Fish Simulation Models for Evaluating Water Project Operations and Habitat Enhancements

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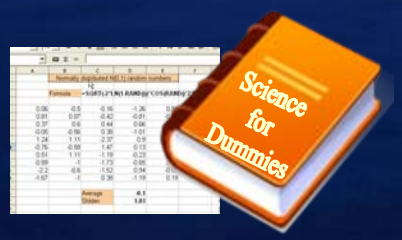
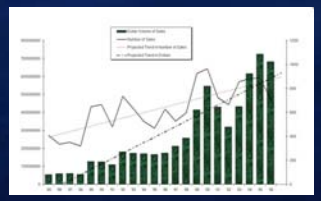
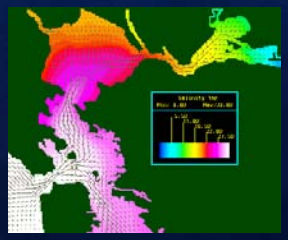
Funded by
Department of Water Resources
Metropolitan Water District
State Water Contractors

The Ecological Detective Process







(1)
Collect Information

Empirical data
Physics
Ecological theory

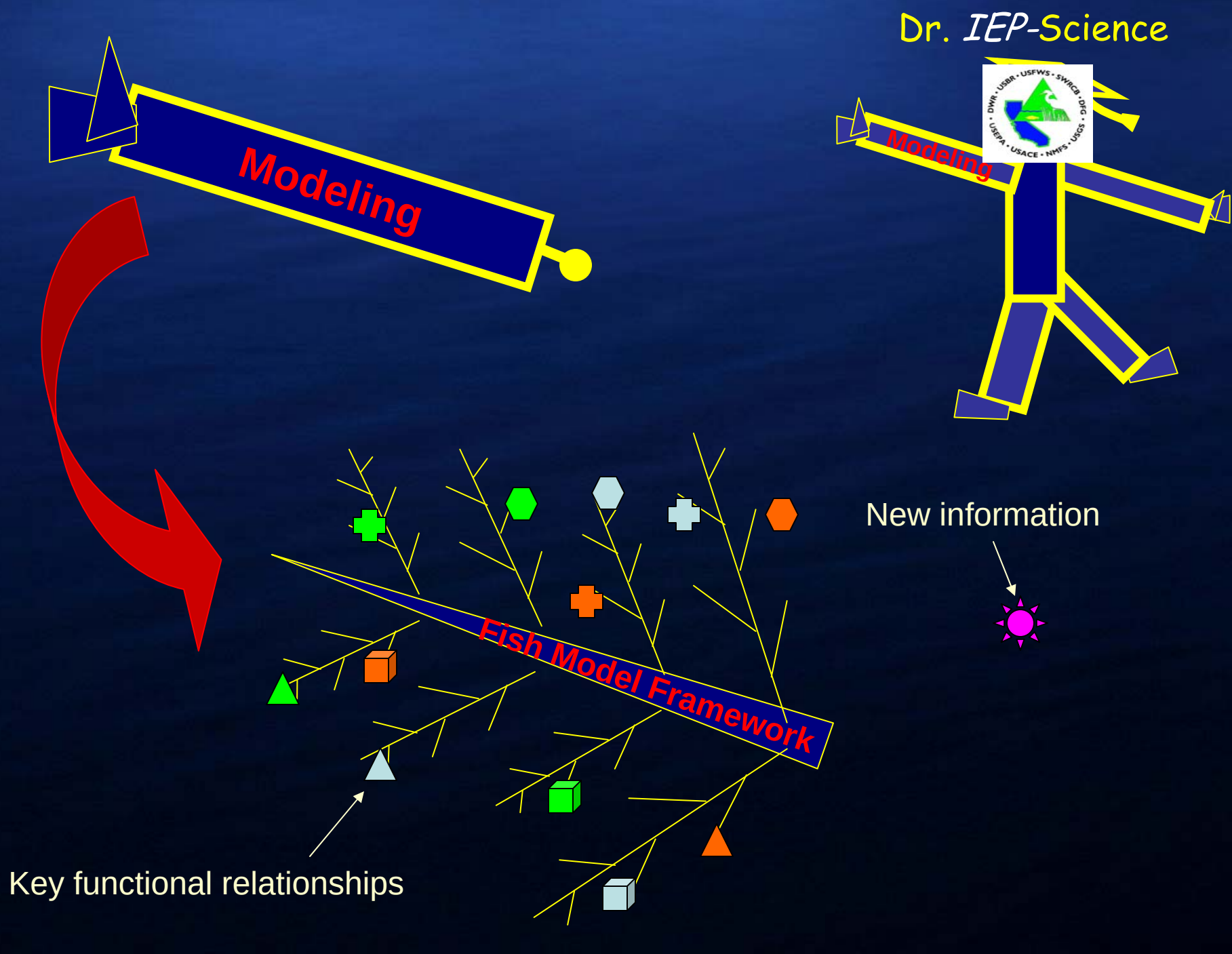
(2)
Analyze & Summarize Data

Descriptive
Estimation methods
Conceptual models

(3)
Develop and Apply Simulation Models

***Hydro Examples**:*
CALSIM, DSM2, PTM, TRIM

***Fish Examples**:*

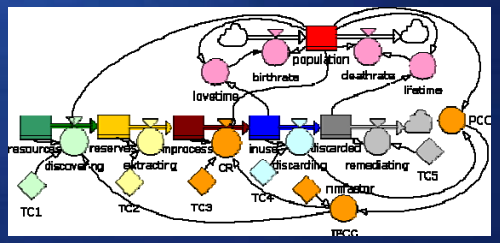

Dr. IEP-Science
Modeling
Modeling
Fish Model Framework
New information
Key functional relationships

$$L\left(\theta \mid R_k, n_j\right) \propto \prod_{j=1}^{912} \pi_j^{n_j}$$

Statistical Models

- Parameter values obtained by fitting model to available historic data
- Fewer parameters
- Identify critical factors driving past population trends, provide “real world” predictions
- Static

Examples:
Jolly-Seber mark-recapture
generalized linear
Bayesian nonlinear hierarchical



Simulation Models

- Parameter values based on empirical, statistical, and theoretical data
- More parameters
- Experimental system, compare relative performance of simulated management actions
- Adaptable, modular

Examples:
bioenergetics
predator-prey
Individual-oriented life cycle

Key Fish Modeling Concepts

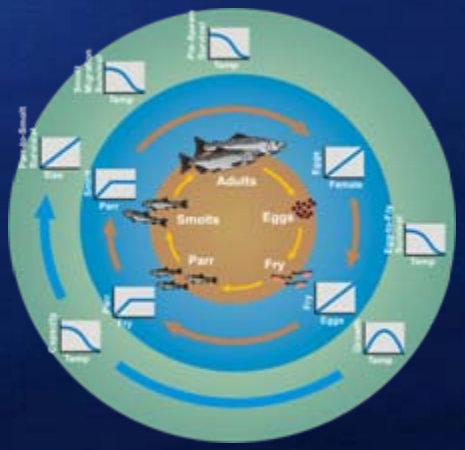
Purpose of fish simulation models:

- Formalize and clarify thinking
- Allow comparison (relative) between alternative management actions
  - ***not*** precise predictions

Some attributes of useful fish simulation models:

- Intuitive: Use available fish data and functional relationships familiar to biologists
- Mechanistic: Emphasize dynamic response of fish to alternative management scenarios
- Transparent: Model logic and functional relationships accessible, no black box
- Adaptive: Model can easily adapt as new information becomes available

Life Cycle Modeling

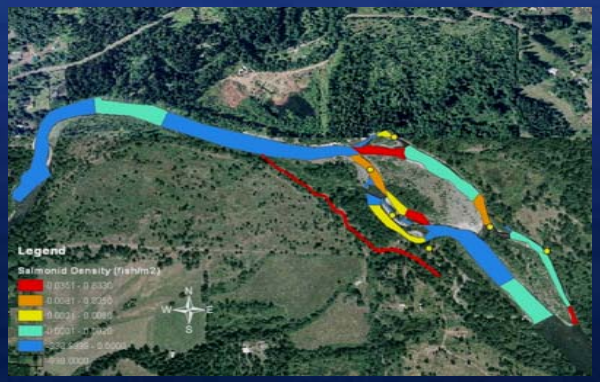


- An Individual-oriented model (but not IBM)
- Assimilates available information, integrates effects across life stages and through years

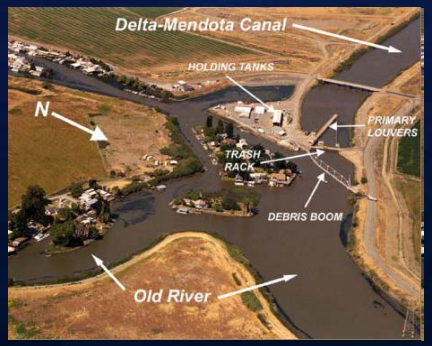
- Winter run Chinook IOS (Interactive Object-oriented Simulation)
  - Developed for DWR Offstream Storage Evaluations, applied to the 2008 OCAP Biological Assessment
  - Operates on daily flows (CALSIM) and daily temperatures (USBR temperature model)

Fish Simulation Modules

habitat capacity



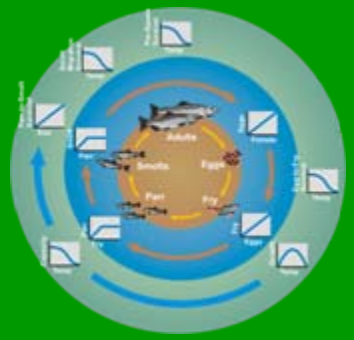
smolt mortality (Delta)



steelhead anadromy

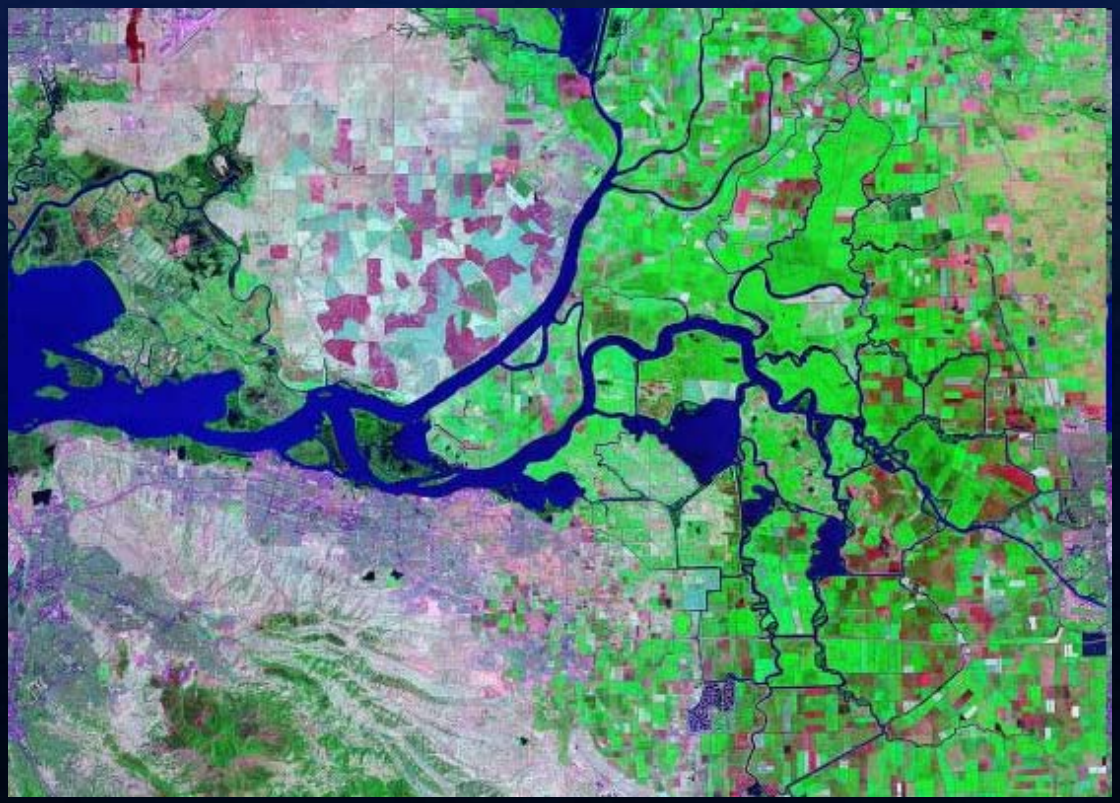
Integrated Life Cycle Model

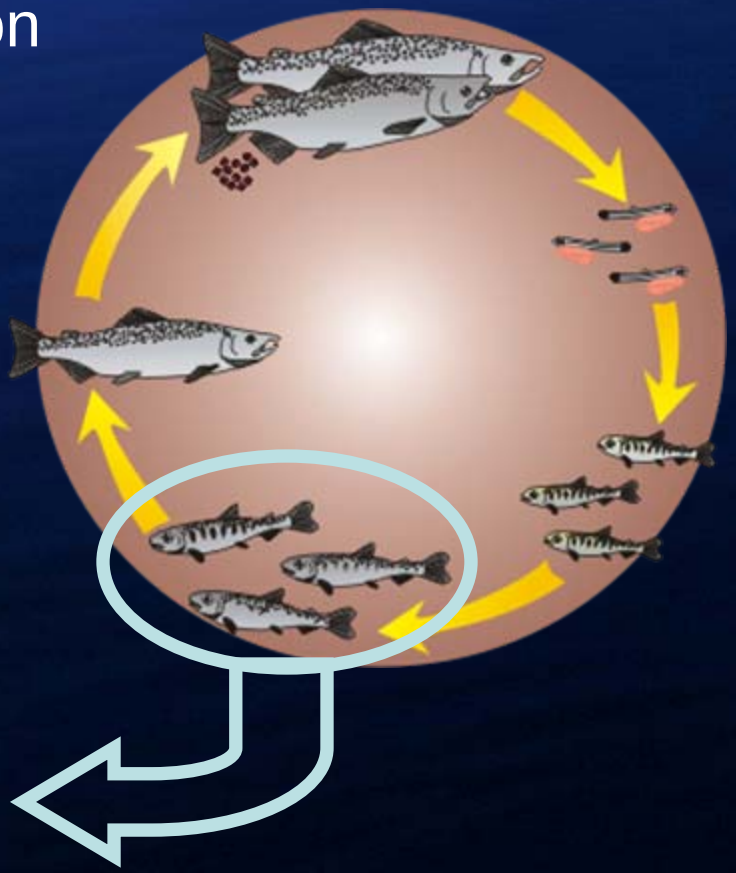
IOS



Delta Passage Model (DPM)

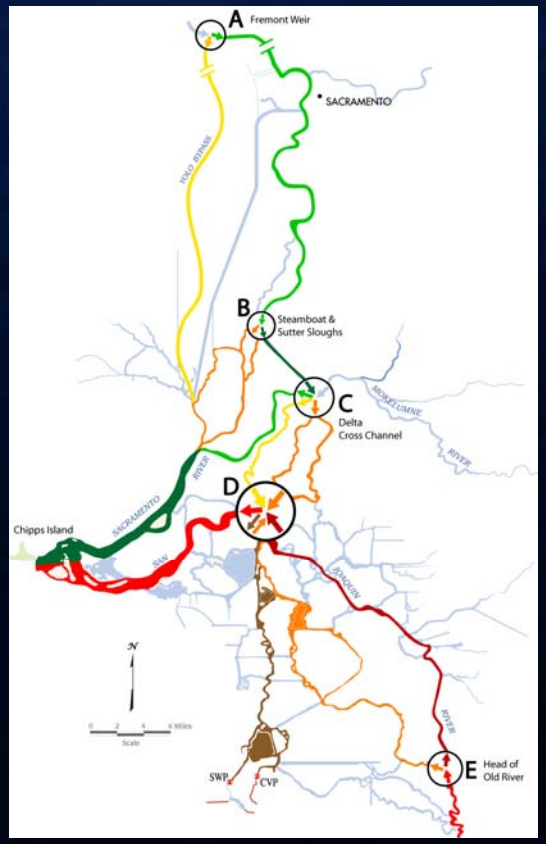
A simulation tool for understanding, exploring, and comparing Delta salmon migration as a function of alternative management scenarios





DPM Physical Input Parameters

- Reach specific flow (daily, averaged from DSM2)
- Delta Cross Channel position (daily)
- Exports (daily)
- Options
  - Yolo Bypass pathway
  - Hood Diversion
  - Other new barriers, major diversions



Key DPM Assumptions

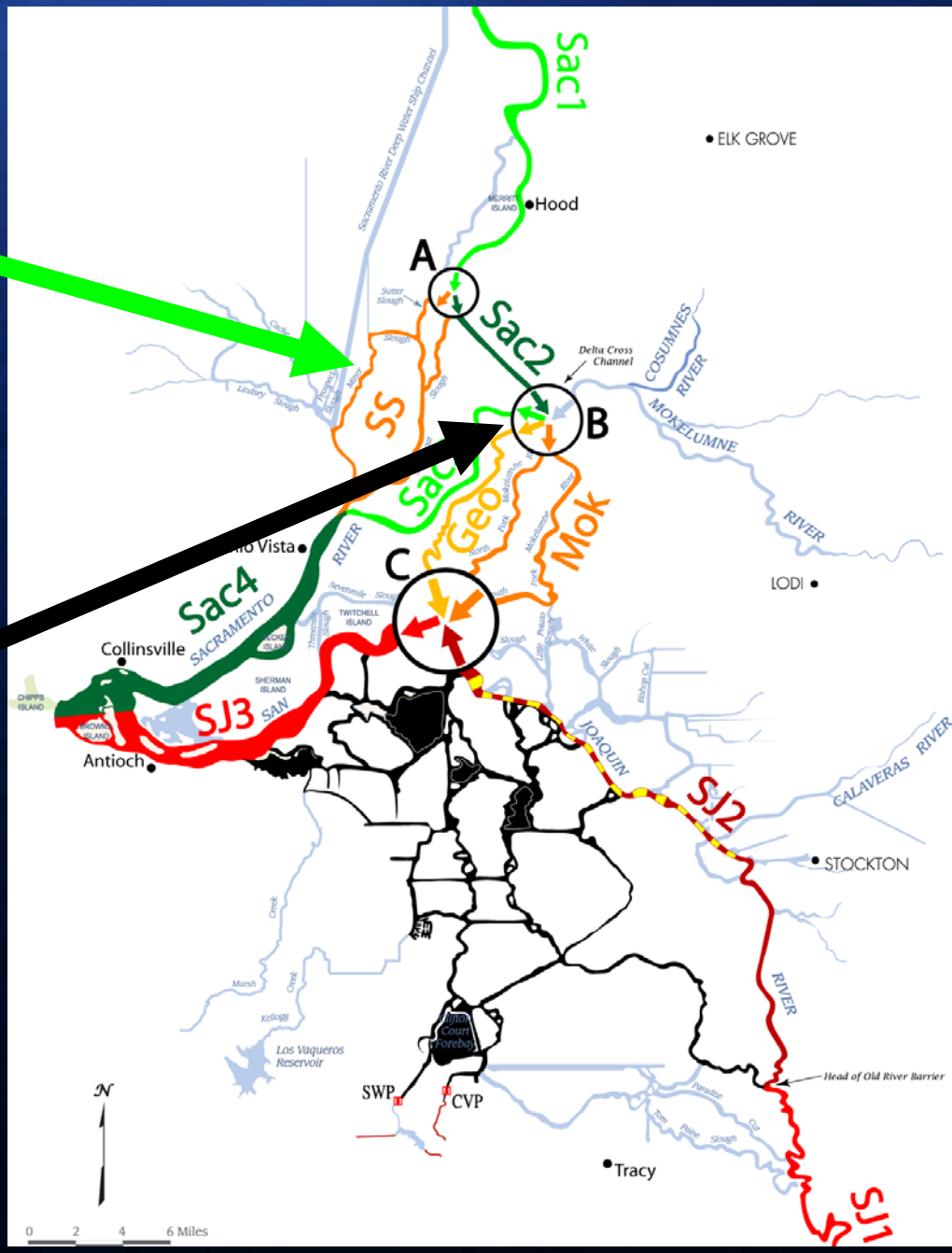
- DSM2 provides reasonable approximation of daily net flow conditions within specified reaches
- Tagged hatchery Chinook reasonably representative of wild origin, volitionally migrating Chinook smolts
- Detailed fish behavior (<1 day) not essential for assessing coarse patterns of movement and mortality
- Delta migration reasonably modeled as function of flow, gate operations, and exports
  - temperature, turbidity, salinity and other factors assumed to be constant

Reaches

- flow (DSM2)
- migration speed
- survival

Junctions

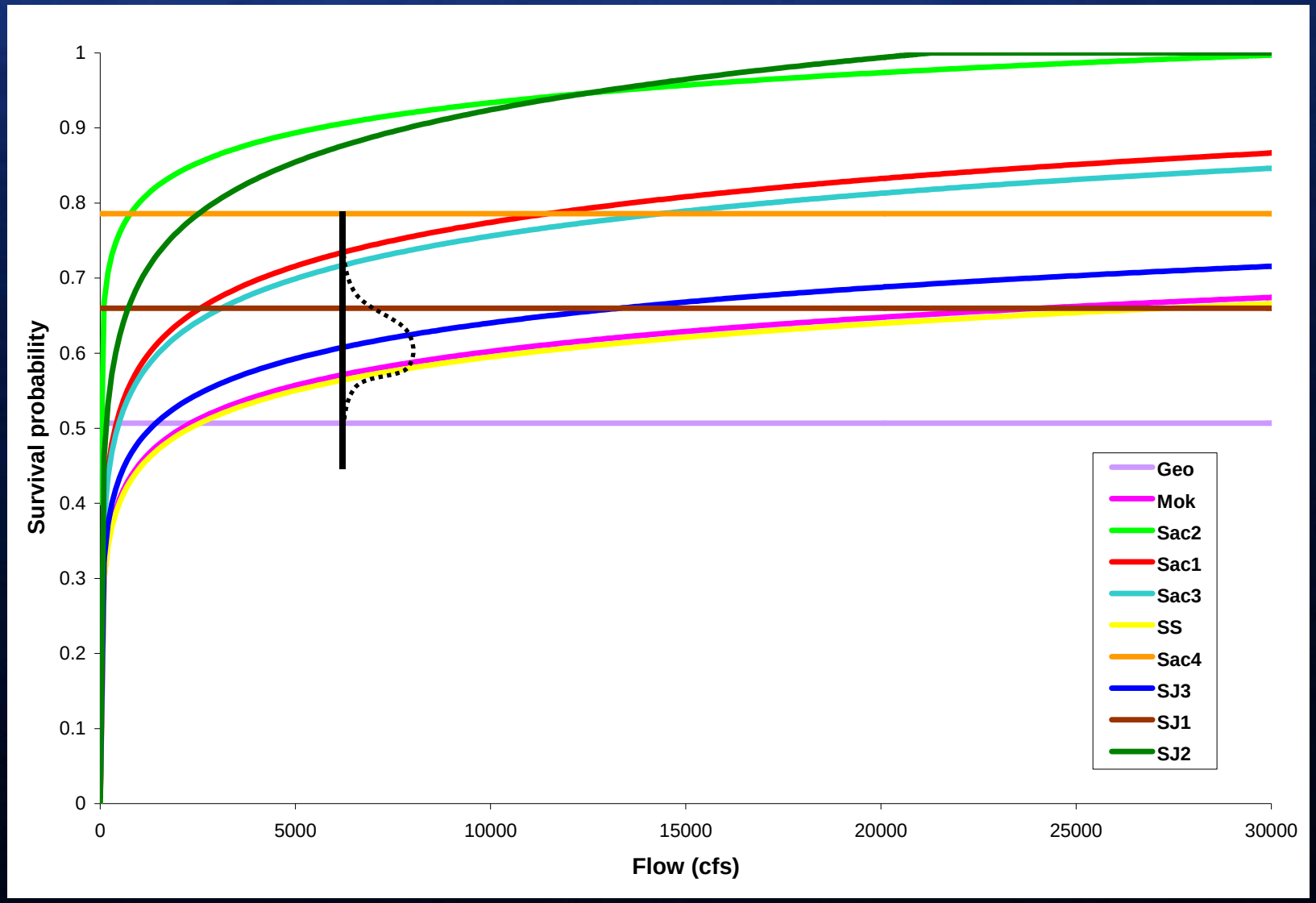
- flow splits (DSM2)
- ‘fish splits’



Critical DPM Information Sources

DPM Functional Relationships

Reach specific survival



DPM Functional Relationships

Fish behavior at flow splits

Perry & Skalski 2008

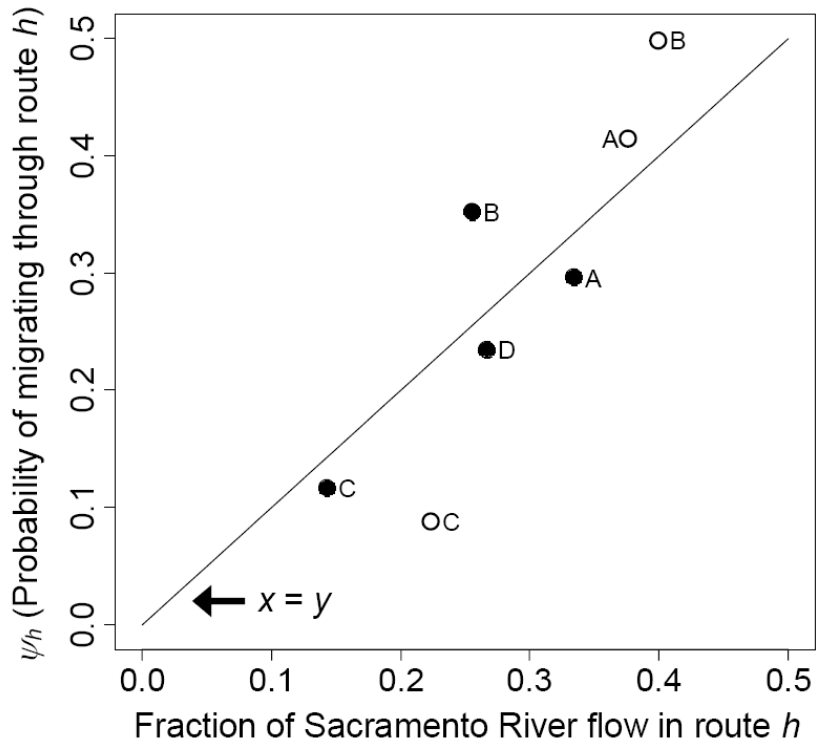
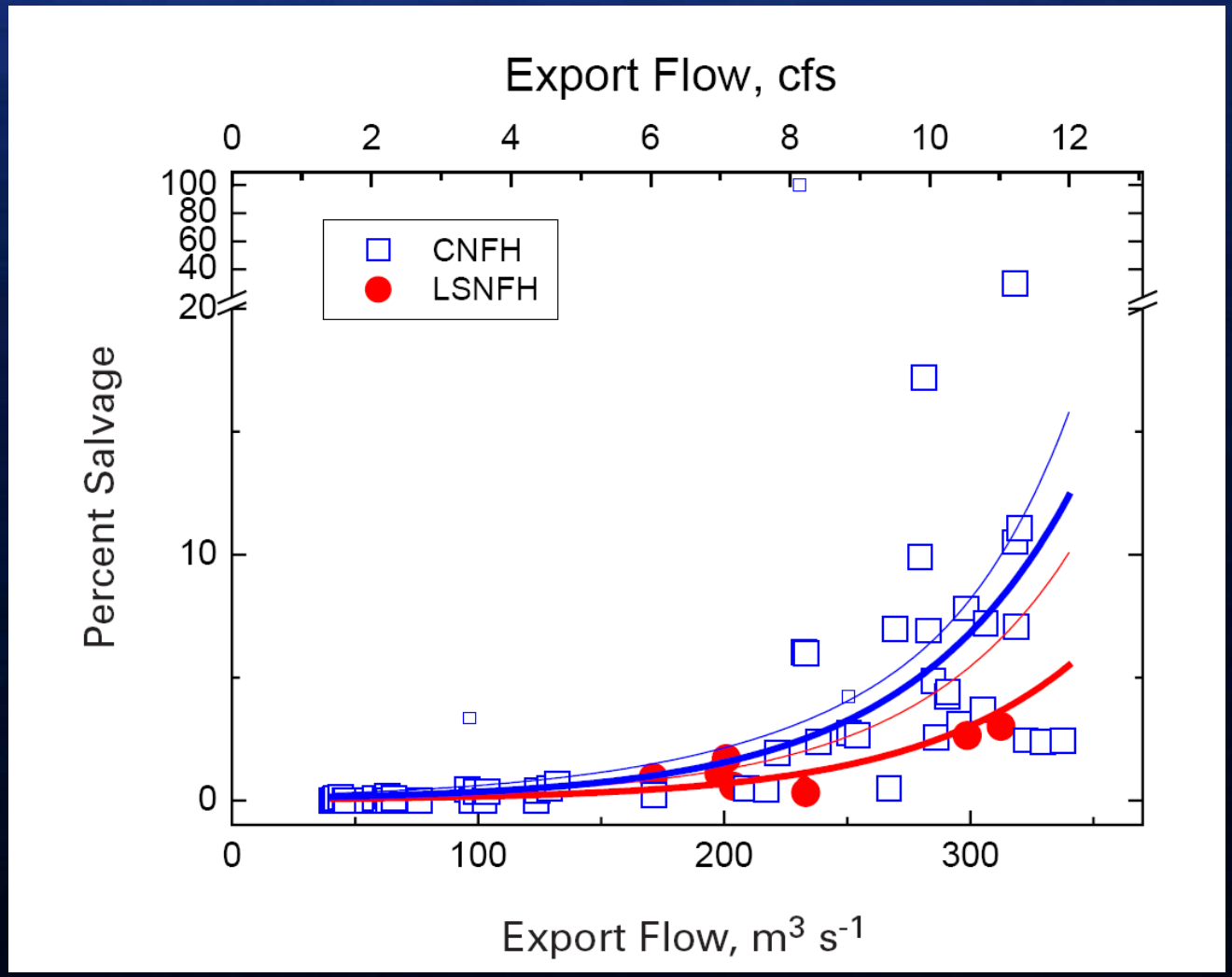


Figure 4.—The probability of migrating through route h (ψ_h) as a function of the proportion of total river flow in route h for tagged late-fall juvenile Chinook salmon released on 5 December 2006 (filled symbols) and 17 January 2007 (open symbols). Data labels A–D represent Steamboat and Sutter sloughs, the Sacramento River, Georgiana Slough, and the Delta Cross Channel, respectively. The reference line shows where the fraction migrating through each route is equal to the proportion of flow in each route.

DPM Functional Relationships

Direct export mortality

Kimmerer 2008



GoldSim Pro - Delta_Passage_10-16-08.gsm

File Edit View Graphics Model Run Help

Container Path: \

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Chinook Salmon Delta Passage Model *Beta Version*

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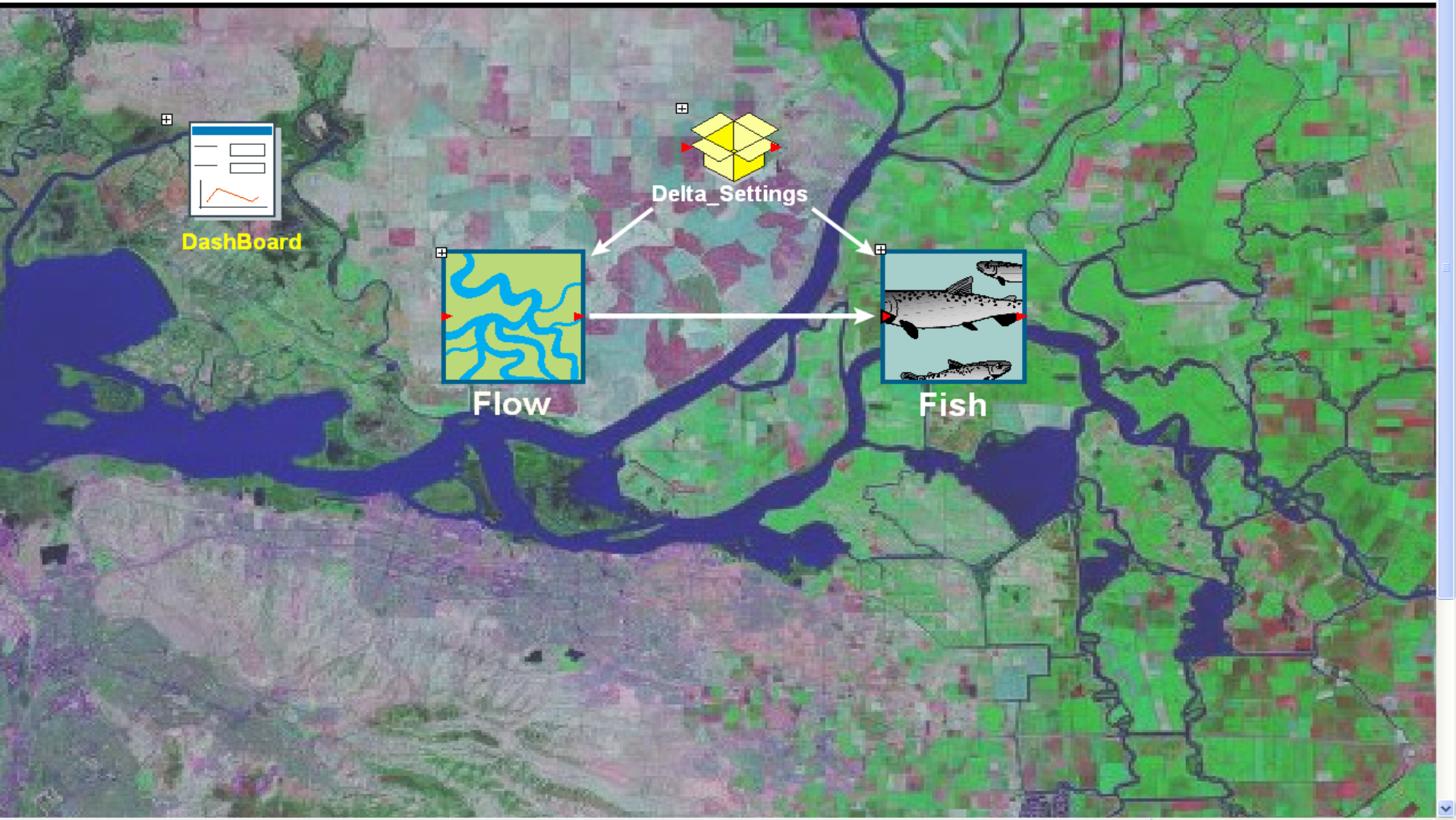

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Scale: 95% | Filter ON | Edit Mode

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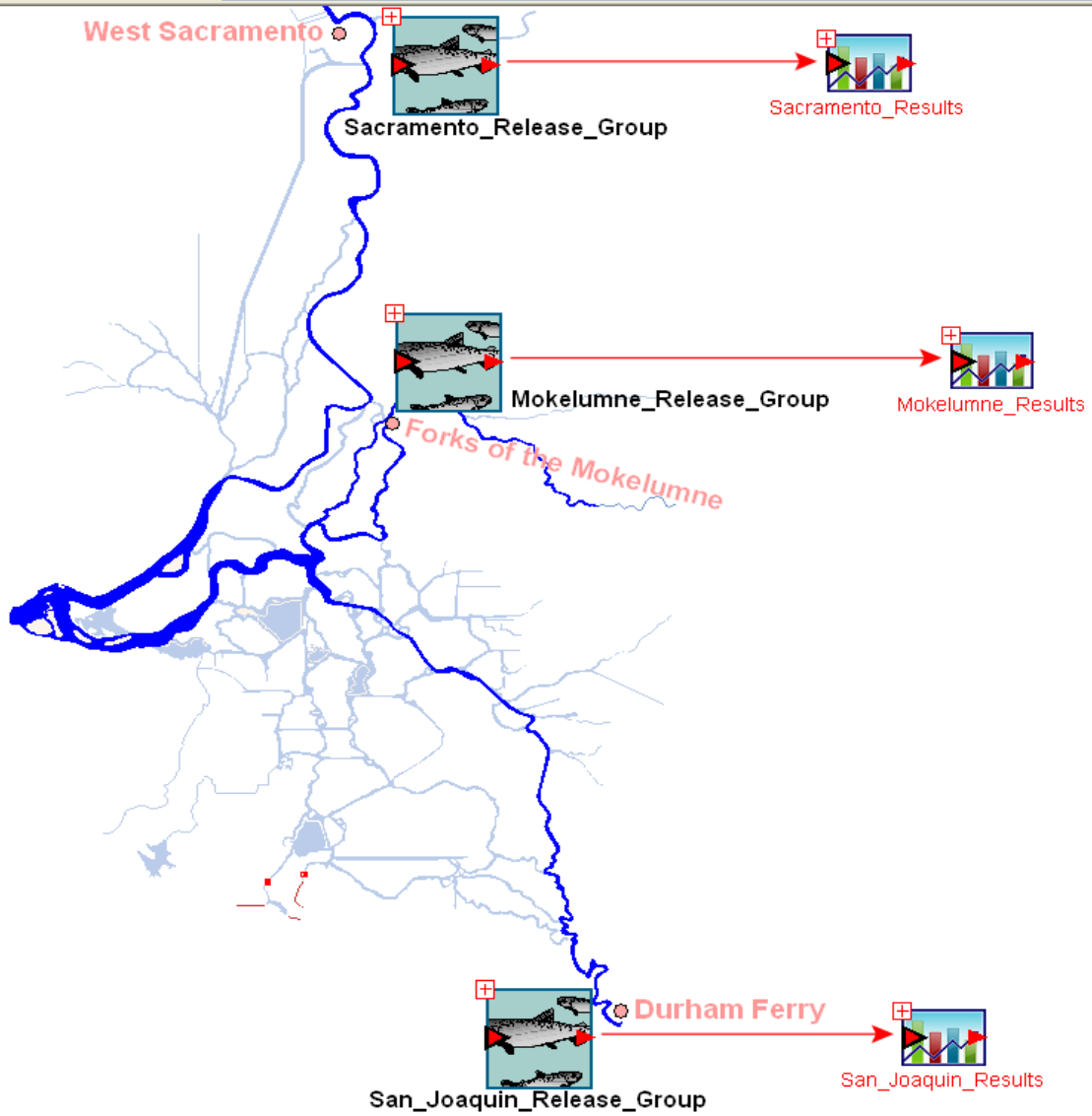

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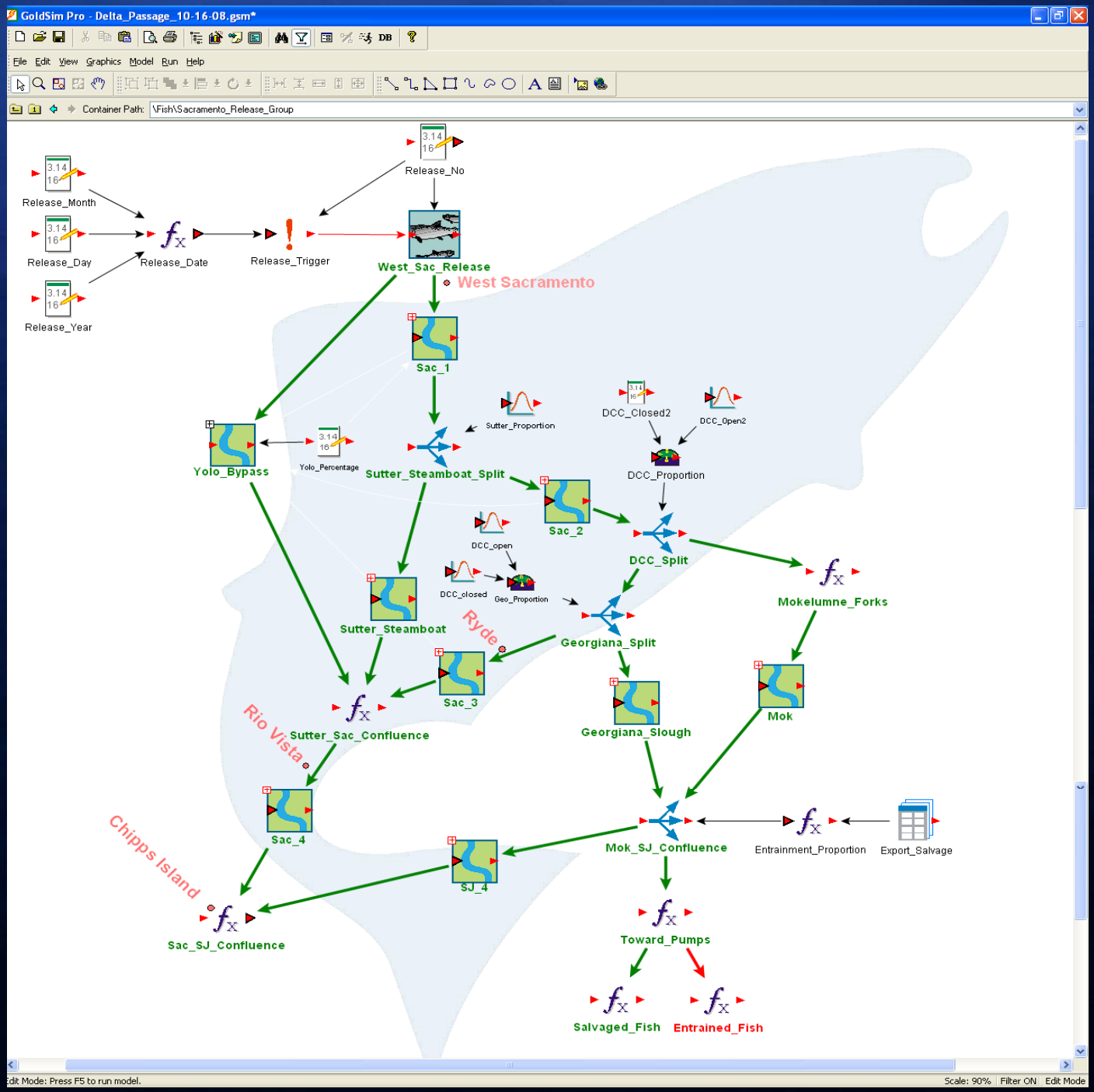
GoldSim Pro - Delta_Passage_10-16-08.gsm*
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Release_Month
Release_Day
Release_Year
Release_Date
Release_Trigger
Release_No
West_Sac_Release
West Sacramento
Sac_1
Yolo_Bypass
Yolo_Percentage
Sutter_Proportion
Sutter_Steamboat_Split
DCC_Closed2
DCC_Open2
DCC_Proportion
Sac_2
DCC_open
DCC_closed
Geo_Proportion
DCC_Split
Mokelumne_Forks
Sutter_Steamboat
Ryde
Georgiana_Split
Sac_3
Sutter_Sac_Confluence
Georgiana_Slough
Mok
Rio Vista
Sac_4
Mok_SJ_Confluence
Entrainment_Proportion
Export_Salvage
Chipps Island
SJ_4
Sac_SJ_Confluence
Toward_Pumps
Salvaged_Fish
Entrained_Fish
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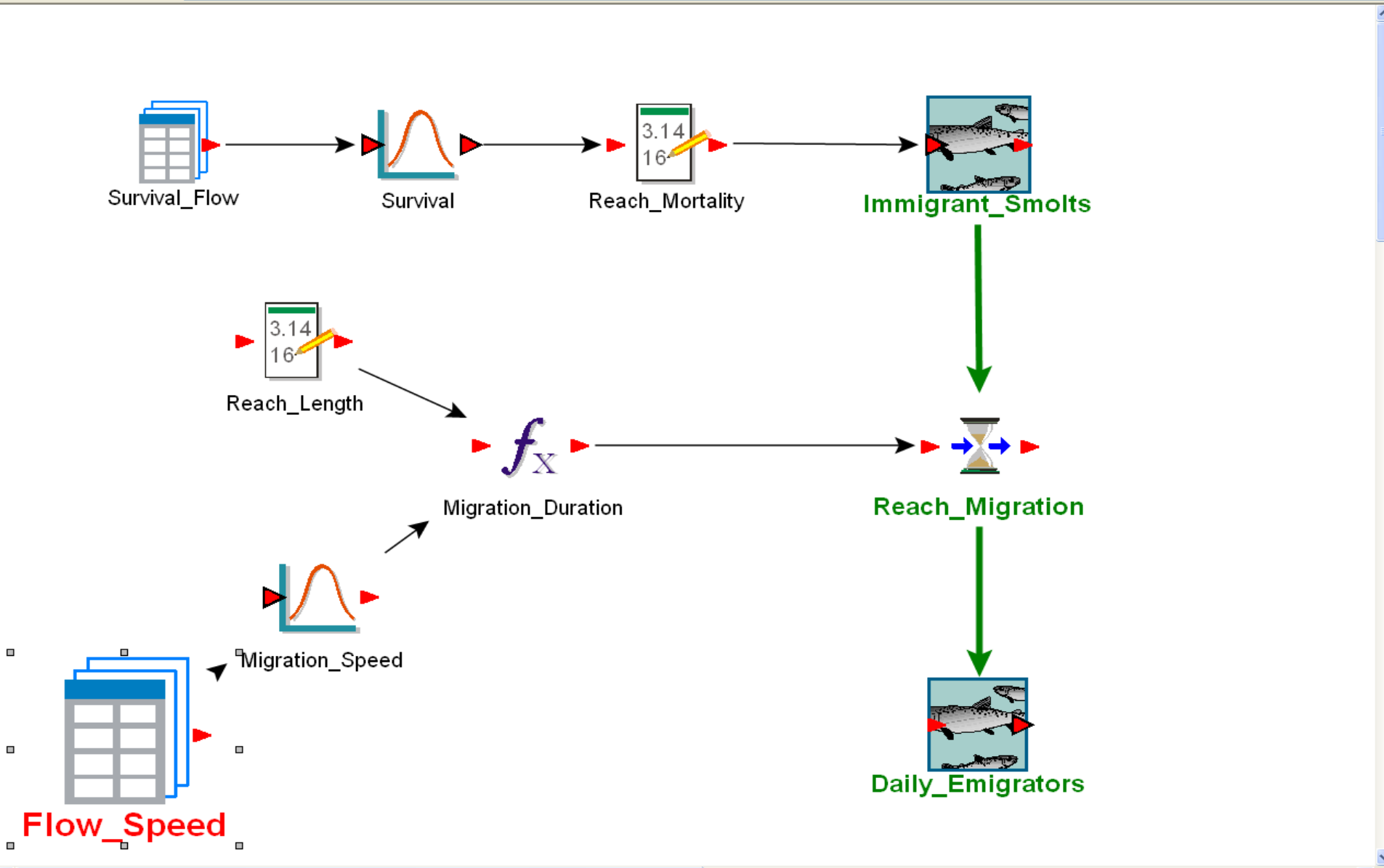

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Scale: 150% Filter ON Edit Mode

GoldSim Pro - Delta_Passage_10-16-08.gsm*

File Edit View Graphics Model Run Help

Container Path: \Fish\Sacramento_Release_Group\Sac_1

Survival_Flow

Survival

Reach

3.14
16

Reach_Length

Migration_Duration

Migration_Speed

Flow_Speed

Reach_Migration

Daily_Emigrators

Truncated Normal [PDF]

Normal Distribution

Parameters

☑ Truncated

Mean: Survival_Flow(Sac1)

Standard Deviation: .038776

Minimum: 0

Maximum: 1e10

Statistics

Mean:	0.030939
Std. Deviation:	Not available
Skewness:	Not available
Kurtosis:	Not available

30
20
10
0
0.00 0.05 0.10 0.15 0.20

☑ Fill Area ☐ Show Marker

Calculator

Cum. Probability:		Value:
0.5	<->	0.026154

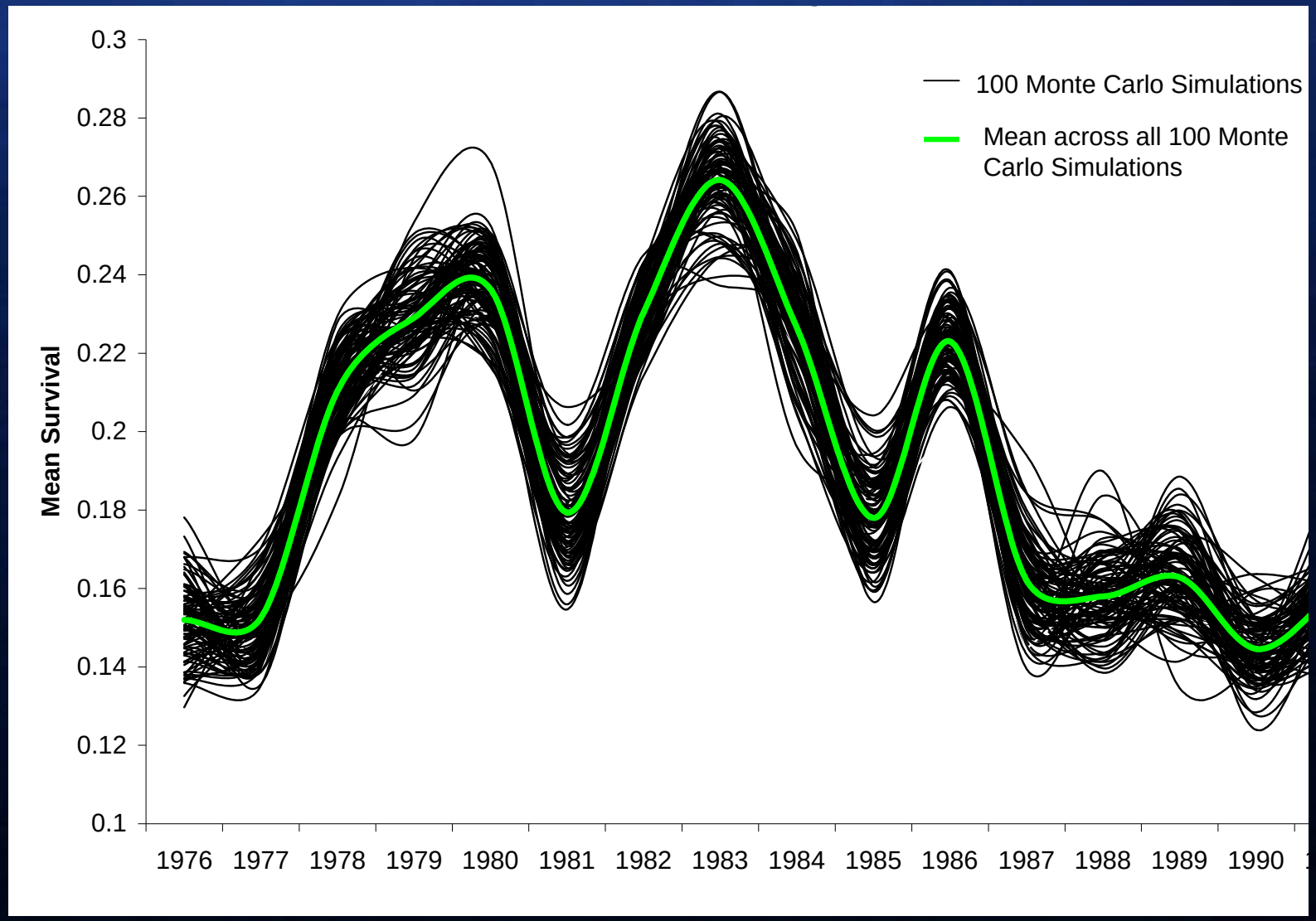
Probability Density:	16.3904
Cond. Tail Expectation:	0.0492884

OK Cancel Apply

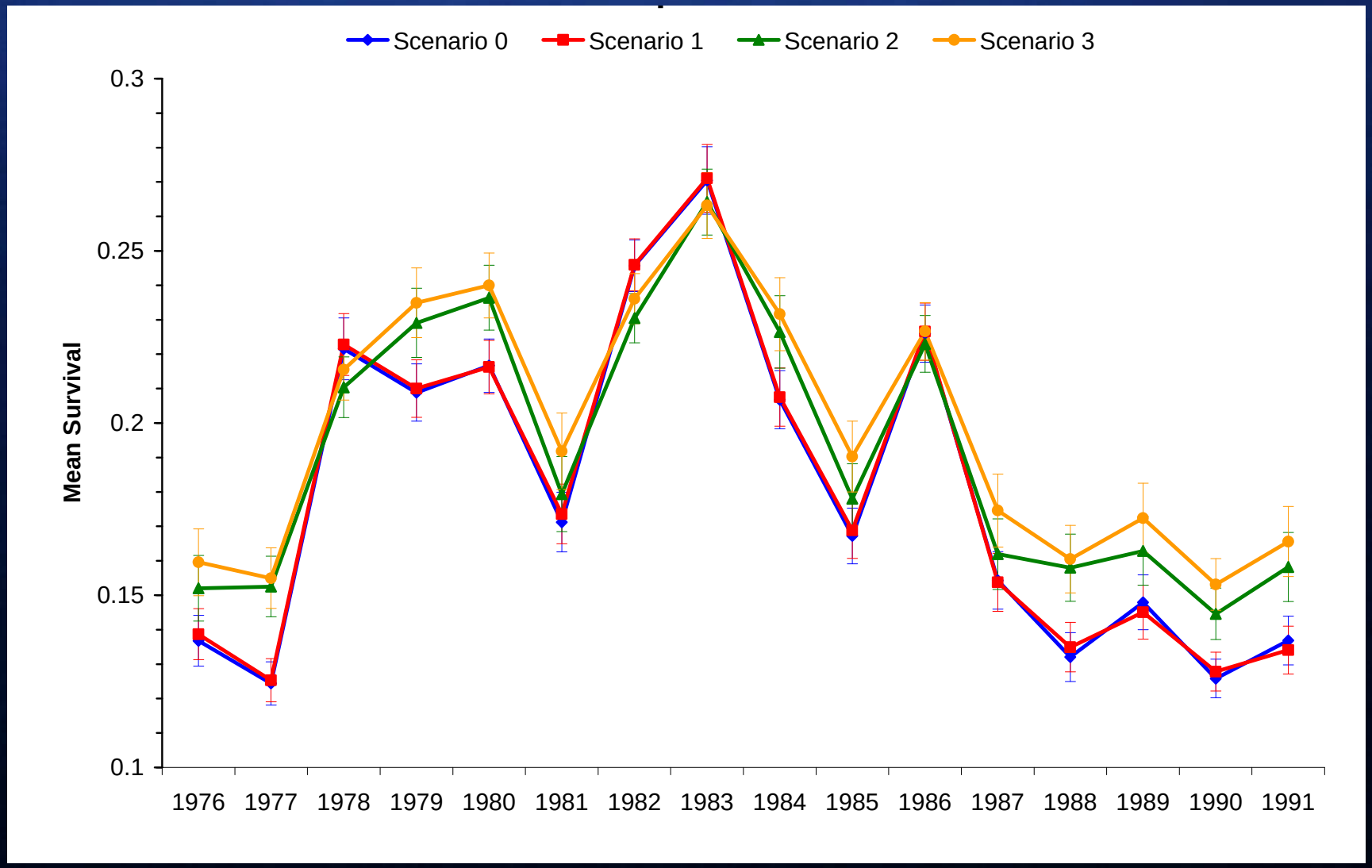
Edit Mode: Press F5 to run model.

Scale: 150% Filter ON Edit Mode

Example Application: Survival from Durham Ferry to Chips Island



Example Application: Alternative scenarios, survival from Durham Ferry to Chips Island



How do we know the simulation model is “right”?

- The fallacy of validation
- What can we do?
  - Calibrate and test model with empirical data
  - Carefully review and critique underlying logic
  - Explore and test model sensitivity
  - Include uncertainty in model

What next?

- Preparing manuscript describing model in detail and including thorough sensitivity analysis
- Expected near-term applications:
  - BDCP
  - OCAP Reasonable and Prudent Alternatives
  - North-of-Delta-Offstream-Storage (NODOS) Investigations
- Future fish mortality and migration studies