The Central Valley spring-run Chinook life cycle model: a tool to manage the recovery of threatened salmon populations

Bay-Delta Science Conference
November 15-17, 2016

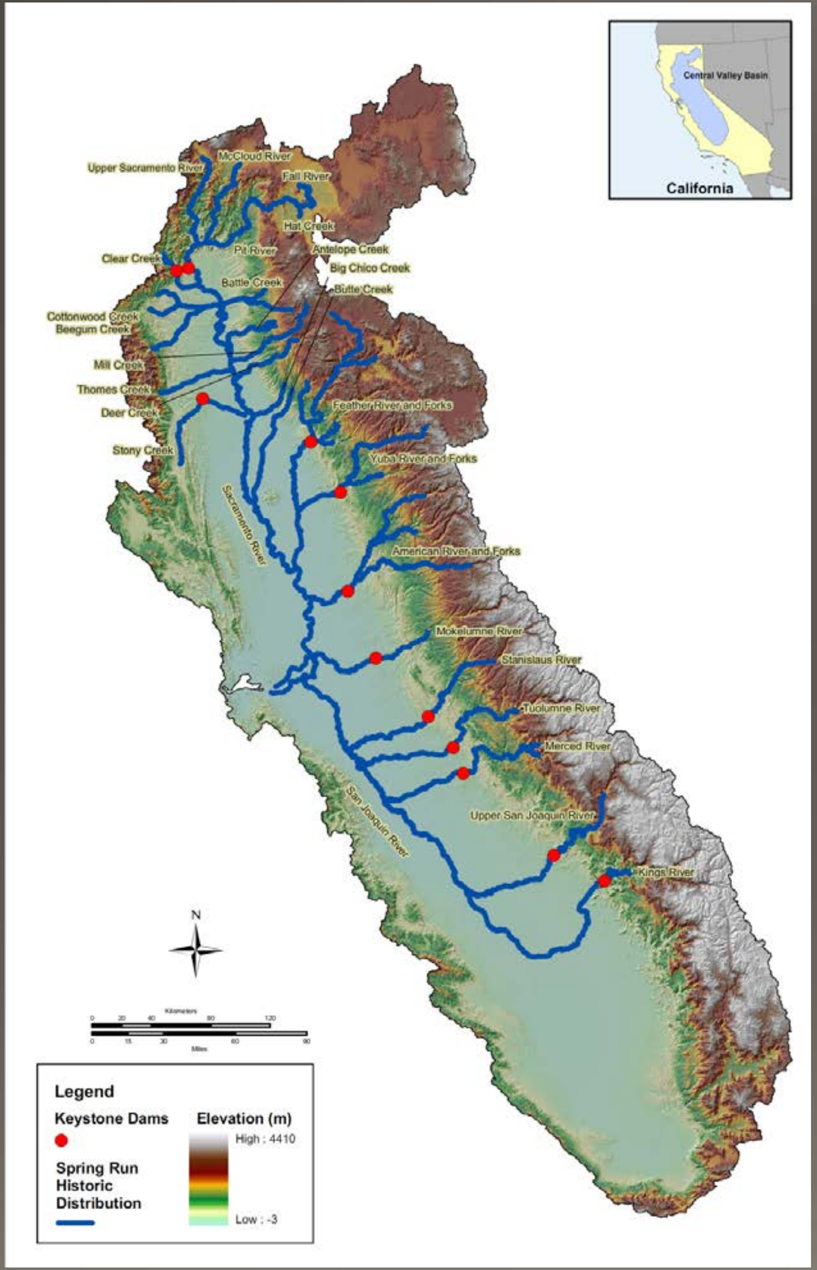
Flora Cordoleani, Noble Hendrix, Eric Danner and Steve Lindley

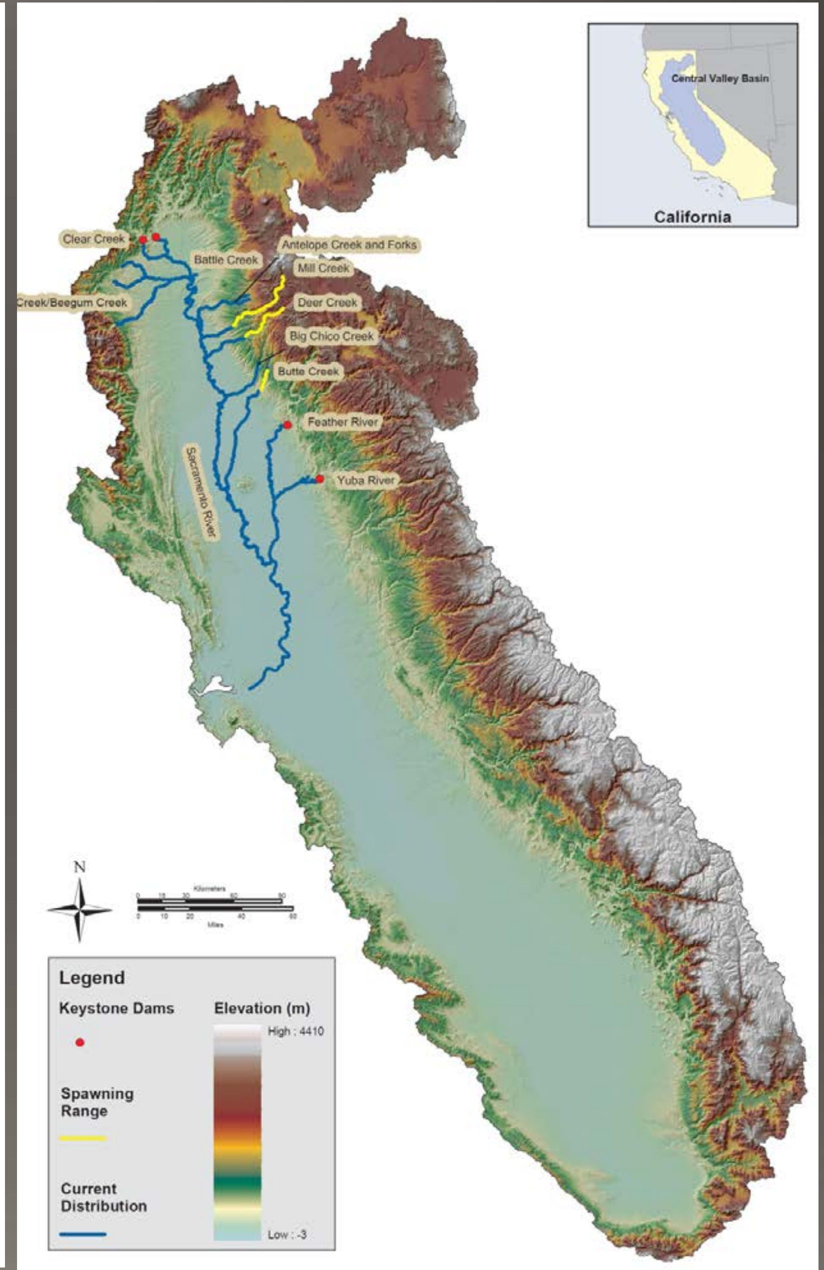
NOAA FISHERIES | Southwest Fisheries Science Center

UNIVERSITY OF CALIFORNIA SANTA CRUZ

Historic vs current distribution of spring-run Chinook

- Only 3 out of 19 historic independent populations of CV spring-run Chinook salmon are extant: Mill, Deer, and Butte creeks
- Represent only the Northern Sierra Nevada diversity group
- Listed as threatened under the federal Endangered Species Act (ESA) since 1999.





Central Valley spring-run Chinook viability status

"The status of the CV spring-run Chinook salmon ESU has probably improved on balance since the 2010 status review, through 2014 [...]."

"The recent declines of many of the dependent populations, high pre-spawn and egg mortality, and uncertain juvenile survival during the 2012 to 2015 drought, ocean conditions, as well as the level of straying of FRFH spring-run Chinook salmon to other CV spring-run Chinook salmon populations are all causes for concern for the long-term viability of the CV spring-run Chinook salmon ESU."
[Johnson and Lindley, SR viability report (2016) and NOAA-NMFS 5 year status review report (2016)]

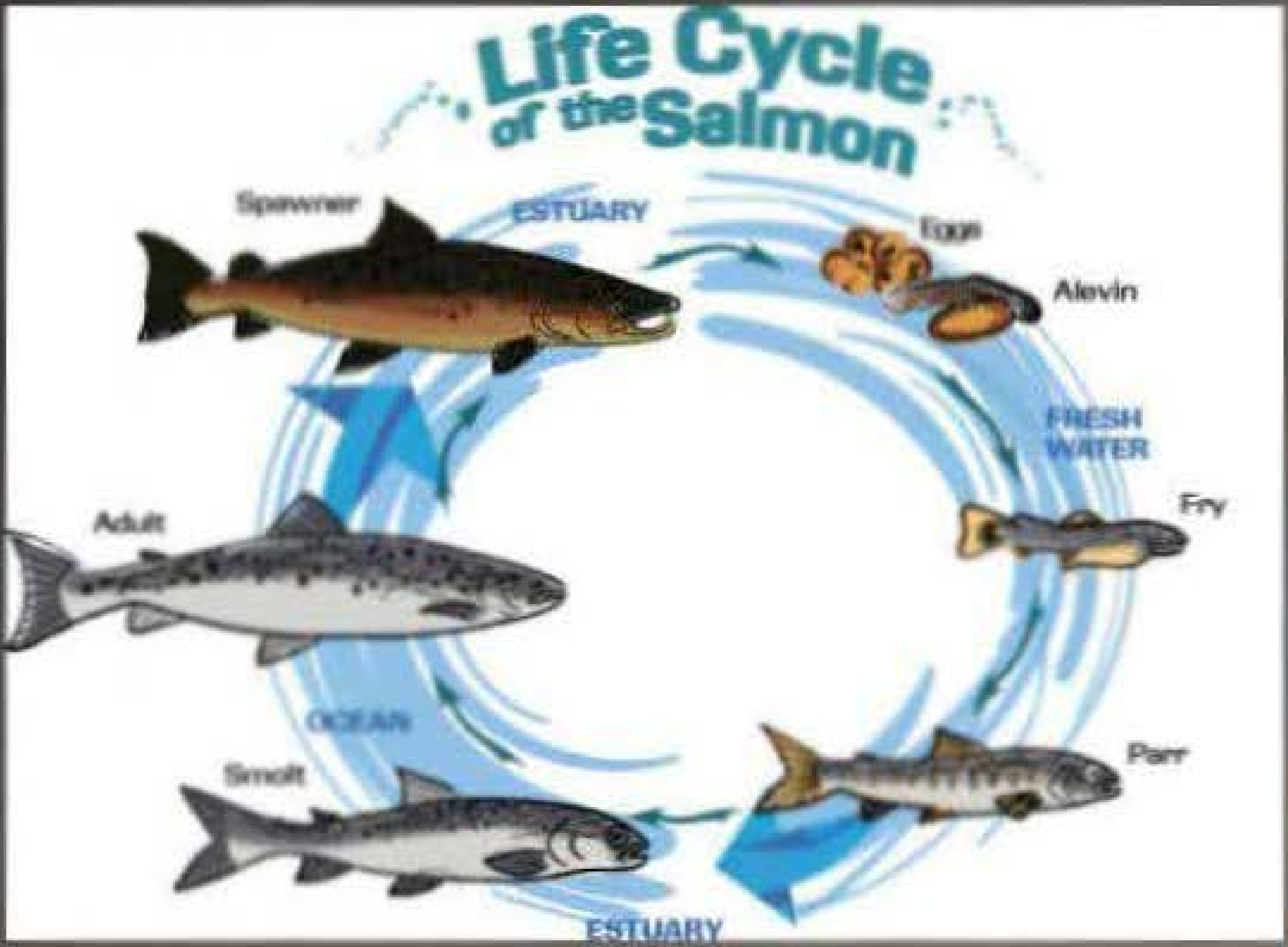
Objectives

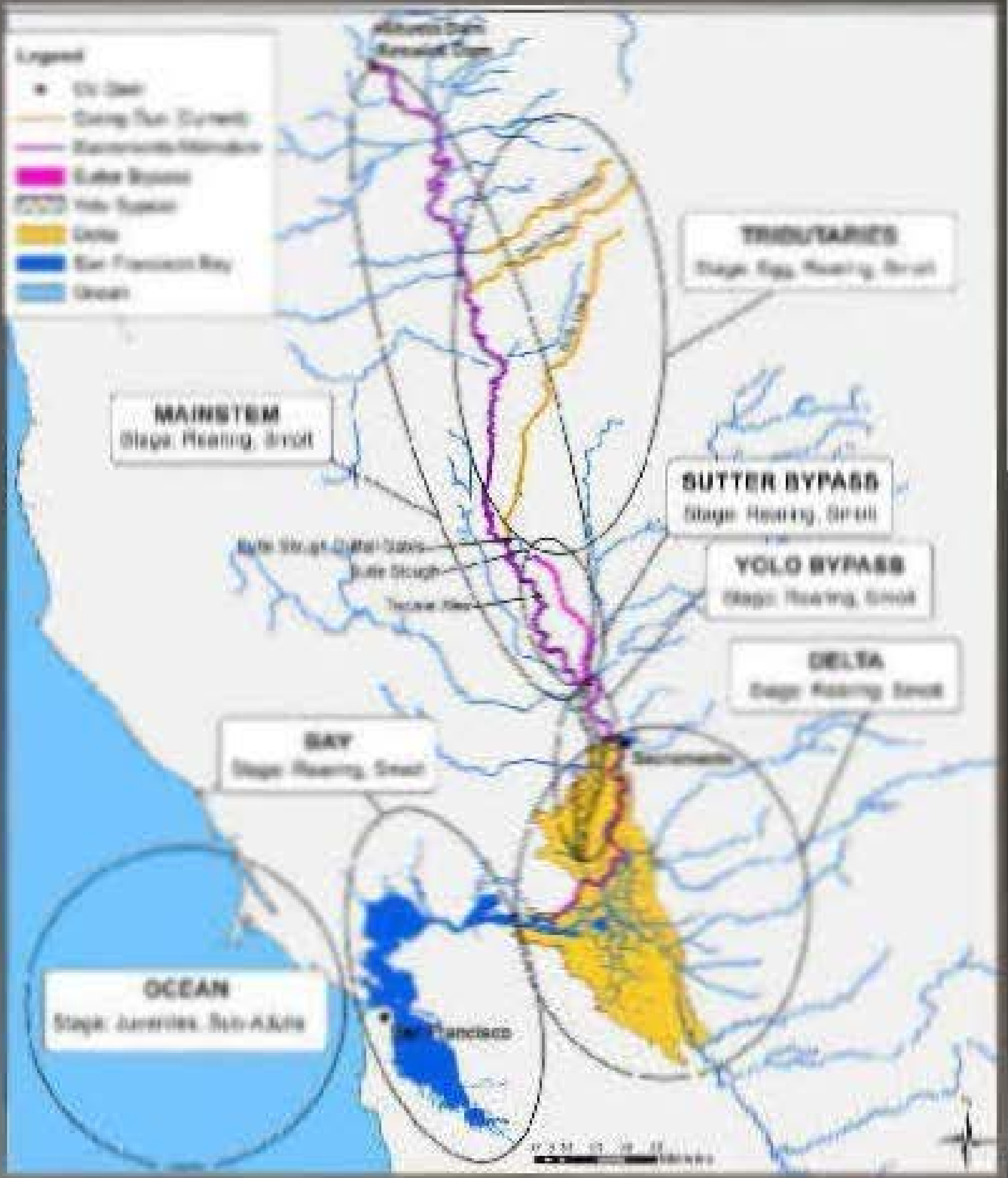
1. Understand clearly the dynamics of Central Valley spring-run Chinook salmon in the freshwater and the ocean

2. Identify the environmental factors influencing changes in abundance of spring-run Chinook salmon populations

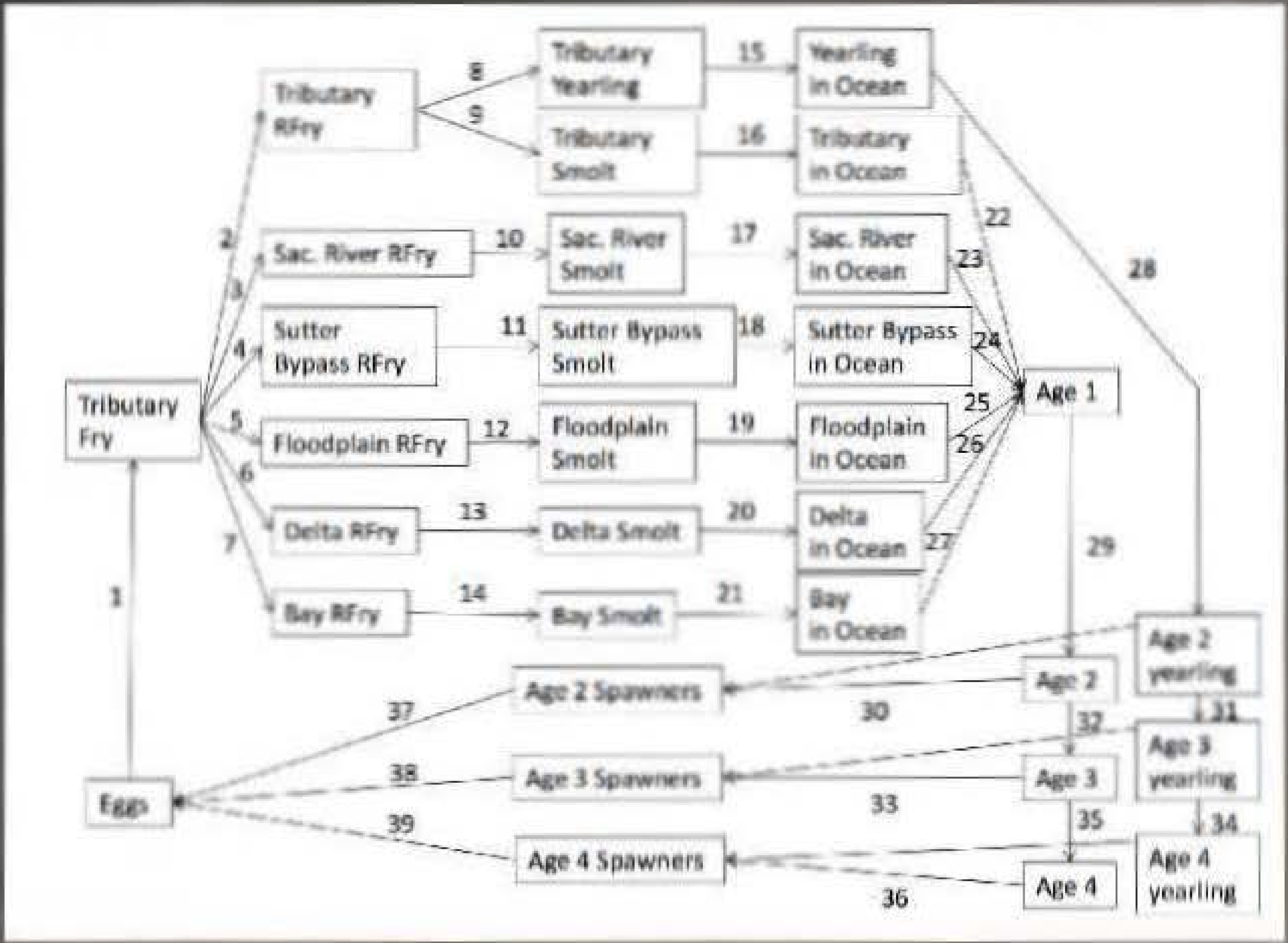
3. Predicting possible impacts of future water management and climate change scenarios on their dynamics

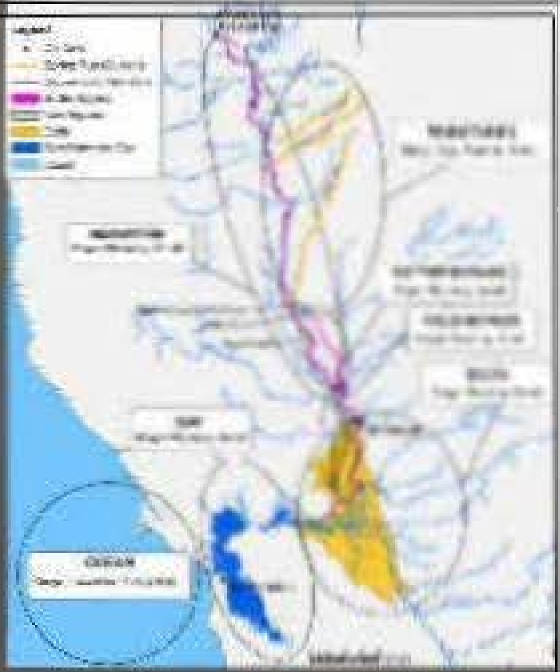
CV spring-run Chinook salmon life cycle





CV spring-run life cycle model

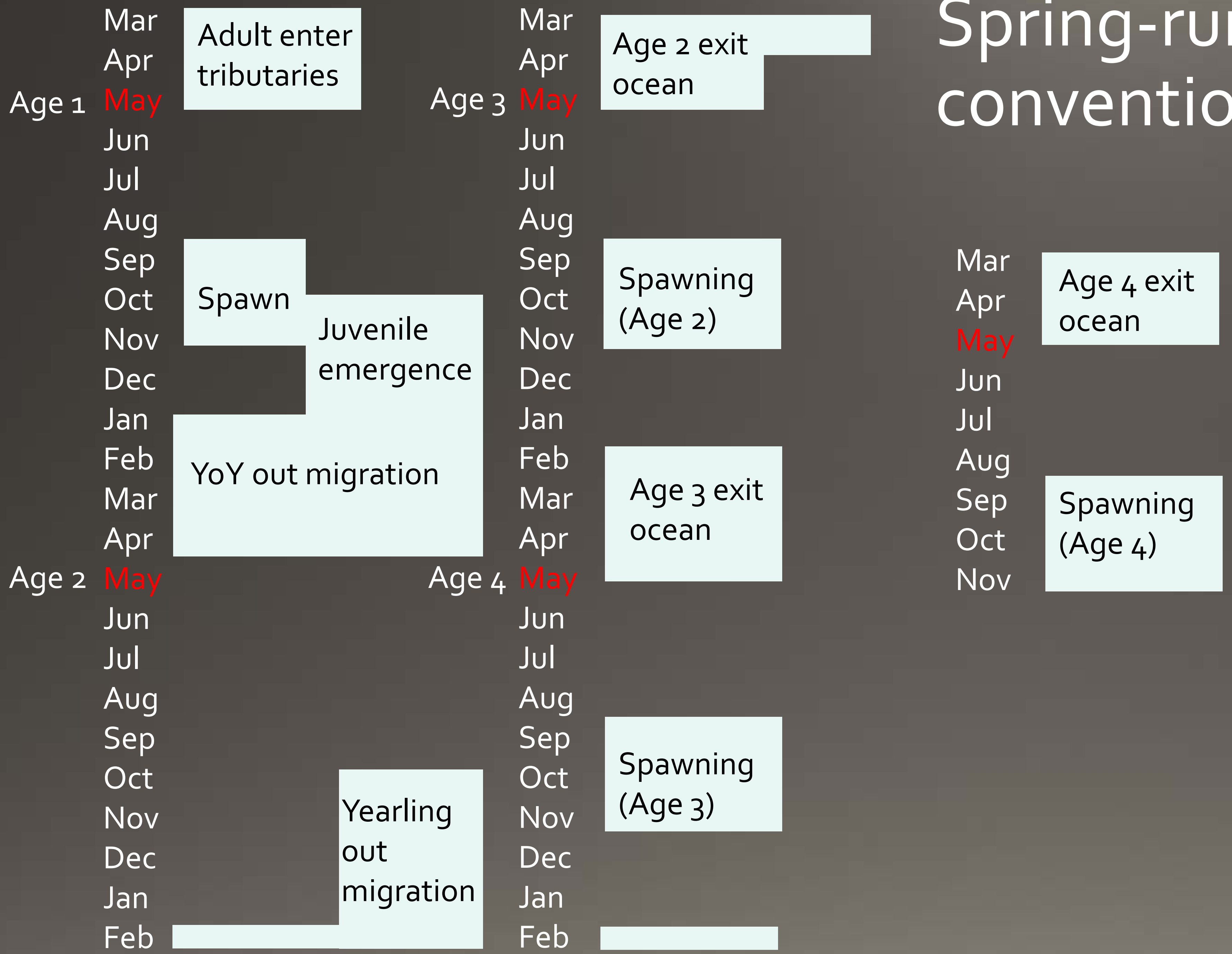




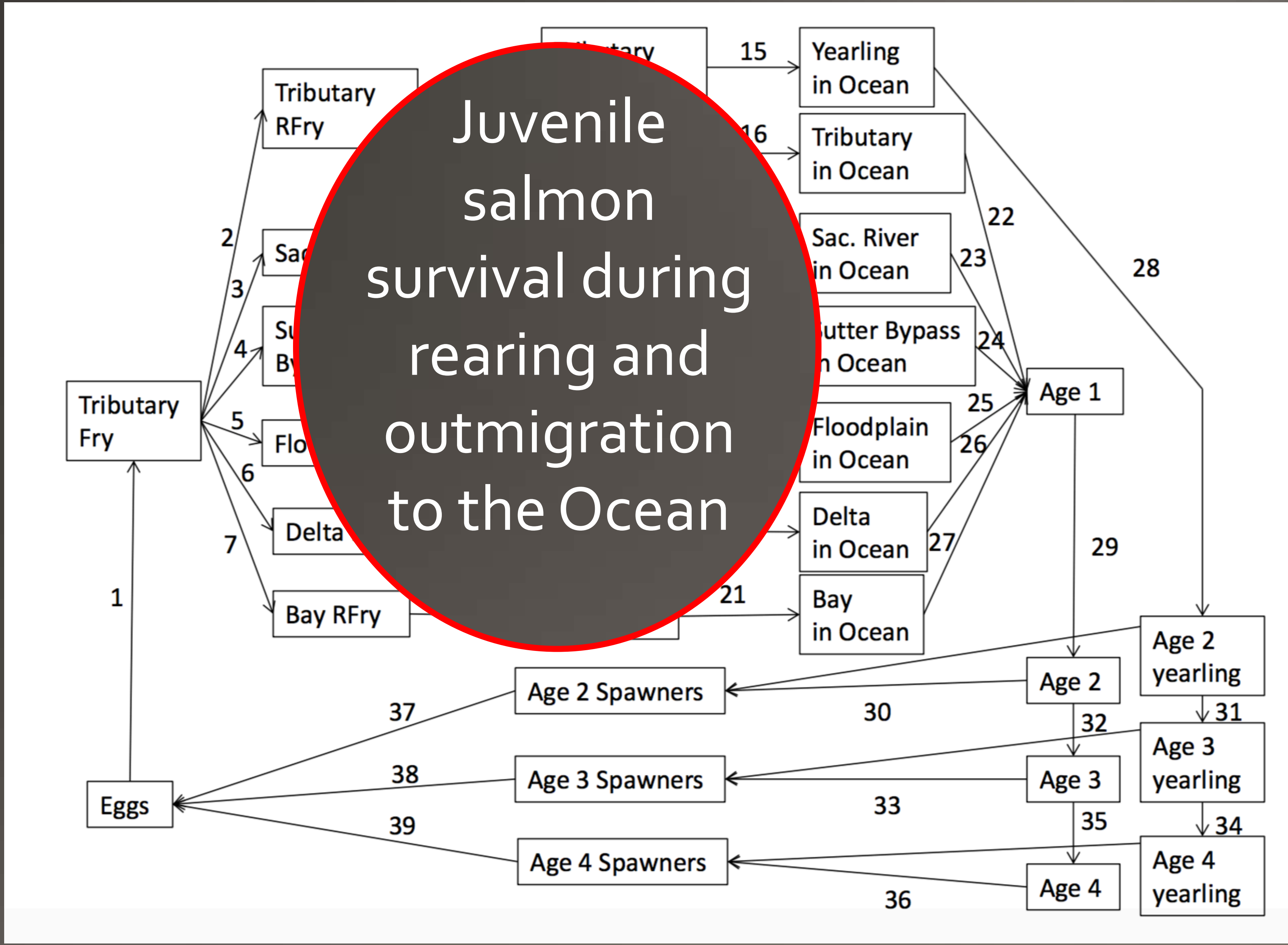
Model Structure

- 76 parameters
- Period of model simulation: 1985 – 2008
- Temporal Resolution
  - Annual for ocean stages
  - Monthly for freshwater stages
- Spatial Resolution
  - Regional depiction of rearing habitat types into Tributaries, Sutter Bypass, Sac. River, Yolo Bypass, Delta, and Bay
- Model validation by fitting simulated adult abundance to historical adult escapement abundance (Grand Tab)

Spring-run aging convention



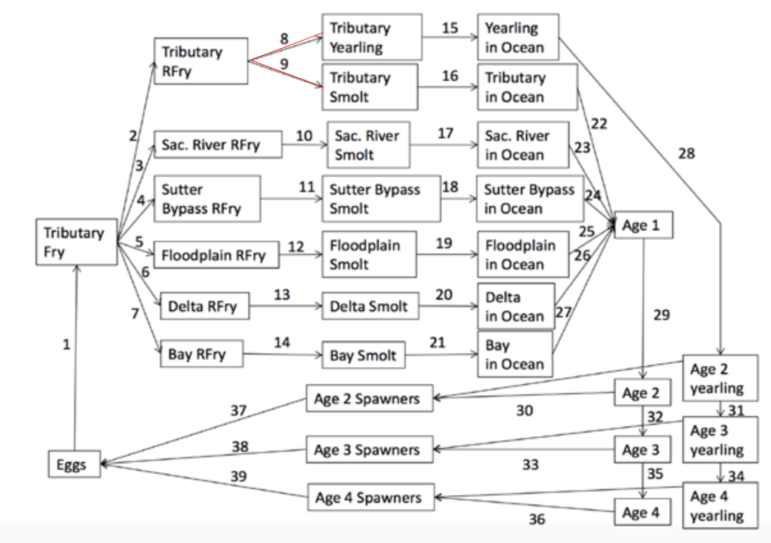
Juvenile salmon survival during rearing and outmigration to the Ocean



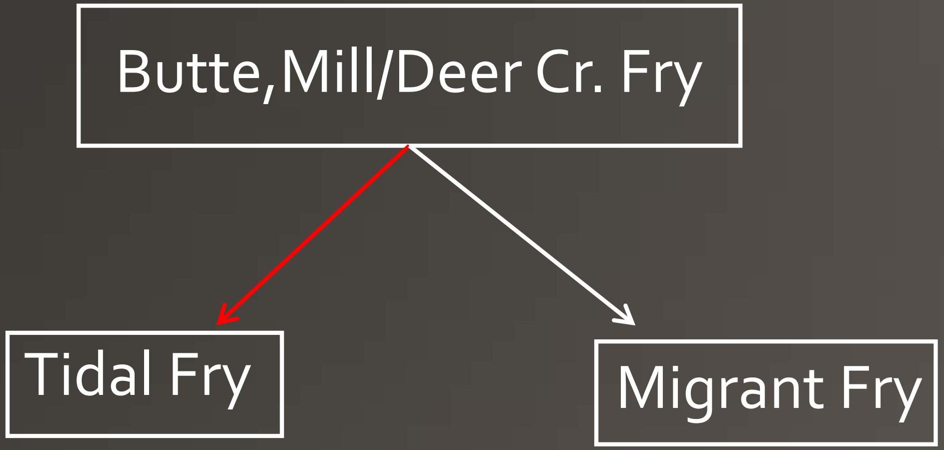
Young of the Year vs Yearling

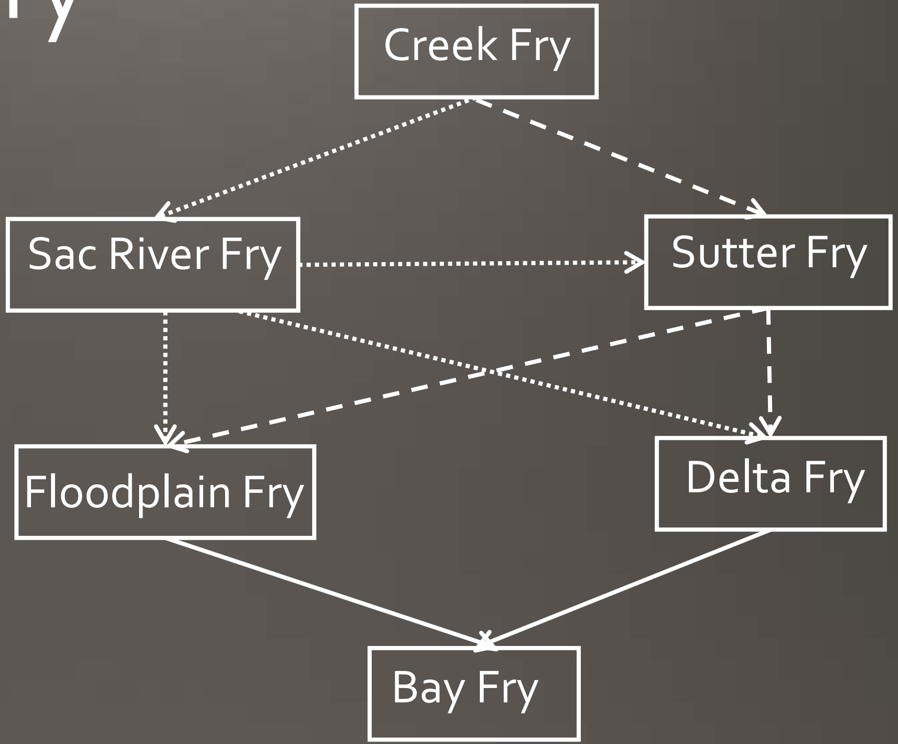
- ➢ Different juvenile rearing/migration strategy for spring-run Chinook

1. Young of the Year that rear for several months and migrate in the spring
2. Yearling that stays an entire year in the natal reaches before migrating to the Ocean



Density independent migration of fry

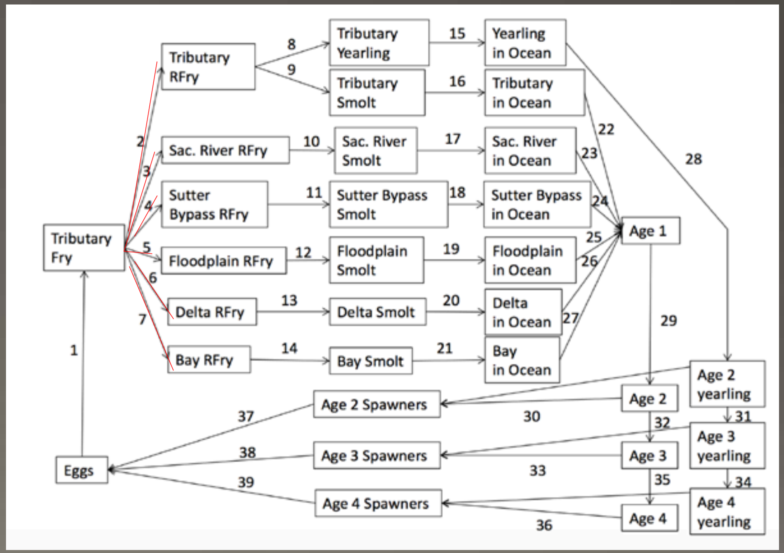




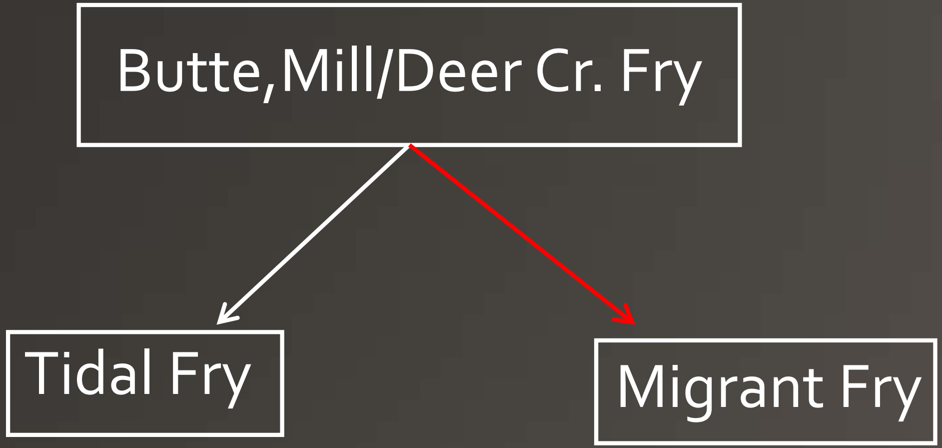
- Tidal Fry disperse instantaneously after emergence

$TidalFry = P_{TF} * Fry$

P_{TF} = Proportion of Tidal fry

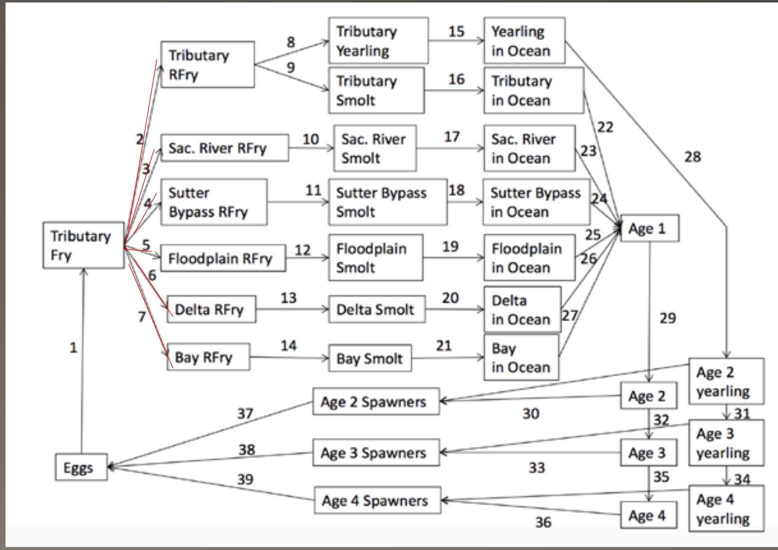


Density dependent migration of fry



$$N_{i,t+1} = \frac{S_i\,(1-m)N_{i,t}}{1+S_i\,(1-m)N_{i,t}/K_{i,t}} \quad \text{and} \quad M_{i,t} = S_i * N_{i,t} - N_{i,t+1}$$

$N_{i,t+1}$ = resident fry abundance
$M_{i,t}$ = migrant fry abundance
S_i = fry survival
m = migration rate without density dependence
$K_{i,t}$ = rearing capacity of habitat i



Rearing Capacity estimate (C. Greene, NWFSC)

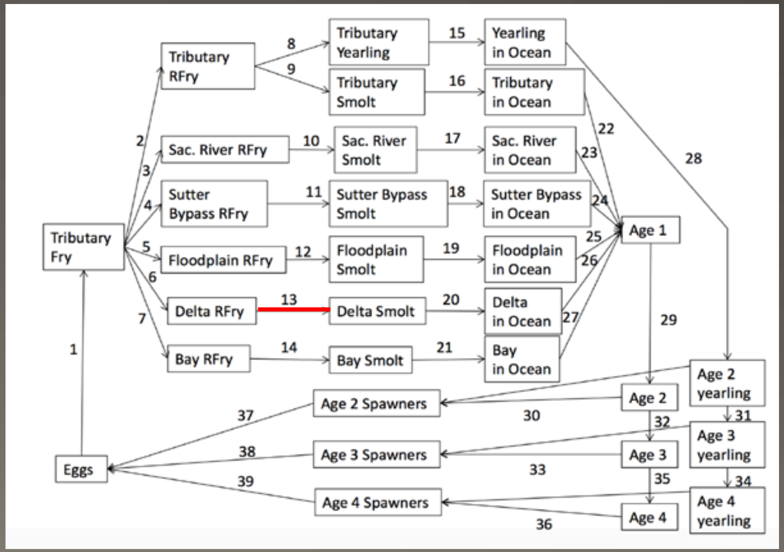
Habitat type	Variable	Habitat quality	Variable range
Mainstem	Velocity	High	<= 0.15 m/s
		Low	> 0.15 m/s
	Depth	High	> 0.2 m, <= 1 m
		Low	<= 0.2 m, > 1 m
Delta	Channel type	High	Blind channels
		Low	Mainstem, distributaries, open water
	Depth	High	> 0.2 m, <= 1.5 m
		Low	<= 0.2 m, > 1.5 m
	Cover	High	Vegetated
		Low	Not vegetated
Bay	Shoreline type	High	Beaches, marshes, vegetated banks, tidal flats
		Low	Riprap, structures, rocky shores, exposed habitats
	Depth	High	> 0.2 m, <= 1.5 m
		Low	<= 0.2 m, > 1.5 m
	Salinity	High	<= 10 ppt
		Low	> 10 ppt

Survival of rearing fry in the Delta

- Use Newman (2003) survival rate relationship:

$$logit(S_{Delta,t}) = B_{rearing} * X_{Rearing,i,t}$$

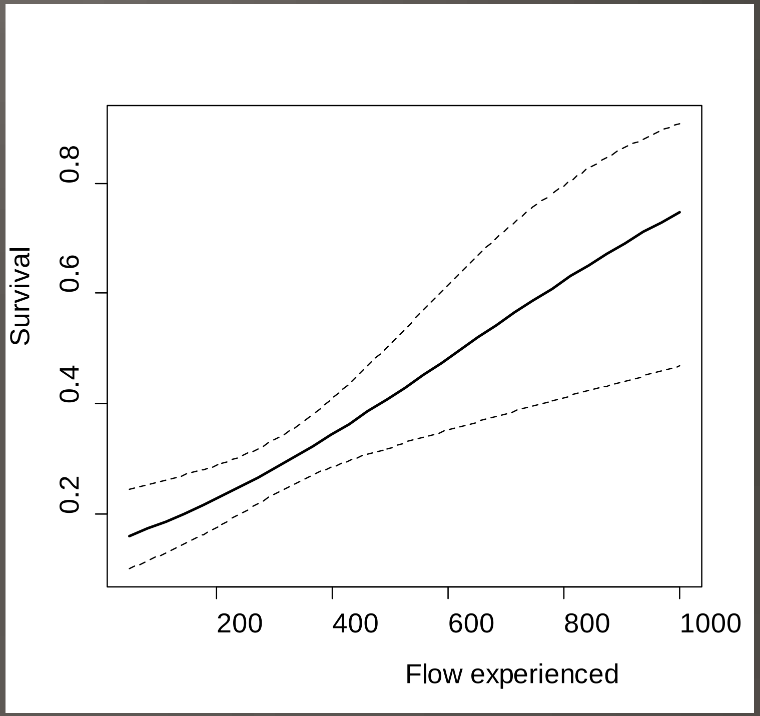
$X_{rearing}$ = Flow, Temperature, Exports, DCC



Survival of smolt migrating to the Ocean

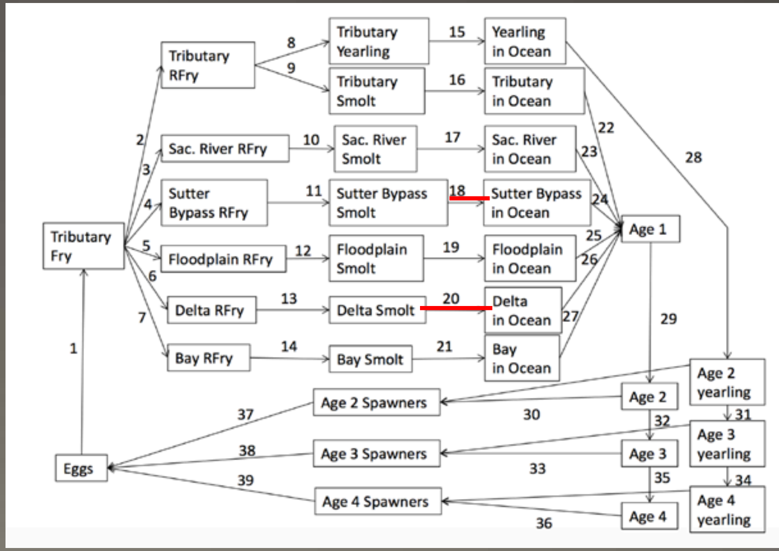
- Survival rate in the Sutter Bypass based on acoustic tagging study:

$$logit(S_t) = B_o + B_1 * Flow$$



- Survival rate through the Delta from:

1. ePTM simulations [Sridharan, V., and Byrne, B.]
2. Newman equations



Early ocean survival

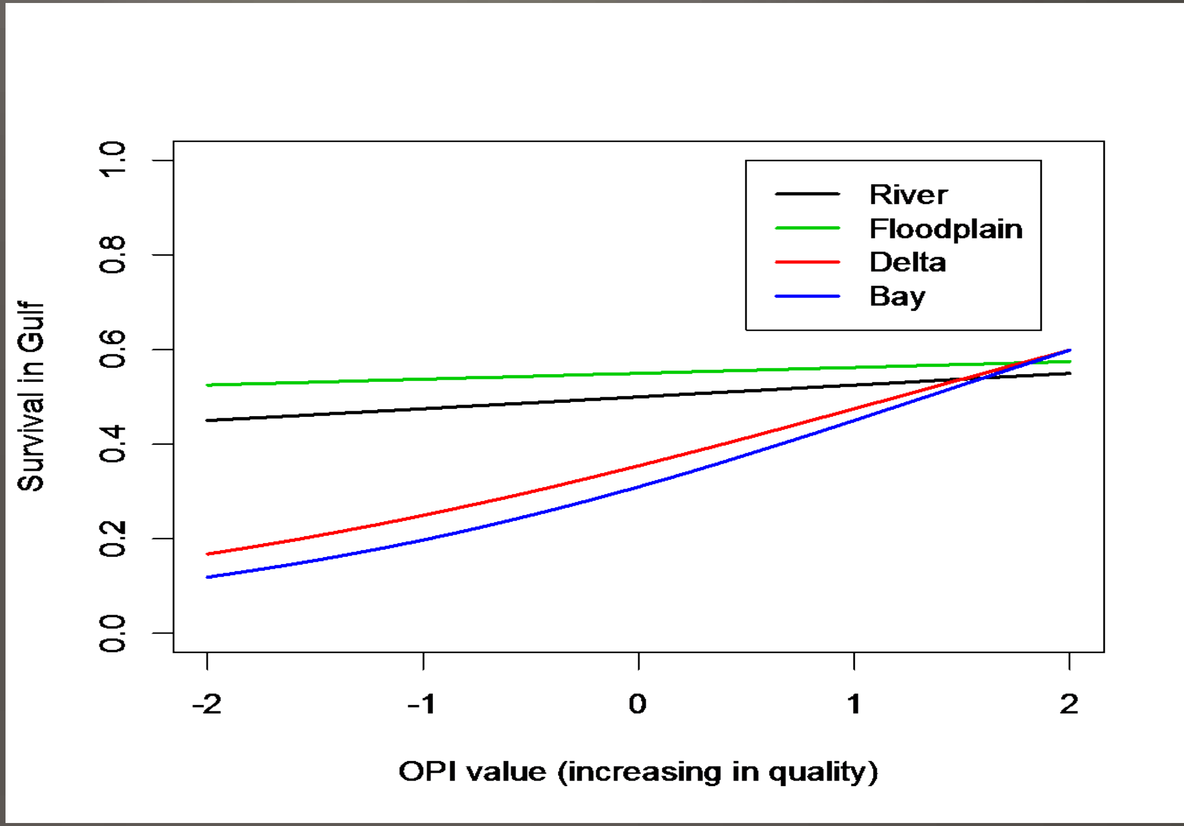
- Early ocean survival of smolts depends on ocean conditions in the Gulf of Farallones and the fish rearing origin

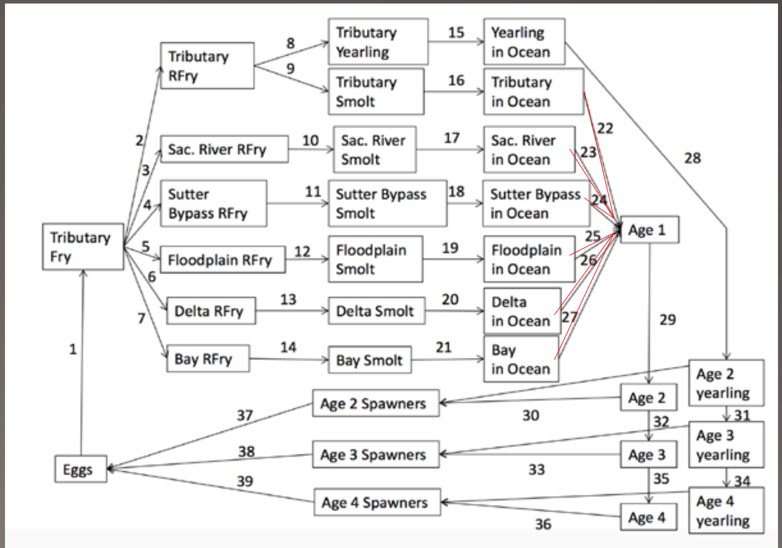
$$logit(S_i) = (B_{o,i} + B_{o\text{-}add,i}) + (B_{1,I} + B_{1\text{-}add,i}) * OPI$$

OPI = Ocean productivity index

$B_{o\text{-}add,I}$ = poor habitat intercept

$B_{1\text{-}add,I}$ = poor habitat slope





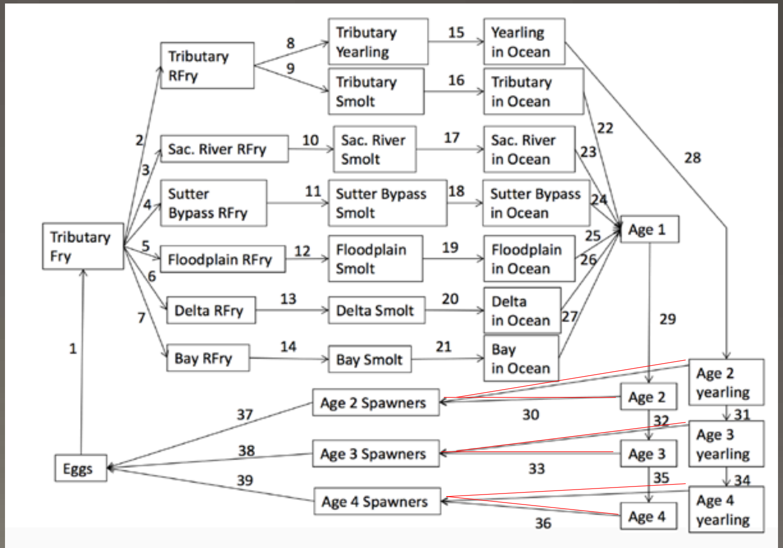
Survival of adult during holding period

- Significant adult pre-spawning mortality events in 2002 and 2003 have been reported for Butte Creek population

Summer pre-spawing survival expressed as a function of water temperature [Thompson et al. (2012)] :

$$S_{ps,t} = \frac{1}{1+e^{-b_1-b_2T}}$$

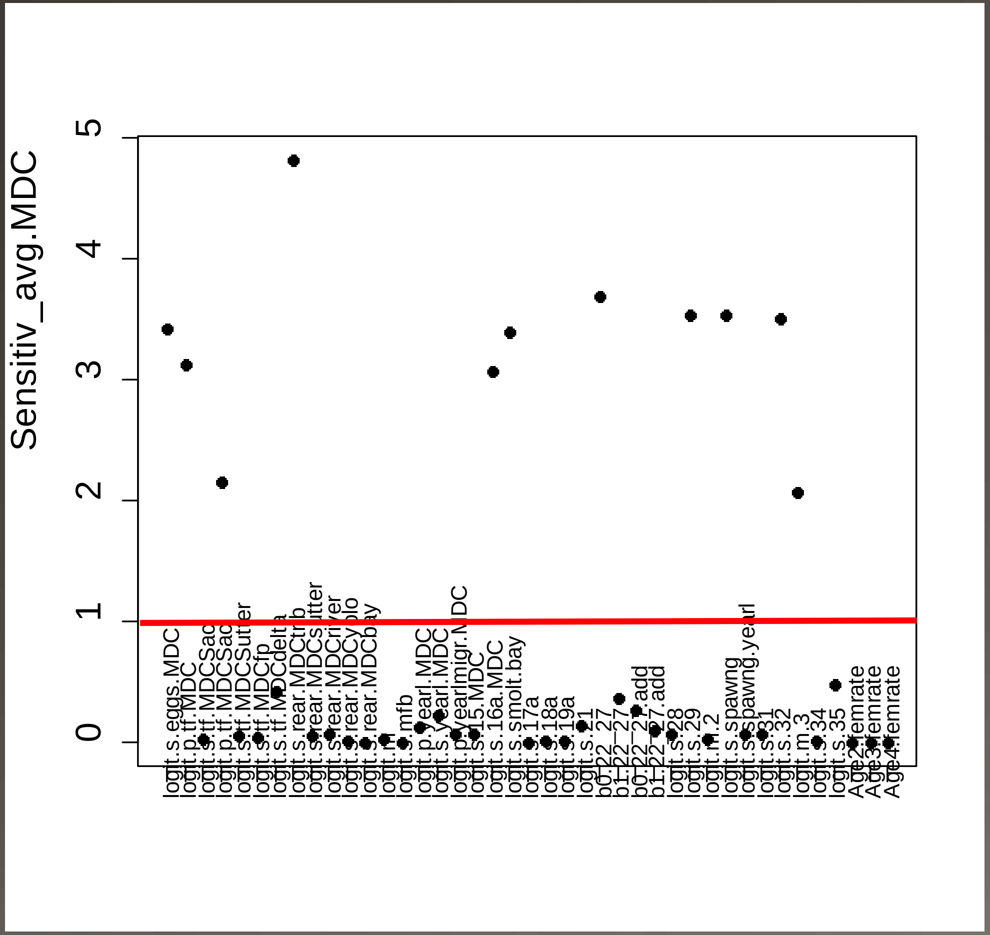
T = Temperature in holding habitat



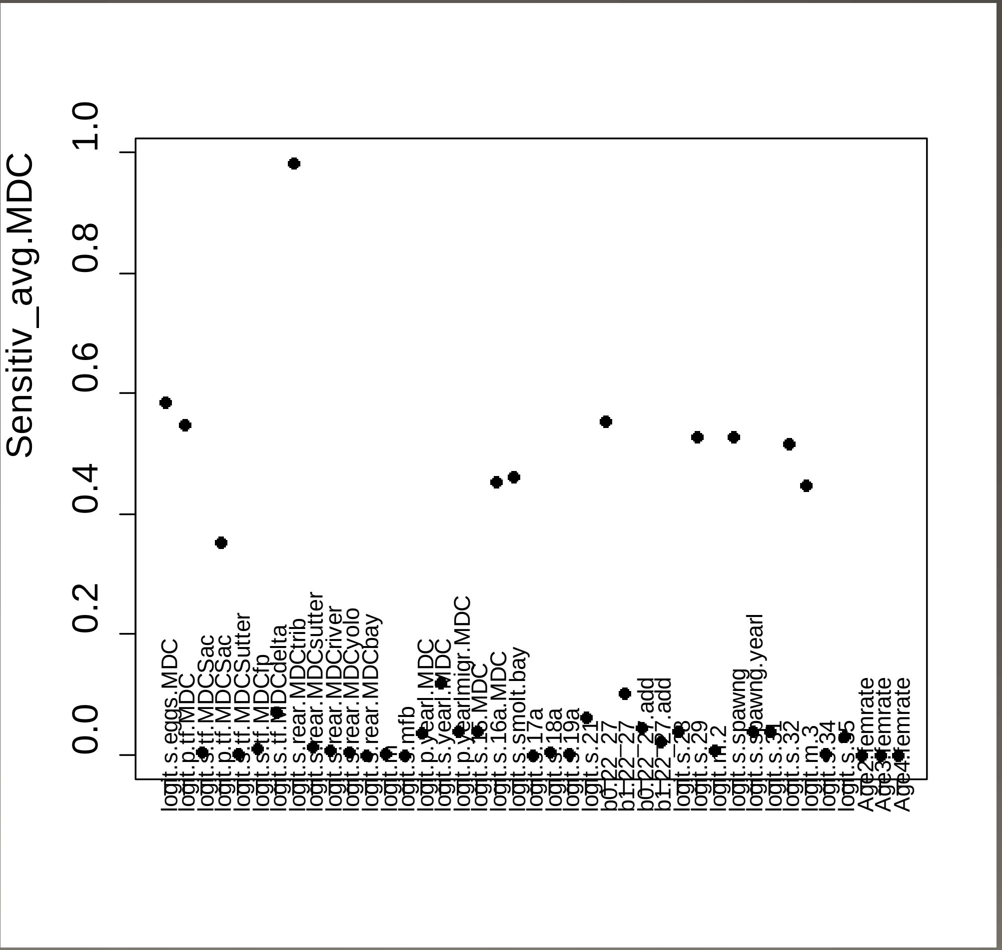
Mill/Deer Cr. Model sensitivity analysis

$$SI = \frac{dist(N\_adult\_+/-10\%, N\_adult\_fixed)/N\_adult\_fixed}{dist(Par\_+/-10\%, Par\_fixed)/Par\_fixed}$$

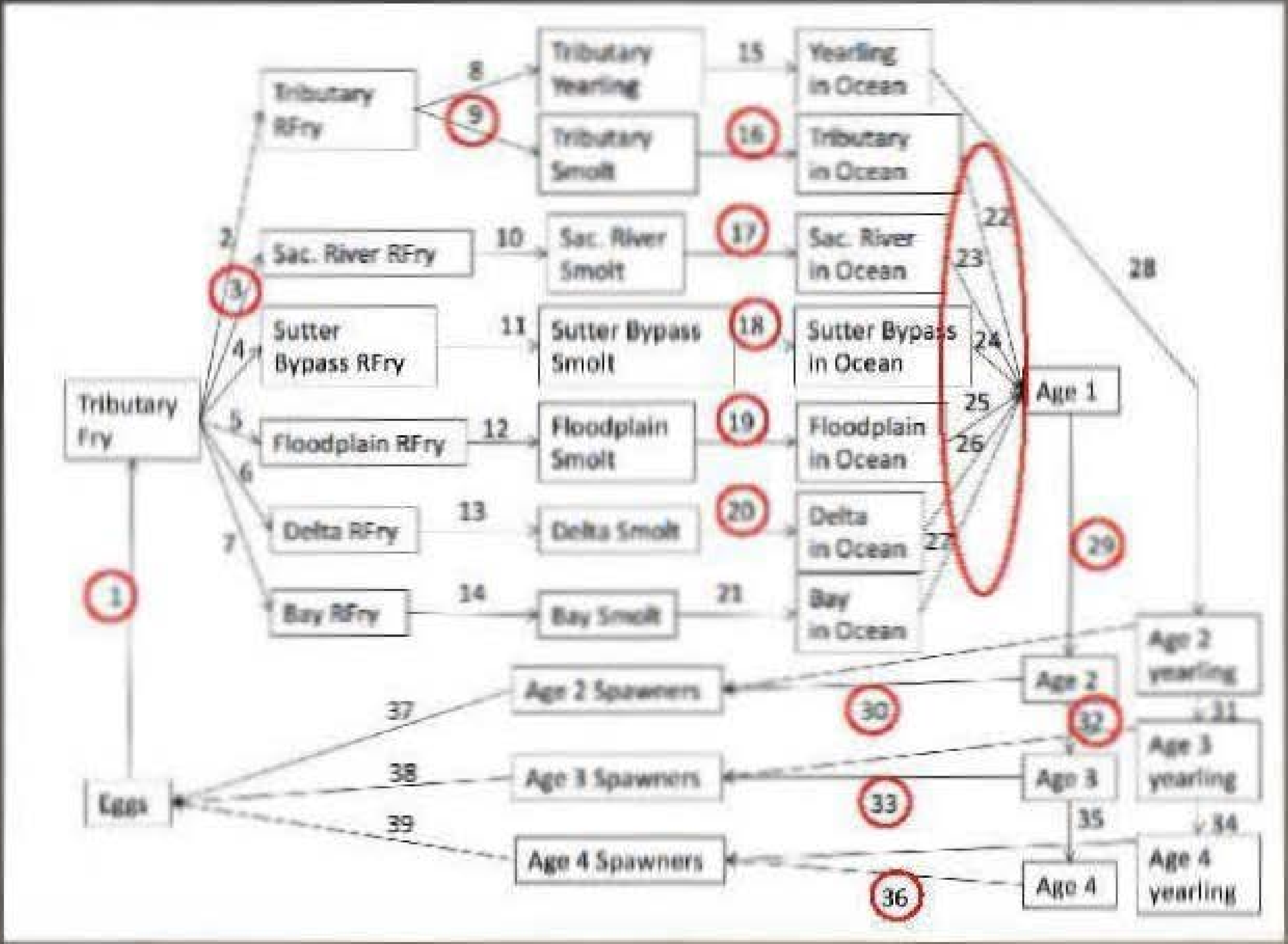
Newman



ePTM

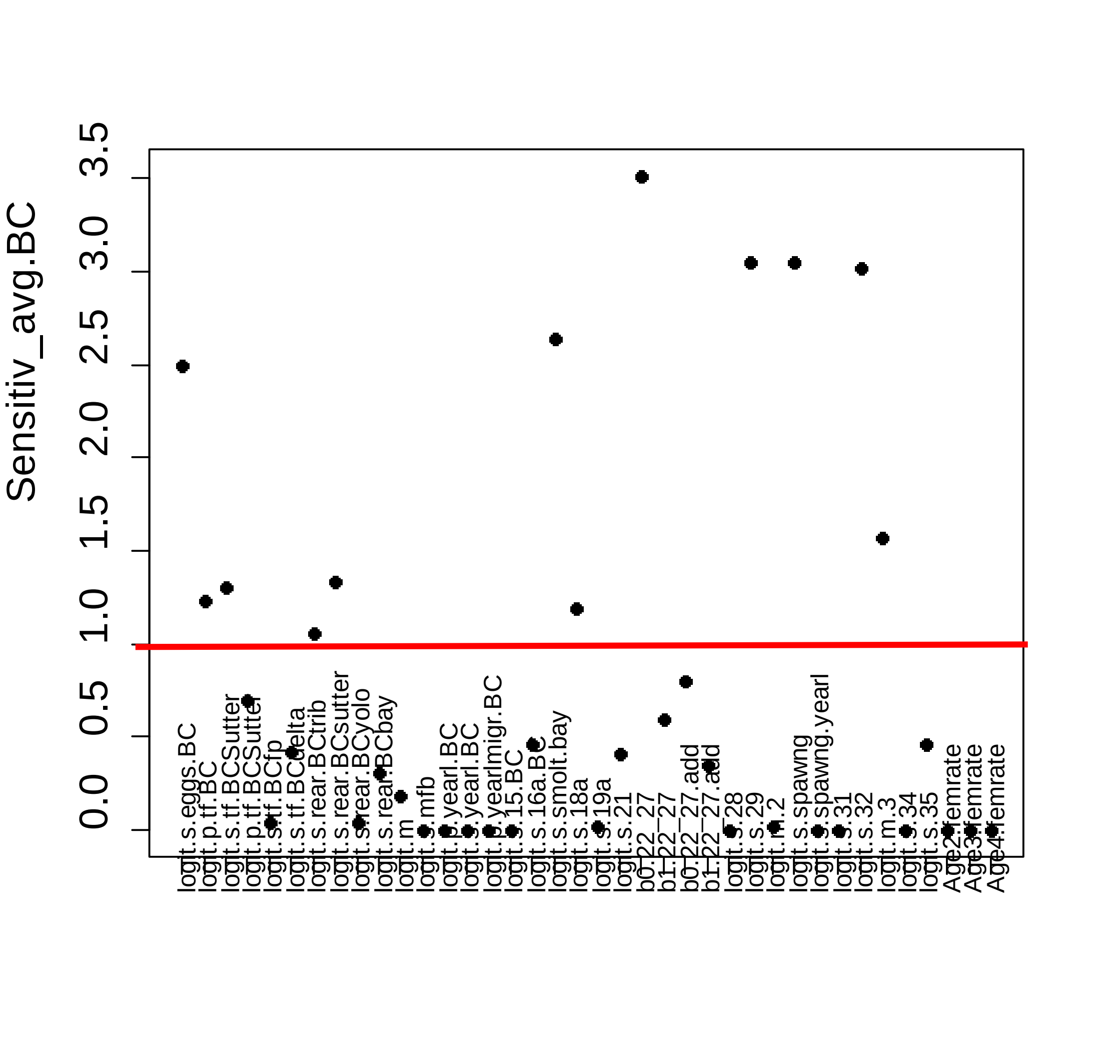


Mill/Deer Cr. model sensitivity analysis

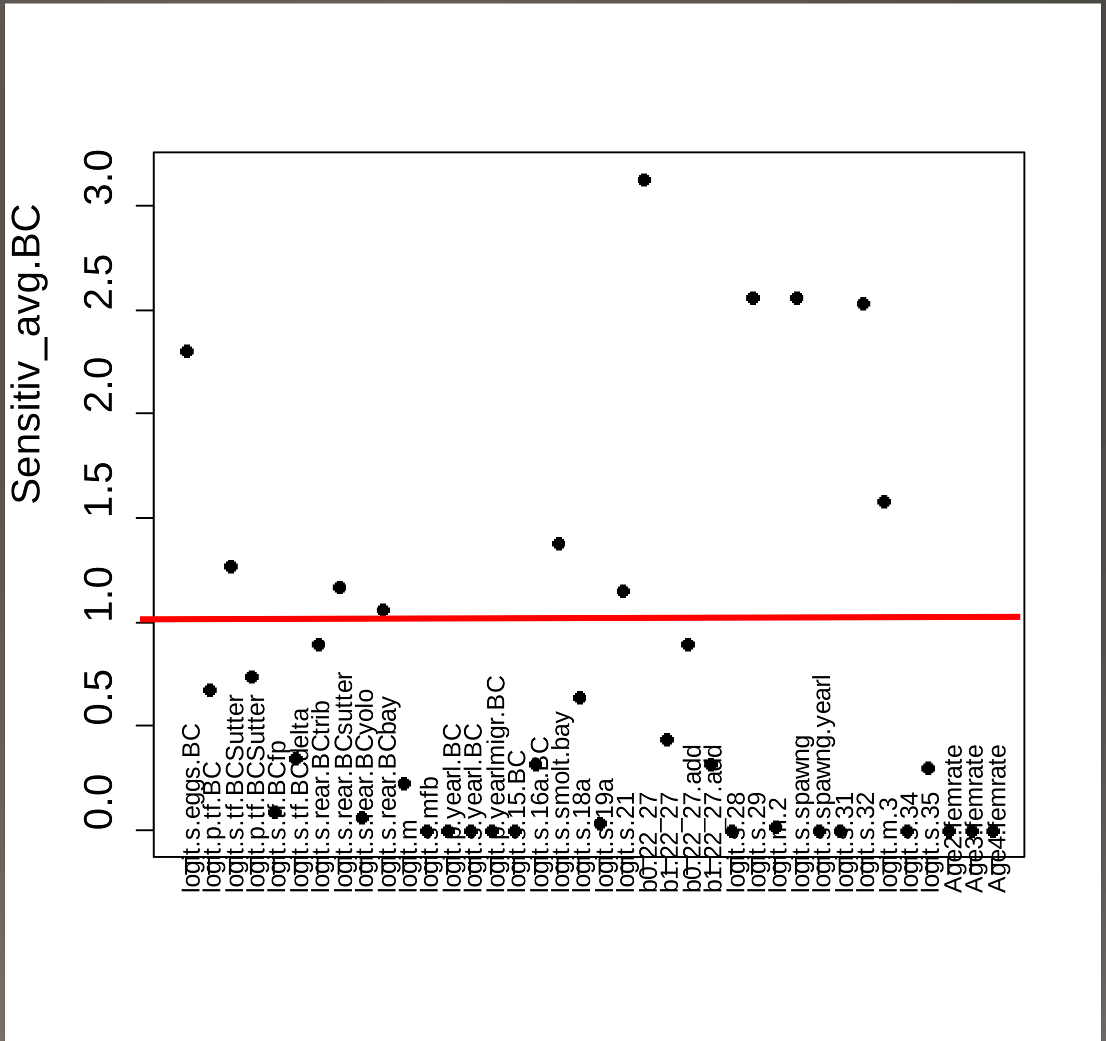


Butte Cr. Model sensitivity analysis

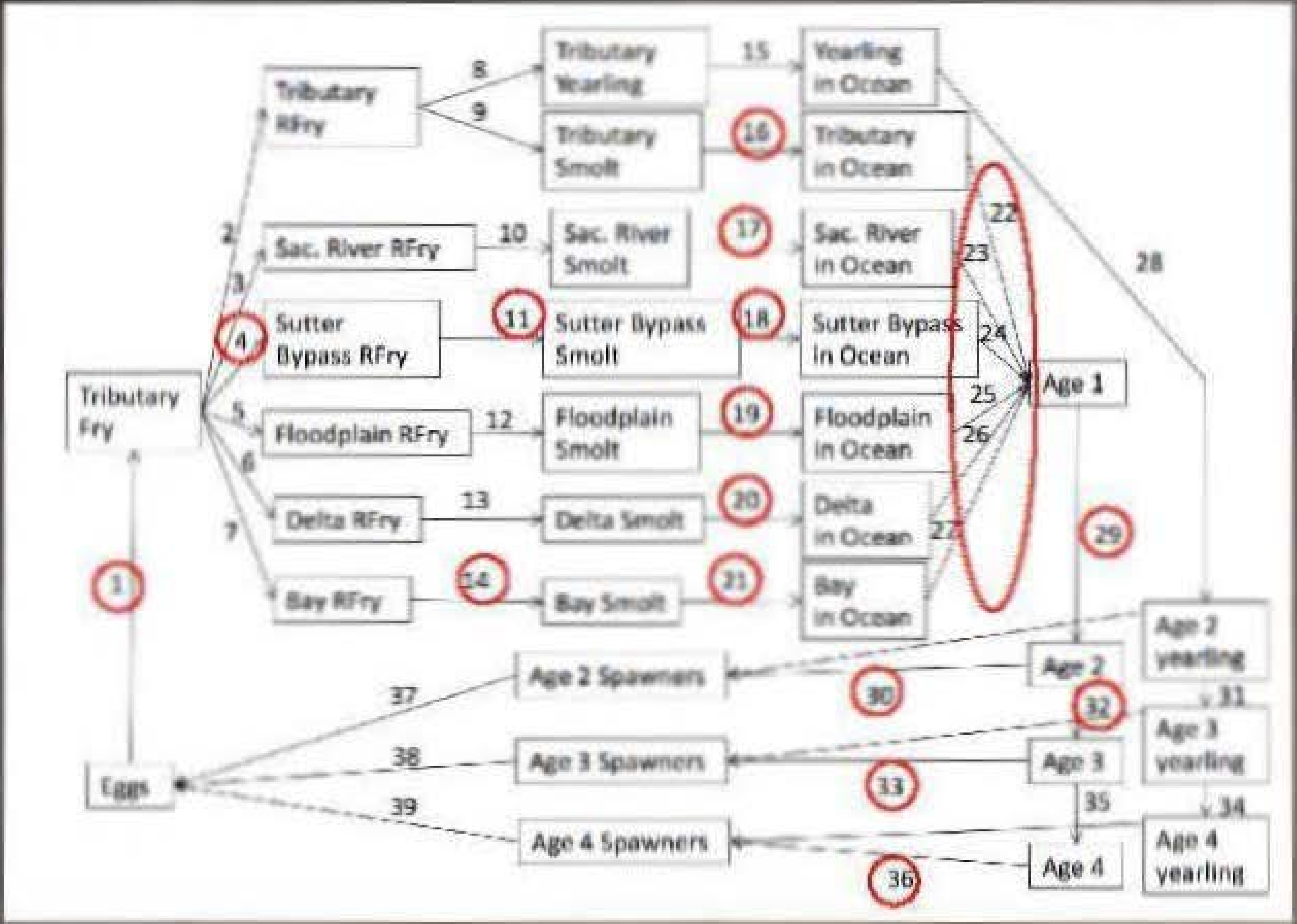
Newman



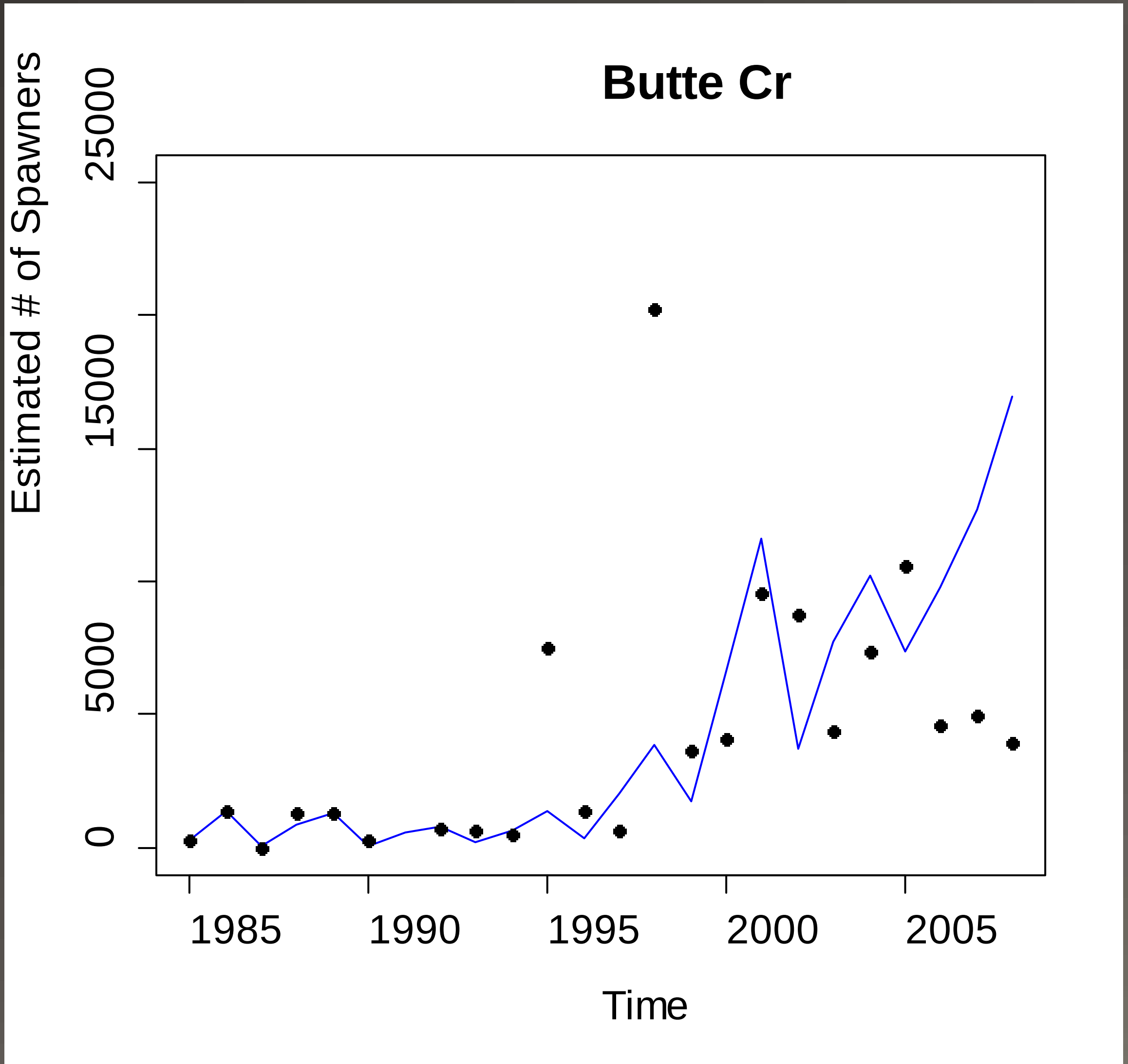
ePTM

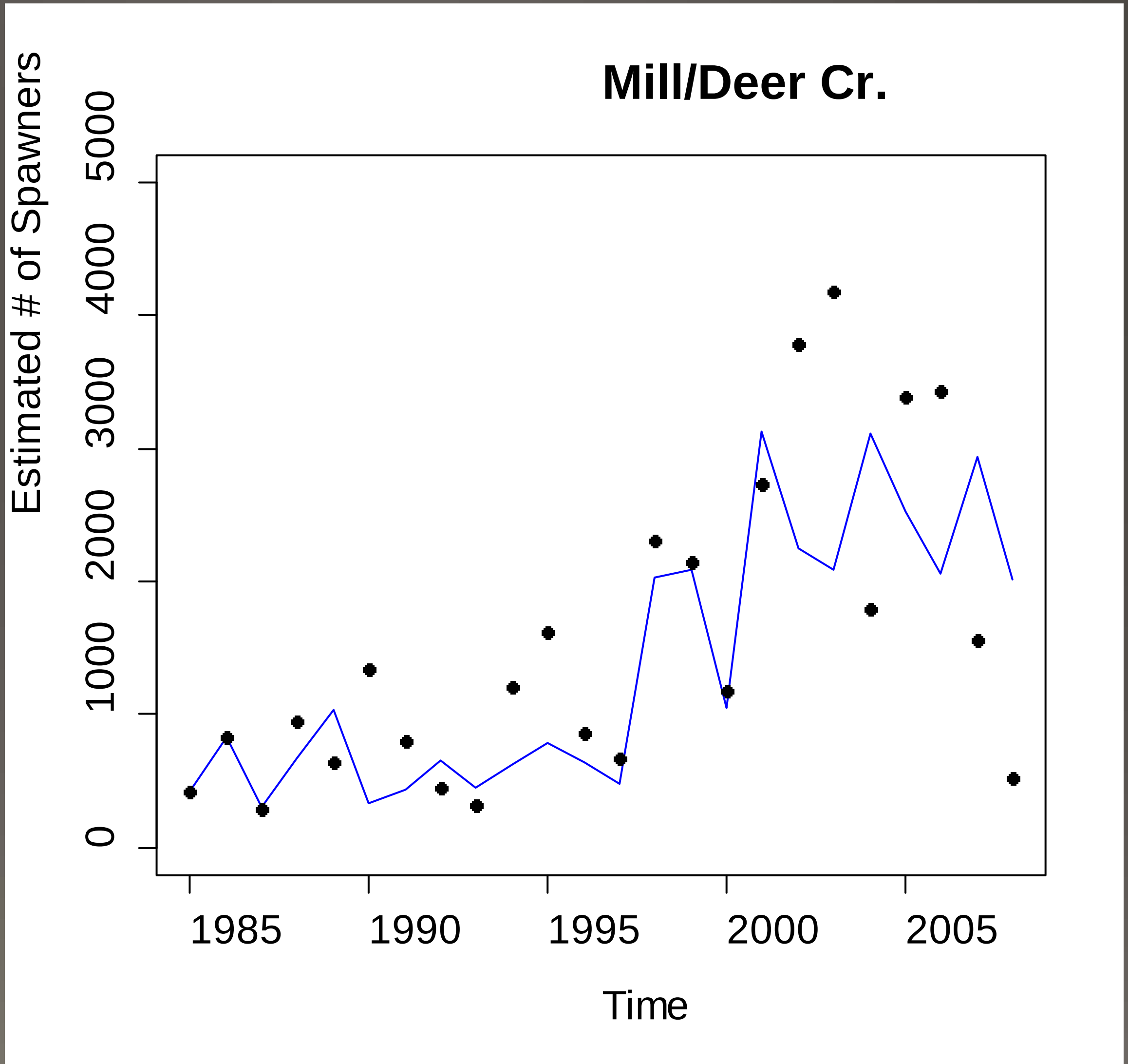


Butte cr. model sensitivity analysis



Model simulations





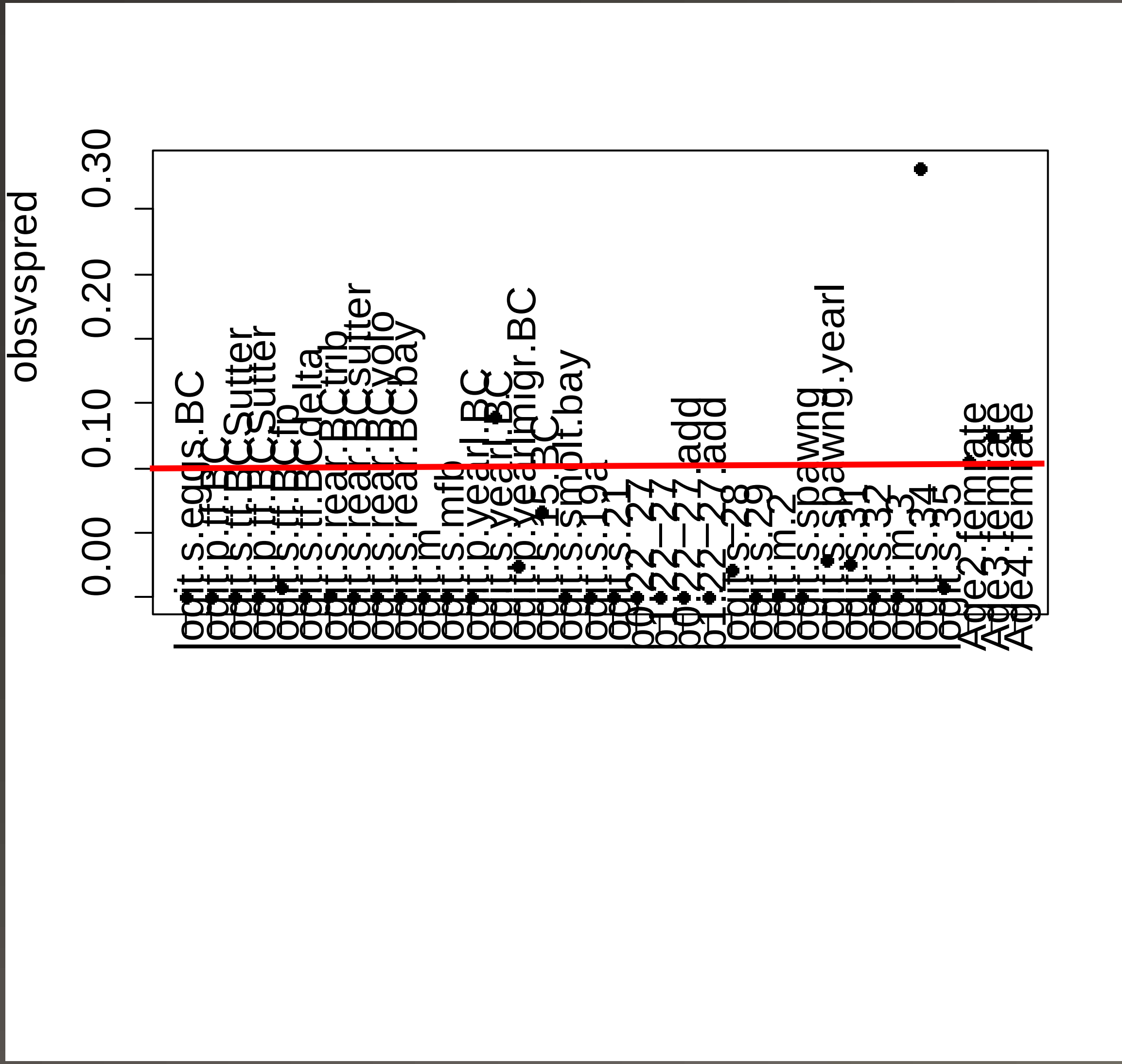
Next Steps

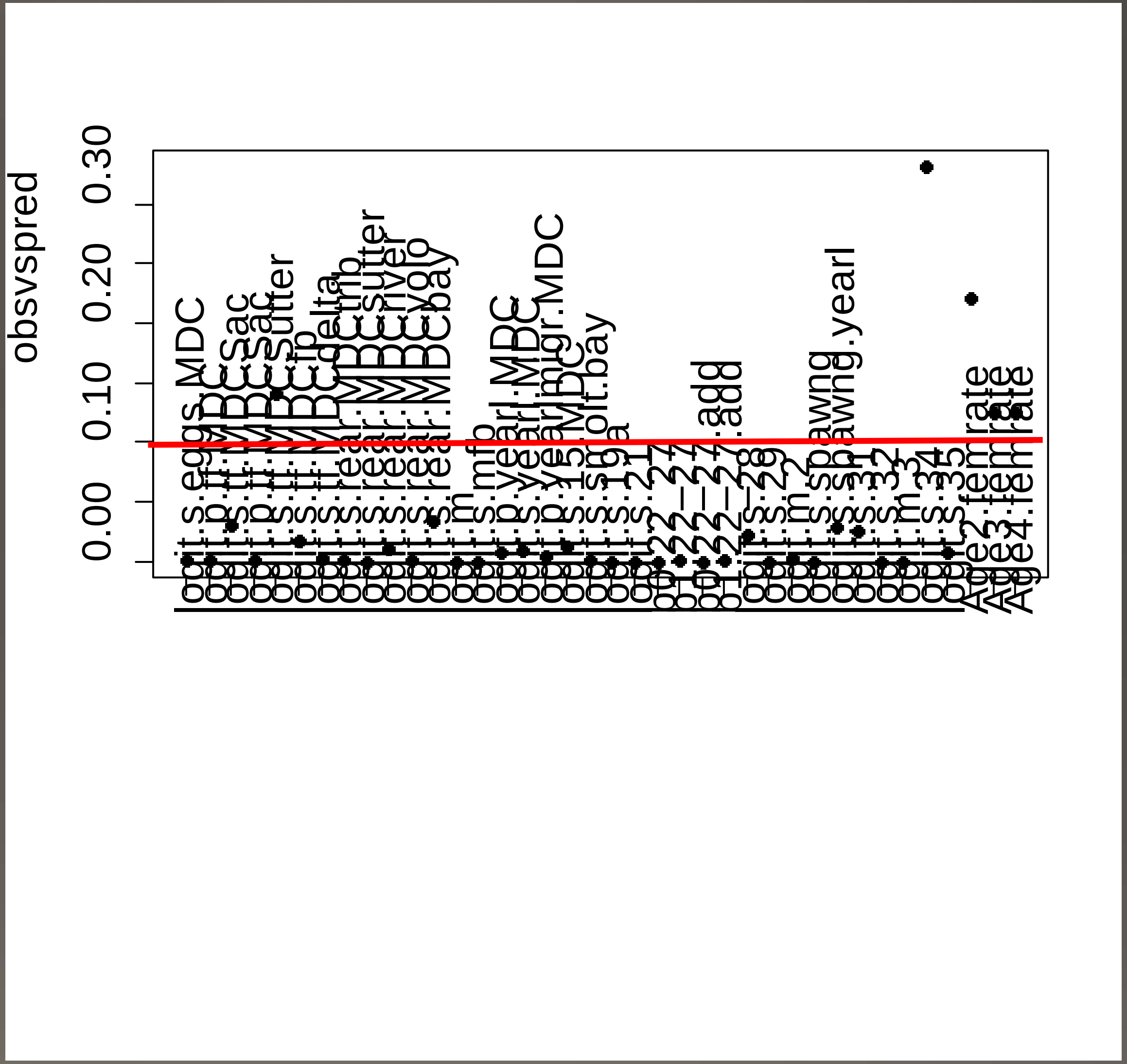
- ➢ Refine parameter values and finish model calibration
  - Rearing capacity in Tributaries and Sutter Bypass
  - Proportion of tidal fry vs rearing fry vs yearling
  - Evaluate relationship between egg survival and temperature in spawning habitat

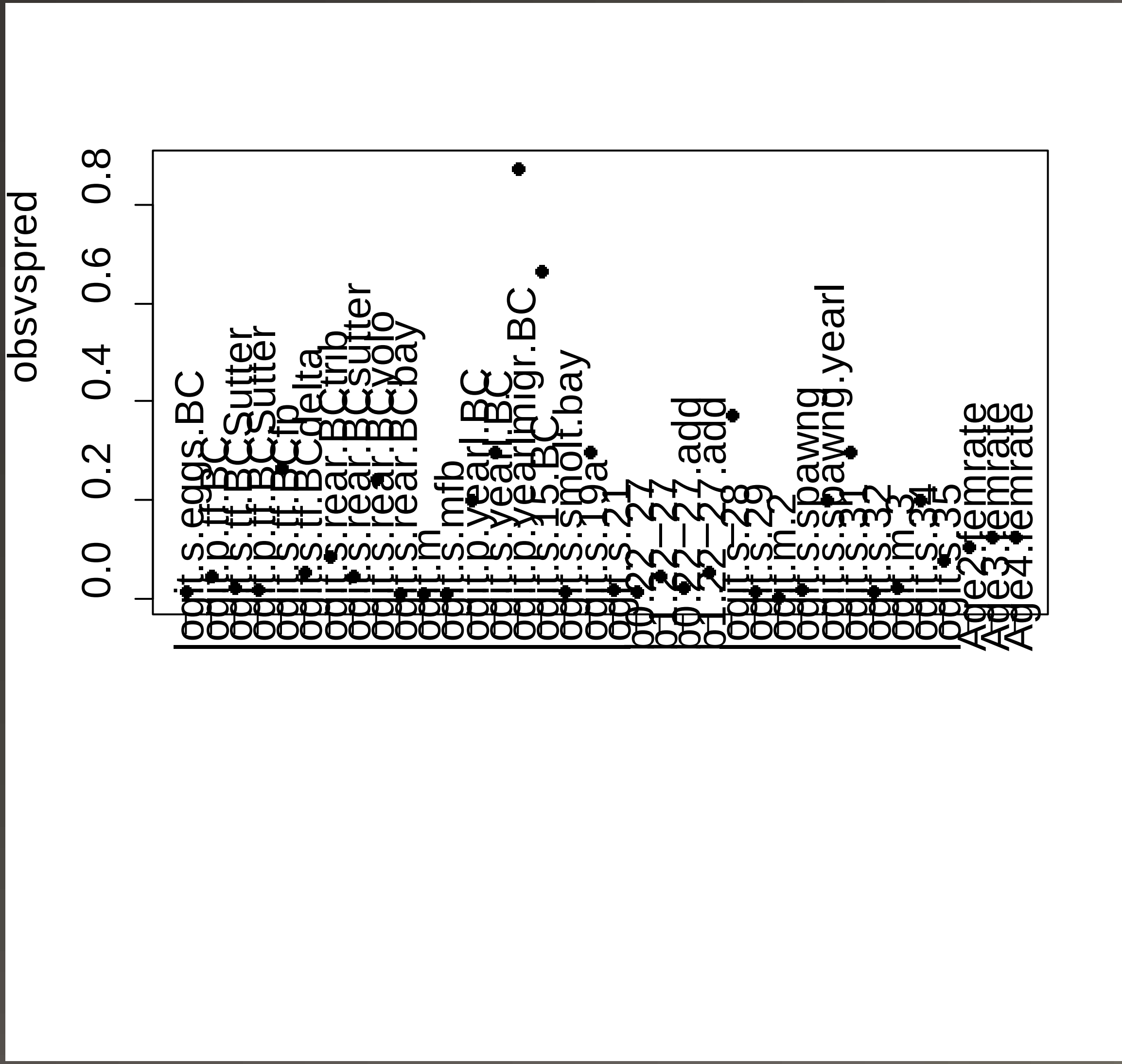
- ➢ Use model for inference in evaluating water management and climate change scenarios
  - Effect of increased temperature in spawning habitat?
  - Sutter Bypass flooding scenarios
  - Delta water management scenarios

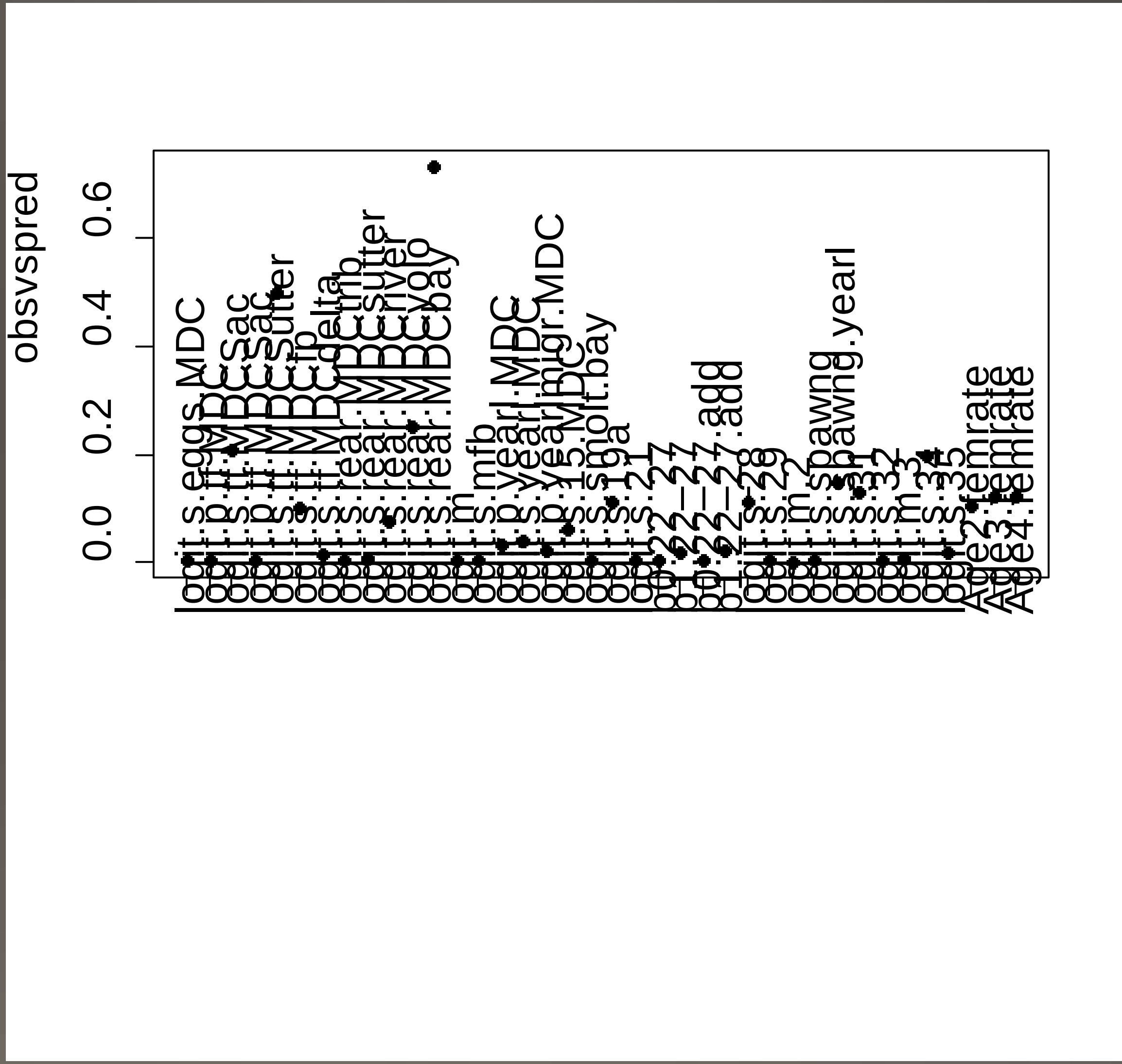
Many thanks to:

- UCSC
- NMFS/NOAA
- US Bureau of Reclamation
- CA Department of Water Resource
- CA Department of Fish and Wildlife


obsvspred
0.00
0.10
0.20
0.30


obsvspred
0.00
0.10
0.20
0.30


obsvspred
0.0
0.2
0.4
0.6
0.8
Age2.femrate
Age3.femrate
Age4.femrate


obsvspred
0.0
0.2
0.4
0.6
Age2.femrate
Age3.femrate
Age4.femrate