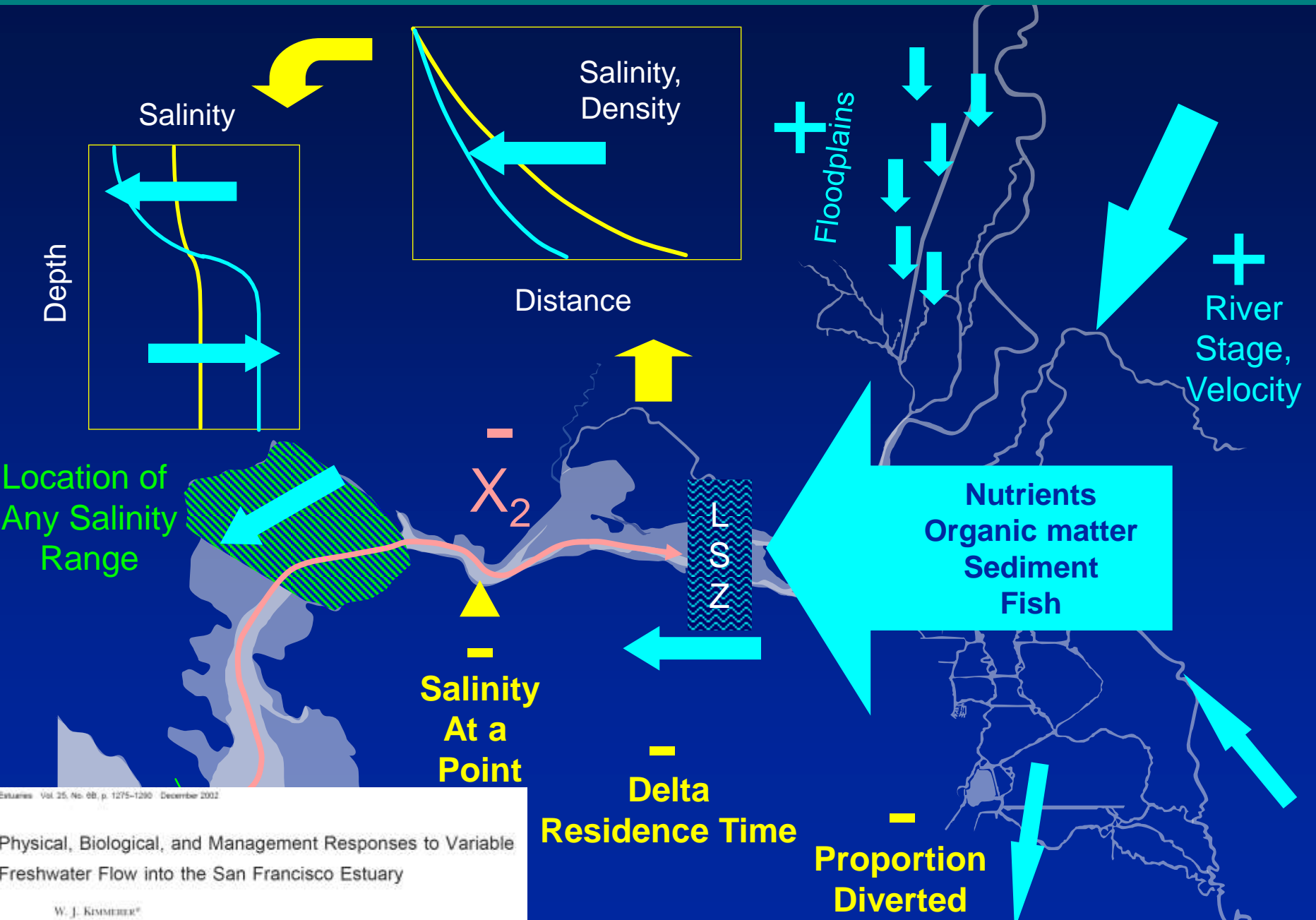


# Effects of Variable Freshwater Flow on Fish and Foodwebs of the San Francisco Estuary

Wim Kimmerer, Toni Ignoffo, Anne Slaughter  
Romberg Tiburon Center, San Francisco State University  
Ed Gross, RMA/UC Davis

# What Changes As Flow Increases?



Estuaries Vol. 25, No. 6B, p. 1275-1290 December 2002

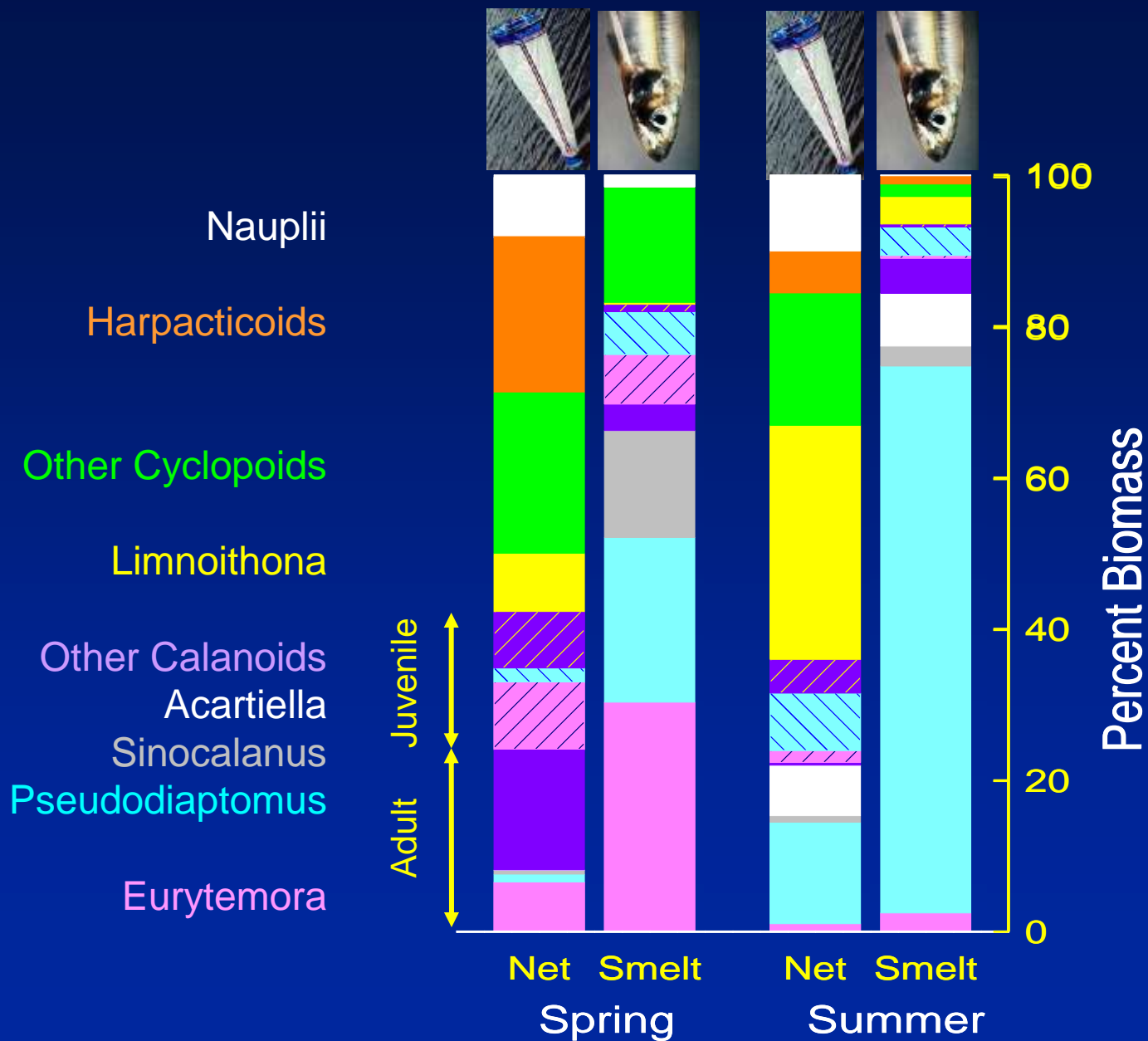
Physical, Biological, and Management Responses to Variable Freshwater Flow into the San Francisco Estuary

W. J. KIMMERER\*

# Key Points

- Subtle flow effects in foodweb
- Low variation with flow:
  - Abundance
  - Growth
  - Mortality
- Transport may limit food supply in LSZ

# What do delta smelt eat?



Summer Diet  
2005-2007  
Mostly  
*Pseudodiaptomus  
forbesi*



# *P. forbesi*: distribution in geographic space



Here be  
delta  
smelt



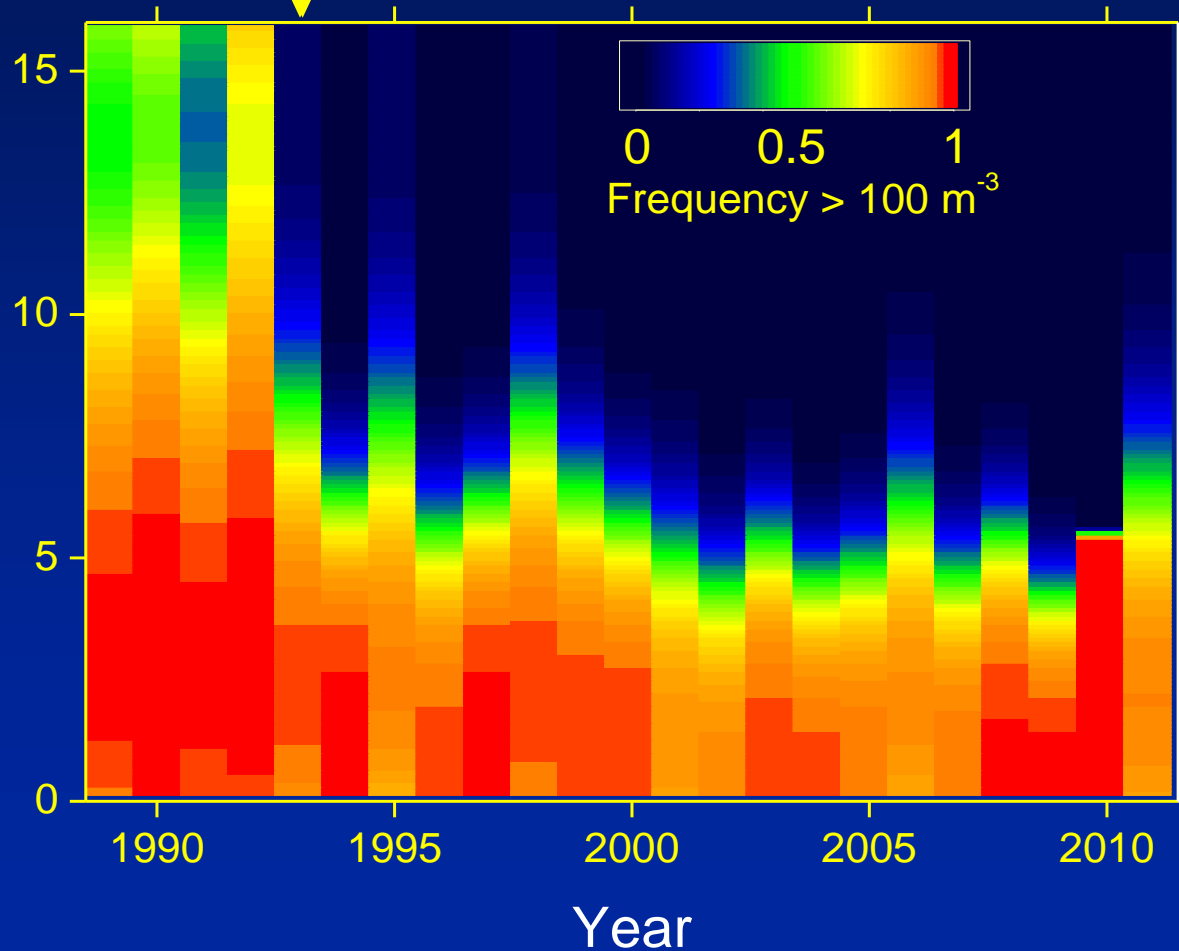
What controls the supply of  
copepods to the LSZ?

Processes in population center?  
Dilution flows?  
Transport?

Adults Juveniles



# *P. forbesi*: distribution in salinity space



Frequency of samples with at least 100 copepods  $m^{-3}$

IEP monitoring data  
Fit with GAM smoother  
By year for June-October

# *Pseudodiaptomus forbesi*: well studied?

## Tidal migration

Kimmerer Bennett Bureau  
1998 L&O, 2002 E&C

## Feeding

York et al. 2011 E&C  
Kayfetz 2014 Thesis

## Growth, fecundity

Kimmerer et al. 2014 JPR  
Kimmerer et al., Ignoffo et al

## Mortality

Kimmerer et al  
Durand & Kimmerer

## Reproduction

Sullivan & Kimmerer 2014  
JPR

## Microcystis effects

Ger et al. 2009, 2010  
Sci. Total Env, JPR,  
Freshw Biol  
Ger et al.  
DuMais 2014 Thesis



## Salinity tolerance

Kayfetz 2014 Thesis

## Contaminants

Weston et al. 2014 SFEWS

## Eaten by clams

Kimmerer & Lougee

## Eaten by copepods

Slaughter et al.

## Eaten by fish

Meng & Orsi 1991 TAFS  
Bryant & Arnold 1997 CFG  
Slater & Baxter 2014 SFEWS

## Box model

Kimmerer, Gross, et al

## Particle model

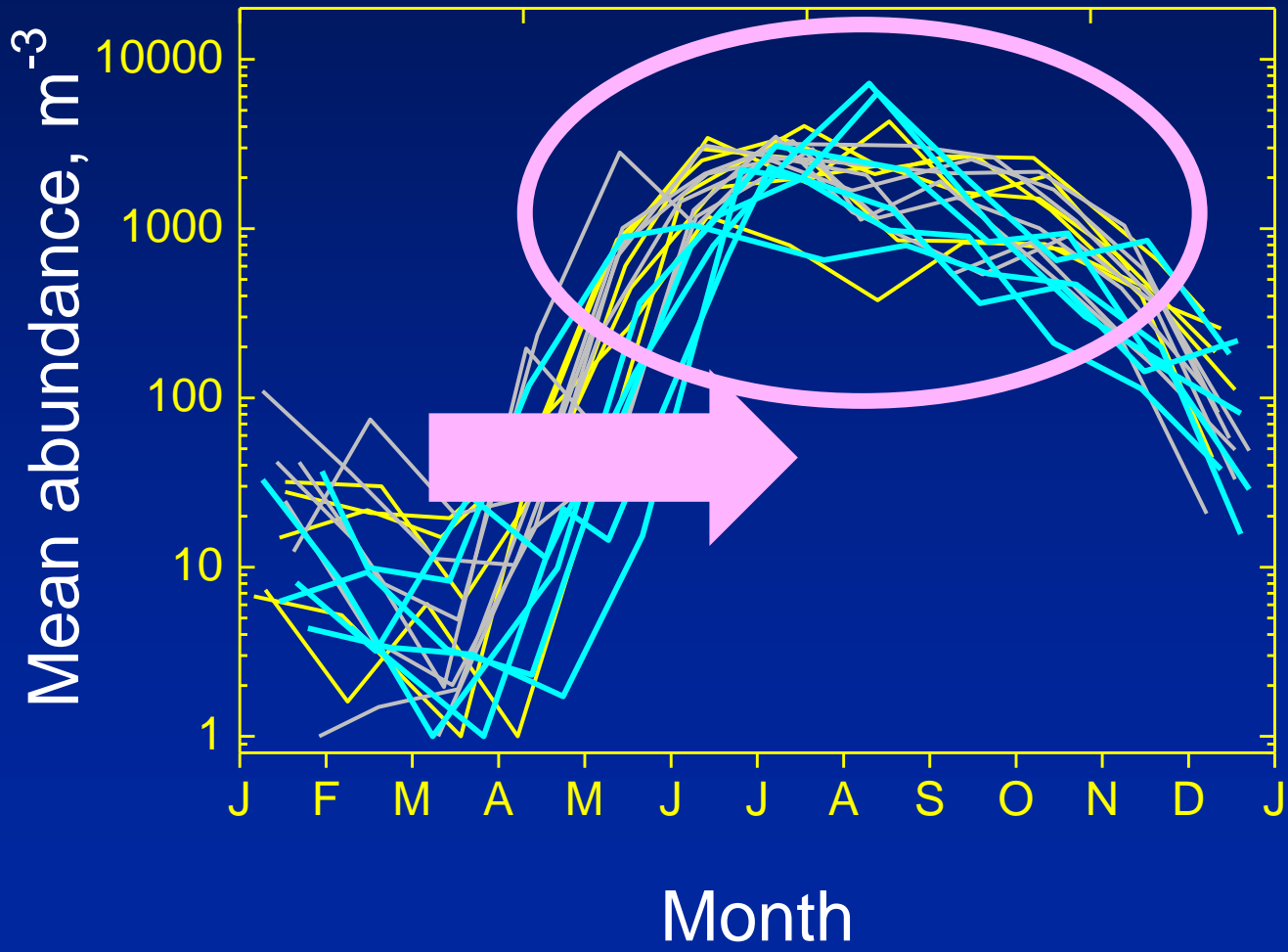
Kimmerer, Gross,  
MacWilliams 2014 L&O

## Individual-based model

Dorman et al.

# *P. forbesi* seasonal pattern

6 lowest flows  
7 intermediate flows  
6 highest flows



Adults only  
Freshwater  
1994 – 2012  
Mean by date



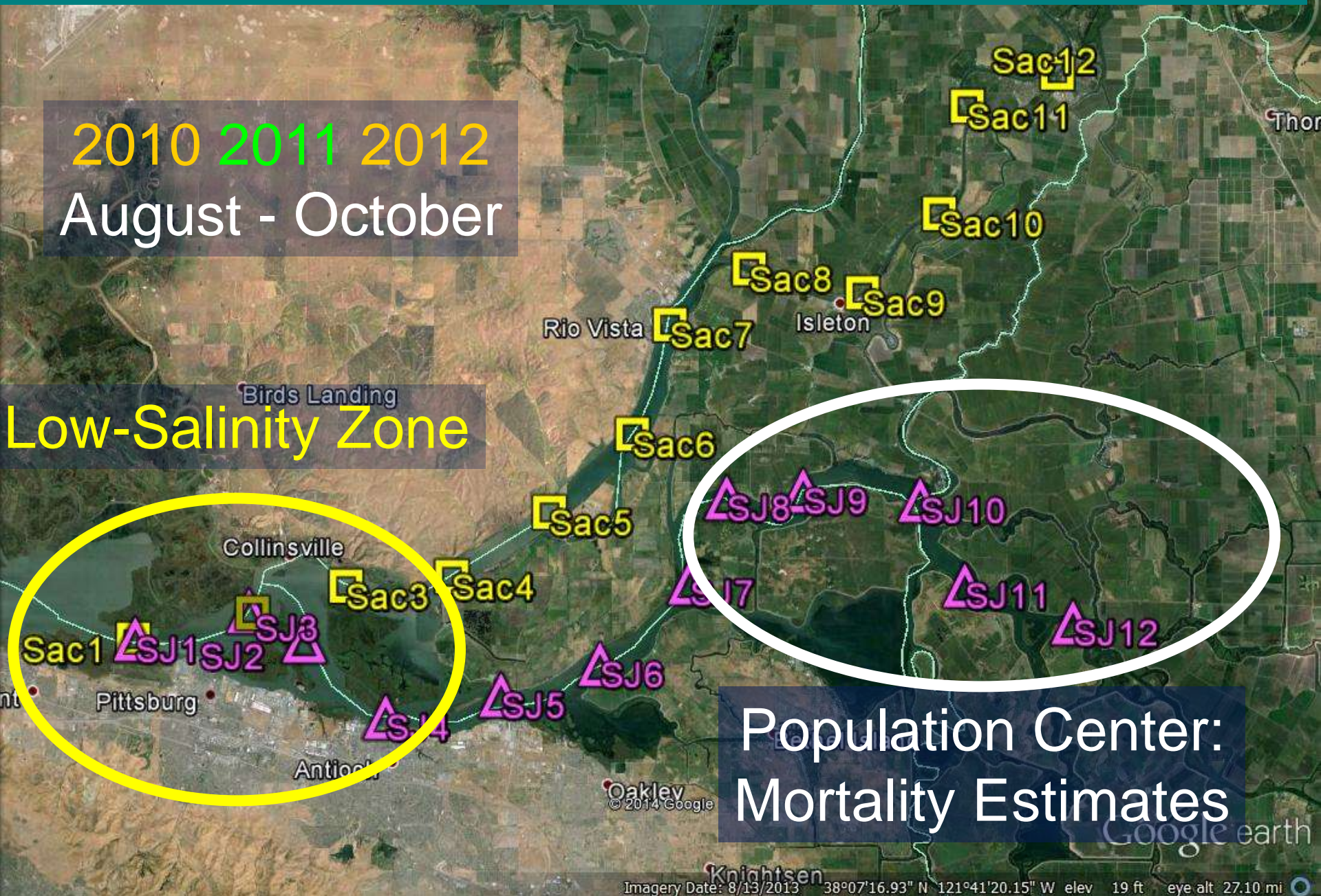
# Fall Habitat transects

2010 2011 2012

August - October

Low-Salinity Zone

Population Center:  
Mortality Estimates



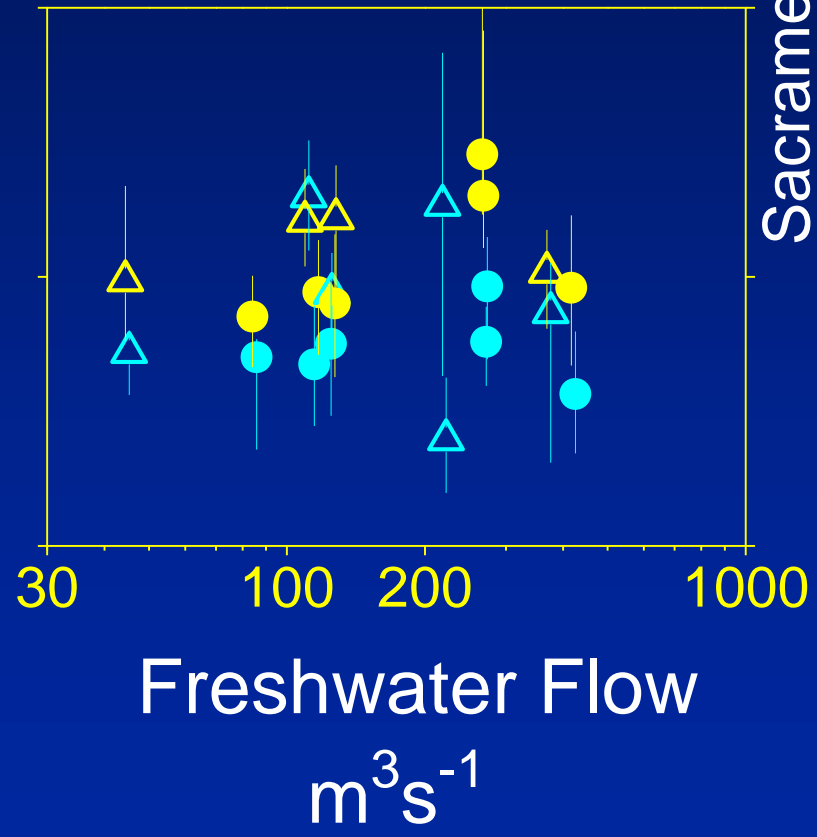
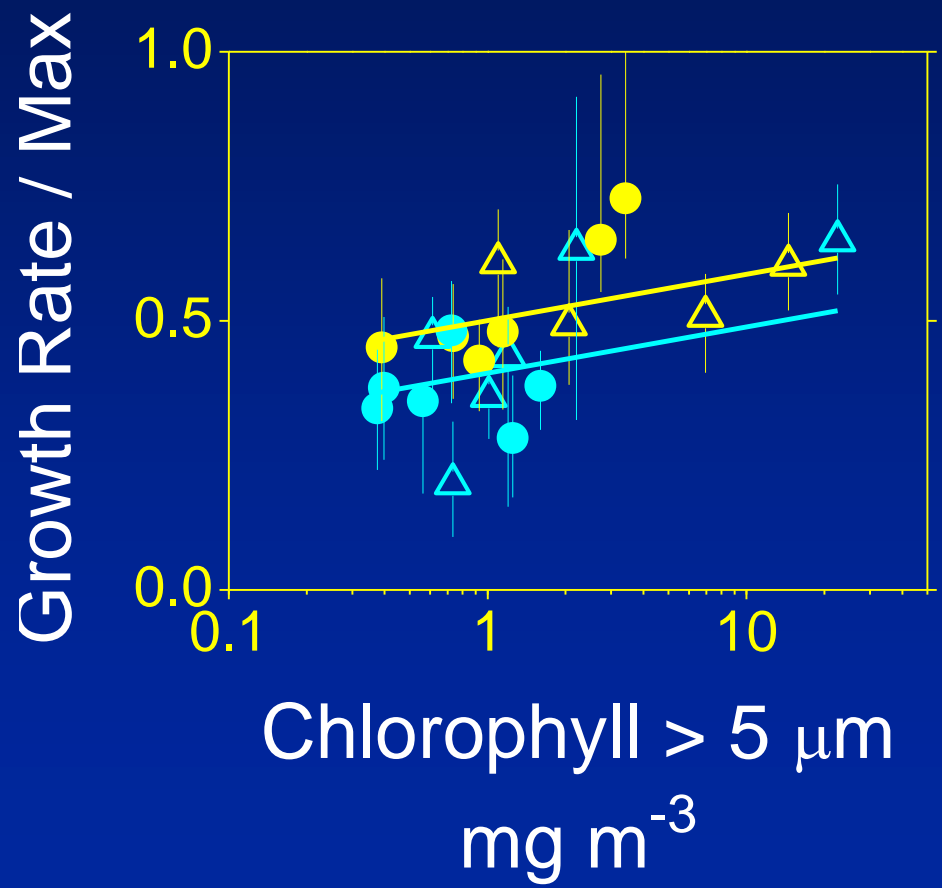
# Productivity: Food-limited growth

Late Juveniles



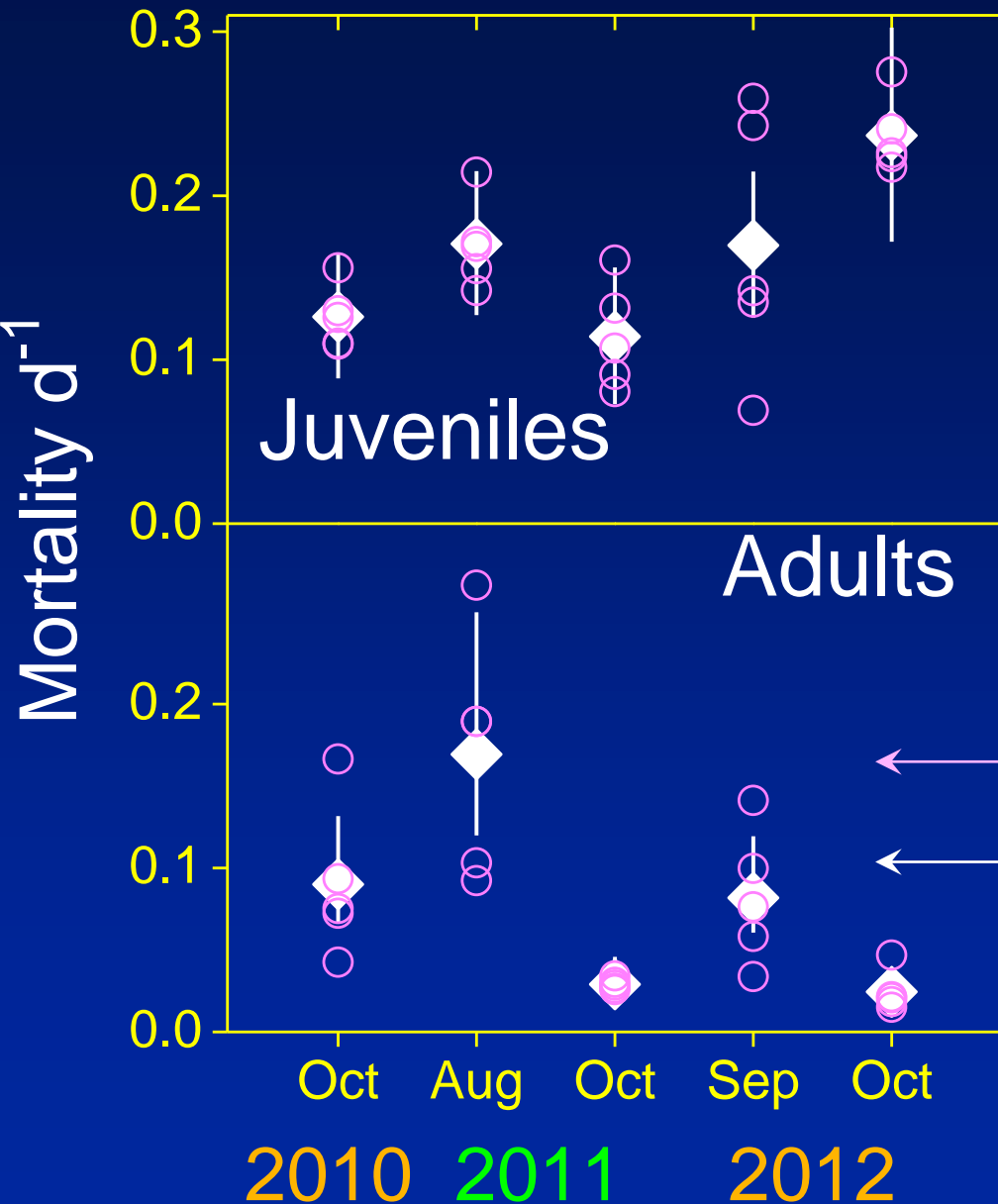
Low-salinity Zone ● ▲  
Freshwater ● ▲

Sacramento  
San Joaquin





# Productivity: Mortality rates

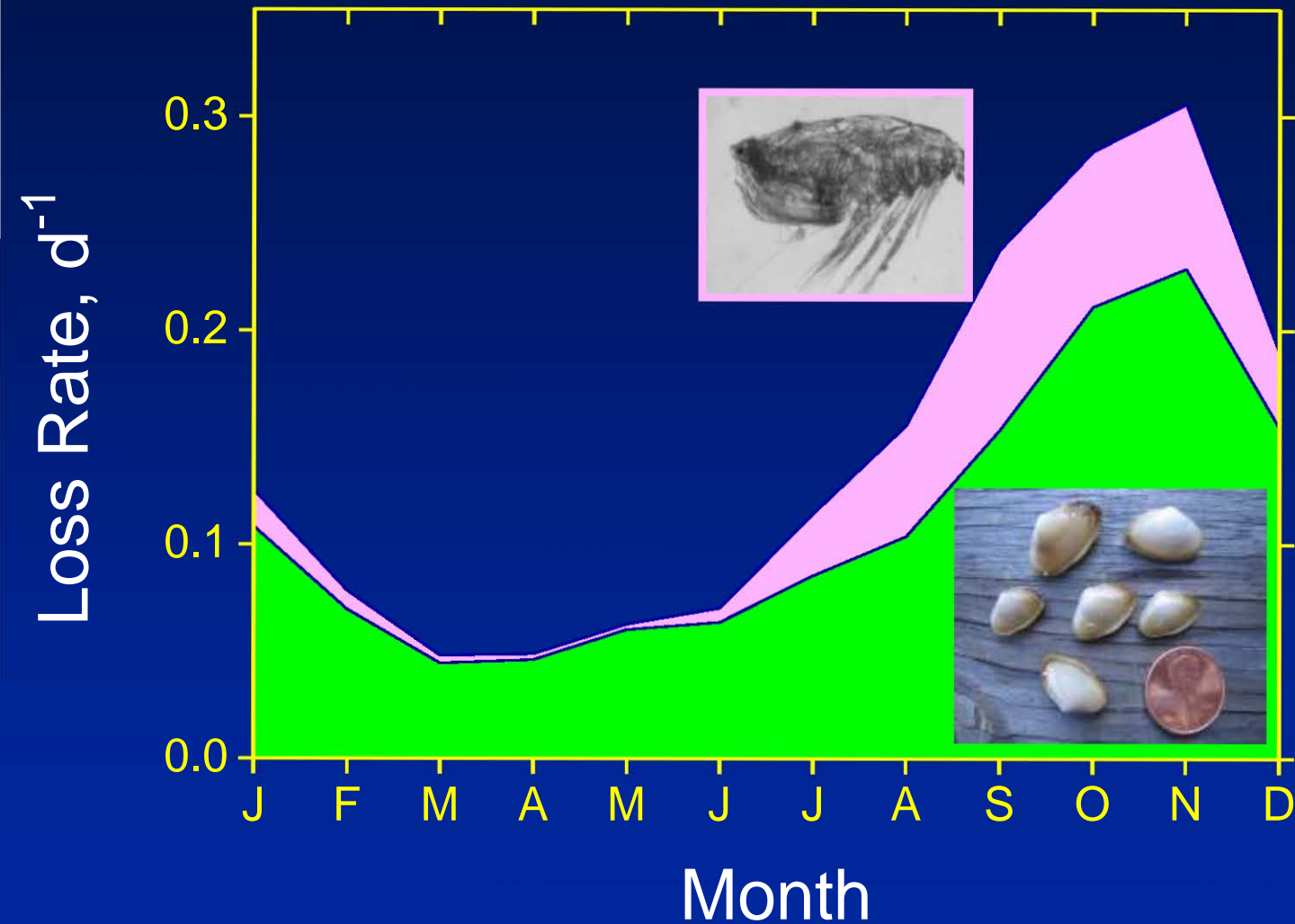


San Joaquin River  
freshwater  
stations



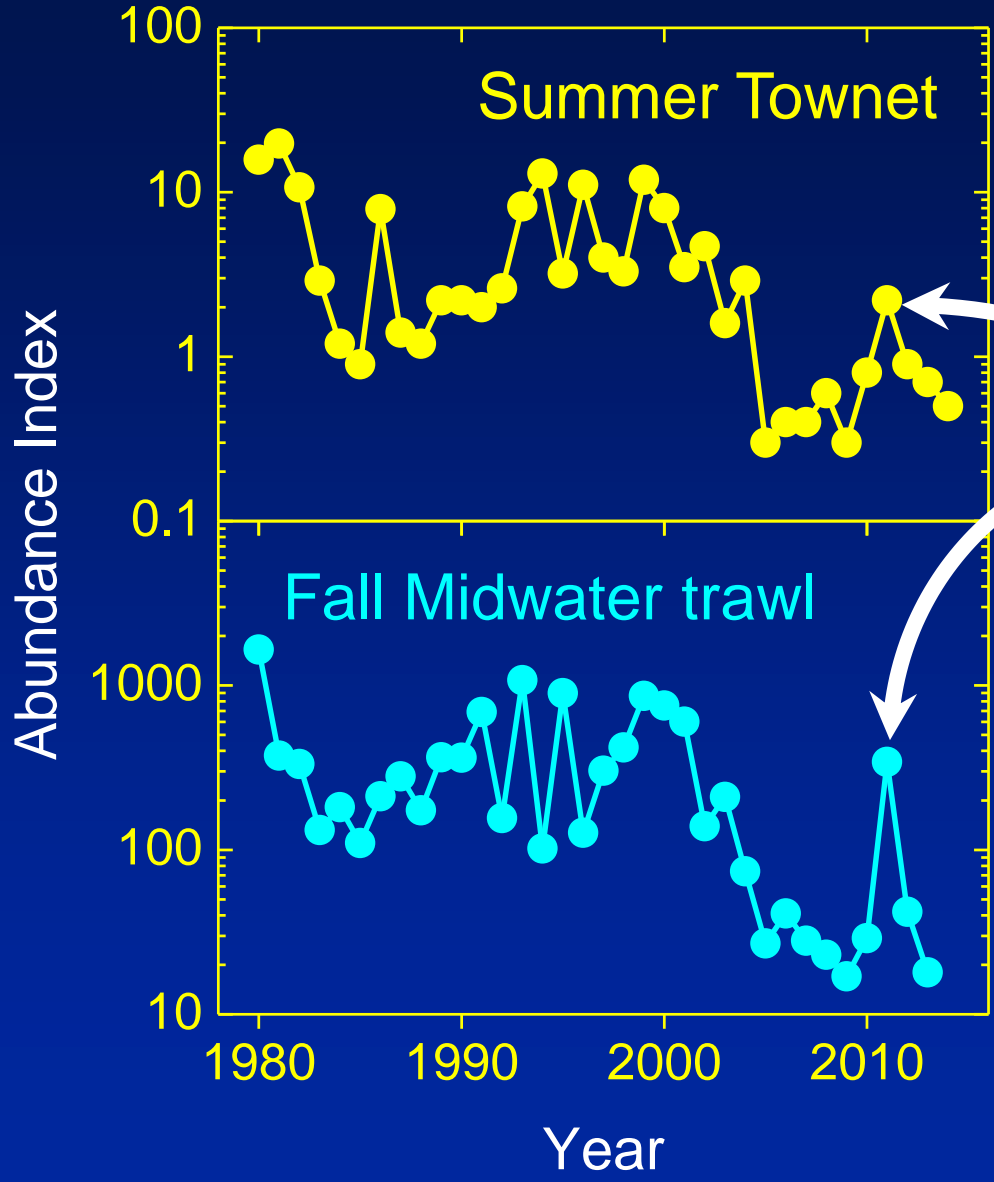
Station values  
Survey means

# *P. forbesi*: nauplii eaten in Low-Salinity Zone



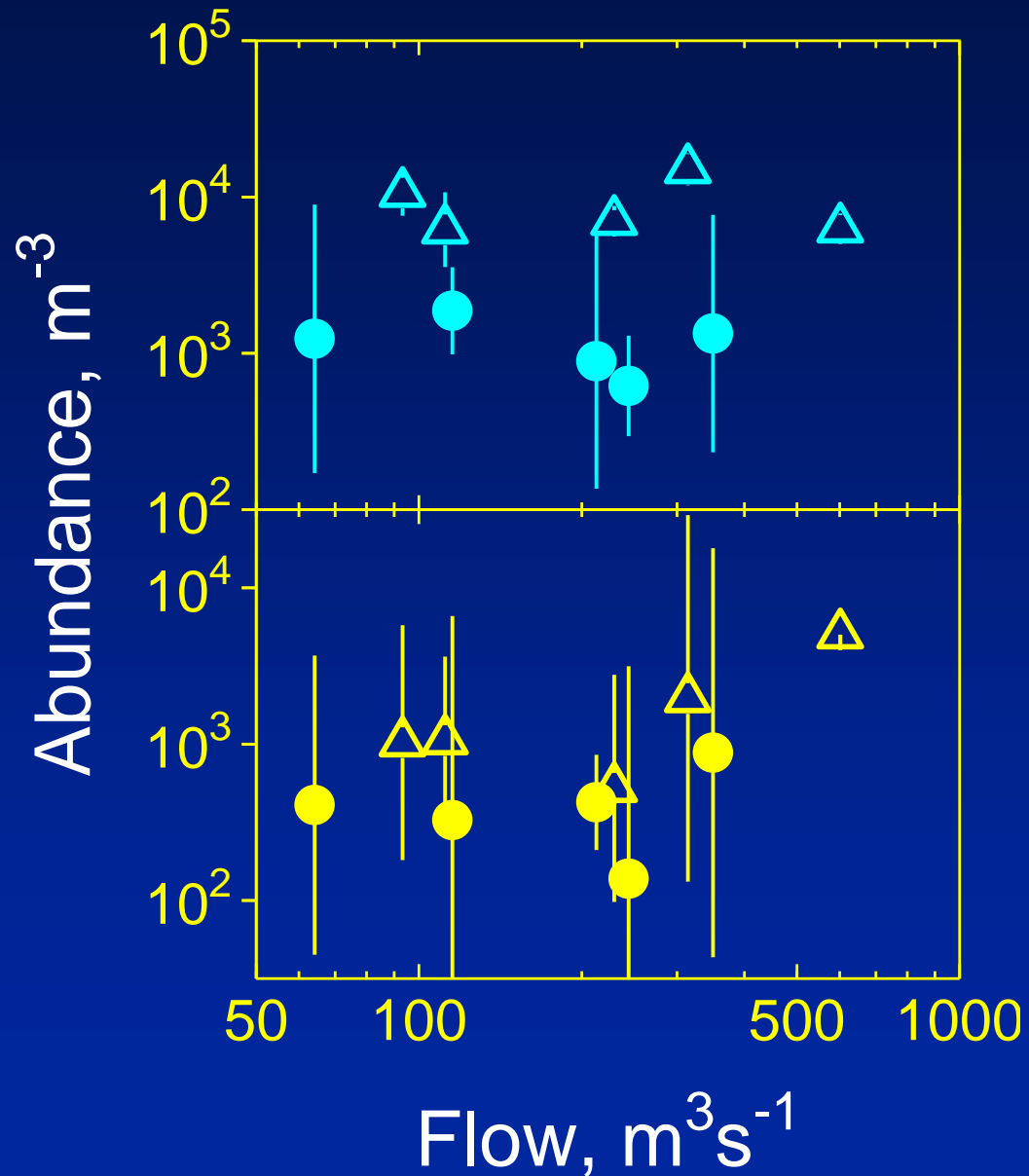
Slaughter et al. in prep.  
Kimmerer and Lougee in prep.  
Based on IEP data

# Delta smelt indices



What happened in 2011?

# Abundance unrelated to flow in fall...



Freshwater  
Low-salinity Zone

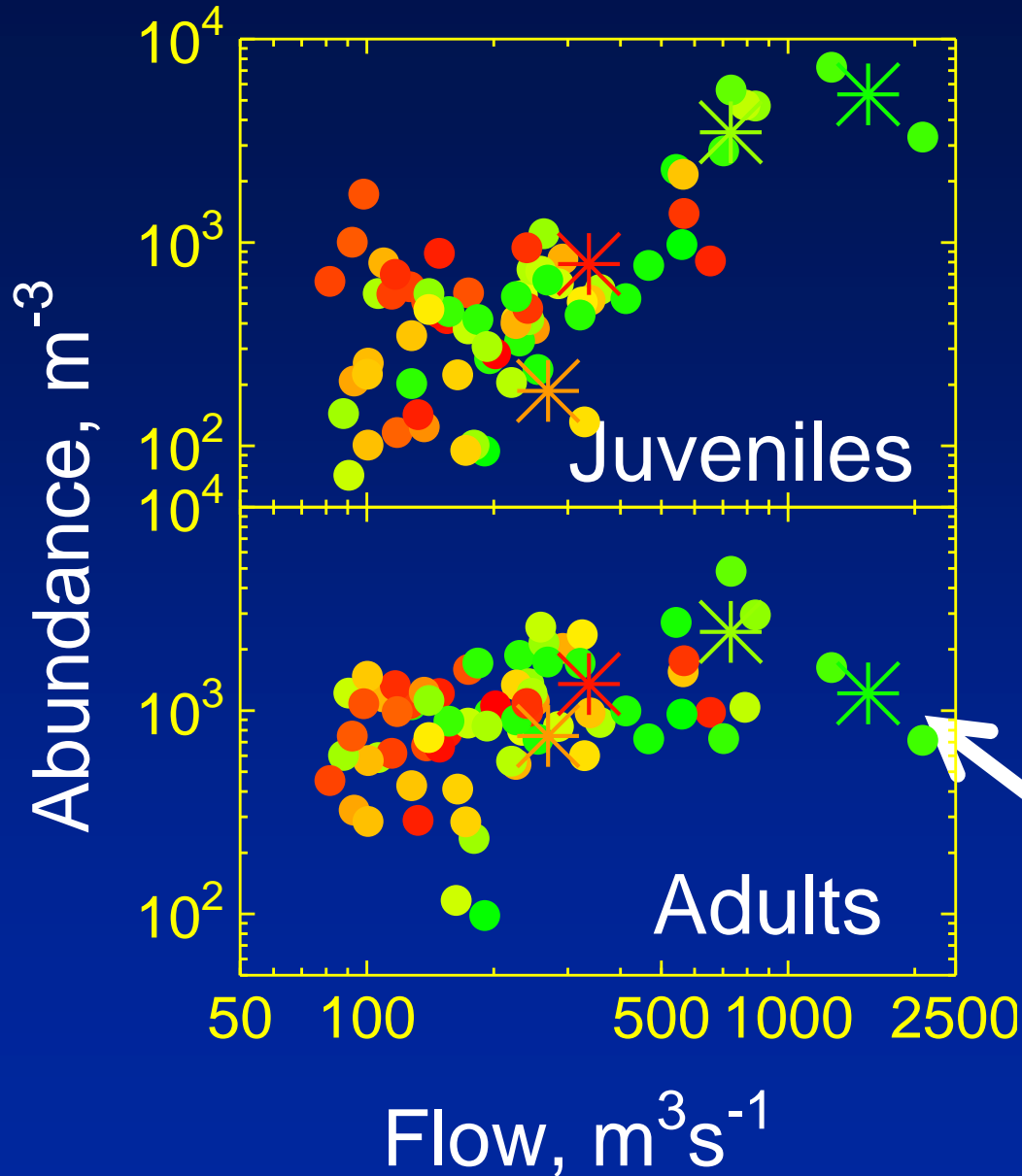


Adults & Juveniles

Sacramento ●  
San Joaquin △



# Abundance in LSZ increases at high flows



June  
September

2011

# Summary

- Flow affects timing
- Little effect on other processes
- Transport to LSZ during high flow
  - Spatial subsidy = flow & mixing
  - Effect greater in early summer than fall
- Next steps?
  - Box modeling
  - Individual-based modeling
  - Investigate density dependence, decline
  - Other species?



Thanks to:  
Lindsay Sullivan, Karen Kayfetz,  
Jan Thompson, April Hennessy,  
Erwin Van Nieuwenhuysse,  
Michael MacWilliams

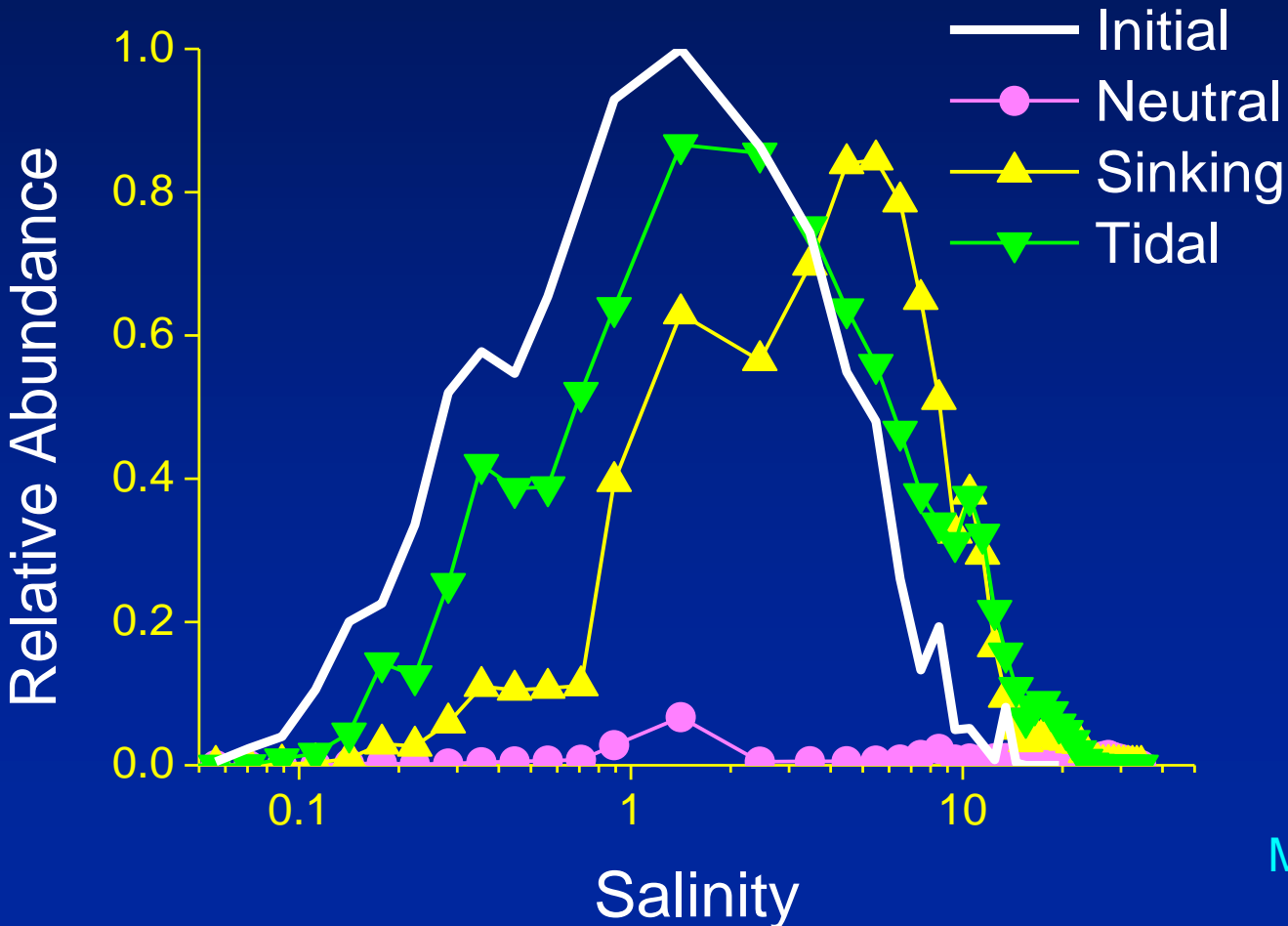
Funding from Interagency  
Ecological Program,  
Delta Science Program



# Consequences of tidal migration

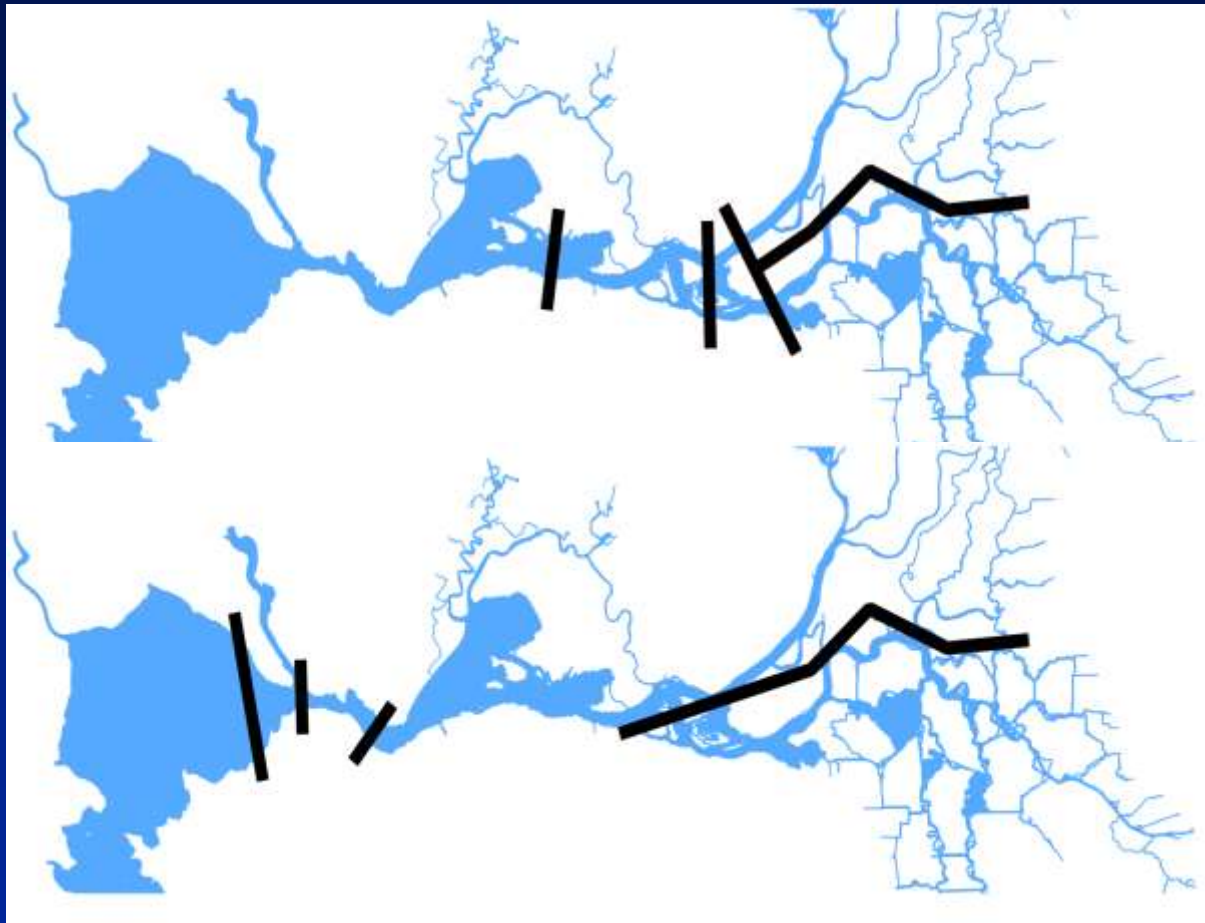
Distributions of particles  
after 45 days

Medium  
Freshwater  
Flow



Kimmerer, Gross, &  
MacWilliams 2014 L&O

# Box model of *P. forbesi*



Model Domain

Outflow:  
 $190 \text{ m}^3\text{s}^{-1}$

$1440 \text{ m}^3\text{s}^{-1}$