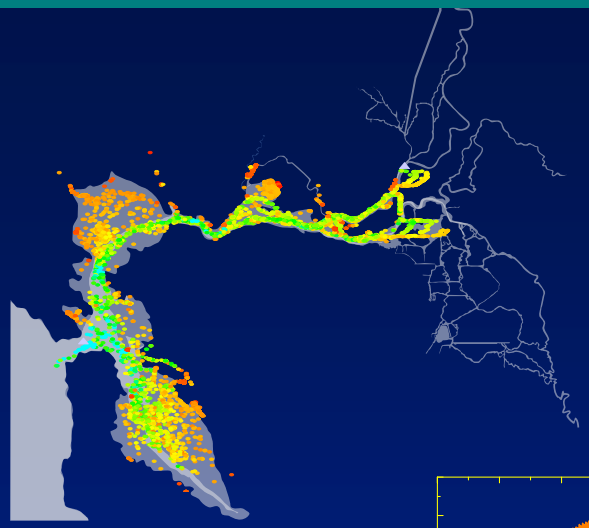
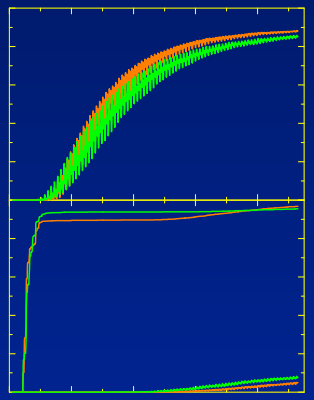
Modeling Approaches for Delta Smelt and Other Fishes in the San Francisco Estuary

Wim Kimmerer
Romberg Tiburon Center for Environmental Studies
San Francisco State University

Examples of the use of Models to Investigate Fish

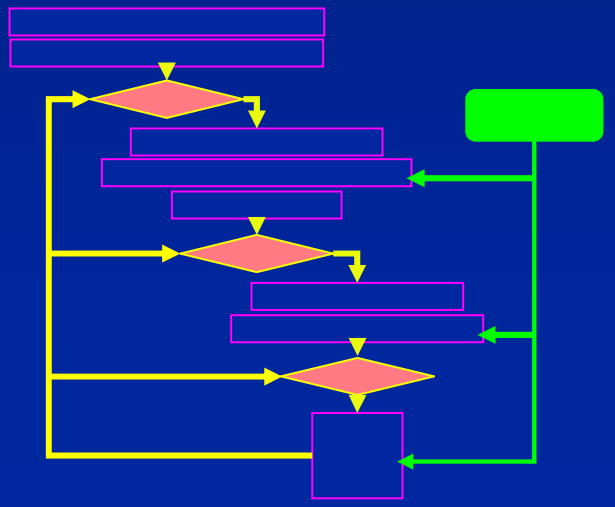


3D modeling in the lower estuary



1D Particle tracking in the Delta

Individual-based model of delta smelt:
Incorporates 1D particle tracking model



3D Modeling in the lower estuary

- Mechanisms for flow relationships
- Flow-habitat relationships
- Retention in estuary
- Entrainment into estuary

<u>Particle Tracking:</u>

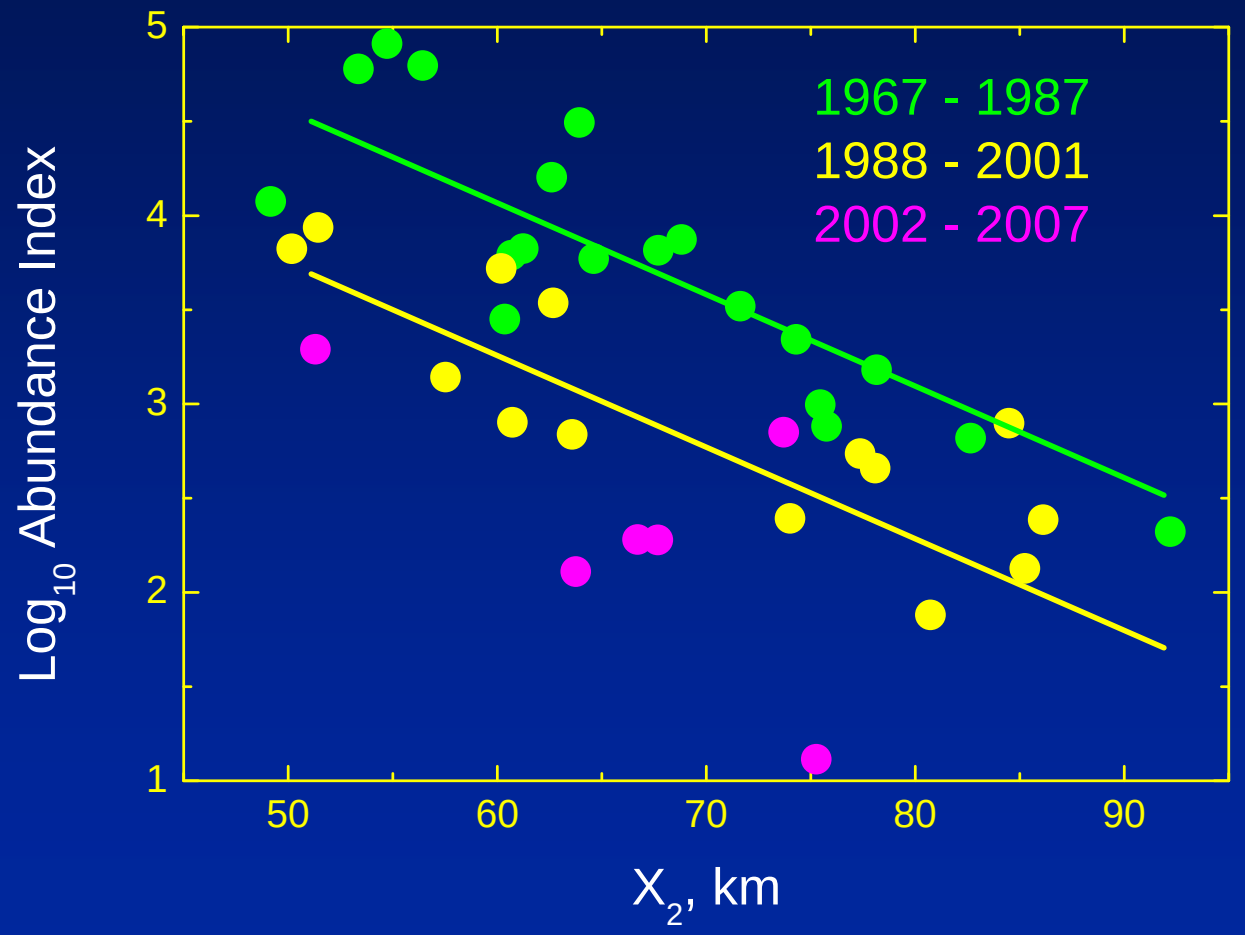
Model hydrodynamics on a grid and export results

Velocity, salinity, depth by cell = particle movement

1D, 2D, or 3D?

Longfin Smelt

What makes abundance increase with outflow? Why do some species increase and not others?



High ⟵ Outflow ⟶ Low

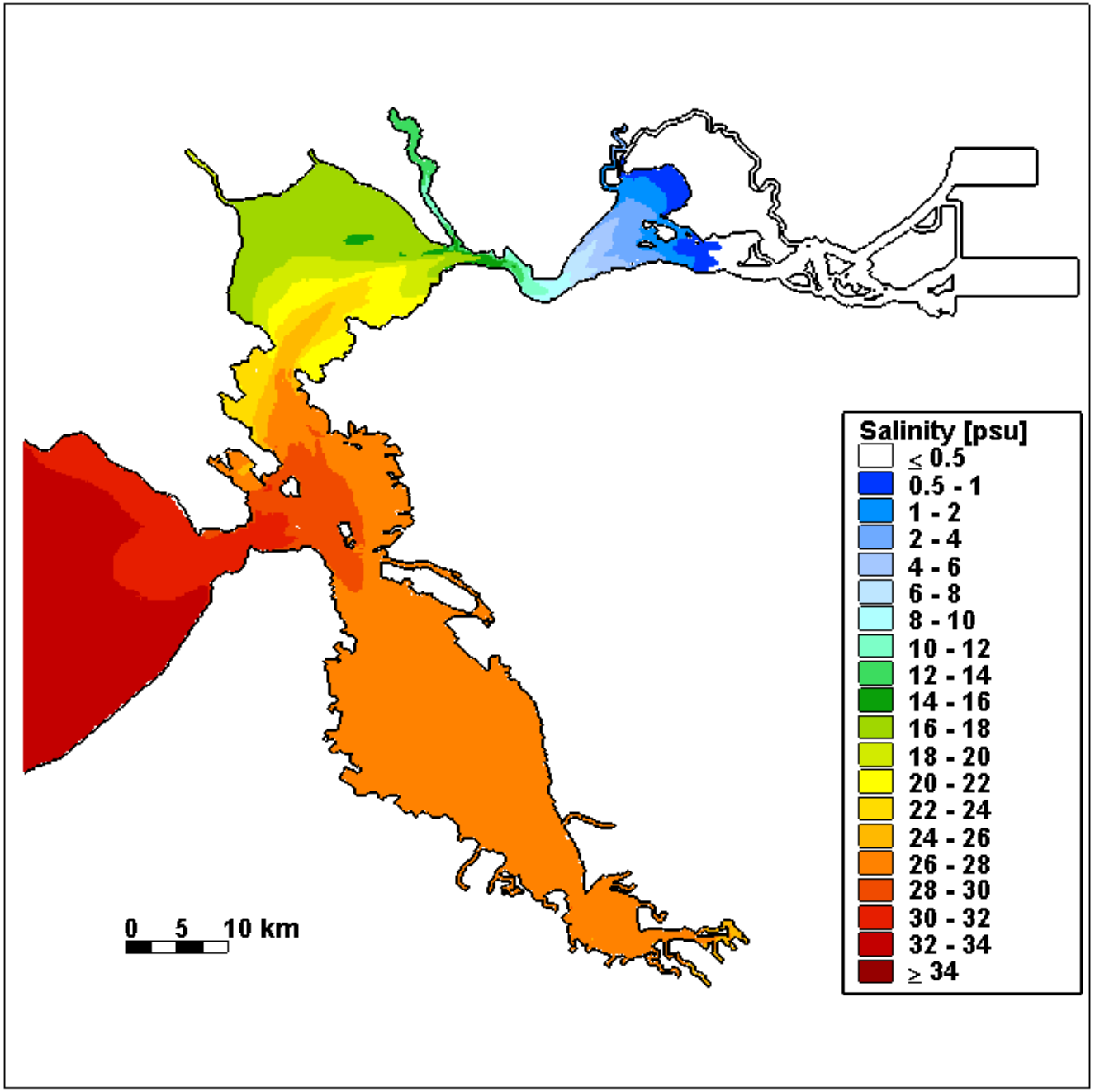
The principal questions:

What causes the increase in abundance of fish with flow?

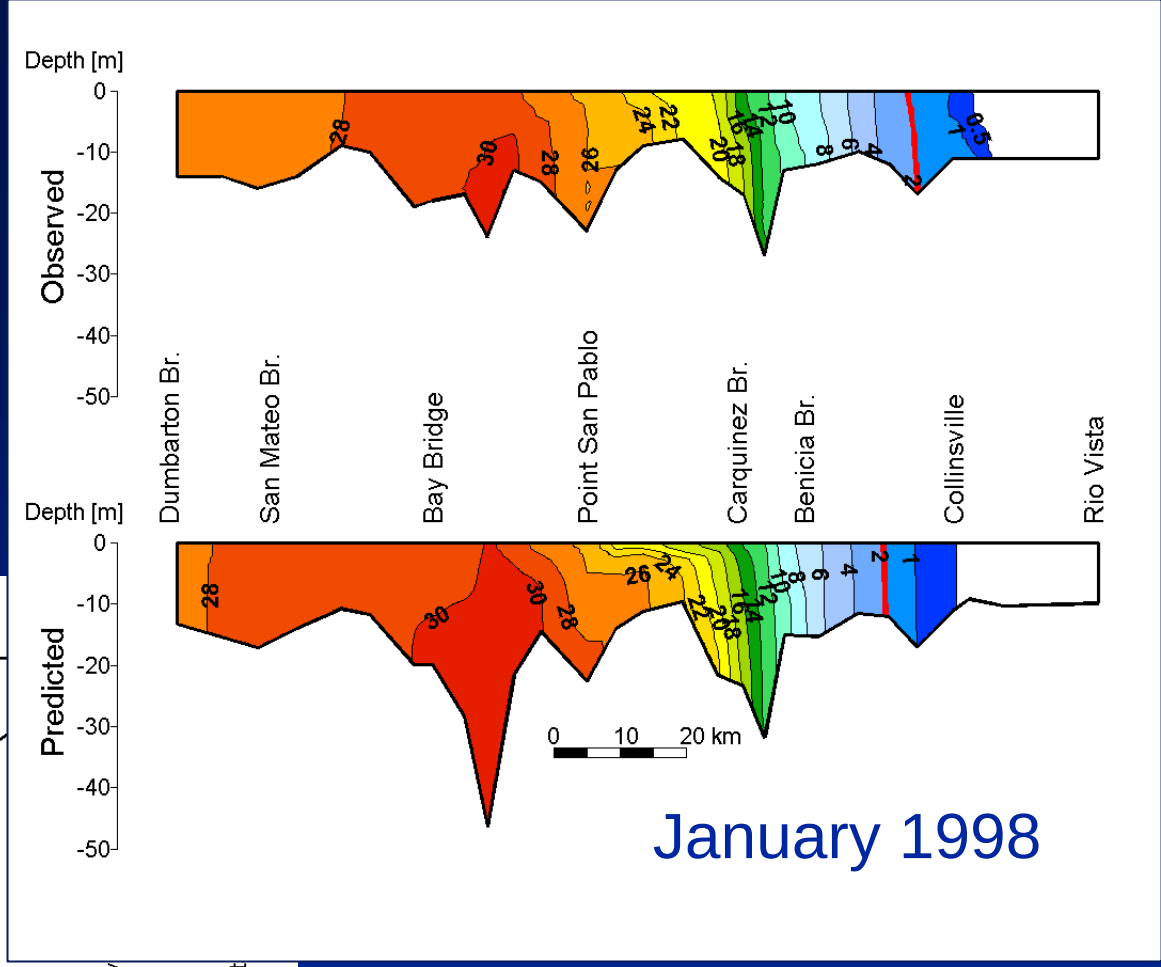
Is it due to an increase in physical habitat?

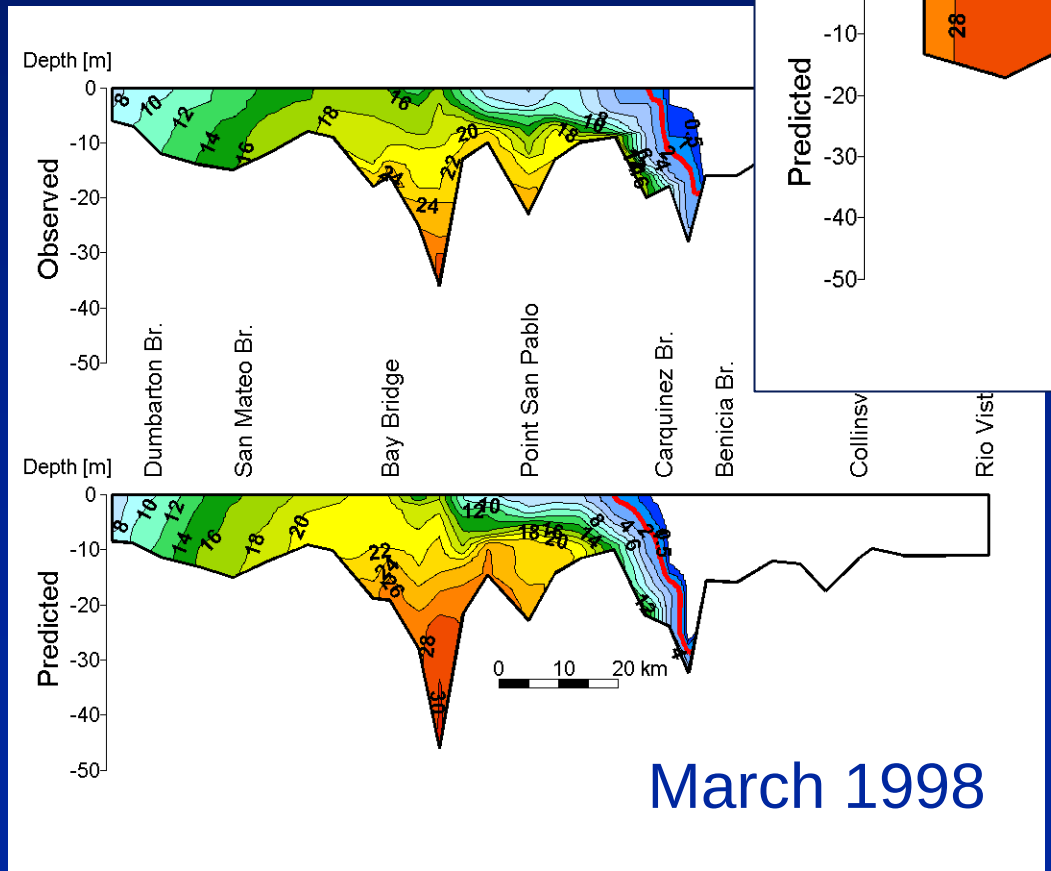
Is it due to changing estuarine circulation patterns?

M3D Model Grid: Water Column Mean Salinity



TRIM3D Calibration

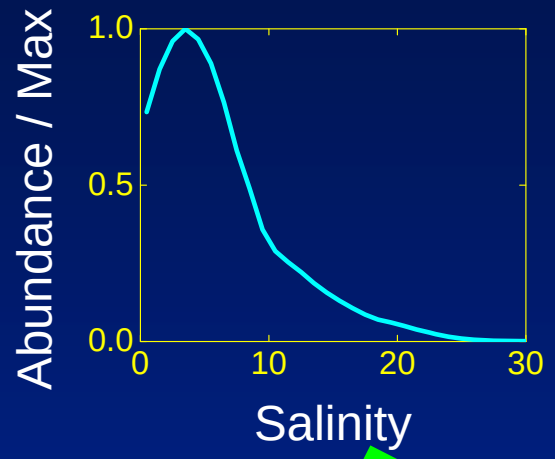




Salinity

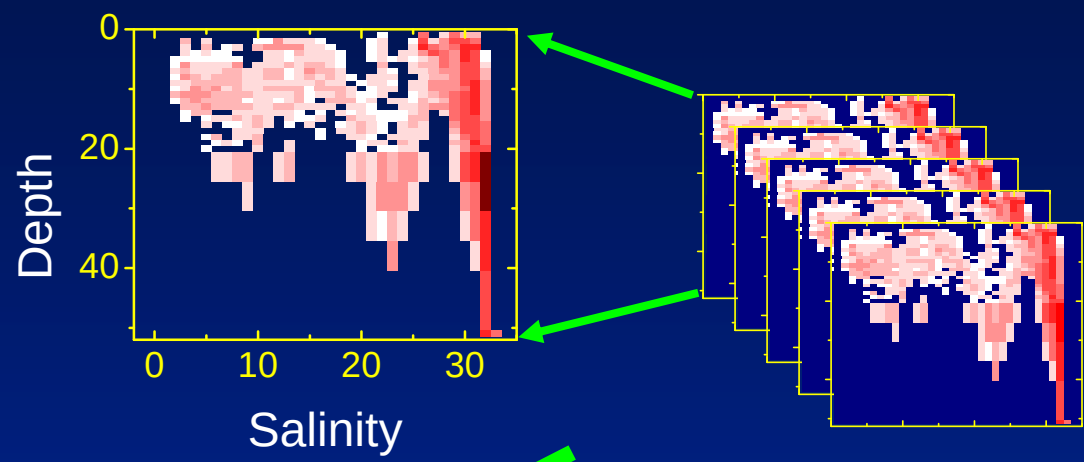
Habitat Calculation

Habitat Curves



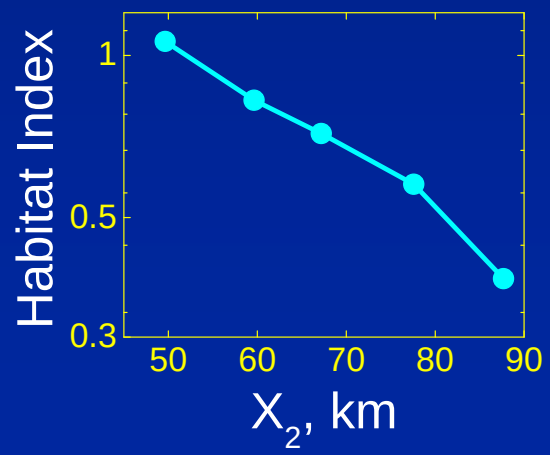
TRIM 3D

Color = Volume



5 Flow Scenarios

Weighting



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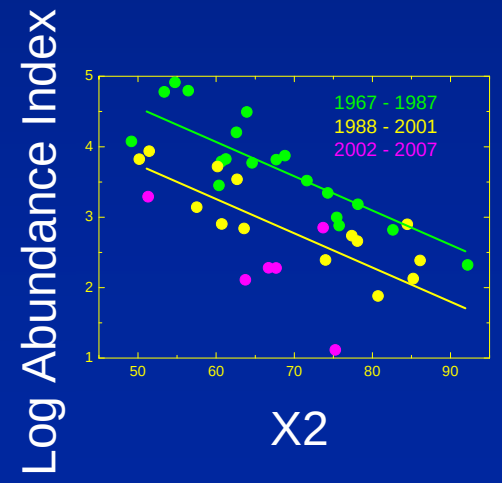
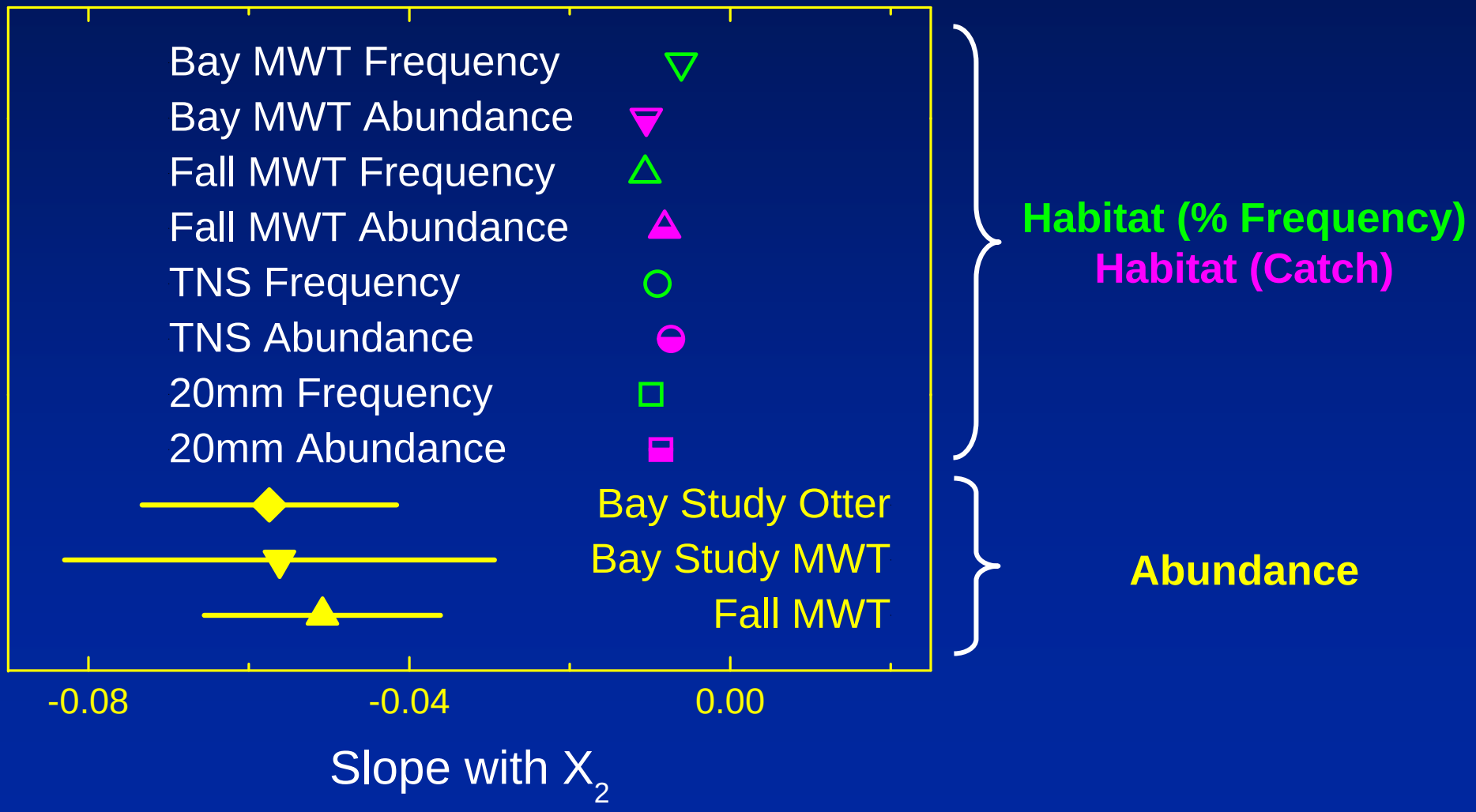
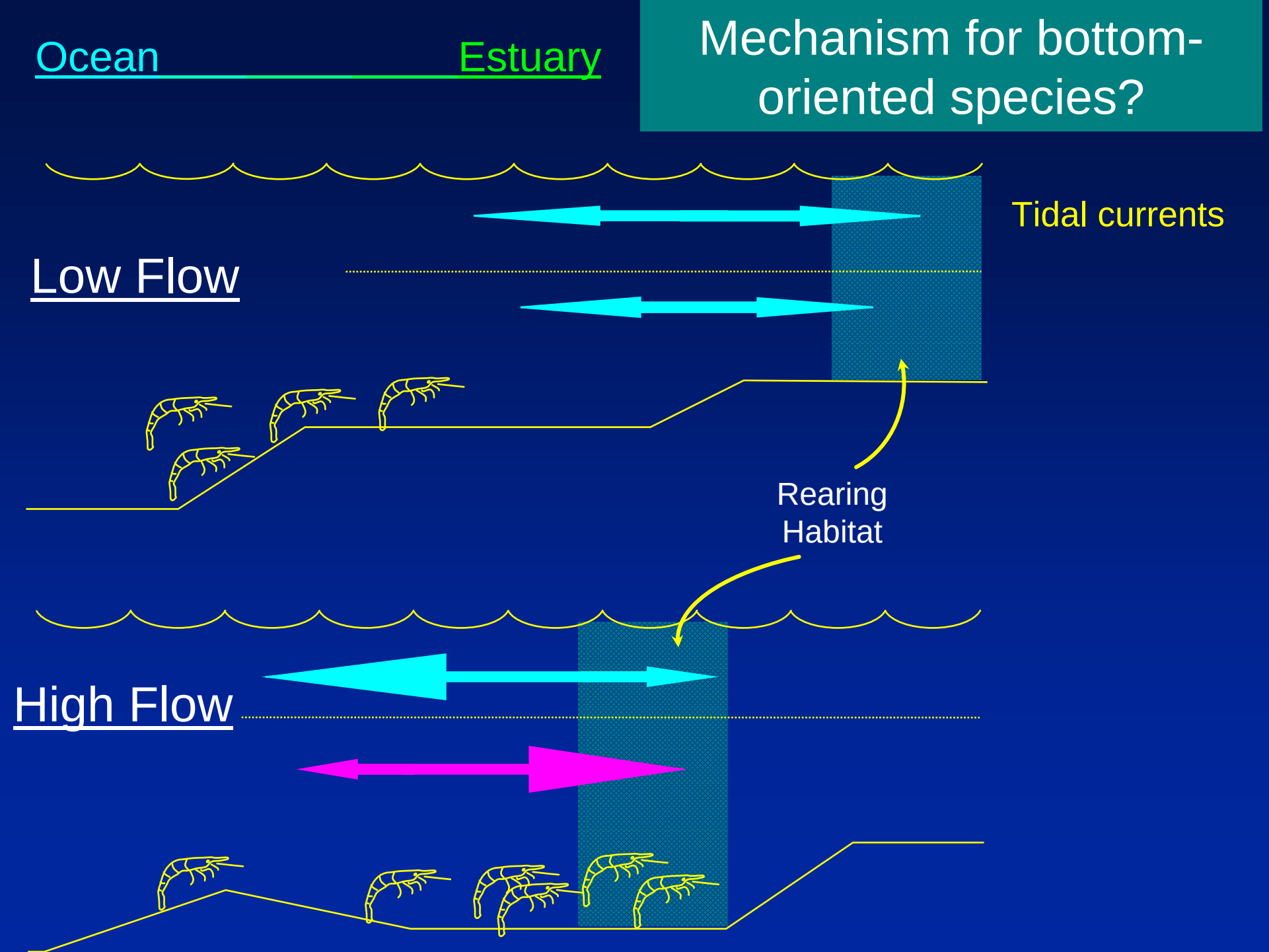


Results for Longfin smelt

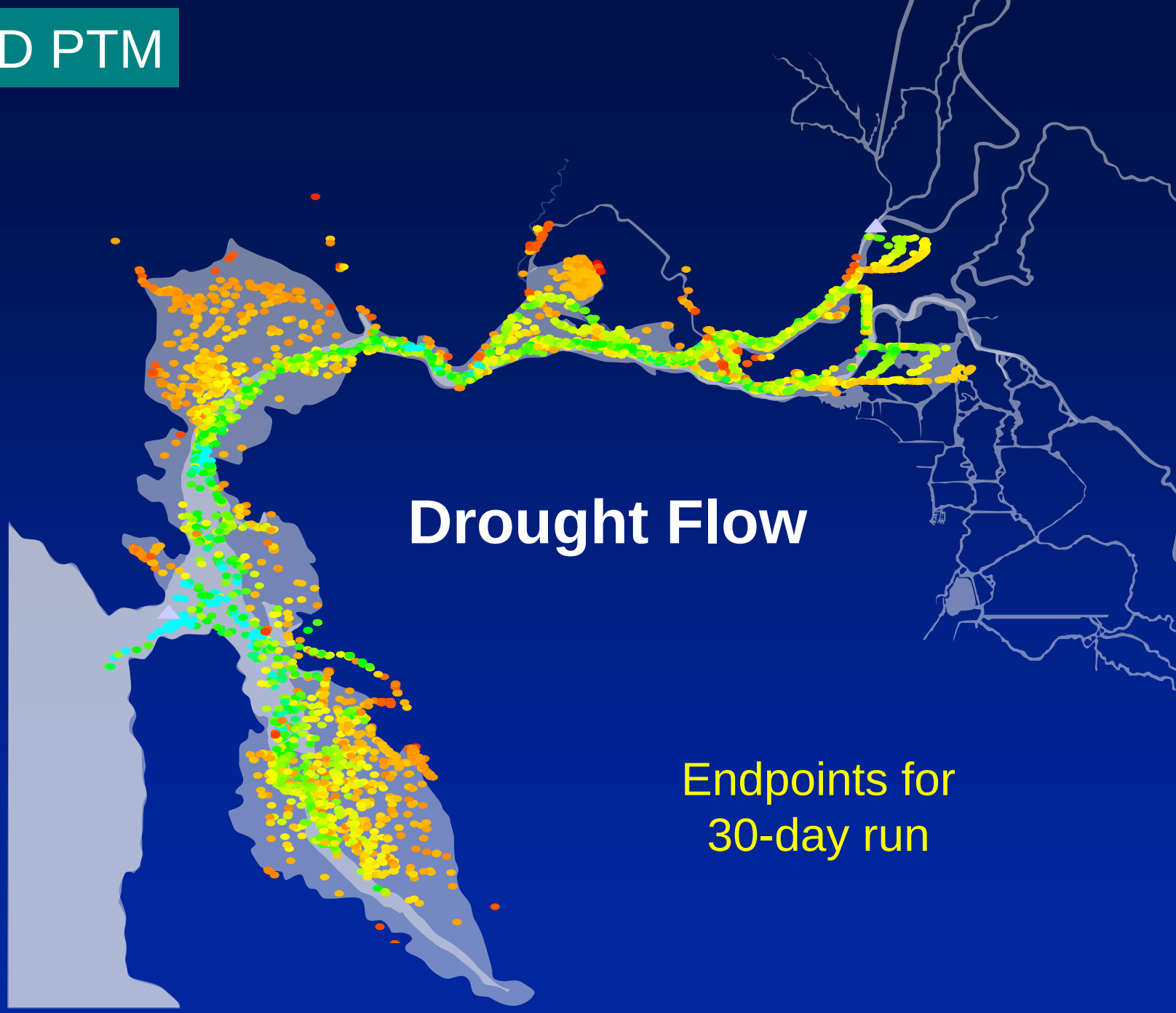
There must be an additional mechanism



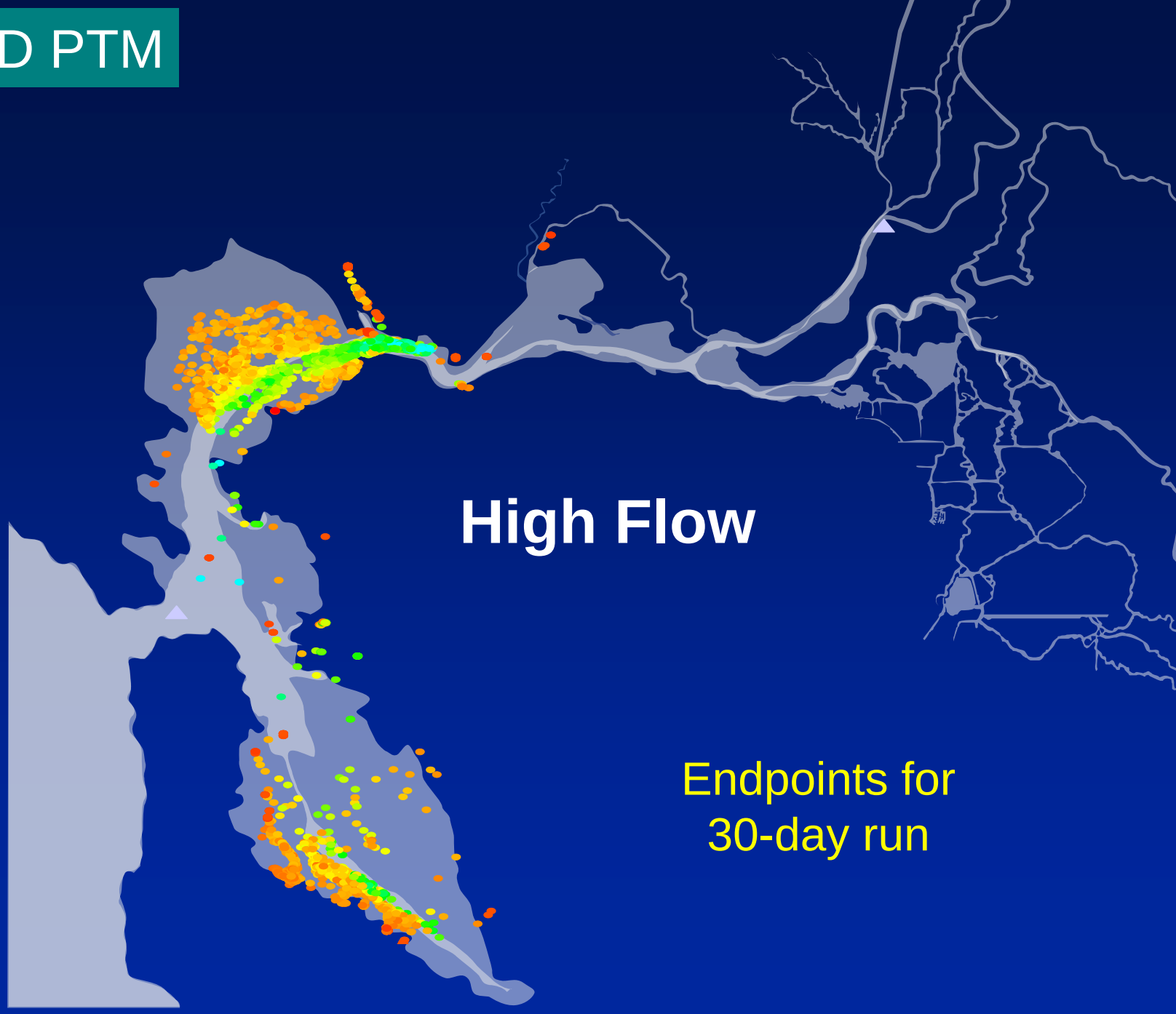
Mechanism for bottom-oriented species?



TRIM 3D PTM



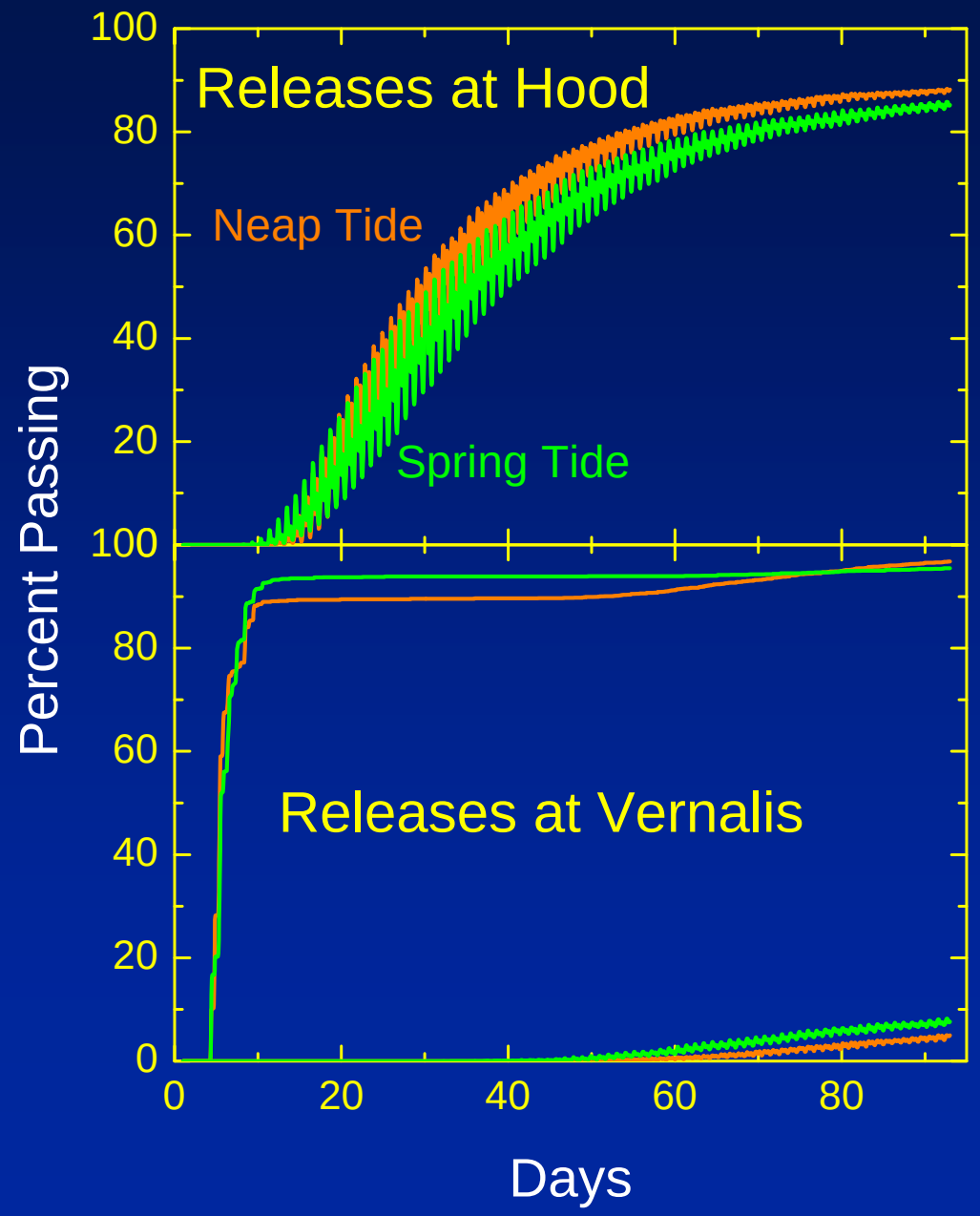
TRIM 3D PTM



1D Particle tracking in the Delta

- Flow patterns
- Entrainment in export pumps

DSM2 PTM - Example



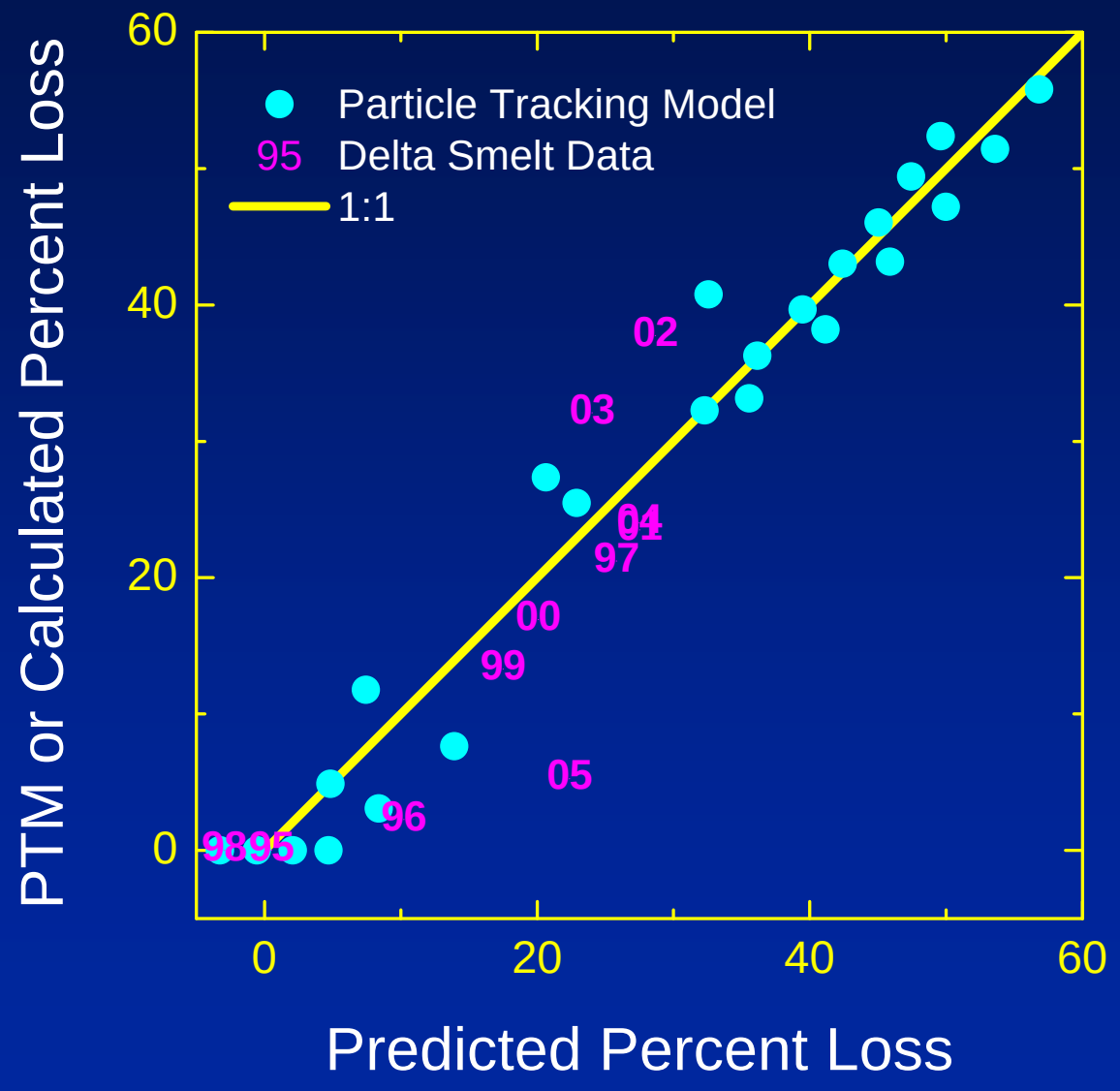
Recovery at Chipps

Recovery at Export Facilities

Recovery at Chipps

Source:
Kimmerer and Nobriga
2008 SFEWS

Delta smelt as particles?



PTM:
Releases throughout Delta Modeled with Inflow and Export Flow

Data:
Fractional losses of juvenile delta smelt from field data.

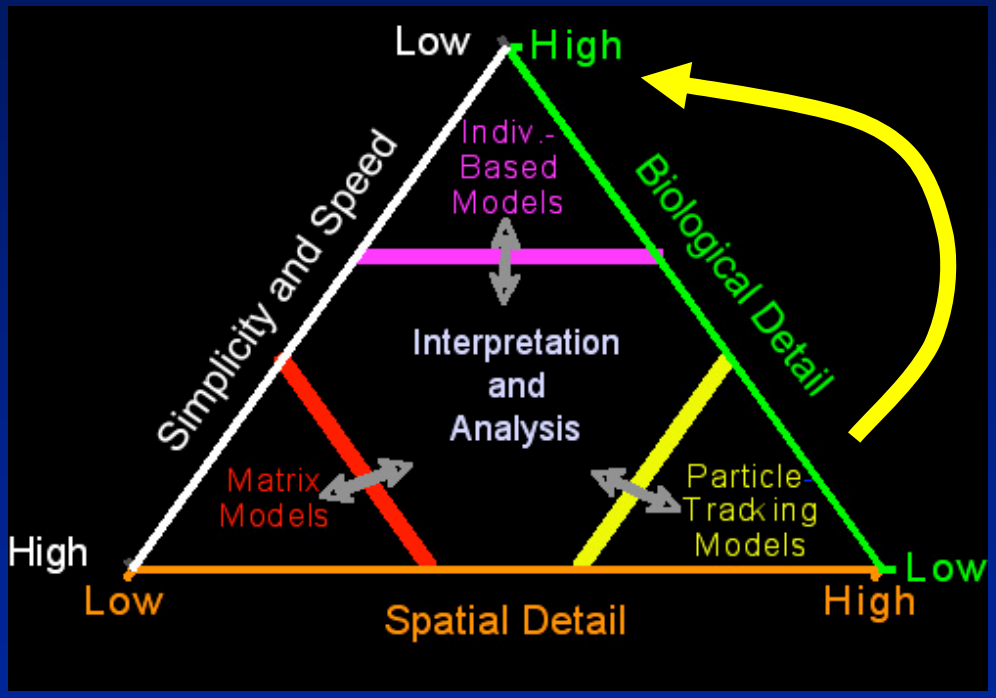
Source: Kimmerer and Nobriga 2008 SFEWS
Kimmerer In Press SFEWS

Individual-based Model of Delta Smelt

- Complete life cycle model
- Uses DSM2 for movement of young stages
- Recent progress and current state

Models and Research Team

Karen Edwards,
Wim Kimmerer, RTC
Kenneth Rose, LSU



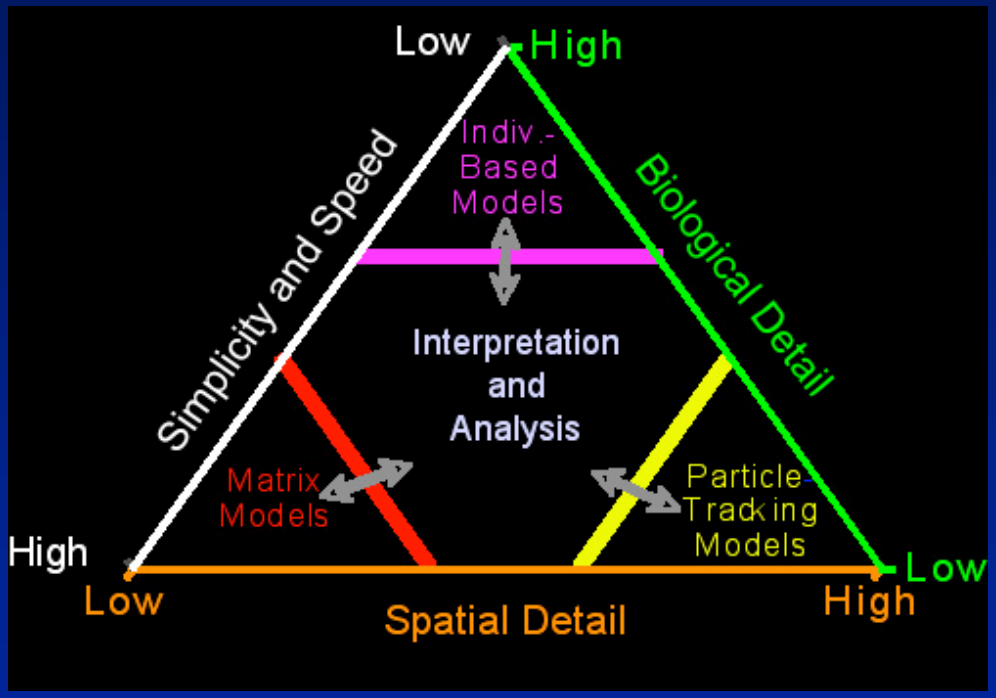
PTM embedded in Individual-Based Model

Bill Bennett, UC Davis

Stephen Monismith, Derek Fong, Jim Hench, Vamsi Sridharan, Stanford University

Model Uses

Explore details of movement and management actions



Investigate long-term patterns and probability of extinction

Explore alternative flow scenarios, alternative mixing schemes

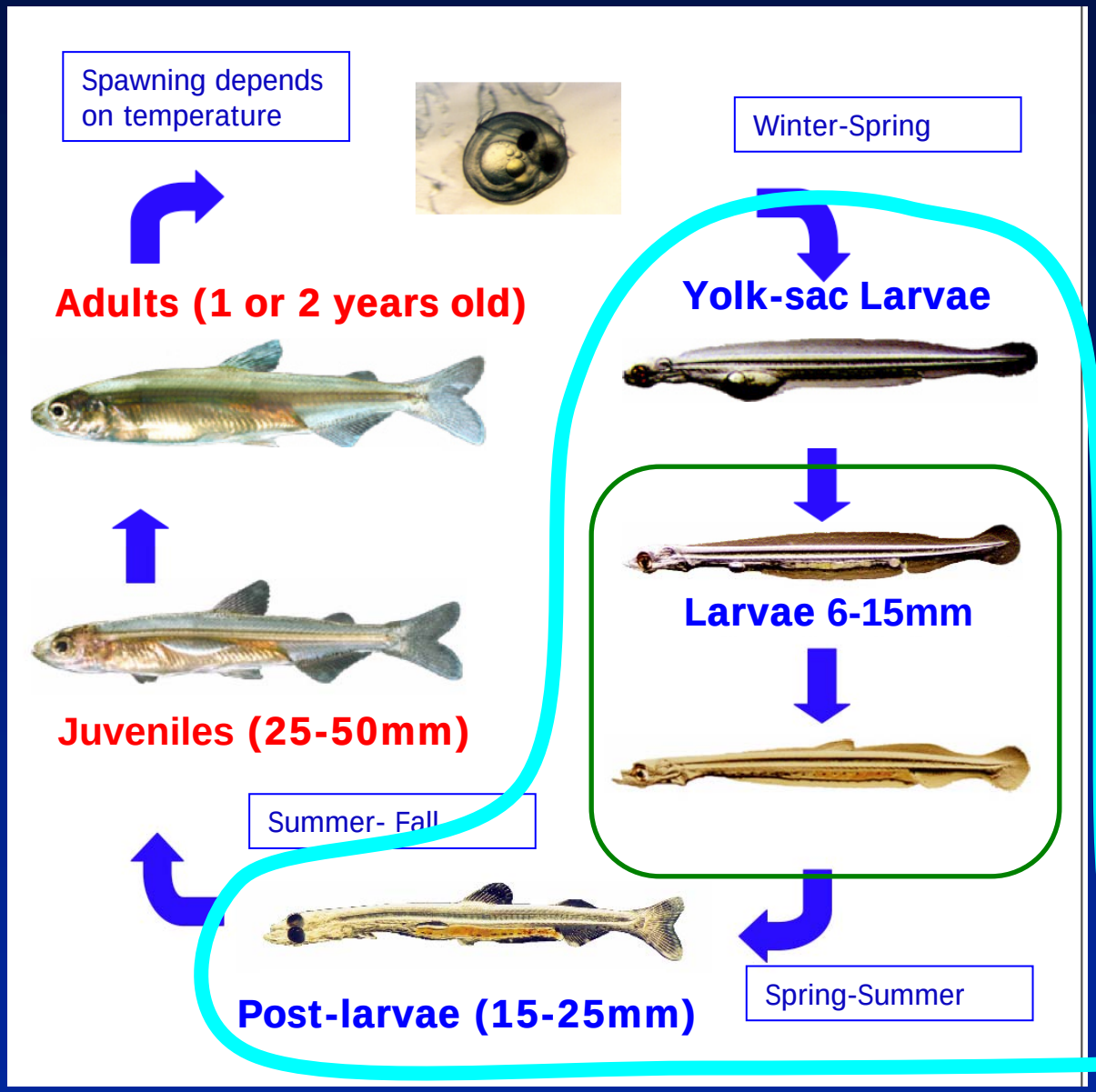
Project Goals & Questions

- Improve understanding of population ecology
- Investigate decline and possible recovery
- Link movement to biology and outcomes
- Environmental controls on abundance
  - Temperature
  - Salinity
  - Turbidity
  - Water diversions
  - Food
  - Contaminants?

Model Description

- Individual-based: Follow “super individuals”
  - Fixed number of model individuals each year
  - Each = declining number of “real” individuals
- Full Life-Cycle Model:
  - Growth
  - Mortality
  - Reproduction
  - Movement

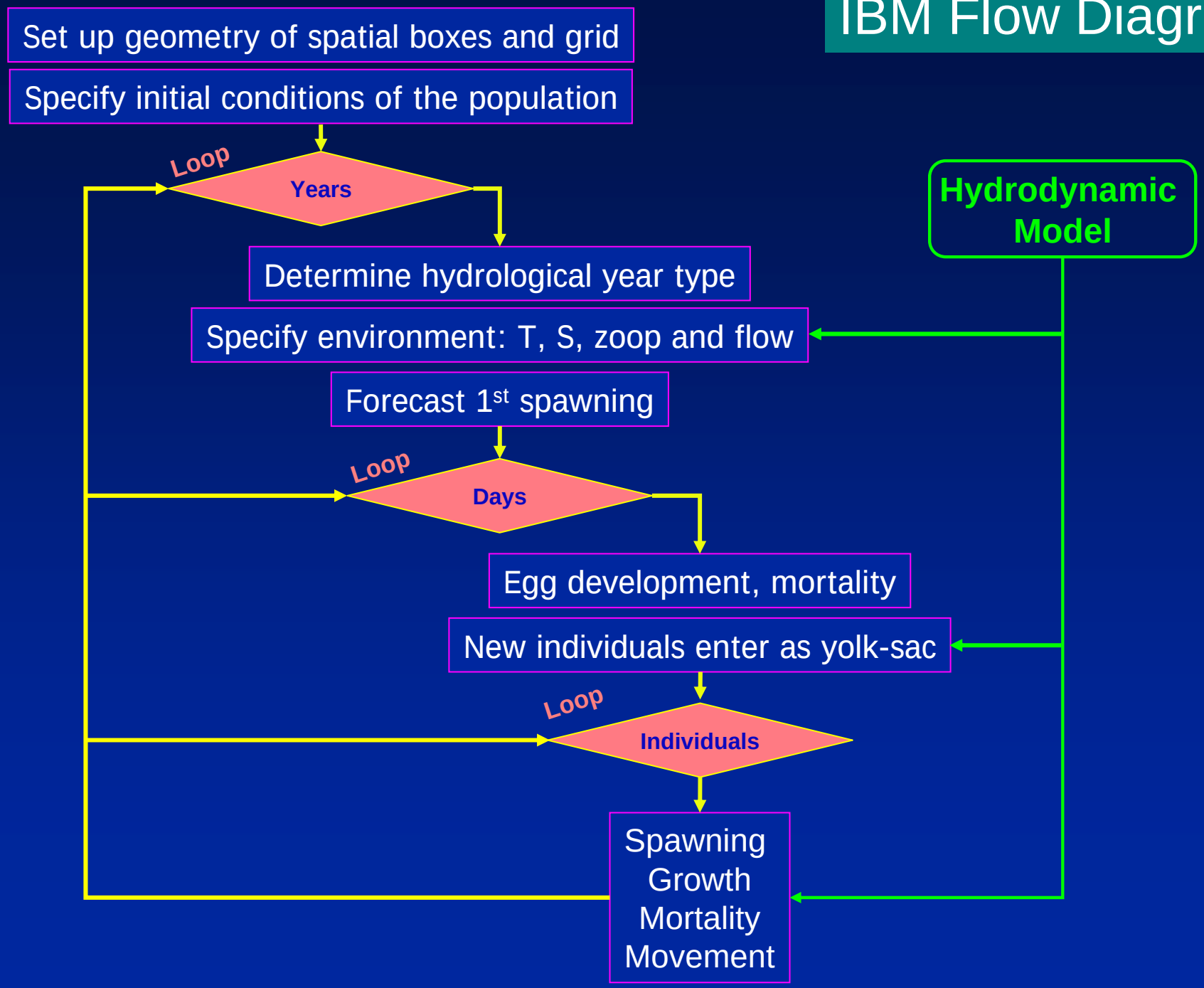
Life Cycle



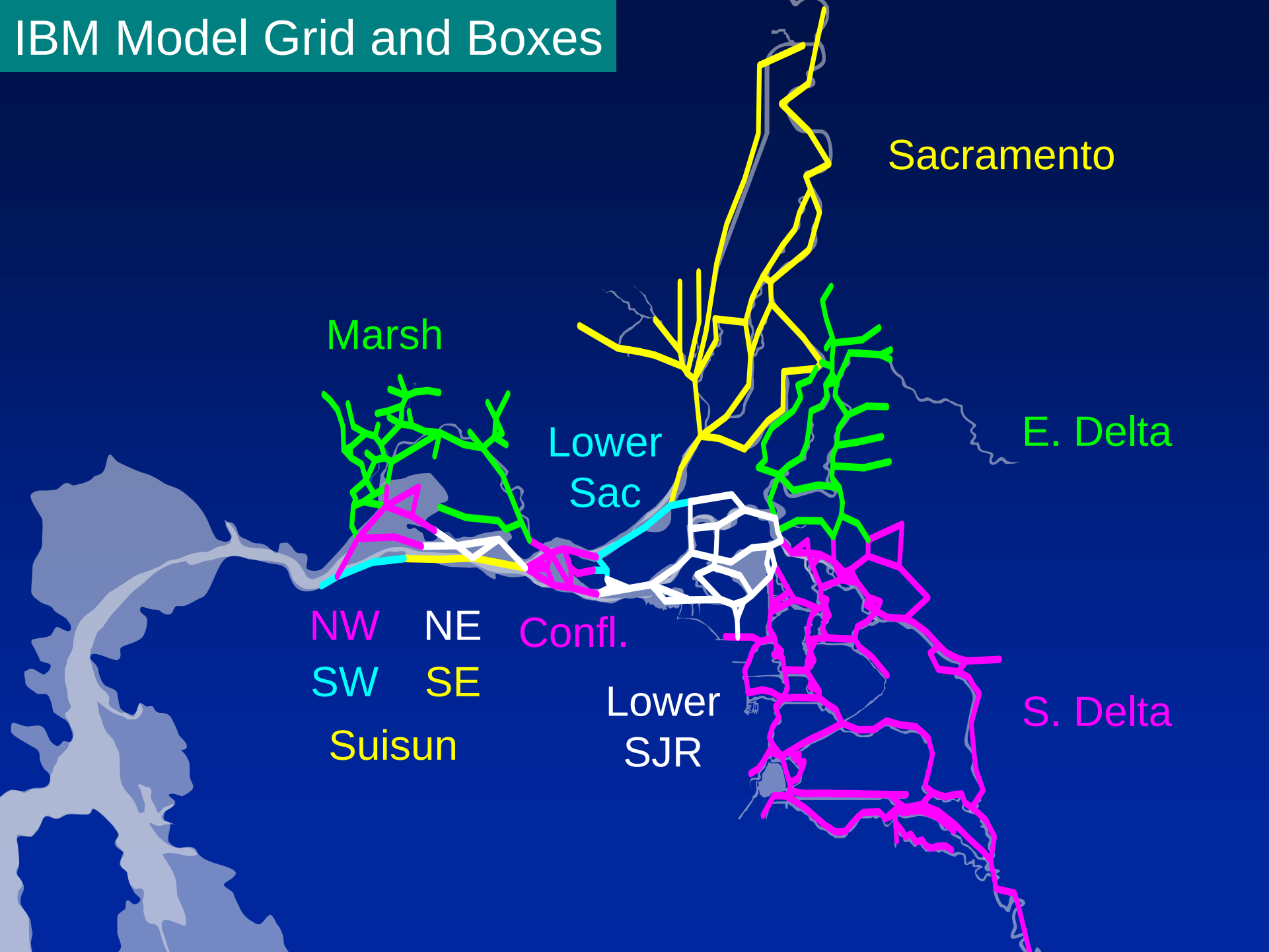
These stages move with the water

Adapted from Baskerville-Bridges, Lindberg, and Doroshov, Manual for the Intensive Culture of Delta Smelt

IBM Flow Diagram



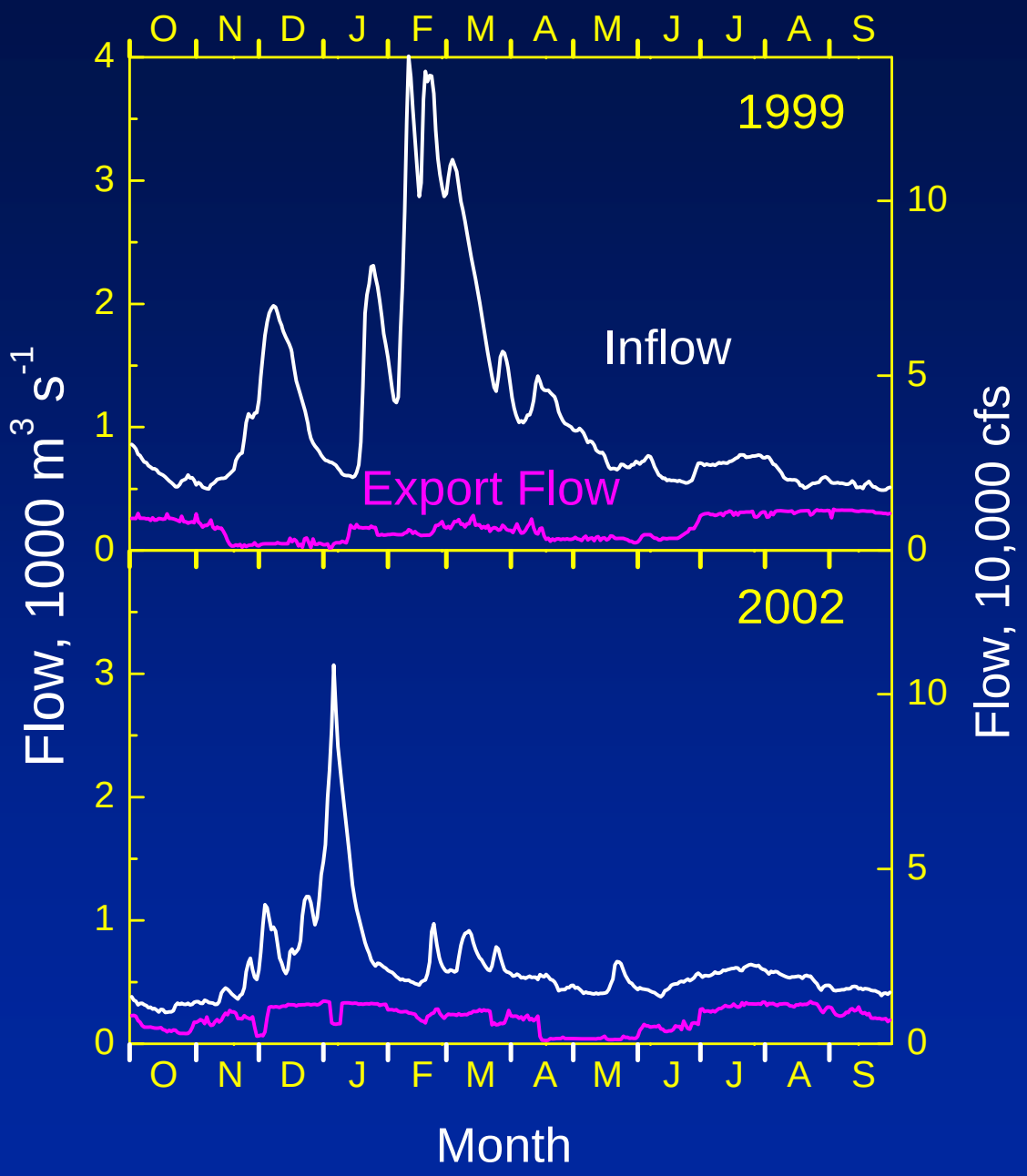
IBM Model Grid and Boxes



Environment

- Hourly output from hydrodynamic model
- Daily water temperature by box
- Daily salinity by box
- Daily turbidity by box extrapolated to channels
- Zooplankton extrapolated to channels

Daily Flow

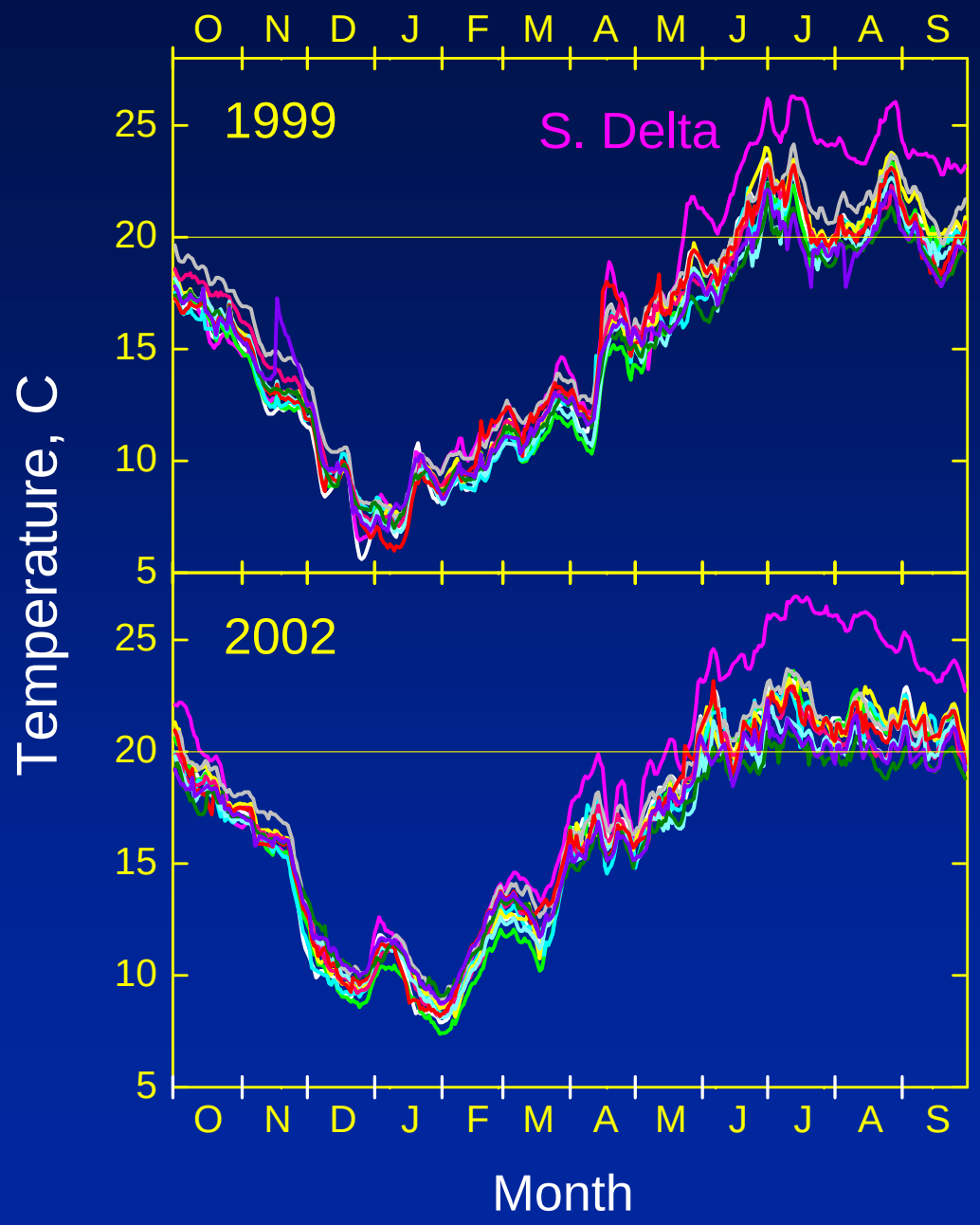


Data from DAYFLOW. Tidal and net flow in channels from DSM2 hydrodynamic model.

Affects movement and losses to export pumping.

Future: affects salinity

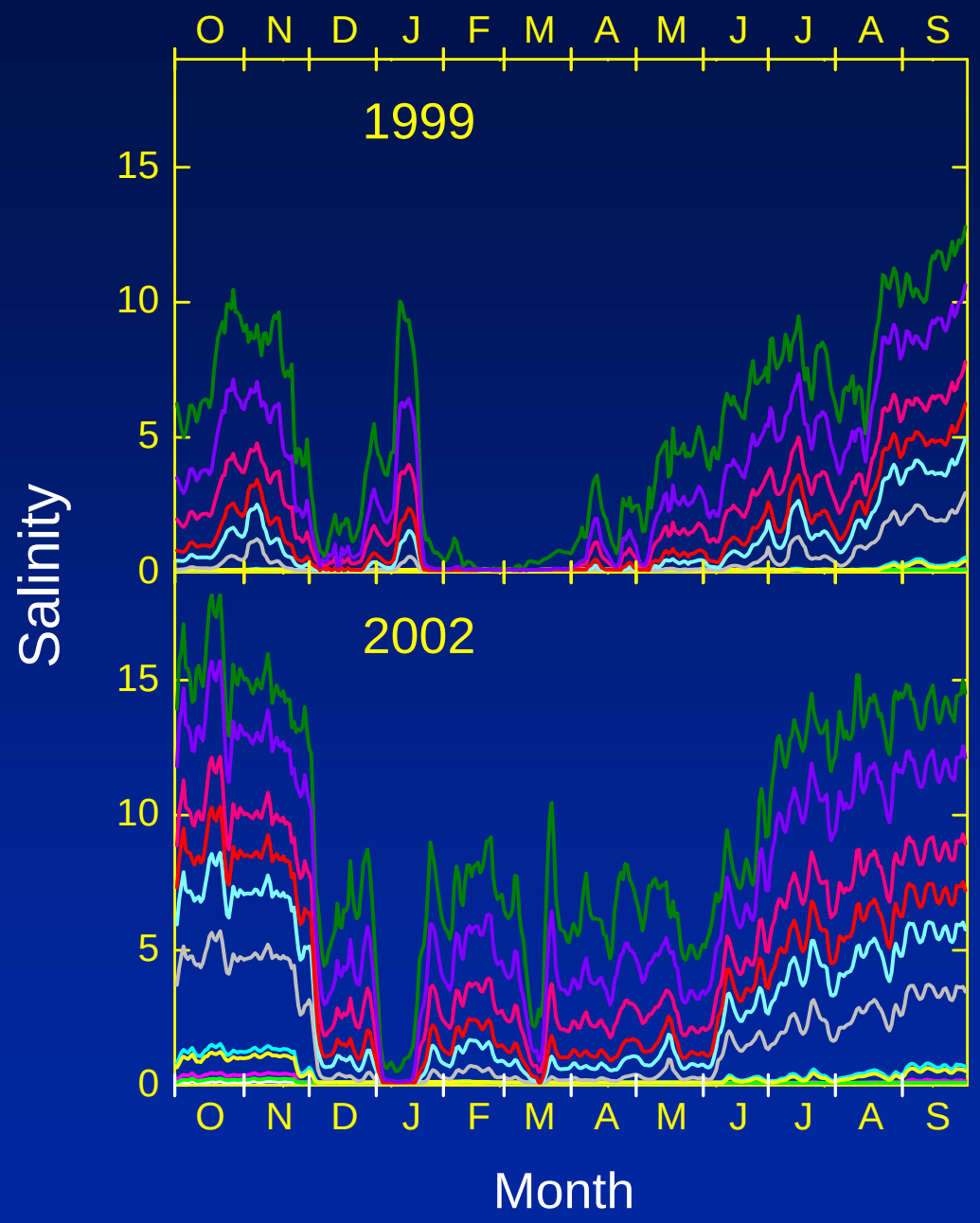
Daily Temperature



Data from IEP Continuous Monitoring stations and discrete stations. Filled in by interpolation and temporal regression.

Affects survival and growth rate

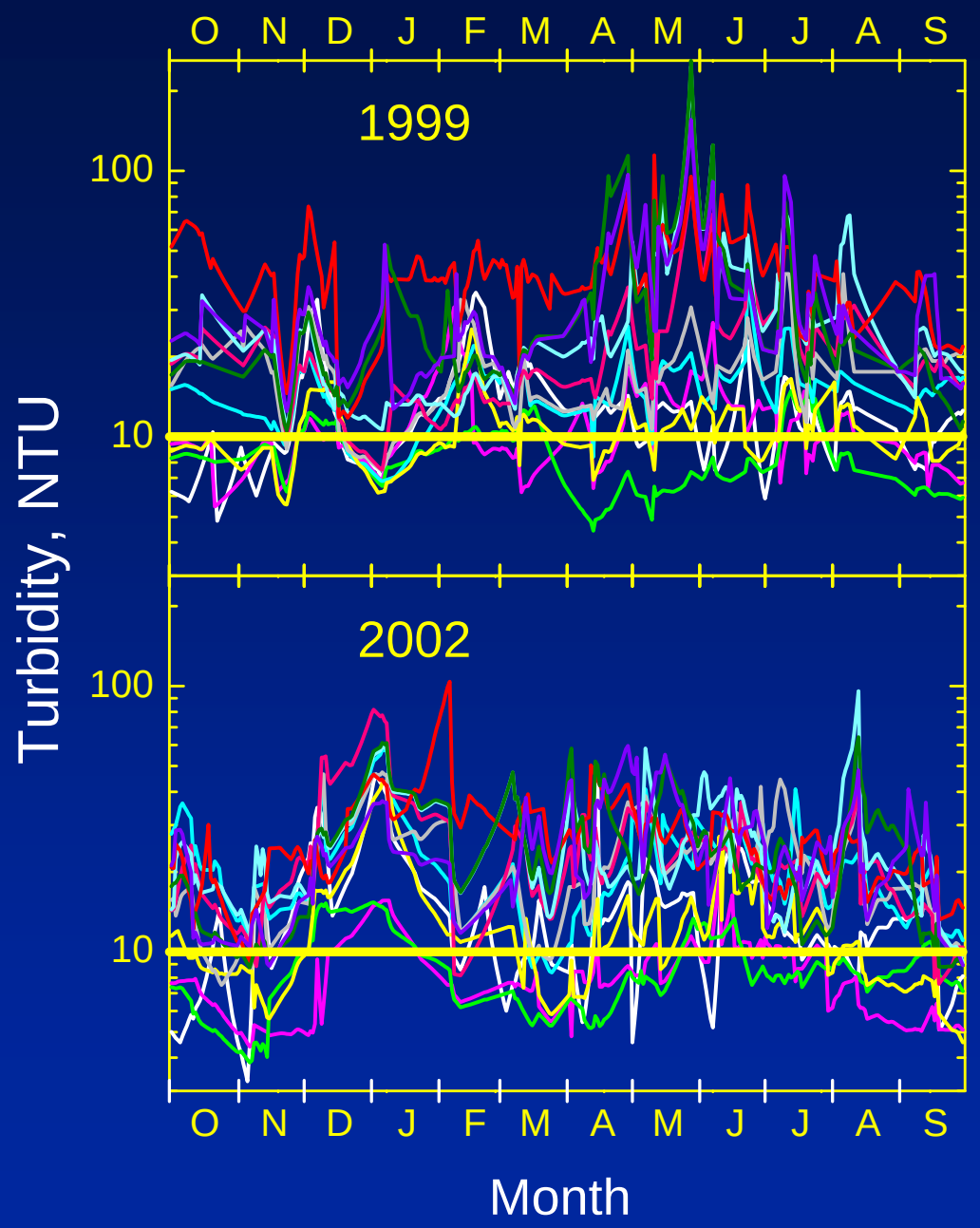
Daily Salinity



Data from IEP Continuous Monitoring stations. Filled in by interpolation and spatial regression.

Affects movement

Daily Turbidity



Secchi depth data from IEP Discrete Monitoring stations. Filled in by interpolation, then projected to individual channels

Affects survival, movement

Spawning

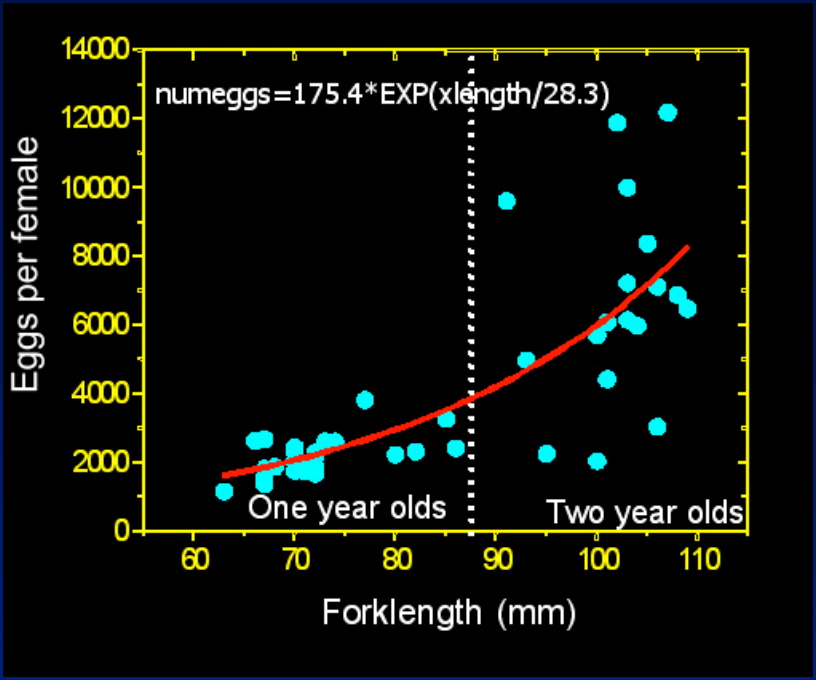


Figure from: B. Baskerville-Bridges, UCD and Bennett, 2005 SFEWS

- Temperature - dependent
- Lunar cycle
- Individuals may spawn twice
- Eggs assigned to box

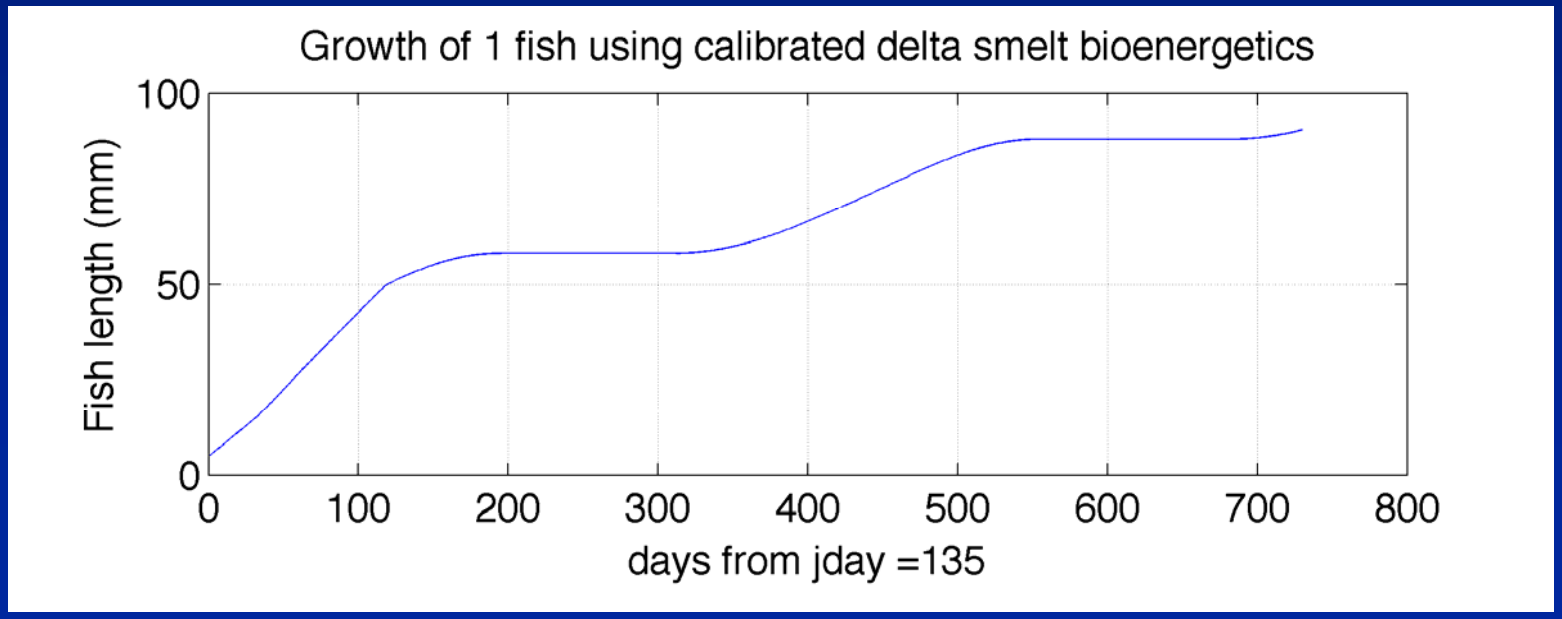
Growth

Wisconsin bioenergetics model:

Weight gain = consumption - metabolism - wastes

Consumption depends on zooplankton biomass

Parameters used to calibrate growth



Mortality

Instantaneous mortality rate (m, 1/day)

Daily survival (S) = e^{-m}

100% mortality of super-individuals at pumps

Rates adjusted in calibration

Stage	Mortality / day
Yolk-sac	0.0915
Larvae	0.0525
Post-larvae	0.0345
Juvenile	0.0155
Adult	0.0100

Movement

- Eggs stay put
- Larval stages:
  - Use particle tracking model (PTM)
  - Hourly time-step
- Juveniles & Adults
  - Kinesis: non-directional response
  - Cues: Salinity and food
  - Time-step: 12 hours
  - Directed migration twice / year

Movie : One fish over lifetime

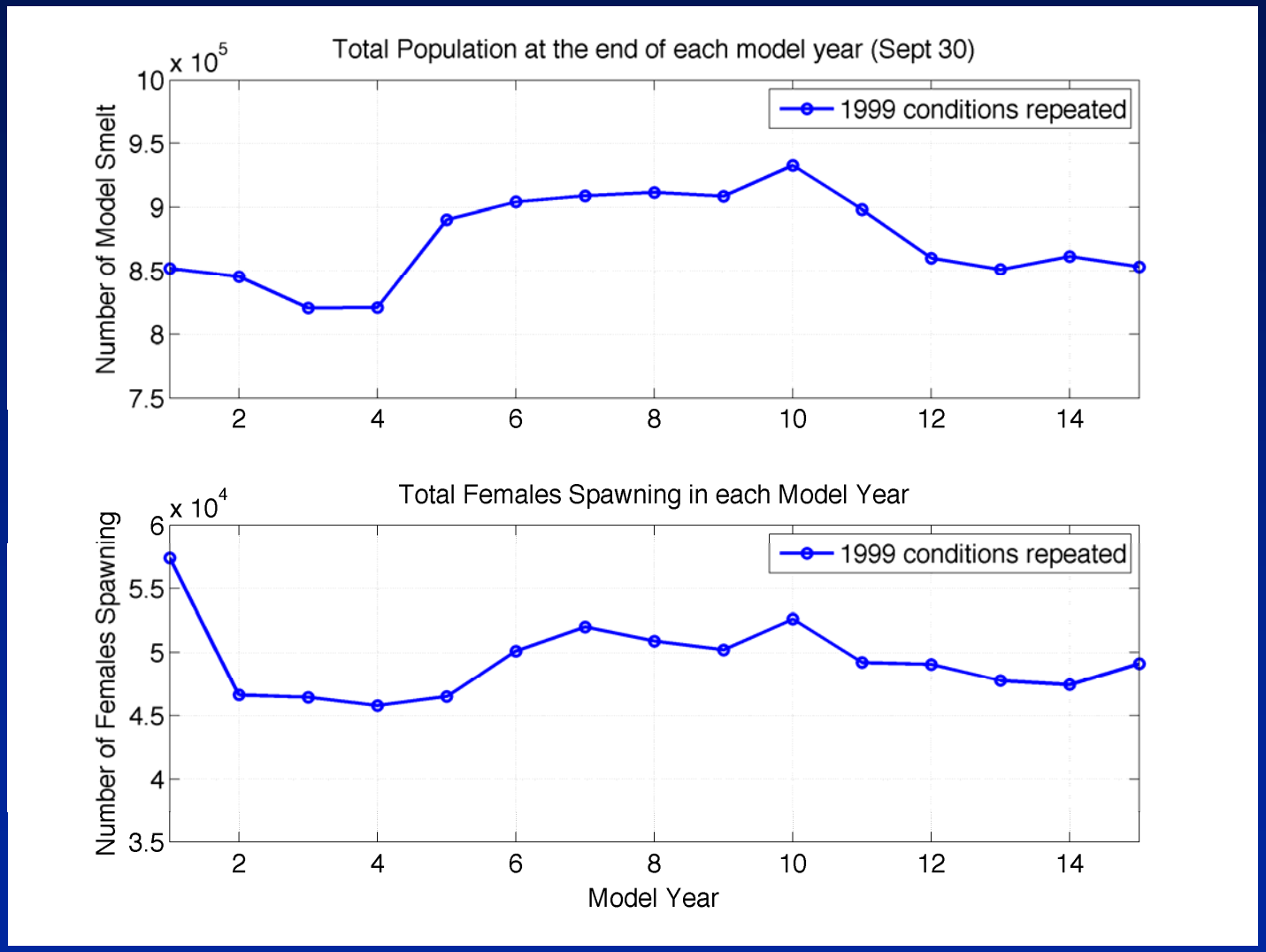
QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

fishmovie.mpg

Simulation Design

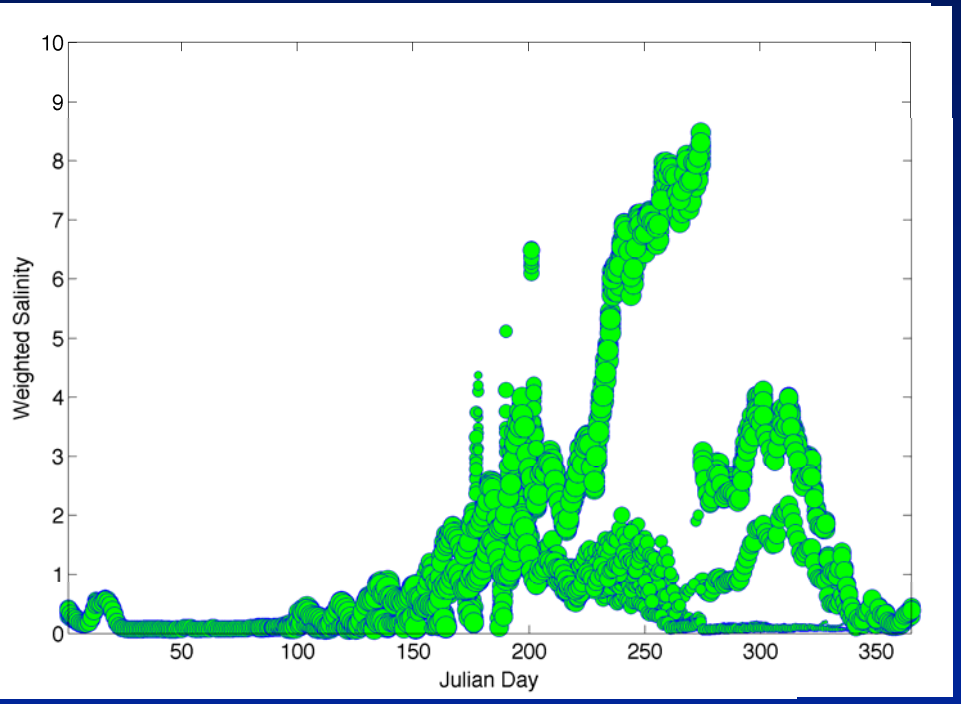
- Calibrate to 1999 conditions
- Scenarios:
  - 1999 repeated
  - 2002 repeated
  - Historical run (1995-2005)
  - Reverse historical run (2005-1995)
- 100,000 individuals produced each year

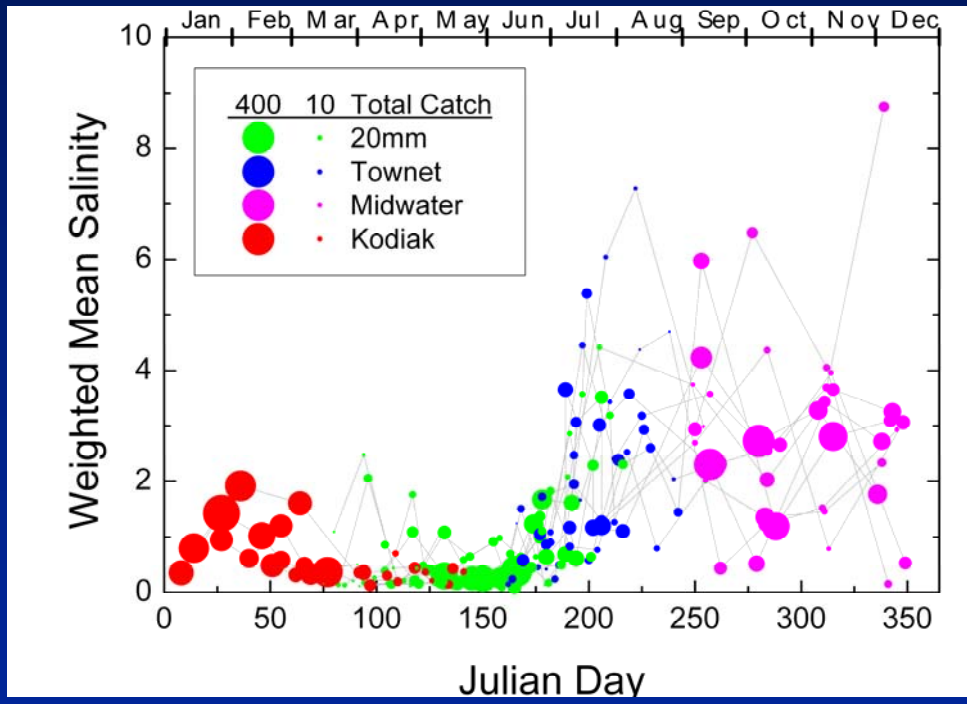
Calibration Results



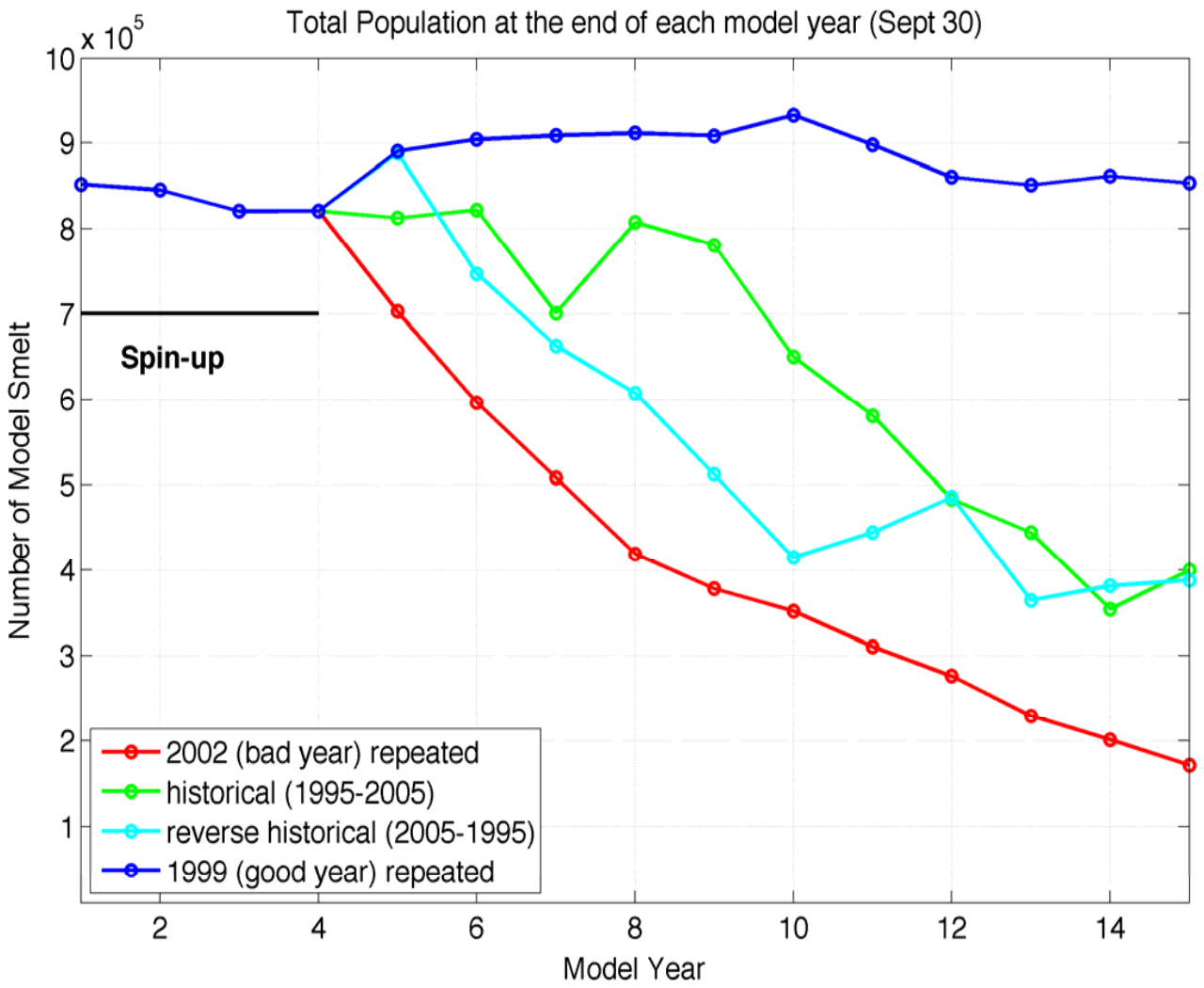
Smelt-weighted salinity

(15 years of 1999 conditions)





Results of First Simulation



What the model can do

Current model:

- Compare some potential causes of decline
- Examine movement and export losses
- Investigate some management actions

With some revision:

- Investigate aspects of hatchery input
- Investigate alternative flow scenarios

Caveats….

- Appears complex yet too simple
- Not a desktop application
- Stretches the data and information
- Can’t predict the future
- Difficulties with some investigations, e.g.:
  - Alterations to physical structure
  - Altered flow affecting zooplankton
  - Changes in predators
  - Genetic aspects

A Work in Progress

- Finalizing recalibration
- First paper (model description) in draft
- Designed first simulations
- Personnel changes

Summary

CALFED BAY-DELTA PROGRAM

Models have many uses

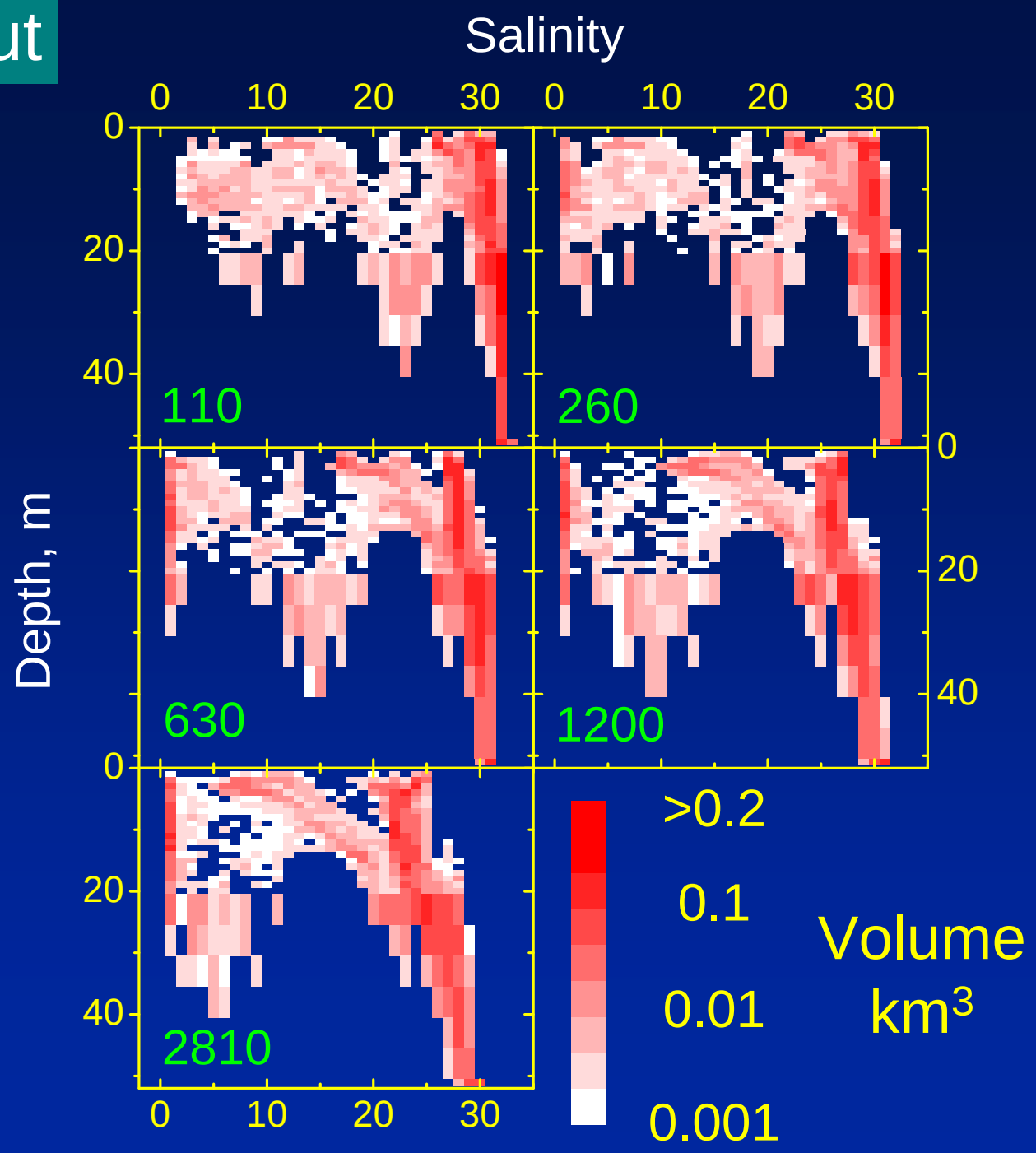
- *Explore conditions that have not existed*
- *Isolate important factors*
- *Conduct "experiments"*
- *Investigate management options*

Work is proceeding on the delta smelt models

Funding from the CALFED Science Program,
CALFED Ecosystem Restoration Program,
and the Interagency Ecological Program
Co-conspirators: Kenny Rose, Karen Edwards, Bill Bennett,
Ed Gross, Mike MacWilliams

TRIM 3D Output

Volume in depth and salinity ranges



Numbers give flow, $m^3 s^{-1}$