11 – April 25), for years classified as wet (2017 was a wet year), was 18 g/day (range 11-32 g/day among these wet years). For the overall simulation period, the Yolo Bypass was a net trap for inorganic Hg, with 20% less exported at the stairsteps than was loaded from tributaries. Similarly, the Yolo Bypass was a net sink for sediment. Trapping efficiency tended to be greater in drier years.

The total amount of flow and the relative contributions of different water sources varied by an order of magnitude or more among the simulated years. For the simulation period, the Fremont Weir was the largest tributary contributor to water, suspended sediments, and uMeHg, followed by the CCSB. The Fremont Weir contributed approximately half of the uMeHg tributary load, followed by Cache Creek Settling Basin at approximately one third. Together, these two sources represented more than 80% of the total tributary uMeHg load for the simulation period. The CCSB was a slightly larger contributor of inorganic Hg, followed closely by the Fremont Weir (51% vs. 43%, respectively). However, the inorganic Hg load from the CCSB could be overestimated under high flow conditions. In wet years, the largest modeled external sources of suspended sediment were the Fremont Weir and the CCSB, with the Fremont Weir representing two thirds of the suspended sediment input to the Yolo Bypass. In wet years, contributions from the Knights Landing Ridge Cut were small, however, its importance increased in dry years, representing up to 90% of tributary sediment inputs. Direct atmospheric loading of inorganic Hg was small, less than three percent of tributary loads for the simulation period.

To examine potential MeHg reductions, nine simulations, developed in consultation with the Regional Board, were carried out to examine the sensitivity of model results to hypothetical 50% reductions to select model input values. Overall, the simulations reduced the predicted export of MeHg from less than 5% to roughly 20%. The largest decrease in MeHg exports (~20%) occurred by decreasing the conversion efficiencies of Hg(II) to MeHg in Yolo Bypass surface sediments. For some of the simulations, the lack of model response to various sensitivity reductions may have suggested that a simulation period of sixteen years was insufficient to observe a change in response. Simulated removal of all vegetation led to a reduction of approximately 60% in net MeHg production in Yolo Bypass sediments. However, surprisingly, removing vegetation by 50% resulted in less than a 5% decline in MeHg exports. These results reflect competing processes in the model, however, they may also reflect modifications required to allow the model to simulate vegetation effects, which may not fully capture real-world vegetation dynamics. Overall, the simulations and experimental evidence available suggest vegetation can have a strong influence on MeHg production in Yolo Bypass.

Delta Modeling Results

The model was calibrated for suspended sediments, Hg (II), and MeHg. Overall, the model calibration results reasonably fit observations of suspended solids, uHg(II), f(Hg (II), uMeHg, and fMeHg in Delta waters.

During the model study period, the Sacramento River was generally the largest inflowing source of uHg(II) and MeHg to the Delta (71% and 52% respectively). The relative importance of tributaries as sources of Hg and MeHg also varied from year to year. Yolo Bypass represented about one third of the external supply of MeHg to the Delta for the overall simulation period, but this ranged from 3-50% among the years simulated. Under some high-flow months, the Yolo Bypass was the largest external source of MeHg to the Delta. Annual freshwater inputs of uHg(II) and uMeHg each varied by approximately 6-fold for water years 2000-2006.

The largest simulated Delta outflows of uHg(II) and uMeHg were exports at Chipps Island (89% and 85% respectively). The Delta was simulated to be a net long-term sink for uHg(II) and uMeHg, exporting roughly half the inflowing load of uHg(II) and 80% of the inflowing uMeHg load (see Chapter 5).

The model was used to explore spatial and temporal patterns of concentrations for suspended sediments, uHg(II) and uMeHg for high, median, and low flow conditions during the Hg calibration period. For the highest flow in the Sacramento River and the Yolo Bypass, suspended sediment and uHg(II) concentrations were higher on the periphery of the Delta and lower in the Central Delta. This pattern was not evident for uMeHg. Similar patterns were not observed under median and low flows. These patterns represent one snapshot in time; further investigation would be required to see if these patterns are consistent under similar flow conditions.

Estimates of simulated open water sediment fluxes were similar to those developed for CalFed; the model estimated Delta open water sediment flux at 0.42 g/day compared to 0.48 g/day in a 2008 CalFed report (see Chapter 3 and Technical Appendix B, Foe and others, 2008).

Management Implications

Technical Studies

Managing vegetation as a key component of reducing winter internal Yolo Bypass methylation has important management considerations and provides a starting point for future open water control studies and development of Best Management Practices (BMPs).

Vegetation senescence experiments suggest that controlling above-ground vegetation mass may be an effective mechanism to control methylmercury production and release to overlying waters during a flood event. Disking vegetation into the soil appears to be a promising approach to reduce the internal production of MeHg in the Yolo Bypass. Controlling vegetative biomass by grazing gave mixed results. The dynamics between vegetation quality, quantity, and vegetation type requires further investigation before grazing as a BMP can be proposed. While not examined, selective flooding of pastures in the fall, prior to the winter flood season, may be another approach to reduce or remove the standing biomass of vegetation and reduce methylmercury production from vegetation during a flood event.

With any of these approaches, it is important to note that DWR is not a landowner in the Yolo Bypass, therefore any changes in land use practices are outside its jurisdiction and must be pursued by the Regional Water Quality Control Board. Any proposed BMP will need to be evaluated holistically within the full context of the environment that the BMP would be used. It is recommended that before additional studies are conducted, landowners and agencies, such as the Resource Conservation Districts, will need to be consulted to determine if the ecological and cost-benefit impacts, associated with potential land use management approaches, are reasonable or practical.

Much attention has been placed on the Cache Creek Settling Basin (CCSB) and its contributions of inorganic Hg and MeHg to the Yolo Bypass. However, our coarse estimates of MeHg mass generated from decaying vegetation suggests that reductions in vegetation biomass could substantially help with the Yolo Bypass load allocation reduction required in the DMCP.

Modeling Studies

Modeling frameworks were successfully developed for both the Yolo Bypass and the Delta. Comparison of simulated results to field observations suggest that the models are successfully reproducing patterns and trends, providing a meaningful, but coarser perspectives, rather than a tightly-constrained analysis. The analysis was constrained by a combination of limited data and knowledge gaps regarding some key processes operating in the Yolo Bypass. To extend the models' usefulness and to improve modeling results, additional data is needed to better characterize inflowing loads and within-system conditions in the Delta and the Yolo Bypass for a range of hydrologic conditions and a range of years. Needed data includes measurements of inorganic Hg and MeHg in unfiltered, particulate, and filtered phases in tributaries, the water column, and sediments of the Delta and the Yolo Bypass, as well as ancillary data such as water chemistry (e.g. suspended sediment concentrations, dissolved organic carbon, pH, temperature) and sediment characterization.

The dynamic nature of flow in the Delta and Yolo Bypass resulted in a high degree of variability in simulated uHg(II) and uMeHg concentrations, inflowing loads and export rates in the short term (e.g. daily) and longer term (e.g. annually). This has important implications when estimating present-day baseline loads, assigning load allocations, and monitoring for compliance with regulations in the future. A multi-year perspective is needed, designed to capture year to year variability, but with sufficient resolution to also capture short term variability (or not be biased by it), and show longer term systematic trends that might occur (e.g., via climate change). It is recognized that characterizing the spatial and temporal patterns in a system as large and heterogeneous as the Delta/Yolo Bypass is a large effort. A carefully coordinated program would be required, and options should be considered to use automated or surrogate sampling techniques where possible (e.g. continuous turbidity data to estimate suspended sediment concentrations). In the Yolo Bypass, the spatial coverage of sampling should reflect the various land uses and include vegetation-related parameters where appropriate.

Moving forward, the ability to model a variety of operational scenarios would be improved by developing a single publicly available hydrodynamic and Hg model for both the Delta and the Yolo Bypass. Additionally, given the important role that vegetation appears to play in MeHg production in the Yolo Bypass, model enhancements should include an improved treatment of vegetation where applicable. Since bioaccumulation in fish is the driver of the DMCP, consideration should be given to adding a bioaccumulation component to the model framework. Similarly, since model analysis indicated that tributary inflows have a strong influence on mercury concentrations in the Delta, consideration could be given to the merits and cons of a model analysis extending upstream and/or downstream of the legal Delta. However, the confidence associated with a model analysis carried out with improved tools would still be limited by the level of data currently available. Therefore, model refinements and data collection efforts need to occur in parallel.