# Using coupled meander migration and vegetation models to estimate LWD inputs to a large river

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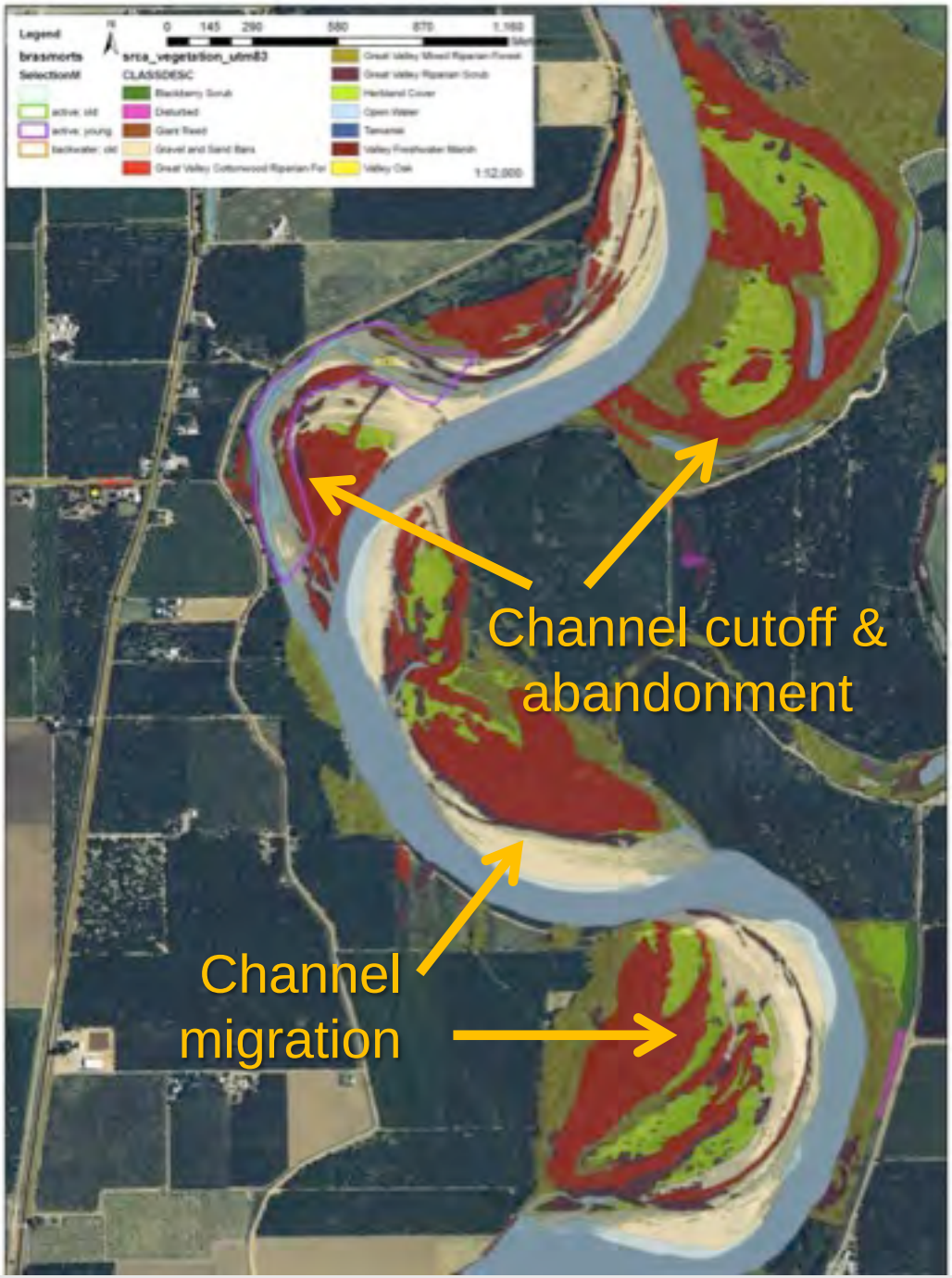
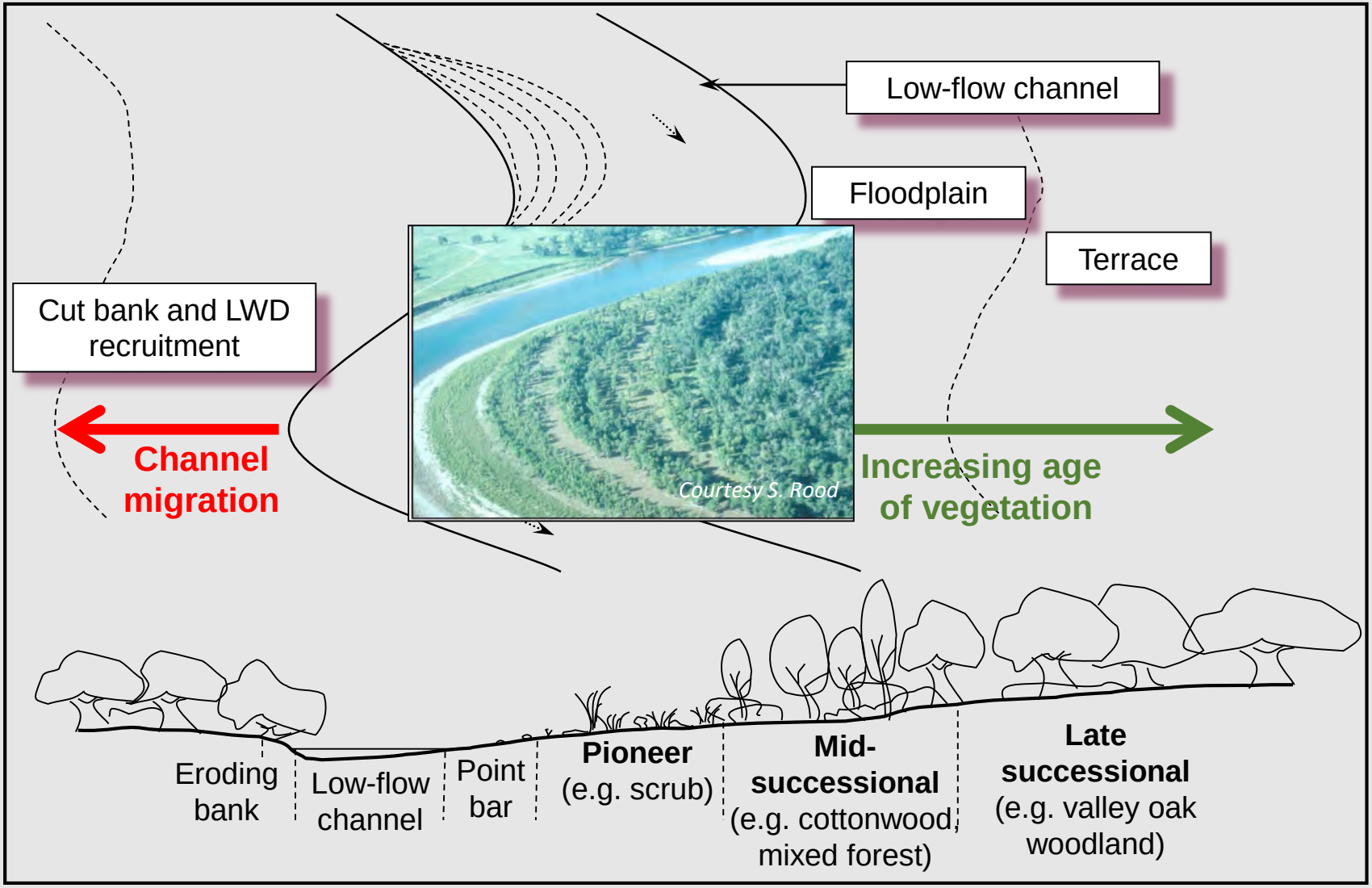
ESF UCSB ESSA The Nature Conservancy




# Riparian forests on meandering rivers

- Hotspots of biodiversity and productivity
- High conservation value for agencies, NGO's, many stakeholders
- Floods and channel migration drive:
  - New stand establishment
  - LWD recruitment
- Dams and bank revetment decrease these processes
  - Less forest area
  - Lower LWD inputs to river

# Co-evolution of floodplains and riparian forest succession




*Stella et al. (2004). Riparian vegetation dynamics on the Merced River. Pages 302-314 in California Riparian Systems Proceedings, Sacramento.*

# Large woody debris on the middle Sacramento River

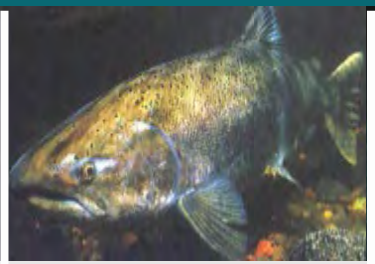

Sacramento Area Flood Control Agency

# Ecological Flow Tool: (SacEFT) – v1


- Multi-species, multi-function decision support framework
- Uses and integrates existing datasets
- Physical submodels drive biological & functional response
- LWD ~ f(Q, bank erosion)

## *Sacramento River*


Steelhead trout


Chinook salmon


Green sturgeon


Bank swallow


Western pond turtle


Fremont cottonwood

| Focal Species Performance Measures | Physical datasets and submodels | | | | |
|---|---|---|---|---|---|
| | Flow | Stage - Discharge | Temperature | Sediment Transport | Meander Migration |
| Fremont cottonwood (FC) | • | • | | | |
| Bank swallow (BASW) | • | | | | • |
| Green sturgeon (GS) | | | • | | |
| Chinook, steelhead (CS) | • | | • | •[1] | |
| Large Woody Debris (LWD) recruitment | • | | | | • |

[1] Certain indicators only. The linkage between channel bed conditions and Chinook and steelhead is restricted to weighted useable area for spawning. According to source data from Mark Gard (USFWS), rearing habitat is unaffected by substrate conditions. We relate substrate suitability curves taken from *River-2D* with substrate conditions predicted by the TUGS sediment transport model.

EFT
Ecological Flows Tool
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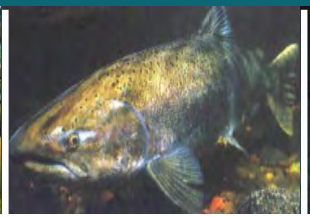
- Annual ‘traffic-light’ summaries and multi-year roll-ups for flow and management scenarios

## Sacramento River


Steelhead trout

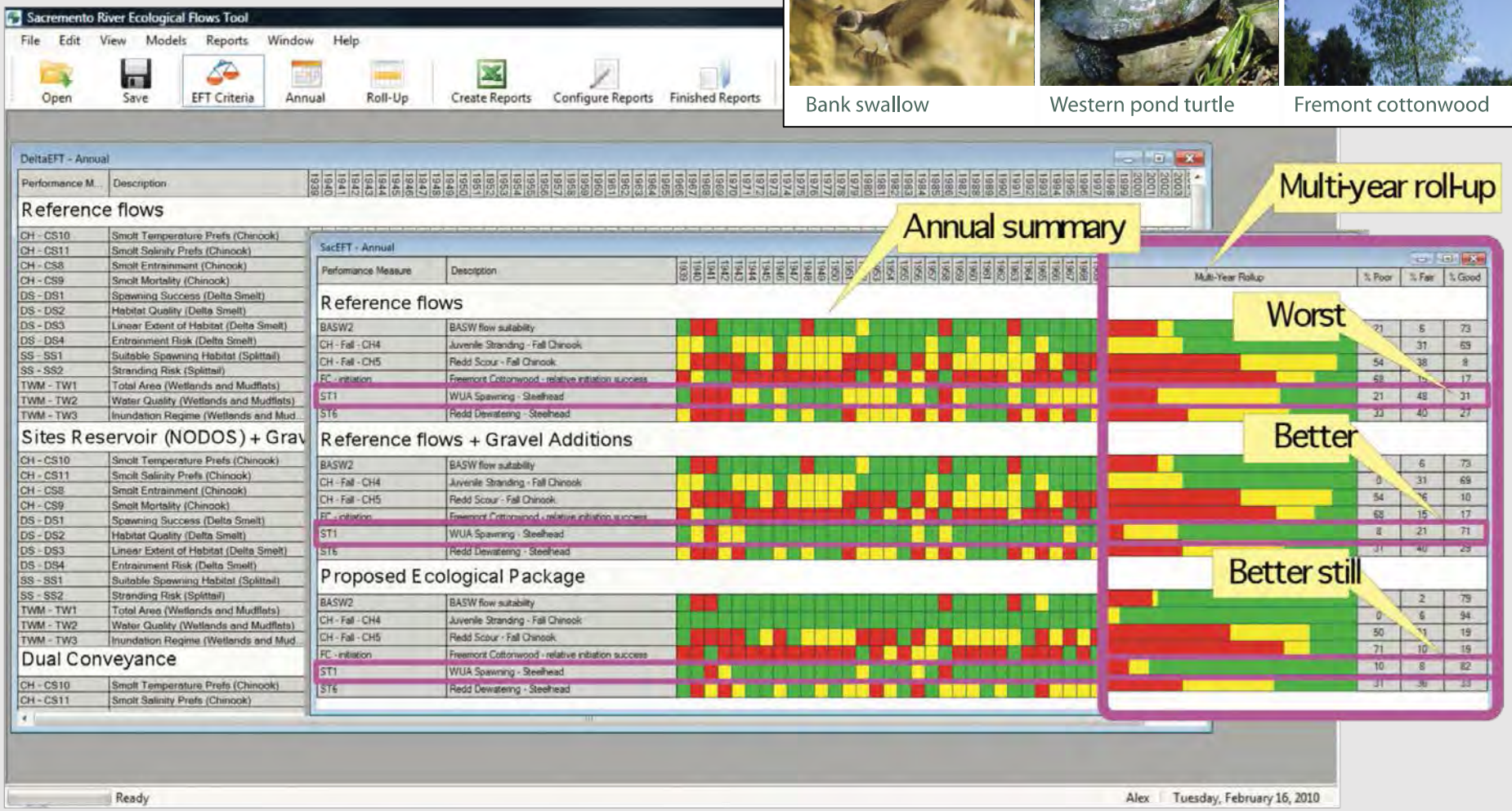

Chinook salmon


Green sturgeon


Bank swallow

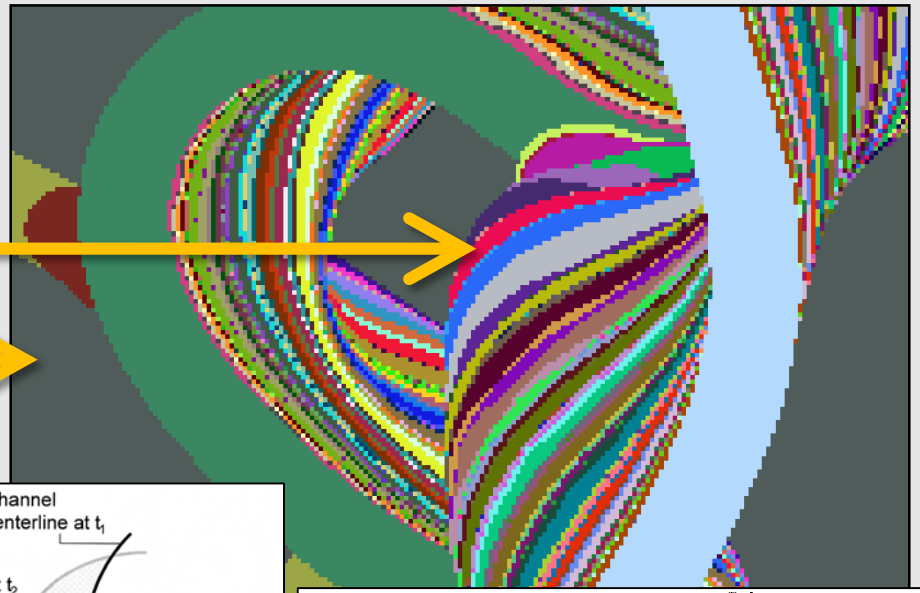

Western pond turtle

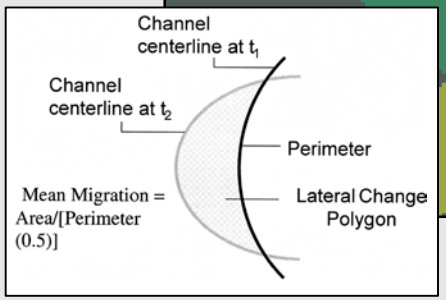

Fremont cottonwood

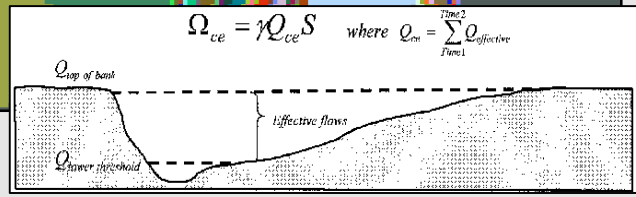


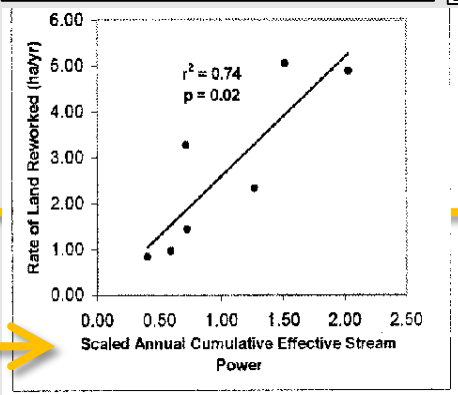
# Modeling Channel Migration

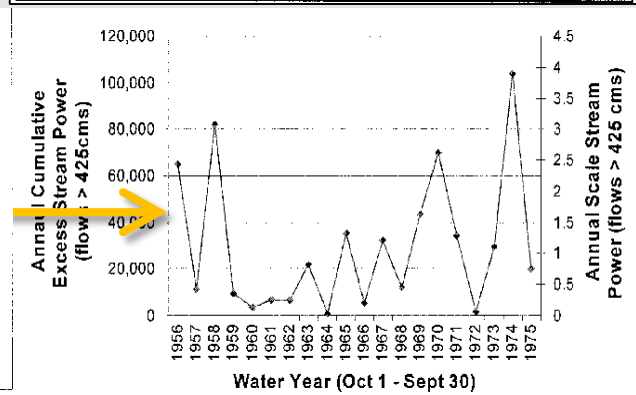
- Floodplain formation processes
  - Bank erosion and channel migration
  - Channel cutoff and abandonment
- Mechanistic meander migration model
  *(Larsen et al., 2006. JAWRA)*
  - Calculate stream power from daily mean discharge data:
    $\boldsymbol{\Omega = \gamma Q S}$
  - Annual cumulative effective streampower $\boldsymbol{\Omega_{ce} = \gamma S * \sum Q_e}$, *w*here $\boldsymbol{Q_e}$ is effective discharge over erosion threshold
  - Calibrate $\boldsymbol{\Omega_{ce}}$ to observed channel migration rates





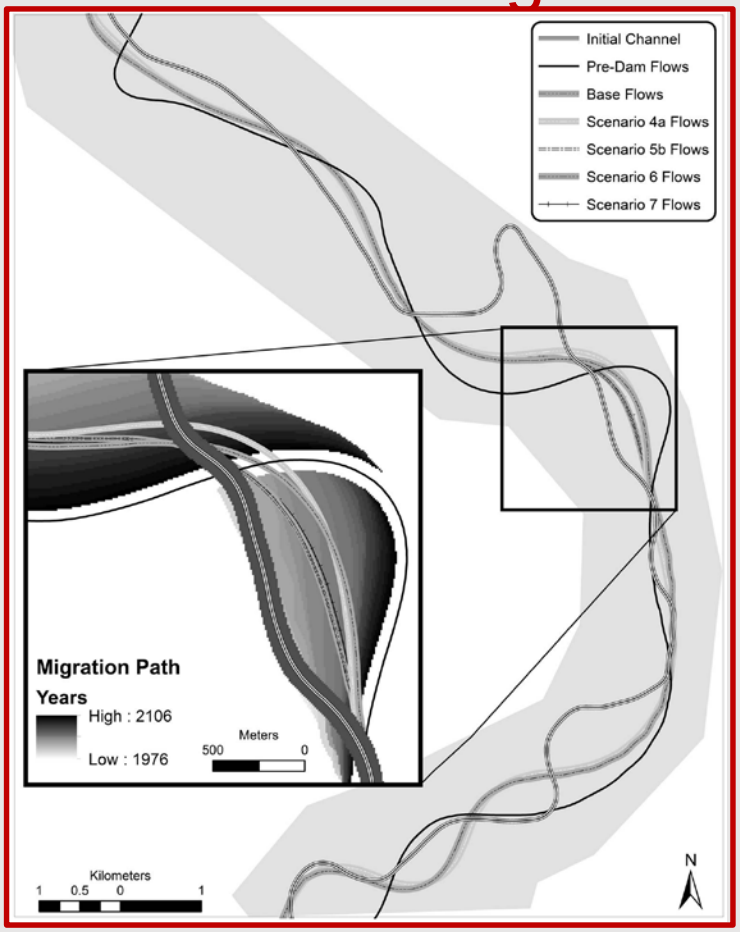



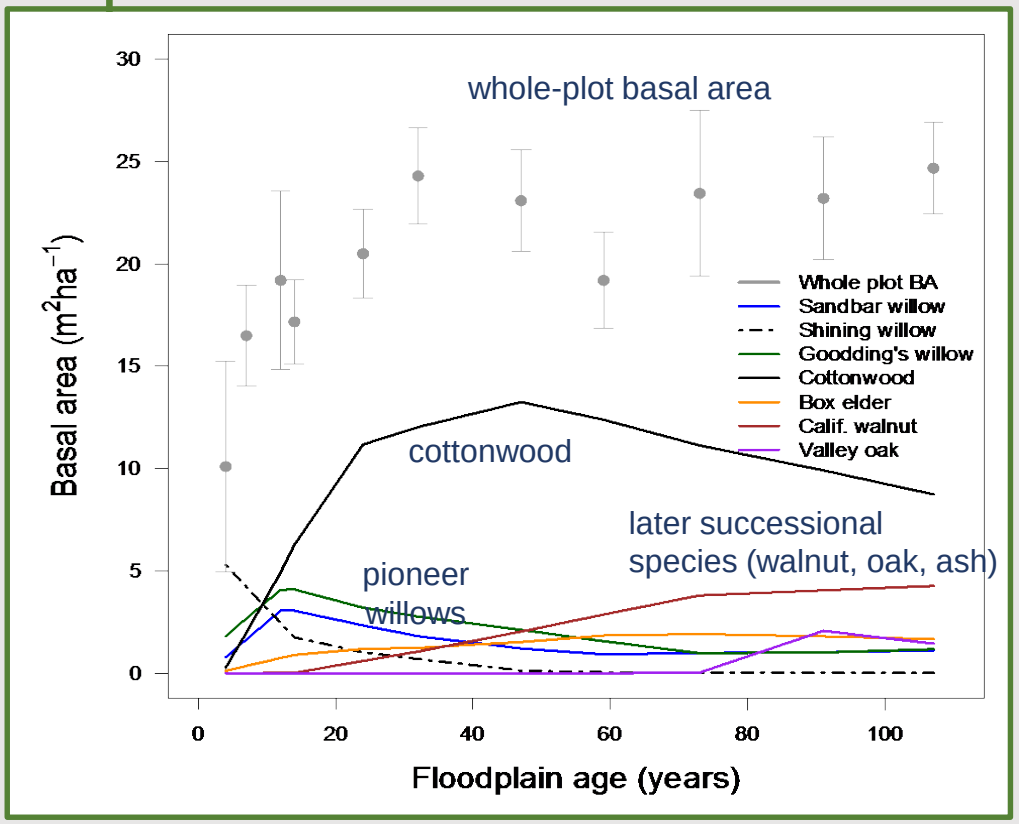



# Dynamic LWD modeling

Predicting LWD inputs by linking

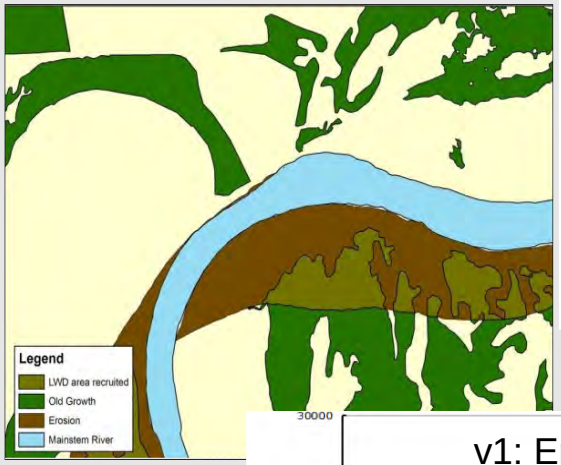
meander migration + riparian forest succession

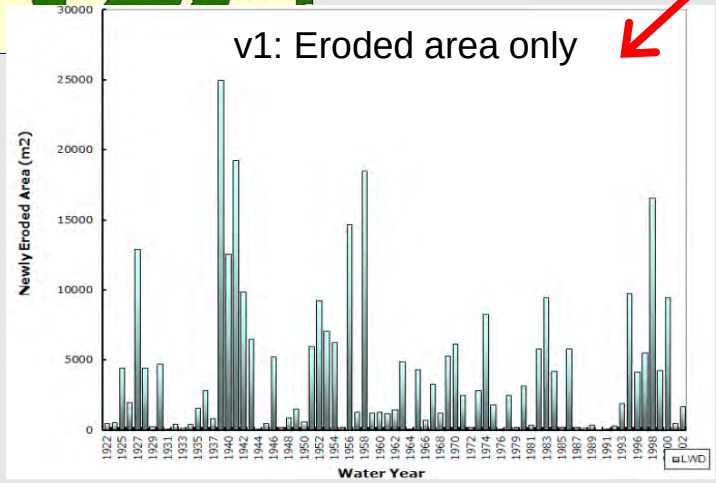


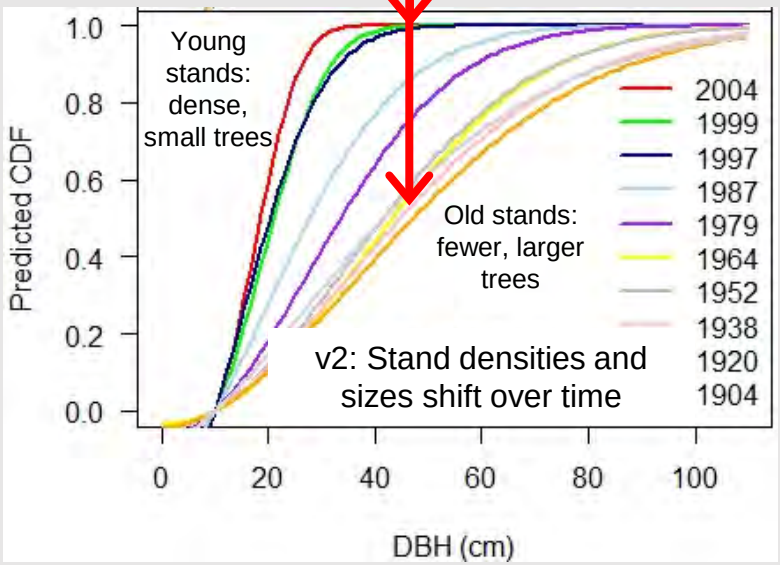



# Improved approach to LWD modeling in SacEFT v2

| | SacEFT v1 indicator | SacEFT v2 enhanced indicator |
|---|---|---|
| **Performance measure** | Newly eroded area in mature vegetation | Number of trees recruited |
| **LWD definition** | Based on age | Based on species groups and size (DBH) |
| **Forest size classes used** | Static | Dynamic with floodplain age |



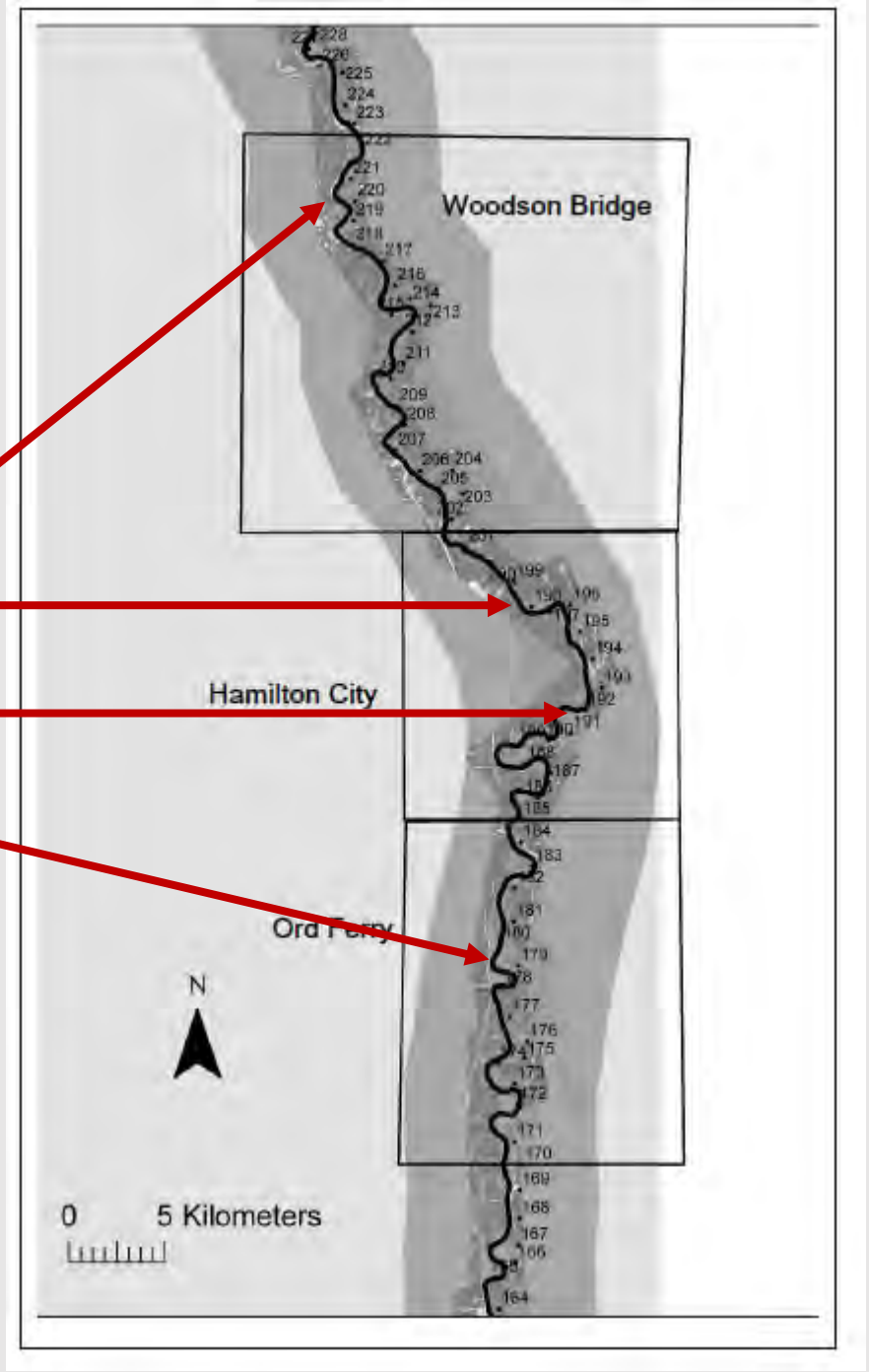



# Study Sites

| Site | River Mile | Bank Length (m) | Owner/ Lessee |
|---|---|---|---|
| Kopta Slough | 220-222 R | 1775 | State/TNC |
| Brayton | 197-198 R | 600 | CDPR |
| Phelan Island | 191-192 R | 1410 | USFWS, Sac & SJDD |
| Llano Seco | 179 R | 1300 | USFWS, Sac & SJDD |

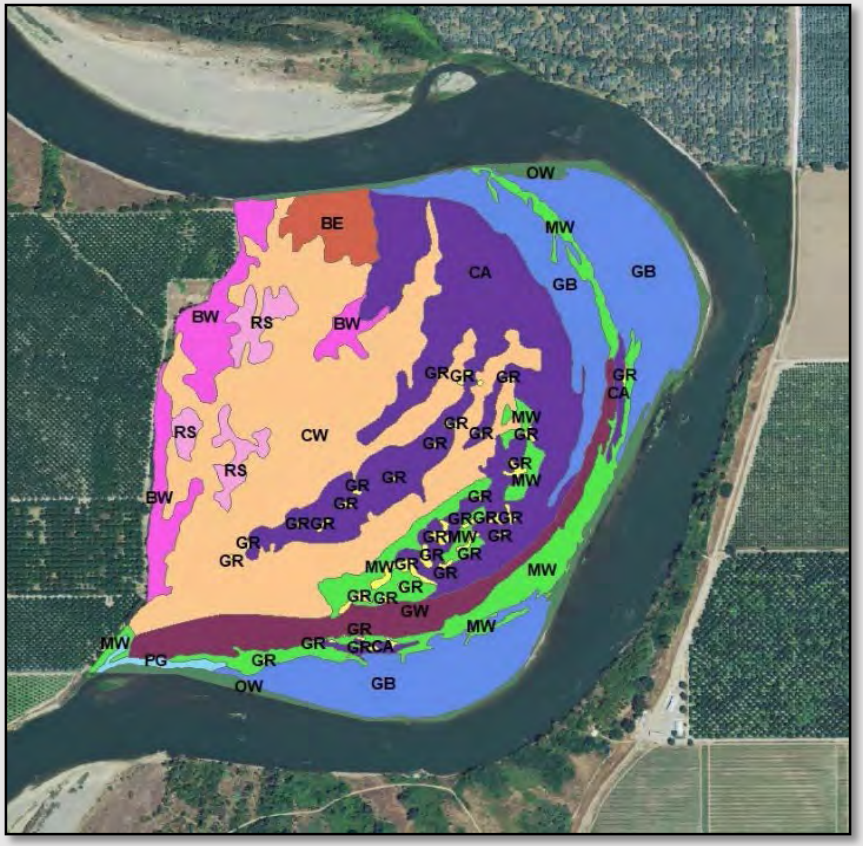
- Forested river bends
- Existing revetment
- High potential for channel migration and LWD recruitment



# Stratifying land cover using existing maps

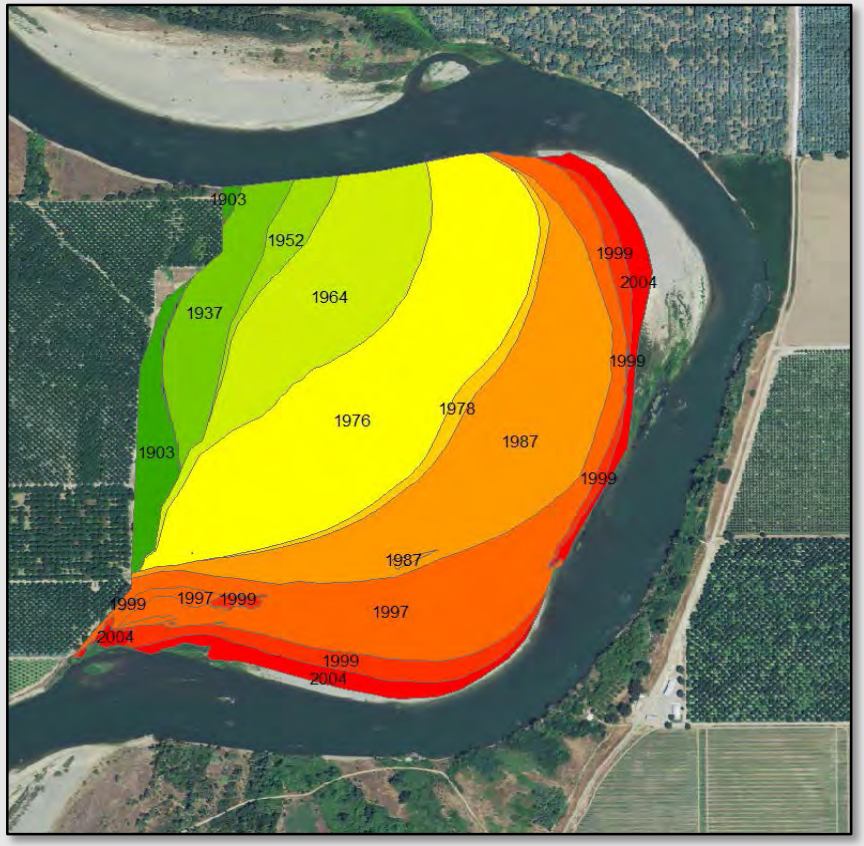
## Vegetation map

*Nelson et al., 2008. CSU Chico and Viers et al., 2010. Proceedings from the ESRI International User Conference.*



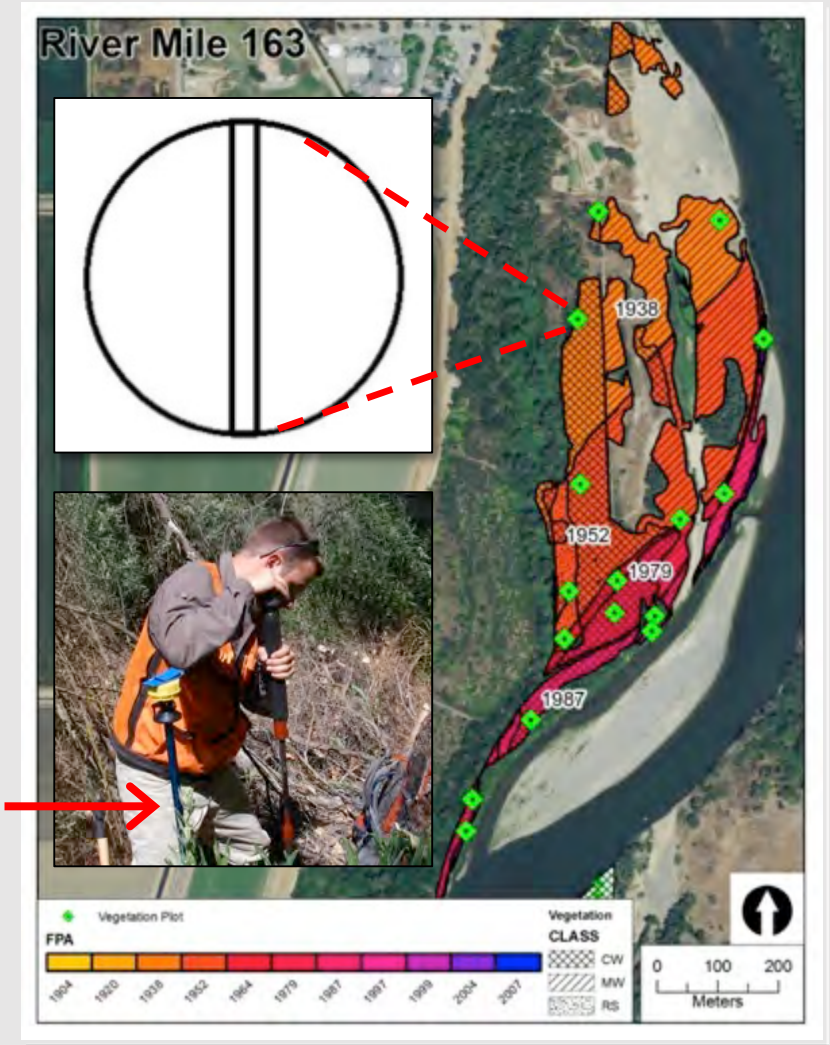

## Floodplain age map

*Greco et al., 2007. Landscape and Urban Planning 81: 354-373.*



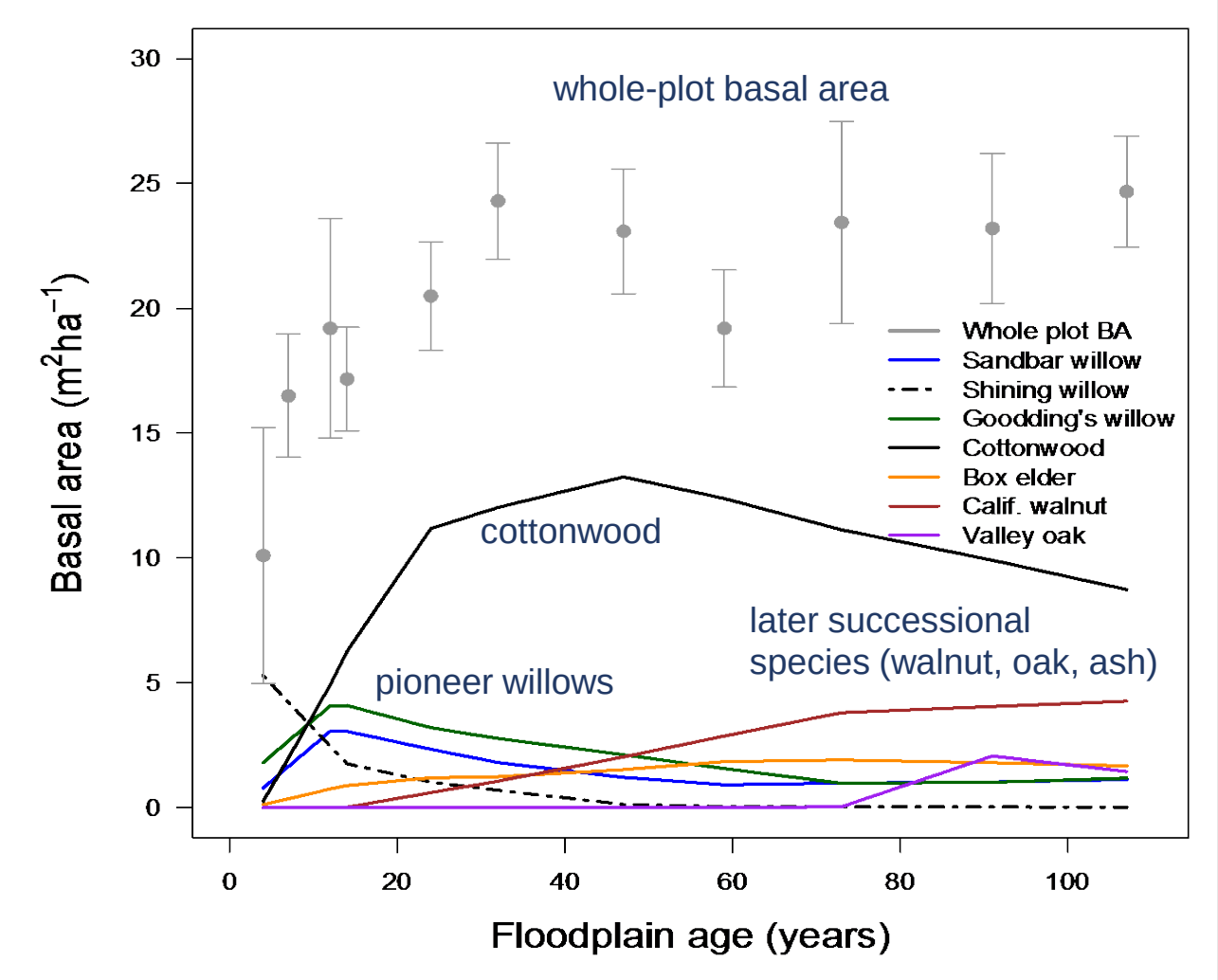
# Sacramento River riparian forest inventory (2010–2012)

- 19 large point bars from Red Bluff to Colusa
- 430 plots (500 $m^2$) in patches stratified by
  - vegetation type (TNC 2007)
  - floodplain age (Greco et al.)
- Tree composition, size, health, snags
- Fine sediment accumulation over the former gravel bar



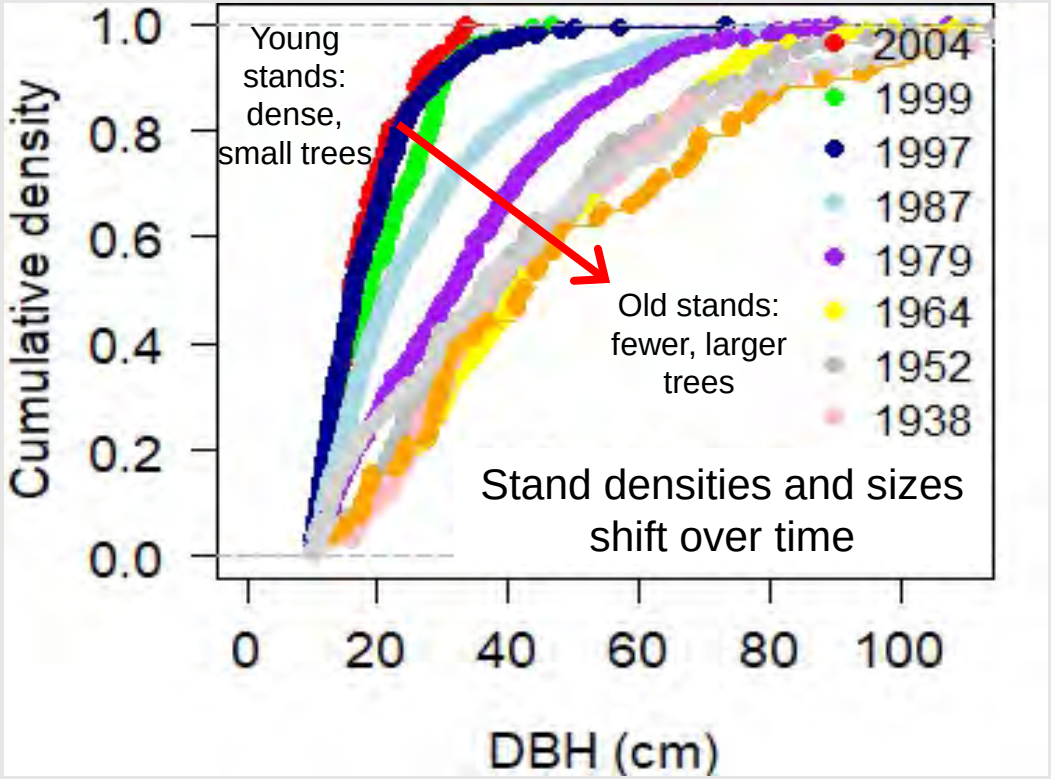

*Stella et al., 2012. Riparian forest dynamics on a large, regulated river (California, USA): impacts and implications for management. Proceedings of the IS Rivers Conference, Lyon, France*

# Riparian succession patterns from vegetation chronosequences

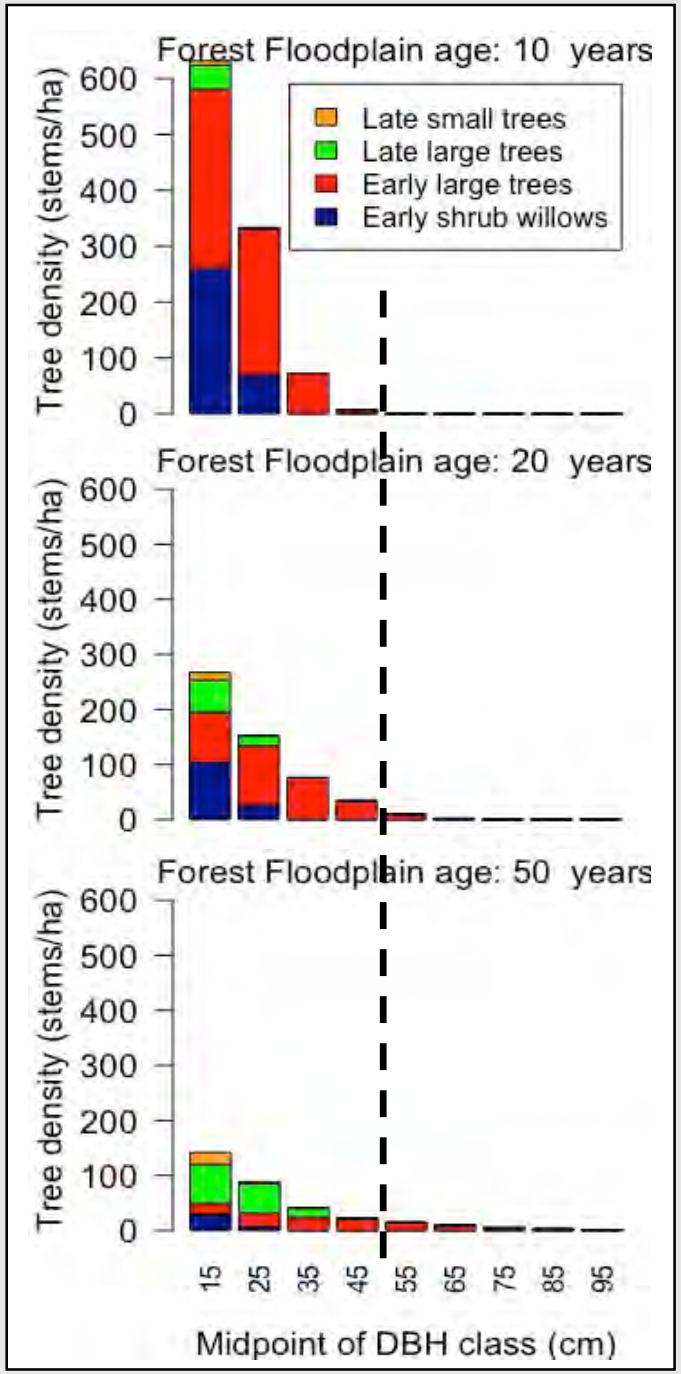



*Stella et al., 2012. Riparian forest dynamics on a large, regulated river (California, USA): impacts and implications for management. Proceedings of the IS Rivers Conference, Lyon, France*

# Modeling tree size (DBH) distributions using empirical inventory data




- Predict LWD, defined as trees >40 cm DBH
- Stratified by structural/composition groups



# Revetment removal scenario: Phelan Island, 2004 – 2086

**Revetment intact**

**Revetment removed**

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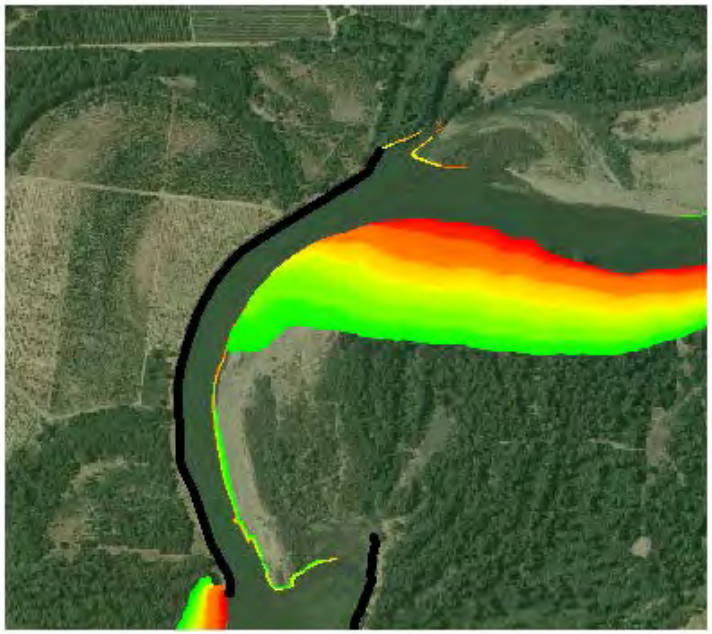
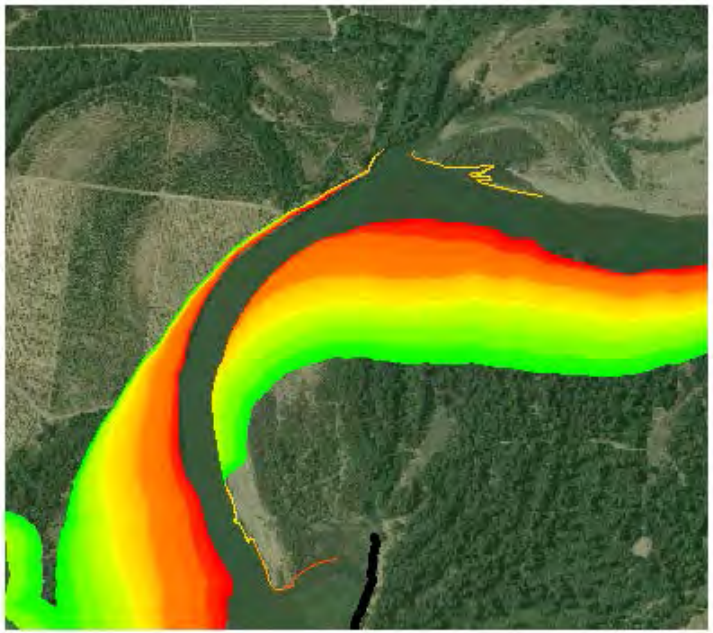
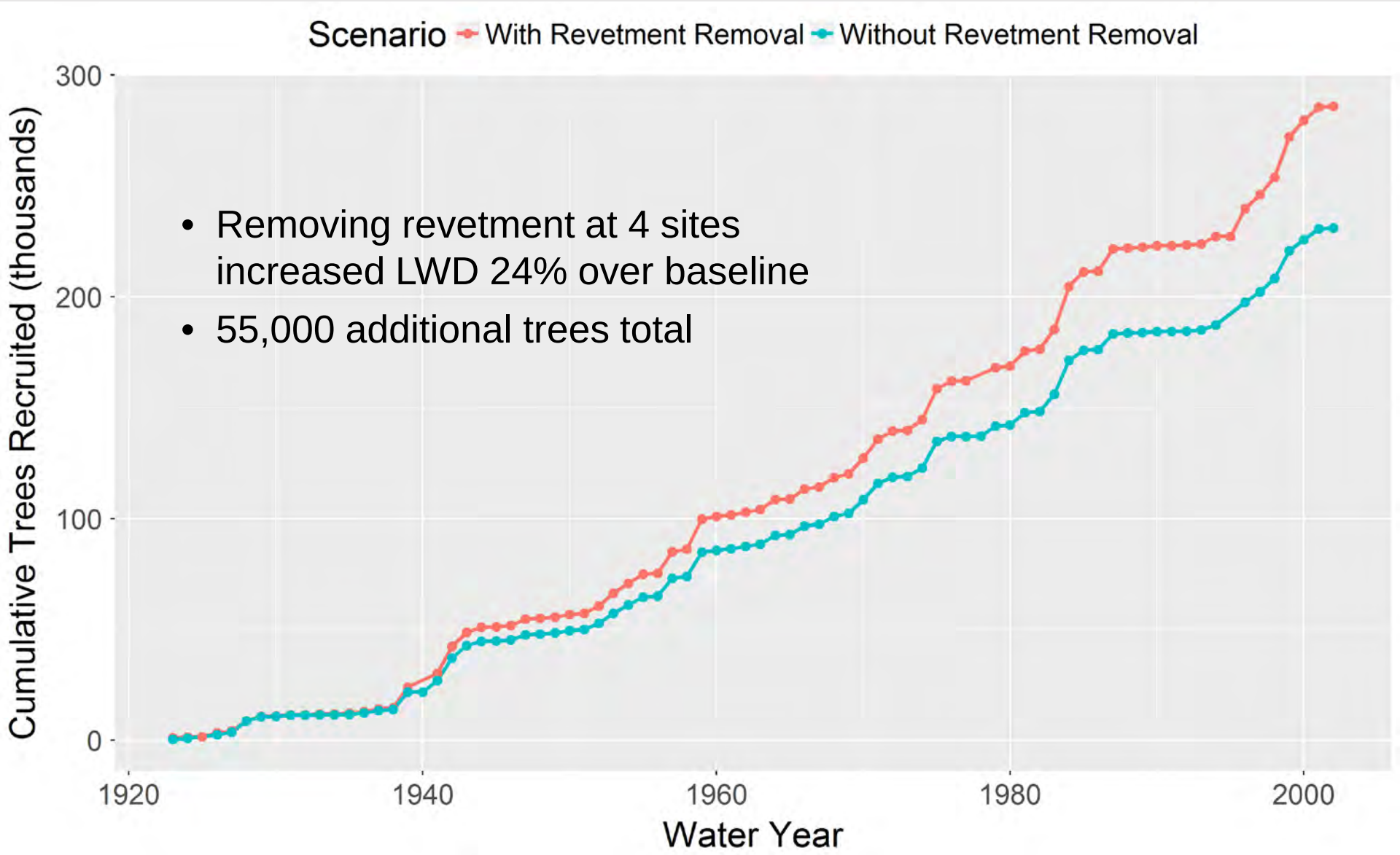
**Revetment intact**



**Revetment removed**



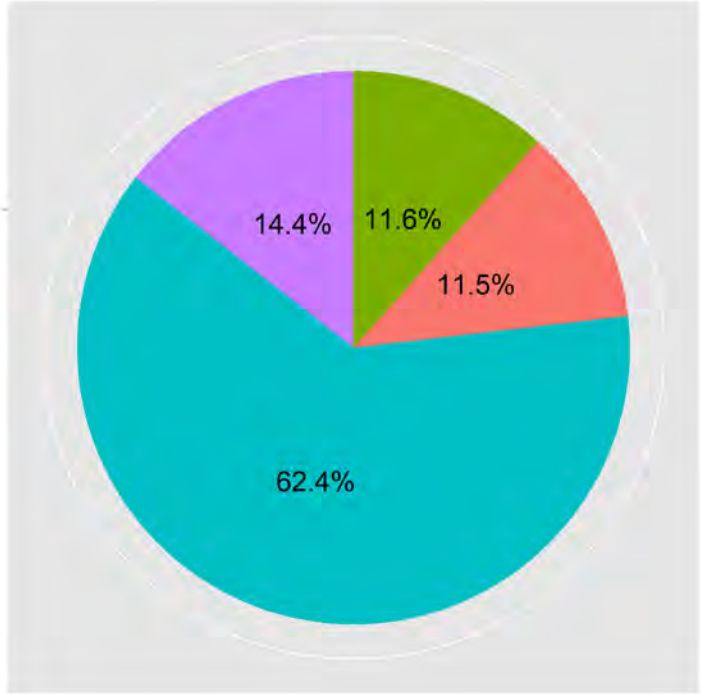
# Cumulative trees recruited as LWD



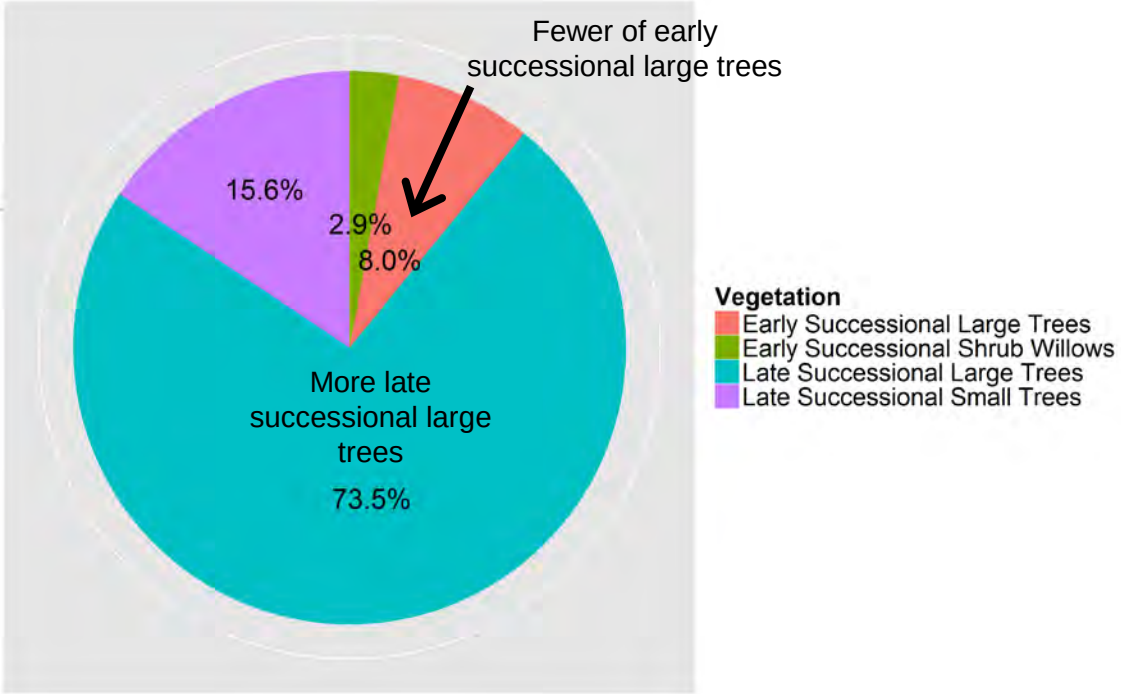

- Removing revetment at 4 sites increased LWD 24% over baseline
- 55,000 additional trees total

# Predicted shifts in veg group proportions

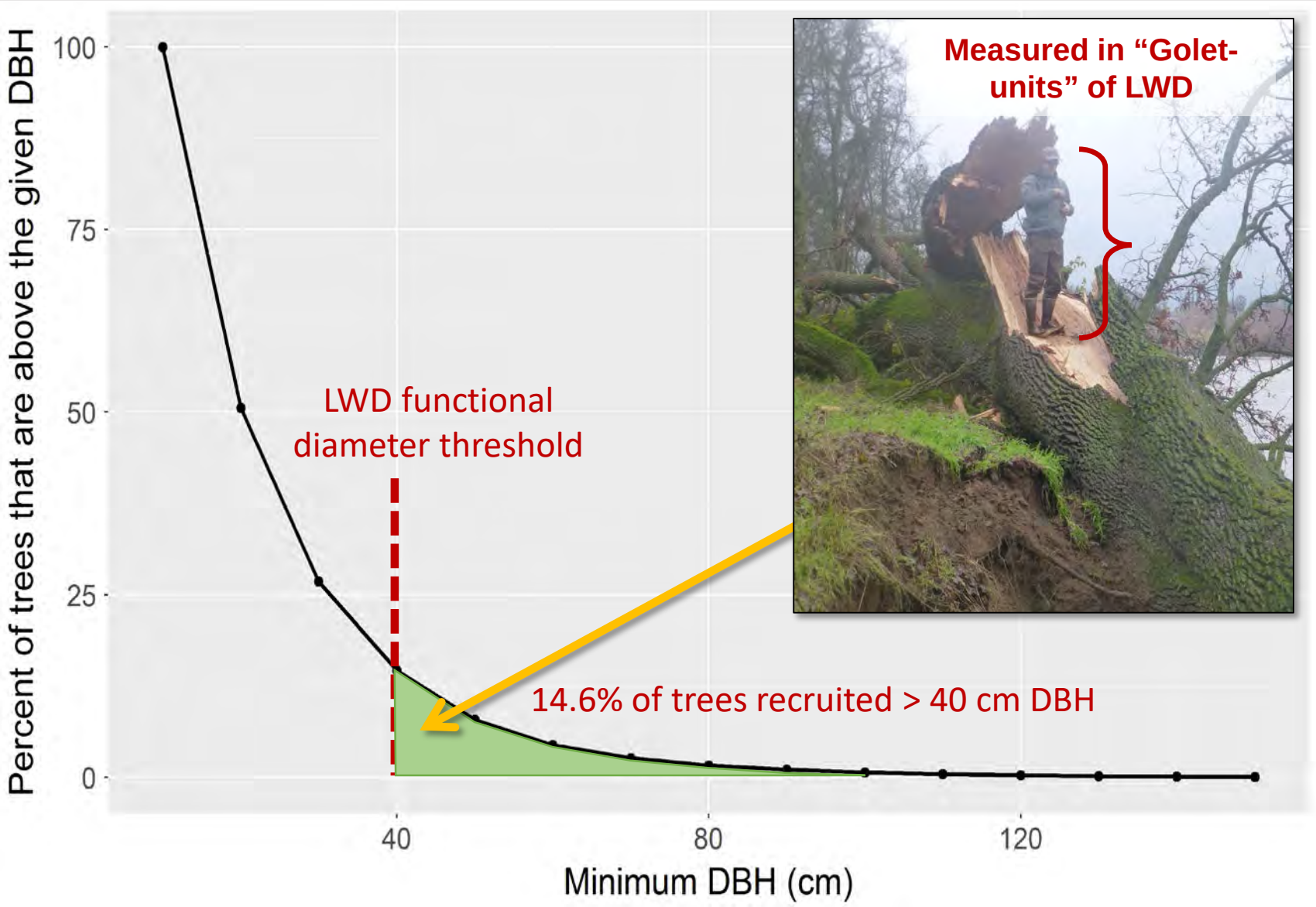
**Revetment intact**




**Revetment removed**

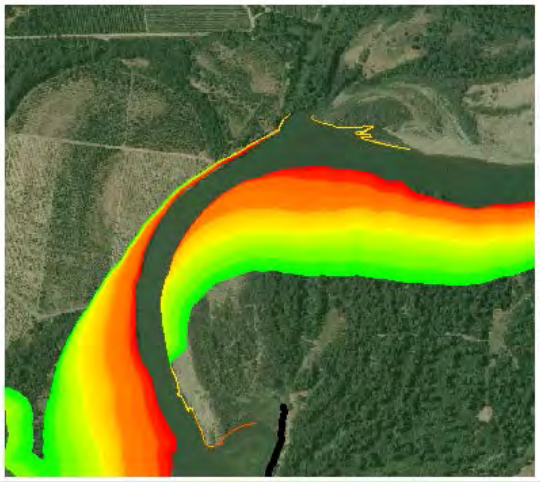


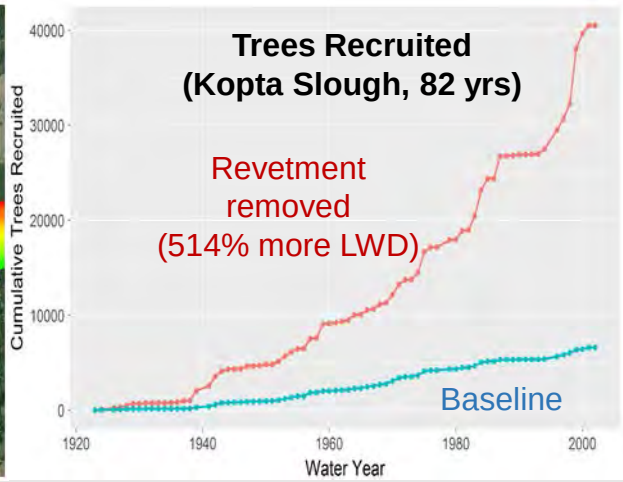
# Predicted functional LWD proportion

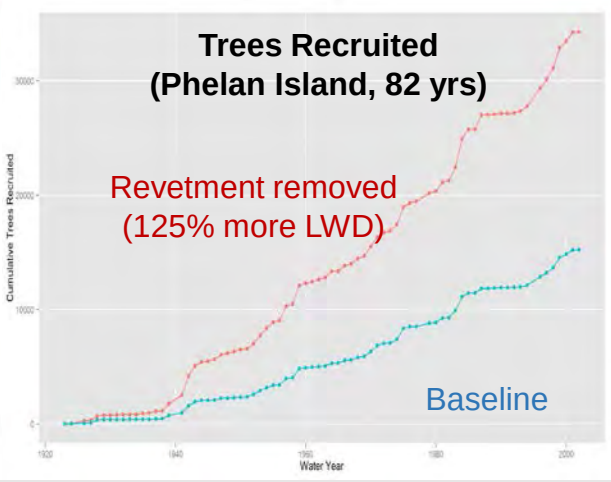


# Comparing the two largest sites

| | Kopta Slough | Phelan Island |
|---|---|---|
| Bank Length (m) | 1,775 | 1,410 |
| Additional eroded area (% increase) | 37.7 ha (327%) | 37.8 ha (129%) |
| Additional trees recruited (% increase) | 33,904 (514%) | 19,041 (125%) |
| Additional trees >40 cm (% total) | 6,238 (18.4%) | 2,875 (15.1%) |
| Additional LWD per meter revetment removed | 3.5 trees/m | 2.0 trees/m |





# Conclusions & Implications

- Predictions at 4 sites increased LWD 24% over baseline
  - 55,000 additional trees total
  - 15% of stems were >40 cm dbh
- Comparing predictions at most promising restoration sites:
  - Additional trees recruited range 125% to >500%
  - 2 to 3.5 more trees recruited per meter of revetment removed
  - Large trees (>40 cm) recruited ranged 15--18% of all trees.
- Simulations help us understand local differences that can assist in selecting effective restoration sites.
- Evaluate effects of flow regimes and management actions (storage reservoirs, revegetation projects)

# Acknowledgements

**Field work & stats help:** J. Riddle, C. Swider, T. Hall, E. White, L. Zhang (SUNY-ESF)

**Sacramento River Ecological Flow Tools (SacEFT)**

- Ryan Luster, The Nature Conservancy
- ESSA Technologies Ltd. 2011. Sacramento River Ecological Flows Tool (SacEFT): Record of Design (v.2.00). Prepared by ESSA Technologies Ltd., Vancouver, BC for The Nature Conservancy, Chico, CA. 111 p. + appendices.

**Meander migration model**

- Larsen EW, Fremier AK, Girvetz EH. 2006. J. Amer. Water Res. Assoc. 42:1063–1075.

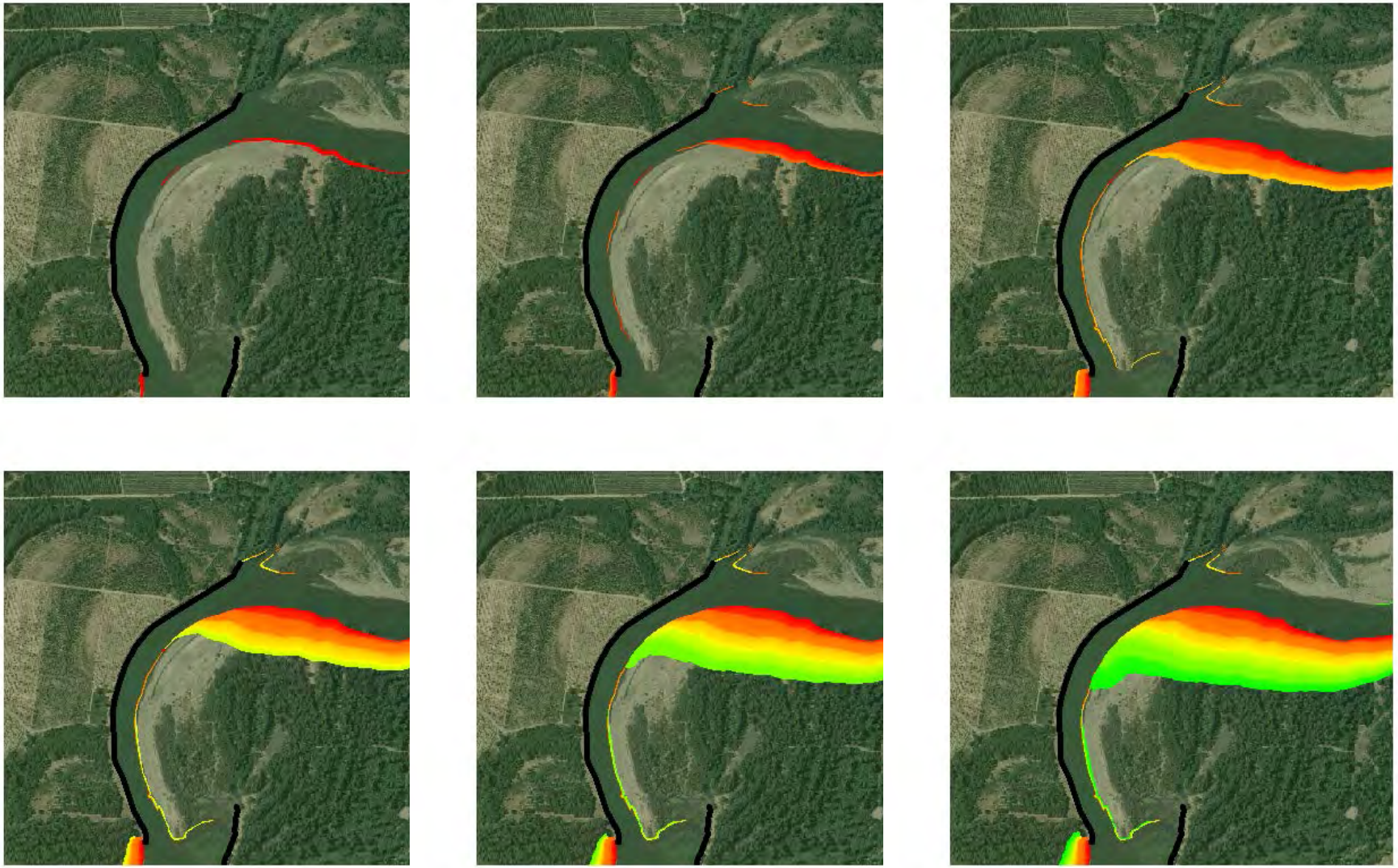
**Vegetation map**

- Nelson C., M. Carlson and R. Funes. 2008. Sacramento River Monitoring and Assessment Program. Geographical Information Center, CSU Chico.
- Viers, J.H., A.K. Fremier, and R.A. Hutchinson. 2010. Proceedings from the 2010 ESRI International User Conference, San Diego, California. 21 pp.

**Floodplain age map**

- Greco, S.E., A.K. Fremier, E.W. Larsen, and R.E. Plant. 2007. Landscape and Urban Planning 81(4):354-373.

# Phelan site – revetment intact



# Phelan site – revetment removed