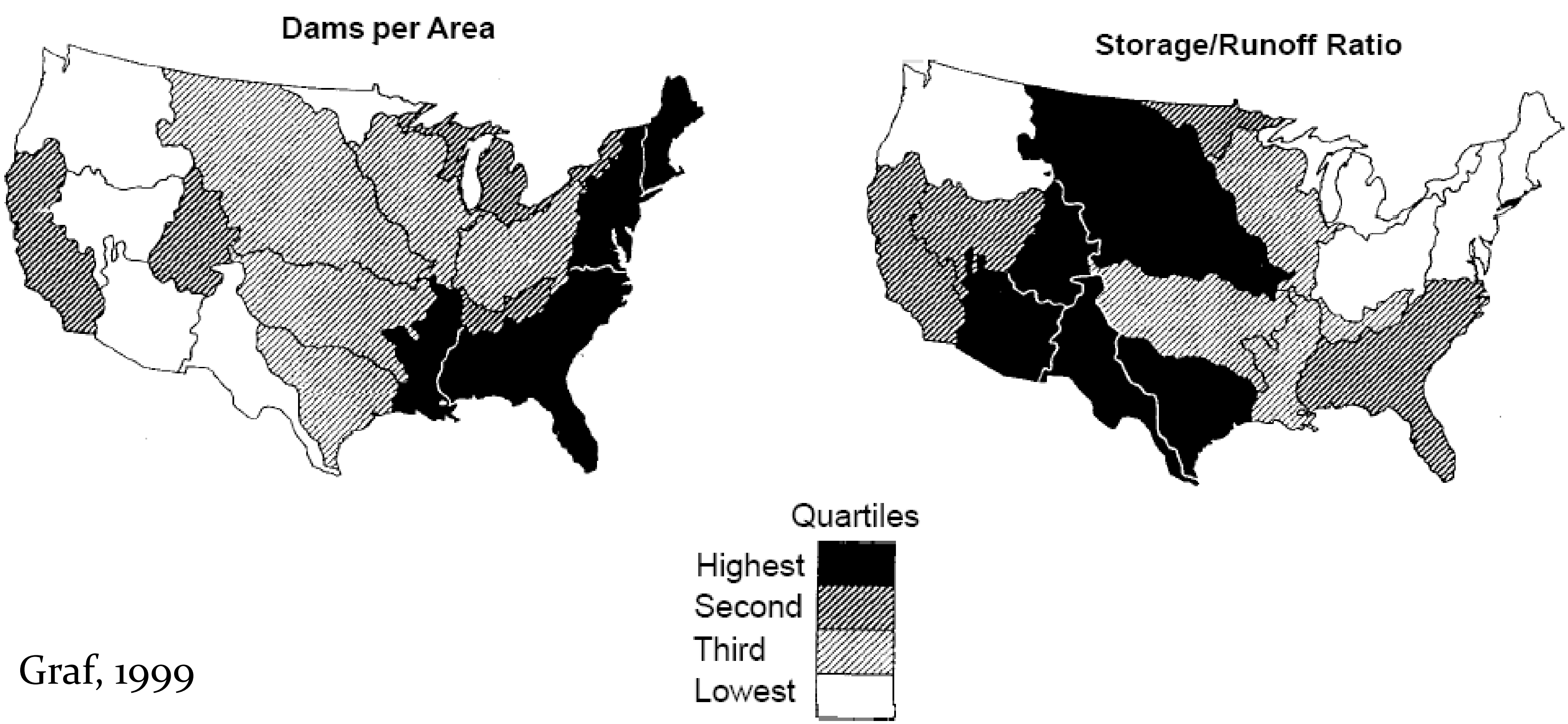
Riparian Tree Response to Variability in Climate and Altered Streamflow along the Dolores River, Colorado

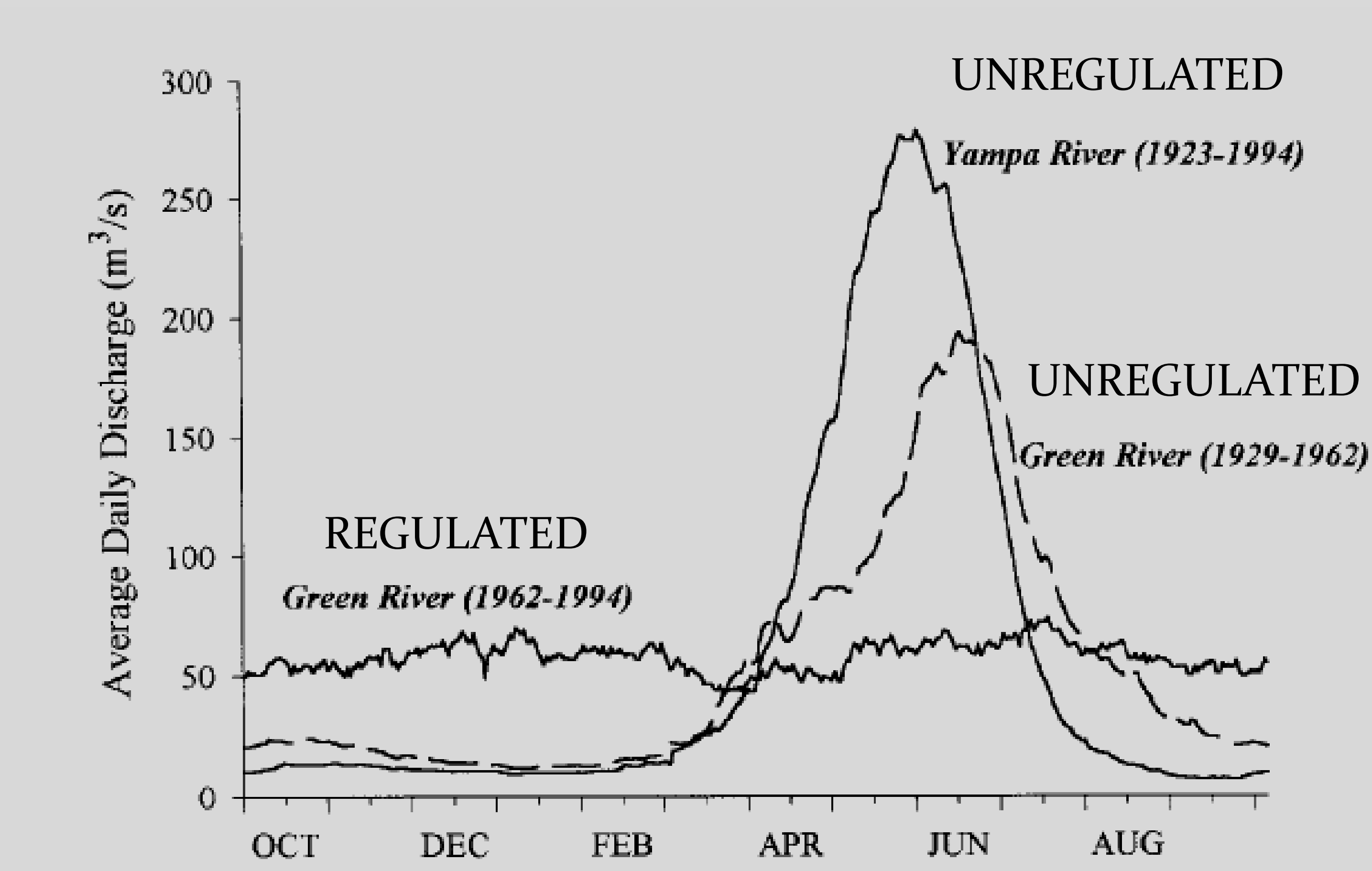
Adam P. Coble
November 30, 2010

River Damming in the Western U.S.



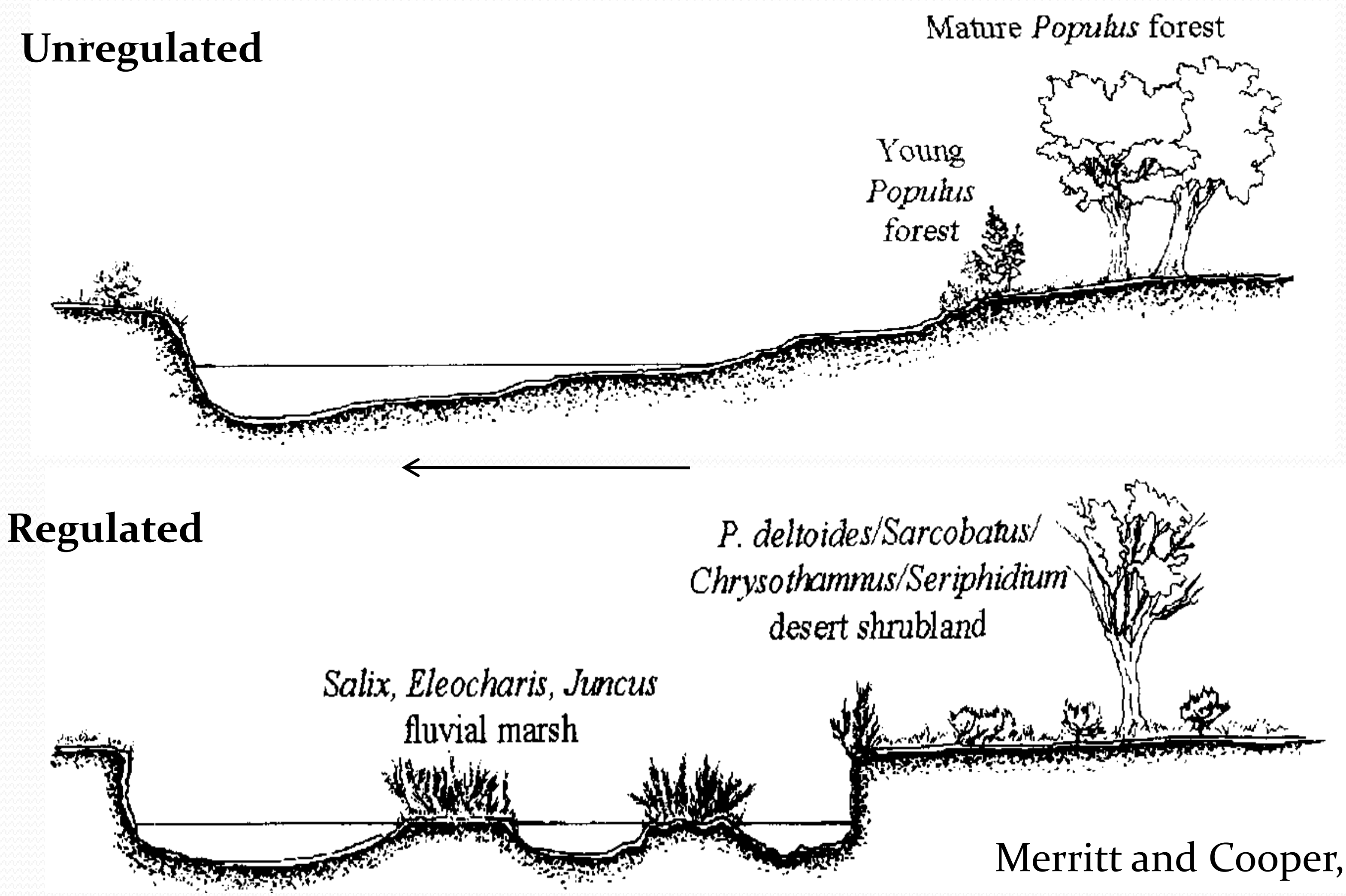
Graf, 1999

An Example of Streamflow Alteration



Merritt and Cooper, 2000

Dam-Induced Channel Adjustments



Merritt and Cooper, 2000

Impacts of River Regulation on Riparian Forests

Reduced forest area

Reduced tree abundance

Loss of seedling habitat

Decline in seedling **establishment**

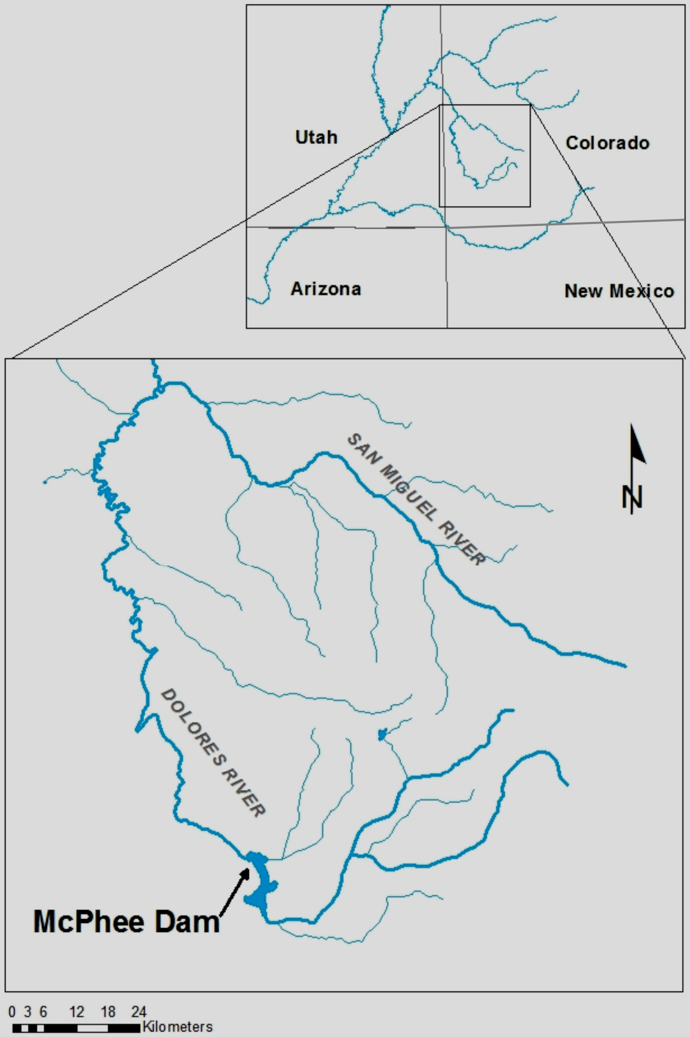
Reduced **tree growth**

Increased seedling survivorship

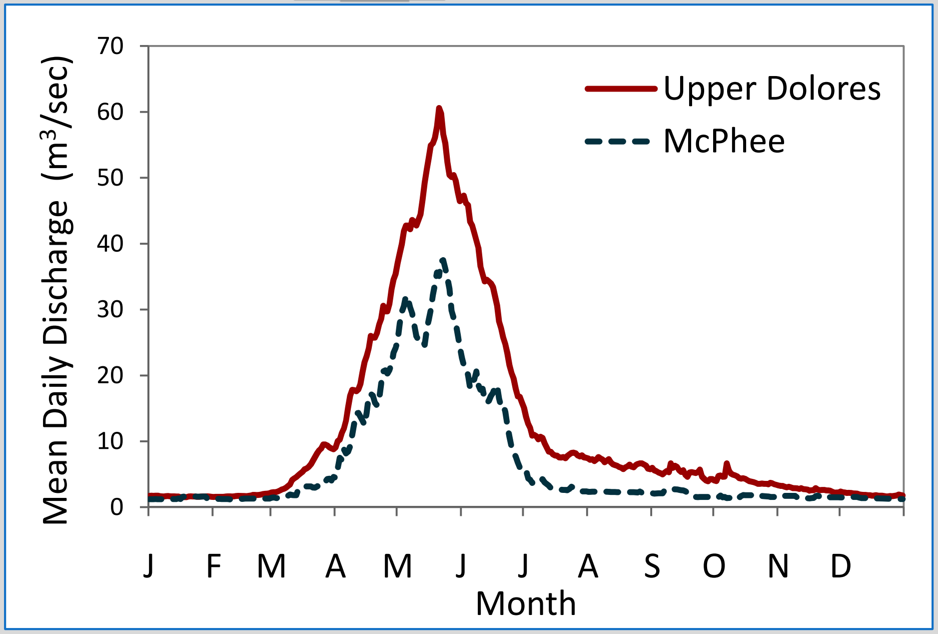
Increased forest density

Primary Cause: **Reduced High Spring Flows**

Dolores River



McPhee Dam constructed in 1984



(1985 – 2008)

Research Questions 1 and 2

- **Does river regulation affect riparian tree establishment along the Dolores River?**
- **What streamflow conditions facilitate riparian tree establishment?**

Controls over Riparian Tree Growth

- Growth +/- associated with streamflow
- Growth response to climate and streamflow can change due to river regulation (Reily and Johnson, 1982)
  - Unregulated river: **streamflow**
  - Regulated river: **temperature** and **evapotranspiration**
- Growth response to climate and streamflow dependent on geomorphic characteristics
  - Wide, alluvial valleys: **streamflow**
  - Bedrock constrained reaches: **temperature**

Research Question 3

- **How does tree growth response to streamflow and climate differ among regulated and unregulated reaches ?**

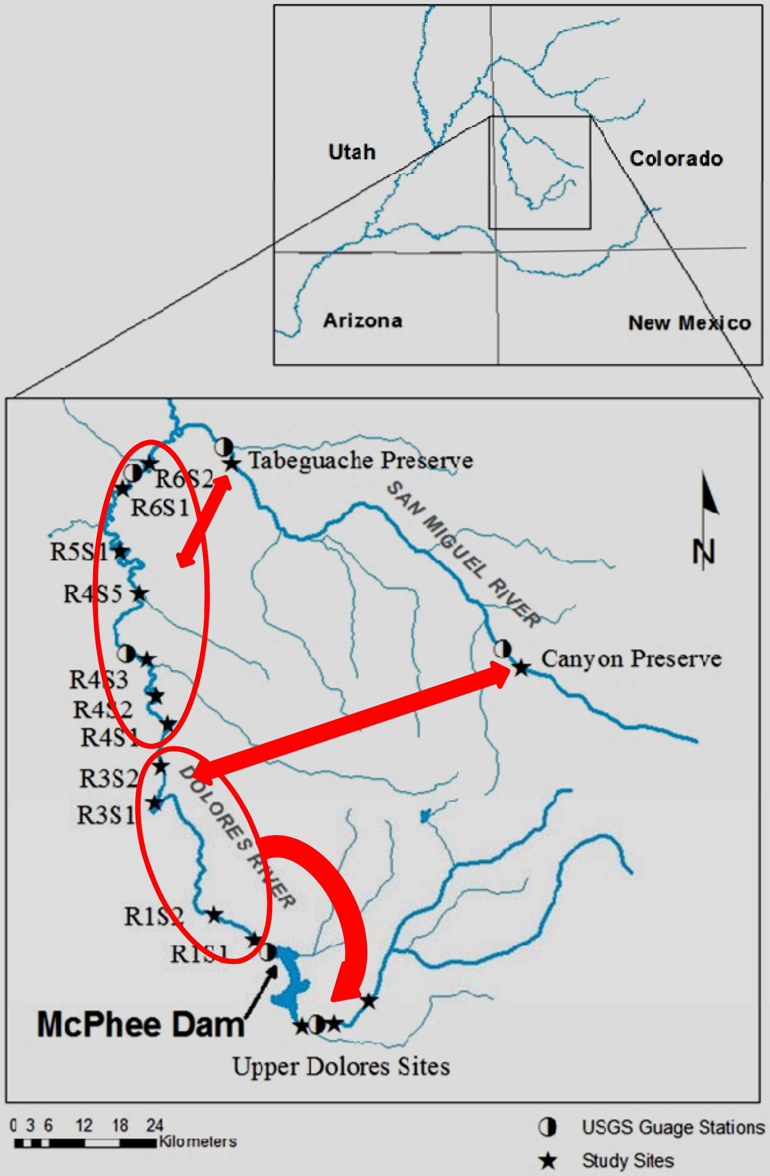
Native Riparian Tree Species

Populus angustifolia
(narrow-leaf cottonwood)

Populus deltoides subsp. *wislizenii*
(broad-leaf cottonwood)

Acer negundo
(box-elder)

Delineation of Segments



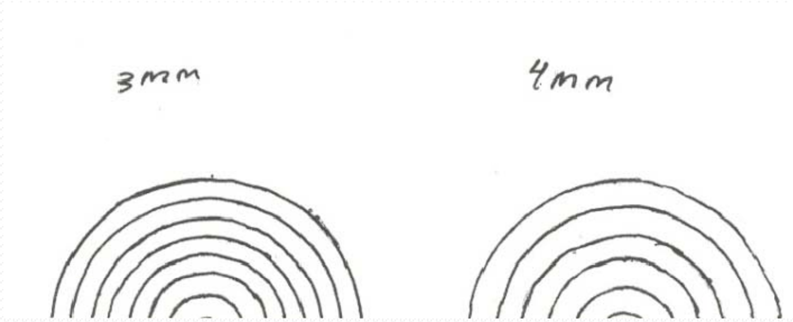
- 6 Reaches defined by Dolores River Dialogue
- Divided each reach into 2, 3, or 5 segments
- 1 study site per segment

Tree Sampling

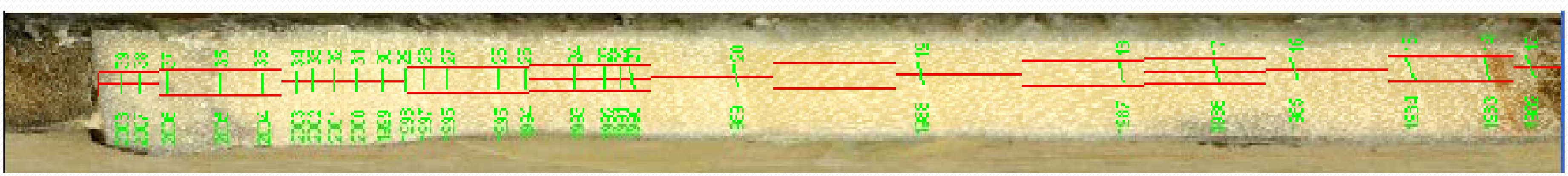
- Assigned trees to 5.0 cm dbh size class
- 3 trees per size class per topographic position per segment

Tree Age Estimation and Tree Growth Measurement

- Estimated tree age (39.6% of trees) using template method



- Measured ring width for mature trees (established prior to 1984) using WinDEDNRO (Regent Instruments Inc., Quebec)



Number of Trees Used in Analysis

Analysis	narrow-leaf	broad-leaf	box-elder
Establishment	224	204	90
Growth	136	67	70

Data Analysis

- 20 Environmental Variables

  Mean Temperature
  Total Precipitation
  Maximum Streamflow
  Minimum Streamflow
  Mean Streamflow
  Palmer Drought Severity Index

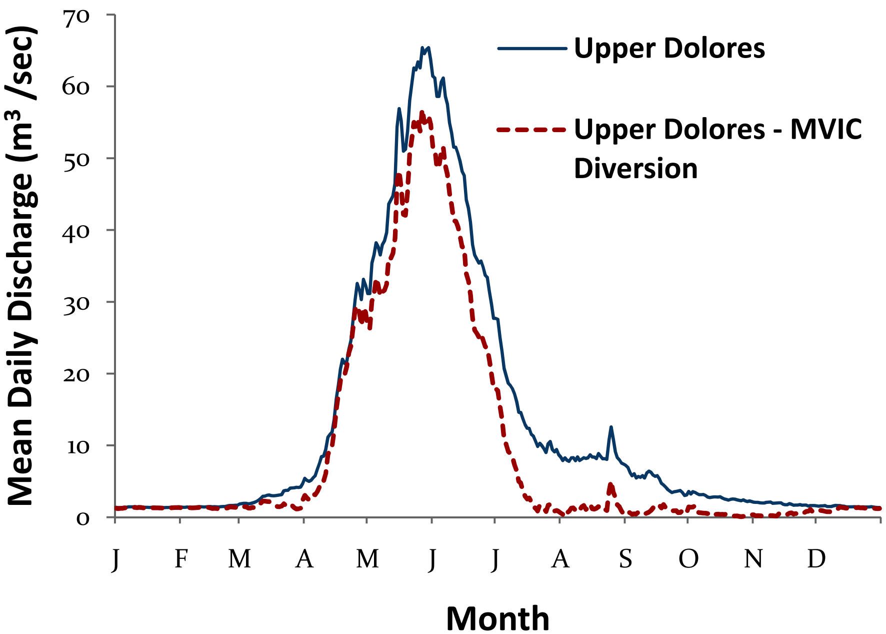
  Winter (Oct. – Mar.)
  Spring (Apr. – Jun.)
  Summer (Jul. – Sept.)

  Previous Yr. Maximum Flow
  Subsequent Yr. Maximum Flow

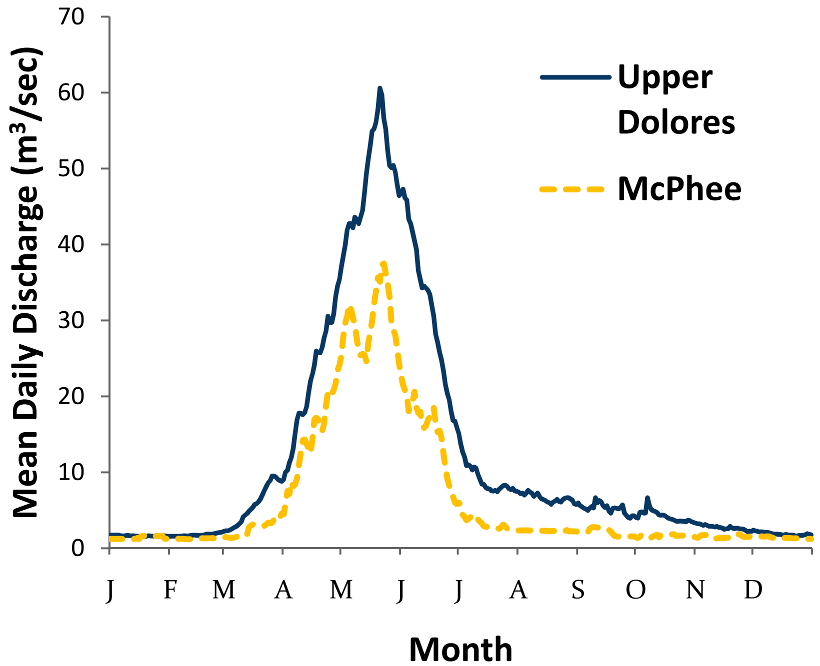
- 3 Climate Stations
- 5 Gauge Stations

Streamflow Alteration Pre- and Post-dam

Prior to dam construction (1961-1984)



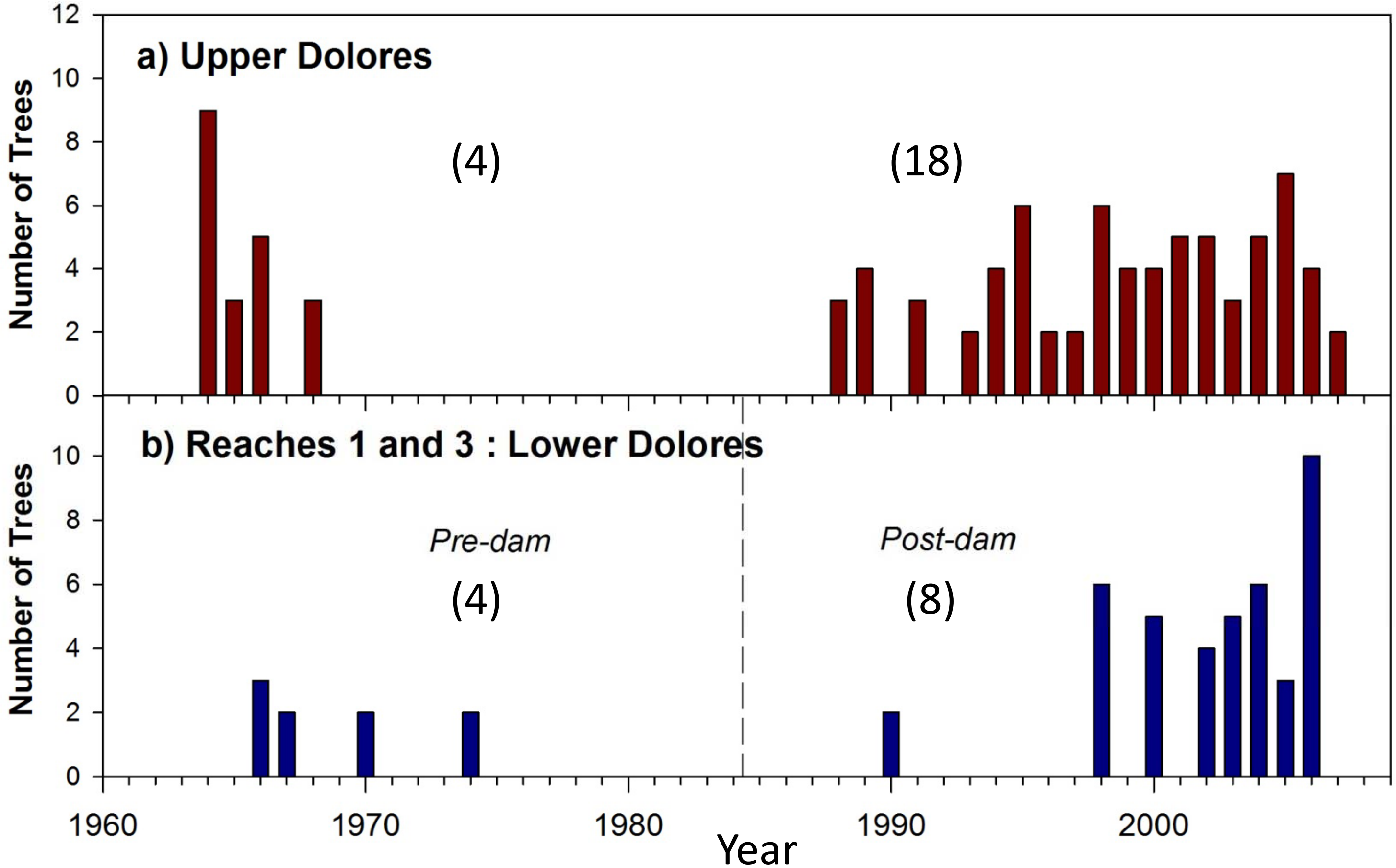
After dam construction (1985-2008)



Research Questions

- **Does river regulation affect riparian tree establishment along the Dolores River?**
- What flow and/or climate events facilitate establishment of native riparian trees?
- How does tree growth response streamflow and climate differ among regulated and unregulated reaches?

Narrow-leaf cottonwood Establishment



Establishment Models:

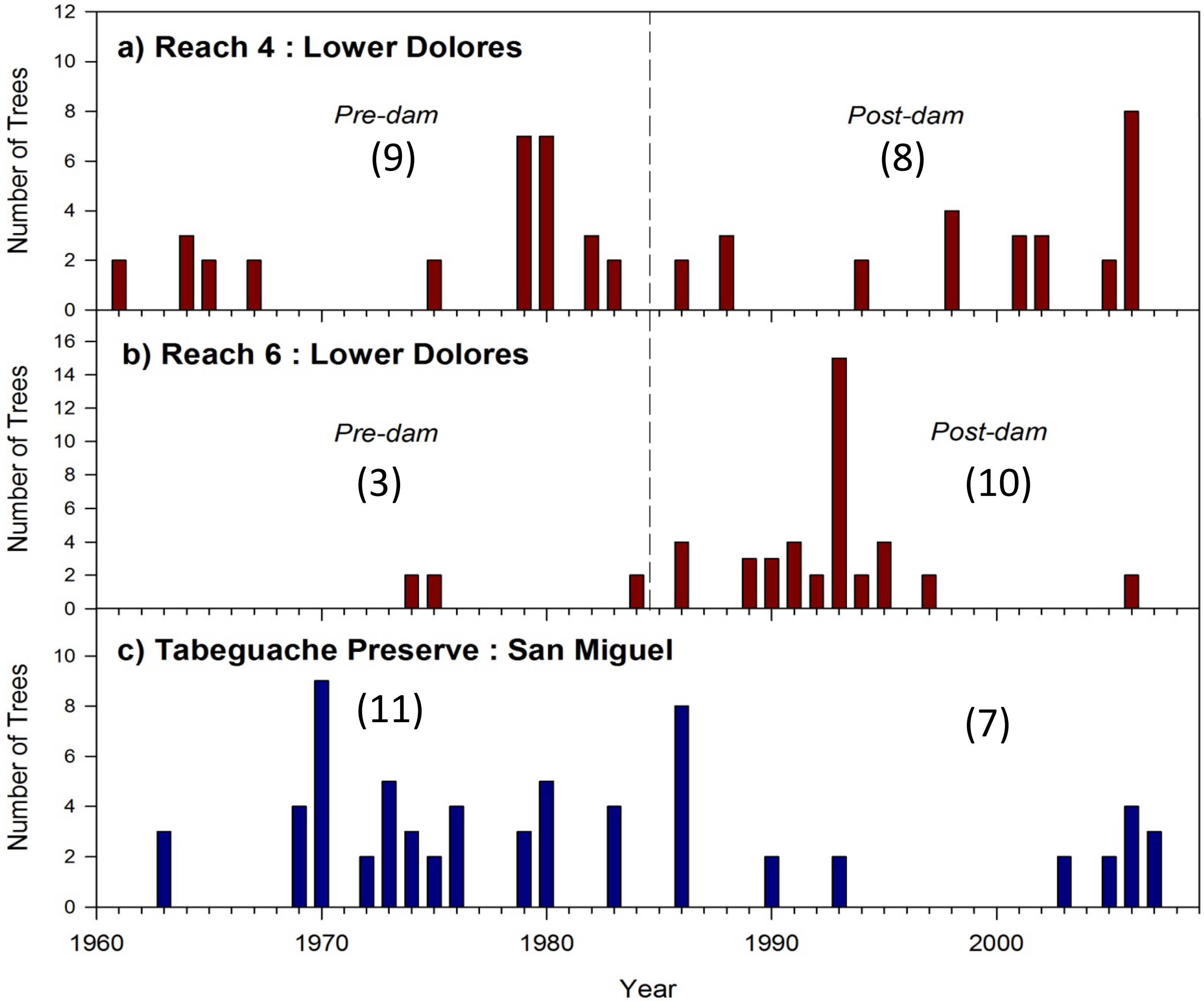
Upper Dolores

Winter Mean Temp (+)
ROC = 0.729
$r^2 = 0.126$
$p = 0.0039$

Reaches 1 and 3

Winter Mean Temp (+)
Spring Precipitation (-)
ROC = 0.889
$r^2 = 0.412$
$p < 0.0001$

Broad-leaf Cottonwood Establishment

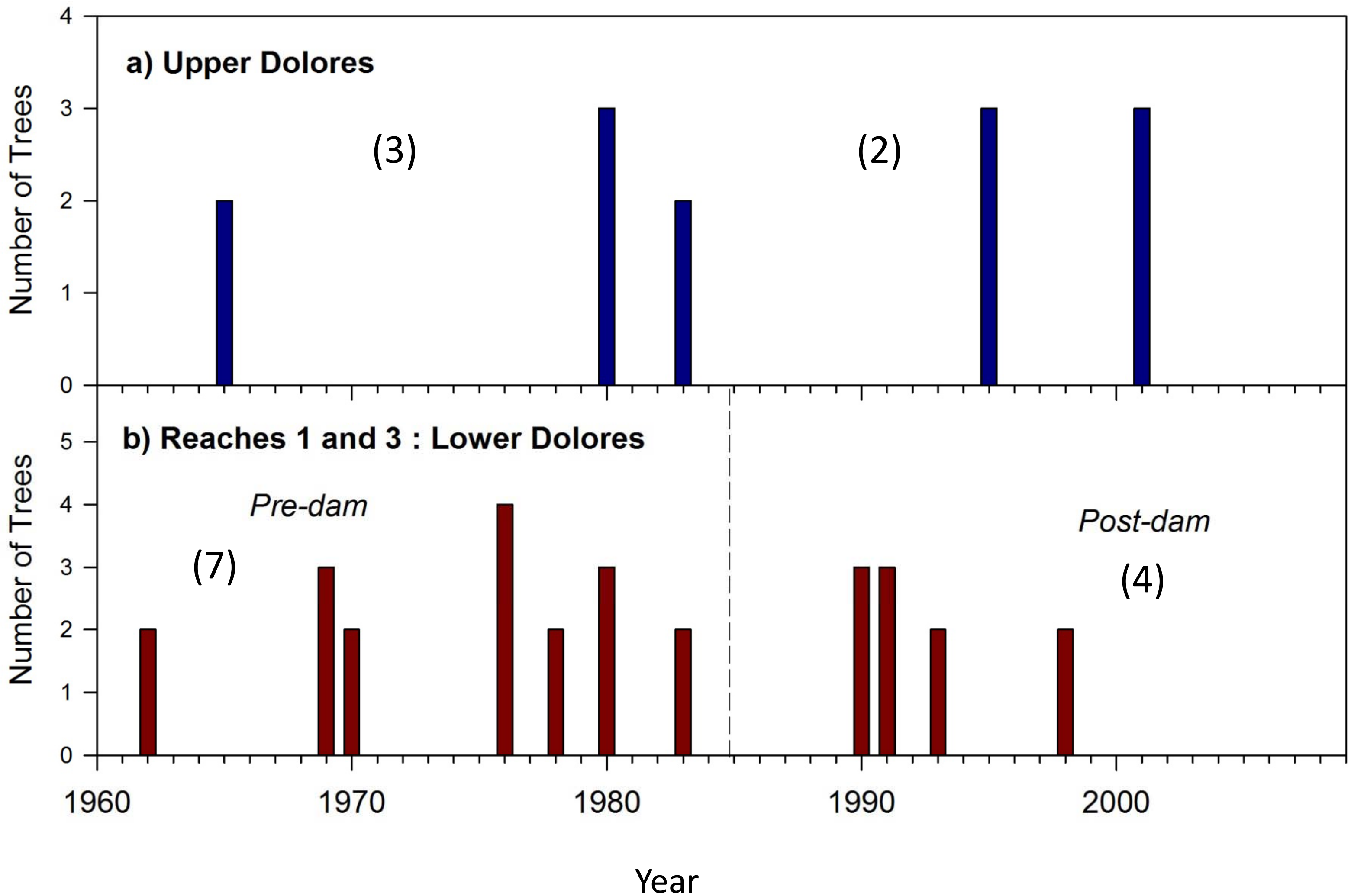


Establishment Model:

Reach 6

Summer Min. Flow(+)
ROC = 0.755
$r^2 = 0.158$
$p = 0.0029$

Box-elder Establishment

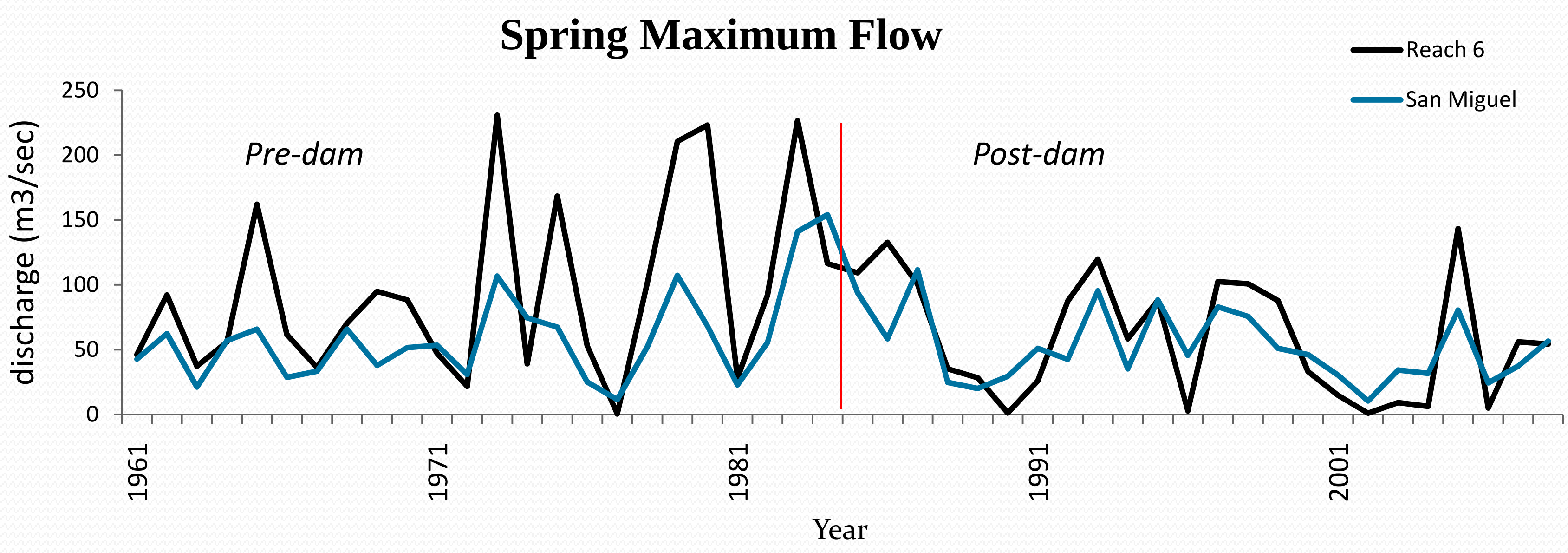


Research Questions

- Does river regulation affect the number of recruitment events?
- **What flow and/or climate events facilitate establishment of native riparian trees?**
- How does tree growth response to variation in streamflow and climate differ among regulated and unregulated reaches?

Relationships between Cottonwood Establishment and Spring Maximum Flow

- Spring maximum flow explained little variation in cottonwood establishment
- Further substantiated by establishment models and large number of establishment events during the post-dam period (1985-2008)



Box-elder Establishment

- Observed a few positive significant relationships between box-elder establishment and spring maximum flow (Upper Dolores & Reaches 4 through 6

- Logistic regression models

Streamflow variables:	Temperature variables:
summer mean flow (+)	winter mean temp. (-)
spring min. flow (+)	spring mean temp. (-)
spring max. flow (+)	summer mean temp. (-)
summer min. flow (+)	

- High streamflow facilitated box-elder establishment
- High temperatures negatively impacted establishment

- Streamflow: stronger controls over box-elder establishment compared to cottonwood

Box-elder established at higher topographic elevations compared to cottonwood

Cottonwood: channel or ephemeral channels

Box-elder: intermediate zones between channel and 1st bench

Streamflow: stronger control over box-elder growth compared to cottonwood

			Correlations between growth and mean flow	
			Narrow-leaf	**Box-elder**
Reach	**Regulation Status**	**Mean Flow**	**R^2**	**R^2**
Reach 3	Pre-dam	Winter	0.423*	0.112
		Spring	0.274*	0.441*
		Summer	0.214	0.438*
	Post-dam	Winter	0.019	0.143
		Spring	0.212	0.585**
		Summer	0.407*	0.470*

* p-value < 0.05

Streamflow: stronger control over box-elder growth compared to cottonwood

			Correlations between growth and mean flow	
			Broad-leaf	**Box-elder**
Reach	**Regulation Status**	**Mean Flow**	**R^2**	**R^2**
Reach 4	Pre-dam	Winter	0.119	0.032
		Spring	0.232	0.452*
		Summer	0.275*	0.358*
	Post-dam	Winter	0.087	0.441*
		Spring	0.145	0.323*
		Summer	0.205	0.409*

* p-value < 0.05

Mature box-elder trees grew at higher topographic elevations compared to cottonwood

Cottonwood

0.76 – 1.22 meters above active channel

Box-elder

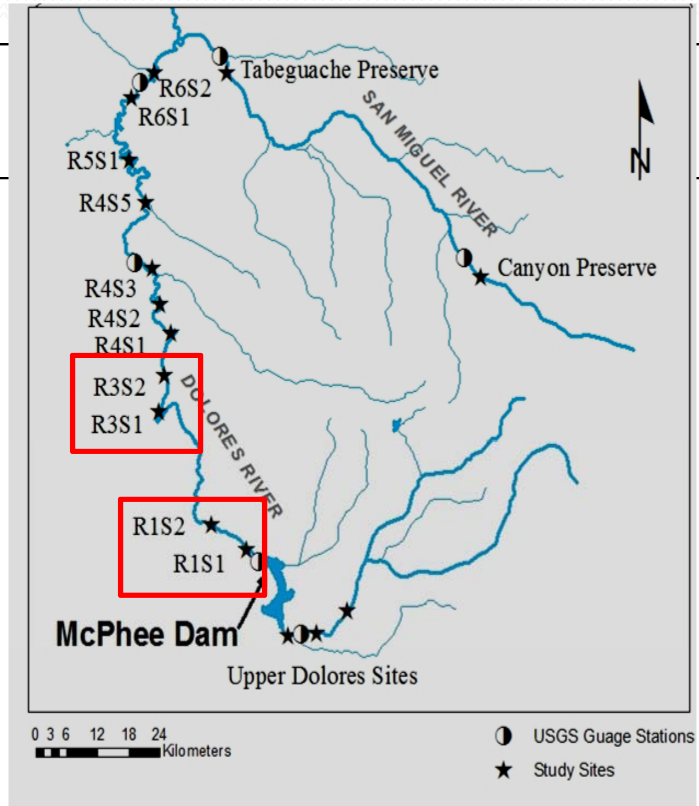
1.2 – 2.4 meters above active channel

Research Questions

- Does river regulation affect the number of recruitment events?
- What flow and/or climate events facilitate establishment of native riparian trees?
- **How does tree growth response to streamflow and climate differ among regulated and unregulated reaches?**

Narrow-leaf cottonwood growth: shift in seasonal response to streamflow

River	Reach	Season	Growth vs. Mean Flow - R^2
Dolores	Reach 1	Winter	0.055
		Spring	0.274*
		Summer	0.125
		Winter	0.003
		Spring	0.072
		Summer	0.323*
	Reach 3	Winter	0.423*
		Spring	0.274*
		Summer	0.214
		Winter	0.019
		Spring	0.212
		Summer	0.407*



* p-value < 0.05

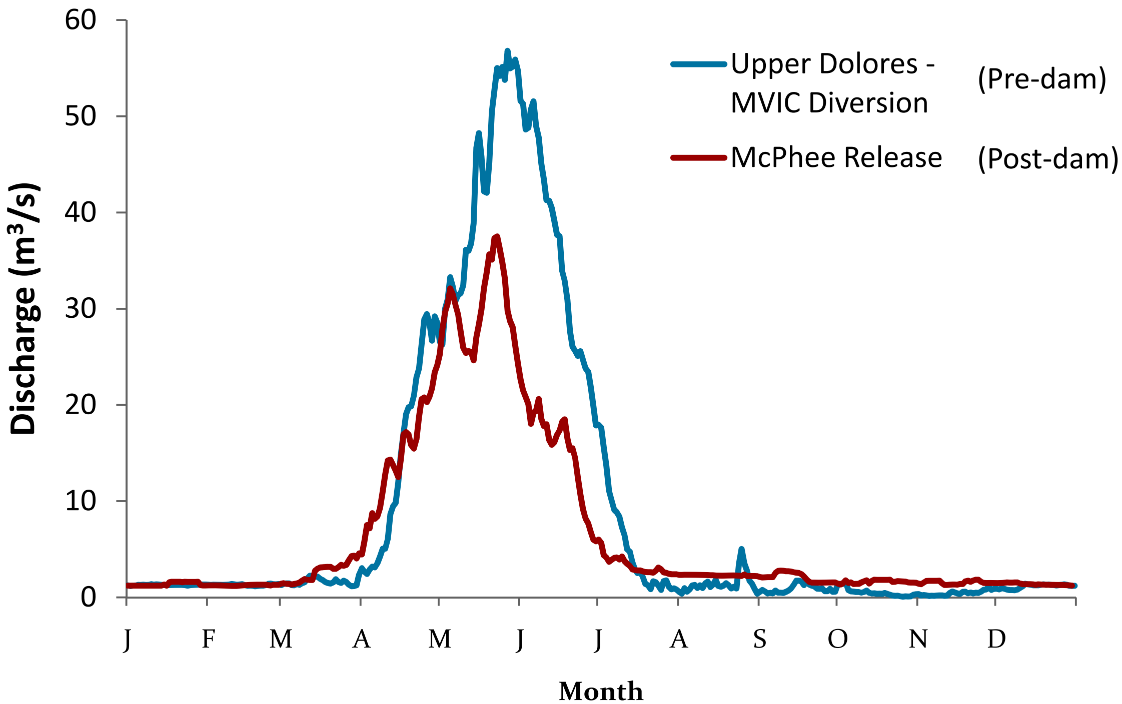
Narrow-leaf cottonwood growth: shift in seasonal response to streamflow

Pre-dam (1961-1984)

Spring streamflow ⟶ Growth

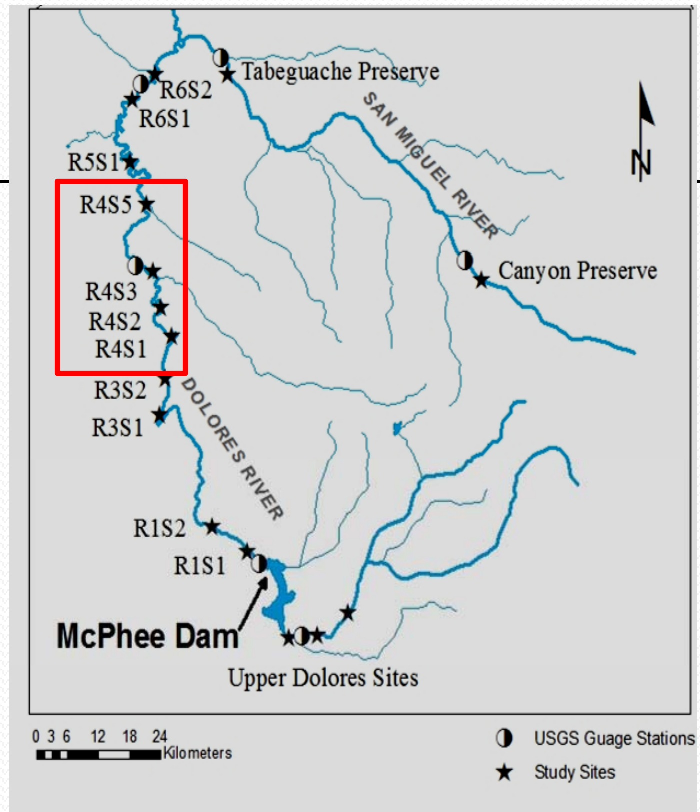
Post-dam (1985-2008)

Summer streamflow ⟶ Growth



Shift in Growth Response at Reach 4 for two species

Species	Post-dam (1984– 2008)
Box-elder	Winter PDSI (r^2 = 0.414)
Broad-leaf cottonwood	Summer PDSI (r^2 = 0.391) Summer MIN Flow



In Conclusion:

- **Does river regulation affect riparian tree establishment along the Dolores River?**
  - Observed frequent establishment events for all species under regulated streamflow
  - Our results suggest no apparent affect on the number of establishment events of broad-leaf cottonwood and box-elder

In Conclusion:

- **What streamflow conditions facilitate riparian tree establishment?**
  - Cottonwood: no positive association with spring maximum flow
  - High streamflow facilitated box-elder establishment in both spring and summer seasons

In Conclusion:

- **How does tree growth response to streamflow and climate differ among regulated and unregulated reaches?**

  - Shifts in growth response:

Narrow-leaf cottonwood: growth more sensitive to summer flows under dam regulated flows

Broad-leaf Cottonwood

Box-elder

Pre-dam (Canal diversion) → Post-dam (Dam regulation)

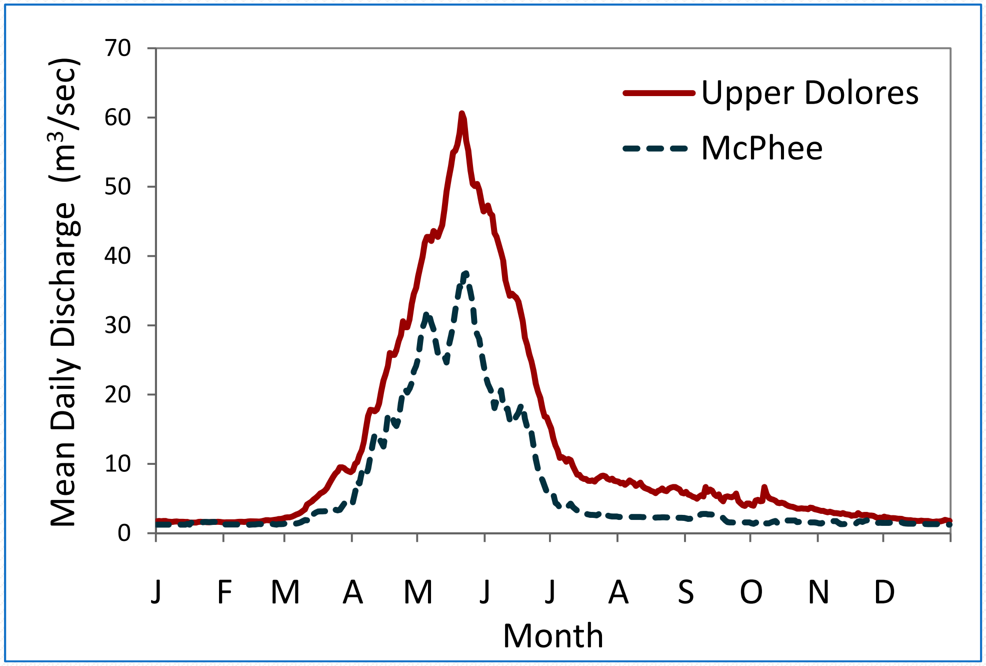
Streamflow → **PDSI**

In Conclusion:

- **How does tree growth response to streamflow and climate differ among regulated and unregulated reaches?**
  - At Reach 4, growth more sensitive to drought under dam regulated flows
  - **Streamflow alteration** increased sensitivity to regional drought.

Streamflow Recommendations for Cottonwood Establishment

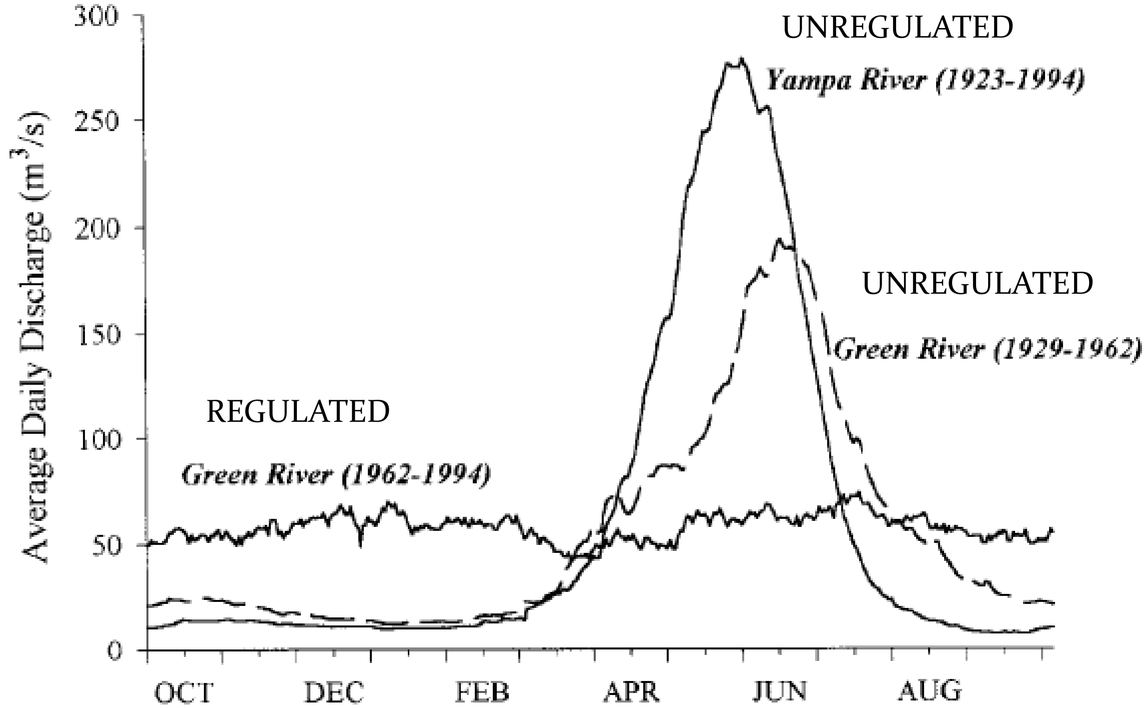
- Cottonwood maintain seasonal variation in streamflow
  - High streamflow during the months of May – June
  - Base flows in summer months at or above long-term average



(1985-2008)

Streamflow Recommendations for Cottonwood

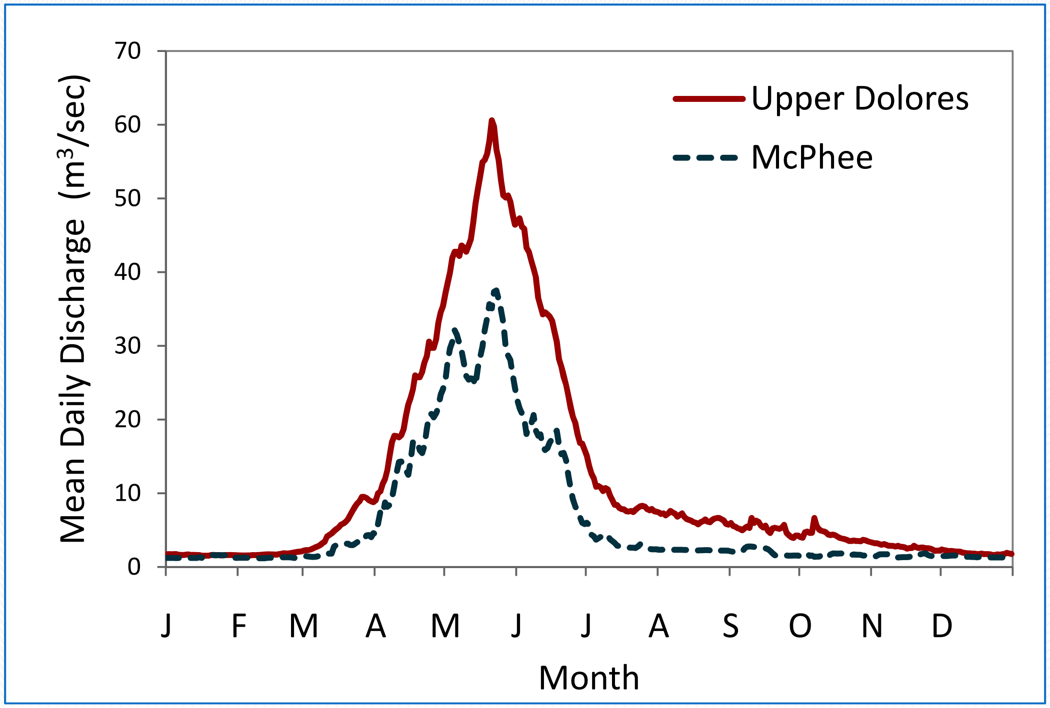
- Extreme departure from seasonal variation in streamflow resulted in:
  - Loss of habitat for cottonwood
  - Decline in cottonwood establishment



Merritt and Cooper, 2000

Streamflow recommendations for box-elder

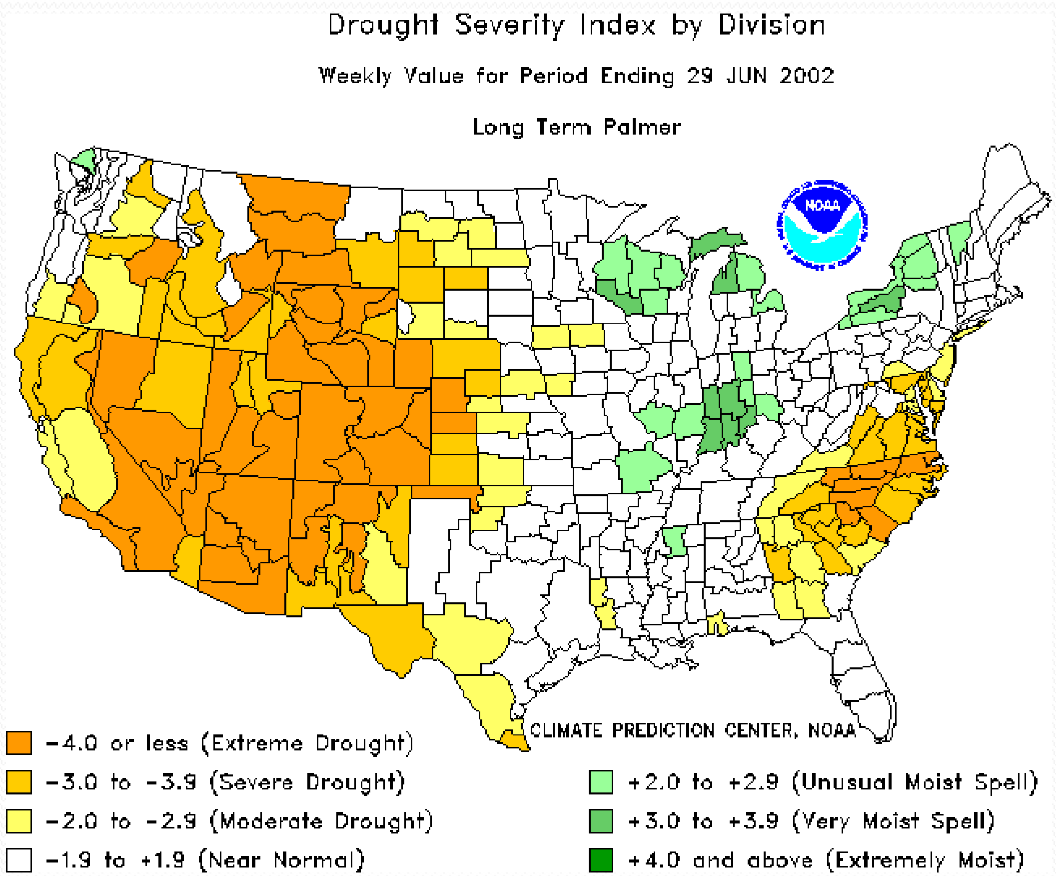
- Maintain above average streamflow during spring and summer seasons



(1985-2008)

Streamflow Recommendations for Native Riparian Tree Growth

- Sensitivity to PDSI increased due to river regulation
- Climate models predict more frequent drought (Seager et al., 2007)



Acknowledgements

NORTHERN ARIZONA UNIVERSITY

School of Forestry

DOLORES RIVER DIALOGUE

Office of the Vice President for Research

My committee:

Dr. Thomas Kolb
Dr. Margaret Moore
Dr. Kristen Waring

Field and Lab Assistance

Rob Anderson

Jeff Kane
John Godbey
Elizabeth Camarata
Don Normandin and ERI
David Graf
Dolores Public Lands Office
Cara MacMillan

Landowners

Vicki Phelps
Mark Youngquist
Larry and Jim Suckla
The Nature Conservancy
Bureau of Land Management
U.S. Forest Service

Questions?

Data Analysis

- Multiple logistic regressions were used to model riparian tree establishment (establishment vs. non-establishment)
- **Establishment year**: a year of large recruitment events where two or more trees established in a reach
- Prior to logistic regression analysis – screened out variables using a univariate test
- Stepwise logistic regression used to select climate and flow variables
- Multivariate models of tree **growth** selected based on lowest AIC value

Tree Age Estimation: Comparison of Two Methods

1) Template method (Applequist, 1958)

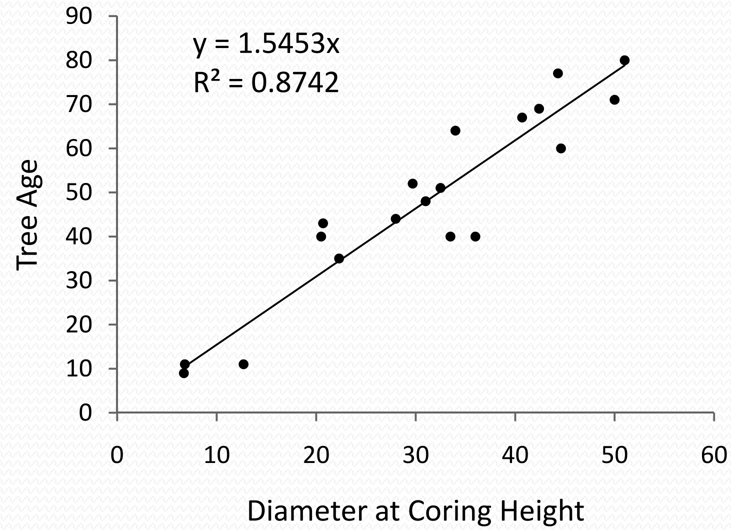
Pith

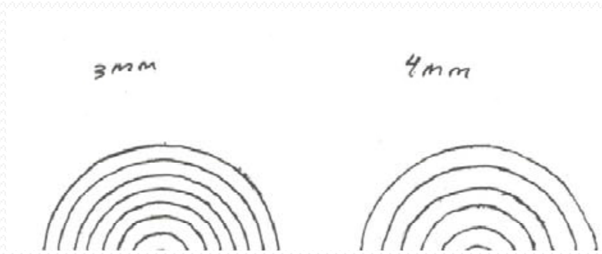
No Pith

Observed Age

Predicted Age

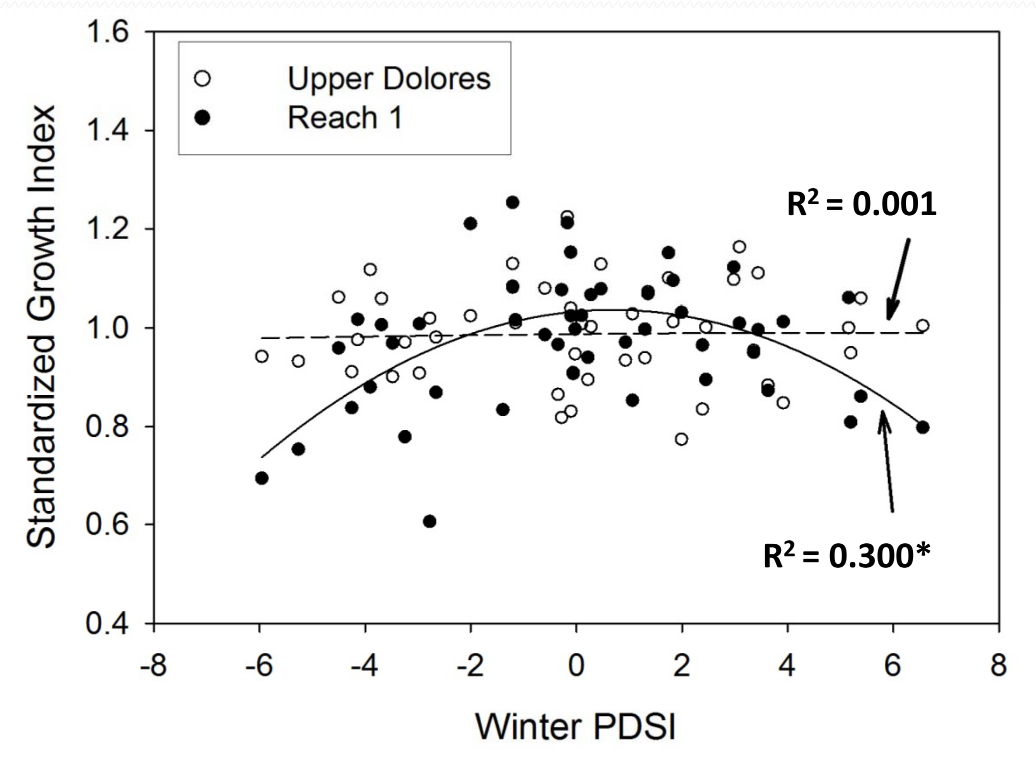
2) Age-diameter at coring height model

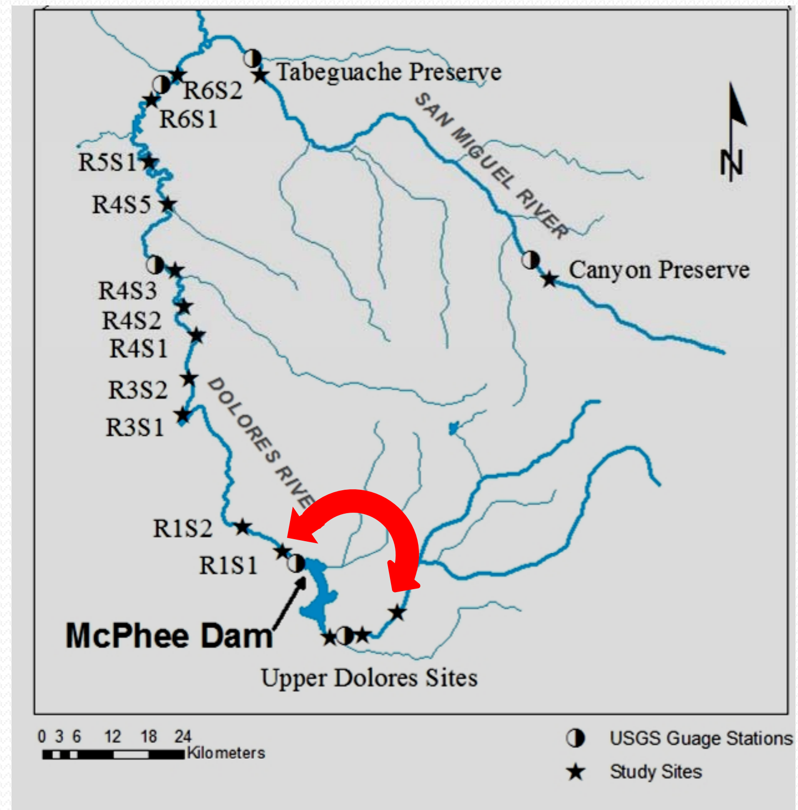




River Damming and Diversion Increased Growth Sensitivity to Drought

P. angustifolia **(1961-2008)**

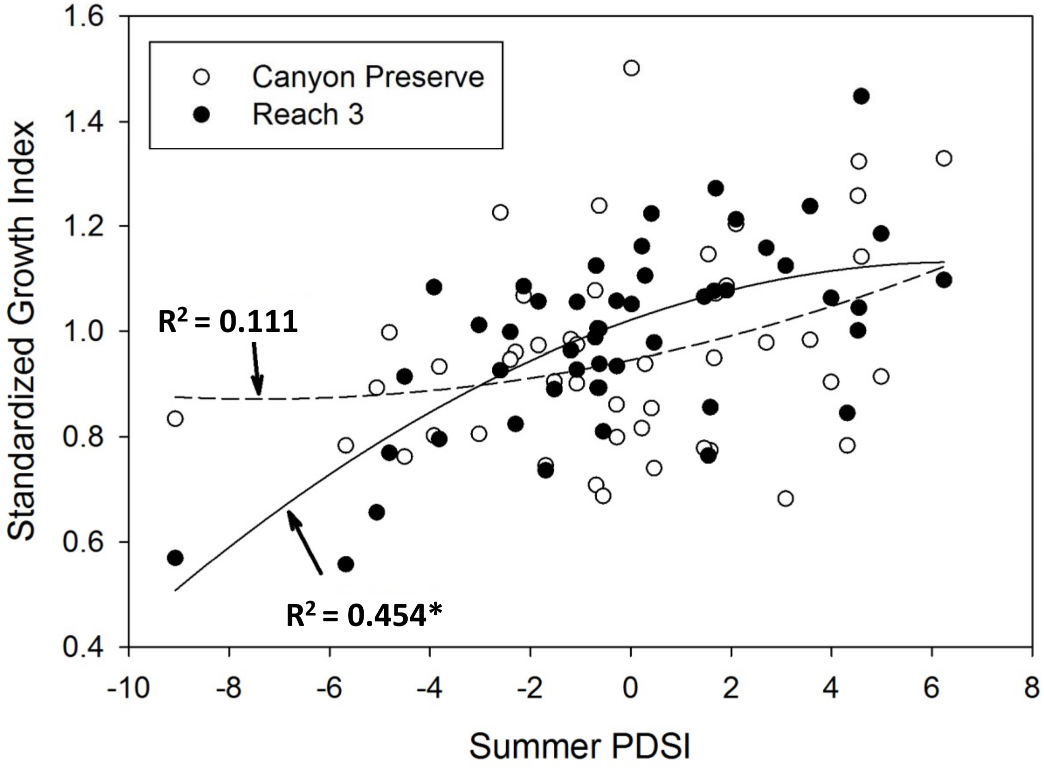


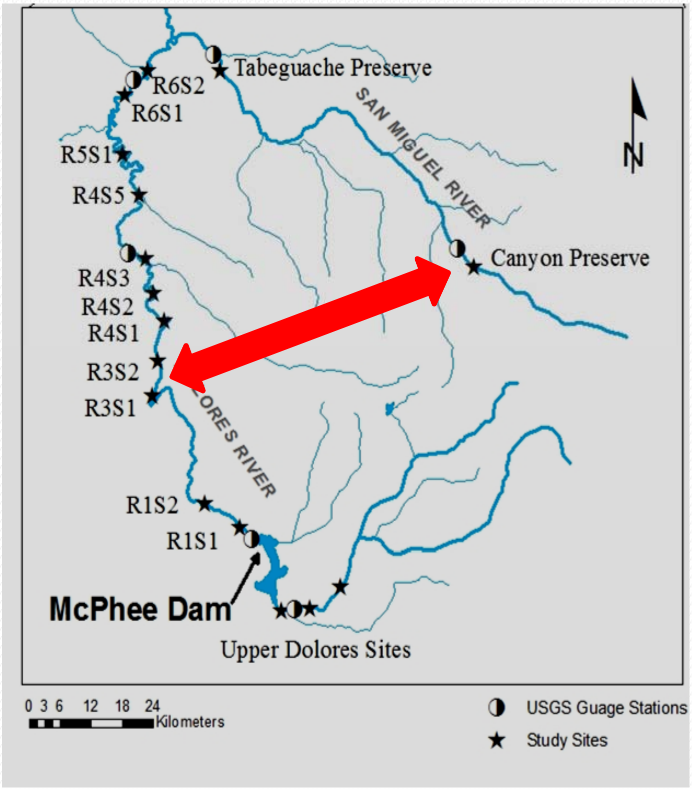


* p-value < 0.05

River Damming and Diversion Increased Growth Sensitivity to Drought

P. angustifolia **(1961-2008)**

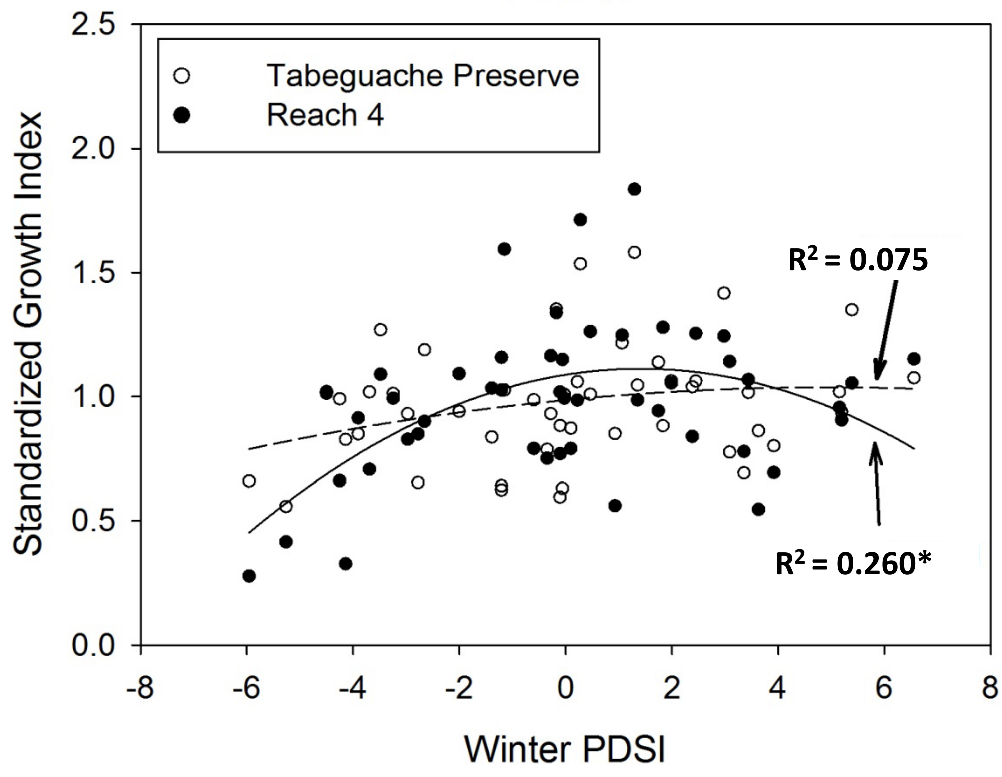


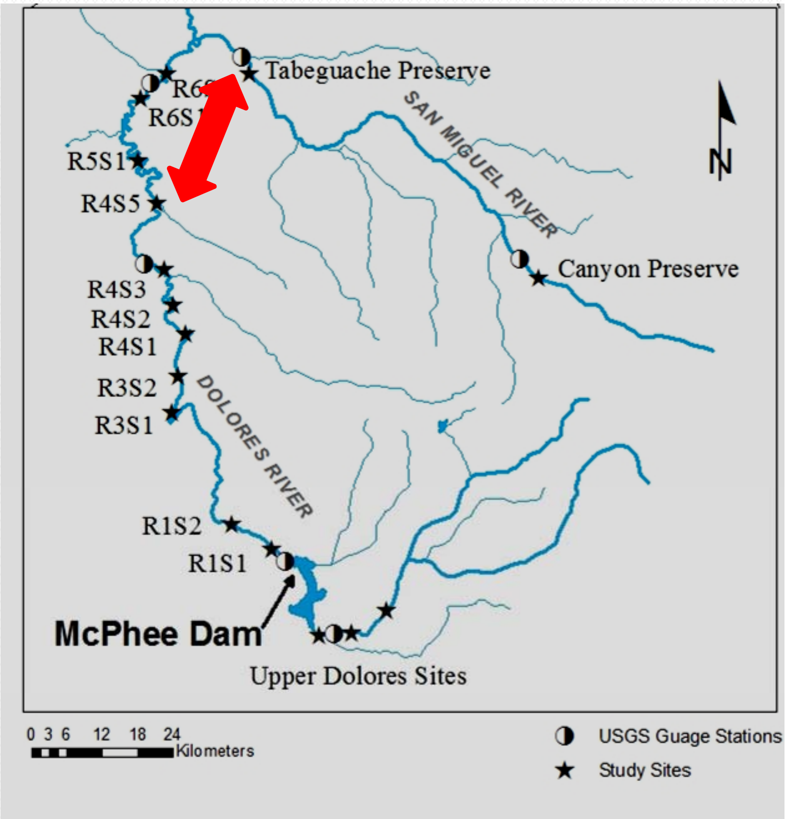


* p-value < 0.05

River Damming and Diversion Increased Growth Sensitivity to Drought

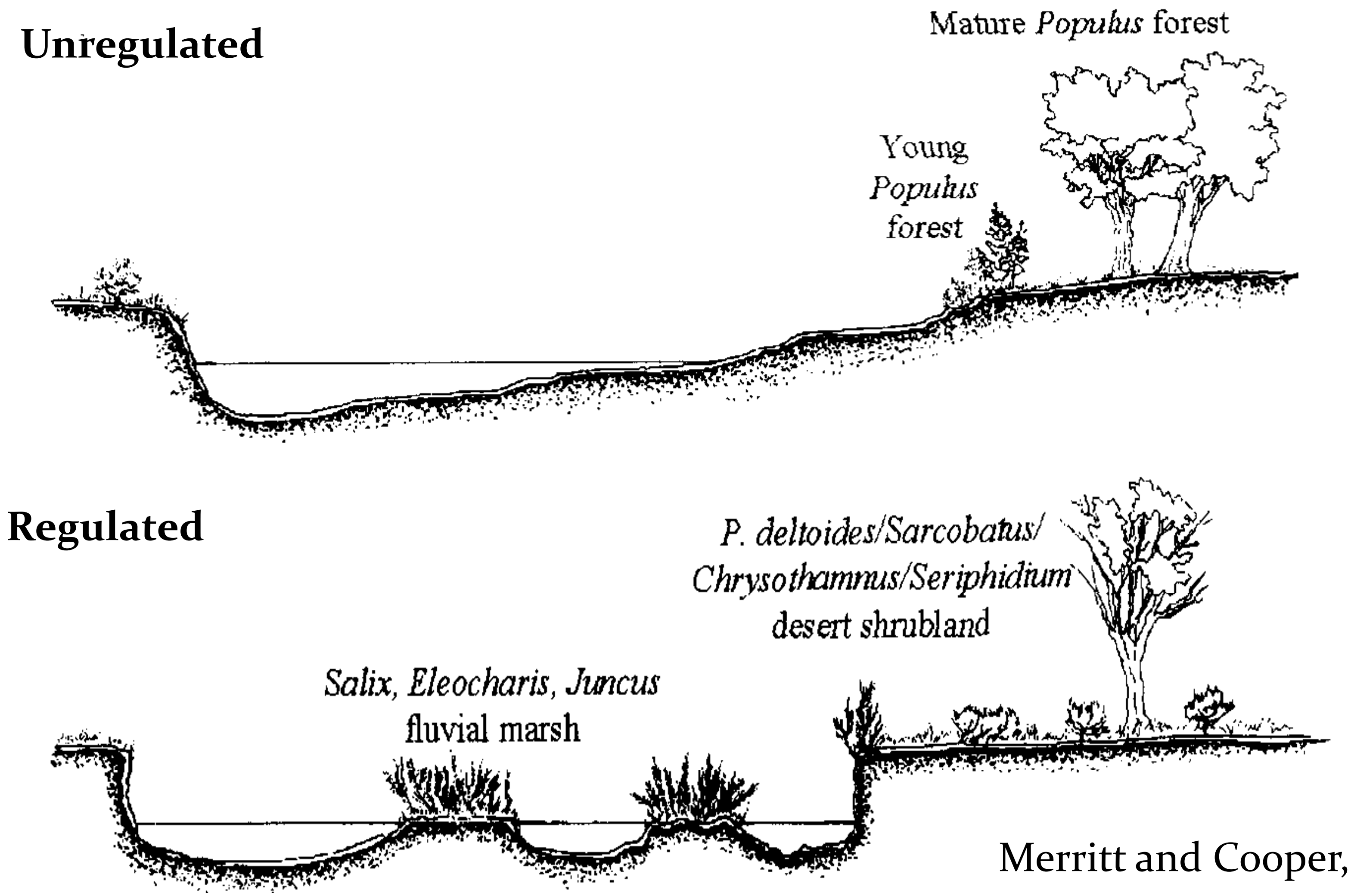
Populus deltoides **(1961-2008)**





* p-value < 0.05

Dam-Induced Channel Adjustments



Merritt and Cooper, 2000