Juvenile Salmon Response to Levee Repair on the Sacramento River

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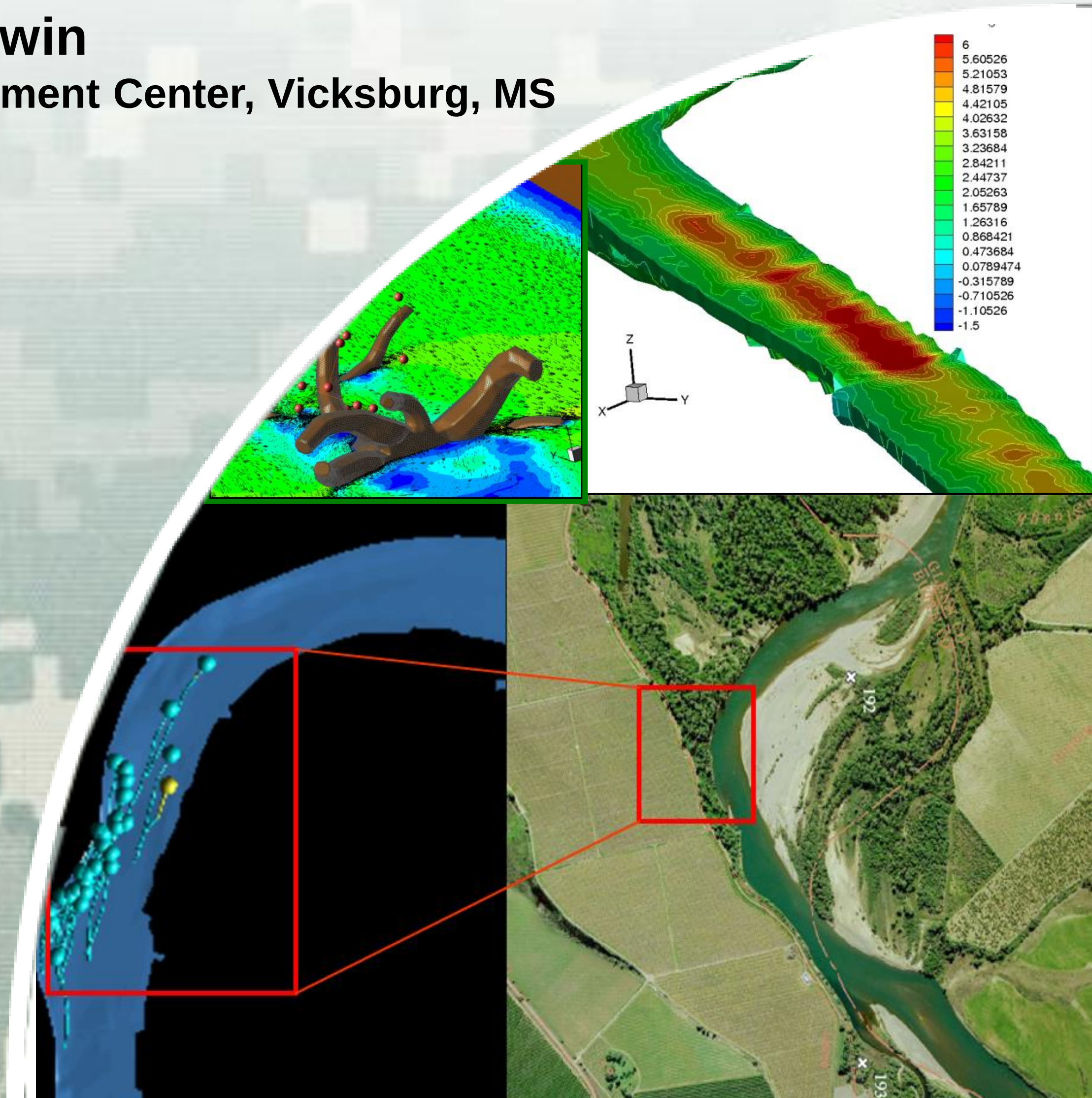

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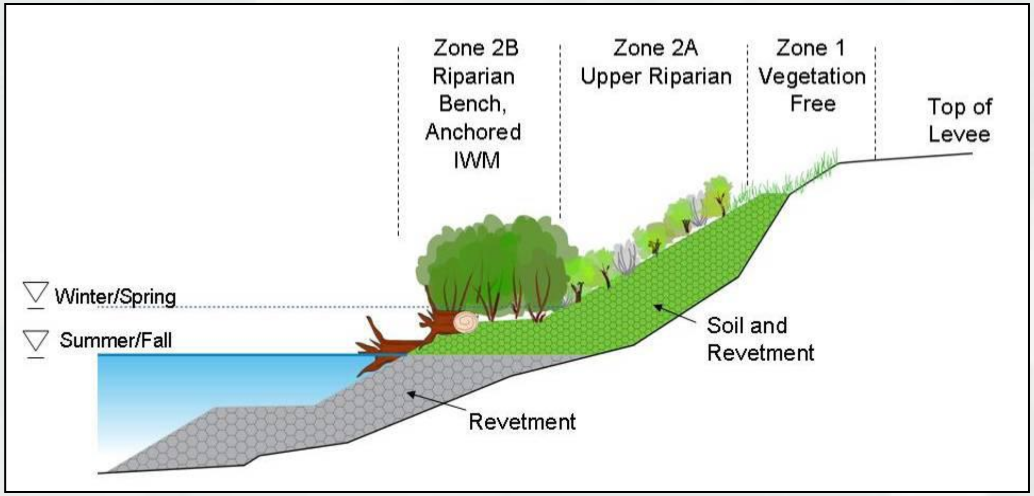
Approach

- Construct enhanced levee repairs designed to promote salmonid rearing
- Many variations, commonly include woody material, native vegetation and shallow water benches
- Numerical “mock-up” of a river environment – populate with virtual fish
- Compare movement across scenarios



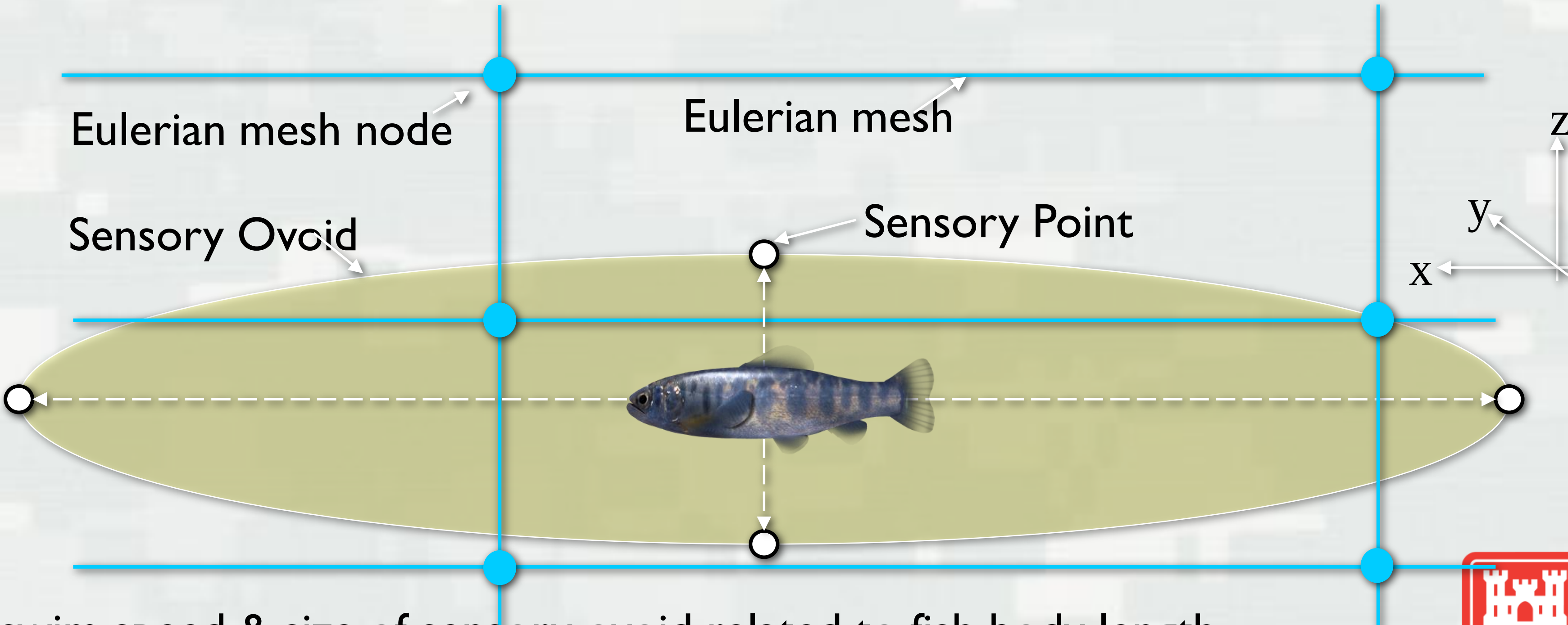
Modeling to Understand Behavior?

- In Physics-based disciplines;
  - replace natural system with equations
  - study mathematical behavior
  - draw conclusions about natural system
- Consider the question of "Fish behavior in response to flow"
  - flow pattern description uses deterministic paradigm
  - fish mechano-sensory system tightly coupled to fluid variables
- Statistical studies of "fish behavior in response to flow" are seldom conclusive – need a fresh approach

ELAMs: Understand & Forecast Fish Movement

Important Attributes of the ELAM (Goodwin et al. 2014)

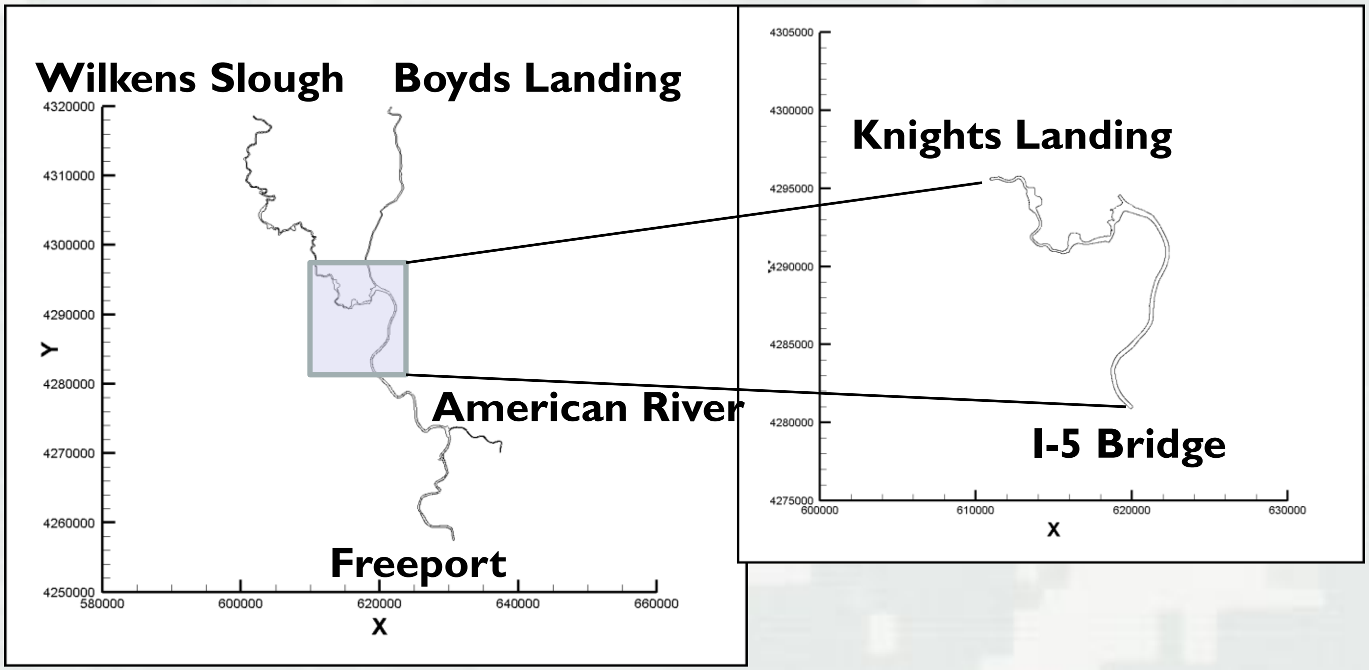
- capture temporal & spatial scales of complex biological processes
- venue for inter/trans-disciplinary education & integration
- information transformed to meet requirements of linked processes



*swim speed & size of sensory ovoid related to fish body length

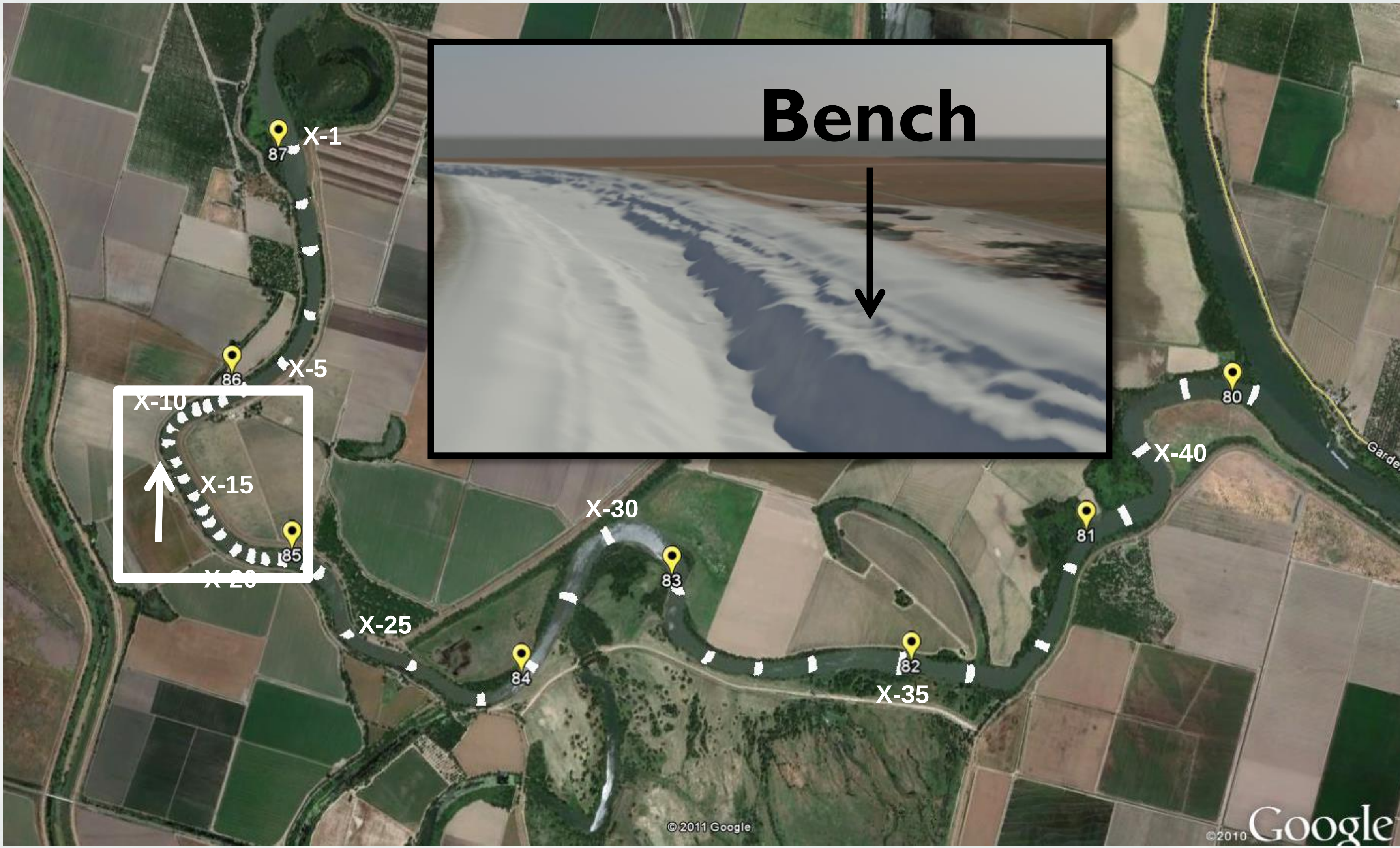
CFD Model Attributes & Notes

- ADH (USACE-ERDC), 192,467 elements, 2D, depth averaged
- Domain: 20 km long, December to April; 2010-2011; 2011-2012; 2012-2013

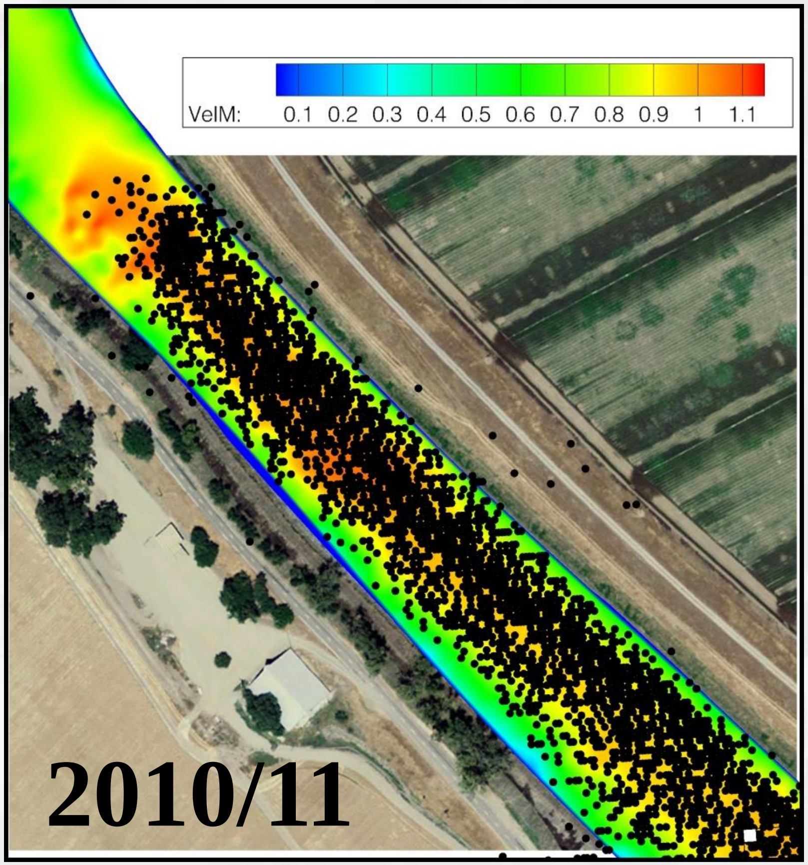


Cross-section locations

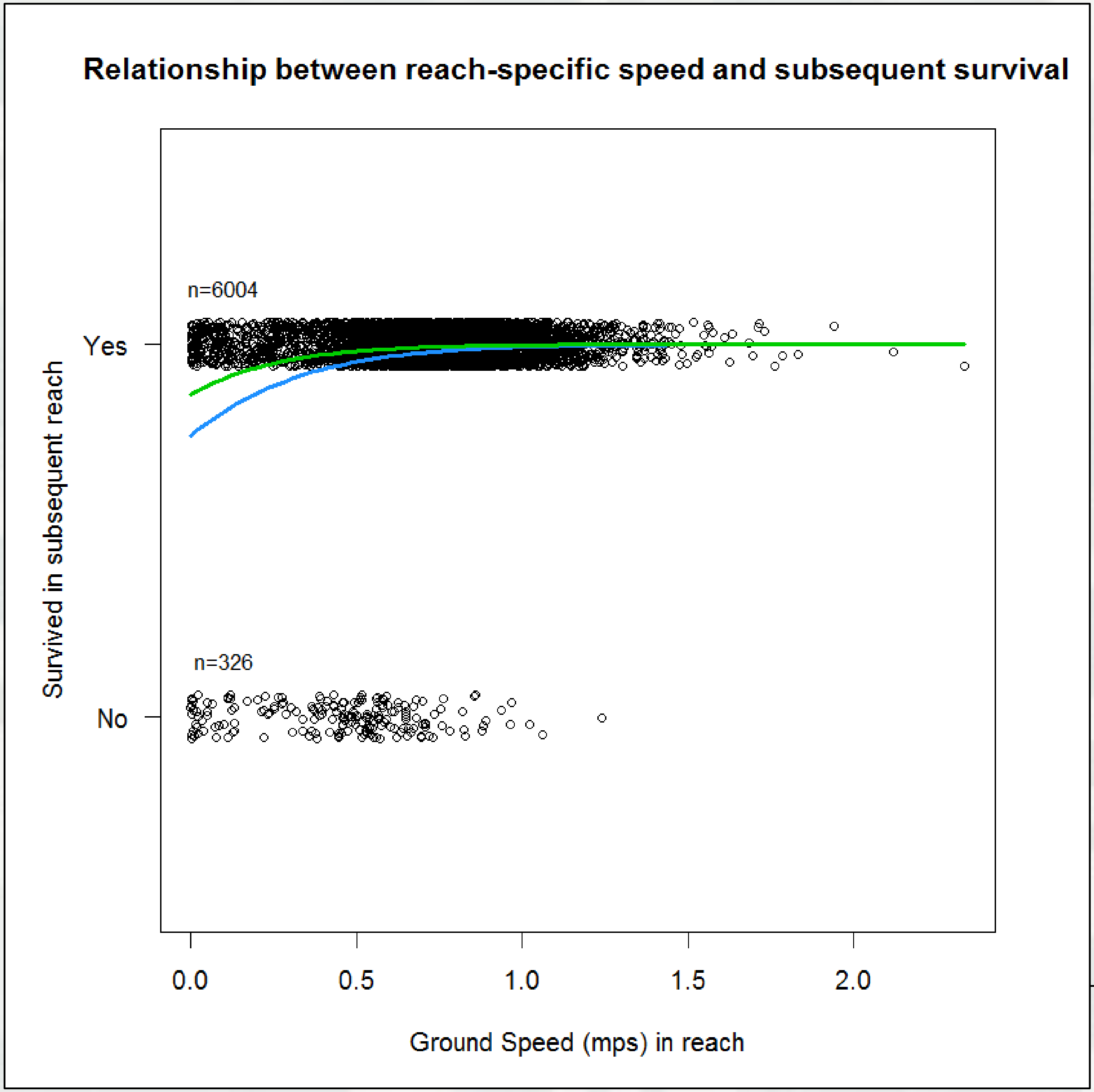
42 cross-sections, ~0.2 mile spacing for most of reach
Closer spacing (~300 ft) between RM85-86



Telemetry data



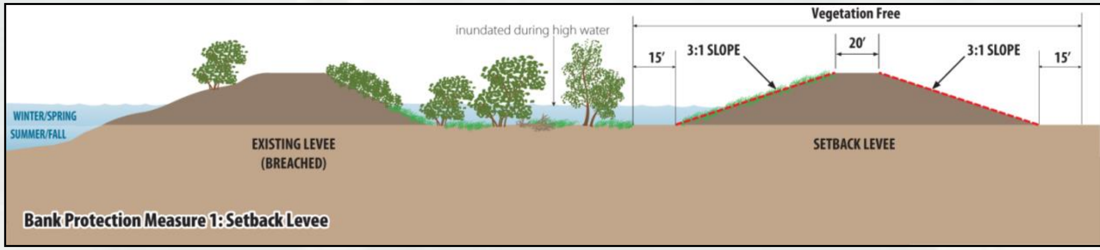
Slow fish survive at lower rates

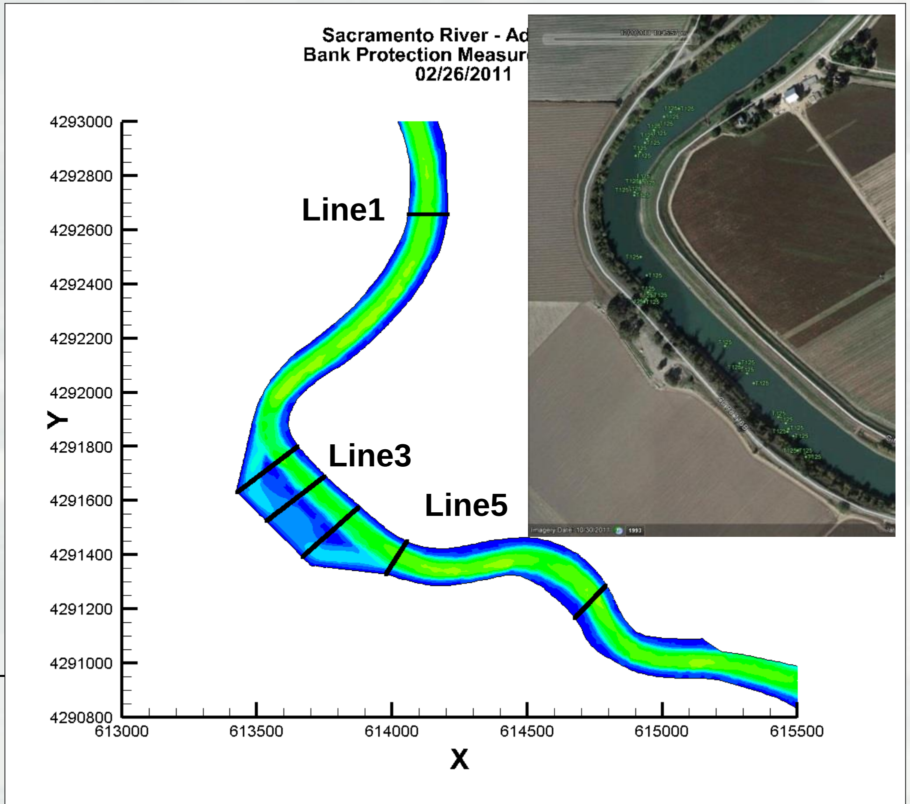


- **Blue line is a logistic model (general linear model, binomial family, with logit link)**
- **Green line is a general linear mixed model (same as above) where slope is allowed to vary with reach (i.e. reach is random variable)**
  - **This model gave a better fit than the models where the intercept was allowed to vary with TagID**

Observation: Habitat improvement designed to slow fish down

- Case study: Setback Levee
- Located at RM 85.6
- 1000 m long, 300 m deep, inundate at common winter flow but drain at lower flows



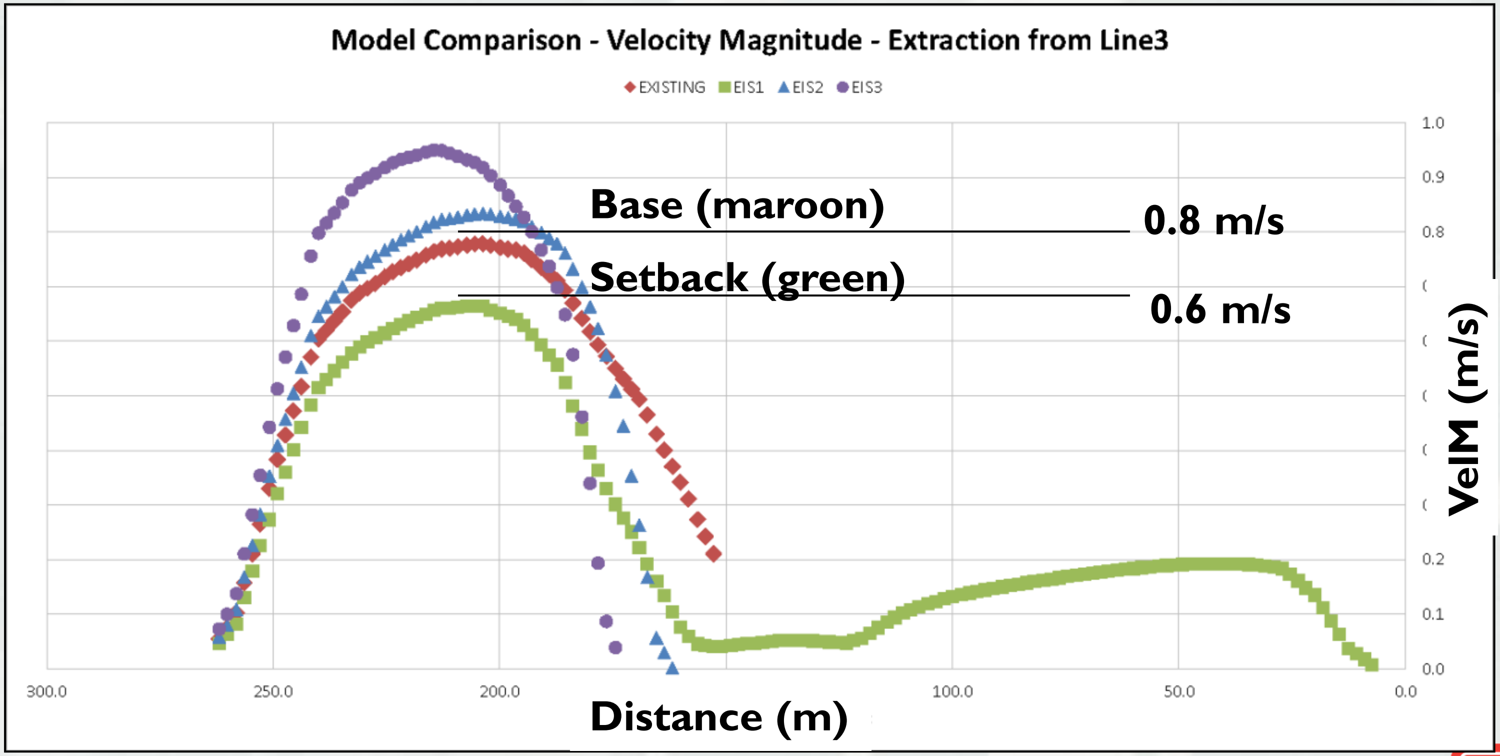


[Base conditions animation]

[Setback levee animation]

Velocity impacts of setback levee

- Setback levee reduces velocity



Survival modeling – path length and travel time using ELAM

- Anderson et al. (2005) derived a survival model
  - ► S = f(time and distance traveled)
  - ► Implications for predator-prey interactions
  - ► "XT-model"

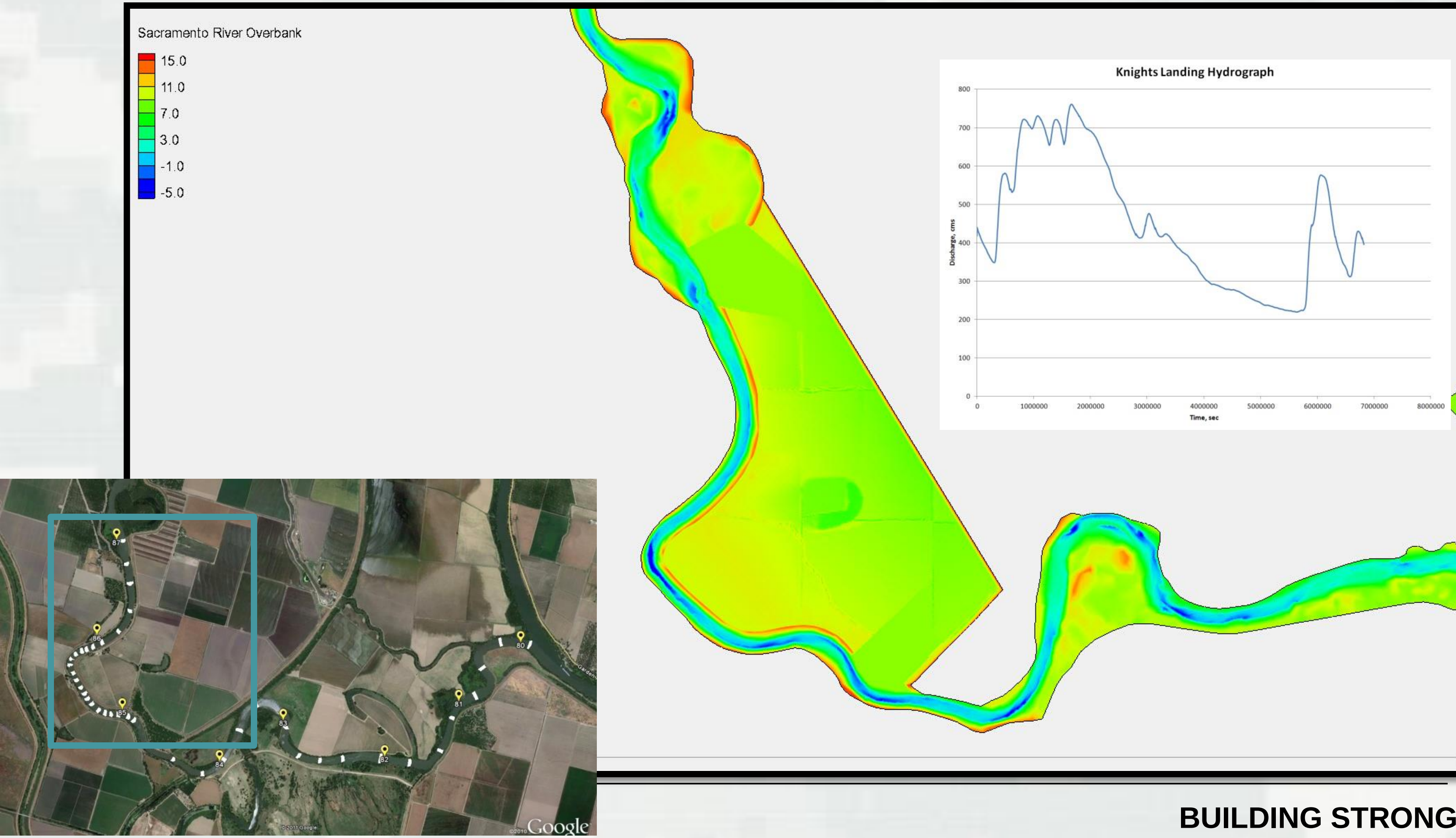
$$S = \exp\left(- 1/\lambda * \mathrm{sqrt}\left(x^2+\omega^2 t^2\right) \right)$$

- Troubling conclusion- setback levees reduce migratory survival

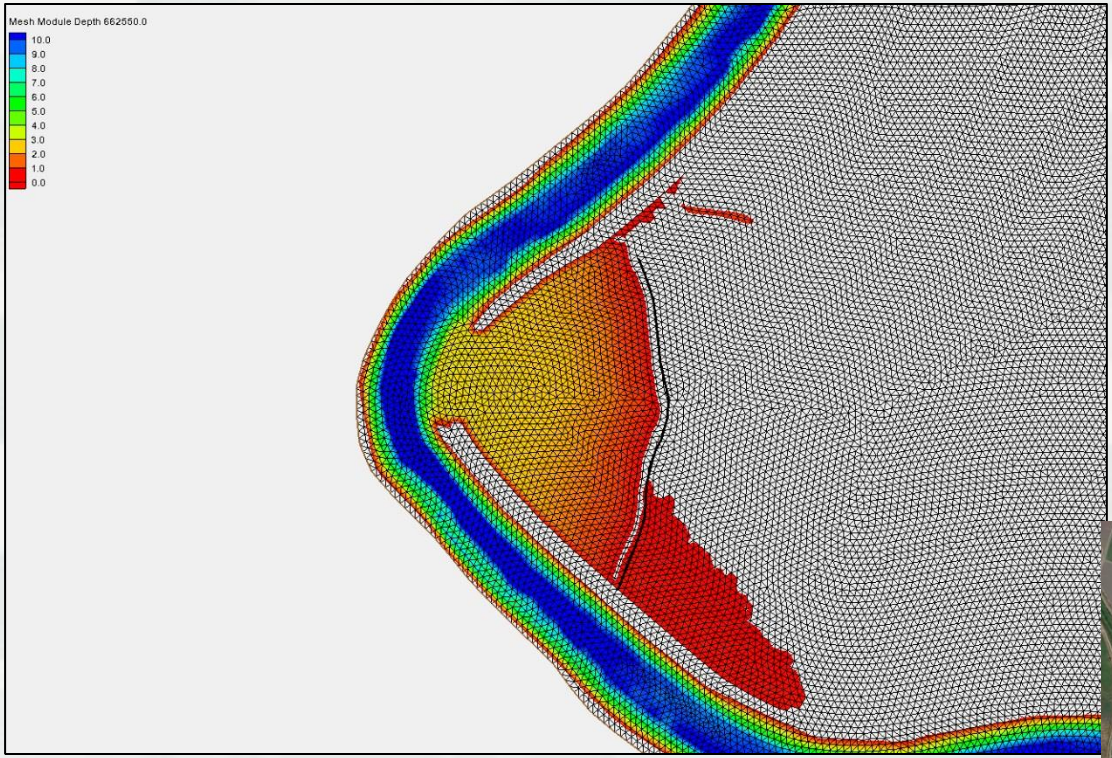
Short path – >99% survival

Long path – 96% survival

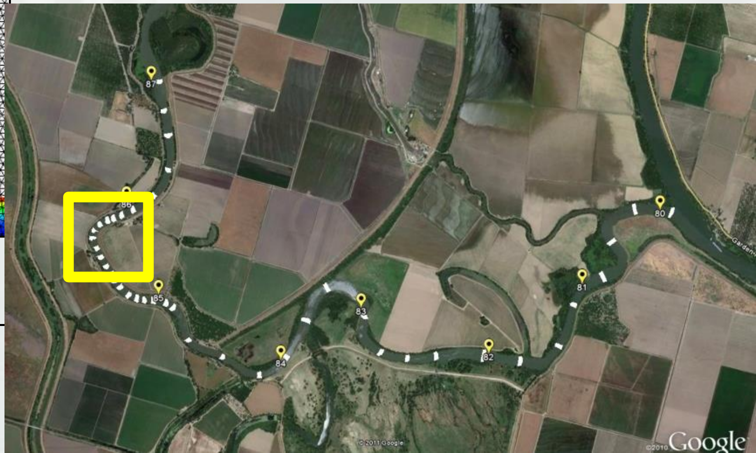
BIG setback


Sacramento River Overbank
15.0
11.0
7.0
3.0
-1.0
-5.0
Knights Landing Hydrograph
Discharge, cms
0
100
200
300
400
500
600
700
800
0
1000000
2000000
3000000
4000000
5000000
6000000
7000000
8000000
Time, sec
87
86
85
84
83
82
81
80
Google

Geomorphological setback – big habitat benefit



Animation



Conclusions

- Simulation useful to understand setback levee survival outcomes
- Setback as designed only reduces water velocity and thus decreases migratory survival without producing rearing benefits
- Data was critical for defining basic boundaries of simulation
- Simulation suggest alternative setback levee designs – more investigation needed
- Fish tracks in energetic environments are difficult and noisy – technology limitations
- Predator contamination of data set present analysis challenges – technology limitation
- We need behavioral data for rearing fish