IOS: A modeling tool for evaluating environmental and water project effects on salmon populations

Funded by
Department of Water Resources
California Urban Water Agencies
Metropolitan Water District

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All Models Must Have Snappy Acronyms

Interactive Object-oriented Salmon Simulation (IOS)

Alternatives…

Object Oriented Population Simulation (OOPS)

Graphical Integrated Modeling Process (GIMP)

North-of-Delta-Offstream-Storage Project (NODOS)

- Increase water supply and reliability
- Improve Delta water quality
- Improve system flexibility
- Environmental benefits
  - Improve cold water reliability
  - Improve fish passage at RBDD
  - Reduce May-Sep agricultural diversions
  - Pulse flows

Artist's Conception of Sites Reservoir

NODOS Fish Modeling Needs

- **NODOS Project is complex**
  - Need a model integrating a diverse array of potential project effects (discharge, temperature, diversions, habitat improvements, fish passage)
- **Critical project attributes undefined, many alternative and competing project configurations**
  - Need tool to evaluate and compare NODOS operation and enhancement alternatives
- **Project effects may be gradual and may differ by location**
  - Need model that can capture temporal and spatial complexity
  - Need a model than can evaluate long term, cumulative effects of potential NODOS actions

Don’t we have reliable fish modeling tools?

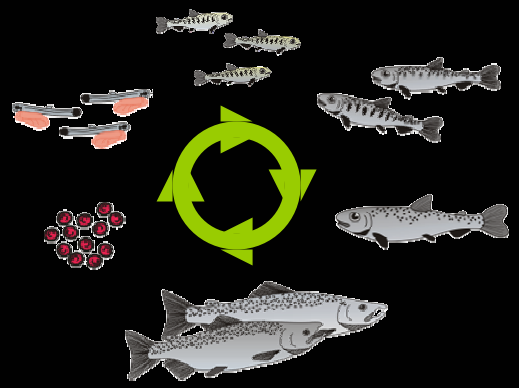
Some fish modeling tools are available, but generally suffer from one or more significant deficiencies

- Most models emphasize physical factors and do not represent best available ecological data (e.g. PHABSIM)
- Most models are a “black box” (e.g. SALMOD)
- Most models are built by modelers (not biologists)
- Most models provide an answer, but no context
  - population effects? cumulative effects? uncertainty?

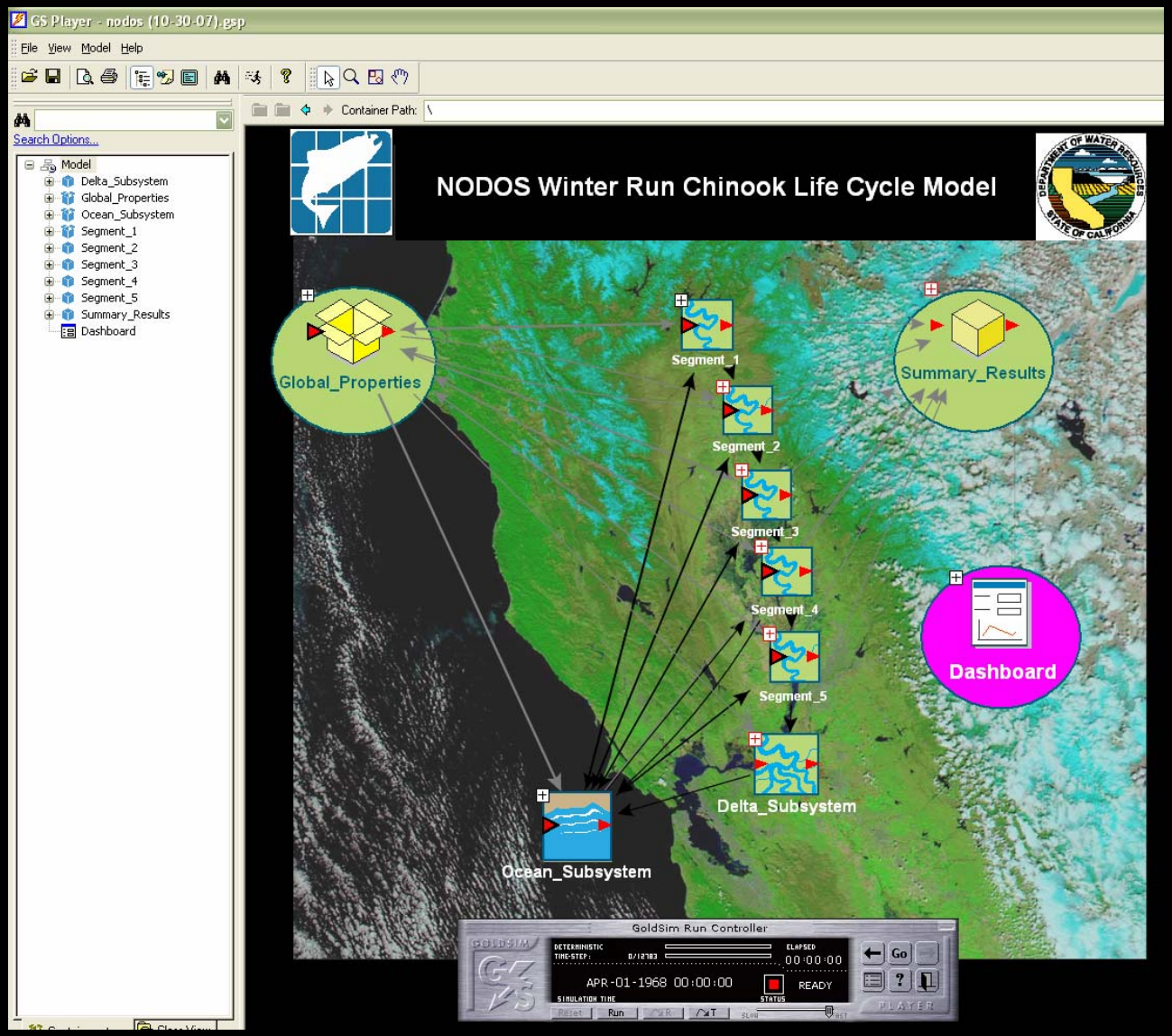
Life Cycle Modeling Framework Guidelines

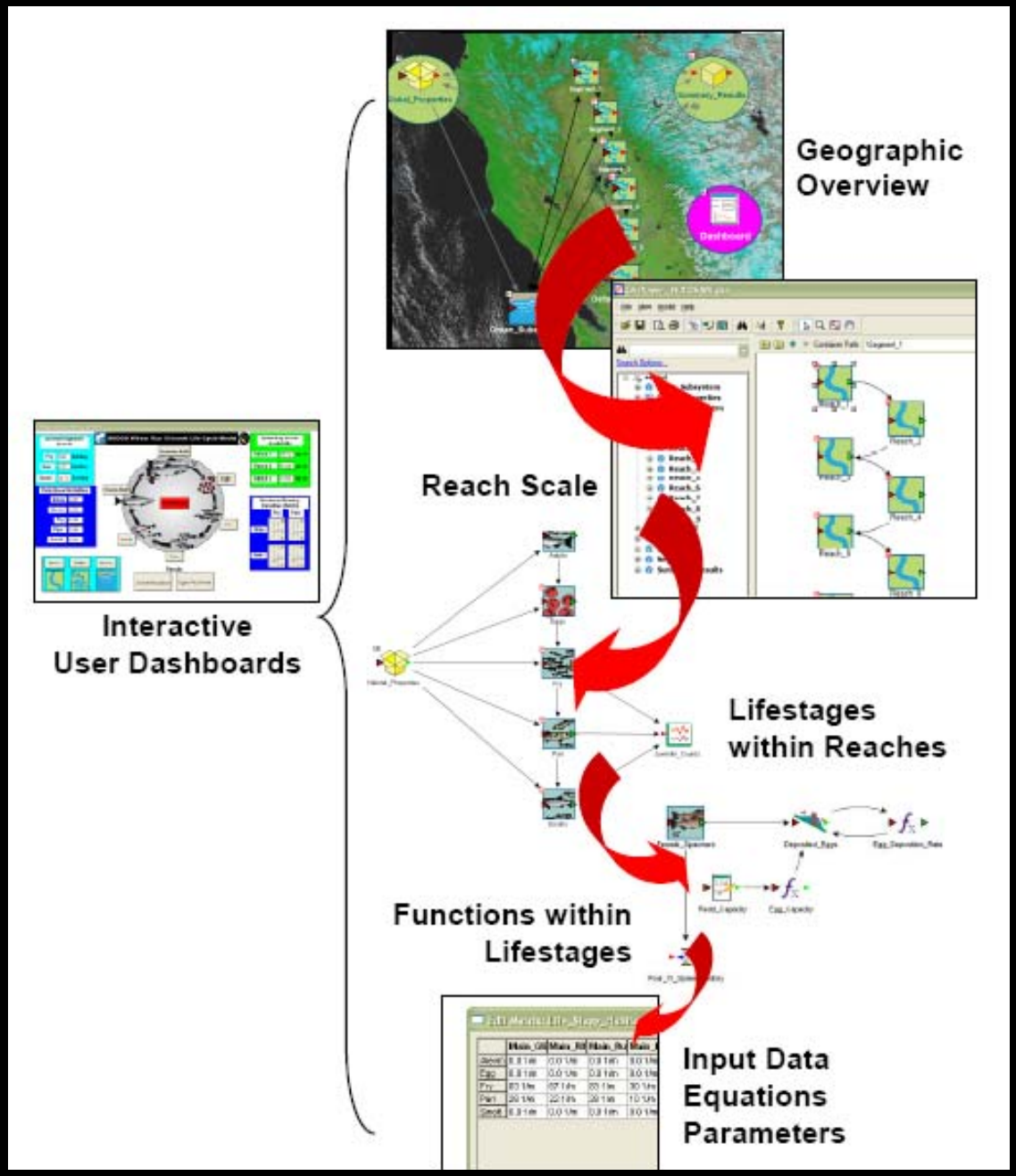
- Build on Existing Analytical Foundations
- Rely on Demonstrated Cause-Effect Relationships
- Use Readily Available Data
- Focus on Key Factors

Life Cycle Modeling



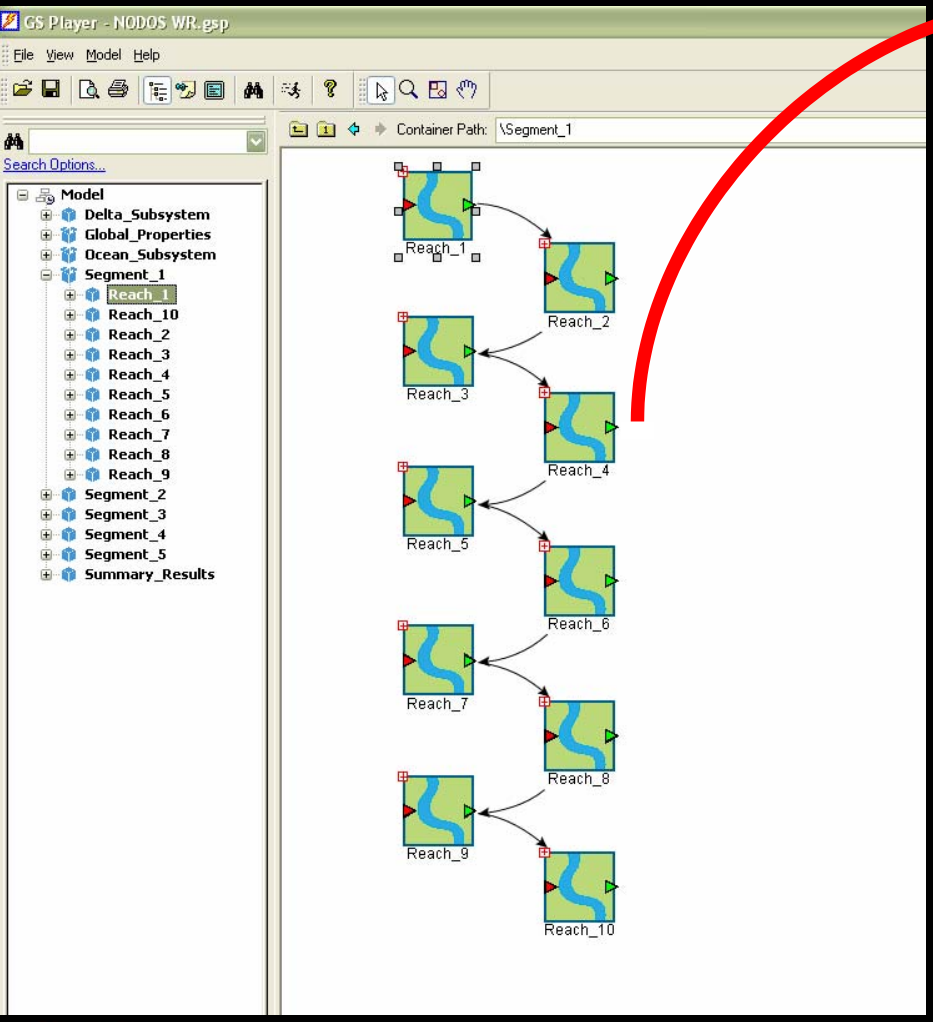
IOS Model: Geographic Overview

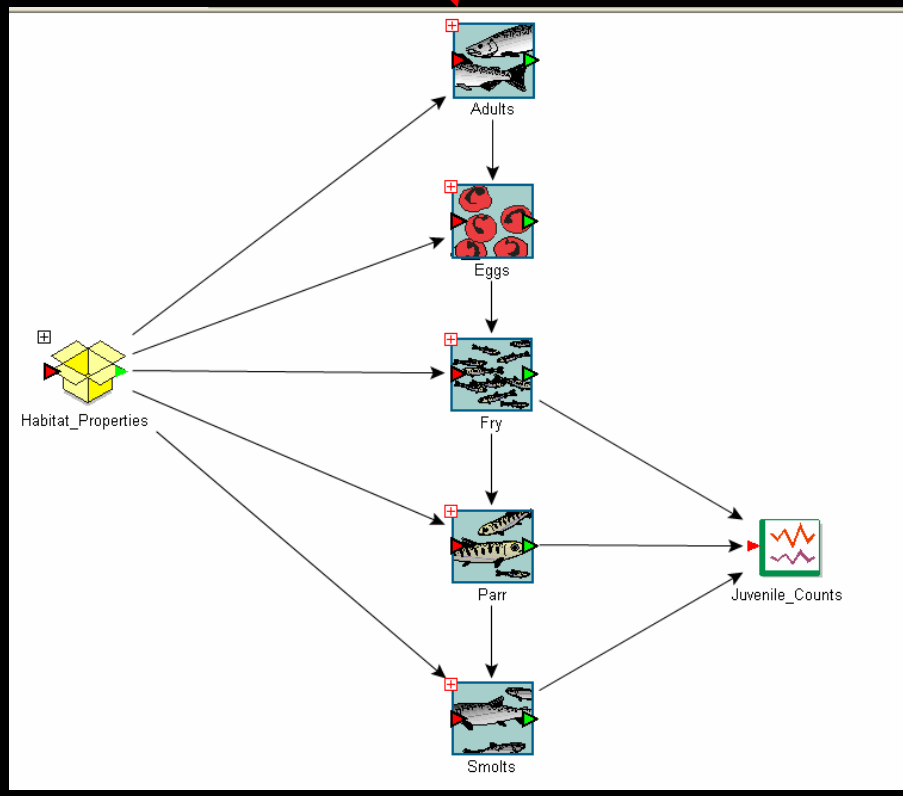



Geographic Overview
Reach Scale
Interactive User Dashboards
Lifestages within Reaches
Functions within Lifestages
Input Data
Equations
Parameters

IOS Model: Life stages within reaches

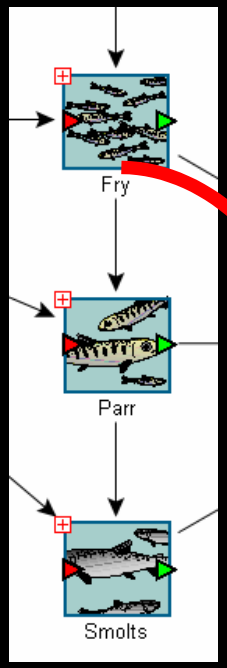
View within Segment 1 “container” (Reaches 1-10)



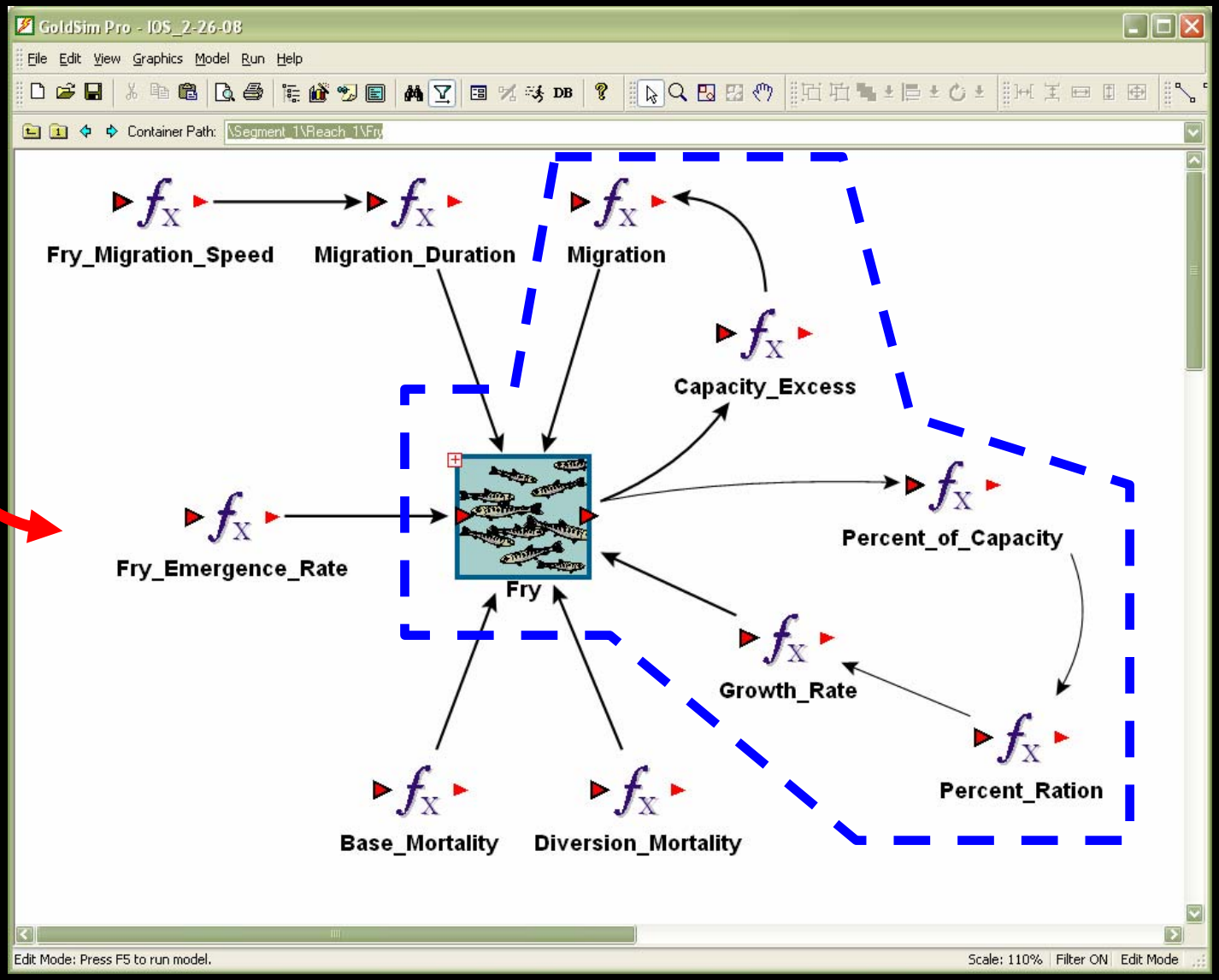


View within a reach “container”

IOS Model: Fry rearing

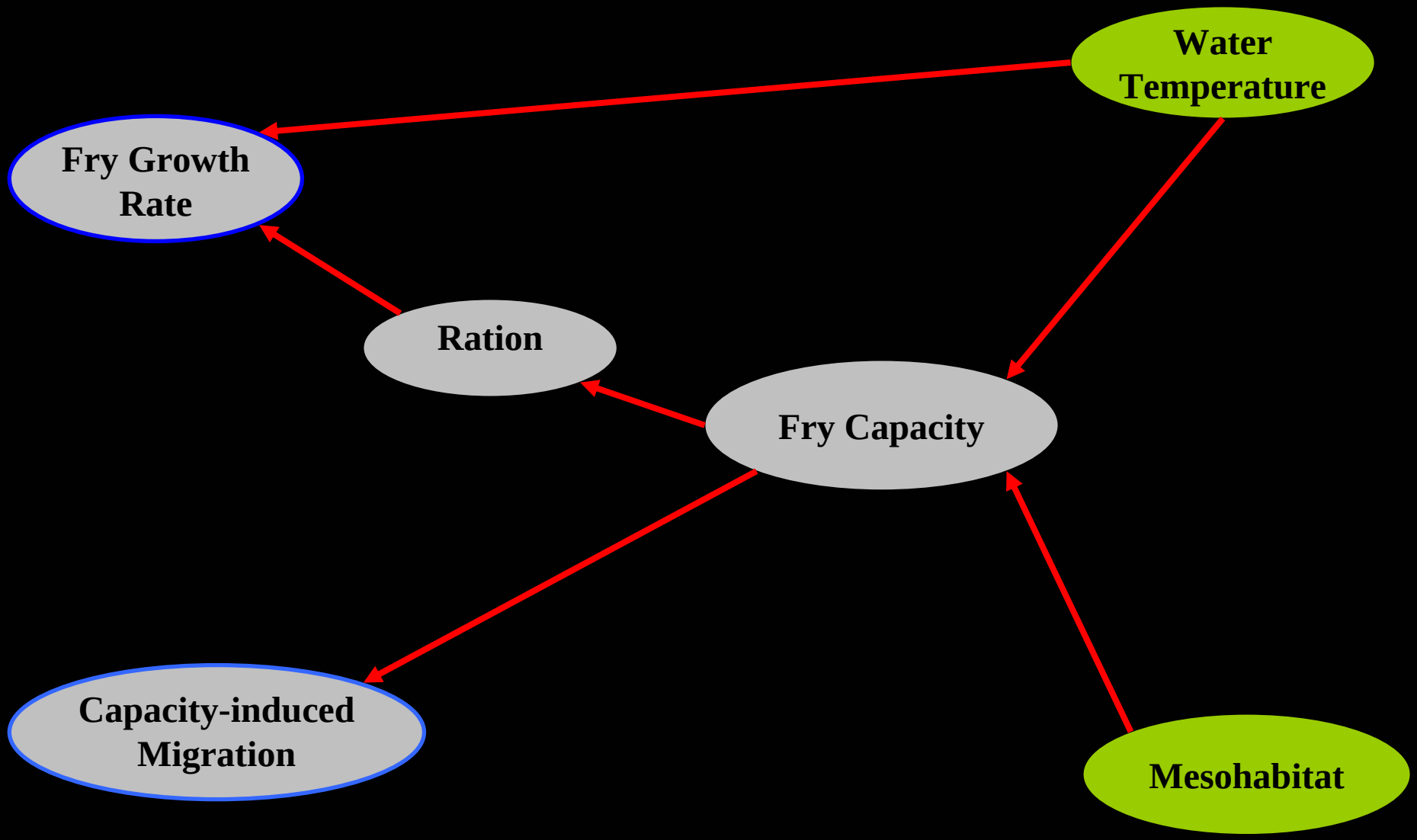


Juvenile salmon containers



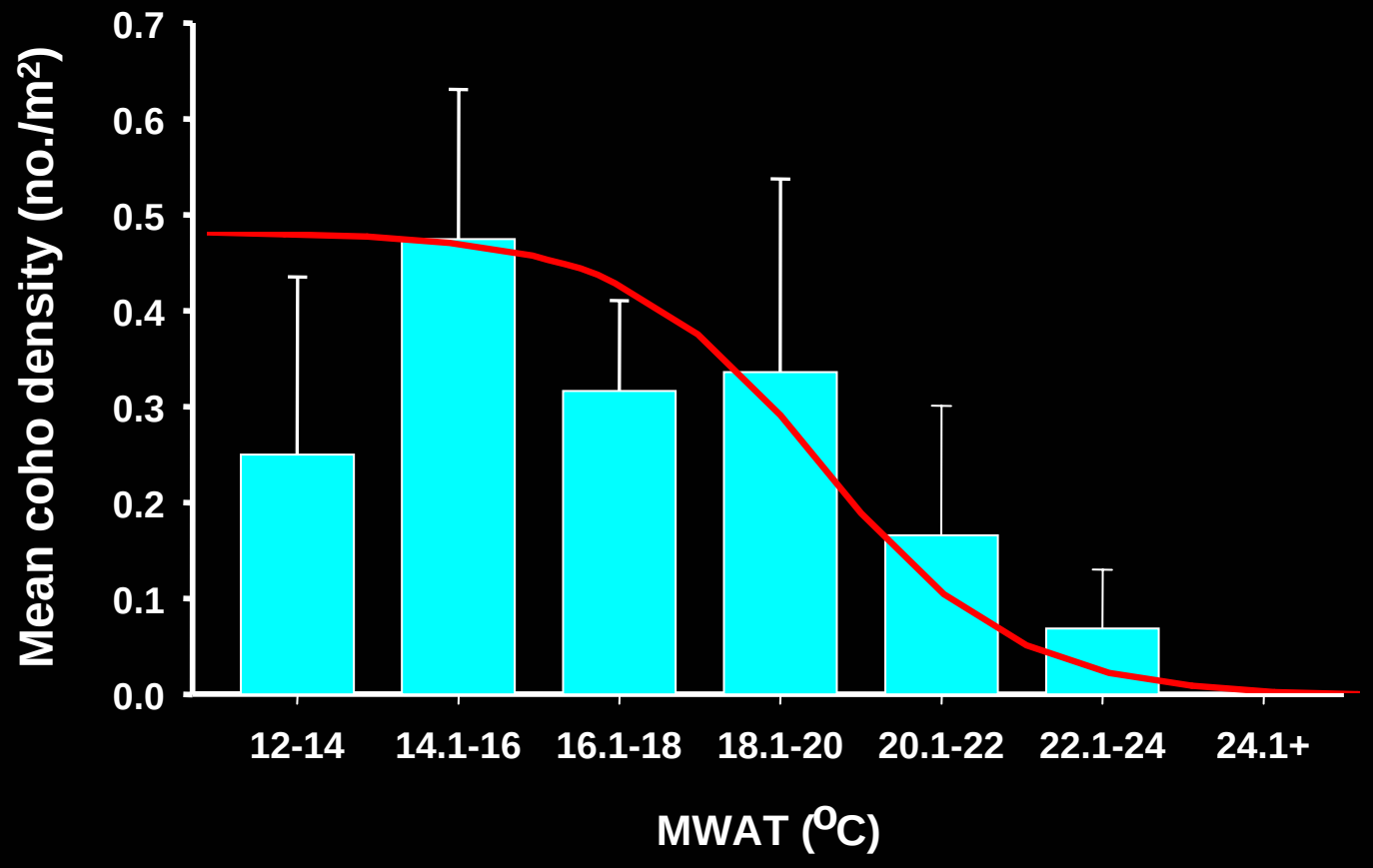
View within fry life stage container

Salmon Fry Within Reach: Conceptual



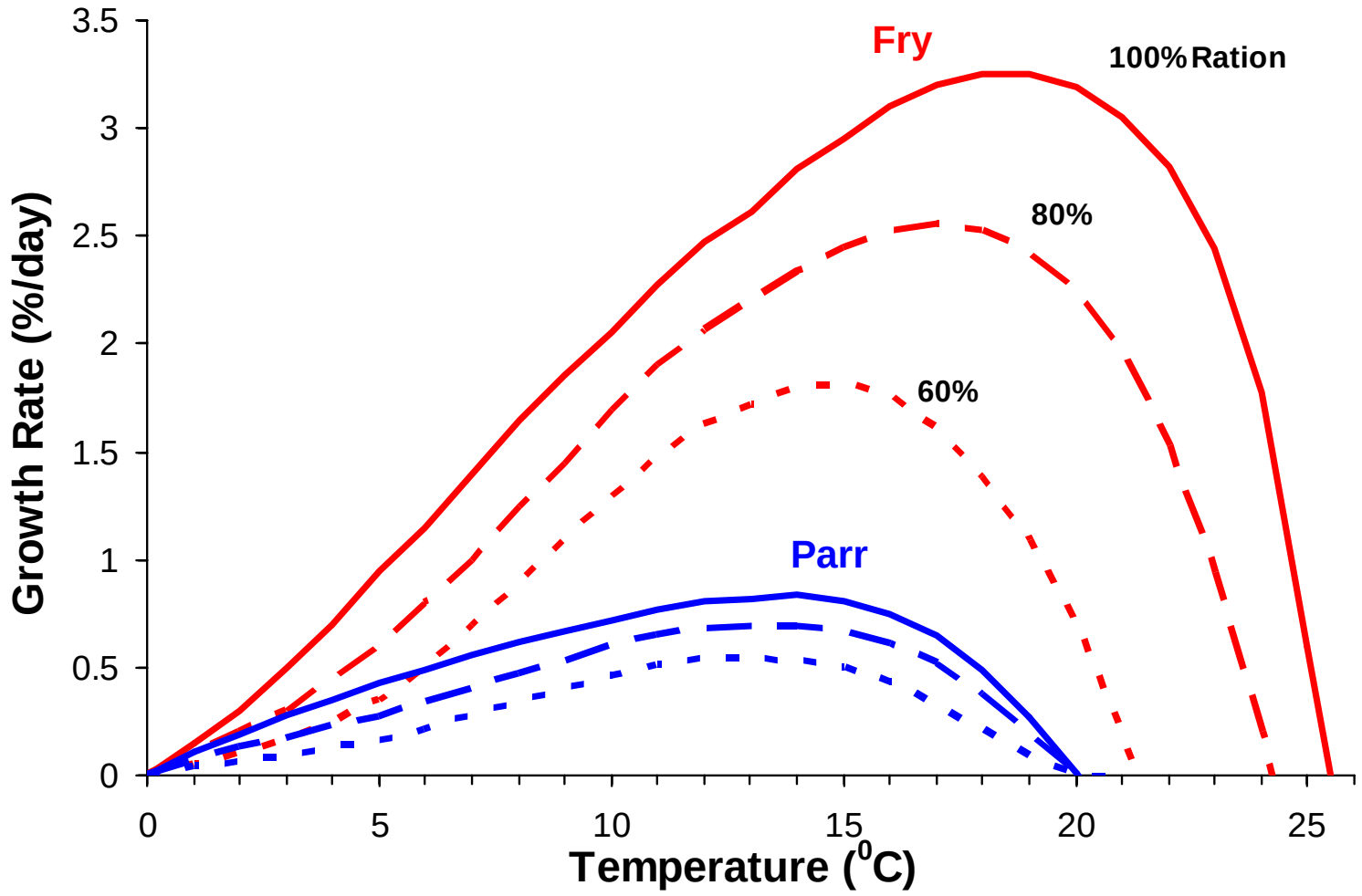
Juvenile Coho Density vs. Temperature

260 Oregon Coast Sample Sites



Extended Bar shows 2 Standard Errors

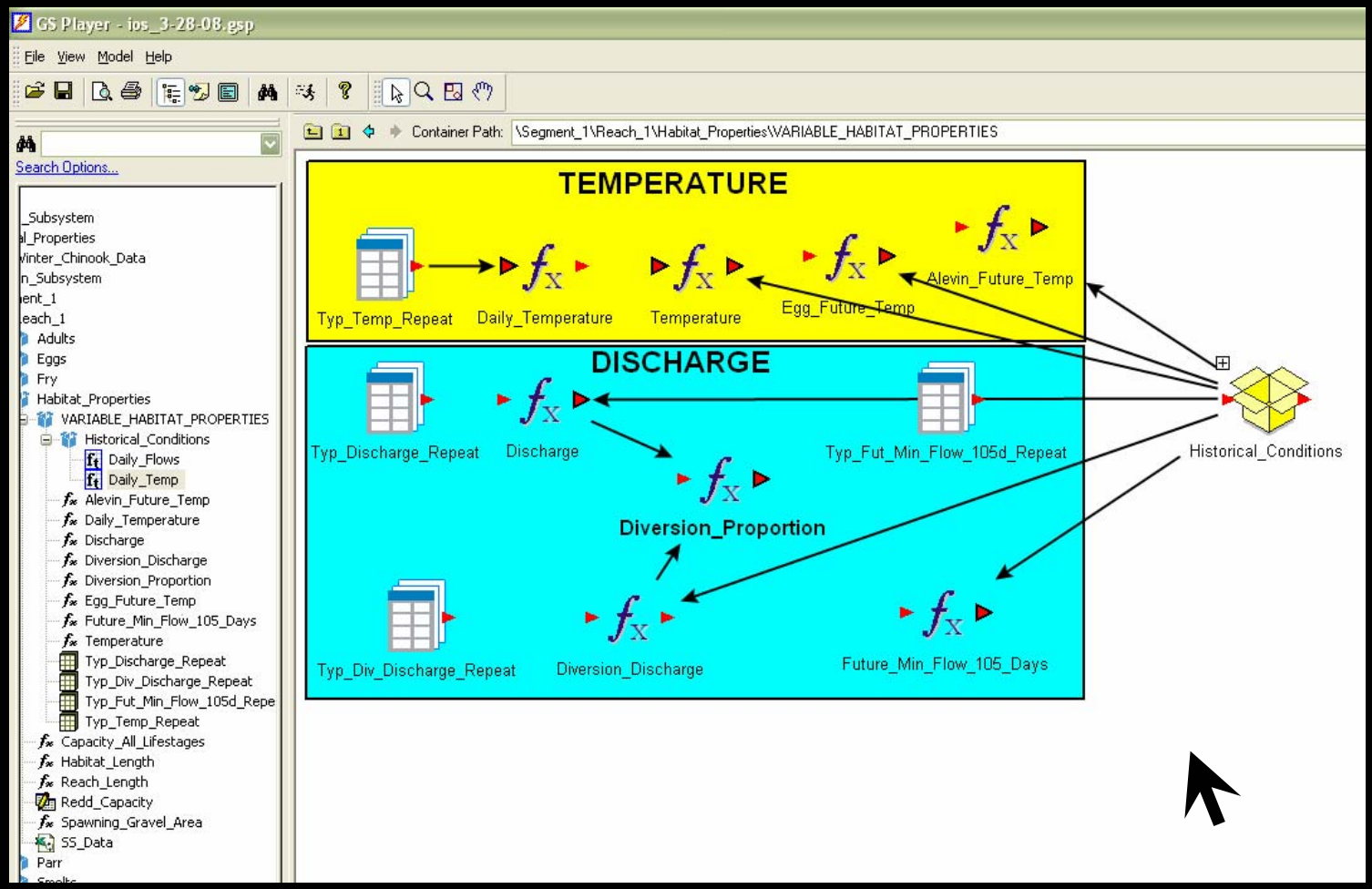
Growth depends on Temperature & Ration



adapted from Brett et al. (1982) and Shelbourne et al. (1973)

Temperature Dependent Processes in IOS

- Egg and Alevin Incubation Time
- Egg and Alevin Mortality Rate
- Rearing Habitat Capacity (fry, parr)
  - Higher river temperatures decrease rearing habitat capacity
- Emigration Survival (fry, parr, and smolts)
- Growth Rate (fry and parr)
  - Both high and low water temperatures decrease growth rate, intermediate temperatures optimize growth
- Delta Survival (all juveniles in the Delta)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Diversion_Proportion
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Typ_Div_Discharge_Repeat
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Reach_Length
Redd_Capacity
Spawning_Gravel_Area
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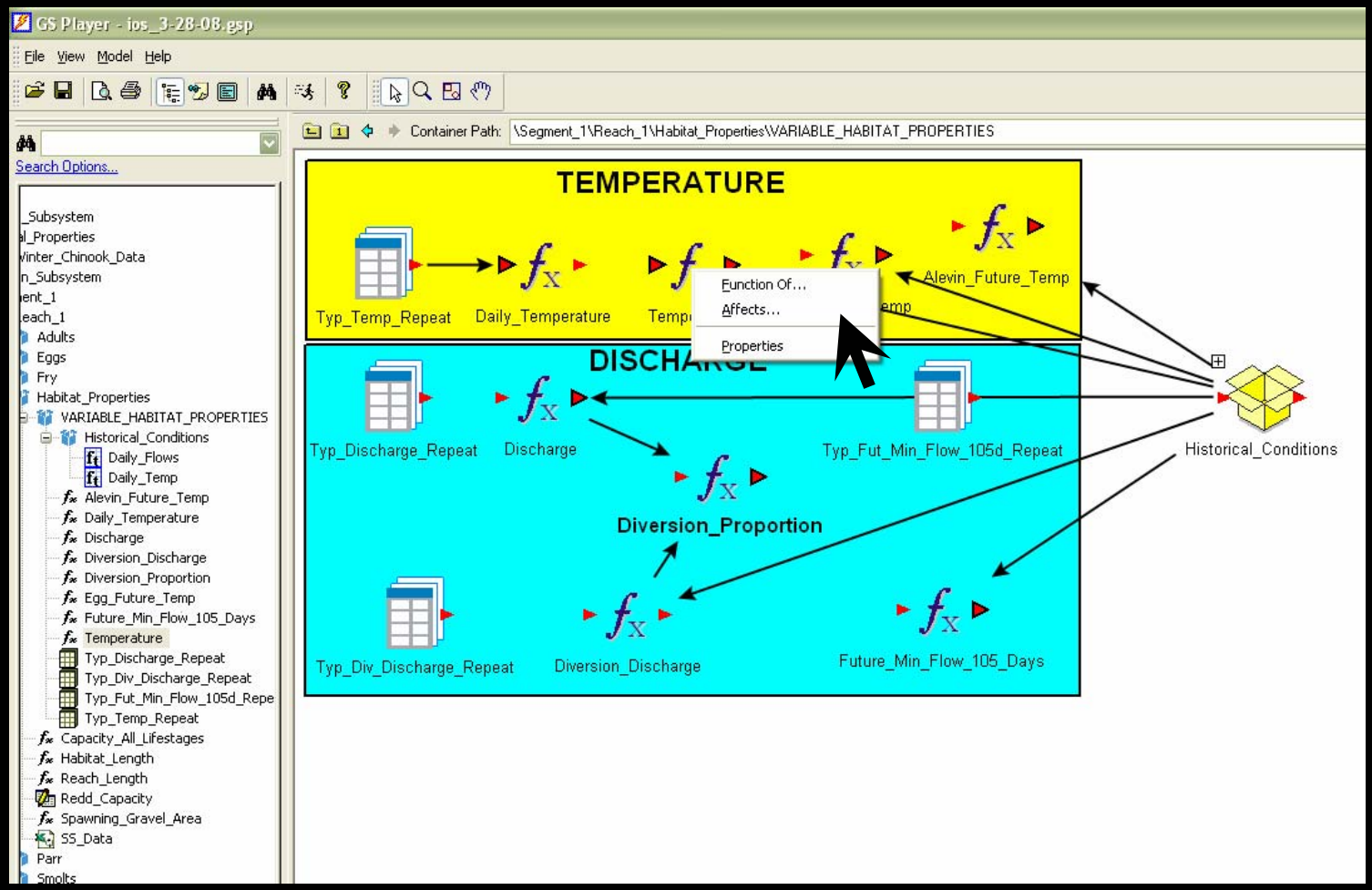
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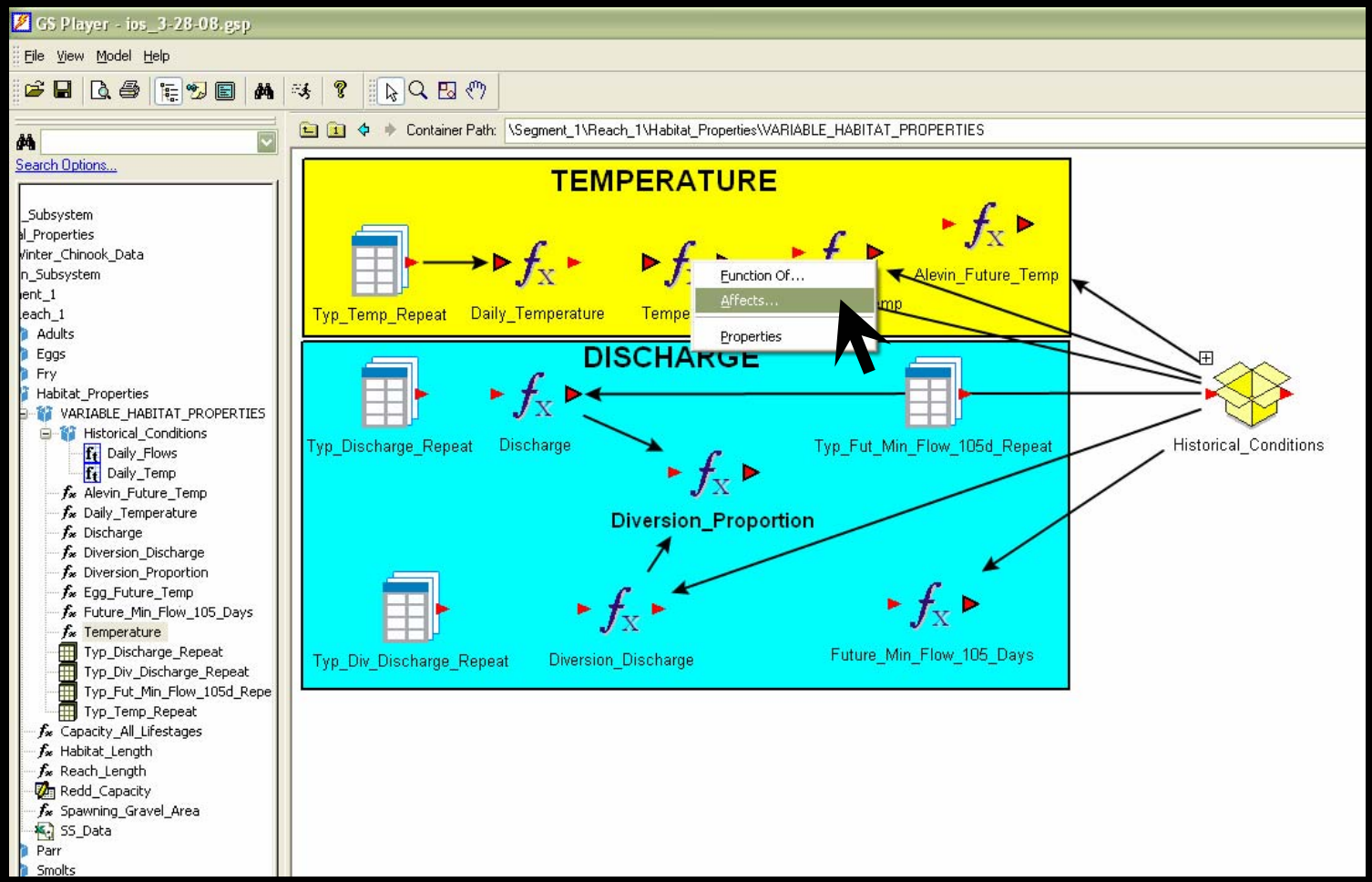
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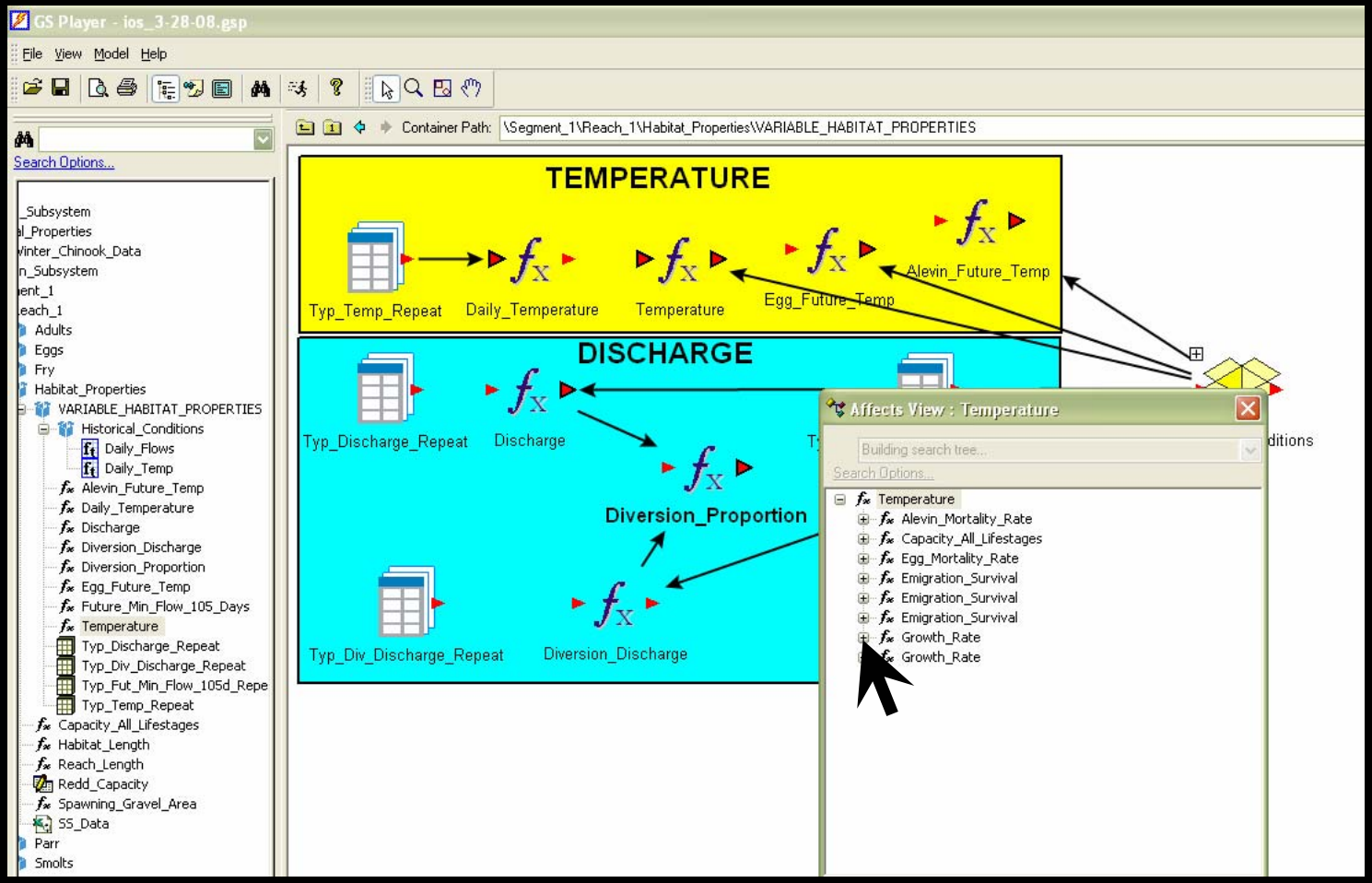
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Capacity_All_Lifestages
Egg_Mortality_Rate
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Growth_Rate
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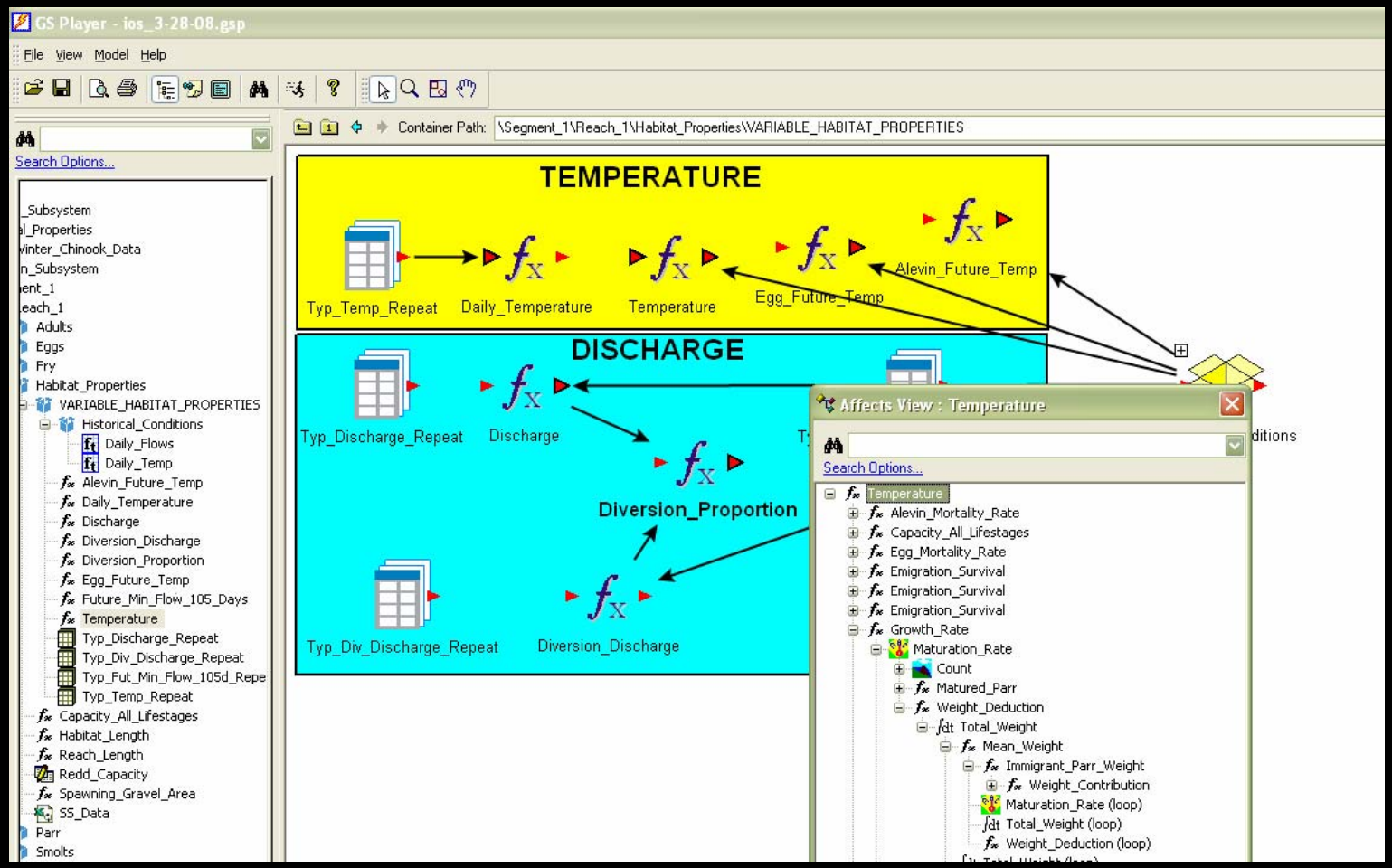
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Emigration_Survival
Emigration_Survival
Growth_Rate
Maturation_Rate
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Matured_Parr
Weight_Deduction
Total_Weight
Mean_Weight
Immigrant_Parr_Weight
Weight_Contribution
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Total_Weight (loop)
Weight_Deduction (loop)
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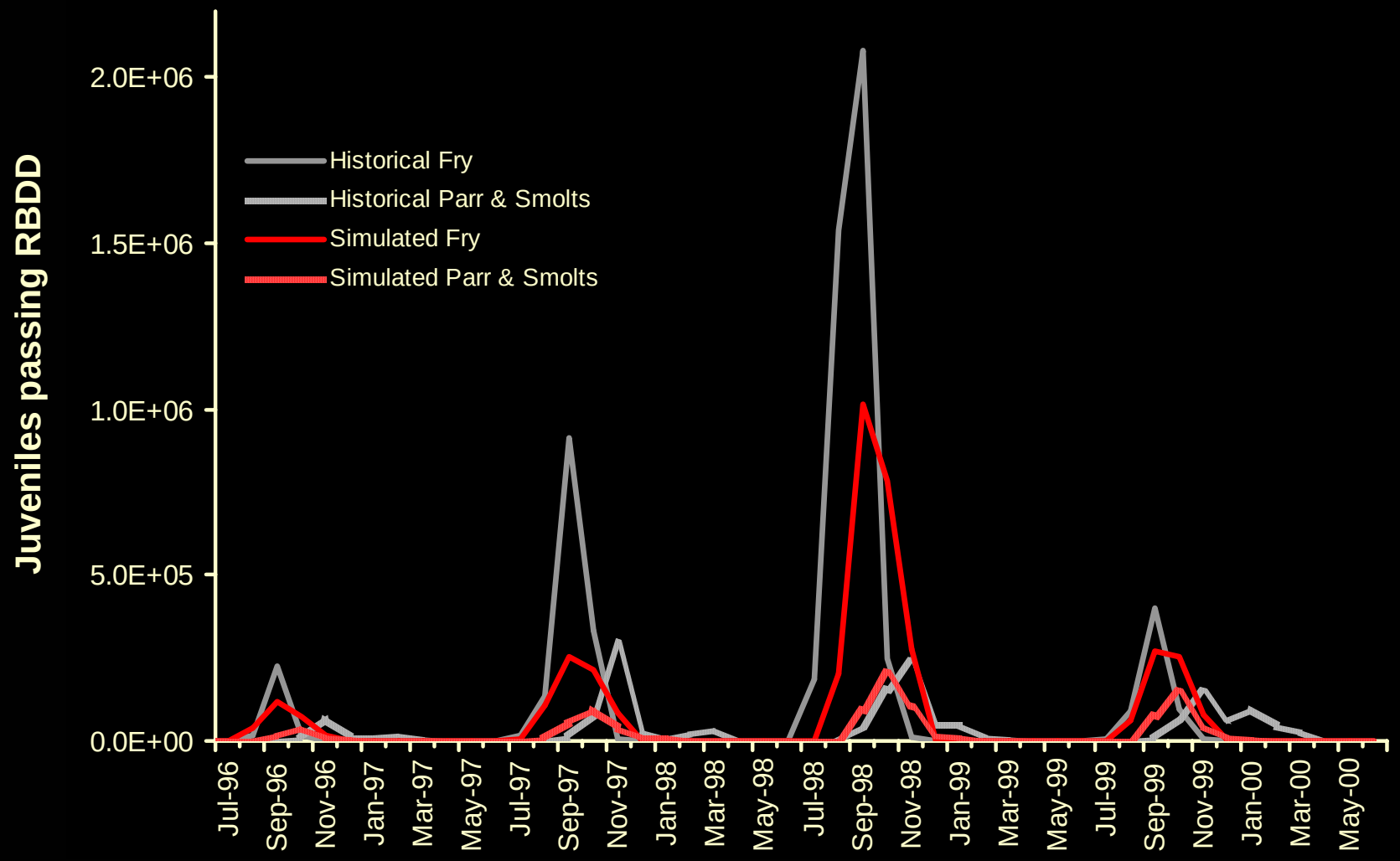
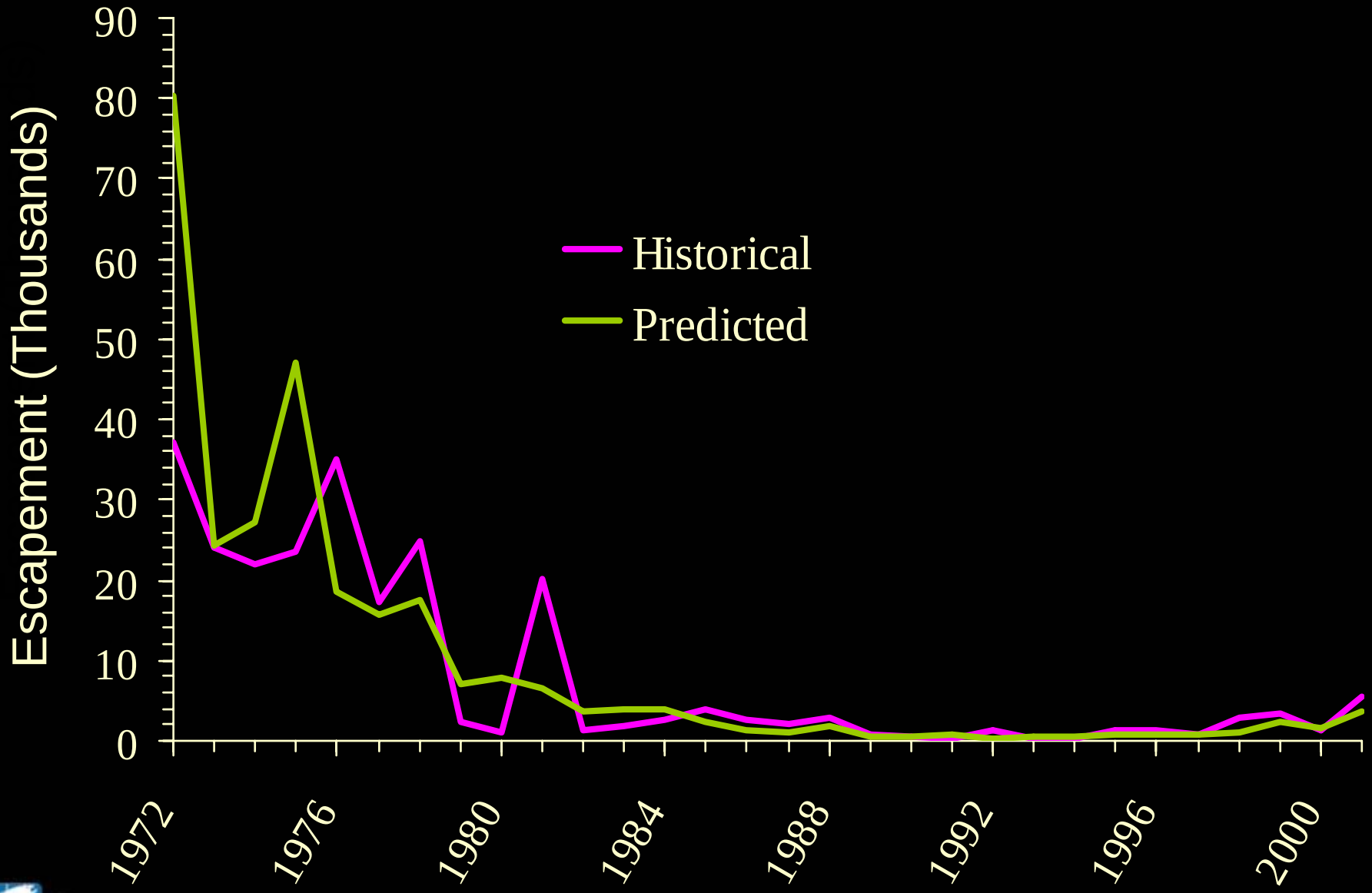
Typ_Temp_Repeat
Capacity_All_Lifestages
Habitat_Length
Reach_Length
Redd_Capacity
Spawning_Gravel_Area
SS_Data
Parr
Smolts

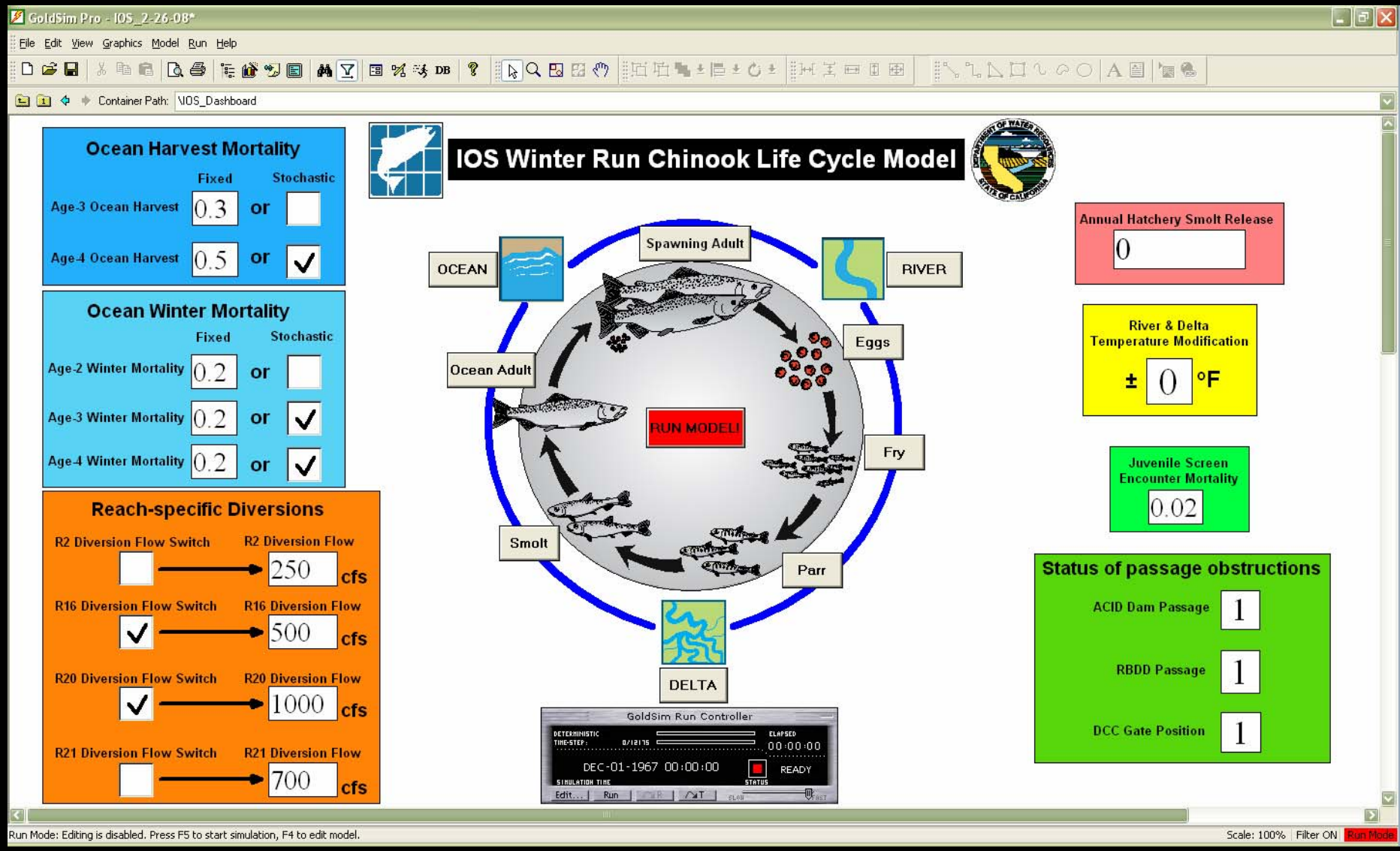
IOS Model Calibration: RBDD passage



IOS Winter Run Hindcast Results



IOS Model Dashboard



IOS Model Recap: Key Features

- Create complex, but useful life cycle models by assimilating and integrating studies

- Explore sensitivity and uncertainty within the model
  - Focus future studies, improve understanding
  - Evaluate alternative operation scenarios
  - Use probability distributions and stochastic events to quantify uncertainty

- Explain and defend decisions to stakeholders

IOS Model: Where to next?

- Interagency review of winter run Chinook IOS is underway
- Spring run model is on deck
- Preparing for analysis of North-of-Delta-Offstream-Storage (NODOS) alternatives
- Working to incorporate new information
  - Ocean effects
  - Acoustic tag studies, juvenile salmon

GS Player - delta rules (1-11-08).gsp

File View Model Help

Search Options...

Model
- Results
- DashBoard
- DCC
- DCC_Div_Value
- DCC_Mean_Div
- DCC_to_Ryde
- DCC_to_Ryde_Surv
- Fish_Release
- Freeport_to_Sutter
- Freeport_to_Sutter_Surv
- GEO_Div_Value
- Georgiana_Diversion
- Georgiana_Mean_Div
- Georgiana_Slough
- Georgiana_Surv
- Lower_Mok_R_to_Sac_R
- Lower_Mokelumne_to_S.
- Mok_S_Fork_Div_Value
- Mok_S_Mean_Div
- Mokelumne_Forks
- N_Mok_R_to_Sac_R
- N_Mokelumne_to_Sac_R
- Overall_Survival
- Rio_Vista_to_San_Joaqu
- Rio_Vista_to_SJ_Surv
- Ryde_to_Rio_Vista
- Ryde_to_Rio_Vista_Surv
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- S_Mokelumne_to_Sac_R
- Sac_to_Freeport
- Sac_to_Freeport_Surv
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- Sutter_Slough_Div_Value
- Sutter_Slough_Surv

Containment ... | Class View

Container Path:

Return to the Dashboard by clicking the "+" symbol

Zoom in by holding down the control button and moving your mouse wheel

Sacramento

Freeport

Sacramento River

Ryde

Rio Vista

Chipps Island

San Joaquin River

GoldSim Run Controller

REALIZATION: 1/1 ELAPSED

TIME-STEP: 1000/1000 00:00:00

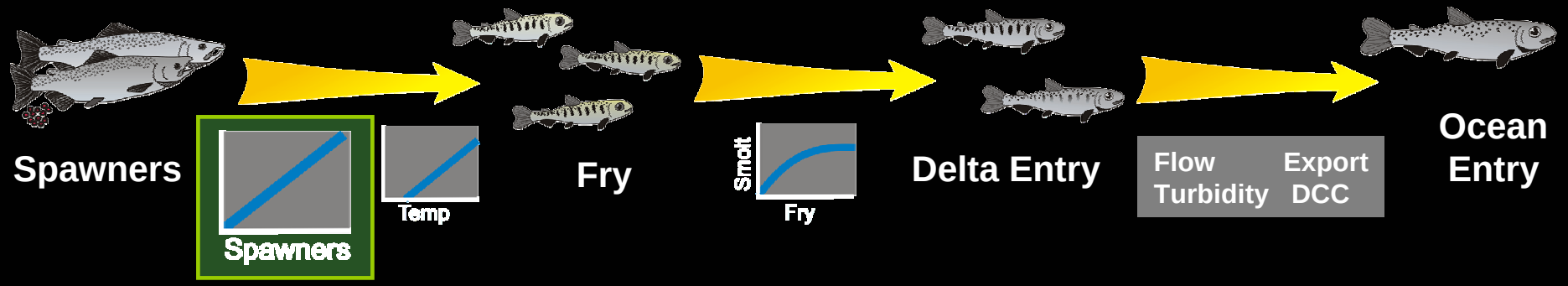
1000 day RESULTS

SIMULATION TIME STATUS

Go

Reset Run

Result Mode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Turbidity
Export
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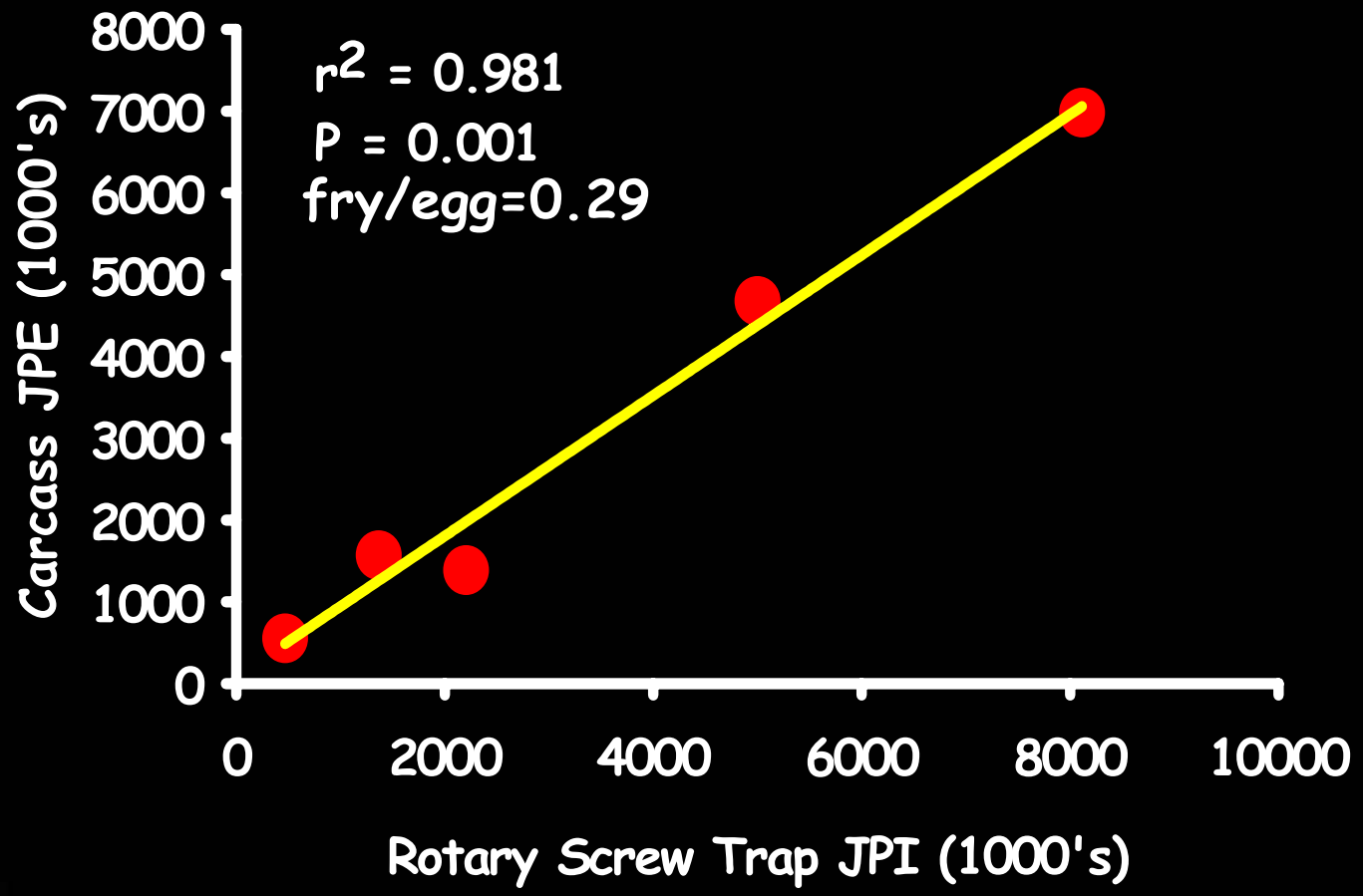
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P = 0.001
fry/egg=0.29
Carcass JPE (1000's)
8000
7000
6000
5000
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0
2000
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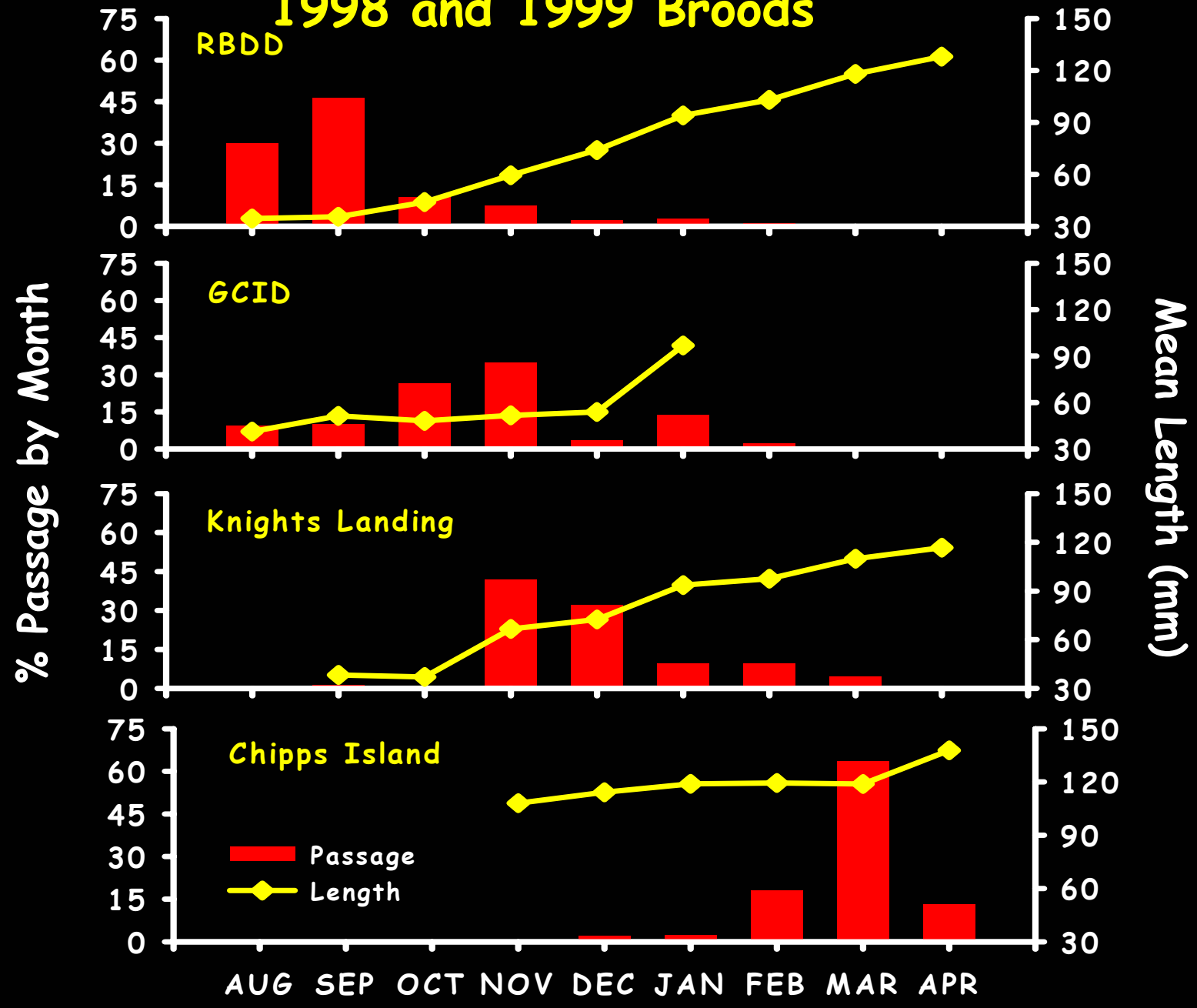
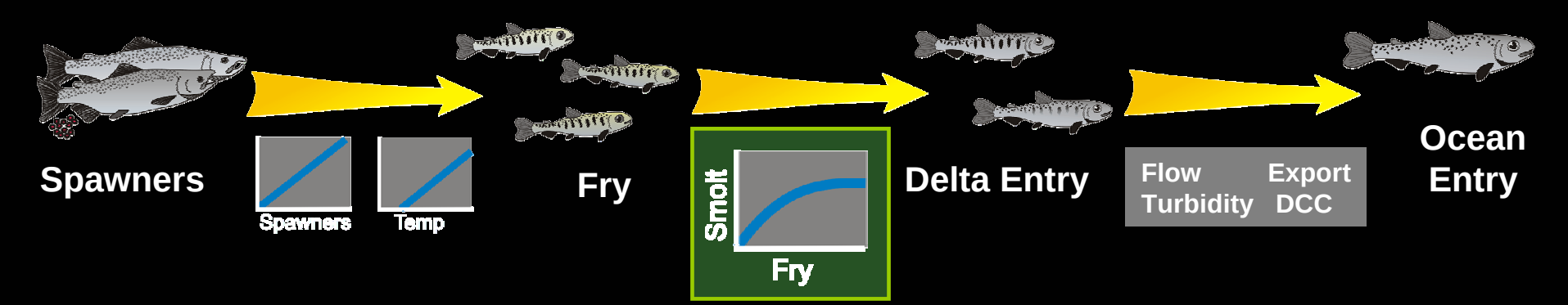
Rotary Screw Trap JPI (1000's)

1998 and 1999 Broods

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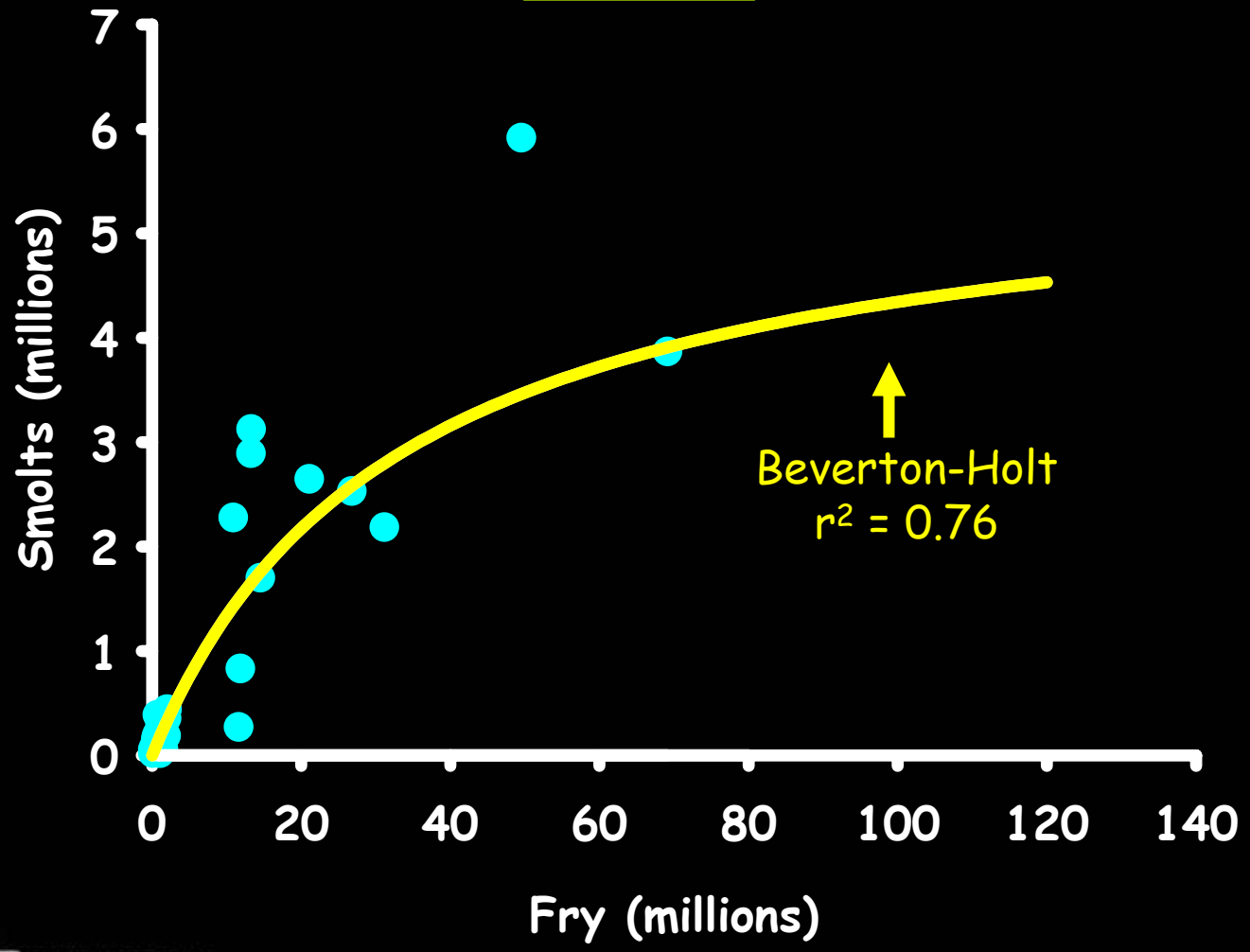

Smolts (millions)
0
1
2
3
4
5
6
7
0
20
40
60
80
100
120
140
Fry (millions)
Beverton-Holt
r² = 0.76

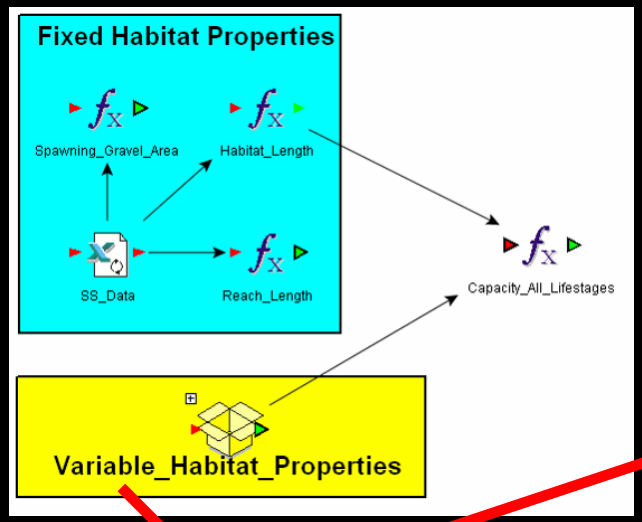
Recent Life Cycle Modeling Projects

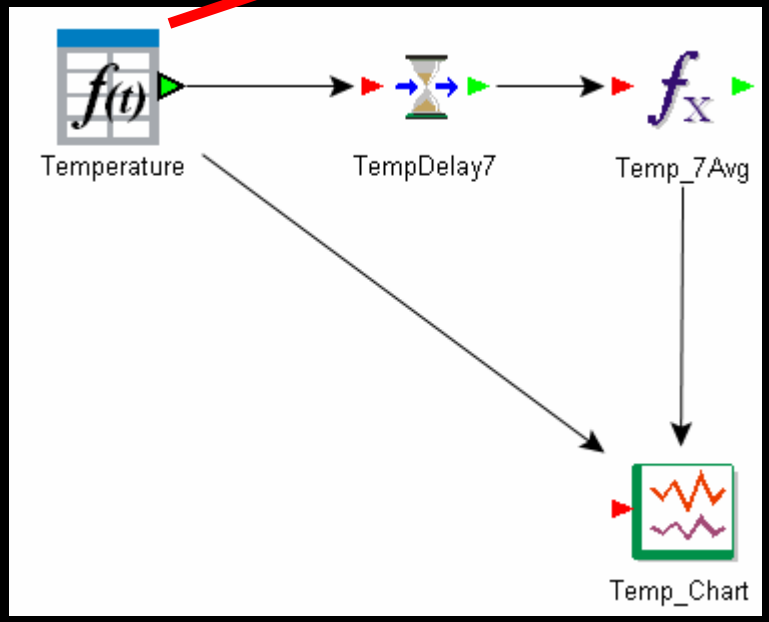
- Sacramento Spring Chinook
- Sacramento Winter Chinook
- Klamath River Coho
- Clackamas River Chinook, Coho, and Steelhead
- San Joaquin Fall Chinook
- Deschutes River Steelhead
- Yakima Basin Bull Trout

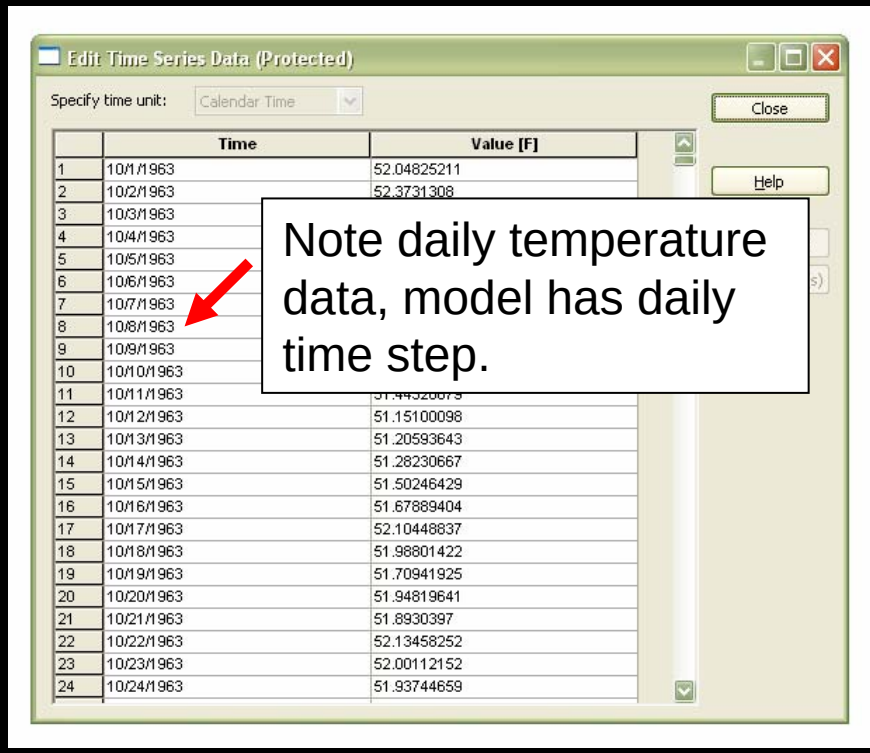
IOS Physical Input Parameters

- River Flow (daily)
- River Temperature (daily)
- Diversion Flow (daily)
- Mesohabitat
- Spawning Gravel
- Migration Barrier status (daily)
- Delta Flow (weekly)
- Delta Temperature (weekly)
- Delta Exports (weekly)
- Delta Salinity (weekly)
- DCC Gate Position (weekly)

IOS Model: Data





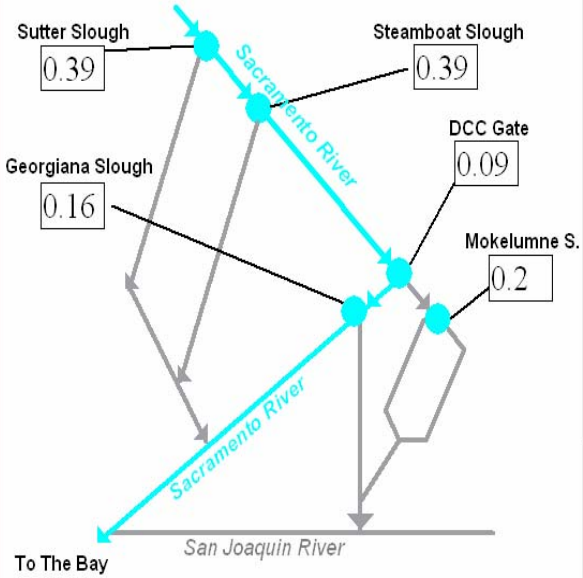


Note daily temperature data, model has daily time step.

Reach 1 temperature input data, linked from Excel spreadsheet “Reaches”

Models salmonid passage and survival through the California Delta. - DashBoard1

Proportion of Fish Diverted



Survival Results

Mean		0.419
Standard Deviation		0.0521
95% Confidence Interval	Upper	0.521
	Lower	0.317

Survival Graph

Go To Model

RUN

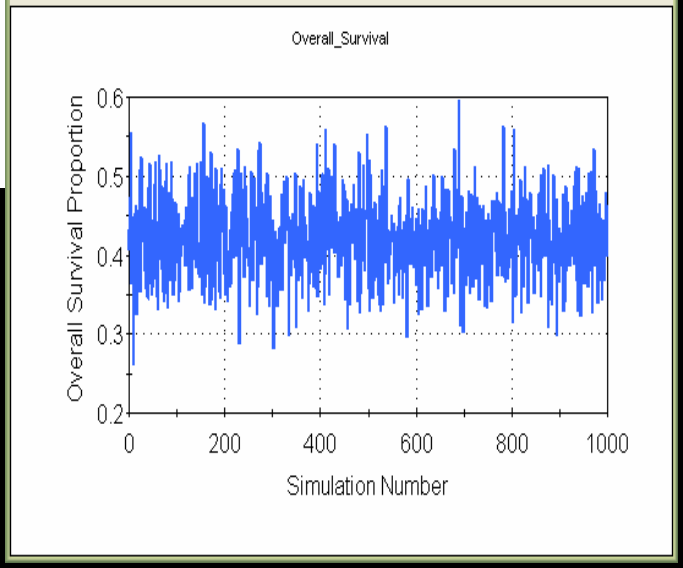
Model Description

This model simulates survival of Chinook salmon smolts as they migrate from the Sacramento River through the Delta. Along their path, fish encounter decisions points (channel splits) and experience reach-based survival probabilities. The model is set to run and display results from 1000 "realizations". In each "realization" 250,000 salmon smolts are planted into the Sacramento River main stem and then run through to the Bay (Chipps Island). Default values for proportions of fish taking each pathway are based upon best available experimental data, but users may also experiment with "what if" scenarios by changing these values. Reach-specific survival probabilities are selected for each "realization" from a probability distribution drawn from best available mark-recapture experimental data.

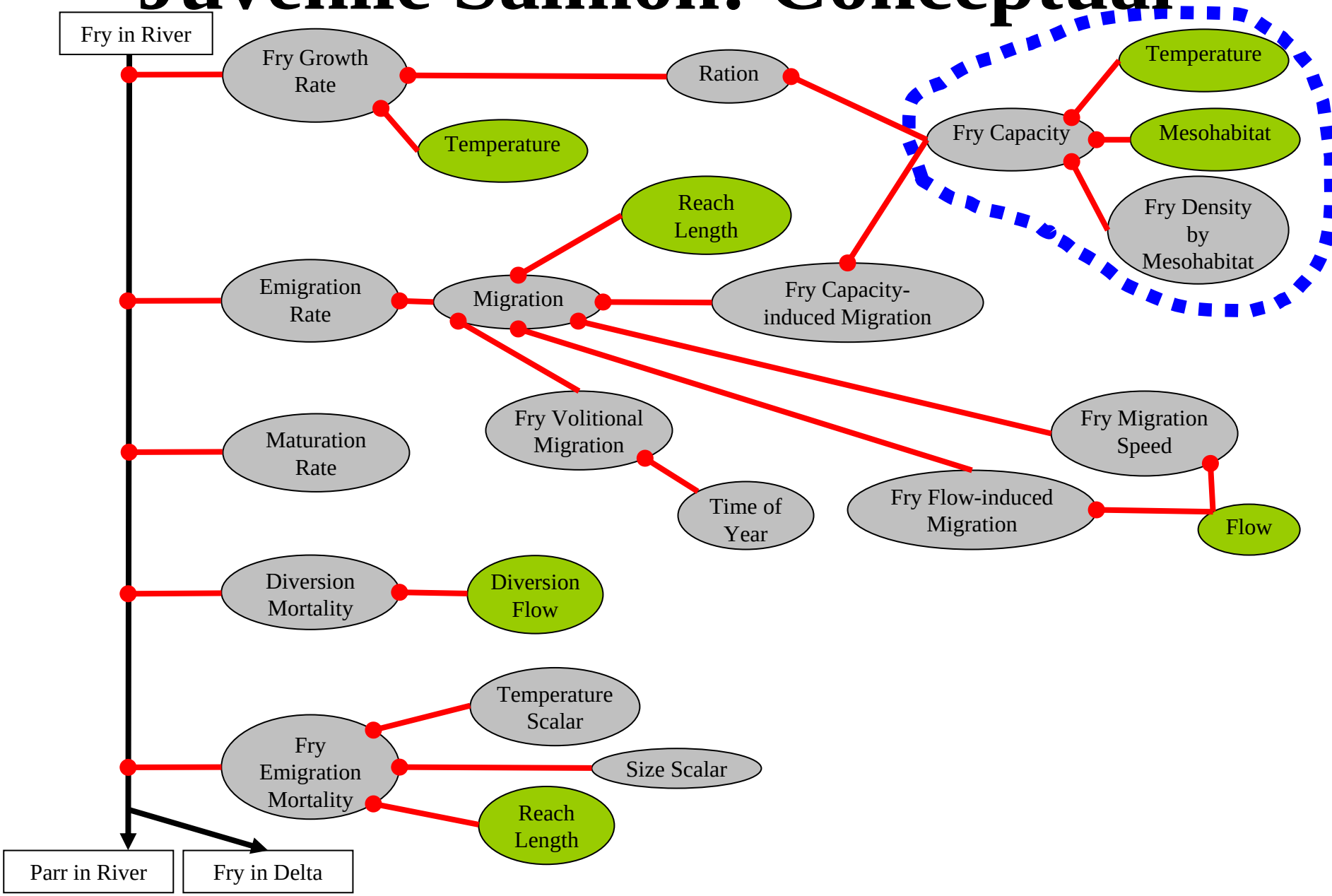
The user can navigate to the Simulation model by clicking the "Go To Model" button. Data information sources and underlying mathematical expressions may be viewed by selecting various model elements.

The model can be run by hitting the "RUN" button. The through-delta survival statistics for each run are displayed to the left. A graph depicting all 1000 "realizations" can be viewed by clicking the "Survival Graph" button.

Time History



Juvenile Salmon: Conceptual



IOS Winter Run Hindcast Results

The Problem: disconnected fishery science

Fisheries data are often difficult to interpret and put into a useful context.

- Studies are often general and descriptive
  - don't explicitly target critical management questions
- Quantitative studies are usually very focused on a specific location or a detailed question
- Results are not readily amenable for use by physical modelers or managers.

The Problem: disconnected operations models

CALSIM or similar physical models…

- Generate lots of data, but often not high value data for biological assessment
  - e.g. monthly means, rather than daily maximums
- Need feedback from population models
  - focus on biologically significant outputs
  - inform boundaries on operational alternatives

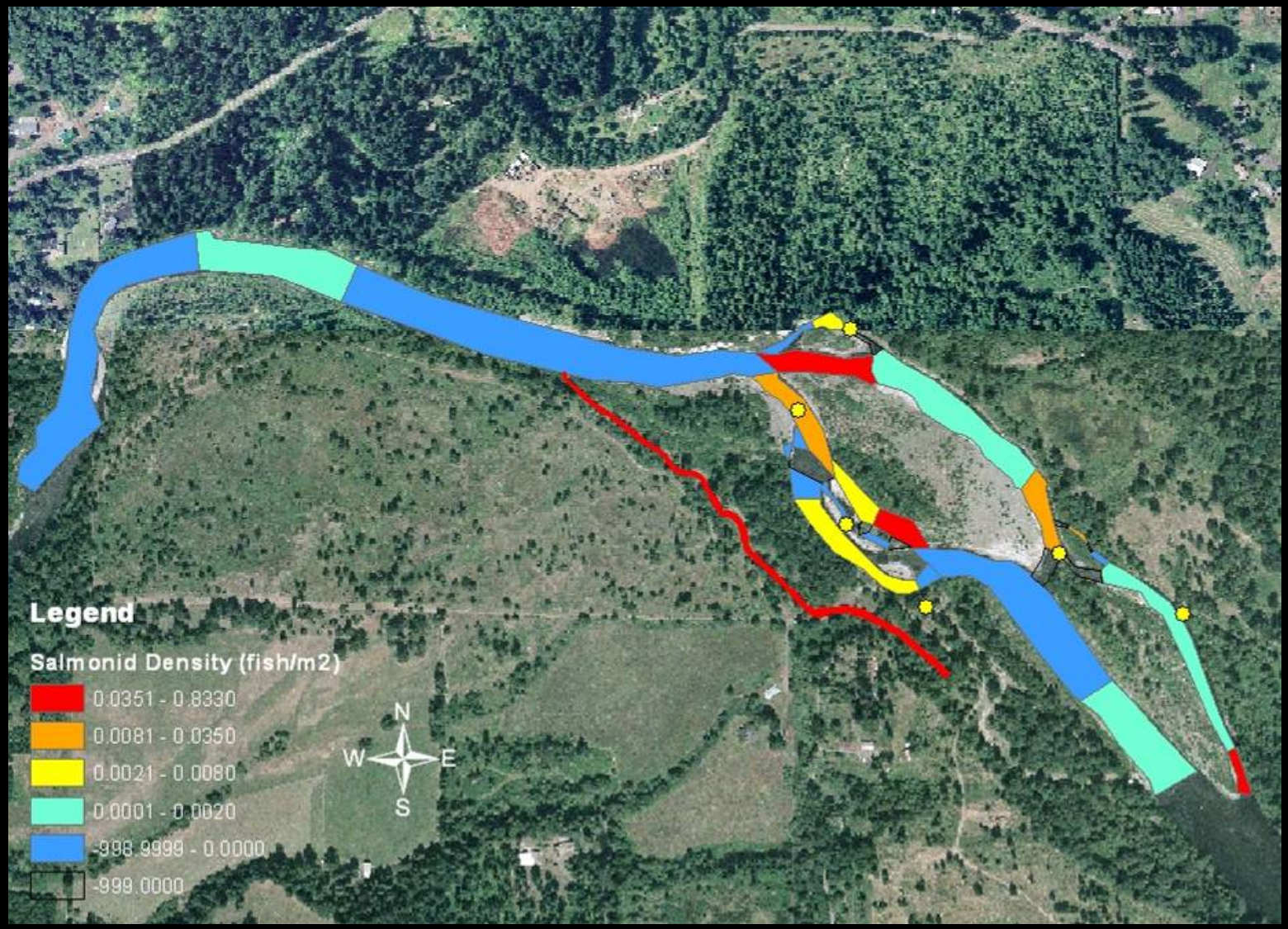
Decision makers need reliable tools

Managers require tools integrating disparate data sources and best available information.

Managers need a “blackboard” where:

- Alternative project operations can be evaluated and compared.
- Restoration benefits can be assessed.
- Critical uncertainties can be quantified.
- Management decisions can be explained and defended to stakeholders.

IOS Model: Mesohabitat



Complex Channel

Simple Channel