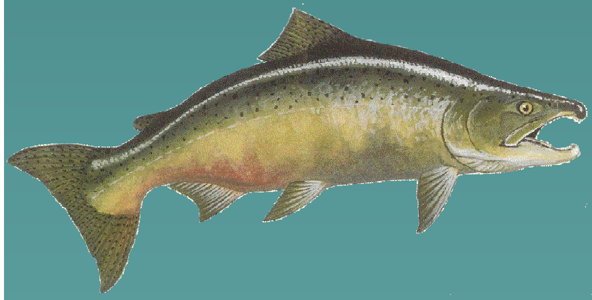
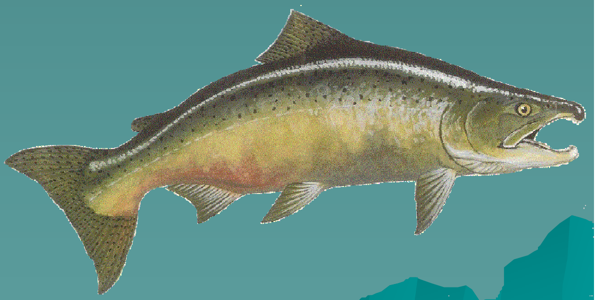
San Joaquin River
Salmon Population Model



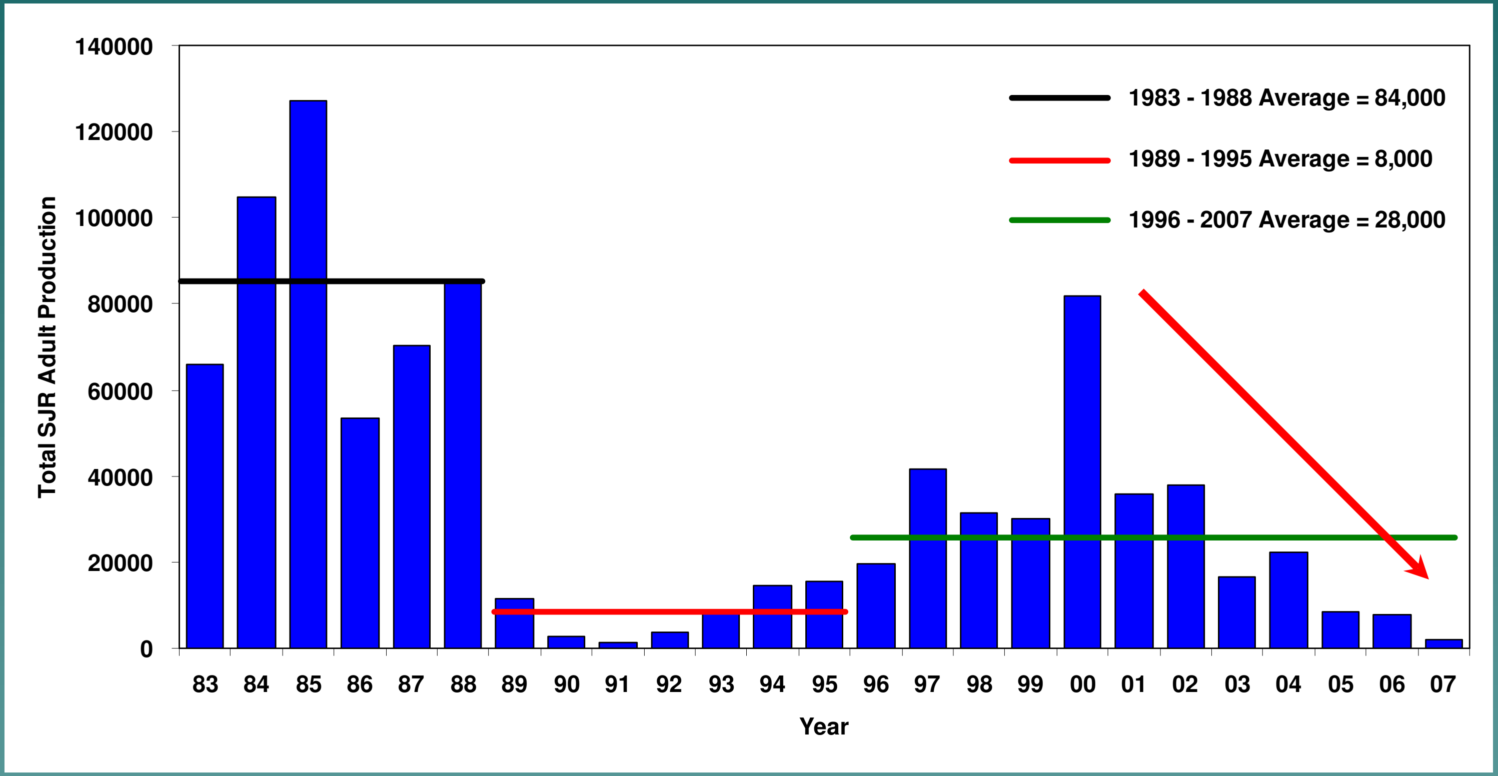


SWRCB SJR
Flow Workshop
Sept. 17, 2008

Dean Marston
CDFG

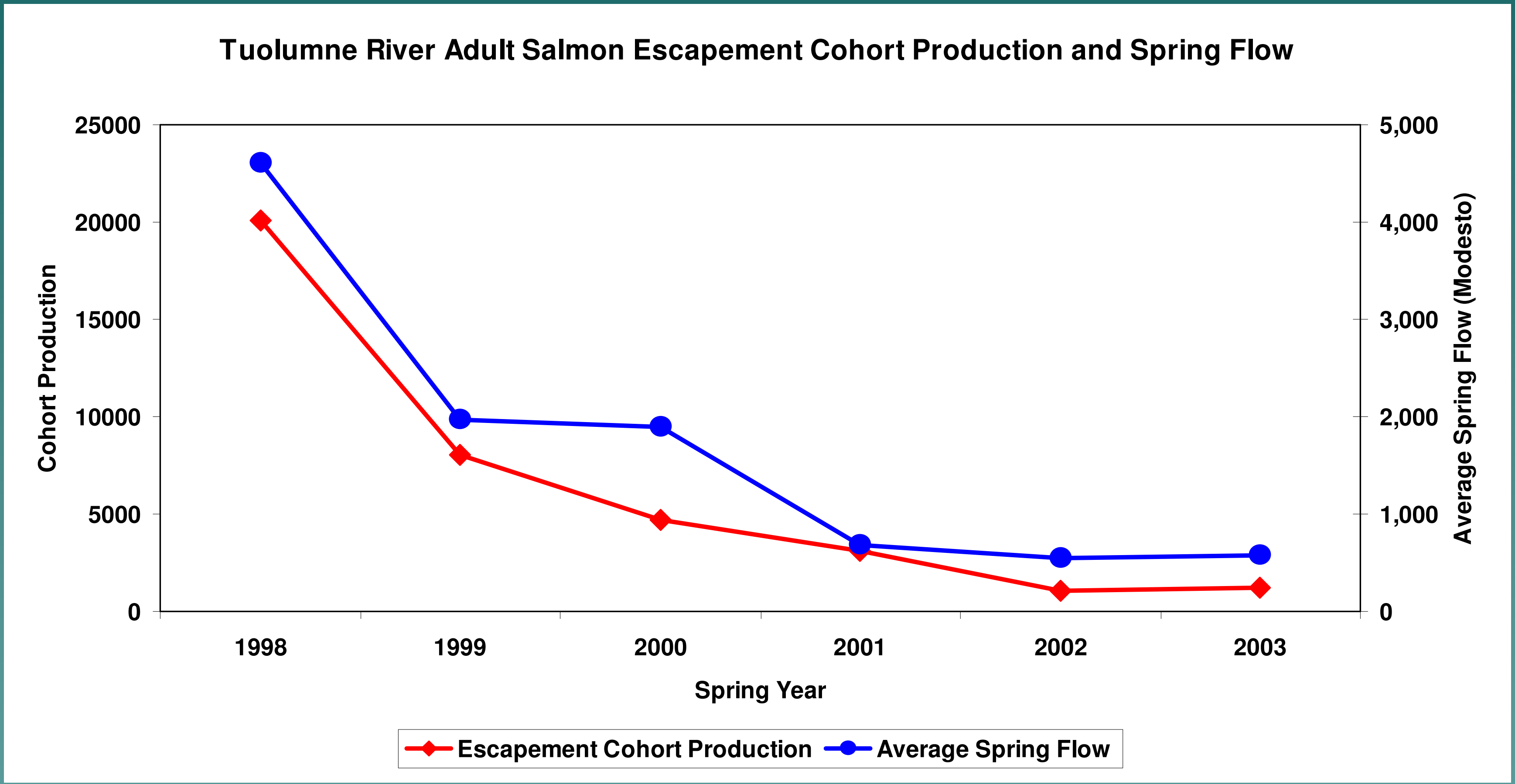
Dr. Alan Hubbard
U.C. Berkeley

SJR Salmon Trend



Source: USFWS-AFRP

Tuolumne River Escapement



SJR Adult Salmon Status

- **Production Trend <u>down</u> not up**
- **Post '99 Decline <u>consistent with</u> spring flow reduction since 1999**
- **Escapement decline began <u>prior to</u> 2005 Ocean condition downturn**
- **Post-drought trend includes <u>substantial</u> ocean harvest reduction**
- **Tuolumne River at <u>moderate-high</u> extinction risk (*Mesick 2008*)**
- **Change Needed: Status Quo <u>not</u> working**

Models

- No “perfect” models
- If you have “all” the data: no model needed
- Models by nature operate on premise that you take what info you have and extrapolate from it and make inferences
- Model utility depends upon performance (reality double check)
- Models are always in “refinement”

Model Purposes

- **Science:**
  - Evaluate Role of South Delta Spring flow on SJR fall-run juvenile thence adult salmon production
  - Link Bay-Delta WQCP Objectives (flow & fish)
- **Planning:**
  - One tool for Gaming scenarios (H20 cost vs fish benefits)
- **Education:**
  - Delta not isolated-Part of a system
  - Link Juvenile and Adult Production
- **Policy:**
  - Consider beneficial use distribution

Model History Summary

- 2005: SWRCB Periodic Review
  - Built simple salmon production model
  - Preliminary flow recommendations
- 2006: Peer review
- 2007: Model Contracting
- 2008: Model Refinement
  - Peer Review response
  - Intermediate model (V.1.5)
  - Next Generation (V.2.0) in progress

Peer Review Summary: “Positives”

- **Model General:**
  - provides additional insight into role of spring flow, magnitude, duration, and frequency related to Chinook salmon
  - fits the historical escapement record using an empirical approach
  - is well documented, data carefully analyzed, results probably pretty good
- **Model Specific:**
  - Ocean survival a constant: OK as first step
  - Adult replacement ratio: reasonable health metric

Peer Review Summary: “Criticisms”

- Model needs refinement for management use
- Model Lacks:
  - Density Dependence
  - Resolution
  - Statistical parameter fitting
- Model does not include:
  - Important sources of mortality:
    - ocean conditions & harvest
    - delta exports
    - predation
    - water temperature

DFG Response to Comments

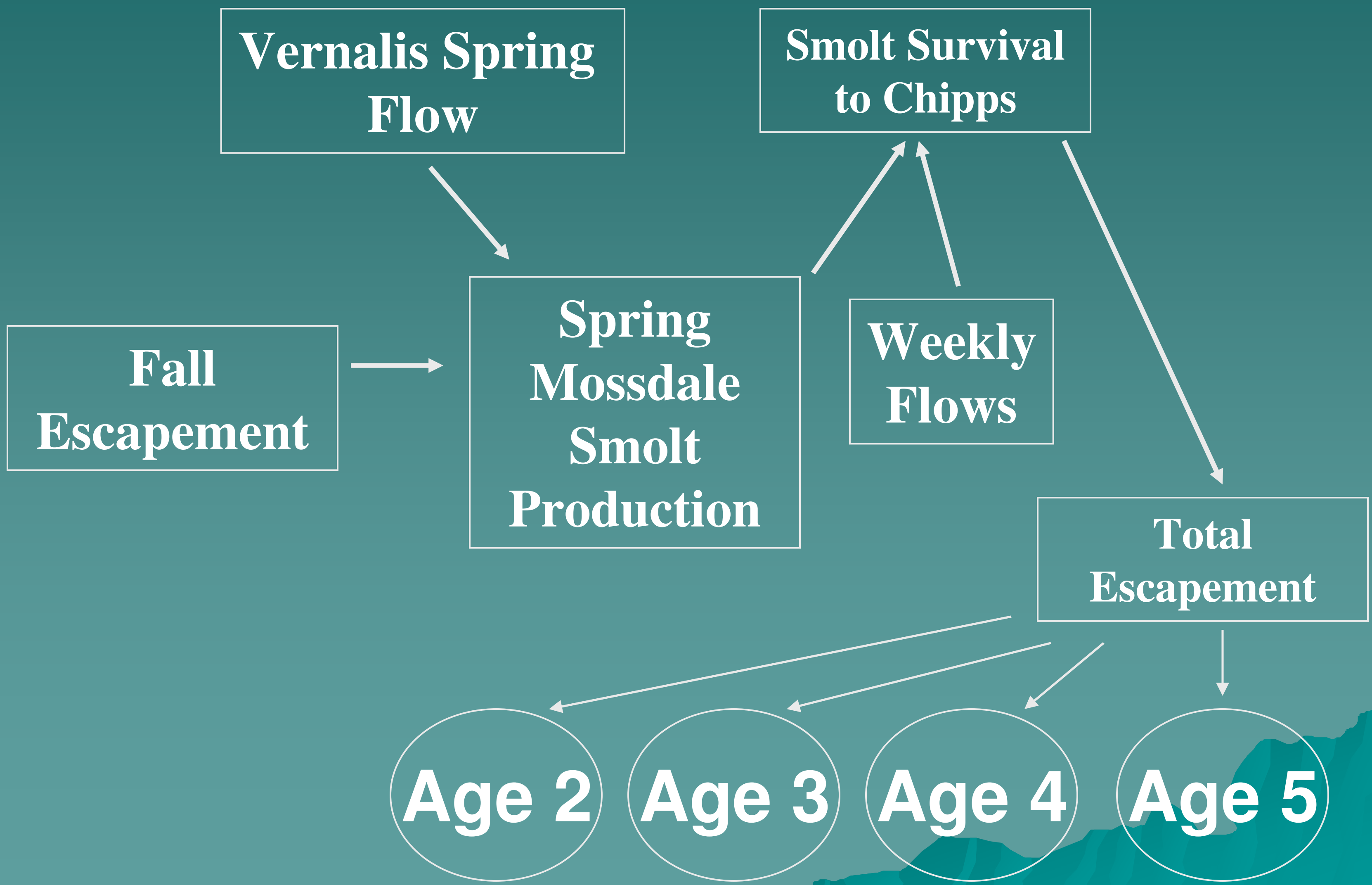
- Two Staged Response
- Version 1.5
  - Replacing linear regression sub-models with proper generalized linear methods
    - Accounts for nonlinearities in data
    - Allows use of probabilities to ID best fit
- Version 2.0
  - Add parameters (predation, ocean conditions, harvest, juvenile growth etc)
  - Allow biological understanding to drive outcomes (rather than simply empirical relationships)

Statistical Models of Version 1.5

Version 1.5 - What is it?

- **Is** - Simple linking of statistical models.
- **Is not** - a system's model - does not complete the circle. Version 2.0 is such a model.
- **What can it do?** Estimate the differences in brood year escapement productivity as a function of flow.

Model (Brood Year to Escapement)



Model Strategy

Proper Model

- Examine relationships empirically using smooths (generalized additive models).
- Fit corresponding parametric model implied by smooth.
- Inference (e.g., confidence intervals) not formally correct – many issues to deal with (autocorrelation, model selection, etc.).

Mossdale Smolt Production

GAM smooths by Variable

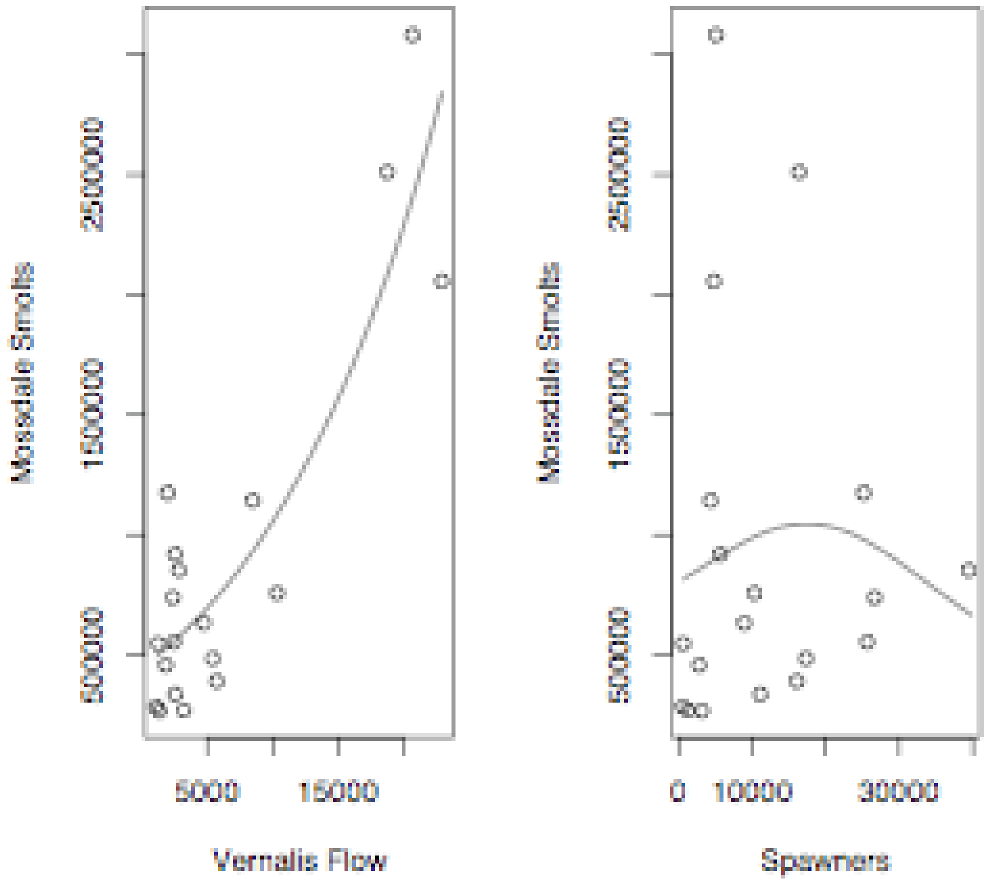
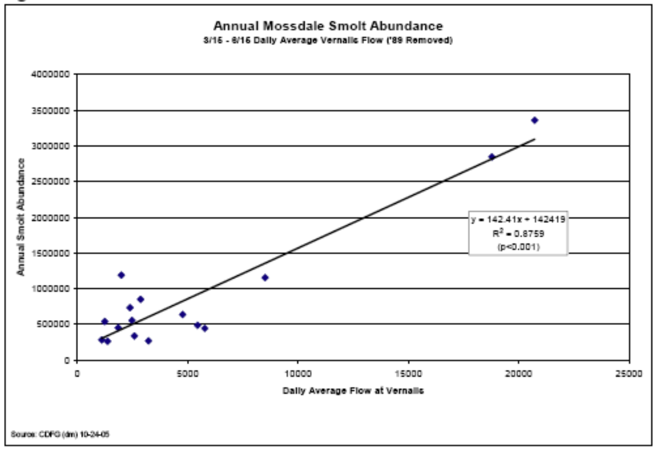


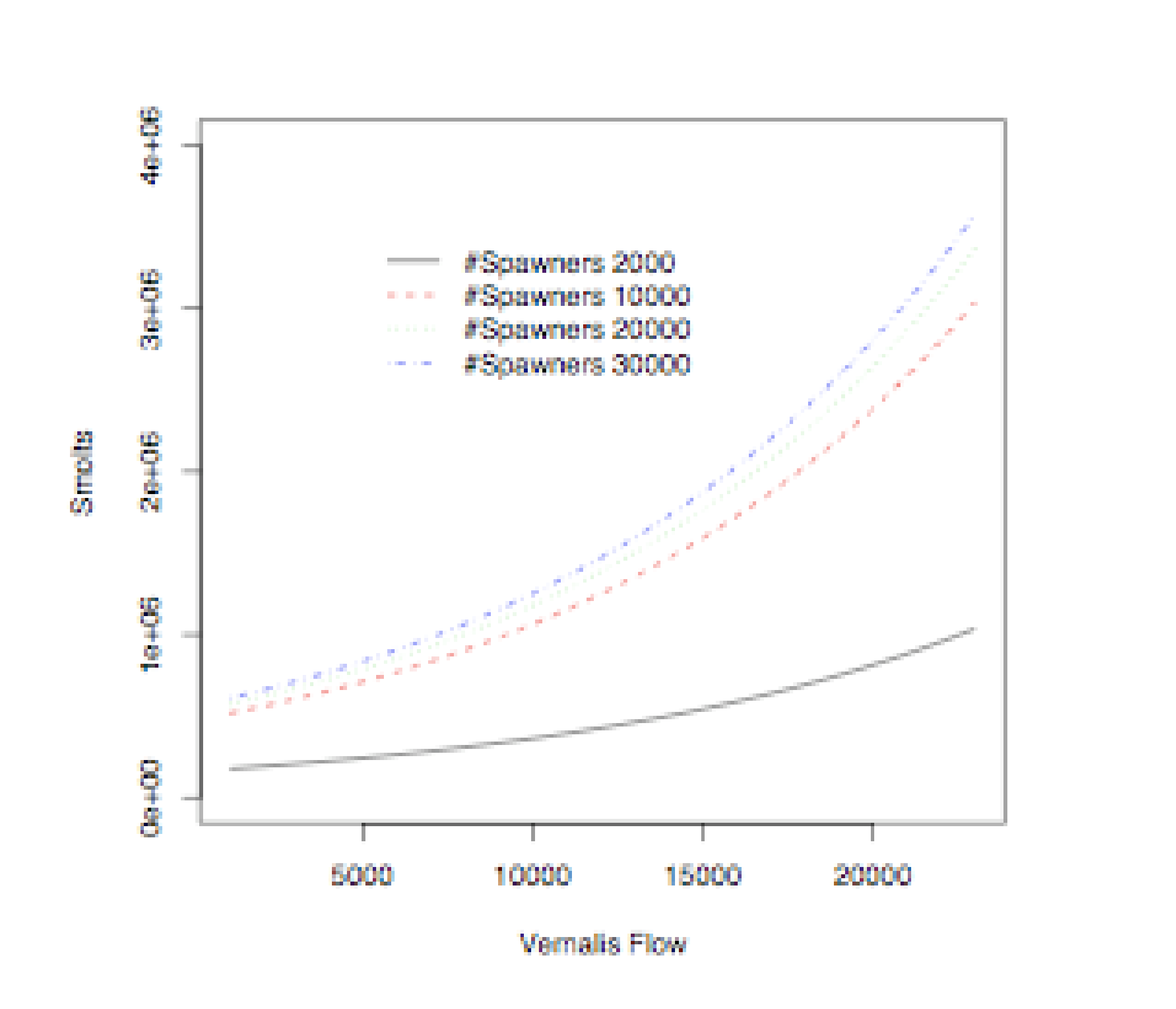
Figure 32. Mossdale Smolt Abundance as a Function of Vernalis Flow



Version 1.0

Mossdale Smolt Production

Poisson (log-linear) fit with both variables (#Spawners, Vernalis Flow)



Form of Mossdale Smolt Model

- **The fitted model has the form: S_t is the number of smolts at Mossdale, spring of year t, E_{t-1} is the escapement the previous Fall, *Flow* is average spring Vernalis flow**

$$\log(S_t) = 11.7 + 8.1x10^{-5} * Flow + 0.15 * \log(E_{t-1})$$

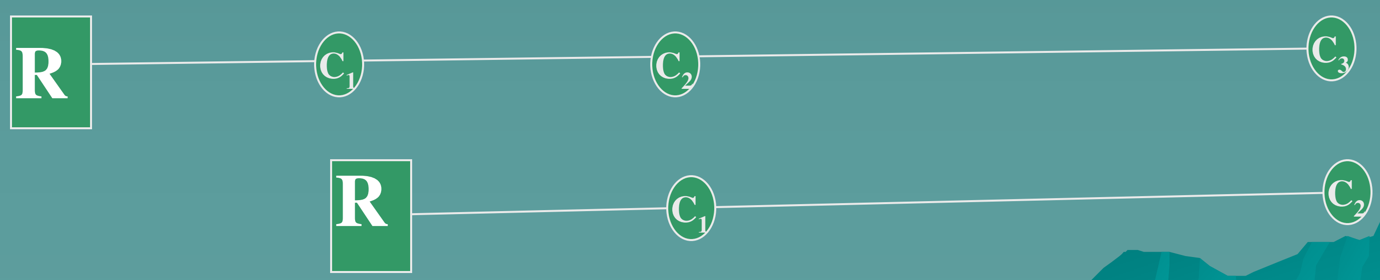
- **Implies 5.9 times the numbers of fish** comparing the **max to the min flow** in the data, keeping spawners fixed.
- **Implies 1.9 times the numbers of fish** comparing the **max to the min numbers of spawners** in the data, keeping flow fixed.

Delta Survival Model

(Mossdale to Chipps)

- Estimate based on the idea that:

1. Survival decreases with distance
2. The percentage surviving over a section of the system can be determined from comparing the capture % from overlapping capture release experiments.



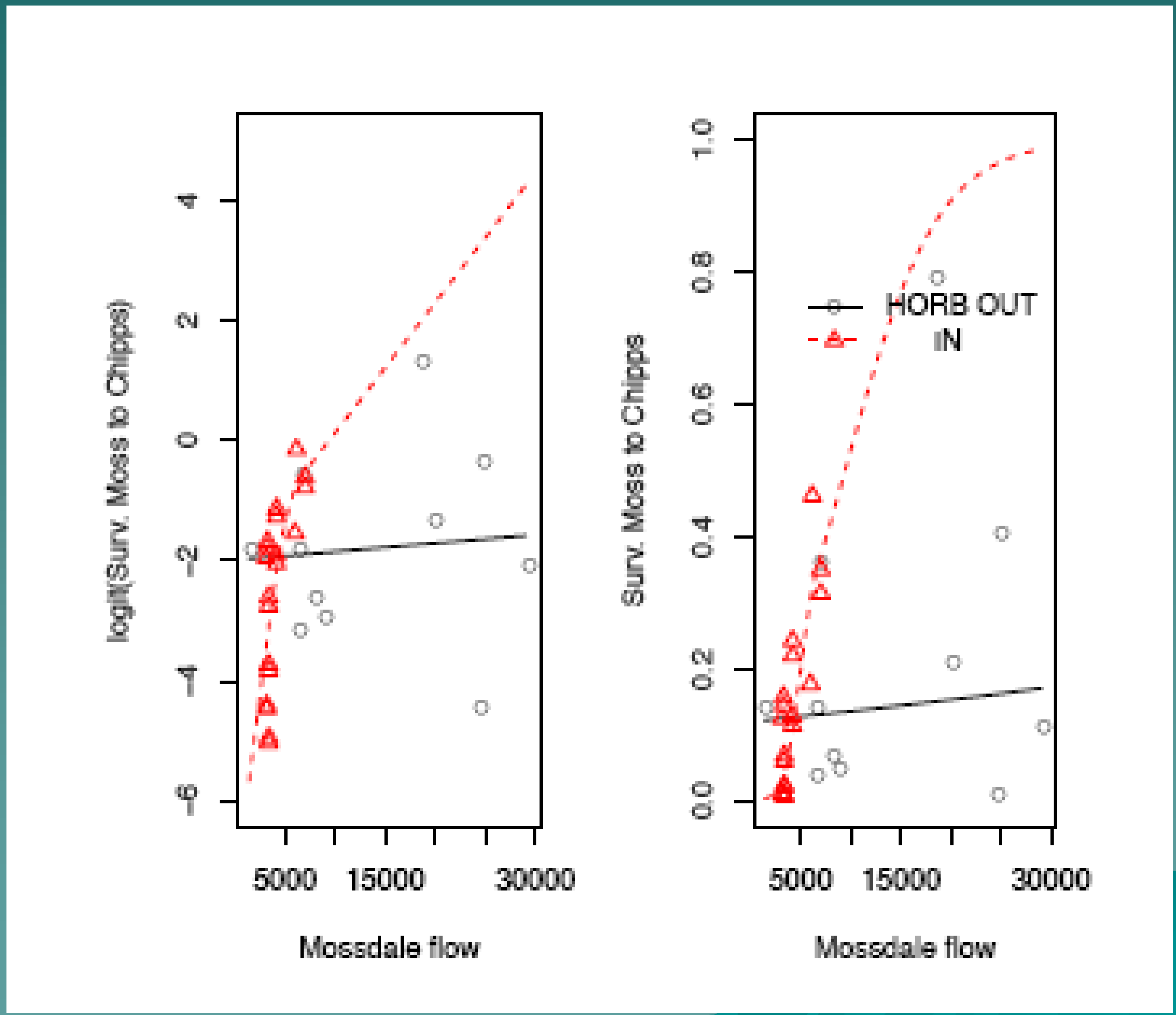
Delta Survival Model, cont.

- Survival probability estimated as*: $$\hat{S}_{MD\to CI} = \frac{(Y_{MD\to Ant} + Y_{MD\to CI} + Y_{MD\to Oc})/R_{MD}}{(Y_{JP\to CI} + Y_{JP\to Oc})/R_{JP}}$$
- Estimate survival probability as function of flow at Mossdale.
- Do separately by HORB status (in and out) $$\log\left(\frac{\hat{S}_{MD\to CI}(flow, HORB)}{1-\hat{S}_{MD\to CI}(flow, HORB)}\right) = f_{HORB}(flow)$$

- * From Ken Newman's Report, March, 2008.

Delta Survival

Smooths on logit (left) and probability (right) scale



Delta Survival Model - Final Models

- Smooths suggest the linear-logistic will fit relatively well.

$$\log\left(\frac{\hat{S}_{MD\to CI}(flow,HORB)}{1-\hat{S}_{MD\to CI}(flow,HORB)}\right)=\alpha_{HORB}+\beta_{HORB}*Flow$$

$$\hat{\alpha}_{IN}=-5.7,\quad \hat{\beta}_{\mathrm{IN}}=7.8x10^{-4}$$

$$\hat{\alpha}_{OUT}=-2.0,\quad \hat{\beta}_{OUT}=1.4x10^{-5}$$

- What this means is that comparing the 75th to 25th percentile of observed flows, with HORB in, estimate a 21-fold increase in survival, with HORB out, 1.1-fold increase.

Delta Survival

Final Logistic Model

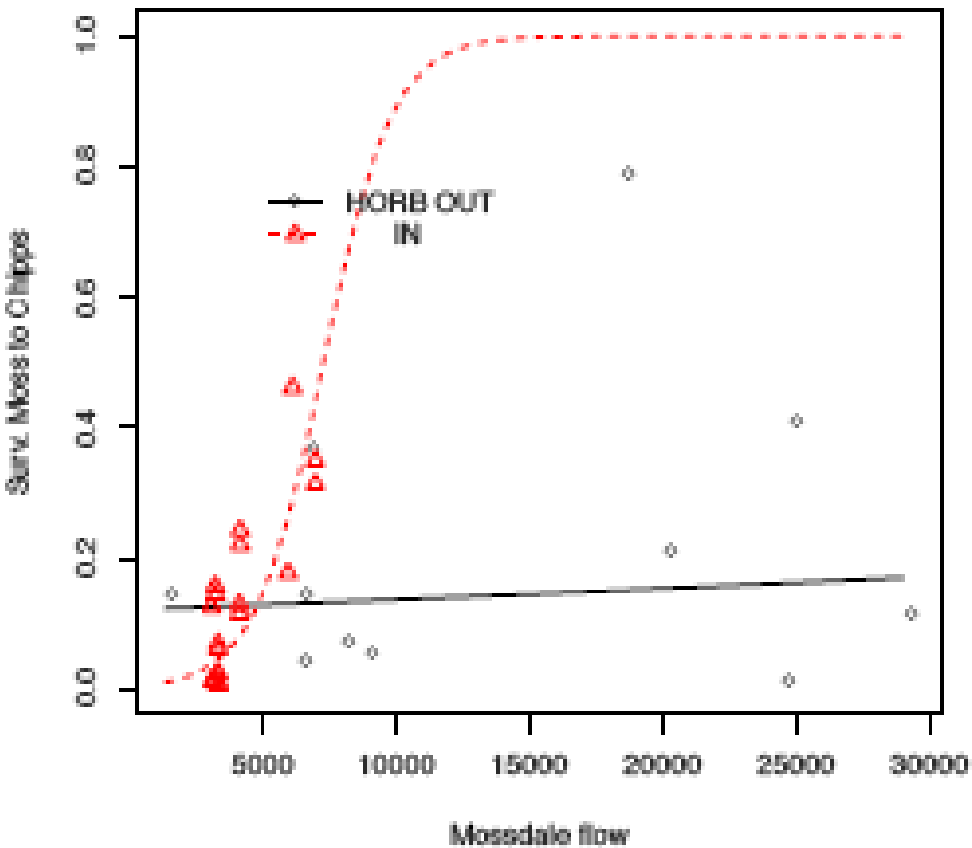
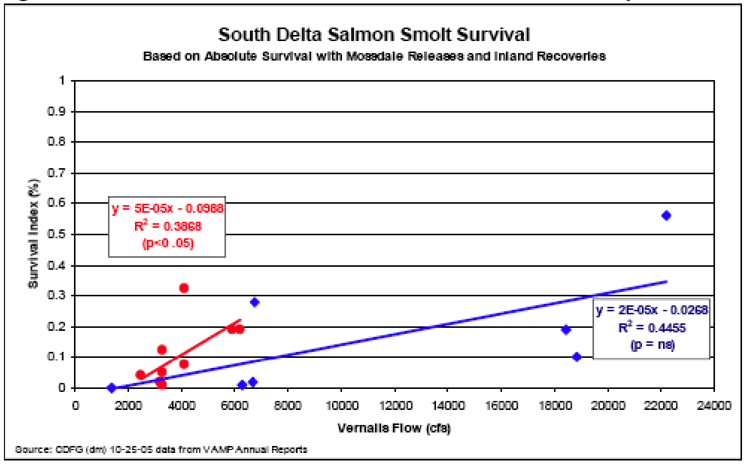


Figure 34. South Delta Salmon Smolt Survival – Inland CWT Recovery.



Version 1.0

Cohort Production Model -
Chipp Smolts to Escapement

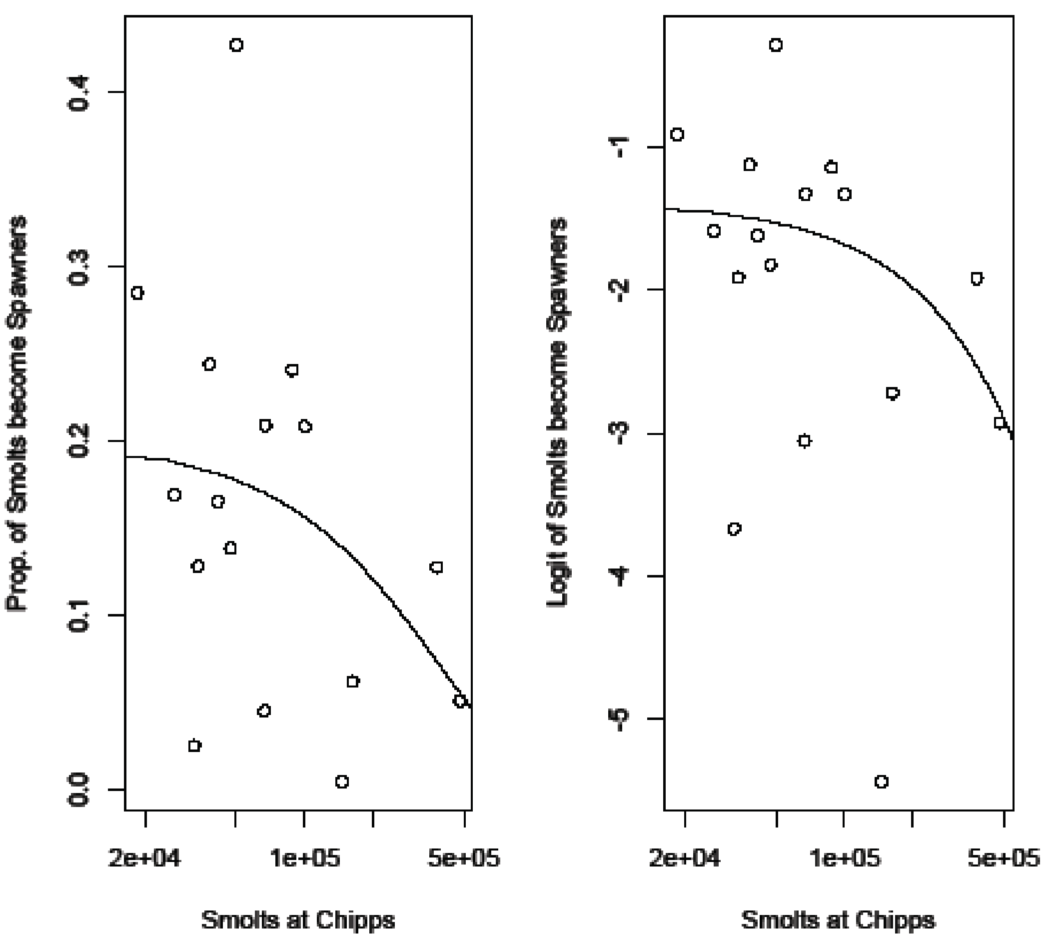
- Just fit a simple model relating the estimated number of smolts at Chipps to the total escapement from that brood year.
- Use Mossdale smolts, apply Delta Survival model using observed flows and HORB status to predict number of smolts at chips - this is predictor variable.
- Outcome is total escapement from the brood year:

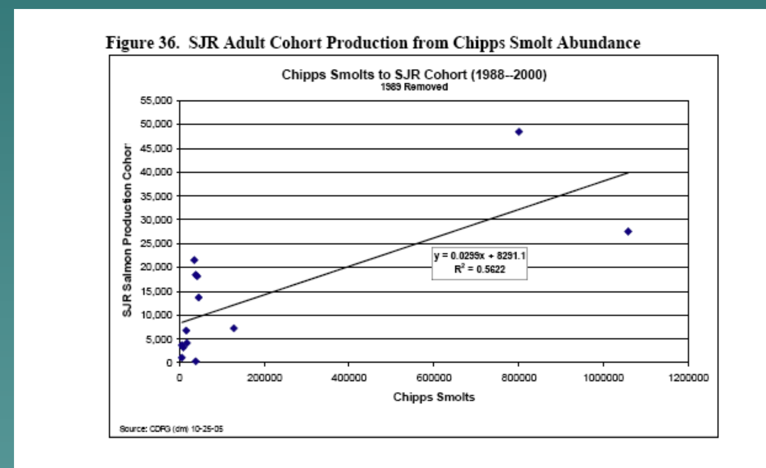
$$\log\left(\frac{S_{Chipps \rightarrow Escape}(N_{Chipps})}{1 - S_{Chipps \rightarrow Escape}(N_{Chipps})}\right) = f(N_{Chipps})$$

where N_{Chipps} is the estimated total number of smolts surviving to Chipps and $S_{Chipps \rightarrow Escape}$ is the estimated total escapement from the brood year.

Proportion of Smolts returning as Spawners

GAM smooths (left on proportion scale, right on logit scale)

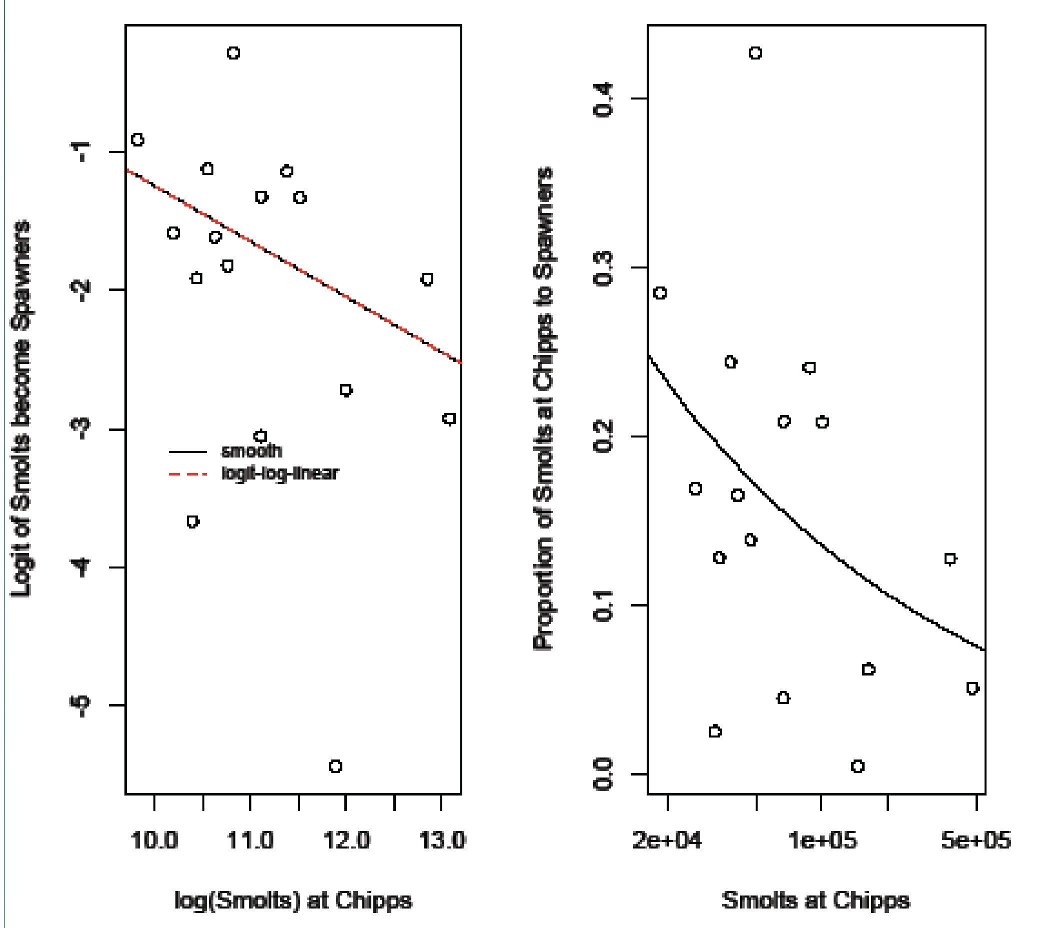




Version 1.0

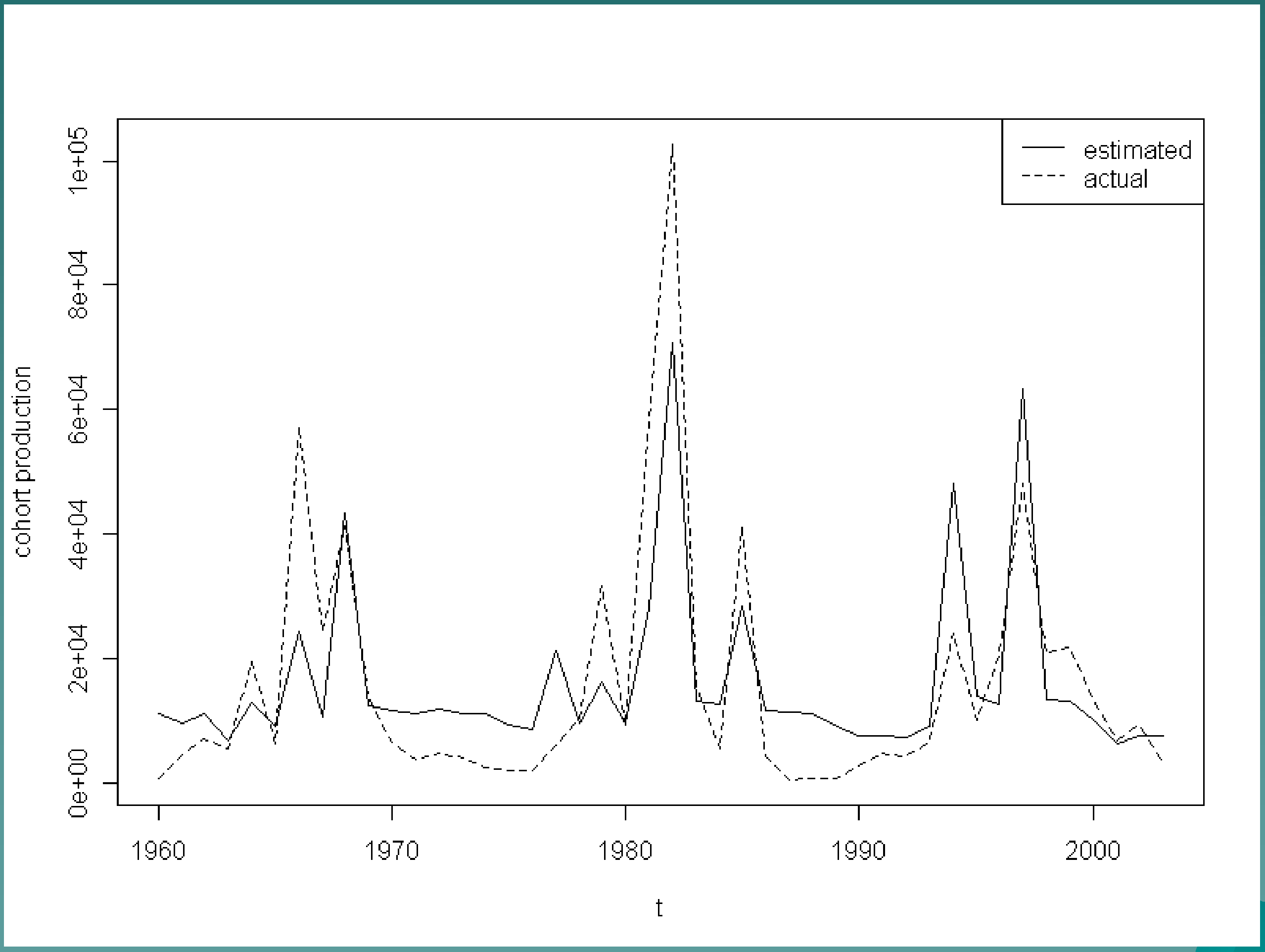
Proportion of Smolts returning as Spawners as function of log(Smolts)

Final logistic model fit (left on logit scale, right on proportion scale)



$$\log\left(\frac{S_{Chipps \to Escape}(N_{Chipps})}{1 - S_{Chipps \to Escape}(N_{Chipps})}\right) = 3.93 - 0.46 * \log N_{Chipps}$$

Model Runs



estimated
actual
cohort production
0e+00
2e+04
4e+04
6e+04
8e+04
1e+05
1960
1970
1980
1990
2000
t

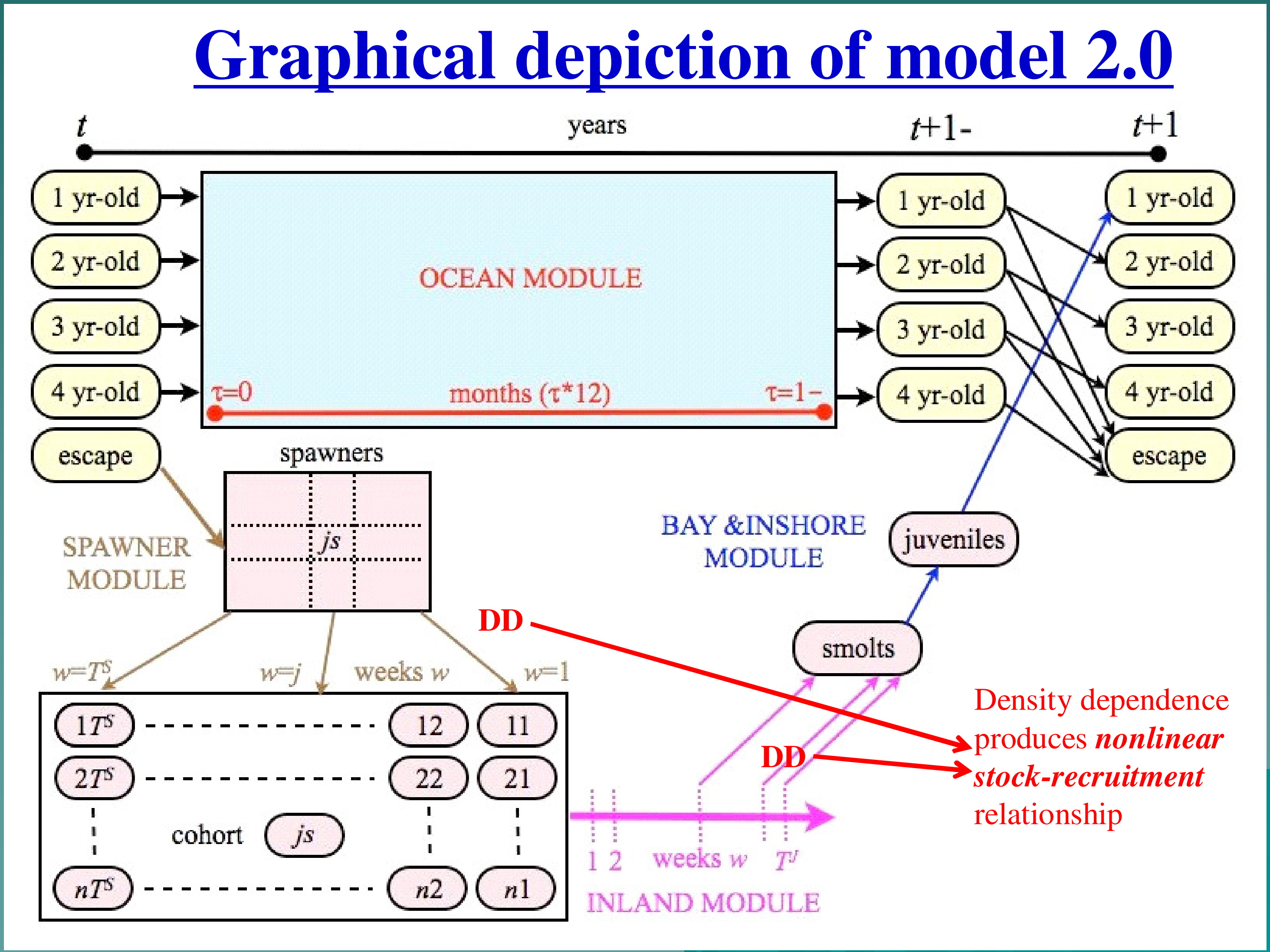
Scenarios

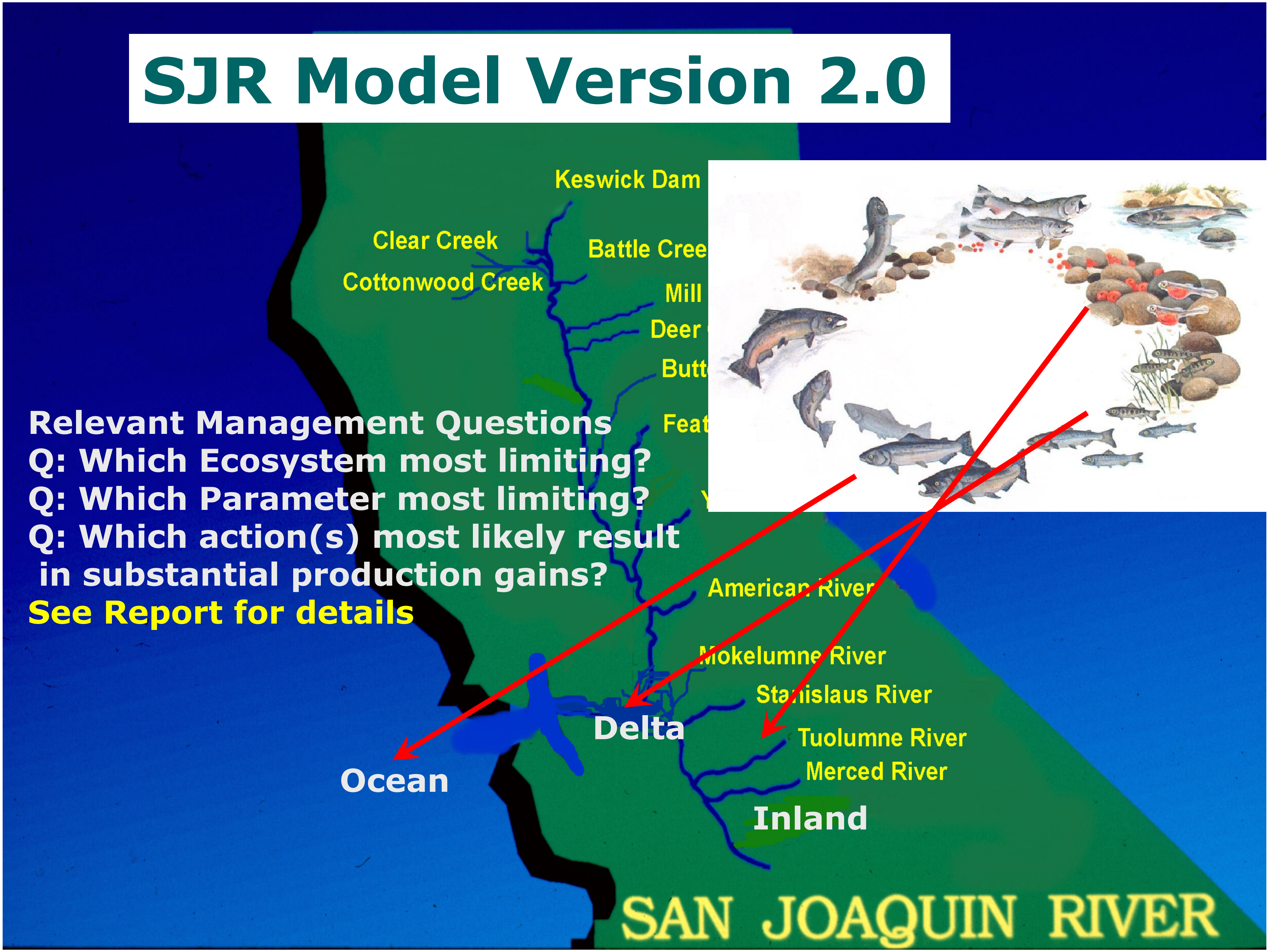
Case	Flow	HORB in		#	#	Delta (#)	Ratio	Days	Delta (AF)	Cost (AF per fish)
		From	To	Spawners	Escapement Cohort Prediction	Relative to Case 0	Relative to Case 0	HORB In	Relative to Case 0	Relative to Case 0
0	1,500	NA	NA	16,088	1,938	NA	NA	NA	NA	NA
1	2,500	1-Apr	30-Apr	16,088	6,359	4,420	3.3	30	59,504	13.5
2	5,000	1-Apr	30-Apr	16,088	6,771	4,833	3.5	30	208,264	43.1
3	10,000	1-Apr	30-Apr	16,088	7,672	5,734	4.0	30	505,785	88.2
4	2,500	1-Apr	15-May	16,088	7,864	5,926	4.1	45	89,256	15.1
5	5,000	1-Apr	15-May	16,088	8,562	6,624	4.4	45	312,397	47.2
6	10,000	1-Apr	15-May	16,088	10,136	8,198	5.2	45	758,678	92.5
7	2,500	1-Apr	30-May	16,088	9,958	8,019	5.1	60	119,008	14.8
8	5,000	1-Apr	30-May	16,088	11,076	9,137	5.7	60	416,529	45.6
9	10,000	1-Apr	30-May	16,088	13,677	11,739	7.1	60	1,011,570	86.2

Conclusions

- Empirical positive relationship of average spring flow and the estimated number of Spring smolts that pass Mossdale per fish that spawned.
- Empirical positive relationship of concurrent Mossdale flow and survival of smolts from Mossdale to Chipps from release-capture experiments. Association strongly affected by HORB status.
- Work to be done - 1) using more refined RST data, 2) more refined flow/temperature data, 3) using statistical methods to simultaneously estimate parameters of model, 4) getting proper statistical inference on these estimates, ...

Next Generation-V.2.0.



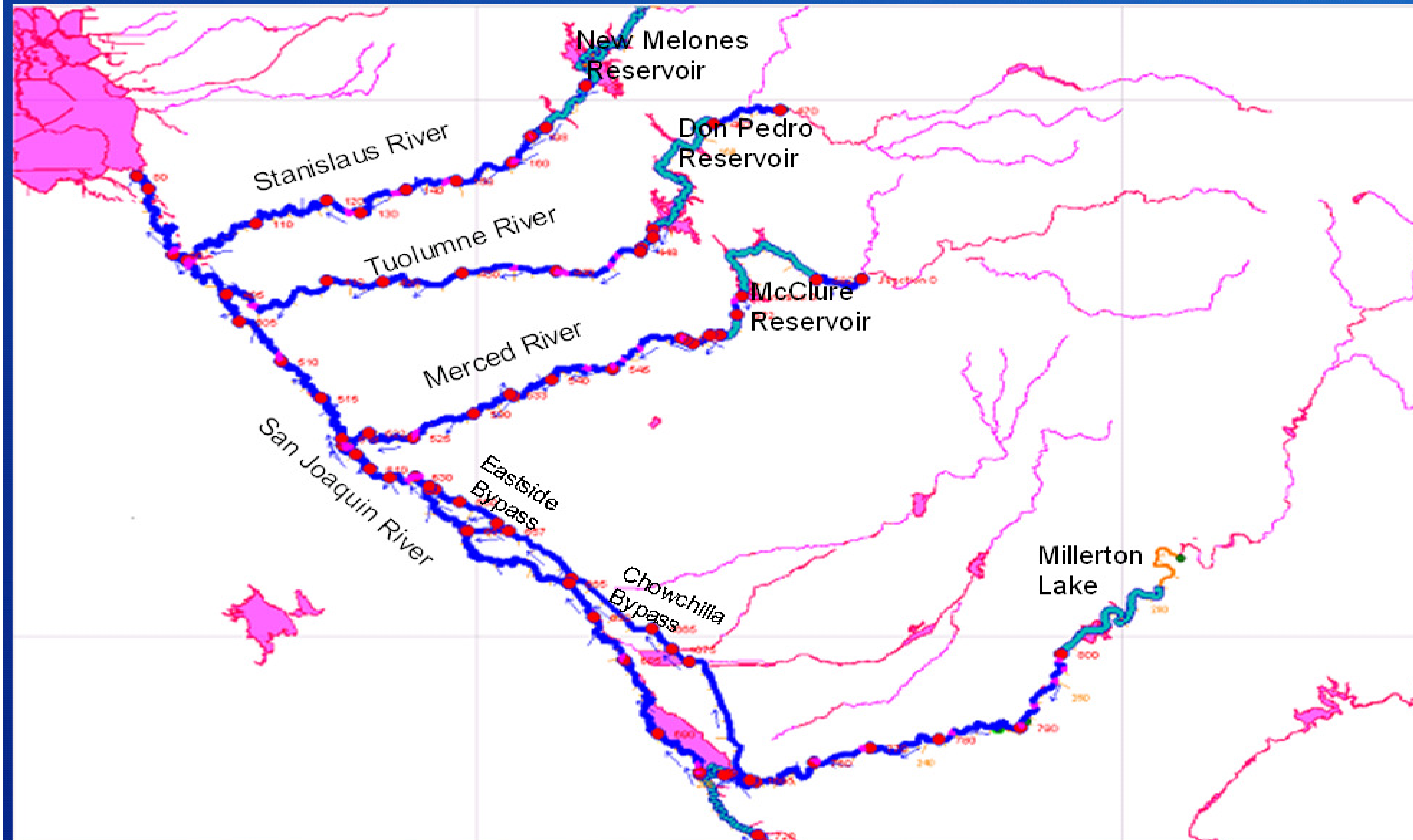

SJR Model Version 2.0
Keswick Dam
Clear Creek
Cottonwood Creek
Mill
Relevant Management Questions
Q: Which Ecosystem most limiting?
Q: Which Parameter most limiting?
Q: Which action(s) most likely result
in substantial production gains?
See Report for details
American River
Mokelumne River
Stanislaus River
Tuolumne River
Merced River
Delta
Ocean
Inland
SAN JOAQUIN RIVER

Water Temperature

- H20 Temperature: Emerging issue in SJR basin
  - Cooler H20 Temps associated with smolt higher survival
  - Higher trib and delta flows associated with cooler H20 temps
- Water Temp Model:
  - Benefits vs cost

SJR Basin-Wide Water Temperature Model

Covers Main-Stem SJR and all Main Reservoirs and Tributaries in the Basin



SJR Basin-Wide Water Temperature Model

- **CALFED (ERP) Sponsored Model**
- **Simulates System Operation (daily) and Computes Temperature Response in Reservoirs and Streams (sub-daily (6hr)).**
- **Both Long-Term and Short-Term Water Temperature Management planning Tool.**
- **Approved by Most SJR Stakeholders.**
- **Already being Used (e.g., Stanislaus Operation, Friant Restoration, CVRWQB 303(d) Listing Proceedings).**

Conclusion

- **Model one of many tools**
- **CDFG offering tool to SWRCB to make informed decisions**
  - **Fish & flow empirical relationship**
  - **Tributary and Delta connectivity**
- **CDFG offering SWRCB assistance**
  - **Use model**
  - **Adapt model for SWRCB needs**
- **Model refinement continues with next version due in 2009**

Thank You