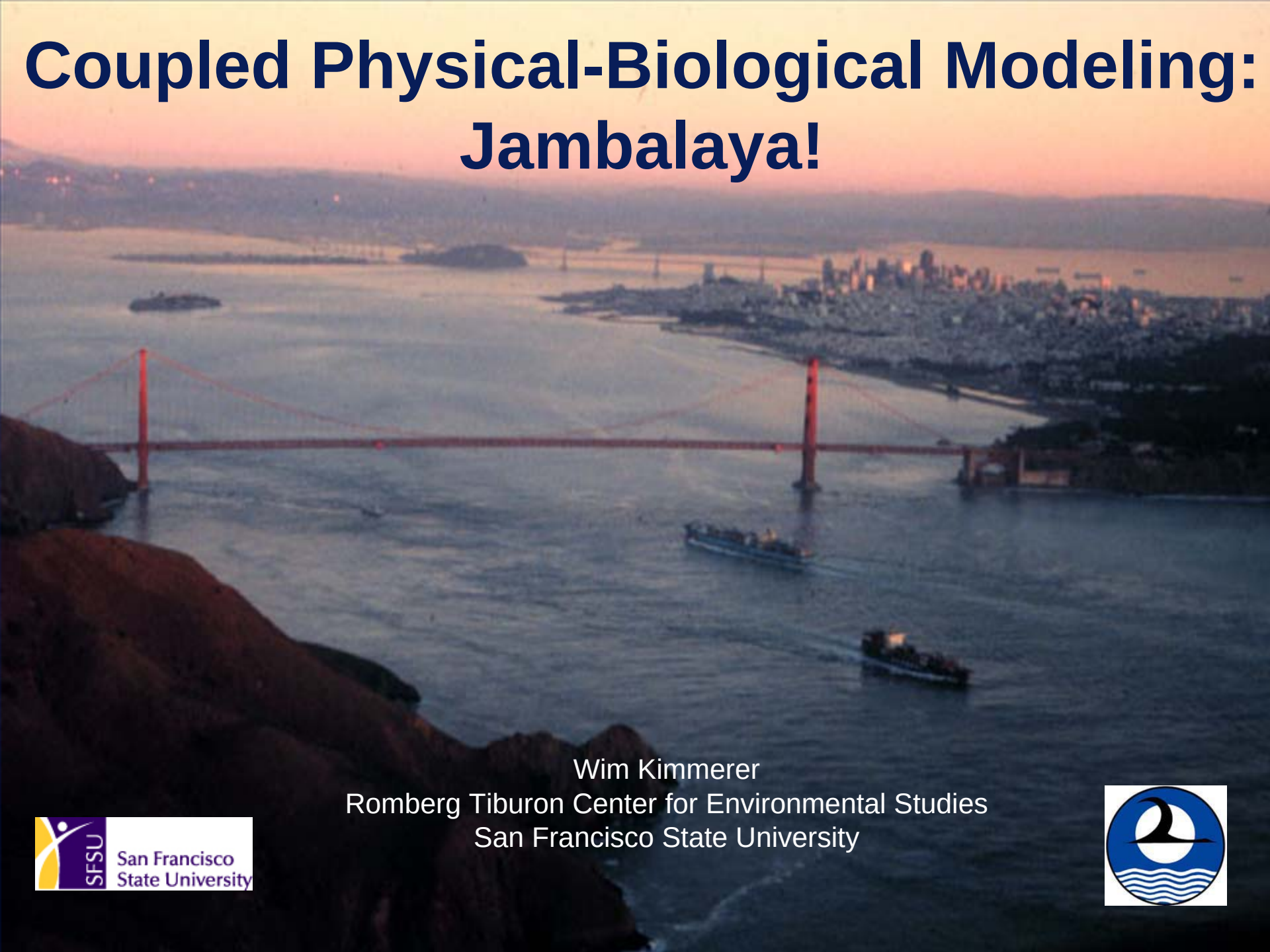
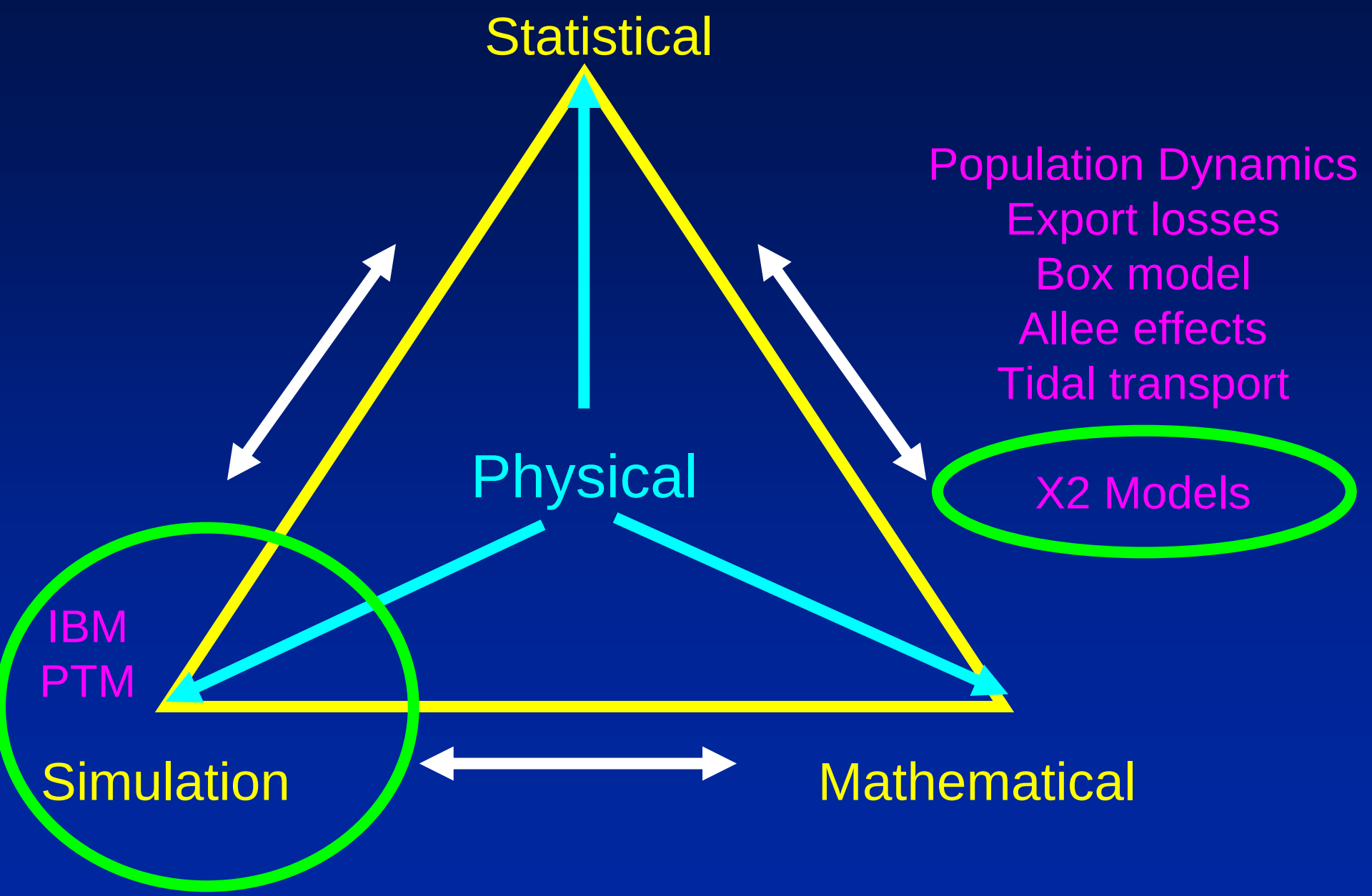
Coupled Physical-Biological Modeling: Jambalaya!

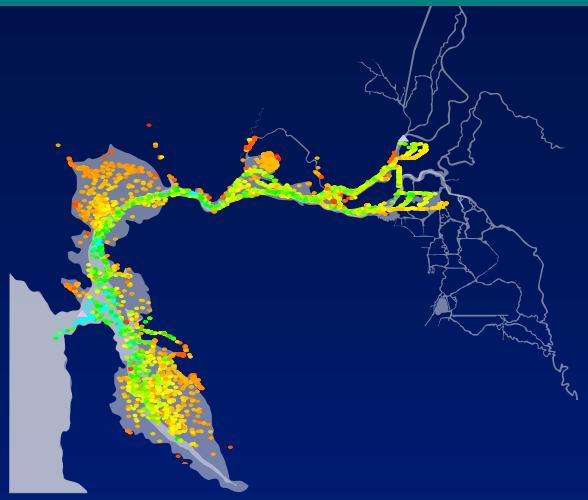


Wim Kimmerer
Romberg Tiburon Center for Environmental Studies
San Francisco State University

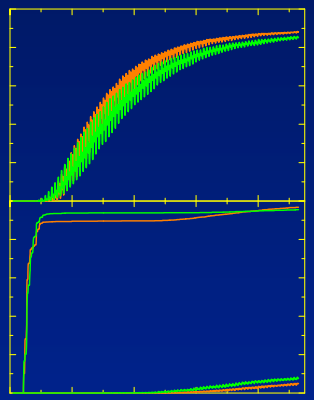
Classes of Biological Models



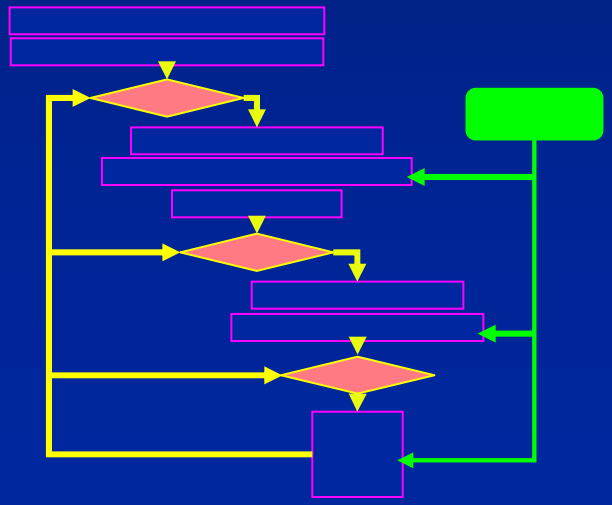
Examples of Physical-Biological Models



3D modeling: “X2 Project” (CALFED



1D Particle tracking (IEP)



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

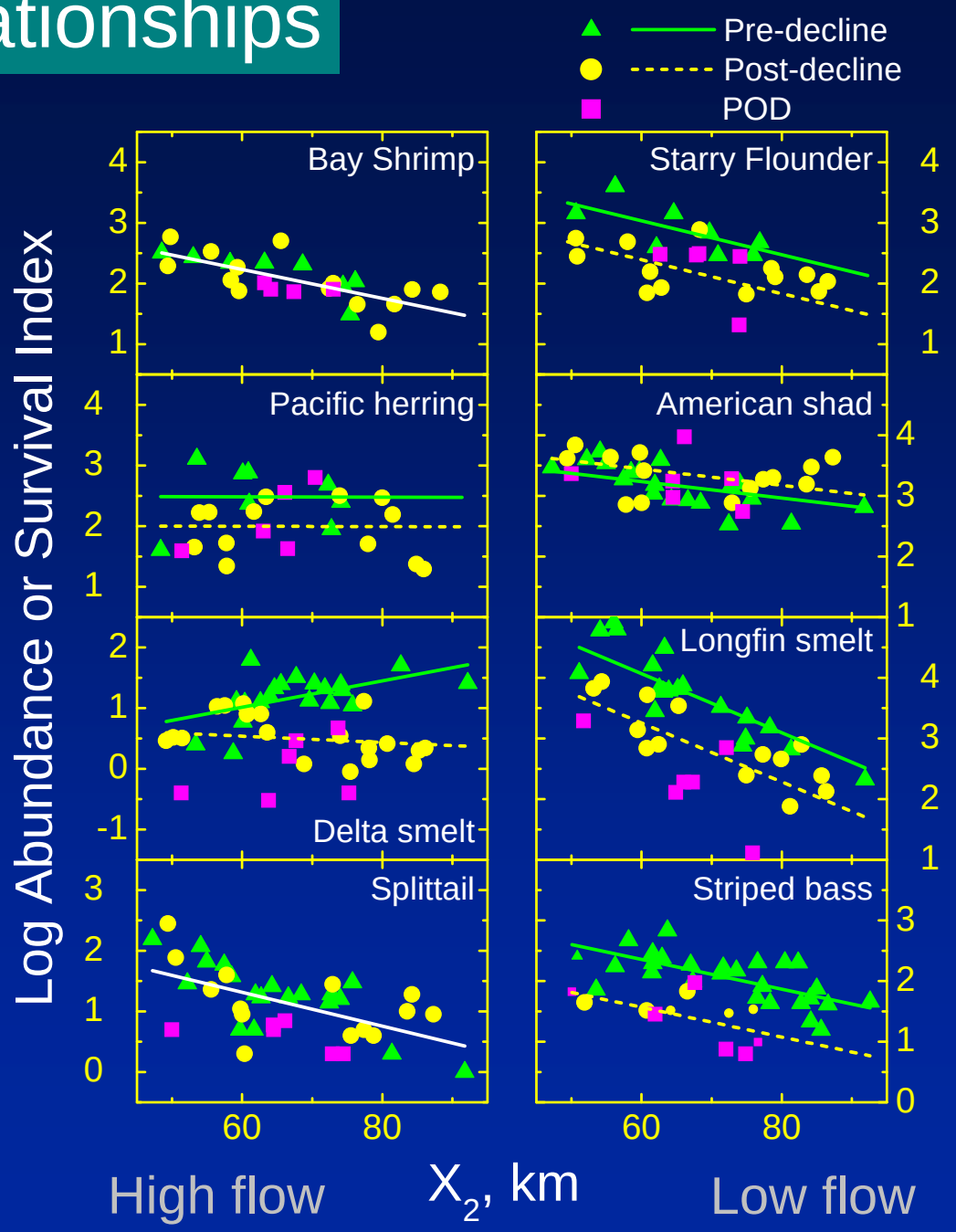
And a few other things…

Updated Fish-X_2 Relationships

No change in slopes, lower in some POD years

Decline after 1987 except delta smelt (1981) and striped bass (1995)

Kimmerer, Gross, & MacWilliams
Estuaries & Coasts (2009)



Classes of Mechanism

F: Food supply increases with flow

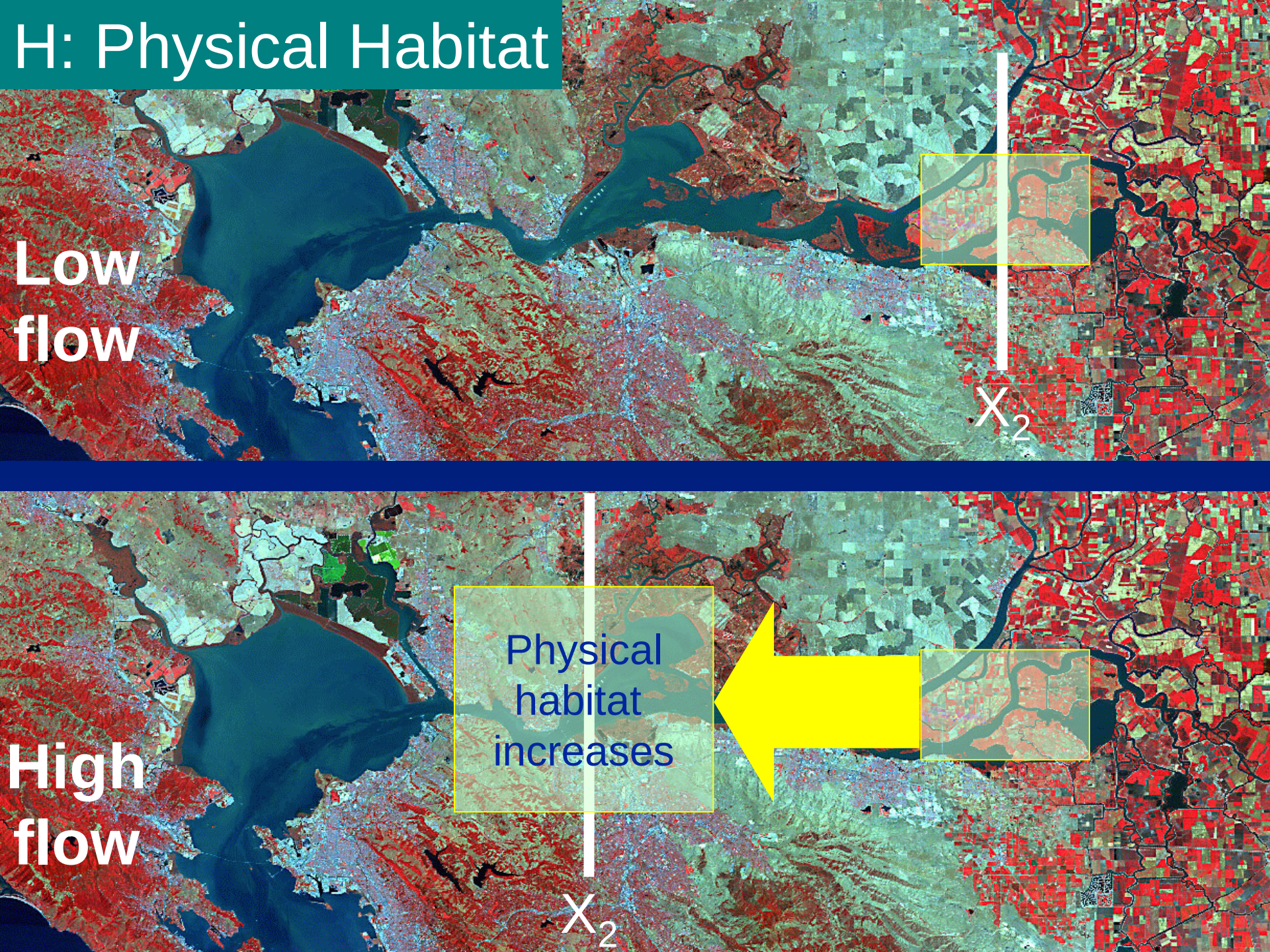
T: Rates of transport increase with flow

Q: Water quality improves with flow

H: Area or volume of habitat increases with flow

Results from: Kimmerer, Gross, & MacWilliams
Estuaries & Coasts (2009)

H: Physical Habitat



Habitat Characteristics

"Habitat" = Volume in Salinity (and Depth) ranges

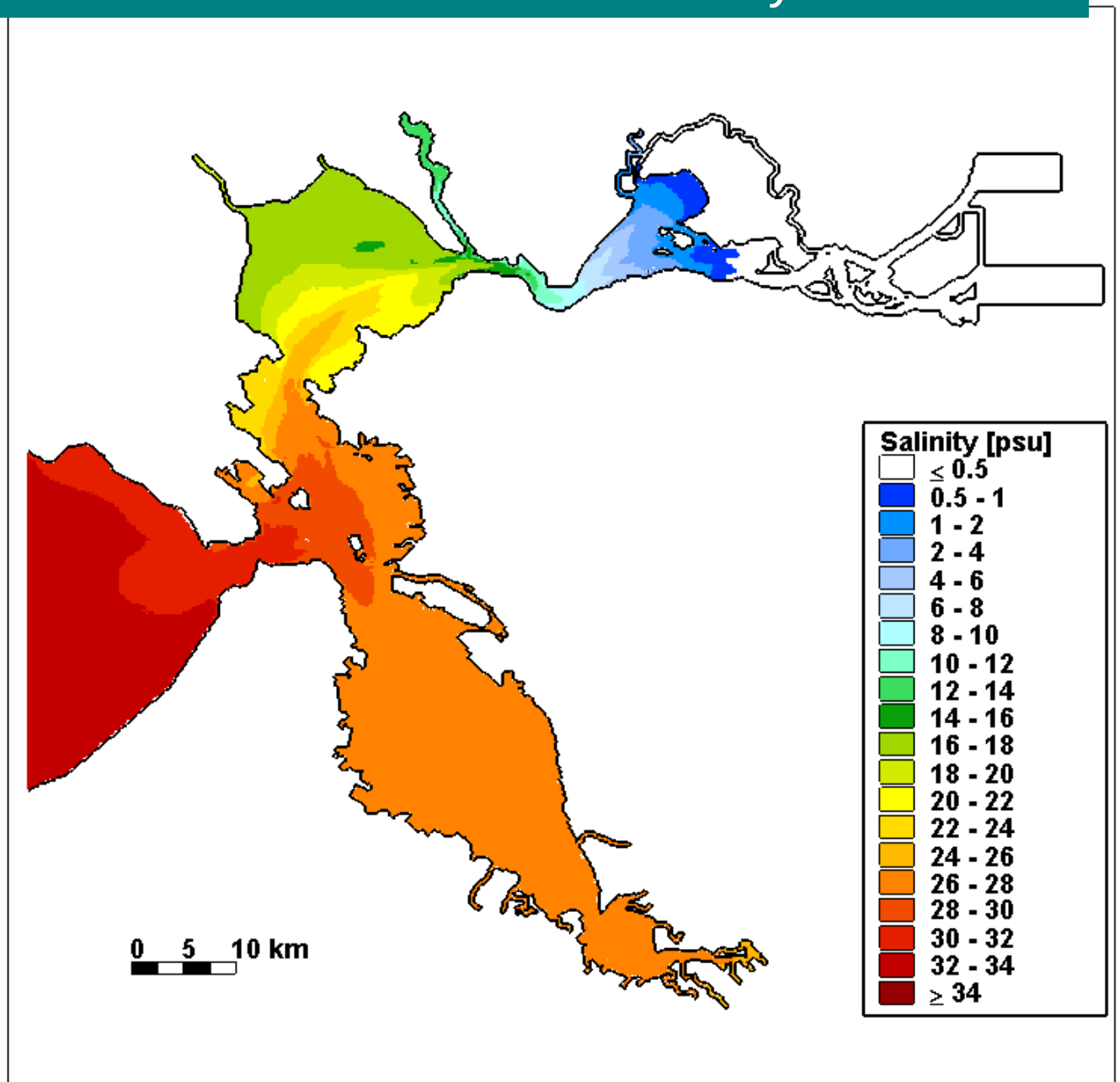
(Abundance $\propto$ Habitat volume)

Abundance ↑ as habitat ↑

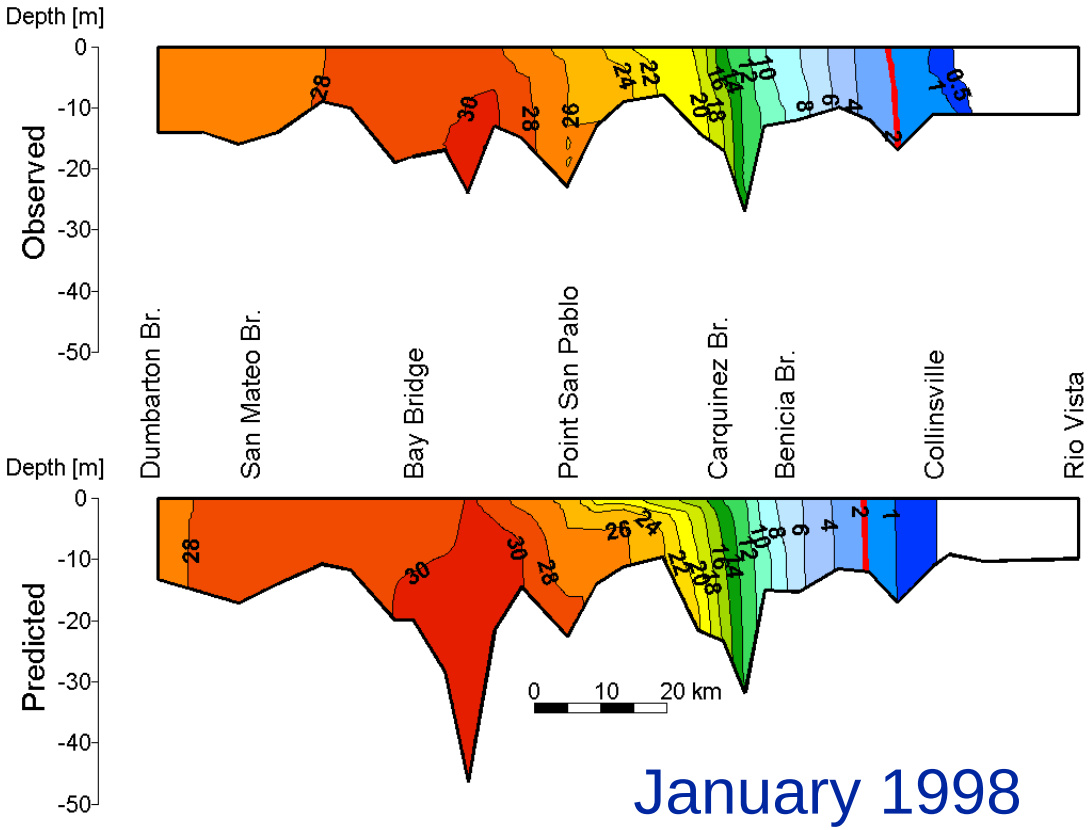
Not:

- (Turbidity)
- Physical or hydrodynamic complexity
- Connection to shore or marsh features
- Predator refuge
- Food

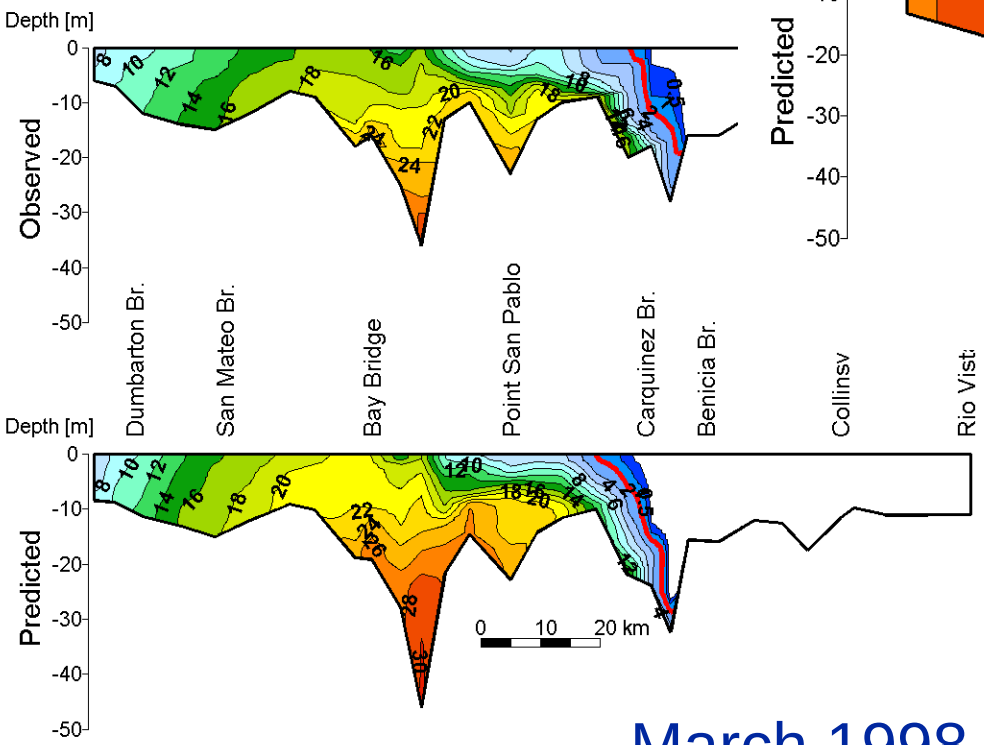
TRIM3D Model Grid: Example at Intermediate Flow Water Column Mean Salinity



TRIM3D Calibration



January 1998

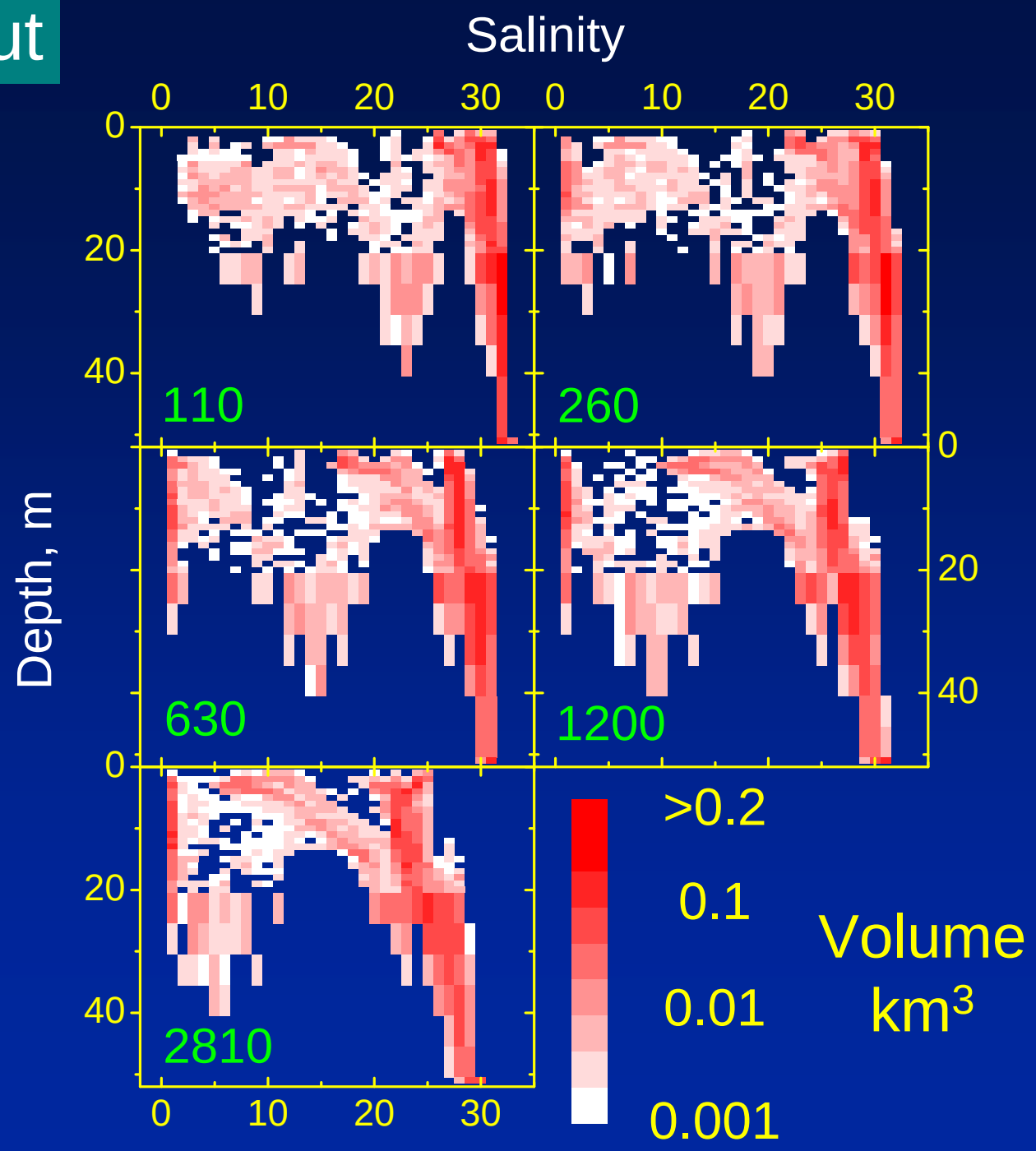


March 1998

Salinity

TRIM 3D Output

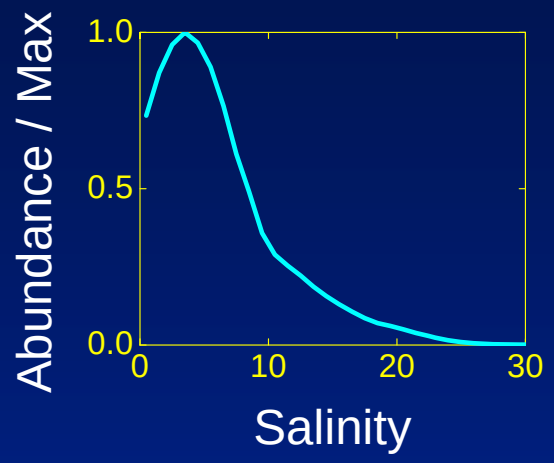
Volume in depth and salinity ranges



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

Example

Habitat Curves



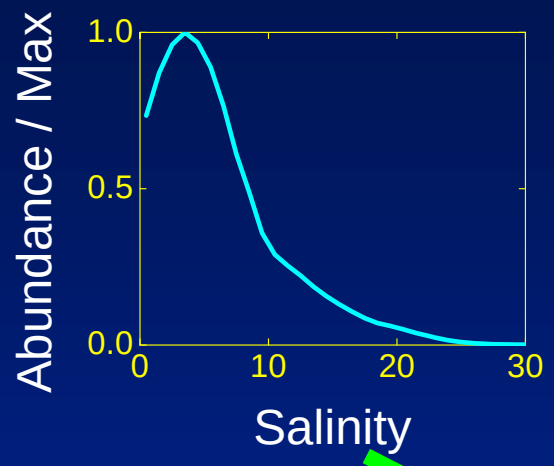
Determined from field data:

- 4 sampling programs
- 5,000 to 13,000 data points included
- Generalized Additive Models
- Fit to Salinity + Depth (Otter Trawl)
  - or Salinity (all others)
- Abundance and Frequency data

Feyrer et al. 2007
CJFAS 64: 723

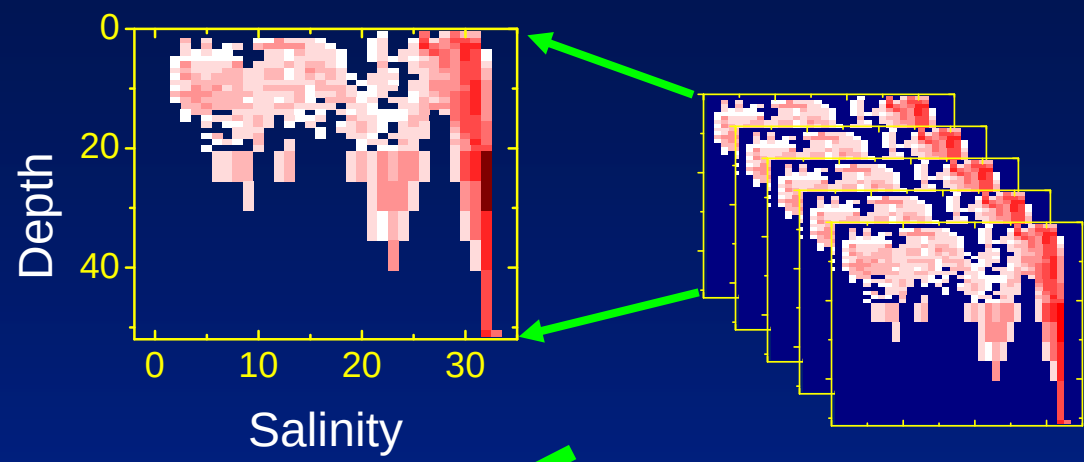
Example

Habitat Curves

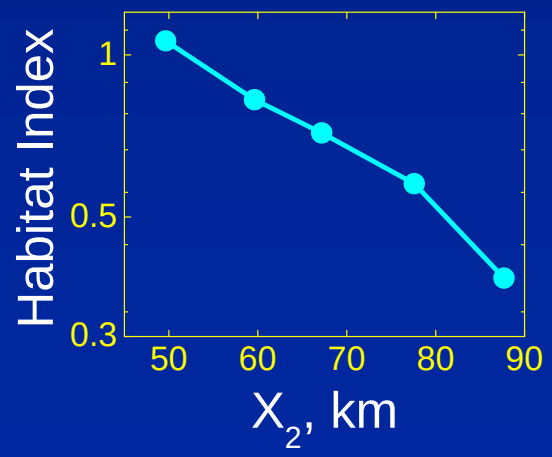


TRIM 3D: 5 Flows

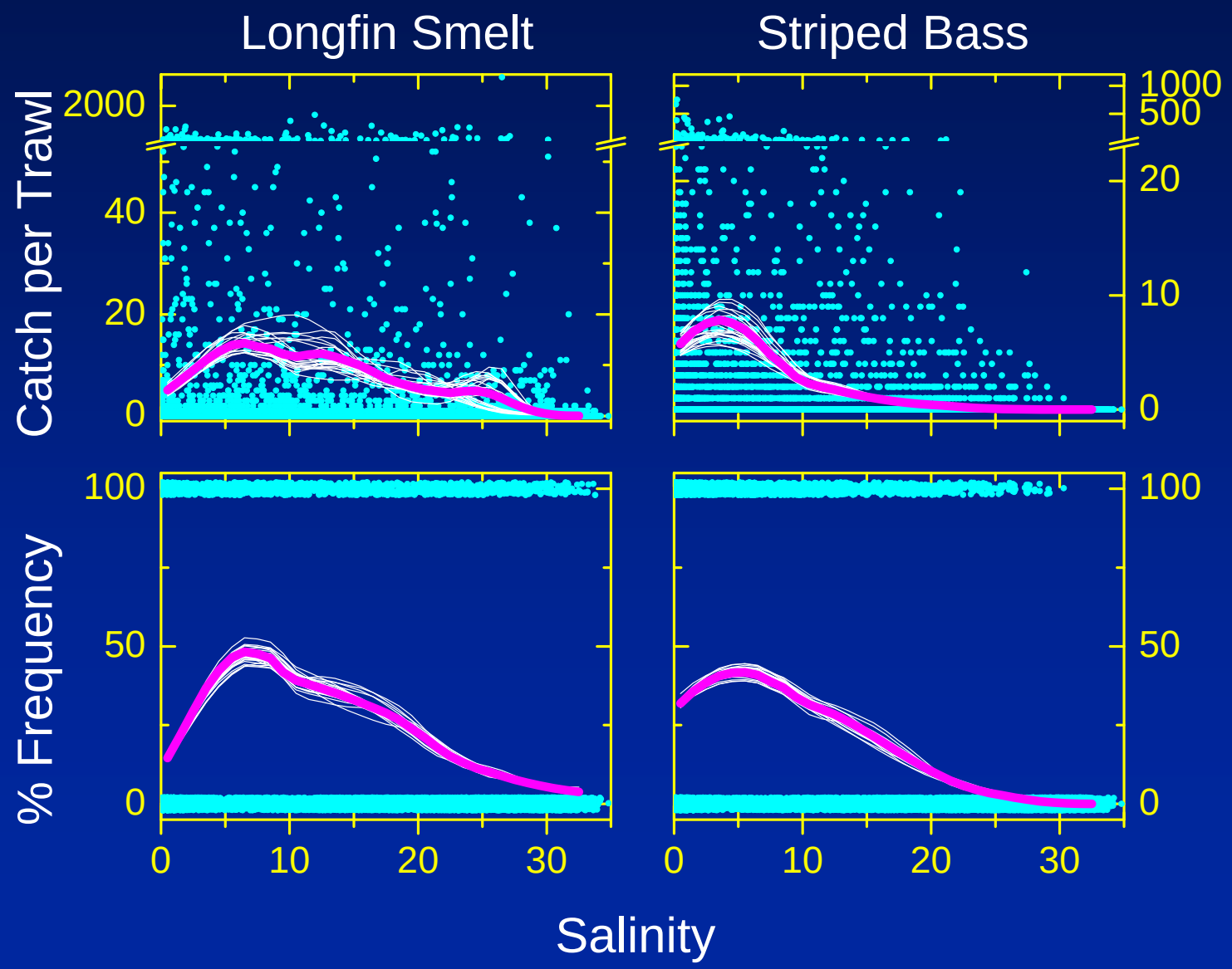
Color = Volume



Weighting



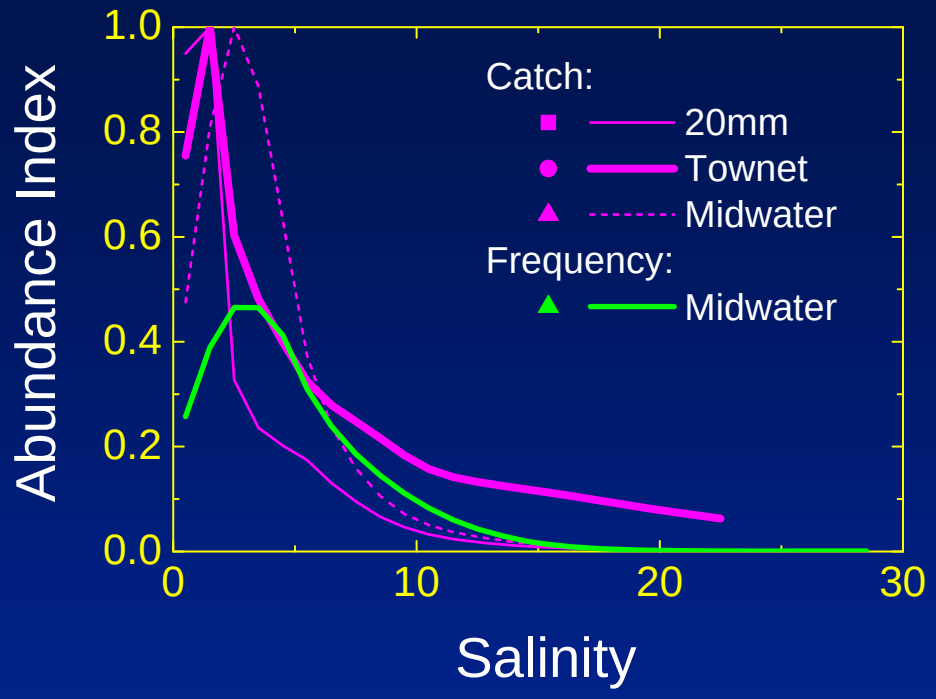
Example Habitat Curves

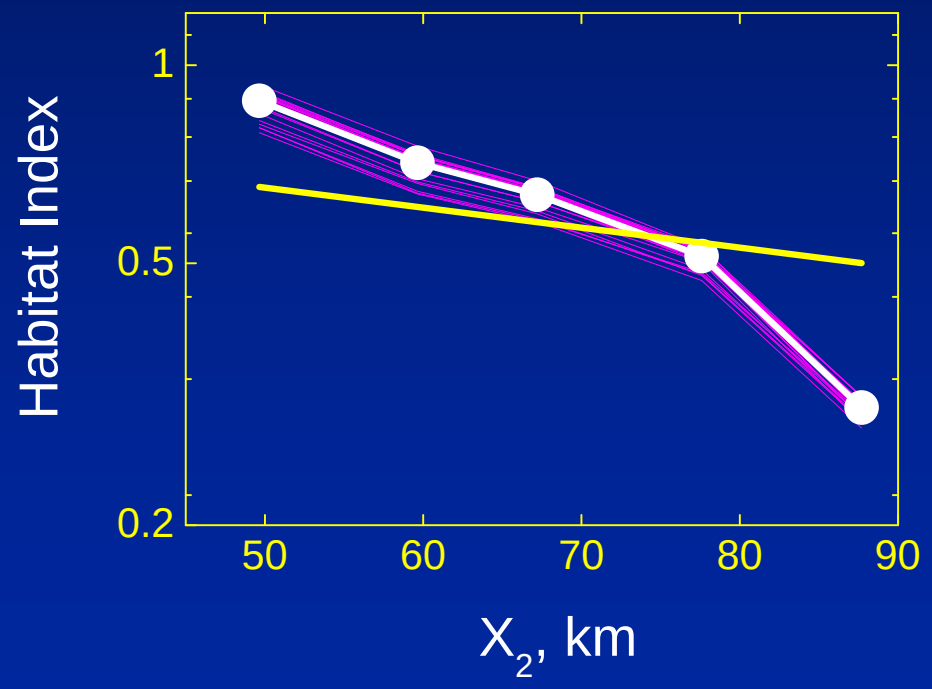


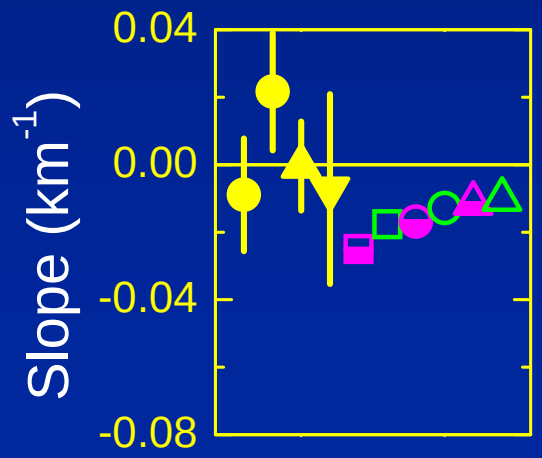
Data from Bay Study Midwater Trawl

Delta Smelt

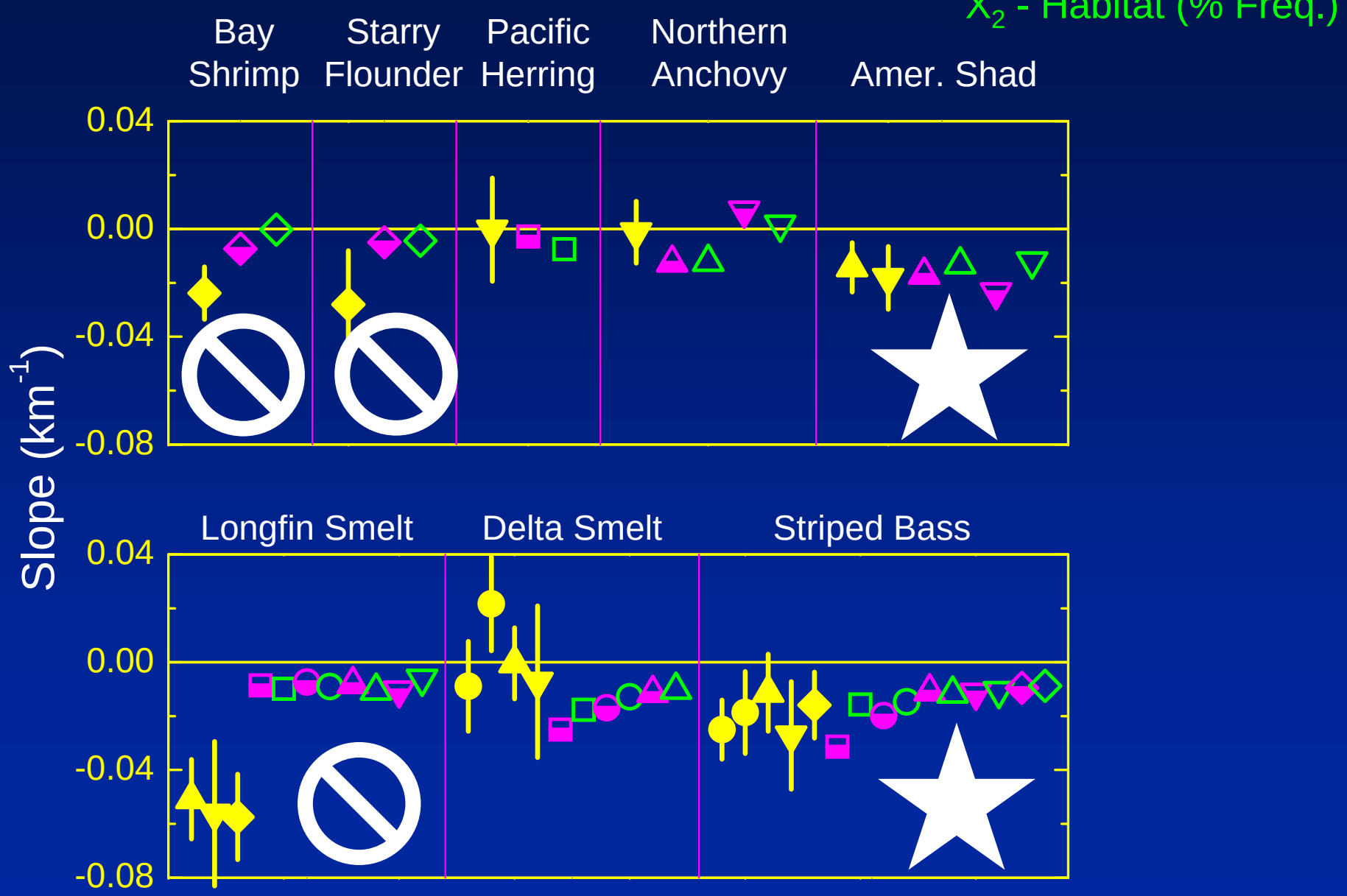
Compare Slopes:
Habitat Index (catch)
Habitat Index (% Freq)
Abundance-X_2







Bottom Line


X_2 - Abundance
X_2 - Habitat (Catch)
X_2 - Habitat (% Freq.)
Bay Shrimp
Starry Flounder
Pacific Herring
Northern Anchovy
Amer. Shad
Longfin Smelt
Delta Smelt
Striped Bass
Slope (km^{-1})
0.04
0.00
-0.04
-0.08

Classes of Mechanism

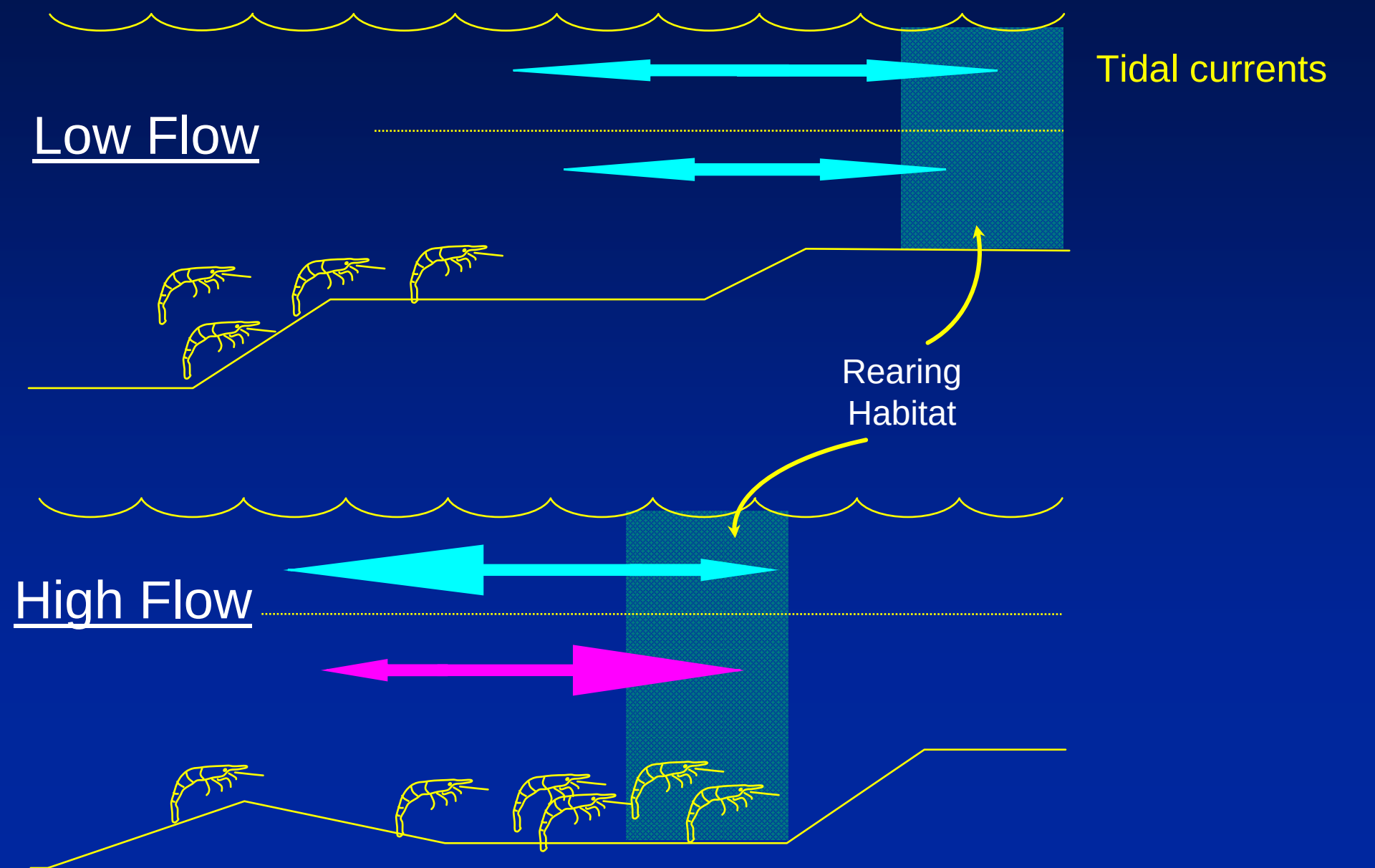
F: Food supply increases with flow

T: Rates of transport increase with flow

Q: Water quality improves with flow

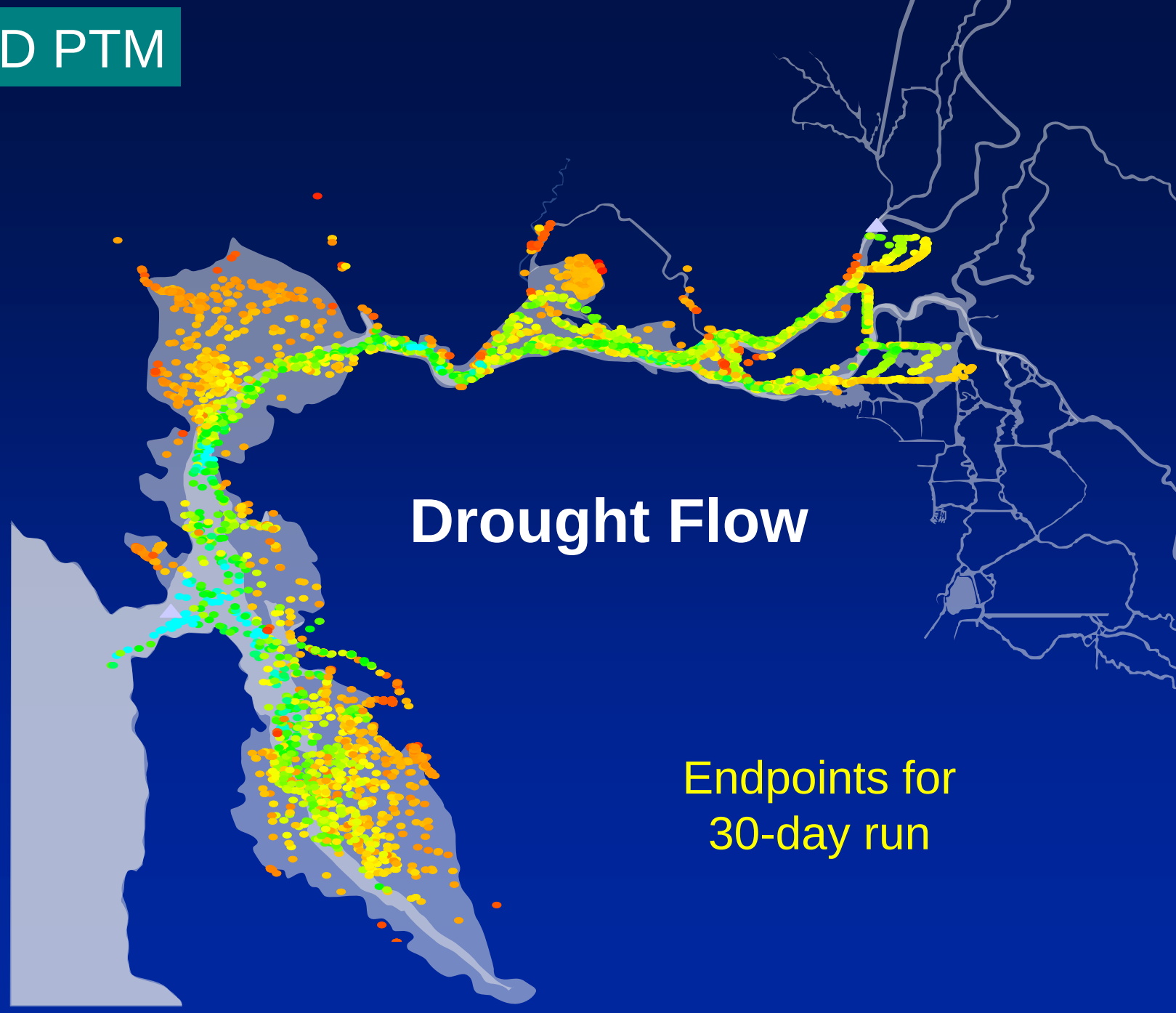
H: Area or volume of habitat increases with flow

Mechanism for bottom-oriented species?

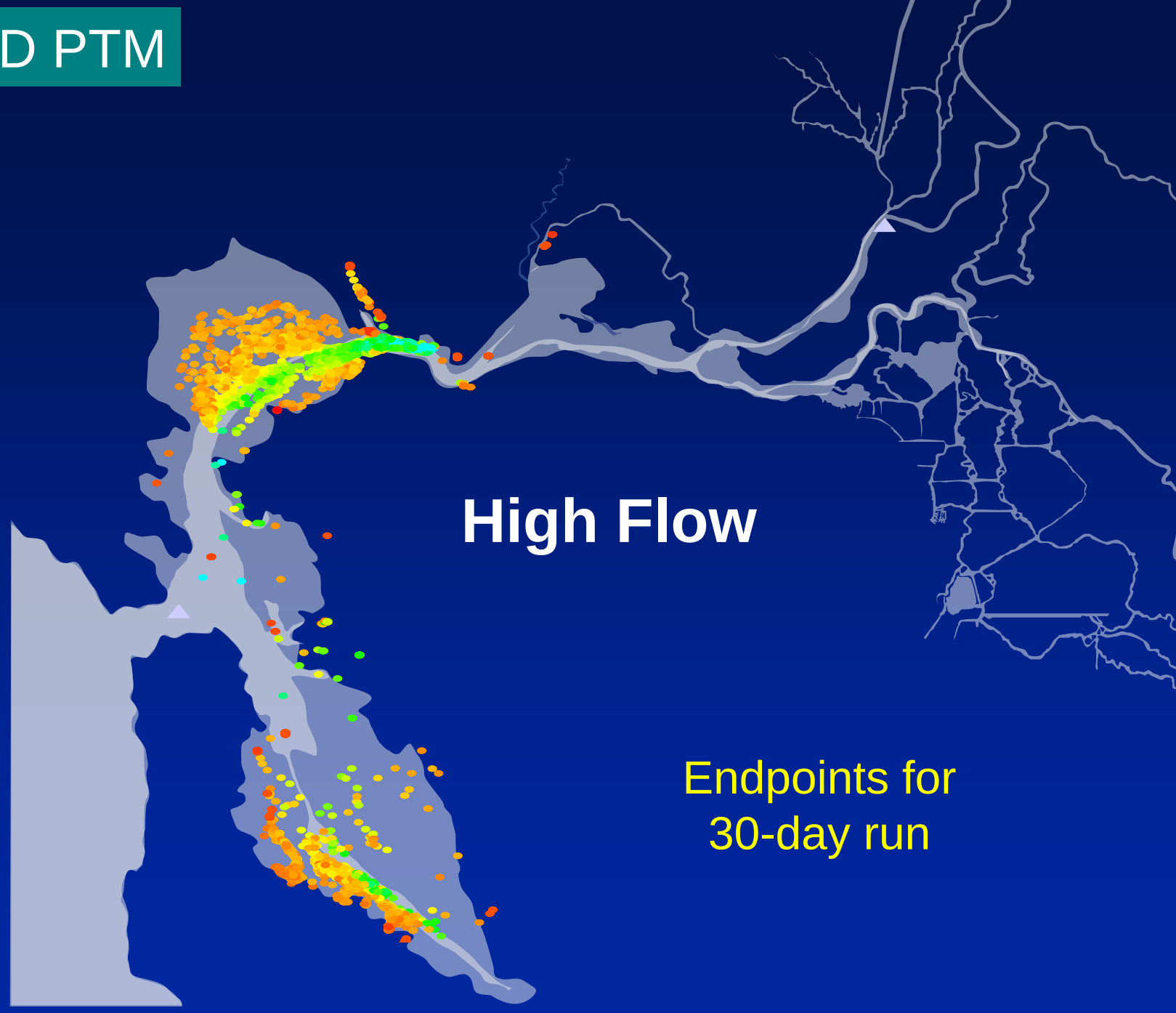


(A brief sob story)

TRIM 3D PTM

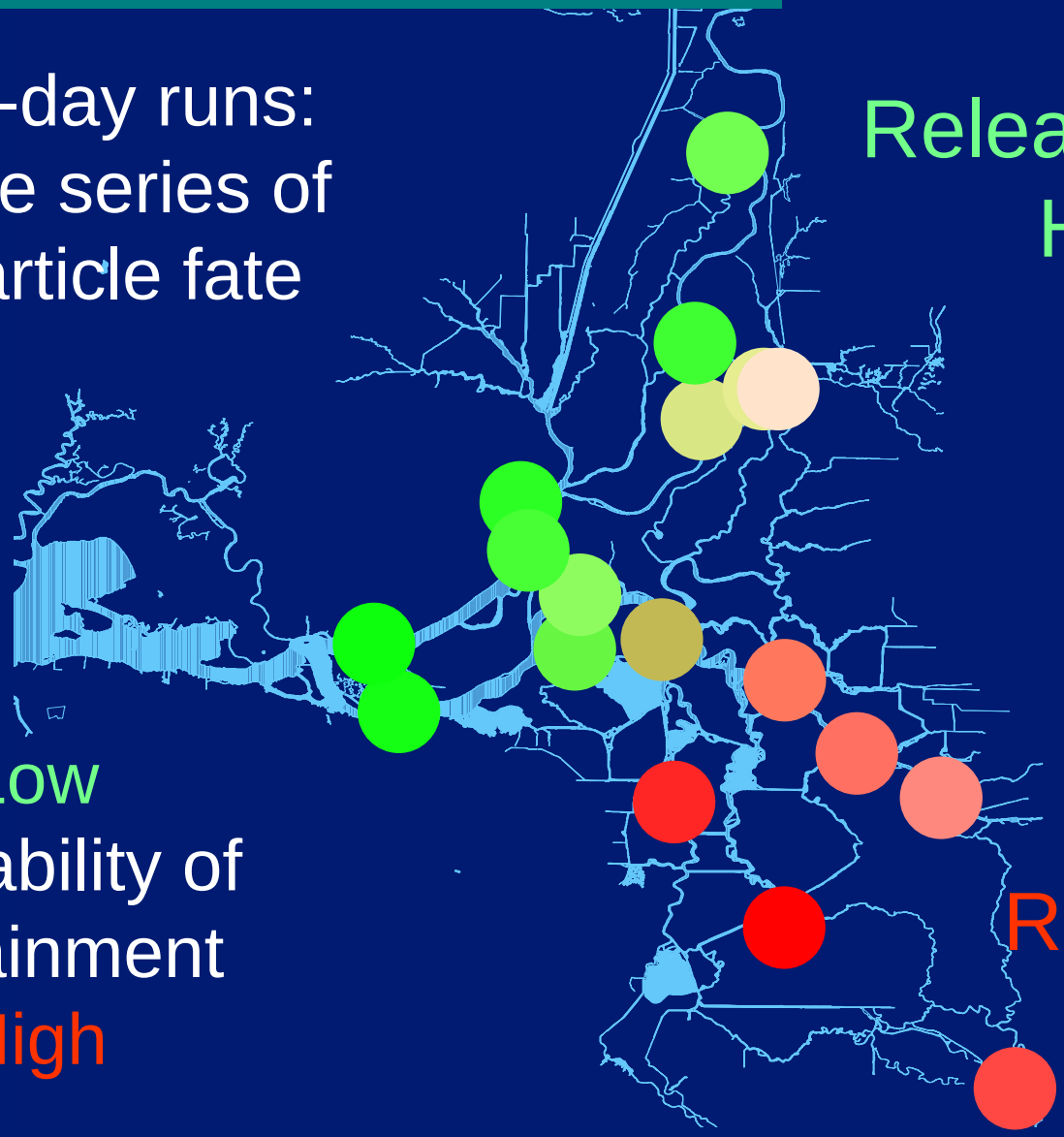


TRIM 3D PTM



DSM2 Particle Tracking Model

90-day runs:
time series of
particle fate



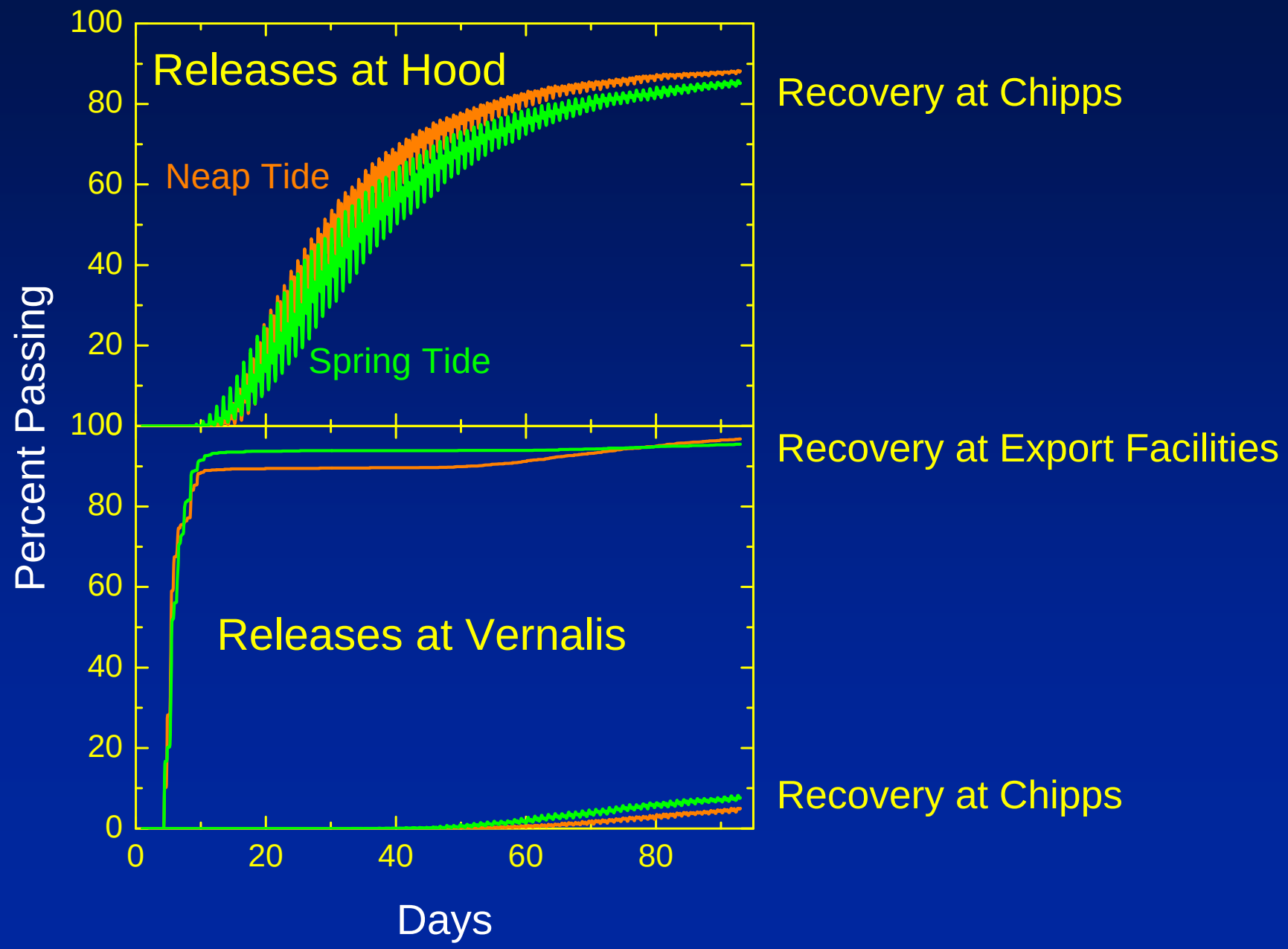
Release point:
Hood

Low
Probability of
entrainment
High

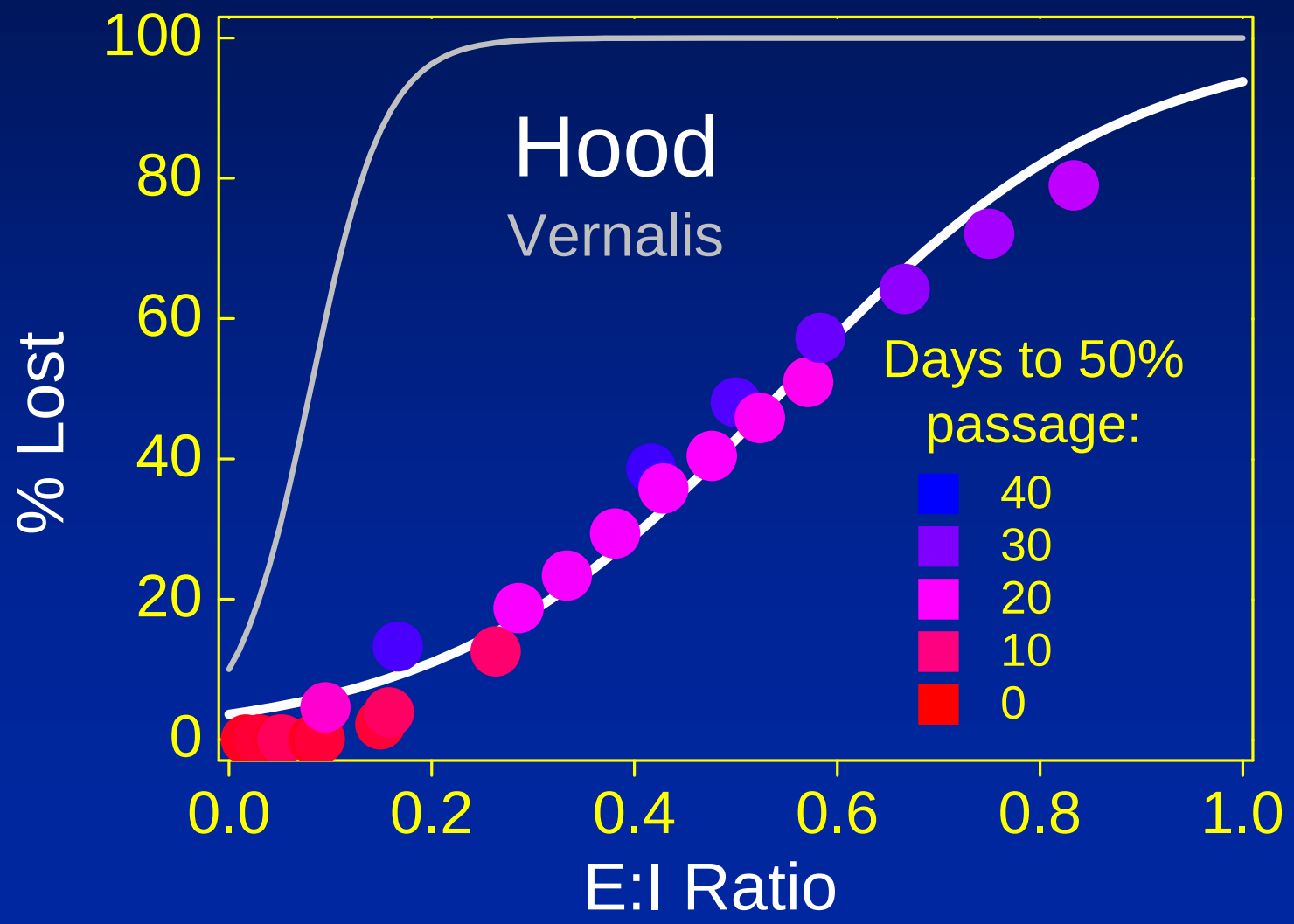
Release point:
Mossdale

Kimmerer & Nobriga SFEWS (2008)

DSM2 PTM - Example

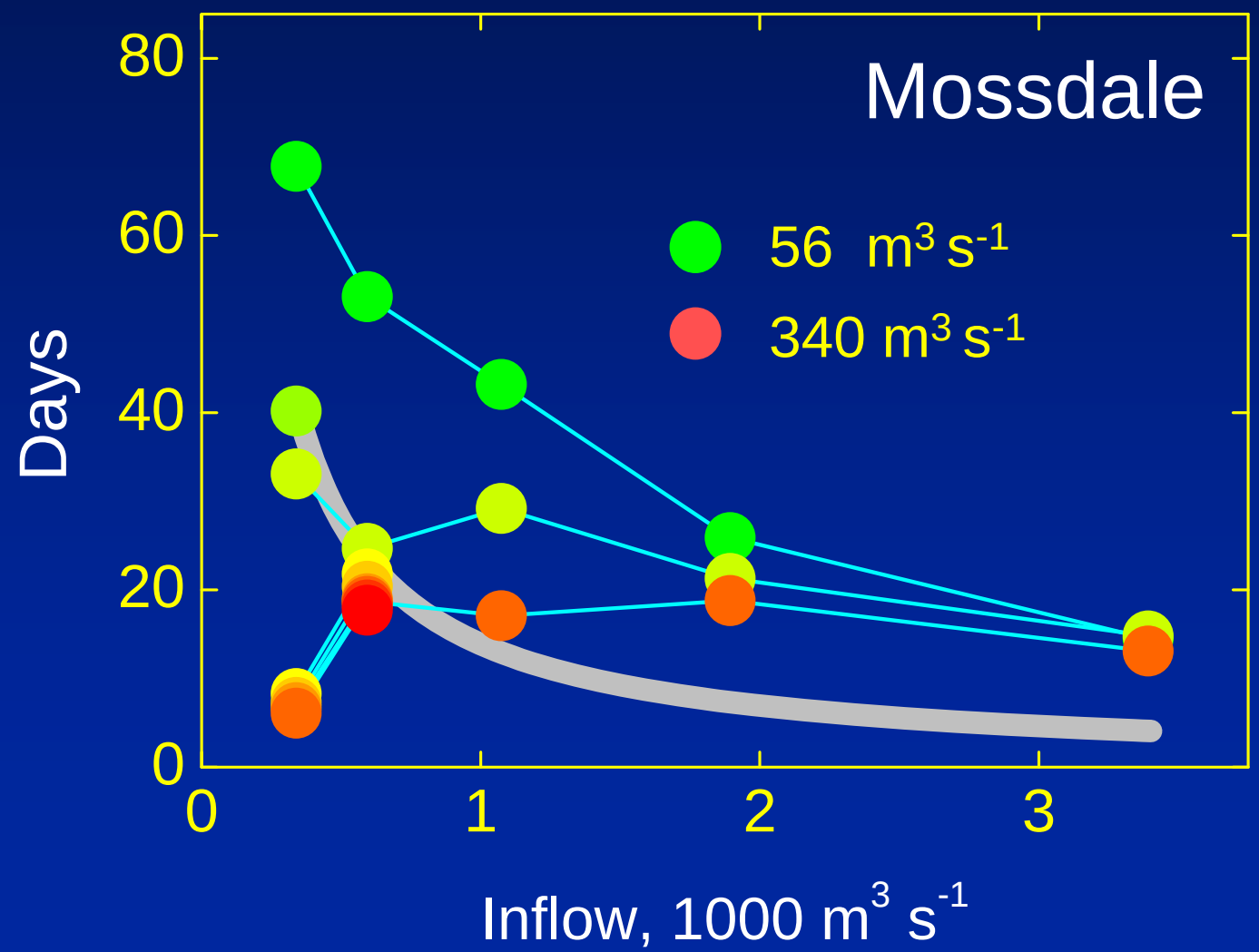


DSM2 PTM – Effect of Export:Inflow Ratios

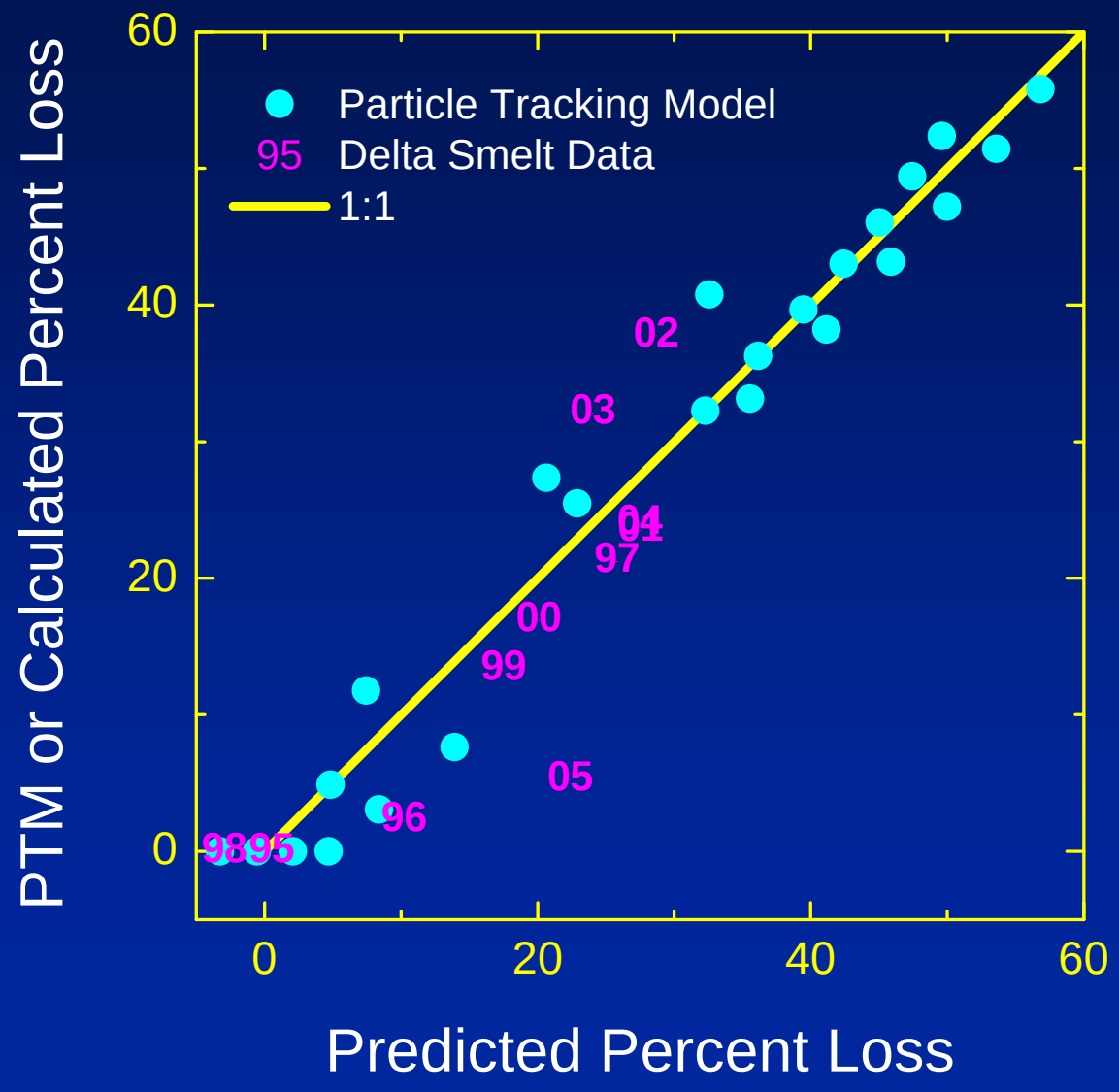


DSM2 PTM – Timing

Time for 75% of particles to leave Delta



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 2008 SFEWS

Individual-based Model of Delta Smelt

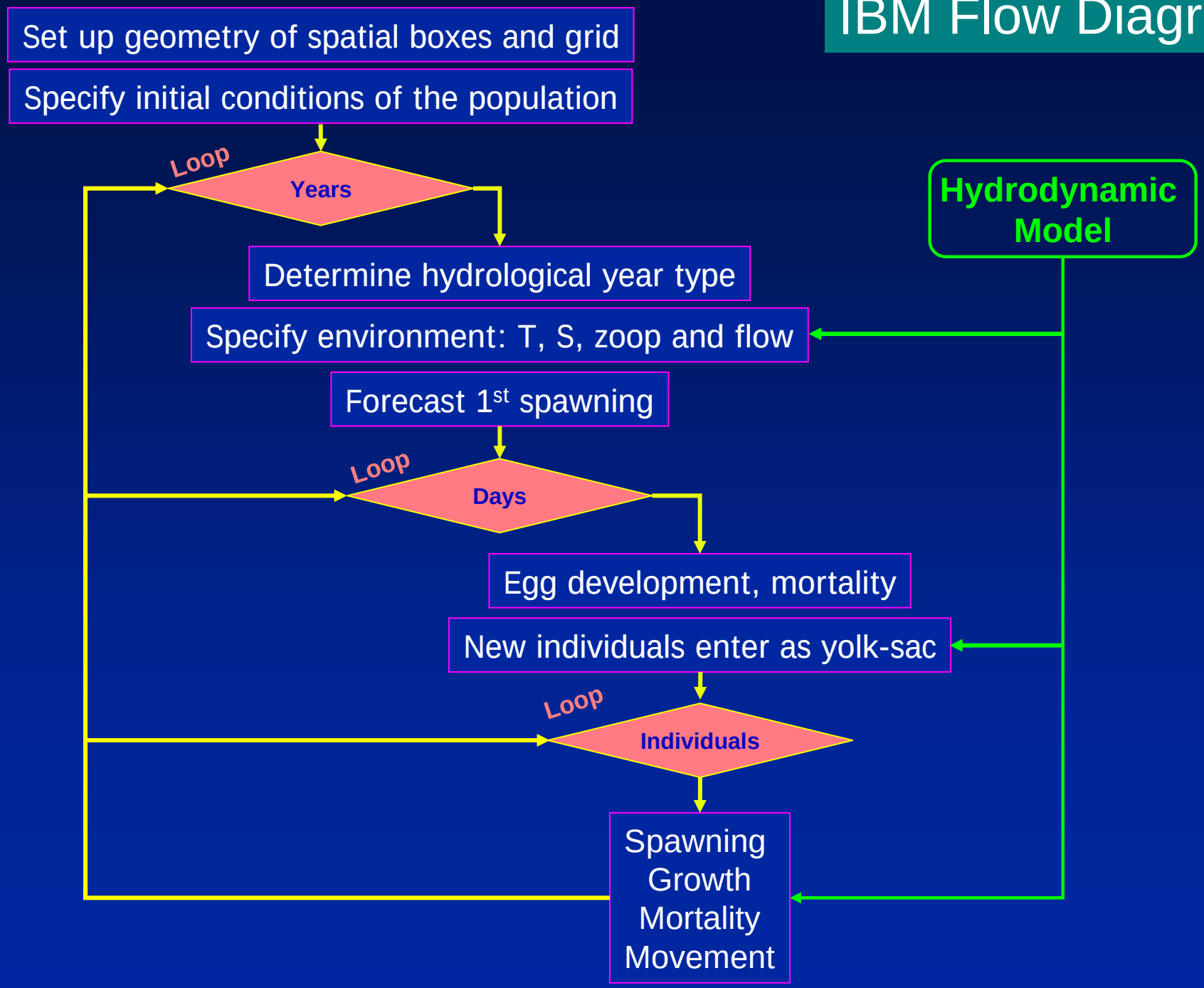
- Complete life cycle model
- Uses DSM2 for movement of young stages

Rose, Edwards Kimmerer in prep.

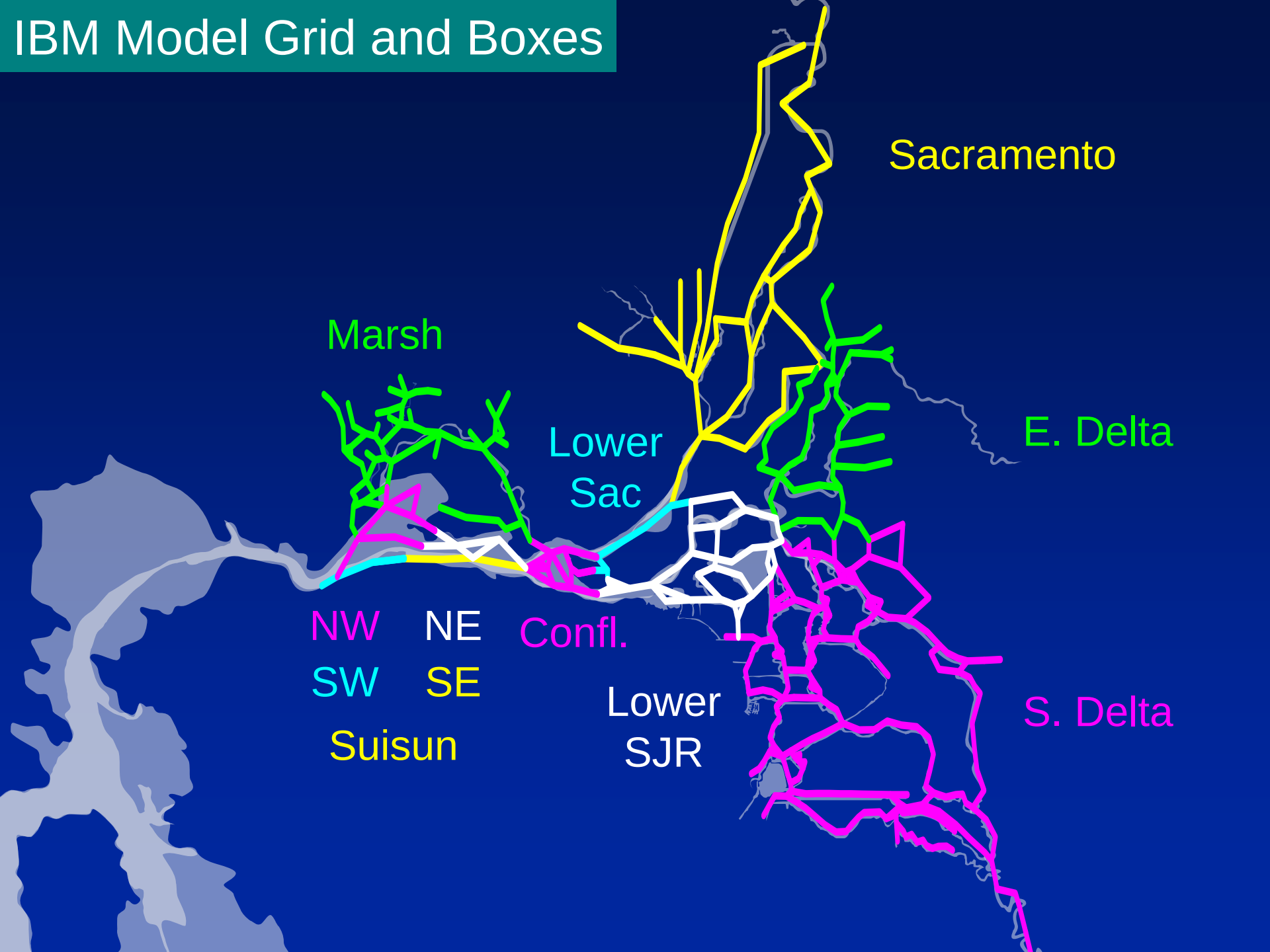
Model Description

- 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

IBM Flow Diagram



IBM Model Grid and Boxes

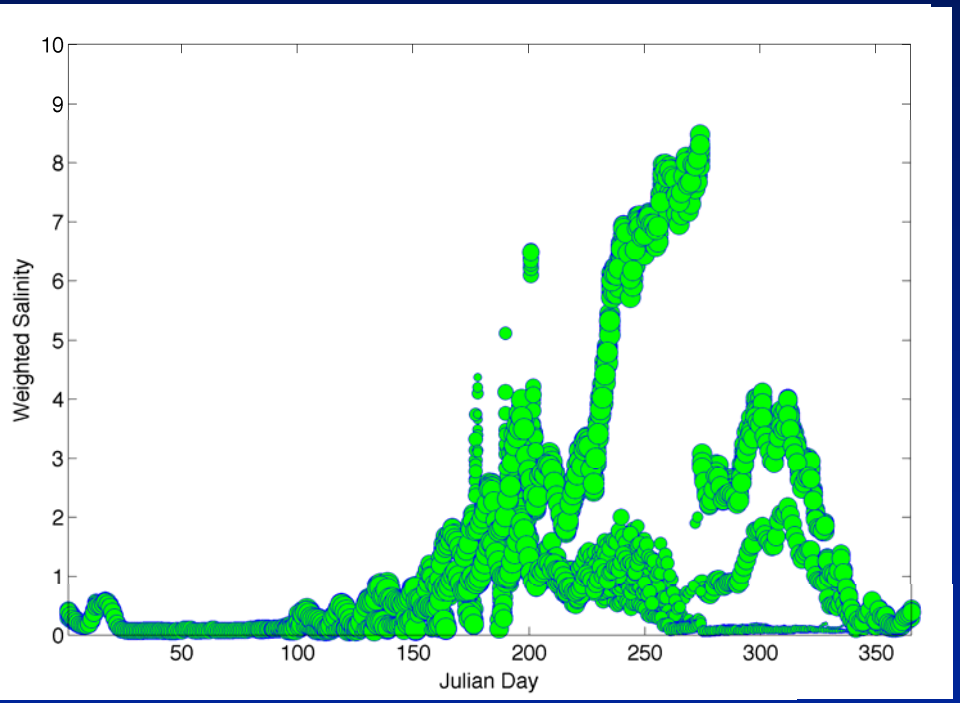


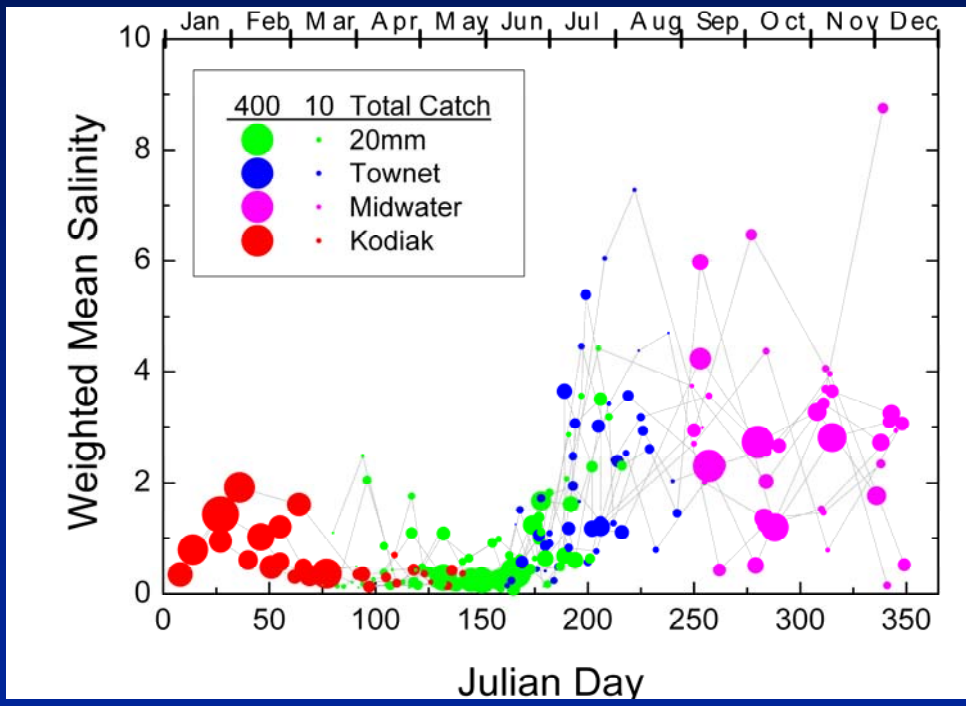
Movement

- 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

Smelt-weighted salinity

(15 years of 1999 conditions)





Other modeling projects

- Tidal transport of copepods and larval fish (IEP)
- Export losses of smelt and salmon (CALFED)
- Foodweb dynamics (CALFED)
- Box models of phytoplankton, zooplankton (CALFED)
- Copepod mortality and clam effects (IEP)
- Statistical modeling of fish abundance (IEP- NCEAS)
- Allee effects (extrapolation to field; NSF)

Conclusions

Many ways of modeling physics and biology

Sometimes simpler is better

Some work becomes obsolete quickly!

Co-conspirators: Kenny Rose, Karen Edwards, Bill Bennett, Ed Gross, Mike MacWilliams, Matt Nobriga

Thanks for data: Marty Gingras, Kathy Hieb, Kelly Souza