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

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What Changes As Flow Increases?

- Nutrients
- Organic matter
- Sediment
- Fish

- Depth
- Salinity
- Salinity, Density
- Distance
- Proportion
- Diverted

- Location of Any Salinity Range
- X₂
- Delta Residence Time
- LSZ
- Nutrients
- Organic matter
- Sediment
- Fish

- Floodplains
- River Stage, Velocity
- Proportion Diverted

- Changes As Flow Increases?
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

Nauplii
Harpacticoids
Other Cyclopoids
Limnoithona
Other Calanoids
Acartiella
Sinocalanus
Pseudodiaptomus
Eurytemora

Adult
Juvenile

Net Smelt Spring
Net Smelt Summer

Slater & Baxter 2014 SFEWS
Kimmerer et al. 2014 JPR
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?
**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?

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P. forbesi seasonal pattern

Mean abundance, m⁻³

6 lowest flows
7 intermediate flows
6 highest flows

Month

Adults only
Freshwater
1994 – 2012
Mean by date

IEP Monitoring data
Productivity: Food-limited growth

Late Juveniles

Low-salinity Zone
Freshwater

Sacramento
San Joaquin

Growth Rate / Max

Chlorophyll > 5 \( \mu \text{m} \)
mg m\(^{-3} \)

Freshwater Flow
m\(^3\)s\(^{-1} \)

0.1 1 10
0.5
1.0
30 100 200 1000

Chlorophyll > 5 \( \mu \text{m} \)

mg m\(^{-3} \)
Productivity: Mortality rates

San Joaquin River freshwater stations

Juveniles

Adults

Mortality d\(^{-1}\)

Station values
Survey means

2010 2011 2012
*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?

Fall MWT Index, CA DFW
Abundance unrelated to flow in fall…

Flow, m$^3$s$^{-1}$

Abundance, m$^{-3}$

Low-salinity Zone
Sacramento
San Joaquin

Adults & Juveniles

Kimmerer et al. in prep.
Abundance in LSZ increases at high flows

Juveniles

Flow, m$^3$s$^{-1}$

Abundance, m$^{-3}$

Adults

June

September

2011

IEP monitoring data
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?
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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 m$^3$s$^{-1}$

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