Lower Food Web Dynamics of the Sacramento-San Joaquin Delta

Jennifer Bigman, Delta Science Program, Delta Stewardship Counil, jennifersbigman@gmail.com
Garrett Liles, Delta Science Program, Delta Stewardship Counil, garrett.liles@deltacouncil.ca.gov
Marina Brand, Delta Science Program, Delta Stewardship Counil, marina.brand@deltacouncil.ca.gov
Brian Bergamaschi, United States Geological Survey, bbergama@usgs.gov

The highly studied lower food web in the Sacramento-San Joaquin Delta involves many complex relationships and dynamics across its constituents (Bennett et al. 1995, Kimmerer 2004, Lehman 2004, Glibert 2010). Large shifts of both phytoplankton and zooplankton abundance and species composition have occurred over the last few decades (Lehman 1996, Jassby et al. 2002, Bollens et al. 2011, Winder and Jassby 2011). Declines of phytoplankton have occurred, as well as a shift from a largely diatom-dominated system to non-diatom species (Lehman 1996, Lehman 2000, Kimmerer 2004). Declines of many zooplankton species and the invasion of new species have greatly altered lower food web dynamics (Kimmerer 2004, Winder and Jassby 2011). These relationships are strongly influenced by various regulating factors that facilitate changes in the lower food web such as hydrodynamic transport mechanisms, light limitation, nutrient concentration, toxicity, and grazing by invasive clams (Lisa Lucas, workshop presentation, Alex Parker, workshop presentation, Jan Thompson, workshop presentation). The intense modification of the entire Delta system has also greatly influenced the lower food web of the ecosystem (Nichols 1986, Kimmerer 2004, Whipple et al. 2012). Understanding lower food web dynamics is crucial to providing insights regarding the overall functioning of the entire system. To synthesize our current knowledge on this topic, a symposium, *Lower Foodweb Dynamics in California's Bay-Delta Ecosystem: Current Understanding and Future Interactions with a Changing Landscape,* was held at the University of California, Davis, on February 18th, 2013. The purpose of this symposium was to provide recent scientific results that further inform the current state of knowledge regarding lower food web dynamics in the Bay-Delta system. The poster will summarize the results of this symposium.

Keywords: food webs, physical dynamics, zooplankton, phytoplankton

Poster topic: Food Webs

Impacts of Population Growth on the San Francisco Bay and Delta Ecosystem (SFE)

Curtiss Davis, Oregon State University, cdavis@coas.oregonstate.edu
Nicholas Tufillaro, Oregon State University, nbt@coas.oregonstate.edu
Richard Dugdale, RTC, San Francisco State University, rdugdale@sfsu.edu
Frances Wilkerson, RTC, San Francisco State University, fwilkers@sfsu.edu
Alex Parker, The California Maritime Academy, aparker@csum.edu
Fei Chai, University of Maine, Fei_Chai@umit.maine.edu
Yi Chao, Remote Sensing Solutions, Inc, ychao001@gmail.com

One challenge facing Earth system science is to understand and quantify the impacts and feedbacks of human influences on rivers and estuaries and coastal zone biology and ecology. This collective system has important interplay with human population and economics, especially in regions of high population density like the San Francisco Bay and Delta Ecosystem (SFE). The goal of this recently funded NASA Interdisciplinary Science project is to put in place an approach and modeling framework for the scientific basis of an ecosystem approach to the stewardship of the SFE including freshwater and marine resources within the SFE and adjacent ocean ecosystems. Our SFE project combines four components: (1) satellite observations, (MODIS, MERIS, HICO on the international space station, LDCM-OLI and in the future Sentinel-3 OLCI); (2) field observations (nutrients, phytoplankton, suspended sediments, CDOM and optical properties); (3) the CoSiNE ecological model integrated with (4) a SELFE hydrological model of SFE. This project builds upon long established remote sensing and field programs in the SFE and on the physical and biological models of the SFE being developed as part of the current NASA Interdisciplinary Science SESAME project to understand and predict variations in central California salmon populations. Our measurements and models will encompass the dynamics of the SFE in order to determine how increasing population density and demand for fresh water can affect this watershed including human impacts from its upper reaches to the continental shelf. We will explicitly include water diversion and flow management, nutrient inputs from sewage plants and other sources and the effects of the mix of nutrients on the phytoplankton populations in the SFE. Throughout this project we will share our data, model results and insights with SFE agency leaders responsible for managing this complex system.

Keywords: physical models, remote sensing, ecosystem modeling, nutrients, phytoplankton, water diversions

Poster topic: Food Webs

What Would Fish be without Food? How Herbicides Affect Aquatic Communities from Bottom-Up

Simone Hasenbein*, UC Davis Vet Med APC, shasenbein@ucdavis.edu
Sharon P. Lawler, Dept. of Entomology and Nematology, UC Davis, splawler@ucdavis.edu
Stephanie Fong, State and Federal Water Agency, Sacramento, CA, sfong@sfcwa.org
Jürgen Geist, Aquatic Systems Biology Unit, Technische Universität München, Germany, geist@wzw.tum.de
Richard E. Connon, UC Davis Vet Med APC, reconnon@ucdavis.edu

Herbicides, used in both agricultural and urban areas, are found in the Sacramento-San Joaquin Delta watershed at concentrations that are potentially toxic to phytoplankton. Furthermore, herbicides are directly applied to control invasive aquatic vegetation. Consequently, there is increasing concern over direct effects on primary production, and indirect effects on zooplankton and other aquatic invertebrates. Here we evaluate the effects of herbicides commonly detected in the Delta; diuron and hexazinone, as well as their degradates, on the algal species *Pseudokirchneriella subcapitata*, as well as on naturally developed invertebrate communities.

We first conducted laboratory exposures on *P. subcapitata* to determine effective concentrations for the herbicides, applied both individually and in mixtures, over 96h. We then assessed effects of environmentally relevant concentrations, as well as toxic concentrations determined in the study above, over a period of four months in outdoor mesocosms. Phytoplankton and periphyton growth, chlorophyll-α, zooplankton and macroinvertebrate communities were monitored.

Concentrations that are commonly detected in the Delta caused a significant decrease in growth of *P. subcapitata* in both single and mixture exposures. In the mesocosm study, chlorophyll-α was significantly decreased, associated with a negative trend in the abundance of aquatic invertebrates.

We present information on the impact of herbicide mixtures to both algal and aquatic invertebrate communities, as well as their interactions as important components of food web dynamics in the Delta. The information obtained is a valuable resource for future watershed management towards the protection of the fragile delta ecosystem.

Keywords: herbicides, algal species, mixture toxicity, aquatic communities, mesocosms

Poster topic: Food Webs

Analysis of Nutrient Mitigation and Organic Matter Production in Waters of Liberty Island

Tricia Lee*, Romberg Tiburon Center- San Francisco State University, triciall@mail.sfsu.edu
Nicole Travis, Romberg Tiburon Center- San Francisco State University, ntravis@mail.sfsu.com
Alexander Parker, The California Maritime Academy Romberg Tiburon Center- San Francisco State University, aparker@csum.edu
Frances Wilkerson, Romberg Tiburon Center- San Francisco State University, fwilkers@sfsu.edu
Tamara Kraus, USGS California Water Science Center, tkraus@usgs.gov
Brian Bergamaschi, USGS California Water Science Center, bbergama@usgs.gov
Richard Dugdale, Romberg Tiburon Center- San Francisco State University, rdugdale@sfsu.edu

Shallow, flooded and tidally influenced areas of the Sacramento-San Joaquin Delta are sites of increased water residence time compared to the faster flowing adjacent river ecosystem, thus providing the opportunity for phytoplankton nutrient uptake and growth. As such, flooded islands are thought to provide particulate organic carbon in the form of phytoplankton to support food webs of surrounding waters as a bottom-up influence (the outwelling hypothesis) and may serve as a sink for anthropogenic nutrients via phytoplankton uptake. One such flooded area, Liberty Island in the Cache Slough Complex, was monitored in spring 2014 in locations with a range of nutrient and chlorophyll concentrations. To observe phytoplankton response to the varying conditions, water for 10 L enclosure experiments was collected from three areas and monitored over a six-day period. As nitrogen concentrations and speciation (i.e. ammonium and nitrate) were spatially variable across the wetland, the phytoplankton communities showed different growth potentials when drawing down nitrogen in the enclosures. Nutrient and chlorophyll concentration data were compared between enclosures and the water column to assess the primary production and nutrient uptake in the absence of advective processes. Our analysis provides insight into how Liberty Island could be used as a model for management of flooded areas and development of restored wetland areas in the Delta to support organic carbon production and nutrient mitigation.

Keywords: Nutrients, Phytoplankton, Wetlands, Particulate Organic Material Production

Poster topic: Food Webs

Spatial and Temporal Variation in Aquatic Plant and Invertebrate Communities in Suisun Bay and the Sacramento-San Joaquin Delta

Jennifer Miller, Romberg Tiburon Center, SFSU, millerj@sfsu.edu
Evyan Borgnis, Romberg Tiburon Center, SFSU, elborgnis@gmail.com
Julien Moderan, Romberg Tiburon Center, SFSU, jmoderan@gmail.com
Katharyn Boyer, Romberg Tiburon Center, SFSU, katboyer@sfsu.edu

Having documented >1100 acres of native *Stuckenia* spp. (pondweeds) in Suisun Bay and west Delta, we conducted a survey to document patterns in plant and invertebrate assemblages along a salinity gradient from brackish to fresh. At 8 sites (4 in the Delta and 4 in Suisun Bay) we collected quarterly samples for 1 year of all plants and macro- and epiphytic algae present; extracted, identified, and counted all invertebrate species from these samples. We found Delta sites to be dominated by non-native *Egeria densa* in spring and summer, with a transition to higher species diversity by late summer/fall. This compares to the brackish Suisun sites being dominated mainly by *Stuckenia* spp. (*S. filiformis* and *S. pectinata*). We also found a wide range of spatial and seasonal variation in invertebrate species composition and abundance. In particular, we observed a large decline in abundance of all invertebrate species during winter in Suisun Bay, coinciding with the senescence of vegetation. Additionally, summer collections indicated dominance of gastropod species, and fall collections showed the greatest abundance and diversity of invertebrate and plant species. We also observed consistent spatial differences in invertebrate species composition, relating to the salinity gradient of our 8 sites from the fresh Delta to the saltier Suisun Bay. The most central site, which has intermediate salinity (Sherman Lake), hosts a mixture of the species residing in nearby sites. These results indicate relationships between salinities, season and both abundance and species composition of invertebrate species inhabiting submerged vegetation in the Delta and Suisun Bay. These findings may help predict subsequent invertebrate community diversity shifts and changes in abundance with foreseen climatic changes including increased salinity associated with sea level rise. The findings may also elucidate seasonal and spatial food source fluctuations for fish species of concern thought to feed on these invertebrates.

Keywords: Salinity, invertebrates, SAV, Stuckenia, Food webs, adaptation, habitat

Poster topic: Food Webs

Effect of a Diet Devoid of Docosahexaenoic Acid on Fish Larval Vision

Alejandro Ruiz*, UC Davis Vet Med APC (Anatomy, Physiology and Cell Biology), aruiz@ucdavis.edu
Swee Teh, UC Davis Vet Med APC (Anatomy, Physiology and Cell Biology), sjteh@ucdavis.edu

Diets containing omega-3 highly unsaturated fatty acids (HUFAs) such as docosahexaenoic acid (DHA) are essential for eye development and growth of fish. A laboratory study using larval medaka, *Oryzias latipes* was carried out to test the effect of early HUFA supplementation and deprivation on larval vision when their parents were fed a diet either supplemented (DHA+) or devoid (DHA-) of HUFA. Larvae from breeders given the DHA- diet improved their visual acuity when given the DHA+ diet after eight days of treatment. In contrast, the larvae from breeders given the DHA+ diet decreased their visual acuity when given the DHA- diet after sixteen days of diet treatment. Levels of Arachidonic acid (ARA) in the eye did not vary across the diet treatments and larval age. Linoleic acid (LA) was only greater in larvae given the DHA+ diet from breeders given the DHA+ diet 16 dph than in larvae given the DHA- diet from breeders given the DHA- diet 0 dph. Enzyme activity expressed as product-to-precursor ratios for delta6-desaturase and elongase-5 was greater in the eyes of larvae given a DHA- diet whose parents received a DHA- diet, than in eyes of larvae that received a DHA+ diet whose parents received a DHA+ diet. However, there was no difference for the ratio elongase-5 and delta5-desaturase. The high enzymatic activity in eyes of larvae that received the DHA- diet may be explained as a metabolic response to synthesize the deficient dietary DHA in retina required for vision from the predominant dietary essential fatty acid, LA. These results suggest that larvae require exogenous food of high quality and that it is possible that larval vision may be compromised when they prey on items low on DHA. These findings may apply to larval delta smelt but studies are needed to confirm this hypothesis.

Keywords: Docosahexaenoic acid, Fatty acid, composition, Optokinetic response, apparatus, Enzyme activity

Poster topic: Food Webs

Limiting the Impact of Benthic Grazers and Maximizing Foodweb Enhancements under BDCP

Kathleen Swanson, ICF International, kathleen.swanson@icfi.com
Chip McConnaha, ICF International, willis.mcconnaha@icfi.com
Jennifer Pierre, ICF International, jennifer.pierre@icfi.com
Lenny Grimaldo, ICF International, lenny.grimaldo@icfi.com

The BDCP proposes 65,000 acres of tidal natural community restoration in the Delta, which is intended, in part, to alter the supply of food necessary for the maintenance and conservation of native fishes. Restoration of these marsh and tidal habitats may greatly increase phytoplankton growth with a potential for large positive effect on the food-limited pelagic ecosystem. However, benthic grazing could offset these gains on local and regional scales. Field observation and analysis show that benthic grazing rates can limit the food production and value of delta restoration for foodweb enhancement. In some cases benthic grazing could result in shallow habitat zones acting as sinks for phytoplankton rather than sources of growth, but the magnitude of these impacts is highly uncertain. Negative phytoplankton growth in shallow regions can outstrip positive phytoplankton growth in deeper, sub-tidal habitat. Restoration of tidal habitat can provide significant foodweb enhancements if benthic grazing in shallow water habitats is limited. Habitat restoration should be carefully designed to limit colonization by benthic grazers and to maximize transport of phytoplankton from highly productive shallow areas to deep habitats where benthic grazing effectiveness is limited in order to maximize the positive benefit to the foodweb. Salinity, depth, and hydrologic connectivity all play a role in determining the relative strength of potential phytoplankton growth and grazing. These physical habitat characteristics can be used to guide restoration design to maximize phytoplankton growth such that benthic grazer colonization is impeded or phytoplankton is transported away from areas rapidly cleared by bivalves.

Keywords: foodweb, phytoplankton growth, bivalve grazing, restoration, BDCP

Poster topic: Food Webs

Are There Phytoplankton Blooms and Elevated Primary Productivity in the Fall in the Northern Estuary? (Fall Habitat Study)

Frances Wilkerson, Romberg Tiburon Center, San Francisco State University, fwilkers@sfsu.edu
Alex E Parker, California Maritime Academy, aparker@csum.edu
Richard Dugdale, Romberg Tiburon Center, San Francisco State University, rdugdale@sfsu.edu
Sarah Blaser, Romberg Tiburon Center, San Francisco State University, sblaser@gmail.com

Most efforts to understand the low salinity zone (LSZ; salinity 0.5 to 5) and upstream freshwater habitats of the San Francisco Estuary have focused on studies in spring. We measured conditions including phytoplankton standing stocks, community composition and primary production rates in the Sacramento and San Joaquin rivers and the LSZ each fall from 2010 to 2013. In fall 2010 chlorophyll in all regions was low (< 4 µg/L) compared to spring of the same year. In fall 2011 there was excess freshwater, a more seaward location of the LSZ and in late October a phytoplankton bloom (chlorophyll ~30 µg/L) was observed in the lower Sacramento River. The bloom was dominated by the diatom *Aulacoseira* that had long chains, typically 15-20 cells per chain. At these stations, nutrients were lower with ammonium concentrations < 2 µM and nitrate ~15 µM. In fall 2012, a similar bloom was observed in the lower Sacramento River in October (40 µg/L) and into Suisun Bay (14 µg/L) accompanied by lower nutrients, especially ammonium concentrations. Primary production was also measured and showed elevated C uptake rates in 2011 and 2012 contributing to the bloom development. These fall phytoplankton blooms have not been previously recognized and represent an important feature of the fall habitat in the LSZ. A better understanding of the causes of these fall blooms could be used in adaptive management of fall outflow for delta smelt protection

Keywords: nutrients, primary productivity, phytoplankton, low salinity zone, fall bloom

Poster topic: Food Webs

Recent Progress of the Sacramento-San Joaquin Delta and Suisun Bay Ecopath Model

Marissa Wulff, USGS, mwulff@usgs.gov
Larry Brown, USGS, lrbrown@usgs.gov
Howard Townsend, NOAA, howard.townsend@noaa.gov
Mejs Hasan, NOAA, mejs.hasan@noaa.gov

Improvements are being made to the Ecopath with Ecosim* (EwE) Sacramento-San Joaquin Delta and Suisun Bay (herein referred to as the Delta) ecosystem model so that it will be useful as a decision support tool for resource management. To date, we have developed a biomass-based fish food web model of the Delta with Ecopath and initiated hypothesis exploration using temporal simulations of the modeled food web via Ecosim. The current model parameterization of decreased primary productivity and increased submerged aquatic vegetation (SAV) are the best drivers for improving the simulation model's fit to data (relative abundance indices for the pelagic organism decline (POD) species and largemouth bass (*Micropterus salmoides*)). These results support the idea that the Delta has shifted from a pelagic food web to a SAV-associated food web. This initial model is limited because it does not incorporate spatial heterogeneity within the model domain. We are currently developing a spatial component of the EwE model using Ecospace that will allow us to explore how freshwater-pelagic, low-salinity pelagic, and freshwater-littoral food webs interact within the Delta. Spatial modeling is accomplished by identifying foraging, dispersion, and predator avoidance parameters for each functional group (a species or group of species) relative to the range of defined habitats. With completion of the spatial model, we will have a working model of the system that can be used in conjunction with time-dynamic Monte Carlo simulations to explore the possible effects of resource management decisions on the food web dynamics within the Delta ecosystem. This information can be used to help evaluate and optimize the utility and outcomes of such decisions.

* *Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government*

Keywords: Food web, Ecopath with Ecosim, pelagic organism decline, largemouth bass

Poster topic: Food Webs