Cosumnes-Mokelumne Water Quality Studies

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Executive Summary

A number of visions for the future of Central Valley aquatic ecosystems include actions that could significantly affect the supply, transport and fate of nutrients, algae, dissolved and particulate organic matter, dissolved oxygen and other food web resources. These resources are critical to the overall health and integrity of Central Valley River-Bay-Delta aquatic ecosystems. A major goal of this research is to develop an understanding of the relationship between water quality and food resources at the watershed scale that is applicable to Central Valley Rivers. Results of this study provide a first step toward formalizing a scientific rationale for ecosystem restoration and management of Central Valley River-Bay-Delta aquatic ecosystems. The findings of this research will help guide restoration and management efforts by providing an explicitly defined framework for scenario development and evaluation. It will also focus applied research by providing a tool for formulating hypotheses about how the system functions and how it would likely react to substantial changes in its physical, chemical or biological structure or the processes that create and maintain ecosystem structure.

Water quality is the integrative element linking physical, chemical and biological components of a watershed. Water quality is a reflection of linked processes occurring within and between terrestrial and aquatic ecosystem. Water quality is the dominant factor regulating the health and productivity of aquatic ecosystems (Figure 1).

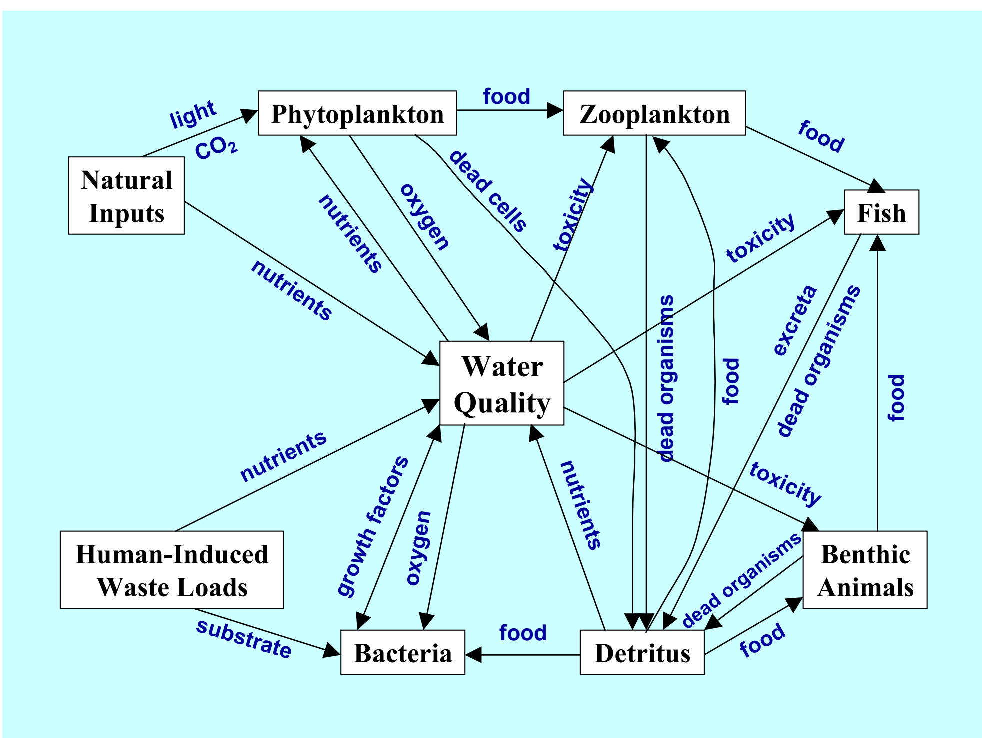

Figure 1. Schematic demonstrating the role of water quality in aquatic ecosystems.

Transport (fluxes) of energy (reduced carbon compounds) and nutrients within and between subwatersheds is also an important factor regulating aquatic ecosystems. The primary objective of the water quality component of the Cosumnes-Mokelumne paired basin study was to examine linkages between upland watershed processes and the health and lower trophic level productivity of aquatic ecosystems. A unique aspect of this study was the ability to evaluate the effect of impoundment (Mokelumne versus Cosumnes) on water quality and constituent fluxes.

Specific Objectives: The principal objectives of this project were to: (1) determine spatial and temporal patterns in water quality and food resources; (2) determine food and nutrient fluxes within the Cosumnes River watershed; (3) develop an empirical model to define relationships between food resources and ecosystem-level physicochemical properties; (4) evaluate the role of impoundment (dams and reservoirs) on water quality and timing of constituent fluxes; and (5) develop a long-term water quality monitoring plan for the Cosumnes River watershed.

Spatial and temporal patterns in water quality and constituent fluxes
A major goal of this component of the study was to answer the question: Do uplands have an important impact on the lower watershed and Bay-Delta aquatic ecosystems? While the answer to this question is not clear-cut, we can state that the uplands do not provide a large flux of nutrients or food resources to the lower elevation subwatersheds (those below the Michigan Bar gauging station); however, the lower watershed is the source of most nutrients and food resources. Water quality at the large watershed scale is primarily influenced by land use, geology, vegetation, climate and water diversions. Those subwatersheds with suburban development have the most detrimental impact on water quality. Surprisingly, intensive agriculture in the lower portions of the watershed does not have overwhelming impacts on most constituents.

Temporal patterns of stream water chemistry in the Cosumnes River watershed were examined on the annual, seasonal and storm-event scales. Water quality displayed a distinct annual hydrologic pattern with three water quality seasons: baseflow, stormflow, and meltflow. The baseflow season (July – October) is dominated by groundwater chemistry primarily originating from high elevations, and thus does not vary much across the basin. During the baseflow season discharge is negatively correlated to ionic concentration, and sediment and nutrients are generally below detection. The stormflow season (November – March) is separated into a flushing period (where discharge is positively correlated to river water conductivity) and a dilution period (where discharge is negatively correlated to conductivity). During average flow years, virtually the entire annual load of nutrients and sediment moves through the watershed during the stormflow season. Because stormflow hydrologically links the land with local waterways, the stormflow season shows the greatest variance among sites across the diverse landscape of the Cosumnes watershed. Chemistry of the meltflow season (April – June) is dominated by dilute upland snowmelt, and there is little chemical variation across the watershed. Storm-scale analysis revealed that progressive flushing occurs with each storm event and that source area dynamics play an important role in chemograph response. These results provide baseline water chemistry that can be used by scientists and regulators as a reference for chemical variation in unimpounded flow from the Sierra Nevada. They also provide essential information for developing an effective water quality monitoring plan for the Cosumnes watershed.

Relationships between food resources and ecosystem-level physicochemical properties
Our primary objective for this component of the study was to determine water quality and geographical factors regulating primary productivity, primarily in the form of algae biomass. Algae production can be in the form of phytoplankton or periphyton. In our studies we focused on the algae fraction that was mobilized (phytoplankton and displaced periphyton) in the stream channel and that could affect aquatic ecosystems in the Bay-Delta aquatic ecosystem. We used chlorophyll-a concentrations to estimate algae biomass.

From a land-use analysis, chlorophyll-a concentration in the Cosumnes Basin was most strongly related to the area of suburban development and agriculture. Streams draining forest vegetation at the highest elevations had very low chlorophyll-a concentrations. Chlorophyll-a concentrations showed maximum concentrations in the winter and summer. The summer maximum is due to favorable growth conditions (temperature and low stream flow), while the winter maximum was related to displacement of periphyton from the stream channel. Nutrient concentrations were not strong predictors of chlorophyll-a concentrations, with the exception of high concentrations found downstream of a wastewater treatment facility. Because of the generally low nutrient concentrations found in the upper watershed, algae production was severely limited by low nutrient concentrations (N and P). With respect to the Bay-Delta aquatic ecosystem, the Cosumnes watershed does not provide many food resources during the summer period of maximum productivity. The lack of streamflow in the lower watershed completely eliminates the transport of food resources during the summer period and food resources transported during the winter are of limited value due to the cooler temperatures and shorter hydrologic residence times.

Effects of impoundment on water quality and timing of constituent fluxes
One of the most exciting aspects of conducting research in the Cosumnes Watershed is that the basin itself is a rare resource: the last free-flowing river draining the western Sierra Nevada. To study the Cosumnes without comparing the results to those found in neighboring impounded watersheds would be to miss an enlightening opportunity to witness the affect that impoundment has on water quality.

Our study of the Mokelumne and Cosumnes Watersheds brought to light a number of intriguing conclusions. Chemical flux analysis of both basins showed that the uplands are an important source of DOC, non-nutrient major anions, and major cations. The Pardee-Camanche reservoir system, like all deep water large impoundments in California, acts as a sink for these same elements. What this means is that the chemistry in the Delta may have been controlled by upland, rather than lowland, export of dissolved species prior to the damming of 19 of the 20 major inflows. Presently, with impoundments acting as chemical sinks and lowlands being intensively cultivated and populated, the Deltas water chemistry is controlled by chemical export from local lowland sources. During average flow years, the Pardee-Camanche reservoir system also acts as a nutrient sink, eliminating the nutrient spikes which are usually associated with early winter storms. These nutrients are subsequently released later in the season at much lower levels. The result is a temporal shift in nutrient export to the lowlands. In dry years the same temporal pattern emerges, but instead of acting as a nitrate sink the reservoirs act as a source. The reservoirs also act to thermally buffer outflow. With such thermal buffering occurring and nutrient export being altered it is assumed that downstream aquatic ecosystems have been impacted from pre-impoundment conditions.

Proposed water quality monitoring plan for Cosumnes watershed

A long-term basic water quality monitoring program is essential to provide background information for all watershed studies in the Cosumnes basin (*e.g.,* water quality modeling, terrestrial-aquatic linkages, aquatic biology, and hyporheic investigations). We developed a proposal for a long-term water quality monitoring program for the Cosumnes watershed that will serve as baseline/trend monitoring program. The intent of the monitoring program is to capture a representation of the spatial and temporal variability of a particular water quality parameter. We believe a minimum of five sites are necessary for intensive water quality monitoring. To allow for the calculation of constituent loads, gauging stations should be installed at three of the currently ungauged sites. Each of the five intensive sites should be equipped with an automatic pump sampler to collect flow-proportional samples during storm events. During baseflow conditions, grab samples should be collected from each site biweekly when flows at Michigan Bar are less than 800 cfs and weekly when flows exceed 800 cfs. Coupling of parameter concentrations and stream discharge will allow calculation of constituent fluxes (loads – kg or Mg) with a high degree of confidence and precision. In addition, all five sites should be equipped with data-logged sensors to provide continuous readings of temperature, electrical conductivity and turbidity. We estimate that a total of 224 samples per year would be collected for analysis.