Insights from the Inland Sea: The Hydrology and Management of the Yolo Bypass Floodplain

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This presentation is designed as an introduction to the Yolo Bypass, a leveed, 59,000-acre floodplain of the lower Sacramento River. It is a highly successful component of a flood control system that conveys floodwaters from several waterways to the Sacramento–San Joaquin Delta. Complete inundation of the floodplain results in a doubling of the wetted area of the Delta, creating an "inland sea" approximately 1/3 the size of San Francisco Bay. Lateral variability is also important as the unique flow and topography of the Bypass often result in incomplete mixing and the formation of spatially persistent tributary bands during high flow events. The historical record suggests that at least some of floodplain is seasonally inundated from Sacramento River and west-side tributaries in most years. Modeling results also demonstrate that relatively low flow events can result in substantial inundation as a result of the low elevation gradient of the floodplain. These patterns generate complex relationships between flow, surface area, and depth. The hydrology of the system is also influenced by land use in the basin including local water diversions, canals, weirs, road crossings, berms, and multiple habitat types such as agriculture, grasslands, managed wetlands, perennial channels, and ponds.

Keywords: Floodplain, hydrology, Delta, modeling, inundation
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Yolo Bypass as a Source of Delta Phytoplankton: Not Just a Legend of the Fall?

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The Yolo Bypass is the primary floodplain of the San Francisco Estuary, designed primarily as a flood-control system for the greater Sacramento Valley. Studies have historically focused on the benefits of the inundated floodplain habitat during the winter and spring months for fish and lower trophic levels. However, in the fall of 2011, and again in 2012, significant phytoplankton blooms occurred upstream of the confluence of the Sacramento and San Joaquin rivers. Substantial evidence from water isotopic studies and ongoing water quality monitoring within the region suggested that these phytoplankton blooms were supported in part by elevated fall agricultural drainage flows in the Yolo Bypass. Phytoplankton blooms that provide an essential base to the San Francisco Estuary food web have become increasingly rare in recent decades. This decline has been linked to decreases in both zooplankton and pelagic fish abundance. In fall of 2013, a multi-agency collaborative study with the Department of Water Resources, Central Valley Water Resources Control Board, Bureau of Reclamation, and University of California Davis investigated the spatial and temporal trends of phytoplankton, nutrients, flow and water quality conditions before, during, and after increased fall agricultural flows in the Yolo Bypass. The initial results from this study provide insight into the complexity of nutrient dynamics in the Yolo Bypass and the importance of possible flow thresholds in the transport and development of downstream phytoplankton blooms. Our hope is that continued investigation into the processes that facilitate increased fall phytoplankton biomass could yield management tools to benefit the Delta pelagic food web.

Keywords: Yolo Bypass, phytoplankton, flow, fall, agriculture, blooms, food web, pelagic
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Nutrient and Chlorophyll Concentrations in the Lower Yolo Bypass

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Nutrient and chlorophyll concentrations were monitored monthly in the lower Yolo Bypass for a year. Purpose of the monitoring was to describe chlorophyll concentrations prior to restoration and determine whether nutrients controlled primary production. The conceptual model was that algal production would primarily occur on the two shallow, flooded islands and be transported off-site in the surrounding deeper channels. A comparison of nutrient concentrations and the Redfield ratio suggested that nitrogen will limit primary production. Chlorophyll concentrations increased northward in both channels and flooded islands. Concentrations at the northern end of the Bypass were about 3 and 5 times greater in winter and summer than in the Sacramento River at Rio Vista. In summer, nitrogen concentrations were highest in Cache Slough and decreased northward on the flooded islands and adjoining channels. Very low nitrogen concentrations were measured in the northern portion of Liberty Island and surrounding channels. Amendment experiments confirmed that nitrogen limited accumulation of algal biomass. In contrast, in winter no consistent nitrogen gradient was observed and nitrogen limitation of algal biomass accumulation is not predicted to occur. The primary source of nitrogen in summer is from the Sacramento Regional Wastewater Treatment Plant (SRWTP) and is tidally dispersed north into the Bypass from Cache Slough. In contrast, in winter the nitrogen sources are from the SRWTP in the south and from the Cities of Davis and Woodland Wastewater Treatment Plants discharging down the Toe Drain from the north. Nitrogen from the two northern sources does not typically enter the Bypass in summer as flow in the Toe Drain is negative. Nitrogen limitation in the Bypass may be important as wetlands, such as are being proposed for the lower Yolo Bypass, are known to be strong denitrifiers and restoration may further decrease nitrogen concentrations and reduce primary production.

Keywords: Nitrogen, nitrogen limitation, chlorophyll, Liberty Island, Toe Drain
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Evaluation of Flow Thresholds and Their Effects on the Composition and Relative Abundance of Lower Trophic Biota in the Yolo Bypass, California, USA

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Previous work in the Yolo Bypass has demonstrated that providing river-floodplain habitat connectivity can quickly enhance production of lower trophic levels, and thus potentially benefit secondary consumers such as Chinook Salmon, *Oncorhynchus tshawytscha*. Despite the considerable amount of research in this area, there is still a lack of knowledge regarding the extent to which productivity in the Bypass influences downstream areas, although some research suggests that floodplain inundation represents one of the most effective approaches to improving primary productivity in the Bay-Delta Estuary. Studies in the Yolo Bypass suggest that the food web of the floodplain is much more productive than the adjacent Sacramento River, linking increases in productivity to the quantity of flow and hydrologic residence times in the Yolo Bypass. However, specific flow thresholds for enhanced lower trophic productivity have not yet been identified. We use data from a long-term study of the Yolo Bypass to explore the community composition of zooplankton and drift invertebrates in Yolo Bypass between 1999-2012. Those data will also be used to examine changes in the relative abundance of those taxa in relation to environmental conditions, as well as to test whether any specific flow thresholds exist (magnitude and duration of inundation), which result in enhanced productivity of lower trophic levels. The results from this study will provide further insight regarding Yolo Bypass food web ecology, as well as baseline monitoring information and guidance for future Yolo Bypass restoration projects.

Keywords: food web, primary productivity, floodplain, flow thresholds, Yolo Bypass
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You are What You Eat: Isotope Forensic Science to Track Floodplain Rearing on the Yolo Bypass

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Benefits of floodplain rearing for salmonids have been well documented, yet the population-level benefit in terms of increased survival during downstream migration and ocean residence remain unquantified. This is largely due to methodological challenges linking habitat-use in one life stage to long-term survival benefits. Here we explore whether differences in the floodplain food web relative to the riverine food web provide a unique "fingerprint" that could be used to identify individuals that spent a portion of their early life rearing on the Yolo Bypass. The phytoplankton in the water in the Yolo Bypass has been shown to have a uniquely lower sulfur isotope composition ($\delta^{34}S$) than phytoplankton in other water sources in rivers and the Delta, presumably because of rice farming providing a useful fingerprint for the base of the food web (Kendall, Bay-Delta Science Conference, 2010). Like carbon isotopes and unlike nitrogen isotopes, sulfur isotopes of organisms show minimal change with increasing food web position. Thus, isotopic differences at the base of the food web propagate up the trophic hierarchy from the water, to invertebrate prey, and into the muscle, and ear bone (otolith) protein of fishes feeding on that food web. We will present results on sulfur isotopes in prey items in the stomach, muscle, and fin tissue of archived juvenile salmon collected on the floodplain in 1998, relative to juveniles foraging in the mainstem Sacramento River. Results from this study will be discussed in the context of whether sulfur isotopes are a unique, temporally, and spatially robust marker functioning at the appropriate scales to characterize floodplain habitat use by juvenile fish. Sulfur isotopes are permanently recorded in otoliths and future work will investigate their use to reconstruct floodplain habitat use and residence time for different native fish species such as salmon, steelhead, sturgeon, and splittail.

Keywords: Sulfur isotopes, diet, floodplain, habitat use, tracer
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Telemetry Studies of Adult Chinook Salmon and White Sturgeon in the Yolo Bypass

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Given substantial evidence over nearly fifteen years for its benefits to native fishes during flooded periods, the Yolo Bypass has become the focus of interest in managing seasonally flooded habitat in the Delta. Adult fishes such as Chinook salmon (*Oncorhynchus tshawytscha*), sturgeon (*Ascipenser* spp.), and Sacramento splittail (*Pogonichthys macrolepidotus*) seasonally enter Yolo Bypass at its base, located north of Rio Vista. While splittail will spawn on the floodplain, the prevailing view is that the area acts like a giant "fish trap" for salmon and sturgeon en route to spawning areas on the upper Sacramento River; they are drawn into the floodplain's perennial channels following late fall or early winter flows with no exit from the Bypass at its upstream end. The Fremont Weir is located at the northern tip of the Bypass, and is only connected to the Sacramento River during brief periods of high flows. Hence, the Yolo Bypass represents one of the most serious passage barriers to migratory fishes in the Central Valley. However, beyond a general description of the timing and occurrence of large numbers of migrating Chinook salmon, sturgeon, splittail, and striped bass, remarkably little is known about what happens to these fish once they enter Yolo Bypass. How is the Bypass affecting fish positively, negatively, and/or neutrally? Which stimuli influence whether the fish choose to enter the Bypass or not, and whether they can get out if they choose? In an effort to address these questions, UC Davis and the California Department of Water Resources are currently conducting research on the way that native fishes use the Yolo Bypass for transport and habitat. We present here the results of telemetry studies on migrating adult Chinook salmon and white sturgeon between 2012 and 2014.

Keywords: floodplain, migration, telemetry, conservation, movement, behavior, sturgeon, chinook, salmon
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Who's There? Genetic Tools Reveal Habitat-use by Juvenile Chinook Salmon in the Yolo Bypass

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The Yolo Bypass provides critical floodplain habitat for a number of special status fishes, including the threatened and endangered populations of Central Valley Chinook salmon (*Oncorhynchus tshawytscha).* Therefore, the Yolo Bypass has been identified as a high restoration priority; however, we have a limited understanding of how the different populations of Chinook salmon use the habitat in the Yolo Bypass and how this compares to their habitat use in the mainstem of the Sacramento River. The major obstacle to an understanding of habitat-use has been an inability to accurately identify individual salmon to their run of origin. To address this shortcoming, we developed a new genetic panel of single nucleotide polymorphisms (SNPs) to identify Chinook to their run of origin. We then sampled juvenile Chinook found in the Yolo Bypass and the mainstem Sacramento River, applied our new SNP panel to identify them to their run of origin, and evaluated habitat use. We found differences in use of floodplain habitat among the different runs, which has implications for the management of the floodplain habitat in the Yolo bypass. Restoration plans should be developed in light of these results, considering which populations of Chinook juveniles are most likely to be affected by proposed actions. As our data collection occurred during drought years, this work should be continued in a long-term monitoring plan to compare habitat use of wet and dry years. Additionally, our newly developed panel of SNPs offers an exciting new tool for identifying both adult and juvenile Chinook salmon and will greatly improve our ability to conduct informative field studies throughout the Bay-Delta system and Central Valley.

Keywords: Chinook, salmon, genetics, SNPs, assignment, run-type, habitat use, floodplain, tools
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Managing Floodplain Productivity: Slow it Down, Spread it Out, Grow 'Em Up

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Each winter and spring broad, shallow wetlands were inundated as the rivers covered the floodplains, of the pre-development Central Valley. The Valley has been engineered to drain efficiently and rapidly, shedding high volumes of storm water quickly through incised, armored flood channels. This rapid high-volume drainage system is the antithesis of the historic prolonged, broad and shallow seasonal inundation of the predevelopment flood pattern. Levees and drainage of marshes and floodplains diminished seasonal primary productivity and may literally "starve" rivers, by interrupting the flood processes that create seasonal engines of trophic productivity.

The Agricultural Floodplain Habitat Investigation at Knaggs Ranch on Yolo Bypass, is demonstrating that ***mimicking*** historical floodplain processes – spreading water out over the winter rice fields which replaced many marshes and floodplains – can still produce phenomenally productive aquatic food webs. Which in turn can support rapid growth and improved body condition of juvenile salmon.

The first two years of the project demonstrated that winter-flooded rice fields can provide high quality floodplain rearing habitat, as evidenced by the fastest growth rates of juvenile Chinook salmon ever recorded in the Central Valley. Two elements were added in 2014; varying field depth and volition passage (fish were allowed to leave the fields on their own at any time). Results were once again encouraging: growth was similarly rapid but survival was substantially increased.

The project provides evidence when native fish and bird populations are exposed to a system they " recognize" – habitats similar to those under which they evolved and to which they are adapted – they respond quickly and favorably. A better understanding of how to manage floodplain dynamics may allow integration of "engines" of natural productivity into the design and operations of a central valley water infrastructure built in era before ecological function was a system objective.

Keywords: Knaggs, floodplains, reconciliation, salmon, rice
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Depth and Flow: Do Juvenile Salmon Demonstrate Preference on a Managed Agricultural Floodplain?

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The 59,000 acre Yolo Bypass is an engineered floodplain managed for agriculture, wildlife and flood control. Several studies have documented benefits of the Yolo Bypass floodplain to juvenile salmonids, making it a target area for restoration. However, design parameters that may maximize benefits to native fishes in floodplain and wetland restoration projects (e.g., how deep? how much water?), are often unknown, particularly in an agricultural context. Since 2012, the Knaggs Ranch Experimental Agricultural Floodplain Investigation has examined salmon growth, survival, and behavior on an agricultural parcel that is farmed for rice during the spring and summer. In 2014, we investigated behavioral associations of juvenile salmon in relation to various water depths and proximity to inflow, as part of the larger Knaggs Ranch investigation.

A 0.35-acre experimental field was constructed with three enclosed sections, each with three depth treatments (18”, 30”, 42”) arranged in varying sequences relative to inflow (upstream, midstream, downstream). Passive integrated transponder (PIT) tag detection antennae were placed in every depth panel (9 total). 149 juvenile hatchery salmon between 58 mm and 75 mm were implanted with 12 mm PIT tags and released in the experimental field. During the 2-week experimental period, there were approximately 3.8 million PIT tag detections. Survival and growth rate across all enclosures was very high (95% and 1.15 mm/d, respectively). Results indicate that both depth and position relative to inflow influenced where individuals spent the most time, with fish preferring deeper areas closer to inflow. These results can inform the design of floodplain restoration projects and management strategies so they may maximize benefits to juvenile salmon based on behavioral preferences in the floodplain landscape.

Keywords: floodplain, wetlands, Yolo Bypass, salmonids, habitat, rearing, behavior, restoration, management
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Invertebrate Abundance and Colonization Pathways on a Managed Floodplain in the Yolo Bypass

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Evidence from the Yolo Bypass suggests that agricultural floodplains provide a valuable seasonal winter habitat for juvenile Chinook salmon. As part of a managed inundation study ("Knaggs project") in the northern Yolo Bypass rice fields, we investigated the trophic resources available to juvenile Chinook salmon. Specifically, we examined the relative contribution of soil and drift invertebrates to the invertebrate community across three agricultural habitat types: stubble, fallow, and disked. Although soil emergence was an important colonization pathway in our study, drift was the main contributor to the invertebrate community in the experimental floodplain. Additionally, soil emergent invertebrate abundance was positively influenced by agricultural land use with densities greater than 2,400 individuals/m^2 in rice stubble and fallow fields. However, disking decreased abundances to less than 1,500 individuals/m^2. The abundance and diversity of invertebrates that colonized via drift did not significantly differ between habitat types, but produced abundant trophic resources for rearing Chinook salmon during experimental flooding with invertebrate densities greater than 150,000 individuals /m^3. In particular, the main food resource for juvenile Chinook salmon, *Daphnia pulex,* had abundances ranging from 2,300 individuals/m^3 in the beginning of the study period to greater than 51,900 individuals/m^3 at the end of six weeks. As drift was the most significant colonization pathway in our study, it is important to assess the invertebrate community and abundance within water used to artificially inundate managed floodplains.

Keywords: Floodplains, Zooplankton, Chinook salmon, Yolo Bypass, Agriculture
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