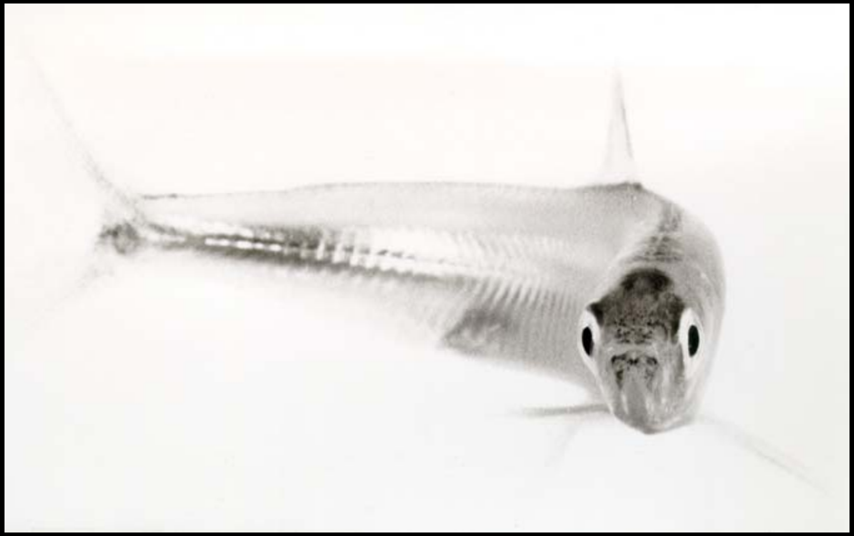
The Decline of Pelagic Fishes in the San Francisco Estuary: An Update



Dr. Ted Sommer

California Department of Water Resources

IEP Pelagic Organism Decline Management Team

POD Management Team

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Randy Baxter DFG
Rich Breuer DWR
Larry Brown USGS
Mike Chotkowski USBR
Steven Culberson CBDA
Marty Gingras DFG
Bruce Herbold USEPA
Anke Mueller-Solger DWR
Ted Sommer DWR
Kelly Souza DFG

POD Principal Investigators

- Dept Fish and Game
  - Randy Baxter, Marade Bryant, John Budrick, Kevin Fleming, Kelly Souza, Steve Slater, Kathy Hieb, Marty Gingras
- Dept Water Resources
  - Matt Nobriga, Fred Feyrer, Ted Sommer, Bob Suits, Marc Vaysièrres, Heather Peterson, Zoltan Matica, Peggy Lehman, Lenny Grimaldo, Mike Mierzwa, Jim Wilde, Karen Gehrts, Tanya Veldhuizen
- US Bureau of Reclamation
  - Mike Chotkowski
- US EPA
  - Bruce Herbold
- US Fish and Wildlife Service
  - Gonzalo Castillo, Ken Newman
- US Geological Survey
  - Joseph Simi, Cathy Ruhl, Pete Smith
- UC Davis
  - Bill Bennett, Swee Teh, Inge Werner, David Ostrach, Frank Loge
- SF State University
  - Wim Kimmerer, John Durand
- SF Estuary Institute
  - Daniel Oros, Geoff Siemering, Jennifer Hayworth
- Consultant
  - Bryan Manly, BJ Miller

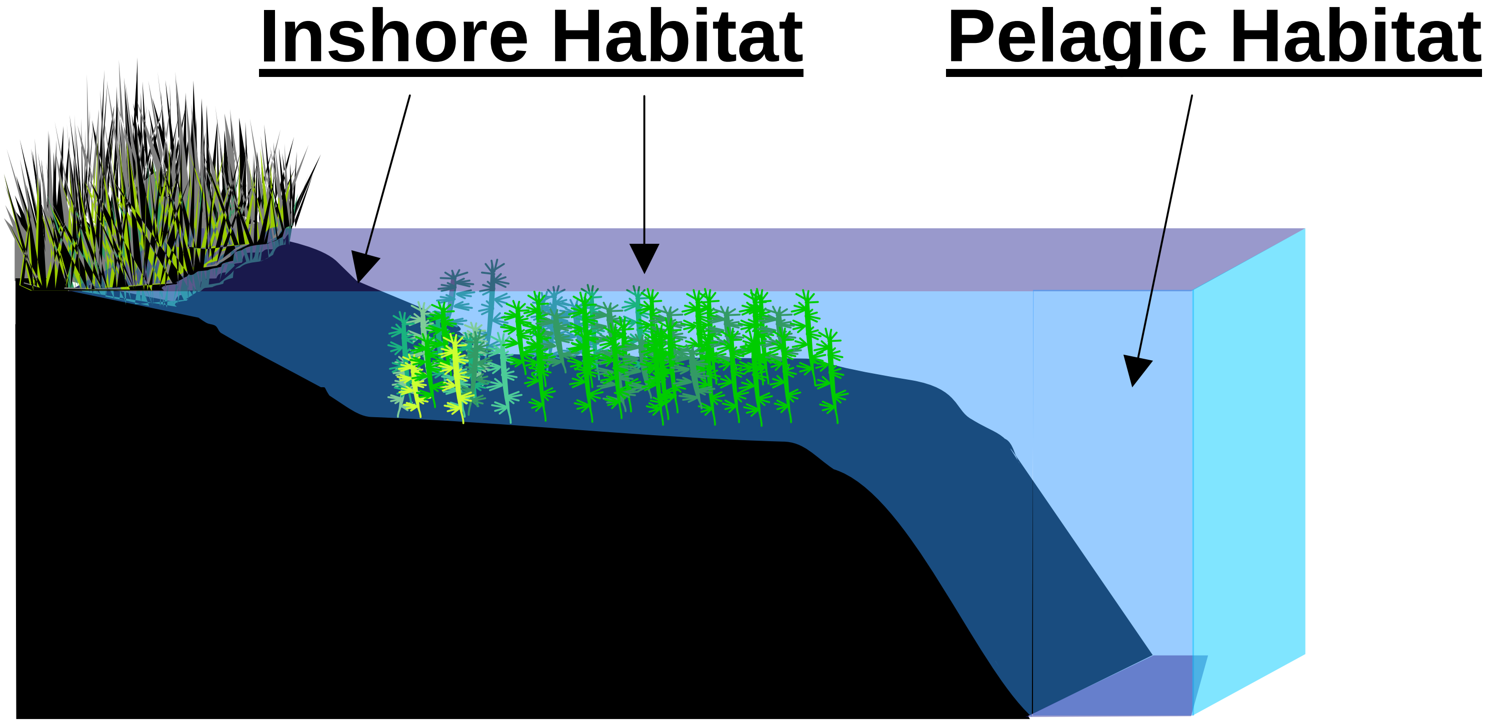


Figure from L. Grimaldo

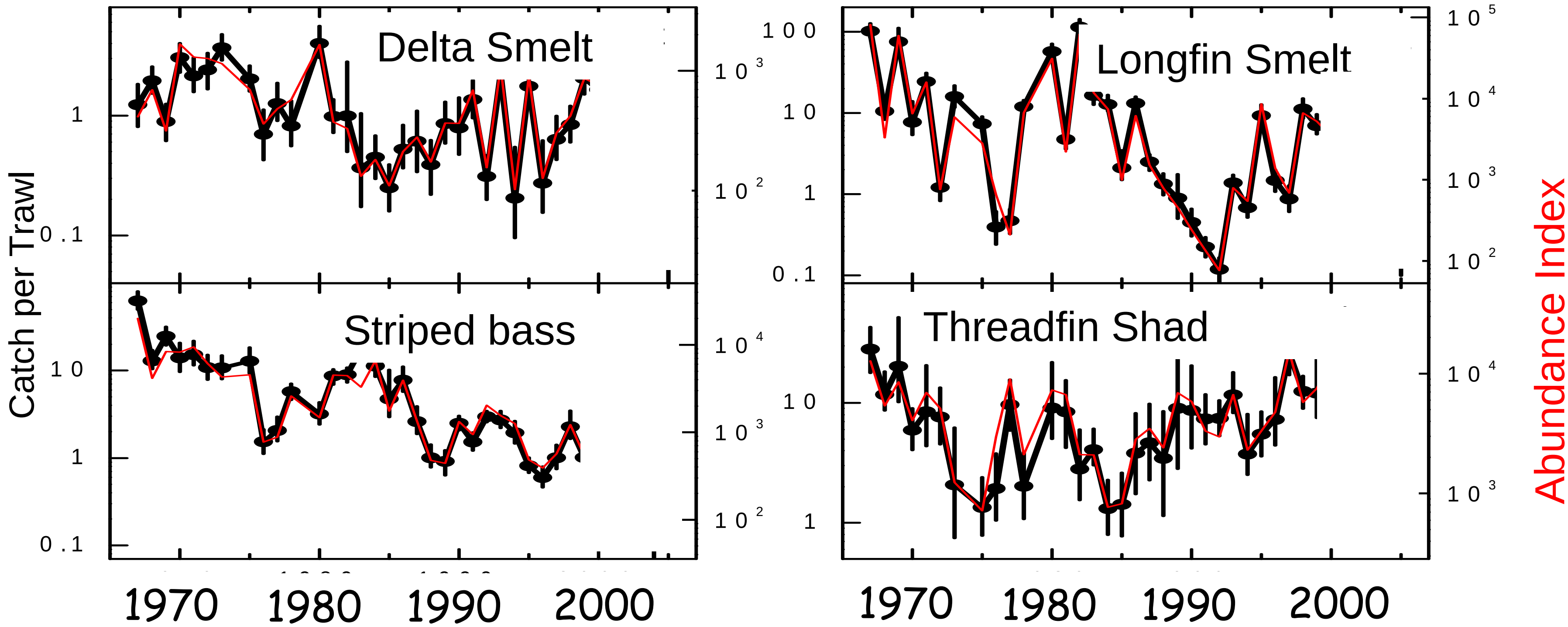
Delta smelt

Longfin smelt

Threadfin shad

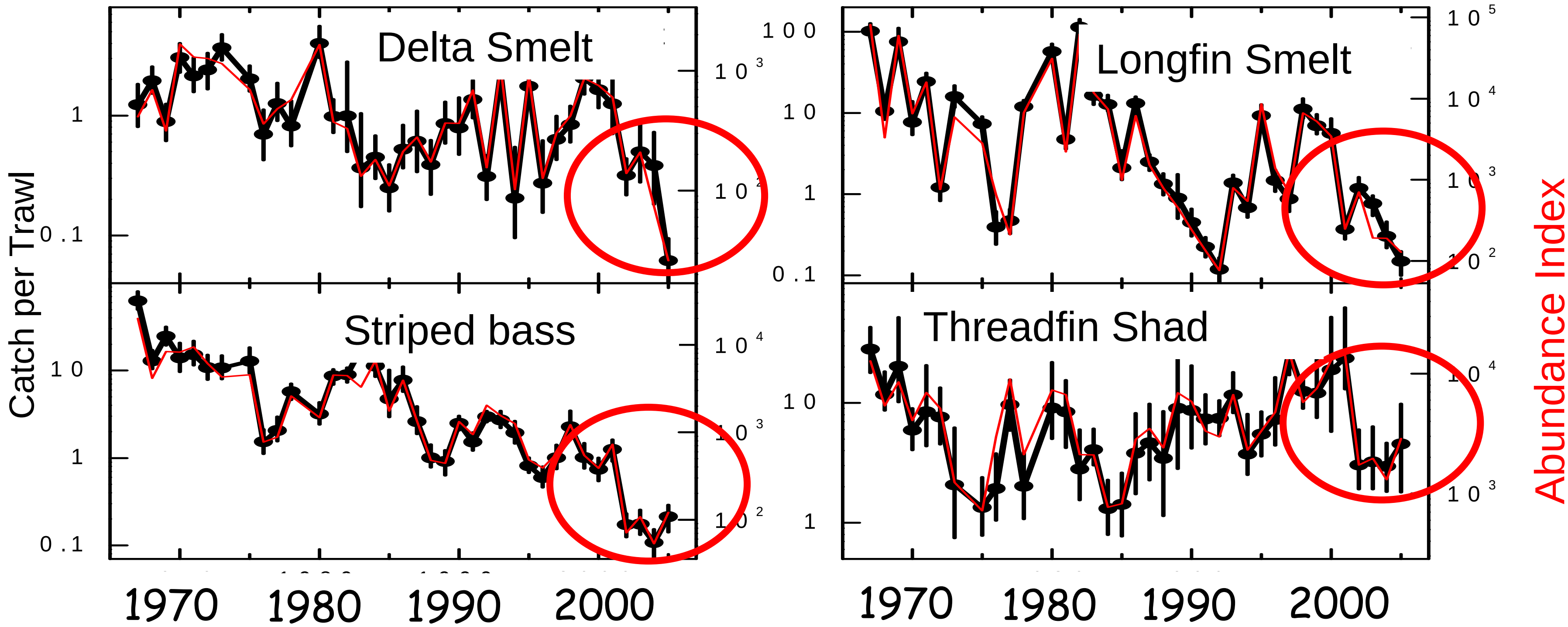
Striped bass

Abundance Levels Are Highly Variable



Source: Kimmerer and Nobriga (2005); Sommer et al. (In Review)

The Pelagic Organism Decline



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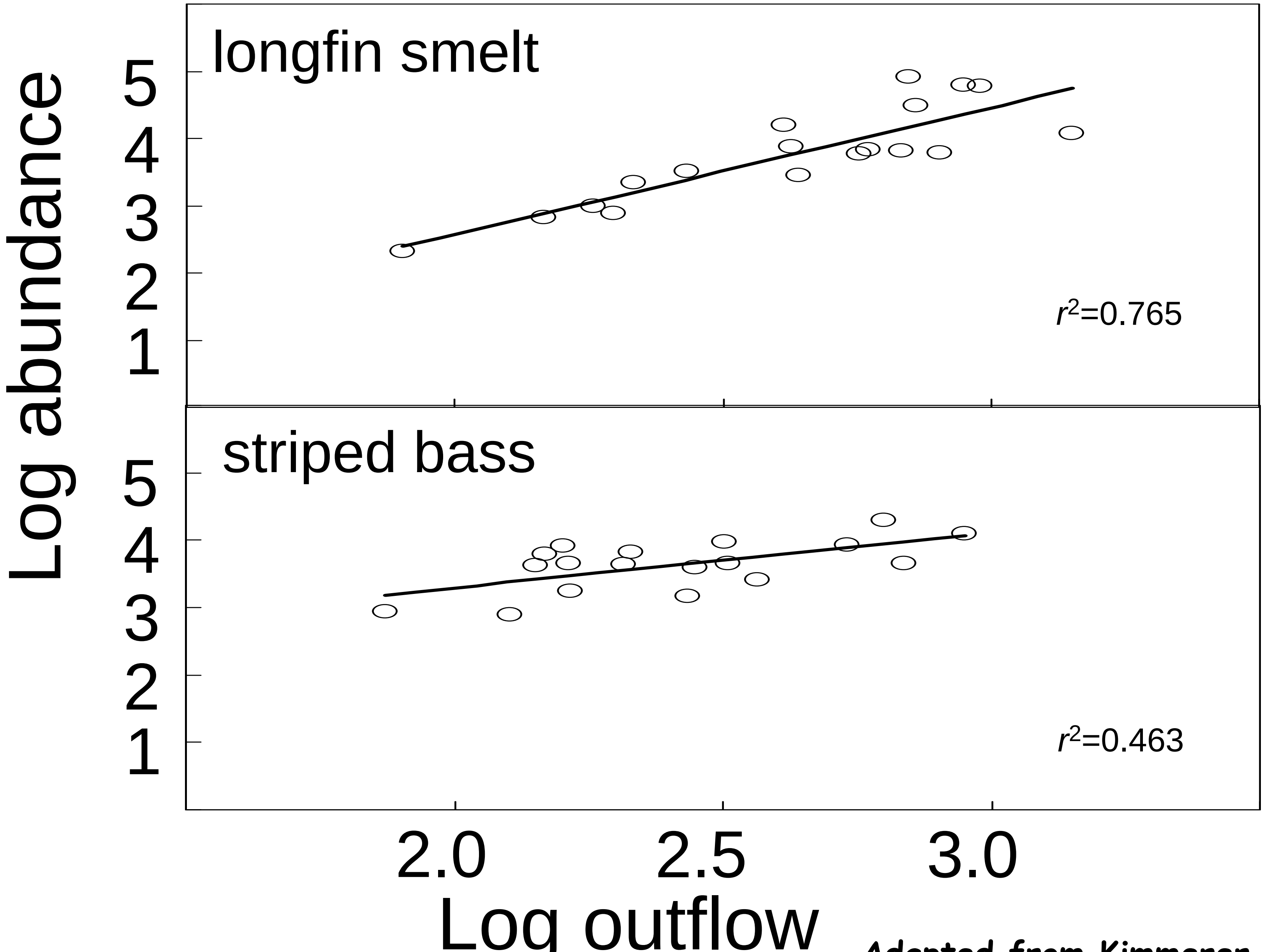
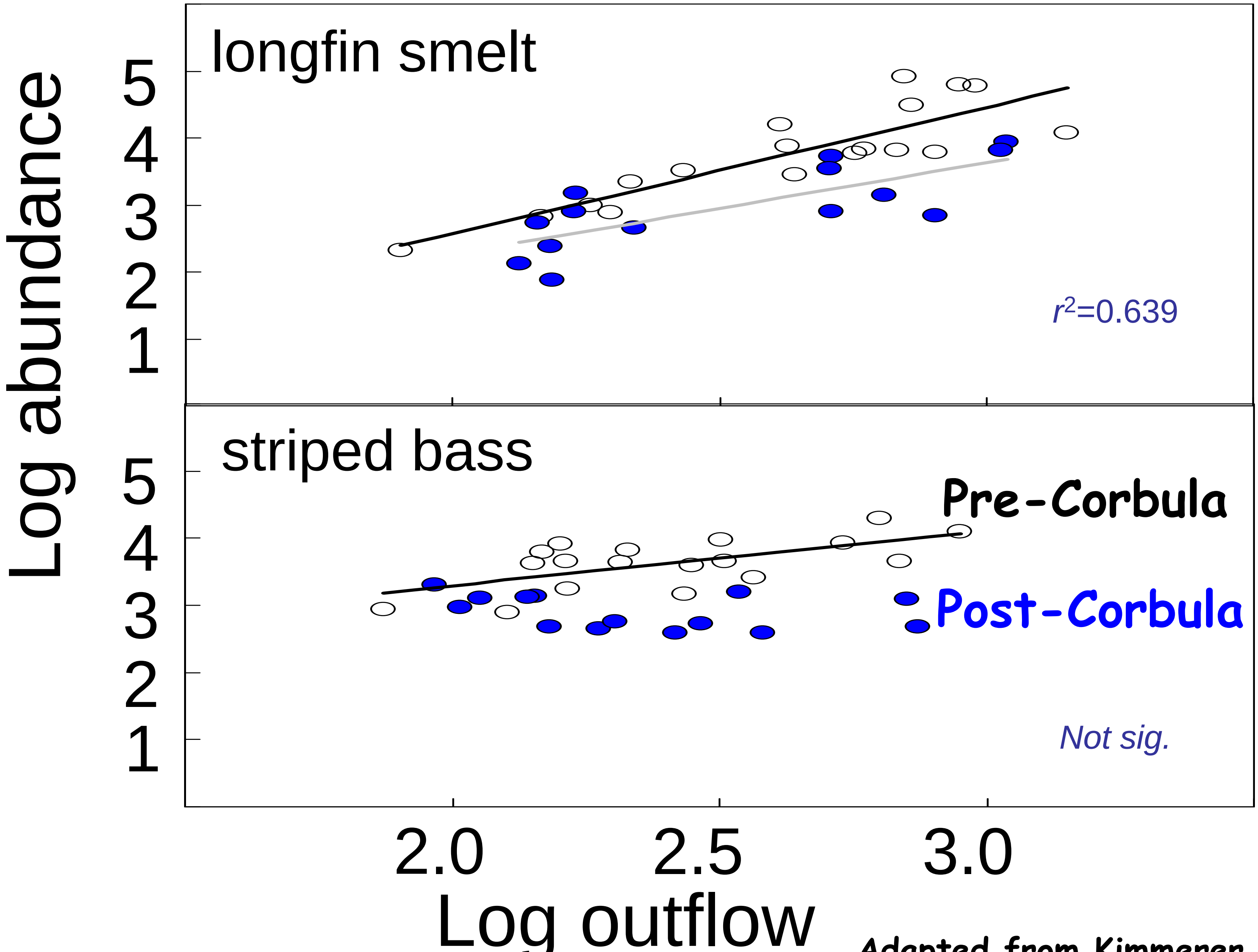
Historically Flow Has Helped Predict Fish Abundance



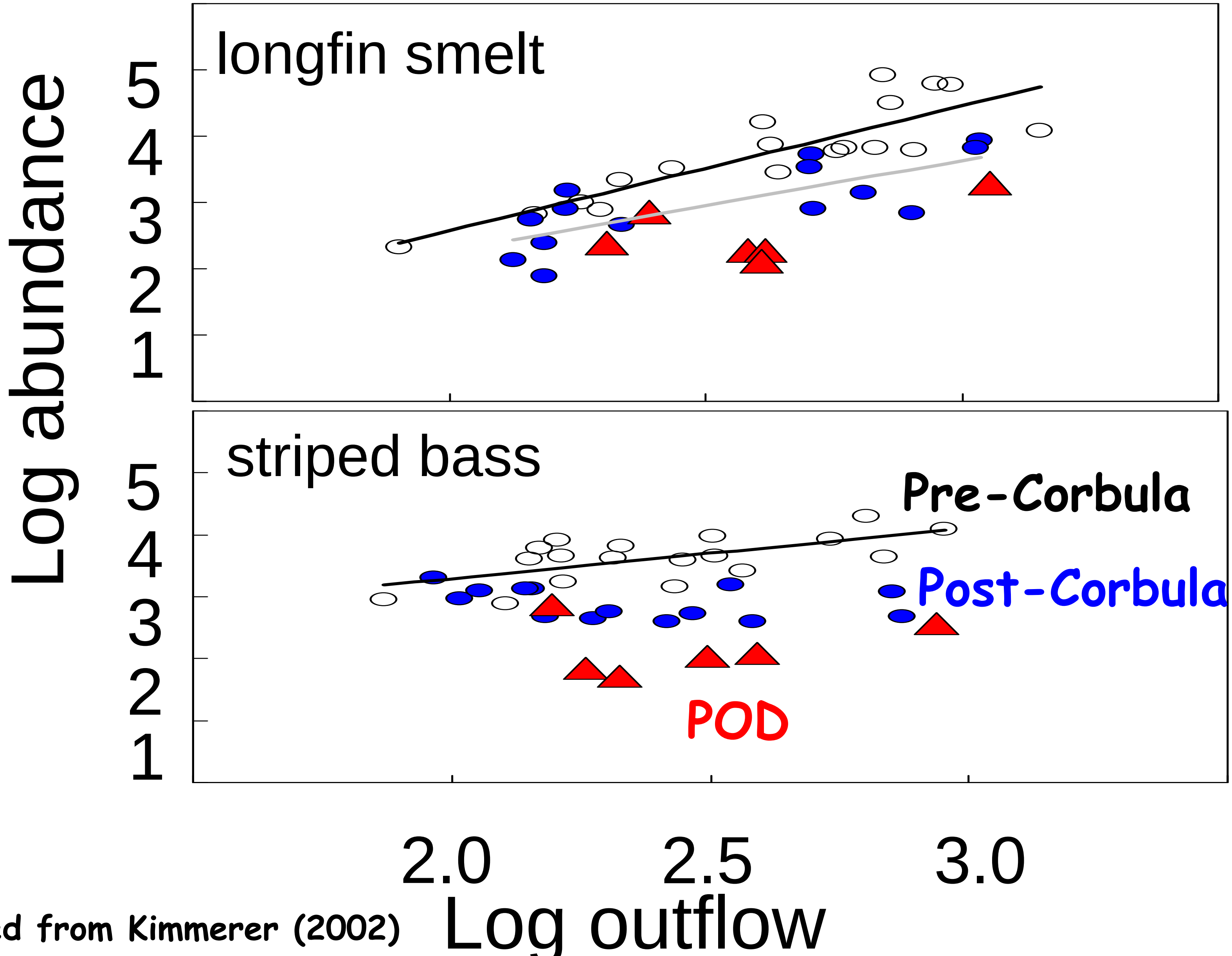
Adapted from Kimmerer (2002)

Invasive Species Shifted These Relationships



Adapted from Kimmerer (2002)

POD Has Further Shifted Abundance-Outflow Relationships



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POD: What We Know Now
Caveats

- Synthesis is from POD MT, not all PIs.

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- The story will change…probably a lot.
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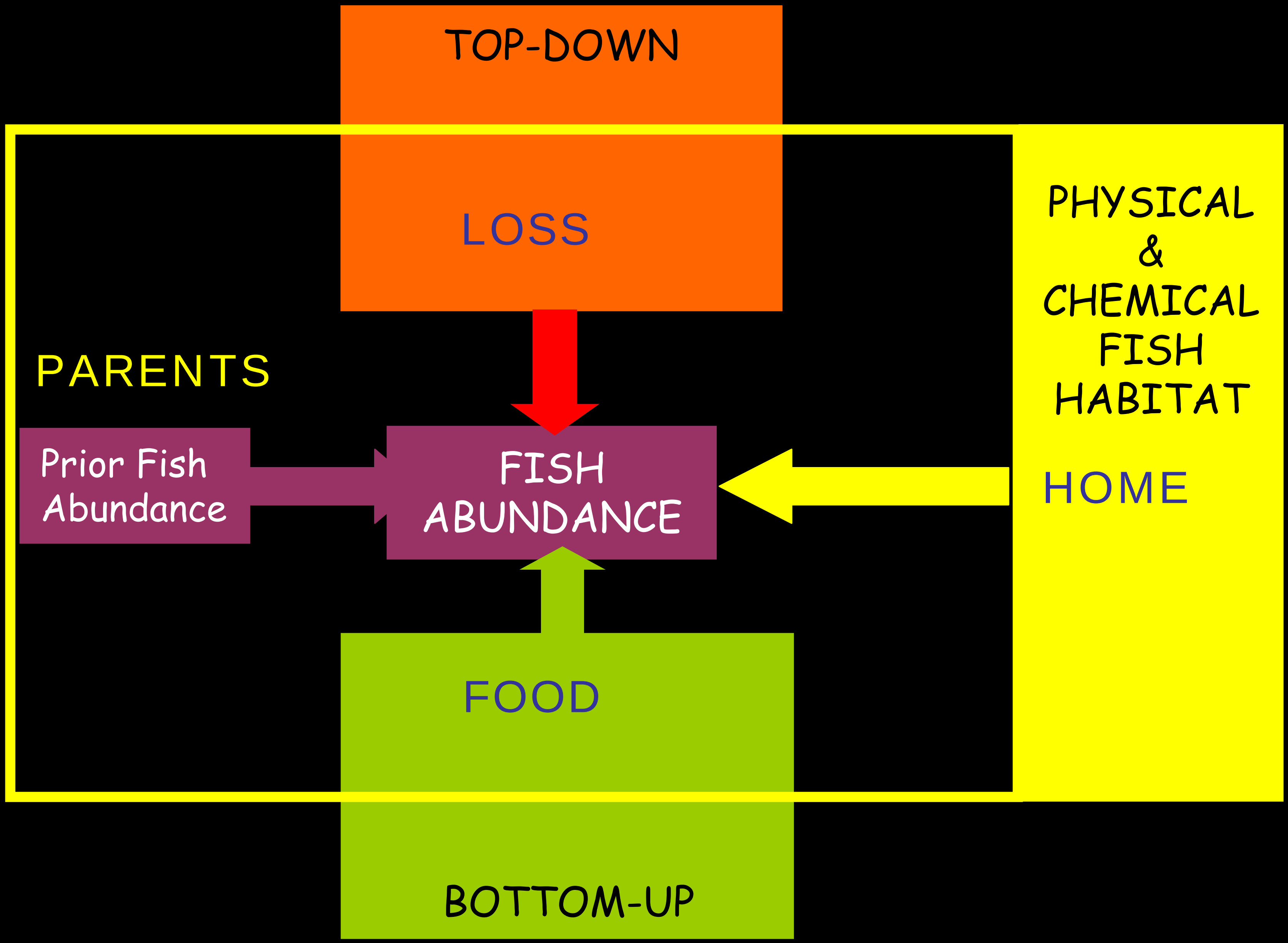
- Very few results have been peer-reviewed.
- The management implications of this effort are therefore unclear.



TOP-DOWN
LOSS
PARENTS
Prior Fish Abundance
FISH ABUNDANCE
PHYSICAL & CHEMICAL FISH HABITAT
HOME
FOOD
BOTTOM-UP

The 'Big Three' Questions

- Did anything change at the same time as the Pelagic Organism Decline?
- How and why did these factors change?
- Did these factors affect populations of pelagic organisms?

Quick Answers

	Change with POD?	Mechanism?	Population Impact?
Stock	Yes	????	Yes
Habitat	Yes	Yes	Yes
Food	Some	Some	Yes
Mortality	Yes	Yes	Yes

Prior Abundance → PRESENT ABUNDANCE

Stock - Recruitment Effects

- Extremely low stocks

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- Extremely low stocks.
- Environmental variables strongly affect recruitment


PHYSICAL
&
CHEMICAL
FISH
HABITAT
FISH
ABUNDANCE

PHYSICAL
&
CHEMICAL
FISH
HABITAT

FISH
ABUNDANCE

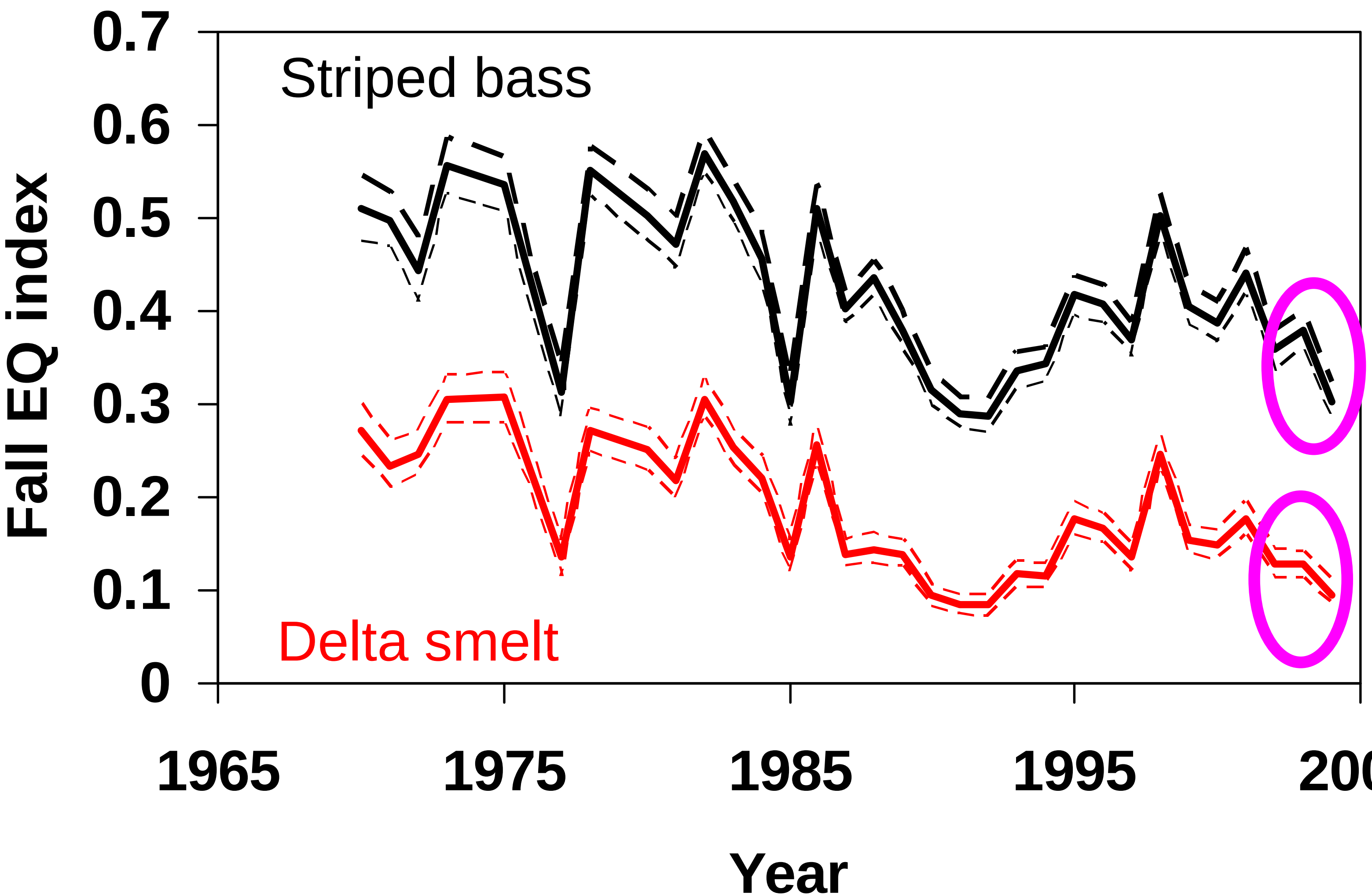
Temperature
Turbidity
Salinity

Contaminants

Disease

Toxic algae

Fall "habitat quality" has deteriorated



Source: Feyrer et al. (CJFAS, In press)

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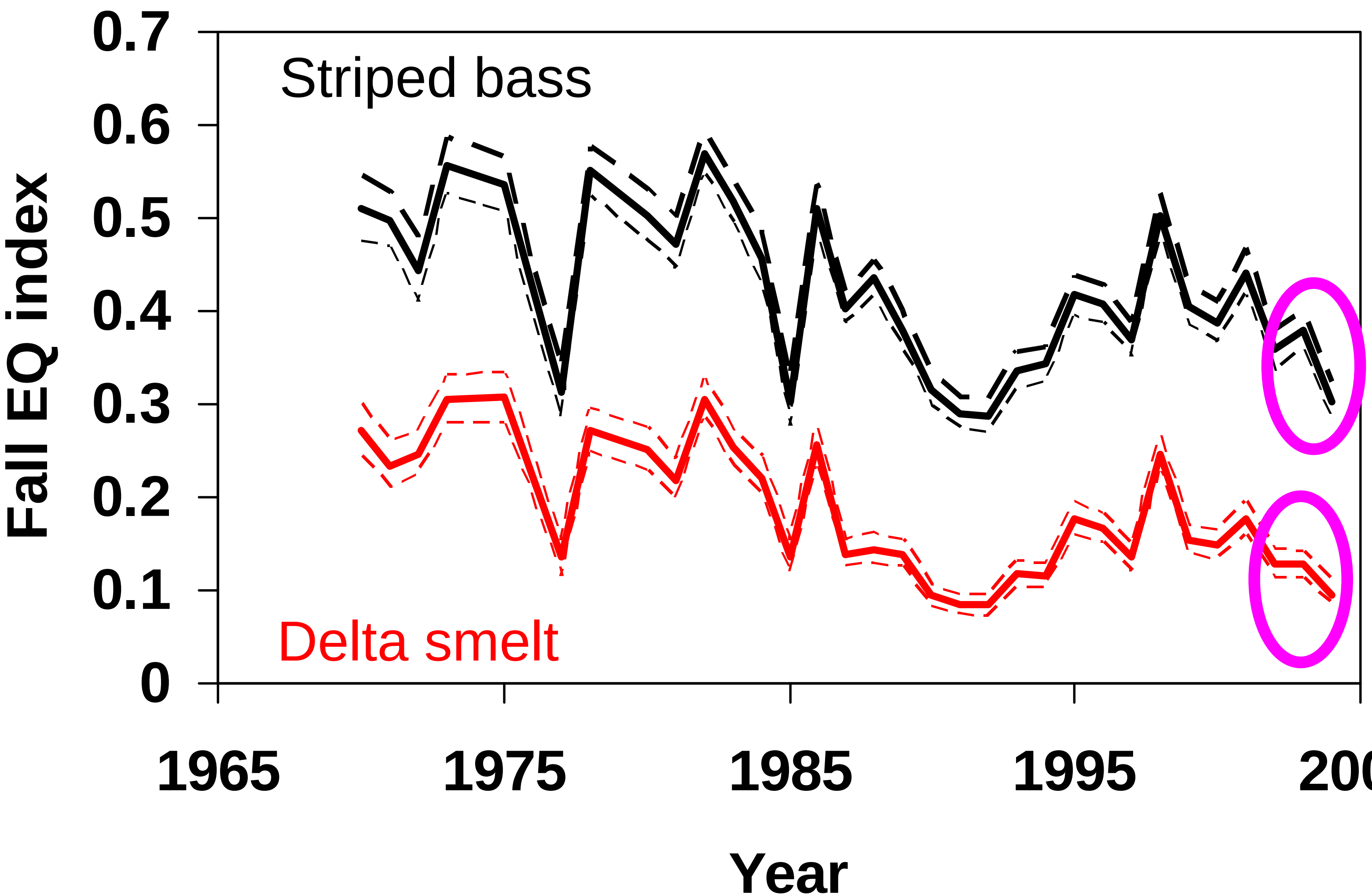
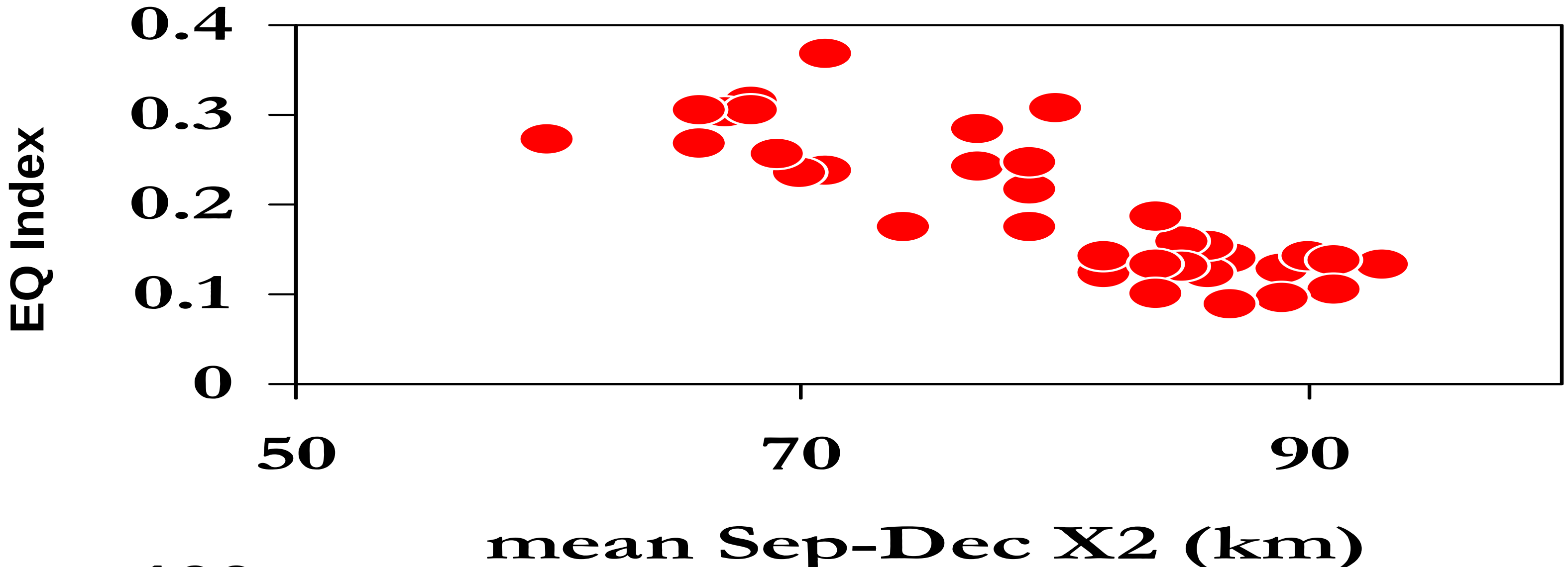
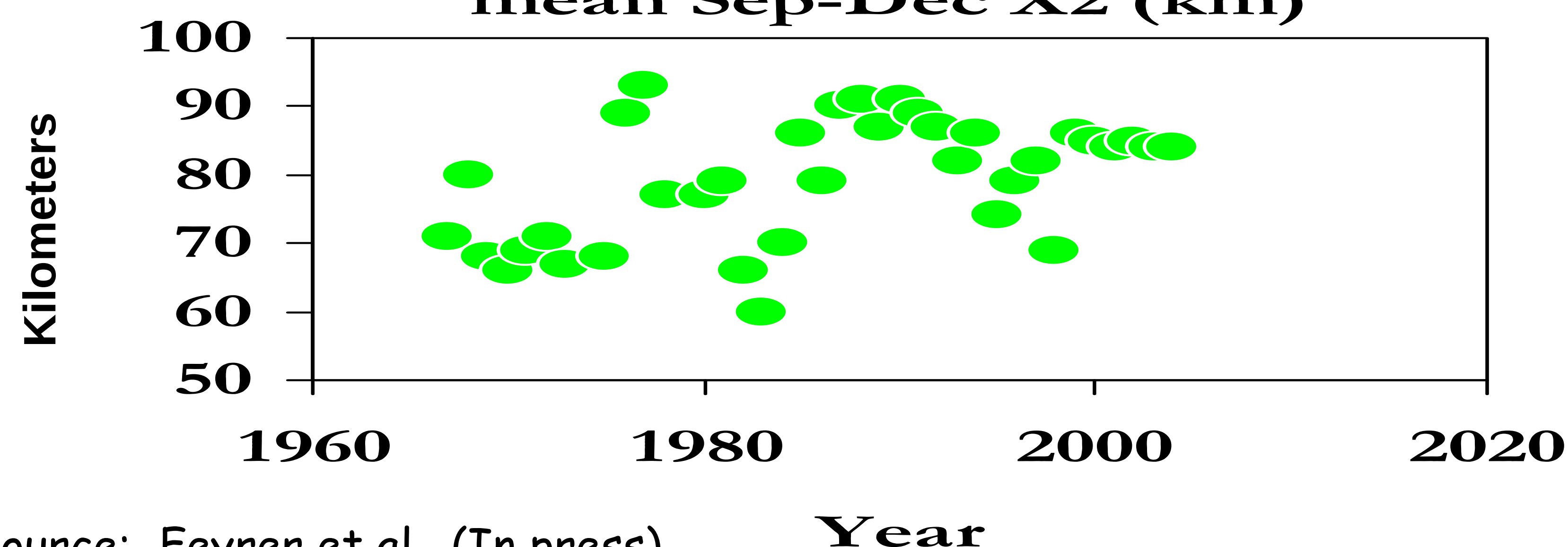


Fall EQ + Fall Abundance predicts juvenile production

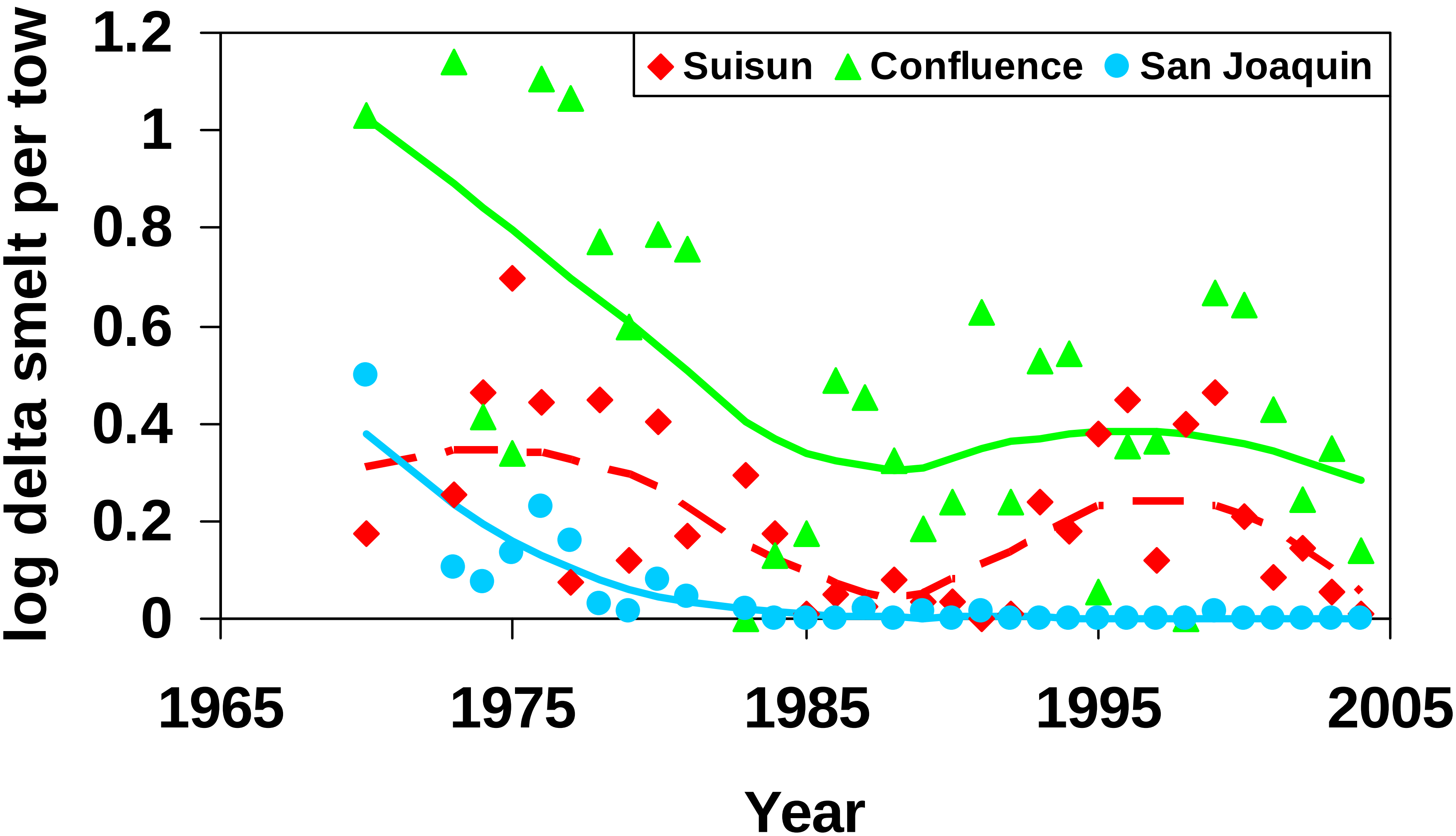
Fall habitat quality decreased as salinity intruded





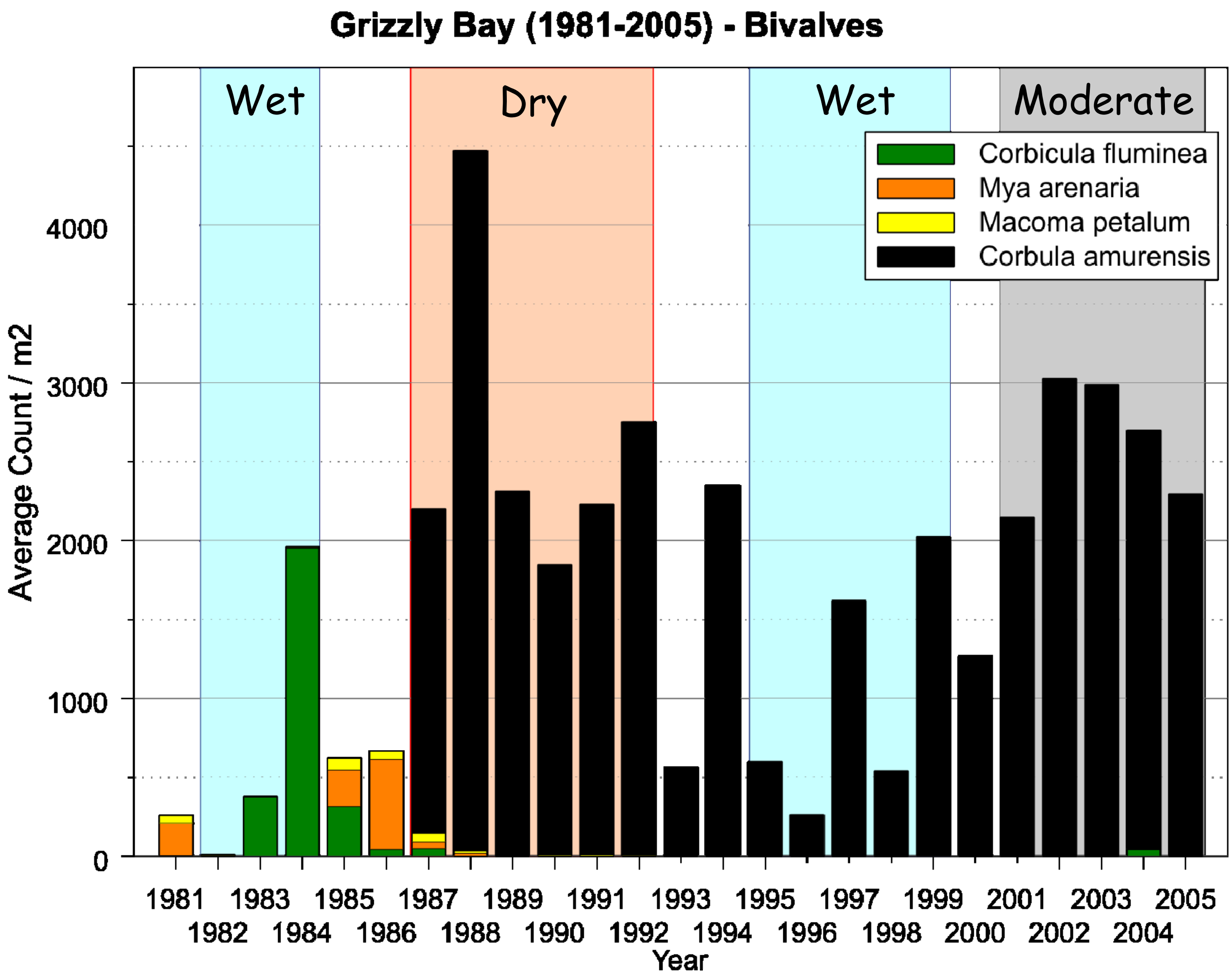
Source: Feyrer et al. (In press)

Summer habitat changes affect regional delta smelt catches



Source: Nobriga et al. (In review)

Salinity variation also affects clams

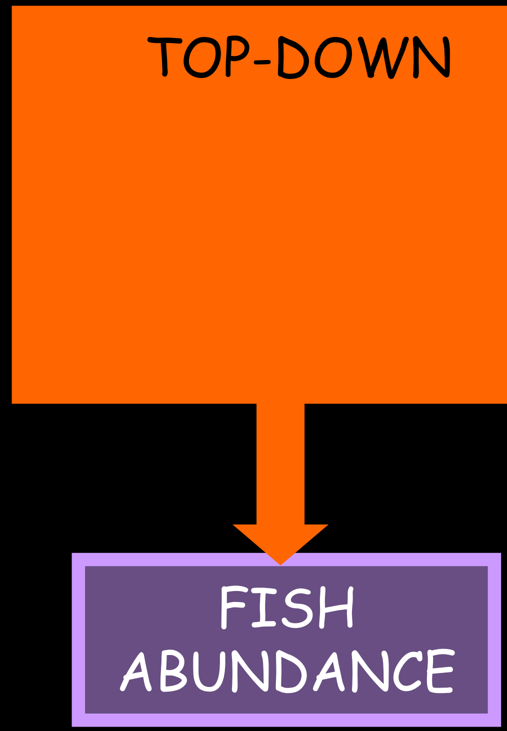


Source: Marc Vaysierres and others (DWR)

Other habitat stressors

- Bioassays showed little effect (<5 %) in 2005 or 2006.
- <15% <u>adult</u> delta smelt impaired
- 100 % of <u>young</u> striped bass show multiple infections

Source: Inge Werner, Swee Teh, and Dave Ostrach (UCD)


TOP-DOWN
FISH ABUNDANCE

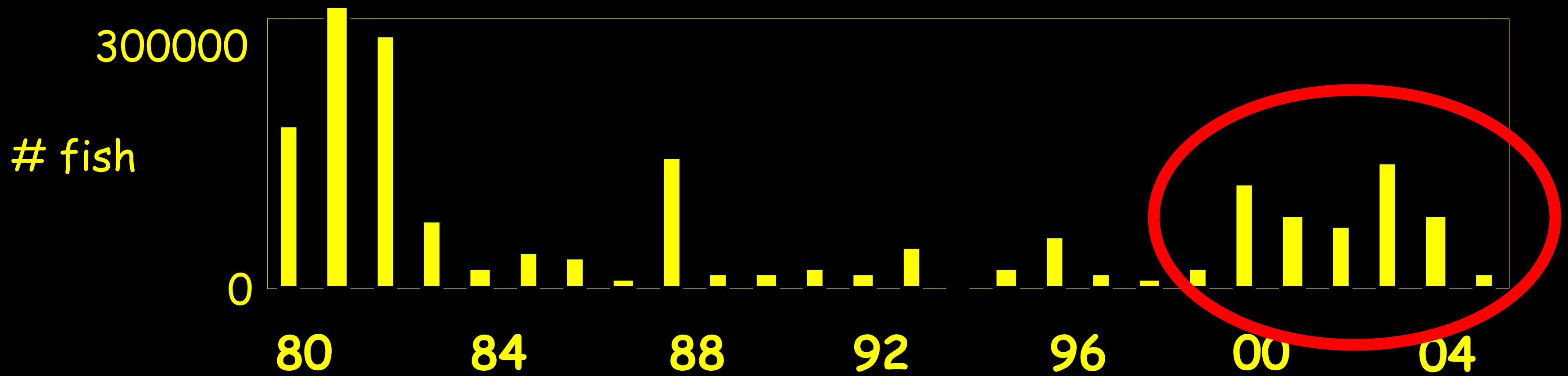
TOP-DOWN

Water Diversions

Predation

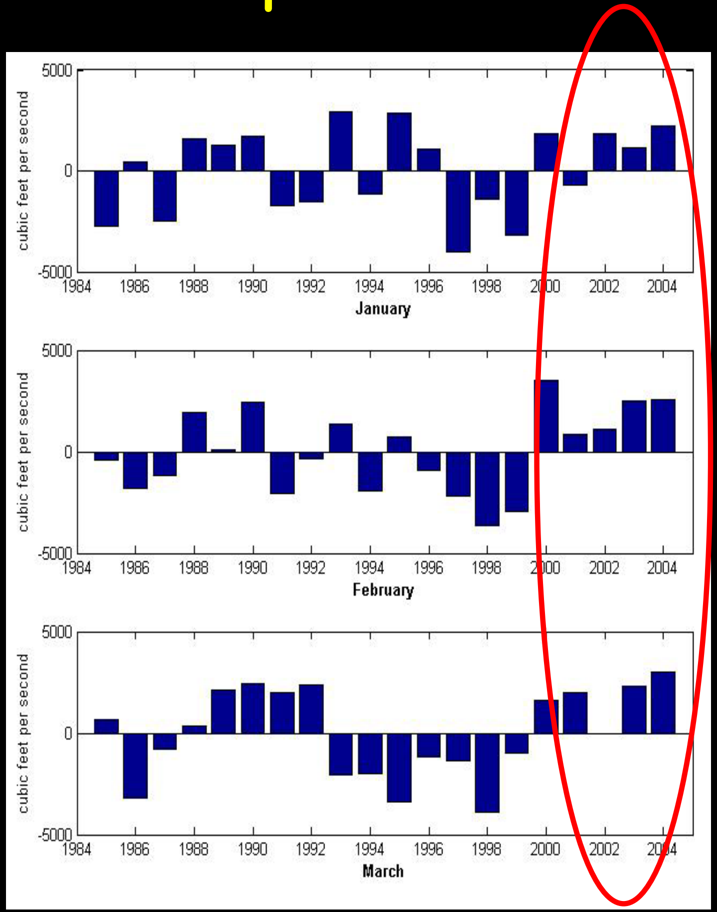
FISH ABUNDANCE

Winter Salvage of Delta Smelt (Nov-Mar)

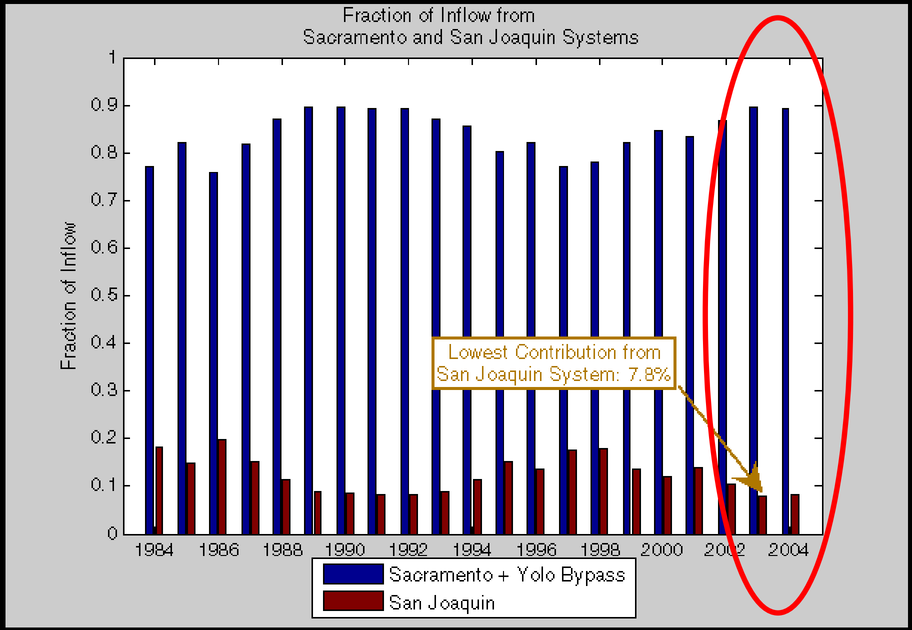


Source: IEP (2005)

Increased winter exports



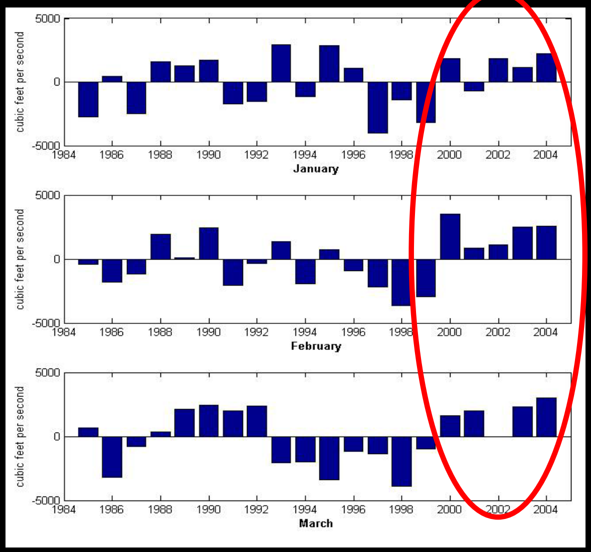
Low San Joaquin River flow

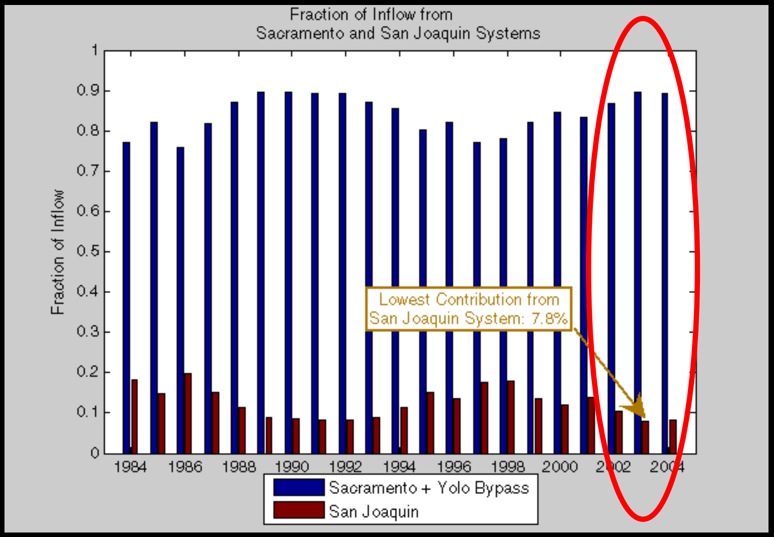


Source: Simi and others (USGS)

Increased winter exports

Low San Joaquin River flow

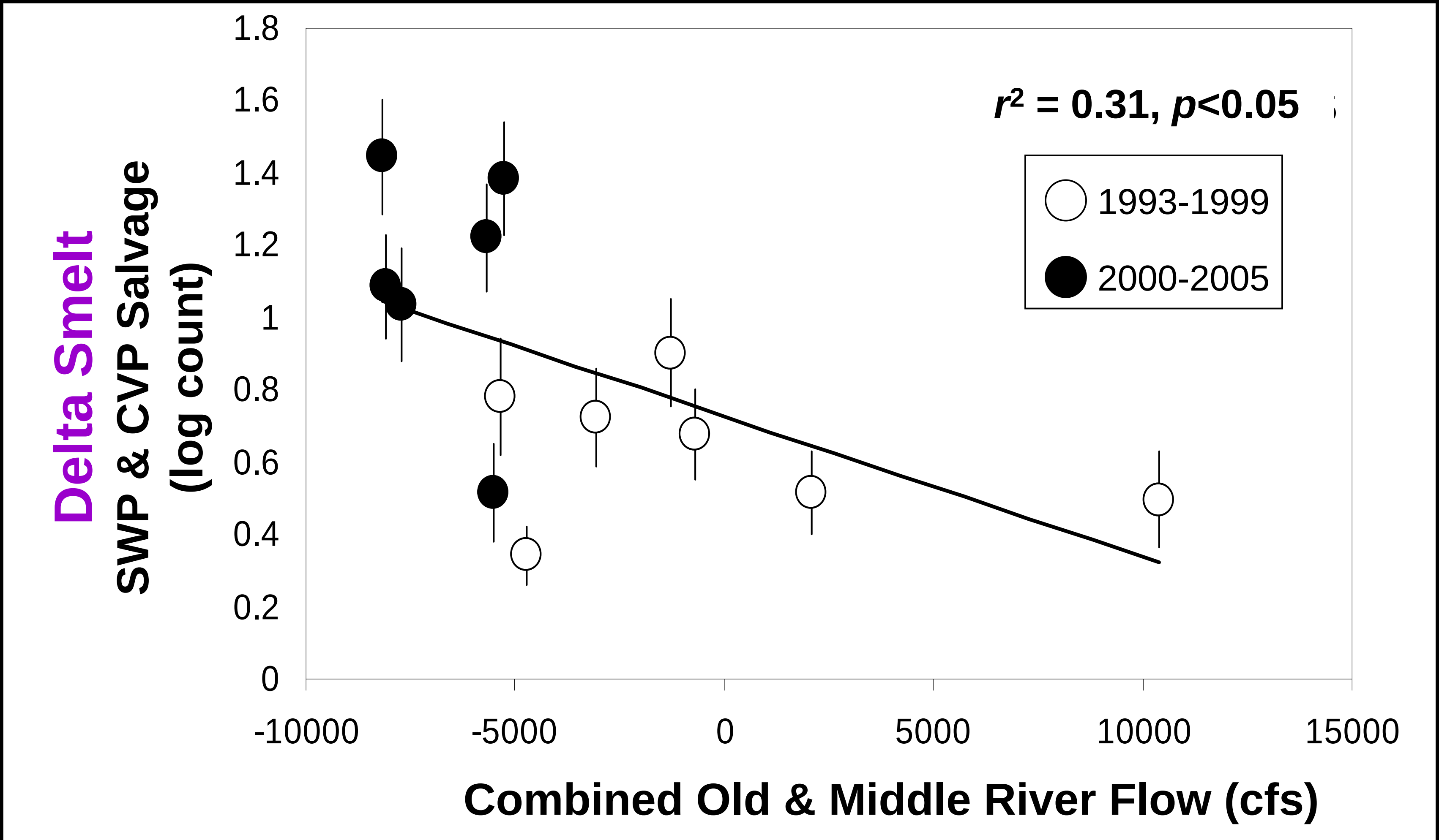




Entrainment

Increase in winter salvage.

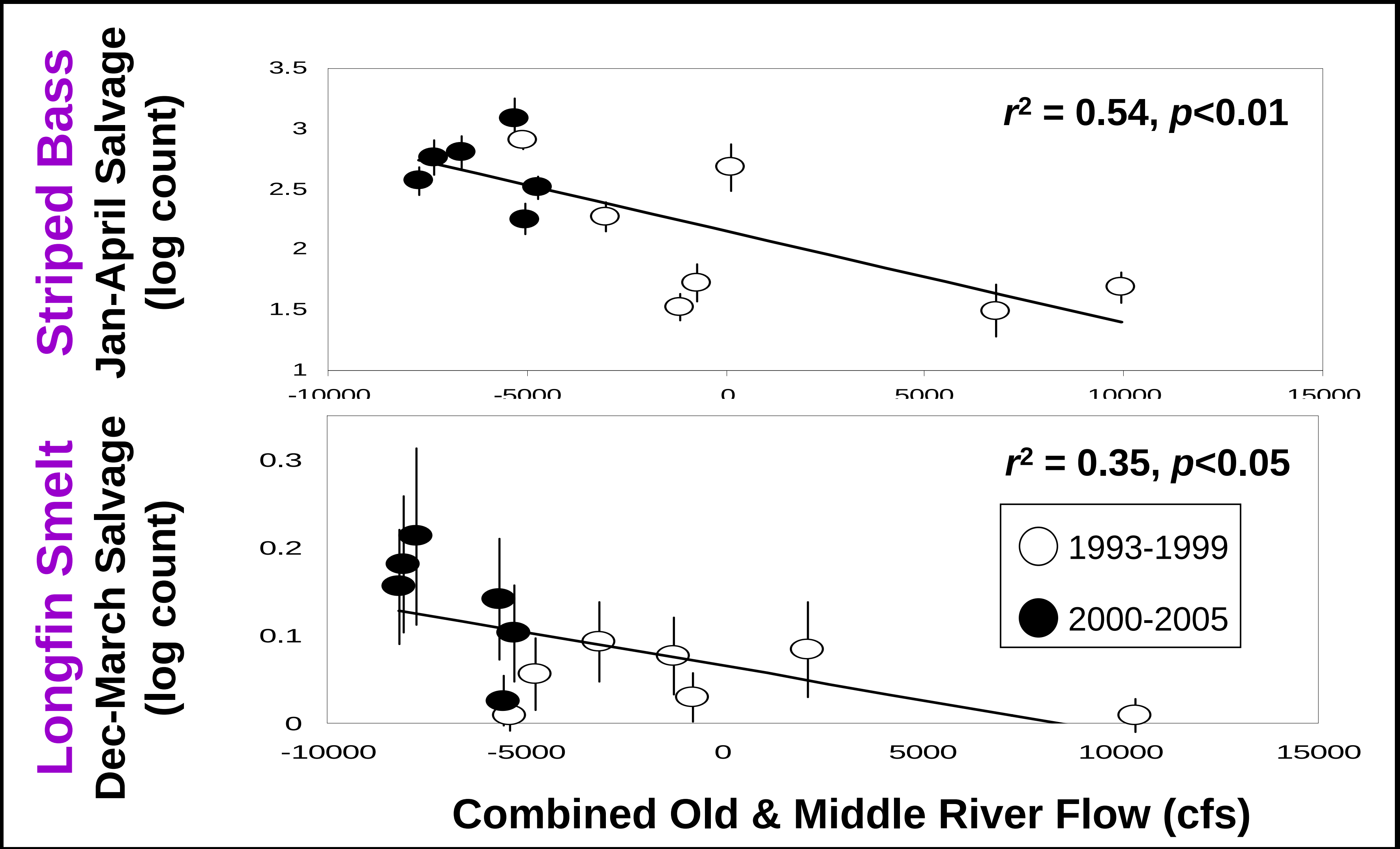
Negative Old & Middle River Flows Apparently Increase Adult Delta Smelt Entrainment



Mean Values for December-March 1993-2005

Source: Adapted from Pete Smith (USGS)

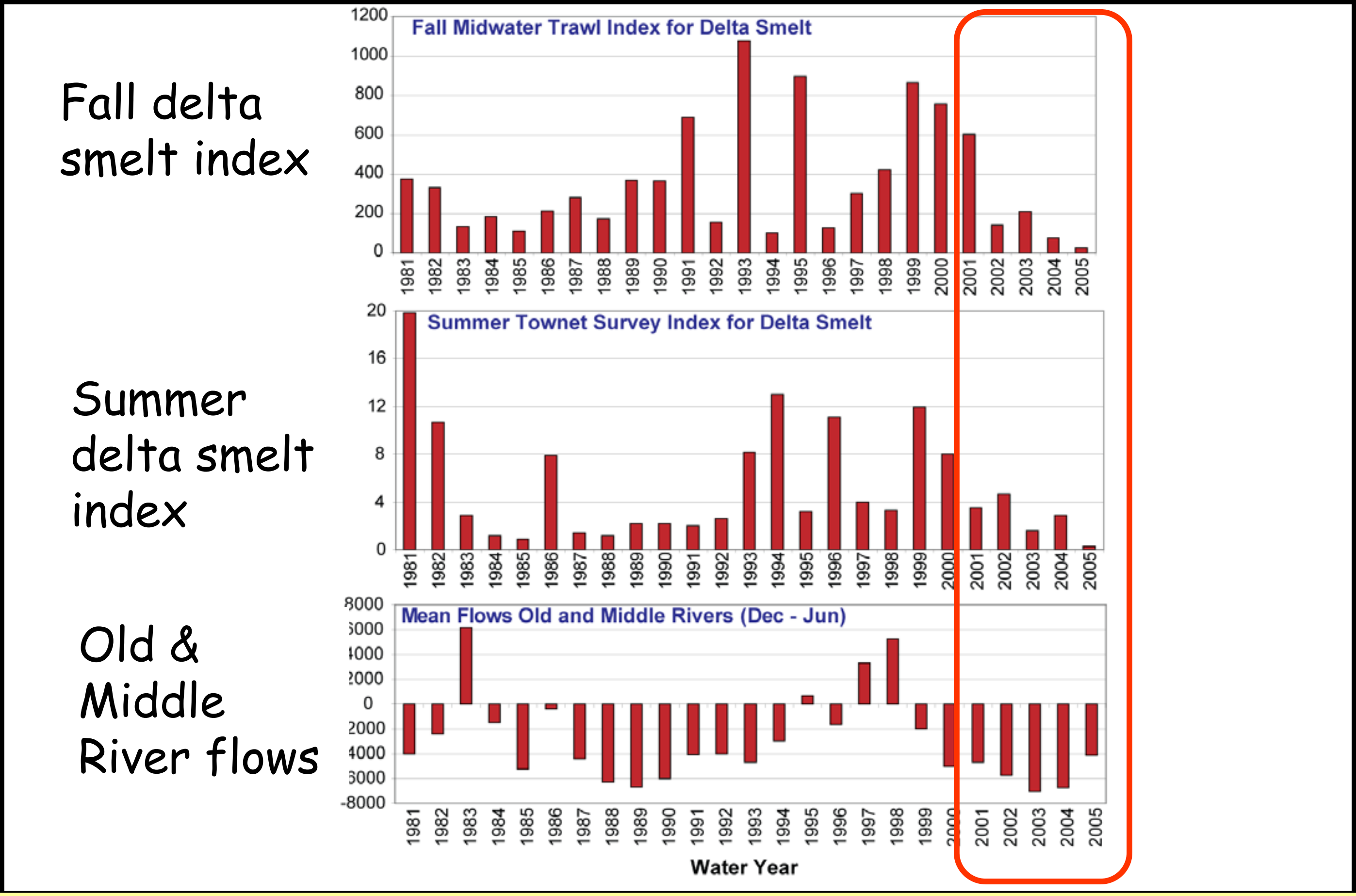
Negative Old & Middle River Flows Seem to Have Similar Effects on Striped Bass & Longfin Smelt Entrainment



Mean Values for indicated periods 1993-2005

Source: L. Grimaldo, DWR

Negative Old & Middle River Flows Coincided with Low Smelt Indices in POD Years, But Not in All Previous Years



In Log-Linear Modeling Over 1981-2004, Monthly or Semi-Monthly Exports or O&M River Flows Individually Explain No More Than 1.5% Of The Variation In Fall Catches

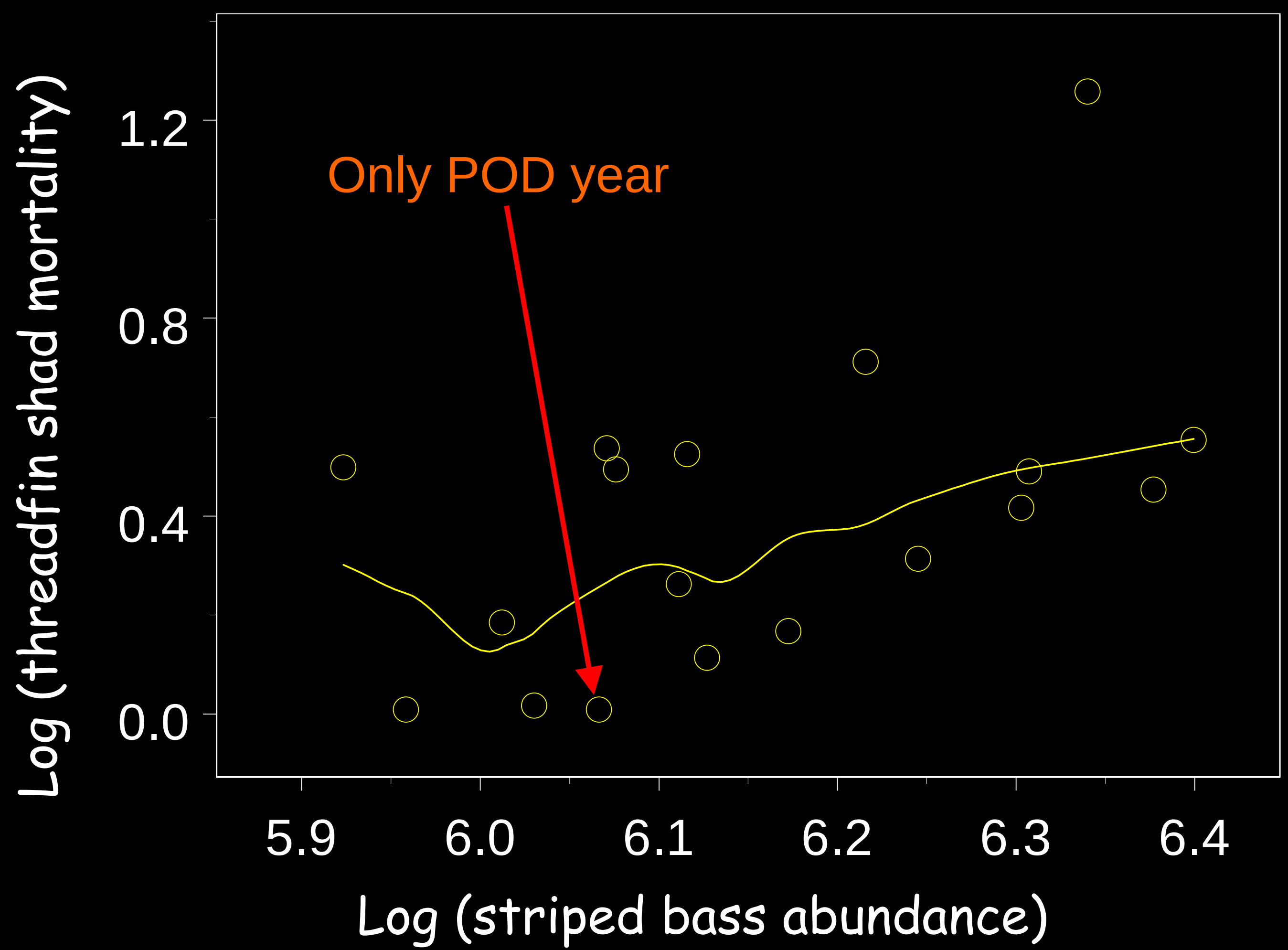
Source: Bryan Manly and Mike Chotkowski (USBR)

Bennett Hypothesis:
Not All Smelt Are Created Equal

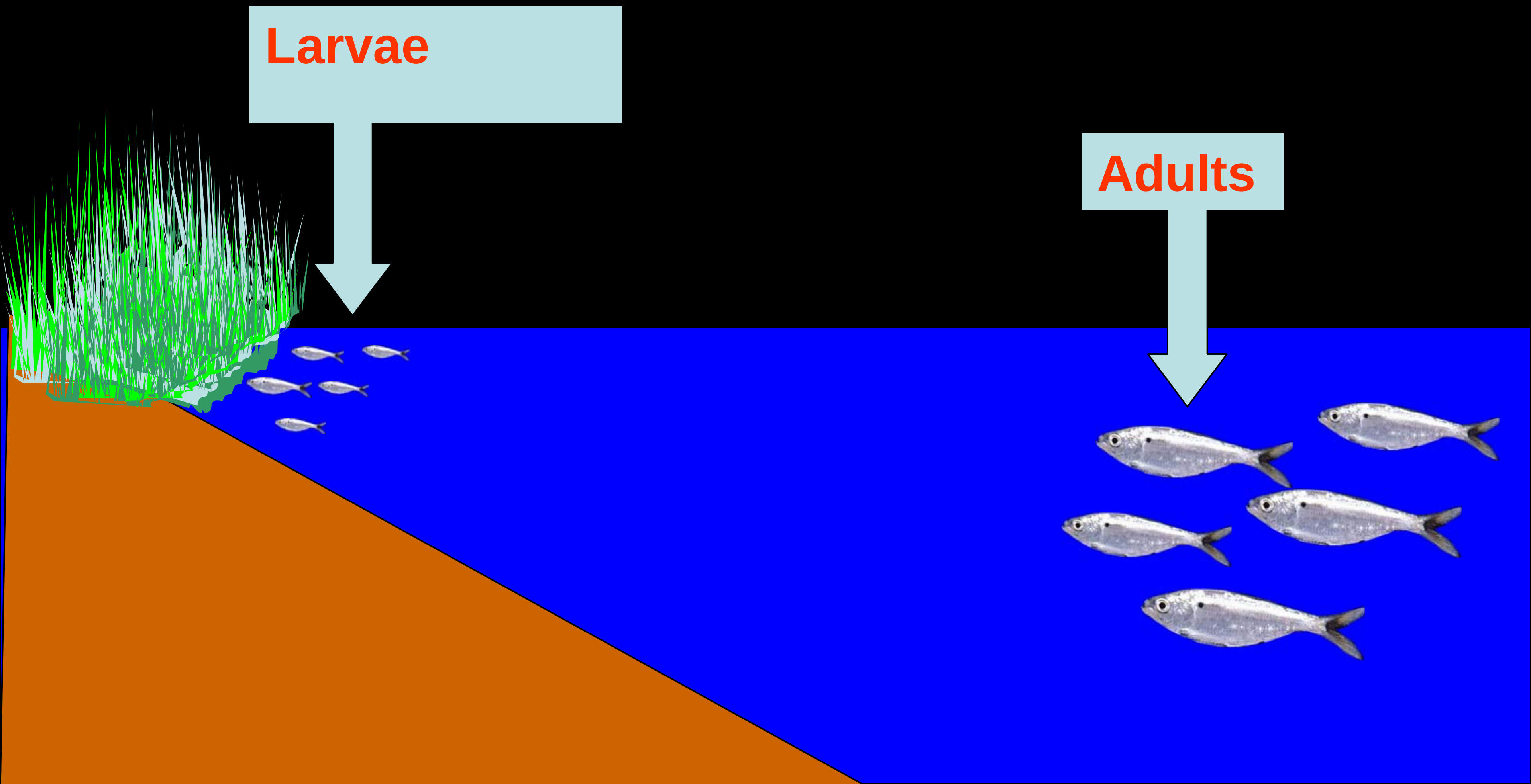
Larger/older females:

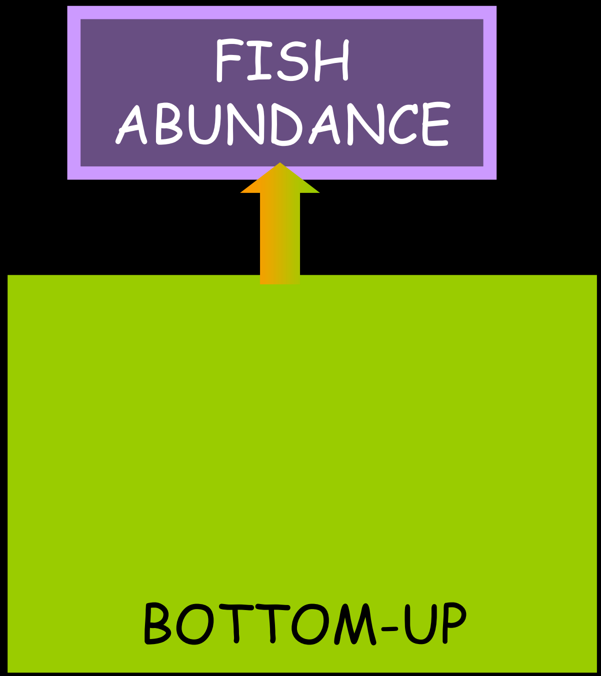
- Have higher fecundity.
- Spawn early and repeatedly.
- Produce larger offspring that have higher fitness.
- Are more subject to water project effects.

Evidence of Fish Predation Effects



There Also May Be Substantial Inshore Predation for Some Species




FISH ABUNDANCE
BOTTOM-UP

FISH ABUNDANCE

Food availability

Food quality

BOTTOM-UP

Trends in the Pelagic Food Web

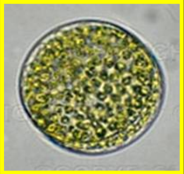
Phytoplankton

- Chlorophyll levels very low compared to other estuaries
- Long term declines, especially in Suisun Bay
- But: No evidence of a recent decline in the Delta

Zooplankton (fish food species)

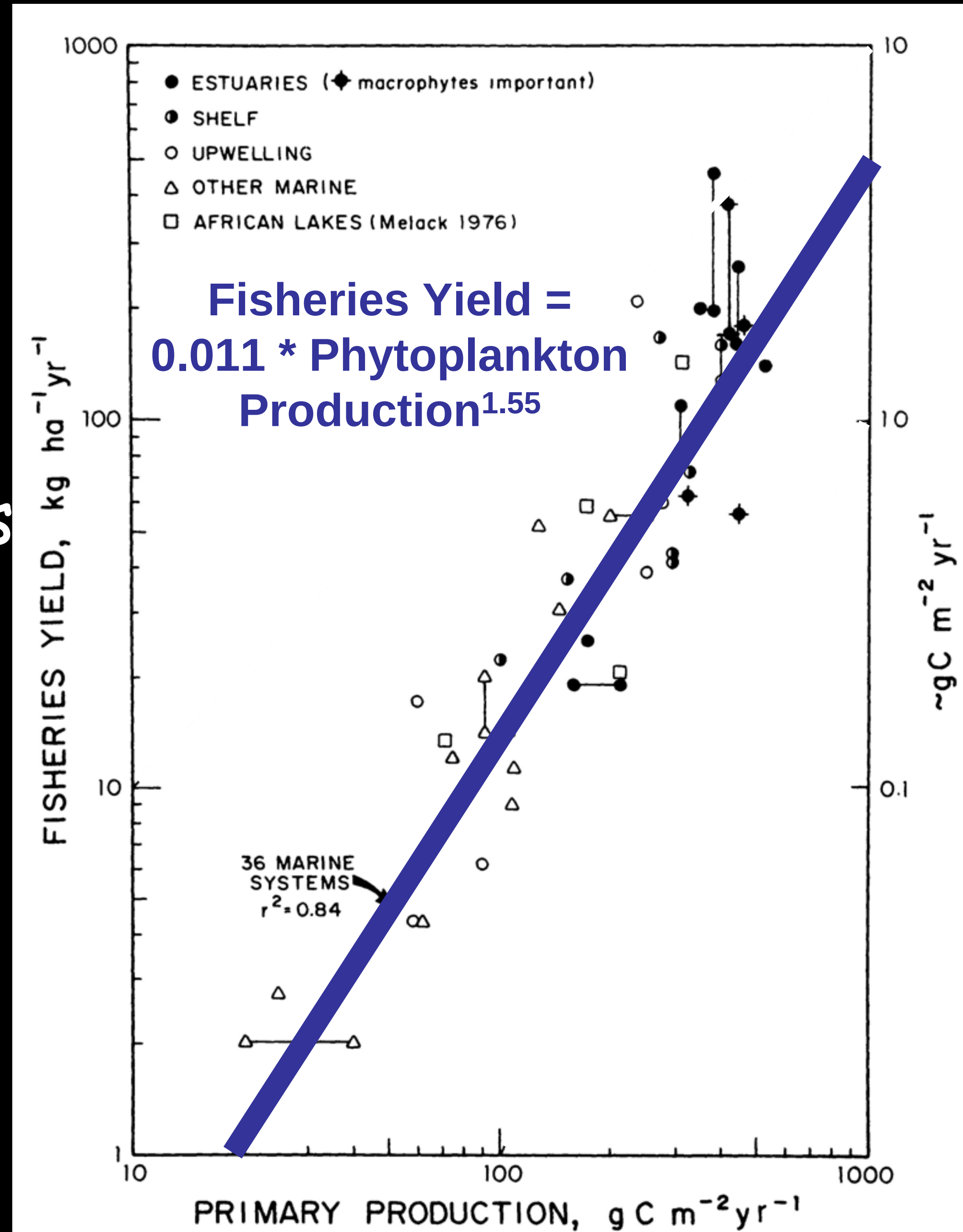
- Long term declines throughout the system

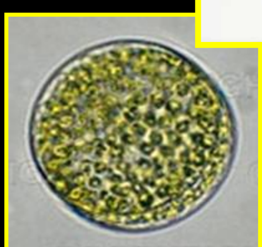
- Recent declines in Suisun Bay
- "Waves" of species invasions



Phytoplankton Primary Production

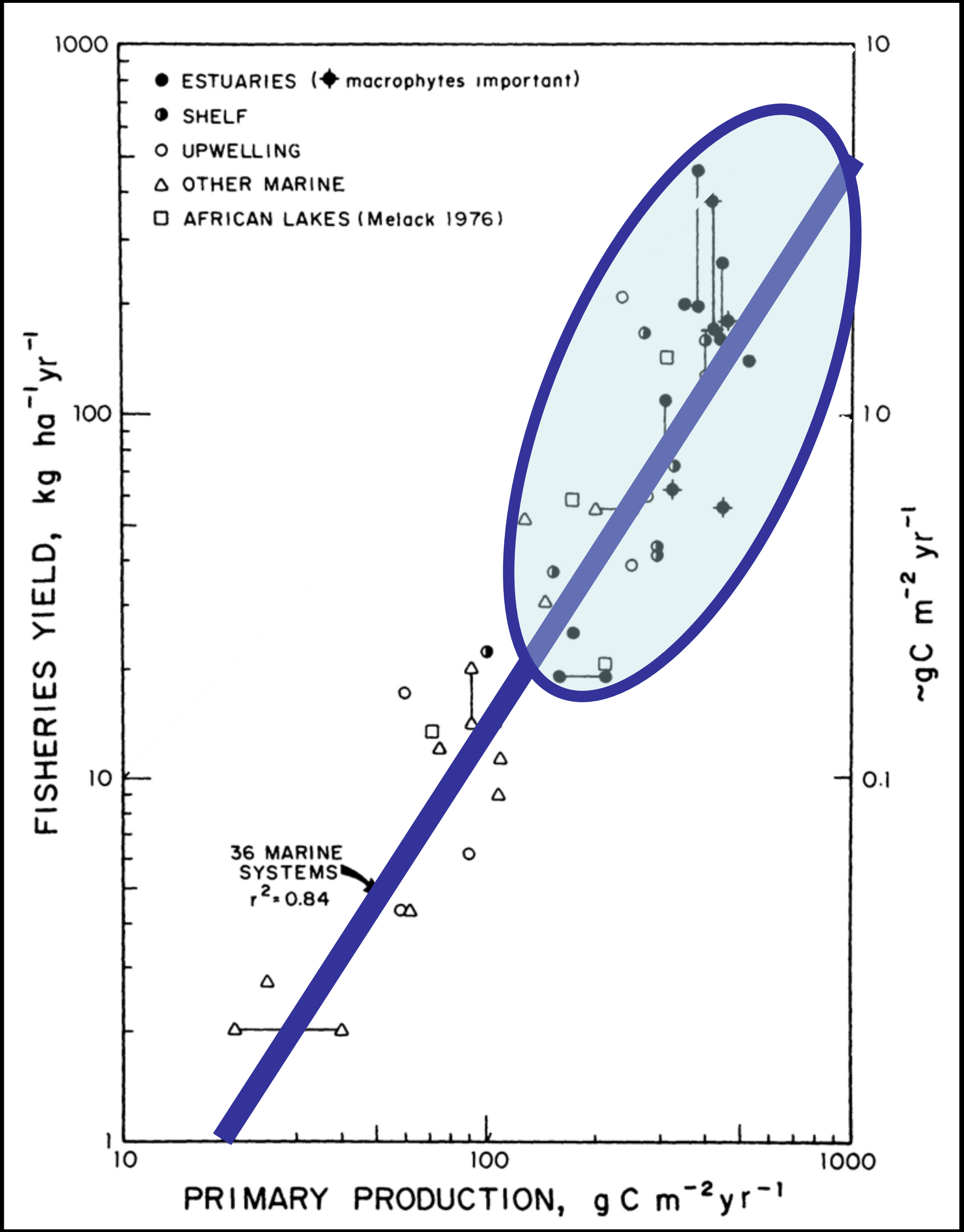
... is related to Fisheries Yields in many Marine Systems (Nixon 1988)





Phytoplankton
Primary Production

… in Estuaries is
typically very HIGH



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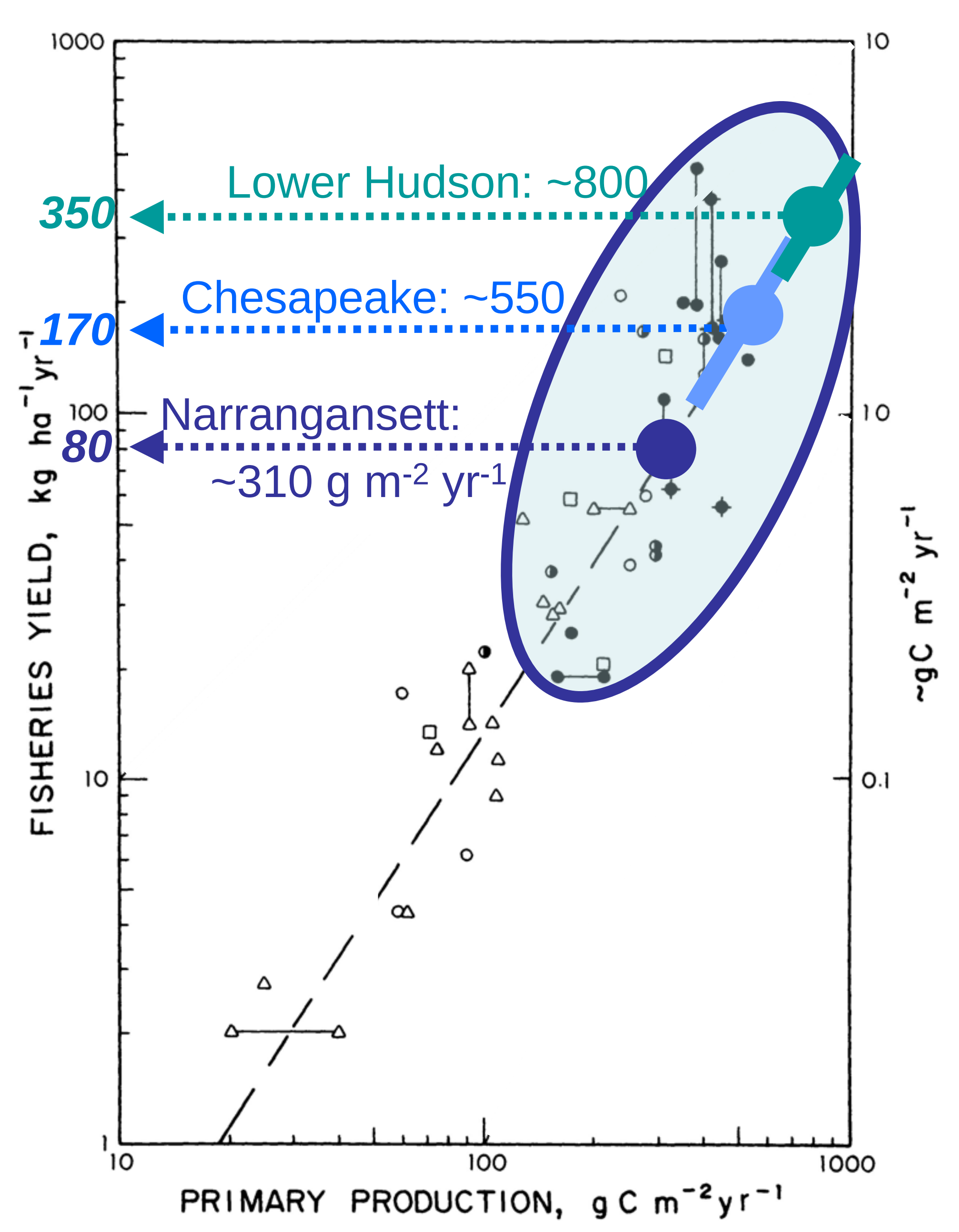
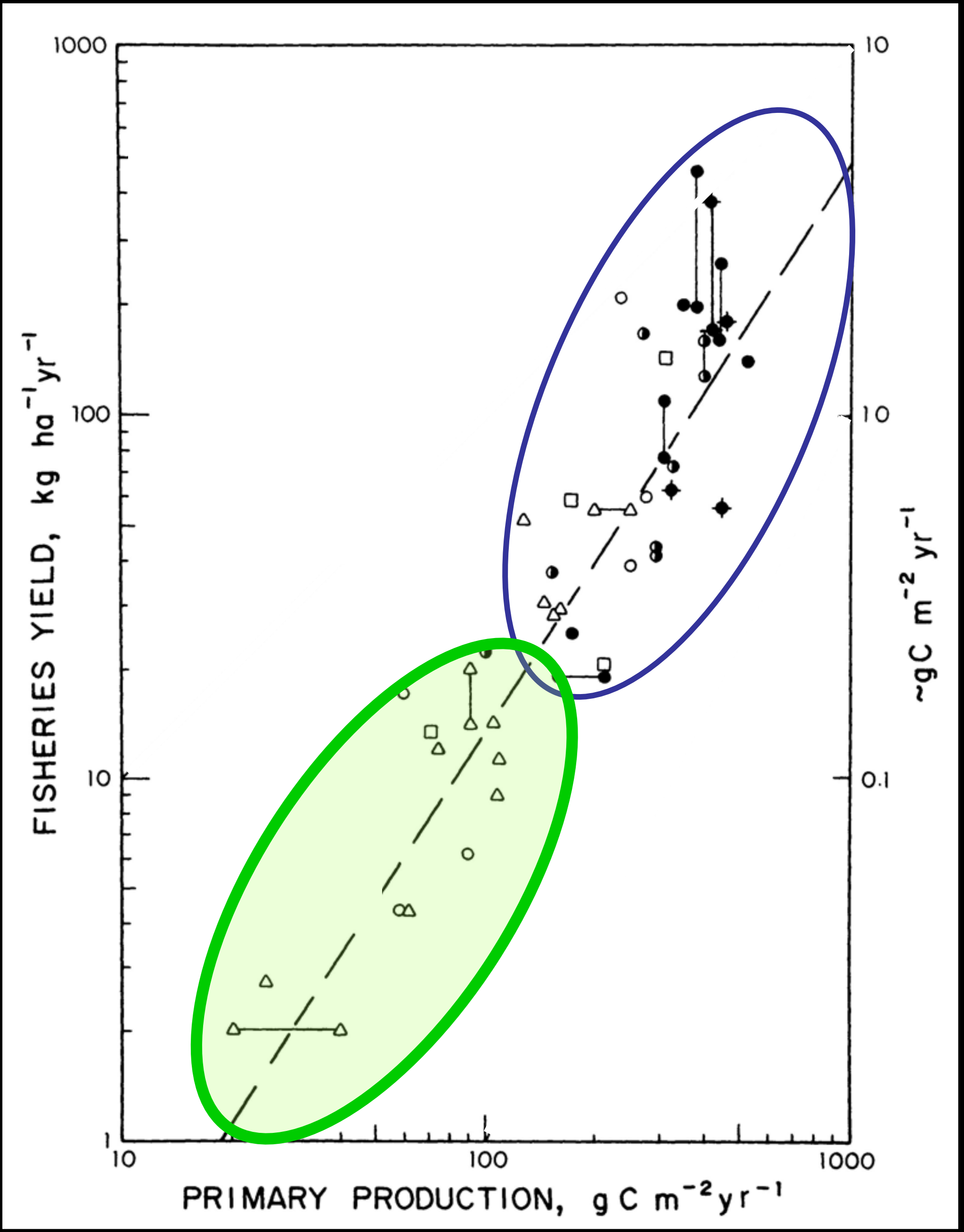


Source: S. Nixon, 1988

Phytoplankton Primary Production

... in the Delta & Suisun Bay is usually very LOW

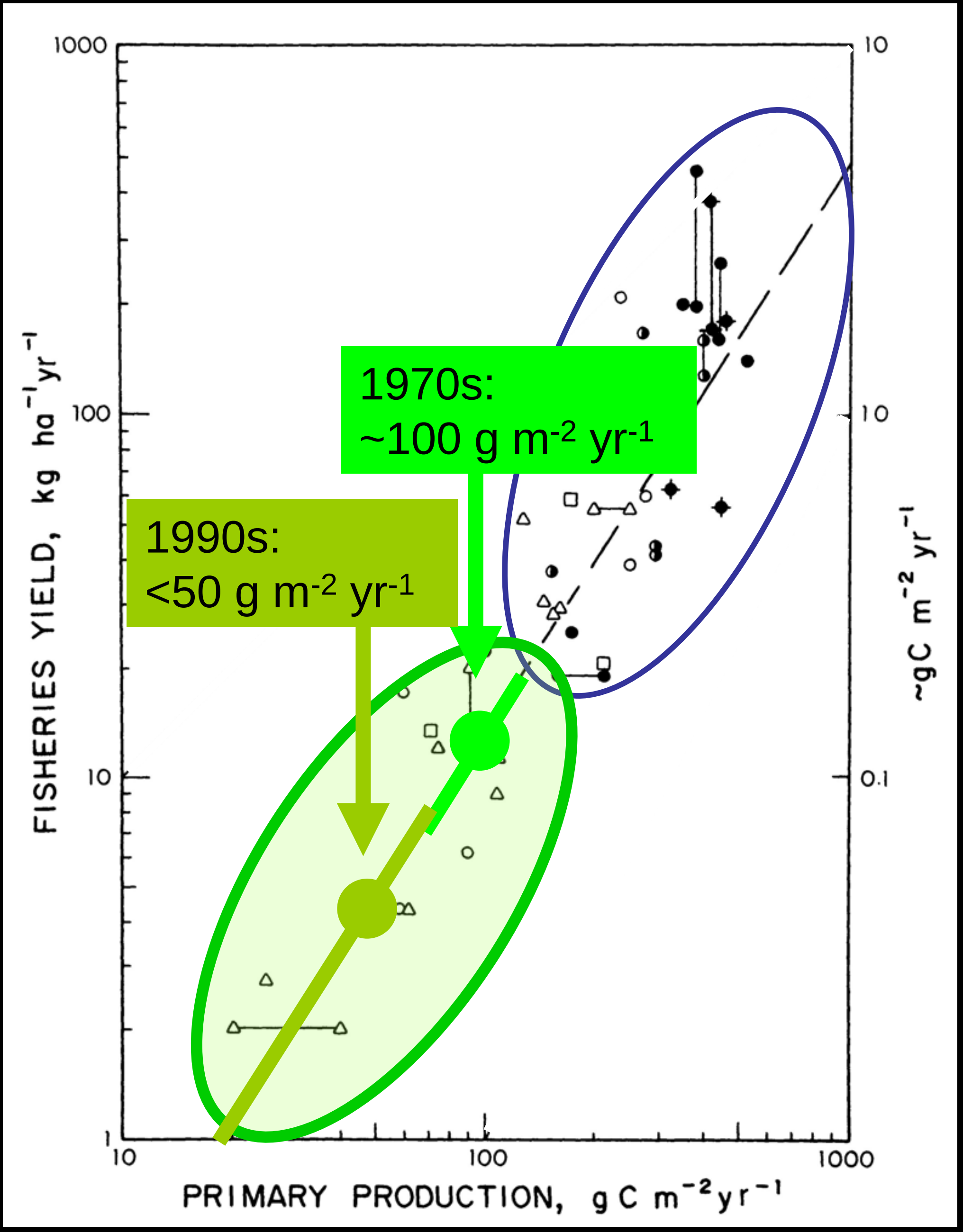


Sources: A. Jassby (UCD), J. Cloern (USGS), IEP data

Phytoplankton Primary Production

... in the Delta & Suisun Bay is usually very LOW

... and has DECLINED since the 1970s



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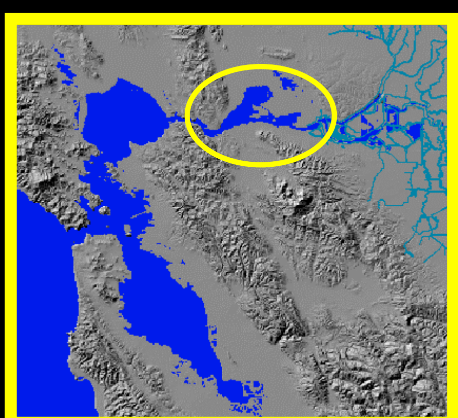
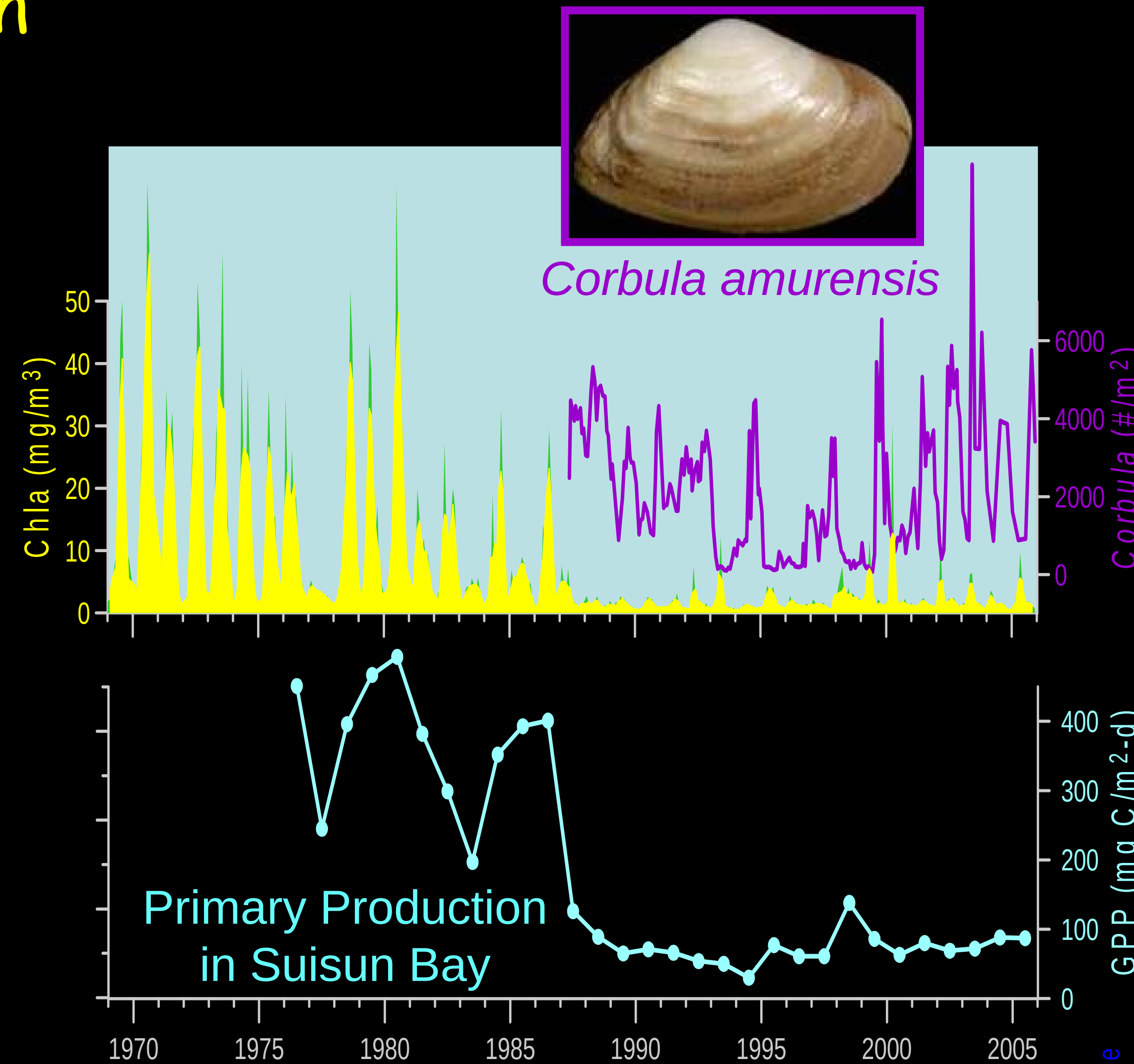
Phytoplankton Primary Production

... CRASHED in Suisun Bay right after the 1987 *Corbula* invasion





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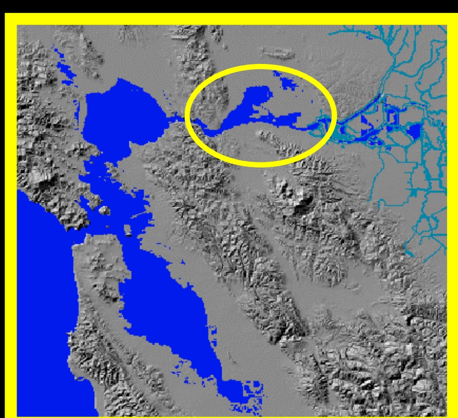

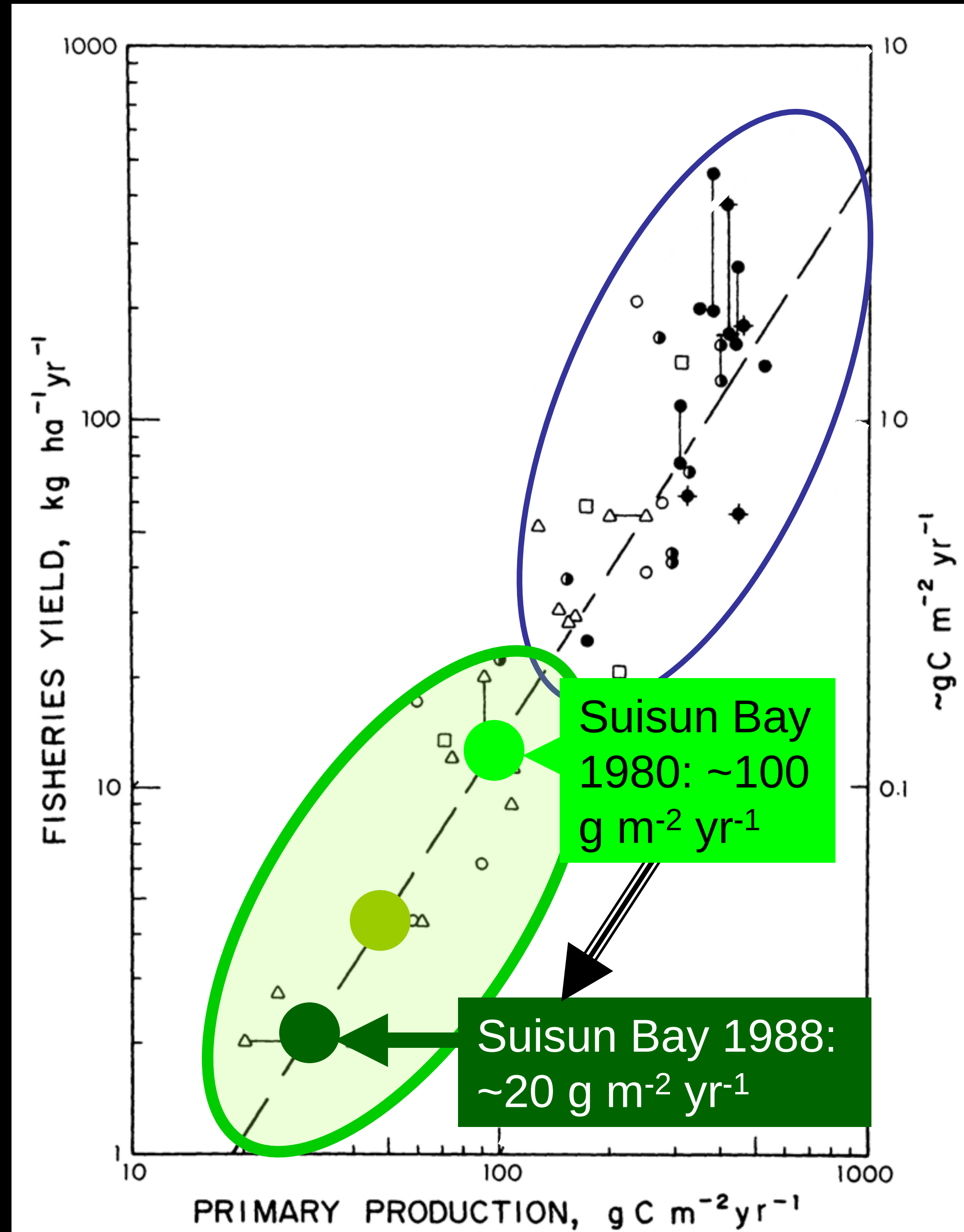

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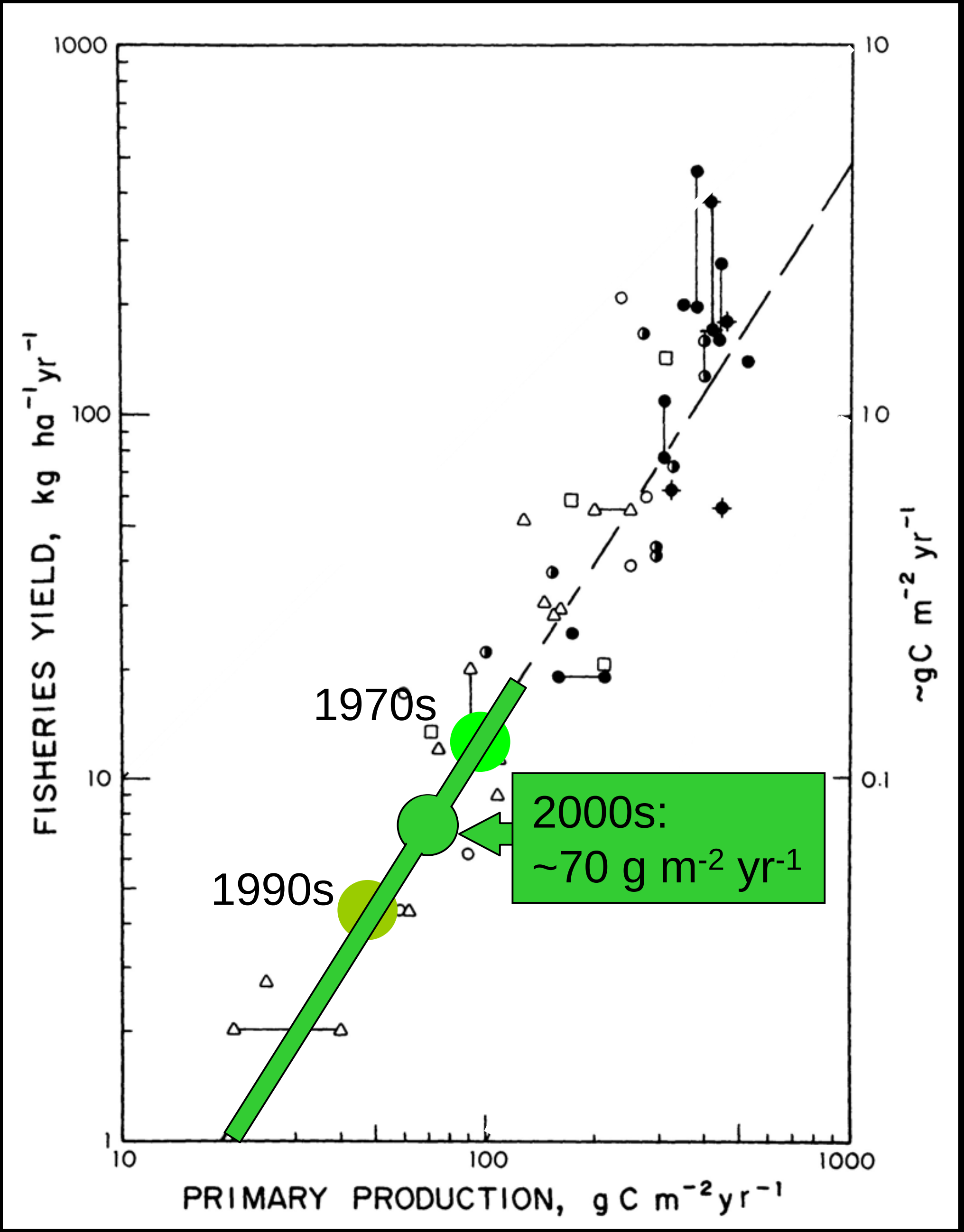
BUT:

Phytoplankton Primary Production

… during the POD years is slightly UP in the Delta & Suisun Bay.



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Phytoplankton Primary Production

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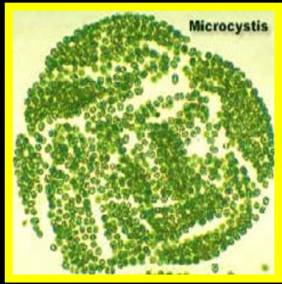
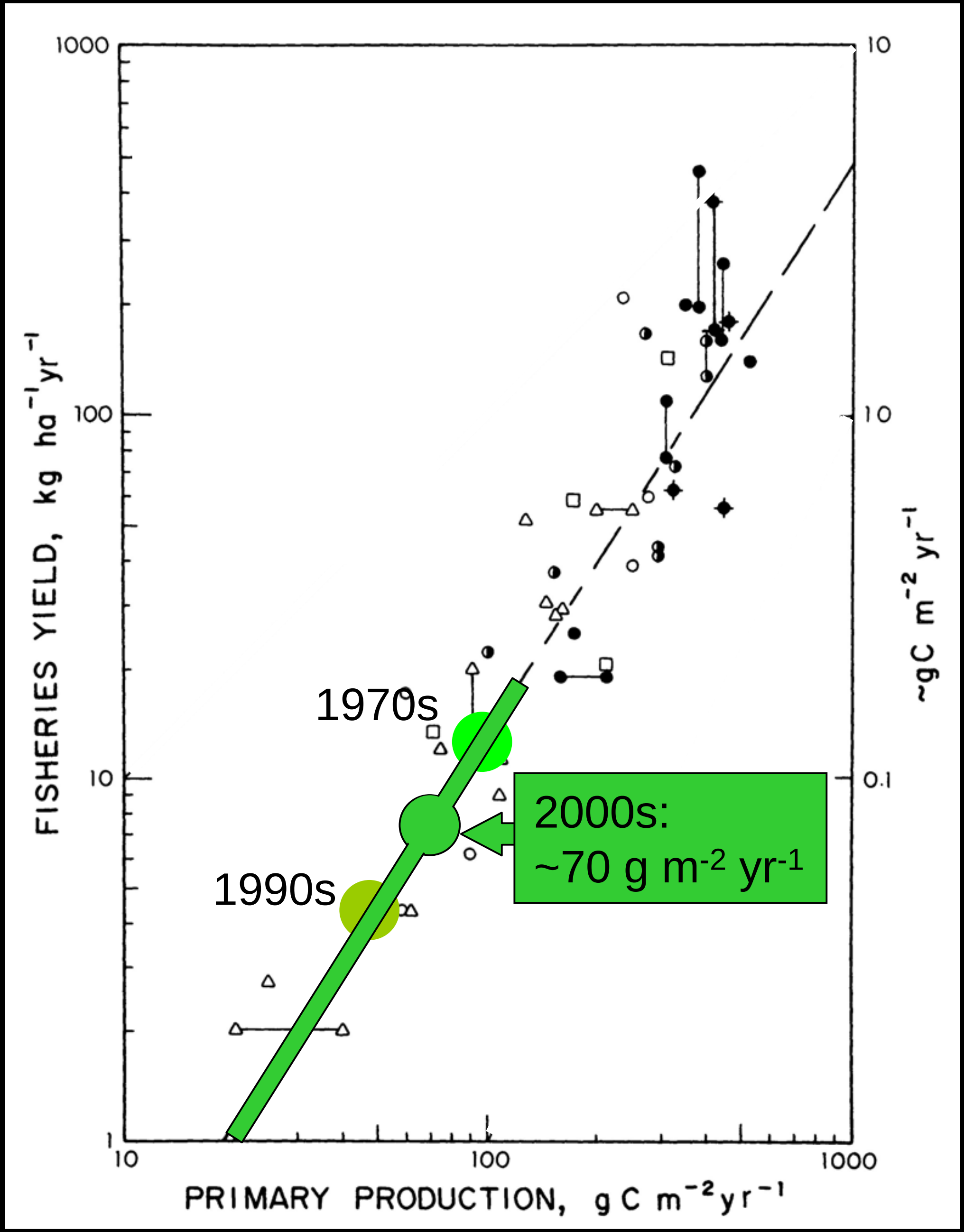
Quality???





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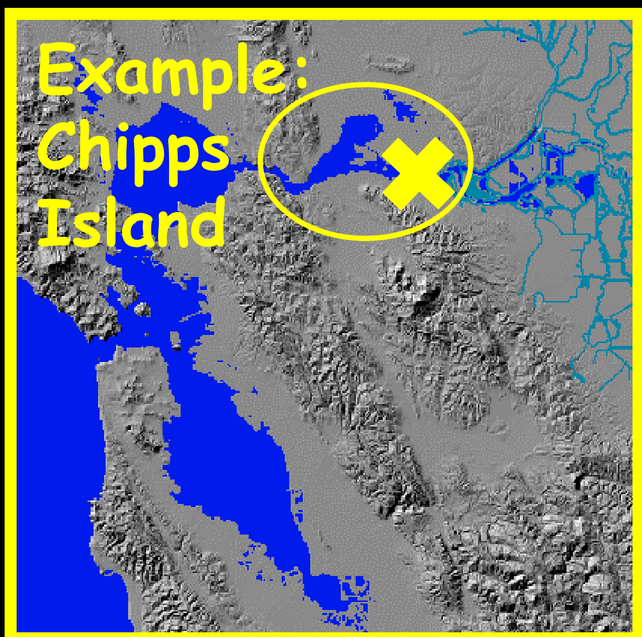
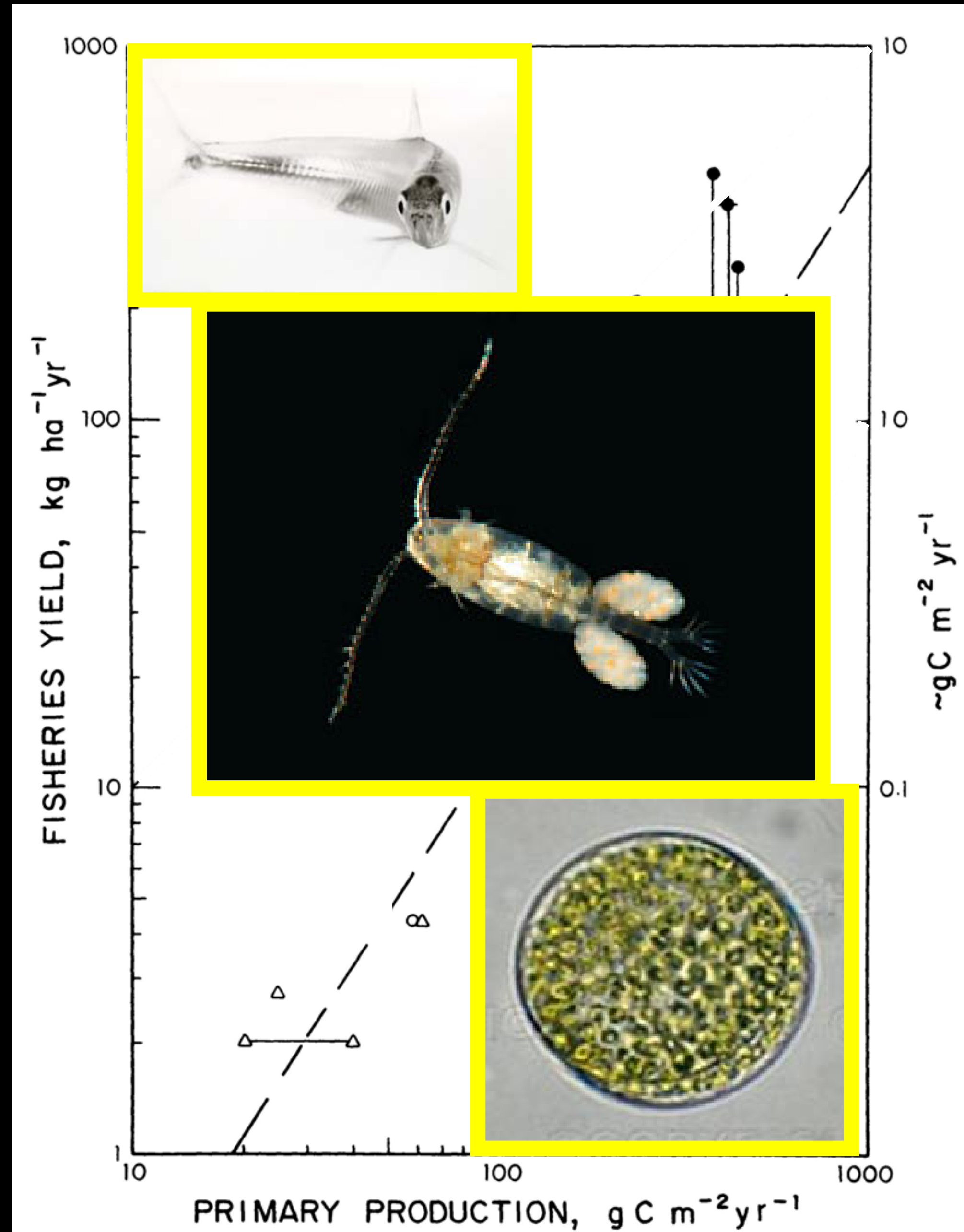
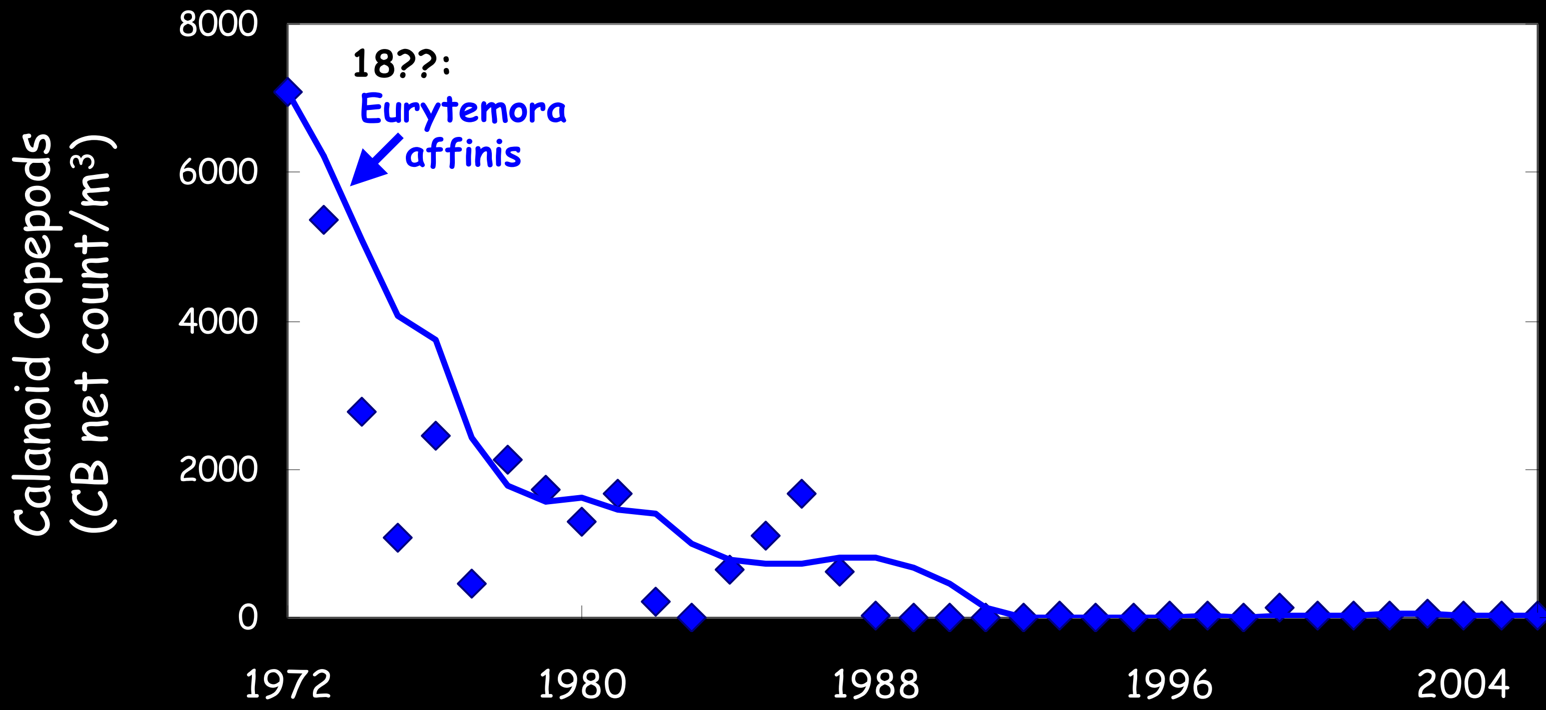
Zooplankton: Waves of Invasions and Declines





Zooplankton Species Invade in "Waves"



Adult copepods at Chipps Island, yearly averages with 5-year moving average lines

Source:
A. Mueller-Solger (DWR), IEP data

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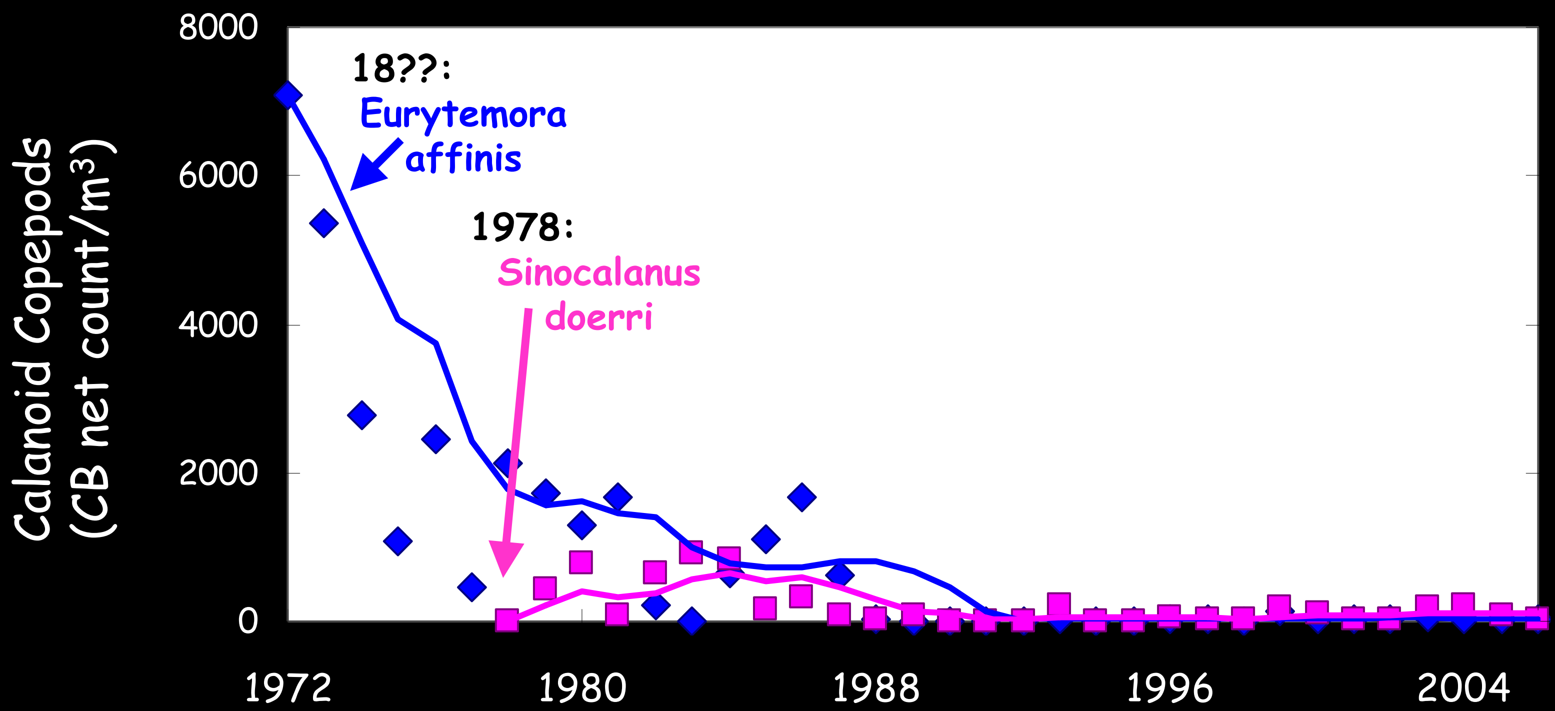

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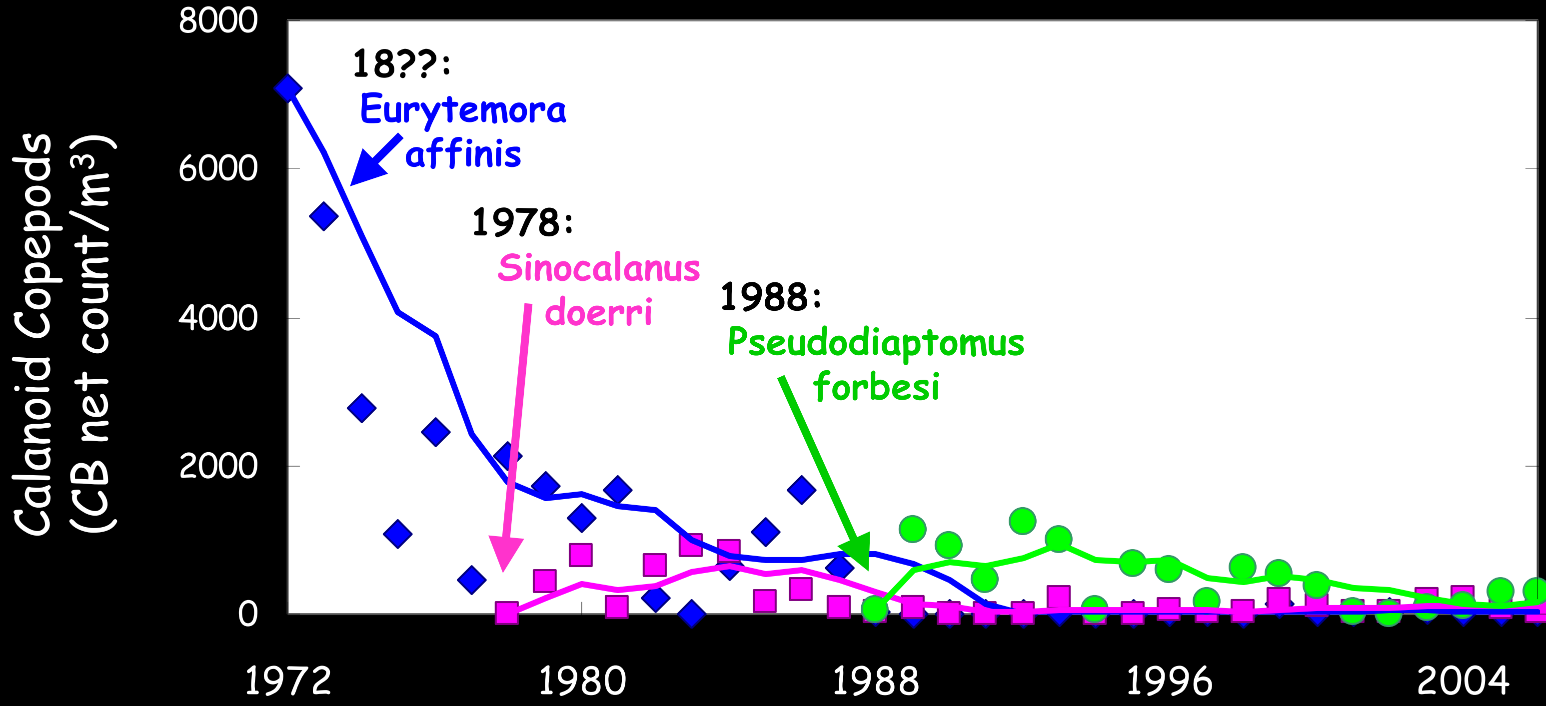

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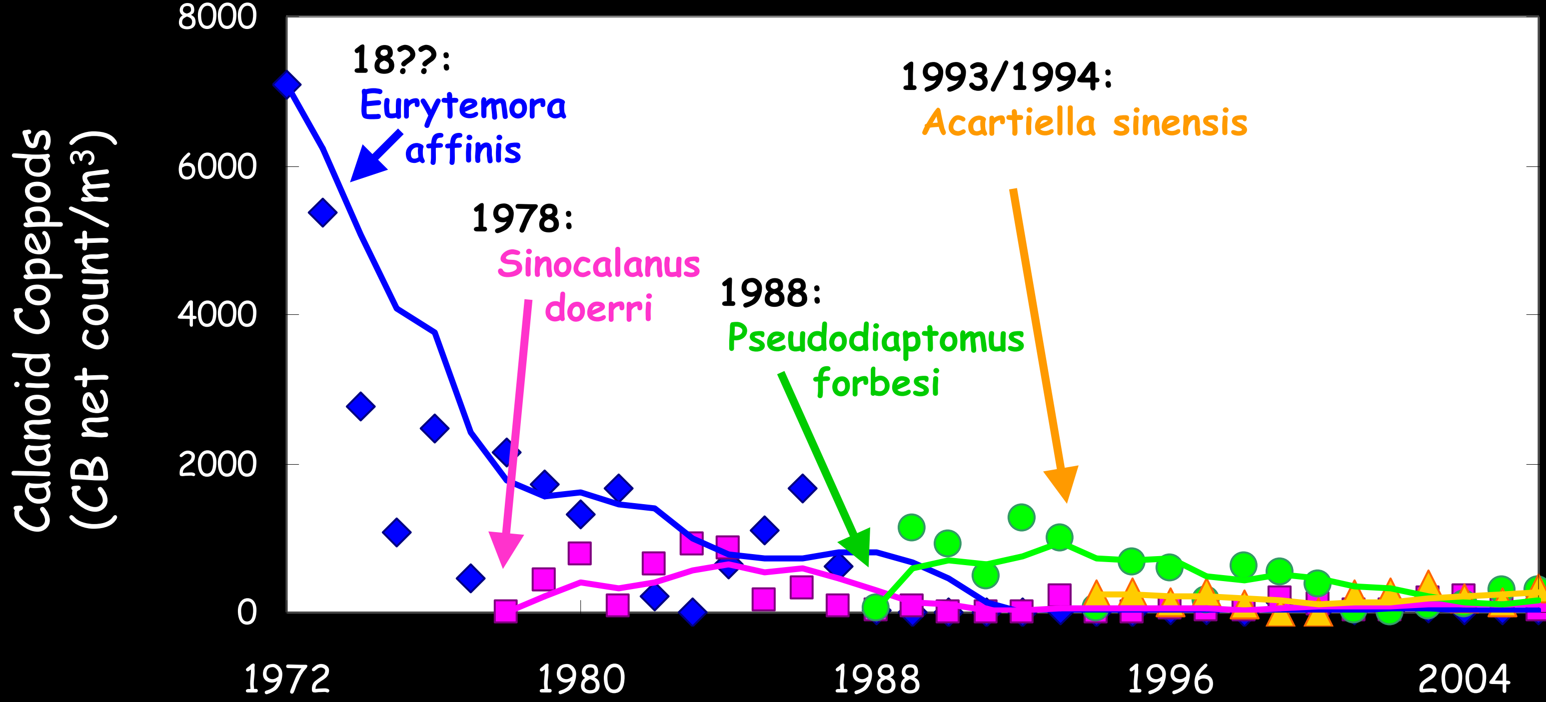

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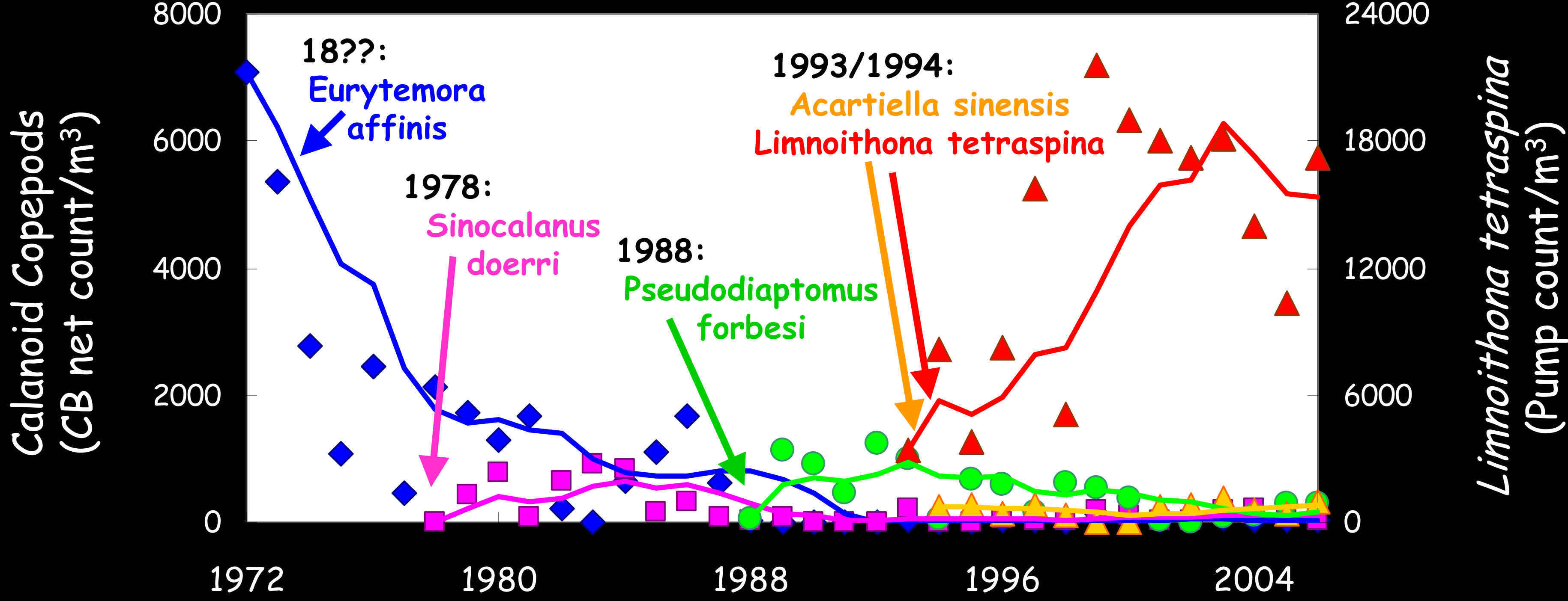

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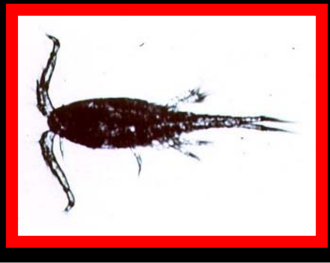

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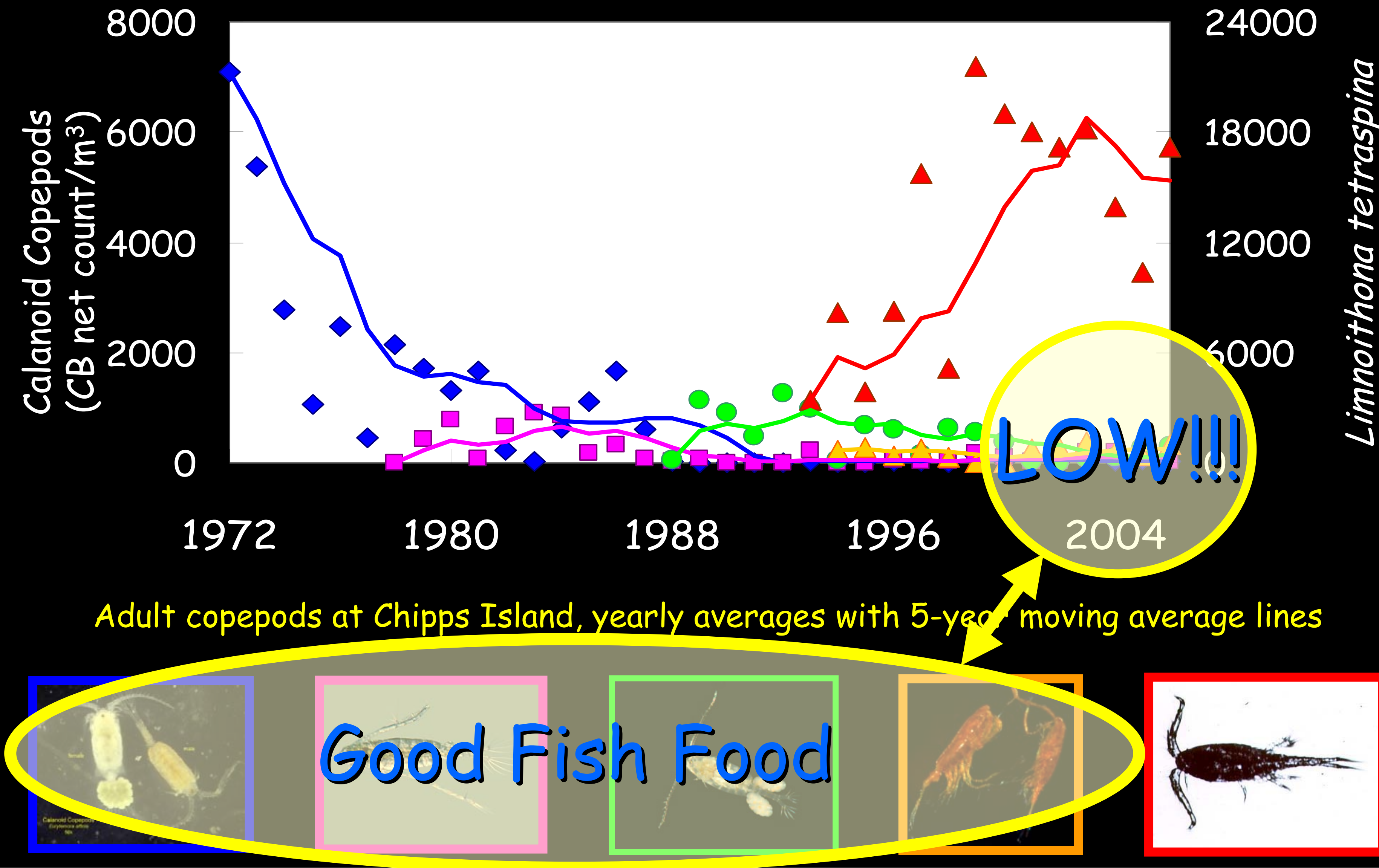

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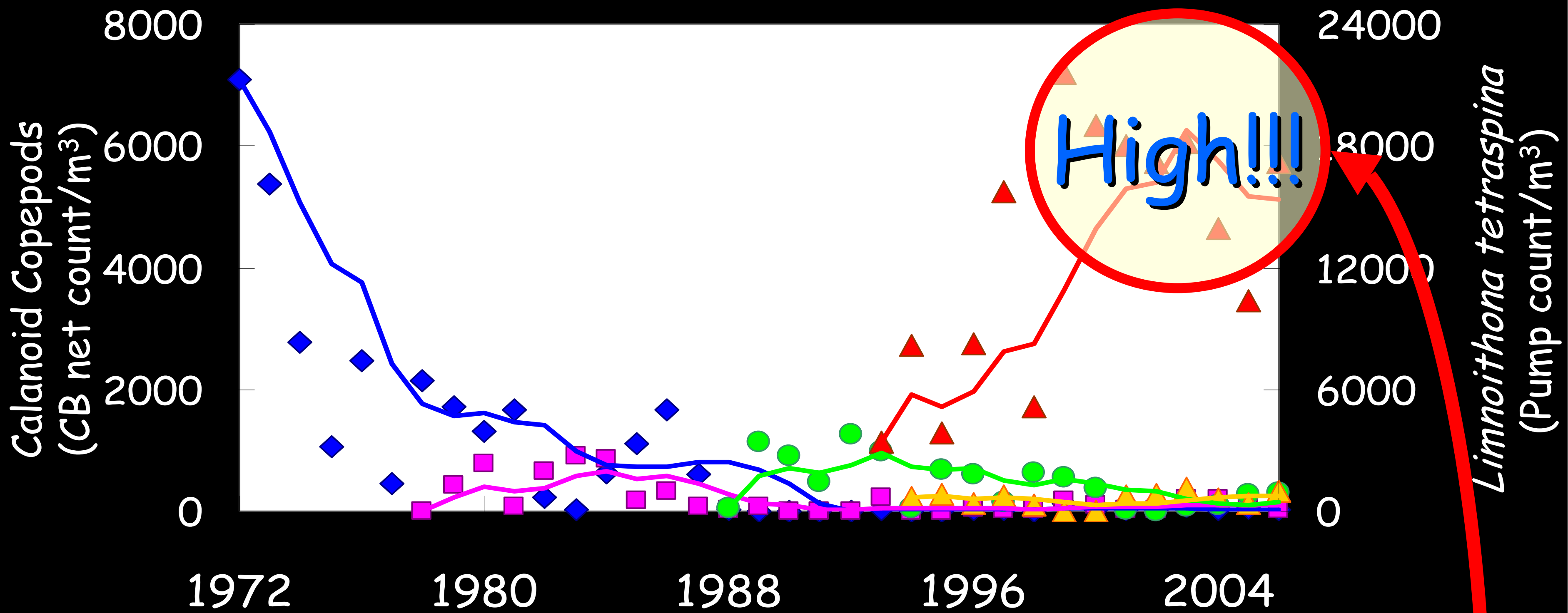

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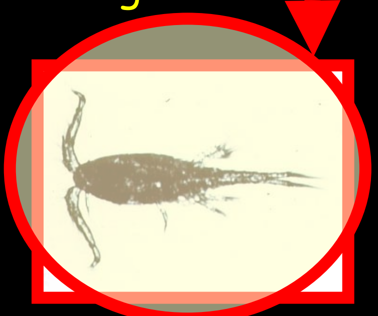
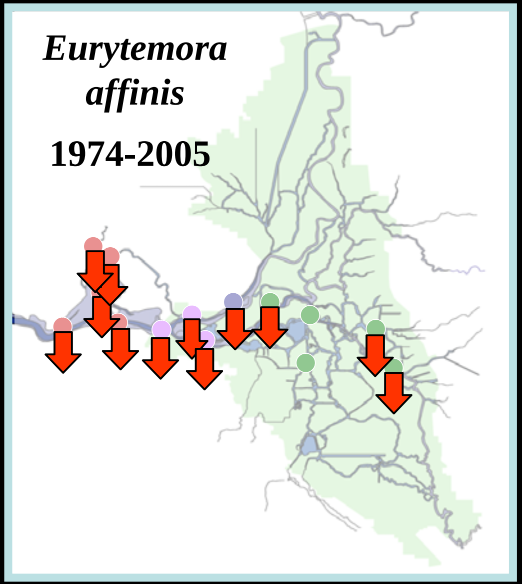
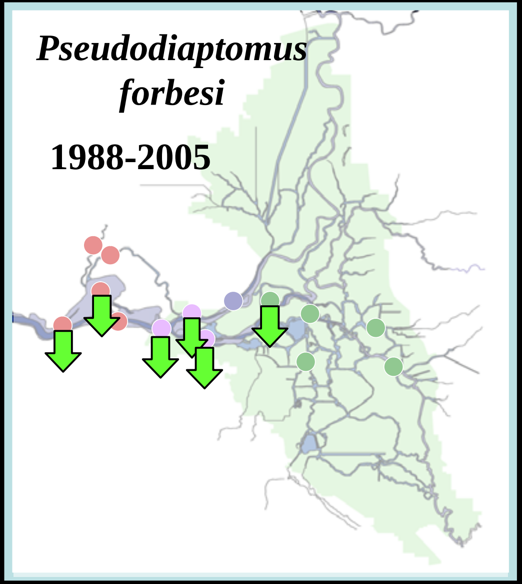


Important Fish Food Species have Declined

Eurytemora affinis declined at almost all IEP stations



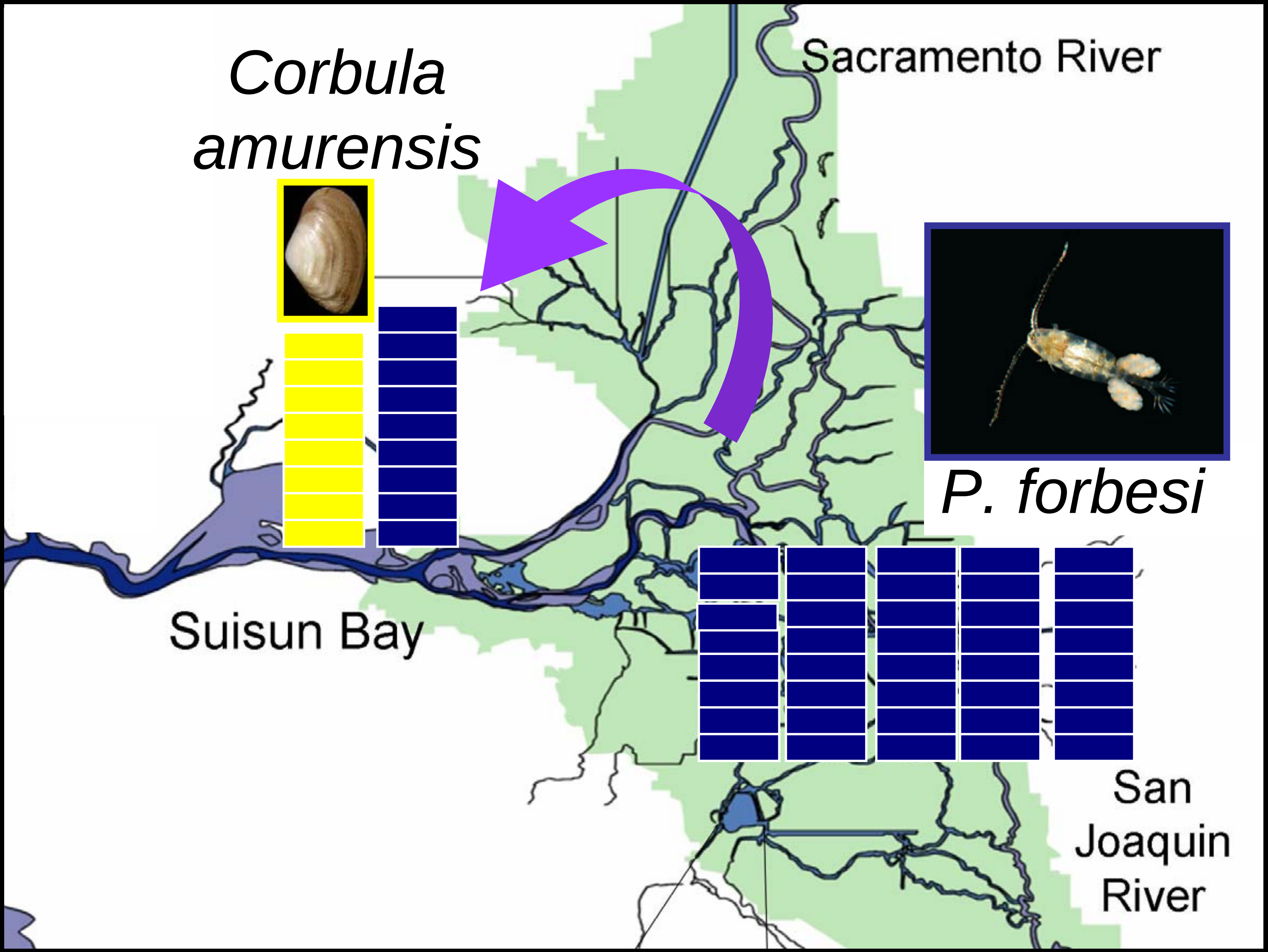
Pseudodiaptomus forbesi declined in Suisun Bay & the Confluence



Trends significant at $p<0.05$, *Seasonal Kendall Test*

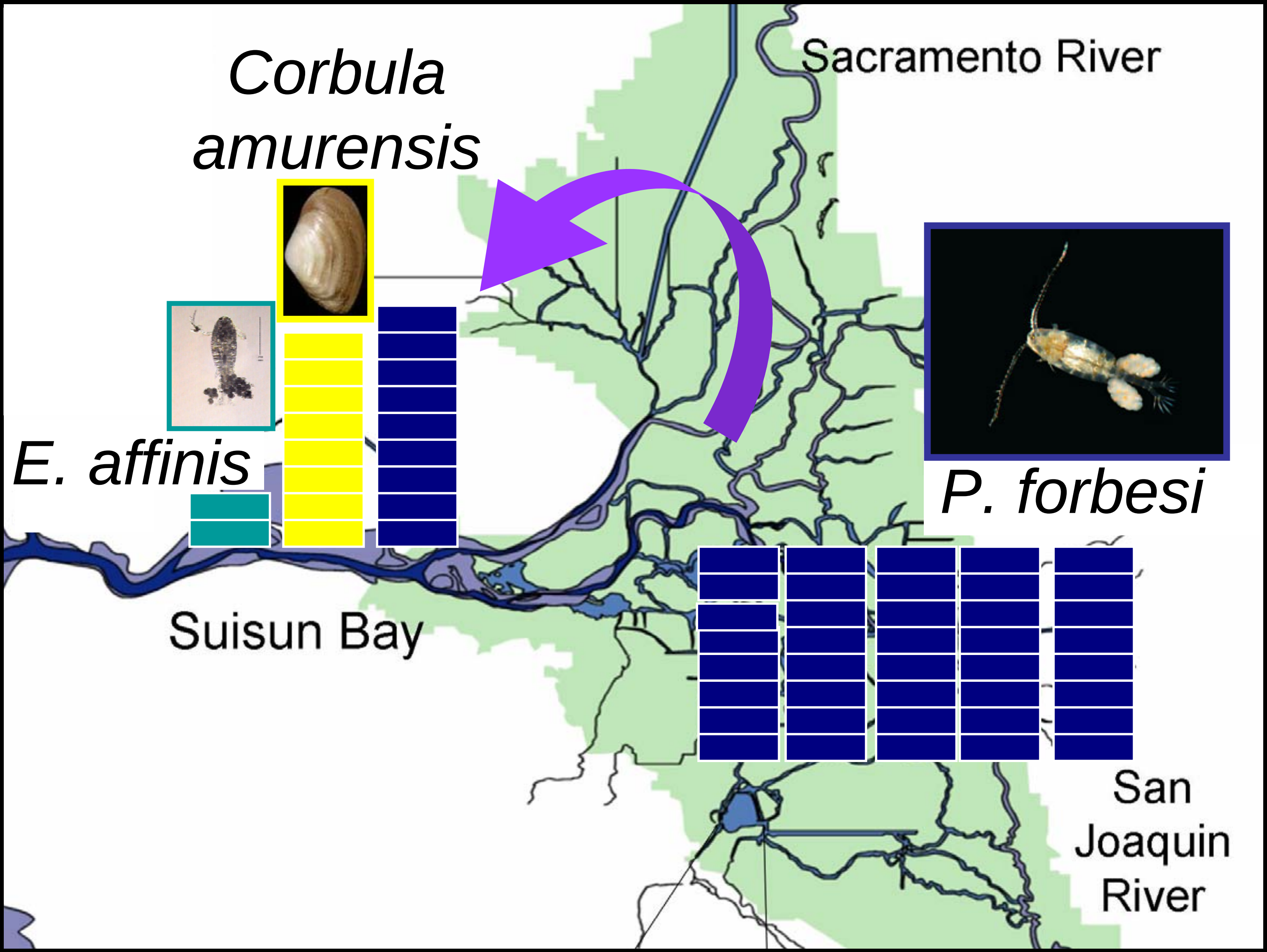
Source: A. Mueller-Solger, DWR

P. forbesi & *E. affinis* Abundance in Suisun Bay is Affected by Upstream Subsidies and Clam Grazing



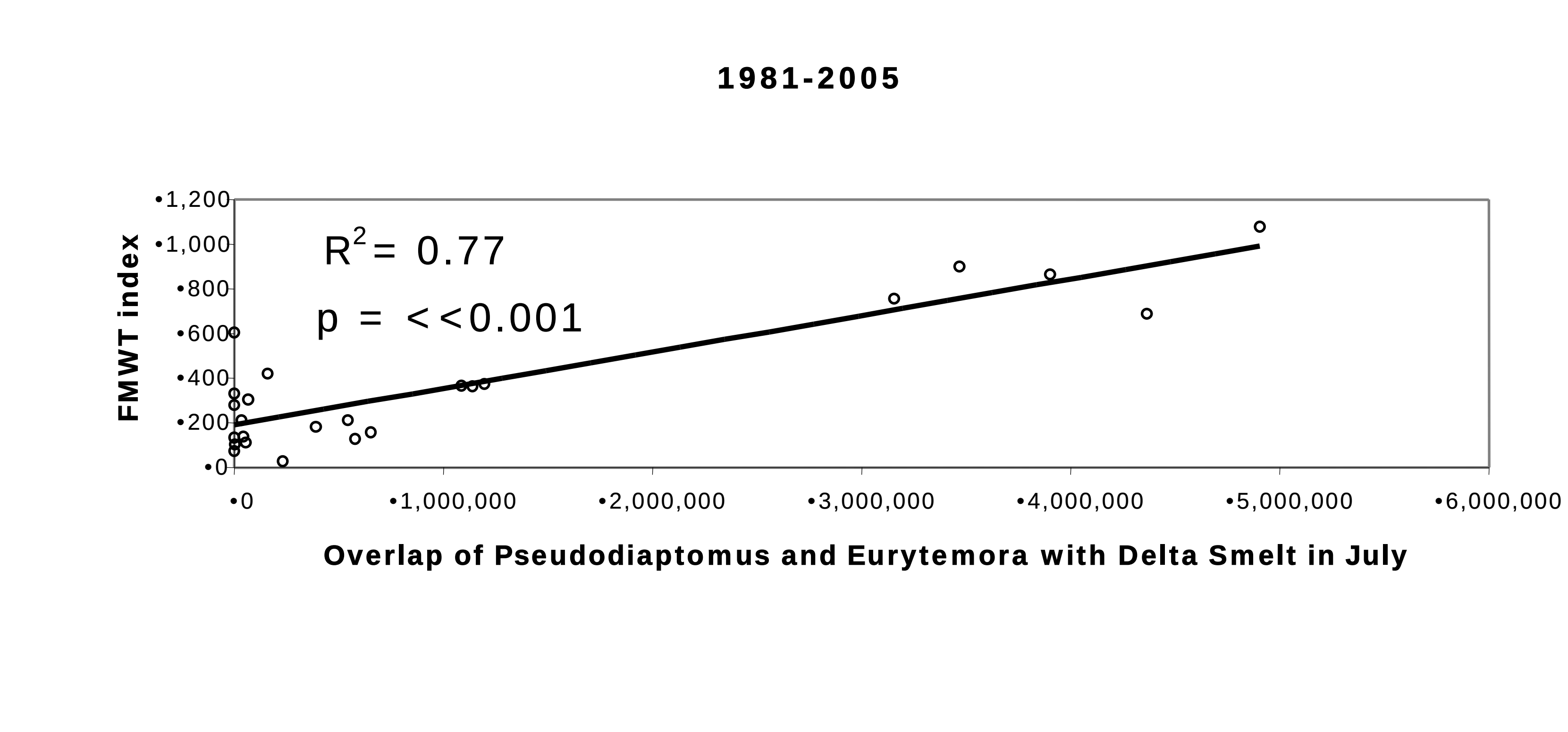
Adapted from John Durand (SFSU)

P. forbesi & *E. affinis* Abundance in Suisun Bay is Affected by Upstream Subsidies and Clam Grazing



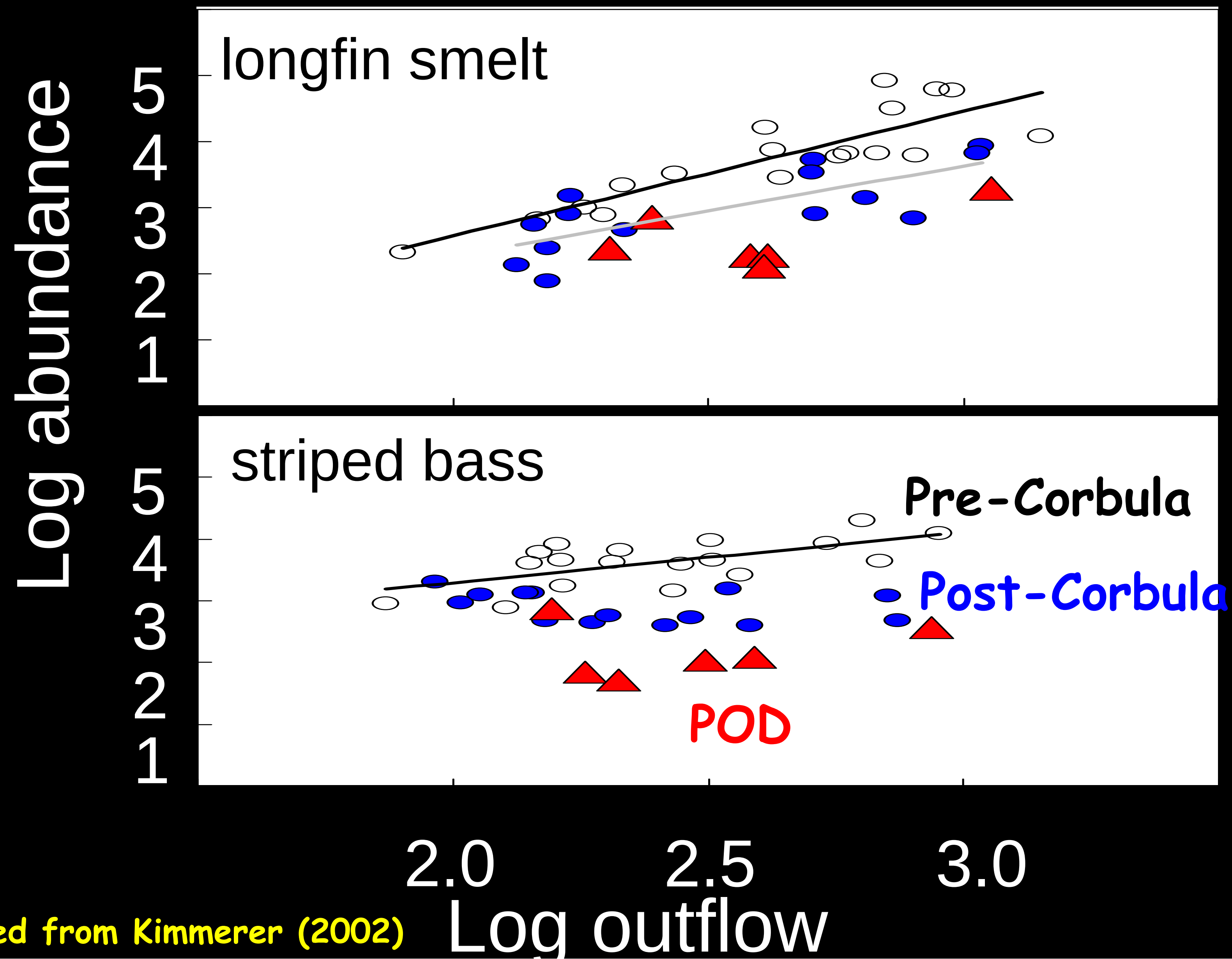
Adapted from John Durand (SFSU)

Overlap with Food Species Helps Predict Adult Delta Smelt Recruitment

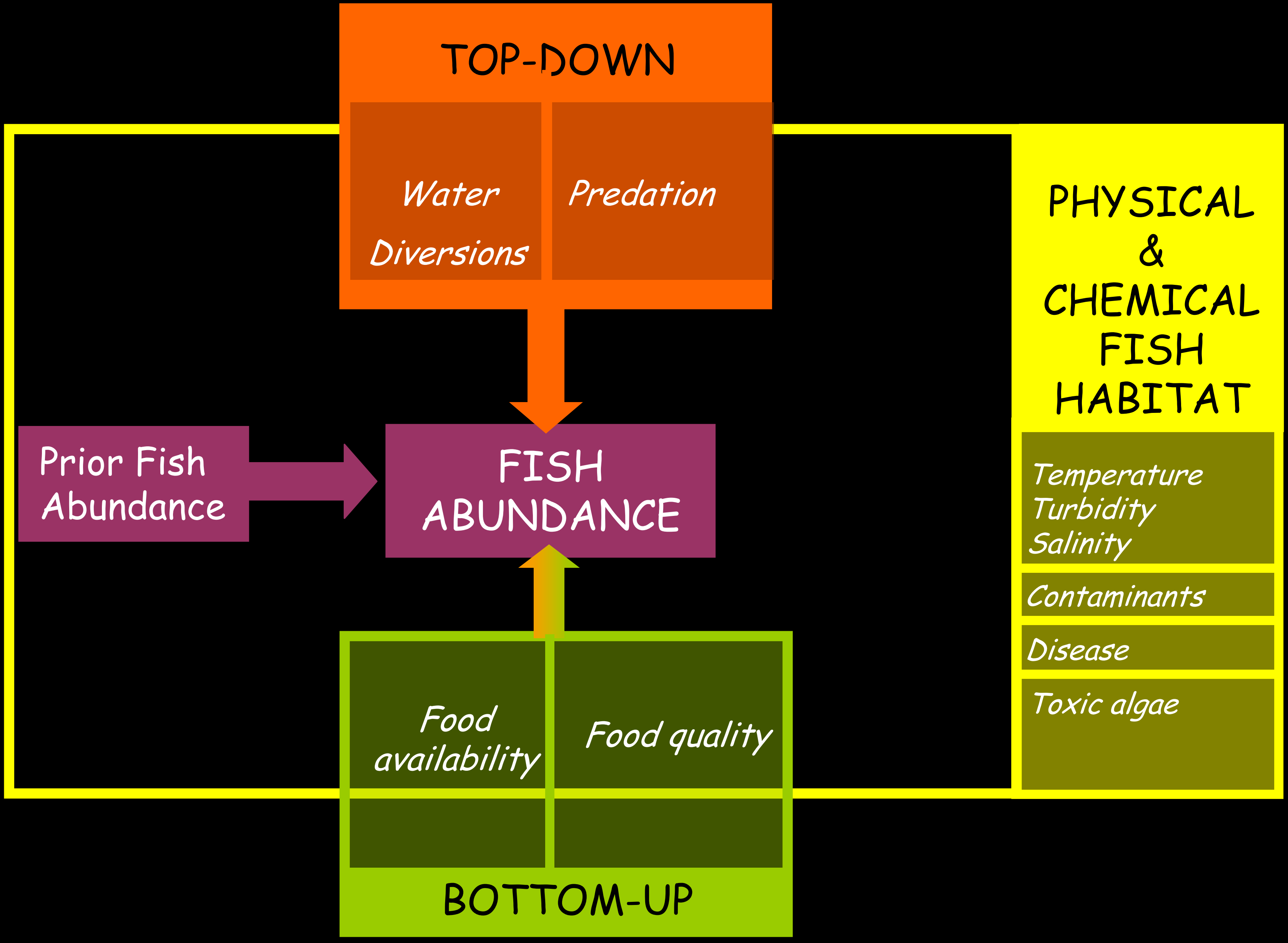


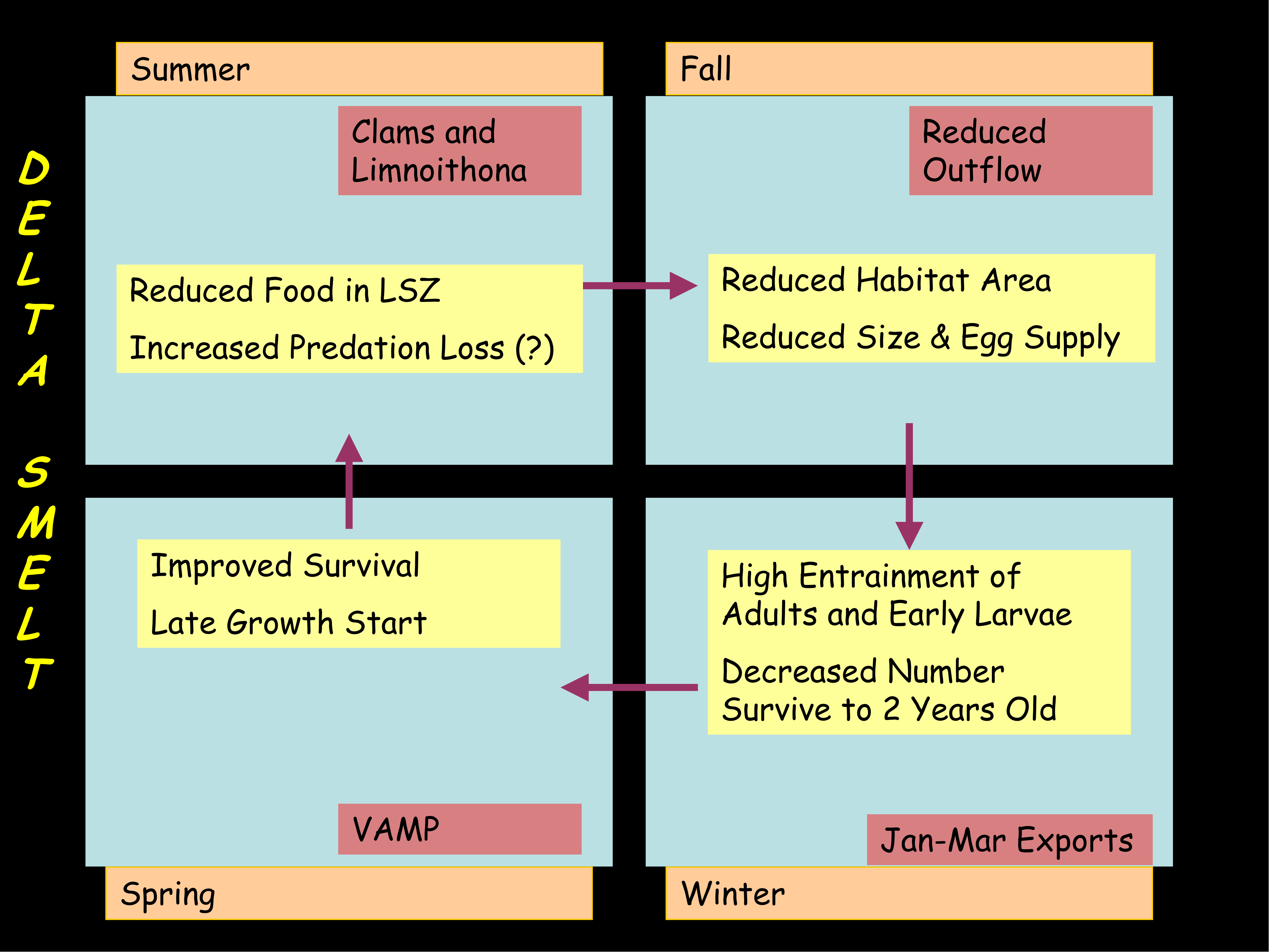
Source: BJ Miller

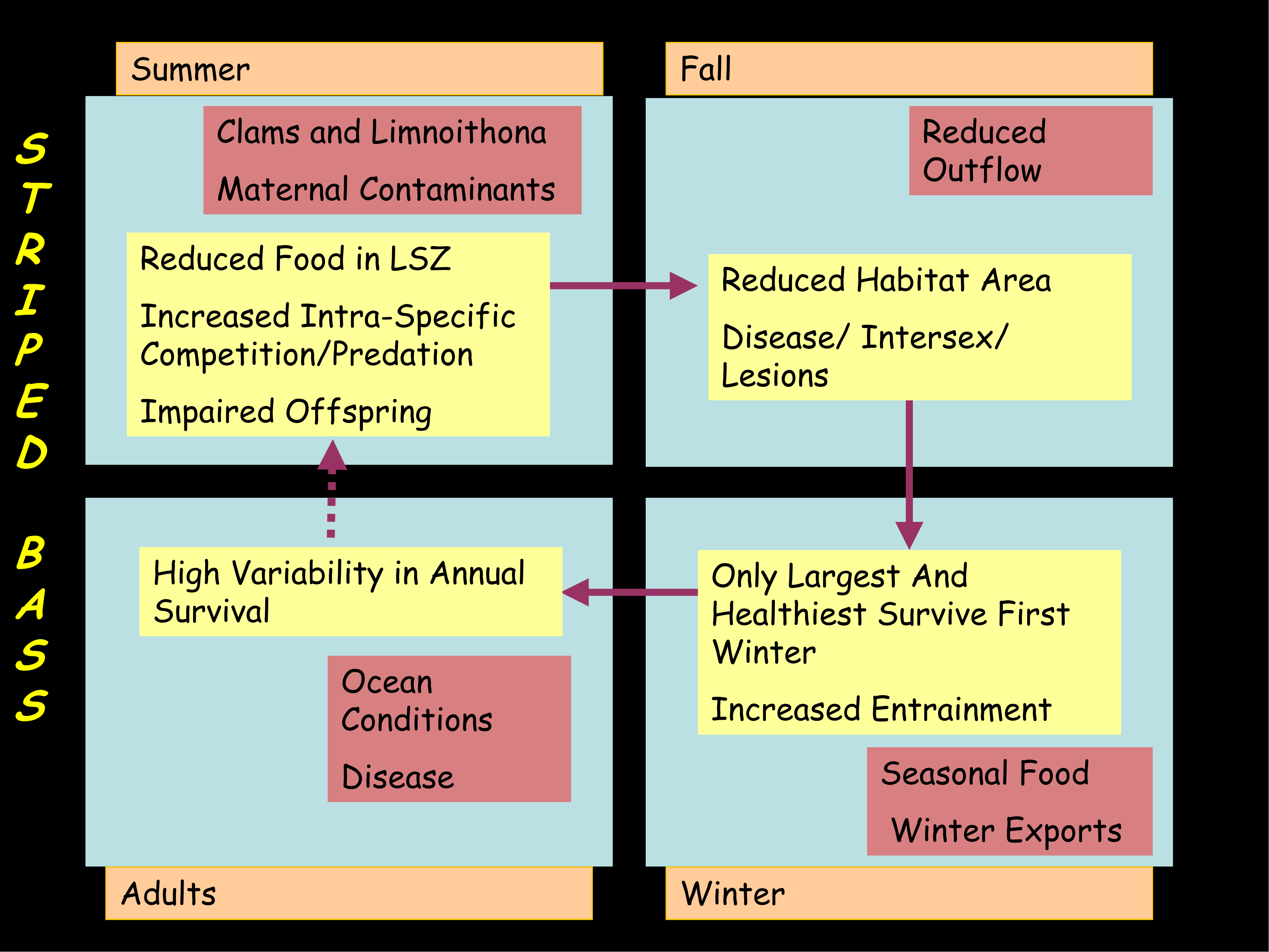
Reduced Food Availability Affects Abundance-Outflow Relationships

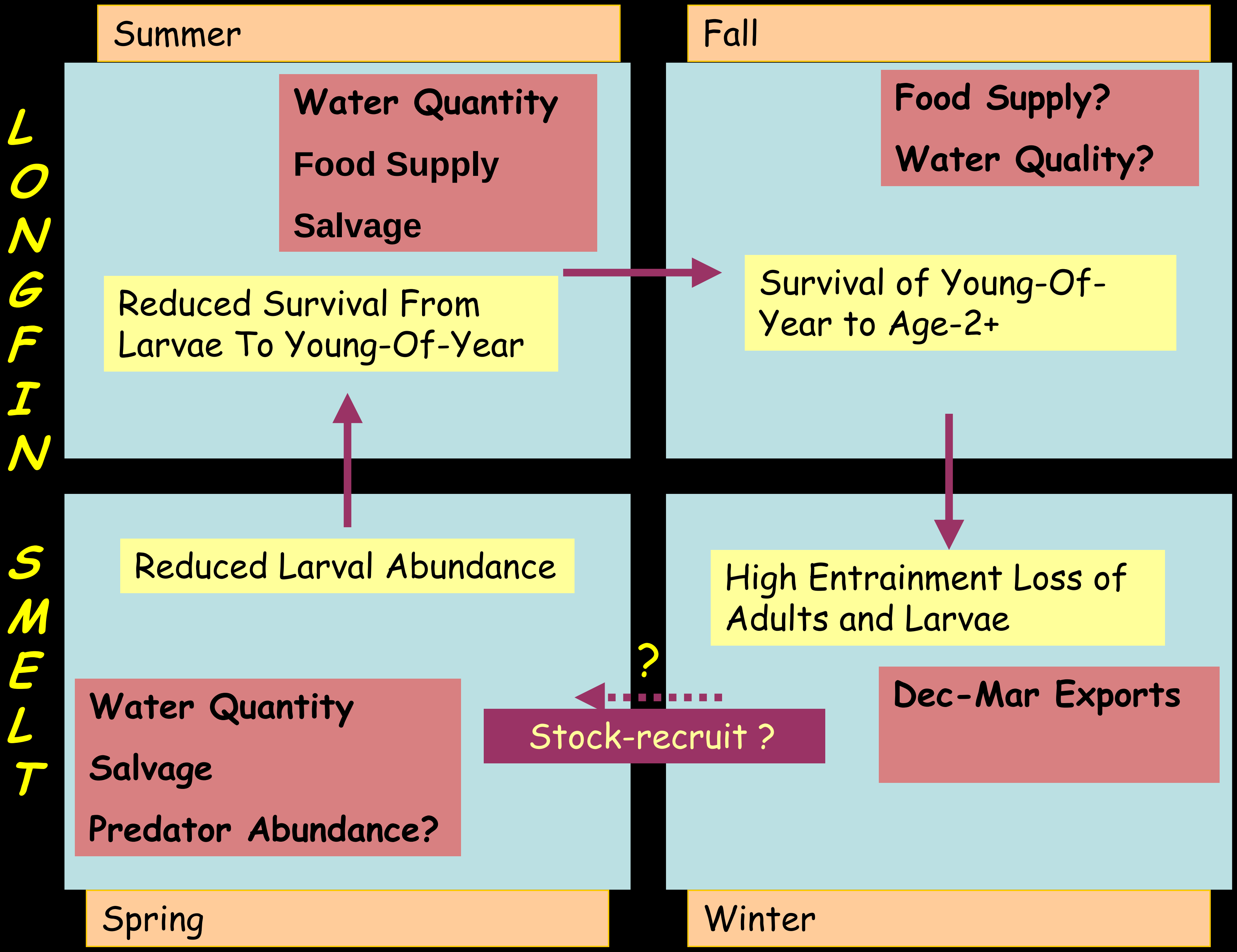


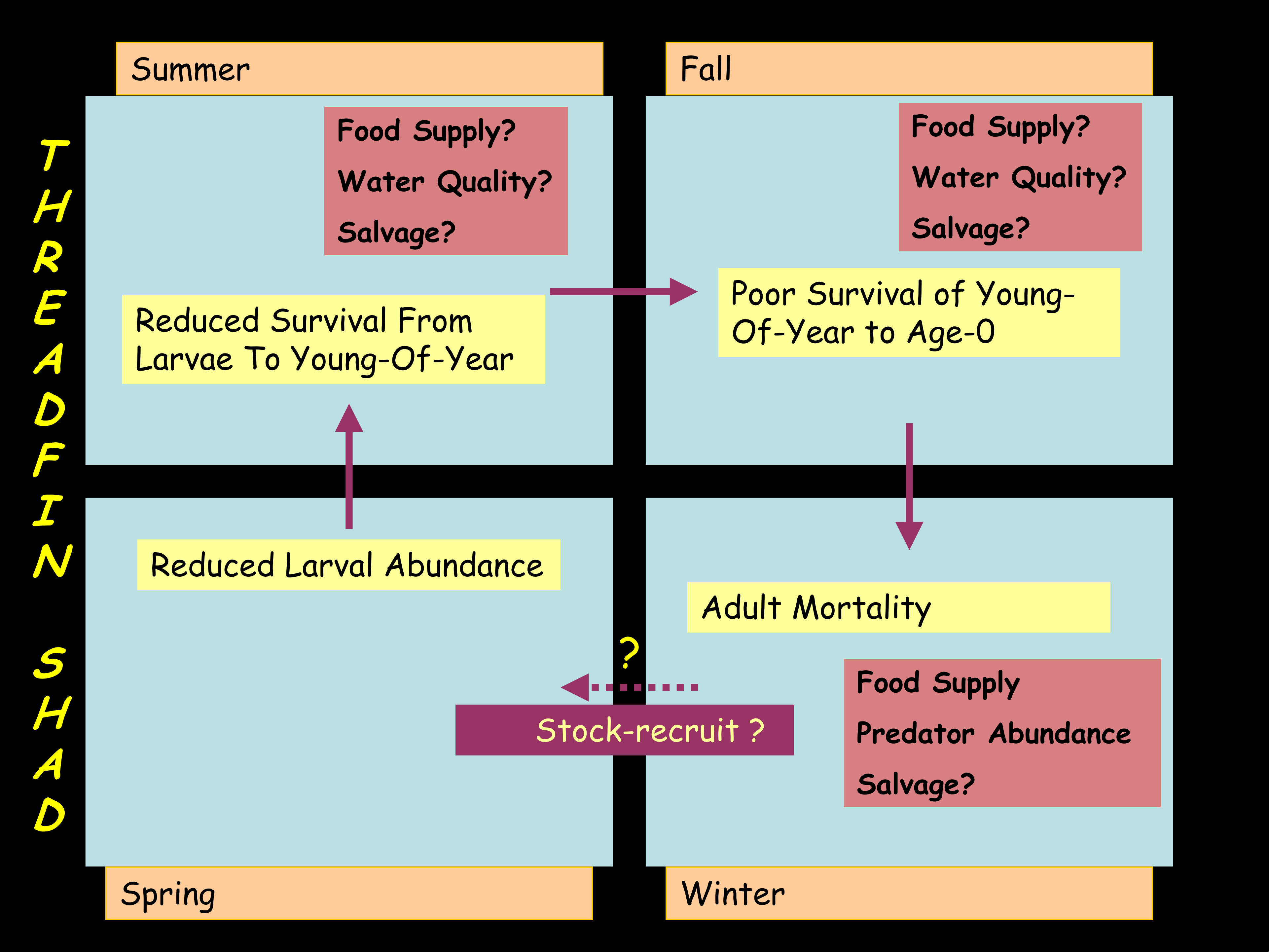
Adapted from Kimmerer (2002)


TOP-DOWN
Water Diversions
Predation
PHYSICAL & CHEMICAL FISH HABITAT
Prior Fish Abundance
FISH ABUNDANCE
Temperature
Turbidity
Salinity
Contaminants
Disease
Toxic algae
Food availability
Food quality
BOTTOM-UP


DELTA SMELT
Summer
Clams and Limnoithona
Reduced Food in LSZ
Increased Predation Loss (?)
Fall
Reduced Outflow
Reduced Habitat Area
Reduced Size & Egg Supply
Winter
High Entrainment of Adults and Early Larvae
Decreased Number Survive to 2 Years Old
Jan-Mar Exports
Spring
Improved Survival
Late Growth Start
VAMP


STRIPED BASS
Summer
Clams and Limnoithona
Maternal Contaminants
Reduced Food in LSZ
Increased Intra-Specific Competition/Predation
Impaired Offspring
Fall
Reduced Outflow
Reduced Habitat Area
Disease/ Intersex/ Lesions
Only Largest And Healthiest Survive First Winter
Increased Entrainment
Seasonal Food
Winter Exports
Winter
High Variability in Annual Survival
Ocean Conditions
Disease
Adults


LONGFIN SMELT
Summer
Water Quantity
Food Supply
Salvage
Reduced Survival From Larvae To Young-Of-Year
Fall
Food Supply?
Water Quality?
Survival of Young-Of-Year to Age-2+
Winter
High Entrainment Loss of Adults and Larvae
Dec-Mar Exports
Spring
Reduced Larval Abundance
Water Quantity
Salvage
Predator Abundance?
?
Stock-recruit ?


THREADFIN SHAD
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

2006-2007 POD Studies

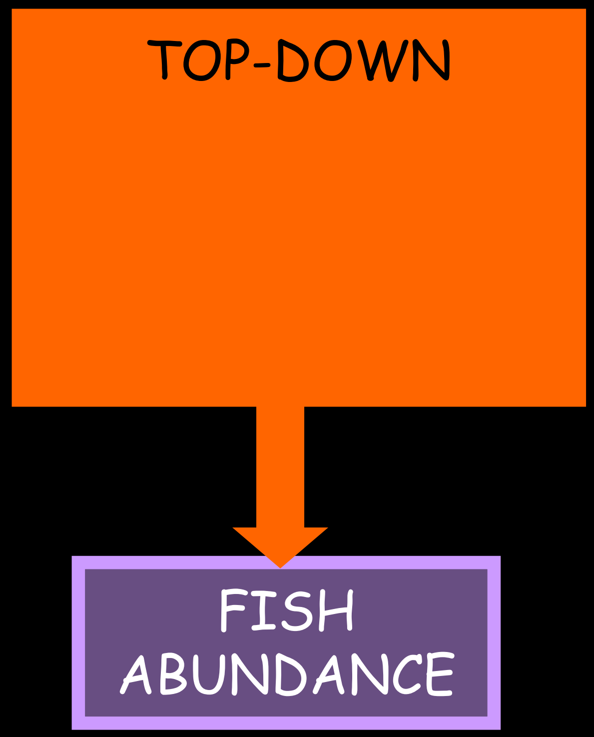
- 2006 Budget $3.7 + million
- 60 study components

Prior Abundance → PRESENT ABUNDANCE

-Fish and Zooplankton Surveys (DFG)
-Gear Efficiency Studies (DFG)
-Pelagic Fish Population and Egg Supply Estimates (DFG/USFWS)
-Threadfin Shad Population Dynamics (DWR)
-Statistical Analyses of Fish Abundance Trends (USBR/Manly)
-Delta Smelt Growth and Survival (UCD)
-Delta Smelt Stock Structure (UCD)
-Trends in Apparent Growth Rates (DFG)

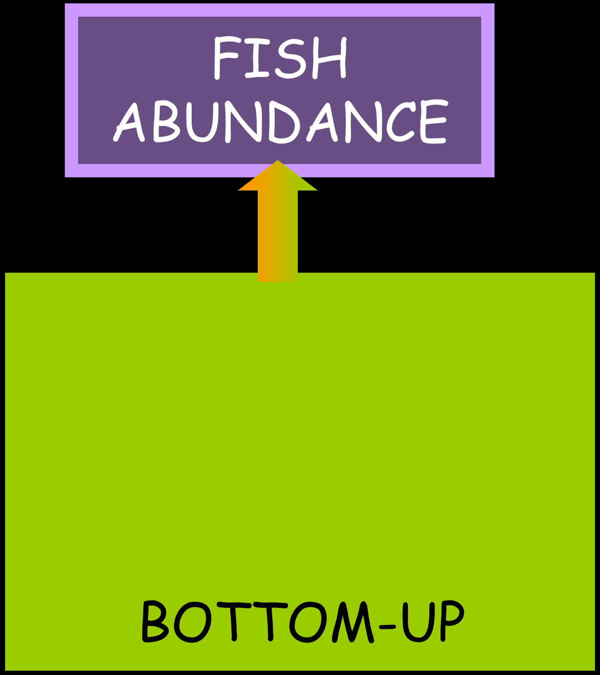
PHYSICAL & CHEMICAL FISH HABITAT

- -Fall and Summer Habitat Trends (DWR)
- -Temporal and Spatial Changes in Habitat (EPA)
- -Trends in Aquatic Weeds (UCD)
- -Effects of Aquatic Weeds on Turbidity (USGS)
- -Bioassays (UCD)
- -Fish Pathology (UCD, USFWS)
- -Climate Effects (USGS)
- -Hydrologic Changes (USGS)
- -Microcystis Studies (DWR)
- -Salinity Effects on Clams (SFSU)



-Effect of Fish Behavior on Entrainment Risk (DWR)
-Effects of Hydrodynamics on Fish Salvage Trends (USGS)
-Particle Tracking Simulations of Entrainment (DWR)
-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)

- Phytoplankton Trends (UCD)
- Zooplankton Trends (DWR)
- Zooplankton Community Structure (SFSU)
- Sources of Food Web Disruption (SFSU/UCD)
- Changes in Benthic Biomass and Abundance (DWR)
- Fish Diet and Condition (DFG)
- Food Match/Mismatch (DFG)



Synthesis: Next Steps

- 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

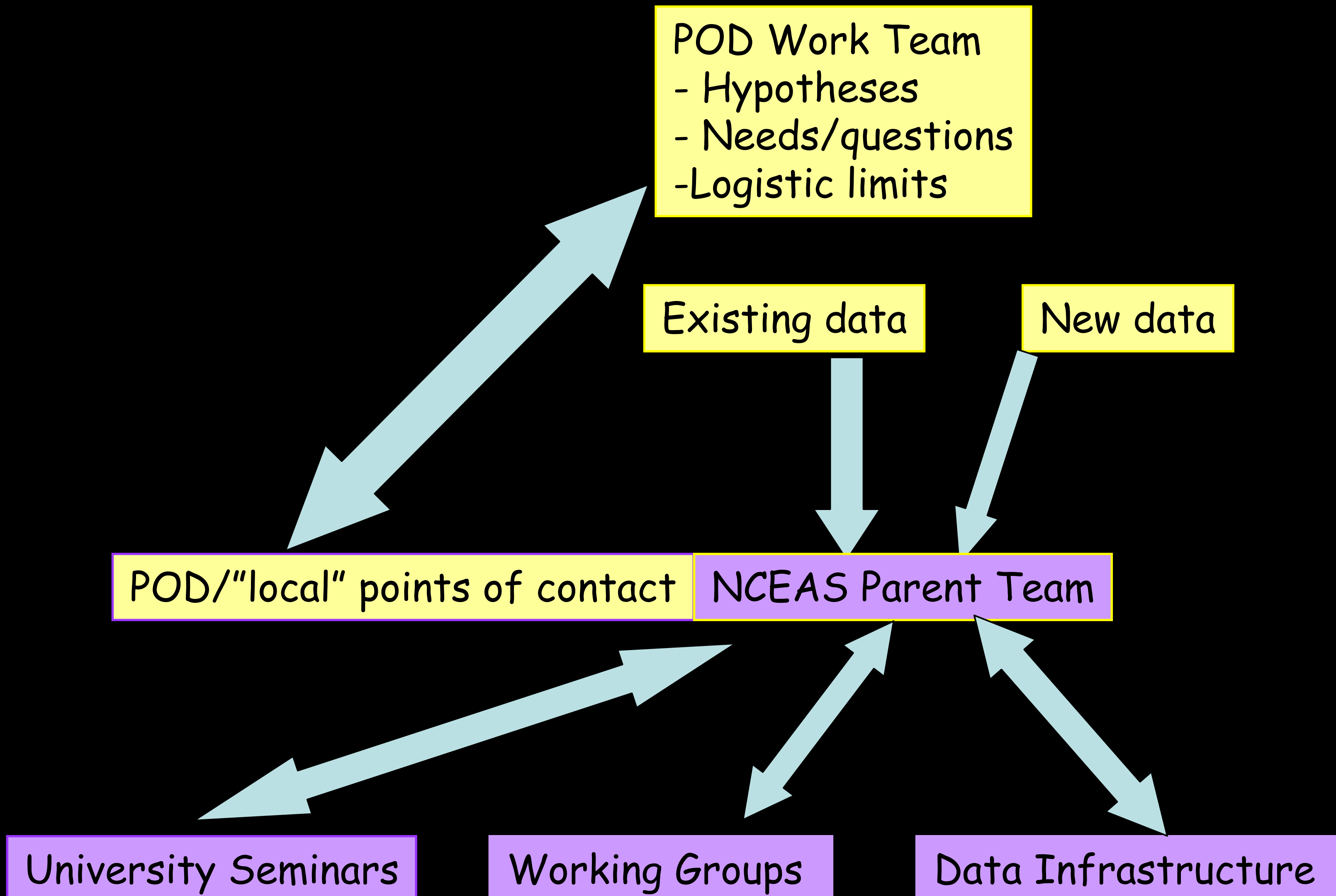
  National Center for Environmental Analysis and Synthesis (NCEAS), UCSB

NATIONAL CENTER for ECOLOGICAL ANALYSIS and SYNTHESIS

UCSB

- Neutral location, setting, facilities, equipment, and staff to support focused synthetic work
- >400 projects conducted by more than 3700 participants (~45% non-academic)
- > 1200 publications in respected, peer-reviewed journals
- In top 1% of 38,000 scientific institutions in citations in ecology

NATIONAL CENTER for ECOLOGICAL ANALYSIS and SYNTHESIS
UCSB



Parent Team Members

Fish Health – Daniel Schlenk, UC Riverside

Fish Population Modeling – Julian Dodson, Universite Laval

Geospatial Statistics – Dave Krolich, ECorp

Ecosystem Modeling - George Jackson, Texas A&M

Estuarine Hydrodynamics – Dave Jewett, US EPA

POD Timeline for Review

- Project Work Teams (Continuous)
- Peer-Reviewed Publications (Continuous)
- Presentations at Major Meetings
  - American Fisheries Society National Meeting (Sep 2007)
  - State of the Estuary Conference (Oct 2007)
- Completion of Study Elements (Fall 2007-2008)
- POD/NCEAS Synthesis Report I (Late 2007)
- Review by CALFED Science (Late 2007)
- POD/NCEAS Synthesis Report II (2008)

Planning

e.g. Pelagic Fish Action Plan, Delta Vision, CALFED, BDCP, SDIP, DRMS, IEP...

Operations

e.g. Delta Smelt Working Group, Water Operations Management Team, Data Assessment Team ...

POD Investigations

Studies, Review, Synthesis, Presentations, Publications

Questions?