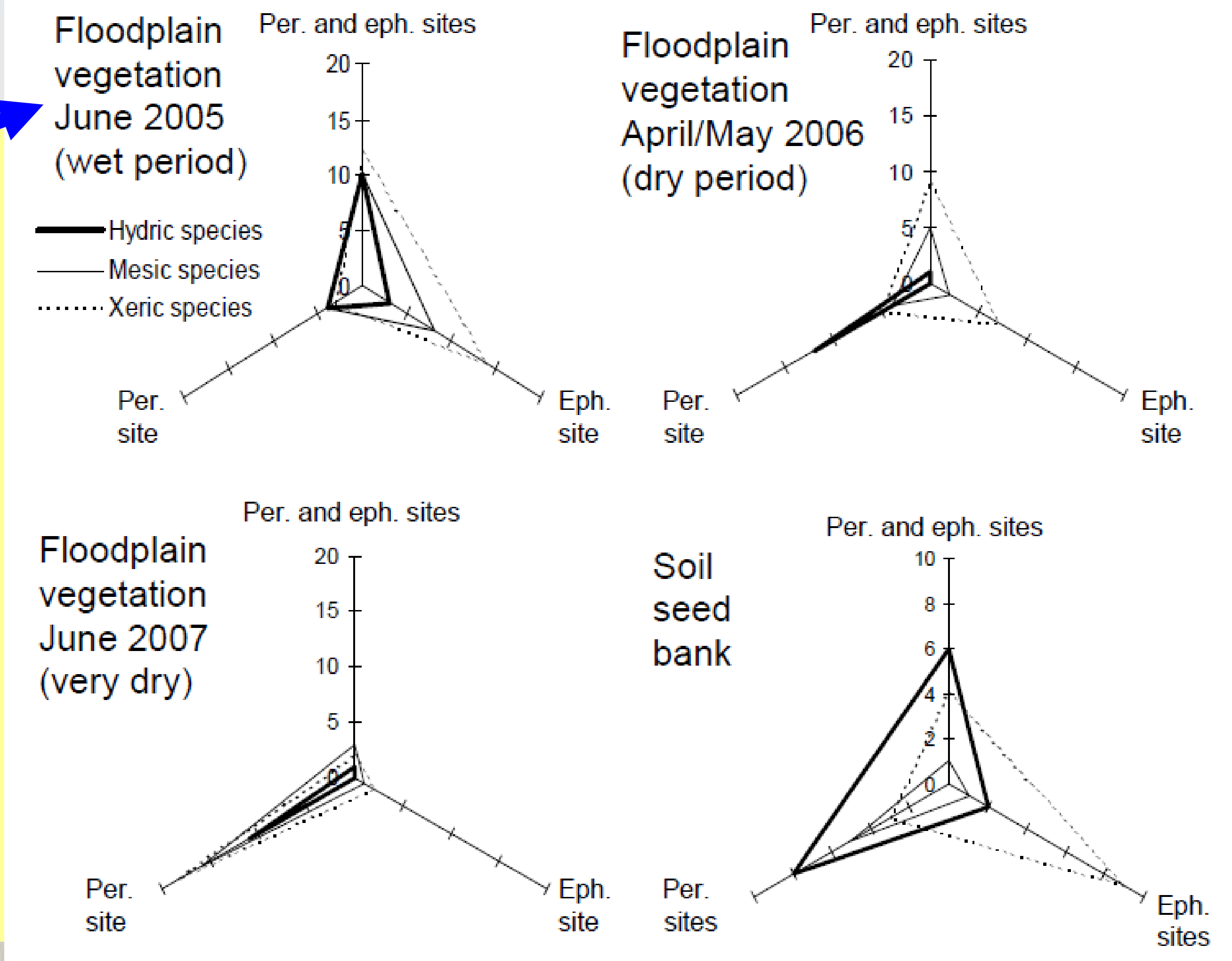
Problem statement: Temporal and spatial response of streamside vegetation to fluctuations in stream flow poorly known.

Methods: Multi-year field monitoring of vegetation (and soil seed banks) at ephemeral, intermittent, and perennial sites through wet-dry period.



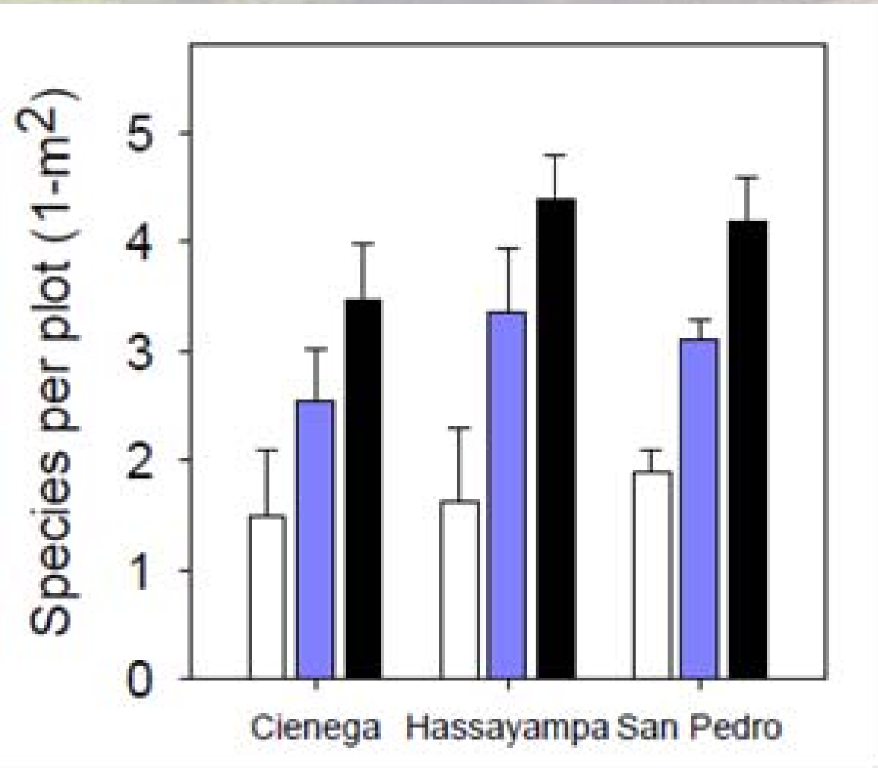
Stromberg JC, AF Hazelton, MS White, JM White, RA Fischer. 2009 (expected). Ephemeral wetlands along a spatially intermittent river: Temporal patterns of vegetation development.

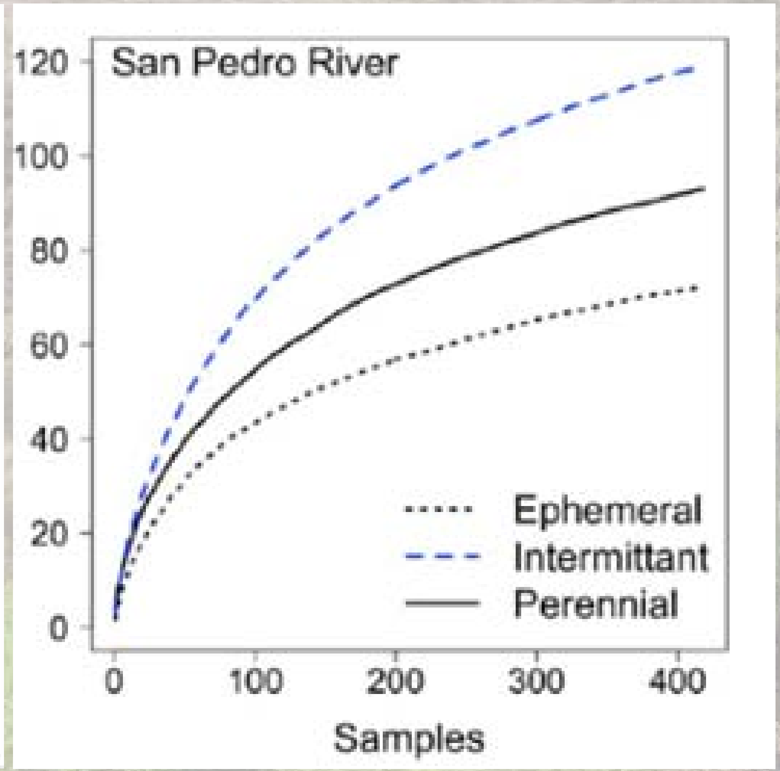
Results: In years with wet winters, flood runoff sustains flows at ephemeral sites, allowing for development of "ephemeral wetlands"



The "spider" charts show numbers of hydric, mesic, and xeric plant species present only at a perennial site, only at an ephemeral site, or at both hydrologic site types, during different years.

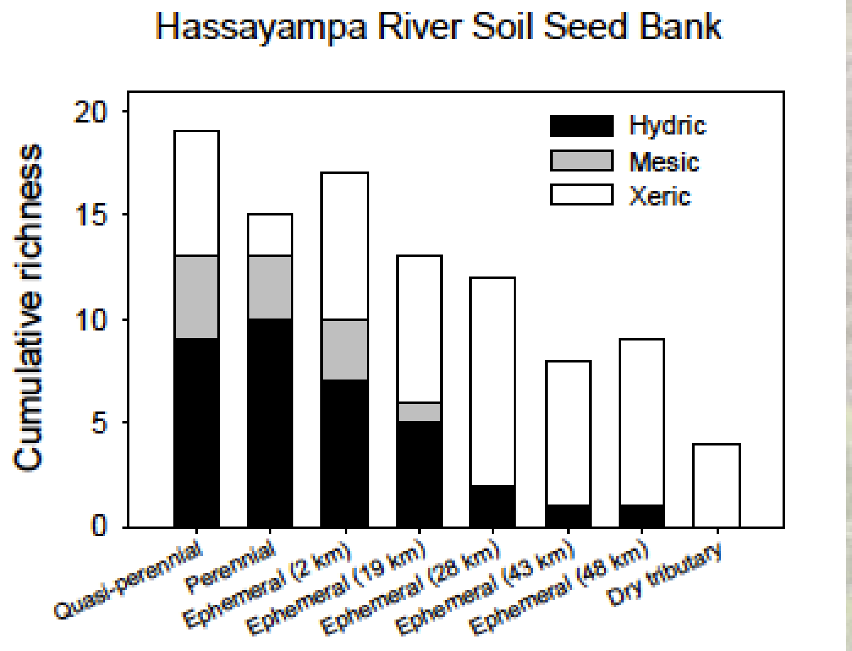
Variability in water availability over time drives variability in biotic diversity





Soil seed banks provide resilience, allow distinct plant communities to develop in years with varying flow conditions.

Diversity of seed banks influenced by proximity to perennial reach.



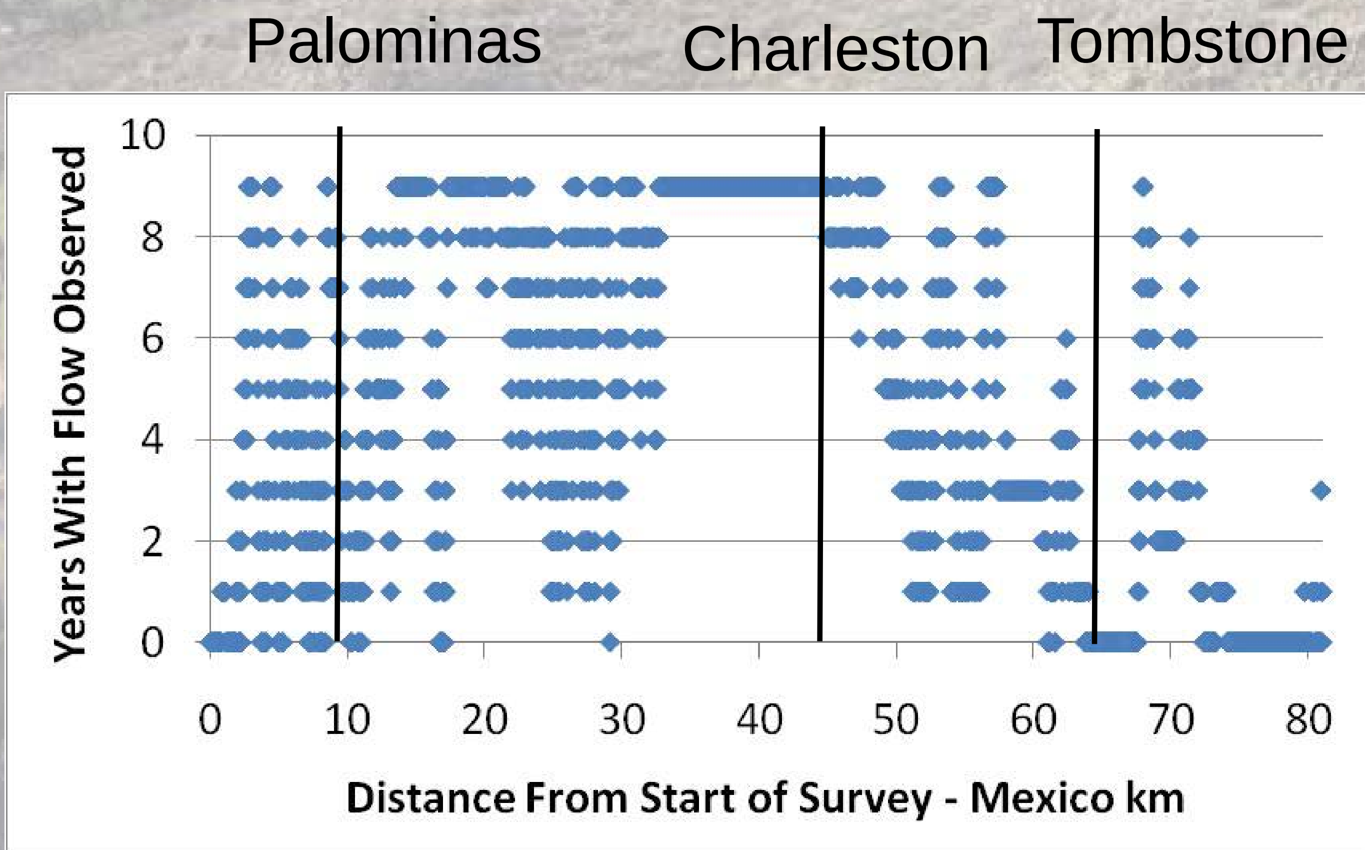
Density and diversity of wetland species in soil seed banks of ephemeral reach decline with distance downstream from a perennial reach

Conclusion: Spatial distribution of wet and dry reaches influences vegetation response to stream flow changes.

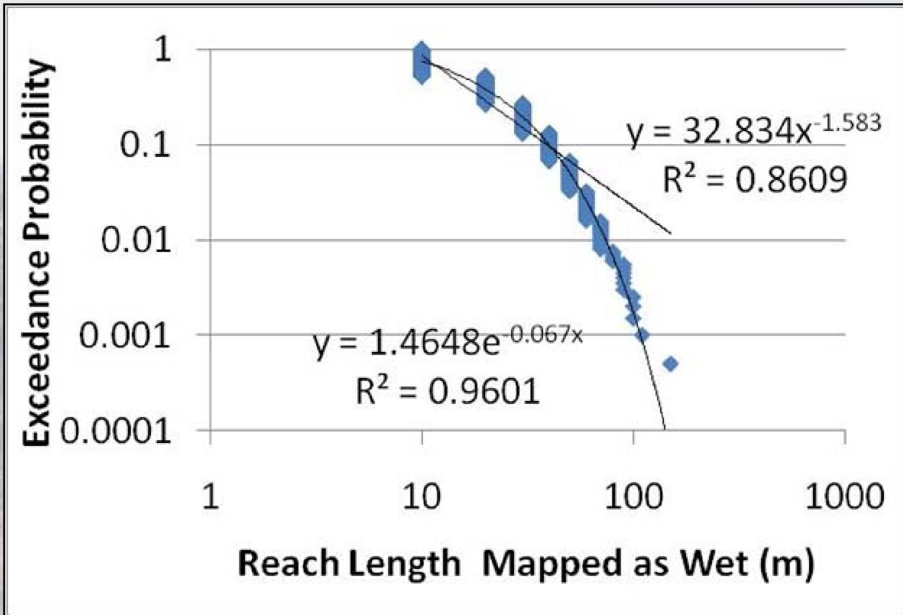
Citizen Wet Dry Mapping

Annual TNC volunteer effort to Map Wet and Dry reaches of San Pedro

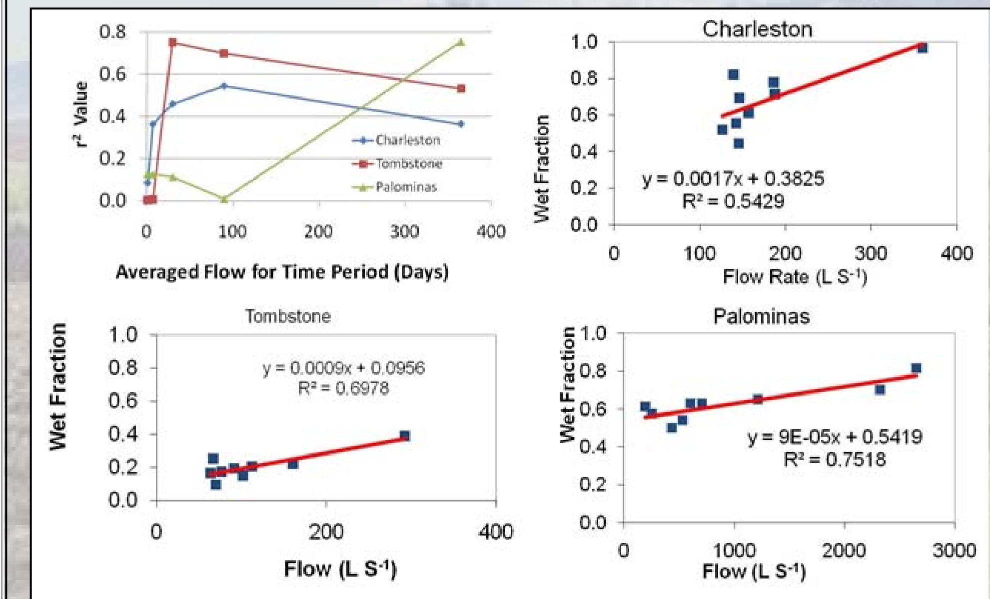
3rd Saturday of June – reliably driest day of the year



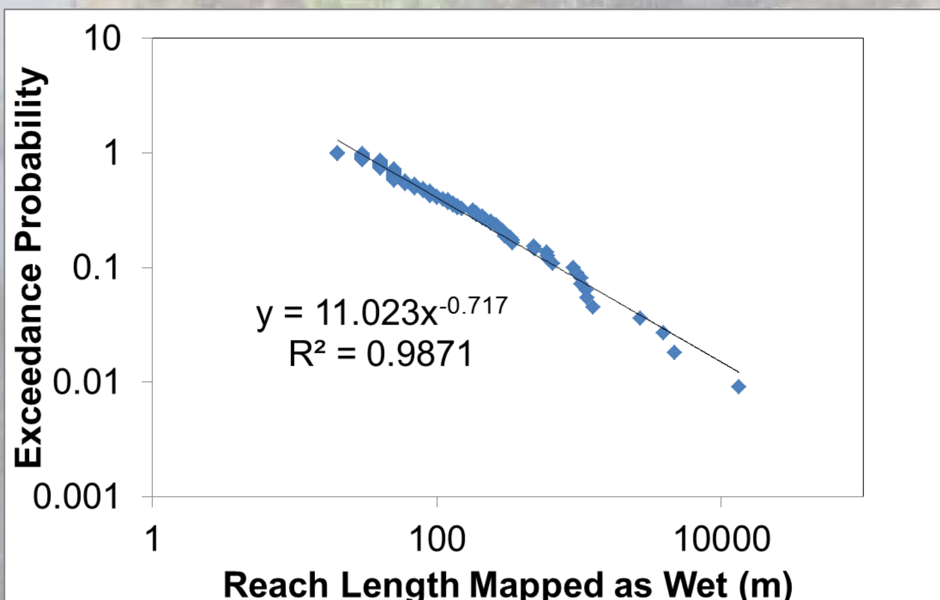
Cooperative effort of Upper San Pedro Partnership and UA-Project NEMO



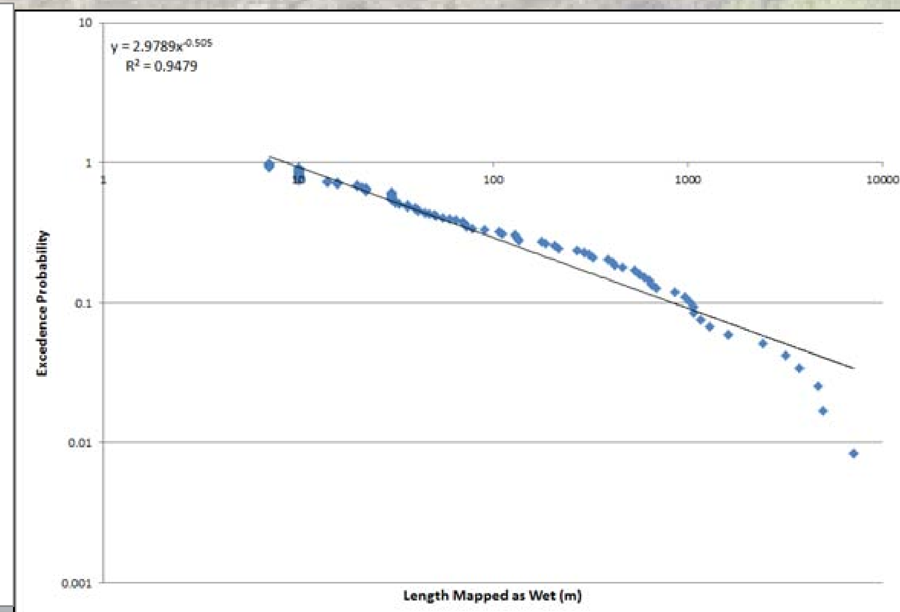
Exceedance Probability
1
0.1
0.01
0.001
0.0001
y = 32.834x^-1.583
R² = 0.8609
y = 1.4648e^-0.067x
R² = 0.9601
1
10
100
1000
Reach Length Mapped as Wet (m)



r² Value
Charleston
Tombstone
Palominas
Averaged Flow for Time Period (Days)
Charleston
Wet Fraction
y = 0.0017x + 0.3825
R² = 0.5429
Flow Rate (L S-1)
Tombstone
Wet Fraction
y = 0.0009x + 0.0956
R² = 0.6978
Flow (L S-1)
Palominas
Wet Fraction
y = 9E-05x + 0.5419
R² = 0.7518
Flow (L S-1)



Exceedance Probability
10
1
0.1
0.01
0.001
y = 11.023x^-0.717
R² = 0.9871
1
100
10000
Reach Length Mapped as Wet (m)



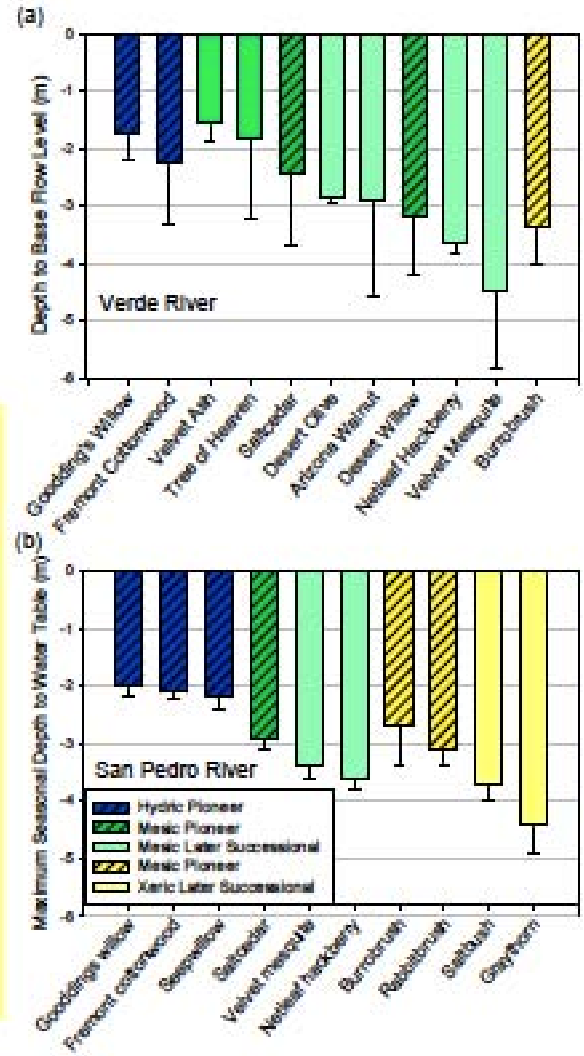
y = 2.9789x^-0.505
R² = 0.9479
Excedence Probability
Length Mapped as Wet (m)

Thresholds #2: Groundwater depth and decline of woody riparian plants

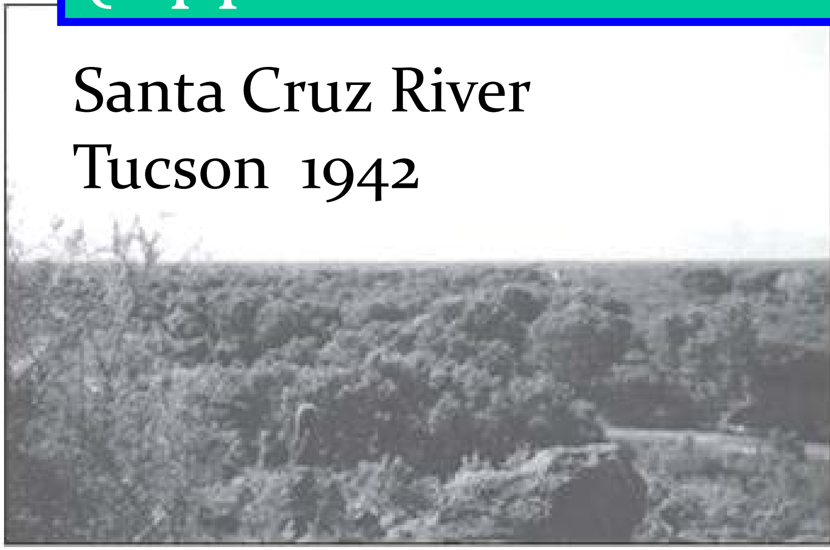
Problem statement: Regional uniformity of riparian vegetation response to declines in water table is unknown.

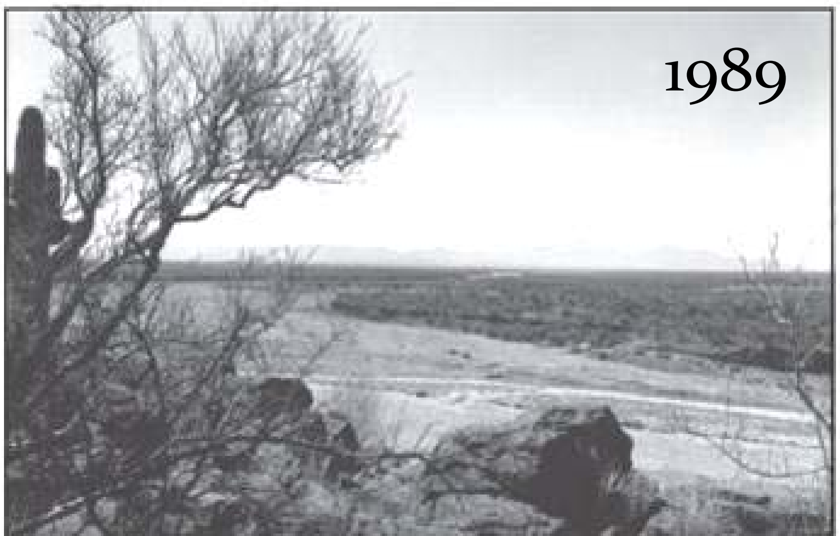
Methods: Monitoring wells monitored at multiple sites, multiple rivers; woody vegetation sampled for abundance and composition.

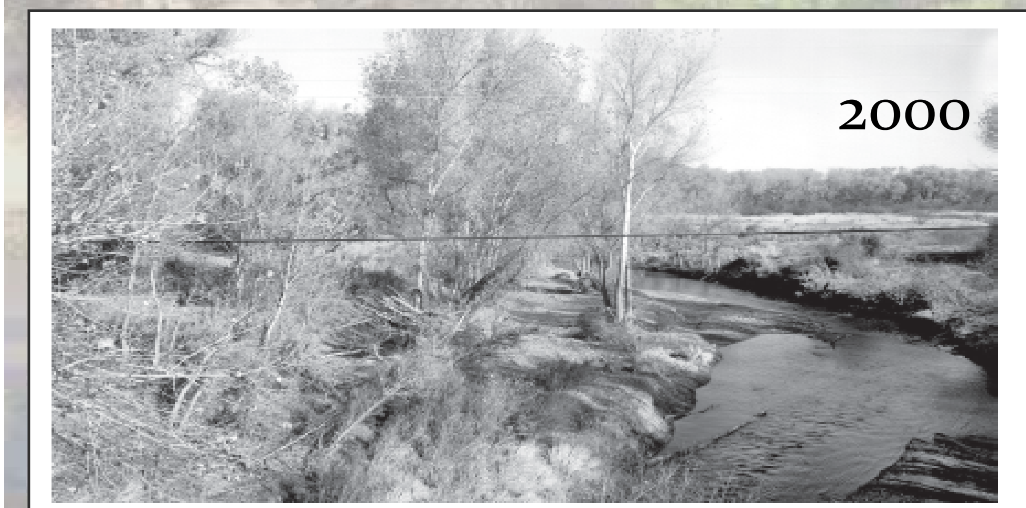
Results: Woody species, grouped by strategy type, show similar trends among rivers.



Legacies from the past shape the present (Upper San Pedro is not dammed or diverted)



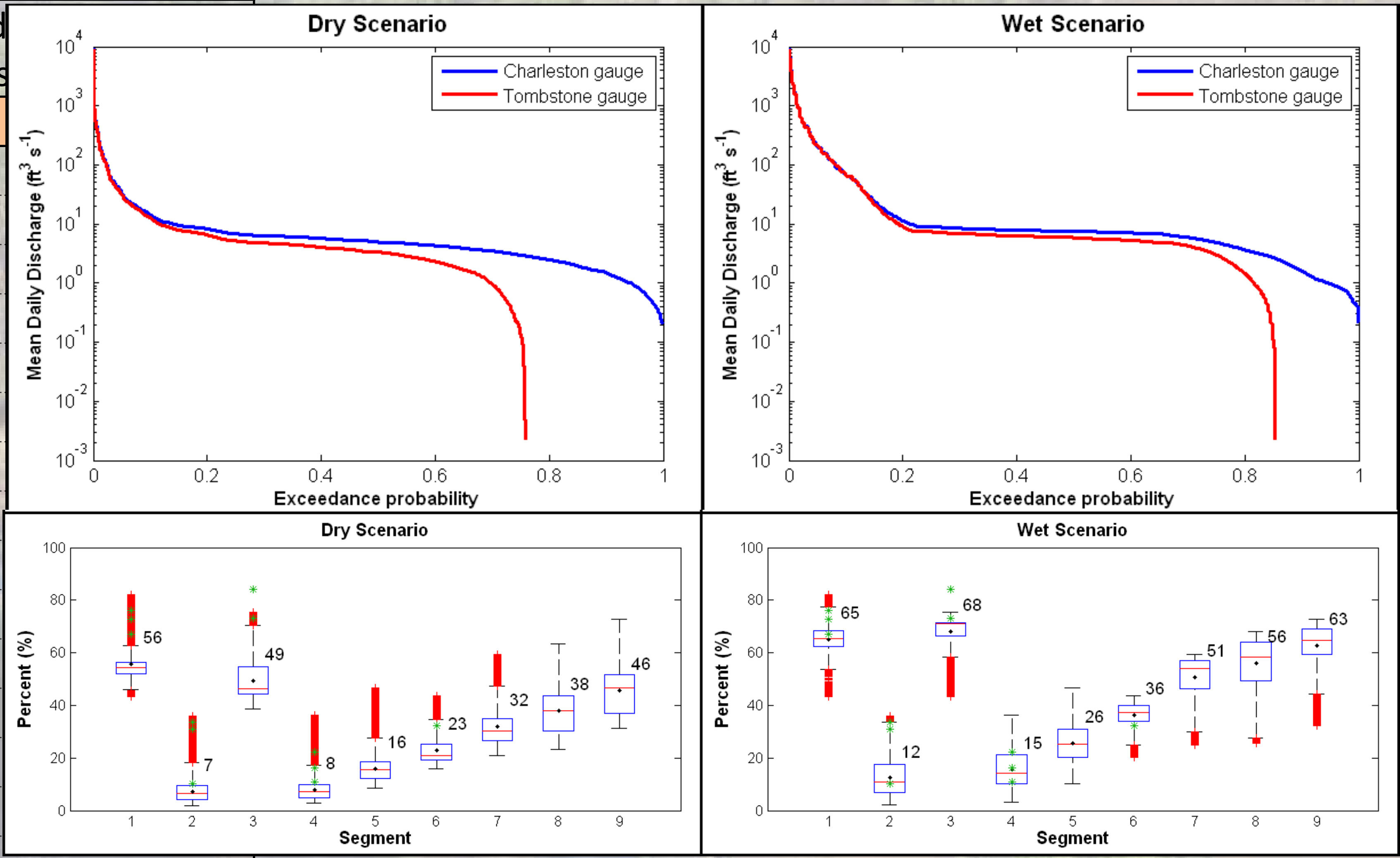




Slide provided by Julie Stromberg

Wet Dry Scenarios run through model identifies perennial reaches

San Ped
Mons
Dry
1962
1968
1973
1978
1979
1980
1989
1991
1993
1994
1995
1997
1998
2002
2003

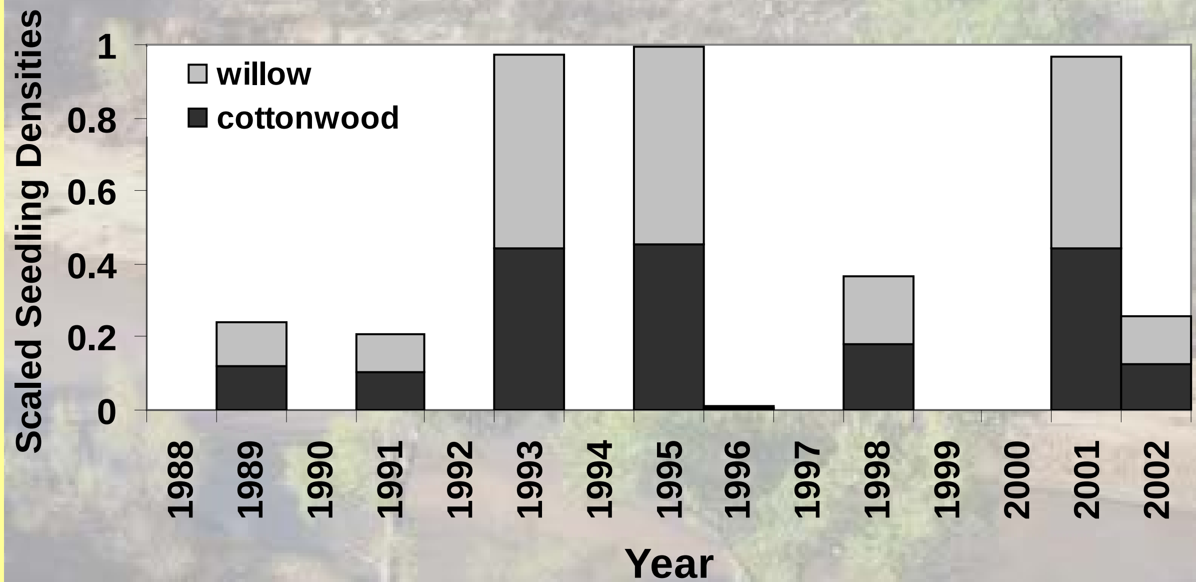


Percent Summer Floodwater in Riparian Groundwater

Problem statement: Recruitment response of riparian tree species to interactions between depth to water table and flood patterns not yet quantified.

Methods: Modeling approach being used to estimate potential seedling densities of riparian tree species (Mark Dixon, Univ. South Dakota).

Results: Modeled densities vary among San Pedro River sites with different stream hydrology and among years with different flow conditions.



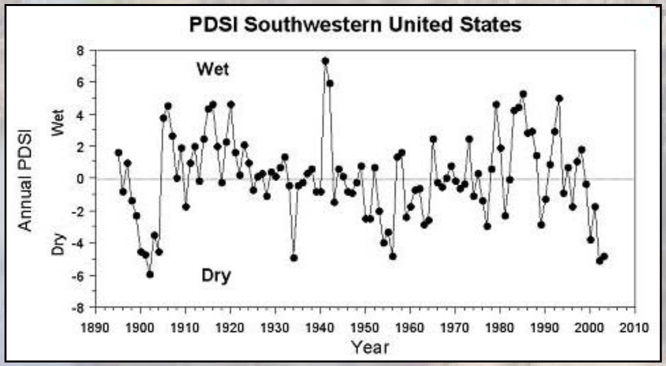
Problem statement: Effects on riparian vegetation of interactions between groundwater and flooding poorly known.

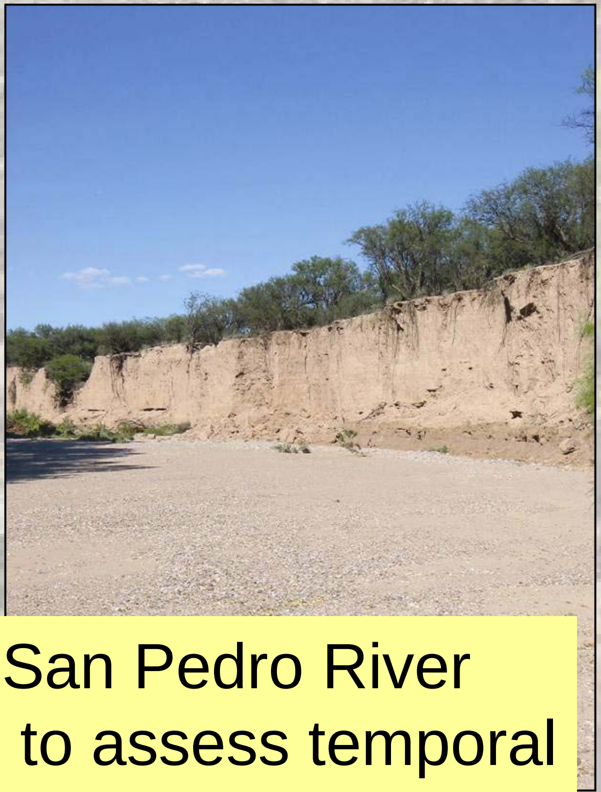
Methods: As a general guide for extrapolating how riparian vegetation on the San Pedro River may respond to changes in floods and drought, we <u>contrasted vegetation traits</u> between sites classified as ‘wet’ vs. ‘dry’ and ‘high’ vs. ‘low’ flood intensity. Low-flow and high-flow conditions varied independently among sites.

Stromberg JC, SJ Lite, MD Dixon. In press. Effects of stream flow patterns on riparian vegetation of a semiarid river: Implications for a changing climate. River Research and Applications

Problem statement: <u>Legacies</u> of past extreme flood events may be shaping current vegetation trajectories and response to climate change.

Climate extremes + land use extremes → Historic entrenchment of San Pedro River

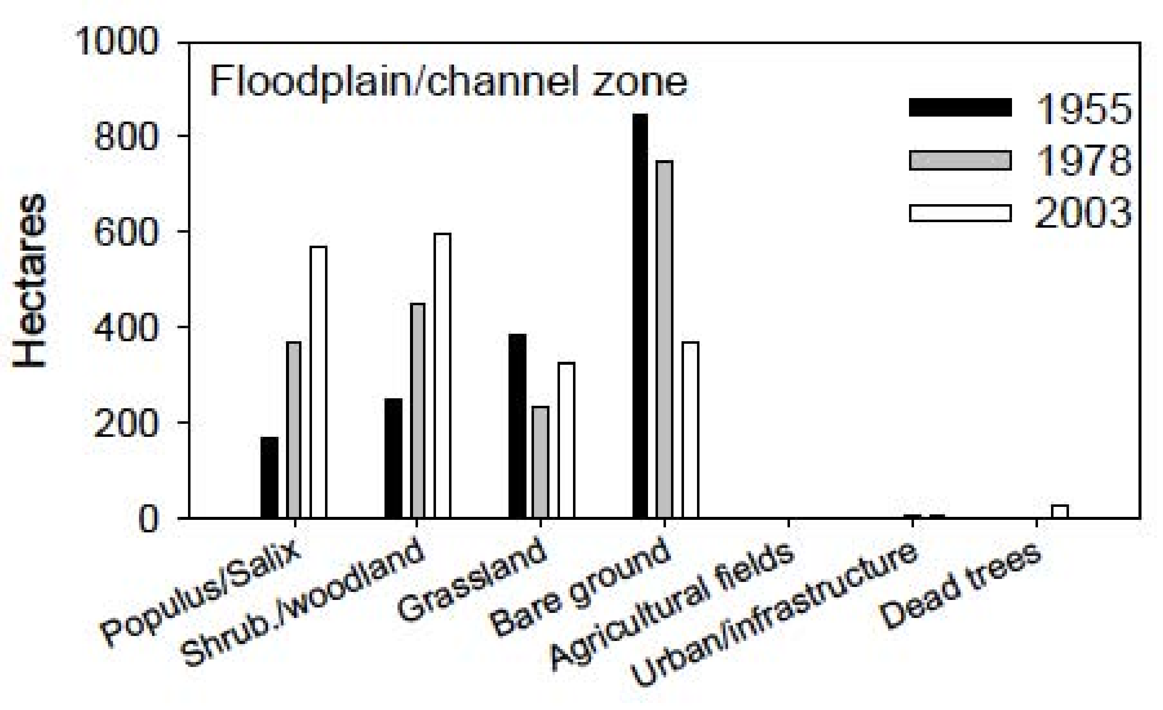




"It was probably during the 1896 flood that a channel almost 244 m wide and 6 m deep developed…" (Hereford and Betancourt 2009).

Methods: Aerial photographs of the Upper San Pedro River from 1935, 1955, 1978 and 2003 analyzed to assess temporal and spatial trends in vegetation cover type abundance.

Results: As a legacy of past extreme disturbance, pioneer woody vegetation has been expanding over past ½ century.



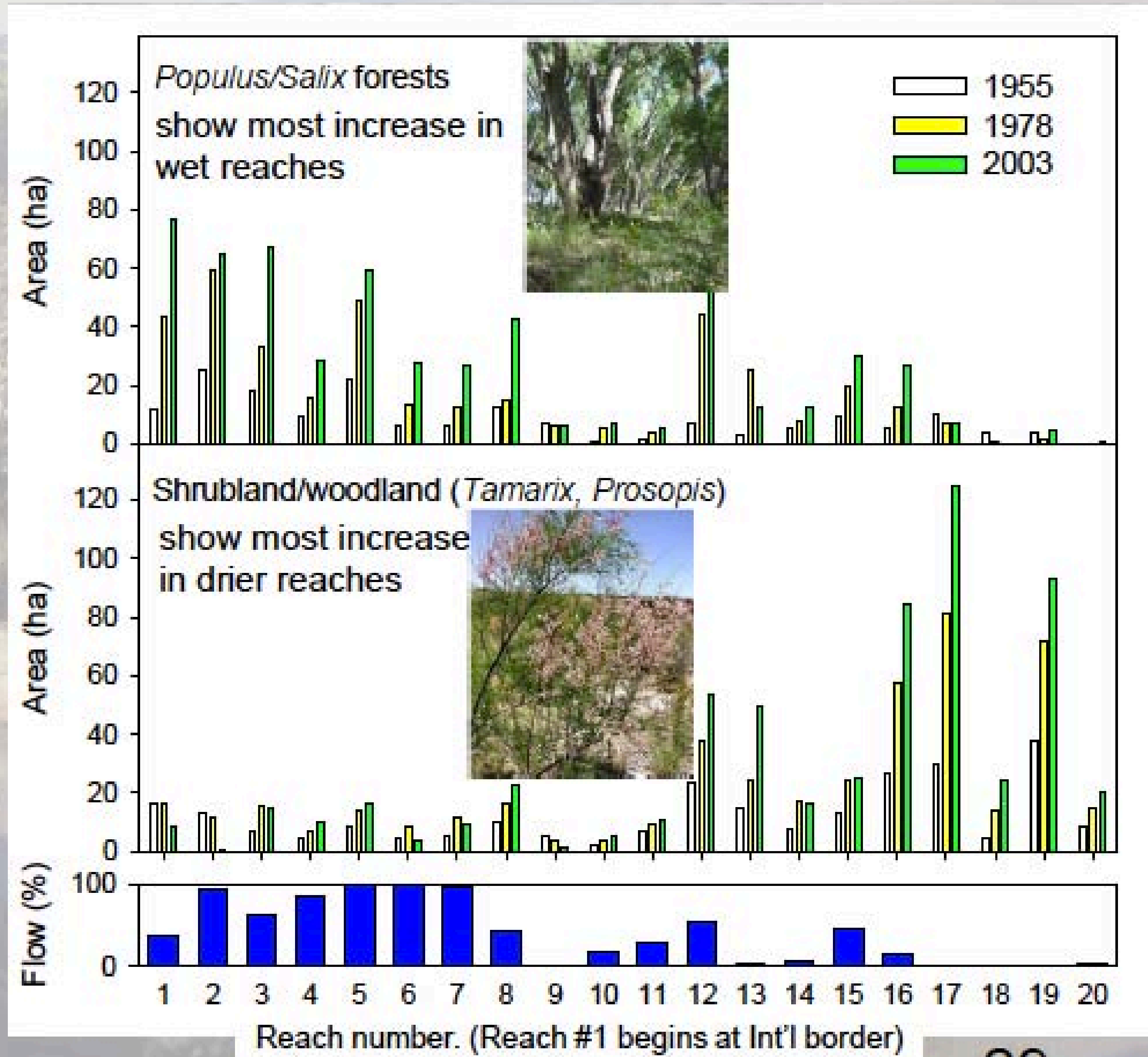
	Status in 2003				
	Populus Salix	Shrub./ wood.	Grass-land	Bare ground	Farm +urban
Status in 1955					
Populus/Salix	15%	3%	7%	9%	0%
Shrub./wood.	10%	46%	4%	23%	0%
Grassland	19%	22%	41%	18%	0%
Bare ground	56%	29%	48%	50%	0%
Farm + urban	0%	0%	0%	0%	0%
Sum	100%	100%	100%	100%	100%

Most *Populus/Salix* points mapped in 2003 arose from bare ground (as mapped in 1955)

As the pioneer forests expanded in the post-entrenchment floodplain, water availability shaped species composition.

Conclusion:

Riparian forest patterns are a product of interactions between recent climatic cycles and land and water use and past extreme events that set in motion trajectories of change.

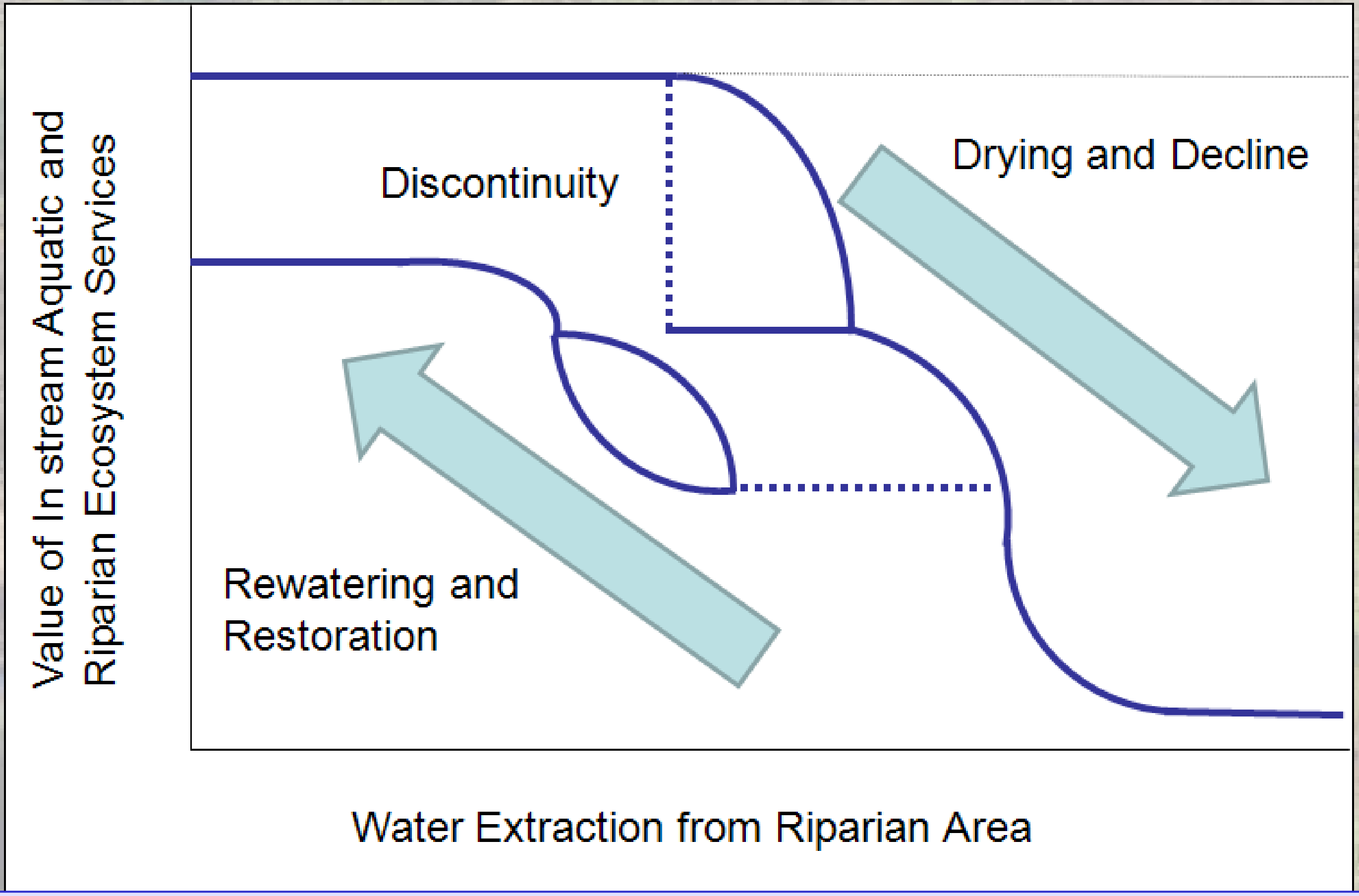


Flow % = percent of reach with perennial flow in 2007/2008, based on data from TNC

Future and ongoing work:

1) Now finishing completion of groundwater model
2) With NSf funding working with Francina Dominguez on dynamically downscaled cliamte scenarios.
3) Scenarios will be fed into surface water model of system (Enrique Vivoni ASU)
4) Impacts on groundwater, geomorphology and biology will be simulated
5) Ultimately to understand Effect on Ecosystem Services with Brookshire et al on marginal value of ecosystem services with changes in hydrologic conditions.

Threshold Impacts of Water Extraction on Riparian System Ecosystem Services



Hypothesis: Restored systems will not reach the previous level of services provided

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- Andrew Hautzinger (*USFWS*)
- Stan Culling (*AZGF*)

Email questions to **tmeixner@hwr.arizona.edu**

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