Hydrodynamics structure zooplankton-phytoplankton interactions over a 7-year period in the Sacramento Deep-Water Ship Channel

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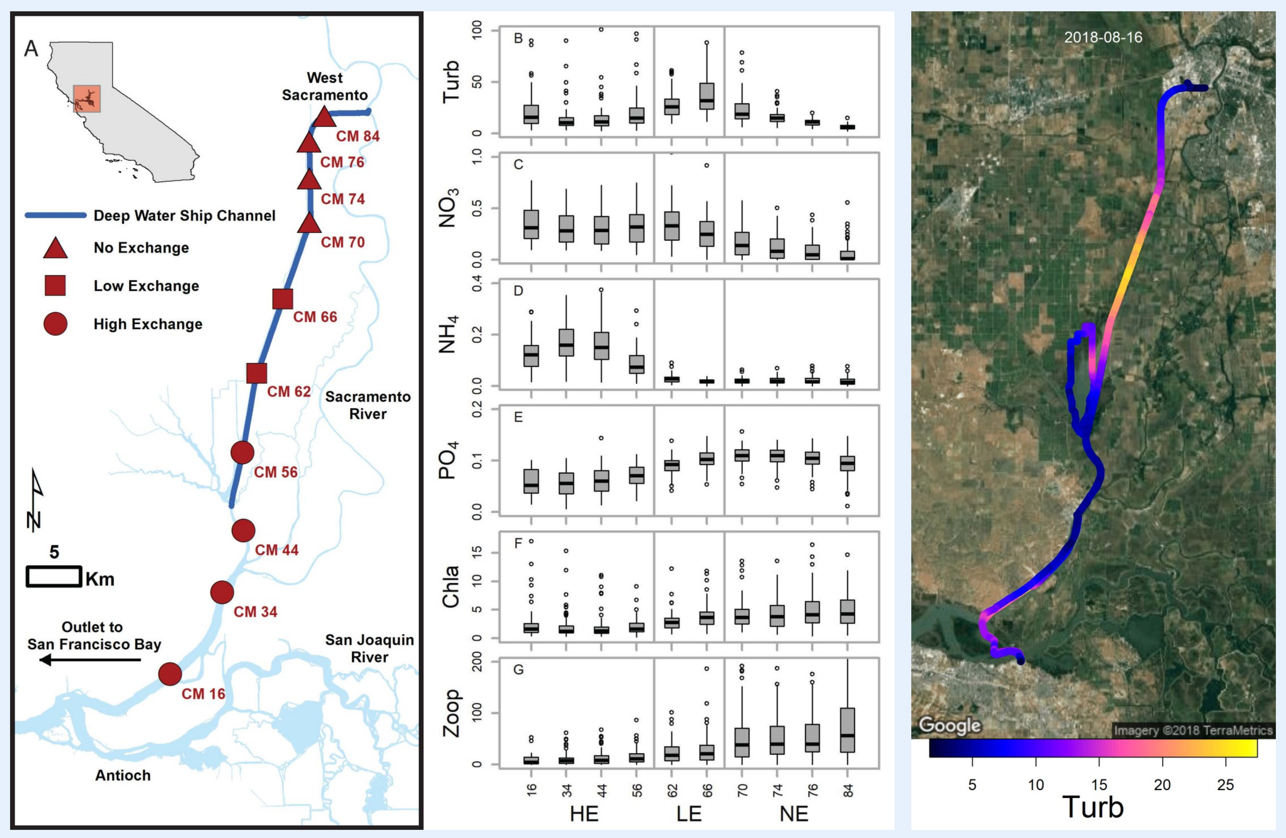
Drivers of plankton biomass in the North Delta: what can we learn from a 'simple' terminal system?

- Higher trophic levels of the pelagic food web in San Francisco Estuary (SFE) are food-limited
- Terminal channels and sloughs still support high chlorophyll and zooplankton biomass
- Zooplanktivorous fishes such as Delta Smelt and Threadfin Shad occupy these habitats [1]
- Difficult to quantify drivers of phytoplankton and zooplankton in spatially and temporally complex estuaries—can a simple artificial system help our understanding?

Study Site: Sacramento Deep Water Ship Channel

- Seaward to landward gradient in hydrodynamic exchange[2], turbidity, and water chemistry
- Sampled 10 fixed stations ~ monthly from 2012 – 2019 (n=74), spanning spatial gradients



Landward

No Exchange (NE) Zone

Long water residence time (weeks-months)
Low dissolved inorganic N (DIN)
Low turbidity

Low Exchange (LE) Zone

Residence time > 7 days
High DIN
High turbidity

High Exchange (HE) Zone

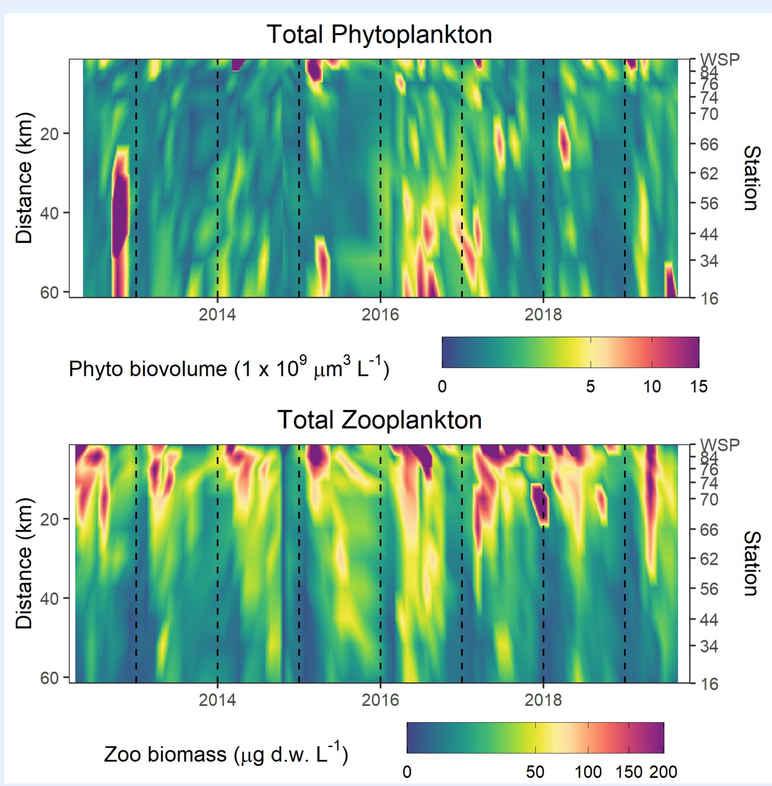
Daily tidal exchange
High DIN
Moderate turbidity

Seaward

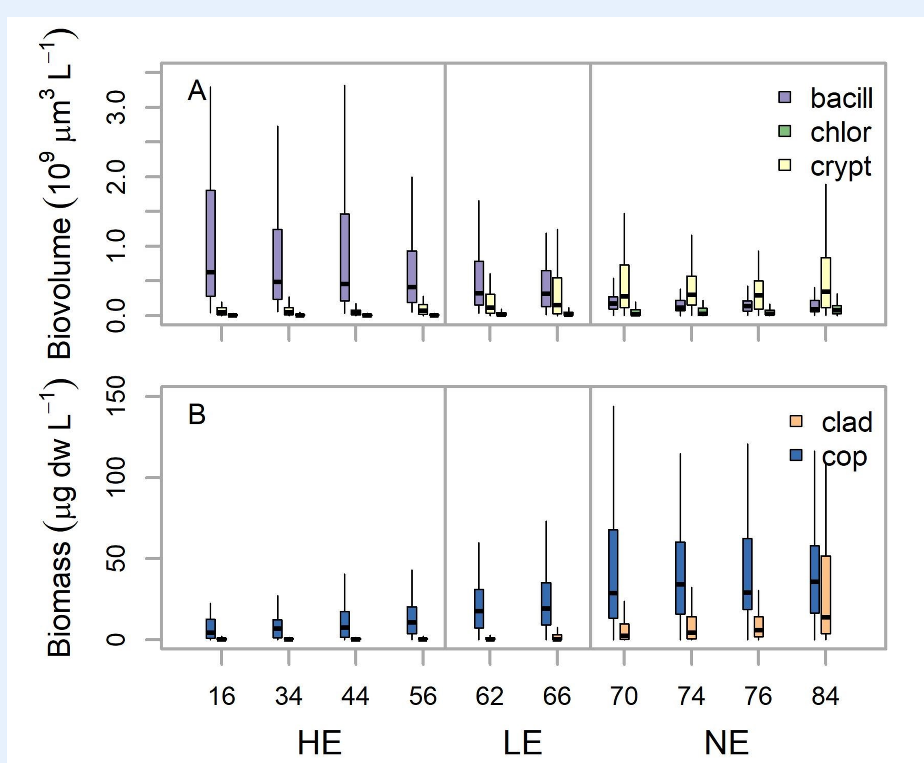
a) Sampling stations within each hydrodynamic exchange zone. b-g) Turbidity (NTU), nitrate (mg N L^{-1}), ammonium (mg N L^{-1}), phosphate (mg P L^{-1}), chlorophyll-a (µg L^{-1}), and zooplankton biomass (µg dw L^{-1}) at each station. Stations ordered from seaward (HE) to landward (NE) along x-axis.

Plankton biomass and community composition differ among hydrodynamic zones

- Lower phytoplankton biovolume in landward direction, but higher chlorophyll-a
- Diatoms (bacillariophyta) dominate seaward reaches, cryptophytes dominate landward reaches
- Higher zooplankton biomass in landward direction
- Copepods dominate throughout the DWSC, but cladoceran biomass highest in landward reaches



Spatial and temporal patterns in total phytoplankton and zooplankton biomass

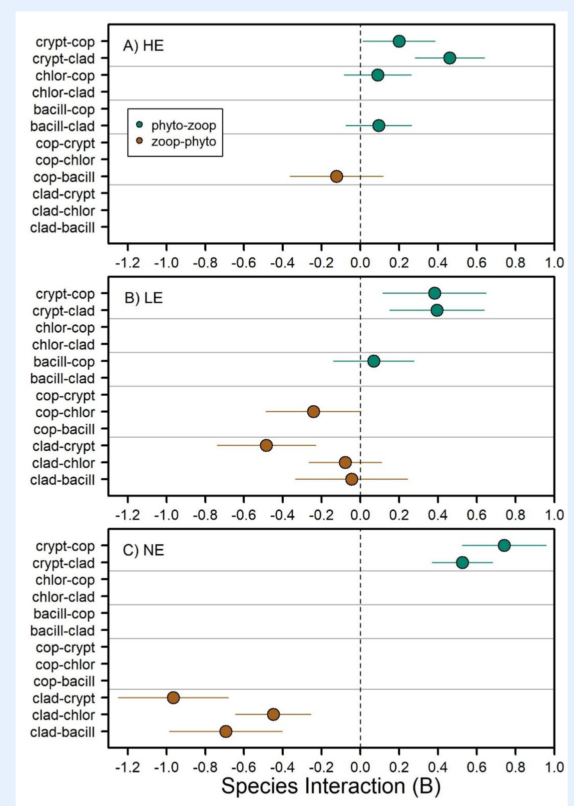


Biomass of dominant phytoplankton (A) and zooplankton (B) taxa at each station

Takeaways and Implications

1. Trophic interactions between zooplankton and phytoplankton were strongest in landward reaches with long residence times
2. The effects of trophic interactions were stronger than effects of all abiotic drivers except for water temperature
3. Chlorophyll-a and total phytoplankton were poor predictors of zooplankton dynamics—monitoring specific phytoplankton taxa is important for food web studies

Q1: Do trophic interactions between zooplankton and phytoplankton vary across environmental gradients?

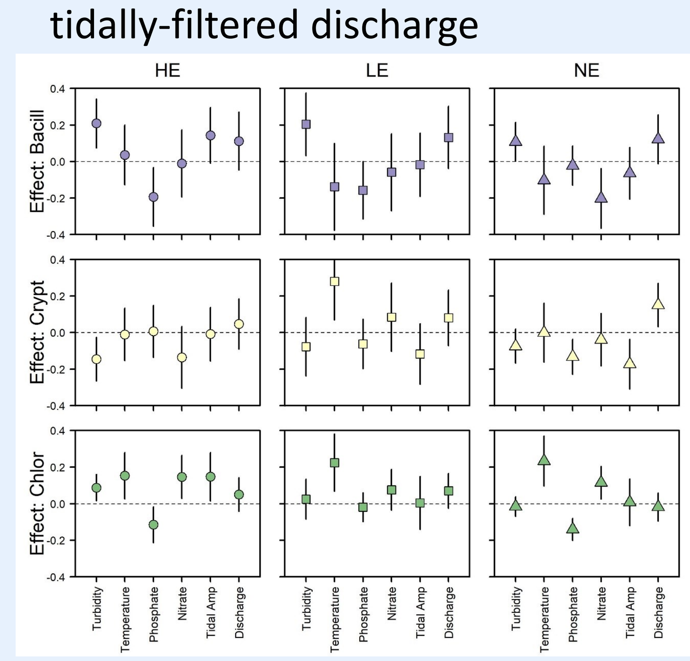


- Stronger bottom-up and top-down interactions between phytoplankton and zooplankton in landward reaches with long residence time
- Cryptophytes have positive bottom-up effects on both copepods and cladocerans
- Cladocerans, not copepods, have strong top-down effects on phytoplankton

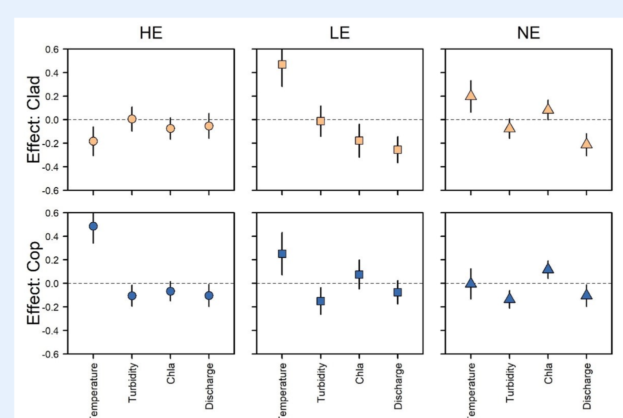
Standardized effects (x-axes) of phytoplankton on zooplankton ('bottom-up effects'; green dots) and zooplankton on phytoplankton ('top-down'; brown dots) in each hydrodynamic zone (A-C). Y-axis labels show all potential interactions ('taxa1-taxa2' refers to the effect of taxa 1 on taxa 2). 95% CI's spanning zero show a non-significant effect.

Q2: Do environmental drivers of phytoplankton and zooplankton dynamics vary along a hydrodynamic gradient?

- Significant spatial and taxonomic differences in effects of drivers
- Strongest phytoplankton drivers: turbidity, phosphate, water temperature (i.e. 'season')
- Strongest zooplankton drivers: water temperature ('season'), turbidity, tidally-filtered discharge



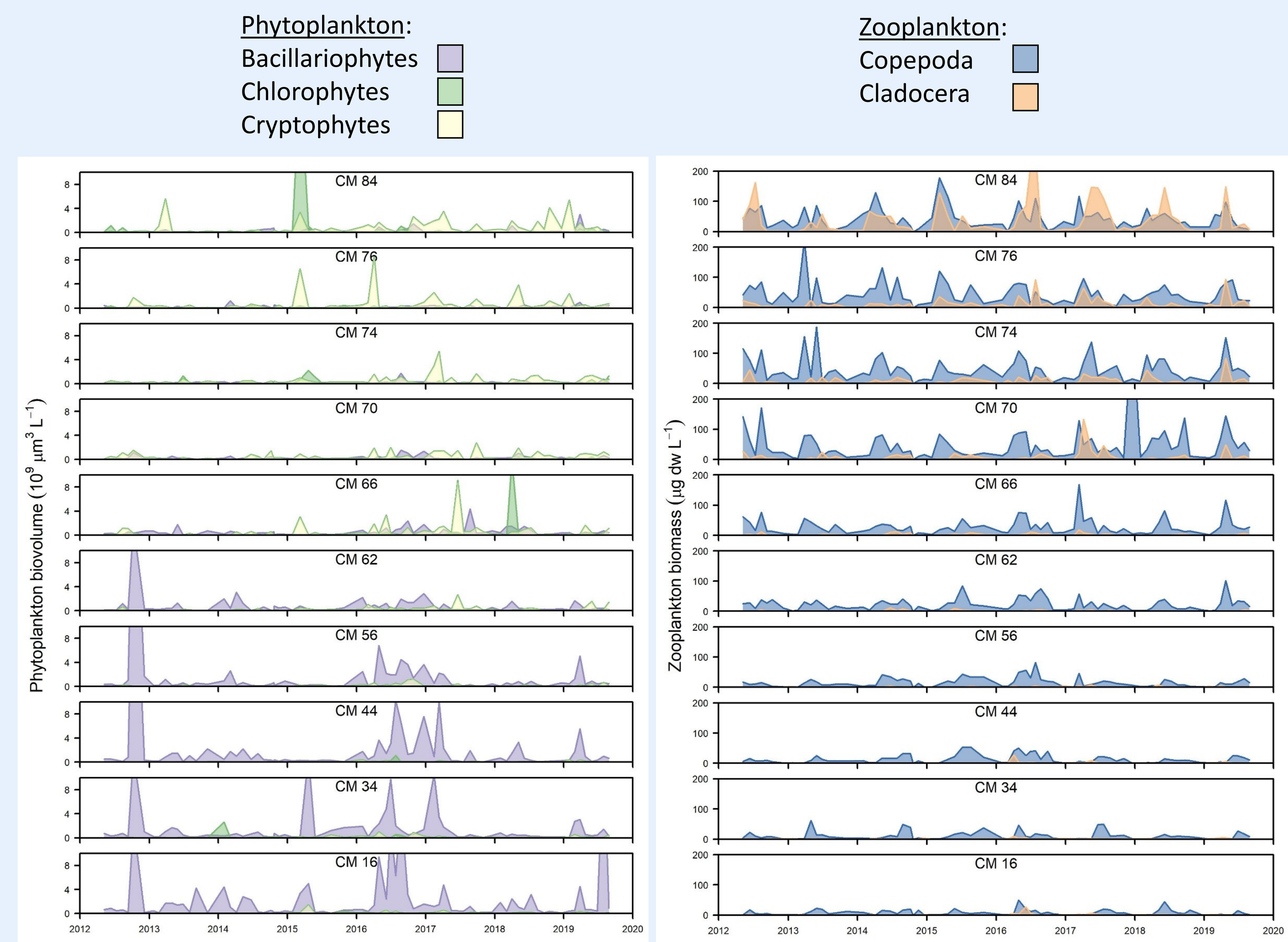
Standardized effects of environmental drivers (y-axis) on phytoplankton taxa (rows) in each hydrodynamic zone (columns)



Standardized effects of environmental drivers (y-axis) on zooplankton taxa (rows) in each hydrodynamic zone (columns)

Modelling Approach

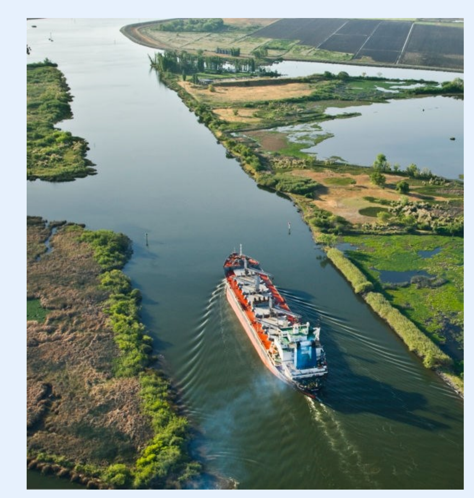
- Used multivariate autoregressive state space (MARSS) models to estimate effects of environmental drivers (ex. turbidity) for major taxa in each hydrodynamic zone
- Models also estimated trophic interactions between the major zooplankton and phytoplankton taxa in each zone
- Time series were standardized to allow comparison of effect sizes among taxa and hydrodynamic zones



Phytoplankton and zooplankton time series used in models. Stations arranged from landward (top) to seaward (bottom)

Next steps:

- Model seasonal variation in zooplankton-phytoplankton interactions, and add predators (zooplanktivorous fishes)
- Model interactions at finer taxonomic resolution or among functional groups
- Investigate controls in phytoplankton at shorter time scales



References

1. Sommer, T., & Mejia, F. (2013). A place to call home: A synthesis of delta smelt habitat in the upper San Francisco estuary. San Francisco Estuary and Watershed Science, 11(2).
2. Stumpner, P. R., Burau, J. R., & Forrest, A. L. (2020). A Lagrangian-to-Eulerian Metric to Identify Estuarine Pelagic Habitats. Estuaries and Coasts, 44(5), 1231–1249.

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