Rearing capacity for winter-run Chinook salmon in mainstem, floodplain, and estuary habitats

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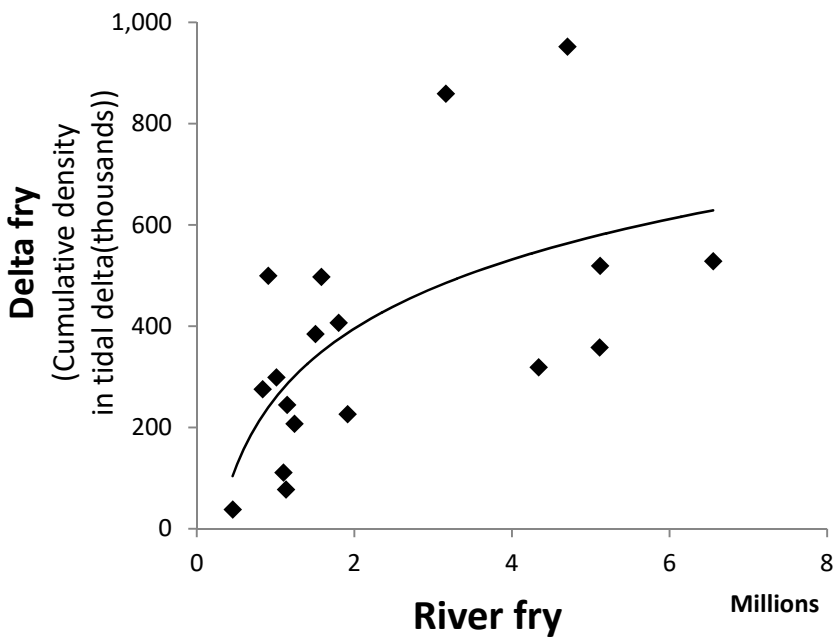
Big habitat questions

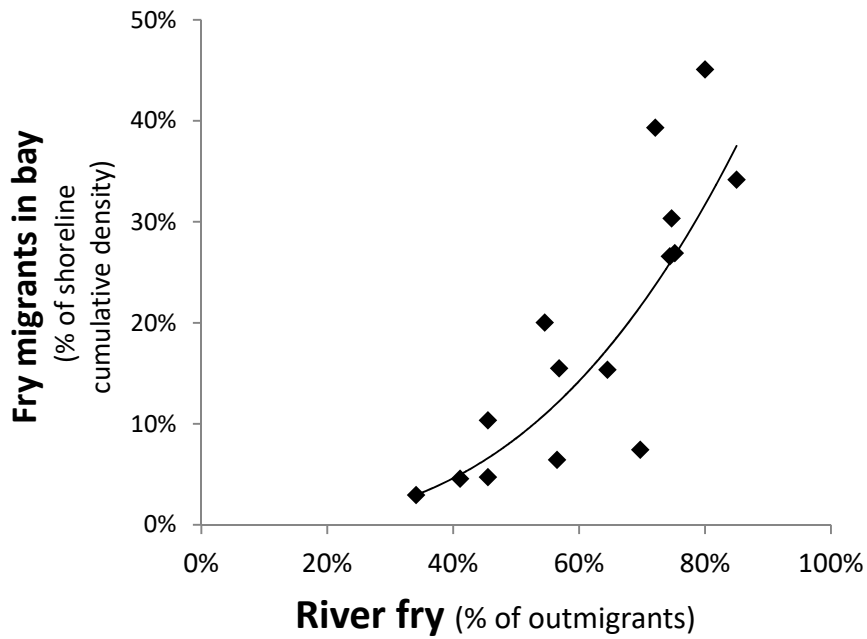
1) Is there enough high quality habitat to support freshwater & estuarine rearing?

2) Do proposed water management actions adversely affect rearing habitat?

3) How can habitat restoration actions improve conditions for juvenile salmon?

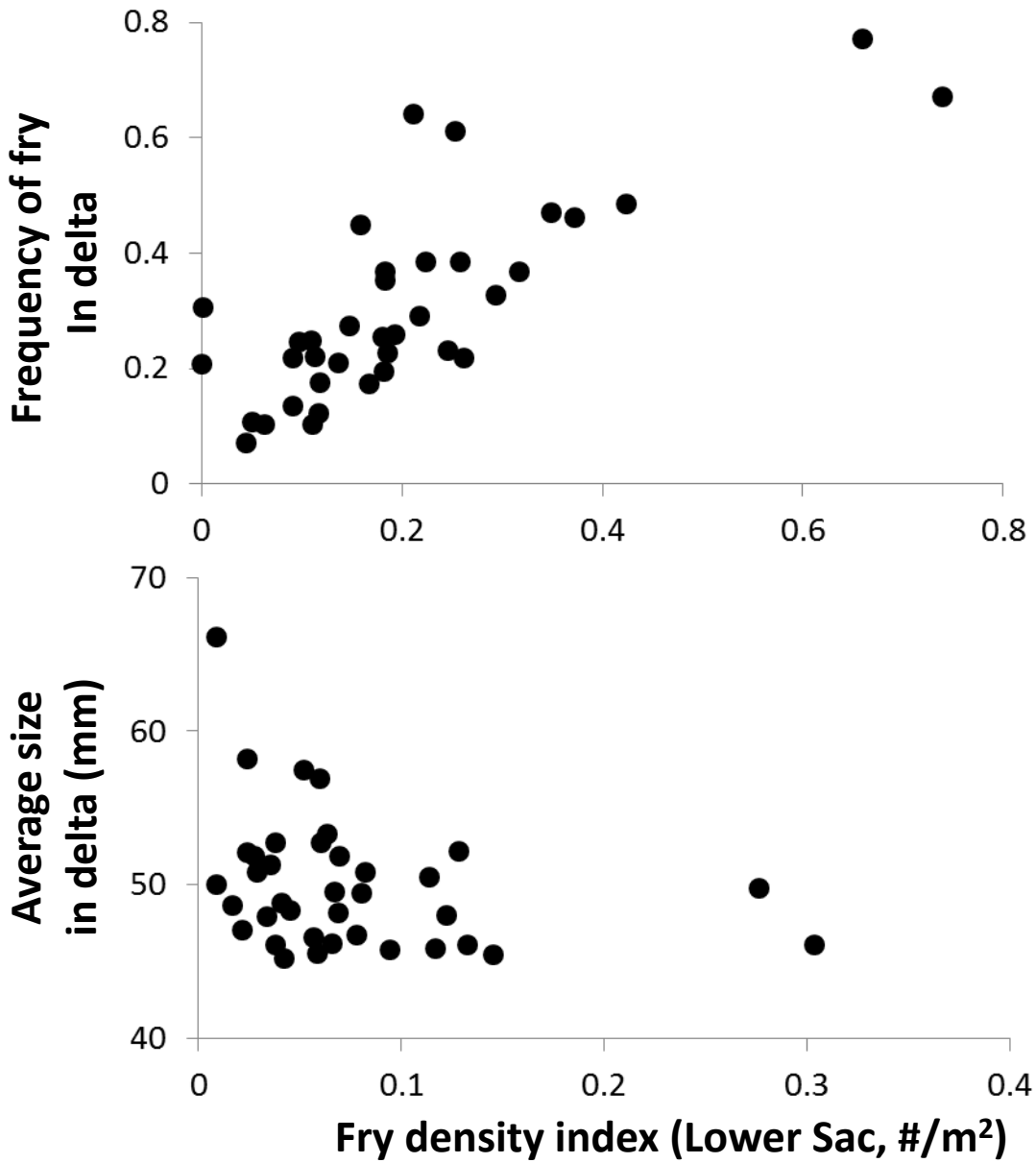
Evidence of habitat limitations





Skagit River, WA

Evidence in the Sacramento Delta?



- **USFWS Beach seine dataset**
- **Each point = 1 year of data**

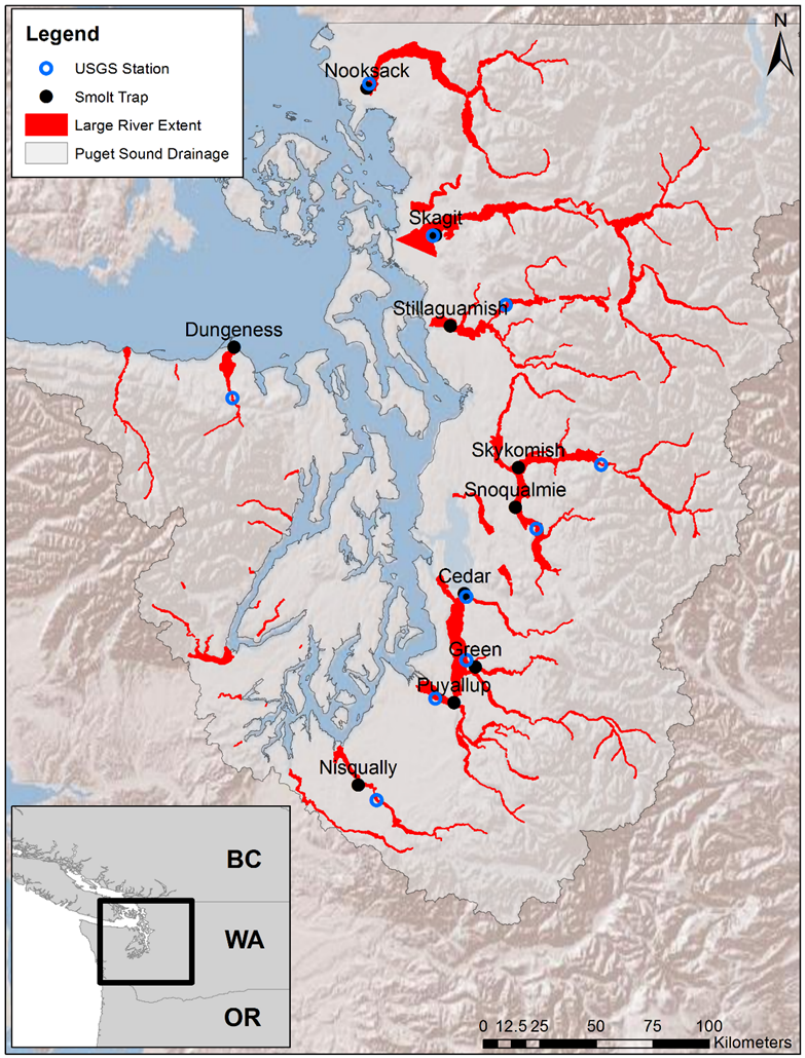
Habitat complexity and productivity

Central question:

Does productivity of juvenile Chinook salmon track floodplain habitat complexity?

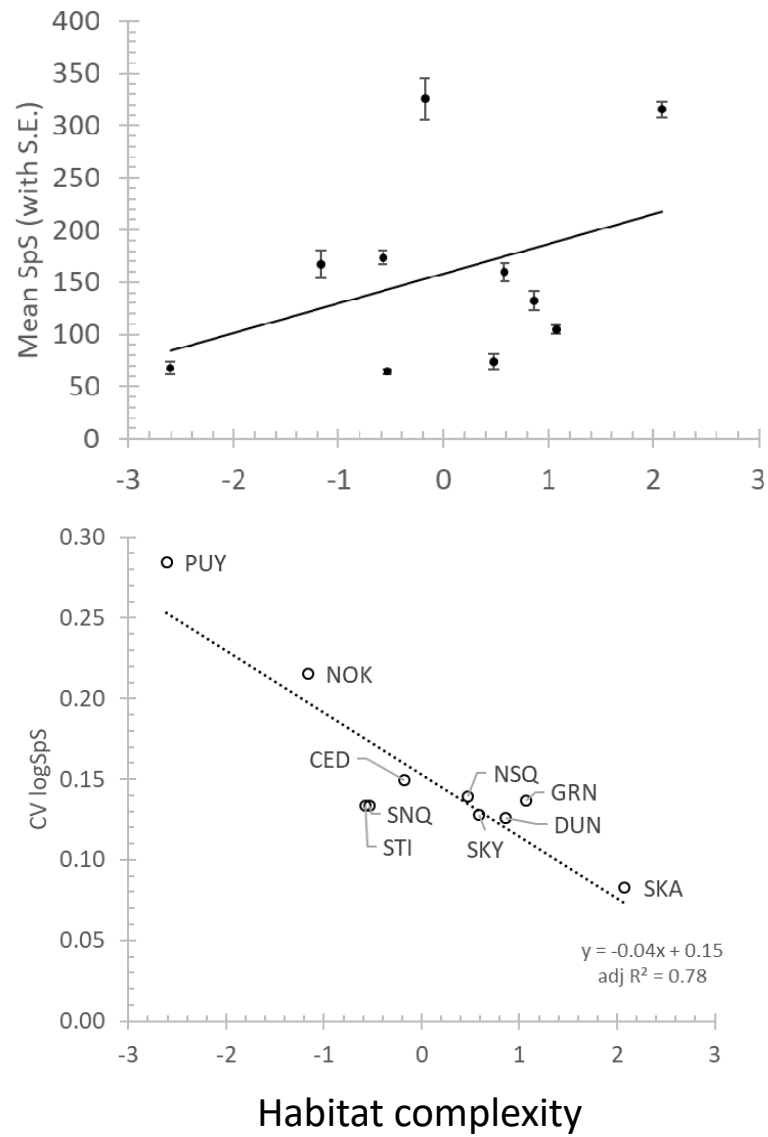
Address using:

- Digitized large river habitat features throughout Puget Sound as part of the PSHSTM program
- Derived habitat complexity metrics for each system
  - Log jam density
  - Braid & side channel : mainstem ratios
  - Braid & side channel node densities
- Smolt trap and spawner abundance data from WDFW and Tribes:
  - Subyearling outmigrants per spawner



Habitat complexity and productivity

- Best models included habitat complexity with annual variation explained by peak flows or spawner densities
- Smolts per spawner (SpS) increases with increasing habitat complexity
- Variation in productivity decreases with increasing habitat complexity
  - Complexity buffers populations from peak flows and spawner density



How the life cycle model incorporates habitat

1) What is capacity and how does it work in the model?

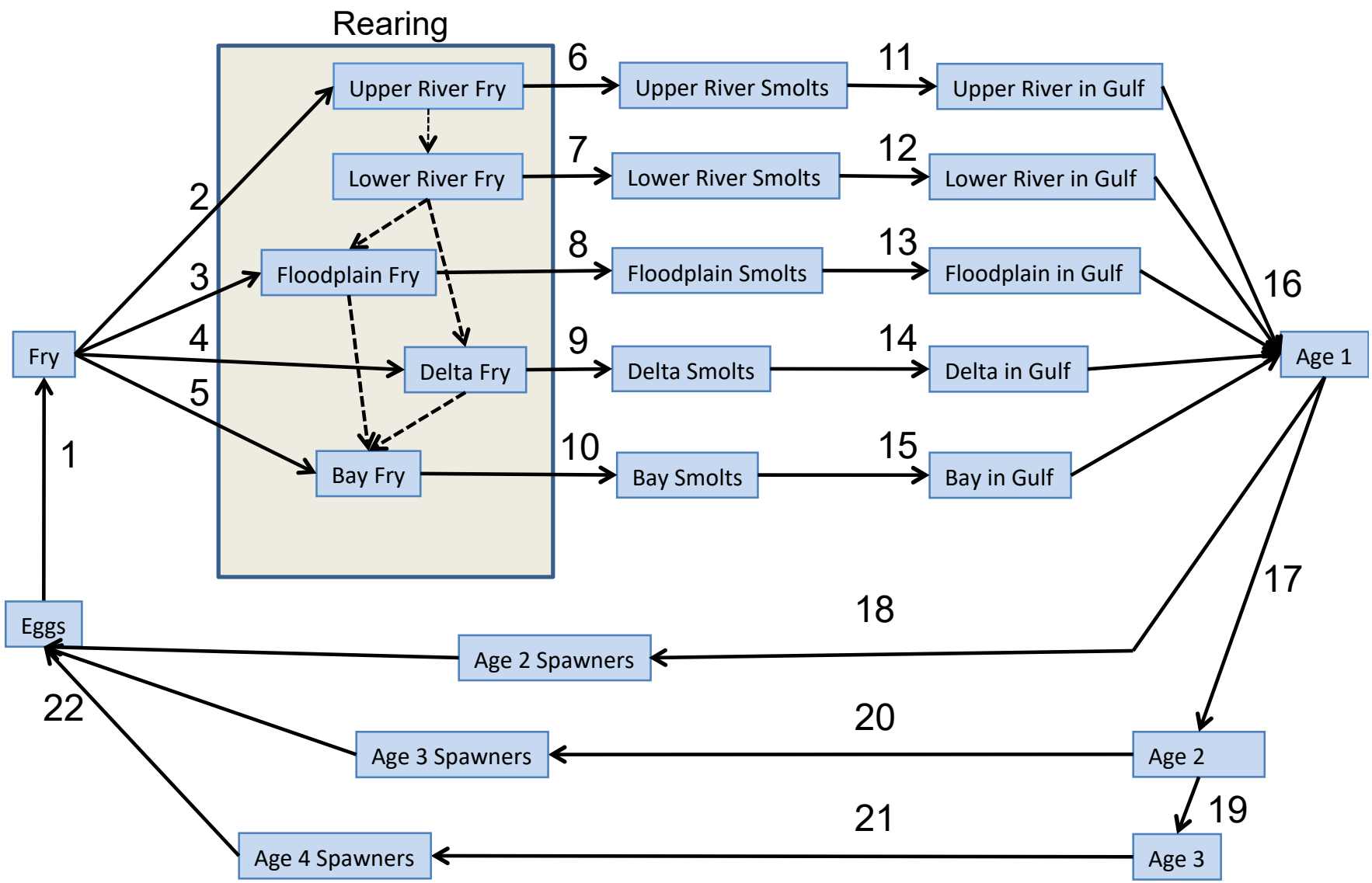
2) How is it calculated and what are the assumptions of the calculation?

3) How do baseline estimates vary as functions of time and river flow?

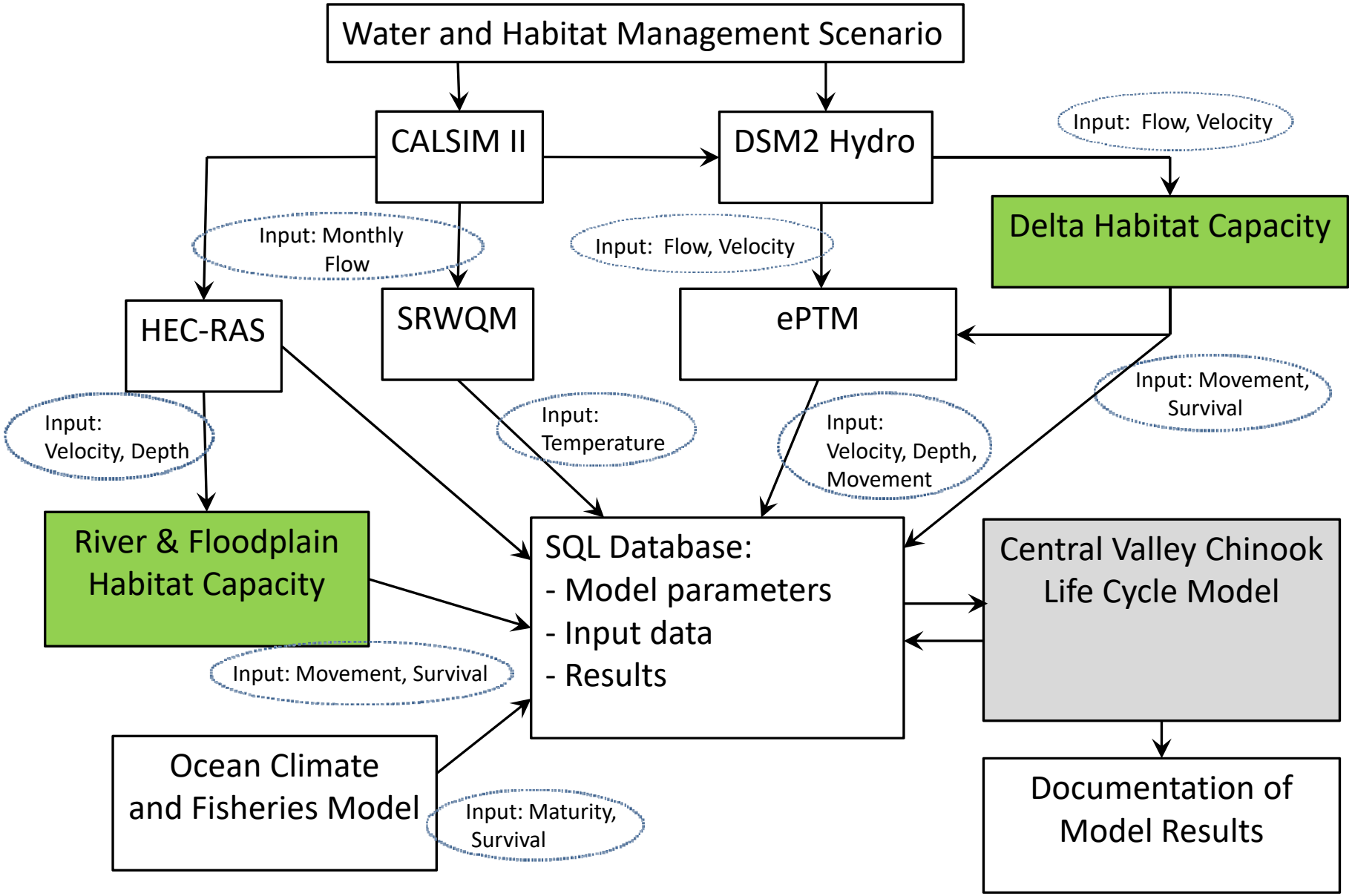
4) How is habitat incorporated into the ePTM?

5) What changes in productivity can we model?

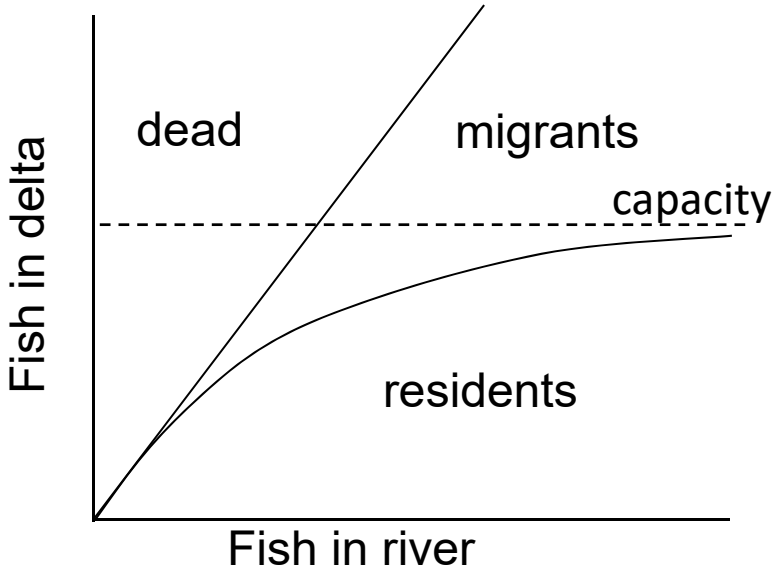
Life cycle model schematic



Capacity in a multimodel framework



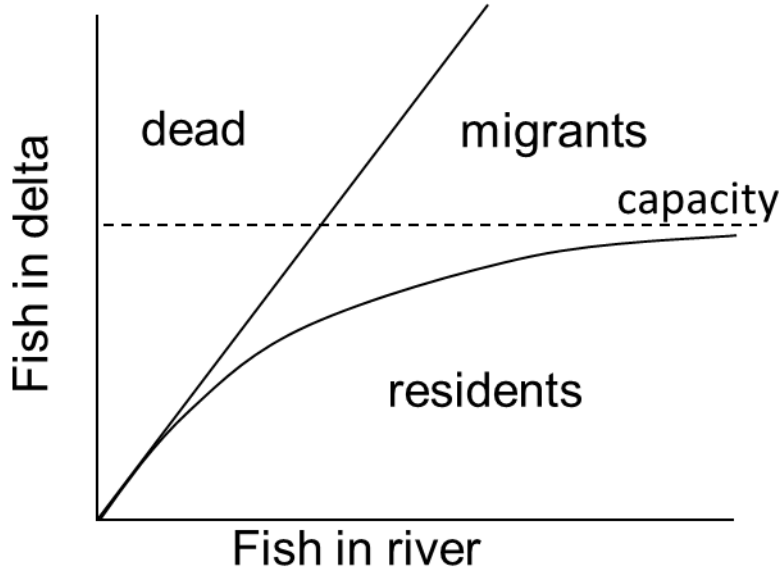
What is capacity?

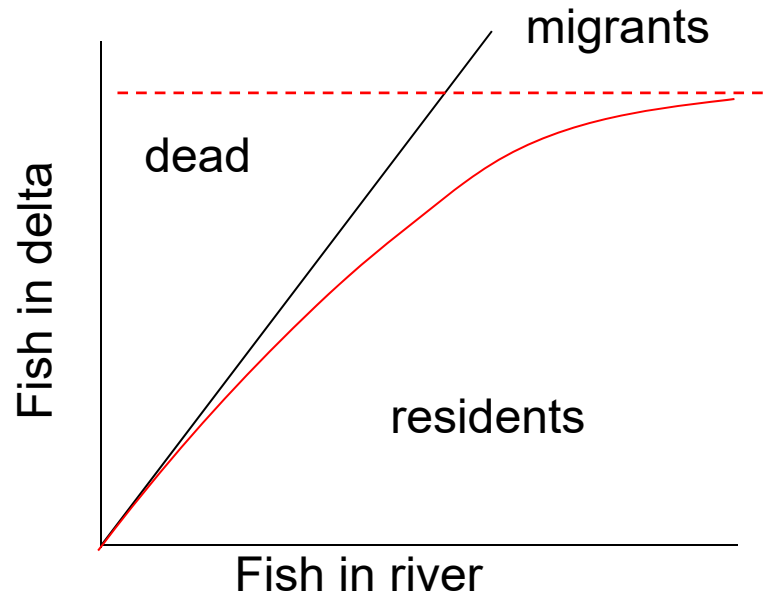


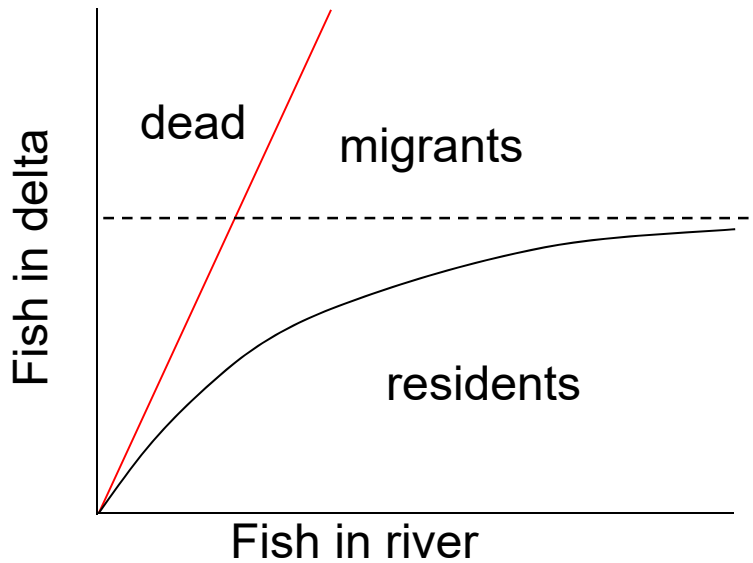
Maximum number of fish that the habitat can support

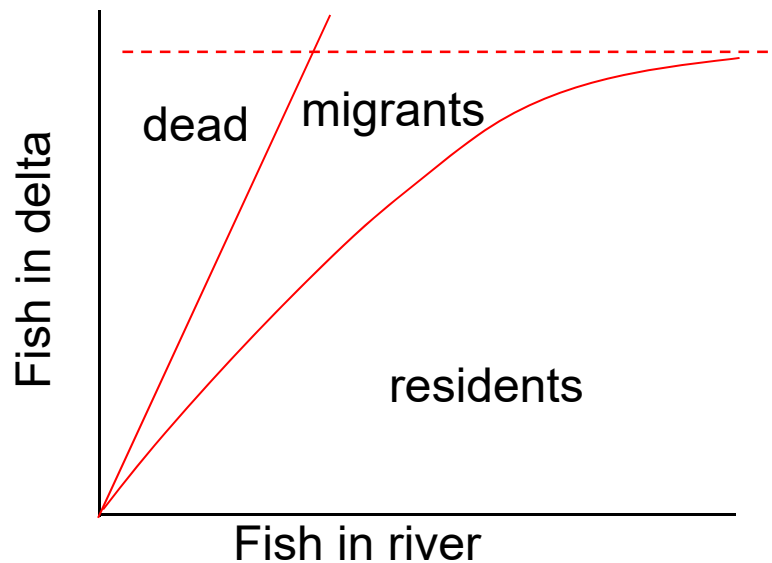
Assume “excess” capacity migrates downstream

How does habitat restoration effect populations?

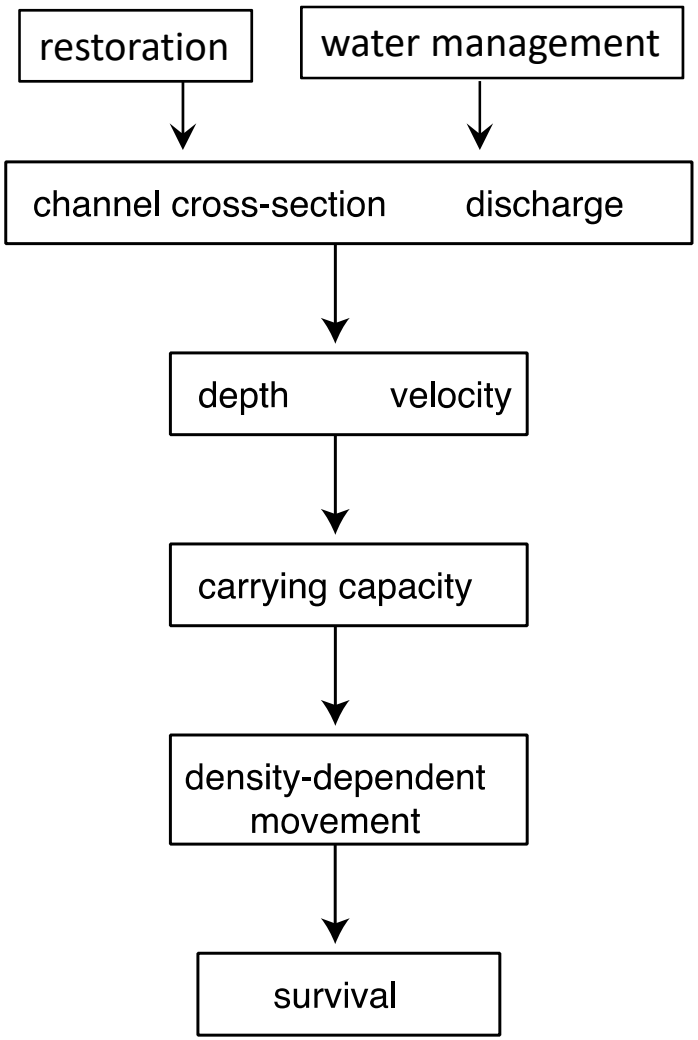




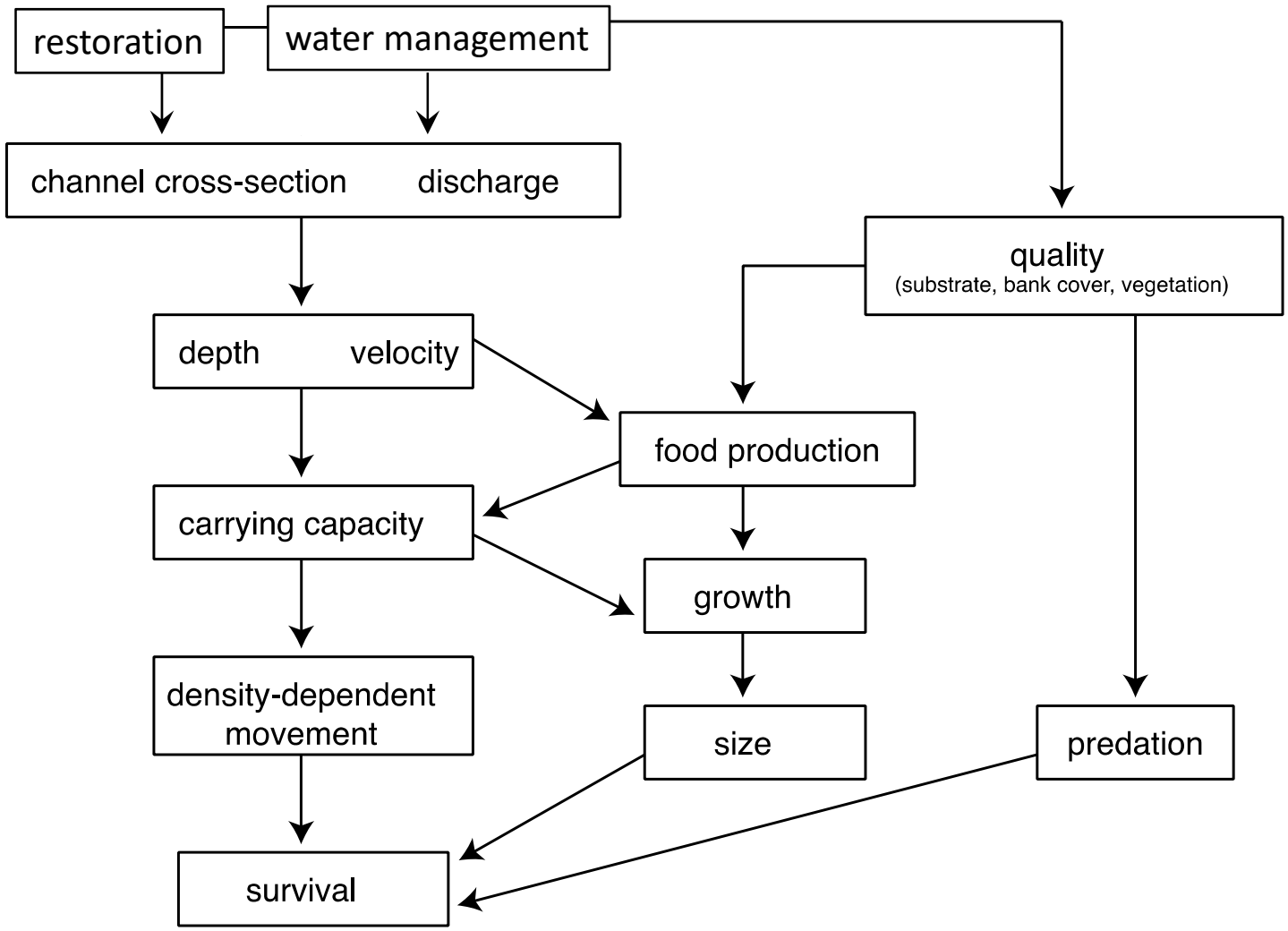




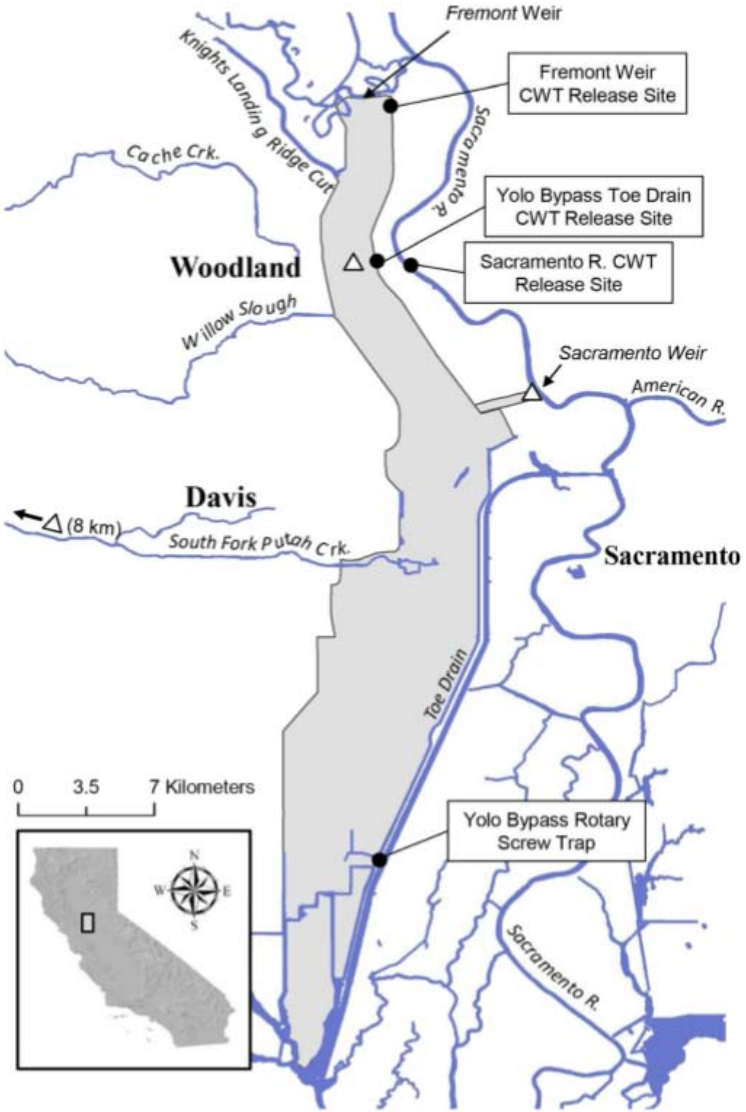
The CVLCM and habitat conservation measures

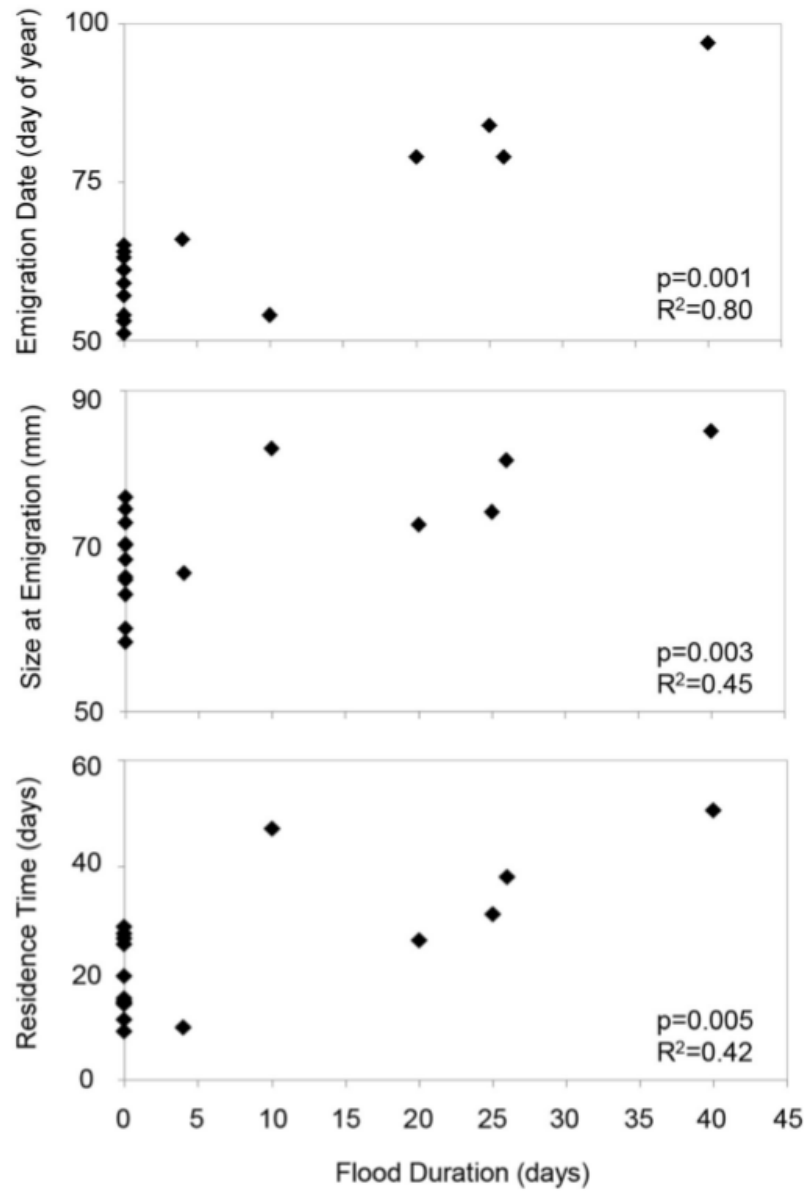


The CVLCM and habitat conservation measures



How do juvenile Chinook respond to water management? Findings in Yolo Bypass

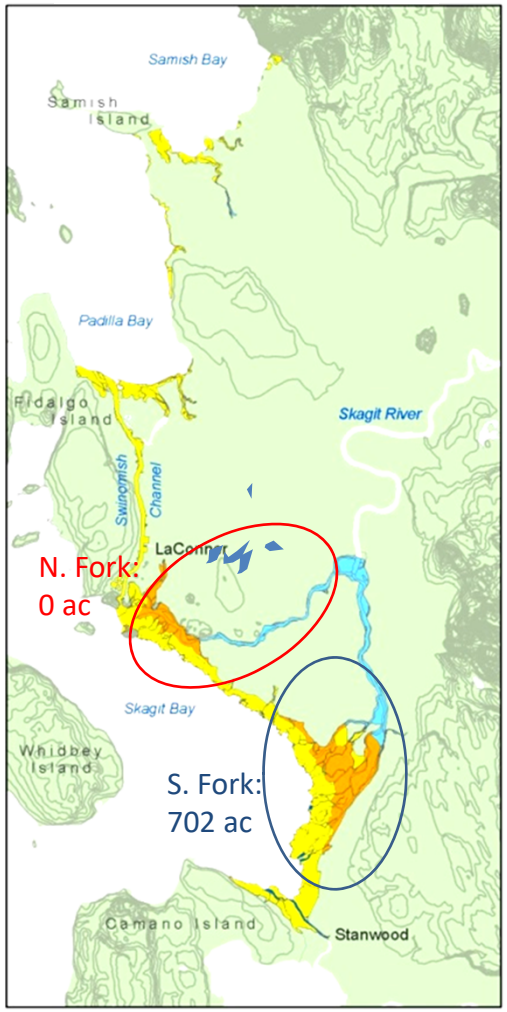




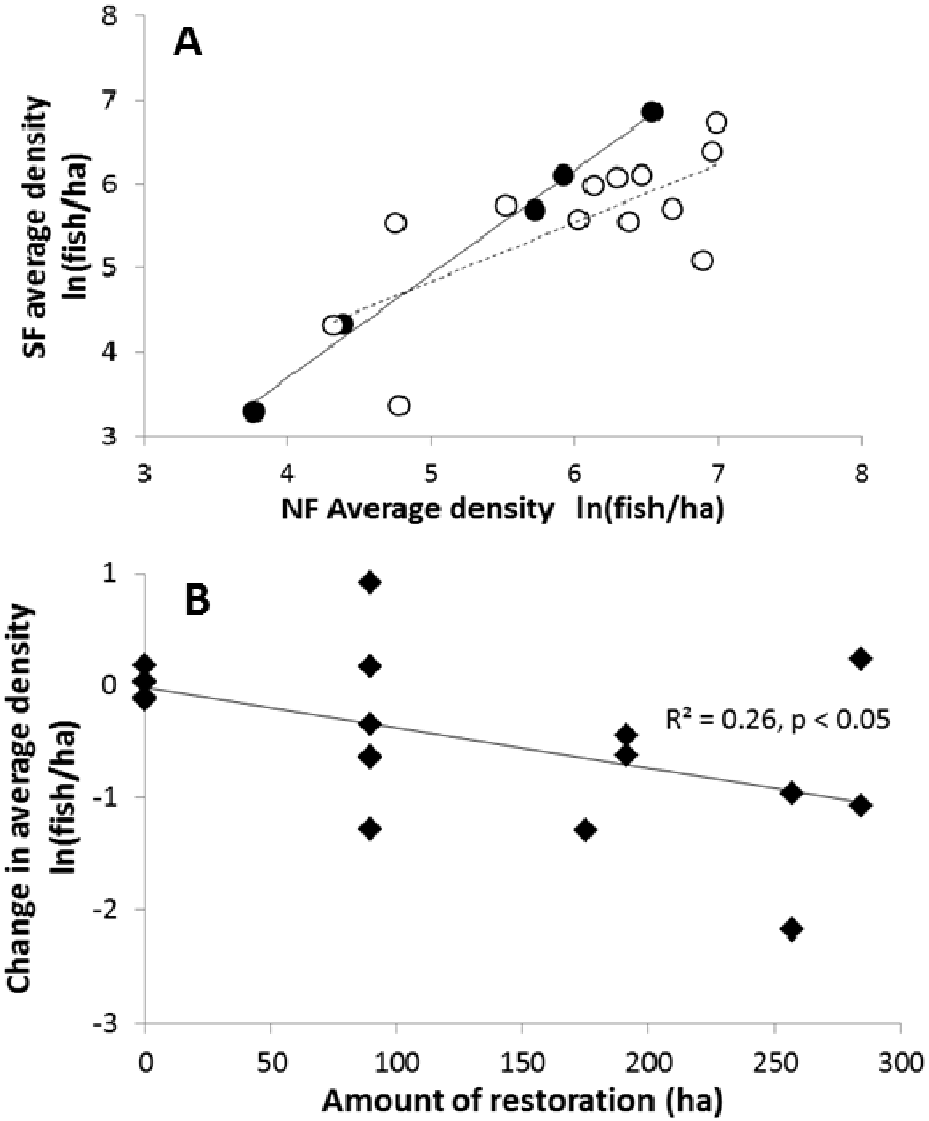
Takata et al. 2017

How do juvenile Chinook salmon respond to estuary restoration? Long-term monitoring in the Skagit estuary

BACI design



Skagit River System Coop



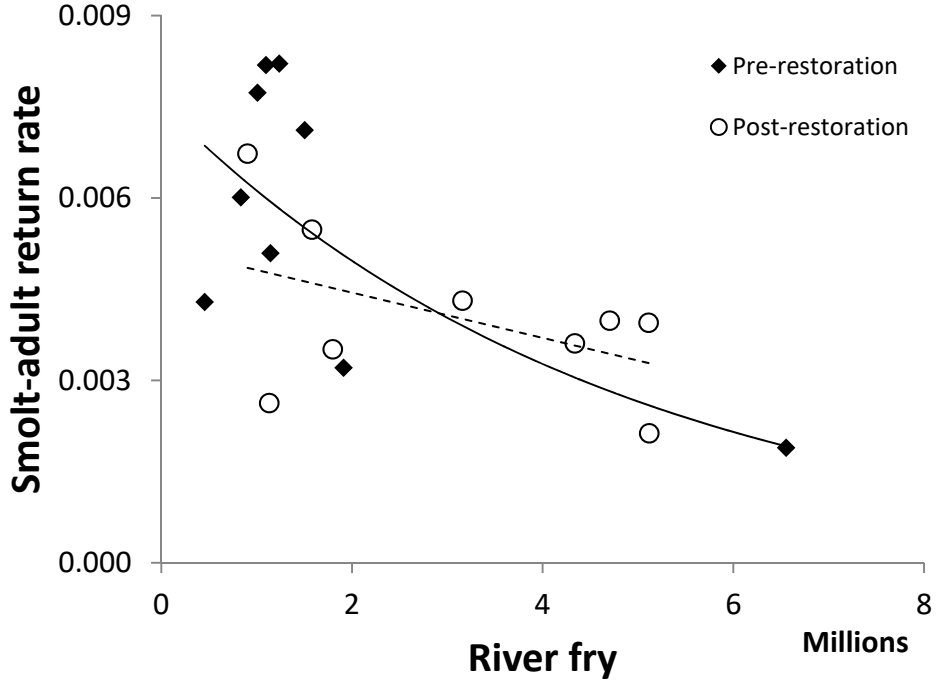
Are all Chinook metrics sensitive to restoration?

BACI design

- Density – YES
- Residence time – YES
- Body size -- REVERSE

Before/After design

- Density – NO
- Residence time – YES
- Body size – REVERSE
- Marine survival -- NO



Questions?

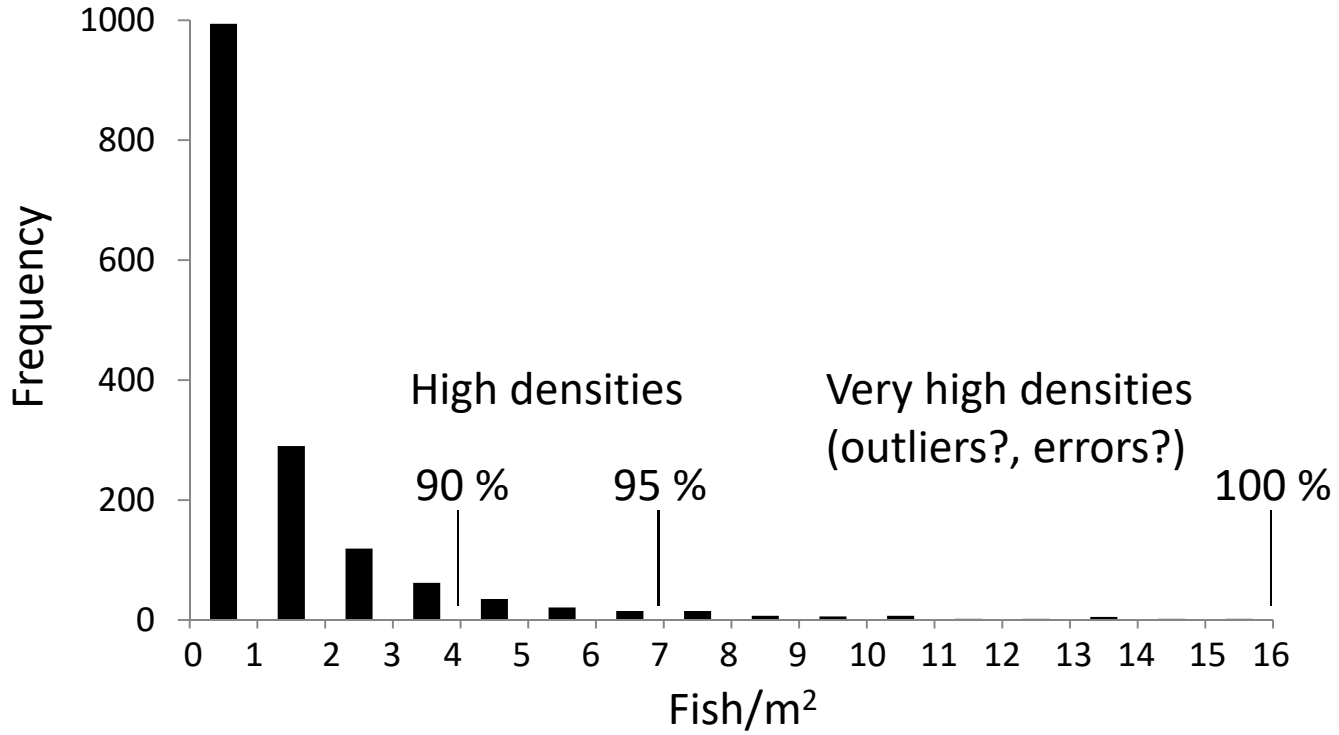
What is capacity?

$$\textbf{Capacity} = \sum^{\textbf{Types}} \textbf{habitat area} * \textbf{max. density}$$

Assumptions:

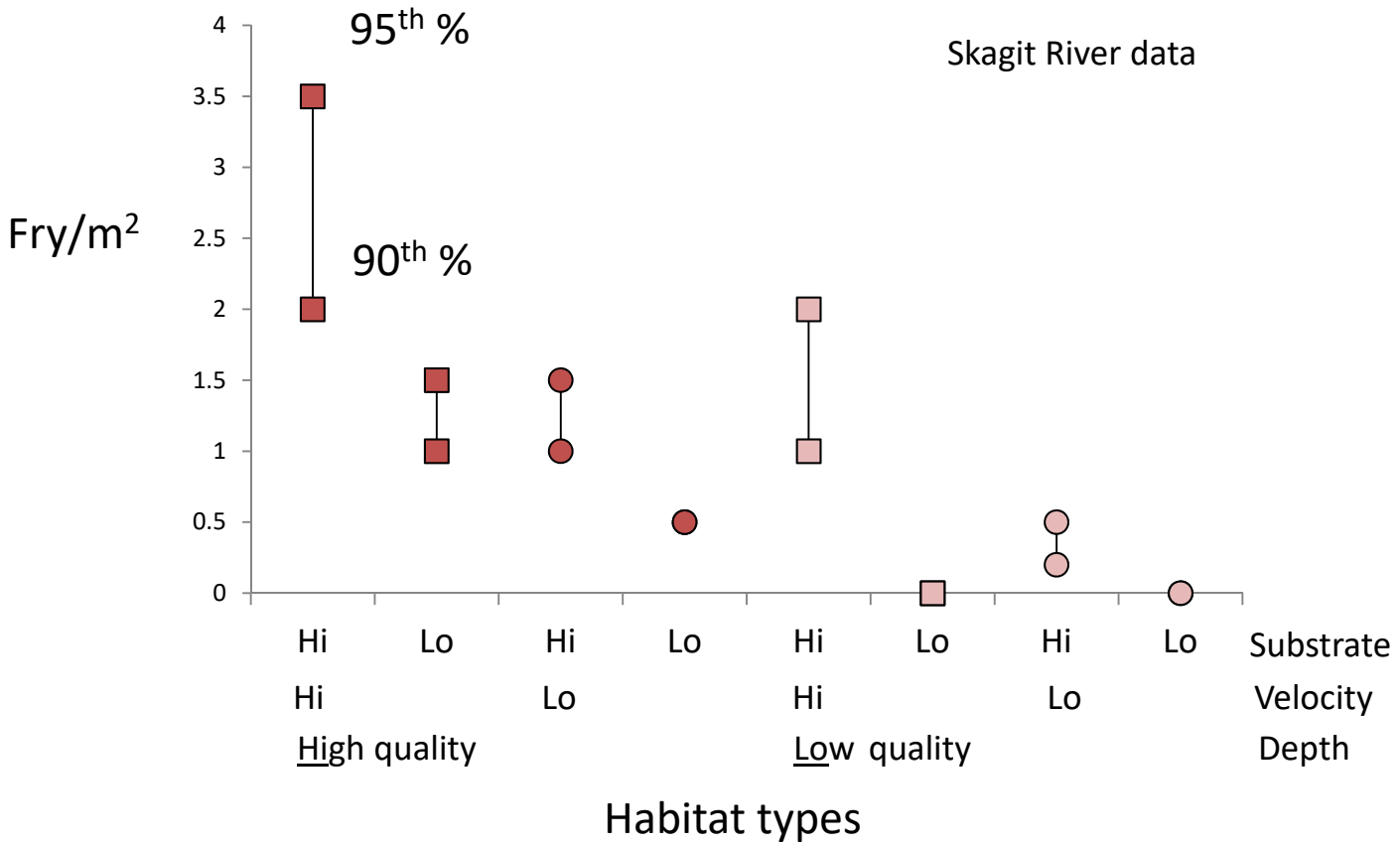
- Habitat types are relevant to fish
- Habitat areas can be estimated
- Max. densities do not vary within habitat types
- Max. densities are really max!
  - Shifting baselines
  - Hatchery inputs
  - Evidence of density dependence at current levels

What range of density = “capacity”?



Boat electrofishing data from upriver Skagit River mainstem habitats
Juvenile Chinook densities linked to habitat features (Beechie et al. 2005)

River and floodplain max densities



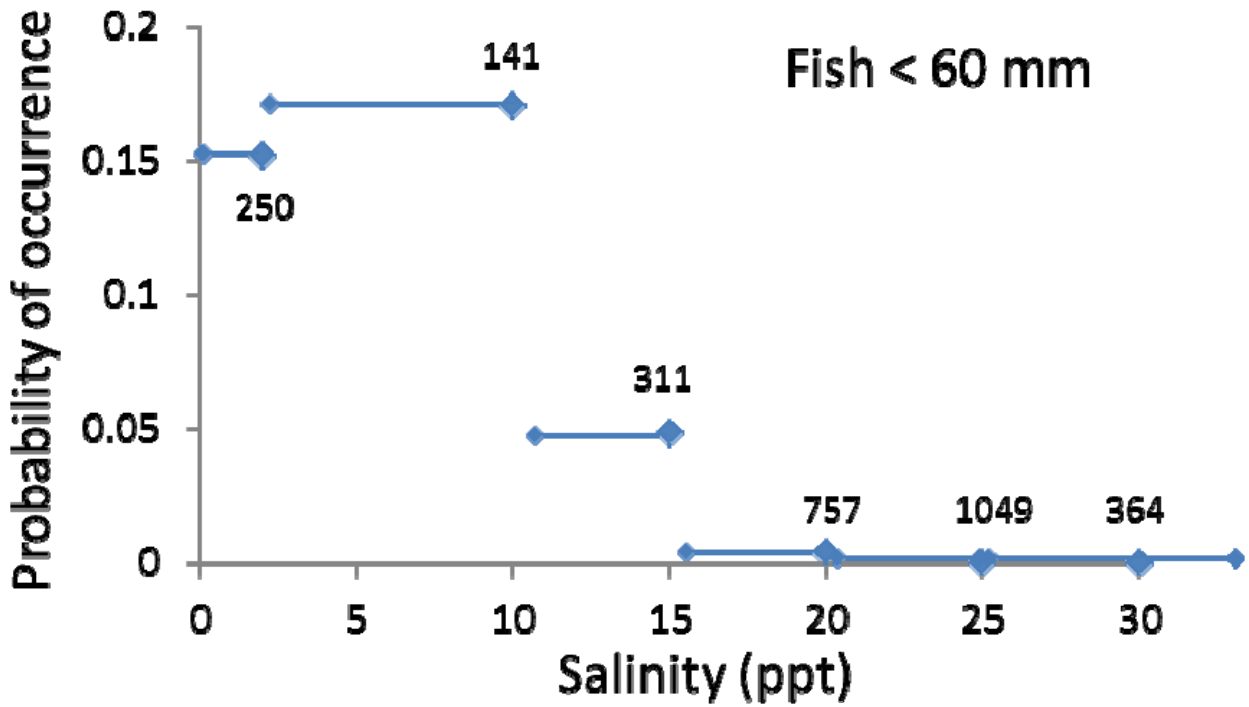
Data from Beechie et al. 2005

Capacity estimation for fry in the winter-run model

Habitat	Habitat types	References
River and floodplain	High and low quality • **depth** • **velocity** 4 habitat types	 Beechie et al. 2005, Beakes et al. 2012 Beakes et al. 2012
Delta	High and low quality • channel type • **depth** • cover type 8 habitat types	 Beamer et al. 2005, Healey 1991 Beamer et al. 2005 Hood 1991, Beamer et al. 2005
Bay	High and low quality • shoreline type • **depth** • **salinity/X10** 8 habitat types	 Beamer et al. 2005 Beamer et al. 2005 Jassby et al. 1995, Greene et al. unpub.

Bold: varies with river flow

Capacity estimation for fry in the winter-run model



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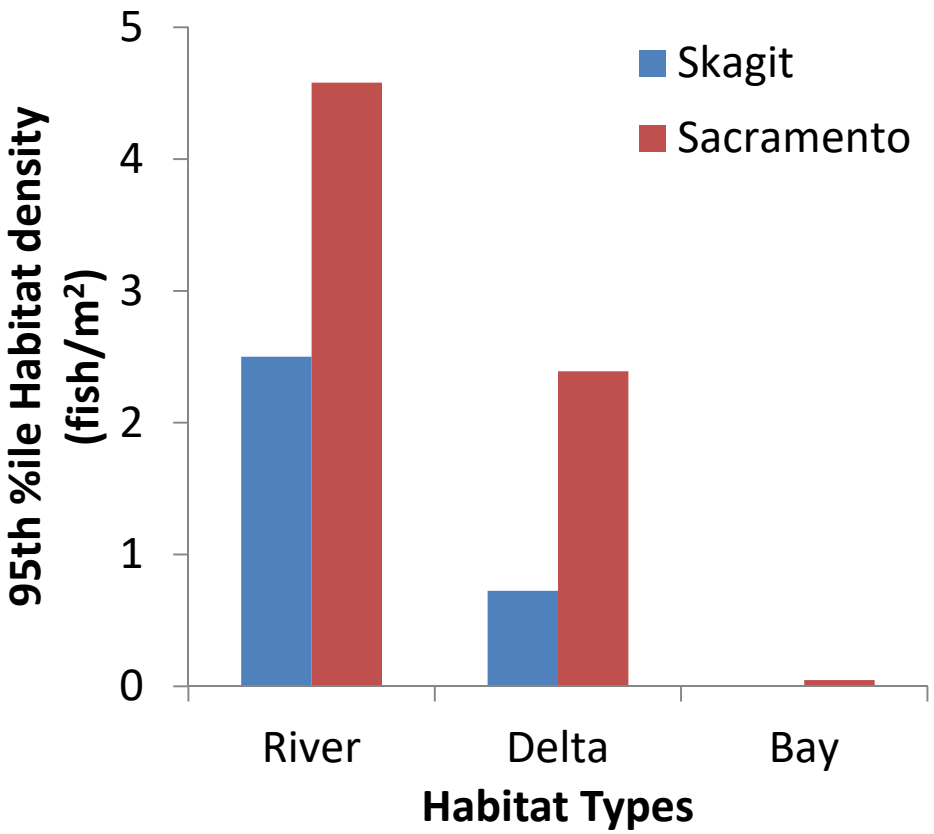
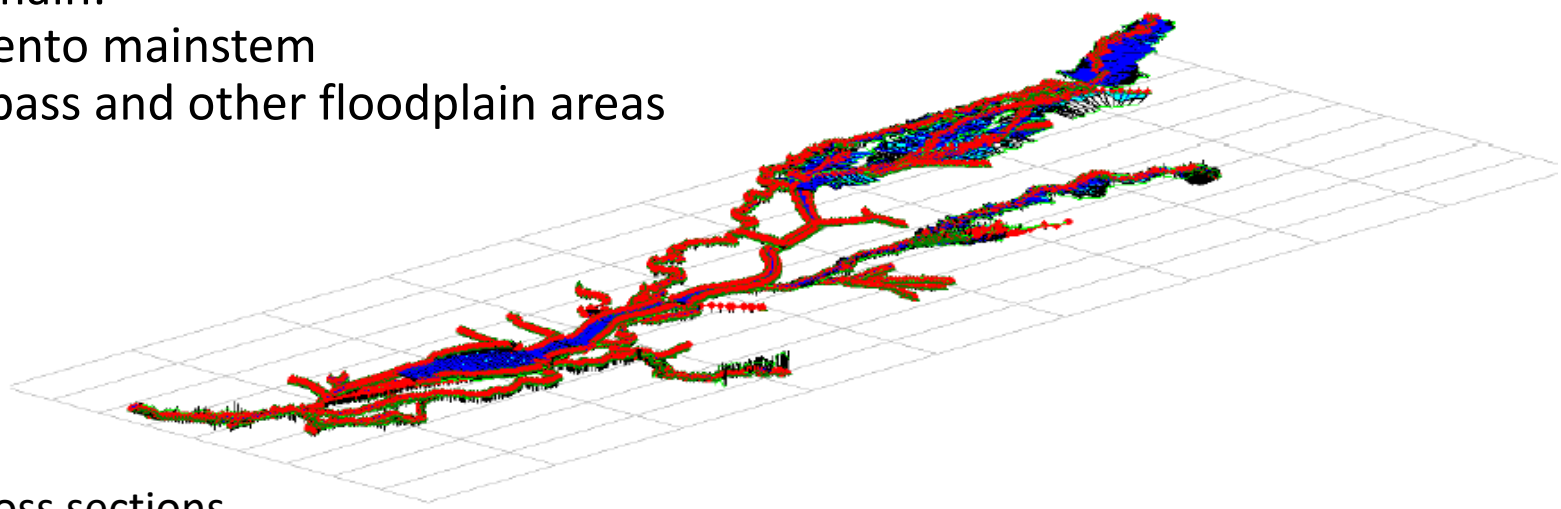


Mapping habitat: river and floodplain HEC-RAS Model

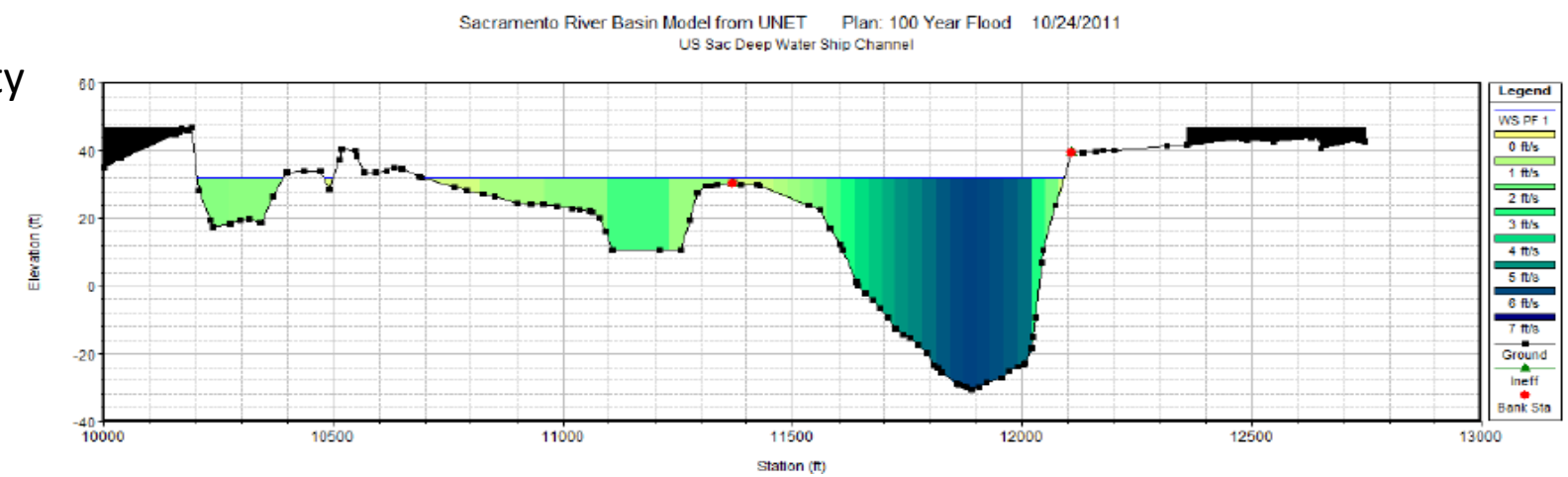
Model domain:

- Sacramento mainstem
- Yolo Bypass and other floodplain areas

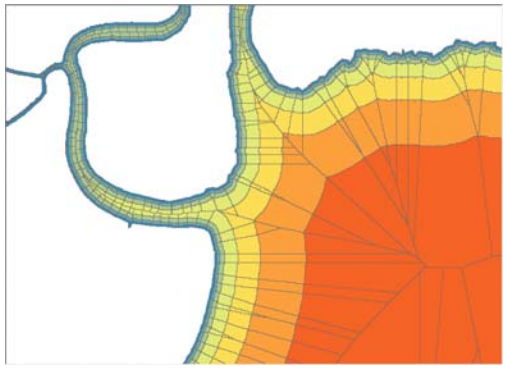


HEC-RAS cross sections

- Mainstem and overbank portions
- Depth
- Velocity



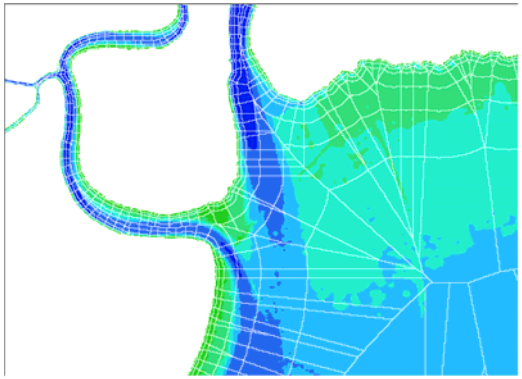
Mapping delta and bay habitats



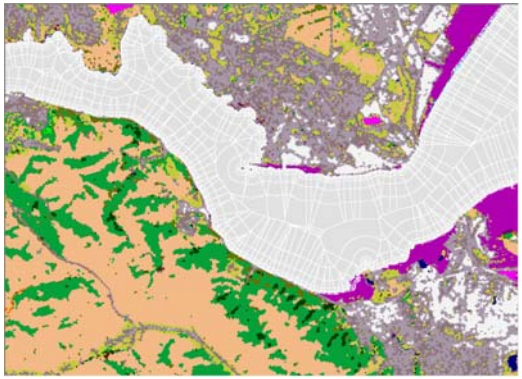
20
21 - 50
51 - 100
101 - 250
251 - 500
501 - 1000
1001 - 2500
2501 - 5000

Distance from bank (m)

Summary unit



Depth

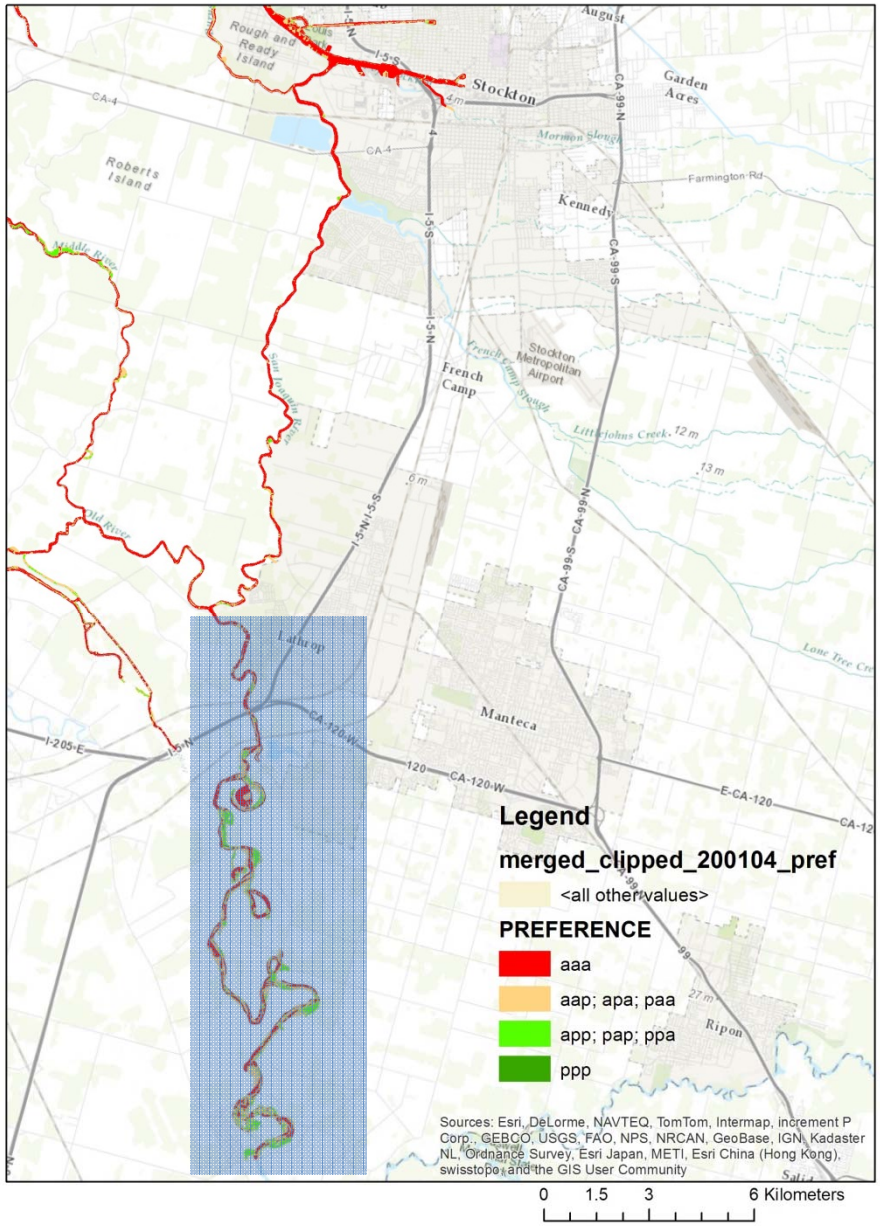


LULC

ESI or Levee

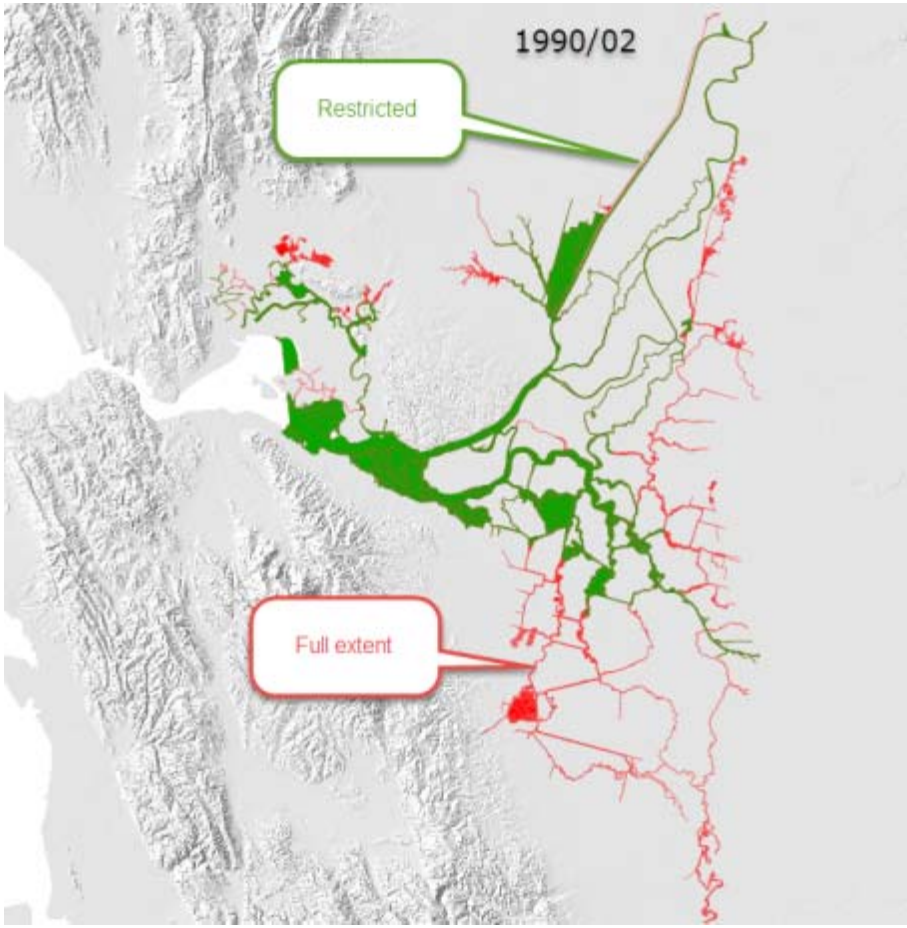
Channel Type

Mapping delta habitats



Incorporating connectivity

General concept: not all channel systems are readily accessible



Predict presence/absence at beach seine sites using Poisson regression model

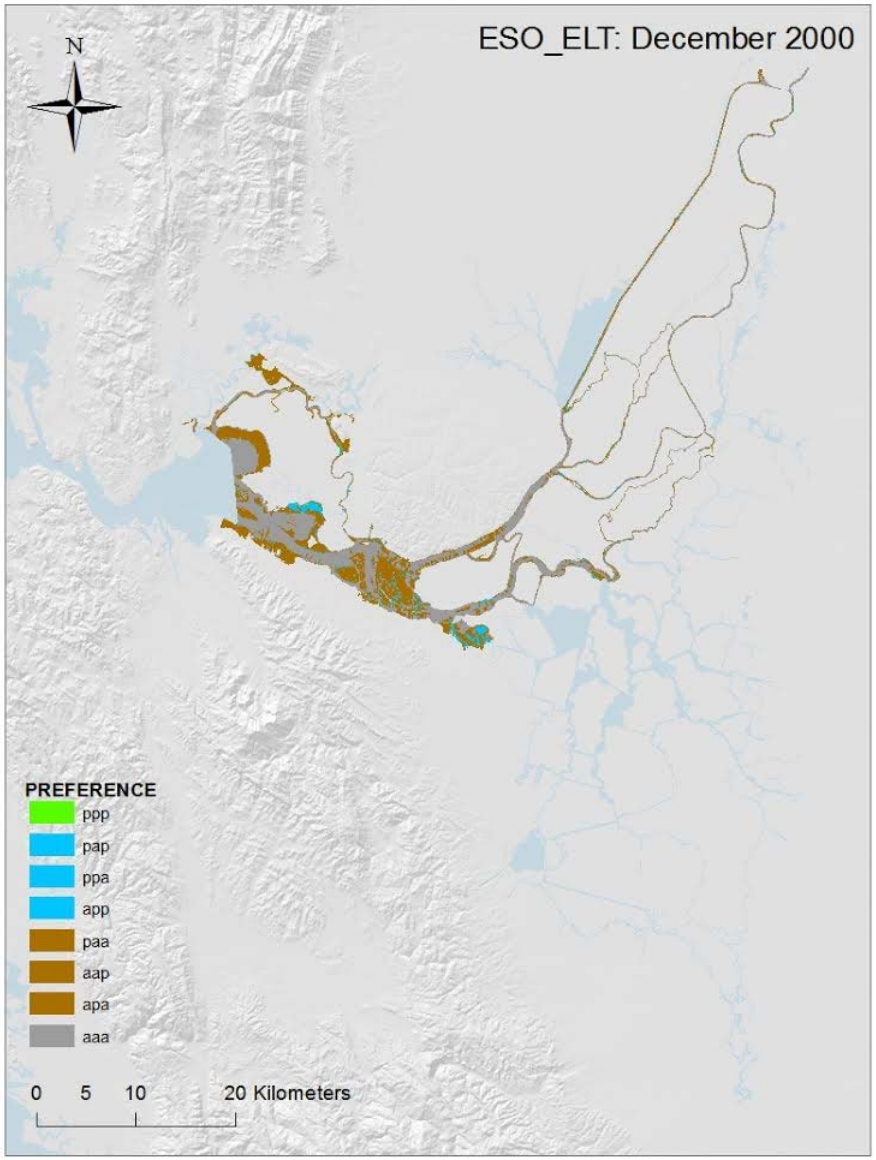
Parameters:

- Sacramento vs San Joaquin flow
- Distance from river
- Channel width
- DSM2 modeled flow
- Adults contributing to cohort

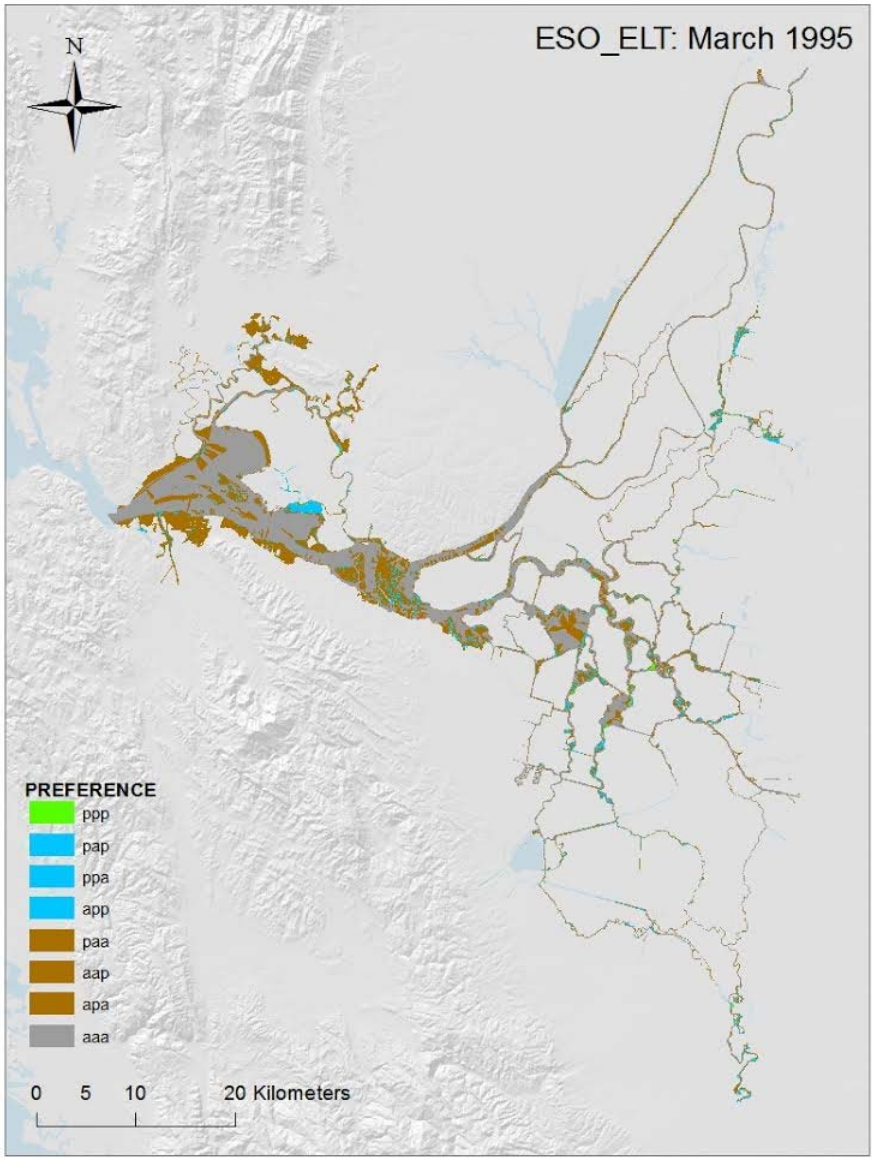
Use model parameters to predict presence across the delta

Mapping delta habitats

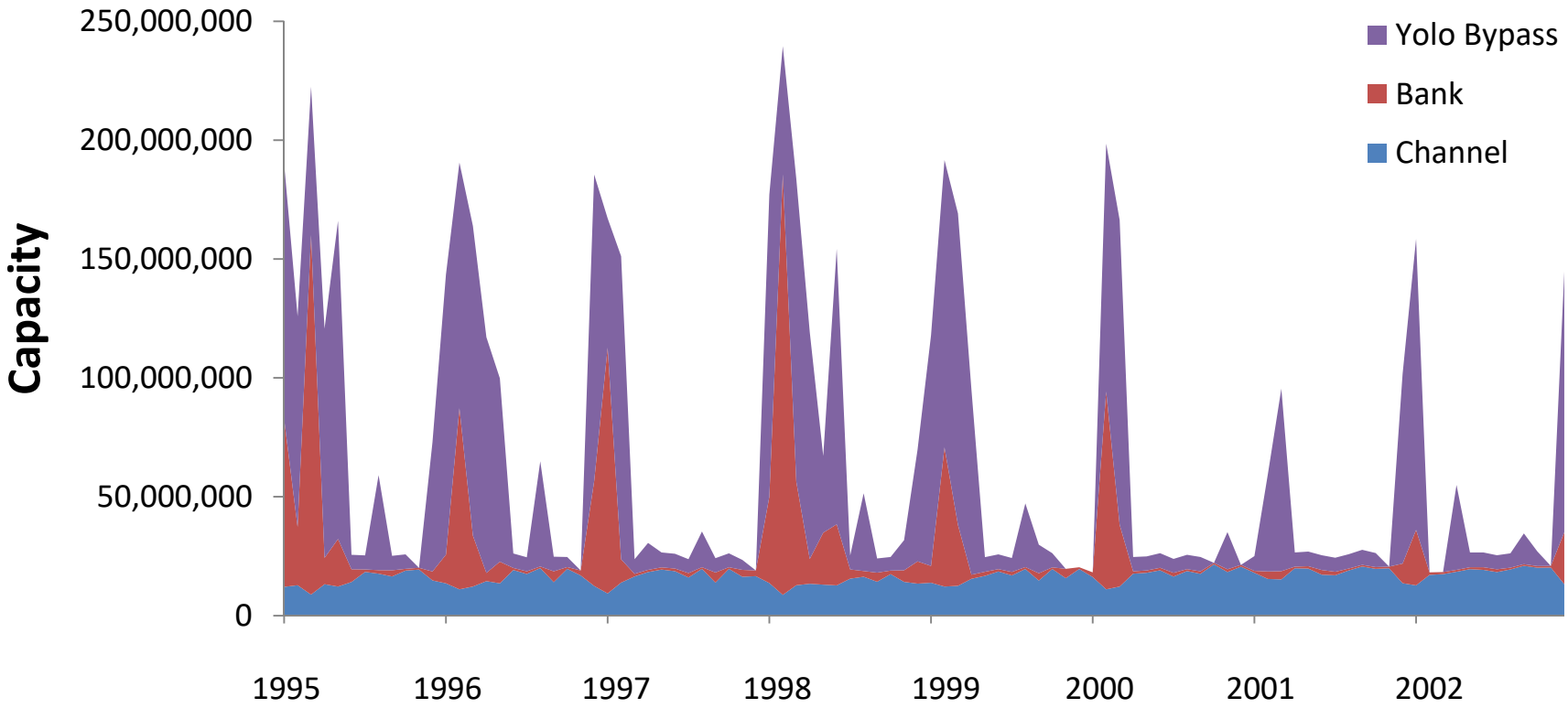
Dry year and month



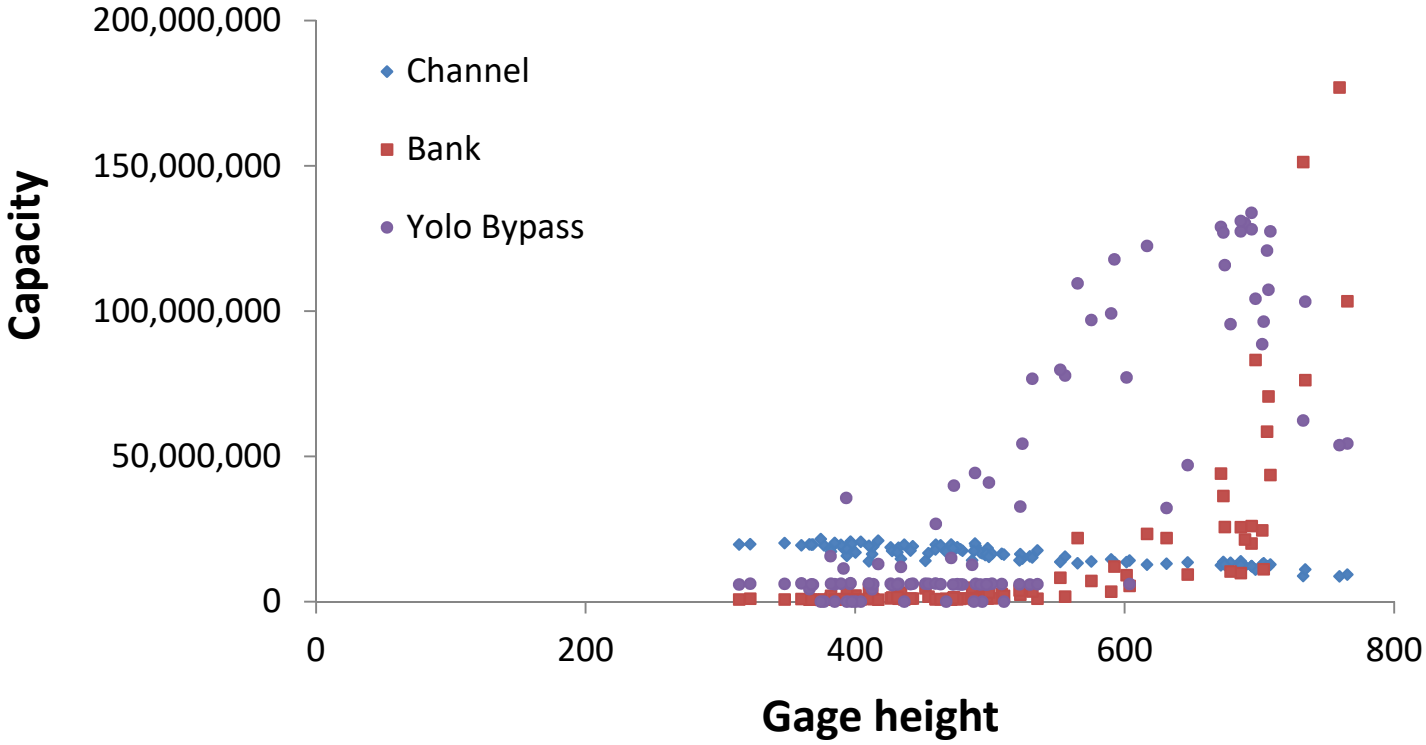
Wet year and month



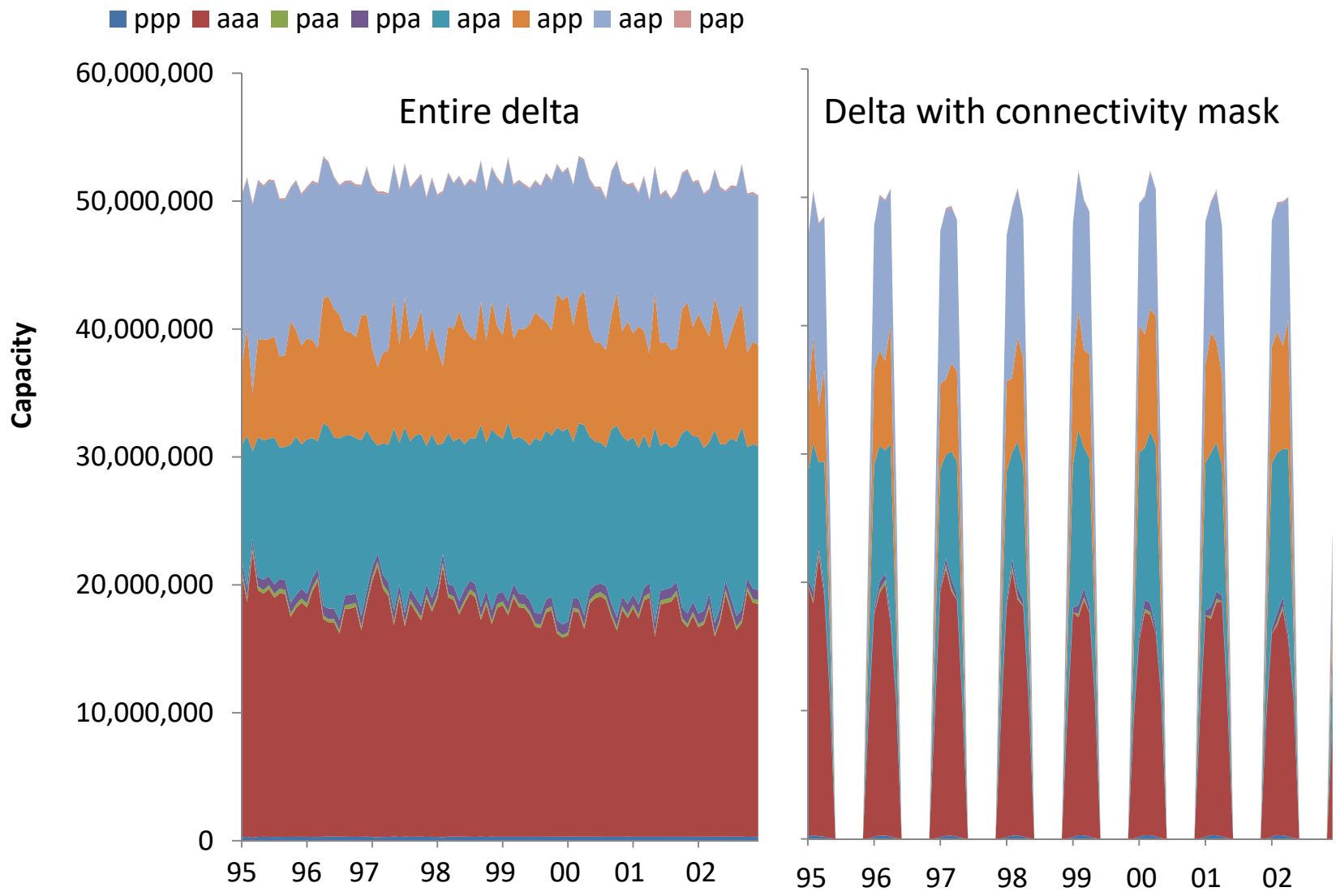
River/floodplain habitat capacity



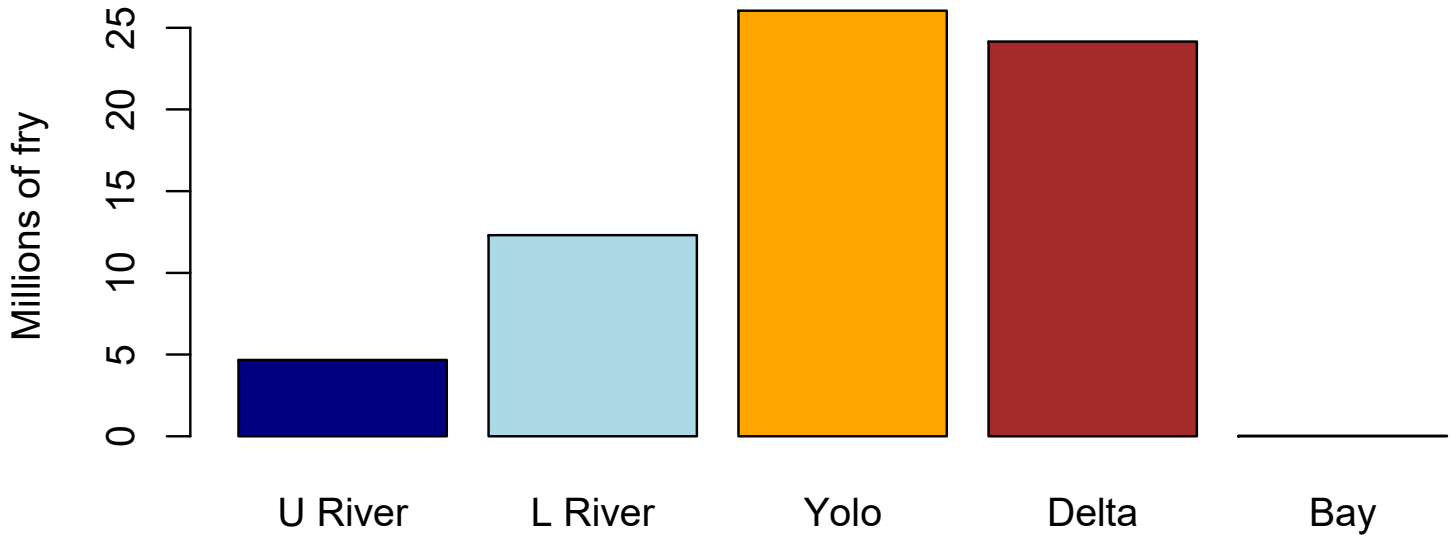
How habitat capacity varies with flow



Delta habitat capacity

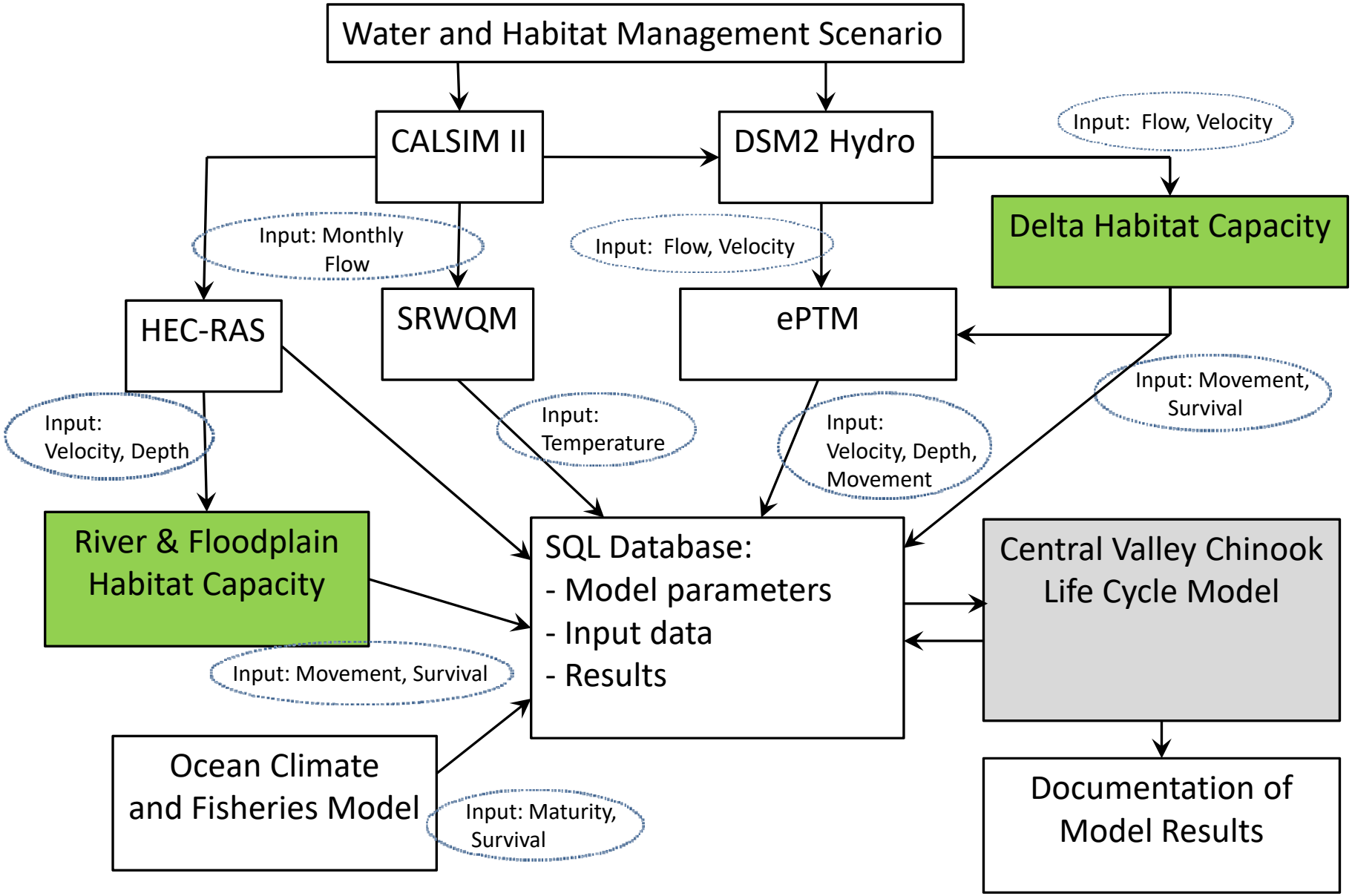


Fry capacity of each habitat

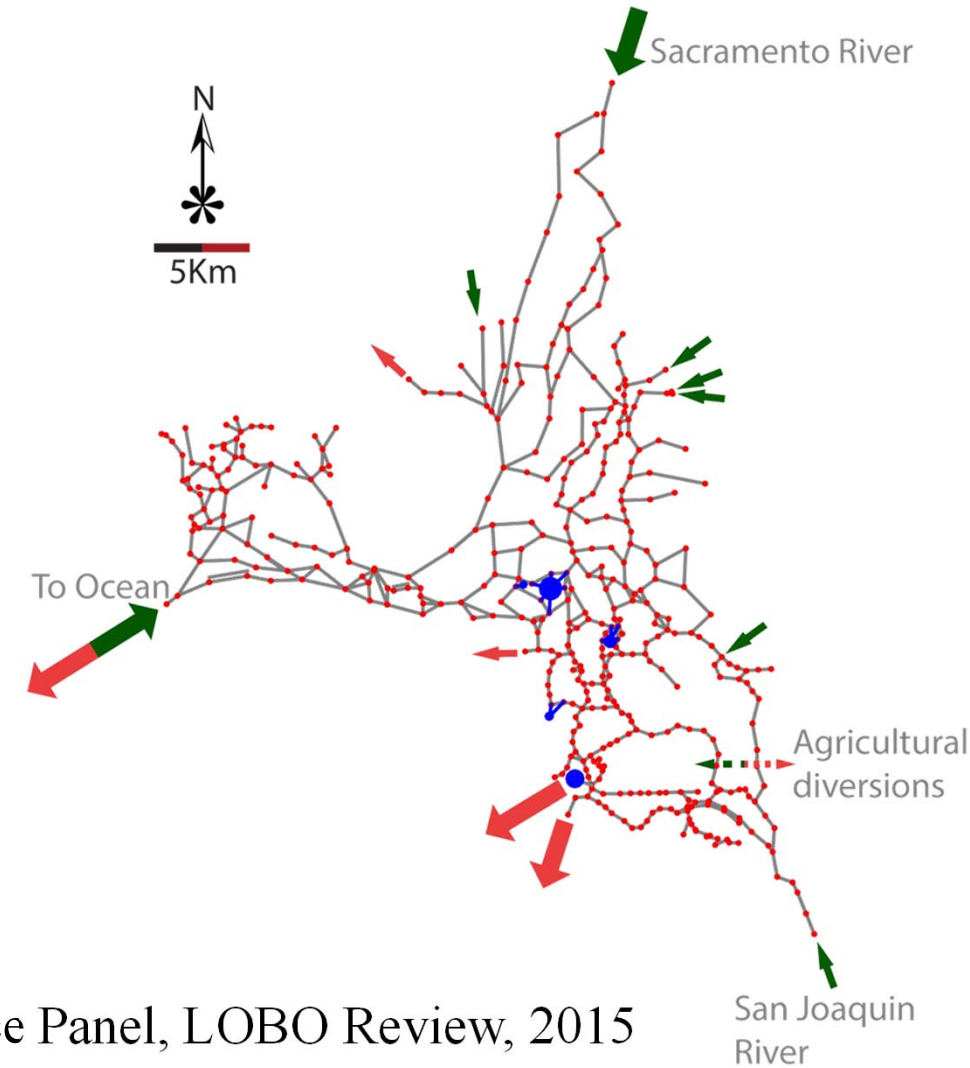


Questions?

Habitat capacity and the ePTM



Smolt survival using Enhanced Particle Tracking Model (ePTM)



Source: Delta Science Panel, LOBO Review, 2015

Habitat capacity and the ePTM

In each month:

Find accessible nodes using connectivity mask

Total carrying capacity of a node =
Sum of carrying capacities of habitat types weighted by area of each habitat type at that node

Importance of each node =
Total carrying capacity of habitat areas of that node /
Total carrying capacity of habitat areas in the whole Delta

Scaled up number of fish released per node =
Number of fish released per node x importance of each node

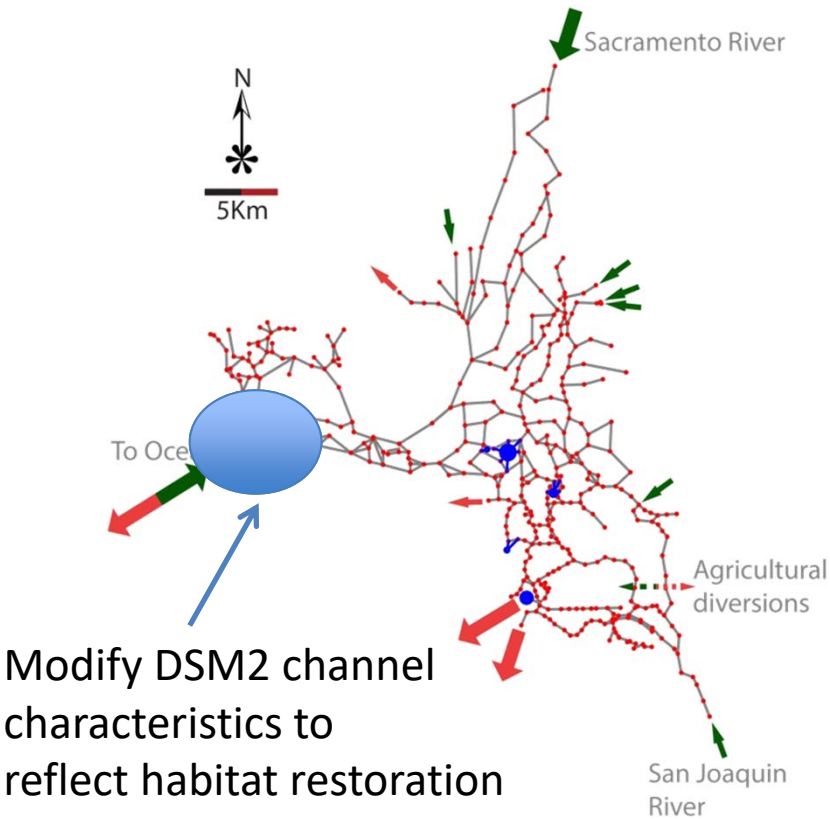
Through-Delta survival =
Average survival of fish released from each node weighted by scaled up number of fish released per node

Habitat capacity and the ePTM

- How is habitat incorporated?
  - It influences the initial distribution of fry
- What aspects of habitat are not incorporated?
  - Mortality from delta entry to starting point in delta
  - Extended rearing in higher quality habitats
  - Differential survival of smolts that have started in higher quality habitat

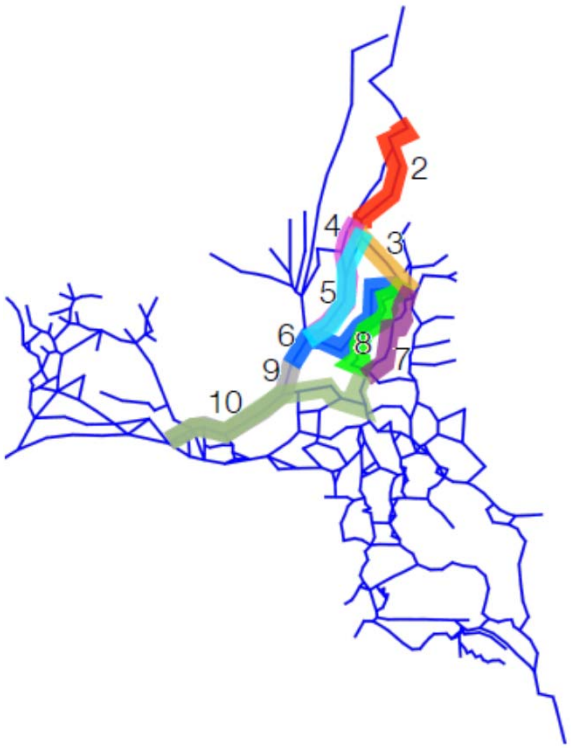
Tidal Restoration Analysis
Coupled ePTM and LCM modeling

- Evaluate a restoration scenario to reduce tidal amplitude in the delta
- Modify channel characteristics to reflect restoration
- Run ePTM
- Run LCM



Predator management
Coupled ePTM and LCM modeling

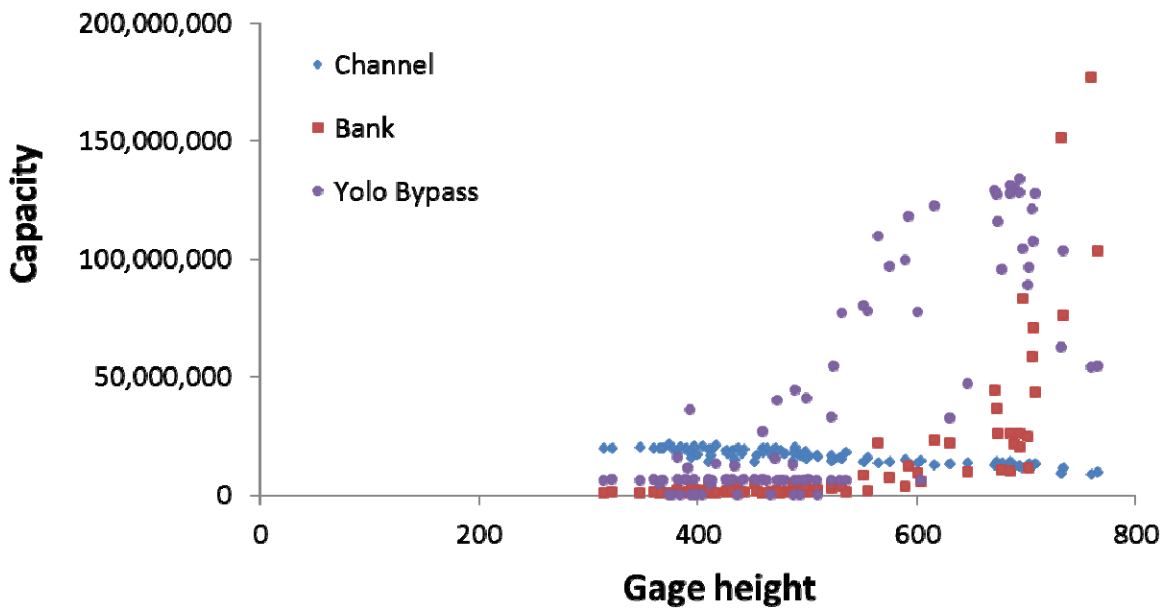
- Evaluate a scenario to reduce predation rate
- Modify reach-specific predatory density in ePTM
- Run ePTM
- Run LCM



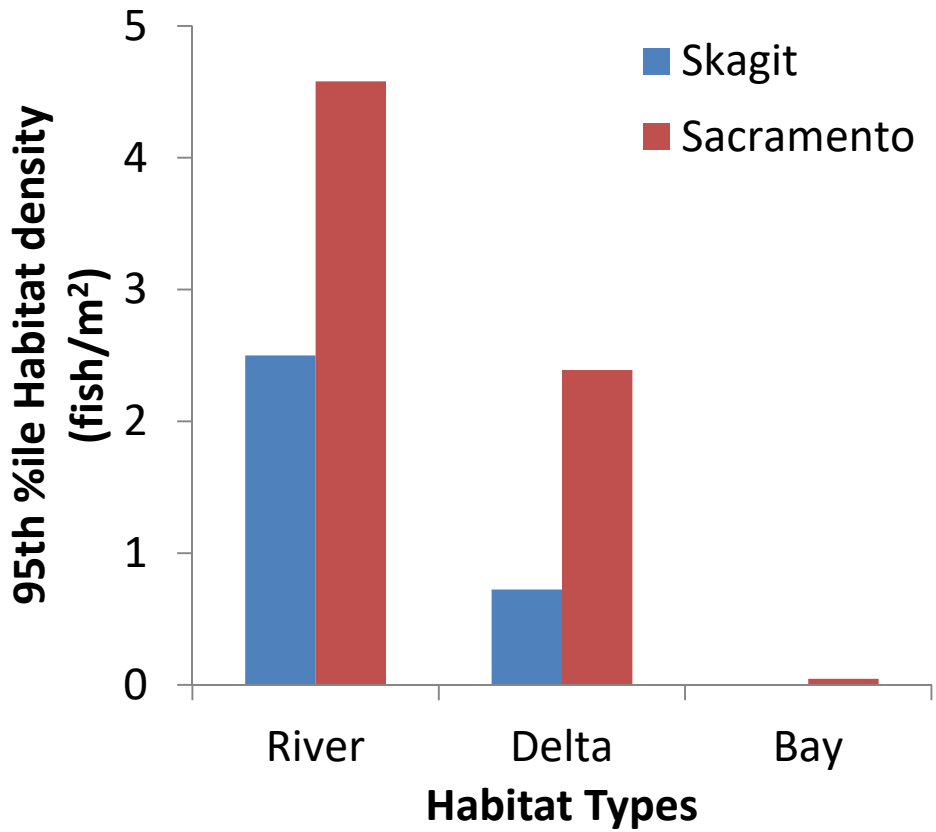
Altering the reach-specific survival probability to reflect changes In predator densities

General conclusions

- Across all rearing environments, total habitat capacity for fry is plentiful
  - Most limited in San Francisco Bay
- The vast amount of habitat capacity comes from lower quality habitats
- Habitat capacity is expected to change dynamically as a function of river flow in all rearing habitats



Uncertainties



- Max. densities – Skagit data provide a conservative estimate
- Other variables may influence capacity
  - Other abiotic aspects (e.g., temp)
  - Biotic aspects (e.g., SAV)
- Does habitat quality correspond with differential mortality as well as density?

Important research directions

- Improve knowledge of habitat use by fry in the delta
  - What habitats are being used by fry?
  - What structural and dynamic habitat features best predict presence, abundance, and extended use by fry?
- Ground-truth maps of habitat types
  - Test GIS accuracy
  - Test whether fish habitat use matches assumptions
- Incorporate variable survival by habitat types
  - Coupling restoration with population experiments

Questions?