Floodplain as Habitat for Native Fish: Lessons from California's Yolo Bypass

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ABSTRACT. In the following paper we describe the Yolo Bypass, the primary floodplain of the San Francisco Estuary. The partially leveed floodplain is a major flood control feature for the Sacramento Valley based on its ability to safely convey floodwaters that would otherwise inundate Valley communities. Agricultural lands and seasonal and permanent wetlands within the Bypass represent a key link for waterfowl migrating through the Pacific Flyway. Our studies demonstrate that the floodplain also provides important seasonal habitat for fish. Sampling to date shows that the Bypass supports at least 42 fish species, including both migratory and resident types. The floodplain appears to be especially valuable habitat for two federally-listed fish, Sacramento splittail (*Pogonichthys macrolepidotus*) and juvenile chinook salmon (*Onchorhynchus tshawytscha*). The region has considerable potential for additional fish and wildlife benefits as a result of new habitat restoration efforts.

INTRODUCTION

In California's Central Valley, few environmental events are as dramatic as the seasonal conversion of floodplain into an inland sea. These events have shaped the geography of the valley floor, creating unique plant and animal communities. Much of the historical floodplain has been lost to development, but some large tracts remain hydrologically connected to the river channels. In the Delta region of the San Francisco Estuary, the largest contiguous area of floodplain is the Yolo Bypass (Figure 1). We had several reasons to hypothesize that Yolo Bypass floodplain might be important to native fish. First, floodplain has been found to be important habitat in a variety of other locations including small streams (Halyk and Balon 1983; Ross and Baker 1983) and large rivers (Copp and Penaz 1988) in temperate (Gehrke 1992; Turner et al. 1994) and tropical locations (Winemiller and Jepsen 1998). Second, one of the most consistent patterns in the Estuary is that high flow years are known to enhance populations of a variety of fish and invertebrates (Jassby et al. 1995). However, the exact mechanisms for these relationships remain largely unknown. Positive effects of flow on fish might include increased habitat availability, food supply and larval transport and reduced predation or competition (Bennett and Moyle 1996). Floodplain inundation is one of the unique characteristics of above normal water years and may be responsible for some of these positive effects. Finally, because much of the historical floodplain in the Sacramento Valley had been lost to development, river channelization and levee construction, we expected that remnant floodplain habitat such as Yolo Bypass would have exceptional biological value.

The purpose of this article is to review recent research on how aquatic species use the seasonally inundated floodplain habitat. In this review we illustrate that: 1) floodplain represents one of the single most important habitats for native fish in the region; and 2) the basin is also exceptionally important for flood control, agriculture, wetlands and wildlife, suggesting that floodplain can support multiple land uses without eliminating processes needed to sustain aquatic species.

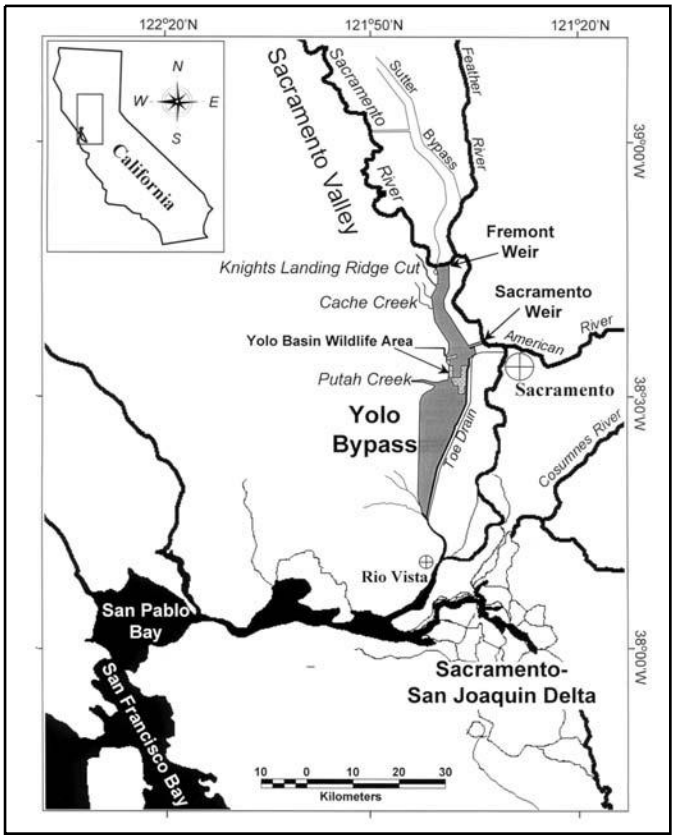
METHODS

We have been conducting sampling in the Yolo Bypass since 1995, with emphasis on juvenile chinook salmon (*Onchorhynchus tschawytscha*) and other native species. The area has formidable sampling challenges due to its large size and hydrologic variability, requiring diverse methods to address different biological questions. Our sampling program has included egg and larval tows, screw trap, gill nets, electrofishing, drift and zooplankton nets, beach seine and purse seine. Details about these methods can be found in Sommer et al. (1997) and Sommer et al. (2001).

STUDY AREA

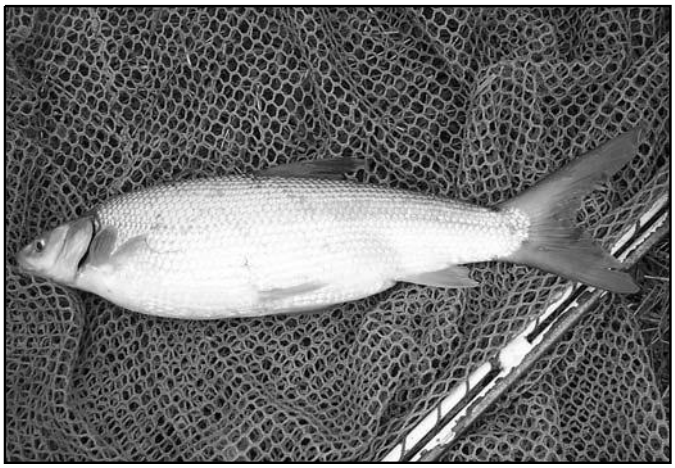
The San Francisco Estuary and its two component regions, Sacramento-San Joaquin Delta and downstream Bays (Figure 1), comprise one of the largest estuaries on the Pacific Coast of North America. Yolo Bypass, a 24,000 ha floodplain is the primary floodplain of the Sacramento-San Joaquin Delta. The majority of the floodplain basin is leveed to protect surrounding communities from floodwaters. The Yolo Bypass (Photograph 1) presently floods in more than half of years, typically during high flow periods in winter and spring.

FIGURE 1. Location of Yolo Bypass relative to the Central Valley, the San Francisco estuary and its tributaries.



PHOTOGRAPH 1. Yolo Bypass during floodplain inundation.

PHOTOGRAPH 2. Sacramento splittail (*Pogonichthys macrolepidotus*), a federally-listed minnow which uses the Yolo Bypass as key spawning, rearing and foraging habitat.



Complete inundation of the floodplain approximately doubles the wetted area of the Delta and is equivalent to about one-third the area of San Francisco and San Pablo bays. Besides Yolo Bypass, the only other Delta region with substantial connectivity to portions of the historical floodplain is Cosumnes River, a small relatively undammed watershed.

The hydrology of the Yolo Bypass is complex with inundation possible from several different sources (Figure 1). The floodplain has historically been inundated as early as October and as late as June, with a typical peak period of inundation during January-March. The primary input to the Yolo Bypass is through Fremont Weir in the north, which conveys floodwaters from the Sacramento and Feather rivers. In major storm events (eg >5,000 m3·sec-1), additional water enters from the east via Sacramento Weir, adding flow from the American and Sacramento rivers. Flow also enters the Yolo Bypass from several small west side streams: Knight's Landing Ridge Cut, Cache Creek, Willow Slough Bypass and Putah Creek. These tributaries can substantially augment the Sacramento basin floodwaters or cause localized floodplain inundation before Fremont Weir spills. After floodwaters recede, the basin empties through the Toe Drain, a perennial riparian channel on the eastern edge of the Bypass. The floodplain is relatively well drained as a result of land grading for agriculture; there are no major topographic features to impede the drainage of flood flows to the lower Sacramento-San Joaquin Delta.

The floodplain was spared urban development due to the early recognition that high river levees alone were insufficient to protect valley communities from flooding (Kelley 1989). This remnant floodplain now forms an integral part of the Sacramento Flood Control System and has functioned exceptionally well. To illustrate this point, total Sacramento basin flow exceeded the design capacity of the river channel below Sacramento in 58% of years during 1956-1998, when excess flows were diverted to the Yolo Bypass floodplain (Source: U.S. Geological

Survey stream flow data). The capacity of the Yolo Bypass has not yet been exceeded, despite 70-year flood events in 1986 and 1997.

Seasonal agriculture is the dominant land use on the floodplain, but approximately one third of the area is a mosaic of more "natural" habitat types on the floodplain including riparian, wetlands, upland and permanent (perennial) ponds. Farming activity is concentrated in late spring and summer, when flooding is uncommon. The primary agricultural crops in Yolo Bypass are sugar beets, rice, wild rice, safflower, tomatoes, corn and other grains. Flood control agencies have flood easements during all months, occasionally leading to a delay spring planting during late season storms. The floodplain also has substantial areas of wetlands, many of which are managed for waterfowl. The largest contiguous area is the Yolo Basin Wetlands, a 1,250 ha project (Figure 1) managed by the California Department of Fish and Game. Land for the project was purchased in 1991 and wetlands were constructed through the cooperative efforts of several agencies and environmental groups. Habitat types include seasonal wetlands (940 ha), uplands (196 ha), perennial wetlands (75 ha) and riparian forest (11 ha).

The Yolo Bypass represents a critical link on the Pacific Flyway, a migration route traveled by vast numbers of waterfowl. Examples of species that use the newly-created Yolo Basin Wetlands wildlife area and surrounding agricultural lands include mallard, northern shovelers, ruddy ducks, snow geese, northern pintails, American wigeon, green-winged teal, Ross' geese and Canada geese. Refuge managers seasonally flood in October and maintain ponds for migratory waterfowl through January. The region also supports numerous species of shorebirds, raptors, songbirds and mammals.

In stark contrast to the mosaic of habitat types in Yolo Bypass, the adjacent Sacramento River (Figure 1) has little habitat diversity. Like much of the Delta, the Sacramento River is bounded by steep levees covered with rip-rap or narrow riparian corridors. The deep channel has minimal shallow water habitat (typically >5 meters mean depth), essentially no submerged vegetation and only minor bands of emergent vegetation.

Results Of Fish Studies

Our field sampling demonstrates that Yolo Bypass provides habitat to a wide suite of fish species (Table 1). Sampling to date has shown that the floodplain is used by at least 42 fish species including seasonal fish and resident fish that are year-round residents in perennial water sources. Examples include federal and state-listed species (steelhead trout, delta smelt, spring-run and winter-run chinook salmon) and sport fish (striped bass and white sturgeon).

Similar to other Sacramento-San Joaquin Delta habitats, there are more introduced than native species in the Yolo Bypass floodplain (Table 1). Introduced species are one of the major environmental issues in the Delta, where they frequently dominate the fauna on a year-round basis (Bennett and Moyle 1996). However, unlike the other Sacramento-San Joaquin Delta habitats the floodplain is seasonally dewatered during late spring through autumn. This prevents exotic species from establishing year-round dominance except in perennial water sources. Moreover, many of the native fish are adapted to spawn and rear in winter and early spring (Moyle 2001) during the winter flood pulse. Introduced fish typically spawn during late spring through summer, when the majority of the floodplain is not available to them. For these reasons, we hypothesize that floodplain habitat provides a competitive edge for native fish. Although this hypothesis is difficult to test, we can at least demonstrate that the floodplain offers special benefits to native fish. To help illustrate the importance of the Yolo Bypass we discuss observations on two native fish, Sacramento splittail and juvenile chinook salmon.

The native minnow Sacramento splittail (Photograph 2) is perhaps the most floodplain-dependent species in the Sacramento-San Joaquin Delta (Sommer et al. 1997). In 1999 the species was listed as threatened under the Federal Endangered Species Act as a result of concerns about reduced distribution and abundance (USFWS 1999). The legal status of splittail is current under review as a result of legal actions, but the species remains a major target of restoration activities and water management in the Delta. For much of the year, splittail are resident in the San Francisco Estuary; however, in autumn and winter they seasonally migrate upstream to spawn in the Sacramento-San Joaquin Delta and its tributaries. Studies by Sommer et al. (1997) demonstrated that the Yolo Bypass is one of the single most important habitats for the species. Their sampling showed that adults move onto the floodplain in winter and early spring to forage and spawn on flooded vegetation. Splittail rear on the Yolo Bypass and emigrate to the river channels and estuary as floodwaters recede. These results are comparable with more "natural" floodplains such as the Cosumnes River, a nearby largely undammed watershed that was recently identified as a major spawning and rearing area for splittail (Dr. Peter Moyle, University of California at Davis, unpublished data). As one indication of the importance of the floodplain habitat to splittail, Sommer et al. (1997) showed that larval production of splittail for two floodplain habitats (Yolo and Sutter bypasses) was significantly higher than surrounding river channels. They also found that the duration of flooding of the Yolo Bypass was strongly correlated with splittail year class strength. As shown in Figure 2, it appears that strong year classes are not

TABLE 1. Yolo Bypass fish species observed during 1997-2000. Federally-listed species are identified as Threatened (FT) or Endangered (FE) and state-listed species are identified as Threatened (ST) or Endangered (SE). Source: Department of Water Resources, unpublished data.

Native Species		Introduced Species	
Chinook Salmon	*Onchorhynchus tschawytscha*	American shad	*Alosa sapidissima*
Fall-run		Threadfin shad	*Dorosoma petenense*
Spring-run (ST)		Common carp	*Cyprinus carpio*
Winter-run (FE,SE)		Goldfish	*Carassius auratus*
		Fathead Minnow	*Pimephales promelas*
Steelhead trout (FT)	*Oncorhyncus mykiss*	Golden shiner	*Notemigonus crysoleucas*
Pacific lamprey	*Lampetra tridentata*	Red shiner	*Cyprinella lutrensis*
River lamprey	*Lampetra ayresi*	Channel catfish	*Ictalurus punctatus*
Hitch	*Lavinia exilicauda*	White catfish	*Ameiurus catus*
Sacramento blackfish	*Orthodon microlepidotus*	Black bullhead	*Ameiurus melas*
Sacramento pikeminnow	*Ptychocheilus grandis*	Brown bullhead	*Ameiurus nebulosus*
Sacramento sucker	*Catostomus occidentalis*	Wakasagi (pond smelt)	*Hypomesus nipponensis*
Sacramento splittail (FT)	*Pogonichthys macrolepidotus*	Inland silverside	*Menidia beryllina*
Prickly sculpin	*Cottus asper*	Western mosquitofish	*Gambusia affinis*
Pacific staghorn sculpin	*Leptocottus armatus*	Bluegill	*Lepomis macrochirus*
Threespine stickleback	*Gasterosteus aculeatus*	Redear sunfish	*Lepomis microlophus*
Tule perch	*Hysterocarpus traski*	Green sunfish	*Lepomis cyanellis*
Delta smelt (FT,ST)	*Hypomesus transpacificus*	Warmouth	*Lepomis gullosus*
White sturgeon	*Acipenser transmontanus*	Black crappie	*Pomoxis nigromaculatus*
		White crappie	*Pomoxis annularis*
		Bigscale logperch	*Percina macrolepida*
		Largemouth bass	*Micropterus salmoides*
		Smallmouth bass	*Micropterus dolomieu*
		Spotted bass	*Micropterus punctatus*
		Striped bass	*Morone saxatilis*
		Shimofuri goby	*Tridentiger bifasciatus*
		Yellowfin goby	*Acanthogobius flavimanus*

produced unless there is at least three weeks of Yolo Bypass flooding during the March-April spawning and rearing period. It is therefore not surprising that Sommer et al. (1997) reported a major decline of splittail during the 1987-1992 drought, when the fish had no access to Yolo Bypass floodplain spawning habitat. Note, however, that the relatively long life span (frequently >5 years) of splittail probably helps to buffer the population against the effects of extended drought.

Juvenile chinook salmon represent another good example of the value of the floodplain habitat to native fish. There are four races of chinook salmon in the Sacramento Valley: winter, spring, late-fall and fall-run (Yoshiyama et al. 2000). Historical data indicates that all races have declined in abundance since the 1950s, but the spring, winter and late-fall run have shown the most pronounced declines. There are multiple causes for these long-term reductions including habitat loss, habitat degradation, water diversions and oceanic conditions. These declines led to the federal listing of winter-run as “endangered” in 1991 and spring-run as “threatened” in 1999.

Although there are multiple races, most young chinook salmon emigrate from upstream riverine spawning habitats during winter and spring, then enter the Sacramento-San Joaquin Delta (Fisher 1994). In low flow periods, downstream migrants are confined to the Sacramento River and similar Delta channels. During flood pulses the Yolo Bypass floodplain provides an alternative migration corridor. The results of Sommer et al. (2001) indicated that this seasonal floodplain habitat provides better rearing conditions than the adjacent Sacramento River channel. They noted two major advantages of floodplain: 1) increased area of suitable habitat and 2) increased food resources.

Young chinook salmon typically prefer habitat that is shallow and has low velocity (Everest and Chapman 1972). Sommer et al. (2001) estimated that complete inundation of the Yolo Bypass floodplain creates a wetted area approximately ten times larger than the comparable reach of the Sacramento River. Moreover, they observed that the river channel lacked the broad, low velocity shoal areas preferred by young salmon because flows are confined to deep, narrow rip-rapped channels. By contrast, Sommer et al. (2001) noted that Yolo Bypass has extensive shoals (mean depth typically < 2 meters) and substantial habitat complexity.

Another important attribute of floodplain habitat is an enhanced food web. Sommer et al. (2001) found that drifts insect (primarily chironomids) were 1-2 orders of magnitude more abundant in the floodplain than the adjacent Sacramento River channel during 1998 and 1999 flood events. This finding is consistent

with other floodplain studies, which show that seasonal habitat is exceptionally productive for invertebrates (Gladden and Smock 1990). Sommer et al. (2001) also observed that the higher drift insect abundance was reflected in the diets of juvenile salmon; Yolo Bypass salmon had significantly more prey in their stomach than salmon collected in the Sacramento River. However, they noted that the increased feeding success may have been partially offset by significantly higher water temperatures on the floodplain habitat, resulting in increased metabolic costs for young fish. The higher water temperatures were a consequence of the broad shallow shoals, which warm faster than deep river channels. Through bioenergetic modeling, Sommer et al. (2001) concluded that floodplain salmon had substantially better feeding success than fish in the Sacramento River, even when the prey data were corrected for increased metabolic costs of warmer floodplain habitat.

Sommer et al. (2001) found that improved rearing conditions allowed juvenile salmon to grow substantially faster in the Yolo Bypass floodplain than the adjacent Sacramento River. They showed that mean salmon size increased significantly faster in the seasonally-inundated Yolo Bypass floodplain than the Sacramento River, suggesting better growth rates. As for splittail, results from the Cosumnes River suggest that more "natural" floodplains also provide good habitat for young salmon (Dr. Peter Moyle, University of California, unpublished data).

Although these results suggest that several habitat measures may be better for young salmon in the Yolo Bypass, floodplain habitat carries stranding risks. The relative importance of stranding mortality is difficult to evaluate because we have no reliable estimate of the total number of salmon which migrate through the Sacramento River and its tributaries. However, the Yolo Bypass floodplain has been graded for agriculture using laser leveling technology, resulting in an exceptionally welldrained topography. Our observations indicate that highly efficient drainage promotes successful emigration of young salmon. Sommer et al. (2001) examined this issue by doing paired releases of juvenile coded-wire-tagged salmon in Yolo Bypass and Sacramento River to obtain comparative survival data for fish migrating through each habitat type. They found that the Yolo Bypass floodplain release groups had somewhat higher survival indices than Sacramento River fish in both 1998 and 1999; however, the sample size (n=2) was too low to demonstrate statistical significance.

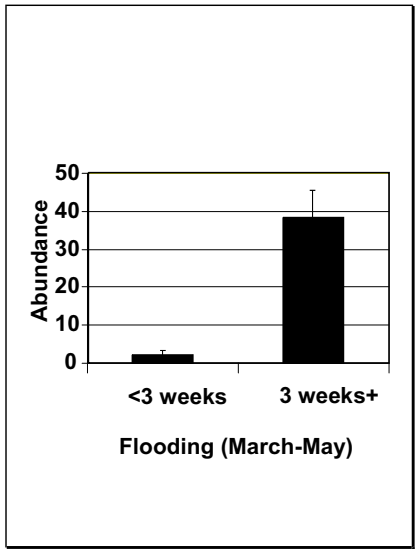
OTHER BENEFITS OF FLOODPLAIN TO AQUATIC COMMUNITIES

Yolo Bypass fish studies demonstrate that the floodplain provides key habitat for native and nonnative fish. However, floodplain inundation may also have benefits to organisms downstream in the brackish portion of the Estuary. At the base of the estuarine food web, phytoplankton are responsible for most of the primary production in the Estuary (Jassby et al. 1996). To the detriment of the Estuary, there has been a major long-term decline in phytoplankton biomass as a result of multiple factors including benthic grazers (Alpine and Cloern 1992), water exports and low outflow (Jassby et al. 1995) and climate change (Lehman 2000). Modeling studies by Jassby and Cloern (2000) suggest that phytoplankton produced in Yolo Bypass may be an important source of organic carbon to the Estuary, at least during flood events. Moreover, Yolo Bypass is probably also a major pathway for detrital material, a significant additional source of organic carbon to the food web of the phytoplankton-deficient Estuary. This conclusion is supported by Schemel et al. (1996), who found that the Yolo Bypass is the major pathway for organic matter to the Estuary in wet years.

FUTURE RESTORATION EFFORTS

Although our evidence demonstrates that the Yolo Bypass floodplain represents one of the most ecologically important regions in the San Francisco Estuary, we believe that habitat values can be enhanced through habitat restoration. A suite of floodplain restoration projects are being considered as part of the CALFED (2000) program, an ambitious State, federal and local effort to cooperatively resolve long-standing problems in the San Francisco Estuary and its tributaries. The major limitation of Yolo Bypass is that it has poor connectivity to the

FIGURE 2. Comparison mean year class strength of splittail in years when Yolo Bypass is inundated for less than three weeks during March-April to years when the floodplain is inundated for more than three weeks. Abundance data are based on Sommer et al. (1997) from the fall midwater trawl survey for 1975-1998.



remainder of the Delta in dry years. The Yolo Bypass is inundated an average of every two years, albeit native fish including young chinook salmon and splittail do not have access to the seasonal floodplain habitat during drought periods such as 1987-1992. Department of Water Resources is presently working on a CALFED-funded project to determine whether parts of the Yolo Bypass could be modified to create modest flooding in drier years, thereby supporting listed species such as salmon and splittail. The co-investigators on this project are Natural Heritage Institute and Yolo Basin Foundation, both local environmental groups. The idea of using managed flooding to improve habitat for aquatic species is conceptually similar to seasonal flooding used by Yolo Bypass wildlife areas and duck clubs to support waterfowl.

As described in our companion paper (Harrell and Sommer, this volume), an additional issue in the Yolo Bypass is that adult fish that migrate upstream through the floodplain cannot pass Fremont Weir except during flood periods. Some species such as splittail may be able to spawn in the Yolo Bypass Toe Drain, but chinook salmon have no low flow option unless they locate Putah or Cache creeks. Sturgeon likely have difficulties passing Fremont Weir during flood flows, preventing them from reaching upstream spawning habitat in all years. As such, we believe that Fremont Weir represents one of the major fish passage issues in the lower Sacramento Valley and needs to be resolved through future restoration efforts.

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