POD Update: January 2008

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Ted Sommer, DWR
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Pelagic (Open Water) Habitat
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

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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 Fish Abundance

Home

Food

Bottom-up

Loss

Top-down

Physical & Chemical Fish Habitat

Parents
Prior Abundance

PRESENT ABUNDANCE

Updates
- 2007 abundance data.
- "Population" estimates.
Stock - Recruitment Effects

Juvenile Production

POD Years

Threadfin shad

Delta smelt

Fall Midwater Trawl (Adults)
Have Delta Smelt Dropped Below Critical Population Levels?

R² = 0.88

Recent Trend

Source: Anke Mueller-Solger (DWR); IEP (2007)
Summer abundance in 2007 once again very low.

Delta Smelt

Striped Bass

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**: Second lowest in 2007 with an index of 28.
- **Striped Bass**: Third lowest in 2007 with an index of 82.
- **Longfin Smelt**: Record low in 2007 with an index of 14.
- **Threadfin Shad**: Record high in 2007 with an index of 3177.
How Do Recent Abundance Levels Compare to Historical Relationships With Flow?

Sommer et al. (2007)
Corbula Shifted Abundance-Outflow Relationships

- longfin smelt
- striped bass

Sommer et al. (2007)
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
FISH ABUNDANCE

PHYSICAL & CHEMICAL FISH HABITAT

- Temperature
- Turbidity
- Salinity
- Nutrients
- Contaminants
- Disease
- Toxic algae

Updates
- Mechanisms for habitat changes.
- Possible new insight into toxicity (e.g. NH3, 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

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

Fish & zooplankton collection
Invertebrate toxicity test sites
Sites with invertebrate toxicity in 2007
POD & Nutrients

The Good

The Bad

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

Increasing Ammonia levels in Delta and Suisun Bay

Sewage Treatment Plants

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

50% “Effect Level” ~ 0.012 mg/L
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)
How should biomarkers be used to determine whether contaminants significantly stress POD fishes?

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 Entrainment of Adult Delta Smelt During Winter

Source: IEP (2005), Grimaldo et al. (In prep)
Winter Salvage of Other Pelagic Fishes

- **Adult Longfin Smelt**
- **Age 1+ Striped Bass**
- **Threadfin Shad**

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

$r^2 = 0.31, p<0.05$

Combined Old & Middle River Flow (cfs)

Mean Values for December–March 1993–2005

Source: Source Lenny Grimaldo (In Review)
What Explains the Differences in Delta Smelt Salvage Between Years?

<table>
<thead>
<tr>
<th></th>
<th>Juveniles</th>
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Source: Lenny Grimaldo et al. (In prep)
## What Affects Delta Smelt Salvage Within a Given Year?

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Source: Lenny Grimaldo et al. (In prep)
Do Water Diversions Have a Significant Effect on Adult Delta Smelt Abundance?

Exports or Old and Middle River Flow

Delta Smelt Catch

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?
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*

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

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

**Striped Bass**

- Shift in X2 relationship after *Corbula* introduction.

**Longfin Smelt**

- Early survival correlated with zooplankton.

**Threadfin Shad**

Sources: Kimmerer (2002); Nobriga (In review); Feyrer and Sommer (Unpublished data)
FISH ABUNDANCE

PHYSICAL & CHEMICAL FISH HABITAT

TOP-DOWN

Water Divisions
Predation

Prior Fish Abundance

FISH ABUNDANCE

Temperature
Turbidity
Salinity
Contaminants
Disease
Toxic algae

Food availability
Food quality

BOTTOM-UP
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

Typical Recent Fall Distribution
Fall Salinity Intrusion May Reduce Fish Survival or Condition
“First Flush” Triggers Upstream Movement
Upstream Movement is Active Migration
Many Potential Migration Cues...

- Reduced food
- Reduced light
- Reduced water velocity
- Change in "smell"
- Reduced temperature
- Time of Year
- Reduced food
Many Potential Migration Cues...

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

- Faster water velocity
- Reduced temperature
- Change in "smell"
- Reduced light
- Time of Year
- Reduced food
Fish Migrate Quickly in Groups
Smelt Do Not “Home” To Natal Spawning Sites
Smelt Hold For Long Periods Before Spawning
Summer

- Reduced Food in LSZ
- Increased Predation Loss (?)
- Clams and Limnoithona

Spring

- Improved Survival
- Late Growth Start

Fall

- Reduced Habitat Area
- Reduced Size & Egg Supply
- Reduced Outflow

Winter

- High Entrainment of Adults and Early Larvae
- Decreased Number Survive to 2 Years Old
- Jan-Mar Exports
Summer - LSZ

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

Fall - LSZ

- Reduced Habitat Area
- Disease/Intersex/Lesions

Winter - LSZ

- Only Largest And Healthiest Survive First Winter
- Increased Entrainment

Clams and Limnoithona
Maternal Contaminants

High Variability in Annual Survival

Ocean Conditions
Disease

Seasonal Food Winter Exports

Reduced Outflow
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+

Spring - Bay

Water Quantity
Salvage
Predator Abundance?

Reduced Larval Abundance

Winter - Delta

High Entrainment Loss of Adults and Larvae

Dec-Mar Exports

Stock-recruit
Reduced Survival From Larvae To Young-Of-Year

Reduced Larval Abundance

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

Adult Mortality

Food Supply?
Water Quality?
Salvage?

Food Supply?
Water Quality?
Salvage?
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)
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<td>DWR, USGS</td>
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<td>Turbidity Sources and Signals</td>
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<td>Hydrologic Changes</td>
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<td>Salinity Effects on Clams</td>
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<td>Fish Tissue Selenium Analysis</td>
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- 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