Methylmercury and Total Mercury in Fish and Water from the Sacramento-San Joaquin Delta: Year Three (July 2018 - June 2019)

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Executive Summary

Monitoring of methylmercury (MeHg) in sport fish and water was conducted by the Delta Regional Monitoring Program (Delta RMP, or Program) from July 2018 through June 2019 (following the fiscal year schedule for the Program. This was the third year of MeHg monitoring by the Program (the first year occurred in fiscal year 2016/17, the second year in fiscal year 2017/18). MeHg is an organic form of mercury that bioaccumulates in aquatic ecosystems and is highly toxic to humans as well as to fish, birds, and mammals. Delta RMP MeHg monitoring addresses high priority information needs related to implementation of the Sacramento–San Joaquin Delta Estuary Total Maximum Daily Load (TMDL) for Methylmercury (Wood et al. 2010). This data report presents the methods and results for the third year of MeHg monitoring by the Delta RMP.

The design of the mercury monitoring has evolved from year to year, and this continued in year 3. Fish monitoring at one new station—Sherman Island—was added in 2018, bringing the total number of fish monitoring stations to 7. The Sherman Island fish station was paired with the Sacramento River at Mallard Island water monitoring station to represent conditions in the West Delta subarea. Water monitoring was conducted at 8 stations on a monthly basis, except for the months of November and December 2018. One water station (Delta-Mendota Mendota Canal at Byron-Bethany Road) was not paired with a fish station because it was only monitored to support development of an updated aqueous MeHg mass balance. Sediment monitoring was conducted in year 2, but discontinued in year 3 due to funding limitations and the lower relative priority of this element.

About 15% of all samples were analyzed for quality assurance and quality control purposes. Ninety-five percent of the lab results for this project, including all of the results for MeHg and total mercury (THg), met all of the requirements of the Delta RMP Quality Assurance Project Plan. Results that did not meet all of the measurement quality objectives outlined in the QAPP included three ancillary water parameters: dissolved organic carbon, total suspended solids, and volatile suspended solids.

Two species of sport fish, largemouth bass (*Micropterus salmoides*) and spotted bass (*Micropterus punctulatus*), were collected at 7 stations in August and September 2018. The annual mean MeHg (measured as THg, which is a routinely used proxy for MeHg in predator fish) concentration in bass ranged from 0.34 parts per million (ppm) (wet weight) at Middle River to 1.47 ppm at the Lower Mokelumne River. Concentrations of MeHg in unfiltered water ranged from less than 0.011 - 0.24 ng L^{-1}. Concentrations of THg in unfiltered water, which is measured to aid in interpretation of results for MeHg, ranged from 0.57 - 26 ng L^{-1}.

Historic data from the same or nearby monitoring stations from 1998–2011 are also presented to provide context. Mercury monitoring results from Delta RMP year 3 for both sport fish and water were generally comparable to historic observations. Mean year 3 MeHg concentrations in fish at two stations were significantly higher than year 2 concentrations: San Joaquin River at Vernalis and Middle River at Borden Highway. The year 3 mean for sport fish from San Joaquin River at Vernalis (1.46 ppm) was far higher than the 2017 mean (0.53 ppm) and all of the other means in the long-term time series for this station. Mean sport fish concentrations at the other four stations that were also monitored in 2017 were not significantly different from the 2017 means. The mean MeHg concentration in sport fish at the newly added Sherman Island station in 2018 was similar to mean concentrations observed in this area in prior studies.

The sample size for water concentrations from the first three years of monitoring is small. More intensive (near monthly) sampling began at the end of year 2 (beginning of 2018) and continued into year 3. A separate interpretive report (Davis et al. 2021) evaluates patterns in the water data and correlations between MeHg concentrations in water with those in fish.

For the next several years, annual monitoring of sport fish is planned to more firmly establish baseline concentrations and evaluate inter-annual variation in support of monitoring of long-term trends as an essential performance measure for the TMDL. The future monitoring design for water will be determined in 2020.

Introduction

Concentrations of methylmercury (MeHg) in fish from the Sacramento–San Joaquin Delta (the Delta) (Figure 1) exceed thresholds for protection of human and wildlife health. The Delta Methylmercury Total Maximum Daily Load (TMDL) (Wood et al. 2010) is the driver of actions to control MeHg in the Delta, establishing water quality goals and directing various discharger groups to conduct monitoring and implement measures to minimize impairment of beneficial uses.

MeHg concentration in largemouth bass[1] is the most important performance measure of progress in addressing MeHg impairment in the Delta. The TMDL established three water quality objectives for MeHg in fish tissue: 0.24 µg/g, or parts per million (ppm), on a wet-weight basis in muscle of large, trophic level four (TL4) fish such as black bass[2]; 0.08 ppm in muscle of large TL3 fish such as common carp (*Cyprinus carpio*); and 0.03 ppm in whole TL2 and TL3 fish less than 50 mm in length such as inland silverside (*Menidia beryllina*). Furthermore, the TMDL established an implementation goal of 0.24 ppm in largemouth bass muscle at a standard size of 350 mm as a means of ensuring that all fish tissue objectives are met. Largemouth bass are widely distributed throughout the Delta and are excellent indicators of spatial variation due to their small home ranges. Past data from 1998–2001 for largemouth bass were a foundation for the development of the TMDL, including the division of the Delta into eight subareas (Figure 1).

Additional data on MeHg in water has also been identified as a high priority information need. The analysis conducted for the TMDL established that there is a statistically significant relationship between the annual mean concentration of MeHg in unfiltered water and mean MeHg in 350 mm largemouth bass when the data are organized by subarea. This linkage provides a connection, essential for management, between MeHg inputs and impairment of beneficial uses. Because of this linkage, the TMDL established an implementation goal of 0.06 ng L^{-1} of unfiltered aqueous MeHg. In response to TMDL control study requirements, the Department of Water Resources (DWR) is developing numerical MeHg transport and cycling simulation models for the Delta and Yolo Bypass. Monitoring of aqueous MeHg is therefore needed to:

1) better quantify the fish-water linkage that is the foundation of the TMDL,
2) evaluate attainment of the TMDL implementation goal,
3) support calculations of total mercury (THg) and MeHg loads and mass balances,

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[1] Nearly all of the mercury present in edible fish muscle is MeHg, and analysis of fish tissue for THg provides a valid, cost-effective estimate of MeHg concentration (Wiener et al. 2007).

[2] "Black bass" refers collectively to largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), and spotted bass (*Micropterus punctulatus*).

4) support development of mercury models for the Delta and Yolo Bypass, and
5) support evaluation of the fish data by providing information on processes and trends.

This data report presents the methods and results for the third year of monitoring (covering the fiscal year from July 2018 through June 2019) by the Delta Regional Monitoring Program (the first year occurred in fiscal year 2016/17, the second year in fiscal year 2017/18). In this third year, the Delta RMP continued mercury monitoring of fish and water. Black bass were collected in late summer (August and September) 2018 from seven stations distributed across the subareas. Monitoring of THg and MeHg (and ancillary parameters) in water continued, with this round of monitoring starting in July 2018. Historic data from the same or nearby monitoring stations are also presented to provide context.

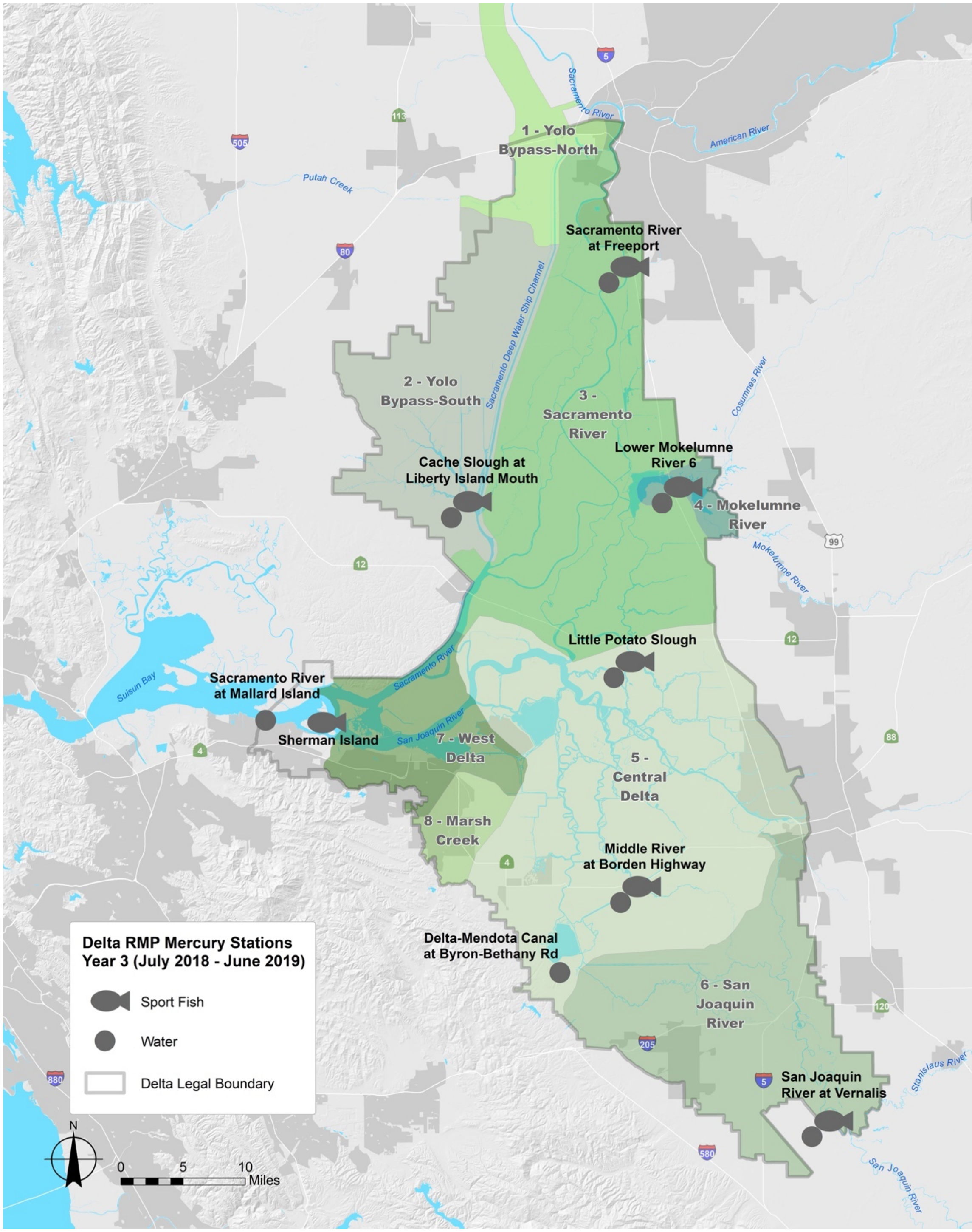
Sediment monitoring was conducted in year 2 but discontinued in year 3 due to funding limitations and the lower relative priority of this element.

Applicable Management Decisions and Delta RMP Assessment Questions

The Delta MeHg TMDL provides a plan for restoring surface waters in the Delta that are impaired by MeHg. It is the embodiment of management decisions for MeHg in the Delta, establishing limits for the amount of mercury waterways can receive while meeting water quality goals, and calling for a variety of control studies and actions. The Delta RMP is conducting mercury monitoring in order to support the TMDL review and implementation.

The Delta RMP has established two tiers of assessment questions for the mercury monitoring program. Primary assessment questions are explicitly addressed by the monitoring and drive the monitoring design. Secondary assessment questions are addressed to some extent by the monitoring but are not drivers of the monitoring design. The monitoring will contribute some information but will not fully answer the secondary assessment questions. An interpretive report on the first three years of monitoring (Davis et al. 2021) will evaluate progress in answering the primary and secondary assessment questions.

Figure 1 Map showing the boundary of the Delta, the eight subareas delineated in the TMDL, and the sampling stations for fish and water in year 3 of Delta RMP mercury monitoring. Lower Mokelumne River 6 station was not sampled for water until October 2017. The Sherman Island station was added for fish in Year 3.



Primary Assessment Questions

There are three priority assessment questions addressed by the Delta RMP MeHg monitoring. One priority question is from the Status and Trends category of the Delta RMP management and assessment questions. The second priority assessment question is associated with sources, pathways, loadings, and process, and the third priority assessment question focuses on fish-water linkage analysis.

Status and Trends

- ST1. What are the status and trends in ambient concentrations of MeHg and THg in sport fish and water, particularly in subareas likely to be affected by major existing or new sources (e.g., large-scale restoration projects)?
  - ST1.A. Do trends over time in MeHg in sport fish vary among Delta subareas?

Question ST1A is a high priority for managers that relates to the MeHg TMDL and is a primary driver of the sampling design for fish monitoring. Annual monitoring of MeHg in fish tissue is urgently needed to 1) more firmly establish baselines for each Delta subarea and 2) to characterize the degree of interannual variation, which is essential to designing an efficient monitoring program for detection of long-term trends. In addition to addressing status and trends, this monitoring is establishing a foundation for tracking the effectiveness of management actions—another category of the Delta RMP core management questions.

Sources, Pathways, Loadings and Processes

- SPLP1. Which sources, pathways, and processes contribute most to observed levels of MeHg in fish?
  - SPLP1.A. What are the loads from tributaries to the Delta (measured at the point where tributaries cross the boundary of the legal Delta)?

A mass budget for MeHg in the Delta is a critical element of the TMDL. The mass budget provides essential context for understanding the importance of inputs from discharges and internal sources and processes. Obtaining data to expand and update the dataset on MeHg inputs to the Delta is a high priority to support TMDL refinement and implementation. MeHg export from the Delta is similarly an important component of the mass budget and a high priority information need.

Fish-Water Linkage Analysis
(new priority question articulated by Mercury Subcommittee)

FWLA1. What is the relationship between MeHg in black bass and MeHg in water?

Another priority question addressed by Delta RMP MeHg monitoring relates to the linkage analysis discussed in the previous section, which is a key element of the technical basis for the TMDL. This question was not articulated in the core management and assessment questions established by the Delta RMP Steering Committee, but was nevertheless identified as a priority by the Mercury Subcommittee. Additional data on MeHg in water is one of the key datasets needed to strengthen the technical foundation of the TMDL.

Secondary Assessment Questions

Sources, Pathways, Loadings and Processes

SPLP1. Which sources, pathways and processes contribute most to observed levels of MeHg in fish?

- SPLP1.B. How do internal sources and processes influence MeHg levels in fish in the Delta?
- SPLP1.C. How do currently uncontrollable sources (e.g., atmospheric deposition, both as direct deposition to Delta surface waters and as a contribution to nonpoint runoff) influence MeHg levels in fish in the Delta?

Forecasting Scenarios

FS1. What will be the effects of in-progress and planned source controls, restoration projects, and water management changes on ambient MeHg concentrations in fish in the Delta?

These secondary assessment questions regarding Sources, Pathways, Loadings, and Processes and Forecasting Scenarios relate to one of the major control studies called for in the TMDL: an effort to combine modeling, field data, and laboratory studies to evaluate the potential effects of water project operational changes on MeHg in Delta channels. The California Department of Water Resources (DWR) is currently developing two mathematical models, one each for the Delta and Yolo Bypass, that may allow testing of various land and water management scenarios (DiGiorgio et al. 2016). These models may be useful in addressing this set of Delta RMP assessment questions. The opportunity to inform these models, which are being developed with considerable funding from DWR, makes monitoring to address these questions a near-term priority for the Delta RMP. The water monitoring included in this study will generate data that are valuable for verifying trends and patterns predicted by the MeHg models. It should be noted that these models are being developed to predict concentrations of MeHg in the water column but will not include a bioaccumulation component that translates the water concentrations into fish tissue concentrations.

Methods

Sample collection and analysis followed protocols described in detail in the Delta RMP Quality Assurance Project Plan (QAPP), version 4.2 (Jabusch et al. 2018).

Sample Collection

In year 3, fish samples were collected from seven stations in the Delta and water samples were collected at the seven fish stations and one additional station (Figure 1). Fish collections were completed in September 2018 (one event) and water collections occurred from July 2018 through June 2019 (nine events). Details on sampling stations and dates are listed in Table 1 and in greater detail in the cruise report (Appendix 1).

Fish collection methods are briefly described here with greater detail given in Appendix 1. The field crew from Moss Landing Marine Laboratory collected 16 individual bass from each station by electrofishing. At each station, all fish collected were of the same species: at 6 of the 7 stations, the field crew collected largemouth bass (*Micropterus salmoides*), however at the Sacramento River at Freeport, they collected spotted bass (*Micropterus punctulatus*). Upon collection, each fish collected was tagged with a unique ID. Physical parameters measured for each individual fish included: weight, total length, fork length, and presence of any abnormalities. Large fish (greater than 370 mm) were partially dissected in the field using the following protocol: fish were placed on a cutting board covered with a clean plastic bag where the head, tail, and entrails were removed using a clean cleaver. Fish samples were stored on dry ice for the duration of transport to the Marine Pollution Studies Laboratory – Department of Fish and Wildlife (MPSL-DFW) at the Moss Landing Marine Laboratory (MLML) in Moss Landing, CA. At MPSL-DFW samples were stored in a -30 °C freezer until processed for authorized dissection and analysis.

A handheld YSI instrument was calibrated before and after each fish sampling event and was cleaned with DI water between stations. It was used to measure the following ancillary water column parameters at each station: temperature, pH, dissolved oxygen concentration, conductivity, salinity, and turbidity.

Table 1 Sampling station code, name, latitude, longitude, and collection dates. Listed north to south.

Station Code	Station Name	Latitude	Longitude	Fish Collection Dates	Water Collection Dates
510ST1317	Sacramento R @ Freeport	38.4556	-121.5019	2018-08-20	2018-07-09 2018-08-13 2018-09-10 2018-10-08 2019-01-21 2019-02-18 2019-03-20 2019-04-22 2019-05-20 2019-06-18
544ADVLM6	Lower Mokelumne R 6	38.2554	-121.4401	2018-08-21	2018-07-09 2018-08-13 2018-09-10 2018-10-08 2019-01-21 2019-02-18 2019-03-20 2019-04-22 2019-05-20 2019-06-18
510ADVLIM	Cache Slough at Liberty Island Mouth	38.2421	-121.6854	2018-08-20	2018-07-09 2018-08-13 2018-09-10 2018-10-08 2019-01-21 2019-02-18 2019-03-20 2019-04-22 2019-05-20 2019-06-18
544LILPSL	Little Potato Slough	38.0963	-121.4960	2018-08-21	2018-07-09 2018-08-13 2018-09-10 2018-10-09 2019-01-21 2019-02-18 2019-03-20 2019-04-22 2019-05-20 2019-06-18

Station Code	Station Name	Latitude	Longitude	Fish Collection Dates	Water Collection Dates	
207SRD10A	Sacramento River at Mallard Island	38.0429	-121.9201	NA[1]	2018-07-10 2018-08-14 2018-09-11 2018-10-09 2019-01-22 2019-02-19 2019-03-21 2019-04-23 2019-05-21 2019-06-19	7/10/18 8/14/18 9/11/18 10/9/18 1/22/19 2/19/19 3/21/19 4/23/19 5/21/19 6/19/19
510ST1666	Sherman Island	38.0431	-121.8044	2018-08-21, 2018-09-11	NA[1]	
544MDRBH4	Middle R @ Borden Hwy (Hwy 4)	37.8908	-121.4883	2018-08-22	2018-07-09 2018-08-14 2018-09-11 2018-10-09 2019-01-22 2019-02-19 2019-03-21 2019-04-23 2019-05-21 2019-06-18	
544DMC020	Delta-Mendota Canal at Byron-Bethany Road (aka DMC off HWY 4)	37.8121	-121.5790	N/A	2018-07-10 2018-08-14 2018-09-11 2018-10-09 2019-01-22 2019-02-19 2019-03-21 2019-04-23 2019-05-21 2019-06-19	
541SJC501	San Joaquin R @ Vernalis/Airport Way	37.6756	-121.2642	2018-08-22, 2018-09-12	2018-07-10 2018-08-14 2018-09-12 2018-10-09 2019-01-22 2019-02-19 2019-03-21 2019-04-23 2019-05-21 2019-06-19	

[1] The Mallard Island station is used for estimating output from the Delta in the MeHg mass budget but is not good fishing habitat. Sherman Island is a nearby station in the West Delta that is good fish habitat.

Water sampling methods are briefly described here and in greater detail in Appendix 1. Water samples were collected using a depth-integrated sampler (SWAMP Clean Water Team SOP 2.1.1.4) modified to accommodate a 4 L glass bottle and to collect trace metal samples cleanly. Care was taken to lower and raise the bottle through the water column at a sufficient rate so that the bottle was not completely filled upon retrieval. A new pre-cleaned bottle was used for each station and sampling event.

Aliquots of raw water for the determination of MeHg, total Hg, and total suspended solids (TSS) were collected, prior to collecting filtered samples, by vigorously shaking the 4 L bottle and pouring off unfiltered water sample aliquots.

Aliquots of filtered water for the determination of dissolved organic carbon (DOC), MeHg and total Hg were filtered in the field using a Cole-Parmer Masterflex® E/S™ portable peristaltic pump, acid-cleaned tubing sets, and trace metal clean 0.45 µm groundwater filters.

Samples for chlorophyll *a* analysis were field-filtered by forcing water with a 60-mL syringe through a filter holder containing a 25 mm glass microfiber filter. Filters were placed on dry ice for transport to MPSL-DFW.

All water samples were immediately stored on wet ice (4°C) following collection and transported to MPSL-DFW.

Sample Preparation and Analytical Methods

Water samples for Hg determination were preserved by acidification within 24 hr of collection. Aqueous total Hg and MeHg analysis followed modified U.S. Environmental Protection Agency (USEPA) Method 1631E and Method 1630, respectively. THg[3] in fish tissue was determined using a Milestone Direct Mercury Analyzer (DMA-80) following USEPA Method 7473.

Analysis of TSS and volatile suspended solids (VSS) was conducted by passing a subsample through a 0.45 µm pre-combusted glass fiber filter, drying at 105 °C, and determining TSS as the mass of material retained on the filter. The same filter was dried further at 550 °C for 3 hr with difference in mass determining VSS.

Samples were analyzed for chlorophyll *a* by fluorescence following USEPA Method 445.0 using a Turner Instruments TD700.

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[3] Nearly all of the mercury present in edible fish muscle is MeHg, and analysis of fish tissue for THg provides a valid, cost-effective estimate of MeHg concentration (Wiener et al. 2007)

Statistical Methods

The measurement of MeHg in individual black bass samples (Appendix 2) provided a foundation for statistical procedures to adjust for the relationship with fish length (MeHg and total length data shown in Appendix 2; statistical methods shown in Appendix 3; summary data in Appendix 4). A length of 350 mm has been used for length-adjustment of black bass in the Methylmercury TMDL and in past studies (e.g., Davis et al. 2008, Melwani et al. 2009, Wood et al. 2010), and represents the middle of the distribution of legal-sized (>305 mm, or 12 inches) fish that are commonly caught.

Estimates of mean length-adjusted concentrations at each station presented in this report are based on simple linear regressions of the data for each station. This approach provides an independently-derived estimate of the station mean that can be compared to any other station mean of interest: other station means from the same sampling period; means from the same station in past sampling; or any other station mean of interest.

Results

Quality Assurance

The Delta RMP's mercury monitoring element has a rigorous program of quality assurance and quality control (QA/QC) described in detail in the Quality Assurance Project Plan (QAPP) version 5 (Yee et al. 2018). About 15% of all samples analyzed were for QA/QC purposes. Of the 993 total lab results, 947 (95%) met the requirements of the QAPP (Yee et al. 2018). For MeHg and THg measurements in fish and water, 100% met the requirements of the QAPP. For ancillary water parameters, 88% of the measurements met the requirements of the QAPP. For dissolved organic carbon, 46 of 94 results did not meet the requirements of the QAPP due to holding time exceedances stemming from a problem with analytical instrumentation and a decision to send the samples to a subcontract lab. The hold time limit was 30 days; the maximum hold time was 115 days. In spite of this hold time exceedance, the investigators have high confidence in the data – the values for the samples in question are typical of values for the Delta areas sampled. Corrective action will be implemented to minimize hold time exceedances if similar problems occur in the future. Total suspended solids and volatile suspended solids results had only one field blank, less than the 4 required to achieve the 1 per 20 frequency in the QAPP. Collection of field blanks for these analytes following the QAPP requirements will be included in future years. These cases where the requirements of the QAPP were not met are discussed further in Appendix 5 as part of a detailed summary of all QA results for this dataset.

Fish

Results from the third round of Delta RMP fish monitoring are presented in Figure 2 and Figure 3, with data from prior fish sampling in or near these stations provided for context. The existing long-term time series are characterized by significant gaps in monitoring and a high degree of inconsistency in stations, species, and sampling approaches over time.

Monitoring at an additional station (Sherman Island) was initiated in 2018. The mean concentration of MeHg in largemouth bass at this station (0.42 ppm) (all fish results presented in wet weight) was similar to the means at two adjacent stations (Middle River at Borden Hwy – 0.43 ppm; Little Potato Slough – 0.34 ppm), but lower than the mean at Cache Slough at Liberty Island Mouth – 0.55 ppm (Figure 2; Appendix 4). Limited data are available for evaluating long-term trends at Sherman Island: a Sherman Lake station was sampled in 2000, but aside from that the nearest stations with data are the San Joaquin River off Point Antioch Near Fishing Pier (2 miles from the current station, sampled in 1998 and 1999) and Big Break (3 miles from the current station, sampled in 2005 and 2007).

The regression between total length and MeHg concentration in fish tissue at Sherman Island was not significant at alpha=0.05 (Appendix 3), so a simple mean was calculated for this station based on results for fish greater than 305 mm in length. Length:MeHg regressions were significant ($p<0.05$) for all of the other stations in 2018, so length-adjusted (350 mm) means were calculated.

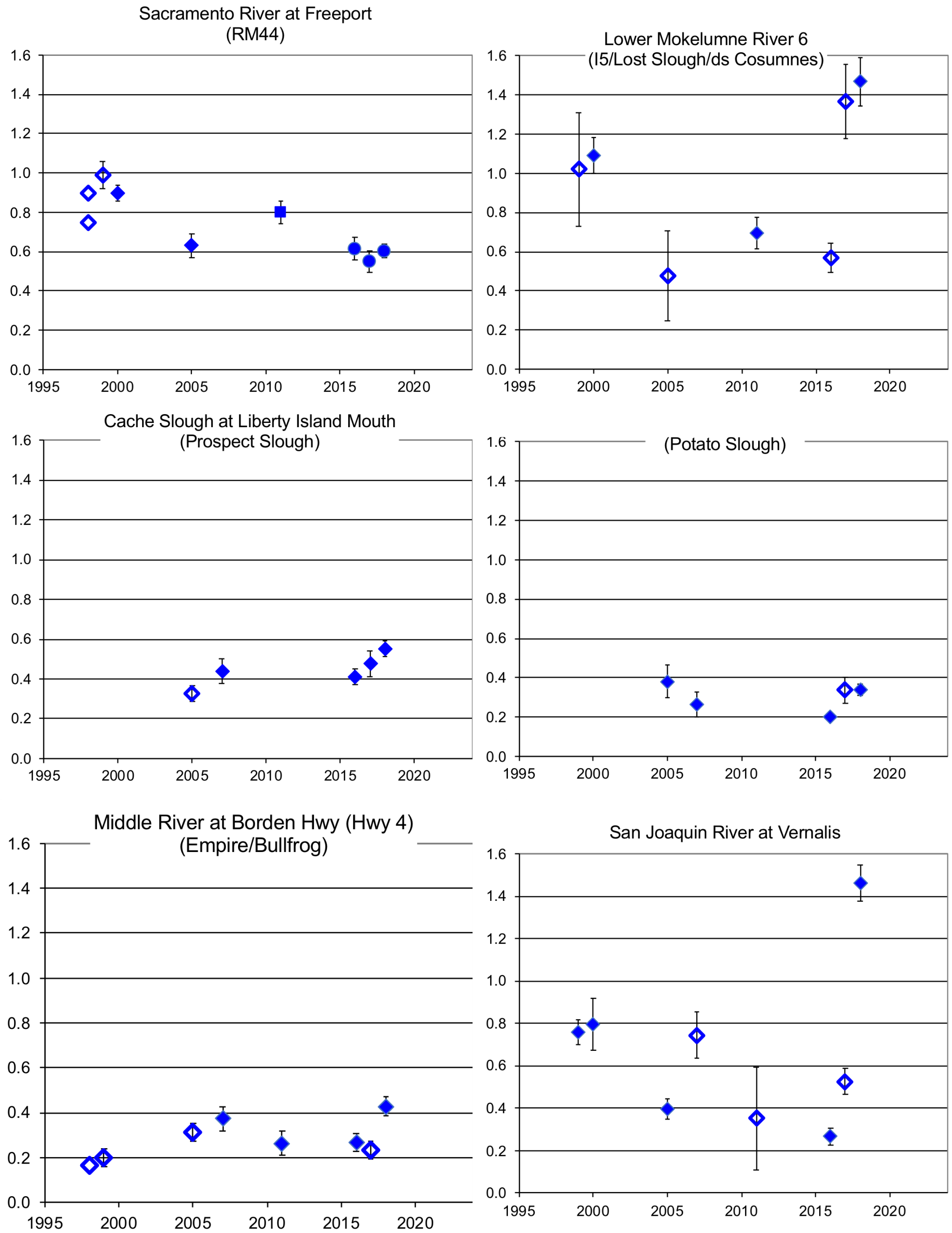
Variation in the availability of largemouth bass at the Sacramento River at Freeport continues. In 2016, 2017, and again in 2018, spotted bass were collected, while previous efforts obtained smallmouth bass (2011) and largemouth bass (1998, 1999, 2000, and 2005). Largemouth bass have been collected consistently over the years at the other stations.

Length-adjusted mean concentrations measured in 2018 at 4 of the 6 stations also monitored in 2017 were not significantly different from the 2017 mean (overlapping 95% confidence intervals of the mean) (Figure 3). At two stations, however, the 2018 means were significantly higher than the 2017 means: San Joaquin River at Vernalis and Middle River at Borden Highway (Figure 3). The biggest difference was observed at San Joaquin River at Vernalis, with a much higher mean in 2018 (1.46 ppm) than in 2017 (0.53 ppm). The 2018 mean for the Vernalis station was also far higher than any annual mean in the historic time series for this station – the next highest value was 0.80 ppm in 2000. It should be noted, however, that this 2018 mean is based on fish from a limited size range (nine fish between 200 and 300 mm); not the full size range (200 mm to approximately 500 mm) that is normally targeted and obtained (a complete listing of lengths and MeHg concentrations for each fish is provided in Appendix 2). Nevertheless, the regression for these fish was significant in spite of the limited size range, and the concentrations observed were very high for fish in this small size range. Middle River at Borden Hwy was the other station where the 2018 mean (0.43 ppm) was different (higher) than the 2017 mean (0.23 ppm). The 2018 mean at Middle River was the highest observed at this station, but only 0.06 ppm higher than the next highest year (2007).

The mean concentration observed at Lower Mokelumne River 6 in 2018 (1.47 ppm) was very high and similar to the mean observed in 2017 (1.37 ppm). Both of these means were higher than other annual means observed historically in this area.

Figure 2 Length-adjusted (350 mm) mean MeHg concentration (ppm wet weight) in black bass at each station, August-September 2018. The one exception is Sherman Island, where the length:mercury regression was not significant and a non-adjusted mean of fish >305 mm is presented.

Figure 3 Long-term time series of mean MeHg (ppm wet weight) in black bass for Delta RMP stations and nearby stations sampled historically. Details on page 22.



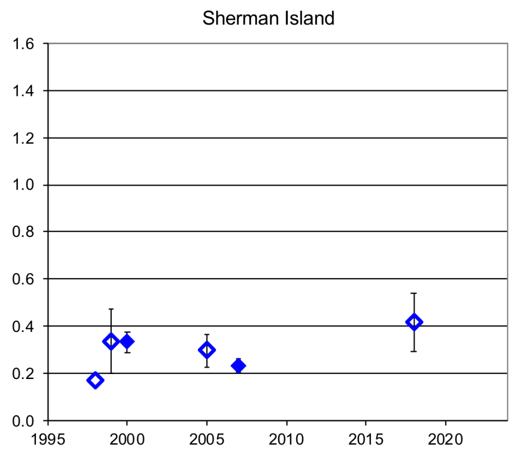

Sherman Island
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1995
2000
2005
2010
2015
2020

Figure 3 Details

Points generally show 350 mm length-adjusted means (exceptions to this noted in plot details below) and error bars indicate two times the standard error. Filled symbols indicate 350 mm length-adjusted means, hollow symbols indicate individual composite samples or arithmetic means when the station did not have a significant length:MeHg regression. Diamonds indicate largemouth bass; squares are spotted bass; circles are smallmouth bass. Data sources: Delta RMP – 2016-2018; the Surface Water Ambient Monitoring Program (Davis et al. 2013) - 2011; the Fish Mercury Project (Melwani et al. 2009) - 2005-2007; the CALFED Mercury Project (Davis et al. 2003) - 1999-2000; the Delta Fish Study (Davis et al. 2000) - 1998; and the Sacramento River Watershed Program (2002) - 1998.

Sacramento River at Freeport
Stations - Freeport: 2016-2018; RM44: All other years
Statistics - Individual composite results: 1998; mean of fish >305 mm: 1999; 350 mm length-adjusted mean: all other years

Lower Mokelumne River 6
Stations - Lower Mokelumne River 6: 2016-2017; Mokelumne River near I-5: 2011; Lost Slough: 2005; Mokelumne River downstream of the Cosumnes River: 1999, 2000
Statistics - Mean of fish >305 mm: 1999, 2005, 2016, 2017; 350 mm length-adjusted mean: all other years

Cache Slough at Liberty Island Mouth
Stations - Cache Slough at Liberty Island Mouth: 2016-2017; Prospect Slough: 2005, 2007
Statistics - Mean of fish >305 mm: 2005; 350 mm length-adjusted mean: all other years

Little Potato Slough
Stations - Little Potato Slough: 2016-2017; Potato Slough (aka San Joaquin River at Potato Slough): 2005, 2007
Statistics - Mean of fish >305 mm: 2017; 350 mm length-adjusted mean: all other years

Middle River at Borden Hwy (Hwy 4)
Stations - Middle River at Borden Hwy (Hwy 4): 2016-2017; Middle River near Empire Cut: 2011; Middle River at Bullfrog: 1998, 1999, 2007; Middle River at HWY 4: 2005
Statistics - Individual composite result: 1998; mean of fish >305 mm: 1999, 2005, 2017; 350 mm length-adjusted mean: all other years

San Joaquin River at Vernalis
Stations - Same station all years
Statistics - Mean of fish >305 mm: 2007, 2011, 2017; 350 mm length-adjusted mean: all other years

Sherman Island
Stations - San Joaquin River off Point Antioch near fishing pier: 1998, 1999; Sherman Lake: 2000; Big Break: 2005, 2007; Sherman Island: 2018
Statistics - Individual composite result: 1998; mean of fish >305 mm: 1999, 2005, 2018; 350 mm length-adjusted mean: all other years

Water

Appendix 6 presents a tabulation of year 3 results for all aqueous analytes.

The concentration of MeHg in unfiltered water ranged from below the method detection limit (MDL) of 0.011 ng L^{-1} to a maximum of 0.366 ng L^{-1}. Figure 4 presents long-term time series of March to October annual means of unfiltered MeHg concentrations for Delta RMP sites. These means, in some cases, are based on limited numbers of samples, as indicated in the caption for Figure 4. Sacramento River concentrations have remained constant with good agreement between historic data and current data. Lower Mokelumne results were similar to previously reported values given the large variability of MeHg concentrations for this site. Cache Slough MeHg concentrations were in good agreement with previously reported values. No historic data are available for Little Potato Slough but MeHg concentrations were consistent with concentrations reported for 2016 and 2017. Middle River MeHg concentrations were within the range of historic data. San Joaquin River MeHg concentrations were similar to previously reported historic results. Sacramento River at Mallard 2018 results were in good agreement with previously reported MeHg concentrations. Delta Mendota Canal MeHg concentrations fell within the range of previously reported MeHg concentrations.

Particulate MeHg concentrations (calculated as the difference of unfiltered and filtered MeHg) ranged from less than the method detection limit (0.011) to 0.242 ng L^{-1} (Appendix 6). Filtered MeHg concentrations averaged 44% of unfiltered MeHg concentrations (Figure 5). Compared to THg (data not shown), a much greater percentage of MeHg is found in the filtered fraction relative to unfiltered concentrations.

Unfiltered total Hg concentrations ranged from 0.57 – 26.3 ng L^{-1}. Filtered total Hg concentrations ranged from 0.32 – 6.96 ng L^{-1}. Total Hg was found to be predominantly in the particulate form and was positively correlated to TSS concentrations (correlation data not shown).

Figure 6 presents monthly aqueous concentrations of unfiltered MeHg and THg and changes in their relative magnitude over time. The temporal pattern in the proportion of MeHg was not consistent on either a station-specific or regional scale. Observed increases in unfiltered MeHg concentration occurred both independently of and concurrently with increases in unfiltered THg concentrations.

The following ranges in ancillary parameters were measured in Delta surface water: temperature = 8.09 – 25.7 °C; pH = 5.9 – 8.1; dissolved oxygen concentration = 3.3 – 12.6 mg L^{-1}; dissolved oxygen saturation = 10 – 123%;

specific conductivity = 60 - 11399 µS cm^{-1}; salinity = 0-6.5 ‰; turbidity = 2 – 188 NTU.

Concentrations of DOC in the Delta were fairly consistent ranging from 0.5 to 7.1 mg L^{-1} for all sites and sampling events.

Chlorophyll *a* concentrations varied widely across sites and time with a range of less than the method detection limit (0.045 µg L^{-1}) to 48 µg L^{-1}.

Similarly, TSS concentrations had a large range both spatially and temporally. The range of TSS was less than the method detection limit (1 mg L^{-1}) to 183 mg L^{-1}. Concentrations of VSS were less than the method detection limit (1 mg L^{-1}) to 26 mg L^{-1}.

Method detection limits and reporting limits for all of the water parameters are provided in Appendix 6.

Figure 4 Annual mean aqueous unfiltered MeHg concentration (ng L^{-1}) at each Delta RMP monitoring station sampled from July 2018 through June 2019. Plots based on available March-October data for each calendar year and number of samples shown in parentheses.

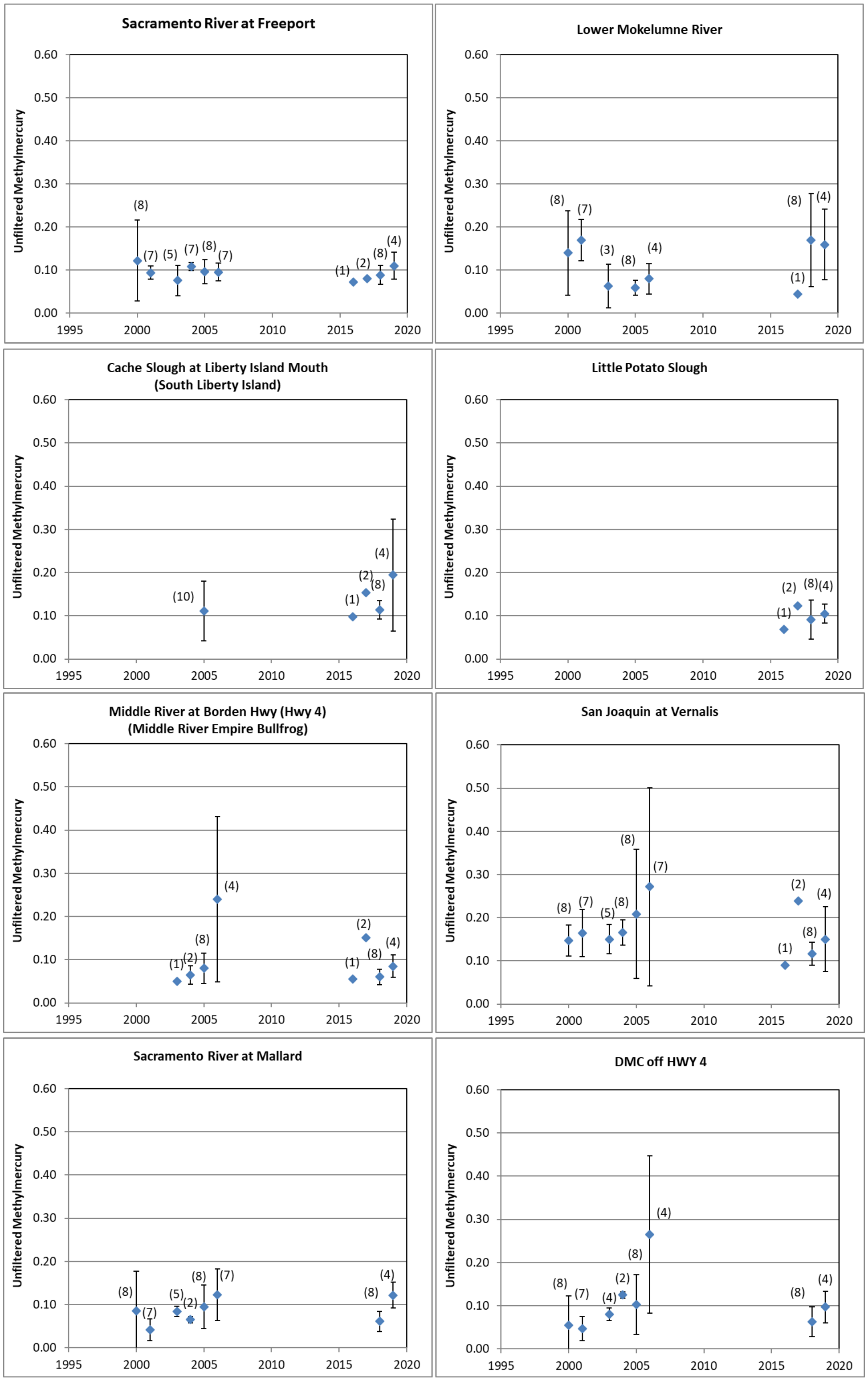


Figure 5 Monthly observations of aqueous concentrations of MeHg (unfiltered and filtered) for Delta RMP stations from July 2018 through June 2019.

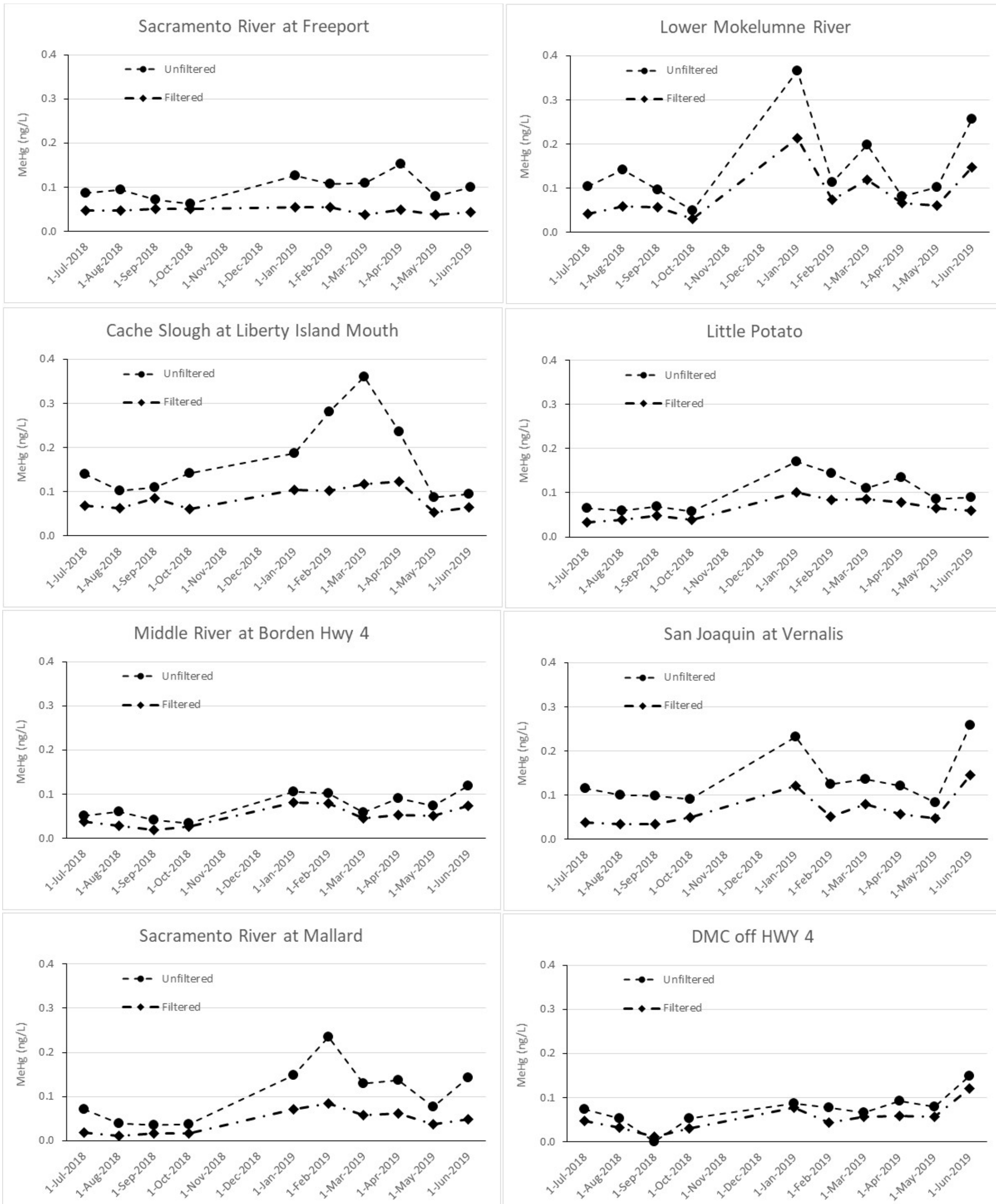
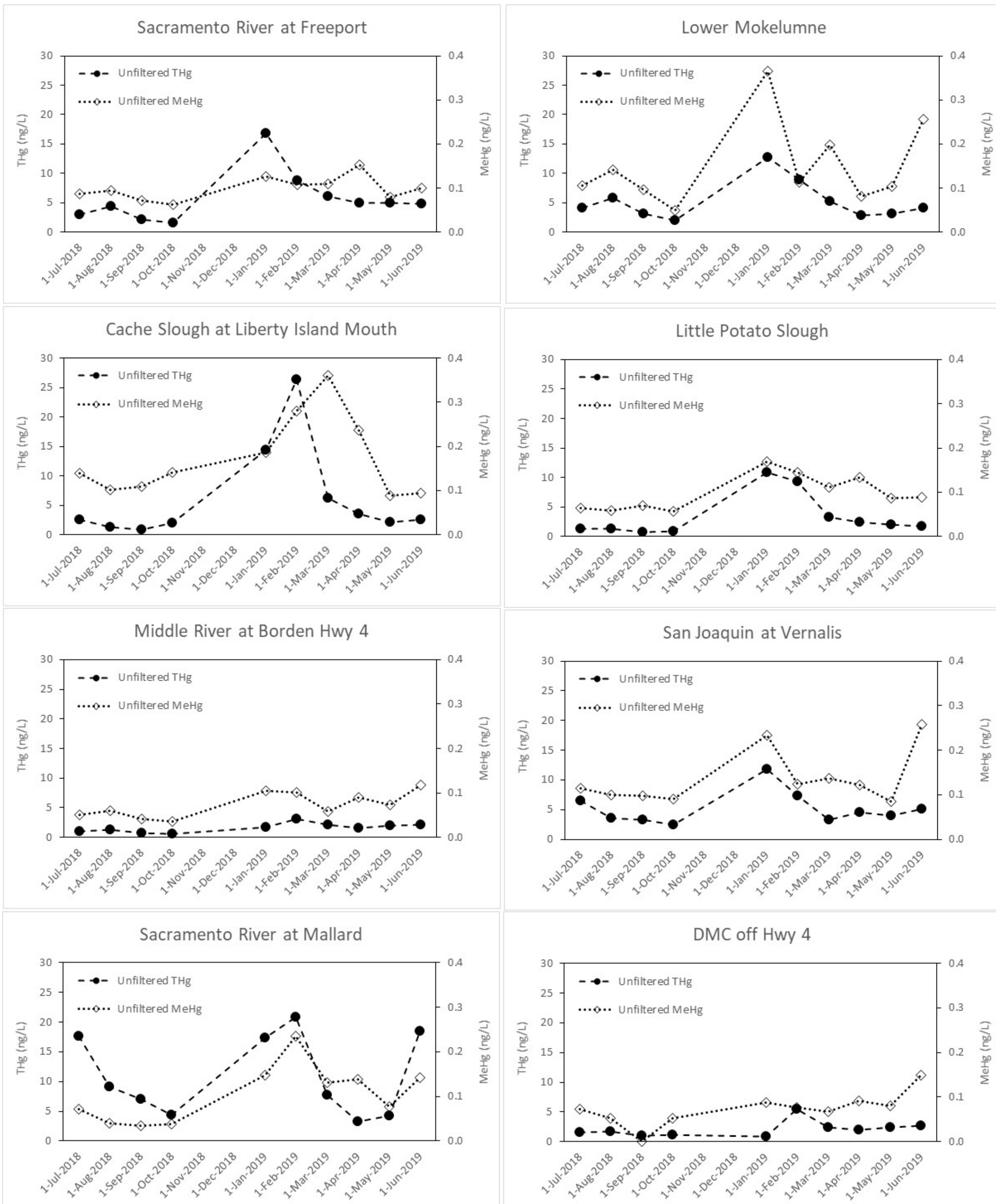


Figure 6 Monthly observations of concentrations of aqueous unfiltered MeHg and THg at Delta RMP stations from July 2018 through June 2019.



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Appendix 1: Cruise Report

Appendix 1
Cruise Report for the
Delta Regional Monitoring Program (Delta RMP)
Monitoring For Status And Trends Of Mercury in Black Bass and Water

For Work Completed July 2018 through June 2019
Sampling Dates: July 9, 2018 – June 18, 2019

Written by: April Sjoboen Guimaraes, Billy Jakl, and Wesley Heim
Marine Pollution Studies Laboratory (MPSL-DFW) at Moss Landing Marine Laboratories

Introduction

This report describes the sampling activities in different subareas of the Delta region of California. This sampling effort focuses on providing essential performance measures for evaluating the effectiveness of the methylmercury (MeHg) TMDL in the Delta. The TMDL is a key management plan that utilizes a conceptual model for MeHg in the Delta that has been based on extensive monitoring and research conducted by CALFED in the 2000s. This conceptual model shows an observed linkage between MeHg concentration in water and the concentrations in predator fish. The observed linkage was strongest with the black bass species, specifically largemouth bass, which represents the indicator of impairment and water quality objectives. Sampling activities included the collection of fish tissue (black bass), and water samples with basic field parameters. Samples were collected by the Marine Pollution Studies Laboratory-DFW (MPSL-DFW) at Moss Landing Marine Laboratories (MLML).

1.0 Cruise Report

1.1 Objectives

The objectives were to provide spatial and temporal fish and water data to update the TMDL conceptual model. Black bass were collected annually using an electrofisher boat at seven fixed stations selected for long-term monitoring. Sixteen black bass were collected spanning a broad size range for each station. Each bass was analyzed individually for mercury to support analysis of covariance based on the length:mercury relationship. The annual fish collection was paired with water collection at seven of the eight water stations.

Water collections provide water concentrations to track performance relative to the established 0.06 ng/L unfiltered MeHg goal in the TMDL, and provide a valuable tool for understanding processes leading to accumulation in fish and impairment. Depth-integrated water samples were collected in the thalweg at eight stations that are strategically located to correlate with the fish monitoring, update the MeHg mass budget for the Delta, and provide information that will be useful input to the mercury model in development for the Delta by DWR. The paired fish and water data will allow further assessment of the strength of the correlation between these two matrices. The chemical analyte groups for the water collection include: total Hg, dissolved Hg, total MeHg and dissolved MeHg. Ancillary water parameters, chlorophyll *a*, dissolved organic carbon (DOC), total suspended solids (TSS), and volatile suspended solids (VSS) were collected to aid in interpretation of the MeHg data.

1.2 MPSL-DFW Sampling personnel

April Guimaraes	Research Tech, Crew Lead
Autumn Bonnema	Project Assistant
Gary Ichikawa	Environmental Scientist
Chris Beebe	Research Tech
Scot Lucas	Research Tech

1.3 Authorization to collect samples

All sampling personnel are MPSL-DFW staff (San Jose State University Foundation and the California Department of Fish and Wildlife) contracted through the San Francisco Estuary Institute/Aquatic Science Center to conduct the sample collection activities listed herein.

1.4 Station selection

Based upon the recommendations of the Delta RMP Steering Committee and Technical Advisory Committee with representatives from the Central Valley Regional Water Quality Control Board, USEPA, California Department of Water Resources, the State and Federal Contractors Water Agency, and various discharger groups, selected stations represent key subareas of the Delta.

1.5 Summary of types of samples authorized to be collected

Up to sixteen (16) black bass individuals of the same species were collected using an electrofisher for each of the seven (7) stations. The sixteen individuals spanned a broad size range to support assessment of the length:mercury relationship and ANCOVA analysis. Upon collection, each fish collected was tagged with a unique ID that corresponded to the latitude/longitude where it was collected. Physical parameters were collected for each individual fish, which included: weight, total length, fork length, and presence of any abnormalities. Fish samples were stored on wet ice for the duration of the trip. Large fish (> 370 mm) were partially dissected in the field using the following protocol: fish were placed on a cutting board covered with a clean plastic bag where the head, tail, and guts were removed using a clean (laboratory detergent, DI) cleaver. The sex of the fish was noted. The fish were then wrapped in tin foil, with the dull side inward, and double-bagged in zipper-closure bags with other fish from the same location. The cutting board was re-cleaned between stations.

At the MPSL-DFW lab, samples were stored in a freezer until they were processed for authorized dissection and analysis.

A depth-integrated water sample was collected at eight (8) stations following MPSL-DFW SOP MPSL-111 Revision 2 using a bucket sampler (SWAMP Clean Water Team SOP 2.1.1.4) modified to accommodate a trace metal cleaned 4L glass bottle (I-Chem Part # 145-4000) (MPSL-101). A new trace metal cleaned 4L glass bottle, tubing and filter were used for each site. In the thalweg, the bucket sampler with the 4L was lowered to 0.5m from the bottom to a maximum depth of 15m and raised through the water column at a sufficient rate so that the bottle was not completely filled upon retrieval, achieving a depth-integrated sample. Total samples were aliquoted into analyte-specific bottles by pouring. The 4L bottle was agitated between samples to maintain consistency. Filtered samples were collected by attaching a 45µm ground water filter to trace metal clean tubing and a peristaltic pump, and aliquoted to the analyte-specific bottle. At each water station, four analytes were collected: total Hg, filtered Hg, total MeHg and filtered MeHg. Ancillary water samples were collected to help interpretation of mercury data at each station: chlorophyll *a*, DOC and TSS/VSS. DOC samples were acidified upon collection. All samples were stored on wet ice for the duration of the trip.

At the MPSL-DFW lab, Hg and MeHg samples were acidified. MeHg, DOC and TSS/VSS samples were stored in a refrigerator and chlorophyll *a* samples were stored in a freezer until they were analyzed.

Basic field parameters (temperature, pH, specific conductance, salinity, dissolved oxygen concentration, dissolved oxygen saturation, and turbidity) along with station information (station depth, location, weather, hydromodifications and habitat) were also noted. All collections and sample processing for water and fish followed the Delta RMP QAPP, version 5 (approved August 29, 2019).

1.6 Results

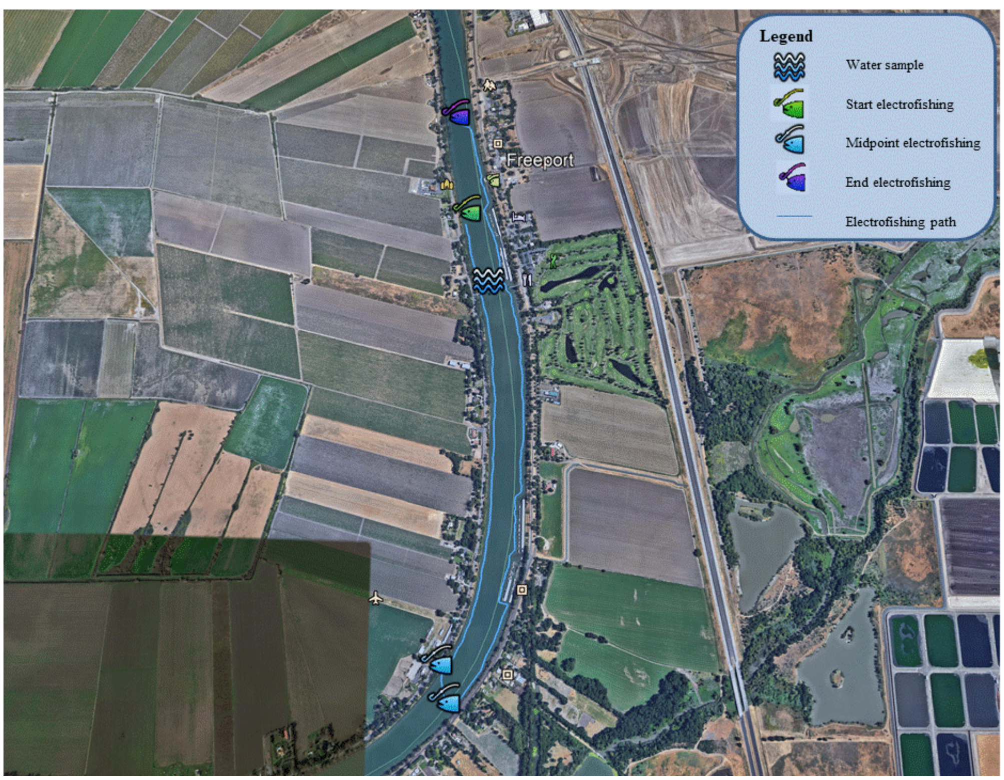
Two MPSL-DFW teams sampled the seven (7) subareas for fish tissue. Several MPSL-DFW crews completed the monthly water sampling efforts. A detailed fish catch, fish total length, descriptions and maps of sample collection for all stations can be found in Table 1.7 below. Also included are the dates of the depth-integrated water sampling events.

Sacramento River at Freeport (510ST1317)

Latitude: 38.4556
Longitude: -121.5019
Collection Objective: Fish (Annually) Water (Monthly)
Collection Method: Electrofishing vessel, depth-integrated water sampler
Date(s) of Fish Collection: 8/20/18
Date(s) of Water Collection: 7/9/18, 8/13/18, 9/10/18, 10/8/18, 1/21/19, 2/18/19, 3/20/19, 4/22/19, 5/20/19, 6/17/19
Samplers: April Guimaraes, Chris Beebe, Autumn Bonnema, Gary Ichikawa, Scot Lucas

Sport Fish Caught: Spotted Bass, TL (mm)															
212	216	218	221	230	231	231	233	252	253	257	289	290	308	375	377

Comments: The sampling vessel was launched from Garcia Bend Park in Sacramento, CA. Sixteen (16) Spotted bass were sampled along the transect adjacent to the target station. All water samples were collected in the thalweg in close proximity of the target coordinates. Due to flood damage on the launch ramp, samples were taken from the bridge as an integrated bucket grab between February 2019 and June 2019.



Cache Slough at Liberty Island Mouth (510ADVLIM)

Latitude: 38.2421
Longitude: -121.6854
Collection Objective: Fish (Annually) Water (Monthly)
Collection Method: Electrofishing vessel, depth-integrated water sampler
Date(s) of Fish Collection: 8/20/18
Date(s) of Water Collection: 7/9/18, 8/13/18, 9/10/18, 10/8/18, 1/21/19, 2/18/19, 3/20/19, 4/22/19, 5/20/19, 6/18/19
Samplers: April Guimaraes, Chris Beebe, Autumn Bonnema, Gary Ichikawa, Scot Lucas

Sport Fish Caught: Largemouth Bass, TL (mm)															
193	206	248	255	262	284	322	328	335	345	360	364	374	408	426	474

Comments: The sampling vessel was launched from either Arrowhead Marina in Clarksburg, CA or Vieira's Resort in Isleton, CA. Sixteen (16) Largemouth bass were sampled along the transect adjacent to the target station. All water samples were collected in the thalweg in close proximity of the target coordinates.

Lower Mokelumne River 6 (544ADVLM6)

Latitude: 38.2554
Longitude: -121.4401
Collection Objective: Fish (Annually) Water (Monthly)
Collection Method: Electrofishing vessel, depth-integrated water sampler
Date(s) of Fish Collection: 8/21/18
Date(s) of Water Collection: 7/9/18, 8/13/18, 9/10/18, 10/8/18, 1/21/19, 2/18/19, 3/20/19, 4/22/19, 5/20/19, 6/18/19
Samplers: April Guimaraes, Chris Beebe, Autumn Bonnema, Gary Ichikawa, Scot Lucas

Sport Fish Caught: Largemouth Bass, TL (mm)															
238	240	249	290	292	295	328	338	344	360	388	392	402	410	475	525

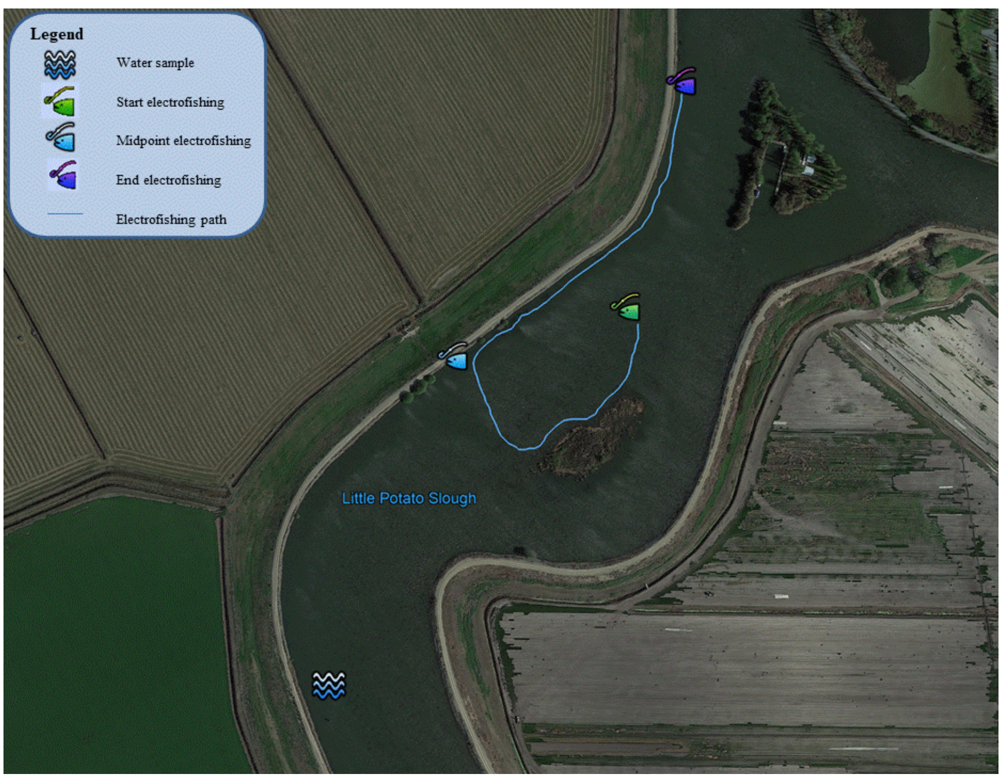
Comments: The sampling vessel was launched from either New Hope Landing or Wimpy's Marina in Walnut Grove, CA. Sixteen (16) Largemouth bass were sampled along the transect adjacent to the target station. All water samples were collected in the thalweg in close proximity of the target coordinates.

Little Potato Slough (544LILPSL)

Latitude: 38.0963
Longitude: -121.4960
Collection Objective: Fish (Annually) Water (Monthly)
Collection Method: Electrofishing vessel, depth-integrated water sampler
Date(s) of Fish Collection: 8/21/18
Date(s) of Water Collection: 7/9/18, 8/13/18, 9/10/18, 10/9/18, 1/21/19, 2/18/19, 3/20/19, 4/22/19, 5/20/19, 6/18/19
Samplers: April Guimaraes, Chris Beebe, Autumn Bonnema, Gary Ichikawa, Scot Lucas

Sport Fish Caught: Largemouth Bass, TL (mm)															
222	228	228	250	290	296	329	336	344	357	361	363	370	420	423	480

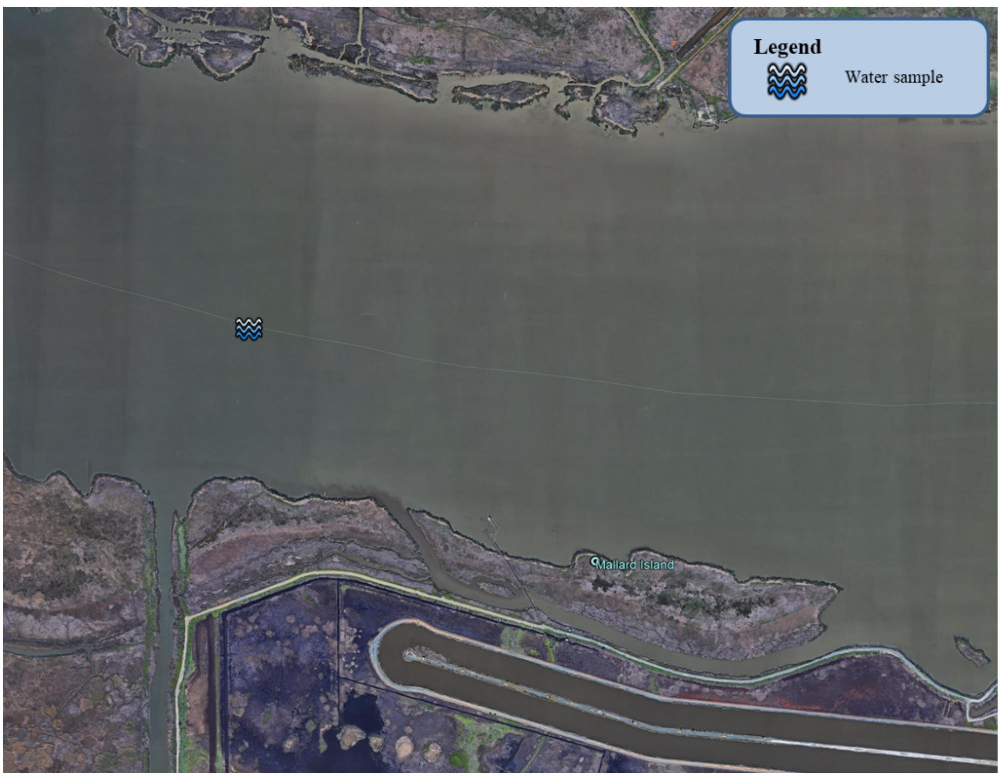
Comments: The sampling vessel was launched from Tower Park Marina in Lodi, CA. Sixteen (16) Largemouth bass were sampled along the transect adjacent to the target station. All water samples were collected in the thalweg in close proximity of the target coordinates.



Sacramento River at Mallard Island (207SRD10A)

Latitude: 38.0429
Longitude: -121.9201
Collection Objective: Water (Monthly)
Collection Method: Depth-integrated water sampler
Date(s) of Water Collection: 7/10/18, 8/14/18, 9/11/18, 10/9/18, 1/22/19, 2/19/19, 3/21/19, 4/23/19, 5/21/19, 6/19/19
Samplers: April Guimaraes, Chris Beebe, Autumn Bonnema, Scot Lucas

Comments: The sampling vessel was launched from Pittsburg Yacht Club in Pittsburg, CA. All water samples were collected in the thalweg in close proximity of the target coordinates. The corresponding fish were collected from Sherman Island (510ST1666).



Sherman Island (510ST1666)

Latitude: 38.0431
Longitude: -121.8044
Collection Objective: Fish (Annually)
Collection Method: Electrofishing vessel
Date(s) of Fish Collection: 8/21/18, 9/11/18
Samplers: April Guimaraes, Gary Ichikawa, Scot Lucas

Sport Fish Caught: Largemouth Bass, TL (mm)															
215	217	234	270	284	290	303	325	335	349	385	393	408	428	429	515

Comments: The sampling vessel was launched from Sherman Island County Park in Rio Vista, CA. Sixteen (16) Largemouth bass were sampled along the transect adjacent to the target station. This site was chosen to correspond with the water samples from Mallard Island (207SRD10A). On the first sampling date the crew used a jet boat and the impeller kept getting clogged with algae, causing problems with the engine overheating and with maneuvering in the high winds. On the second date the crew sampled away from the dense algal areas and in more wind protected areas.

Middle River at Borden Hwy (544MDRBH4)

Latitude: 37.8908
Longitude: -121.4883
Collection Objective: Fish (Annually) Water (Monthly)
Collection Method: Electrofishing vessel, depth-integrated water sampler
Date(s) of Fish Collection: 8/22/18
Date(s) of Water Collection: 7/9/18, 8/14/18, 9/11/18, 10/9/18, 1/22/19, 2/19/19, 3/21/19, 4/23/19, 5/21/19, 6/18/19
Samplers: April Guimaraes, Chris Beebe, Autumn Bonnema, Gary Ichikawa, Scot Lucas

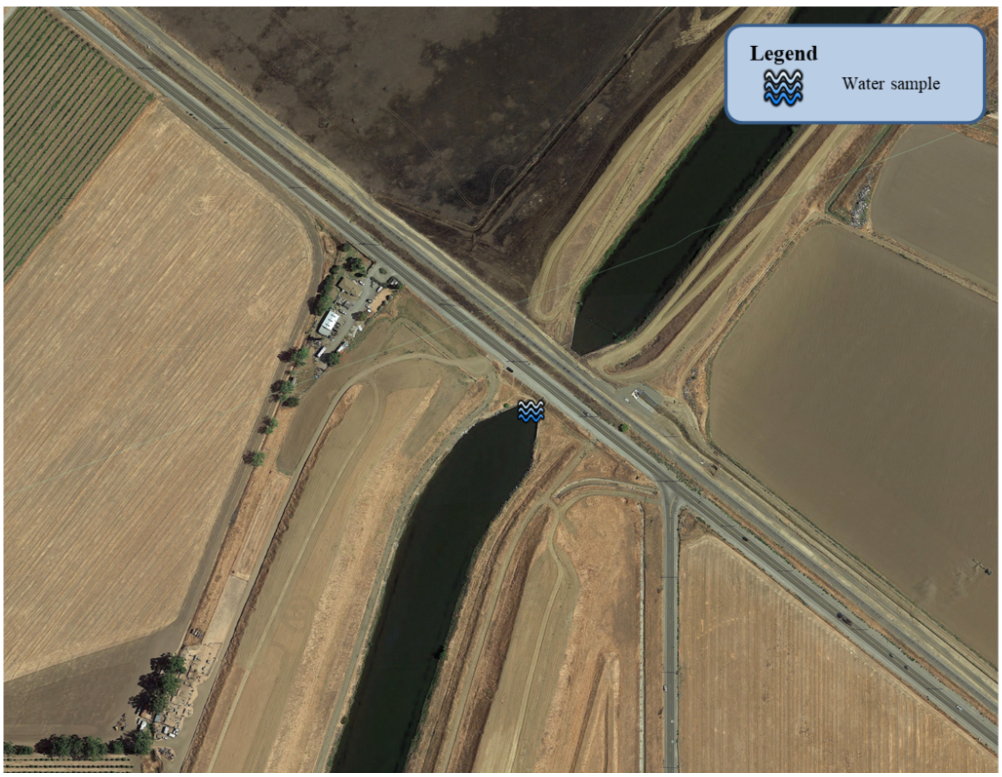
Sport Fish Caught: Largemouth Bass, TL (mm)															
203	214	235	263	275	284	310	315	330	332	351	380	390	427	492	573

Comments: The sampling vessel was launched from Discovery Bay Yacht Harbor in Discovery Bay, CA. Sixteen (16) Largemouth bass were sampled along the transect adjacent to the target station. All water samples were collected in the thalweg in close proximity of the target coordinates.

DMC off HWY 4 (544DMC020)

Latitude: 37.8121
Longitude: -121.5790
Collection Objective: Water (Monthly)
Collection Method: Depth-integrated water sampler
Date(s) of Water Collection: 7/10/18, 8/14/18, 9/11/18, 10/9/18, 1/22/19, 2/19/19, 3/21/19, 4/23/19, 5/21/19, 6/19/19
Samplers: April Guimaraes, Chris Beebe, Autumn Bonnema, Scot Lucas

Comments: All water samples were collected in the thalweg from the bank in close proximity of the target coordinates.

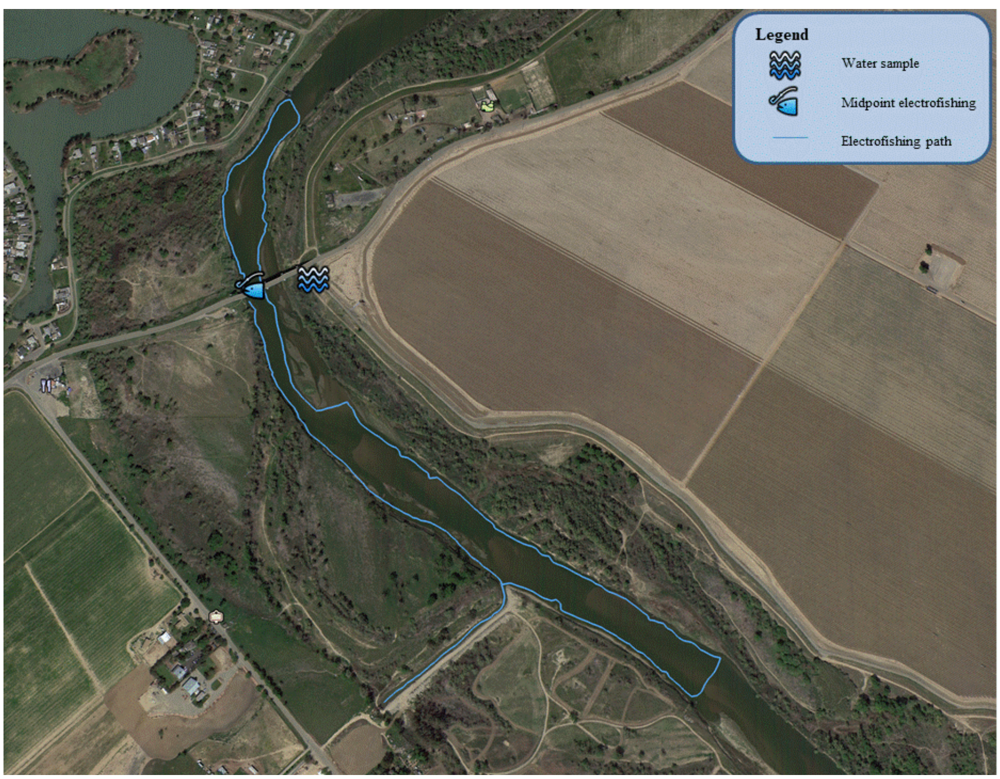


San Joaquin River at Vernalis/Airport (541SJC501)

Latitude: 37.6756
Longitude: -121.2641
Collection Objective: Fish (Annually) Water (Monthly)
Collection Method: Electrofishing vessel, depth-integrated water sampler
Date(s) of Fish Collection: 8/22/18, 9/12/18
Date(s) of Water Collection: 7/10/18, 8/14/18, 9/12/18, 10/9/18, 1/22/19, 2/19/19, 3/21/19, 4/23/19, 5/21/19, 6/19/19
Samplers: April Guimaraes, Gary Ichikawa, Chris Beebe, Autumn Bonnema, Scot Lucas

Sport Fish Caught: Largemouth Bass, TL (mm)								
200	206	242	243	243	249	270	278	280

Comments: The electrofishing vessel was launched from Two Rivers RV Park in Manteca, CA on 8/22/18. Low water levels inhibited access to the site and warranted the use of a different vessel. The alternate electrofishing vessel was launched along the bank on 9/12/18. Nine (9) Largemouth bass were sampled along the transect adjacent to the target station. All water samples were collected near the thalweg along the bank or from the bridge as an integrated bucket grab in close proximity of the target coordinates.



1.7 Summary

A total of seven (7) stations were successfully sampled for fish tissue using a dedicated electrofishing vessel.

Eight (8) stations were successfully sampled for depth-integrated water samples and basic water parameters. Following retrieval, the depth-integrated water sample was aliquoted in the field into appropriate sample containers for analysis. The chemical analyte groups for this monitoring element include: total Hg, filtered Hg, total MeHg, filtered MeHg, and ancillary parameters. Field blanks were collected at a rate of 5%, or a minimum of one (1) field blank per collection event. Field duplicates were collected at a rate of 5% or a minimum of one (1) duplicate per every twenty (20) samples for each analyte, or once per collection event.

Appendix 2: Mercury Concentrations and Ancillary Measurements in Individual Fish

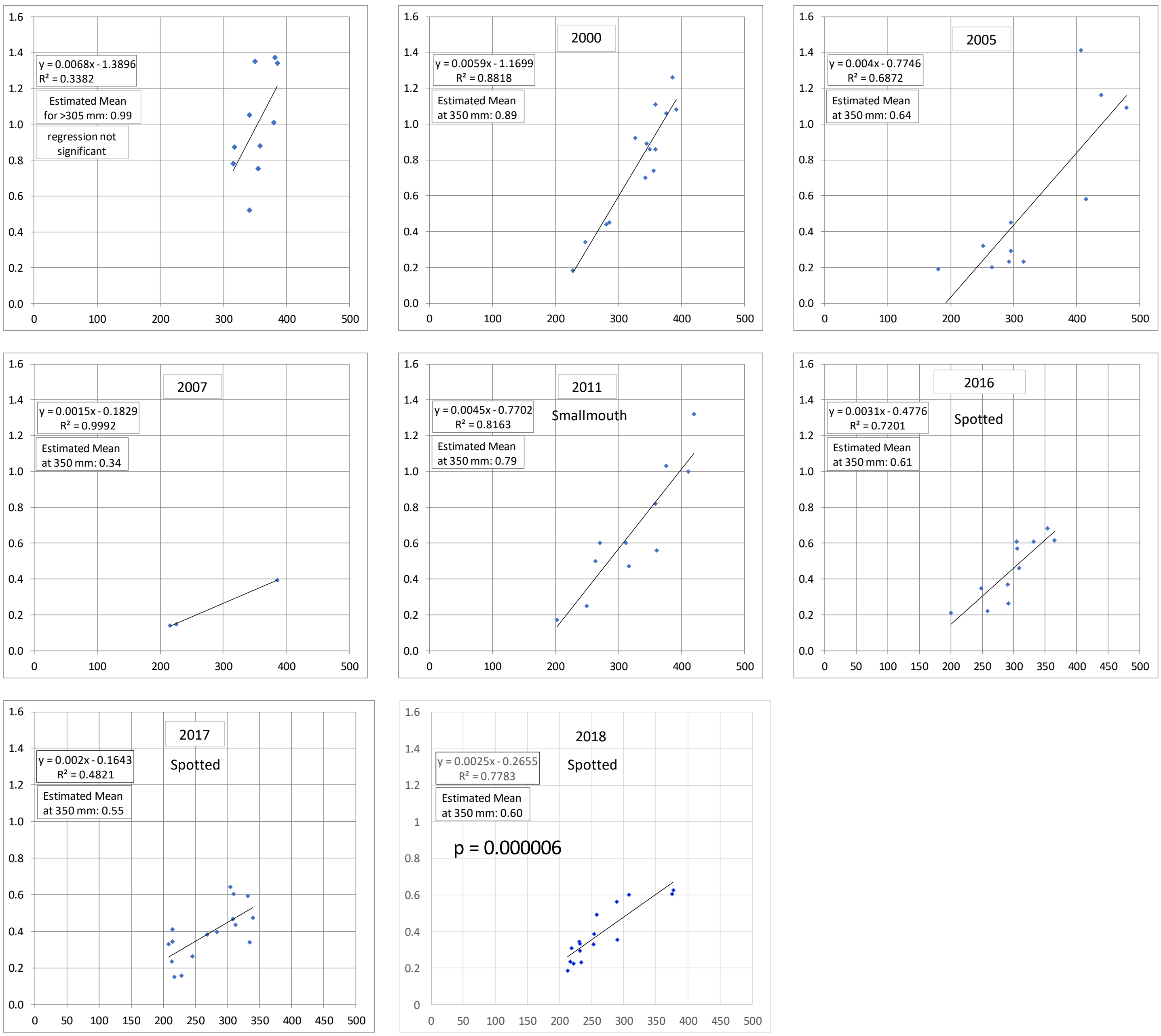
Sample Date	Station	Common Name	SampleID	Parameter	Result	Unit	Total Length (mm)
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5104	Mercury	0.19	ug/g ww	212
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5102	Mercury	0.24	ug/g ww	216
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5101	Mercury	0.31	ug/g ww	218
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5103	Mercury	0.23	ug/g ww	221
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5105	Mercury	0.35	ug/g ww	230
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5106	Mercury	0.30	ug/g ww	231
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5107	Mercury	0.33	ug/g ww	231
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5108	Mercury	0.23	ug/g ww	233
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5111	Mercury	0.33	ug/g ww	252
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5109	Mercury	0.39	ug/g ww	253
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5112	Mercury	0.49	ug/g ww	257
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5113	Mercury	0.56	ug/g ww	289
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5110	Mercury	0.36	ug/g ww	290
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5114	Mercury	0.60	ug/g ww	308
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5115	Mercury	0.61	ug/g ww	375
20-Aug-18	Sacramento River/Freeport-510ST1317	Spotted Bass	I_510ST1317_B5116	Mercury	0.63	ug/g ww	377
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5166	Mercury	1.16	ug/g ww	238
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5165	Mercury	1.52	ug/g ww	240
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5167	Mercury	1.55	ug/g ww	249
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5169	Mercury	1.34	ug/g ww	290
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5170	Mercury	0.90	ug/g ww	292
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5168	Mercury	1.64	ug/g ww	295
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5172	Mercury	1.06	ug/g ww	328
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5173	Mercury	1.48	ug/g ww	338
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5174	Mercury	1.47	ug/g ww	344
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5171	Mercury	1.30	ug/g ww	360
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5177	Mercury	1.57	ug/g ww	388
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5175	Mercury	1.84	ug/g ww	392
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5176	Mercury	1.60	ug/g ww	402
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5178	Mercury	1.41	ug/g ww	410
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5179	Mercury	1.46	ug/g ww	475
21-Aug-18	Lower Mokelumne River 6-544ADVLM6	Largemouth Bass	I_544ADVLM6_B5180	Mercury	2.11	ug/g ww	525
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5117	Mercury	0.19	ug/g ww	193
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5118	Mercury	0.30	ug/g ww	206
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5119	Mercury	0.23	ug/g ww	248
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5121	Mercury	0.29	ug/g ww	255
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5120	Mercury	0.45	ug/g ww	262
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5122	Mercury	0.37	ug/g ww	284
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5124	Mercury	0.65	ug/g ww	322
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5126	Mercury	0.60	ug/g ww	328
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5127	Mercury	0.64	ug/g ww	335
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5123	Mercury	0.49	ug/g ww	345
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5125	Mercury	0.65	ug/g ww	360
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5129	Mercury	0.62	ug/g ww	364
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5128	Mercury	0.58	ug/g ww	374
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5130	Mercury	0.63	ug/g ww	408
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5131	Mercury	0.66	ug/g ww	426
20-Aug-18	Cache Slough at Liberty Island Mouth-510ADVLIM	Largemouth Bass	I_510ADVLIM_B5132	Mercury	0.70	ug/g ww	474
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5149	Mercury	0.27	ug/g ww	222
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5150	Mercury	0.25	ug/g ww	228
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5151	Mercury	0.25	ug/g ww	228
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5153	Mercury	0.18	ug/g ww	250
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5152	Mercury	0.20	ug/g ww	290
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5154	Mercury	0.30	ug/g ww	296
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5156	Mercury	0.26	ug/g ww	329
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5158	Mercury	0.20	ug/g ww	336
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5160	Mercury	0.30	ug/g ww	344
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5157	Mercury	0.33	ug/g ww	357
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5159	Mercury	0.41	ug/g ww	361
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5155	Mercury	0.39	ug/g ww	363
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5161	Mercury	0.42	ug/g ww	370
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5162	Mercury	0.44	ug/g ww	420
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5163	Mercury	0.40	ug/g ww	423
21-Aug-18	Little Potato Slough	Largemouth Bass	I_544LILPSL_B5164	Mercury	0.49	ug/g ww	480
11-Sep-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5189	Mercury	0.34	ug/g ww	215
11-Sep-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5188	Mercury	0.14	ug/g ww	217
11-Sep-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5187	Mercury	0.26	ug/g ww	234
11-Sep-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5191	Mercury	0.44	ug/g ww	270
21-Aug-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5181	Mercury	0.36	ug/g ww	284
11-Sep-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5190	Mercury	0.36	ug/g ww	290
11-Sep-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5192	Mercury	0.45	ug/g ww	303
11-Sep-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5194	Mercury	0.39	ug/g ww	325
11-Sep-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5196	Mercury	0.32	ug/g ww	335
11-Sep-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5193	Mercury	0.19	ug/g ww	349
21-Aug-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5182	Mercury	0.44	ug/g ww	385
11-Sep-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5195	Mercury	0.52	ug/g ww	393
21-Aug-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5184	Mercury	0.54	ug/g ww	408
21-Aug-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5185	Mercury	0.46	ug/g ww	428
21-Aug-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5183	Mercury	0.76	ug/g ww	429

Sample Date	Station	Common Name	SampleID	Parameter	Result	Unit	Total Length (mm)
21-Aug-18	Sherman Island-510ST1666	Largemouth Bass	I_510ST1666_B5186	Mercury	0.14	ug/g ww	515
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5133	Mercury	0.31	ug/g ww	203
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5134	Mercury	0.18	ug/g ww	214
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5135	Mercury	0.43	ug/g ww	235
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5136	Mercury	0.19	ug/g ww	263
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5138	Mercury	0.42	ug/g ww	275
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5137	Mercury	0.40	ug/g ww	284
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5140	Mercury	0.28	ug/g ww	310
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5139	Mercury	0.36	ug/g ww	315
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5141	Mercury	0.39	ug/g ww	330
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5143	Mercury	0.34	ug/g ww	332
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5144	Mercury	0.41	ug/g ww	351
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5142	Mercury	0.46	ug/g ww	380
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5145	Mercury	0.44	ug/g ww	390
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5146	Mercury	0.43	ug/g ww	427
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5147	Mercury	0.60	ug/g ww	492
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	I_544MDRBH4_B5148	Mercury	0.91	ug/g ww	573
12-Sep-18	San Joaquin River at Airport Way near Vernalis	Largemouth Bass	I_541SJC501_B5204	Mercury	0.08	ug/g ww	200
12-Sep-18	San Joaquin River at Airport Way near Vernalis	Largemouth Bass	I_541SJC501_B5197	Mercury	0.12	ug/g ww	206
12-Sep-18	San Joaquin River at Airport Way near Vernalis	Largemouth Bass	I_541SJC501_B5201	Mercury	0.50	ug/g ww	242
12-Sep-18	San Joaquin River at Airport Way near Vernalis	Largemouth Bass	I_541SJC501_B5203	Mercury	0.44	ug/g ww	243
12-Sep-18	San Joaquin River at Airport Way near Vernalis	Largemouth Bass	I_541SJC501_B5205	Mercury	0.29	ug/g ww	243
12-Sep-18	San Joaquin River at Airport Way near Vernalis	Largemouth Bass	I_541SJC501_B5202	Mercury	0.34	ug/g ww	249
12-Sep-18	San Joaquin River at Airport Way near Vernalis	Largemouth Bass	I_541SJC501_B5200	Mercury	0.96	ug/g ww	270
12-Sep-18	San Joaquin River at Airport Way near Vernalis	Largemouth Bass	I_541SJC501_B5198	Mercury	0.73	ug/g ww	278
12-Sep-18	San Joaquin River at Airport Way near Vernalis	Largemouth Bass	I_541SJC501_B5199	Mercury	0.75	ug/g ww	280

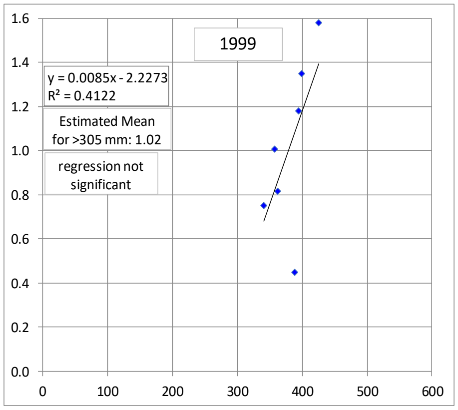
Appendix 3: Mercury Concentration versus Length at Each Station, Including Historic Data

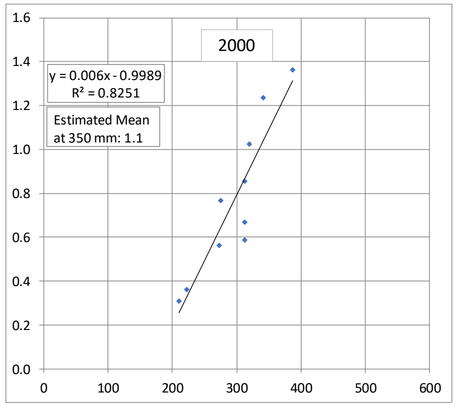
All graphs show MeHg concentrations in black bass (ppm wet weight) on the y-axis and black bass total length (mm) on the x-axis.

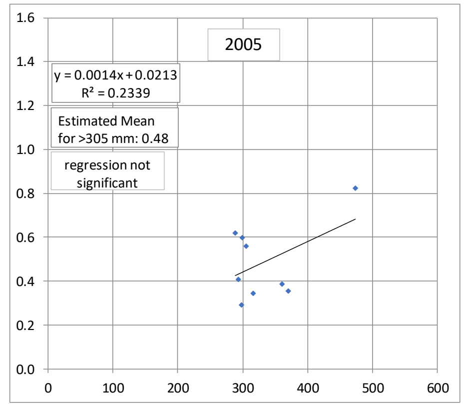
Sacramento River at Freeport

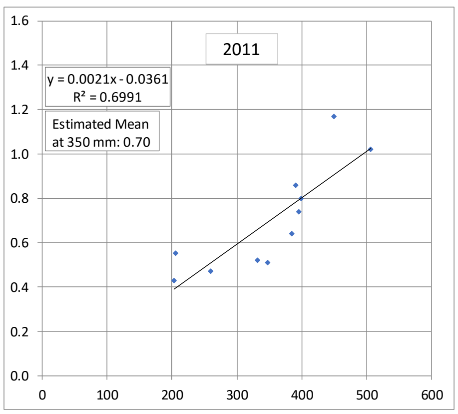


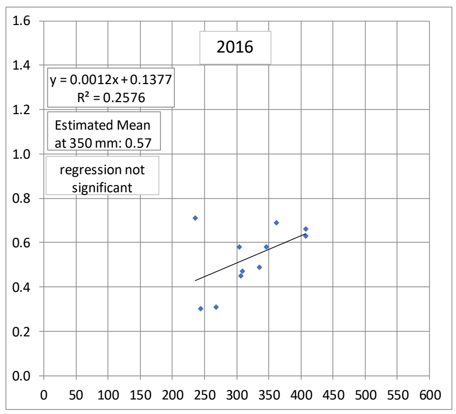
Lower Mokelumne River 6

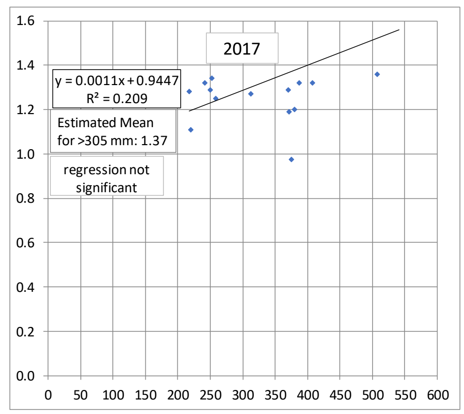


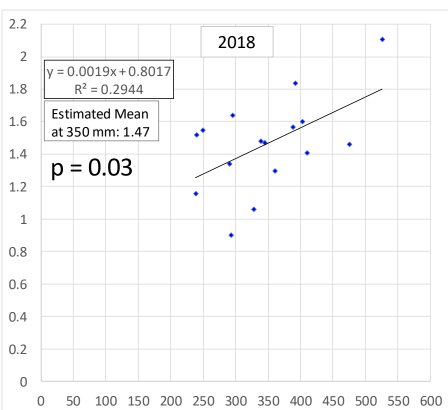




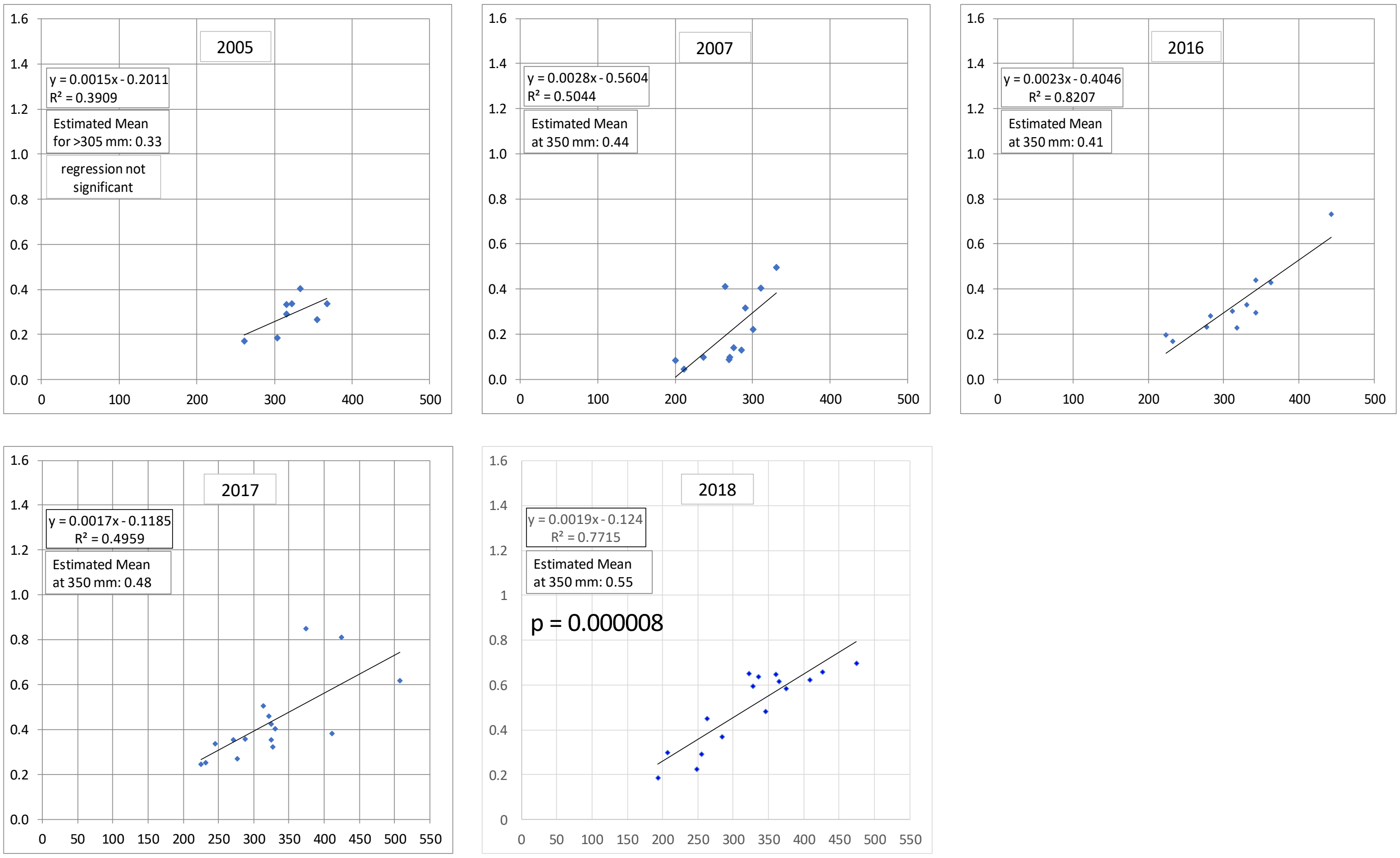




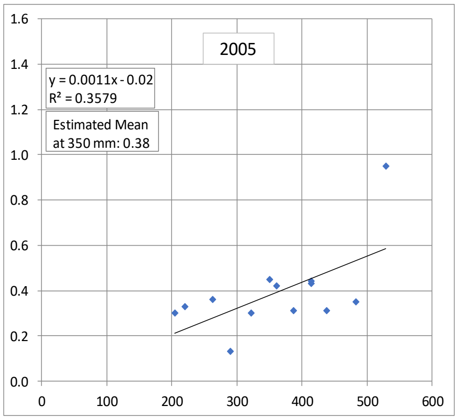


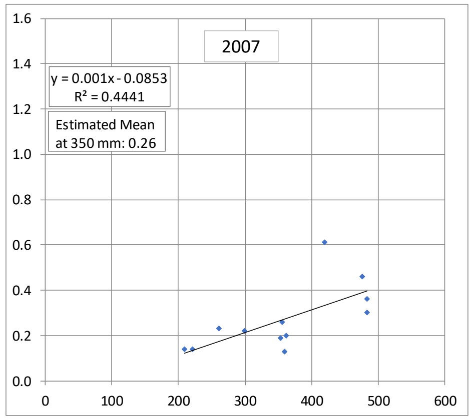


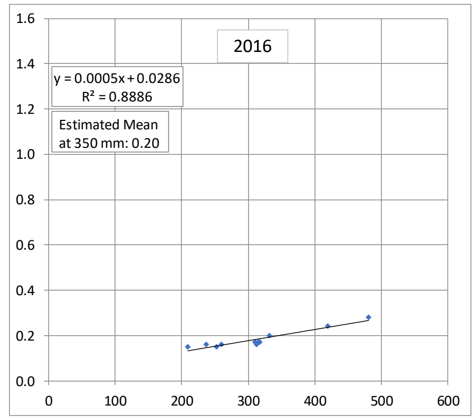
Cache Slough at Liberty Island Mouth

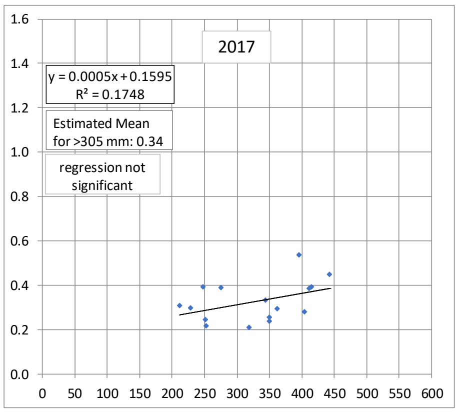


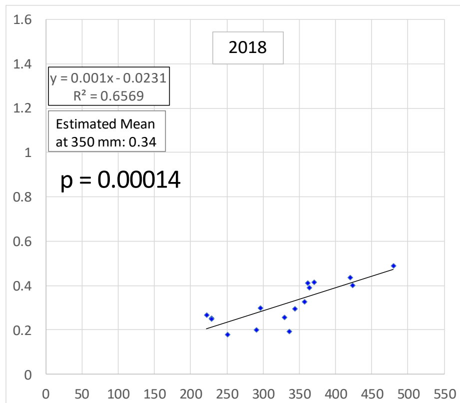
Little Potato Slough



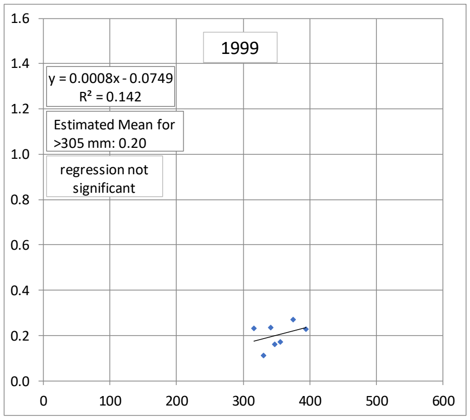


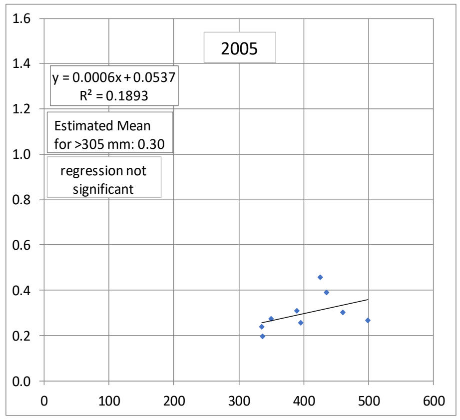


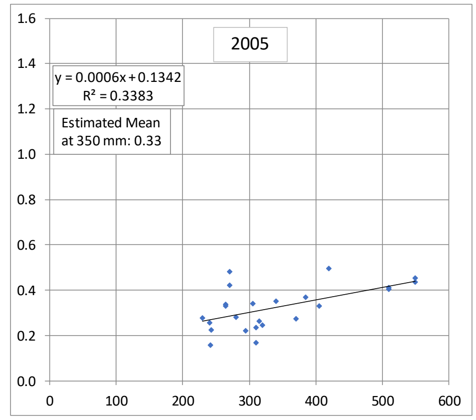


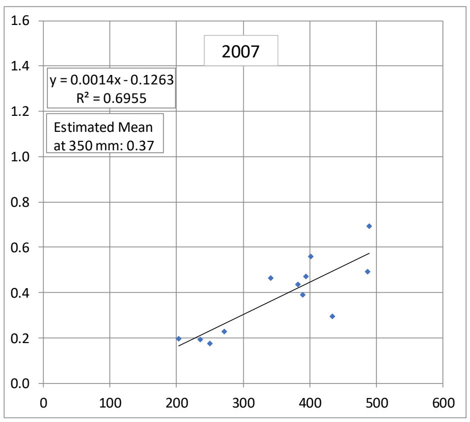


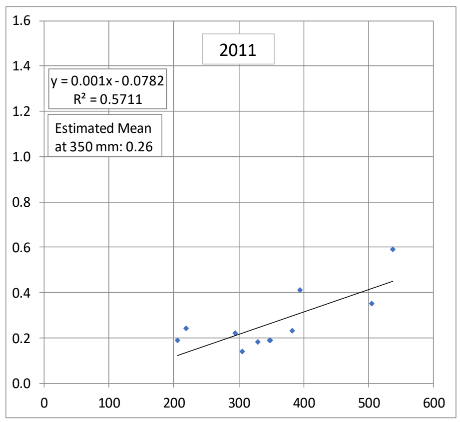
Middle River at Borden Hwy (Hwy 4)

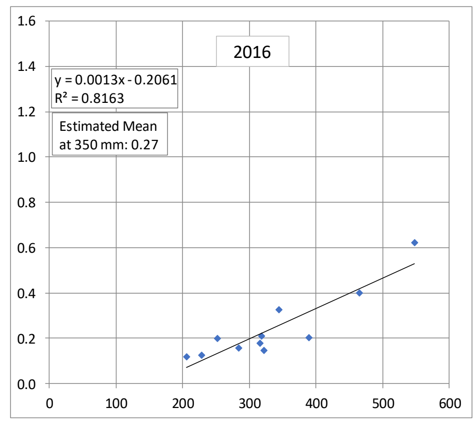


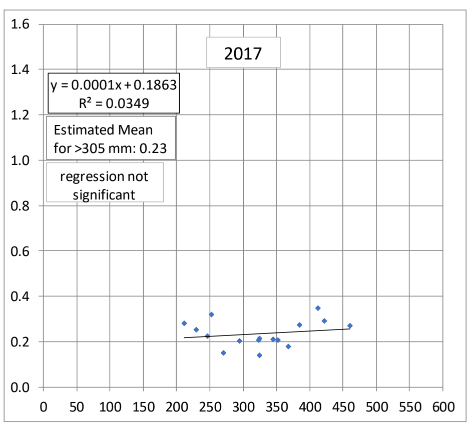


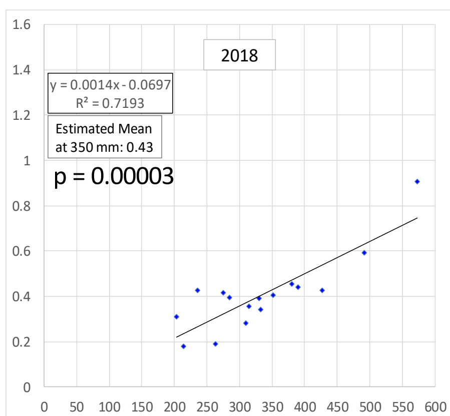




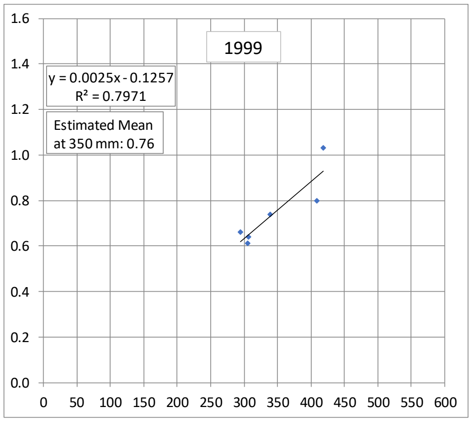


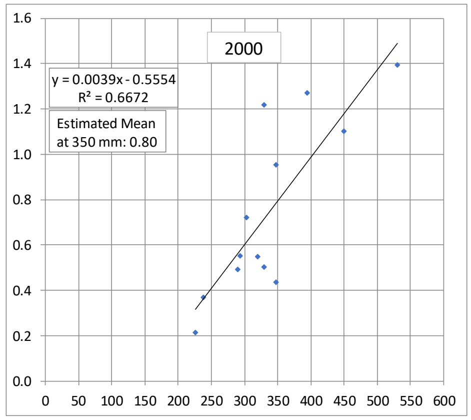


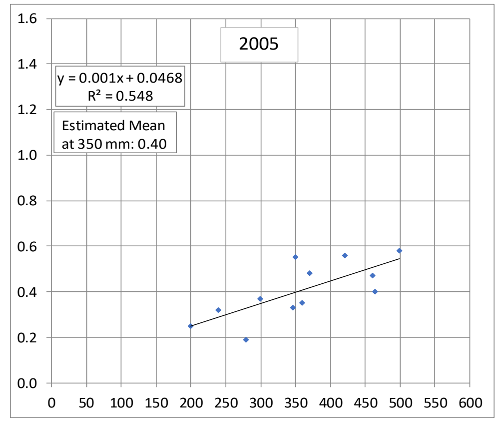


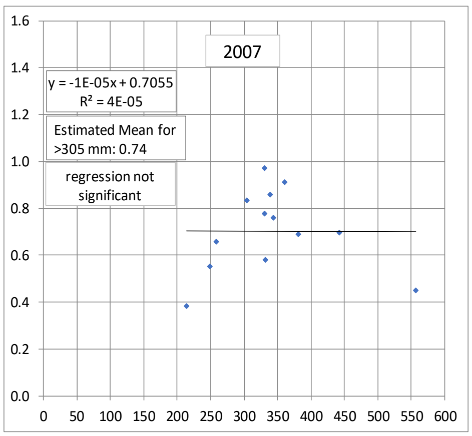


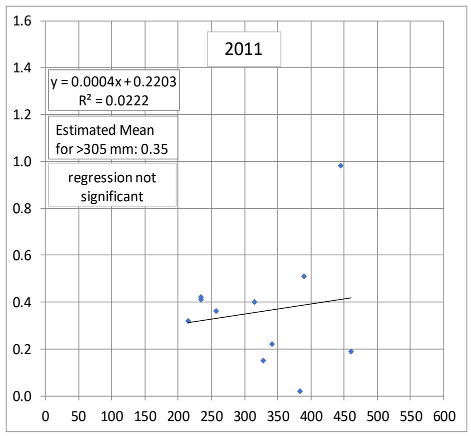
San Joaquin River at Vernalis

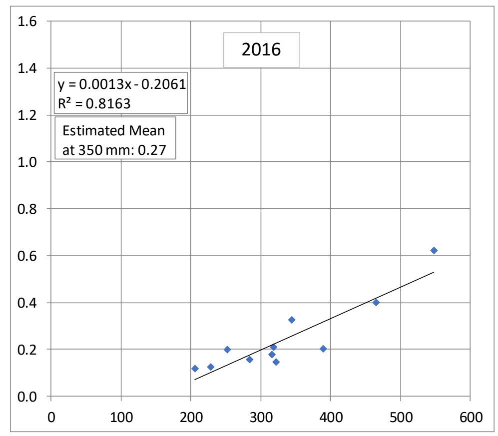


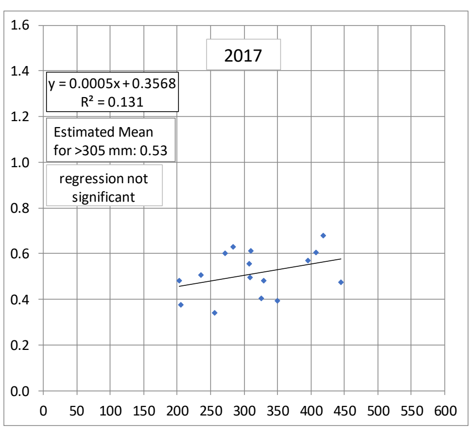


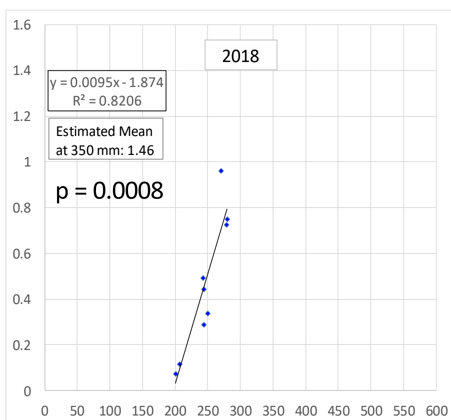




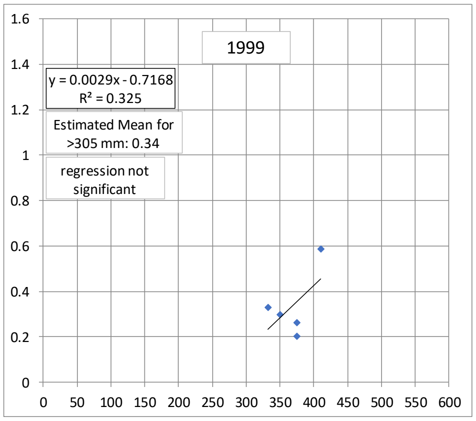


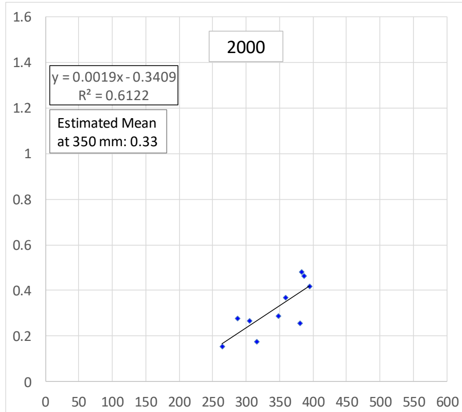


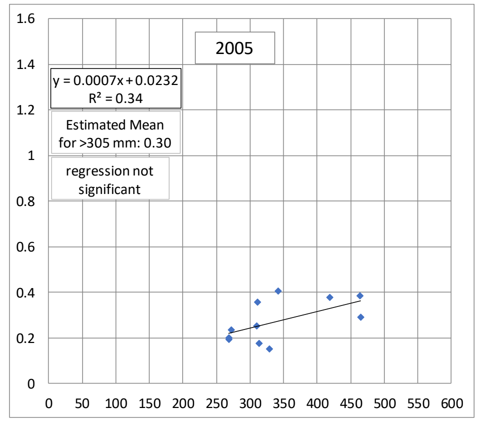


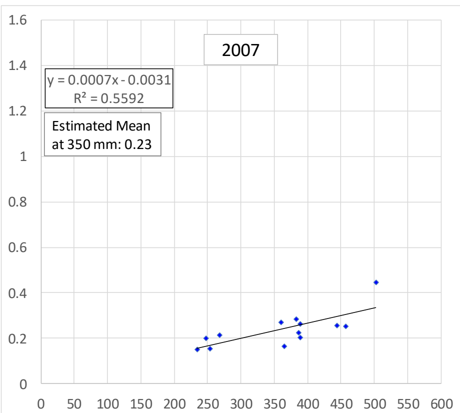


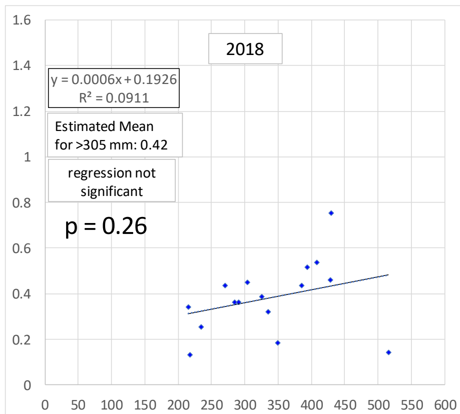
Sherman Island











Appendix 4: Length-adjusted Average Mercury Concentrations in Black Bass

Sample Date	Station	Common Name	Number Of Fish In Sample	Tissue Code	Prep Preservation	Result	Unit	Sample Type
20-Aug-18	Sacramento River/Freeport	Spotted Bass	16	FIL	Skin off	0.60	ug/g ww	350 mm Length-adjusted Mean
21-Aug-18	Lower Mokelumne River 6	Largemouth Bass	16	FIL	Skin off	1.47	ug/g ww	350 mm Length-adjusted Mean
20-Aug-18	Cache Slough at Liberty Island Mouth	Largemouth Bass	16	FIL	Skin off	0.55	ug/g ww	350 mm Length-adjusted Mean
21-Aug-18	Little Potato Slough	Largemouth Bass	16	FIL	Skin off	0.34	ug/g ww	350 mm Length-adjusted Mean
21-Aug-18, 11-Sep-18	Sherman Island	Largemouth Bass	16	FIL	Skin off	0.42	ug/g ww	Mean of fish >305 mm
22-Aug-18	Middle River at Borden Hwy (Hwy 4)	Largemouth Bass	16	FIL	Skin off	0.43	ug/g ww	350 mm Length-adjusted Mean
22-Aug-18, 12-Sep-18	San Joaquin River at Airport Way near Vernalis	Largemouth Bass	9	FIL	Skin off	1.46	ug/g ww	350 mm Length-adjusted Mean

Appendix 5: Quality Assurance Review

Quality Assurance Summary
Delta RMP Mercury Monitoring FY18-19 (Year 3)

This appendix summarizes the quality assurance (QA) review of the Delta Regional Monitoring Program (Delta RMP) 2018–2019 data for laboratory analyses of mercury and ancillary measurements in water and fish (sediment was not monitored in FY18-19).

This review was conducted by ASC scientists and technical staff under the supervision of QA officer Dr. Donald Yee. Samples were collected and analyzed by scientists and technicians from the Marine Pollution Studies Laboratory (MPSL) in Moss Landing, California.

Of the 993 total lab results, 947 (95%) met the requirements of the Delta RMP Quality Assurance Program Plan (QAPP; Yee et al. 2018). For methylmercury (MeHg) and mercury measurements in fish and water, 100% met the requirements of the QAPP. For ancillary water parameters, 88% of the measurements met the requirements of the QAPP. For DOC, 46 of 94 results did not meet the requirements of the QAPP due to holding time exceedances. TSS and VSS results had only one field blank, less than the 4 required to achieve the 1 per 20 frequency in the QAPP.

Table 1 provides a high-level summary of the quality assurance review of the chemical analytical results. Each of these analyses is described in greater detail below.

Table 1. QA Summary for chemical analytical results (RPD = relative percent difference)

Analyte	**Hold Time Check:** Percent of Results Exceeding hold time	**Sensitivity Check:** Percent of Results that are non-detects	**Precision Check:** Percent of Results < 3x Lab Blank result	**Precision Check:** Average Duplicate RPD	**Accuracy Check:** Average % Recovery for sample of known conc.
Water					
Total Mercury	0%	0%	0%	4%	102%
Methylmercury	0%	0.5%	0%	10%	92%
Chlorophyll-a	0%	2%	0%	13%	96%
Dissolved Organic Carbon	49%	1%	0%	5%	99.5%
Total Suspended Solids	0%	0%	0%	3%	99%
Volatile Suspended Solids	0%	40%	0%	12%	-
Fish					
Total Mercury	0%	0%	0%	6%	101%

In the first four columns of Table 1, the "ideal" result is 0%, and lower numbers are considered better. In the fifth, or right-most column, the ideal is 100% recovery. The relative percent difference (RPD) among duplicate samples is calculated based on the "best available" type of duplicates. Similarly, the accuracy check is performed based on the best available QC sample type of a known concentration. ASC's data review procedures are described in our Data Management and Quality Assurance Standard Operating Procedures (SOP).

Approach

About 15% of all samples were analyzed for quality assurance and quality control purposes.

For our QA review, we used the data electronically submitted by the laboratory and compiled it into a local database to verify that the correct number of field samples and required number of QC samples are reported for the requested analyses, as specified in the project Quality Assurance Project Plan, or QAPP, version 5.

We compared the results for QC samples to the acceptance criteria, or measurement quality objectives (MQOs) listed in the QAPP Table 14.2. We did this by independently recalculating reported precision (as relative percent difference, RPD, or relative standard deviation, RSD) for lab replicates, and percent recovery for samples of a known concentration. In order to verify that contamination of samples had not occurred in sampling or lab analysis, we compared the results for blank samples (both field and lab blanks) to method detection limits. In cases where an analyte is detected in a blank, we compare the measured concentration in the blank sample to concentrations measured in field samples to determine the proportion of the signal that originates from lab contamination.

Where deviations from the project's measurement quality objectives were found, we attached a flag or qualifier to the record. In some cases, records may have already been flagged by the reporting lab. Qualifiers added by ASC or the lab indicates that there has been a deviation from the project's quality criteria, and are meant to warn data users that certain records may be inaccurate or imprecise.

In the most severe cases, data may be rejected and not reported. However, for this project, all data were reportable, as we did not find serious violations of the quality objectives that would lead to rejection of data.

The sections below describe the detailed findings of our QA review of the reported datasets.

Mercury in Fish Tissue

QA review and summary by John Ross, April 17, 2019.
Reviewed by Don Yee, May 1, 2019.

The following section describes the quality assurance review for mercury and related analytes in fish tissue. Field crews from the Marine Pollution Studies Laboratory (MPSL) conducted sampling from August 20-22, 2018. Samples were analyzed in the laboratory at Moss Landing, California in February and March 2019. The following analytes were reported:

1. Total mercury[1]
2. Total length
3. Fork length
4. Weight
5. Sex
6. Moisture
7. Estimated age

This QA review focuses on mercury, but also describes the moisture and total solids results.

Overall Acceptability

Overall the dataset is acceptable. 100% of the results are reportable.

Hold Time

Storage and hold time requirements are listed in QAPP Table 12.1. Fish tissue samples may be analyzed up to one year after they are processed, provided that they are stored at or below a temperature of –20°C. All fish tissue samples were analyzed within 200 days or less.

Dataset Completeness

Mercury results were reported for 105 individual-fish composite tissue samples (target species was largemouth, actual catch was 89 largemouth bass and 16 spotted bass) analyzed in 6 lab batches. The number of fish tissue samples was 7 less than the 112 expected (16 fish per site times 7 sampling locations), as the field team was only unable to collect 9 of the target 16 fish samples at one sampling location, the San Joaquin River at Airport Way near Vernalis. No follow-up or corrective action is required; inevitably, some days, field crews simply can't catch as many fish of the primary target species as desired.

Six lab replicates (5 largemouth bass and 1 spotted bass) and 6 matrix spike/matrix spike replicates (all largemouth bass) were analyzed for the 105 composite tissue samples meeting the minimum requirement in the 2019 Delta RMP QAPP of 1 per 20 samples, or 1 per batch for these sample types.

[1] Total mercury measured as proxy of methylmercury because methylmercury comprises more than 90% of the total mercury in fish.

A total of 18 method blanks were analyzed meeting the minimum requirement in the 2019 Delta RMP QAPP of 1 per 20 samples, or 1 per batch for those sample types. Six certified reference material samples (NRC DORM-4: Fish protein certified reference material for trace metals) were also analyzed, although not required by the QAPP. Data were reported not blank corrected.

Mercury samples were analyzed between 174 and 196 days after collection. This is well within the 1-year holding time specified in the 2019 Delta RMP QAPP.

Moisture results were reported for 105 composite tissue samples analyzed in 6 lab batches. Moisture results were also reported for the 6 certified reference materials. There are no minimum requirements or method quality objectives listed in the 2019 Delta RMP QAPP for moisture.

Accuracy

We assessed the accuracy of mercury analysis by inspecting the results for samples of a known concentration. As an indicator of measurement accuracy, we calculate the average percent error between the analytical result and the known concentration in the standard. SFEI's convention is to give preference to the results for certified material samples (CRMs), when present, over matrix spike or matrix spike replicates, as the CRMs are externally validated values.

Analyses of certified reference material were run at a minimum frequency of one per analytical batch (for analytical batches consisting of up to 20 field samples) or per 20 (field) samples for larger analytical batches. Analysis of CRMs allows us to evaluate measurement accuracy, or how close our measurement comes to a consensus/expected value. Matrix spikes, where an environmental sample is "spiked" with a known amount of mercury, provide an alternative determination of method accuracy that can account for matrix interferences or other analytical problems.

The average percent error for the certified reference material samples for mercury of 1.4% (average recovery 101.4%) was well below a target MQO of 25%. No qualifiers were added. The average percent error examined for the mercury matrix spikes was 4% (average recovery 98%), also within the target 25% error. The mercury matrix spike/matrix spike duplicate results met the method quality objective listed in the 2019 Delta RMP QAPP of "expected value ± 25%." The average percent error of 4% was < well below this threshold. Based on this, we conclude that the lab measurements are sufficiently accurate and no flags are required.

The accuracy of the moisture data could not be evaluated as the certificate for the CRM analyzed, NRC DORM-4, does not list a certified value for moisture.

Precision

We analyzed the precision of analysis methods (ability to consistently obtain the same result) by comparing the results for replicate or duplicate samples. The analysis of lab replicates (split and analyzed in the laboratory) allows us to assess the repeatability of lab measurements.

The precision of field samples in the database is flagged following the SFEI convention of using lab replicates in preference to using field replicates, although both are reviewed and described narratively when provided. No field replicates were included in this data submission, nor were any expected or required in the sampling design or quality assurance plan.

Lab replicates were used to decide whether precision flags were needed. The average RPD for the mercury lab replicates was 6%, well below the MQO target of 25%. The maximum RPD was 12%, and the median RPD was 7%. No field replicates were analyzed. Based on these results, we determined that the lab measurements of total mercury in fish are sufficiently precise and no qualifiers were added.

Matrix spike replicates and CRM replicates were examined, but not used for flagging the dataset. The average RPD for the mercury matrix spike replicates was 5%, and for the CRM replicates it was 3%, both below the MQO target of 25%.

The precision of the moisture results could not be evaluated as no lab replicates were analyzed/reported.

The precision of the moisture results could not be evaluated as no lab replicates were analyzed/reported.

Sensitivity

For the sensitivity review, we evaluated the percentage of field samples that are non-detects. This allows us to evaluate whether the analytical methods employed were sensitive enough to detect environmental concentrations of the targeted parameters.

The lab reported results above the method detection limit (MDL) for all field composite tissue samples for total mercury. This indicates that the analysis methods used were of sufficient sensitivity to detect concentrations found in the fish composites.

Blank Contamination Check

The blank contamination review evaluates whether there may have been contamination in the field or laboratory during any stage of sample preparation and analysis. This review allows us to determine whether any contamination occurred that may affect the results, and if so, the magnitude of contamination.

Mercury was not measured in the method blanks at concentrations equal to, or above the reporting limits (RL), meeting the method objective of the 2019 Delta RMP QAPP of being “<RL”. We found no evidence of sample contamination, and no qualifiers were added.

Comparison to Historical Data

As a final check, we compare new analytical results to existing data to check for major changes, which can be a sign of errors, for instance due to units or incorrect calculations. We compared the average mercury concentrations in fish collected in Fall 2018 to those collected in Fall 2016 for Delta RMP mercury monitoring. The average largemouth bass mercury concentration was 193% of the 2016 average, while the spotted bass average was 88% of the 2016 average.

Concentrations vary among individual fish and sites, so two-fold differences in averages are reasonable given interannual variability and the mix of individual samples collected each period.

Mercury and Ancillary Parameters in Water Samples

QA review by John Ross, Oct 9, 2019.
Reviewed and summarized by Don Yee, Oct 28, 2019.

In this section, we describe the analysis of water samples for mercury (Hg), methylmercury (MeHg), and ancillary water quality parameters chlorophyll-a (Chl-a), dissolved organic carbon (DOC), total suspended solids (TSS), and volatile suspended solids (VSS). The QA for these analyses is summarized above in **Table 1**.

Overall Acceptability

Overall the dataset is acceptable. 100% of the results are reportable. The main issue that was encountered was a hold time exceedance for nearly half of the water samples analyzed for dissolved organic carbon.

Hold Time

The lab analyzed water samples for mercury and methylmercury within their hold time limits of 90 and 180 days respectively (see QAPP Table 12.1 for hold times and sample storage requirements). The lab analyzed samples within required hold times were also met for chlorophyll-a (28 day), Total Suspended Solids and Volatile Suspended Solids (7 day).

However, 46 of 94 (49%) dissolved organic carbon (DOC) samples were analyzed past their 30 day hold. The maximum hold time for any DOC sample was 115 days. ASC's QA Officer flagged these results "VH" for a hold time exceedance, but the results are still reported. The problem occurred when the Moss Landing Marine Laboratory had problems with instrumentation and had to send out samples to a subcontractor lab. In spite of this hold time exceedance, the investigators have high confidence in the data – the values for the samples in question are typical of values for the Delta areas sampled.

In the future a decision to send out samples for an alternative lab to analyze should be made sooner. This would have minimized the severity of the hold time violation. ASC staff has discussed the issue with the lab in order to prevent such issues from recurring.

Dataset Completeness

Results were reported for 80 environmental samples (10 sampling events at 8 monitoring sites, see QAPP Table 6.2(b). In addition, the lab reported results for various QC samples of the required type and frequency, as summarized in Table 2 below. The minimum frequency for QC samples is stated in QAPP Table 14.2. Dissolved and total fraction Hg and MeHg samples are processed in the same way for lab analyses, so total fraction lab blanks apply to both fractions. QAPP listed frequencies for QC samples were met, except for field blanks for TSS and VSS. In FY18-19, the PI and project team, given finite budget, decided that the minimal information provided by continuing field blanks was not worth the cost incurred and would be better spent on other sample types and efforts. These field blanks will be included in future sampling.

Program staff failed to update QAPP Table 14.2 to reflect this change.

For ancillary analytes, some QC sample types like CRMs are not available or typically run for analyses. However, there was always at least one type of QC sample analyzed in replicate for precision (at least field replicates, usually also lab replicates, sometimes MS/MSDs), one or more types for recovery (LCS or MS or CRM), and lab blanks to evaluate contamination.

Table 2. Number of sample results submitted by lab for water samples, by sample type. CRM = certified reference material; LCS = laboratory control sample; MS = matrix spike; MSD = matrix spike duplicate.

Analyte	Environ-mental samples	Field duplicates	Lab duplicates	Field blanks	Lab blanks	CRM	LCS	MS	MSD
Target Analytes									
Dissolved Hg	80	10	6	10	-	-	-	10	10
Total Hg	80	10	6	10	40	13	-	14	14
Dissolved MeHg	80	10	3	10	-	-	-	2	2
Total MeHg	80	10	10	10	40	-	13	24	24
Ancillary analytes									
chlorophyll-a	80	10	-	-	30	-	14	-	-
TSS	80	10	10	1	20	8	-	-	-
VSS	80	10	10	1	20	-	-	-	-
DOC	80	10	4	10	15	4	30	14	14

Accuracy

We assessed the accuracy of lab analyses by inspecting the results for samples of a known concentration. As an indicator of measurement accuracy, we calculate the average percent error between the analytical result and the known concentration in the standard. SFEI's convention is to give preference to the results for certified material samples (CRMs), when present, over matrix spike or matrix spike replicates, as the CRMs are externally validated values.

Of the reported analytes, only mercury had natural matrix CRM results, with average recovery errors of 3% (mean recovery 100.5%).

DOC and TSS CRMs were lab created materials, with recovery within targets as well (average 1% error, 100% recovery on DOC, 4% error, 99% recovery on TSS).

Chl-a recovery was evaluated using LCS samples, averaging 7% error, 96% recovery.

Recovery errors on MS samples averaged <10% for Hg, well within its target 25%, and <11% for MeHg, within its 30% target.

Recovery errors on MS samples averaged 28% for DOC, above its 20% target; however, recoveries on the CRM results were acceptable as noted previously, so results were not flagged.

Precision

We analyzed the precision of analysis methods (ability to consistently obtain the same result) by comparing the results for replicate or duplicate samples. The analysis of lab replicates (split and analyzed in the laboratory) allows us to assess the repeatability of lab measurements.

Precision averaged 10% RPD for Hg and MeHg lab replicates, for samples where concentrations were large enough to quantify reliably, i.e. results that were at least 3x the MDL. Variation in Hg and MeHg among field samples duplicates from individual sites was somewhat larger, but still averaged <15% RPD.

Lab precision averaged 12% or better, well within the 25% RPD target for ancillary analytes (DOC, TSS, VSS). Precision on chl a was determined from field replicates, as samples are collected on filters, typically not suitable for subsampling as lab replicates. Variation among field samples duplicates from individual sites was somewhat larger, but still averaged 16% RPD or better for all the ancillary analytes.

Sensitivity

For the sensitivity review, we evaluated the percentage of field samples that are non-detects. This allows us to evaluate whether the analytical methods employed were sensitive enough to detect environmental concentrations of the targeted parameters.

The lab methods were sufficient to detect nearly all analytes in samples, with the exception of VSS, where 40 of 100 samples were non-detect.

There were also 2 chl-a results, 2 Hg, 1 MeHg, and 1 DOC result below detection limits.

Blank Contamination Check

The blank contamination review evaluates whether there may have been contamination in the field or laboratory during any stage of sample preparation and analysis. This review allows us to determine whether any contamination occurred that may affect the results, and if so, the magnitude of contamination.

Samples were reported NOT blank-corrected for DOC and MeHg, but blank-corrected per the listed methods for the other analytes. Lab blanks were all non-detects for the uncorrected analytes. For the blank-corrected analytes, lab blank results (including raw signals below MDL) were averaged by the lab for subtraction from the raw field sample results in the batch. The lab blanks had levels below the detection limit so no results were qualified for blank contamination. DOC was detected in four field blanks at 0.2 to 0.4 mg/L, about 2 to 4x above the detection limit of 0.1 mg/L in samples analyzed by the contract laboratory MBAS, so those field blank samples were flagged. However, field blanks were still at least 6x lower than the average field sample result, so the blank contamination was likely to have minimal impact on reported field samples.

Comparison to Historical Data

As a final check, we compare new analytical results to existing data to check for major changes, which can be a sign of errors, for instance due to units or incorrect calculations. As this is the third year of monitoring for water Hg and MeHg and the various ancillary parameters in the

Delta RMP, the new data, largely from the same sites with the same (or similar) collection and analytical methods, can be directly compared.

Table 3 below lists the reported ranges for the various reported parameters for this year, compared to the range for prior years combined. The data largely span the same range for all analytes, with slightly lower minimum and/or higher maximum reported values for the individual analytes. We did not see any obvious errors in the data as a result of this QA step.

Table 3. Range of Delta RMP reported concentrations 2018-19 versus prior years

Parameter	Delta RMP (prior range)	Delta RMP 2018-19
Mercury		
Dissolved Mercury	0.31 – 7.5 ng/L	<0.12 – 7.0 ng/L
Total Mercury	0.73 – 15.9 ng/L	<0.12 – 26.3 ng/L
Dissolved Methylmercury	0.02 – 0.26 ng/L	0.01 – 0.21 ng/L
Total Methylmercury	0.04 – 0.39 ng/L	<0.01 – 0.38 ng/L
Ancillary		
TSS	1 – 143 mg/L	2 – 183 mg/L
DOC	<0.24 – 8.1 mg/L	<0.18 – 7.1 mg/L
VSS	<1 – 65 mg/L	<2 – 35 mg/L
chl-a	<0.5 – 37 ug/L	<0.28 – 47.5 ug/L

Appendix 6: Mercury and Ancillary Concentrations in Water

StationCode	Station	Sample Date DD/MMM/YYYY	DOC (mg/L)	Chl a (ug/L)	TSS (mg/L)	VSS (mg/L)	ufTHg (ng/L)	fTHg (ng/L)	ufMeHg (ng/L)	fMeHg (ng/L)
510ADVLIM	Cache Sl @ liberty Island Mouth	9-Jul-2018	1.59	1.26	12.1	<MDL	2.60	0.519	0.140	0.068
510ADVLIM	Cache Sl @ liberty Island Mouth	13-Aug-2018	1.79	1.10	5.70	<MDL	1.32	0.492	0.102	0.063
510ADVLIM	Cache Sl @ Liberty Island Mouth	10-Sep-2018	2.07	0.40	3.12	<MDL	0.81	0.461	0.110	0.085
510ADVLIM	Cache Sl @ Liberty Island Mouth	8-Oct-2018	1.57	0.68	11.0	2.04	1.93	0.523	0.141	0.061
510ADVLIM	Cache Sl @ Liberty Island Mouth	21-Jan-2019	5.30	0.78	48.5	5.88	14.4	2.93	0.187	0.104
510ADVLIM	Cache Sl @ Liberty Island Mouth	18-Feb-2019	2.20	1.82	183	25.9	26.3	3.12	0.281	0.103
510ADVLIM	Cache Sl @ Liberty Island Mouth	20-Mar-2019	3.20	23.3	24.4	2.44	6.17	1.33	0.360	0.118
510ADVLIM	Cache Sl @ Liberty Island Mouth	22-Apr-2019	2.50	3.52	13.0	<MDL	3.59	1.18	0.236	0.123
510ADVLIM	Cache Sl @ Liberty Island Mouth	20-May-2019	0.50	1.33	7.83	2.09	2.14	0.754	0.088	0.053
510ADVLIM	Cache Sl @ Liberty Island Mouth	18-Jun-2019	1.70	0.90	9.45	1.84	2.52	0.755	0.095	0.064
207SRD10A	Sacramento R @ Mallard Island	10-Jul-2018	2.03	2.22	66.7	7.53	17.6	0.732	0.072	0.019
207SRD10A	Sacramento R @ Mallard Island	14-Aug-2018	2.23	1.64	33.9	4.76	9.11	0.534	0.040	0.012
207SRD10A	Sacramento R @ Mallard Island	11-Sep-2018	1.91	1.85	23.2	<MDL	6.96	0.508	0.035	0.017
207SRD10A	Sacramento R @ Mallard Island	9-Oct-2018	1.77	1.23	16.7	2.95	4.36	0.462	0.037	0.017
207SRD10A	Sacramento R @ Mallard Island	22-Jan-2019	4.20	1.11	79.5	9.59	17.4	2.13	0.148	0.072
207SRD10A	Sacramento R @ Mallard Island	19-Feb-2019	3.60	1.30	136	21.2	20.8	2.64	0.235	0.085
207SRD10A	Sacramento R @ Mallard Island	21-Mar-2019	2.40	2.72	26.9	2.15	7.76	1.32	0.130	0.059
207SRD10A	Sacramento R @ Mallard Island	23-Apr-2019	1.80	2.68	12.0	2.00	3.29	0.996	0.138	0.062
207SRD10A	Sacramento R @ Mallard Island	21-May-2019	1.80	1.67	16.5	2.63	4.26	0.900	0.077	0.038
207SRD10A	Sacramento R @ Mallard Island	19-Jun-2019	1.80	2.92	86.0	9.00	18.5	1.19	0.142	0.048
510ST1317	Sacramento R @ Freeport	9-Jul-2018	1.15	1.39	16.4	2.55	2.98	0.505	0.086	0.048
510ST1317	Sacramento R @ Freeport	13-Aug-2018	1.56	1.26	27.3	2.39	4.46	0.453	0.094	0.047
510ST1317	Sacramento R @ Freeport	10-Sep-2018	1.34	0.85	14.9	<MDL	2.20	0.398	0.071	0.051
510ST1317	Sacramento R @ Freeport	8-Oct-2018	1.20	1.01	7.11	<MDL	1.59	0.524	0.062	0.052
510ST1317	Sacramento R @ Freeport	21-Jan-2019	6.10	1.90	109	7.81	16.8	2.88	0.127	0.054
510ST1317	Sacramento R @ Freeport	18-Feb-2019	3.00	1.40	53.1	8.33	8.81	2.42	0.107	0.055
510ST1317	Sacramento R @ Freeport	20-Mar-2019	1.40	4.02	35.1	<MDL	6.05	1.07	0.109	0.037
510ST1317	Sacramento R @ Freeport	22-Apr-2019	1.40	3.68	34.2	3.36	4.97	0.842	0.153	0.050
510ST1317	Sacramento R @ Freeport	20-May-2019	1.70	2.06	29.8	4.65	4.96	0.908	0.079	0.038
510ST1317	Sacramento R @ Freeport	17-Jun-2019	1.70	1.85	27.2	3.83	4.87	0.640	0.100	0.044
541SJC501	SanJoaquin R @ Vernalis/Airport Way	10-Jul-2018	2.23	47.5	34.1	7.26	6.51	0.726	0.115	0.038
541SJC501	SanJoaquin R @ Vernalis/Airport Way	14-Aug-2018	2.47	17.6	21.1	4.64	3.52	0.668	0.100	0.034
541SJC501	SanJoaquin R @ Vernalis/Airport Way	12-Sep-2018	2.42	19.2	25.8	4.00	3.28	0.449	0.098	0.034
541SJC501	SanJoaquin R @ Vernalis/Airport Way	9-Oct-2018	2.48	6.59	16.2	3.73	2.50	0.646	0.091	0.050
541SJC501	SanJoaquin R @ Vernalis/Airport Way	22-Jan-2019	7.10	3.77	62.0	6.48	11.8	2.91	0.233	0.122
541SJC501	SanJoaquin R @ Vernalis/Airport Way	19-Feb-2019	4.20	1.94	78.5	13.9	7.41	2.13	0.124	0.051
541SJC501	SanJoaquin R @ Vernalis/Airport Way	21-Mar-2019	2.70	3.97	9.25	<MDL	3.33	1.17	0.137	0.080
541SJC501	SanJoaquin R @ Vernalis/Airport Way	23-Apr-2019	2.00	3.40	26.0	2.67	4.61	0.953	0.122	0.058
541SJC501	SanJoaquin R @ Vernalis/Airport Way	21-May-2019	1.90	1.44	28.6	4.46	4.00	0.951	0.084	0.047
541SJC501	SanJoaquin R @ Vernalis/Airport Way	19-Jun-2019	2.10	3.51	39.8	4.84	5.11	1.15	0.258	0.146
544ADVLM6	Lower Mokelumne R. 6	9-Jul-2018	1.55	4.24	14.8	3.57	4.08	0.742	0.105	0.042
544ADVLM6	Lower Mokelumne R. 6	13-Aug-2018	2.34	8.51	21.4	3.45	5.82	0.838	0.141	0.059
544ADVLM6	Lower Mokelumne R. 6	10-Sep-2018	2.09	3.47	11.9	<MDL	3.13	0.885	0.097	0.057
544ADVLM6	Lower Mokelumne R. 6	8-Oct-2018	1.50	0.913	6.36	<MDL	1.97	0.643	0.049	0.030
544ADVLM6	Lower Mokelumne R. 6	21-Jan-2019	5.70	2.70	14.2	<MDL	12.7	5.05	0.366	0.214
544ADVLM6	Lower Mokelumne R. 6	18-Feb-2019	3.20	1.92	20.3	4.73	8.90	3.30	0.113	0.074
544ADVLM6	Lower Mokelumne R. 6	20-Mar-2019	2.00	1.77	9.68	<MDL	5.27	1.75	0.198	0.119
544ADVLM6	Lower Mokelumne R. 6	22-Apr-2019	1.60	1.26	11.2	<MDL	2.79	0.677	0.082	0.067
544ADVLM6	Lower Mokelumne R. 6	20-May-2019	<MDL	1.20	11.2	2.97	3.09	0.747	0.103	0.060
544ADVLM6	Lower Mokelumne R. 6	18-Jun-2019	1.70	1.11	16.9	2.46	4.14	0.762	0.256	0.147
544DMC020	DMC off HWY 4	10-Jul-2018	2.63	8.52	9.74	2.25	1.54	0.491	0.073	0.047
544DMC020	DMC off HWY 4	14-Aug-2018	2.36	2.84	10.5	<MDL	1.67	0.318	0.053	0.033
544DMC020	DMC off HWY 4	11-Sep-2018	2.04	2.70	7.41	<MDL	1.05	0.388	<MDL	0.012
544DMC020	DMC off HWY 4	9-Oct-2018	2.46	1.89	7.92	<MDL	1.12	6.96	0.053	0.030
544DMC020	DMC off HWY 4	22-Jan-2019	5.20	0.562	9.39	<MDL	0.904	2.80	0.087	0.077
544DMC020	DMC off HWY 4	19-Feb-2019	3.00	0.974	27.6	7.14	5.48	2.12	0.077	0.043
544DMC020	DMC off HWY 4	21-Mar-2019	2.70	0.967	3.88	<MDL	2.39	1.20	0.067	0.057
544DMC020	DMC off HWY 4	23-Apr-2019	2.10	4.65	5.49	<MDL	2.03	0.996	0.092	0.059
544DMC020	DMC off HWY 4	21-May-2019	1.90	0.56	8.28	2.42	2.42	1.12	0.080	0.056
544DMC020	DMC off HWY 4	19-Jun-2019	3.60	1.26	9.56	2.39	2.71	1.27	0.149	0.121
544LILPSL	Little Potato Slough	9-Jul-2018	1.56	2.47	4.61	<MDL	1.27	0.472	0.065	0.034
544LILPSL	Little Potato Slough	13-Aug-2018	1.86	3.53	5.64	<MDL	1.29	0.439	0.059	0.039
544LILPSL	Little Potato Slough	10-Sep-2018	1.80	1.01	2.78	<MDL	0.741	<MDL	0.069	0.049
544LILPSL	Little Potato Slough	9-Oct-2018	1.67	0.911	2.44	<MDL	0.862	0.541	0.057	0.038
544LILPSL	Little Potato Slough	21-Jan-2019	6.10	1.44	32.9	4.88	10.8	3.49	0.170	0.101
544LILPSL	Little Potato Slough	18-Feb-2019	4.30	1.08	18.2	4.42	9.30	3.51	0.144	0.084
544LILPSL	Little Potato Slough	20-Mar-2019	2.00	0.688	4.34	<MDL	3.23	1.42	0.111	0.085
544LILPSL	Little Potato Slough	22-Apr-2019	1.70	1.18	7.87	<MDL	2.37	0.921	0.134	0.079
544LILPSL	Little Potato Slough	20-May-2019	1.80	0.809	3.95	<MDL	1.97	0.951	0.086	0.066
544LILPSL	Little Potato Slough	18-Jun-2019	1.70	1.00	5.79	<MDL	1.78	0.579	0.089	0.060
544MDRBH4	Middle R. @ Borden Hwy (Hwy4)	9-Jul-2018	2.67	7.74	5.48	2.47	0.974	0.511	0.051	0.037
544MDRBH4	Middle R. @ Borden Hwy (Hwy4)	14-Aug-2018	2.23	2.74	8.13	<MDL	1.22	0.361	0.060	0.029
544MDRBH4	Middle R. @ Borden Hwy (Hwy4)	11-Sep-2018	2.08	3.00	4.21	<MDL	0.652	0.429	0.041	0.020
544MDRBH4	Middle R. @ Borden Hwy (Hwy4)	9-Oct-2018	2.28	2.46	3.13	<MDL	0.572	0.423	0.035	0.027
544MDRBH4	Middle R. @ Borden Hwy (Hwy4)	22-Jan-2019	5.10	0.567	4.09	<MDL	1.68	0.881	0.105	0.082
544MDRBH4	Middle R. @ Borden Hwy (Hwy4)	19-Feb-2019	6.20	<MDL	6.20	3.28	3.07	1.95	0.101	0.079
544MDRBH4	Middle R. @ Borden Hwy (Hwy4)	21-Mar-2019	2.80	2.45	4.62	<MDL	2.09	1.10	0.058	0.046
544MDRBH4	Middle R. @ Borden Hwy (Hwy4)	23-Apr-2019	0.50	1.26	3.40	<MDL	1.57	0.897	0.090	0.053
544MDRBH4	Middle R. @ Borden Hwy (Hwy4)	21-May-2019	2.20	0.824	4.91	1.81	1.91	0.968	0.073	0.051
544MDRBH4	Middle R. @ Borden Hwy (Hwy4)	18-Jun-2019	4.90	1.56	8.30	1.81	2.15	0.856	0.118	0.073
		Method Detection Limit	0.24	0.045	1.00	1.00	0.200	0.200	0.011	0.011
		Reporting Limit	1.00	0.045	3.00	3.00	0.200	0.200	0.031	0.031