Nutrient and food resource fluxing through the river floodplain system: An analysis of flood pulse phases as a control on patch dynamics across a restored floodplain.

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Objectives:

1. Quantify the flux of nutrients and food resources across the channel-floodplain boundary while delineating the chemical and hydrological signature of different stages of the flood pulse.
2. Study the influence of the flood pulse on the spatial distribution of suspended algal biomass across the surface of a restored floodplain.

Background: The study site was located 34 km south of Sacramento, CA on the lower Cosumnes River, approximately 5.5 km upstream from the confluence with the Mokelumne River (Fig. 1). In 1997, four breaches were cut into the levee bordering the eastern edge of the channel. Two inlet breaches (Tn and Ts) allow river water to enter the 36 ha restored floodplain during floods. Mean flood transit time across the floodplain in 2005 was approximately 1 day; during which time the floodplain held an average of 90 000 m^3 of floodwater. After traversing the floodplain, water egresses through two exit breaches (Te and Tw). Mean discharge across the floodplain in 2005 was 6.09 $m^3\ s^{-1}$, while during this same period mean discharge in the main channel (as measured at USGS gage #11335000) was 37.1 $m^3\ s^{-1}$.

Methods: Between December 2004 and June 2005, samples were collected with ISCO 6700 autosamplers at Tn, Te, and Tw. Water Quality at Ts was assumed to be identical to Tn chemistry. Samples were analyzed for Chl-a, DOC, TIN, TP, TDS, TSS, and VSS. Additionally, a YSI 6600 multiparameter sonde (temperature, pH, TDS, Chl-a, turbidity) with GPS capabilities was employed to collected data at an average of 120 sites across the surface of the floodplain. The autosamplers collected samples during flooding events on a 2-hour time-step. During the 172 days of flooding, 175 samples (169 matched pairs) were collected from each of the three sites. During this same period monitoring of the surface waters of the floodplain was conducted on 22 separate occasions.

Key Findings:

1. Our analysis indicates that periodic connection and disconnection of the floodplain with the channel is vital to the functioning of the floodplain as a source of concentrated suspended algal biomass for downstream aquatic ecosystems.
2. Peak Chl-a levels on the floodplain occurred during disconnection, reaching levels as high as 25 $\mu g\ l^{-1}$. Chlorophyll-a distribution across the floodplain was controlled by water age and local physical/biological conditions, the latter of which were primarily a function of water depth.
3. During connection, the primary pond on the floodplain exhibited low Chl-a (mean = 3.6 $\mu g\ l^{-1}$) and the shallow littoral zones had elevated concentrations (mean = 5.2 $\mu g\ l^{-1}$); during disconnection, the shallow zones Chl-a increased (mean = 11.2 $\mu g\ l^{-1}$), but the pond experienced the greatest algal growth (mean = 14.2 $\mu g\ l^{-1}$).

4. Storm-induced floodwaters entering the floodplain not only displaced antecedent floodplain waters, but also redistributed floodplain resources, creating complex mixing dynamics between parcels of water with distinct chemistries. Incomplete replacement of antecedent floodplain waters led to localized hypoxia in non-flushed areas.
5. The floodplain was an annual sink for all constituents measured (total suspended sediment (TSS): 372 Mt ha^{-1} yr^{-1}, volatile suspended sediments (VSS): Mt ha^{-1} yr^{-1}, total inorganic nitrogen (TIN): 0.43 Mt ha^{-1} yr^{-1}, DOC: 3 Mt ha^{-1} yr^{-1}, and Chl-a: 0.01 Mt ha^{-1} yr^{-1}) but closer analysis revealed that some small flooding events caused net DOC and Chl-a export from the floodplain.
6. Partitioning of the phases of the flood pulse revealed three physically and chemically distinct stages: the flushing phase, the transport phase, and the draining phase. The flushing phase was a brief period of export on the rising limb of the flood, this phase only occurred after an extended period with no upstream connection. The transport phase dominated the flux balance of the system and was marked by retention of all the measured constituents on the floodplain. The draining phase began when outflow from the floodplain exceeded inflow, this phase was an export phase for both DOC and Chl-a.
7. The fact that small floods were not dominated by the retentive transport phase helps explains why these floods tended to cause net export, rather than retention, of materials on the floodplain.
8. We propose the notion of "floodplain proportional flooding" for restored floodplain systems, whereby flood size should not overwhelm floodplain volume. In this way residence time is increased as is the potential for the floodplain to be a source for DOC and phytoplankton, valuable food resources for downstream aquatic ecosystems.
9. The degree of complexity revealed in this analysis makes clear the need for high-resolution spatial and temporal studies such as this to begin to understand the functioning of dynamic and heterogeneous floodplain ecosystems.

Recommendations for management & monitoring: If a primary goal of future floodplain restoration is to create an additional source of food resources for downstream aquatic systems then we recommend "floodplain proportional flooding", whereby the median flood size does not overwhelm the capacity of the floodplain. Such flooding will assure high MRT on the floodplain for at least one half of the annual floods and thus increase export of DOC and phytoplankton. Given this we must also note the importance of large floods which can export large woody debris and coarse particulate organic matter from the floodplain to the channel, these are also important avenues for energy transfer across the river-floodplain system. Previous studies that have monitored the flux of materials across the channel floodplain boundary have used a relatively coarse sampling strategy. This study has shown that there exist biogeochemically distinct phases to the flood pulse and heterogeneous algal biomass distribution across the floodplain which can not be quantified without high resolution sampling. As such, we recommend intensive sampling in both space and time in order to characterize dynamic and heterogeneous floodplain ecosystem.