

# POD Update: January 2008



Randy Baxter, DFG  
Rich Breuer, DWR  
Larry Brown, USGS  
Mike Chotkowski, USBR  
Peter Hrodey, USFWS  
Matt Nobriga, CALFED  
Marty Gingras, DFG  
Bruce Herbold, USEPA  
Anke Mueller-Solger, DWR  
Ted Sommer, DWR  
Kelly Souza, DFG

# Pelagic (Open Water) Habitat



Delta smelt

Longfin smelt



Threadfin shad

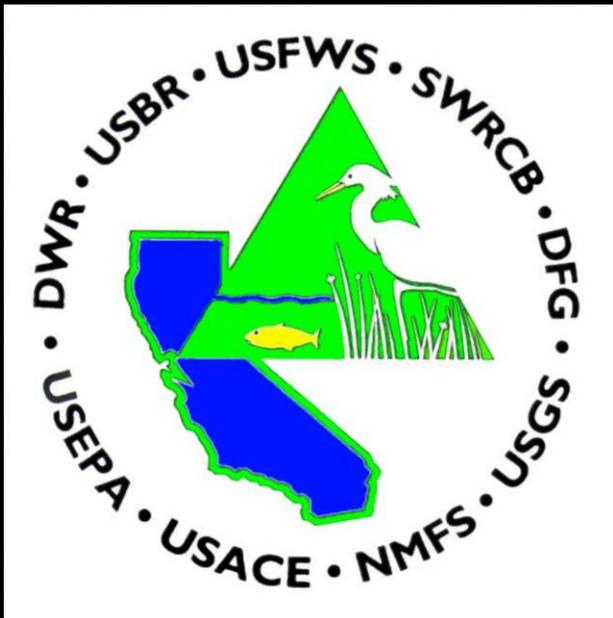


Striped bass

# POD Timeline

Fall 2004	POD Alert for Agency Directors
Spring 2005	POD Investigation Starts
Dec 2005	First POD Progress Report
April 2007	SWRCB POD Workshop
January 2008	Second SWRCB Workshop POD Progress Report

# *POD Management Team*



Randy Baxter DFG

Rich Breuer DWR

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Peter Hrodey, USFWS

Matt Nobriga CALFED

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Bruce Herbold USEPA

Anke Mueller-Solger DWR

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# POD Principal Investigators

- Dept Fish and Game
  - Randy Baxter, John Budrick, Kelly Souza, Steve Slater, Kathy Hieb, Marty Gingras
- Dept Water Resources
  - Fred Feyrer, Ted Sommer, Zoltan Matica, Peggy Lehman, Lenny Grimaldo, Bob Suits, Karen Gehrts, Gina Benigno, Anke Mueller-Solger
- Regional Board
  - Karen Larsen
- US Bureau of Reclamation
  - Mike Chotkowski
- US EPA
  - Bruce Herbold, Debra Denton
- Consultants
  - BJ Miller, Bryan Manly, Susan Anderson
- US Fish and Wildlife Service
  - Gonzalo Castillo, Ken Newman, Scott Foott
- US Geological Survey
  - Joseph Simi, Cathy Ruhl, Pete Smith, Dave Schoellhamer, Heather Peterson
- UC Davis
  - Bill Bennett, Swee Teh, Inge Werner, David Ostrach, Frank Loge, Jim Hobbs
- SF State University
  - Wim Kimmerer, John Durand, Karen Edwards, Lindsay Sullivan
- SF Estuary Institute
  - Daniel Oros, Geoff Siemering, Jennifer Hayworth

# National Center for Ecological Analysis and Synthesis (NCEAS)



- UCSB research center
- Established in 1995
- Core support from National Science Foundation, state of California, UCSB

# NCEAS Activities

- *Steering Committee*
- *Working group on system dynamics*
- *Working group on contaminants*
- *Postdoctoral and graduate support*
- *Database support*

# 2007 POD Progress Report

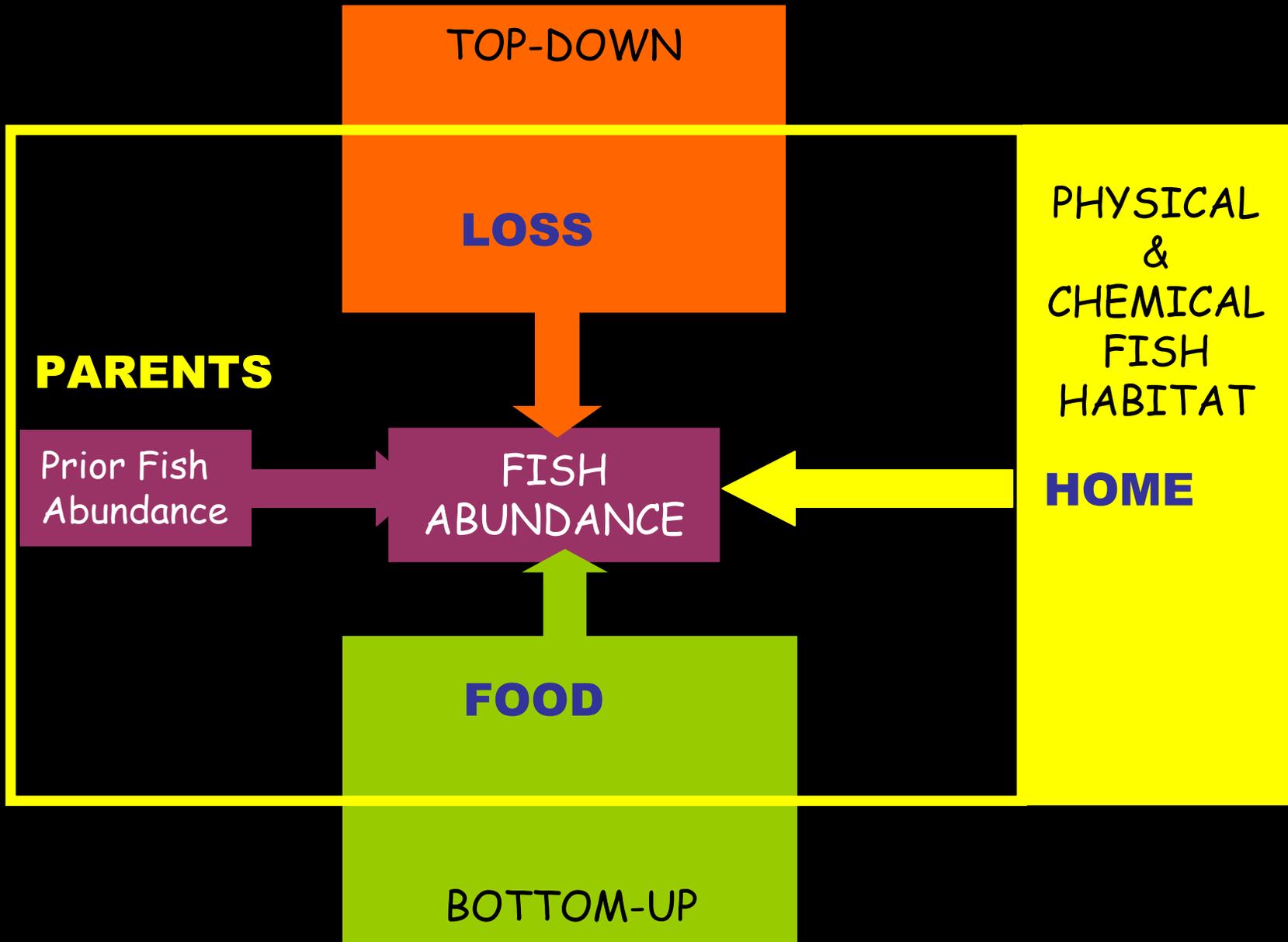


- Printed version available shortly.
- Primarily results through August 2007.
- "Weight of evidence" approach.
- Synthesis is from POD MT.
- Most results not yet published.
- Management implications are still being evaluated.



*"Major ecosystem degradation tends to occur as syndromes of simultaneous failure in multiple services"*

Carpenter et al., Science 314, Oct. 2006





Prior  
Abundance

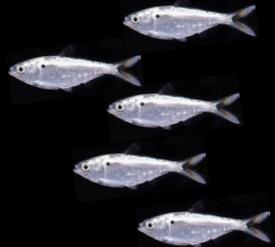


PRESENT  
ABUNDANCE

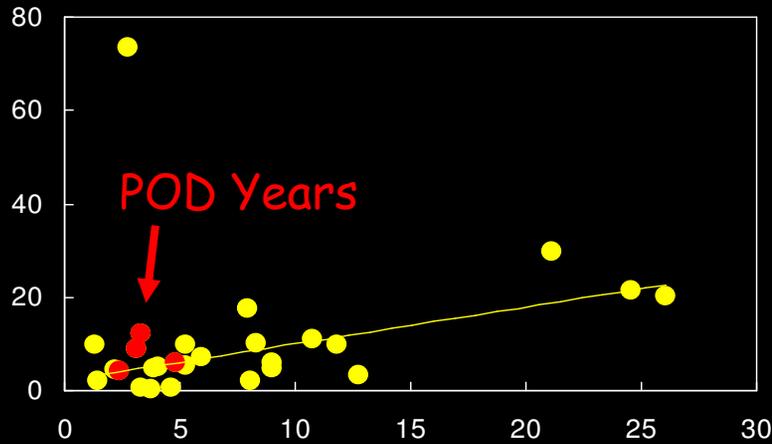
## Updates

- 2007 abundance data.
- “Population” estimates.

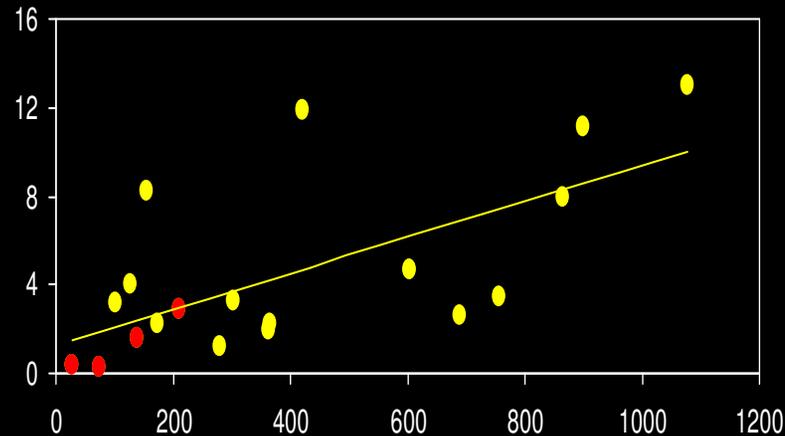
# Stock - Recruitment Effects



Juvenile Production



Threadfin shad

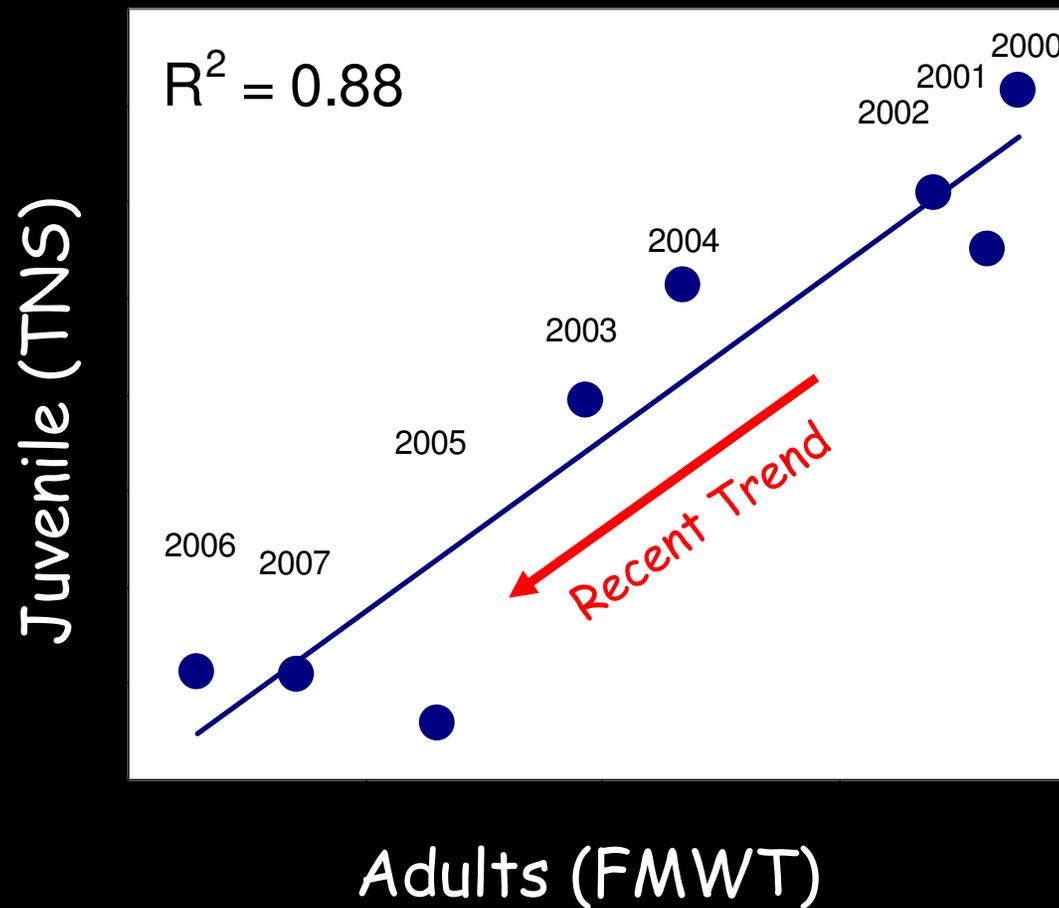


Delta smelt

Fall Midwater Trawl (Adults)

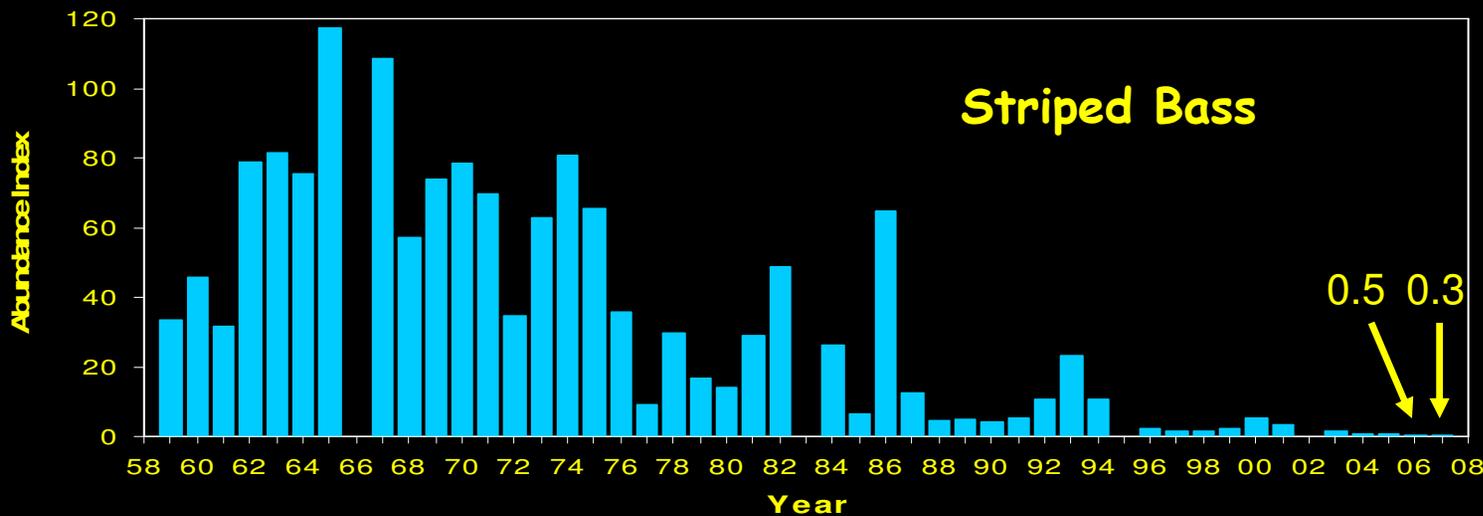
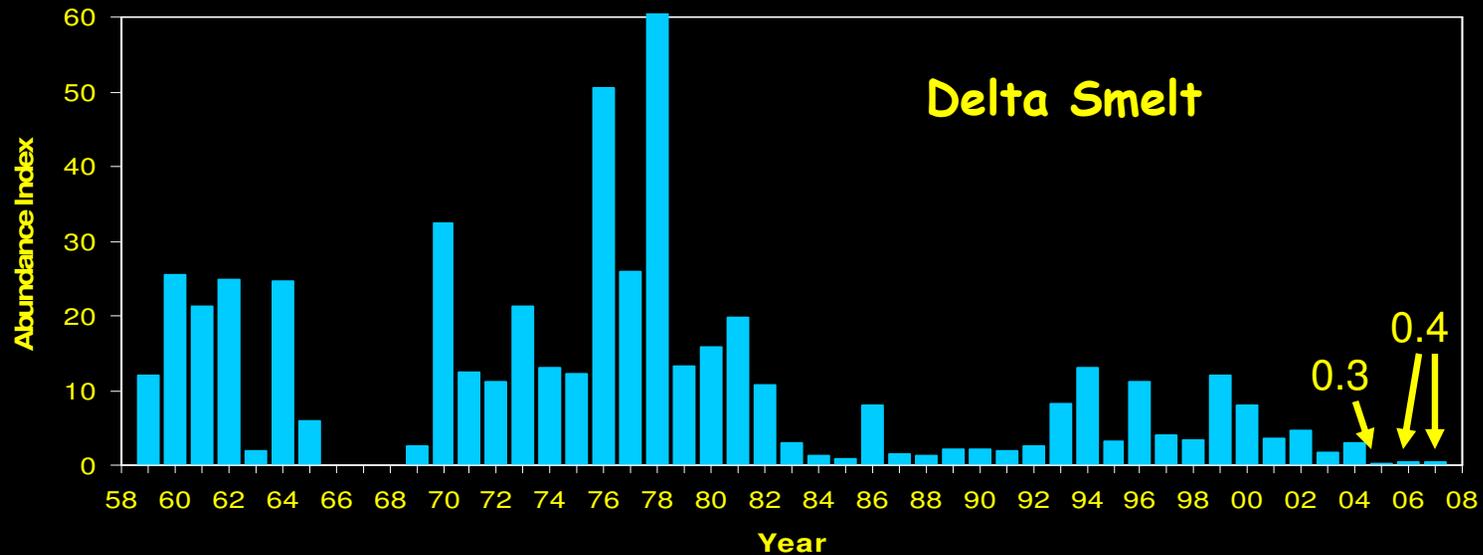


# Have Delta Smelt Dropped Below Critical Population Levels?



Source: Anke Mueller-Solger (DWR); IEP (2007)

Summer abundance in 2007 once again very low.

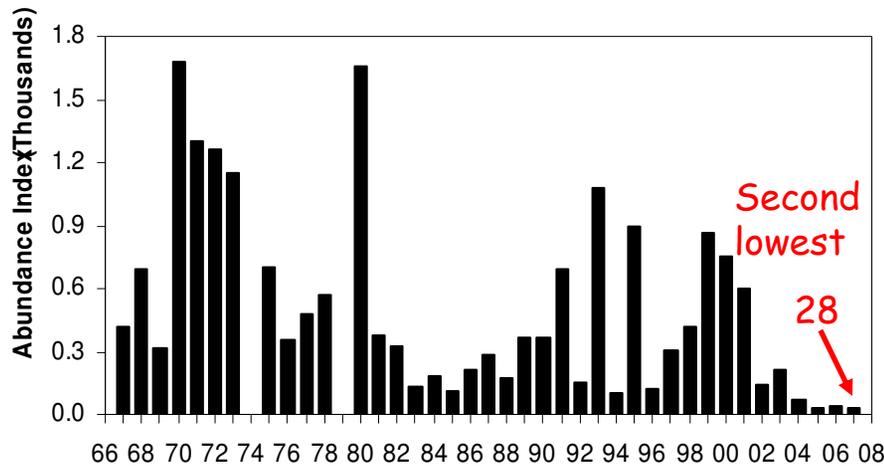


Source DFG 2007 Townet

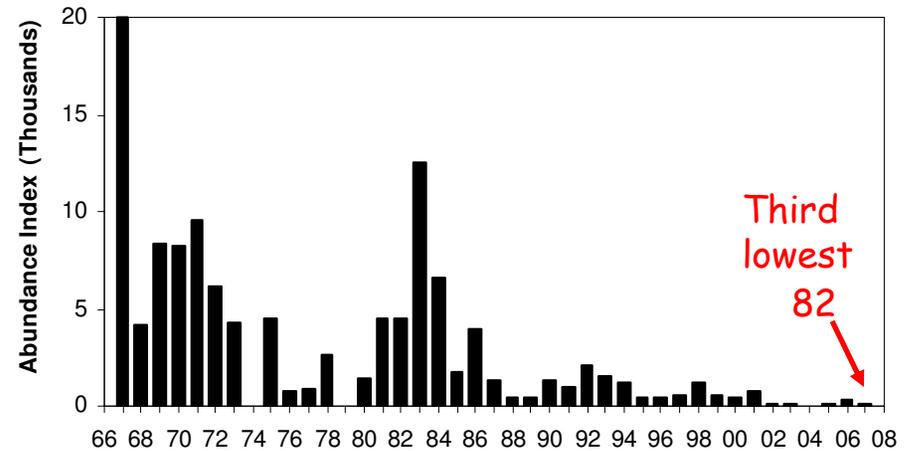
# Fall abundance in 2007 continued to decline for all POD fishes.

Source: DFG 2007 Fall MW Trawl  
No sampling 1974 and 1979

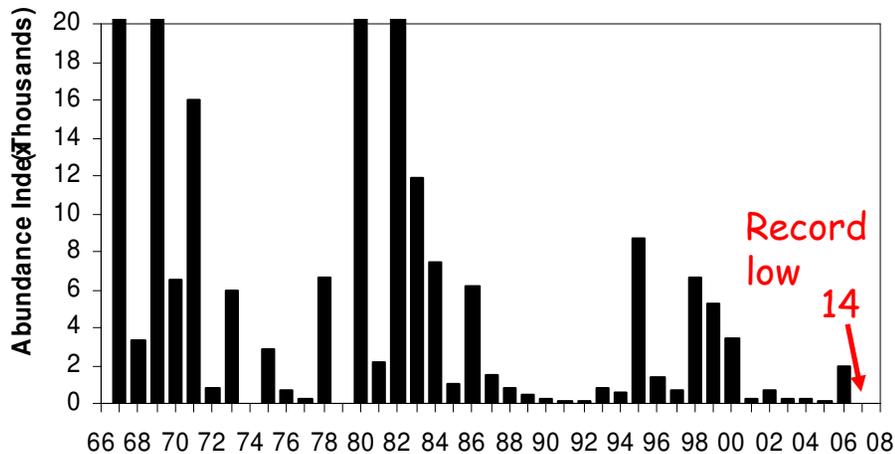
### Delta Smelt



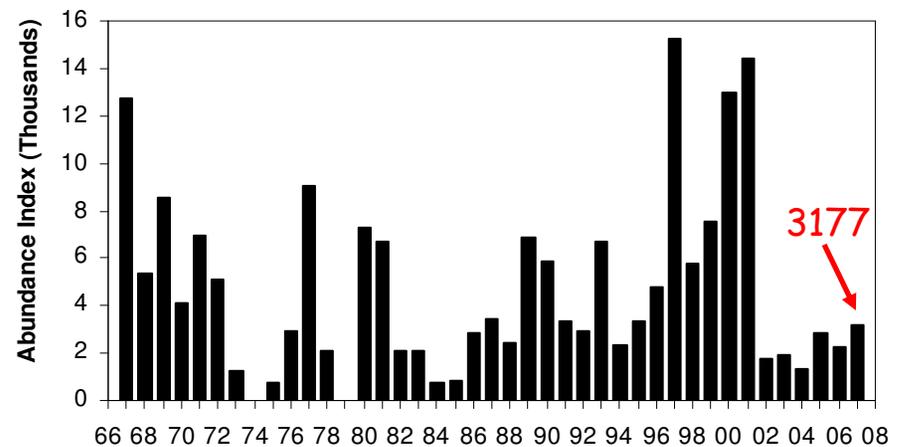
### Striped Bass



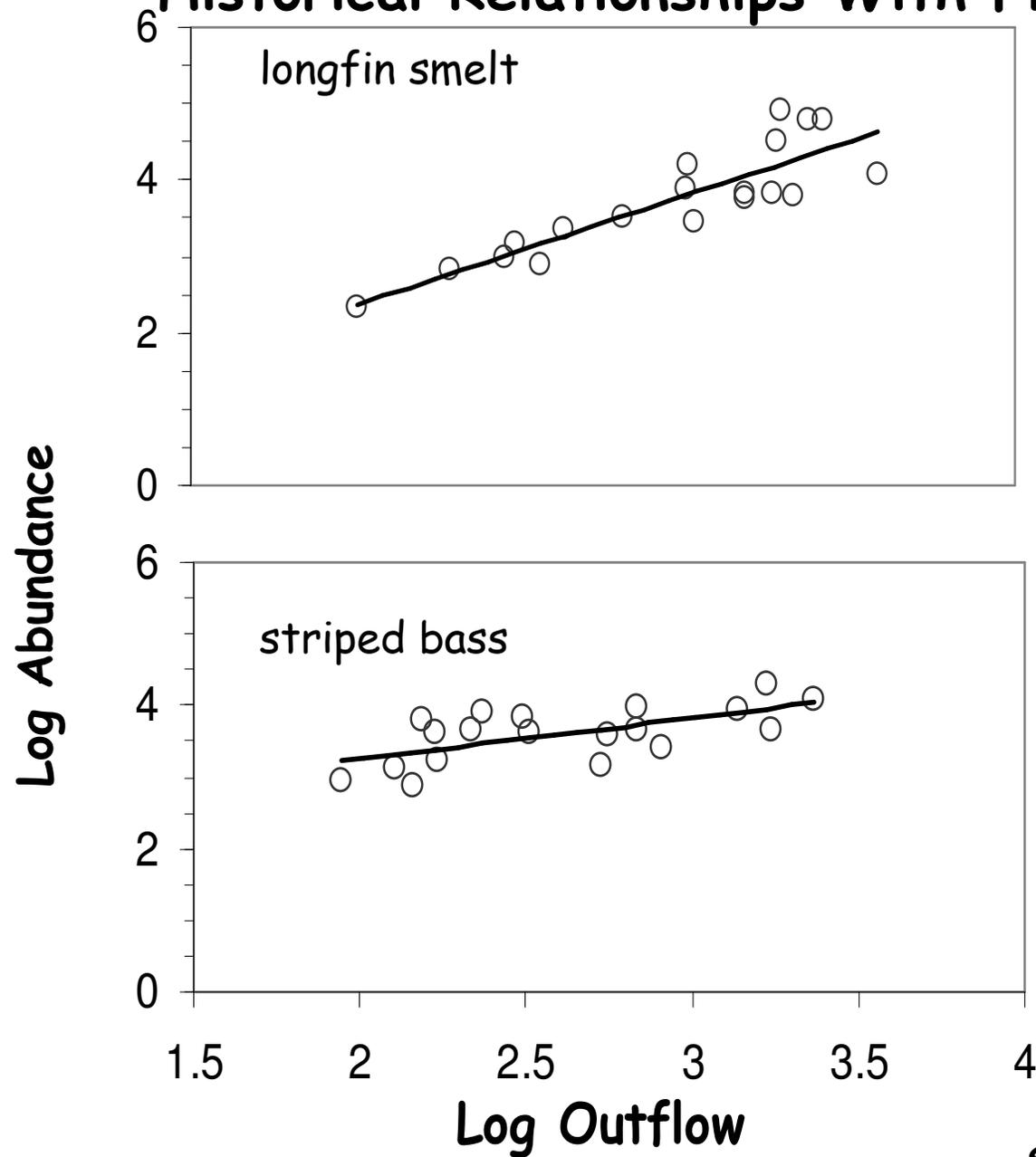
### Longfin Smelt



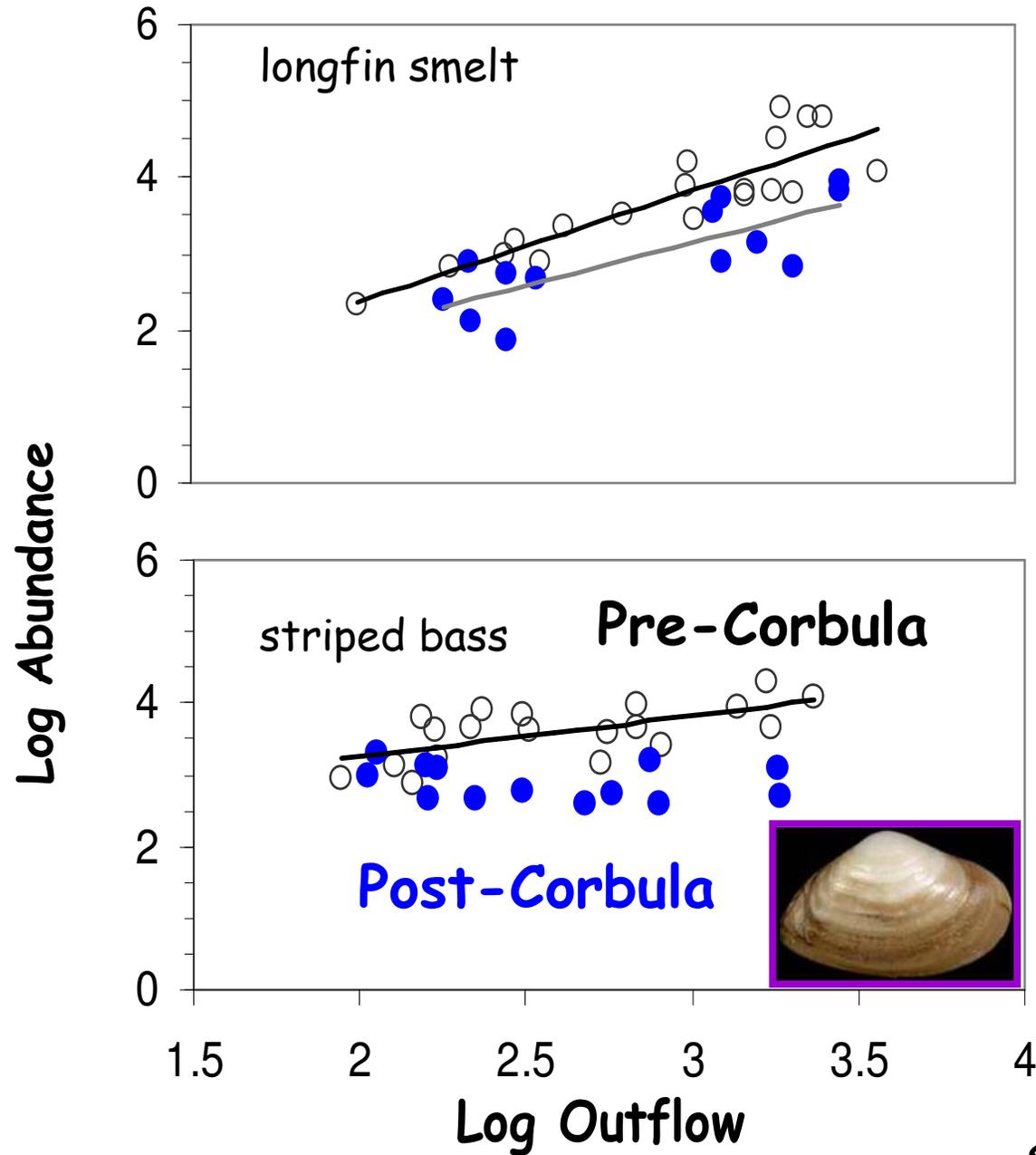
### Threadfin Shad



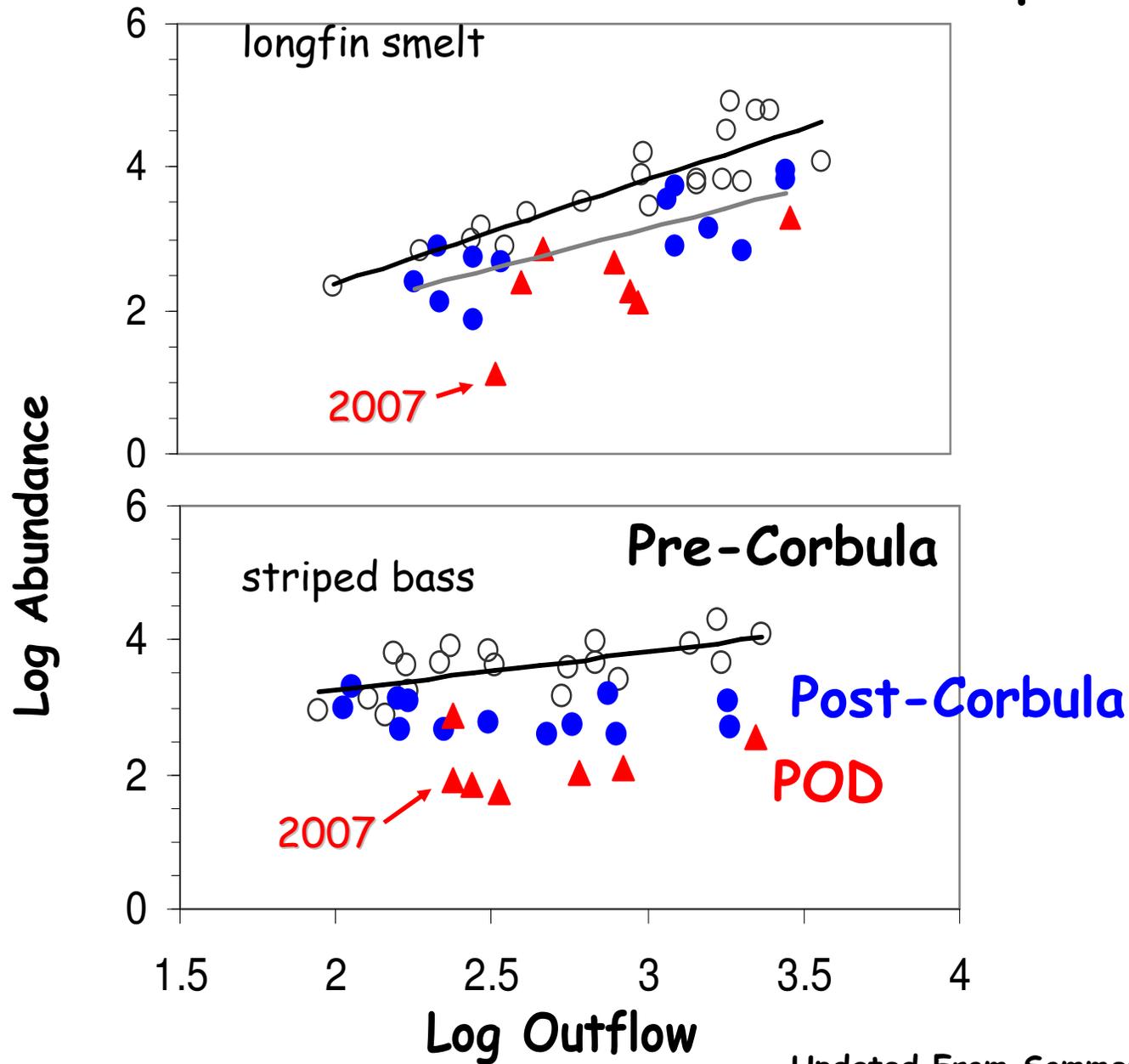
# How Do Recent Abundance Levels Compare to Historical Relationships With Flow?



# Corbula Shifted Abundance-Outflow Relationships



# POD Represents A Further Shift In Abundance-Outflow Relationships

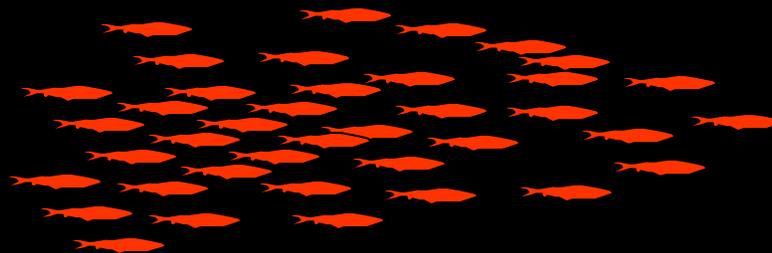


Updated From Sommer et al. (2007)

# Estimation of Delta Smelt Population Size

Ken Newman, USFWS

- Draft manuscript under review.
- *"Statistically sound, but assumption-laden"*
- Substantial new work needed.
- Data to formally be presented at IEP Annual Meeting 2008



FISH  
ABUNDANCE

PHYSICAL  
&  
CHEMICAL  
FISH  
HABITAT



## PHYSICAL & CHEMICAL FISH HABITAT

## FISH ABUNDANCE



*Temperature*  
*Turbidity*  
*Salinity*  
*Nutrients*

*Contaminants*

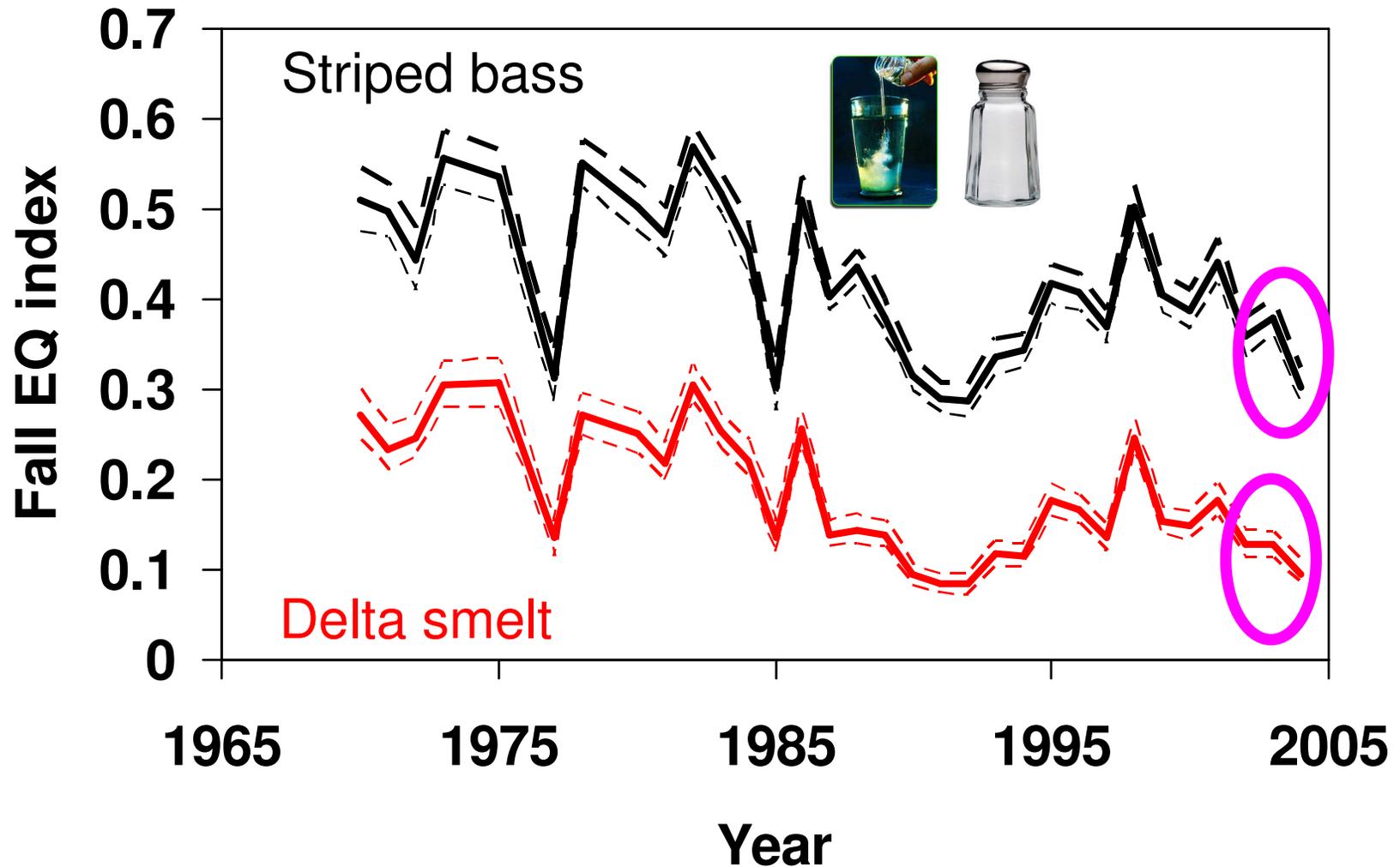
*Disease*

*Toxic algae*

## Updates

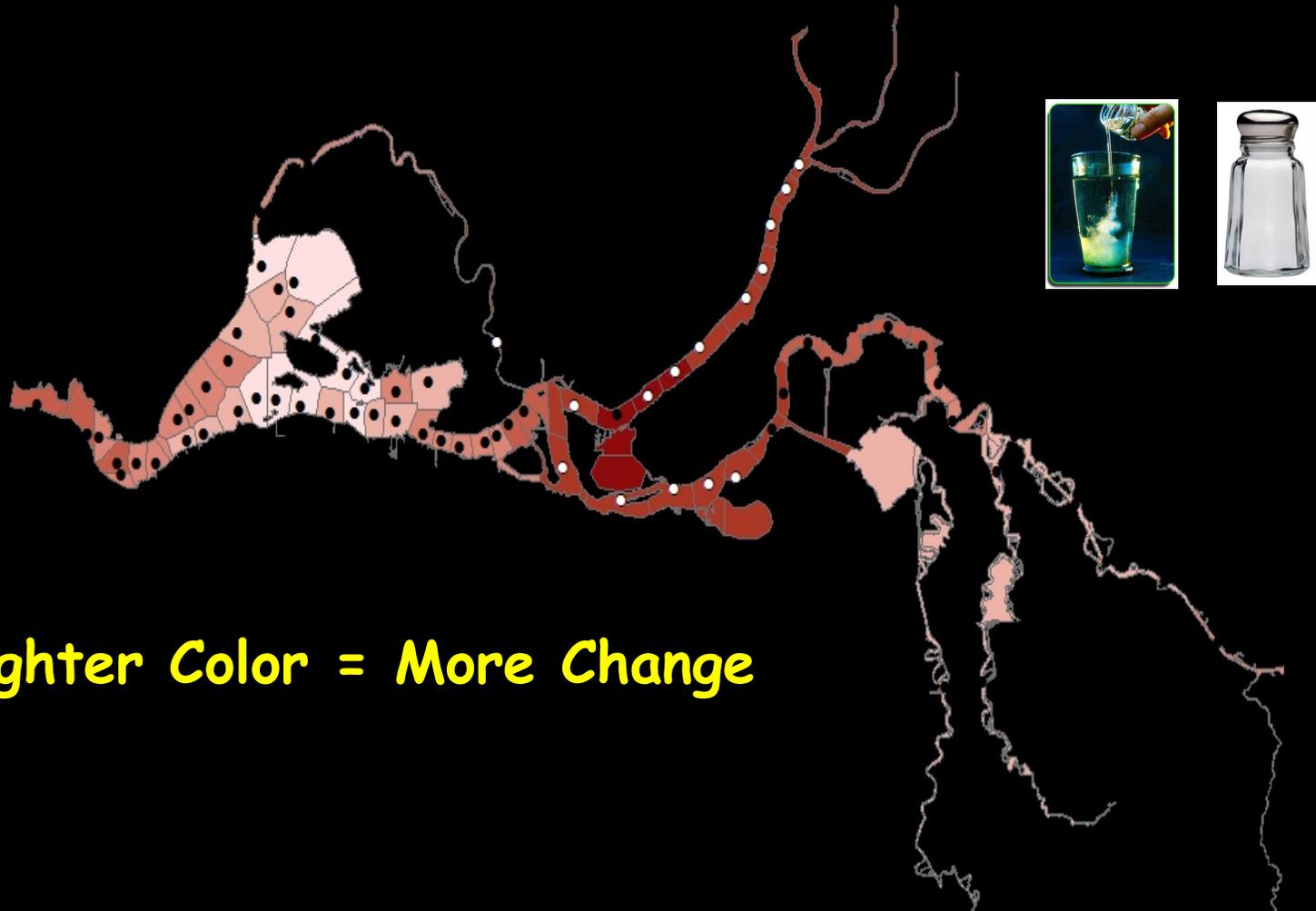
- Mechanisms for habitat changes.
- Possible new insight into toxicity (e.g.  $\text{NH}_3$ , Microcystis).

# Fall "habitat quality" based on salinity and turbidity has deteriorated



Source: Feyrer et al. (CJFAS 2007)

# Fall "Habitat Quality" Showed Major Regional Changes



**Lighter Color = More Change**

Source: Feyrer et al. (CJFAS 2007)

# Causes of Changes in Fall Turbidity

Reduced  
Sediment  
Inputs



Continued  
Spread by  
Egeria



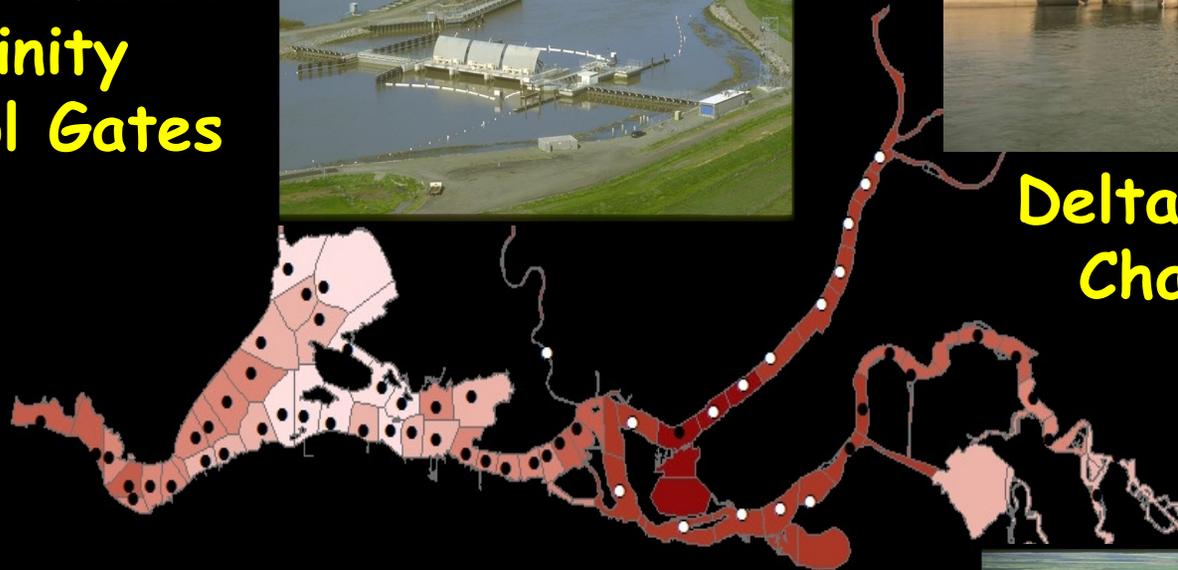
Source: Erin Hestir (UCD), Dave Schoellhamer (USGS)

# Causes of Changes in Fall Salinity

Suisun Marsh  
Salinity  
Control Gates



Delta Cross  
Channel

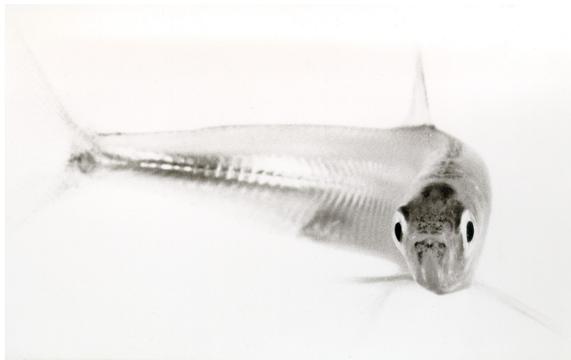
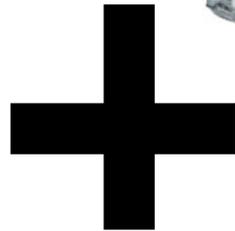
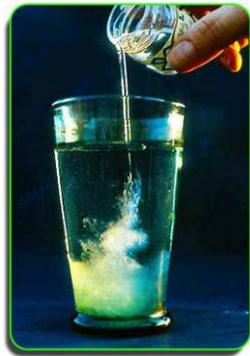


E/I Ratios



Source: Marianne Guerin (CCWD), Dave Fullerton (MWD), Wim Kimmerer (SFSU),  
Chris Enright (DWR)

# Fall "habitat quality" matters to the delta smelt population

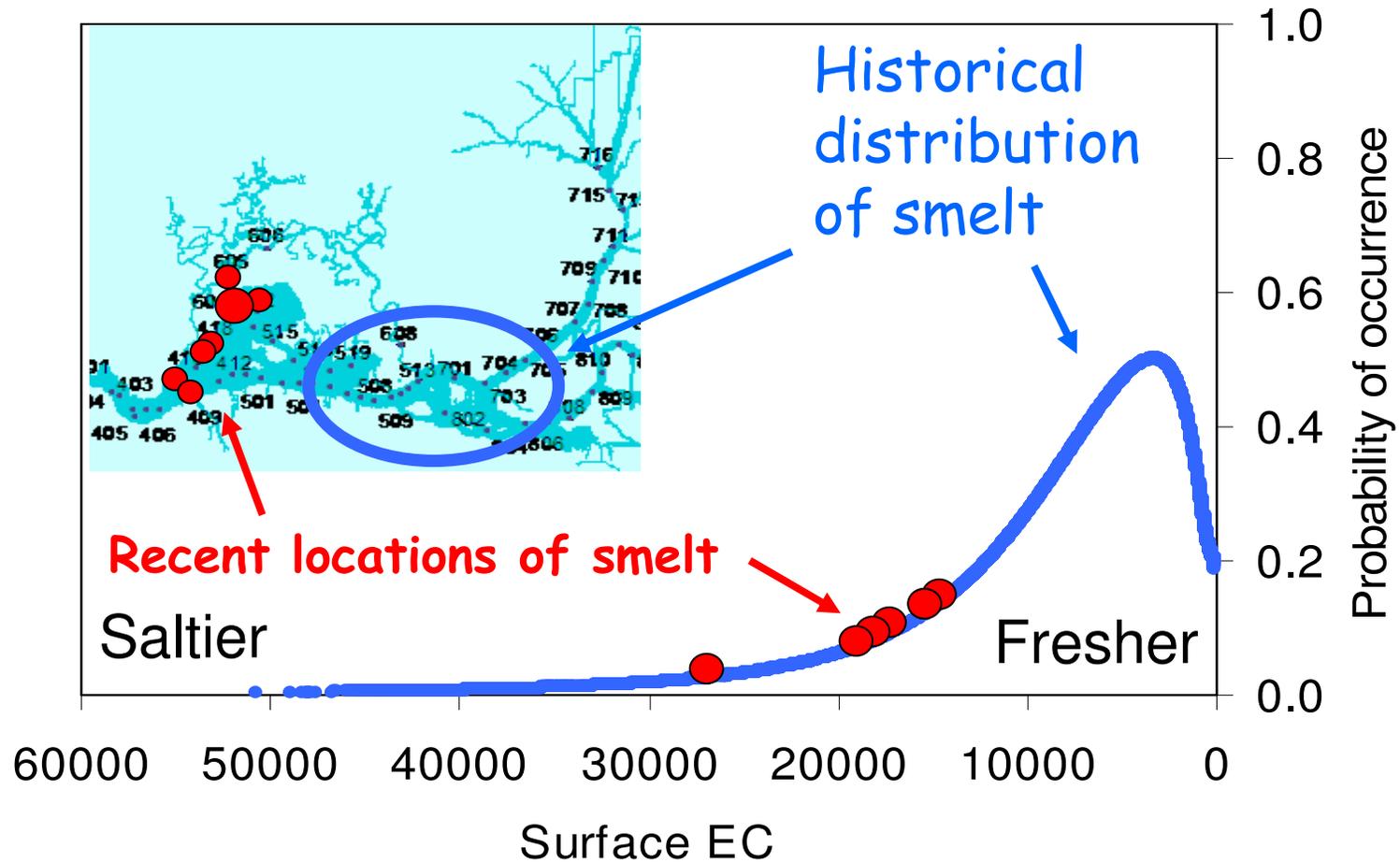


Fall EQ + Fall  
Abundance predicts  
juvenile production

Source: Feyrer et al. (CJFAS 2007)

# Radical Change in Delta Smelt Distribution

September 2007



Source: DFG Fall Midwater Trawl; Feyrer et al. (2007)

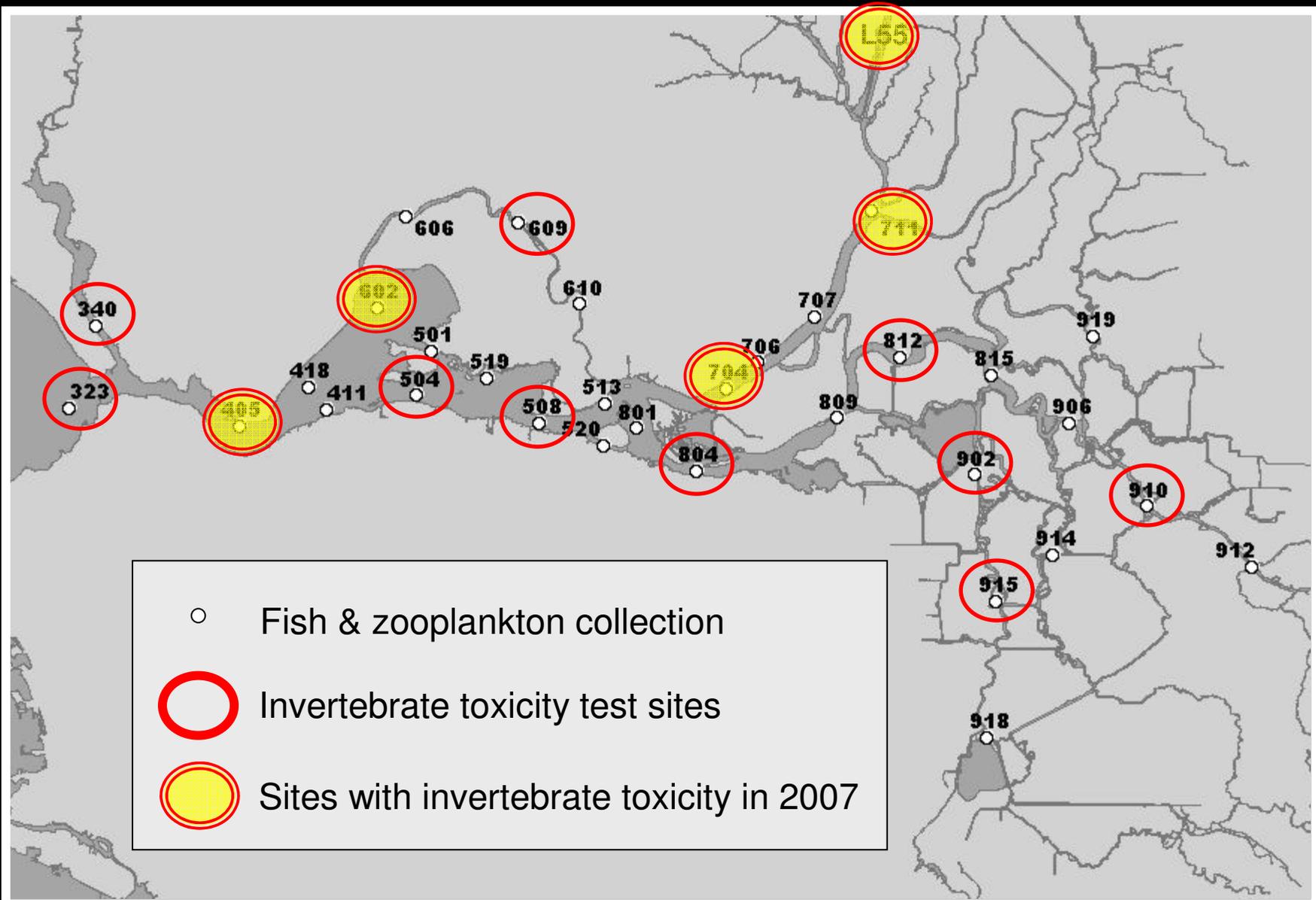
# 2007 Update

- Low Flows = Less Dilution
- Toxicity and Growth Impairment in Some Invertebrate Bioassays
- Ammonia a Rising Concern
- Widespread Microcystis Blooms in Summer
- Biomarker Workshop

Source: Inge Werner (UCD), Peggy Lehman and Anke-Mueller Solger (DWR)

# Jan. - July 2007 Toxicity in the North Delta

Inge Werner, UCD

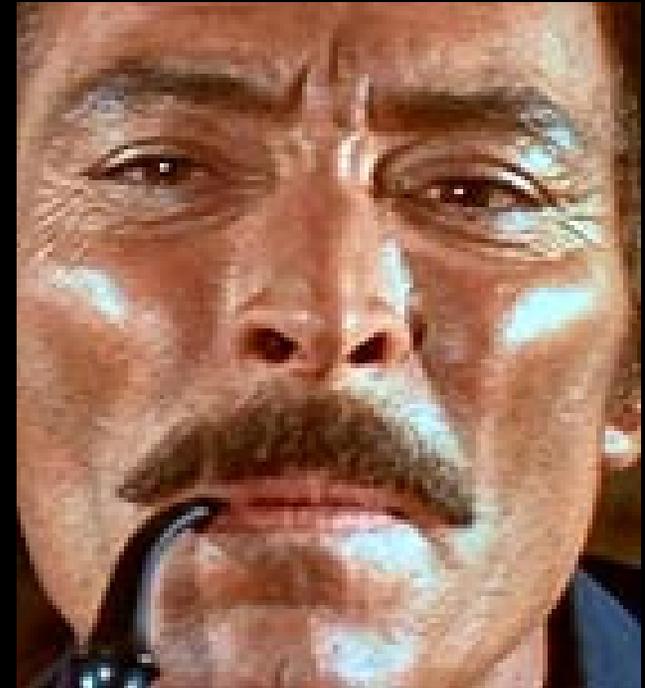


# POD & Nutrients



*The Bad*

*The Good*

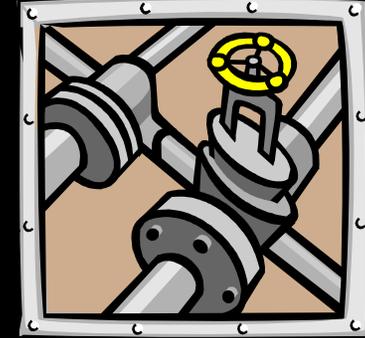


*and The Ugly!*



## POD & Nutrients

### The Good:



- Nutrient inputs can be managed as a “knob”
- More nutrients could mean more pelagic production.
- But: Delta production is often limited by light, not nutrients.

## POD & Nutrients

### The Bad:

In excess, nutrients can become pollutants

### The Ugly:

Nutrient pollution may contribute to the POD via several mechanisms

# POD & Nutrients

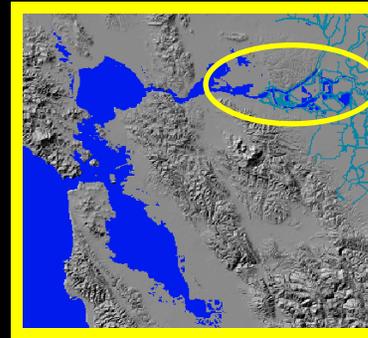
## Example: Ammonia pollution



Sewage Treatment Plants



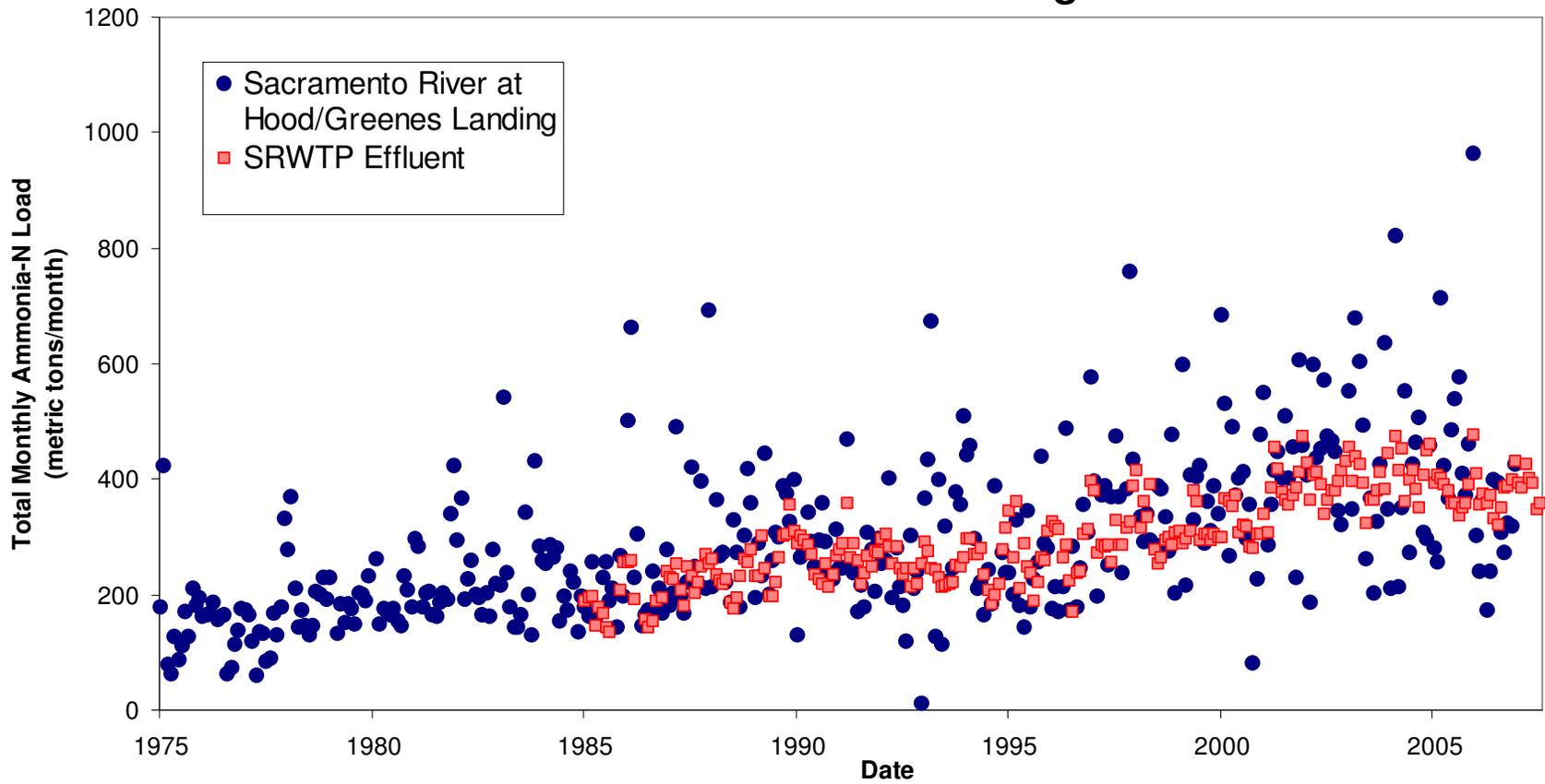
Increasing Ammonia levels in Delta and Suisun Bay



Potential Ecosystem Effects

# ~ 90% of the Ammonia Load at Hood comes from the Sacramento Regional Wastewater Treatment Plant

Monthly Ammonia Loads in the Sacramento River at Hood and in Effluent from the Sacramento Regional WWTP



Sources: A. Mueller-Solger, DWR; A. Jassby, in press SFEWS

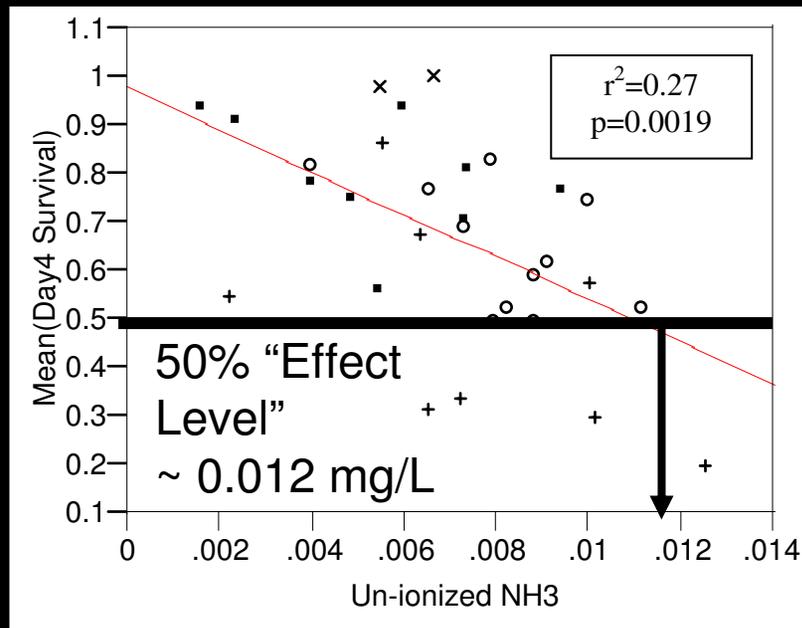
# Unionized ammonia is toxic to fish

- Salmonids are particularly sensitive
- Delta smelt may be more sensitive
- More work needs to be done

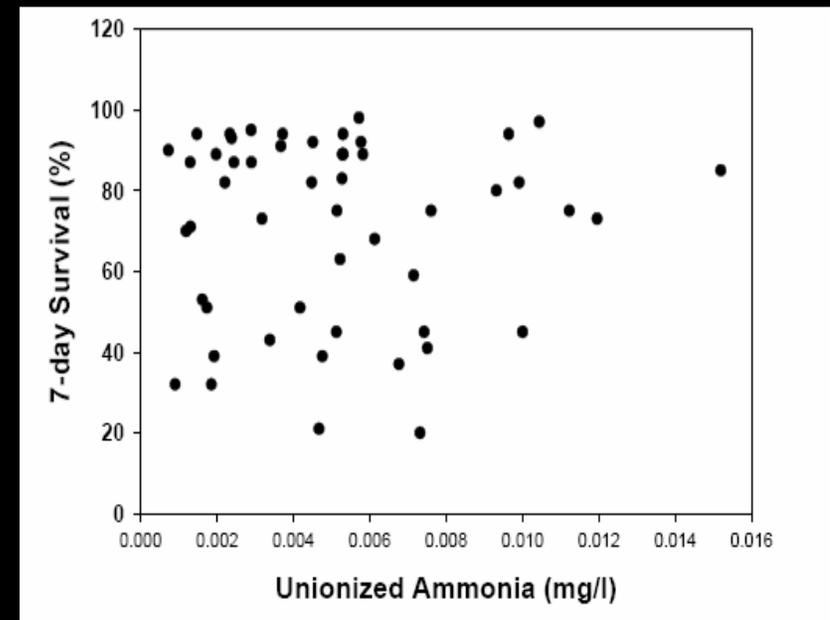
**Delta smelt** survival versus un-ionized ammonia (mg N/L) in ambient Delta water samples and control water

Graphs provided by Dr. Inge Werner, UCD-ATL

2006

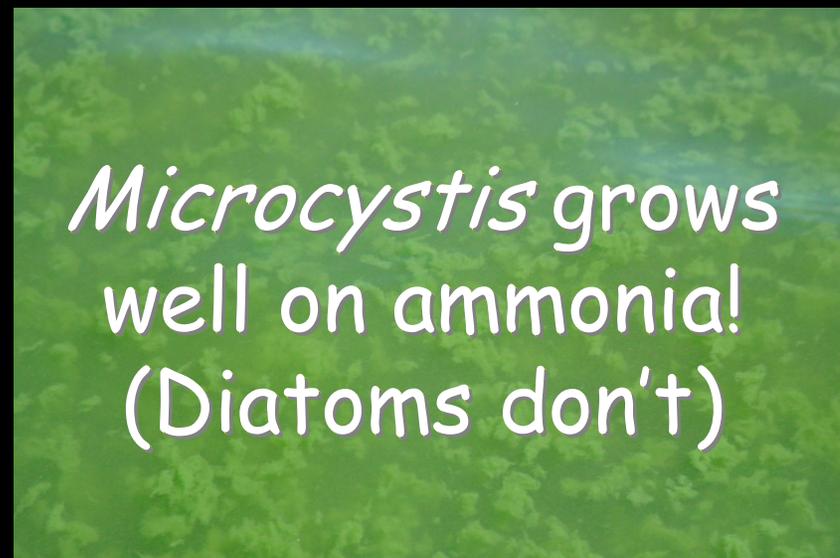
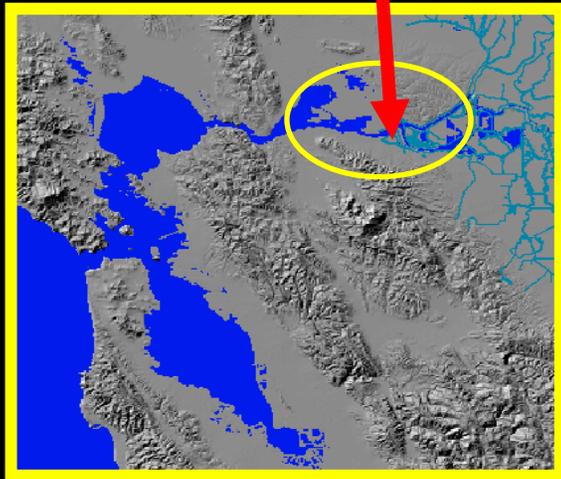


2007



# Widespread blooms of the toxic alga *Microcystis* in 2007

August Levels: 1.3 million cells/mL



*Microcystis* grows well on ammonia!  
(Diatoms don't)

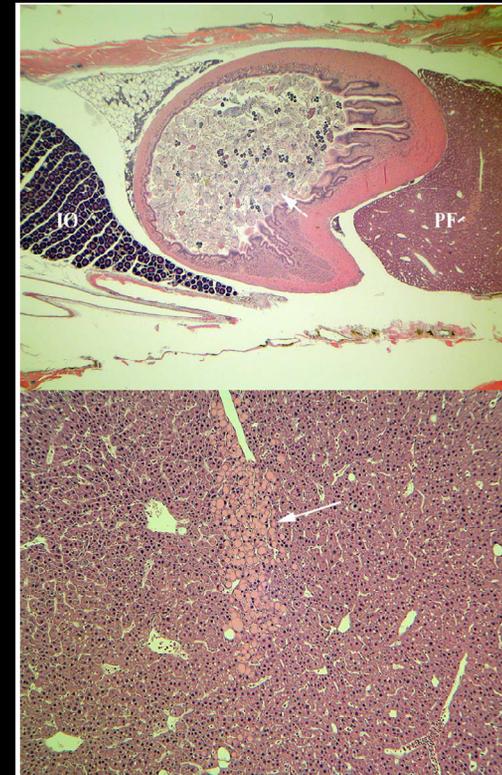
Core Habitat of Delta Smelt

Source: Peggy Lehman (DWR)

# POD Guidance from National Expert Panel on Future Direction of Contaminant Studies

How should biomarkers be used to determine whether contaminants significantly stress POD fishes?

Product - "Biomarker Synthesis"  
White Paper 19 December 2007





FISH  
ABUNDANCE

## Updates

-Detailed analysis of salvage data.

# Water Project Losses

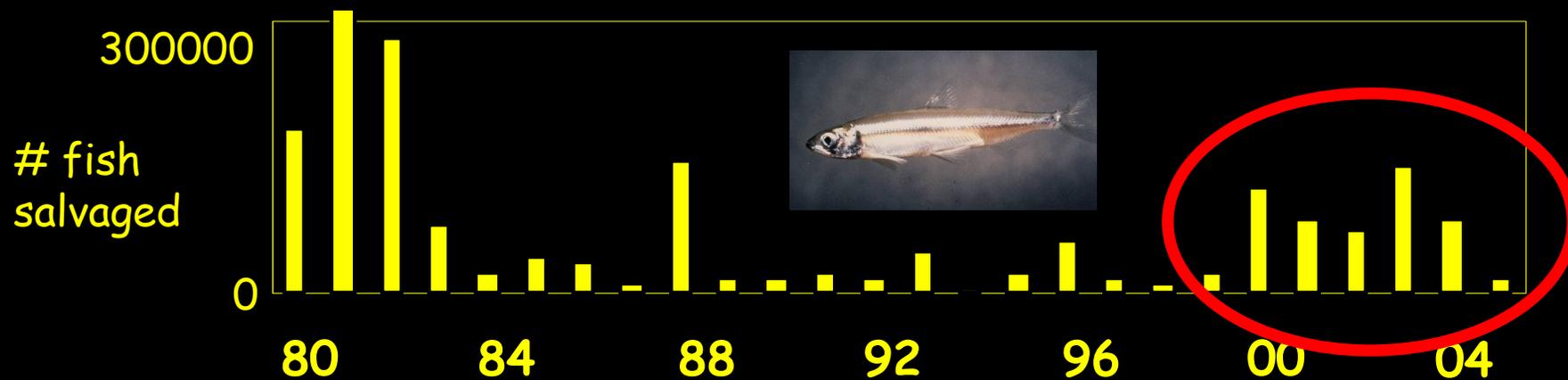


Up to 35-65 Percent  
of Delta Inflow



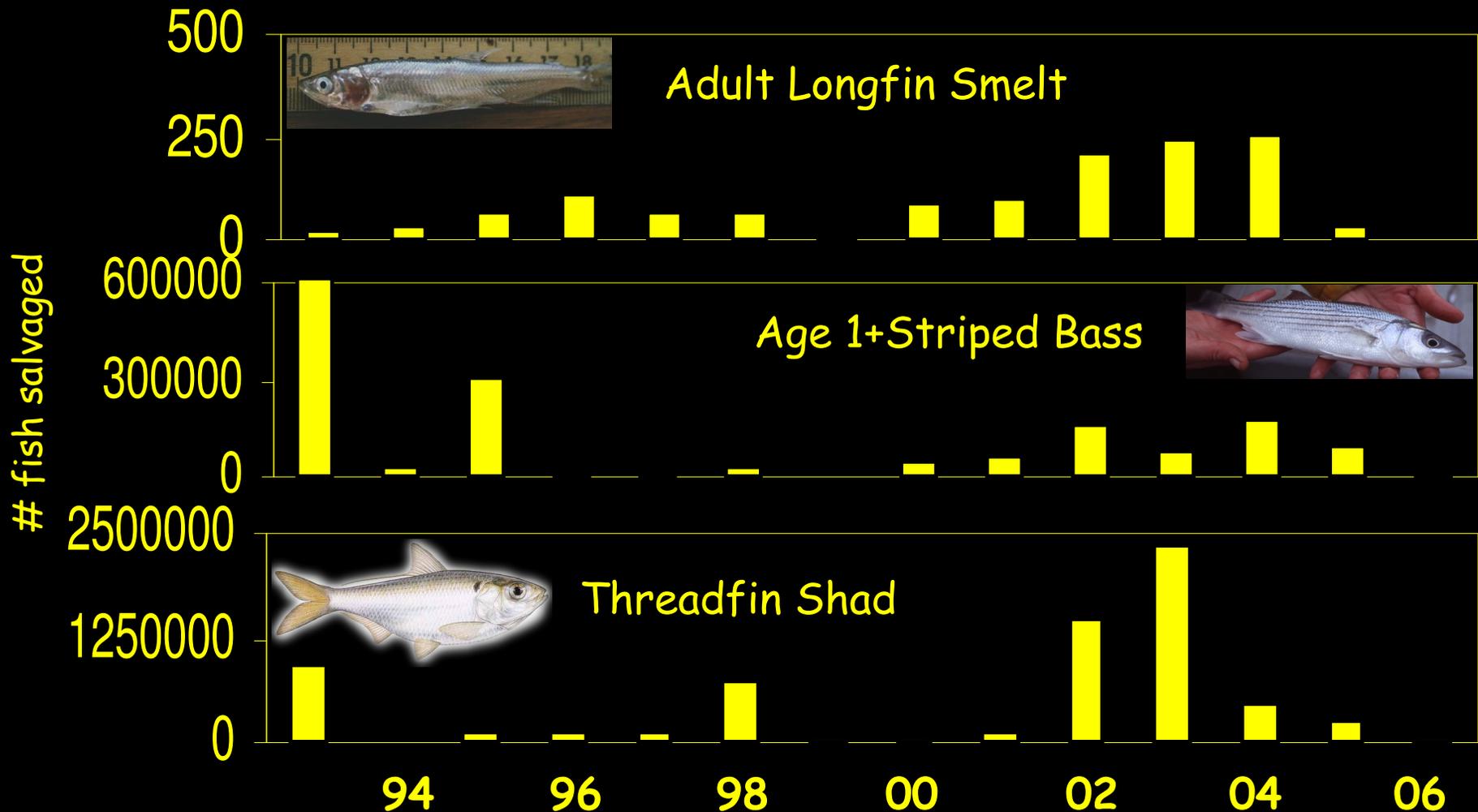
Fish Facilities Provide Data on Numbers Salvaged

# Increased Entrapment of Adult Delta Smelt During Winter



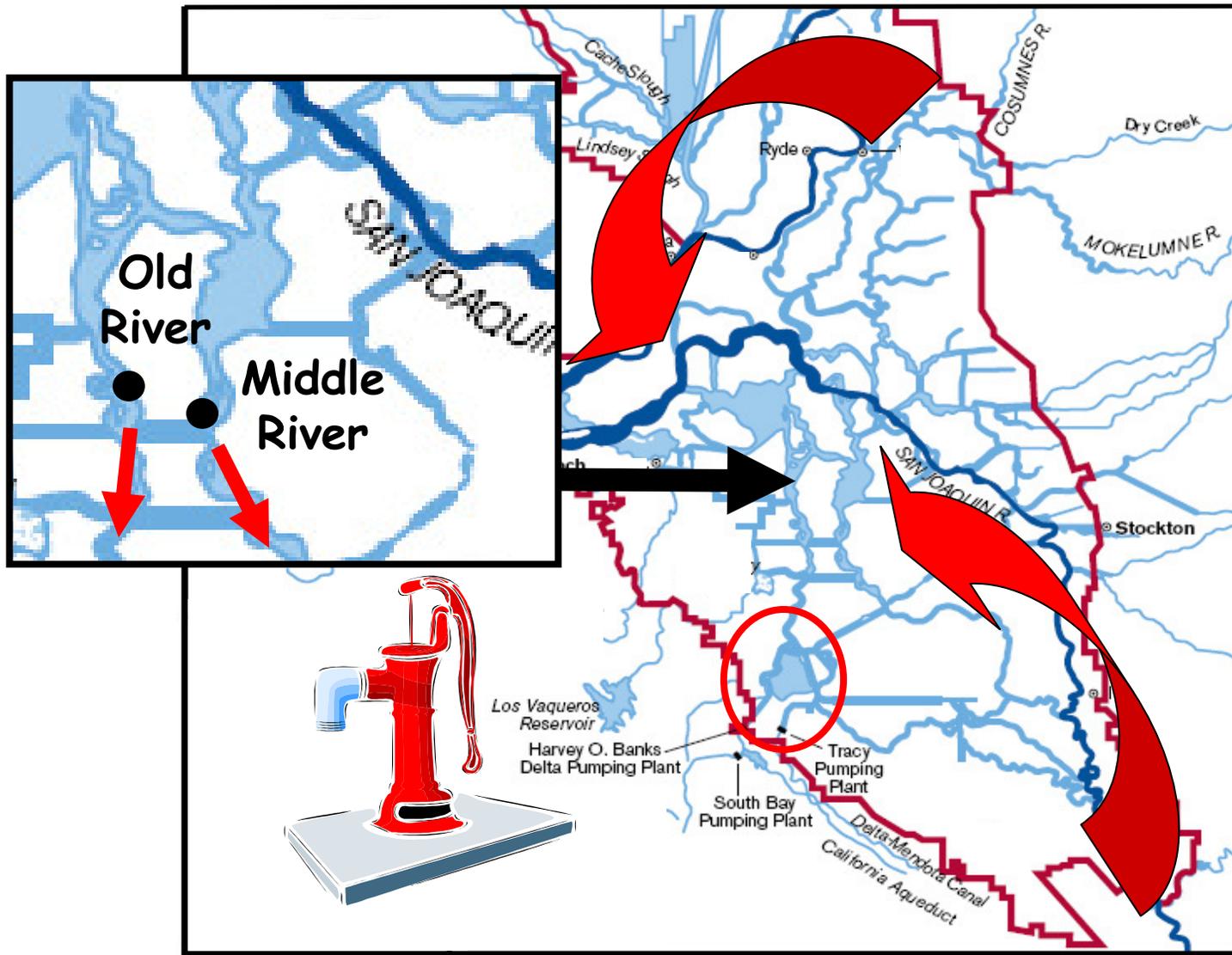
Source: IEP (2005), Grimaldo et al. (In prep)

# Winter Salvage of Other Pelagic Fishes

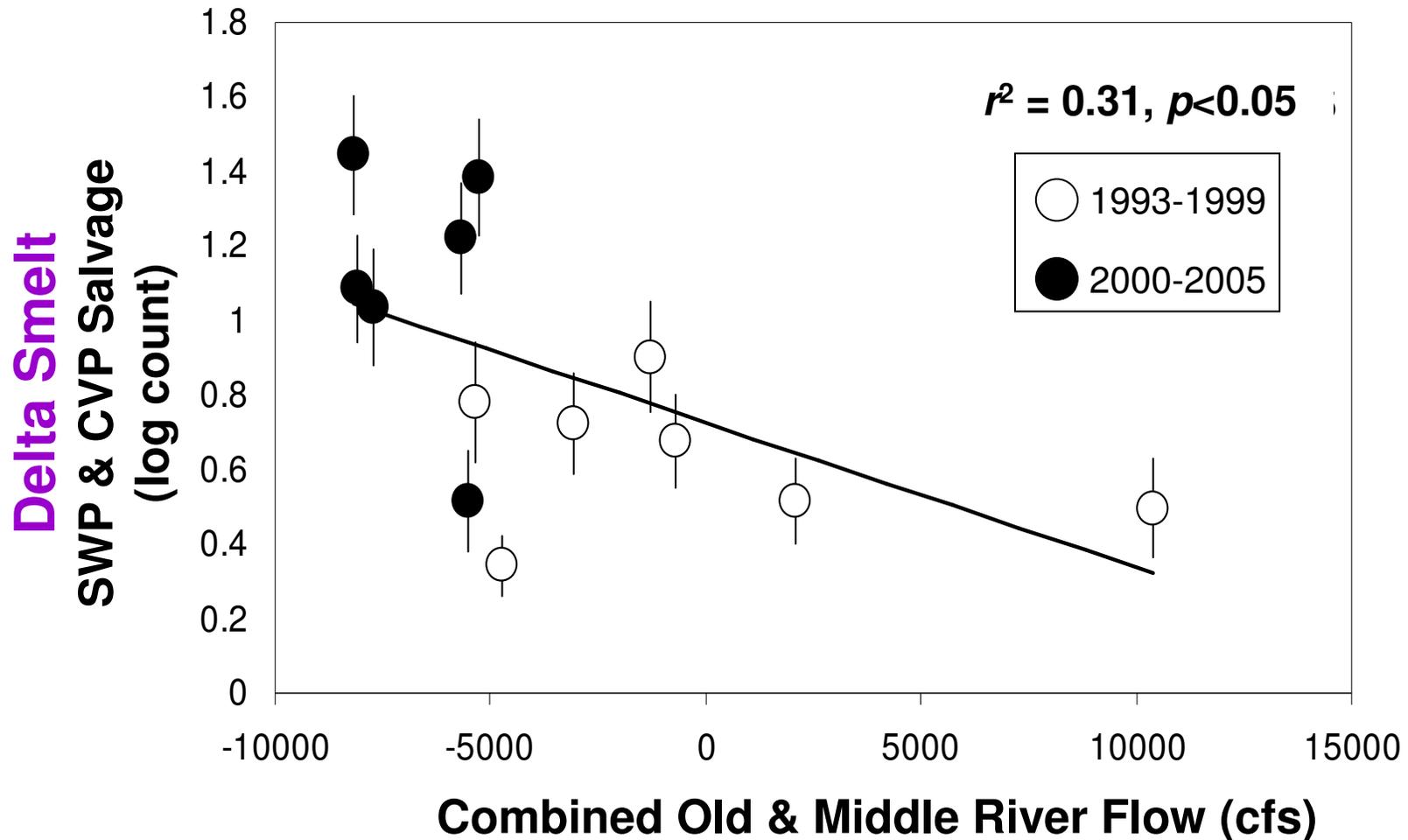


Source: Grimaldo et al. (In prep)

# Old and Middle Rivers Integrator of Hydrodynamic Effects



# Negative Old & Middle River Flows Apparently Increase Adult Delta Smelt Entrainment



Mean Values for December-March  
1993-2005

Source: Source Lenny Grimaldo (In Review)

# What Explains the Differences in Delta Smelt Salvage Between Years?

	Juveniles	Adults
Old & Middle River Flow	No	Yes
Turbidity	No	No
Temperature	No	No
X2 Position	No	No
Food (zooplankton)	Yes	
Fish Abundance	No	No



Source: Lenny Grimaldo et al. (In prep)

# What Affects Delta Smelt Salvage Within a Given Year?

	Juveniles	Adults
Old & Middle River Flow	Yes	Yes
Turbidity	Yes	Yes
Temperature	No	No
X2 Position	No	Yes
Food (zooplankton)	No	
Fish Abundance	Yes	



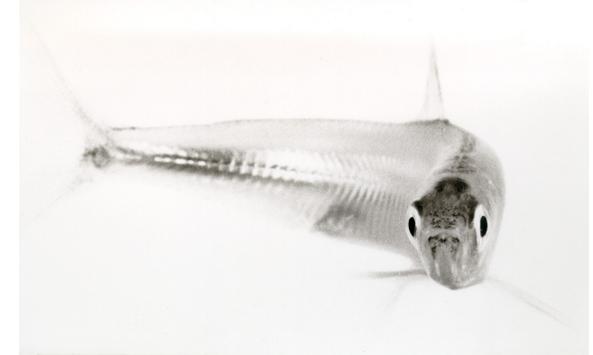
Source: Lenny Grimaldo et al. (In prep)

# Do Water Diversions Have a Significant Effect on Adult Delta Smelt Abundance?



=

Delta Smelt Catch



Exports

or

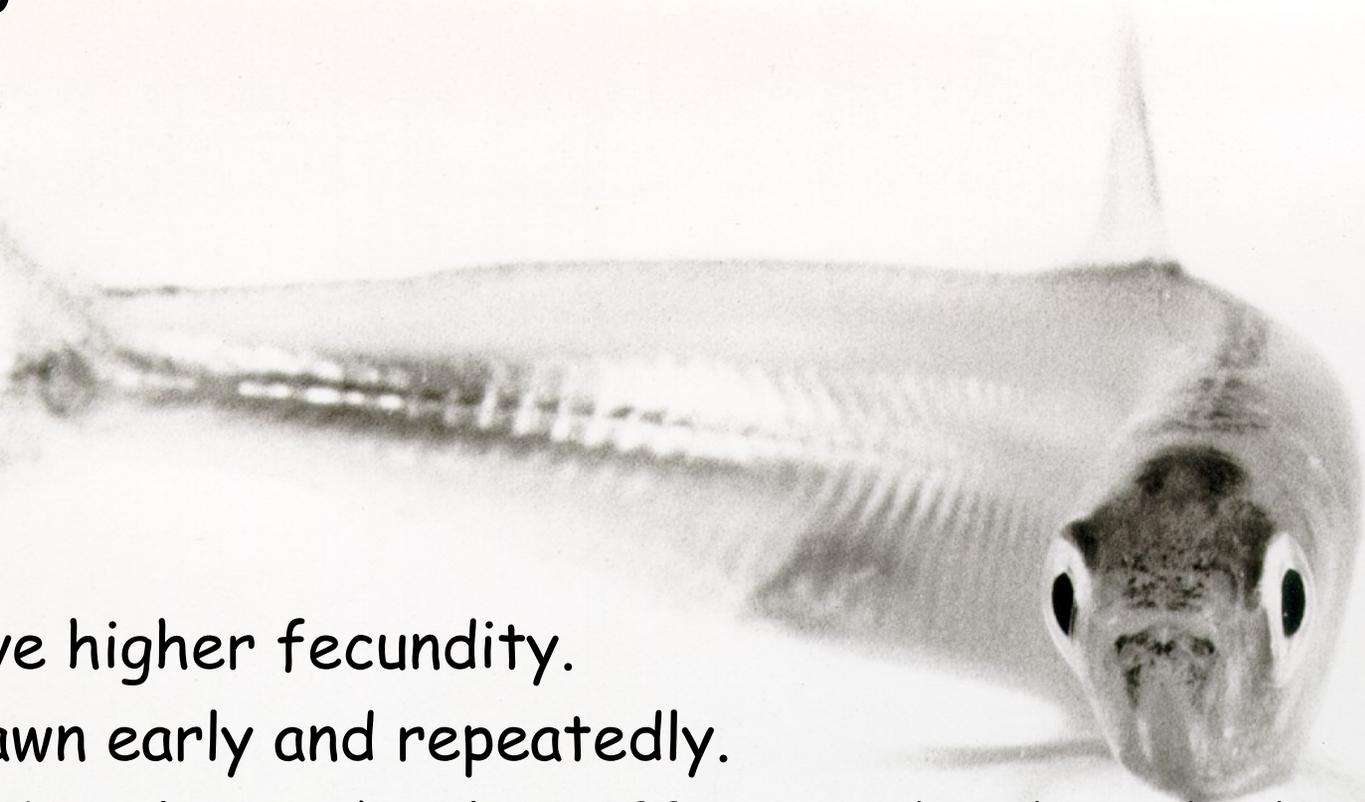
Old and Middle River Flow

Only 1.5% of  
Variation Explained  
Across All Years  
(1981 - 2005)

Source: Log-linear modeling  
by Bryan Manly and Mike  
Chotkowski (USBR)

# Bill Bennett's **BIG MAMA** Hypothesis

Larger/older females:



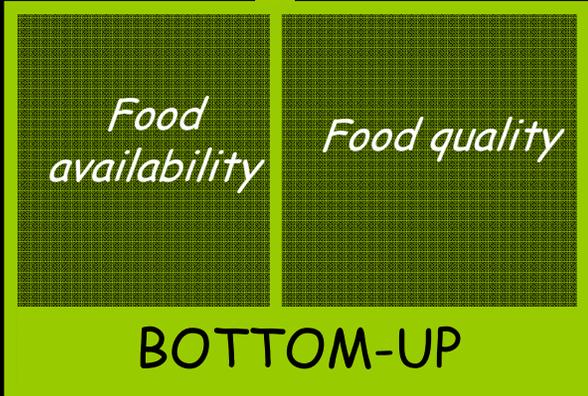
- Have higher fecundity.
- Spawn early and repeatedly.
- Produce larger/earlier offspring that have higher fitness.
- Are more subject to water project effects.

# Updates

- Delta smelt food limitation?



FISH  
ABUNDANCE



# Bigger Changes in Phytoplankton Quality Than in Quantity

## Quantity:

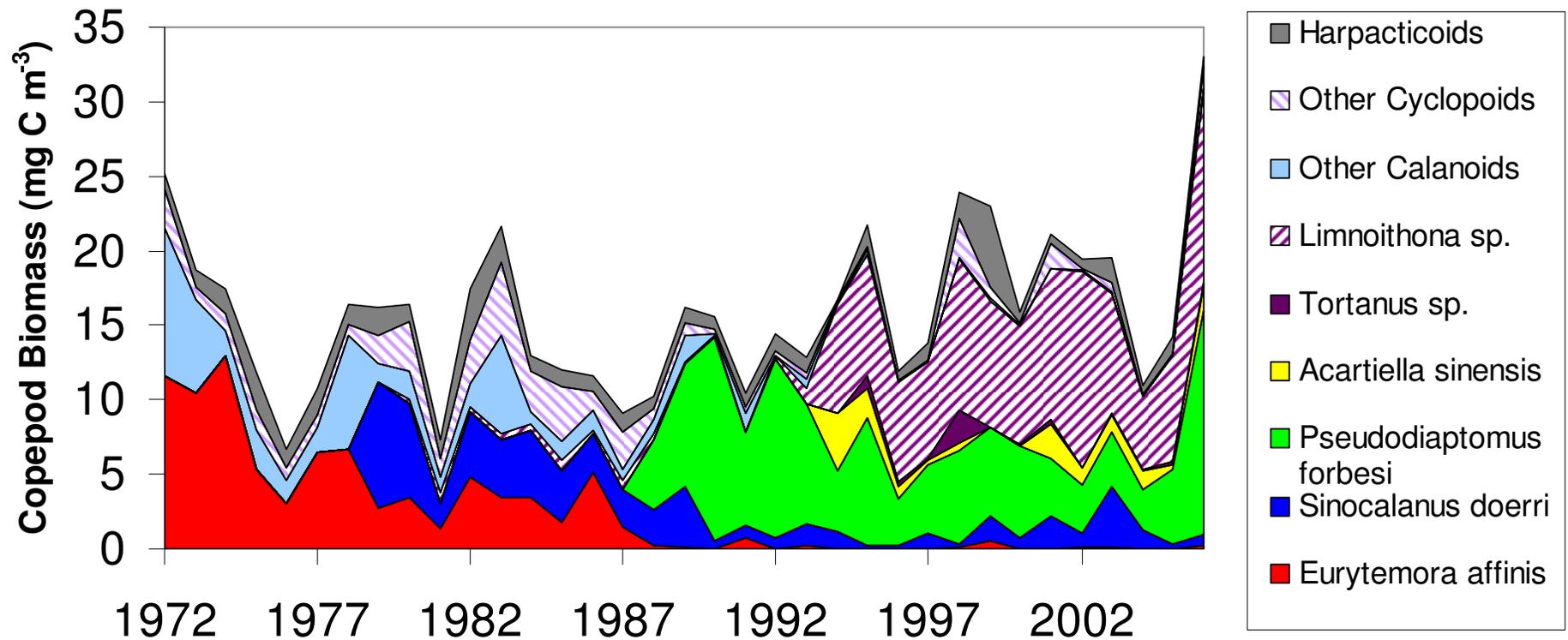
- Low Biomass and Productivity in the Delta & Suisun Bay.
- Prior to 1995: Delta-wide Declines
- **1996-2005: Positive or Neutral Trends**

## Quality:

- On the Rise: Less-Nutritious or Toxic Species, e.g. *Microcystis*

Source: Jassby et al. (2002, In press), Lehman et al. (2005: 2007)

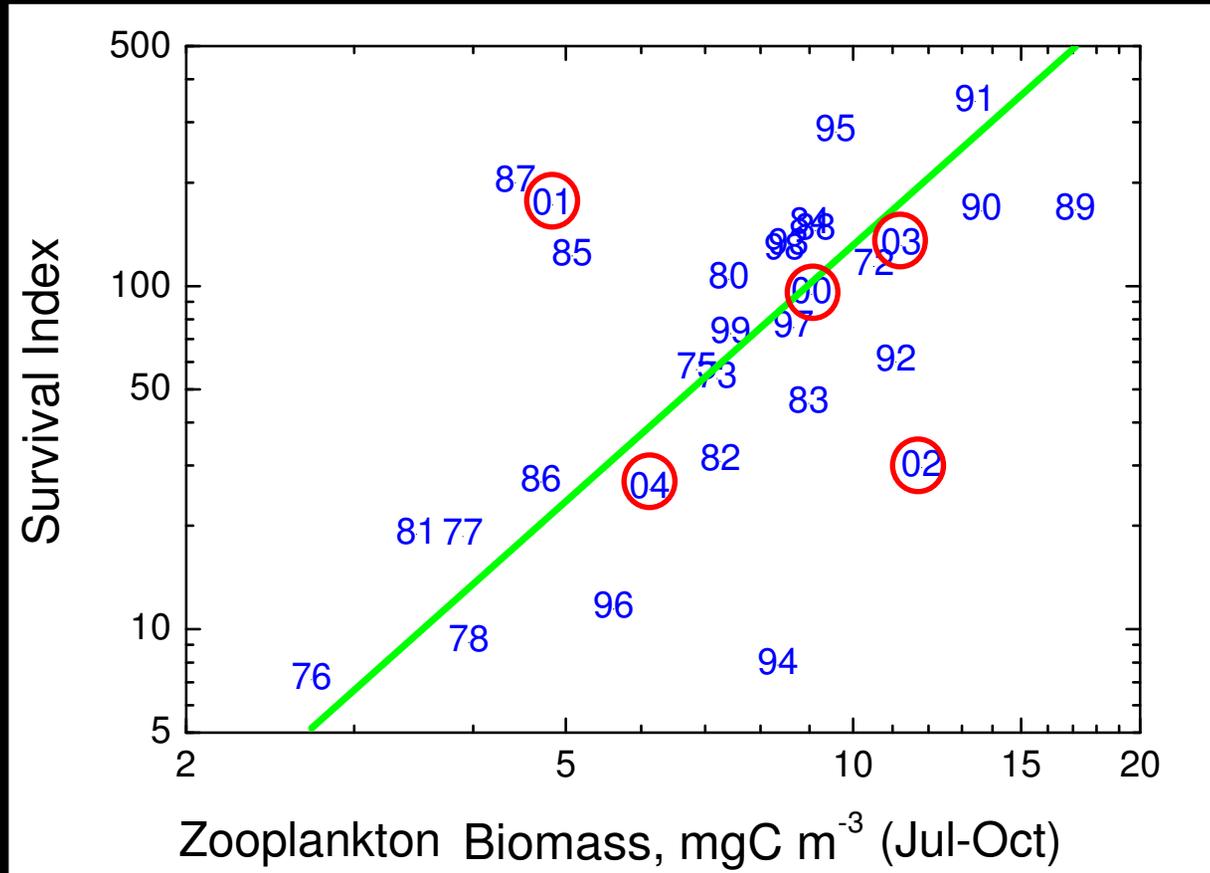
# No Major Change in Zooplankton Biomass, But Big Change In Species



Source: Anke Mueller-Solger (DWR); IEP (2007)

# Food Affects Summer Smelt Survival

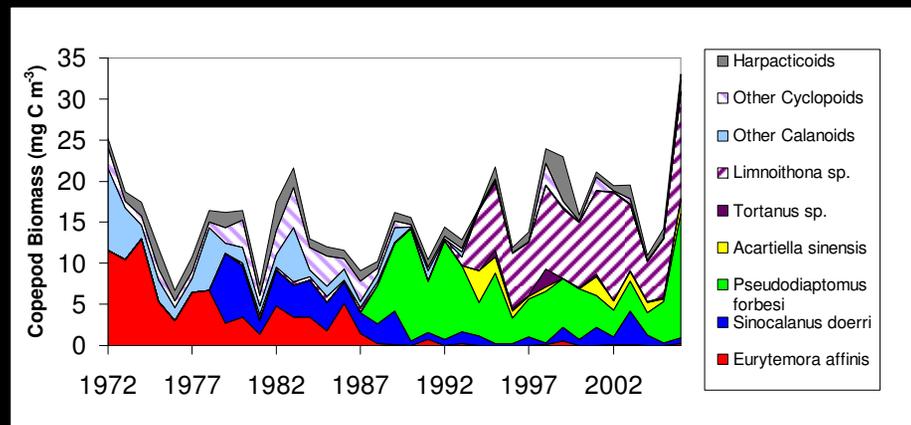
But Recent Levels Were Not Remarkable



Source: Wim Kimmerer (In review)

## So...Are Delta Smelt Food Limited?

- Since 2000, delta smelt have spiraled downward independent of prey density.
- They may not be food limited right now, but over the long-term they likely have been.



# Other Evidence For Food Limitation



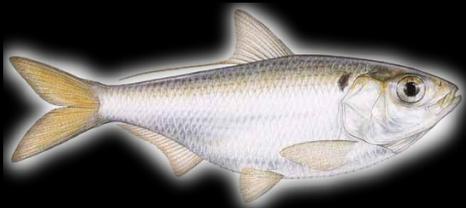
*Striped Bass*

- Shift in X2 relationship after *Corbula* introduction.
- Bioenergetic modeling.

- Shift in X2 relationship after *Corbula* introduction.

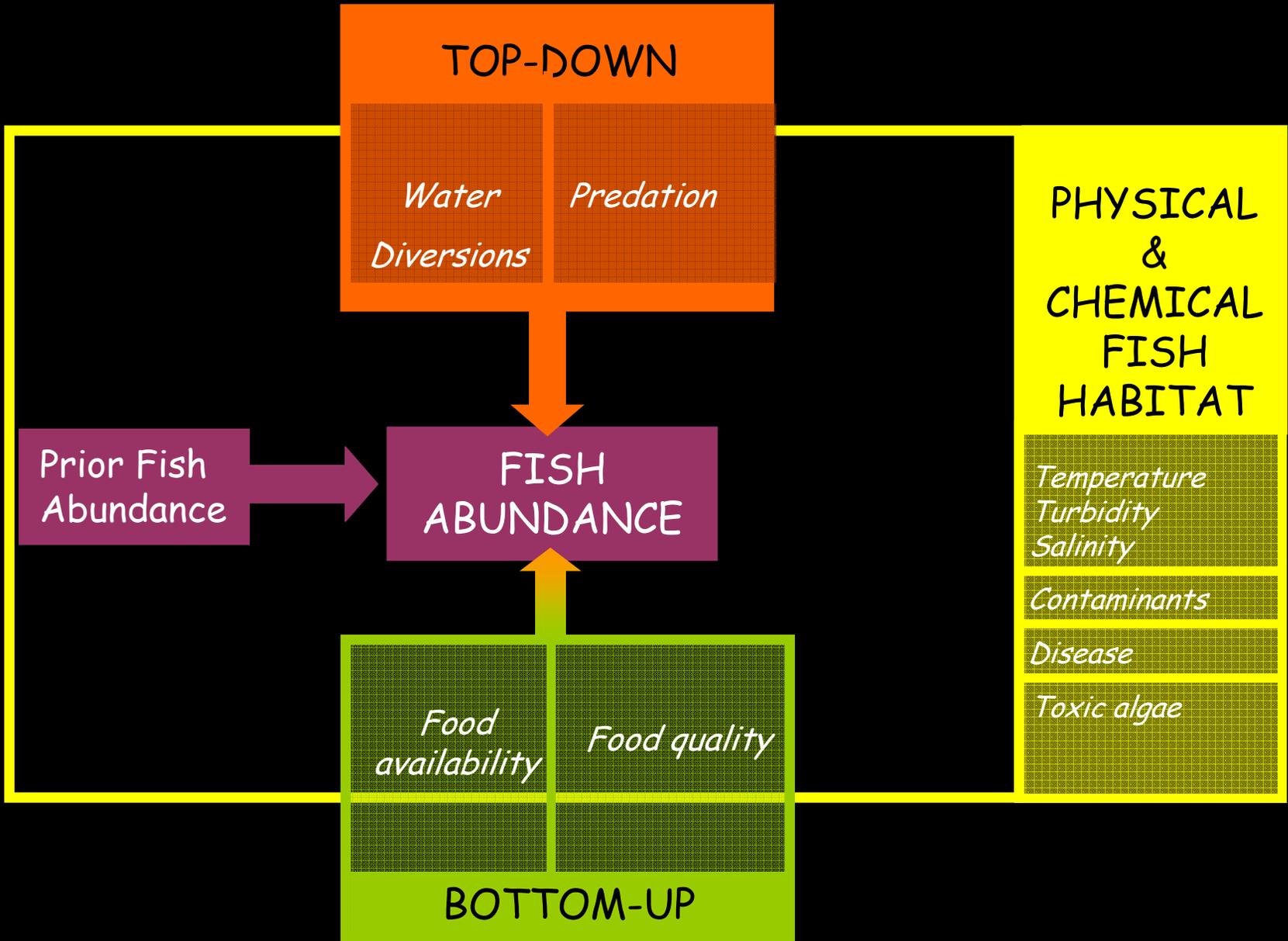


*Longfin Smelt*



*Threadfin Shad*

- Early survival correlated with zooplankton.



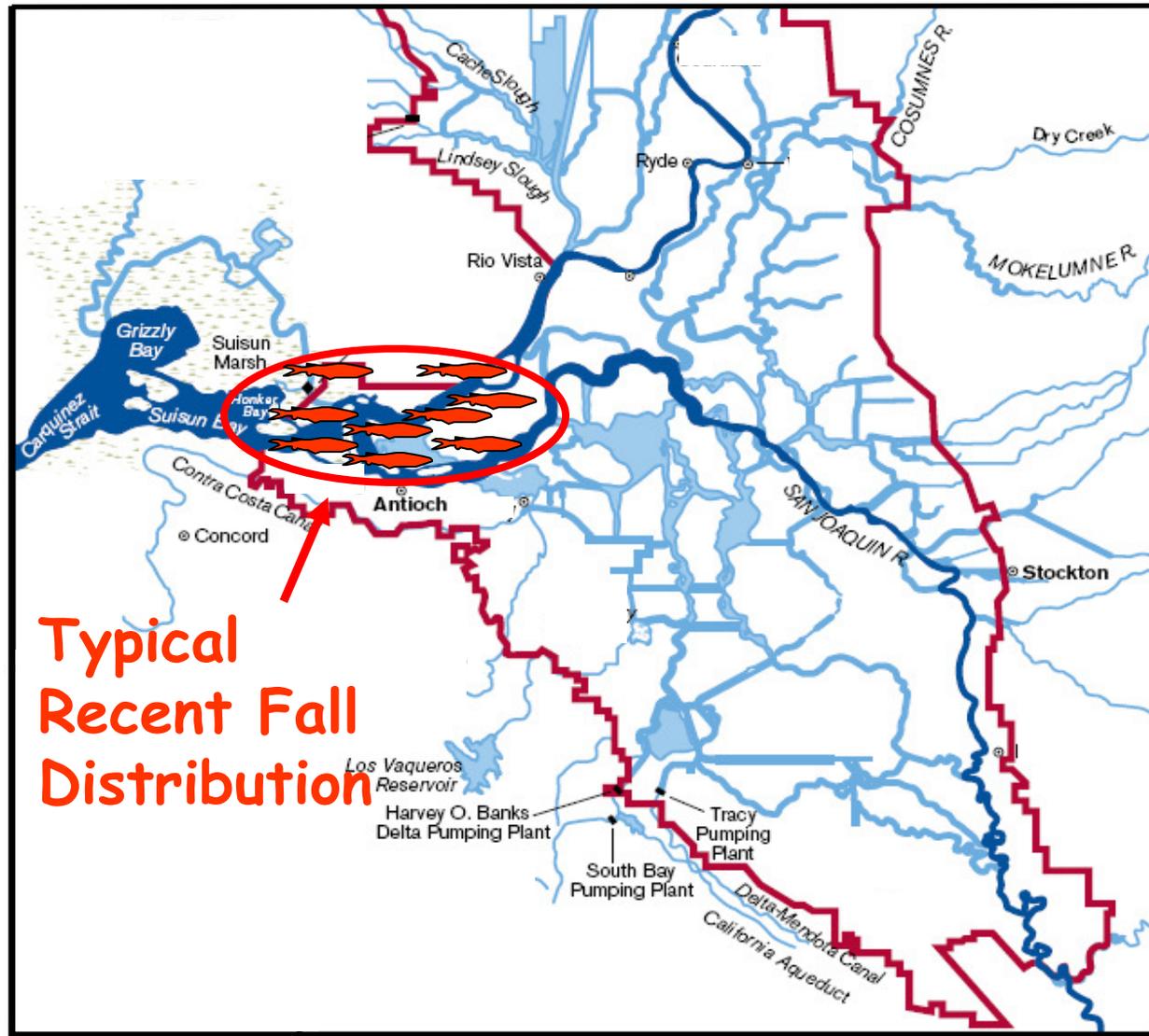
# Delta Smelt Upstream Migration Workshop

CALFED, November 2007

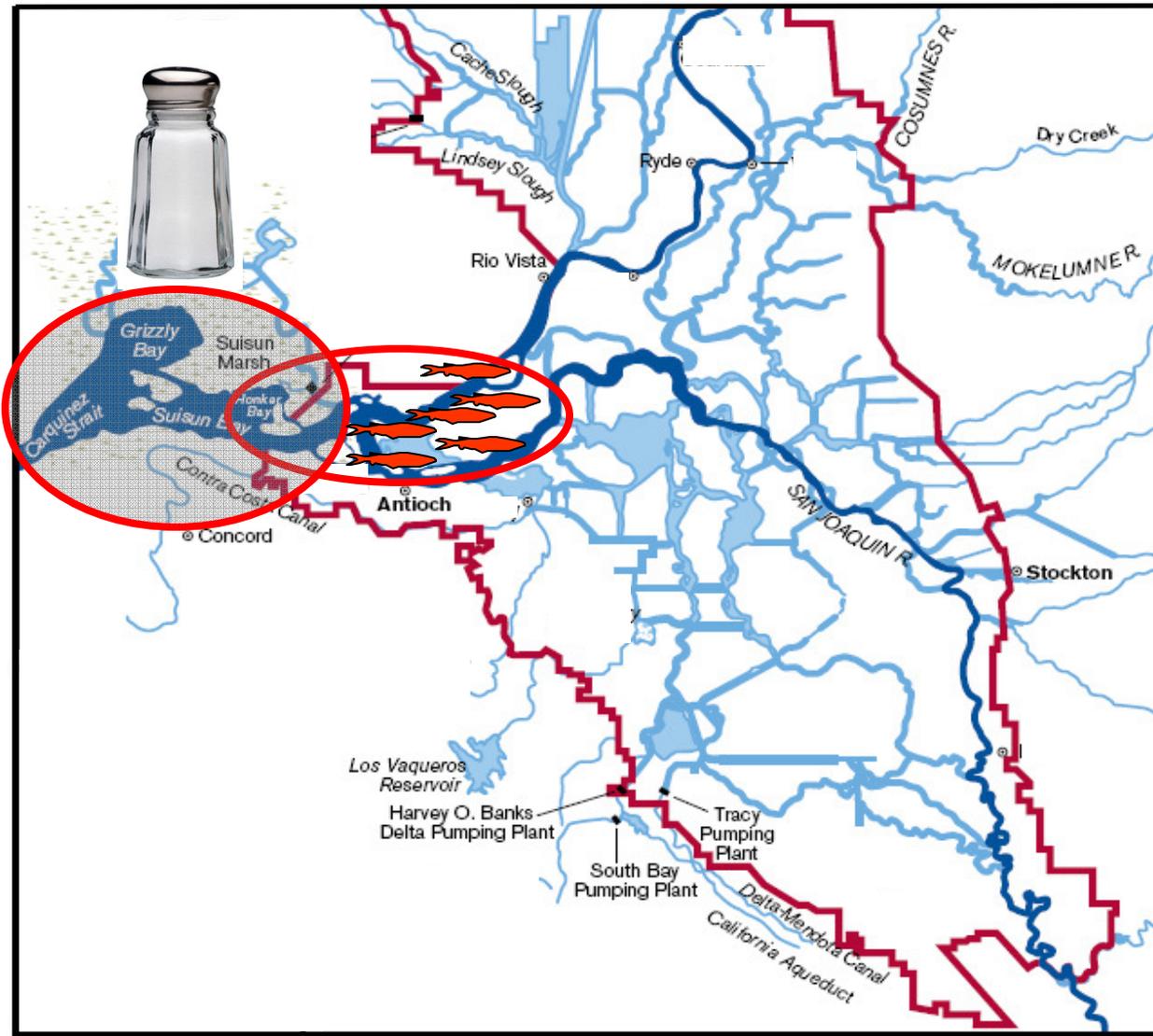
- Experts from West Coast, East Coast, and Canada.
- Wide variety of data sources reviewed.



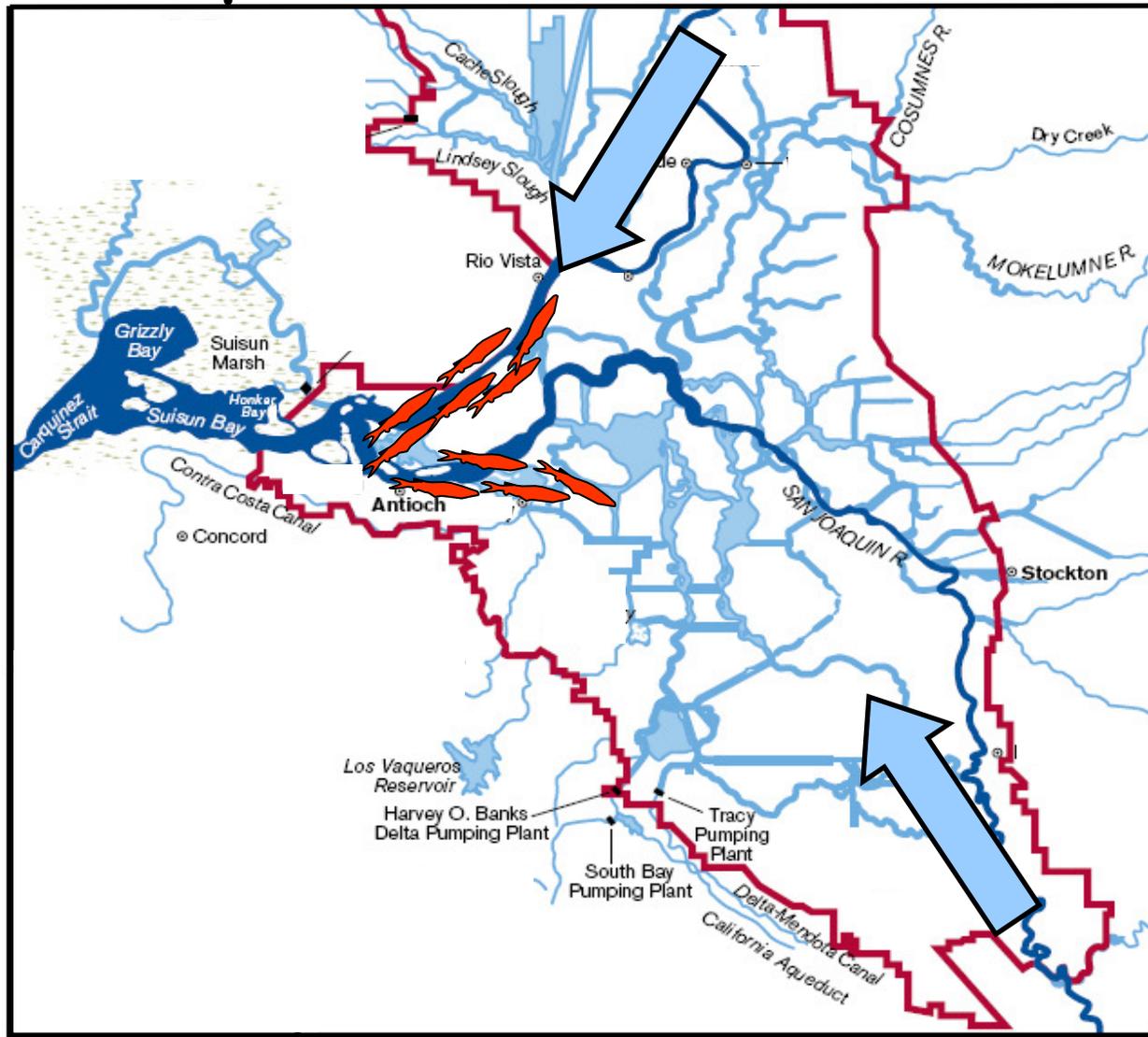
# Upstream Migration: A New Conceptual Model



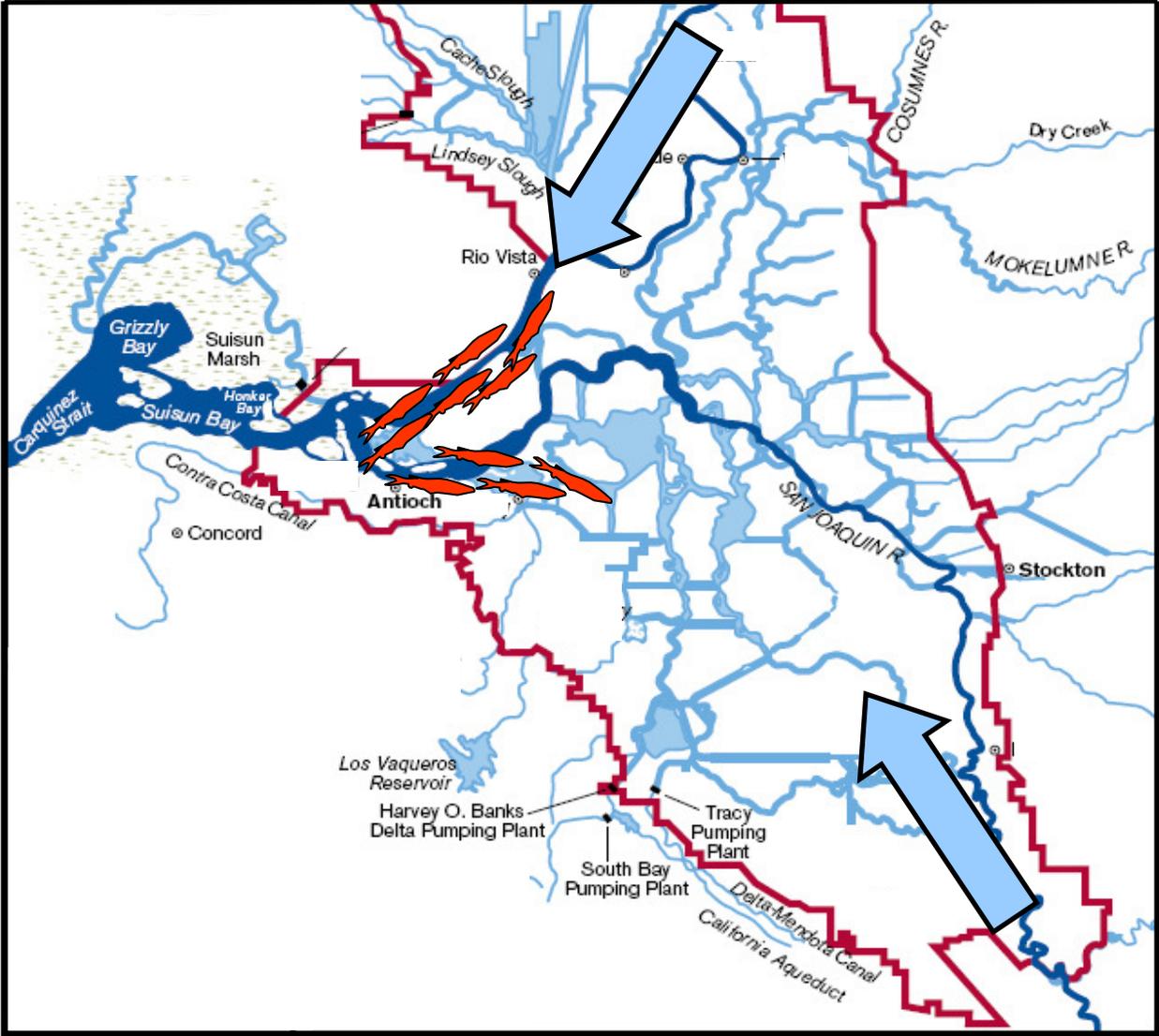
# Fall Salinity Intrusion May Reduce Fish Survival or Condition



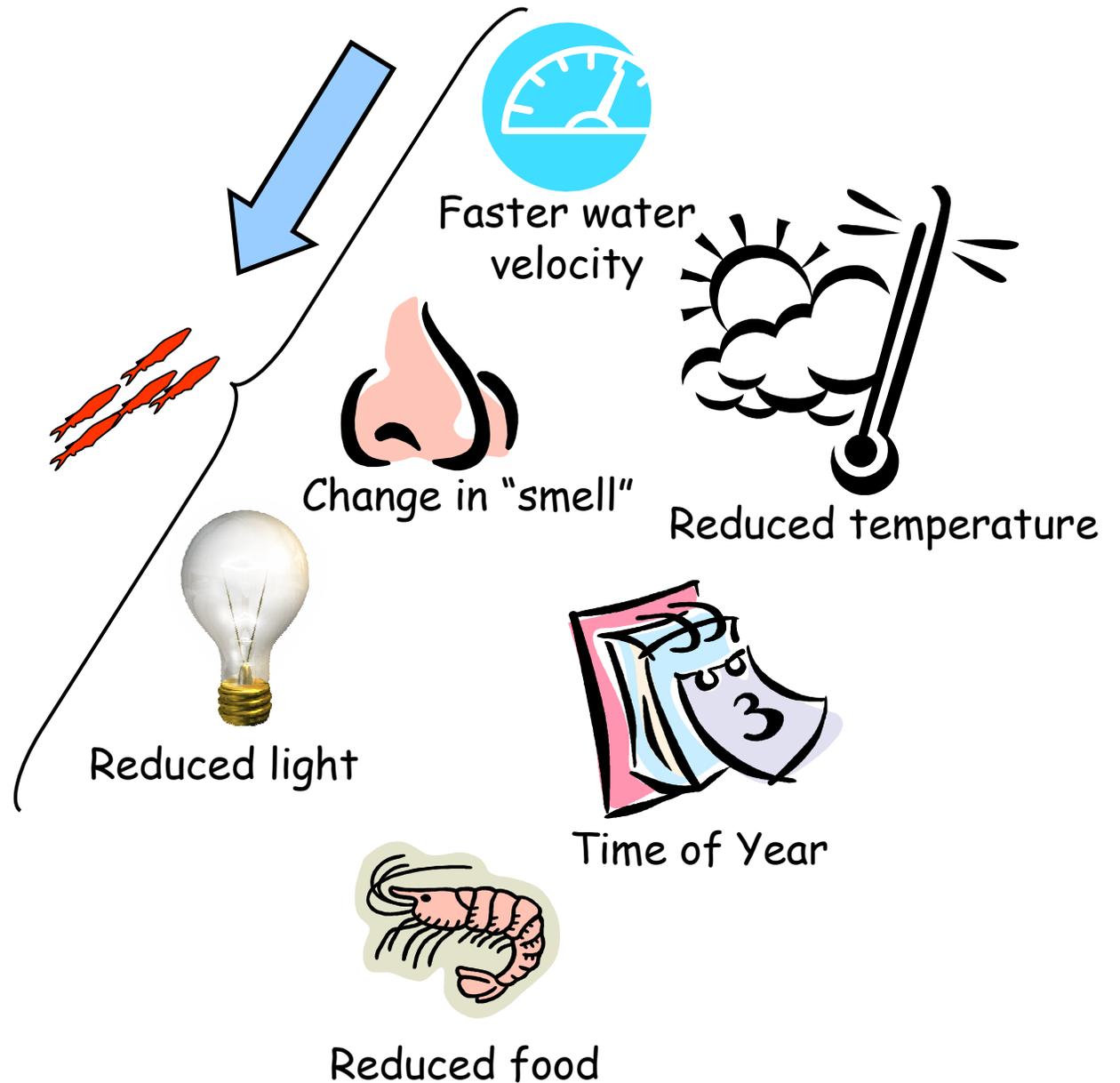
# "First Flush" Triggers Upstream Movement



# Upstream Movement is Active Migration

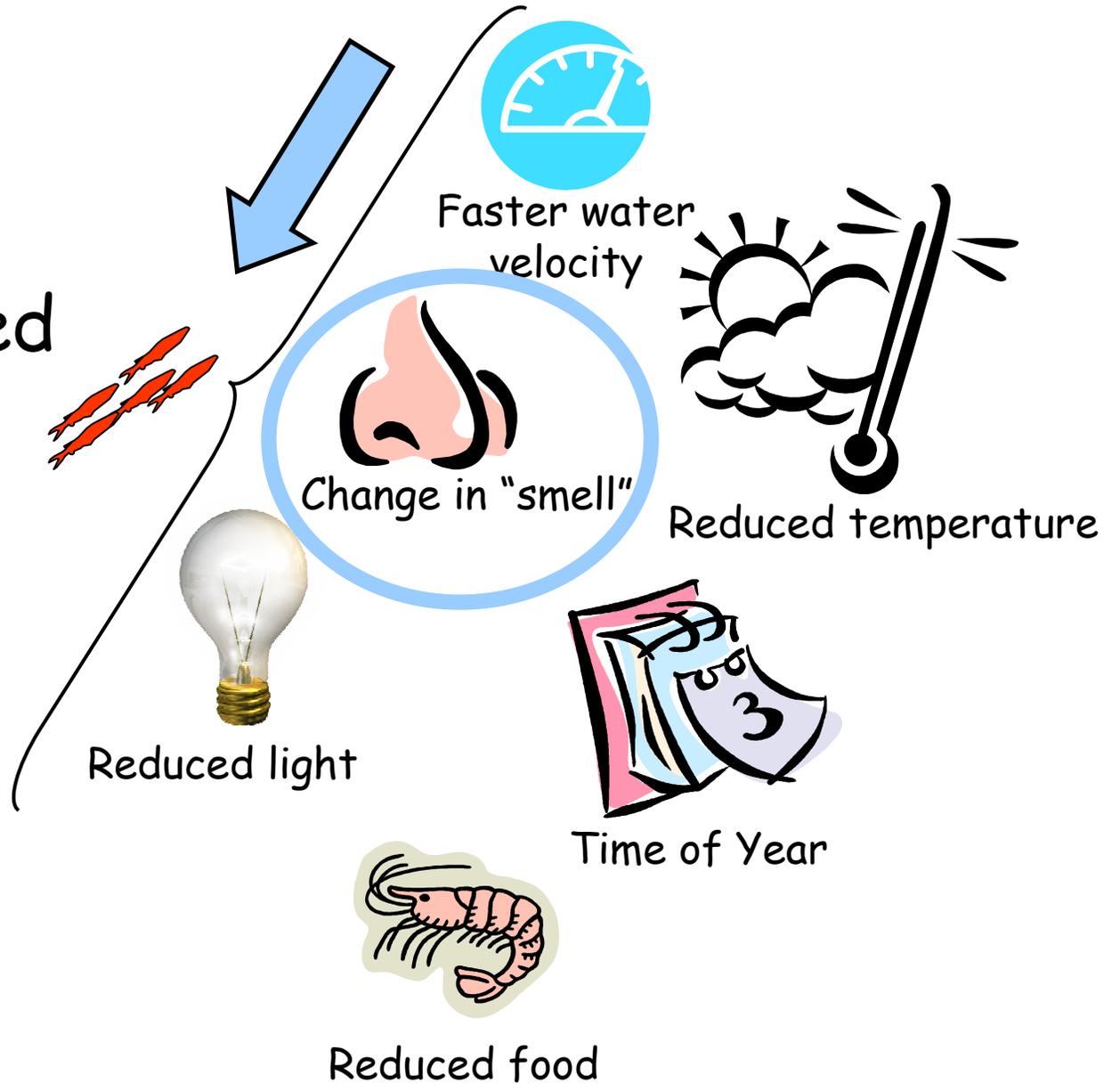


# Many Potential Migration Cues..

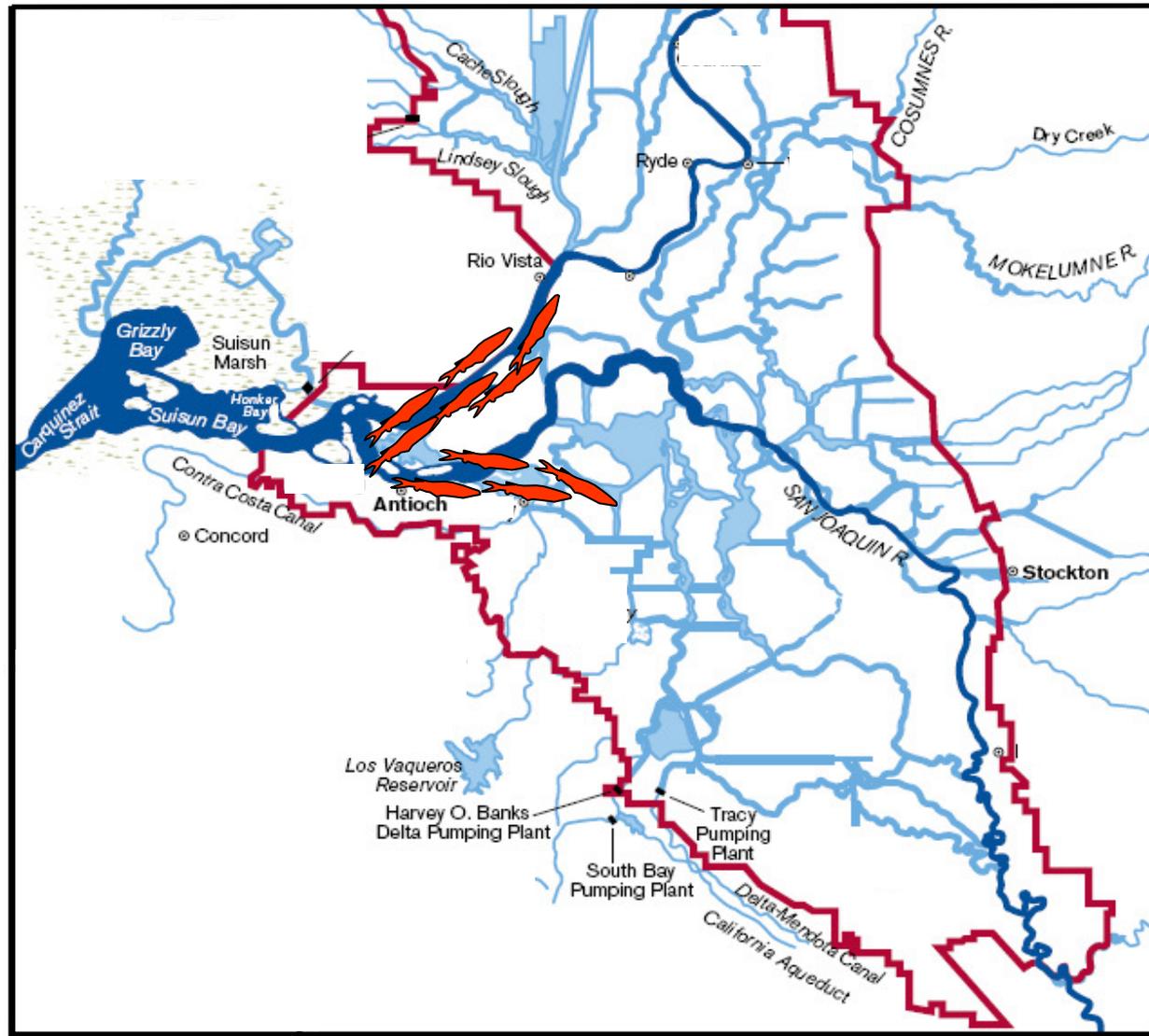


# Many Potential Migration Cues..

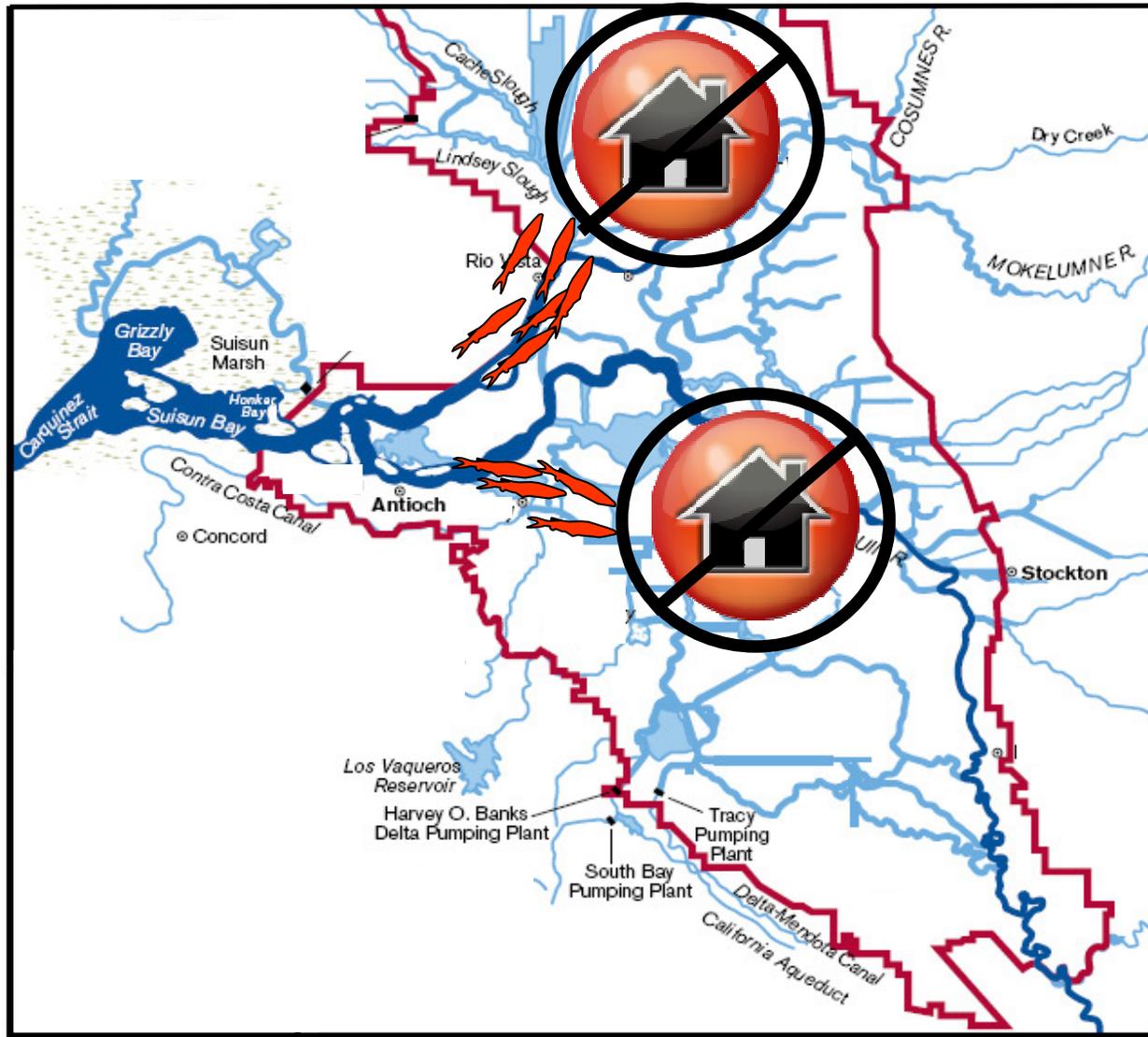
...But Smelt Migration Is Likely Triggered By Olfactory Cues



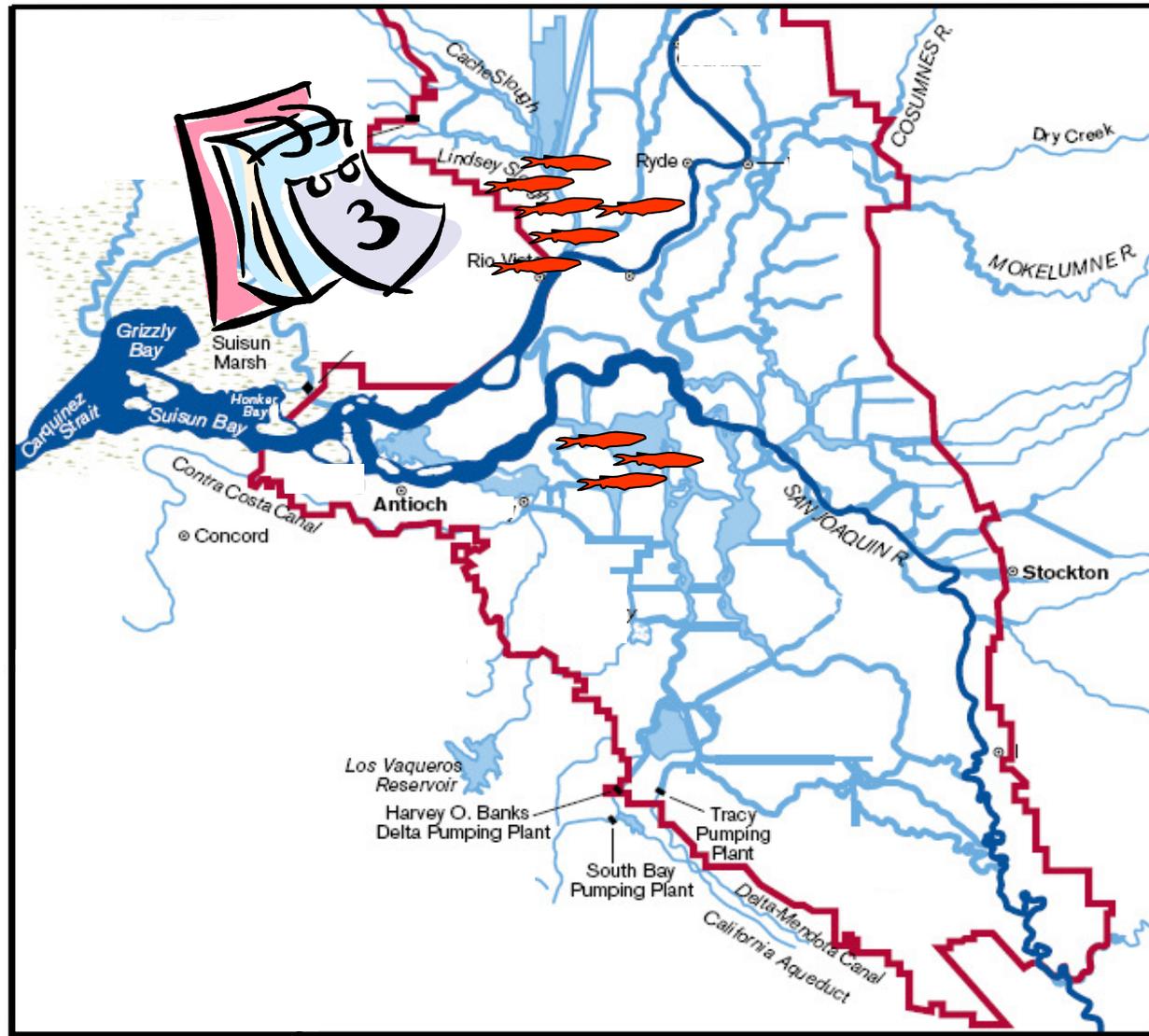
# Fish Migrate Quickly in Groups



# Smelt Do Not "Home" To Natal Spawning Sites



# Smelt Hold For Long Periods Before Spawning



DELTA  
SMELT

Summer

Clams and  
Limnoithona

Reduced Food in LSZ  
Increased Predation Loss (?)

Fall

Reduced  
Outflow

Reduced Habitat Area  
Reduced Size & Egg Supply

STOCK

Improved Survival  
Late Growth Start

High Entrainment of  
Adults and Early Larvae  
Decreased Number  
Survive to 2 Years Old

Jan-Mar Exports

Spring

Winter

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Summer - LSZ

Clams and Limnoithona  
Maternal Contaminants

Reduced Food in LSZ  
Increased Intra-Specific  
Competition/Predation  
Impaired Offspring

High Variability in Annual  
Survival

Ocean  
Conditions  
Disease

Adults - widespread

Fall - LSZ

Reduced  
Outflow

Reduced Habitat Area  
Disease/ Intersex/  
Lesions

Only Largest And  
Healthiest Survive First  
Winter

Increased Entrainment

Seasonal Food  
Winter Exports

Winter - LSZ



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Summer - Bay and Ocean

Water Quantity  
Food Supply

Reduced Survival From  
Larvae To Young-Of-Year

Fall - Bay and Ocean

Food Supply?  
Water Quality?

Survival of Young-Of-  
Year to Age-2+

Reduced Larval Abundance

Water Quantity  
Salvage  
Predator Abundance?

High Entrainment Loss of  
Adults and Larvae

Dec-Mar Exports

Stock-recruit

Spring - Bay

Winter - Delta

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Summer

Food Supply?  
Water Quality?  
Salvage?

Reduced Survival From  
Larvae To Young-Of-Year

Fall

Food Supply?  
Water Quality?  
Salvage?

Poor Survival of Young-  
Of-Year to Age-0

Reduced Larval Abundance

Adult Mortality

Stock-recruit

Food Supply  
Predator Abundance  
Salvage?

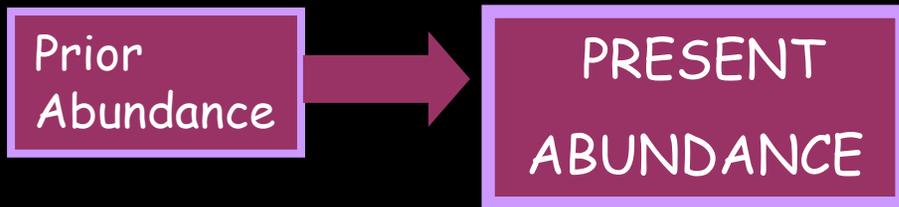
Spring

Winter

# 2008 POD Studies

- 50+ study components
- \$5.8 million for POD





- Gear Efficiency Studies (DFG)
- Video Sampling of Pelagic Fishes (USBR,DWR)
- Expanded 20 mm Survey Larval Monitoring (DFG)
- Pelagic Fish Population and Egg Supply Estimates (DFG/USFWS)
- Longfin Smelt Population Dynamics (DFG/DWR)
- Statistical Analyses of Fish Abundance Trends (USBR/Manly)
- Delta Smelt Growth and Survival (UCD)
- Delta Smelt Stock Structure (UCD)
- Delta Smelt Genetics (UCD)

- Temporal and Spatial Changes in Habitat (UCD)
- Effects of Cache Slough Complex on Delta Habitat (DWR, USGS)
- Turbidity Sources and Signals (USGS)
- Climate Effects (USGS)
- Hydrologic Changes (USGS)
- Microcystis Effects on Threadfin Shad (UCD)
- Salinity Effects on Clams (SFSU)
- Contaminants Synthesis (RWQCB)
- Wastewater Effects on Phytoplankton (SFSU)
- Screening Wastewater Effects on Smelt (UCD)
- Pyrethroid Monitoring (UCB)
- Fish Tissue Selenium Analysis (DFG).

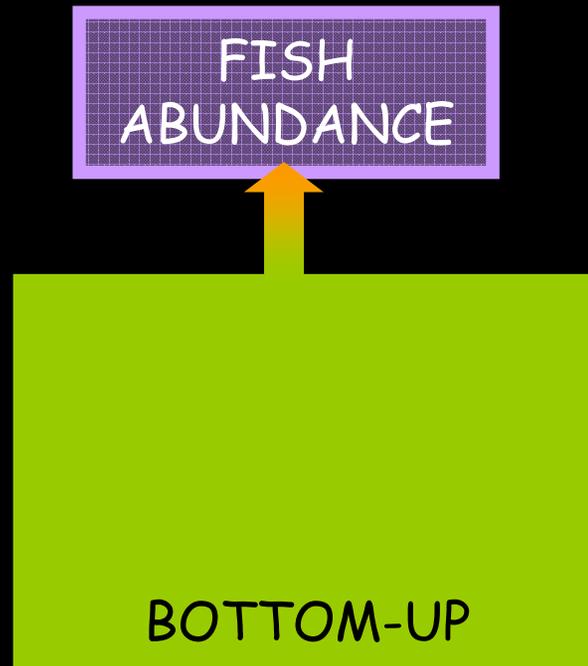
PHYSICAL  
&  
CHEMICAL  
FISH  
HABITAT

TOP-DOWN

FISH  
ABUNDANCE

- Effect of Fish Behavior on Entrainment Risk (DWR)
- Clifton Court Circulation Patterns & Loss (USFWS)
- Effects of Hydrodynamics on Fish Salvage Trends (USGS)
- Particle Tracking Simulations of Entrainment (Consultants)
- Effects of Inshore Predators (UCD)
- Statistical Analyses of Salvage Data (DWR, USBR, Manly)
- Power Plant Studies (Mirant, Tenera, Hanson)
- Salvage History (DFG, USBR)
- Modeling Striped Bass Predation in the Estuary (DWR/DFG)

- Zooplankton and Phytoplankton Trends (DWR/UCD)
- Zooplankton Community Structure (SFSU)
- Delta Smelt Feeding on Zooplankton (SFSU)
- Sources of Food Web Disruption (SFSU/UCD)
- Changes in Benthic Biomass and Abundance (DWR)
- Fish Diet and Condition (DFG)
- Effects of Nutrient Ratios on Phytoplankton (SFSU)
- Phytoplankton Community Changes (DWR)
- Zooplankton and Organic Carbon Quality (UCSD)



# Synthesis:

- Delta smelt life cycle and individual-based models  
Bill Bennett UCD; Wim Kimmerer SFSU; Kenny Rose, LSU
- Striped bass life cycle, individual-based, and dose-response models  
Frank Loge UCD; Kenny Rose, LSU
- Statistical analysis of environmental effects on pelagic fish abundance  
Bryan Manly, Consultant; Mike Chotkowski, USBR
- Synthesis and evaluation  
National Center for Environmental Analysis and Synthesis (NCEAS), UCSB

