TREE COLONIZATION TIMING AND FOREST DYNAMICS

ALONG THE SACRAMENTO RIVER, CALIFORNIA

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Riparian Summit, UC Davis, October 18, 2017

Background

- Riparian Forest Ecology

- Sacramento River Ecology

Study Objectives

Methods

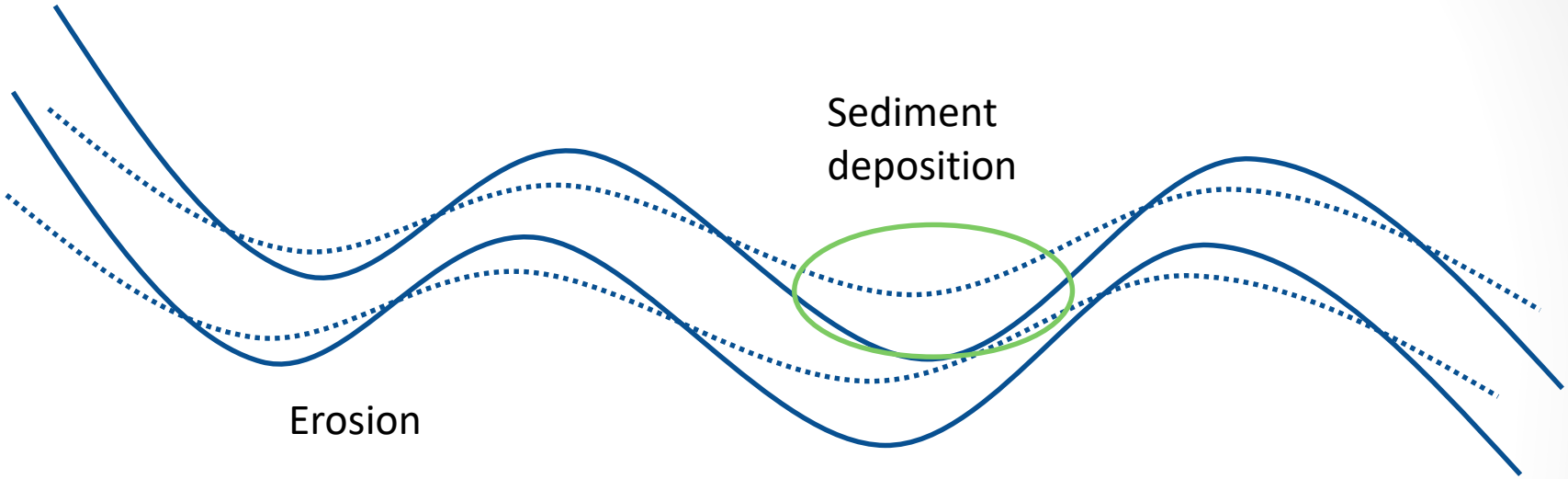
Results

Discussion

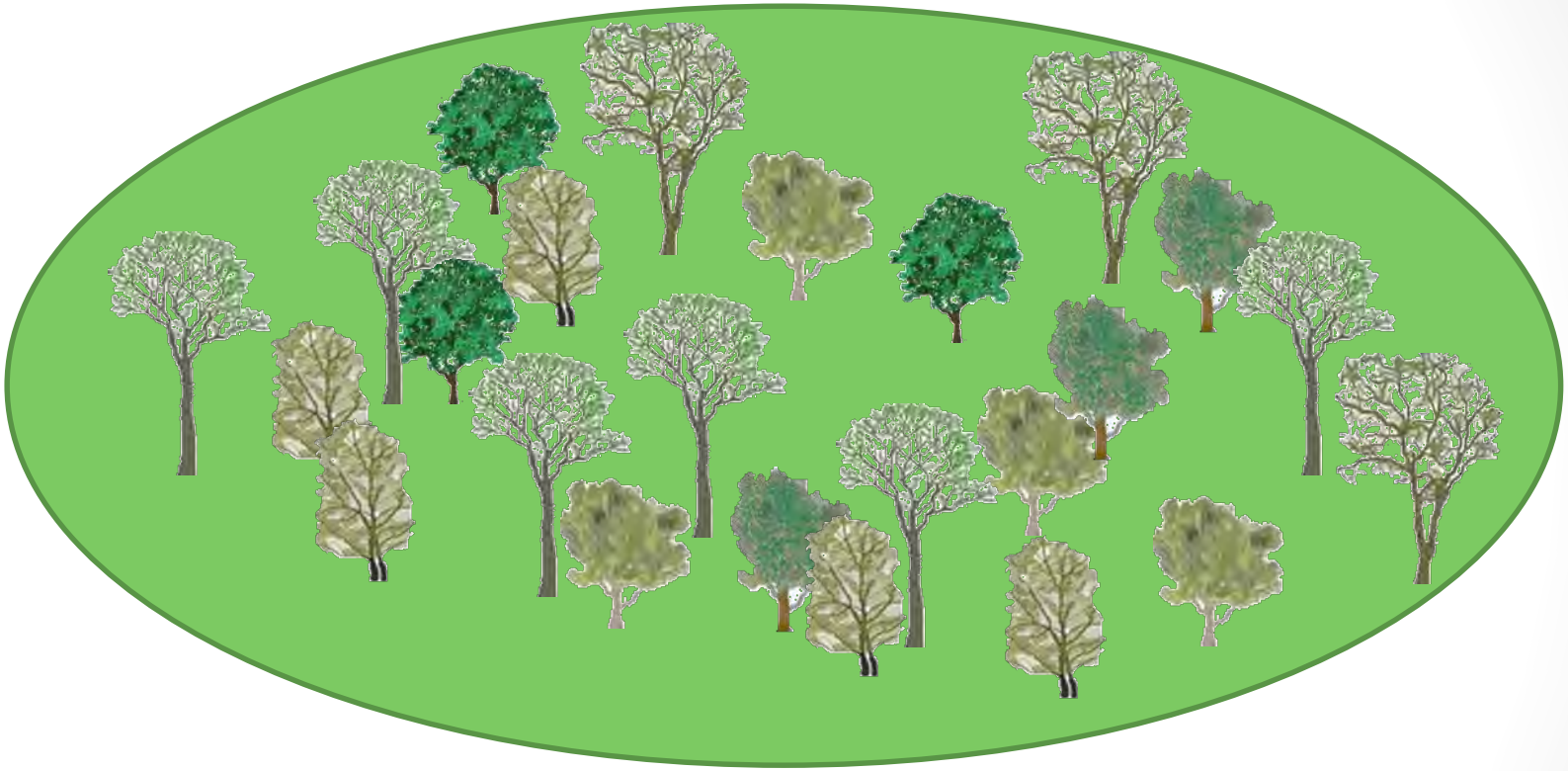
Future Research

Illustration Credit: River Partners

Riparian Zone Dynamics



Sedimentation on the inner bends



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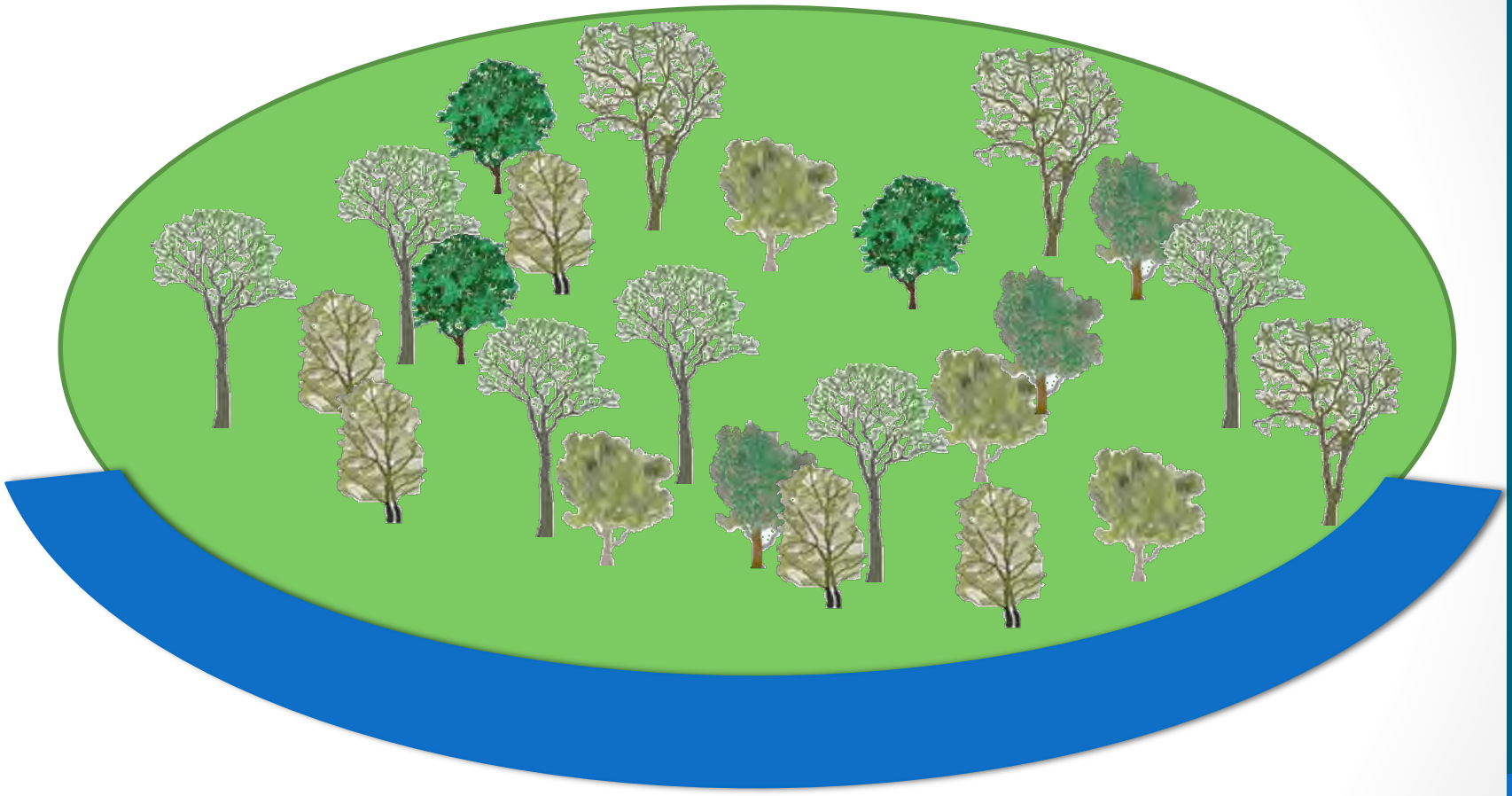
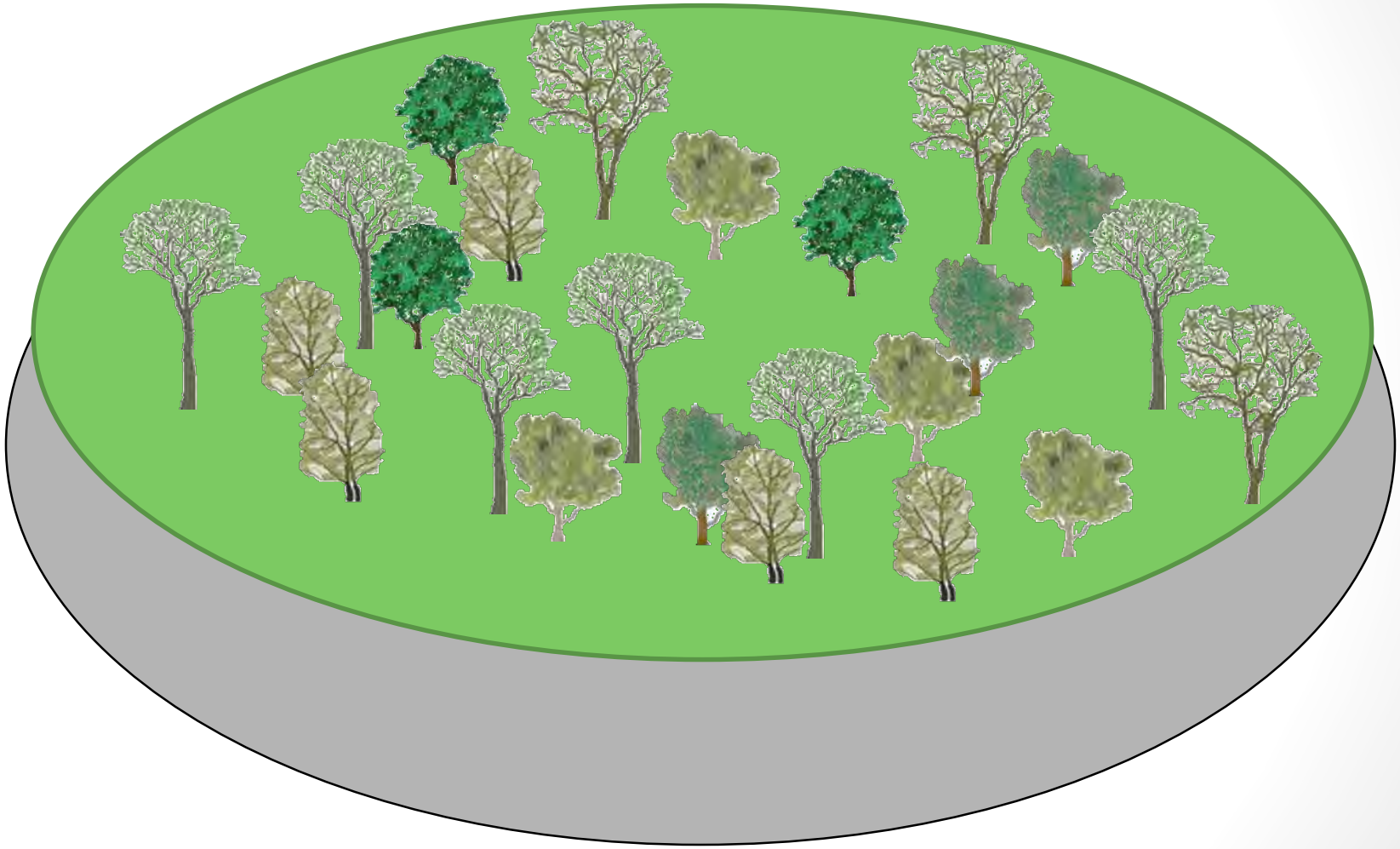
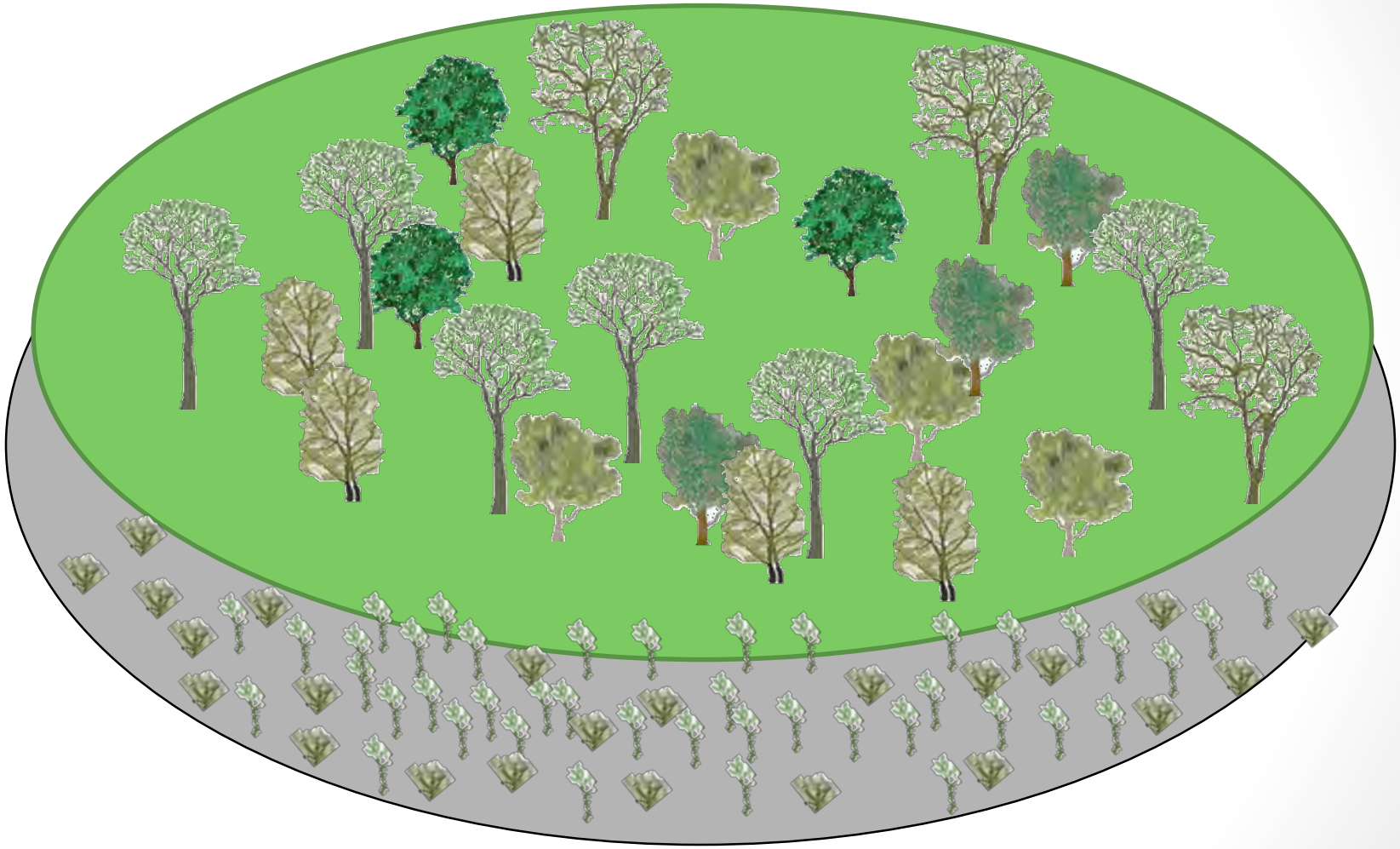


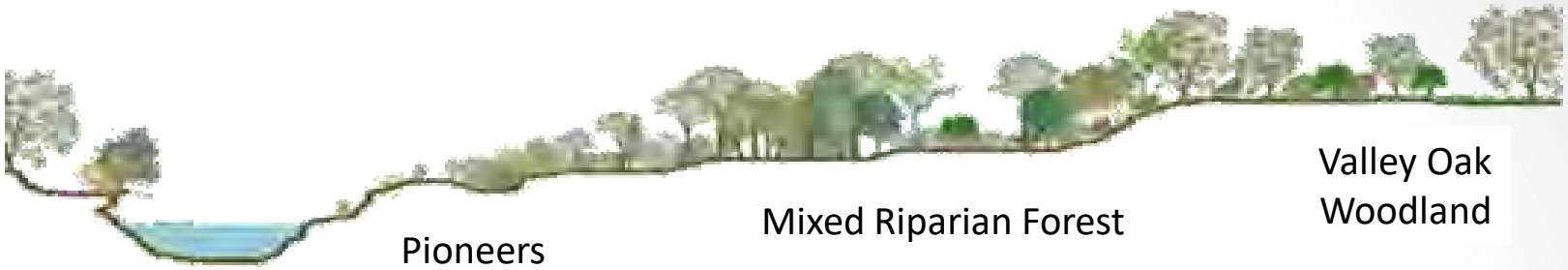
Sedimentation on the inner bends



Sedimentation on the inner bends



Chronosequences: space for time substitutions



Pioneers
(Willow-Cottonwood Forest and Scrub)

Mixed Riparian Forest

Valley Oak Woodland

Sedimentation, Meandering, Scouring

Cottonwood Willow Box elder Ash Walnut Oak

New floodplains

Older floodplains

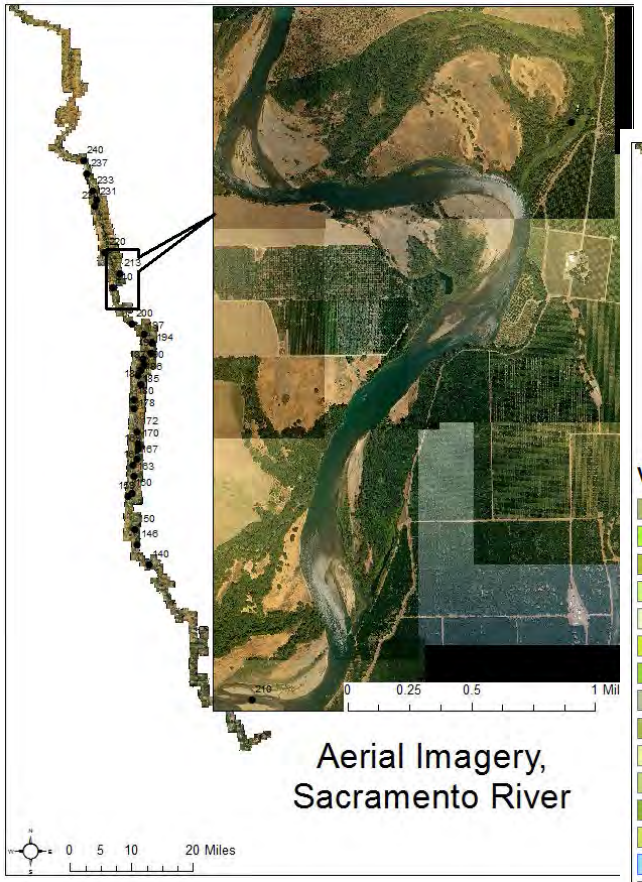
http://www.riverpartners.org/resources/riparian-ecology/physical-river-processes/


Sacramento River, California, U.S.A.
Redding
Shasta County
Lassen County
Red Bluff
Rivermile237
Tehama County
Plumas County
Magalia
Paradise
Chico
Butte County
Glenn County
Oroville
Rivermile146
Grass Valley
Colusa County
Lake County
Yuba City
Linda
Olivehurst
South Yuba City
0 5 10 20 Miles
Redding
Sacramento
San Francisco
Fresno
Los Angeles
N
W
E
S
Middle Reach
0 62.5 125 250 Miles
Andrea Irons, July 2014. Data Sources:
1. U.S. Geological Survey. 2011. National Land Cover Database.
2. CA Dept. of Technology. 2014. State of California Geoportal.

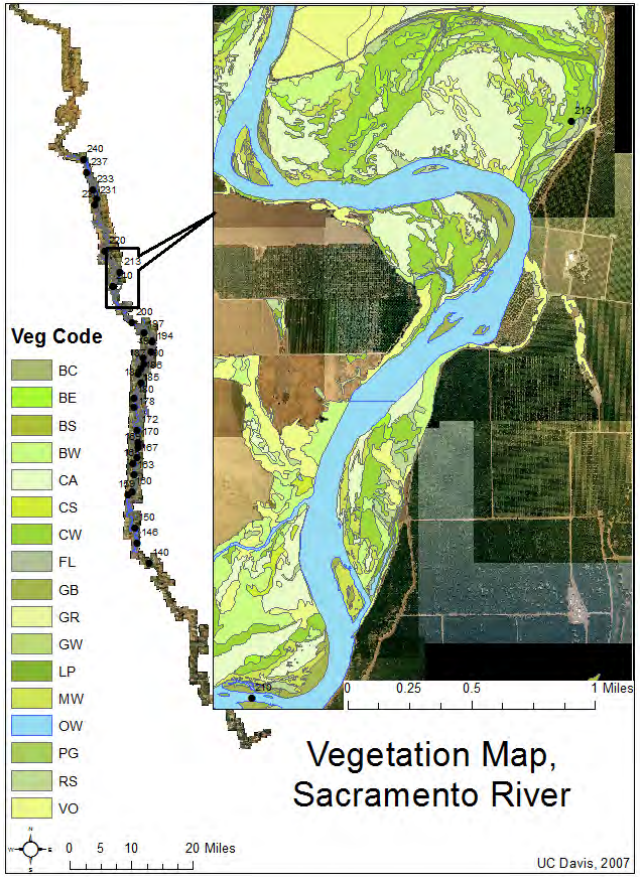
Study Area


Redding
Shasta County
SHASTA DAM
Red Bluff
Rivermile237
Tehama County
Butte County
Glenn County
Oroville
Rivermile146
Grass Valley
Colusa County
Yuba City
Linda
Olivehurst
Lake County
South Yuba City
0 5 10 20 Miles

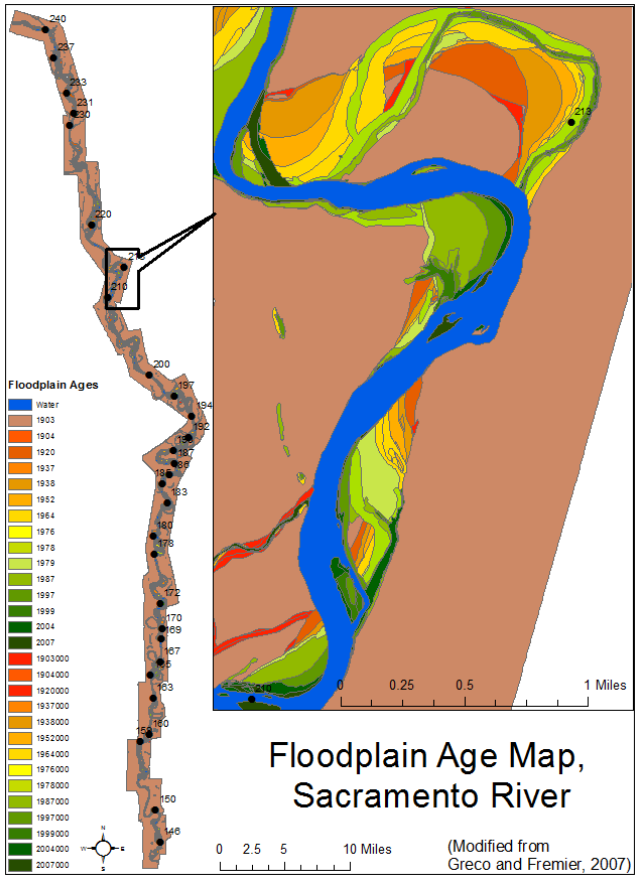
Study Area



Aerial Imagery, Sacramento River



Vegetation Map, Sacramento River



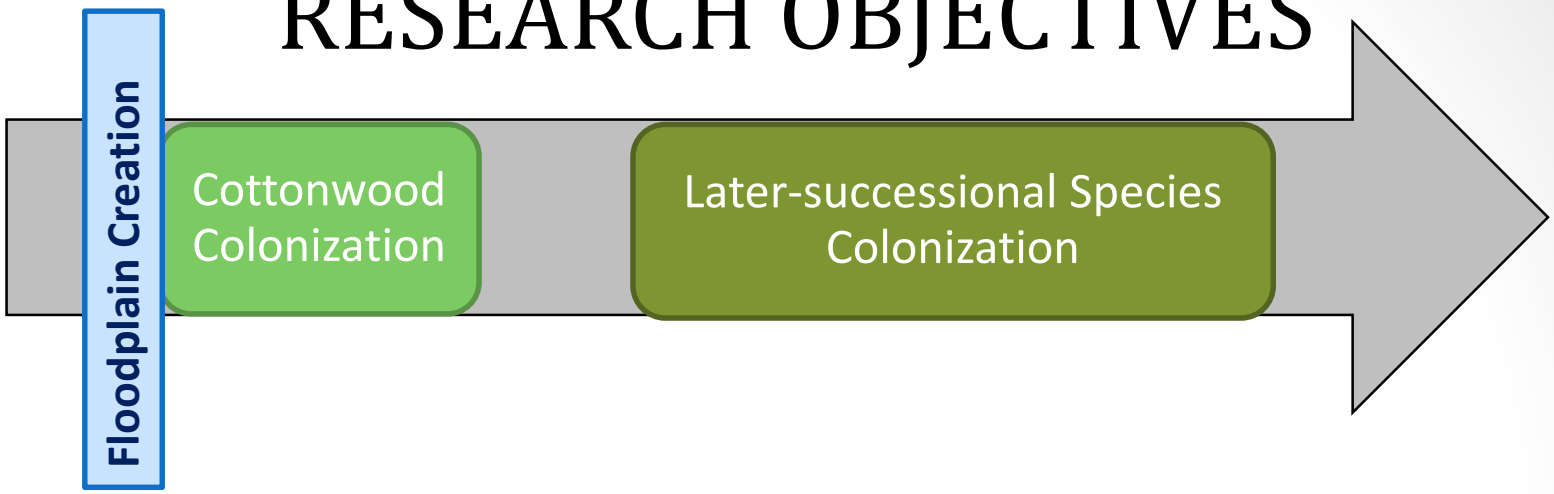
Floodplain Age Map, Sacramento River

(Modified from Greco and Fremier, 2007)

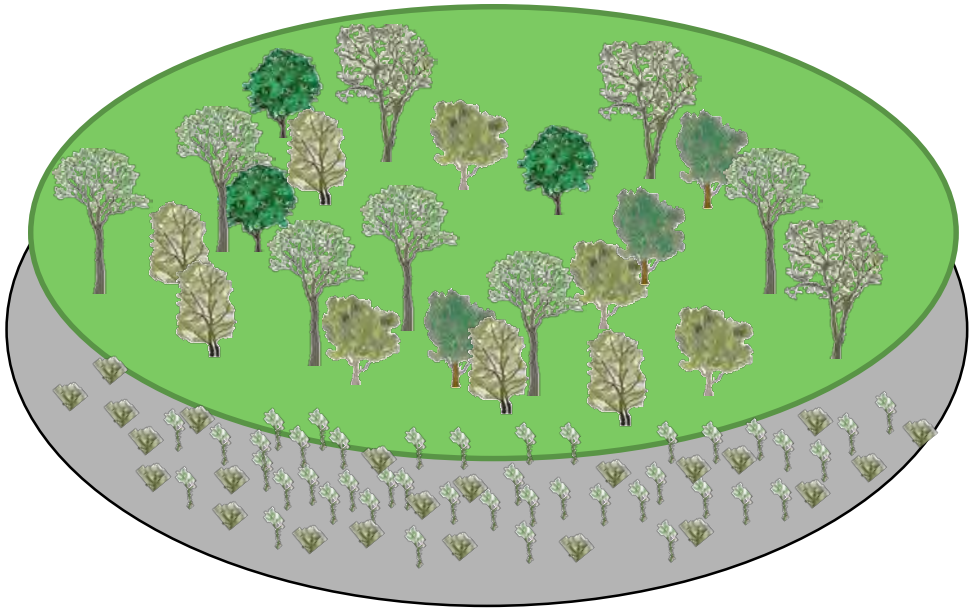
Field Studies:

- Strahan 1984
- Capello 1991
- Wood 2003
- Stella 2011

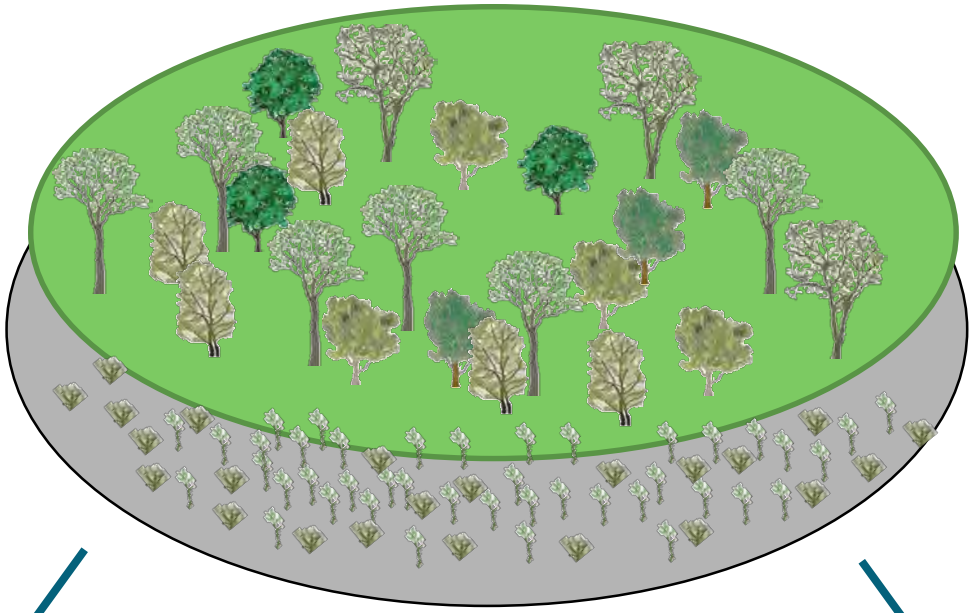
RESEARCH OBJECTIVES



1. Determine ages of dominant trees cored throughout the floodplain of the Middle Reach, Sacramento River
2. Infer relative timing of floodplain colonization for each species by comparing tree ages to their associated floodplain age
3. **Construct a general pathway of forest community succession, focusing on the time lapses between successive species colonization**
4. Discuss plausible ecological drivers of the successional trajectory and explore potential variations to that pattern over time



What is the successional pattern along the Sacramento River's Middle Reach?



Relay Floristics

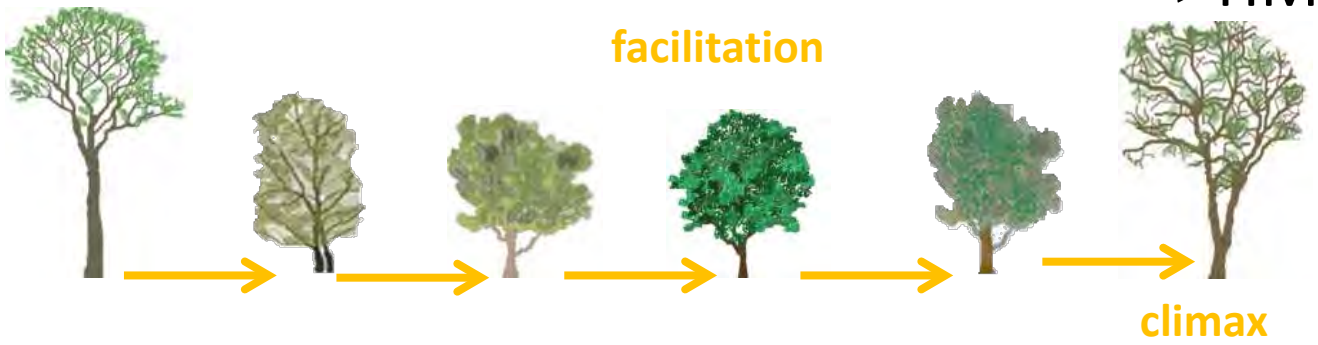
- Pioneer species modify the environment
- Facilitation of later successional species

Initial Floristics

- First to arrive, first to thrive
- Competition determines community composition

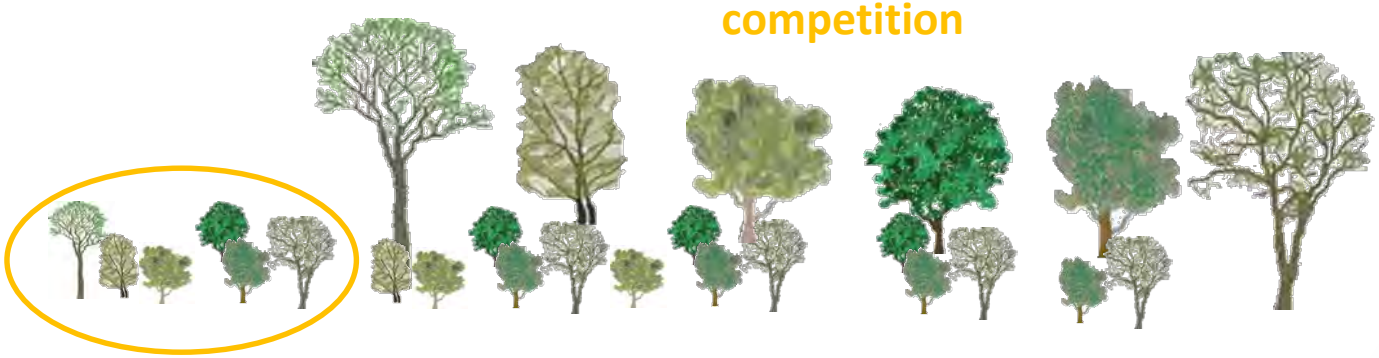
Relay Floristics (Clements, F.E. 1916)

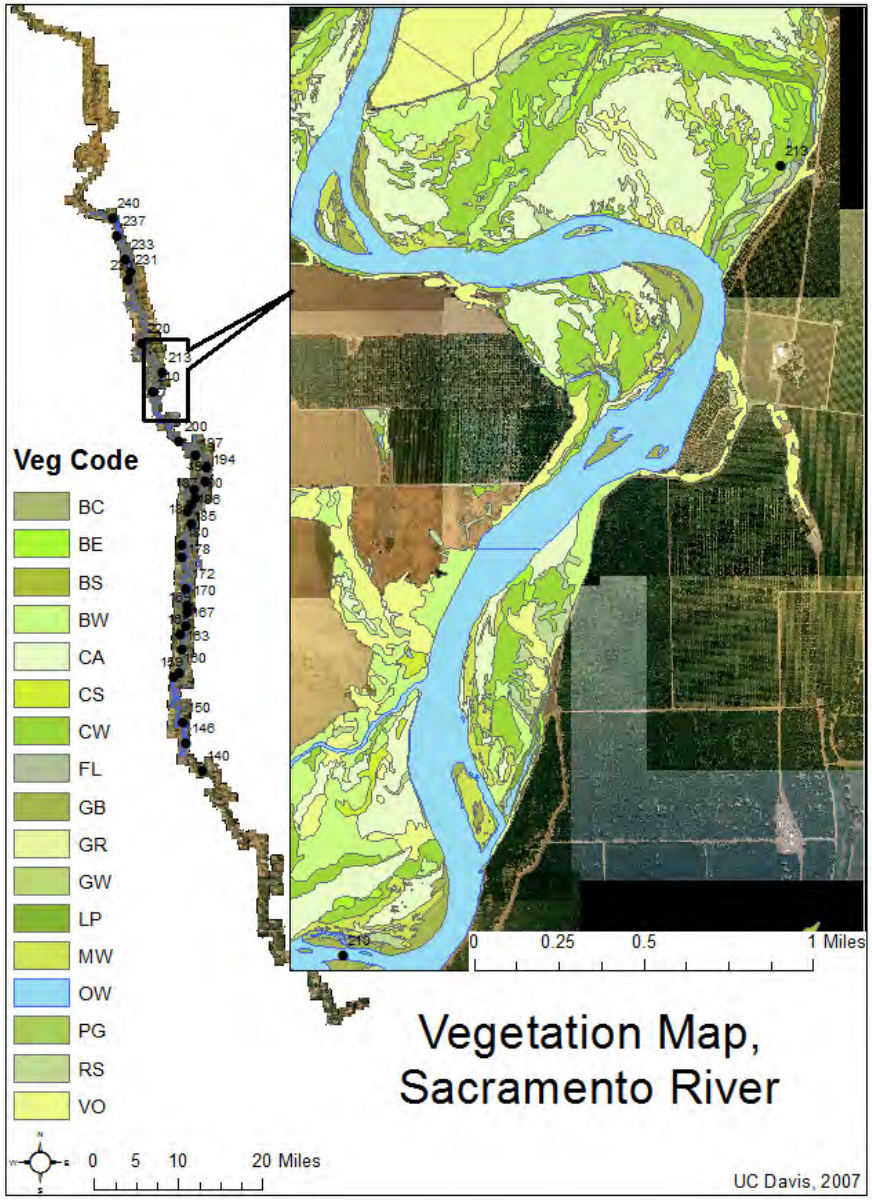
----------->TIME



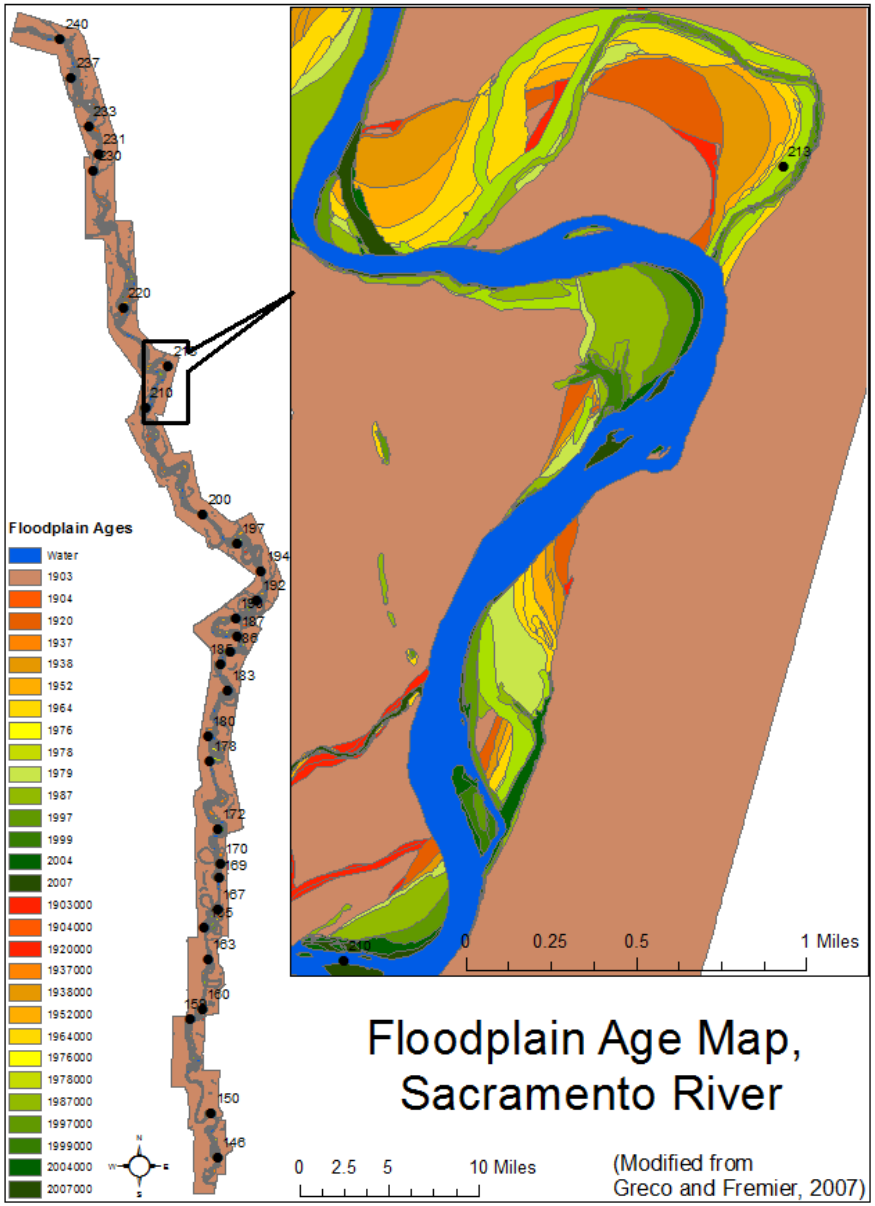
Initial Floristics (Gleason, H.A. 1917; Egler, F.E. 1954)

----------->TIME





Methods: Site Selection



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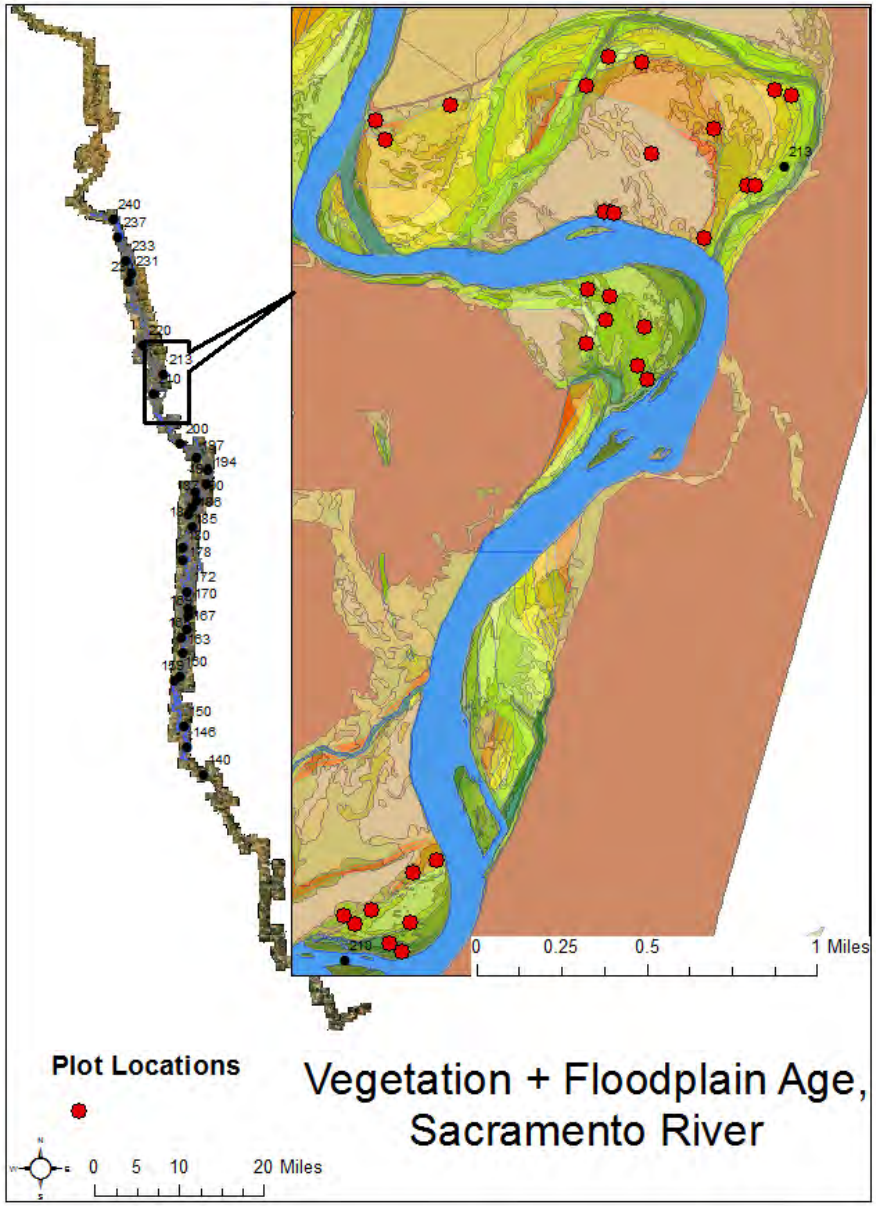
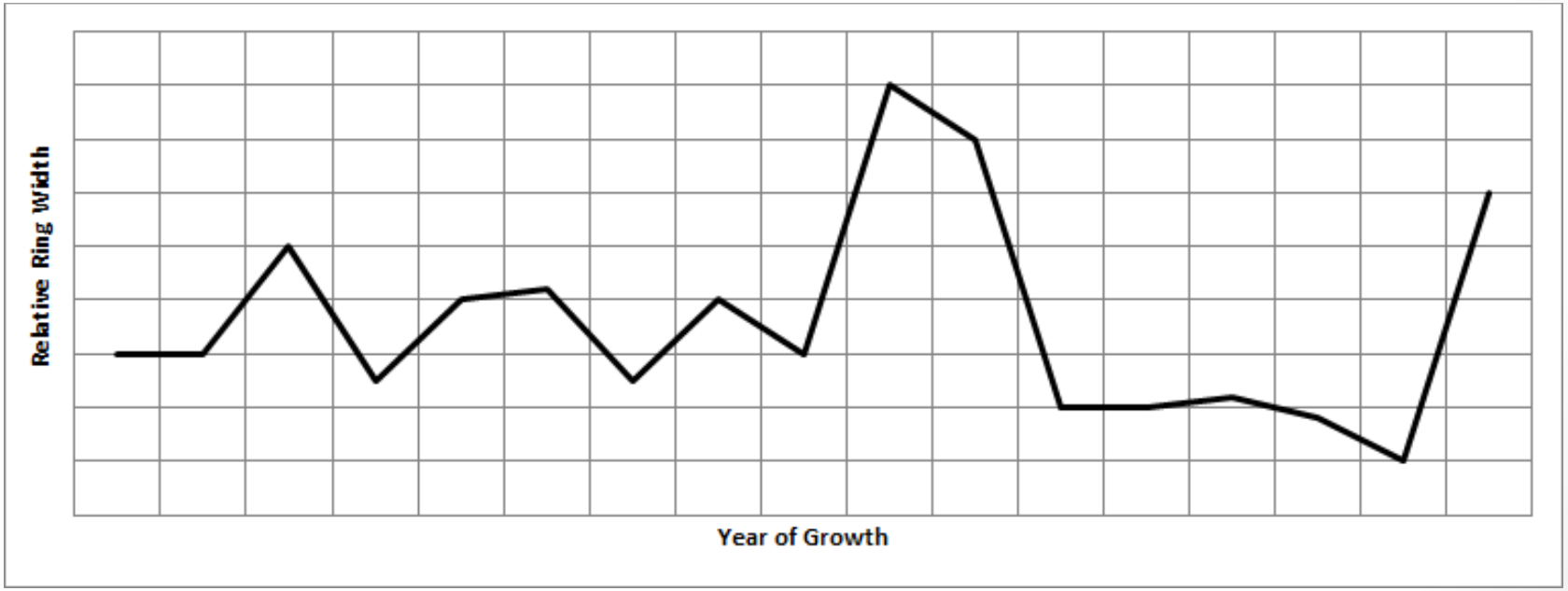


Methods: Site Selection

Lab Methods

- Mounted and sanded 1000+ tree cores
- Ring counts by two independent technicians



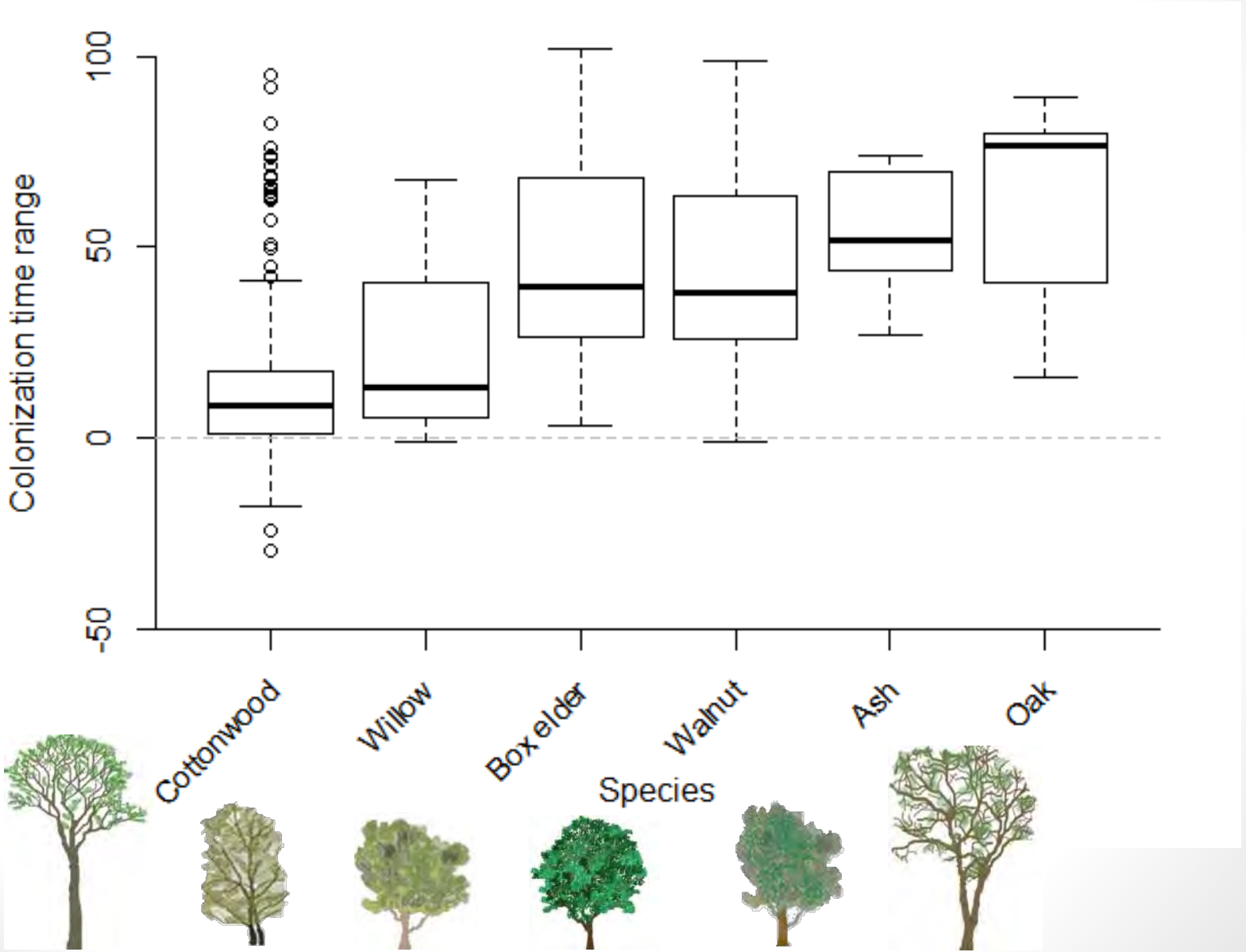
Final Tree Ages and Colonization Times

- Since Monte Carlo simulations incorporate error, all age predictions (1000/tree) were binned and the 95th and 5th percentiles defined, giving an approximation of the distribution of trees through age classes

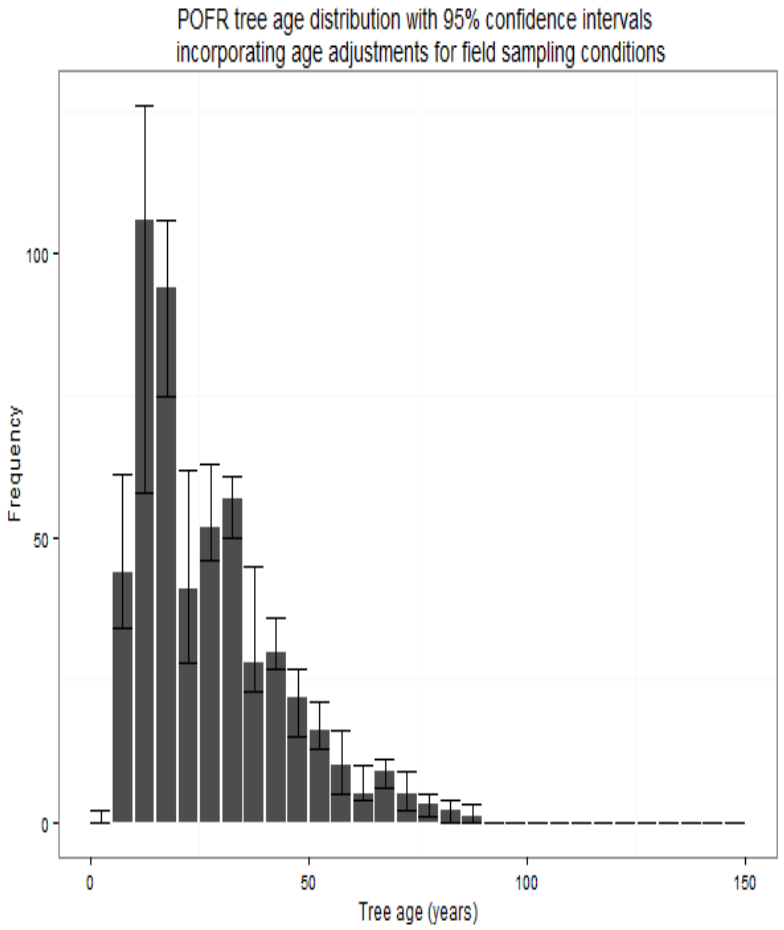
- For final colonization time calculations, added all simulation matrices and took medians as each individual final tree age

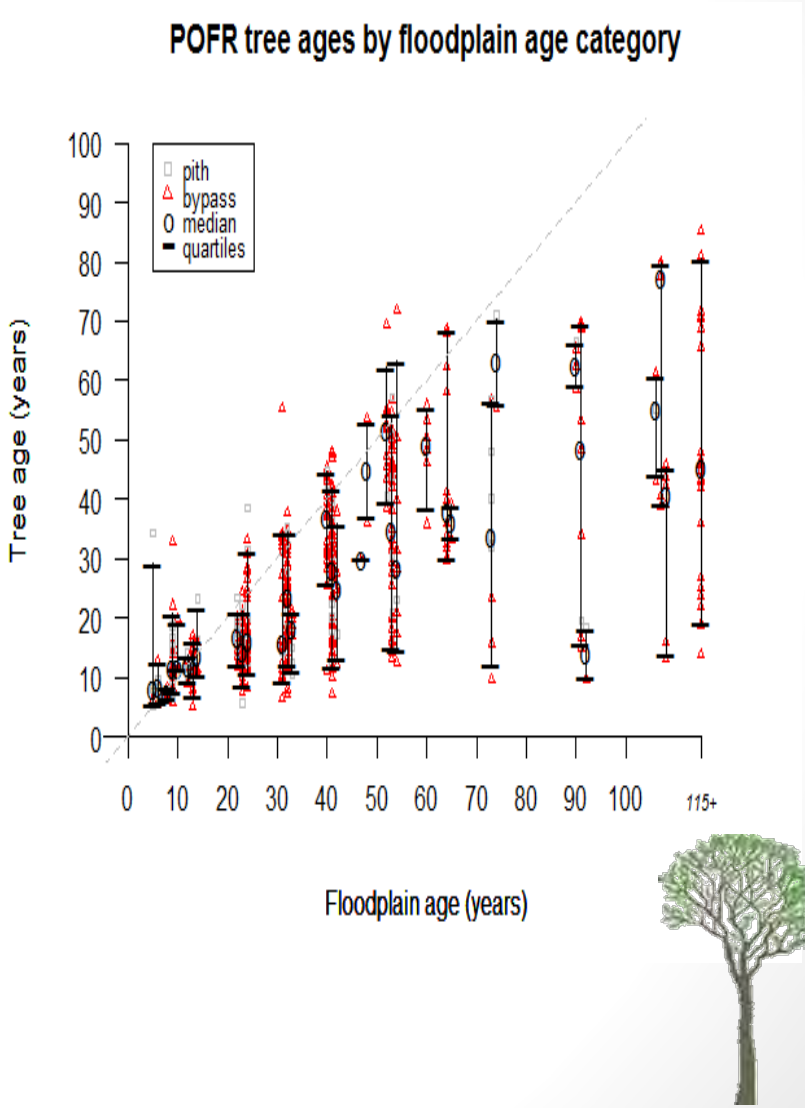
$$\frac{\boldsymbol{Final\ Tree\ Age} - \boldsymbol{Maximum\ Floodplain\ Age}}{\boldsymbol{Colonization\ Time}}$$

General Successional Pattern

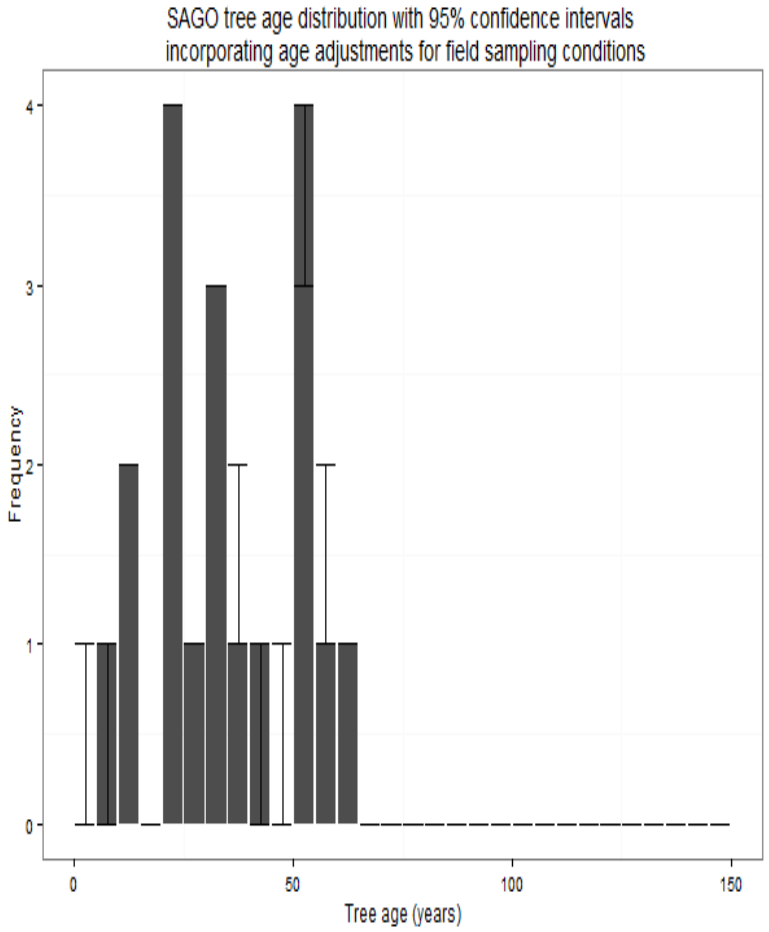


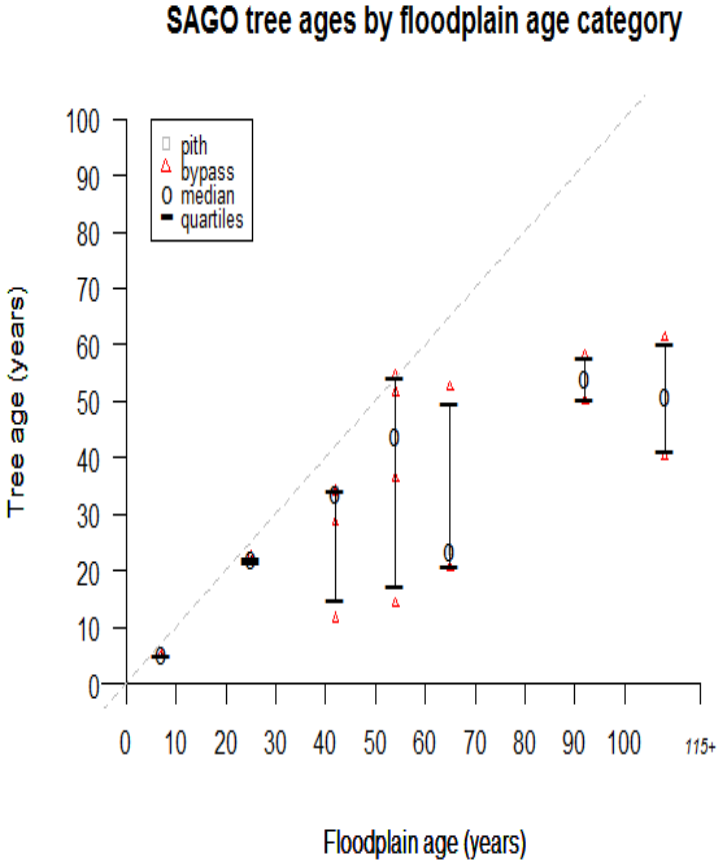
Cottonwood Tree Ages and Colonization Times



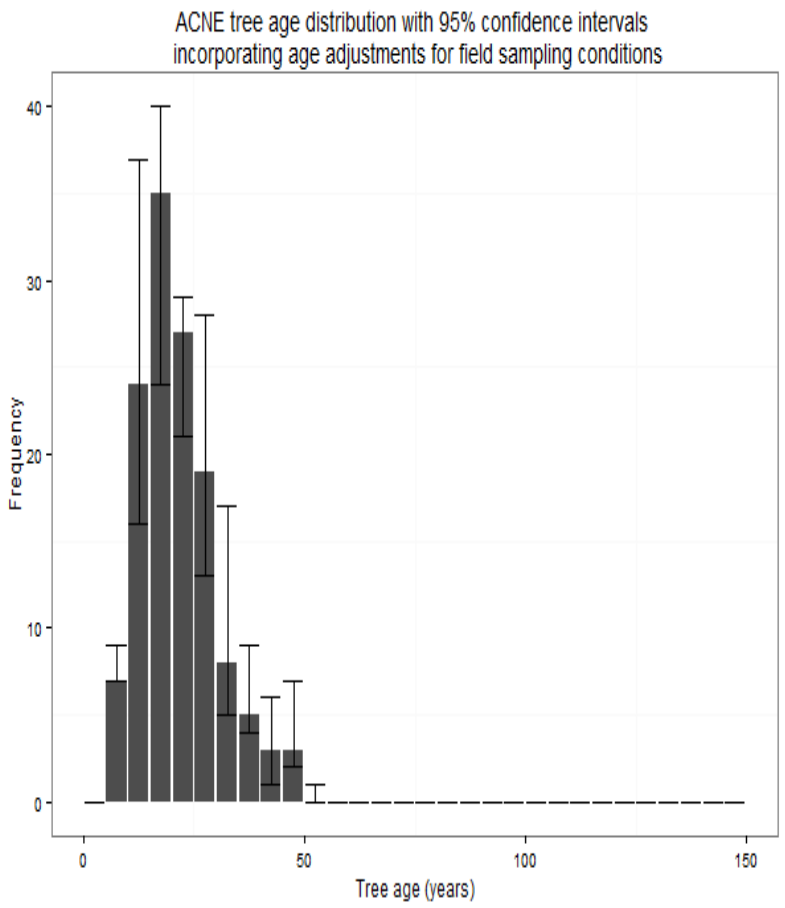


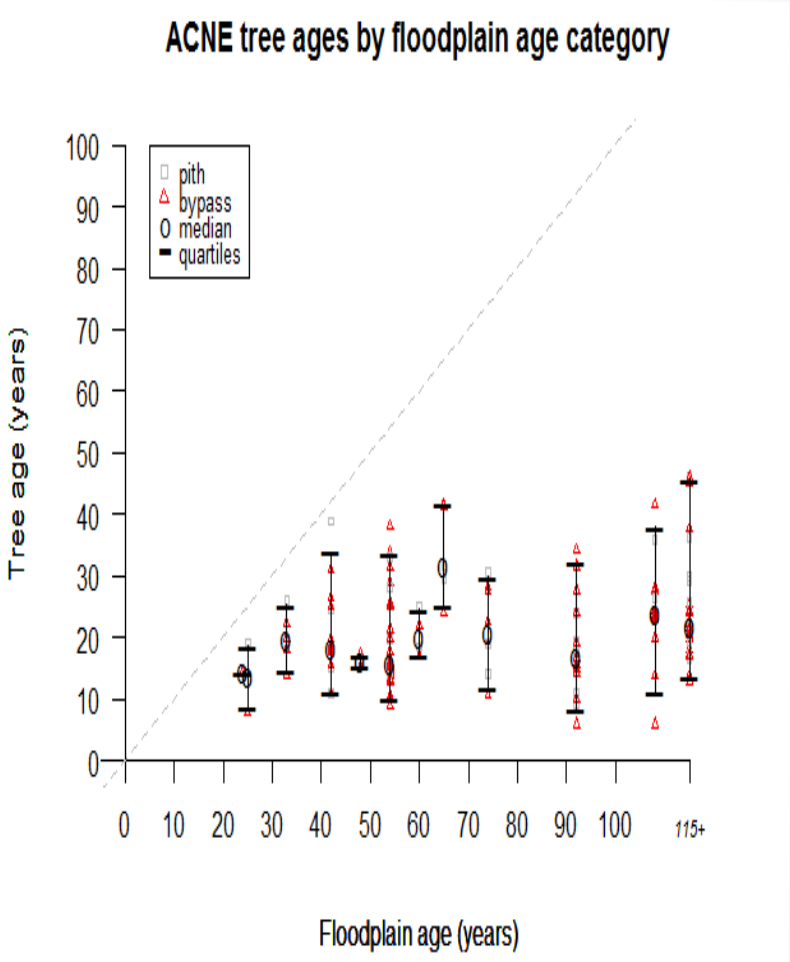
Willow Tree Ages and Colonization Times



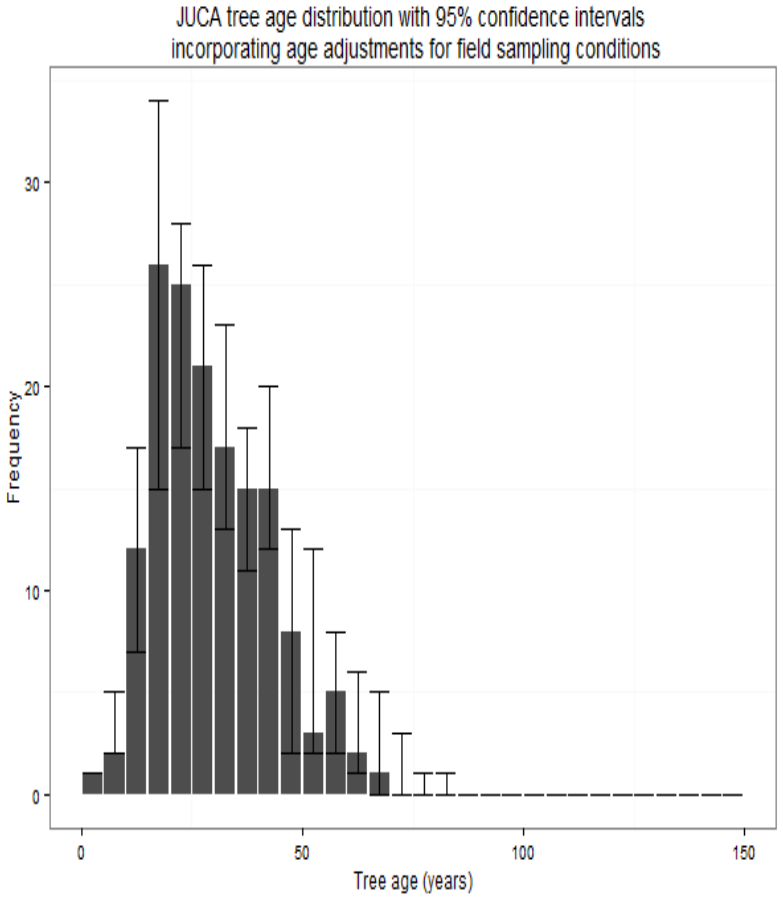


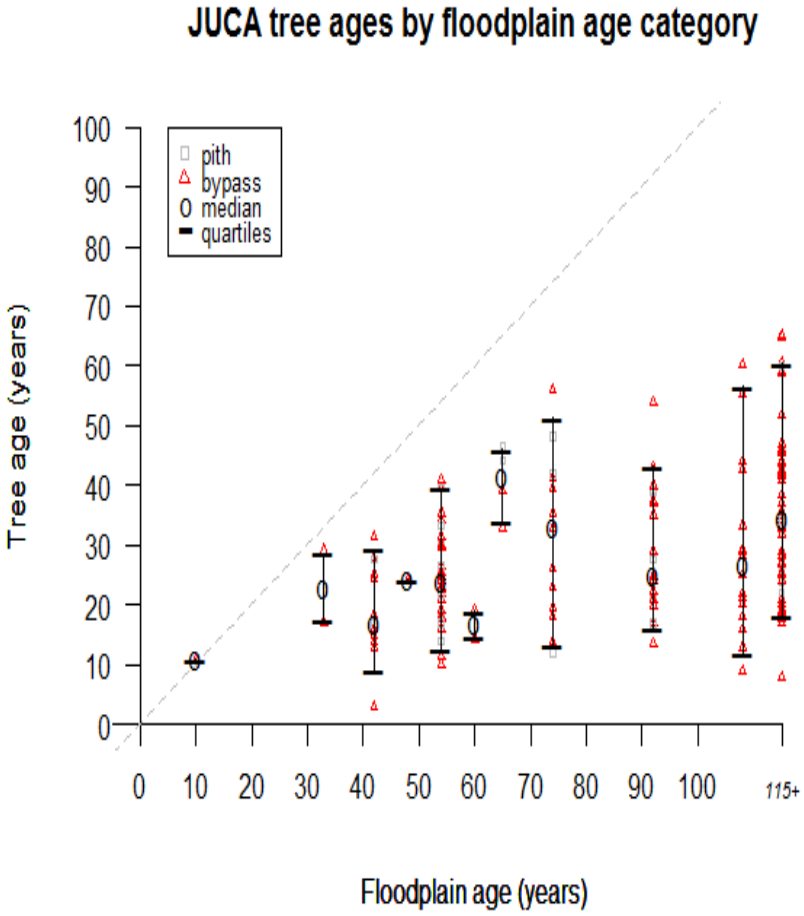
Box Elder Tree Ages and Colonization Times



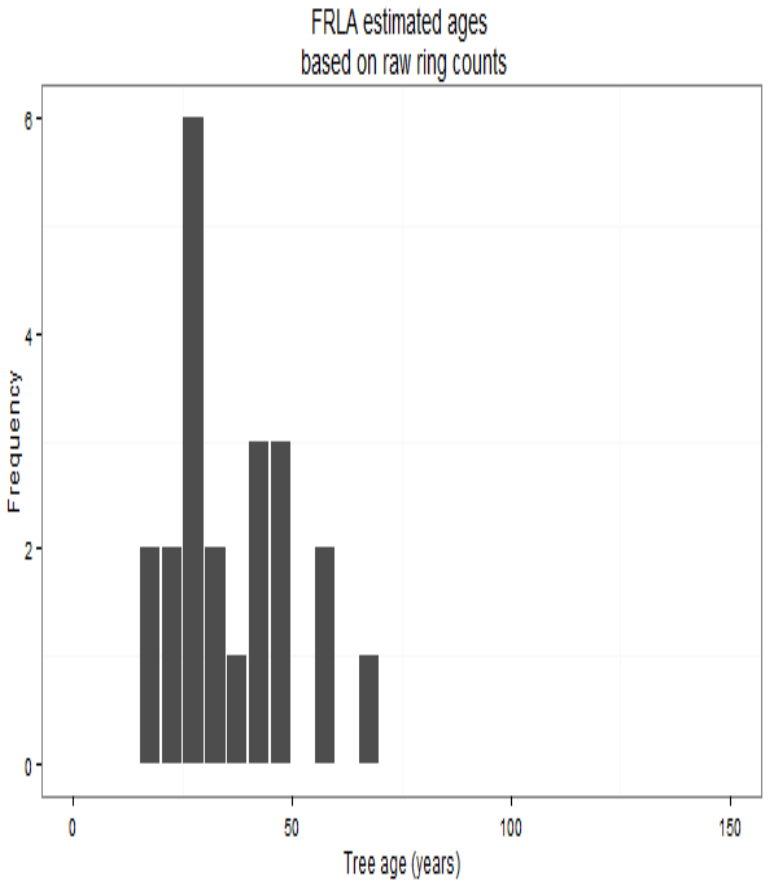


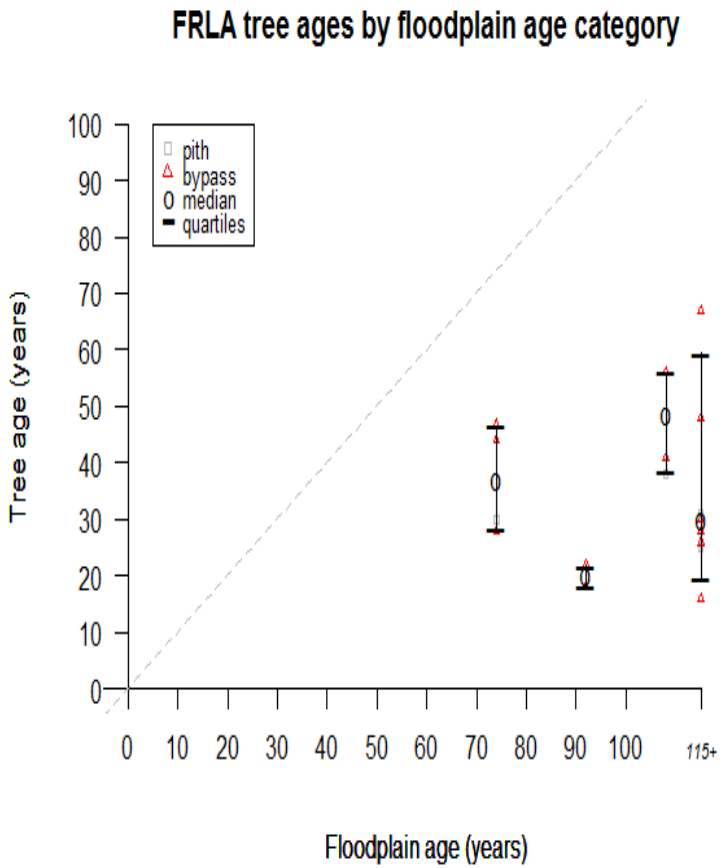
Walnut Tree Ages and Colonization Times



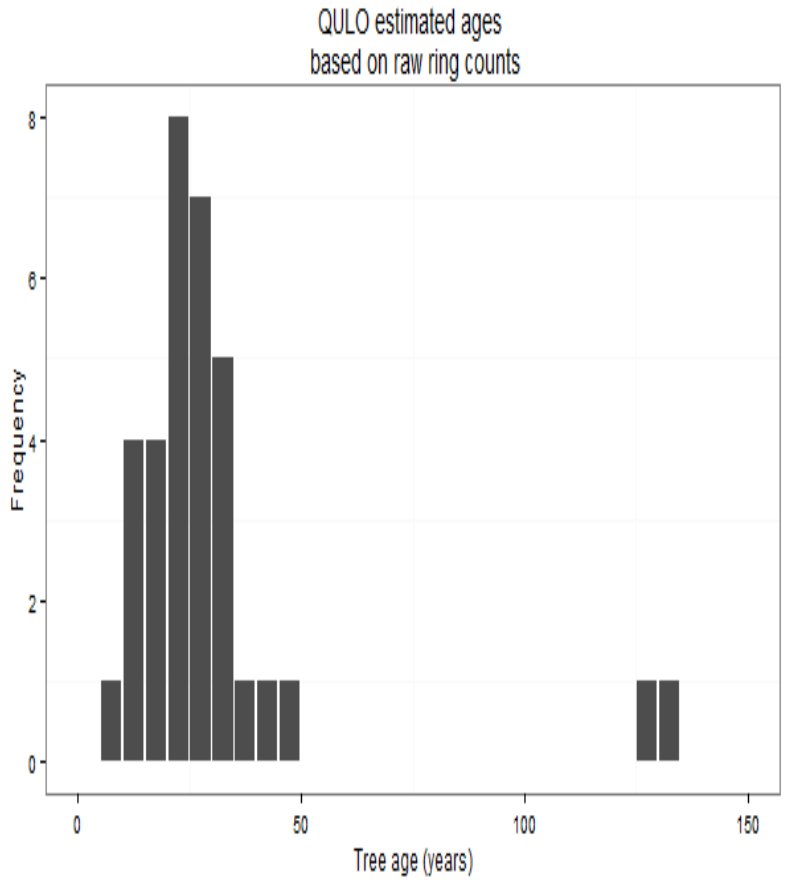


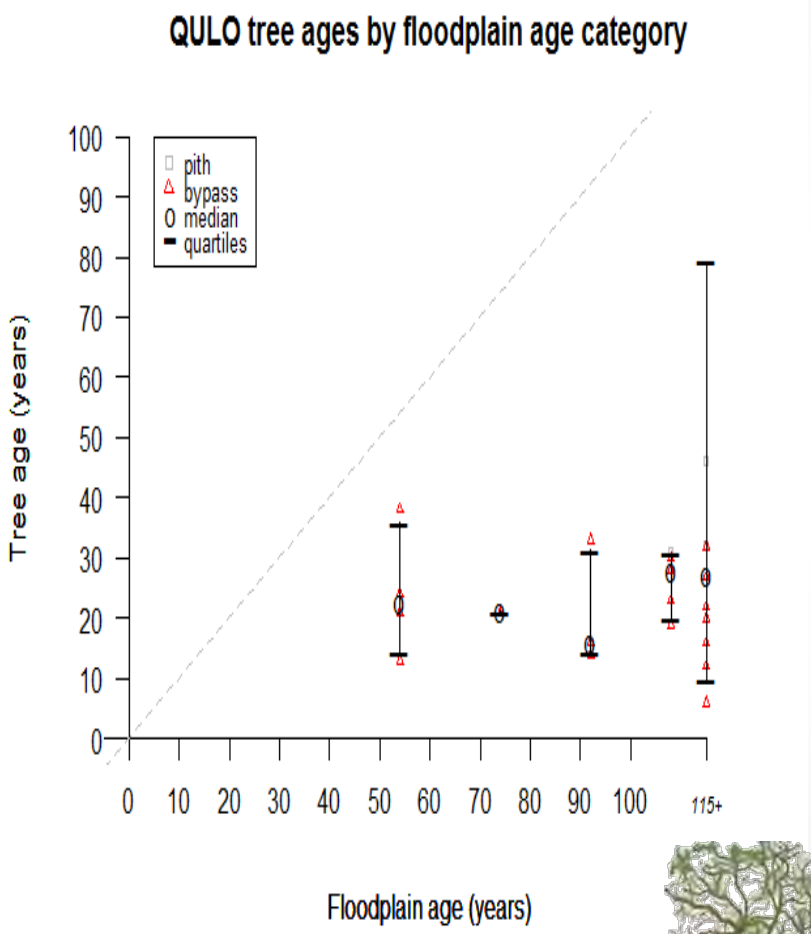
Ash Tree Ages and Colonization Times





Oak Tree Ages and Colonization Times





Ecological implications of results

Cottonwoods have a wider range of colonization times than expected.
Cottonwood establishment does occur soon after floodplain creation
Cottonwoods *also* continue to recruit up to 95 years after floodplain creation
-may be recruiting in successive flood events that open up spaces for colonization

Walnut and Box elder do not seem to require facilitation, as they are capable of establishing within 10 years of floodplain creation in the last forty years.
These species are short-lived relative to oak, so we can't draw any conclusions about its life history on older floodplains at this time.

Ash establishes after 25 years.
This high minimum colonization time suggesting it requires some facilitation from the overstory or else disperses slowly to new floodplains (less likely).

Oaks colonized after 30-40 years on floodplains created prior to the mid-1960's, but the earliest colonizing oak established 13 years after floodplain creation.
Surprising that oaks are capable of colonizing earlier than ashes, but definitely more successful on older floodplains

Succession is not systematic or consistent over time on the Sacramento River

Combination of Initial and Relay Floristics

----------->TIME

Future directions: extrapolating tree age data to inventory plots

We can better define age structures of each species population

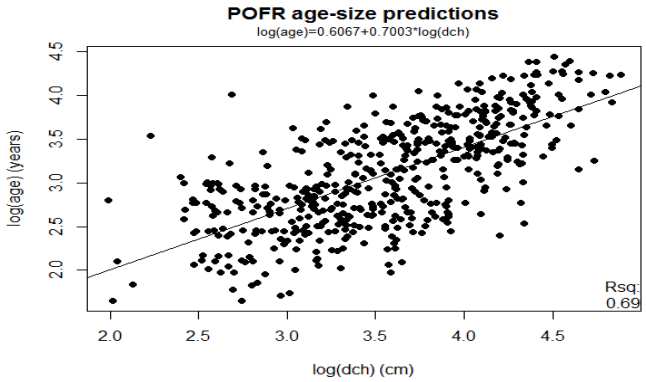
-Use age-DBH relationship to estimate ages of all trees in each plot, extrapolate to reach

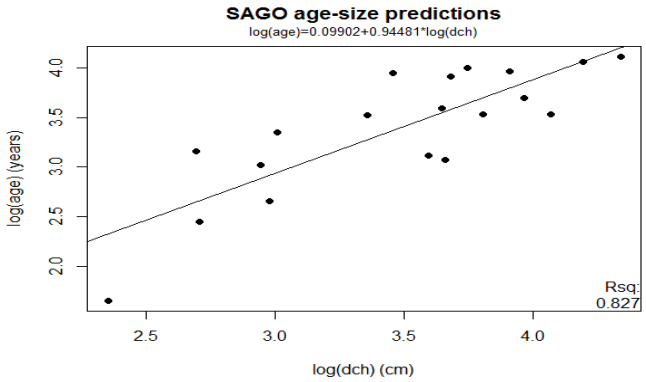
We have an idea of how populations have changed before and after dam construction, but need better models to determine whether population dynamics for each species are stable or declining

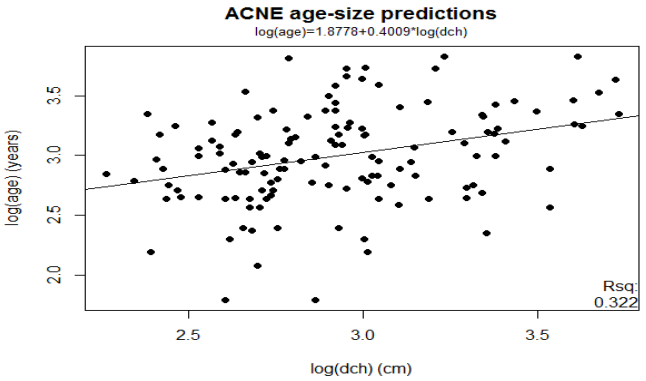
-Are pioneer species populations shrinking over time?

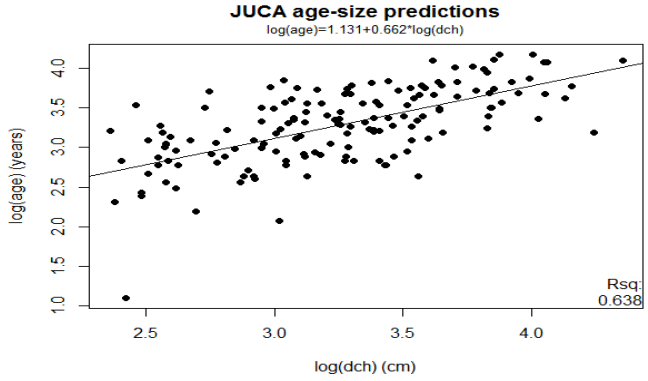
-Is the forest transitioning to later-successional species more rapidly in recent decades?

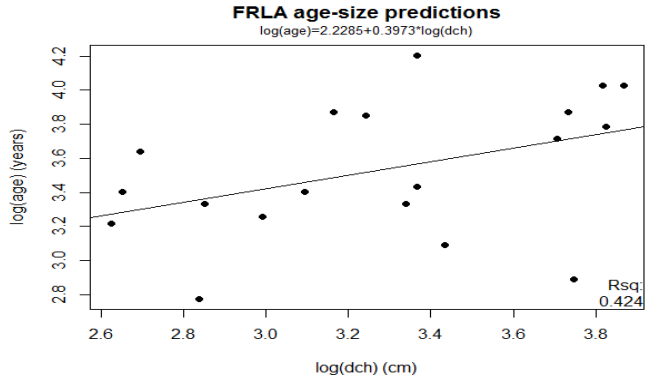
Age-size relationships

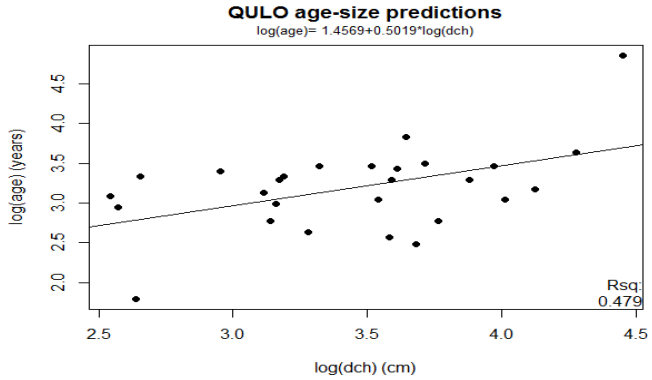






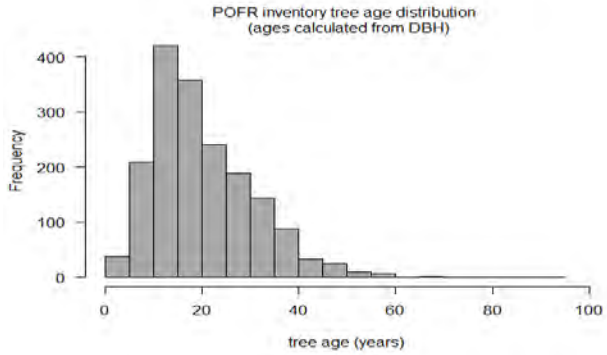


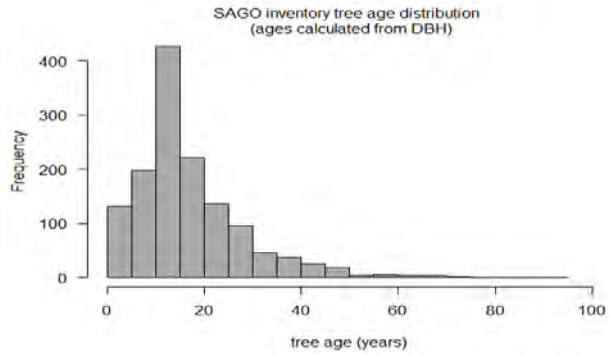


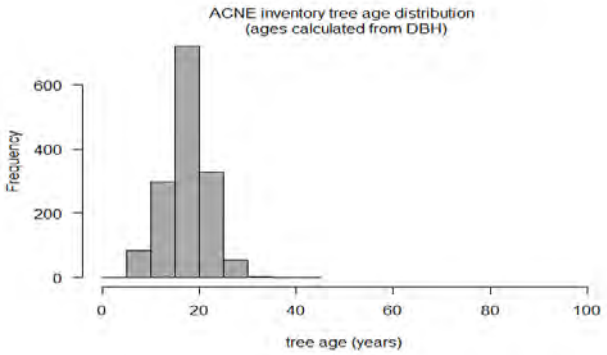


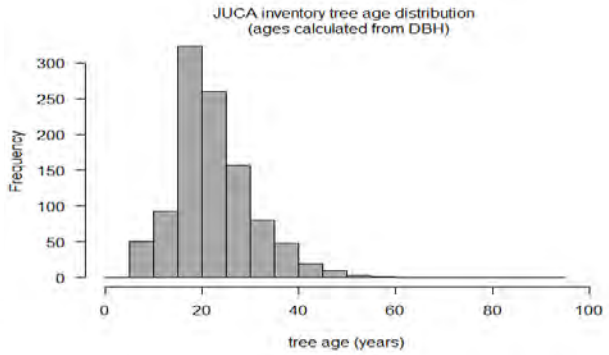
Preliminary Data

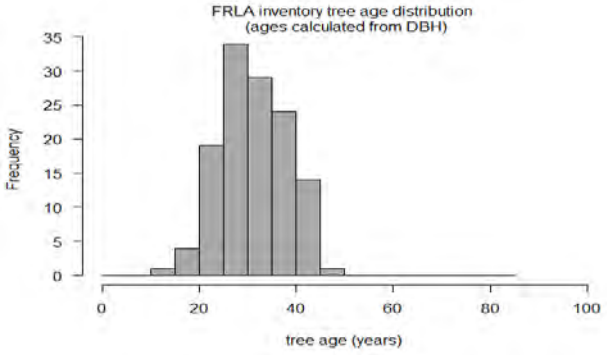
Resulting plot inventory tree ages

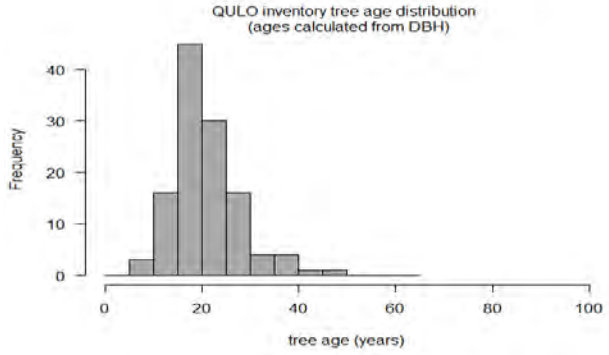












Preliminary Data

Final Conclusions

The forest community demonstrates greater resilience and adaptability than previously thought

- Cottonwoods recruit in mature forests
- Box elder and walnut establish opportunistically
- Oaks can colonize floodplains within 15 years.

We have the ability to broaden or focus our understanding

-Population models can be extrapolated reach-wide

-Further analysis into site variability may better our understanding of species' establishment requirements

THANK YOU

Collaborators & Cooperators:

J. Battles, M. Kondolf, M. Hayden, UC Berkeley
H. Piégay, S. Dufour, CNRS
J. Viers, S. Greco, UC Davis
A. Fremier, U. Idaho
G. Golet, R. Luster, TNC
A. Henderson, CDWR
J. Silveira, K. Moroney, USFWS
H. Lomeli, CDFW

Funding:

CALFED/Sea Grant Science Program
CNRS PICS Grant Program

ESF Field & Lab Crew:

C. Bondi, C. Amundson, C. Olivieri,
J. Riddle, C. Swider, T. Hall, E. Wright, L. Kui
M. Maor, M. Hamilton, P. DiSalvo

Errors Associated with Sampling Conditions

1. Missing rings due to coring high above the tree root collar

2. Missing rings from cores which passed the center of the tree

3. Missing or extra rings associated with stress responses or technician counting error

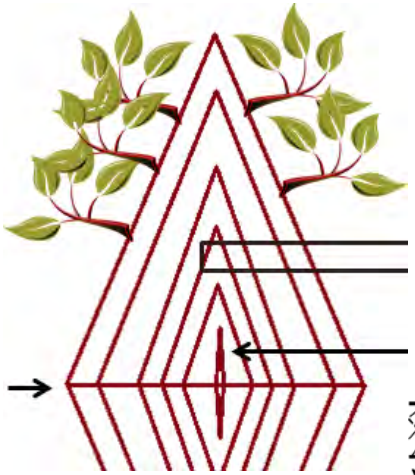
Error Simulations

Species	Missing years to coring height	Missing core length for non-pith cores	Experimental cross-dating correction (COFECHA)
POFR	Applied	Applied	Attempted for subset[3]
SAGO	Applied	Not applied[2]	Not applied[2]
ACNE	Not applied[1]	Applied	Attempted for subset[3]
JUCA	Not applied[1]	Applied	Attempted for subset[3]
FRLA	Not applied[1]	Not applied[2]	Not applied[2]
QULO	Not applied[1]	Not applied[2]	Not applied[2]

- Monte Carlo simulations, 1000 iterations for each tree core
- 3 matrices were added to the base ring counts
- Median of the final matrix was taken to be the final tree age

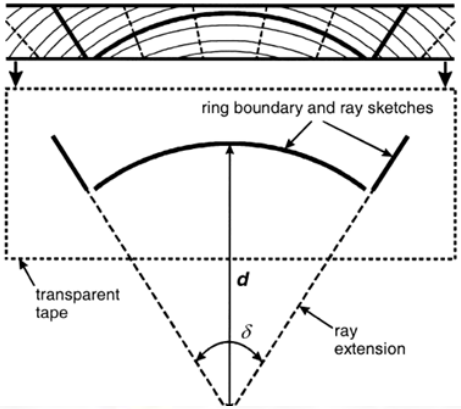
Errors Associated with Sampling Conditions

1. Missing years to coring height



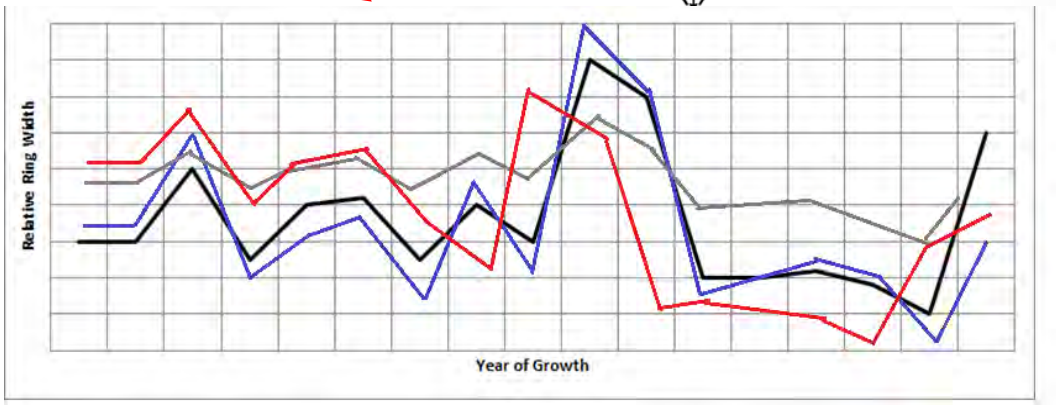
For Willow and Cottonwood

2. Missing rings from non-pith cores

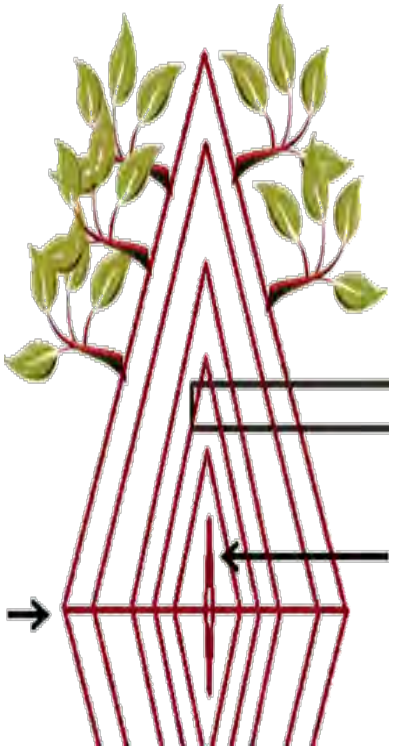


For Cottonwood, Box elder and Walnut

3. Cross dating correction (experimental)



Error Model 1: Years to Coring Height



- Applied to cottonwoods and willows
- Assume root collars are located at fine sediment depth taken at each plot
  - Added sediment depth to coring height to find H_i
- Simulated predictions of missing years ($Y_{i,j}$) for each tree (i) for one thousand iterations (j=1 to 1000)
- Incorporated an error term (ε_j), a value sampled randomly from a normal distribution with SD=0.234

$$\boldsymbol{Y_{i,j} = \beta_0 + \beta_1 H_i + \varepsilon_j}$$

1.5782 (intercept) 0.2571 (slope)

(Hayden 2015)

Error Model 2: Missing Rings for Non-pith Cores

- Applied to cottonwoods, box elders and walnuts (large enough sample sizes)
- Used pith cores to create linear mixed effect model for each species
- Simulated predictions of missing years ($Y_{i,j}$) for each tree (i) for one thousand iterations (j=1 to 1000)
- Incorporated an error term (ε_j), the error of the fixed effect selected for the jth iteration, following a mean of 0 with a SD of the residuals of the fixed effect of cumulative growth

$$\boldsymbol{Y_{i,j} = (\beta_0 + b_{j,k}) + (\beta_1 + m_{j.k})\ln(r_i) + \varepsilon_j}$$

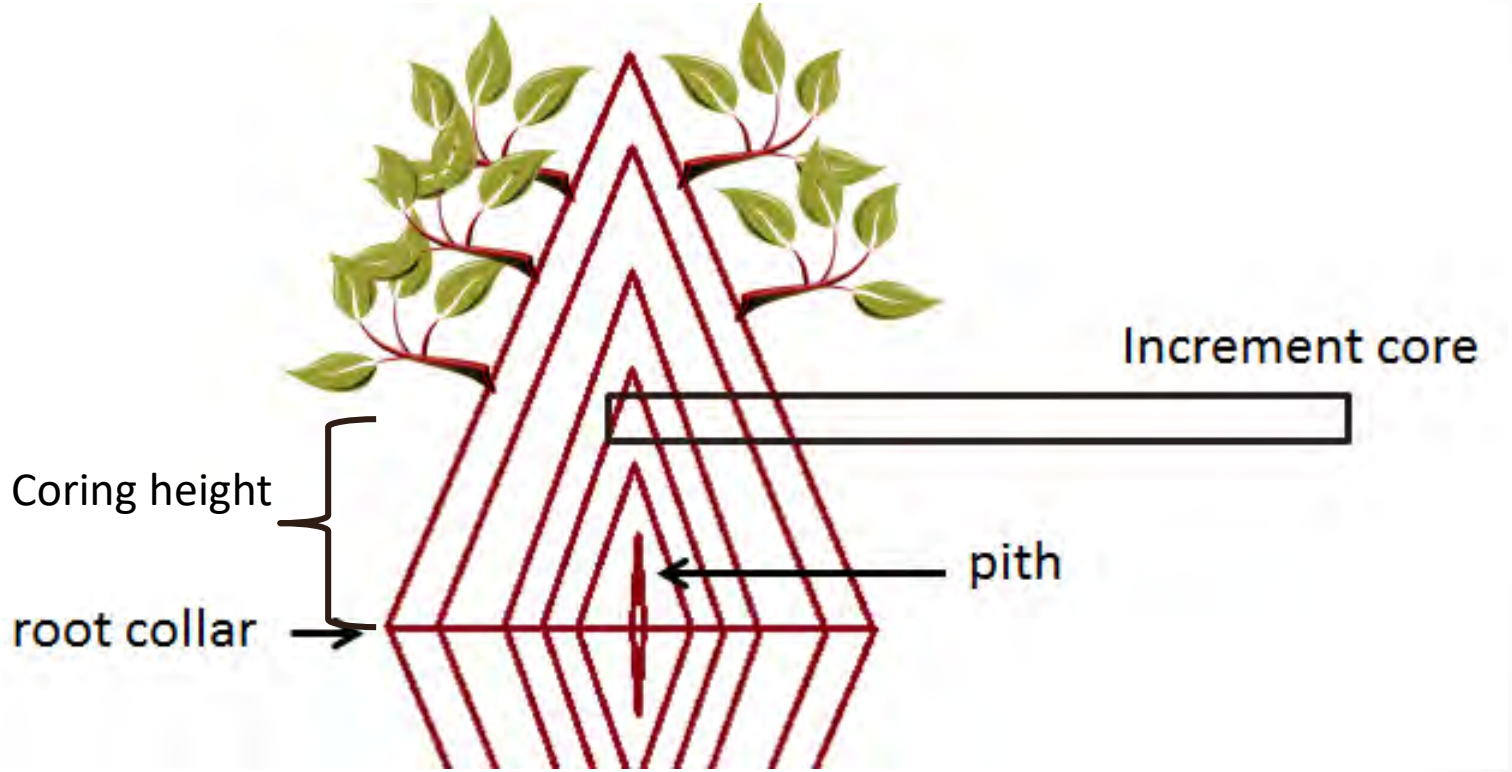
(Hayden 2015)

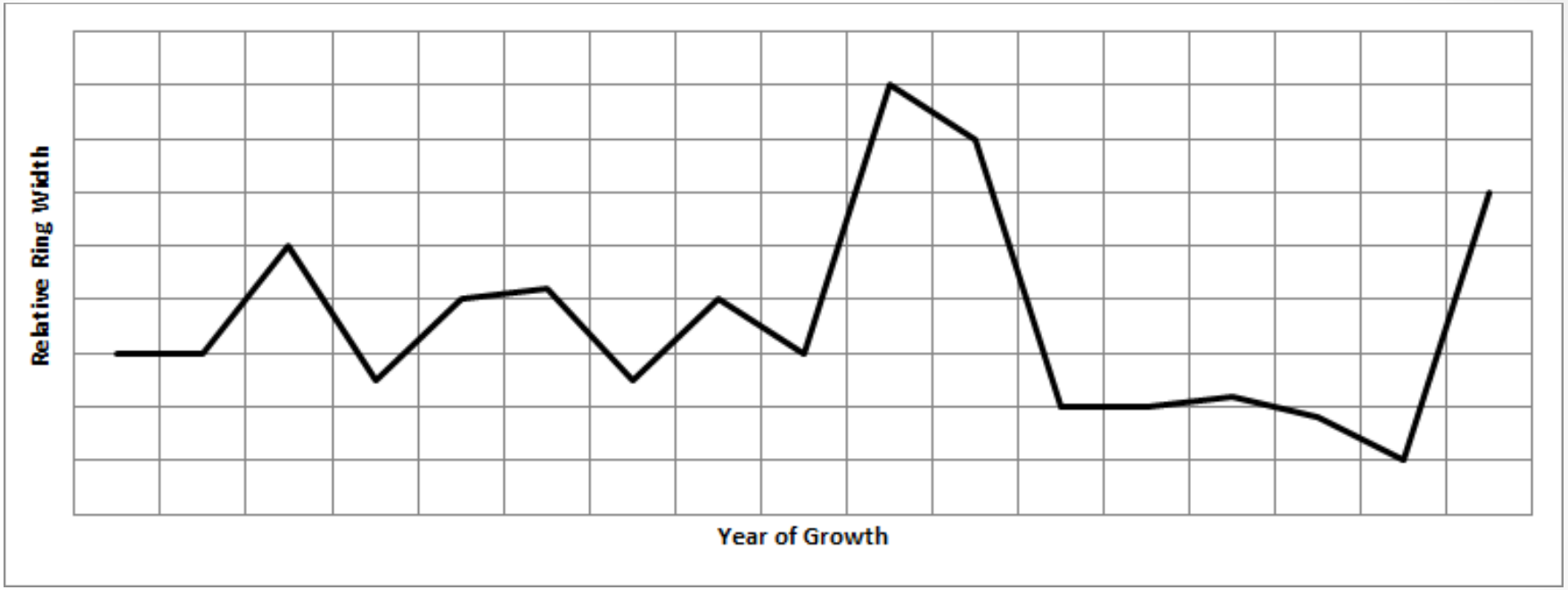
Error Model 3: Experimental Cross-dating Simulation

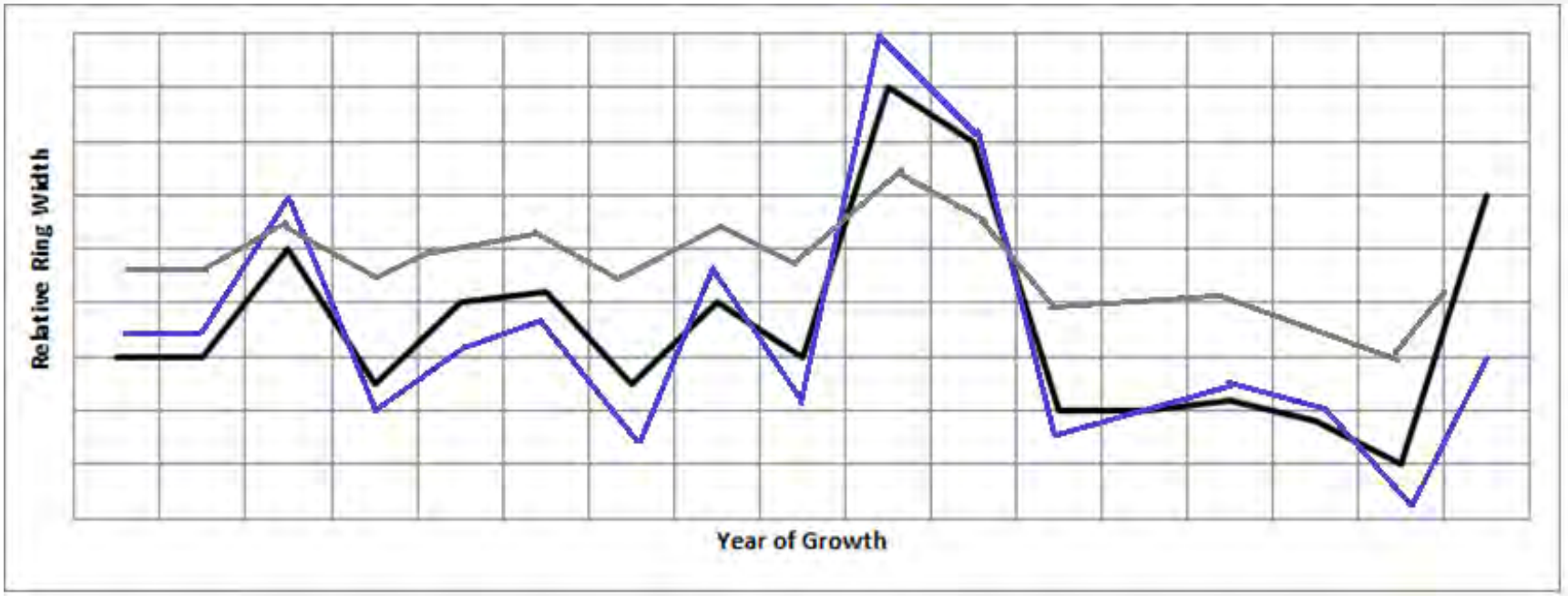
- Applied to cottonwoods, box elders and walnuts (large enough sample sizes)
- COFECHA outputs give correlations with *Master Chronology* associated with adding or subtracting rings
- Shift suggestions for each core were weighted by their respective correlations, such that shifts with higher correlation values were preferentially selected in a Monte Carlo simulation with 1000 iterations.
- Cores with an optimally recommended shift of zero years were excluded from this simulation.
- Results indicated a bias pushing all tree ages toward the average, and were ultimately excluded from final age calculations.

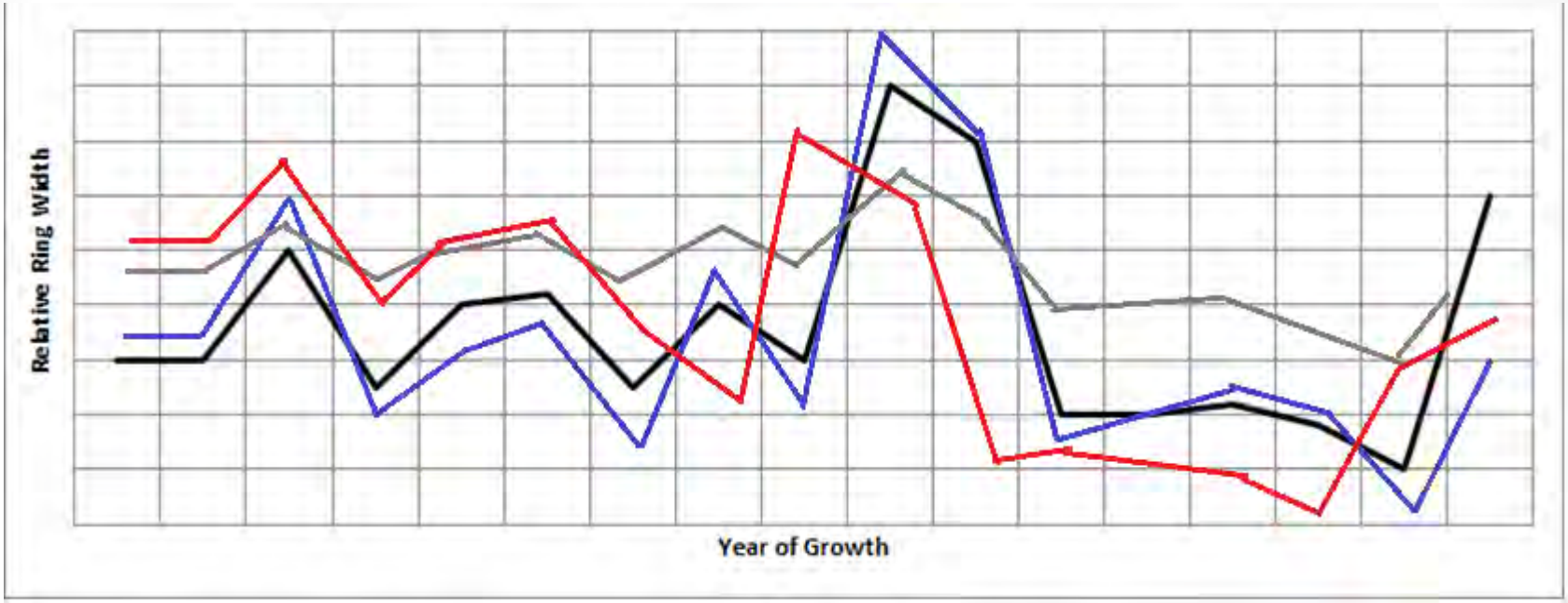
Missing Years to Coring Height

- Cores were taken above the root collar




Relative Ring Width
Year of Growth

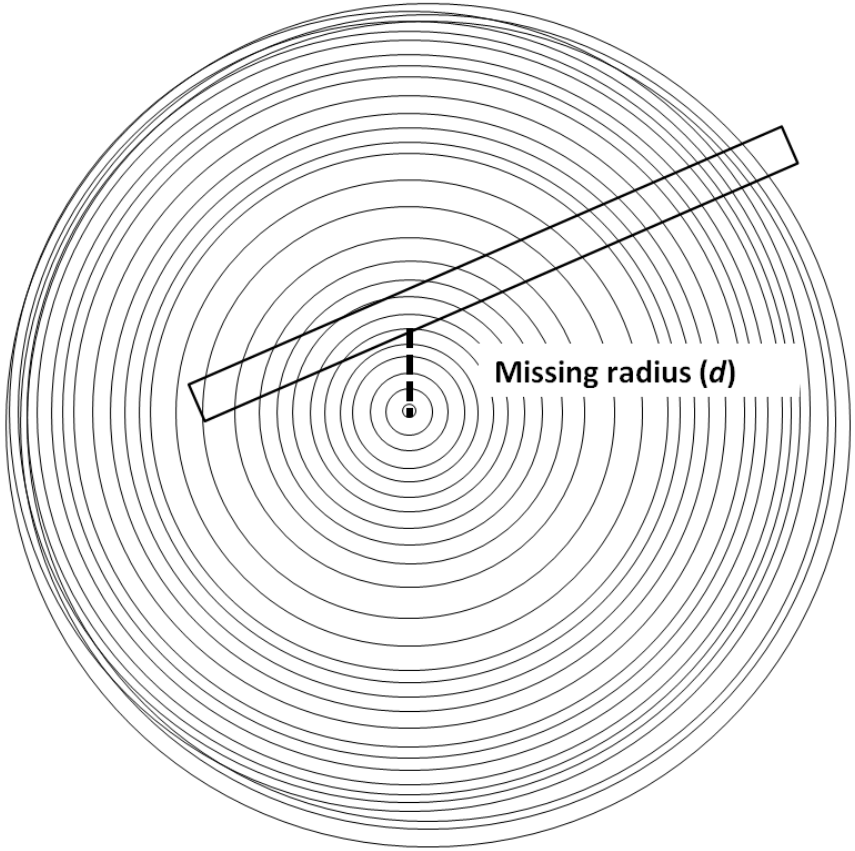

Relative Ring Width
Year of Growth

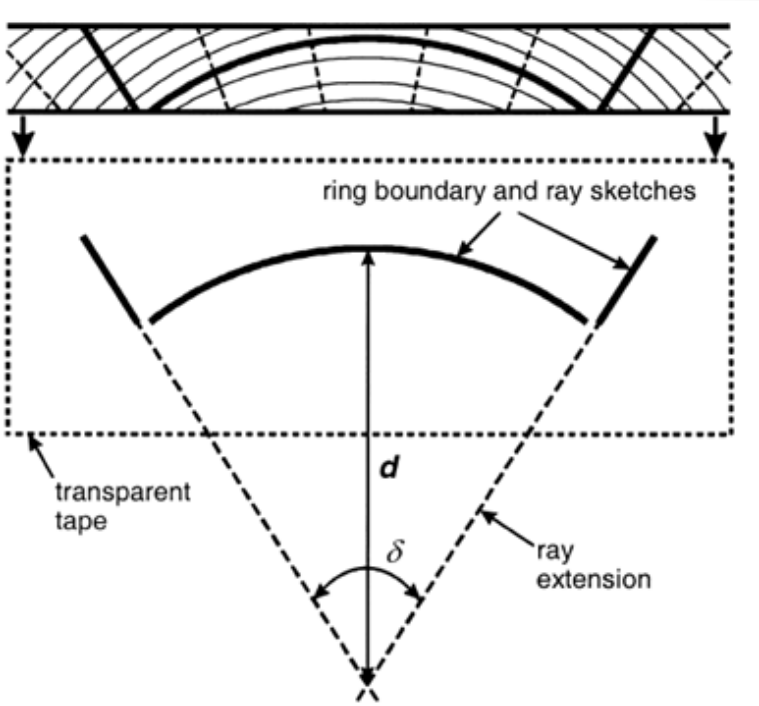


- Missing rings due to tree stress, or false ‘additional’ rings due to sharp changes in the environment stimulating premature growth.
- Could be technician error
- Automated program COFECHA tests for shifts which would increase correlation with the master chronology, which should be physically verified

Lab Methods

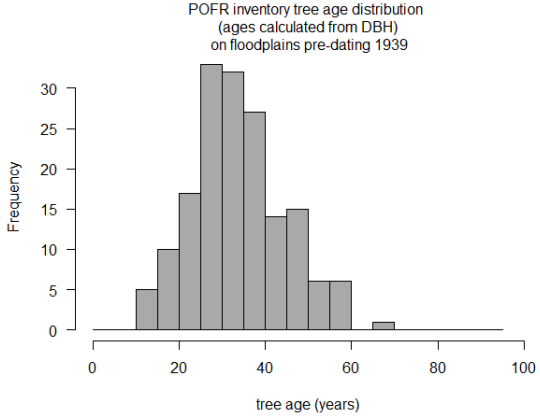
- Measured missing distance to pith for non-pith cores

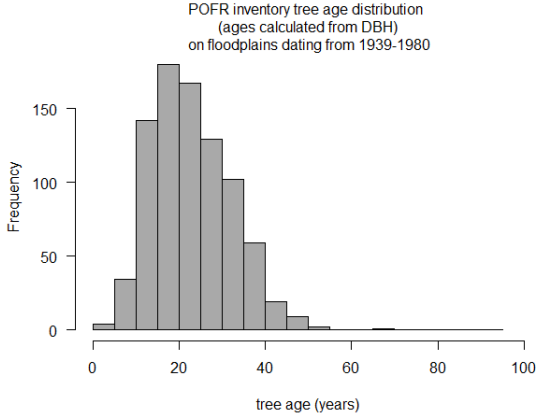


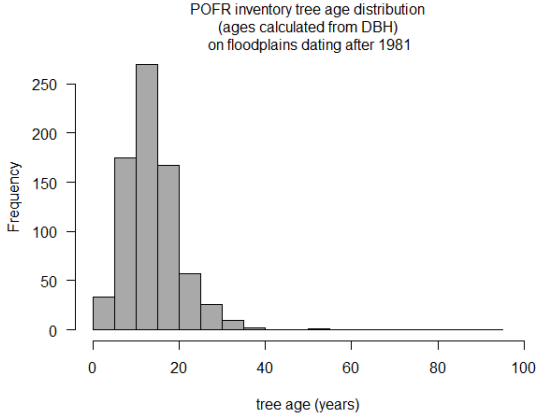


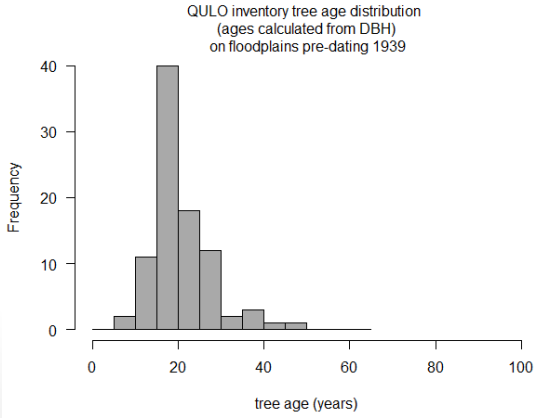
(Modified from Rozas 2003)

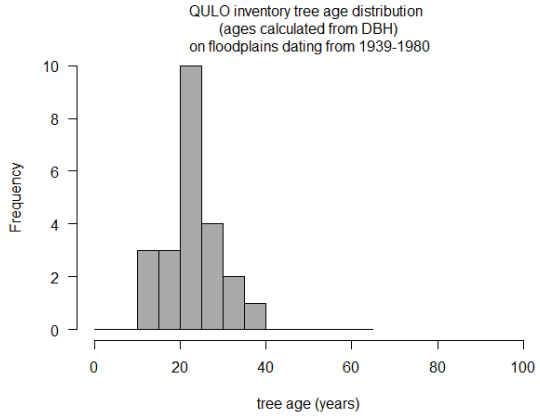
Tree age changes over time

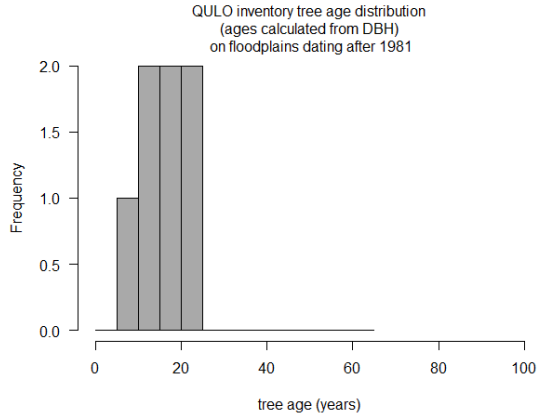




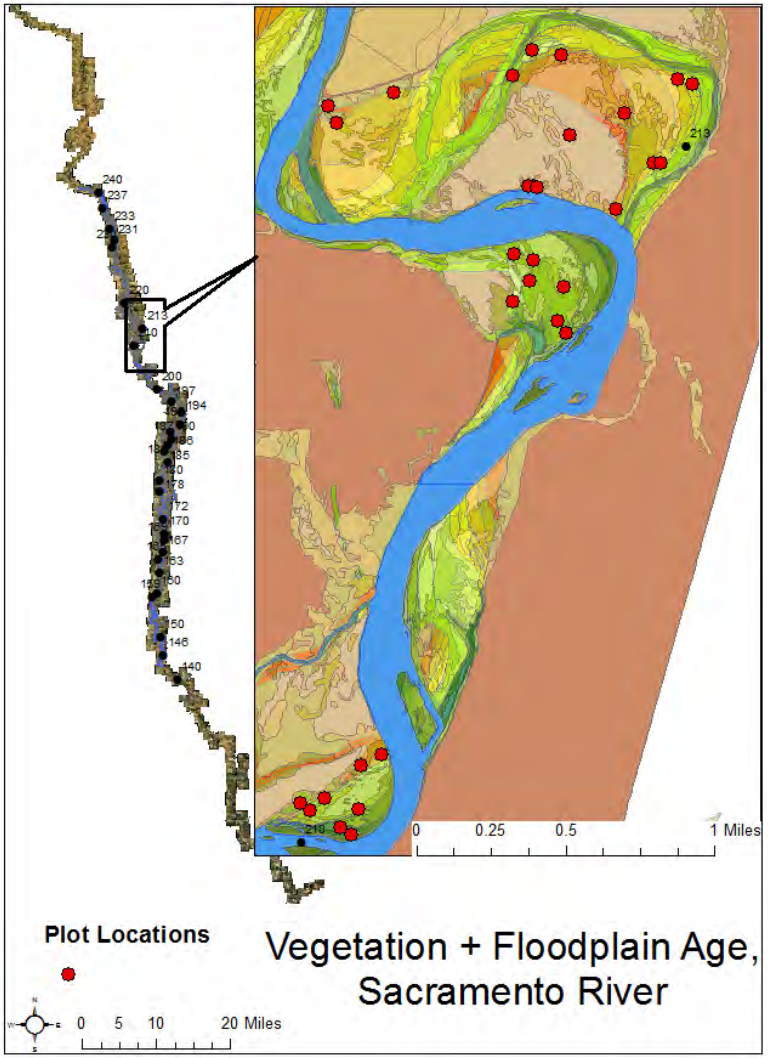








Preliminary Data



- Stratified the sampling area by floodplain age and vegetation type
- Sampled plots in each stratum at each site; 2 plots for cottonwood forest polygons
- 500 m^2 plots (N=441): species, DBH, 5 cores, understory cover

Floodplain Age	Vegetation Type											
	BE	BW	CS	CW	GB	GW	MW	OW	PG	RS	VO	Total
1904	2	9	1	15			6			9	8	50
1920	2	5		10			3			2	1	23
1938	4	6		13			2			5	1	31
1947	3	3		11			9			2	1	29
1952	2	1		6			1			1	1	12
1958				2						1		3
1964	11	8		26			9			6	3	63
1970	1			2								3
1979	4	2		34			13			4	1	58
1987	2	1		31		1	12			4		51
1988				9						1	1	11
1997	2	2		15		4	15		2	2		42
1998		1		4			2			3		10
1999				4			6			2		12
2002				1						1		2
2003				5	1	1	6		4			17
2004					1	1	4		3	1		10
2005					1		1					2
2006					1		1	2	1			5
2007									3			3
Unclassified				2			1				1	4
Total	33	38	1	190	4	7	91	2	13	44	18	441

Dominant Species

Fremont Cottonwood	Goodding's willow	Box elder	Walnut	Oregon ash	Valley oak
Populus fremontii	*Salix goodinggii*	*Acer negundo*	*Juglans sp.*	*Fraxinus latifolia*	*Quercus lobata*
POFR	SAGO	ACER	JUCA	FRLA	QULO

http://www.riverpartners.org/resources/riparian-ecology/physical-river-processes/

Dam Effects

- Channel narrowing
- Reduced migration and meandering
- Sediment starvation
- Increased scouring and incision
- Reduced base flows
- Increased flows in dry season for water conveyance