Reconciling Fish, Birds, and Farming on California's Yolo Bypass

Executive Summary

Floodplains in California and elsewhere are extremely productive habitats with high levels of biodiversity, yet they are often permanently disconnected from rivers by urban or agricultural development. This poses a potential threat to the many native fish, bird and other species that evolved to take advantage of seasonal floodplain inundation. The traditional restoration approach to this problem would recreate historical floodplain in some places by restoring natural hydrologic and successional processes. However levees, dams, and development prevent this approach in much of California. Recognizing these constraints, reconciliation ecology encourages land and water managers to re-engineer human-dominated landscapes to be more inclusive of native species' preferences without eliminating human uses. California's Yolo Bypass, an engineered floodplain on the Sacramento River, is an excellent case study for this new approach to native species management. This summary presents findings from a multi-objective analysis of the Yolo Bypass that suggest approaches for balancing economic and ecological objectives. Results suggest that significant habitat improvement is possible for several fish and bird species with little annual economic losses for farmers, and further that agricultural land uses can be important and useful in the habitat mosaic for fish and birds on the bypass.

Multiple Objectives for Land and Water Management on the Yolo Bypass

The Yolo Bypass (the Bypass) was built in the early 1900s to improve flood protection for the Sacramento Valley. Located within the Sacramento River's historical floodplain and connected to the river by several weirs, the Bypass can carry up to four times the flow of the main channel during large floods. But the Bypass has many additional economic and ecological purposes, including farming, duck hunting, wetland habitat for waterfowl and shorebirds, and important rearing and spawning ground for several fish species, including endangered spring and winter run Chinook salmon.

The Bypass's functionality as fish habitat during floods has received special focus in the last decade. Seasonal wetlands (including floodplain wetlands) are now only 5% of their historical extent in California's Central Valley, despite being very important habitat for many of the state's native fish species. Studies on the Yolo Bypass have shown that juvenile Chinook salmon grow faster and larger in flooded rice and other floodplain habitats than they do in the main river channel, and Sacramento

splittail production is correlated with Bypass inundation. The Bypass has been hailed by the Bay Delta Conservation Plan (BDCP) as the most promising location for restoring floodplain habitat for fish species in the Central Valley. The plan proposes a notch in the upstream Fremont Weir to increase the frequency and duration of inundation during key times of the year for salmon and splittail (Table 1 and Figure 1).

*Table 1: **Summary of the BDCP's list of potential operations for a gated notch in the Fremont Weir. Data Source: BDCP Chapter 3, Tables 3.4.2-1 and 3.4.2-2 (U.S.D.O.I. 2013)***

	Dec 1 – Feb 15	**Feb 16 – Feb 28**	**March 1 – March 23**	**Mar 24 – April 10**	**April 11 – May 15**
Current % of Years with Fremont Weir Overflow	61	50	47	22	17
Potential Frequency of Inundation w/ Modified Weir (% of Years)	69 - 89	67 - 75	72 - 81	61 - 67	19
Proposed Volume (cfs)	Up to 6,000	Up to 6,000	Up to 6,000	Up to 6,000 **only in years with natural overflow (currently 22% of yrs)*	Up to 6,000 **only in years with natural overflow*
Targeted Flood Extent (acres)	17,000	17,000	7,000 – 10,000	7,000 – 10,000	7,000 – 10,000
Proposed Duration	30 – 45 days or longer	30 – 45 days or longer	30 days	30 days	30 days
Targeted Species for Floodplain Habitat (does not include passage)	Winter-run & Spring-run Chinook salmon, and Sacramento splittail	Fall, Winter & Spring-run Chinook salmon, and Sacramento splittail	Fall, Spring and Butte Creek Spring-run Chinook salmon, and steelhead		Late Fall-run Chinook salmon, and steelhead

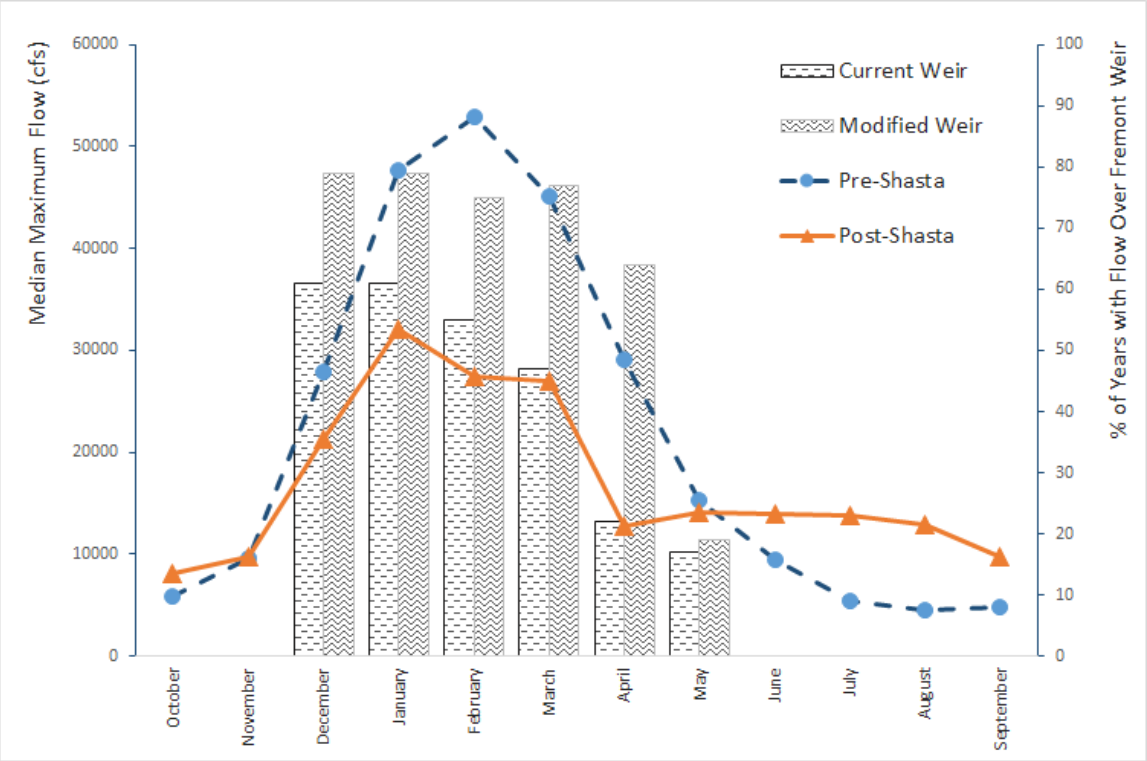

Figure 1. Median monthly high flows in the Sacramento River at Red Bluff, before and after the construction of Shasta Dam (Source: waterdata.usgs.gov), and proposed monthly increases in flood frequency on hte Yolo Bypass (U.S.D.O.I., 2013). Reservoir operations flatten out the flow distribution through time, decreasing the liklihodd of flooding in the winter and especially in the spring. Proposed modifications to the Fremont Weir seek to increase availability of flows during these months to more closely resemble historical flooding.

However these increased flows are not without controversy. While farming and wetland management on the Bypass is adapted to occasional winter flooding, water that stays on fields and management units too long into the spring can delay drawdown for wetland plants, or delay planting for crops, particularly rice and tomatoes. In either case, the growing season is shortened and crop yields reduced, with negative consequences for waterfowl food supplies and the agricultural economy. Figure 2 shows declines in per acre revenues for the major crop types in the northeastern Bypass with delayed plant dates.

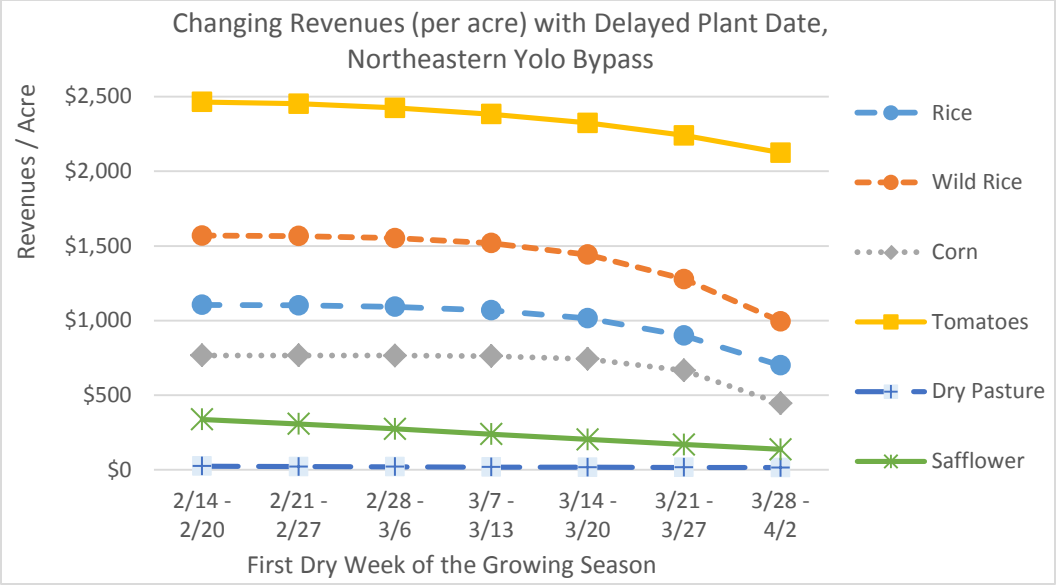

Figure 2. Changing per acre revenues for major crops in the northeastern Yolo Bypass with a delayed plant date. Very similar curves exist for the same crops in other parts of the bypass.

Deeper flooding for fish also could decrease the availability of shallower foraging habitat for wading ducks and shorebird species that require access to seeds and invertebrates at the bottom of the water column (Figure 3). For enhanced fish habitat to be reconciled with other human and bird land uses on the Bypass, planners will have to carefully re-engineer the landscape and manage flooding in a way that provides necessary habitat characteristics for fish while also supporting bird habitats and farming.

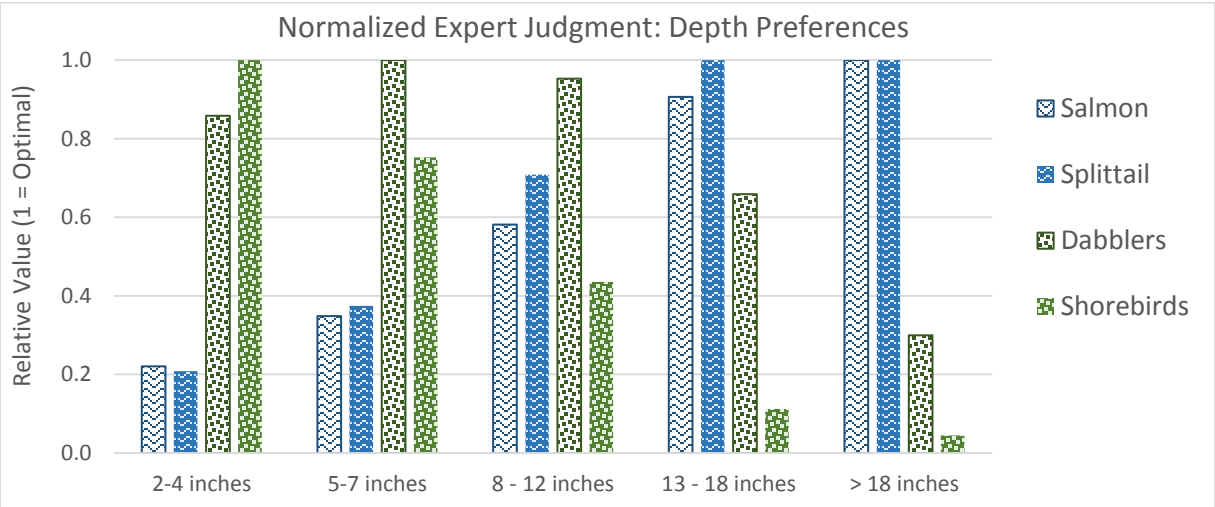

Figure 3. Normalized expert estimates of the value different depth ranges have for fish and birds. Average responses for each depth range were divided by 4 (the score that indicated optimal depths) to get relative scores ranging from 0 to 1.

Using Models to Guide Management of Complex, Multi-purpose Landscapes

Management of land and water resources on large, multi-purpose landscapes, such as the Yolo Bypass, often entails a large number of decisions made at varying geographic and temporal scales. These many decisions, in turn, all imply different consequences for each of the system's objectives. Models like the one developed for this study can integrate large amounts of data and knowledge, and explicitly account for the relationships and tradeoffs among different objectives. This is especially useful in reconciliation planning where many uses and variables interact on a landscape, and deliberate re-engineering requires considering many decisions simultaneously.

Modeling Land Use Decisions with the Yolo Bypass Multiobjective Optimization Model

This study considered three primary objectives for land and water management on the Bypass: maximize economic revenues, improve fish habitat, and improve (or maintain) waterfowl and shorebird habitats. There are two types of management decisions that can impact the performance of these objectives: (1) long-term land use decisions (total acres of each crop or wetland type in different regions across the bypass), and (2) week-to-week flooding management as added water is brought through or over the Fremont Weir. Flooding decisions can be further described by the placement of flows (how many acres of each land use type are flooded, and where), depth of flooding, and the timing and duration of flooding.

A Yolo Bypass Multiobjective Optimization Model (YBMOM) was developed to test iterations of land and water management decisions and maximize net revenues for varying levels of required performance towards fish and bird habitat quality. Agricultural revenue functions were adapted from an earlier report about the effect of winter and spring flooding on the Yolo Bypass to Yolo County (Howitt et al. 2013). Land use data for years 2005 through 2009 were used to assess whether the model reasonably estimates farming decisions on the Bypass with the bird and fish constraints left inactive (i.e. when the only objective is net revenues). The acreage for each crop was manually entered into the model so it could simulate the economic performance of that year (with no flooding except in wetlands). The model was then allowed to change land use decisions as necessary so as to maximize profits; this run was titled "Optimal Econ". A second optimization run was then completed titled Fish and Bird Optimal which introduced flooding up to 20,000 acres and activated the fish and bird habitat quality constraints, optimizing habitat benefits for each to the maximum extent possible before tradeoffs were needed between them, and allowing economic performance to decrease as necessary. Modeled land use decisions in the economic optimization closely resemble the relative prominence of different land

uses in 2009, suggesting that the economic objective function is a fairly good estimate of marginal realities for Bypass farmers (Figure 4).

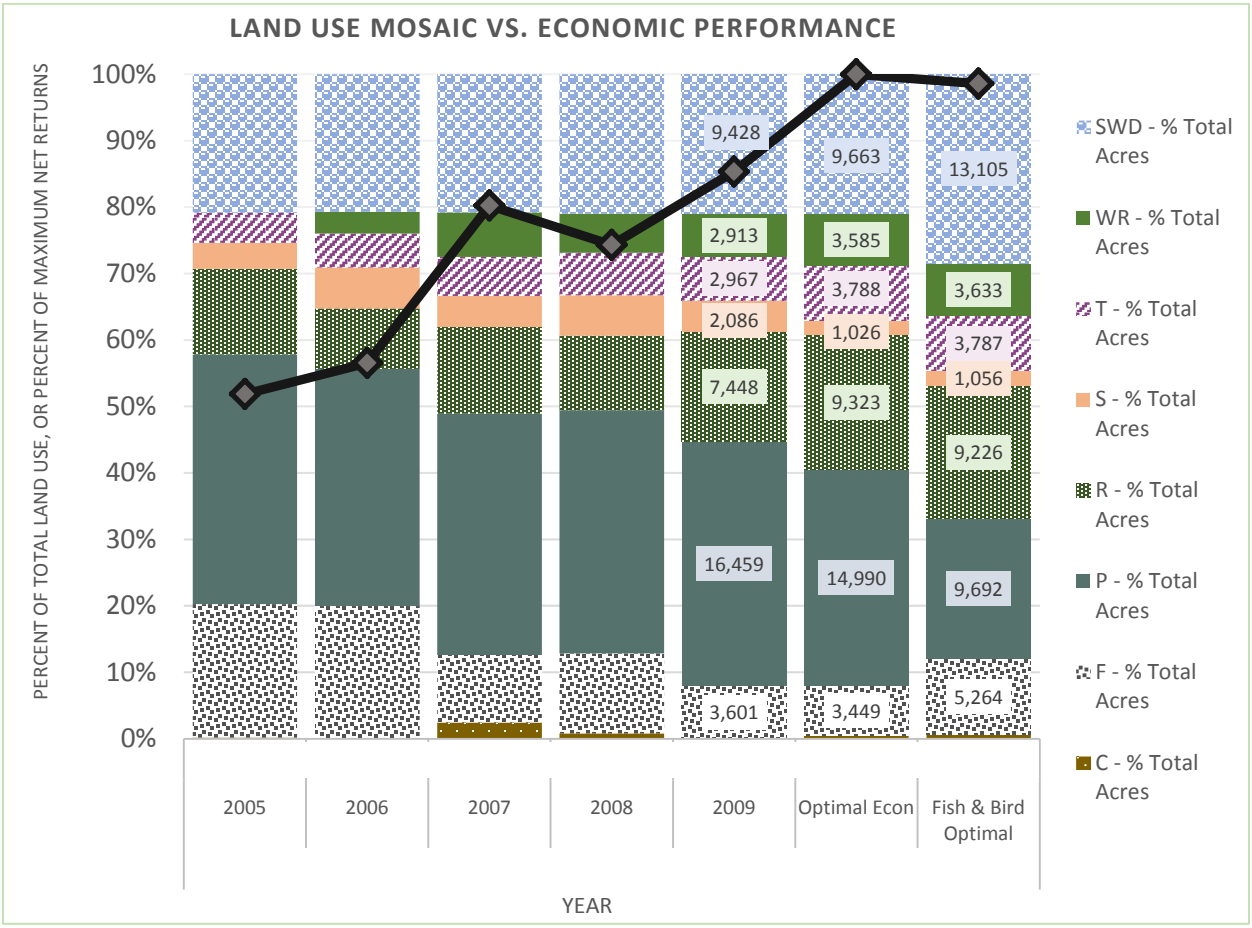

Figure 4. Percent of total area represented by each land use type, per year (histogram), and the percent of maximum profit netted in each year (black line). SWD = seasonal wetland, WR = wild rice, T = tomatoes, S = safflower, R = rice, P = pasture, F = fallow, and C = corn. NOTE: Total area can vary from year to year. 100 percent applies to a different base in 2005 than in 2009. This graph displays only the relative prominence of different land use types through time and in modeled decisions. Acreage of each land use type is displayed for year 2009 and for the modeled land use decisions for more direct comparison. Source for years 2005 - 2009: Yolo County GIS land use layers.

Extensive literature review and expert surveys informed a set of habitat quality functions for Chinook salmon, Sacramento splittail, dabbling ducks, and shorebirds. These functions include weights for the relative habitat quality of each major crop or wetland type on the Bypass (Figure 5).

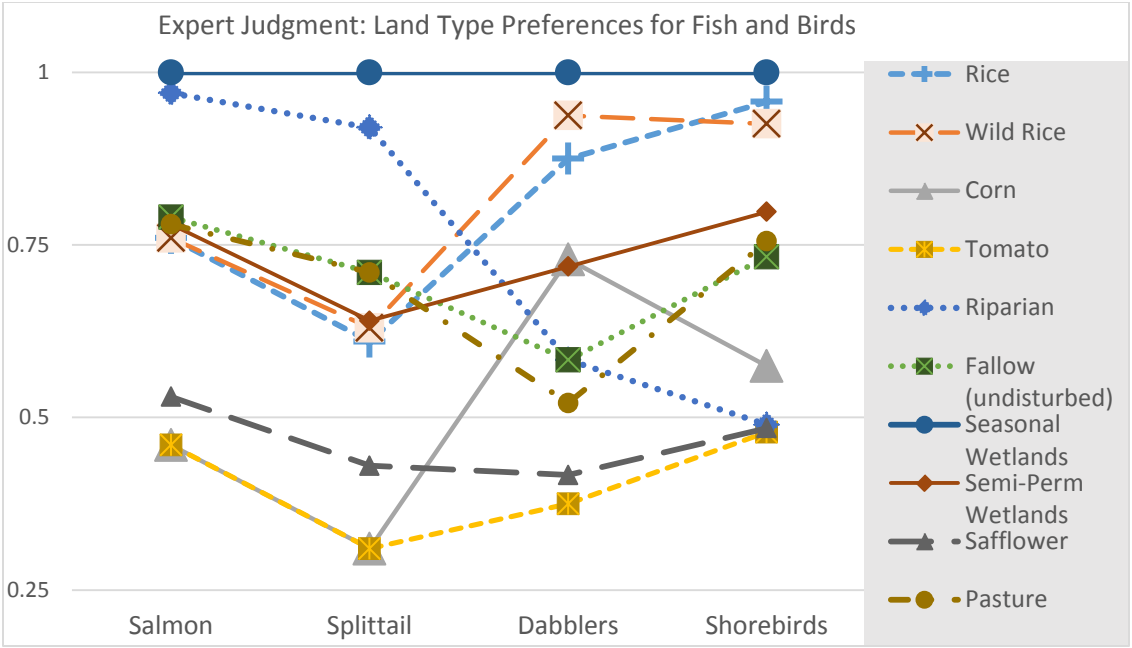

Figure 5. Comparison of species preferences for different land use types on the Yolo Bypass in terms of structure and foraging opportunities. 1 = best habitat available within the Yolo Bypass, not across all habitats ever available to those species.

Model results suggest that the land use mosaic could most efficiently (at least cost) improve habitat quality with a shift from pasture to seasonal wetland, mostly in the southern Bypass (Figure 4). This result persisted under a broad set of runs with varying habitat quality assumptions (weighting schemes). Model results also often suggested that small additions in rice and wild rice acreage could serve as valuable added habitat on the Bypass.

Adding Water – Efficiently Improving Habitat Quality for Fish and Birds with Planned Flooding Management

Habitat quality and economic performance on the Yolo Bypass are not solely functions of the land use mosaic; they also depend on the extent, timing, and duration of a given flooding scenario, with some of those variables implying further components of habitat quality like the heterogeneity or complexity of available land uses. Habitat quality also depends on the depth of flooding (Figure 3). These variables all can be deliberately manipulated by flooding management that uses gates, inflatable dams, and/or other added Bypass infrastructure to help direct flows in a way that maximizes habitat quality at least cost to farmers. Results suggest several guidelines for managing added flows on the Bypass:

1. **Timing** – under almost all habitat quality assumptions, the best start date for a 6 or 8 week inundation lies somewhere in the last week of January or first few weeks of February. This is not just because of the economics of a longer growing season, but is also the best balance of the needs of all four species groupings. However, the best start date also depends on duration of flooding; an early February start date will only have significant benefits for shorebirds, for instance, if it lasts at least 6 weeks. The shorter the duration, the more important timing becomes for each individual species and the harder it is to strike a balance with just one flood event.

2. **Depth** – Inundation depth varies in space and time over the course of a 6 or 8 week flood, and is the one management decision for which general conclusions are difficult. Depth controls exactly when and where a particular species will have viable habitat within the larger flood mosaic, so small changes in weightings or system preferences can make a large difference in the optimal pattern. In general, a Bypass balanced for fish and birds will benefit most from an inundation that starts sometime in late January or early February with shallow flooding during the first few weeks (usually less than 8 inches deep for birds), then deeper for a few weeks (13 - 18 inches) to provide better fish habitat, then a mixture of mudflat to moderately deep habitats as waters recede and shorebirds begin to share the system with fish and dabblers. This is even the case for floods that last only for 6 weeks if they start in February.

3. **Duration** – If flooding begins before the end of February, then it is always valuable (and not necessarily costly) to keep at least some water on wetlands and other lower-value land uses for a full 8 weeks (if possible). When flooding duration was decreased by 2 weeks, attainable habitat quality decreased by about 25%. Long-duration floods optimize the availability of flooded habitat in time and space and make it possible to satisfy a wider variety of species preferences.

4. **Hydraulic Management –** The ability to move and control the area flooded over a 6 to 8 week inundation event can significantly increase the cost-effectiveness of flooded habitat quality improvements on the Bypass. Hydraulic management could direct most flooding to the southern bypass, where agricultural losses are not as high, and phase rice, wild rice, and

sometimes safflower out of the flood footprint by mid-March, when lost yields from a delayed plant date begin to more significantly reduce crop revenues. Hydraulic control of flows also could move water that drains from these fields to wetlands and pasture for the remaining weeks of inundation, so fish and birds can still take advantage of food resources built up in the water column. Finally, it might help managers control for different depth targets, although natural topographic variability in the landscape will also always play a role.

Tradeoffs: Very Minimal Costs for Significant Habitat Improvements

All of the land use and flooding management decisions described in the above sections imply tradeoffs among fish habitat, bird habitat, and annual revenues. Figure 6 shows habitat quality tradeoffs for given annual economic losses with a February 7th start date. For comparison it also plots simulated habitat benefits that are currently achieved on the Bypass in dry years without a notch in the upstream Fremont Weir, and possible habitat gains with added flows on past land use mosaics (years 2006 and 2008). The big story from this figure is that fish and bird habitat on the Yolo Bypass can be improved at little annual cost for farmers. Added water from a notched weir could create fish habitat and improve bird habitat quality relative to current dry years with no annual revenue losses for farmers or duck club owners (the move from the yellow to the green box in Figure 3.2). Also, some land use changes would further optimize the application of that water for habitat without any losses in annual agricultural revenues (the move from the green box to the “no losses” curve in Figure 3.2). Finally, significant improvements in habitat quality are achievable with additional land use changes and $100,000 - $200,000 in annual net revenue losses or compensation. This loss in annual revenues represents less than a 1% loss of total annual crop revenues on an economically optimized (modeled) bypass, and a loss of 1 – 5% of annual historical revenues in real years 2005 – 2009.

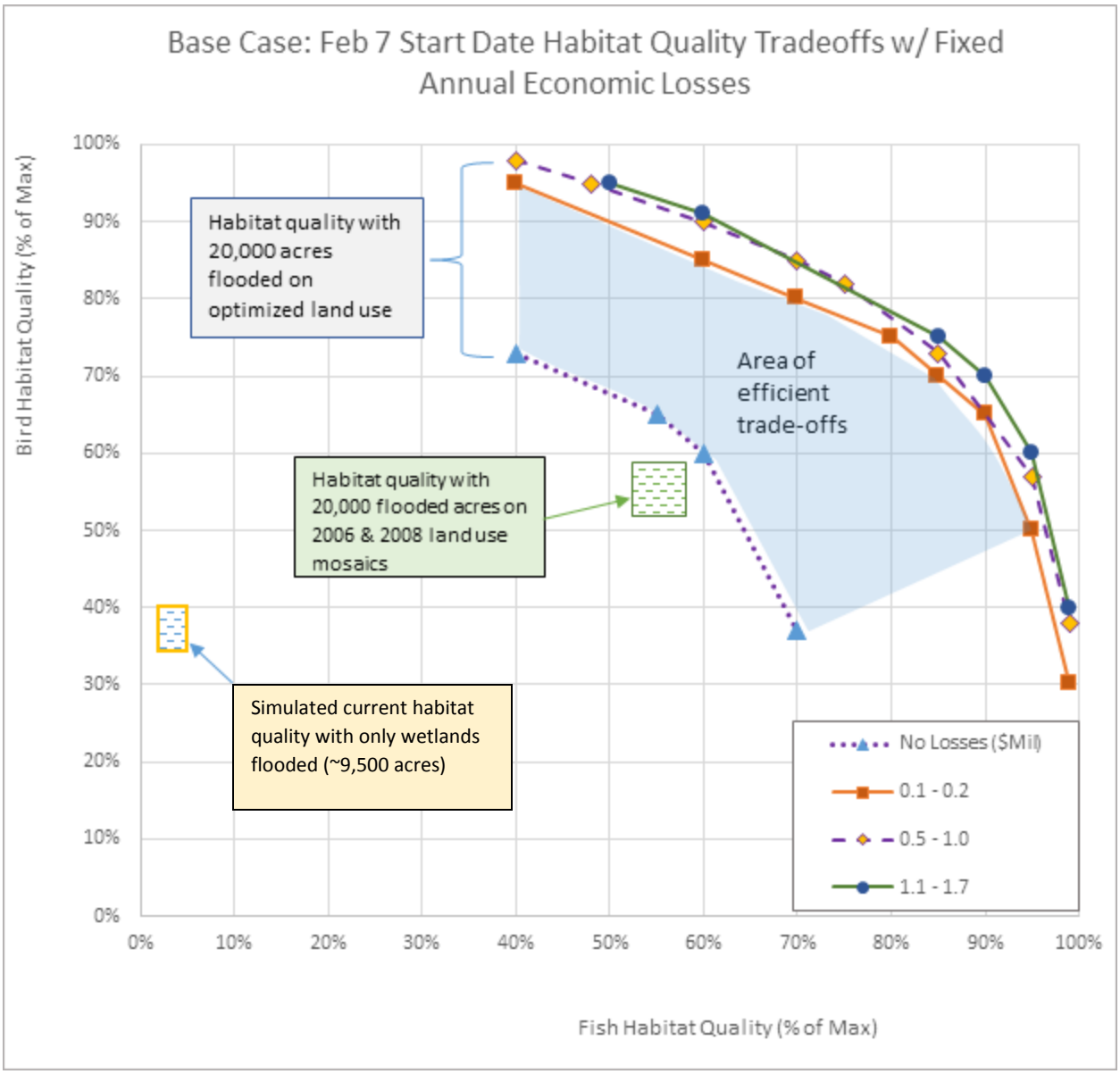

Figure 6. Habitat quality tradeoffs for given losses in annual revenues with a February 7th start date, and varied habitat assumptions and priorities (salmon and dabblers prioritized on the left, and all land uses weighted equally for fish on the right). Blue shaded area shows the regions where tradeoffs among fish, birds, and annual revenues are low for significant gains in habitat quality objectives.

Next Steps

This work makes several recommendations for land use changes with varied implications for different stakeholders on the Yolo Bypass. Trading pasture for wetlands or adding acres of rice and wild rice will have tax implications for Yolo County and financial implications for local farmers and landowners. None of these changes can occur without first deciphering how to finance them, or more specifically, designating who pays for changes in management. The YBMOM can help provide detailed

and zone-specific information about the economic implications of management decisions, and a rough estimate of ecological and economic gains or losses resulting from any changes.

Another potentially required land use change will be the creation of new wetlands and fields devoted to habitat-friendly crops; strategically locating these land uses close together and near the water source will allow applied water to be more easily managed for depth and duration. It is more difficult to flood x acres of rice and y acres of pasture if they are several miles apart and far from the eastern channel that delivers water down the length of the Bypass. The model makes zone-specific recommendations that were not studied in detail here, but would warrant closer examination once water is actually available. This would also help in developing more location specific mitigation or incentive programs for landowners.

Regardless of these needed steps, the qualitative conclusions presented above are robust: even under a wide variety of assumptions on habitat and species preferences, there is much promise for a reconciliation approach to management of the Yolo Bypass that need not be extremely costly to landowners and farmers. This study highlights the ability for birds and fish to both benefit from management of a mixed agricultural and wetland landscape, without large tradeoffs among them. Importantly, agricultural crops are optimally a vital component of the overall habitat mosaic, a sign that even heavily modified floodplains can be improved for native species without eliminating human use. The YBMOM and similar quantitative analysis can help provide detailed suggestions for managing the system when infrastructure modifications allow for more controlled and more frequent inundation.

References

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