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Final Report for Fellowship R/SF-4

My CALFED fellowship (R/SF-4) had three primary research areas: (1) how native fish use California floodplains; (2) developing a method to identify and quantify a particular type of floodplain in the Sacramento Valley; and (3) a white paper for CALFED that reviews, summarizes, and synthesizes research on floodplains generally, and Central Valley floodplains specifically.

1. Native fish and floodplains.

For this research I collaborated with Carson Jeffres, a graduate student at UC Davis (this research was his Master's thesis). We compared the growth rates of juvenile Chinook salmon between various floodplain and riverine habitats. This study built on previous work; (1) in the Yolo Bypass that found that juvenile Chinook grew faster in the flooded Bypass than in the nearby Sacramento River and; (2) in the Cosumnes Preserve which showed that native, wild juvenile Chinook salmon appeared to use the Cosumnes floodplain for rearing when it was inundated.

Juvenile salmon were obtained from a hatchery on the Mokelumne River and placed in enclosures within the Cosumnes River and floodplain (ten fish per enclosure). For two flood seasons (2004 and 2005), six enclosures were placed in each of three different habitat types in the floodplain and two locations in the river (30 enclosures total). Floodplain habitats included an ephemeral pond, flooded terrestrial herbaceous vegetation, and a pond that was permanent during the first year of the study and ephemeral during the second. The river locations were the river channel above the floodplain and the river channel below the floodplain.

The fish were measured at one week intervals, although measurement frequency declined during large flood events that made access difficult. In 2004 fish were measured three times over 4.5 weeks and in 2005 they were measured four times over 8 weeks. After the final measurement the fish were sacrificed and a sub-set were saved for a gut-content analysis.

In general, fish had faster growth rates in floodplain habitats than in the river. During periods of low, clear water, fish growth rates in the river site above the floodplain were comparable to those in the floodplain. However, during higher flows, with more turbid water, growth in the river above the floodplain was significantly lower than on the floodplain. Fish in the river below the floodplain, which was representative of intertidal delta habitat, were consistently low.

The main channel of the Cosumnes River, like those of many Central Valley rivers, is incised and lacks complexity. There are few side channels, backwaters, or accessible floodplain habitats (other than the Cosumnes Preserve). Thus, juvenile fish will tend to be displaced downstream during high flow events. In the Cosumnes, juvenile fish will be flushed downstream to either the intertidal delta or the floodplain. Among these two

habitats, the floodplain appears to provide significantly better habitat for rearing (Figure 1).



Figure 1. Juvenile Chinook on the right were reared within an enclosure within the Cosumnes River floodplain while those on the left were reared within an enclosure in the river below the floodplain (intertidal Delta habitat).

This study confirms that juvenile Chinook benefit from access to floodplain habitats. While river habitats comparable to those above the floodplain can support similar growth rates as the floodplain, this habitat is more variable. During high flows the river offers poor habitat and fish living in this type of habitat will tend to be displaced downstream. The floodplain can provide optimal growing conditions during such floods and likely offers superior habitat conditions to the downstream Delta.

The risk of fish stranding on the floodplain merits further research. However, initial research on the Cosumnes suggests that native fish tend to respond to cues that facilitate emigration from the floodplain during draining and that primarily non-native fish become stranded. This work further supports the concept that floodplain restoration can be an important strategy for restoring Central Valley salmon populations.

This research is summarized in:

Jeffres, C., J. Opperman, and P. B. Moyle. *Submitted*. Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. Submitted to *Environmental Biology of Fishes*.

This work has also been presented at the following conferences:

1. Floodplain Management Association 2005
2. Society for Ecological Restoration 2005
3. Riverine Hydroecology (Stirling, Scotland) 2006

2. Identifying and mapping the floodplain inundated by the Floodplain Activation Flood.

Working in collaboration with Phil Williams and Associates (PWA), we worked to define, identify, and quantify a particular type of floodplain: that which is inundated by a Floodplain Activation Flood (FAF). The FAF is a relatively frequent, long duration, spring-time flood that has particular value for native fish and food web productivity (see text on floodplain conceptual model below for further description of a Floodplain Activation Flood).

The FAF was defined as follows:

1. occurs in two out of three years (67% exceedance probability)
2. duration of at least one week
3. occurs between March 15 and May 15.

These criteria were applied to a series of paired gauges along the Sacramento River and within the Yolo Bypass. This process derived a flood stage elevation that corresponded to the FAF criteria. This flood stage was then used to develop a water surface that was applied to topography for the Sacramento River and surrounding floodplain (from US Army Corps of Engineers' Sacramento-San Joaquin Comprehensive Study), estimating the area of floodplain inundated during the FAF.

We found that there is very little floodplain area inundated by the FAF in the current Sacramento Valley. Nearly all floodplain that corresponds to the FAF is found within the Yolo Bypass.

This work is further described in:

Philip Williams & Associates, L., and J. J. Opperman. 2006. The frequently activated floodplain: quantifying a remnant landscape in the Sacramento Valley, San Francisco, CA.

Williams, P., J. Opperman, E. Andrews, S. Bozkurt, and P. Moyle. Quantifying activated floodplain on a lowland regulated river. *In preparation for* San Francisco Estuary and Watershed Science.

3. The Central Valley Floodplain White Paper

I am continuing to work on the floodplain white paper along with my co-author, Peter Moyle. A central part of the white paper is a conceptual model for Central Valley floodplains, briefly described below.

This work has been presented at the following conferences:

1. Floodplain Management Association, 2005
2. American Geophysical Union and the North American Benthological Society, 2005
3. Society for Ecological Restoration, 2005

4. State of the Estuary Conference, 2005
5. CALFED Science Conference, 2006
6. Riverine Hydroecology (Stirling, Scotland), 2006
7. State of Washington, the Ecological Value of High Flows, 2006

Brief overview of conceptual model:

Floodplains support high levels of biodiversity and are among the most productive ecosystems in the world. They provide a range of ecosystem services to human society, including storage and conveyance of flood flows, groundwater recharge, open space, recreational opportunities, and habitat for a diversity of species, many of them of economic importance. Among the world's ecosystem types, Costanza et al. (1997) ranked floodplains second only to estuaries in terms of the ecosystem services provided to society. In the Central Valley, the most important ecosystem services provided by floodplains include reduction of flood risk and habitat for numerous species, including commercially and recreationally valuable species (e.g., chinook salmon and waterfowl) and for endangered species. Recent research has demonstrated that floodplains provide necessary spawning habitat for the Sacramento splittail, an endemic minnow (Sommer et al. 1997) and that juvenile chinook salmon grow faster on floodplains than in main-stem river channels (Sommer et al. 2001b) (Figure 1). Productivity from floodplains can be exported to the Sacramento-San Joaquin Delta, where food limitation is likely one of the factors contributing to the decline of fish species (Jassby and Cloern 2000, Schemel et al. 2004). Further, in places such as the Yolo Bypass, ecologically valuable floodplains can be compatible with productive agriculture (Sommer et al. 2001a).

Recognizing these valuable services, state and federal agencies have expressed policy goals to restore floodplains in the Central Valley (CALFED Bay-Delta Program 2000). Further, flood management projects in the Central Valley now generally include a floodplain restoration component. To guide these restoration efforts, we convened a floodplain working group, composed of floodplain experts drawn from academia, agencies, NGOs, and the private sector, to define ecologically functional floodplains. This group described three primary components of ecologically functional floodplains:

- ***Connectivity*** between river and floodplain.
- ***Hydrological variability***
- ***Sufficient geographic scale*** for associated ecological benefits to be meaningful on a system- or population-scale.

We developed a conceptual model of floodplain processes based on the scientific literature, our collective experiences studying floodplains, and guidance from the floodplain working group (Figure 2). This conceptual model illustrates the linkages between physical and biological processes in floodplains and can be used to inform floodplain restoration projects.

Organization of the conceptual model.

A diverse range of flows influence floodplain geomorphic and ecological processes, ranging from flows below bankfull to large, rare, and highly erosive floods. Numerous aspects of these flows have geomorphic and ecological significance, including magnitude, frequency, duration, rates of change, and seasonality, as well as antecedent conditions on the floodplain. To simplify, our conceptual model focuses on three types of ‘representative floods,’ characterized by their frequency and magnitude, which are found in the blue boxes in the Hydrology portion of the model. These floods perform geomorphic work, described in the brown-outline boxes in the Geomorphology portion of the model. Hydrologic and geomorphic processes create the conditions for Ecosystem Responses and Processes to occur (green-outlined boxes). The Ecosystem Responses and Processes produce Ecological Benefits, the magnitudes of which are influenced by the geographic scale of floodplain. Two representative floods, the Floodplain Activation Flood and the Floodplain Reorganization Flood are illustrated in Figures 2 and 3 and described below.

Two representative floods

Floodplain Activation Flood. The floodplain activation flood (FAF) is a small-magnitude flood that occurs relatively frequently (e.g., almost every year) (Figure 3). The FAF can be further defined in terms of seasonality and duration—for example a flood that lasts at least one week and occurs in the Spring. The following article by Betty Andrews defines a FAF in terms of frequency, season, and duration and then describes a process to map the floodplain that corresponds to the FAF in the Sacramento Valley. A long duration flood produces characteristic ecological benefits such as habitat for native fish spawning and rearing (Figure 1) and food web productivity. The duration of the flood is important as these processes cannot occur during a short event. The seasonality of the flood also influences which ecological processes occur (see the temporal scale bar (Winter □ Late spring) in one of the ecological process boxes). The importance of duration and seasonality for a FAF is indicated by the question mark adjacent to the flood occurring in late January on the hydrograph in Figure 2 (a short, winter-time flood). Because floodplains can remain inundated for a period of time after the loss of direct connection with river flows, a series of short connections can also function as a floodplain activation flood.

Floodplain Reorganization Flood. The floodplain reorganization flood is a greater magnitude flood that occurs less frequently (Figure 3). This higher energy flood produces geomorphic work including extensive erosion and deposition on the floodplain which creates heterogeneous floodplain topography. In turn, these dynamic events and heterogeneous topography create a diverse ecosystem with vegetation patches of varying age, species composition and structure, and floodplain water bodies of varying successional stage and connectivity to the river. The ecosystem processes that occur during a Floodplain Activation Flood take place within the mosaic of habitat features created during Floodplain Reorganization Floods.

Conclusions

The model illustrates the importance of hydrological variability for an ecologically functional floodplain. For example, a floodplain that rarely is inundated by a Floodplain

Activation Flood will not produce the ecological benefits of food web productivity or spawning and rearing habitat for native fish. A floodplain that is not subject to Floodplain Reorganization Floods will not maintain the mosaic of habitats (e.g., vegetation and water bodies of varying successional stages) that help support floodplain biodiversity. Therefore, floodplain restoration projects should not only focus on reintroducing connectivity between rivers and floodplains. Floodplain managers should also ask the following questions about this connectivity: how often, for how long, in what season, and of what magnitude? The answers to these questions will strongly influence the range of ecological benefits that the restored floodplain can provide.

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Figure 2. Floodplain Conceptual Model



