Trophic Ecology of Zooplankton and Larval Fish the Cache Slough Complex

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The San Francisco Bay-Delta food web production and linkages appear to be declining. Much of that decline is thought to be related to a large phytoplankton decline that occurred after the 1987 introduction of the Asian clam, *Potamocorbula amurensis.* However, the role of the Delta's detrital food web may also be compromised because areas of emergent wetlands in the Bay-Delta are now extremely limited. Detritus-based food webs, however, have received relatively little attention in the region. Given the historical Bay-Delta landscape, non-phytoplankton detrital material could play an important role in supporting planktivores such as delta smelt and other analogous pelagic fishes.

For this project, we tracked food web relationships among primary producers, zooplankton, and larval fish in the Cache Slough Complex- a tidal freshwater region in the north delta exhibiting high numbers of larval delta smelt, as well as emergent marsh ecosystems. We characterized variation in primary prey taxa of planktivorous larval fish (delta smelt, threadfin shad, Mississippi silversides, gobies, and prickly sculpin). We compared larval fish diets across species, as well as across time (April-June 2015), and among six locations representing vegetated and open water habitats. We found minimal differences in diet across space, time, and species. Diets of the larval fish species examined were dominated by the non-indigenous calanoid copepod *Pseudodiaptomus forbesi* (59-100% numerically), followed by rotifers and other unidentifiable copepods. This reflected the assemblage structure of mesozooplankton sampled concurrently with the larval fish, which was also dominated by *P. forbesi*.

Another goal of our study was to determine the respective contributions of phytoplankton and detrital organic matter as food web sources supporting larval fish and zooplankton. Stable isotope (MSI) signatures of larval fish and zooplankton indicate that a mixture of detritus from within the Liberty Island/Cache Slough Complex, phytoplankton and filamentous green algae.

Keywords: food web, larval fish, zooplankton

Poster Topic: Food Webs

Are there Non-Target Impacts of *Eichhornia crassipes* Management on Aquatic Invertebrate Communities?

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We investigated the impacts of *Eichhornia crassipes* management on aquatic invertebrate communities of the Sacramento-San Joaquin River Delta. Using a Before, After, Control, Intervention (BACI) experimental design, we sampled aquatic invertebrate communities per plant biomass before and four weeks after herbicide application in *Eichhornia crassipes* mats. We selected five herbicide treatment locations paired with five control locations. For each sampling event, we collected four random samples of plants and associated invertebrates per site using a custom-built ¼ m^2 quadrat with a 250µm mesh pouch. Invertebrates were preserved in 70% ethanol and sorted to genus level in the laboratory. Plant material was dried and weighed to obtain dry biomass measures. Our assessment of treatment versus control locations before and after the time of treatment indicates that seasonality has a stronger influence on invertebrate abundance and diversity measures than weed management activities. The abundance of invertebrates per plant biomass collected four weeks after the time of treatment was approximately 8% greater at control locations and approximately 10% greater at treatment locations – neither constituting a significant difference. Neither species richness nor evenness are significantly different before and after treatment. The primary community-level difference noted before and after treatment is a significant rise in the number of predators present after treatment. For example, spiders and damselflies are significantly more abundant after treatment and may eventually contribute to increased top-down controls of primary consumer populations. This research is important for informing management decisions surrounding aquatic vegetation and the ways in which management may impact littoral food webs. Overall the impacts of current treatment activities appear to be minimal for invertebrate communities associated with water hyacinth. These findings are useful given the urgency for aggressive water hyacinth management in the Delta and indicate that current management practices are not strongly influencing Delta invertebrate food webs.

Keywords: *Eichhornia crassipes* management, aquatic invertebrate communities, non-target impacts, food webs

Poster Topic: Food Webs

Response of the Yolo Bypass Floodplain to a Spring Flow Pulse

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The Yolo Bypass is the largest floodplain to the Central Valley, with complex hydrology that includes Sacramento River floodwaters and flows from a series of west-side tributaries. This complex network of tributaries all flow into the Toe Drain channel on the east side of the Bypass, which maintains year-round connectivity to the Sacramento-San Joaquin Delta. Much like other seasonal floodplains, late-winter and spring inundation of the Yolo Bypass has shown to enhance both local and downstream phytoplankton productivity. Previous Yolo Bypass floodplain studies have supported the flood-pulse concept (Junk et al 1986), providing evidence that variability in river-floodplain connectivity benefited in-channel phytoplankton biomass. In March 2016, the Yolo Bypass experienced a two week period of floodwaters from the Fremont Weir that inundated the floodplain for approximately three weeks. As a result of continuous data collected in the Toe Drain below Lisbon Weir by a multi-parameter water-quality instrument, we were able to capture a high resolution time-series of estimated chlorophyll-*a* (chl *a*) trends as they varied before, during, and after the inundation period. We further analyzed how the chl *a* concentrations related to key physical variables such as flow, stage, water temperature, turbidity, and specific conductance. Initial analyses show that there are significant differences before, during, and after floodplain inundation for all physical variables (ANOVA $p < 0.001$), with a notable increase in mean water temperature and a decrease in turbidity as the floodplain drained into the Toe Drain. In addition, water temperature and specific conductance were strongly correlated to changing chl *a* concentrations (Pearson Correlation $p<0.001$), throughout the flooding event. Our analyses provide further insight for managers seeking to learn more about the Yolo Bypass floodplain as it functions in local and downstream food web production and export.

Keywords: Yolo Bypass, floodplains, flow, chlorophyll a

Poster Topic: Food Webs

What's For Dinner? A Compositional Study of Particulate Organic Carbon in the San Francisco Bay-Delta

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The San Francisco Bay-Delta boasts an expansive historical data record ranging from fish population surveys to real-time water quality monitoring, but surprisingly little is known about the variability in particulate organic carbon (POC) across time and space and its effect on the lower food web. POC is a major source of energy for zooplankton, which lie at the base of the aquatic food chain. The sources of POC are diverse, especially in dynamic tidal systems such as the San Francisco Bay-Delta. Autochthonous POC may be attributed to phytoplankton, submersed or floating aquatic vegetation, or non-phytoplankton microalgae. Riverine detritus, agricultural drainage, and urban runoff may also contribute to an allochthonous pool of POC that can be processed by the lower food web. As part of a larger study linking POC sources with zooplankton growth, we collected POC samples seasonally along a transect from San Pablo Bay to the Sacramento-San Joaquin Delta, where sampling sites were selected to take advantage of the rich historical survey and monitoring data. Samples were analyzed for lignin, chlorophyll a, $\delta^{13}C$, and $\delta^{15}N$. Feeding experiments with the calanoid copepod *Eurytemora affinis* were conducted in order to assess the relative bioavailability of collected POC. This work sheds light on the spatial and temporal heterogeneity in POC composition, and, linked with water quality monitoring data, may help to predict shifts in carbon sources to the San Francisco Bay-Delta food web with changes in land-use and climate.

Keywords: particulate organic carbon, food web, source

Poster Topic: Food Webs

Is the Cache Slough Complex a Source Region for Zooplankton in the Upper San Francisco Estuary?

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The Cache Slough Complex (CSC) is a highly productive area that supports a resident population of delta smelt. Our project is part of a collaboration among several research groups to determine what makes the CSC good fish habitat and its importance as a source of zooplankton prey for fishes. Our specific focus was on estimating the flux of zooplankton between the shallow flooded islands and channels that connect the CSC to the broader estuary. The southern entrance of Liberty Island was chosen for initial field work because an Acoustic Doppler Current Profiler had been installed there and calibrated to provide high-frequency measurements of discharge needed to calculate the flux of zooplankton. We sampled semi-continuously over a complete tidal cycle during 3 discrete events in June, July and October of 2015. Zooplankton were collected with a submersible pump deployed at 1 m depth and discharging into a 150 um net. Samples were collected for 20 minutes every half hour for 26 hours. The target species, the calanoid copepod *Pseudodiaptomus forbesi*, was identified to gross life stage and counted. The flux of copepods was calculated as the summed product of volumetric discharge and zooplankton abundance. Copepodites were patchy and their highly variable abundance was uncorrelated with flow. Preliminary results with adult abundance suggest no net flux in June, a landward flux into Liberty Island in July, and a possible weak seaward flux out of Liberty Island in October.

Relevance: It is commonly thought that zooplankton produced in shallow habitats are exported to provide a source for the larger estuary. Our results so far do not support this theory; however, similar flux measurements should be made in other locations in the CSC and elsewhere to broaden our understanding of the magnitude and conditions leading to export fluxes.

Keywords: copepods, flux, Liberty Island

Poster Topic: Food Webs

Carbon Uptake by Single Celled Microalgae in the Benthic and Pelagic Zones of Historical Wetlands

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Wetlands of the San Francisco Estuary (SFE) comprise many different hydrological and morphological environments. These diverse habitats provide a variety of ecosystem services, such as carbon sequestration and food web support through organic matter production and export. Due to this provision, former wetlands- both of the SFE and globally- that were historically diked off for agriculture or development are now being converted back to prior condition in order to restore ecosystem processes. At present comprehensive functioning of SFE aquatic wetlands and the ecosystem services they provide are not well defined to enable evaluation of such restoration. This study determined rates of primary production by benthic and pelagic microalgae in historic wetlands to evaluate their relative impacts on carbon cycling and provide a potential framework to evaluate future wetland restoration efforts. Microalgal biomass (chlorophyll concentrations) and productivity ($H^{13}CO_3^-$ uptake) were measured monthly along with nutrients and dissolved inorganic carbon from February to October at two historic wetlands, China Camp State Park (San Rafael, CA) and Rush Ranch Open Space Preserve (Suisun City, CA). Chlorophyll concentrations and areal primary production by benthic microalgae frequently exceeded that of the pelagic microalgae, despite the benthic algae having lower physiological carbon uptake. These results yield insight into the carbon cycling of single celled algae in historic wetlands and provide baseline knowledge for the potential of restored SFE habitats to provide valuable ecosystem services.

Keywords: Carbon cycling, microalgae, benthic, wetlands, restoration, organic subsidies

Poster Topic: Food Webs

Phytoplankton Community Structure in the Lower South Bay Margins

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There has been growing concern over eutrophication in the San Francisco Estuary. Historically this system has shown a strong resilience to the effects of eutrophication, however, over the past decade that resilience appears to be weakening in the form of increased phytoplankton blooms. In particular, the Lower South Bay (LSB) sub-embayment has relatively high nutrient levels because it receives discharge from three wastewater treatment plants. The nutrient inputs combined with a long hydraulic residence time of the shallow LSB raises additional concern for phytoplankton blooms and harmful algal blooms (HABs). There is also concern that restored and managed salt ponds in the LSB may promote growth for HAB species.

The San Jose- Santa Clara Regional Wastewater Facility (Facility), the largest wastewater treatment plant in the LSB, has been monitoring the water quality of LSB for decades. To address the growing concern of potential for eutrophication, we began phytoplankton monitoring in 2013 to track any changes in phytoplankton community structure and to gather baseline information on lower trophic level community composition. Our phytoplankton data show an overall dominance of diatoms in the bayward stations and an increase dinoflagellates in the margin areas (Alviso-Coyote Creek) where there are numerous restored and managed salt ponds. Also within this area is Artesian Slough, which showed the highest phytoplankton densities of our data set. This fresh to brackish slough receives discharge from the Facility as well as two managed salt ponds.

Currently, this is the only monitoring for phytoplankton species in the margins of the Lower South Bay. The tidal exchange between the Lower South Bay and its margins is extensive so it is imperative to characterize phytoplankton in this area to gain a better understanding of how it may vary between ponds and sloughs and during bloom periods.

Keywords: Phytoplankton, salt ponds, Lower South Bay, Harmful Algal Blooms

Poster Topic: Food Webs

Sacramento River Phytoplankton Growth: Relative Importance of River-Water Sources, Light, Nutrients, and Clam and Zooplankton Grazing

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Phytoplankton in the Sacramento River can be an important food source for other aquatic organisms, but phytoplankton biomass has been observed to decline along the river between the City of Sacramento and the confluence with Cache Slough. Recent studies suggest that phytoplankton decline in the river does not appear to be driven by effluent-derived nutrient concentrations. The goal of the project is to evaluate mechanistic factors that potentially limit phytoplankton growth within the Sacramento River. Our approach is to conduct a controlled mesocosm experiment to determine the relative importance of river-water sources, light availability, clam grazing, nutrient concentrations, and zooplankton grazing on phytoplankton growth. In June 2016 we will conduct a phytoplankton growth experiment in a series of 10-L cubitainers. Phytoplankton will be collected from two locations along the Sacramento River, <1 mile and 24 miles upstream of the Sacramento Regional Wastewater Treatment Plant (SRWTP). Phytoplankton will be held in a sheltered location within the river to determine population growth rates under different experimental treatments, including low and high light levels, presence and absence of bivalve grazing, and presence and absence of wastewater effluent, with three replicates each. Each cubitainer will be sampled at 24 and 48 hours for nutrient concentrations, dissolved silica, chlorophyll-a, picoplankton, and phytoplankton enumeration. Following final sampling, the remaining contents of each cubitainer will be used to conduct nutrient uptake experiments. The effect of microzooplankton grazing on phytoplankton biomass (chlorophyll-a) will be assessed in a separate set of 2-L cubitainers filled with varying dilution ratios of unfiltered river water and river water filtered to remove zooplankton, then held in the river for 24 hours. The results of the project will be of value in assessing phytoplankton productivity before the SRWTP upgrades (the EchoWater Project) and may be used to inform future management of the river ecosystem.

Keywords: Sacramento River, phytoplankton growth, mesocosm, light, clams, wastewater effluent, zooplankton

Poster Topic: Food Webs

The Molecular Ecology of SF Delta *Microcystis*

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Problem Statement: *Microcystis* blooms are a growing concern within the SF Delta food web due to their ability to produce harmful metabolites and because of their poor nutritional value. We hypothesized that these blooms may directly influence zooplankton fitness via the production of secondary metabolites (e.g., microcystin) or indirectly due to nutritional stress stemming from their ability to outcompete other beneficial algae (e.g., diatoms and cryptophytes).

Approach: We used a suite of genetic tools, including: quantitative PCR, amplicon and shotgun metagenomics in order to characterize the molecular ecology of SF Delta *Microcystis* blooms. Samples were collected from six sites during the summers of 2011-2012 (*n*=72). Physicochemical data were related to strain composition in order to assess whether certain habitat conditions selected for toxigenic strains of *Microcystis*.

Results: On the basis of 16S-23S rRNA ITS sequencing, we identified the presence of at least 10 strains of *Microcystis* within the freshwater region of the SF Delta, even though only two colony morphologies were observed. We estimate that at least six of these strains are capable of producing the hepatotoxin microcystin. We also identified *Microcystis* genes involved in the production of a number of other secondary metabolites that may negatively influence zooplankton fitness. A comparison of microbial community structure before, during and after a *Microcystis* bloom revealed a significant reduction in microbial diversity during the bloom.

Conclusions/Relevance: In this study, we identified the presence of several strains of *Microcystis* occurring within the Delta, each with the ability to produce a range of bioactive metabolites that may directly or indirectly influence the health and nutrition of key zooplankton species important to the food web. We speculate that trophic upgrading by bacterivorus microzooplankton may be an important link in the Delta food web worthy of future study.

Keywords: *Microcystis*, toxins, genetics, pelagic organism decline, food web

Poster Topic: Food Webs

Are Current Sampling Programs Accurately Describing Zooplankton Distributions on Scales Relevant to Feeding by Fish?

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We conducted a study of zooplankton distributions in the upper San Francisco Estuary at small scales (tens to hundreds of meters). The present study 1) assessed how representative the Interagency Ecological Program (IEP) zooplankton monitoring program is and 2) investigated the variability of plankton on scales similar to those of foraging by fish. Samples were taken near Brown's Island, West Island, and Big Break along the lower San Joaquin River. Sets of 6 samples were taken with a plankton net along transects from near shore to center channel, and sets of 10 samples were taken in the vicinity of a drifter. Sampling took place during June-July 2014 during neap and spring tides, ebb and flood, day and night. Analysis focused on three common copepod species. Transect samples showed little consistent variation along transects except that *Pseudodiaptomus forbesi* at Big Break was less abundant near shore than offshore by day. The ratio of adults to adults+copepodites was strongly related to turbidity by day but not by night, indicating demersal behavior. Drifter samples showed a minimum standard deviation of $\log_{10}$ sample counts of about 0.1, indicating that about 2/3 of replicate samples with adequate counts were within 80-125% of the mean. A measure of difference between plankton samples at pairs of stations was weakly related to distance between sample points but only at scales over ~300 m. These results show that the IEP sampling program is representative of plankton abundance considering small-scale and cross-channel variability, but not for demersal organisms which can be 10-fold more abundant by night than by day. Both sets of samples showed that small planktivorous fish could forage in patches of ~25% higher abundance of the mean.

Keywords: Copepod, Sacramento-San Joaquin Delta, patchiness, fish, demersal behavior, turbidity, salinity

Poster Topic: Food Webs

Delta Boundary Conditions: Plankton Communities and Water Quality in the Sacramento River and its Tributaries

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Phytoplankton in the Sacramento River can be an important food source for other aquatic organisms, but phytoplankton biomass has been observed to decline along the river between the city of Sacramento and the Cache Slough confluence. Recent studies by USGS and others investigating the effects of nutrients from Sacramento Regional Wastewater Treatment Plant (SRWTP) effluent on phytoplankton in the Sacramento River suggested that phytoplankton decline in the river does not appear to be primarily driven by effluent-derived nutrient concentrations. The goal of this project is to evaluate the importance of multiple factors that potentially limit phytoplankton growth within the Sacramento River. Our approach includes coupling a river survey with modeling of water sources and post-survey mapping of phytoplankton growth potential along the river. In May 2016 we conducted a 1-week survey of the river between Knights Landing and Isleton, sampling 11 sites on the mainstem river, and five tributaries along this reach. At each site we collected samples to assess water quality and to estimate the abundance of picoplankton, phytoplankton, microzooplankton, macrozooplankton, and to determine changes in phytoplankton growth rates. At the mainstem sites we also collected clams in five standardized trawls per site. Results will be presented for the variables noted above. River flow is being modeled to identify, for each survey location, the proportion of flow arising from different upstream sources. This research gives a snapshot of conditions along the Sacramento River to inform future management of the river ecosystem, and will provide critical data on Delta boundary conditions for coupled hydrological and ecological models of the river and Delta. The dataset will be of value in assessing river conditions before the SRWTP upgrades (the EchoWater Project), and will encourage the development of hypotheses for future studies to increase our understanding of how river management influences Delta conditions.

Keywords: Sacramento River, tributaries, management, water quality, nutrients, phytoplankton, zooplankton, clams

Poster Topic: Food Webs