Valley Water

Clean Water • Healthy Environment • Flood Protection

March 13, 2020

Mr. Michael Montgomery, Executive Officer
San Francisco Bay Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

Delivered by email: Michael.Montgomery@waterboards.ca.gov and
Carrie.Austin@waterboards.ca.gov

SUBJECT: 2019 Progress Report on Methylmercury Production and Control Studies

Dear Mr. Montgomery:

San Francisco Bay Regional Water Quality Control Board (Water Board) and Valley Water staff have agreed that Valley Water will submit a manuscript to a peer-reviewed journal for publication and pay for it to be made freely available to the public in lieu of a 2019 biennial report. This agreement resulted from discussions between Valley Water and Water Board staff about the significant academic and regulatory value of this study, and the hope that the information would be more widely seen if published in a journal. Studies using hypolimnetic oxygenation to address reservoir methylmercury production are rare in the literature, and the lessons learned to date will be valuable to regulators, reservoir managers, and the public, especially as California's Statewide Mercury Control Program for Reservoirs is developed. The manuscript will be more summary in nature, so it will not include some of the detail that the biennial report ordinarily would. Consequently, supplemental information requested by Water Board staff is included with this cover letter. The manuscript will be submitted to the Water Board after peer review regardless of its acceptance for publication.

Valley Water manages four water bodies affected by historical mercury mining operations: Almaden, Calero, and Guadalupe reservoirs, and Almaden Lake. In addition to reporting on impacted water bodies in the Guadalupe River Watershed, the manuscript and attached materials include information about Stevens Creek Reservoir, which serves as an additional treated reference site located outside of the watershed. Valley Water operates line-diffuser hypolimnetic oxygenation systems at Almaden, Calero, Guadalupe, and Stevens Creek reservoirs. Four solar powered circulators are deployed in Almaden Lake. These treatment systems are operated and evaluated to assess their effectiveness in decreasing methylmercury production and bioaccumulation. Additional background can be found in the 2017 biennial report as well as the Water Board's letters providing comments and acceptance of the report from March 26, 2018 and June 19, 2018, respectively.

The attached materials detail interim results of technical studies required in the Guadalupe River Watershed Mercury TMDL Staff Report (Section 9.4) through October 2019. The studies address the monitoring requirements described in Table 9.1 of the TMDL Staff Report, including special studies, evaluation of methylmercury treatment systems, and calculated mercury loads at discharge points.

Valley Water has made a considerable investment in addressing and studying methylmercury production in reservoirs. Costs for the hypolimnetic oxygenation systems included about $600,000 in construction costs per system, $44,000 per system for power hookups, $25,000 in electricity costs per system per year, ongoing maintenance costs, and significant sampling and analysis costs.

In 2019, Valley Water staff also voluntarily conducted or collaborated on various studies and sampling efforts outside the scope of the TMDL efforts. These included collaborating with USGS researchers on a water column mercury methylation study, conducting a food web study, collecting water samples from Lexington Reservoir for the Regional Water Quality Control Board (RWQCB), escorting RWQCB staff to Guadalupe Reservoir to collect sediment and water samples, and facilitating reservoir access to CA Department of Fish and Wildlife staff for Surface Water Ambient Monitoring Program Bioaccumulation Oversight Group (SWAMP BOG) fish sampling.

Sampling for the water column mercury methylation study occurred in May and August 2019. Valley Water provided reservoir access by boat, some sampling equipment, some analytical services, and staff support to the project. USGS staff are currently working to prepare a manuscript for publication.

Valley Water staff sampled various media and biota for the first year of a food web study in Almaden, Calero, Guadalupe, and Stevens Creek reservoirs to better understand the relationship between trophic structure and mercury biomagnification. Data are currently being analyzed to direct additional sampling in 2020.

At the request of Water Board staff, Valley Water sampled water in Lexington Reservoir for mercury and methylmercury analysis on 6/7, 8/21, and 12/9, 2019. Samples were delivered to the Marine Pollution Studies Laboratory at Moss Landing Marine Laboratories for analysis.

On 10/3, 2019 Valley Water escorted Water Board staff at Guadalupe Reservoir to collect sediment and water samples from a ravine that drains the historical Enriquita Mine portion of New Almaden to prepare for future remediation opportunities in areas with elevated mercury levels. The data analysis and report were shared with Valley Water.

In late 2019, Valley Water staff facilitated access for California Department of Fish and Wildlife to collect fish at Calero, Guadalupe, Almaden, Stevens Creek, and Lexington Reservoirs for tissue analysis as part of the SWAMP BOG program. Analyses and reporting are pending.

Please feel free to contact Kirsten Struve at (408) 630-3138, should you have any questions.

Sincerely,

Vincent Gin
Deputy Operating Officer
Watersheds Stewardship and Planning Division

Enclosures:
Requested Supplemental Information
2020/21 Sampling Plan
2018 and 2019 Fish Assemblage Report for the Guadalupe River Watershed Mercury Total Maximum Daily Load

Cc: Carrie Austin, Kevin Lunde, Melanie Richardson, Lisa Bankosh, Kurt Lueneburger, Kirsten Struve, James Downing, Mark Seelos, Elisabeth Wilkinson

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Guadalupe River Watershed TMDL
2018-2019 Progress Report on Methylmercury Production and Control Measures
Supplemental Information

At the request of San Francisco Bay Regional Water Quality Control Board staff, certain supplemental information that will not be included in the manuscript draft is included here.

Oxygenation System Operations

Oxygenation systems were started and stopped based on reservoir water column stratification. When regular water quality profile sampling indicated that stratification had begun in a reservoir, its hypolimnetic oxygenation system (HOS) was brought online. Figure 1 shows the timing of HOS operation and hypolimnion oxygen saturation in each reservoir for 2018 and 2019. In each case, HOSs were shut down when destratification occurred in the fall. Each system is uniquely engineered for the reservoir in which it is deployed. Flow rates must overcome the pressure differential between the water surface and bottom, and still oxygenate the hypolimnion without mixing the water column. When the systems were first installed, Moby engineering and Valley Water staff calculated the oxygen delivery rates necessary to achieve this balance. Each system is equipped with flow regulators to modify the oxygen delivered. While small adjustments to delivery rates are possible in most reservoirs without adverse effects, the system at Calero Reservoir does not fully oxygenate the hypolimnion even at full capacity. In June of 2019, the oxygen flow rate at Stevens Creek Reservoir was reduced from 8 to 7 CFM in response to observations of turbid water in Stevens Creek downstream of the reservoir. Oxygen saturation declined slightly in response and no change in turbidity was observed. No further reductions were made for fear of reducing oxygen saturation to unacceptable levels. The oxygenation systems were effective at increasing hypolimnetic oxygen concentrations except in Calero Reservoir where a broad basin contour and large hypolimnetic volume appear to preclude such increases even with the system operating at maximum capacity.

Within the planned start and stop times based on stratification, the systems operated continuously except for occasional intentional and unintentional shutdowns. Units were intentionally shut down 24 to 48 hours before the May and August 2019 sampling events for the Water Column Mercury Methylation study to ensure the minimum amount of vertical mixing in the water column at the time of sampling. In addition, occasional automatic shutdowns resulted from excessive heat or power failure. In 2018, the unit at Calero Reservoir experienced power failures that resulted in significant gaps in operation. The Stevens Creek location experienced a significant number of heat-related shutdowns due to the exposed location and high levels of dust. Planned maintenance improvements for 2020 and 2021 and the installation of telemetry equipment to notify staff of shutdowns immediately should result in system reliability improvements.

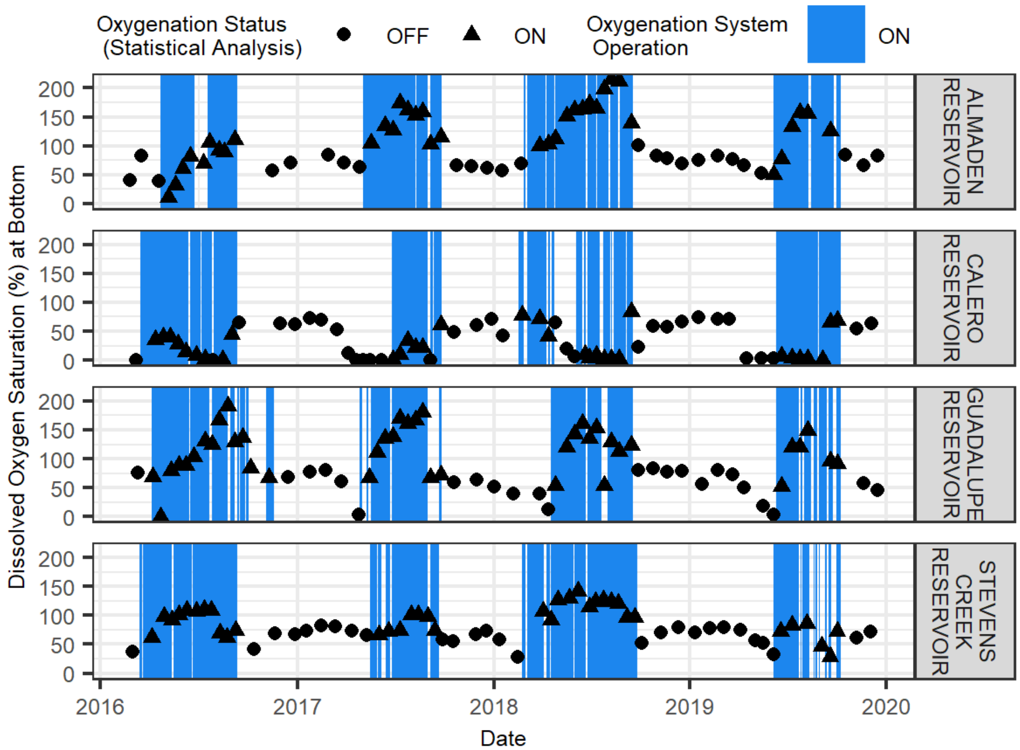


Figure 1: Hypolimnion Oxygen Concentration and Oxygenation System Status

Reservoir and Fish Monitoring

Water Quality Monitoring

Planned reservoir sampling for 18-19 was consistent with the Guadalupe River Watershed Mercury TMDL: Reservoir Monitoring Plan (2018 - 2020), including all listed analytes and locations. The Monitoring Plan is available at: https://s3.us-west-2.amazonaws.com/assets.valleywater.org/B1_District%20Sampling%20Plan_2018.pdf . Table 1 shows monitoring completed for Almaden, Calero, Guadalupe, Stevens Creek reservoirs, and Almaden Lake site 1. Starting in 2018, outlets were no longer sampled at Almaden, Calero, and Stevens Creek reservoirs because previous data showed that measurements at those outlets were statistically indistinguishable from those in the hypolimnion. Sampling at the Guadalupe reservoir outlet was continued to further compare hypolimnion and outlet water quality. At Almaden Lake, both inlet and outlet continue to be sampled.

Sonde measurements were made at one-meter intervals throughout the water column at reservoirs and approximately one half-meter depth at inlets and outlets. Grab samples were collected at five discrete depths at reservoirs depending on thermal conditions as described in the Guadalupe River Watershed Mercury TMDL Reservoir Monitoring Plan.

Table 1: Data Collected During 2018-2019 Monitoring Period

Data	**Sonde**	**Grab Sample**	**Location**
Depth (m)	X		Reservoirs
Temperature (C)	X		Reservoirs & inlets/outlets
Dissolved Oxygen (mg/L)	X		Reservoirs & inlets/outlets
Dissolved Oxygen (%Sat)	X		Reservoirs
ORP (mV)	X		Reservoirs & inlets/outlets
pH	X		Reservoirs
Specific Conductivity (us/cm)	X		Reservoirs & inlets/outlets
Chlorophyll a (ug/L)	X		Reservoirs
Phycocyanin (cells/mL and volts)	X		Reservoirs
Sulfate (EPA 300)		X	Reservoirs
Chloride (EPA 300)		X	Reservoirs
Total Mercury (EPA 1631 E)		X	Reservoirs & inlets/outlets
Total Methylmercury (EPA 1630)		X	Reservoirs & inlets/outlets
Dissolved Methylmercury (EPA 1630)		X	Reservoirs
Ammonia (as N) (EPA 350.1)		X	Reservoirs

Reservoirs in Table 1 include Almaden, Calero, Guadalupe, Stevens Creek, and Almaden Lake site #1. Inlets and outlets include Guadalupe Reservoir outlet, and Almaden Lake inlet and outlet.

In October 2018, Valley Water began collecting samples for dissolved methylmercury analysis to better represent the fraction of methylmercury that is more likely to be available for bioaccumulation. Dissolved methylmercury samples are filtered through a 0.45µm filter so they do not include the methylmercury associated with algal cells or other particles. Valley Water will continue to collect samples for dissolved methylmercury analysis and report on the full dataset in the 2021 biennial report.

Chloride was added to the analyte list in October 2018. Since chloride is unaffected by stratification, the chloride to sulfate ratio can be used as a relative comparator of sulfate reduction. This ratio varied among reservoirs and depths during the 2019 oxygenation period. Valley Water will continue to monitor for chloride and report on the full dataset in the 2021 biennial report.

Temperature

Oxygenation may have temperature effects that vary among reservoirs (Figures 2-5). A full analysis of reservoir outlet temperatures before and after oxygenation system installation and operation will be discussed in the manuscript.

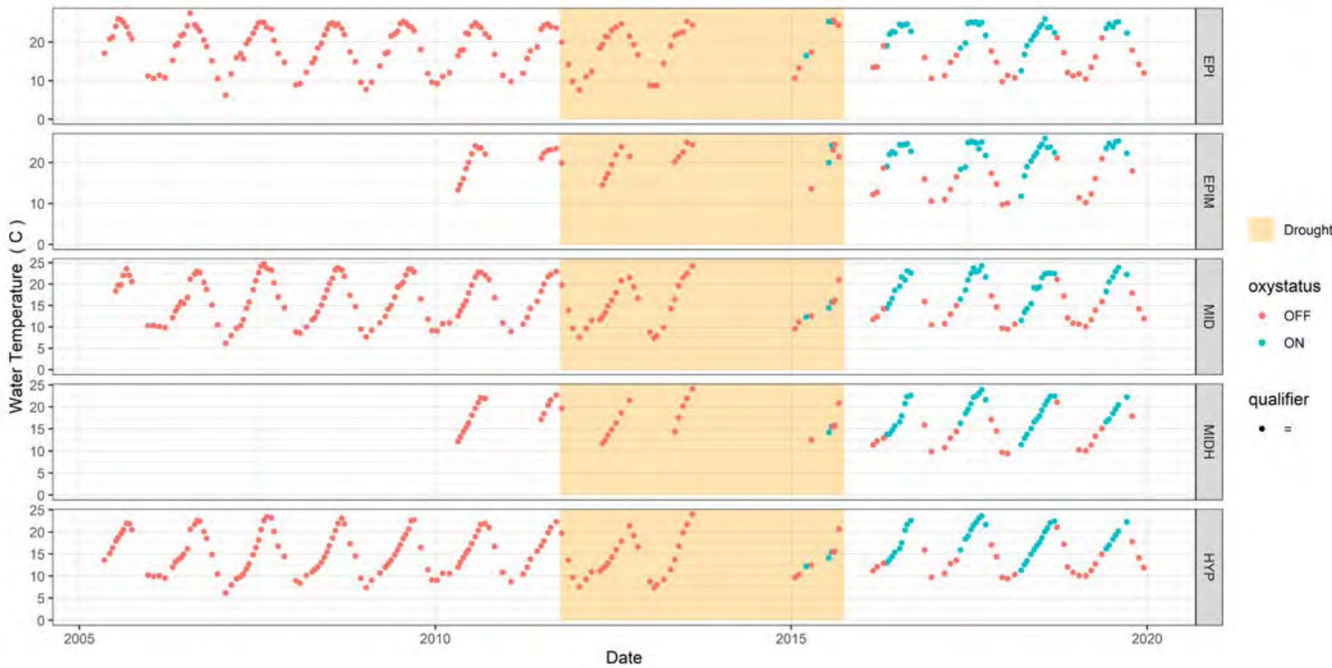


Figure 2: Almaden Reservoir Water Temperature

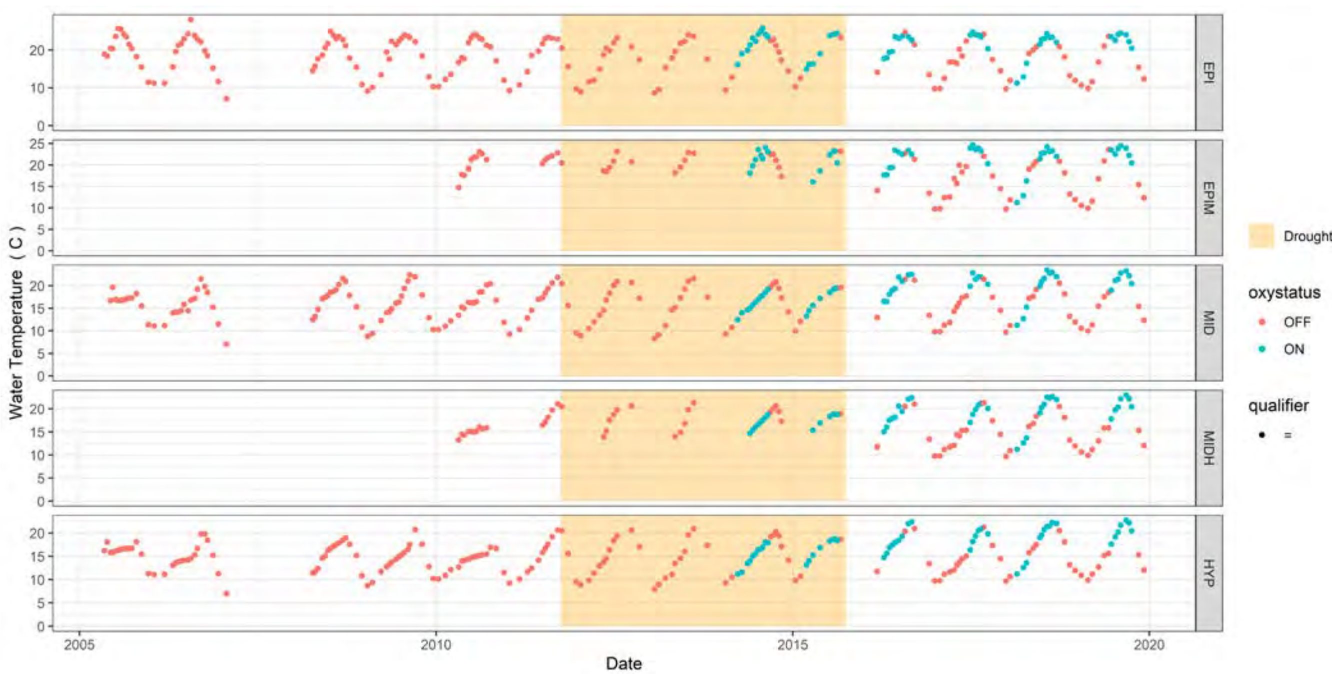


Figure 3: Calero Reservoir Water Temperature

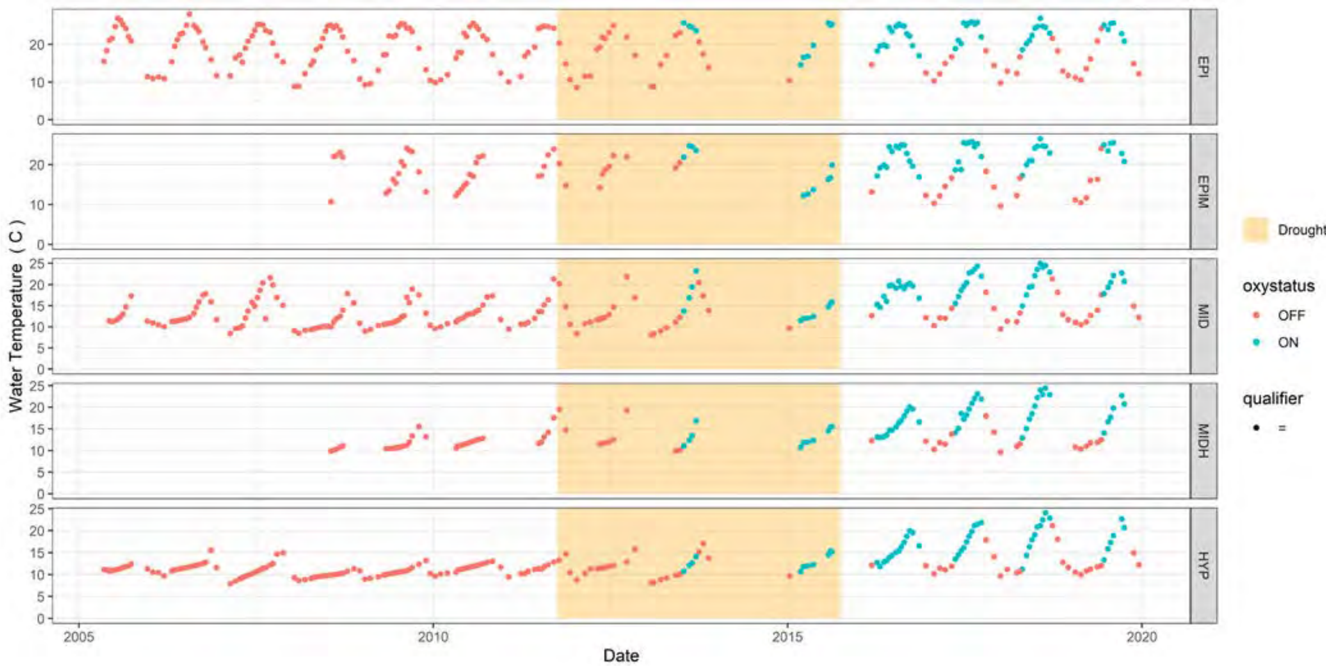


Figure 4: Guadalupe Reservoir Water Temperature

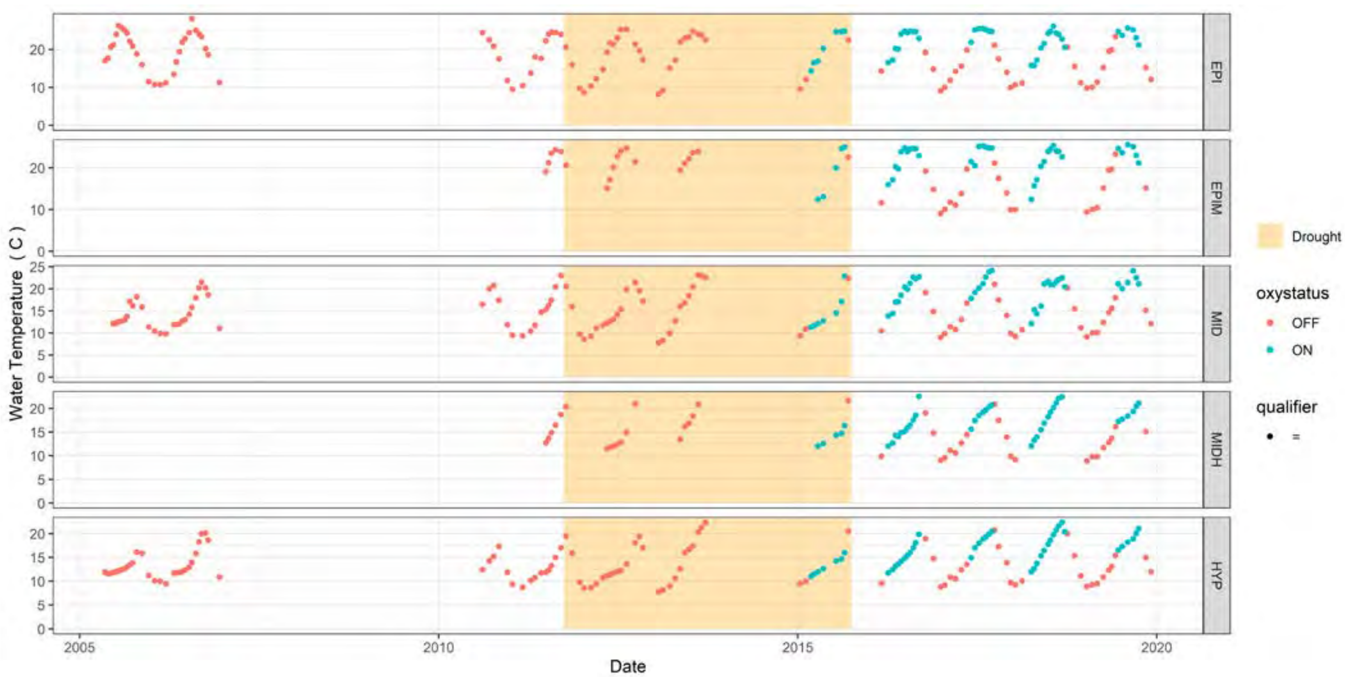


Figure 5: Stevens Creek Reservoir Water Temperature

Dissolved Oxygen

Since oxygenation system operation began, dissolved oxygen levels have remained within relatively consistent ranges at all reservoirs and depths. There have been no notable changes between monitoring years 2018-2019 and 2016-2017 (Figures 6-9).

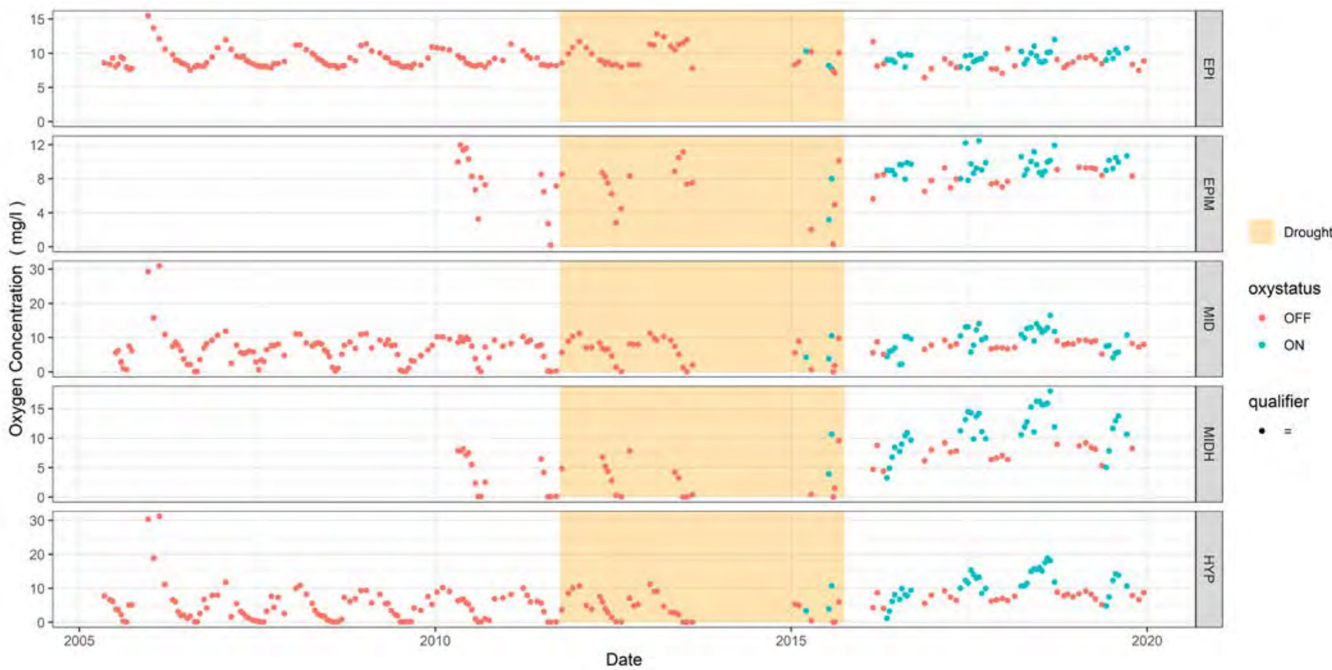


Figure 6: Almaden Reservoir Dissolved Oxygen

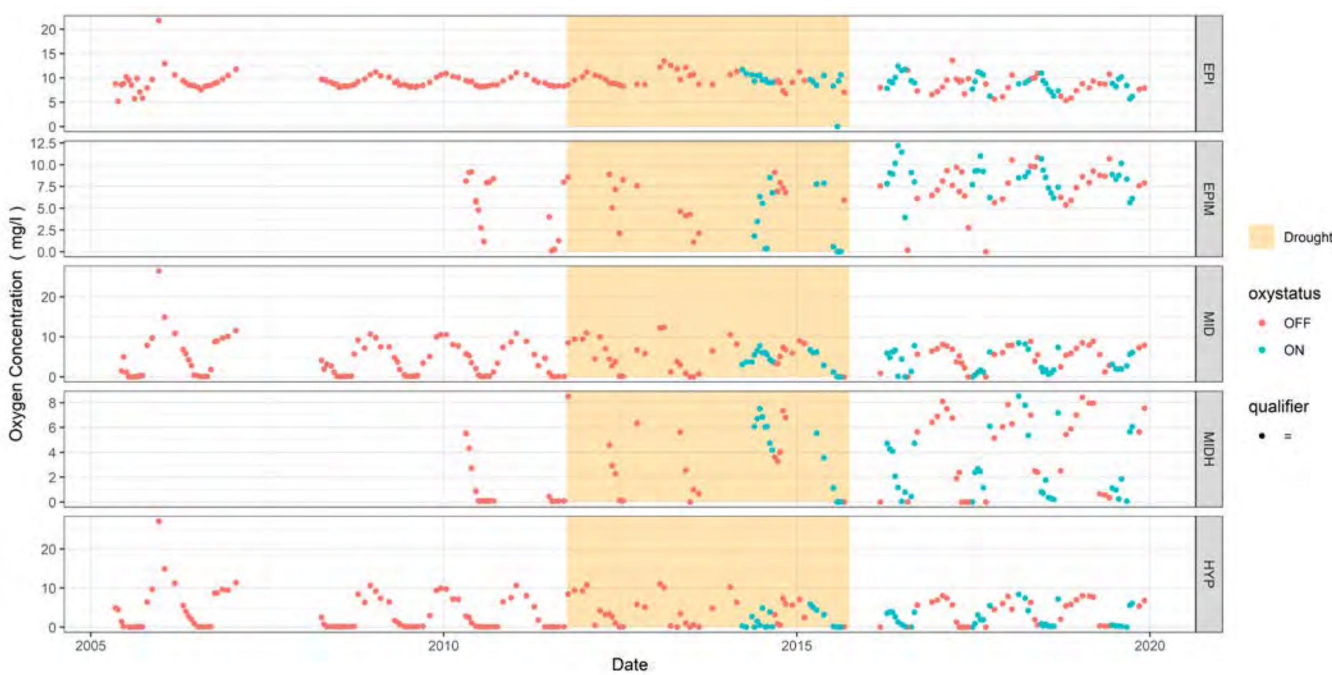


Figure 7: Calero Reservoir Dissolved Oxygen

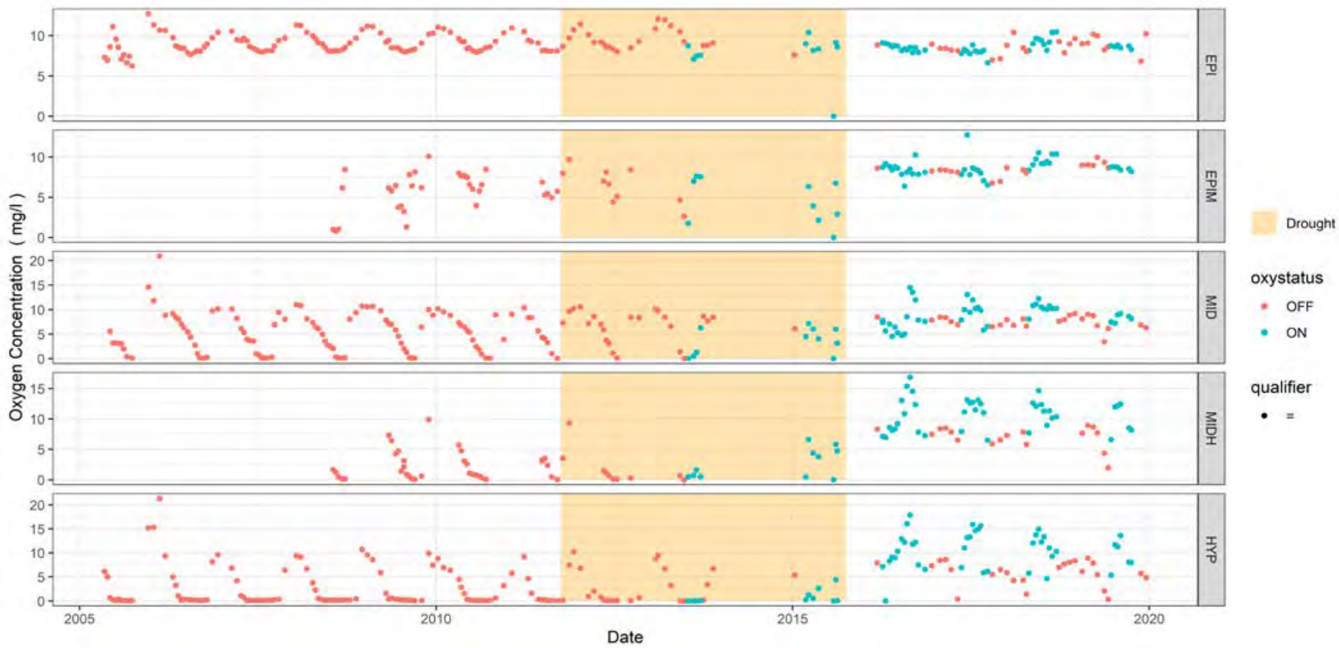


Figure 8: Guadalupe Reservoir Dissolved Oxygen

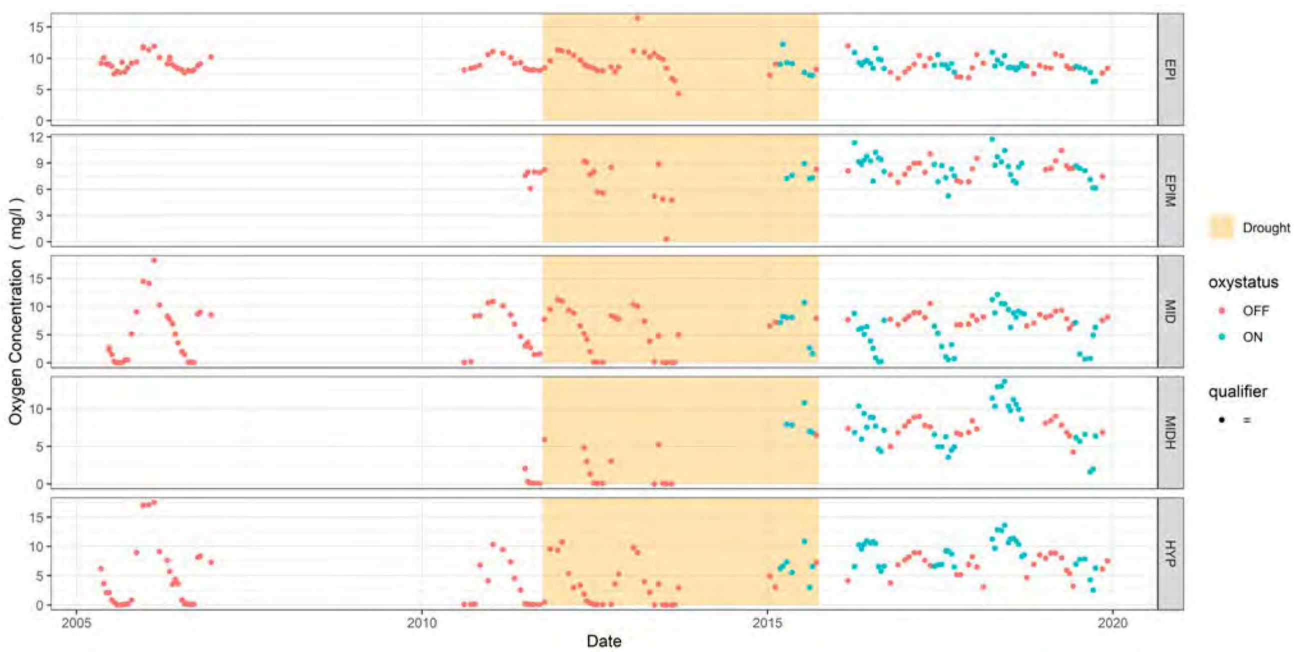


Figure 9: Stevens Creek Reservoir Dissolved Oxygen

Oxidation Reduction

Oxidation reduction levels have remained relatively consistent since operating the oxygenation systems and between monitoring years 2016-17 and 2018-19 at all monitored reservoirs (Figures 10-13).

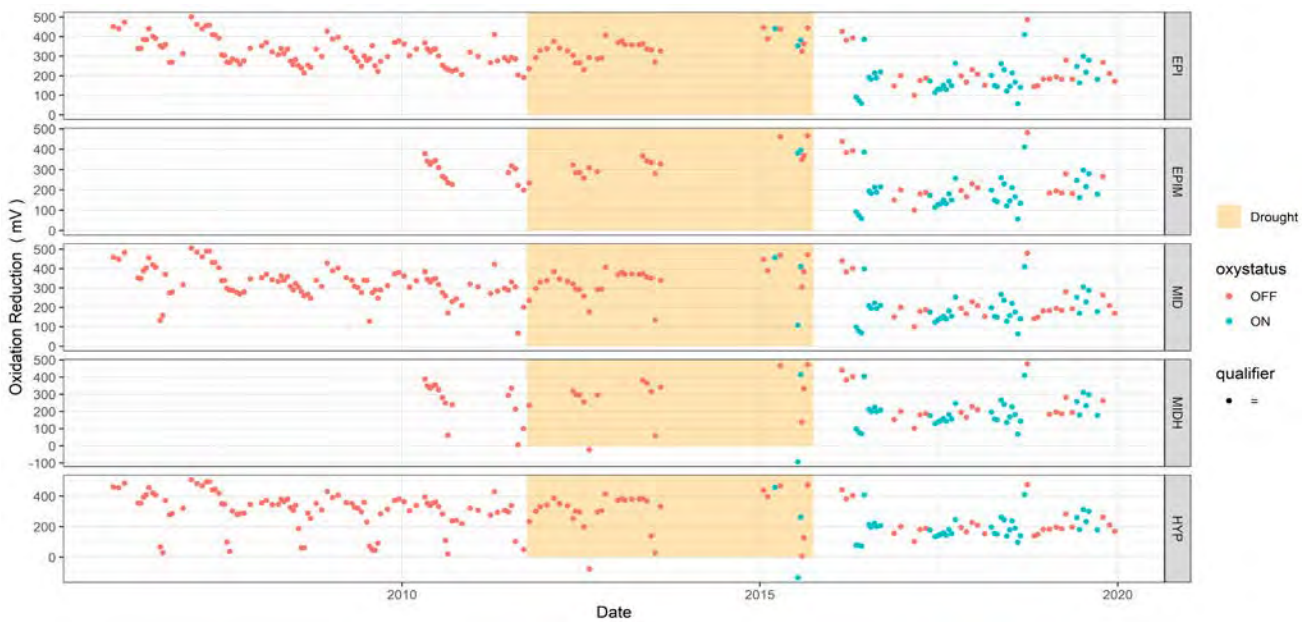


Figure 10: Almaden Reservoir Oxidation Reduction

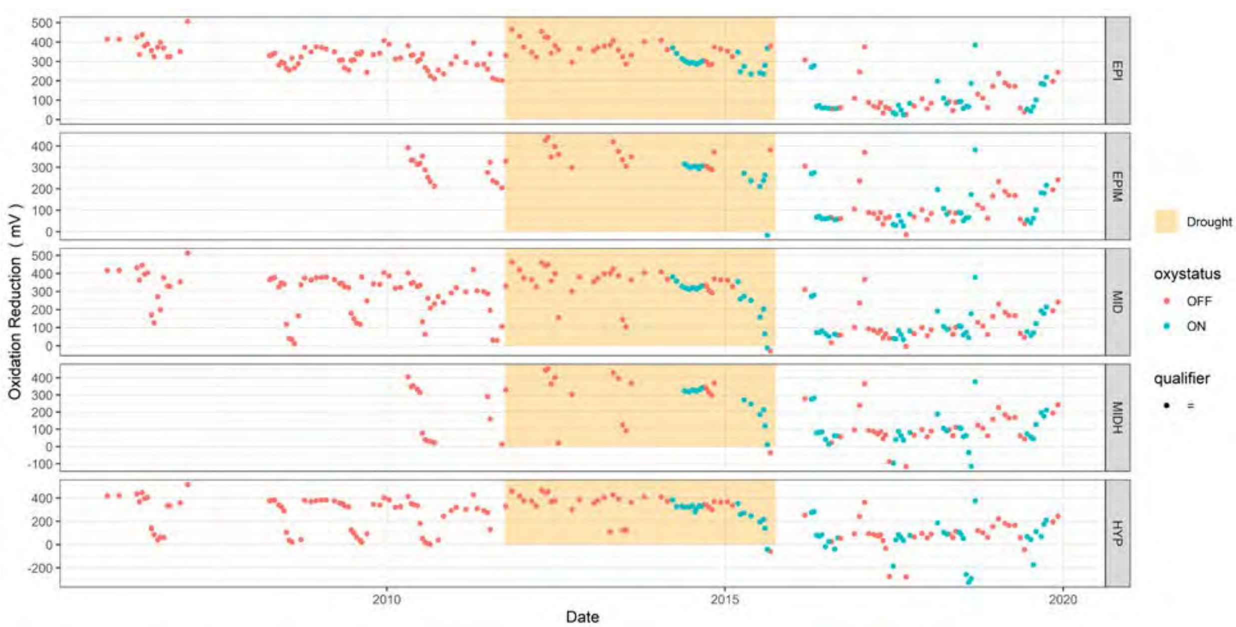


Figure11: Calero Reservoir Oxidation Reduction

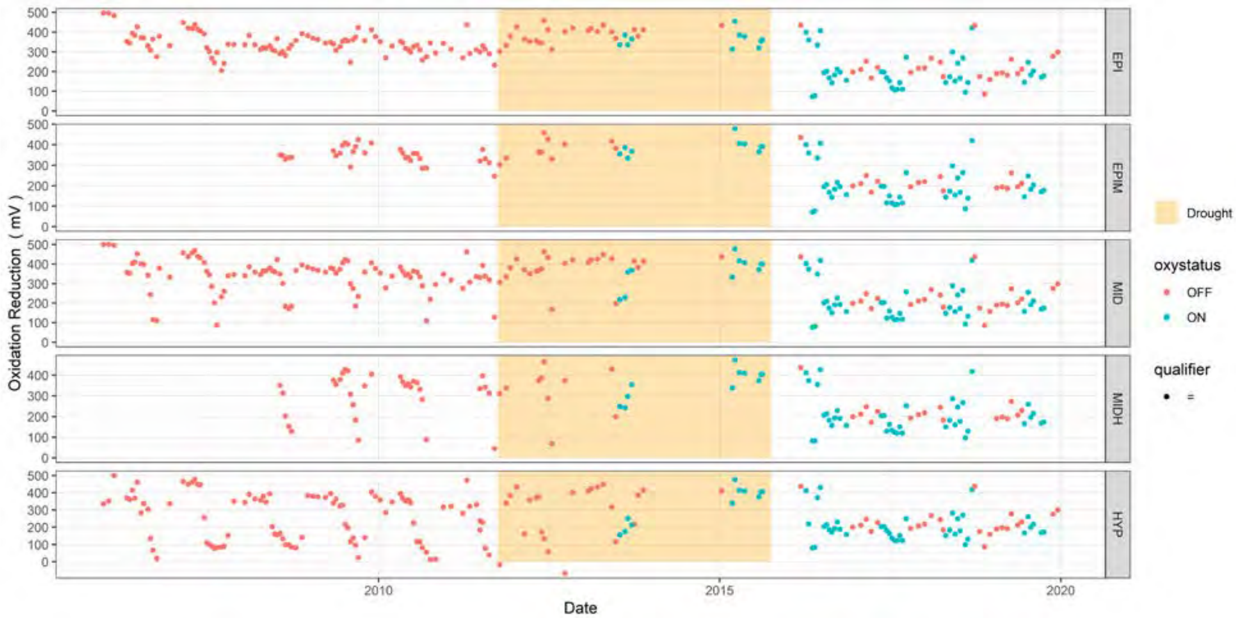


Figure12: Guadalupe Reservoir Oxidation Reduction

Figure 13: Stevens Creek Reservoir Oxidation Reduction

Other Water Quality Parameters

Other water quality parameters monitored during 2018-19 displayed similar seasonal patterns to those reflected in the 2016-17 monitoring period as referenced in Appendix C: Time Series Plots in the 2016-17 progress report (figures 5-12).

Mercury Loads from Points of Discharge

Tables 2-5 show annual total mercury and methylmercury loads calculated from reservoir outlet flows. Discharge concentrations were based on hypolimnion measurements for Stevens Creek, Almaden, and Calero Reservoirs, and from the actual outlet at Guadalupe Reservoir. High mercury loads in Almaden and Calero reservoirs for WY 2019 can be attributed to extremely high mercury values in the hypolimnion in January as sample collection occurred the morning after the January 15-16th, 2019 atmospheric river event.

Table 2: Total Mercury and Methylmercury Loads: Almaden Reservoir

WY	Discharge (MG)	Hg_T FWMC (ng/L)	Hg_T Load (g)	MeHg FWMC (ng/L)	MeHg Load (g)
2010	1285.88	16.86	**82.08**	0.78	**3.78**
2011	4022.09	14.1	**214.62**	0.29	**4.48**
2012	939.97	10.14	**36.08**	0.92	**3.28**
2013	1414.36	10.88	**58.23**	0.52	**2.77**
2014	223.21	9.3	**7.86**	0.96	**0.81**
2015	552.89	15.23	**31.88**	1.2	**2.52**
2016	1609.36	8.48	**51.69**	0.29	**1.77**
2017	10179.68	9.64	**371.52**	0.19	**7.46**
2018	979.28	6.22	**23.04**	0.19	**0.72**
2019	5082.65	96.39	**1854.53**	0.5	**9.58**

Table 3: Total Mercury and Methylmercury Loads: Calero Reservoir

WY	Discharge (MG)	Hg_T FWMC (ng/L)	Hg_T Load (g)	MeHg FWMC (ng/L)	MeHg Load (g)
2010	1025.73	6.85	**26.61**	2	**7.75**
2011	2532.48	7.16	**68.68**	2.48	**23.73**
2012	2448.65	3.39	**31.4**	0.8	**7.48**
2013	1686.61	3.76	**24.03**	0.67	**4.28**
2014	462.99	2.73	**4.79**	0.05	**0.09**
2015	59.93	4.63	**1.05**	0.04	**0.01**
2016	1630.17	4.74	**29.25**	0.8	**4.96**
2017	4318.88	6.6	**107.86**	0.4	**6.46**
2018	2843.44	5.71	**61.44**	0.24	**2.54**
2019	2568.5	23.9	**232.38**	0.32	**3.14**

Table 4: Total Mercury and Methylmercury Loads: Guadalupe Reservoir

WY	Discharge (MG)	Hg_T FWMC (ng/L)	Hg_T Load (g)	MeHg FWMC (ng/L)	MeHg Load (g)
2010	1482.1	32.81	**184.08**	0.85	**4.75**
2011	2230.85	34.32	**289.79**	1.05	**8.89**
2012	622.58	31.26	**73.66**	1.52	**3.58**
2013	788.08	25.7	**76.67**	1.7	**5.07**
2014	294.04	35.96	**40.03**	1.14	**1.27**
2015	346.78	18.97	**24.9**	3.01	**3.95**
2016	1248.11	16.35	**77.23**	0.62	**2.94**
2017	4767.14	30.22	**545.27**	0.17	**3**
2018	670.48	19.87	**50.43**	0.13	**0.32**
2019	2428.23	40.47	**372.03**	0.36	**3.29**

Table 5: Total Mercury and Methylmercury Loads: Stevens Creek Reservoir

WY	Discharge (MG)	Hg_T FWMC (ng/L)	Hg_T Load (g)	MeHg FWMC (ng/L)	MeHg Load (g)
2010	2414.57	4.97	**45.43**	0.94	**8.6**
2011	3563.83	5.3	**71.5**	0.18	**2.4**
2012	883.47	2.54	**8.5**	0.68	**2.27**
2013	1433.36	15.68	**85.06**	0.28	**1.5**
2014	270.04	4.8	**4.91**	0.54	**0.55**
2015	960.46	6.52	**23.72**	0.32	**1.15**
2016	2424.51	4.88	**44.83**	0.12	**1.13**
2017	8726.17	12.8	**422.96**	0.11	**3.56**
2018	951.28	9.19	**33.1**	0.1	**0.36**
2019	4804.42	8.52	**154.9**	0.09	**1.57**

Fish Monitoring

Planned reservoir fish monitoring was consistent with the Guadalupe River Watershed Mercury TMDL Reservoir Monitoring Plan. Targeted vs actual catch categories of fish were consistent for the majority of TL3A fish. Less REI and TL3B category fish were caught during the 2018-2019 monitoring timeframe than were targeted in the monitoring plan. In summer 2018, sampling was conducted by hook and line at Almaden and Guadalupe Reservoirs due to low water levels. Hook and line sampling contributed to skewed size distributions of collected fish as described in the attached assemblage report.

In summer 2019, fish samples were collected between June and August rather than August and September as stated in the monitoring plan to sample when reservoir elevations would allow boat electrofishing. Boat electrofishing at all reservoirs in summer 2019 also allowed for capture of the full range of fish species to support the ongoing food web study, and reduced the potential for skewed size distributions that occurred the previous year. Fish ageing by scale annuli analysis was not conducted during reporting period 2018-2019.

QAQC
Lab analysis of fish samples were contracted to Brooks Applied Labs and analysis of water samples were contracted to Eurofins. Data that do not meet QC requirements are not reported to Valley Water. Sondes used for water quality monitoring were calibrated monthly to bi-monthly following manufacturer standards as described in the Guadalupe River Watershed Mercury TMDL Reservoir Monitoring Plan.

Santa Clara Valley Water District

Guadalupe River Watershed Mercury TMDL: Reservoir Monitoring Plan (2020 - 2021)

Mark Seelos

February 5, 2020

Environmental Planning Unit
Watershed Stewardship and Planning Division

Contents

List of Figures

List of Tables

1 Background and Purpose

In 2008, the San Francisco Bay Regional Water Quality Control Board (Regional Board) amended the Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan) to establish water and fish tissue objectives addressing mercury pollution in the Guadalupe River Watershed. The Santa Clara Valley Water District (District) has voluntarily undertaken technical studies in affected reservoirs to improve knowledge of mercury cycling, bioaccumulation, and remediation methods. The District operates four line-diffuser hypolimnetic oxygenation systems and four solar-powered hypolimnetic circulators aiming to prevent anoxic conditions that facilitate the methylation of mercury. As part of its technical studies, the District evaluates the effectiveness of these systems in reducing methylmercury concentrations in the water column and in fish. Though these studies are voluntary, the Regional Board "will compel the District to undertake monitoring and special studies through California Water Code 13267 requirements" if necessary [4]. The District must report to the Regional Board on the results of these studies in December of odd years.

The District has conducted monitoring to answer three study questions (Special Studies) required in the TMDL:

1. *"How do the reservoirs and lakes in this watershed differ from one another? Factors to consider include, but are not limited to, area of connected wetlands, food web, water chemistry (phosphorus, pH, acid neutralizing capacity, and dissolved organic carbon), water level fluctuations, and infrastructure (outlet structure). Do outlet samples adequately represent hypolimnetic methylmercury concentrations for each reservoir? How significant are these differences?"*

2. *"Is it possible to increase the assimilative capacity for methylmercury in reservoirs and lakes?"*

3. *What are the mercury and methylmercury loads from points of discharge?*

Following submission of the District's *2016 - 2017 Progress Report on Methylmercury Production and Control Measures* [10], the Regional Board concluded that the report "satisf[ies] the Guadalupe TMDL requirement for Special Study 1, which is to evaluate how the reservoirs and lakes in the Guadalupe River watershed differ from one another" [7]. Therefore, this monitoring plan is focused on answering the remaining two study questions.

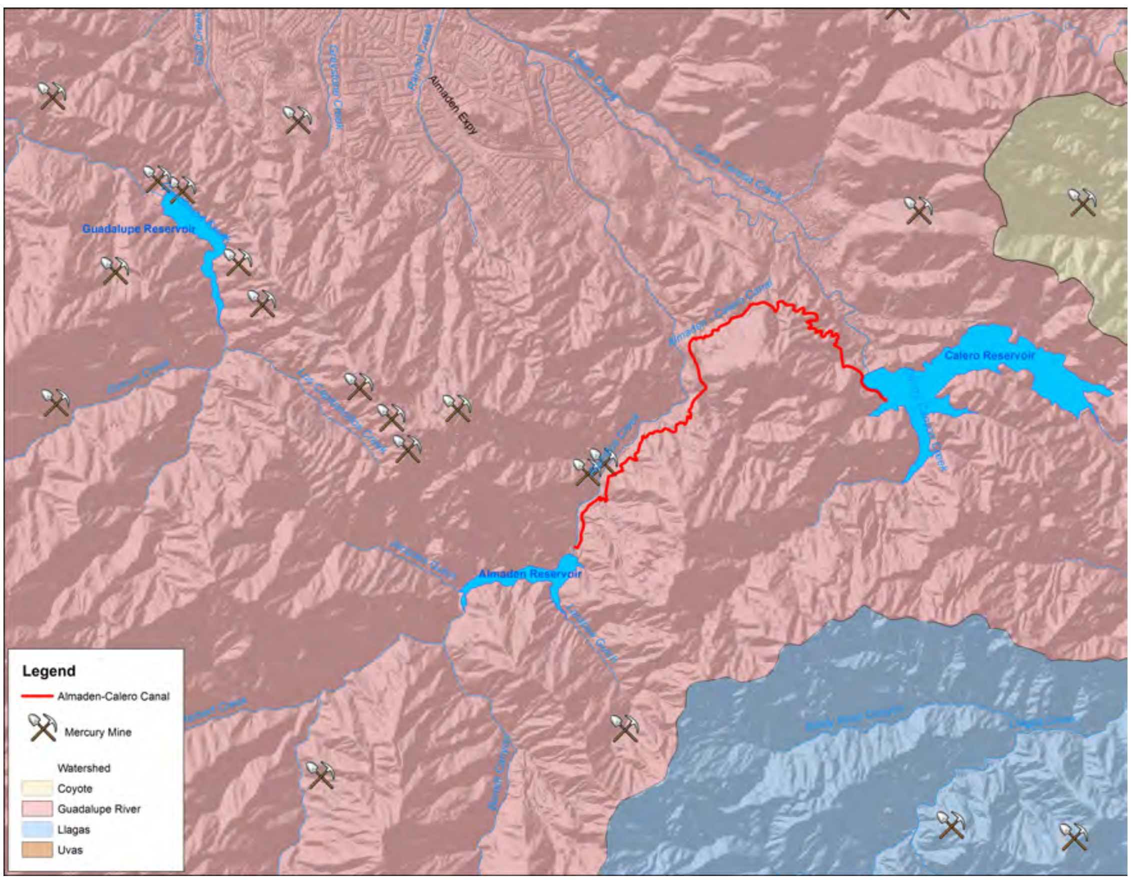
In the TMDL Staff Report, *assimilative capacity* is defined as "less bioaccumulation despite the same methylmercury production." [4]. By this definition, increasing a reservoir's assimilative capacity would involve attempting to reduce bioaccumulation by manipulating the food web or trophic status. However, because the District operates treatment systems intending to reduce methylmercury production in all affected reservoirs, it is not possible to investigate these additional variables independently. Thus, the District addresses Special Study 2 by evaluating the effectiveness of the treatment systems in reducing methylmercury production and bioaccumulation. The Regional Board concurred with this interpretation in its June 2018 letter to the District, stating "[t]he District's oxygenation work is adequately addressing Special Study 2, which is to assess whether it is possible to increase the assimilative capacity for methylmercury in lakes" [7]. In this monitoring plan, influencing a reservoir's *assimilative capacity* for methylmercury is defined as reducing methylmercury production and bioaccumulation.

2 Monitoring Stations

The Guadalupe River Watershed is located in the South San Francisco Bay, draining north (Figure A.1). To maintain compliance with the TMDL, the District conducts monitoring at four mercury-impaired water bodies in the watershed (Almaden Lake, Almaden Reservoir, Calero Reservoir, Guadalupe Reservoir) and one mercury-impaired reference site outside of the watershed (Stevens Creek Reservoir).

Almaden and Guadalupe reservoirs are located adjacent to, and have received mercury mining waste from, the former New Almaden Mining District: North America's largest and most productive historic mercury mine (Figure 1). Calero Reservoir is outside the mining district's catchment area, and is believed to be primarily contaminated by historic and ongoing water transfers from Almaden Reservoir through the Almaden-Calero Canal (Figure A.2).

Figure 1: New Almaden Mining District and Upper Guadalupe Watershed Reservoirs



Stevens Creek Reservoir is located outside of the Guadalupe River Watershed, and has not been impacted by mercury mining. However, the reservoir is listed as impaired for mercury on the Environmental Protection Agency's Clean Water Act Section 303(d) list due to mercury concentrations in fish that exceed regulatory thresholds [2]. Though Stevens Creek Reservoir's mercury source is unknown, a study published in 2010 found elevated wet deposition of mercury in the vicinity of the nearby LeHigh Cement and Permanente Quarry, likely supplying mercury to the reservoir [9].

Reservoirs were previously monitored at two locations: the deepest area (above the reservoir portal), and at the outlet (where water is discharged downstream) (Figures A.3 to A.6). However, because the District demonstrated in its *2016 - 2017 Progress Report on Methylmercury Production and Control Measures* that water quality data measured at the reservoir outlets were statistically indistinguishable from data measured one meter from the reservoir bottom in all reservoirs except Guadalupe [10], the Regional Board approved the elimination of the following monitoring stations: Almaden Reservoir Outlet (station 91850-4), Calero Reservoir Outlet (station 91870-4), and Stevens Creek Reservoir Outlet (station 91910-2). This approval is documented in the Regional Board's March 2018 letter to the District, which states "[Regional] Board staff concur with the proposal to discontinue outlet sampling at Almaden, Calero, and Stevens Creek reservoirs because hypolimnia data will continue to be collected and [are] demonstrated by analysis in this report to be statistically indistinguishable from outlet data" [6].

Almaden Lake was previously monitored at seven locations: Sites 1 - 5, the lake inlet, and the lake outlet. Because little pre-treatment data exist at sites 3 - 5, and Site 2 is very similar to Site 1, the District recommended eliminating Sites 2 - 5 in its *2016 - 2017 Progress Report on Methylmercury Production and Control Measures*. The Regional Board approved this recommendation in its March 2018 letter to the District, stating "Water [Regional] Board staff agree with proposal to eliminate Sampling Sites 2 - 5 at Lake Almaden."

Considering the monitoring site deletions approved by the Regional Board, the following stations will be monitored as part of this plan:

- Almaden Lake Inlet (92401-6)
- Almaden Lake Outlet (92401-7)
- Almaden Lake Station 1 (92401-8)
- Almaden Reservoir (91850-1)
- Calero Reservoir (91870-2)
- Guadalupe Reservoir (91890-1)
- Guadalupe Reservoir Outlet (91890-4)
- Stevens Creek Reservoir (91910-1)

3 Treatment Systems

Almaden Reservoir Three circulators were deployed in Almaden Reservoir in April of 2007. Two epilimnetic circulators intended to improve planktonic assemblages and reduce load or organic matter to the bottom of the reservoir, while one hypolimnetic circulator aimed to improve oxygen levels and suppress hypoxic conditions that facilitate the methylation of mercury. These systems were found to be ineffective in reducing methylmercury production [8]. In April of 2014, the

District installed a line-diffuser hypolimnetic oxygenation system in Almaden Reservoir. It has been operated nearly continuously during periods of thermal stratification since 2016.

Calero Reservoir A line-diffuser hypolimnetic oxygenation system was installed in Calero Reservoir in November of 2011, but was not operated until April of 2013. The system is operated nearly continuously during periods of thermal stratification.

Guadalupe Reservoir Three epilimnetic circulators were deployed in Guadalupe Reservoir in 2007 to improve planktonic assemblages and reduce organic loading to the bottom of the reservoir. These proved ineffective and were subsequently removed [8]. A line-diffuser hypolimnetic oxygenation system was installed in June of 2013, and operated intermittently from July to September. The system was not operated in 2014, operated intermittently in 2015, and is now operated nearly continuously during periods of thermal stratification.

Almaden Lake Almaden Lake is equipped with four solar-powered hypolimnetic circulators. The first was installed at Site 1 in 2006. A second device was installed in March of 2007 (Site 2), and the remaining two were installed in January of 2009. These devices are situated in the deepest portions of the lake, which were the main pits of the historic gravel quarry. Monitoring Site 1 is used to evaluate effectiveness because it is located in the primary quarry pit, and contains the most historical data. The solar circulator at Site 1 was lowered in 2007, after it was initially found to be ineffective due to its position high above the lake bottom. The effects of the lowering appeared to take effect in 2009. Due to inconsistent operation, data collected before 2009 were considered to be pre-treatment.

Stevens Creek Reservoir (Reference Site) A line-diffuser hypolimnetic oxygenation system was installed in Stevens Creek Reservoir in 2013. It operated intermittently in 2015, and is now operated nearly continuously during periods of thermal stratification.

4 Water Quality Monitoring

This section describes the water quality monitoring that will be completed to address study questions 2 and 3.

4.1 Monitoring Analytes

4.1.1 Sonde Profiles

At each sampling event, the District will take water quality profiles at reservoir stations at depth increments ranging from 0.25 meters to 1 meter. These will be collected using Hydrolab DS5 sondes, recording the following parameters:

- Depth (m)
- Temperature (C)
- Dissolved Oxygen (mg/L)
- Dissolved Oxygen (% Sat.)
- ORP (mV)

- Chlorophyll *a* (μg/L)
- Phycocyanin (cells/mL and volts)
- Specific Conductivity (μS/cm)
- pH

Sondes will be calibrated monthly to bi-monthly in accordance with standard procedures from the manufacturer.

4.1.2 Grab Sampling

Past Sampling Previously, the District monitored for total methylmercury at five depths throughout the water column, and the following analytes in the epilimnion (2 meters from the surface) and hypolimnion (1 meter from the bottom):

- Ammonia
- Nitrate
- Nitrite
- Sulfate
- Total Iron
- Total Manganese
- Total Mercury
- Total Phosphorus

Approved Reductions Following the completion of Special Study 1, which in part investigates the chemical differences of the water bodies, the Regional Board approved removing the following parameters:

- Ammonia
- Nitrate
- Nitrite
- Total Iron
- Total Manganese
- Total Phosphorus

This approval is documented in the Regional Board's March 2018 letter to the District, stating "[Regional] Board staff agree with proposal to discontinue monitoring of the following analytes: Ammonia, Total Phosphorus, Nitrate, and Nitrite" and "[Regional] Board staff agree with the proposal to discontinue manganese and iron sampling in reservoirs" [6]. The Regional Board considers Special Study 1 to be adequately addressed.

Future Sampling From October 1, 2018 onward, the District will monitor total methylmercury at five depths throughout the water column, and the following analytes in the epilimnion (2 meters from the surface) and hypolimnion (1 meter from the bottom):

- Sulfate
- Chloride
- Total Mercury
- Dissolved Methylmercury (0.45 micron filter)
- Ammonia

Chloride is conservative throughout the water column, and unaffected by stratification, making the sulfate:chloride ratio an indicator of microbial sulfate reduction. Dissolved methylmercury will be monitored to represent the amount available for bioaccumulation, in contrast with total methylmercury, which includes methylmercury in algae and adsorbed to particles.

Procedures Water samples will be collected using a Wildco beta-type Van Dorn sampling device (2.2 liter) at discrete depths. Epilimnion samples will be collected at a depth of two meters. Hypolimnion samples will be collected approximately one meter above the lake or reservoir bottom. Three middle depth total methylmercury samples will be collected at even intervals between the epilimnion and hypolimnion during mixed conditions. During thermal stratification, these samples will be collected at the top, middle, and bottom of the thermocline. Samples will be dispensed using "Clean Hands-Dirty Hands" procedures of EPA Method 1669 [3] into the containers described in Table 1.

Table 1: Sample Collection Bottles and Preservatives

Analyte	Container Material	Volume	Preservative
Ammonia (as N)	HDPE	500mL	Sulfuric Acid
Low-Level Mercury	Flourinated Polyethelene	250mL, double bagged	Unpreserved
Chloride, Sulfate	HDPE	500mL	Unpreserved
Total Methylmercury	Flourinated Polyethelene	250mL, double bagged	Hydrochloric Acid

Analytical Methods Samples will be analyzed by a certified contracted laboratory (Test America Inc.), and/or by the District's internal Water Quality Laboratory. Table 2 describes the laboratory methods used for chemical analysis, as well as current reporting limits, below which measured values are considered "non-detects". Note that these reporting limits have changed over time, requiring the use of statistical methods for censored data when analyzing parameters with a significant percentage of non-detect values. The contracted lab will use quality control procedures such as method blanks, blank spikes, matrix spikes, and duplicates to ensure the defensibility and accuracy of results.

Inlet and Outlet Sites At the inlet and outlet of Almaden Lake, and the outlet of Guadalupe Reservoir, the District will collect total mercury and total methylmercury samples. Additionally, staff will record the following parameters using YSI ProODO and Pro1030:

Table 2: Laboratory Analysis Methods

Analyte	Method	Current Reporting Limit
Ammonia (as N)	EPA 350.1	0.1 mg/L
Low-Level Mercury	EPA 1631 E	0.5 ng/L
Chloride, Sulfate	EPA 300	1 mg/L
Total Methylmercury	EPA 1630	0.05 ng/L

- Temperature (C)
- Dissolved Oxygen (mg/L)
- ORP (mV)
- Specific Conductivity (μS/cm)

4.2 Monitoring Frequency

Water quality monitoring will occur twice-monthly at each station during periods of thermal stratification, and monthly during mixed conditions. At each reservoir station, District staff will collect a sonde profile, and the grab samples described in section 4.1.2. At each inlet and outlet station, staff will collect data using water quality meters, as well as total mercury and total methylmercury samples.

4.3 Load Calculations

Total annual mercury and methylmercury loads discharged from reservoirs will be calculated using continuous (15 minute) stream flow data recorded by outlet gauges. Loads will be calculated as the total volume of water transferred between sampling events multiplied by mercury and methylmercury concentrations measured. This is the same method used in previous biennial reports.

Total mercury and methylmercury samples collected at the following stations will be used to calculate loads:

- Almaden Reservoir Hypolmnion (91850-1)
- Calero Reservoir Hypolimnion (91870-2)
- Guadalupe Reservoir Outlet (91890-4)
- Stevens Creek Reservoir Hypolimnion (91910-1)

Loads from Almaden Lake will not be calculated because the outflow is not gauged, loads were not calculated previously, and the lake is not a point of discharge (being unimpounded along Los Alamitos Creek).

5 Fish Monitoring

Section 9-35 of the TMDL Staff Report requires the District address the following questions regarding trends in fish tissue mercury concentrations:

1. *What is the seasonal and inter-annual variation in fish mercury in the first 5 years of implementation for remediation effectiveness indicators (REIs) and target fish?*

2. *What is the trend in fish tissue mercury concentrations in target fish over the subsequent 15 years of implementation?*

Fish monitoring is conducted twice annually, and is designed to evaluate the effectiveness of the treatment systems and assess reproductive risks to piscivorous birds. The inter-annual variability portion Study Question 1 was resolved following the Coordinated Monitoring Program's 2017 *Guadalupe River Coordinated Monitoring Program 5-Year Report*. The Regional Board's 13267 letter requiring the second phase of coordinated monitoring states "[previously reported fish data] are useful to quantify the interannual variability of mercury in fish from reservoirs and creeks" [5]. The District continues to investigate seasonal variability in its studies.

5.1 Sampling Methods

The District will collect fish for body burden mercury and assemblage analysis from Almaden, Calero, Guadalupe, and Stevens Creek reservoirs. The Coordinated Monitoring Program (CMP) collects fish from Almaden Lake and required stream sampling sites. Depending on reservoir water level, the District will fish using either boat electrofishing, trolling, or hook-and-line methods. Electrofishing is typically conducted at night to improve sampling efficiency. Other methods are used during daylight hours.

When boat electrofishing is used, fish will be captured using a Smith-Root Model H electrofishing boat. Boat electrofishing samples the water column between the surface and approximately 15 feet of depth, depending on the conductivity and settings. Boat electrofishing possesses a sampling bias including the area that can be sampled, species catch ability, and netting efficiency. Only fish near shore or within the top of the water column can be collected, and reservoir conditions such as turbidity, aquatic vegetation, and water level limit sampling and netting ability. The pelagic tendency of forage fish makes them more susceptible to capture using boat electrofishing, so results may overestimate prey populations relative to predatory fish. Three to five sampling fetches will be collected throughout the reservoirs. Fetches are defined as fifteen-minute passes of specific areas of shoreline, and the distance sampled depends on fish abundance and netting efficiency. The reservoirs are divided into "quadrants," and each quadrant will be sampled during a monitoring event. Sampling will be conducted at night to increase capture efficiency.

When low water levels prohibit the use of the electrofishing boat, samples will be collected using hook-and-line methods. Sampling will be conducted from a 14-foot aluminum Jon Boat. Methods may include open-water trolling along transects and stationary angling along shore margins. Hook-and-line sampling may present a bias toward larger fish, as gape size can limit catchability of smaller fish. Additionally, the sampling location and ability of the angler may confound the collection results. The primary intention of non-electrofishing methods is to collect fish for the body burden analysis, so more emphasis will be placed on collecting target fish than providing an estimate of fish assemblage or size distribution.

5.2 Body Burden Mercury Monitoring

The body burden analysis targets trophic level 3 and 4 fish, including (but not limited to) largemouth bass (*Micropterus salmoides*, TL4), bluegill (*Lepomis macrochirus*, TL3), and black crappie

(*Pomoxis nigromaculatus*, TL3). Common trophic level 3 fish are shown in Table 3. All fish sampled will fall within two size classes: 50 mm to 150 mm, and 150 mm to 350 mm. Fish selected to be sacrificed will be placed in individual zip-lock bag, labeled, and placed on ice for transport back to District facilities. The samples will then be removed from the ice, processed (numbered, remeasured, weighed, and double-labeled), and placed in the freezer in preparation for transport to the contracted laboratory (Brooks Applied Labs, LLC).

Table 3: Common Trophic Level 3 Fish

Common Name	Scientific Name
small bullheads	Ameiurus nebulosus
carp	Cyprinus carpo
small catfishes	Ictalurids
black crappie	Pomoxis nigromaculatus
white crappie	Pomoxis annularis
goldfish	Carassius auratus
killifish	Cyprinodontiformes
bigscale logperch	Percina macrolepida
mosquitofish	Gambusia affinis
California roach	Hesperoleucus symmetricus
golden shiner	Notemigonus crysoleucas
inland silverside	Menidia beryllina

5.2.1 Scientific Collecting Permit

The District Fisheries Biologist will obtain a Scientific Collecting Permit (SCP) from California Department of Fish and Wildlife for take and collection of fish. Species collected must include largemouth bass, black crappie, and bluegill in the 50 - 150 mm and 150 - 350 mm size ranges. The District's current (2018) SCP allows for the collection of 42 fish per reservoir three times per year.

5.2.2 Fish Collection Categories

The TMDL Staff Report requires the collection of three categories of fish. The fish tissue objectives apply to trophic level 3 fish, which are intended to minimize reproductive and developmental risks to piscivorous birds. Additionally, "remediation effectiveness indicators" are required to be monitored as short-term indicators of the effectiveness of management actions.

Remediation Effectiveness Indicators (REIs) are samples designed to be sensitive measures of mercury exposure variability in space and time. In the Guadalupe River Watershed, based on recommendations from the Regional Board, we have chosen "age-1" largemouth bass ranging from 55 to 102 mm in length as the primary REIs [4]. The 55 - 102 mm length for age-1 fish is based on Table 8-4 of Tetra Tech's 2005 *Data Collection Report* [1], which describes minimum and maximum lengths for age-1 fish observed in the affected reservoirs. Because largemouth bass spawn during the springtime, REI samples are collected during the summer sampling event to ensure adequate tissue mass for laboratory analysis. Largemouth bass within the REI size range collected during the springtime are likely to represent the previous year's cohort.

Target Fish (TL3A and TL3B) are defined as 50 to 350 mm trophic level 3 fish. These fish are collected to measure progress in attaining fish tissue objectives of 0.05 mg Hg/kg (wet weight) for 50-150 mm fish (TL3A), and 0.1 mg Hg/kg (wet weight) for 150-350 mm fish (TL3B). These allocations are intended to be protective of piscivorous birds. Thus, trophic level 3 target fish are collected just before or during the avian breeding season (spring sampling event), and during the summer sampling event.

Adult largemouth bass (TL4) range from 102 to 350 mm. Though these fish do not serve as targets or REIs, abundant historical data exists. Adult largemouth bass samples (102 - 200 mm) will be collected during the spring sampling event only, representing the cohort of REI fish measured during the previous summer. This data will serve to determine bioaccumulation rates that occur during the wet season, as well as to minimize extrapolation in length-standardization.

5.2.3 Sample Sizes

Power Analysis District staff conducted a power analysis to determine sample sizes for fish tissue collection events using data collected from 2011 to 2018. We used the *t test* method, with α (probability of incorrectly rejecting the null hypothesis) of 0.05, and a power (probability of correctly rejecting the null hypothesis) of 0.8. These are commonly assigned values in scientific studies. Ideally, the effect size (the statistically discernible difference between two groups) would be set at one times the TMDL target for small fish (0.05 mg/kg) or less. However, because fish tissue mercury concentrations are high and variable, detecting this small a difference would require a sample size of $>$ 30 fish per collection category, which would be unfeasible and prohibitively expensive. Therefore, we have selected an effect size of 25% of the 2011 - 2018 mean mercury concentration of each collection category in each reservoir (ME in table 5). This will allow us to detect practically significant changes in mercury concentrations between groups.

The results of the power analysis are shown in Figure 2. Different potential sample sizes are shown by different colored lines. As sample size increases, the detectable effect size decreases, and power increases. The more samples are collected, the smaller the difference in detectable effect size becomes. This illustrates the concept of "diminishing returns:" the more samples are collected beyond a certain threshold, the less the statistical benefit of the increased sample size.

Figure 2: Power Analysis of Fish Categories by Reservoir

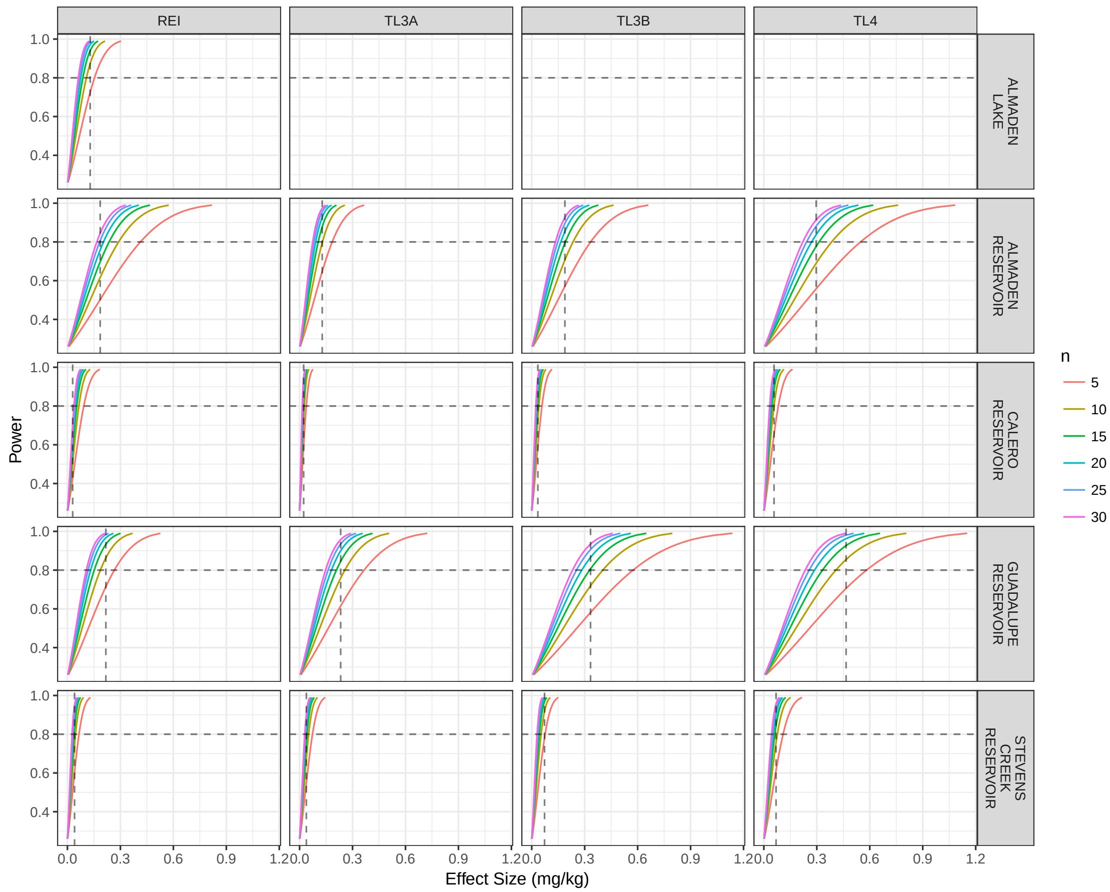


Table 4 shows the ideal sample sizes of the power analysis. These are based on a targeted effect size of 25% of the 2011 - 2018 mean mercury concentrations for each category in each reservoir, α of 0.05, and a power of 0.8. In Almaden and Calero reservoirs, the sum of REI or TL4, TL3A, and TL3B fish required for the above criteria exceeds the 42 fish take limit of the Scientific Collecting Permit.

Sample Size Based on Confidence Interval In addition to the power analysis, District Staff calculated ideal sample sizes to yield 95% confidence intervals with a margins of error of +/- 25% of the 2011 - 2018 mean mercury concentrations for each category in each reservoir. Results are shown in table 5. As coefficient of variation (mean divided by standard deviation) increases, the required sample size increases (Figure 3).

5.3 Assemblage Monitoring

Sampling Quadrants Reservoirs are divided into "quadrants" to investigate spatial differences in fish assemblages. District biologists will sample each quadrant during a monitoring event. These quadrants are displayed in figures A.8 to A.11. Sampling quadrants are consistent with quadrants used in previous years.

Table 4: Sample Sizes from Power Analysis

Reservoir	Category	n
ALMADEN LAKE	REI	8
ALMADEN RESERVOIR	REI	8
ALMADEN RESERVOIR	TL3A	10
ALMADEN RESERVOIR	TL3B	15
ALMADEN RESERVOIR	TL4	17
CALERO RESERVOIR	REI	35
CALERO RESERVOIR	TL3A	15
CALERO RESERVOIR	TL3B	10
CALERO RESERVOIR	TL4	10
GUADALUPE RESERVOIR	REI	8
GUADALUPE RESERVOIR	TL3A	12
GUADALUPE RESERVOIR	TL3B	15
GUADALUPE RESERVOIR	TL4	8
STEVENS CREEK RESERVOIR	REI	10
STEVENS CREEK RESERVOIR	TL3A	15
STEVENS CREEK RESERVOIR	TL3B	8
STEVENS CREEK RESERVOIR	TL4	12

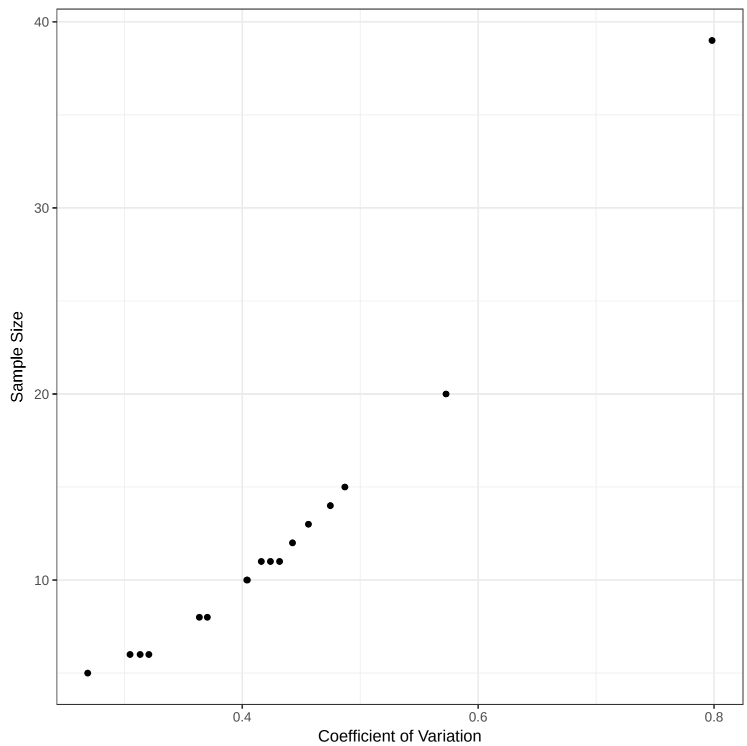
Table 5: Calculated Sample Sizes to Yield 95% Confidence Intervals with 25% Margin of Error

Reservoir	Category	Mean (mg/kg)	SD	ME	CV	n
ALMADEN LAKE	REI	0.515	0.157	0.129	0.304854369	6
ALMADEN RESERVOIR	REI	0.742	0.425	0.186	0.57277628	20
ALMADEN RESERVOIR	TL3A	0.513	0.19	0.128	0.37037037	8
ALMADEN RESERVOIR	TL3B	0.752	0.343	0.188	0.456117021	13
ALMADEN RESERVOIR	TL4	1.186	0.563	0.296	0.47470489	14
CALERO RESERVOIR	REI	0.119	0.095	0.03	0.798319328	39
CALERO RESERVOIR	TL3A	0.092	0.039	0.023	0.423913043	11
CALERO RESERVOIR	TL3B	0.139	0.06	0.035	0.431654676	11
CALERO RESERVOIR	TL4	0.231	0.084	0.058	0.363636364	8
GUADALUPE RESERVOIR	REI	0.871	0.273	0.218	0.313432836	6
GUADALUPE RESERVOIR	TL3A	0.931	0.376	0.233	0.40386681	10
GUADALUPE RESERVOIR	TL3B	1.333	0.59	0.333	0.442610653	12
GUADALUPE RESERVOIR	TL4	1.864	0.598	0.466	0.320815451	6
STEVENS CREEK RESERVOIR	REI	0.161	0.067	0.04	0.416149068	11
STEVENS CREEK RESERVOIR	TL3A	0.154	0.075	0.038	0.487012987	15
STEVENS CREEK RESERVOIR	TL3B	0.29	0.078	0.072	0.268965517	5
STEVENS CREEK RESERVOIR	TL4	0.277	0.112	0.069	0.40433213	10

Abundance and Age Classes After each 15-minute sampling fetch, the electrofishing boat will be anchored away from the shoreline. Fish will be identified to species, measured, and counted. Fork lengths will be measured and recorded for the first 25 individuals of each species observed. These data will be used to infer age classes and relative abundance of each species.

When hook and line or trolling methods are used, all fish will be identified, measured, and counted. These methods are biased toward larger, more predatory fish, so results will likely be less representative of the true assemblage than when boat electrofishing methods are used.

Figure 3: Relationship Between Coefficient of Variation and Required Sample Size



5.4 Monitoring Events

The District will complete two sampling events annually: one in spring, and one in summer.

5.4.1 Spring Sampling Event

A spring sampling event is conducted between the months of March and April. Because the spring event occurs just before or during bird breeding season, target fish collected in this period should represent the reproductive risks to piscivorous birds. Though not required, additional largemouth bass from 102-200 mm may be collected to assess the degree of bioaccumulation that occurs between the summer and spring sampling events. Bass in this size range are assumed to represent the remediation effectiveness indicator cohort sampled in the previous fall. Sampling the same cohort in the spring allows us to investigate the role of reservoir turnover and other seasonal factors that may influence bioaccumulation.

Based on the power and confidence interval sample size analyses described in section 5.2.3, take limitations of the Scientific Collecting Permit described in section 5.2.1, and practical limitations of successfully obtaining the target sample size, the District will attempt to collect the samples described in Table 6

5.4.2 Summer Sampling Event

A summer sampling event is conducted between the months of August and September. Since sunfish spawn during spring, 55 - 102mm largemouth bass collected at this time should represent age-0+ remediation effectiveness indicators. These fish are assumed to have been exposed

Table 6: Fish Sample Target for Spring Sampling Event

Category	n
TL3A	14
TL3B	13
TL4 (102 - 200 mm)	15

exclusively to conditions in which the treatment systems were operated, during the season of peak methylmercury production, and therefore adequately assess remediation effectiveness. Additional target fish are collected during the summer sampling event to investigate seasonal variability in mercury concentrations.

During the summer sampling event, the District will attempt to collect the samples described in Table 7.

Table 7: Fish Sample Target for Summer Sampling Event

Category	n
TL3A	14
TL3B	13
REI (55 - 102 mm)	15

6 Data Management

All data will be stored managed in the District's Environmental Monitoring Information Management System (EM-IMS) database. The database contains modules for storing water quality, fish tissue, and fish assemblage data. Data management will be the responsibility of the Environmental Planning Unit.

7 Additional Studies

The District may engage in additional studies and collaborations in attempt to answer key management questions that complicate effective methylmercury controls.

8 Reporting

As required by the TMDL Staff Report, the District will submit technical reports to the Regional Board detailing the studies described herein in December of odd years (2019, 2021, etc.).

9 Sampling Summary Tables

Sample collection summaries are shown in tables 8 and 9.

References

[1] Guadalupe river watershed tmdl project technical memorandum 5.3.2: Data collection report. Technical report, Tetra Tech, 2005.

[2] 2010 integrated report (clean water act section 303(d) list / 305(b) report). Technical report, State Water Resources Control Board, 2010.

[3] U.S. Environmental Protection Agency. *Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels*, July 1996.

[4] Carrie Austin, Sandia Potter, James Ponton, Dyan Whtye, and Thomas Mumley. Guadalupe river watershed mercury total maximum daily load (tmdl) project staff report for proposed basin plan amendment. Staff, California Water Quality Control Board San Francisco Bay Region, 2008.

[5] San Francisco Bay Regional Water Quality Control Board. Water code section 13267 technical report requirement for a monitoring plan for mercury in waters downstream of new almaden mercury mining district, guadalupe mercury mine, and/or bernal mercury mine, June 2017.

[6] San Francisco Bay Regional Water Quality Control Board. Comments on 2016–2017 progress report on methylmercury production and control measures, June 2018.

[7] San Francisco Bay Regional Water Quality Control Board. District currently meeting requirements in the guadalupe river watershed mercury total maximum daily load, June 2018.

[8] Santa Clara Valley Water District. Methylmercury production and control in lakes and reservoirs contaminated by historic mining activities in the guadalupe river watershed. Technical, Santa Clara Valley Water District, 2013.

[9] Sarah Rothenberg, Lester McKee, Alicia Gilbreath, Donald Yee, Mike Connor, and Xuewu Fu. Wet deposition of mercury within the vicinity of a cement plant before and during cement plant maintenance. *Atmospheric Environment*, 44(10):1255–1262, 2010.

[10] Mark Seelos. Guadalupe river watershed mercury tmdl: 2017-2018 progress report on methylmercury production and control measures. Staff, Santa Clara Valley Water District, 2017.

Table 8: Sampling Summary Table

Water Body	Station	Analyte	Matrix	Depths	Frequency	Analysis
Almaden Lake	92401-6	Oxidation Reduction Potential	Water	1	monthly or semi-monthly	Sonde
		Oxygen Concentration	Water	1	monthly or semi-monthly	Sonde
		Specific Conductivity	Water	1	monthly or semi-monthly	Sonde
		Temperature	Water	1	monthly or semi-monthly	Sonde
		Total Mercury	Water	1	monthly or semi-monthly	Laboratory
		Total Methylmercury	Water	1	monthly or semi-monthly	Laboratory
	92401-7	Oxidation Reduction Potential	Water	1	monthly or semi-monthly	Sonde
		Oxygen Concentration	Water	1	monthly or semi-monthly	Sonde
		Specific Conductivity	Water	1	monthly or semi-monthly	Sonde
		Temperature	Water	1	monthly or semi-monthly	Sonde
		Total Mercury	Water	1	monthly or semi-monthly	Laboratory
		Total Methylmercury	Water	1	monthly or semi-monthly	Laboratory
	92401-8	Ammonia (N)	Water	2	monthly or semi-monthly	Laboratory
		Chloride	Water	2	monthly or semi-monthly	Laboratory
		Chlorophyll a	Water	Profile	monthly or semi-monthly	Sonde
		Dissolved Methylmercury	Water	2	monthly or semi-monthly	Laboratory
		Oxidation Reduction Potential	Water	Profile	monthly or semi-monthly	Sonde
		Oxygen Concentration	Water	Profile	monthly or semi-monthly	Sonde
		Oxygen Saturation	Water	Profile	monthly or semi-monthly	Sonde
		pH	Water	Profile	monthly or semi-monthly	Sonde
		Phycocyanin	Water	Profile	monthly or semi-monthly	Sonde
		Specific Conductivity	Water	Profile	monthly or semi-monthly	Sonde
		Sulfate	Water	2	monthly or semi-monthly	Laboratory
		Temperature	Water	Profile	monthly or semi-monthly	Sonde
		Total Mercury	Water	2	monthly or semi-monthly	Laboratory
		Total Methylmercury	Water	3	monthly or semi-monthly	Laboratory
Almaden Reservoir	91850-1	Ammonia (N)	Water	2	monthly or semi-monthly	Laboratory
		Chloride	Water	2	monthly or semi-monthly	Laboratory
		Chlorophyll a	Water	Profile	monthly or semi-monthly	Sonde
		Dissolved Methylmercury	Water	2	monthly or semi-monthly	Laboratory
		Oxidation Reduction Potential	Water	Profile	monthly or semi-monthly	Sonde
		Oxygen Concentration	Water	Profile	monthly or semi-monthly	Sonde
		Oxygen Saturation	Water	Profile	monthly or semi-monthly	Sonde
		pH	Water	Profile	monthly or semi-monthly	Sonde
		Phycocyanin	Water	Profile	monthly or semi-monthly	Sonde
		Specific Conductivity	Water	Profile	monthly or semi-monthly	Sonde
		Sulfate	Water	2	monthly or semi-monthly	Laboratory
		Temperature	Water	Profile	monthly or semi-monthly	Sonde
		Total Mercury	Water	2	monthly or semi-monthly	Laboratory
		Total Methylmercury	Water	5	monthly or semi-monthly	Laboratory
	Reservoir	Assemblage	Fish	NA	semi-annually	Laboratory
		Percent Solids	Fish	NA	semi-annually	Laboratory
		Total Mercury	Fish	NA	semi-annually	Laboratory
Calero Reservoir	91870-2	Ammonia (N)	Water	2	monthly or semi-monthly	Laboratory
		Chloride	Water	2	monthly or semi-monthly	Laboratory
		Chlorophyll a	Water	Profile	monthly or semi-monthly	Sonde
		Dissolved Methylmercury	Water	2	monthly or semi-monthly	Laboratory
		Oxidation Reduction Potential	Water	Profile	monthly or semi-monthly	Sonde
		Oxygen Concentration	Water	Profile	monthly or semi-monthly	Sonde
		Oxygen Saturation	Water	Profile	monthly or semi-monthly	Sonde
		pH	Water	Profile	monthly or semi-monthly	Sonde
		Phycocyanin	Water	Profile	monthly or semi-monthly	Sonde
		Specific Conductivity	Water	Profile	monthly or semi-monthly	Sonde
		Sulfate	Water	2	monthly or semi-monthly	Laboratory
		Temperature	Water	Profile	monthly or semi-monthly	Sonde
		Total Mercury	Water	2	monthly or semi-monthly	Laboratory
		Total Methylmercury	Water	5	monthly or semi-monthly	Laboratory
	Reservoir	Assemblage	Fish	NA	semi-annually	Laboratory
		Percent Solids	Fish	NA	semi-annually	Laboratory
		Total Mercury	Fish	NA	semi-annually	Laboratory

Table 9: Sampling Summary Table, cont.

Water Body	Station	Analyte	Matrix	Depths	Frequency	Analysis
Guadalupe Reservoir	91890-1	Ammonia (N)	Water	2	monthly or semi-monthly	Laboratory
		Chloride	Water	2	monthly or semi-monthly	Laboratory
		Chlorophyll a	Water	Profile	monthly or semi-monthly	Sonde
		Dissolved Methylmercury	Water	2	monthly or semi-monthly	Laboratory
		Oxidation Reduction Potential	Water	Profile	monthly or semi-monthly	Sonde
		Oxygen Concentration	Water	Profile	monthly or semi-monthly	Sonde
		Oxygen Saturation	Water	Profile	monthly or semi-monthly	Sonde
		pH	Water	Profile	monthly or semi-monthly	Sonde
		Phycocyanin	Water	Profile	monthly or semi-monthly	Sonde
		Specific Conductivity	Water	Profile	monthly or semi-monthly	Sonde
		Sulfate	Water	2	monthly or semi-monthly	Laboratory
		Temperature	Water	Profile	monthly or semi-monthly	Sonde
		Total Mercury	Water	2	monthly or semi-monthly	Laboratory
		Total Methylmercury	Water	5	monthly or semi-monthly	Laboratory
	91890-4	Oxidation Reduction Potential	Water	1	monthly or semi-monthly	Sonde
		Oxygen Concentration	Water	1	monthly or semi-monthly	Sonde
		Specific Conductivity	Water	1	monthly or semi-monthly	Sonde
		Temperature	Water	1	monthly or semi-monthly	Sonde
		Total Mercury	Water	1	monthly or semi-monthly	Laboratory
		Total Methylmercury	Water	1	monthly or semi-monthly	Laboratory
	Reservoir	Assemblage	Fish	NA	semi-annually	Laboratory
		Percent Solids	Fish	NA	semi-annually	Laboratory
		Total Mercury	Fish	NA	semi-annually	Laboratory
Stevens Creek Reservoir	91910-1	Ammonia (N)	Water	2	monthly or semi-monthly	Laboratory
		Chloride	Water	2	monthly or semi-monthly	Laboratory
		Chlorophyll a	Water	Profile	monthly or semi-monthly	Sonde
		Dissolved Methylmercury	Water	2	monthly or semi-monthly	Laboratory
		Oxidation Reduction Potential	Water	Profile	monthly or semi-monthly	Sonde
		Oxygen Concentration	Water	Profile	monthly or semi-monthly	Sonde
		Oxygen Saturation	Water	Profile	monthly or semi-monthly	Sonde
		pH	Water	Profile	monthly or semi-monthly	Sonde
		Phycocyanin	Water	Profile	monthly or semi-monthly	Sonde
		Specific Conductivity	Water	Profile	monthly or semi-monthly	Sonde
		Sulfate	Water	2	monthly or semi-monthly	Laboratory
		Temperature	Water	Profile	monthly or semi-monthly	Sonde
		Total Mercury	Water	2	monthly or semi-monthly	Laboratory
		Total Methylmercury	Water	5	monthly or semi-monthly	Laboratory
	Reservoir	Assemblage	Fish	NA	semi-annually	Laboratory
		Percent Solids	Fish	NA	semi-annually	Laboratory
		Total Mercury	Fish	NA	semi-annually	Laboratory

A Maps

Figure A.1: Guadalupe River Watershed Location

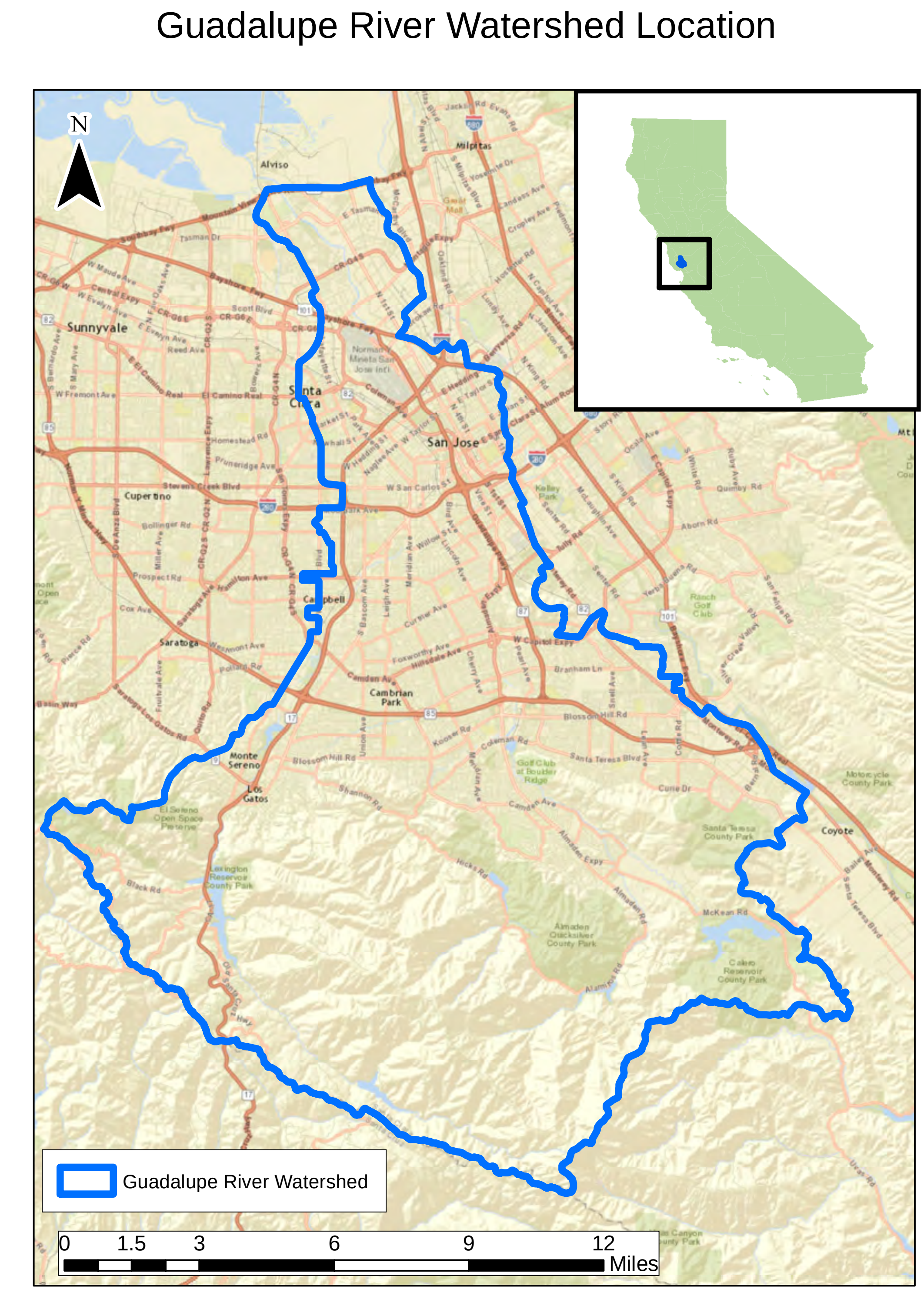


Figure A.2: Hydrologic Connectivity of Upper Guadalupe River Watershed

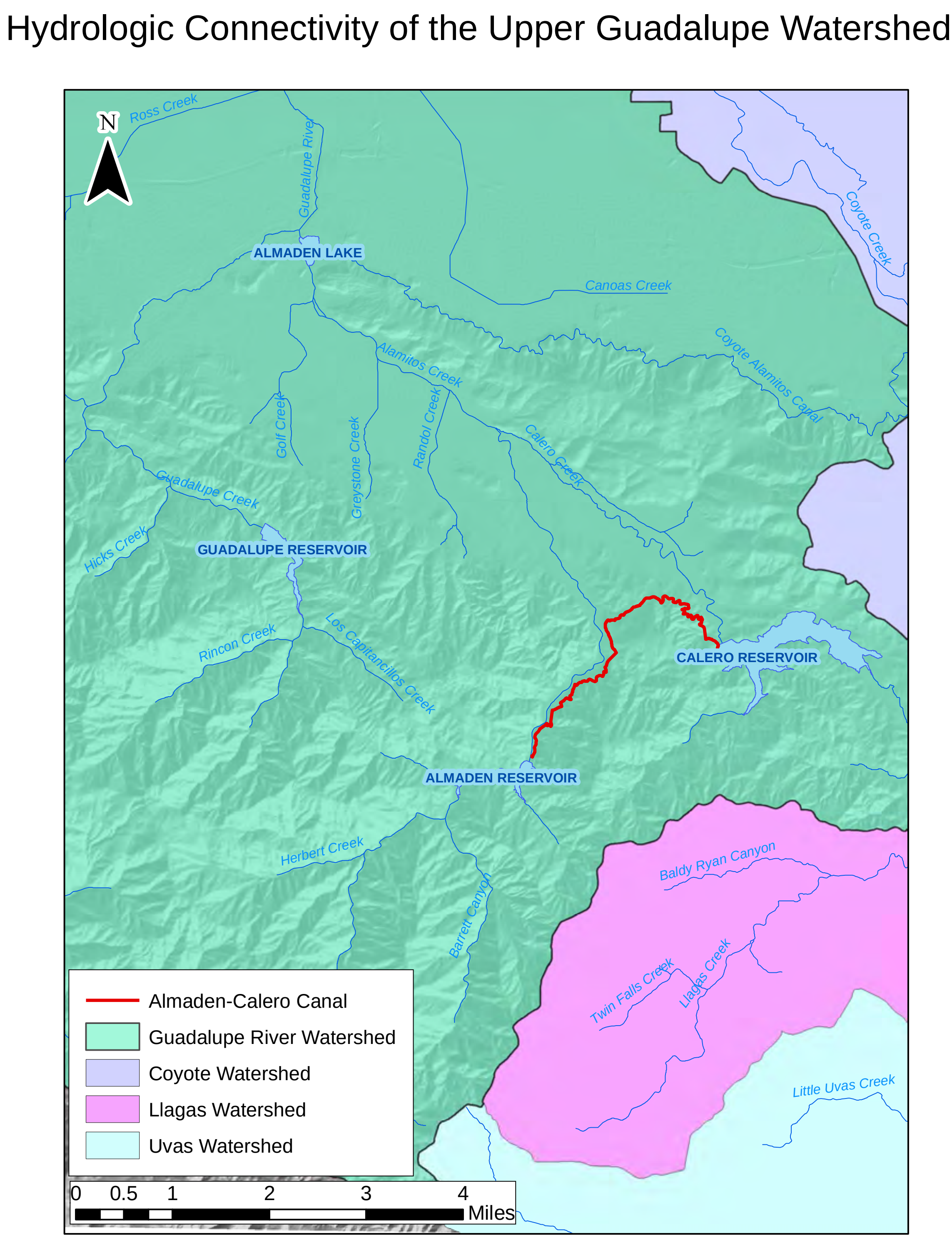


Figure A.3: Almaden Reservoir Sampling Sites

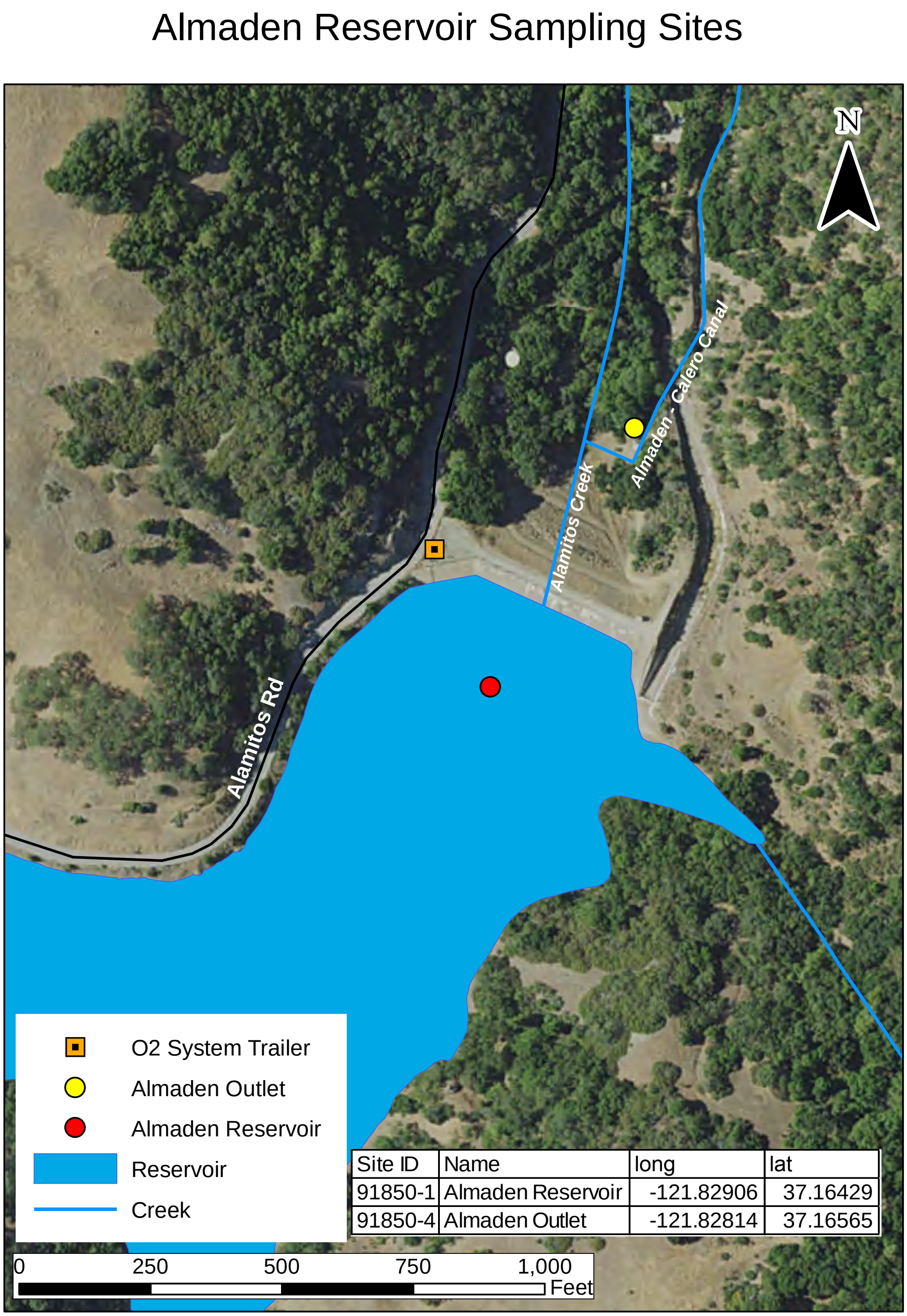
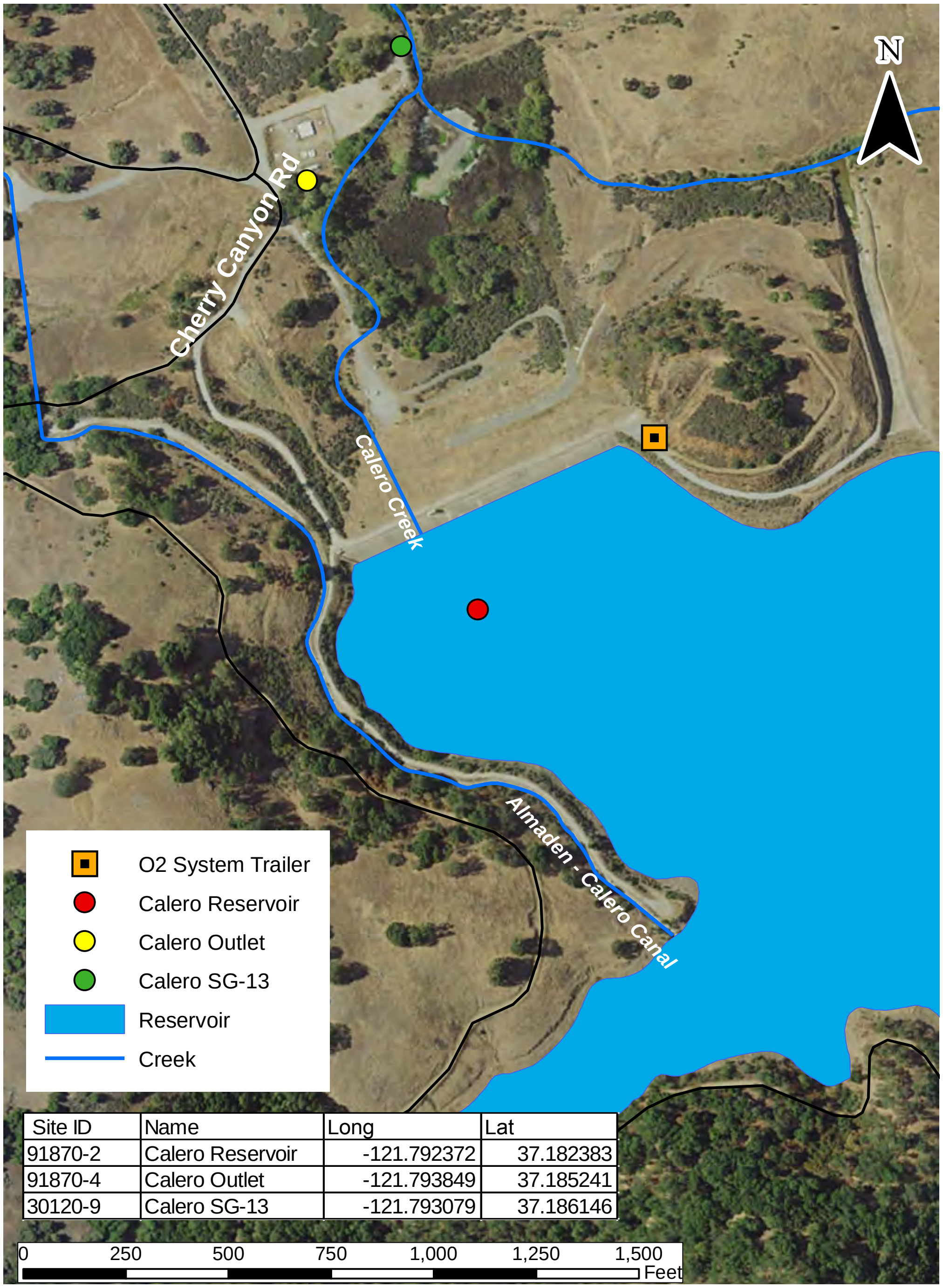


Figure A.4: Calero Reservoir Sampling Sites

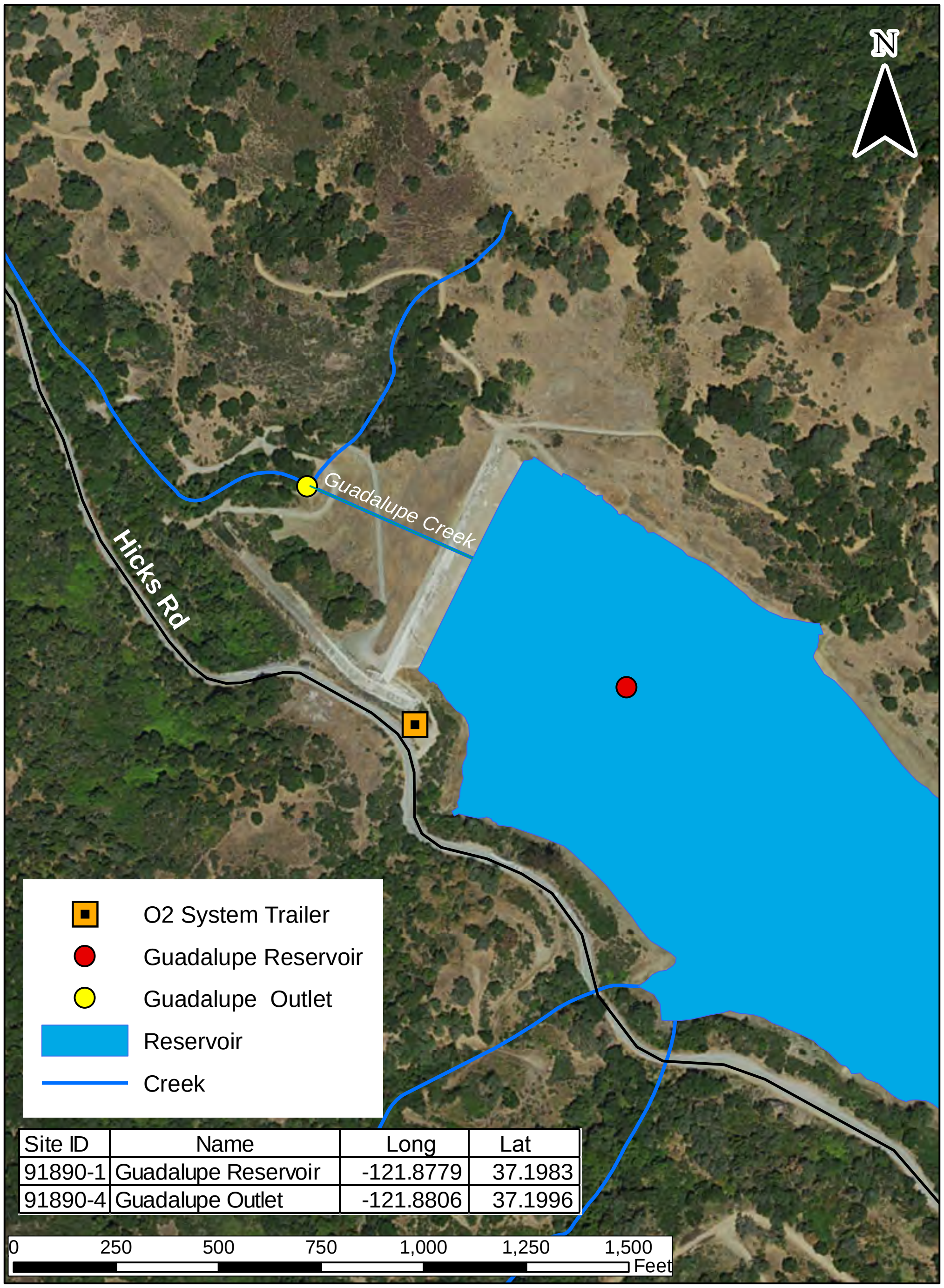
Calero Reservoir Sampling Sites



Site ID	Name	Long	Lat
91870-2	Calero Reservoir	-121.792372	37.182383
91870-4	Calero Outlet	-121.793849	37.185241
30120-9	Calero SG-13	-121.793079	37.186146

Figure A.5: Guadalupe Reservoir Sampling Sites

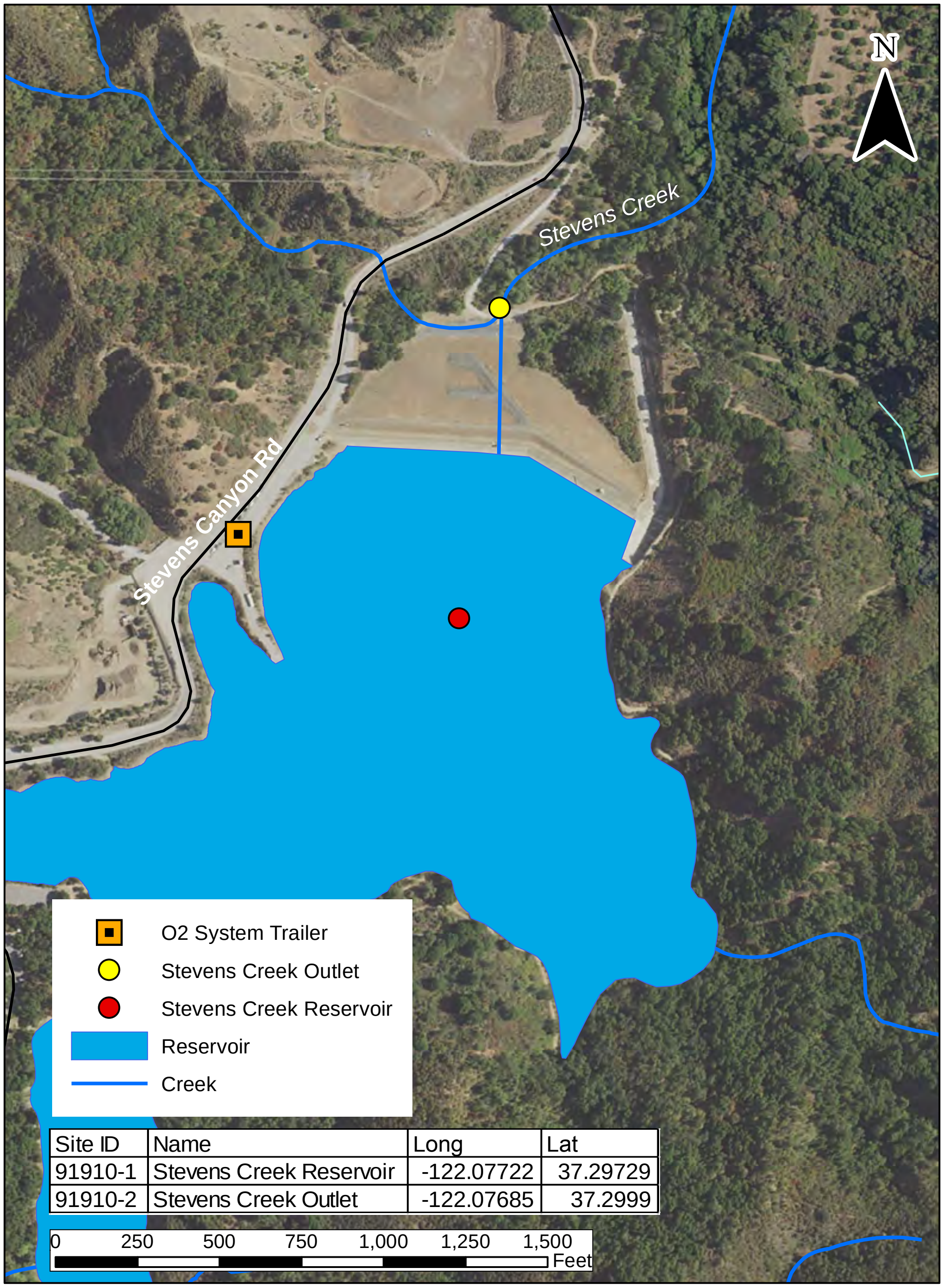
Guadalupe Reservoir Sampling Sites



Site ID	Name	Long	Lat
91890-1	Guadalupe Reservoir	-121.8779	37.1983
91890-4	Guadalupe Outlet	-121.8806	37.1996

Figure A.6: Stevens Creek Reservoir Sampling Sites

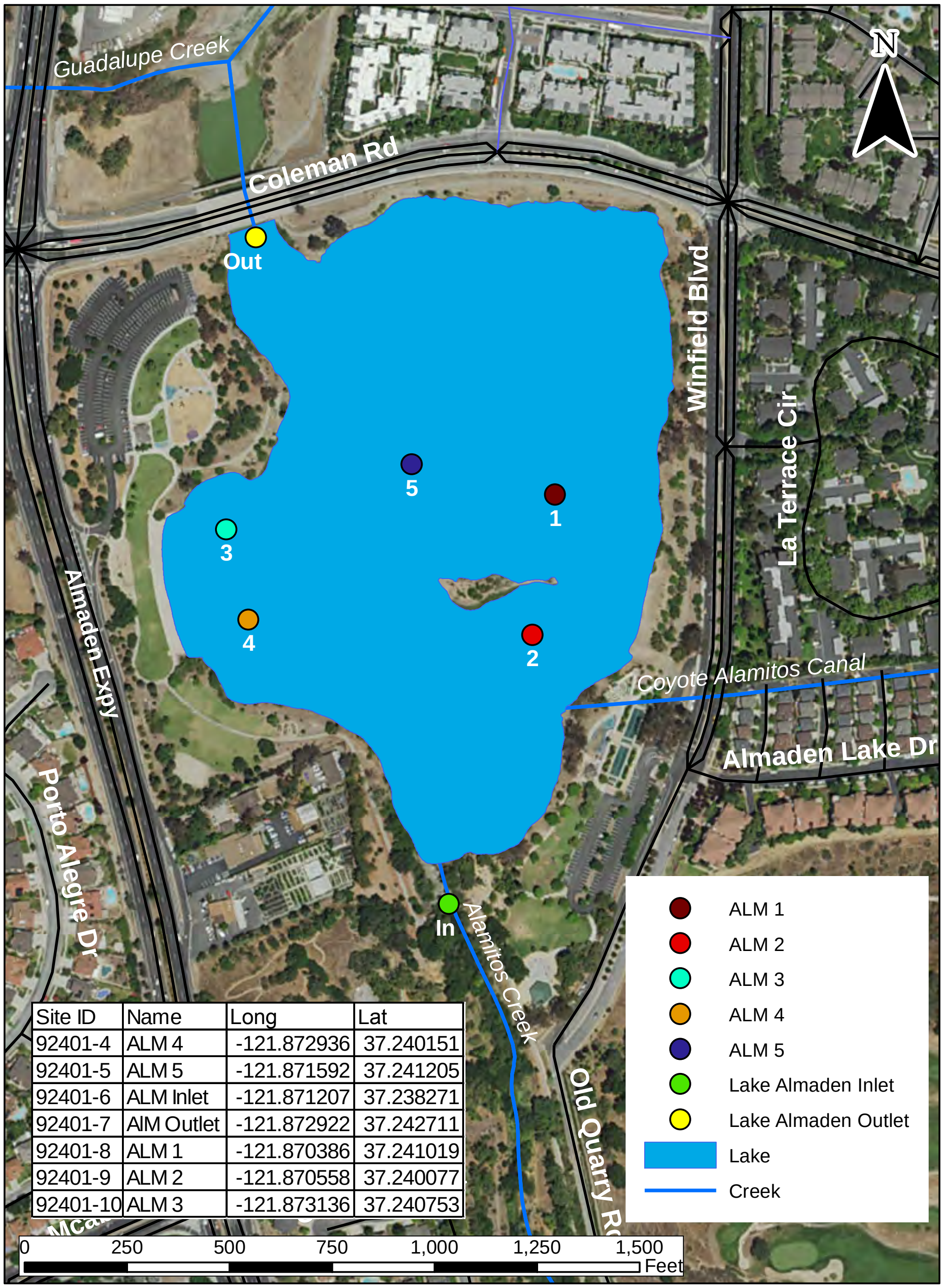
Stevens Creek Reservoir Sampling Sites



Site ID	Name	Long	Lat
91910-1	Stevens Creek Reservoir	-122.07722	37.29729
91910-2	Stevens Creek Outlet	-122.07685	37.2999

Figure A.7: Almaden Lake Sampling Sites

Lake Almaden Sampling Sites



Site ID	Name	Long	Lat
92401-4	ALM 4	-121.872936	37.240151
92401-5	ALM 5	-121.871592	37.241205
92401-6	ALM Inlet	-121.871207	37.238271
92401-7	AlM Outlet	-121.872922	37.242711
92401-8	ALM 1	-121.870386	37.241019
92401-9	ALM 2	-121.870558	37.240077
92401-10	ALM 3	-121.873136	37.240753

Figure A.8: Almaden Reservoir Fish Monitoring Quadrants

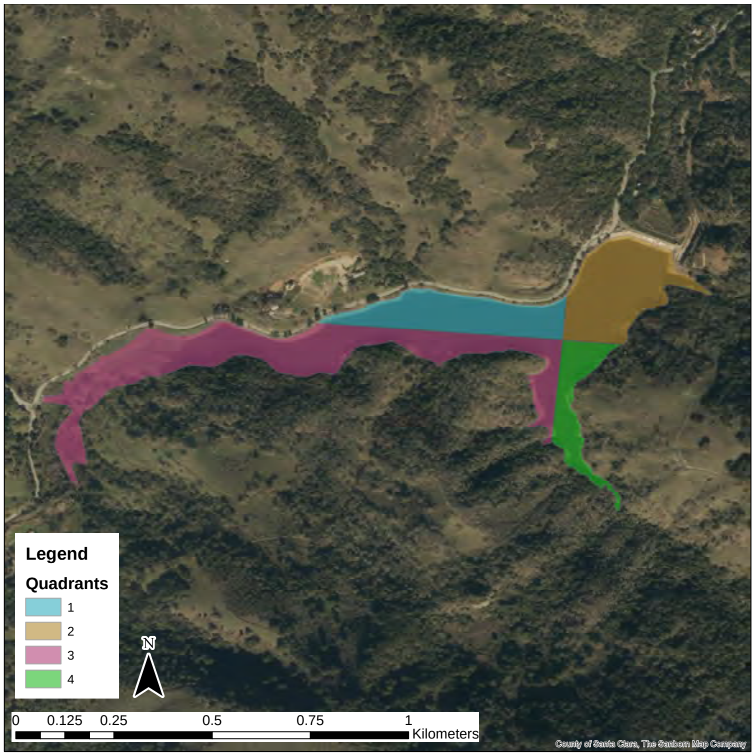


Figure A.9: Calero Reservoir Fish Monitoring Quadrants

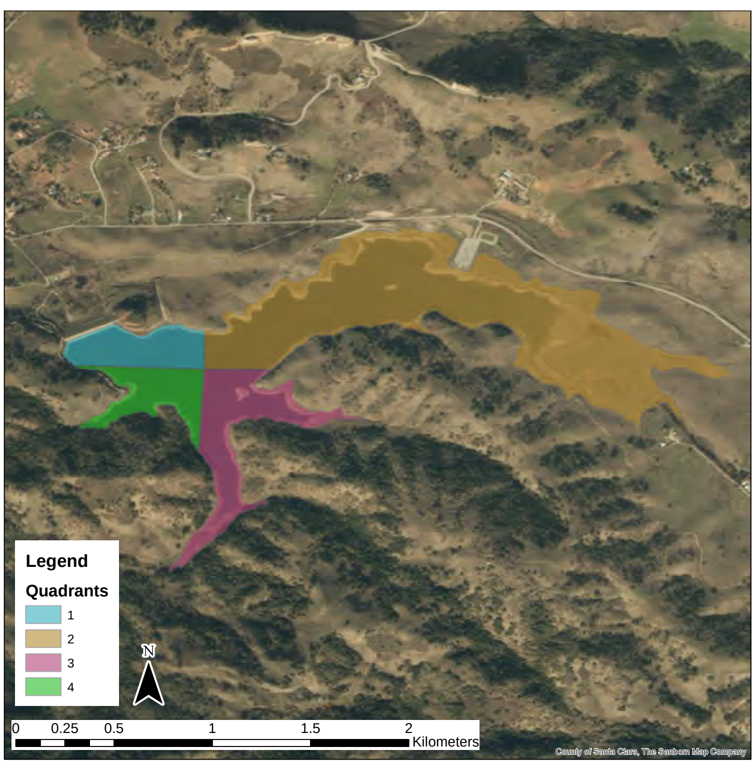


Figure A.10: Guadalupe Reservoir Fish Monitoring Quadrants

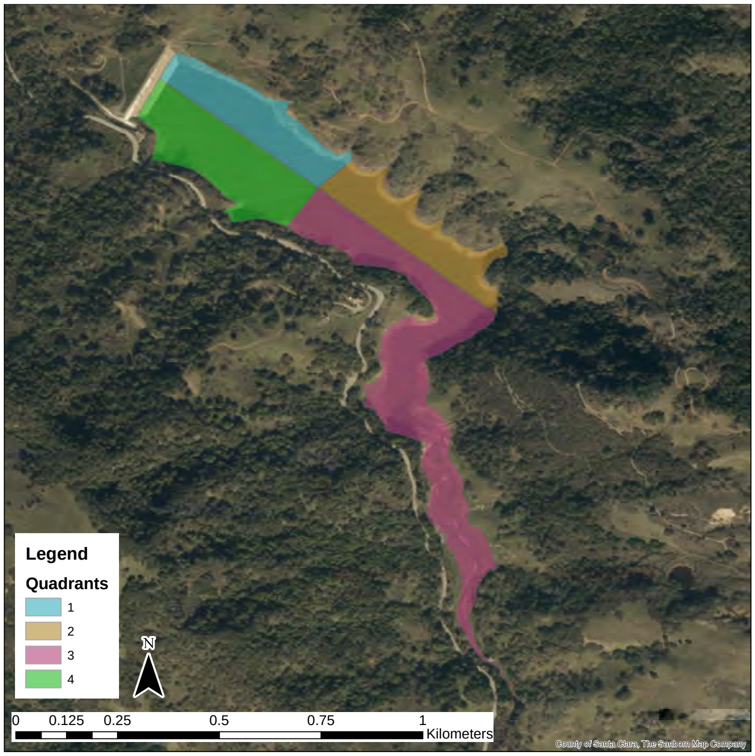
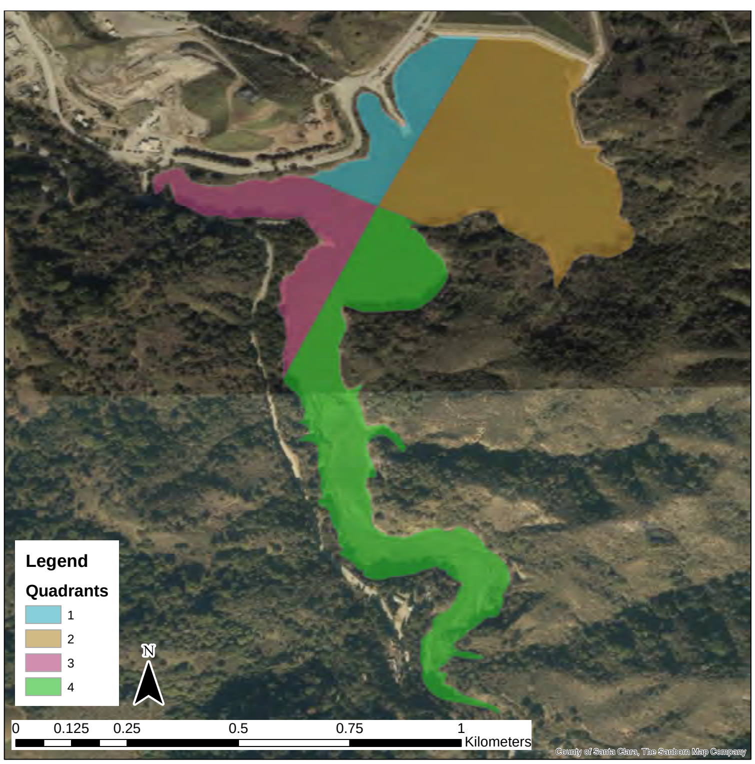


Figure A.11: Stevens Creek Reservoir Fish Monitoring Quadrants



2018 and 2019 Fish Assemblage Report for the Guadalupe River Watershed and Stevens Creek Reservoir Mercury Total Maximum Daily Load Monitoring

Prepared by:

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5750 Almaden Expressway
San Jose, CA 95118

February 11, 2020

Contents

List of Figures

List of Tables

Introduction

The Guadalupe River Watershed covers a 274-square kilometer area in the cities of San Jose, Los Gatos, Monte Sereno, Campbell, and Santa Clara. Valley Water (previously the Santa Clara Valley Water District) operates five reservoirs in the Guadalupe Watershed including Lexington, Vasona, Guadalupe, Almaden, and Calero (Figure 1). One additional reservoir in the watershed, Lake Elsman, is not operated by Valley Water. The watershed holds more than 129 kilometers of streams, with major tributaries of the Guadalupe River including Los Gatos, Ross, Alamitos, Canoas, and Guadalupe Creeks (Figure 1). The watershed supports many beneficial uses such as drinking water supply, sport fishing, and habitat for wildlife including special-status species. However, it is estimated that 6,500 tons of mercury entered local streams as a result of mining that began during the California Gold Rush and continuing into the 1970s. Mercury can occur in the environment in many forms with varying biological absorption rates. Methylmercury is the most bioavailable form. Mercury concentrations that exceed the United States Environmental Protection Agency (EPA) human health mercury fish criterion (0.3 mg/kg) have been measured in fish tissue at numerous creeks and reservoirs in the Guadalupe River Watershed and throughout the State. According to the State Water Resources Control Board, elevated mercury concentrations in fish tissue may also pose a threat to wildlife such as piscivorous birds, amphibians, and mammals that feed on contaminated fish, with mercury concentrations increasing as it moves up the food chain (California Water Boards 2019).

The Guadalupe River Watershed Mercury Total Maximum Daily Load (TMDL) is a regulatory driver requiring agencies such as the EPA, Food and Drug Administration (FDA), and other state and local authorities to address mercury impairment in the system. In addition to addressing mercury impairment in the Guadalupe watershed, the Guadalupe River Watershed Mercury TMDL will attempt to reduce the load of mercury entering San Francisco Bay in accordance with requirements in the San Francisco Bay Mercury TMDL.

The Basin Plan Amendment for the Guadalupe River Watershed Mercury TMDL calls for special studies to provide information that improves understanding of mercury cycling in the watershed, and to test assumptions used in developing the TMDLs. Further, reduction of methylmercury production in the watershed reduces the risks of methylmercury exposure to wildlife and humans.
The objectives of this study are to:

1) Characterize fish assemblages in mercury impaired reservoirs, informing the interpretation of fish tissue mercury data, and maintaining compliance with the Guadalupe River Watershed Mercury TMDL.
2) Produce dataset describing fish assemblages in Valley Water reservoirs, providing baseline data and estimates of interannual assemblage variability for current and future studies.

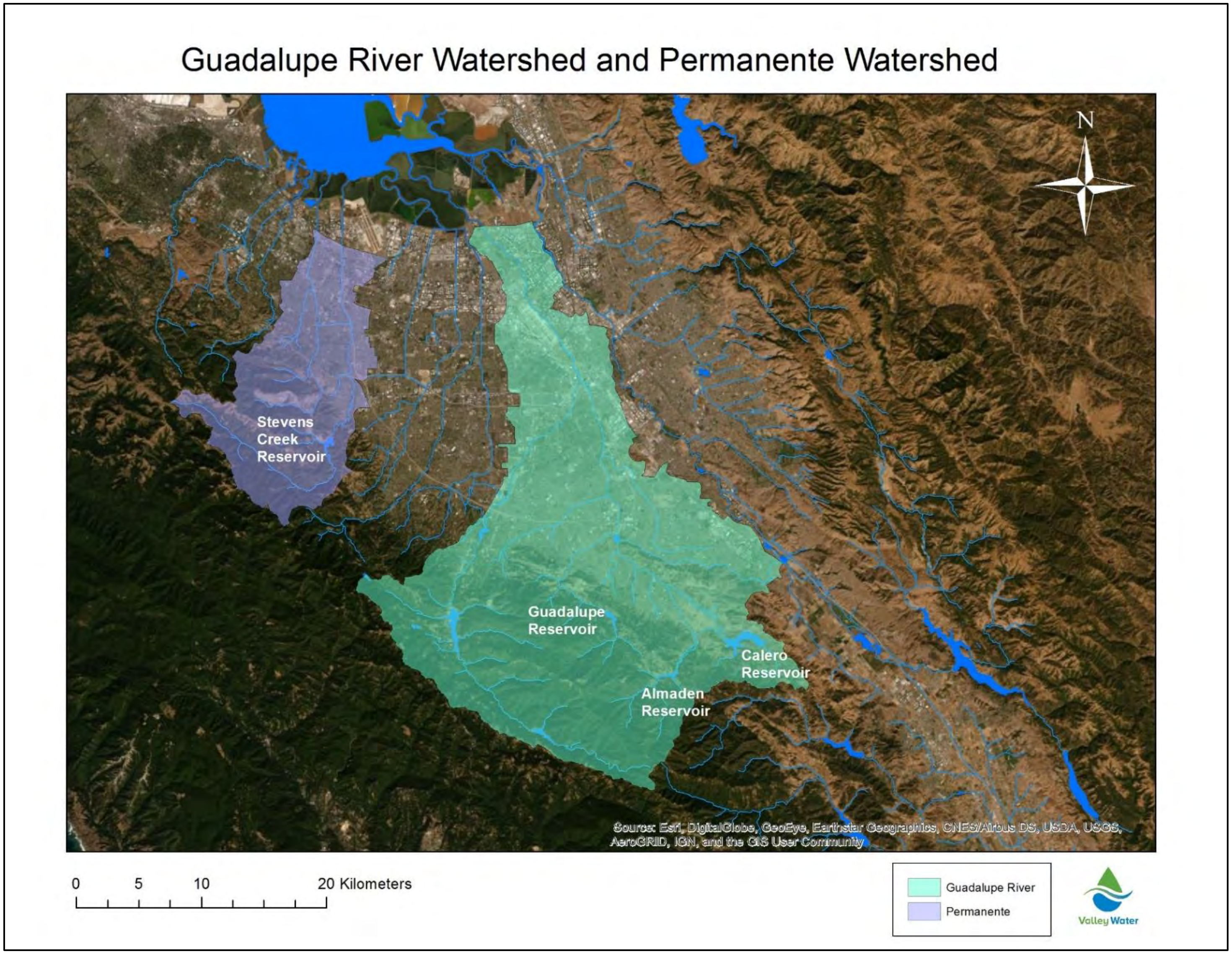

Figure 1: Map of Guadalupe River Watershed, its reservoirs, and major tributaries, as well as Stevens Creek Reservoir in the Permanente Watershed.

To address mercury pollution in reservoirs, Valley Water implemented a comprehensive monitoring and control program in 2005. This included the installation of oxygenation systems into reservoirs listed as impaired for mercury (Calero, Guadalupe, and Almaden), which intend to prevent anoxic conditions under which the methylation of mercury can occur. Valley Water also installed an oxygenation system in Stevens Creek Reservoir, as a reference site to account for variation in mercury source. Stevens Creek Reservoir is impaired due to mercury in fish, but does not have a mining source. It is reasonable to assume that limiting the production of the bio-available form of mercury will reduce mercury accumulation in fish tissues. There is further potential to affect fish assemblages by oxygenating additional levels in the water column.

Since it would be difficult to predict the effects of these actions on fish populations, in 2012 Valley Water began sampling fish assemblages in reservoirs with oxygenation systems installed (Almaden, Calero, Guadalupe, and Stevens Creek Reservoirs). The goal was to document fish assemblages in the reservoirs before and after oxygenation and assess changes over time. Data has been collected to record fish presence and relative changes in fish populations, and the 2018-2019 sampling event represents the seventh and eighth year of monitoring. Datasets are not continuous for each reservoir over the eight-year monitoring period as on occasion sampling constraints and conditions that did not facilitate sampling were encountered. Therefore, data gaps occur for some years at some reservoirs.

Sampling timing was variable by season during the early years of monitoring. In 2016 a more standardized approach was implemented. To account for seasonal variation in fish assemblage, sampling occurred twice per year at each reservoir consistently in the spring and summer from 2016 to 2019, with a slightly earlier sampling period in the summer of 2019. Boat-based electrofishing is the preferred method of sampling due to increased capture efficiency over other methods, but due to low reservoir water levels at Guadalupe and Almaden Reservoir in summer 2018, boat electrofishing was not possible during this period. Therefore, hook and line (angling) surveys were conducted in the summer at both of these reservoirs to obtain samples for the mercury body burden analysis, but this method did not provide an adequate assessment of assemblage due to reduced sample size and biases in catch (resulting from limitations of the gear used as well as preferential targeting of species used for the body burden analysis). The sampling period in summer 2019 was pushed earlier in the year when reservoir elevations would allow for the use of boat electrofishing. An additional study on the reservoirs food web was conducted, so it was necessary to eliminate the bias associated with hook and line sampling. Boat electrofishing was conducted at Stevens Creek and Calero Reservoirs during all sampling periods in both years.

The effort reported herein is a continuation of this sampling effort including fish assemblage and relative abundance data collected in Guadalupe, Almaden, Calero, and Stevens Creek Reservoirs in the summer and spring of 2018 and 2019. Comparisons of prior years' data are included as well. This report covers all species encountered during the sampling, but focuses on fish targeted for body burden analysis and provides detailed analysis into those specific species. These species typically include: largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), and black crappie (*Pomoxis nigromaculatus*). In summer of 2019, pumpkinseed (*Lepomis gibbosus*) and threadfin shad (*Dorosoma petenense*) were added to the body burden analysis. These are subject to the regulatory targets established in the 2008 Guadalupe River Watershed Mercury TMDL. Methods of field collection and laboratory analysis and associated data on mercury body burden analyses were reported in Valley Water's Guadalupe River Watershed Mercury TMDL: 2016-2017 Progress Report on Methylmercury Production and Control Measures.

Methods

Reservoir Fish Sampling

Boat-based Electrofishing

In 2018 and 2019, fish were captured using a Smith-Root Model H electrofishing boat. Settings were 120-340 volts DC, 60 pulse per second, and 80% of selected range. Four fetches (stations) were sampled at each reservoir. Sampling was initiated at night, shortly after dusk. Stations were located along the shoreline following the reservoir margin with sampling occurring in water 0.5 to 4.5 meters (m) in depth. Two forward netters and two flank netters were positioned on the boat to cover the whole area with a captain driving the boat and controlling shocking duration. Station distances were defined by the amount of shoreline sampled in 15-minute time spans with position tracking recorded on a GPS. At the end of each sampling station, the boat was stopped and anchored away from the shoreline and fish were identified to species. Fork length (FL) in millimeters (mm) was taken for the first 25 individuals of each species captured at each station. After the first 25 individuals of each species were measured, the remaining fish of each species were plus counted. Once recovered, all other fish were immediately released unharmed back to the reservoir from which they were collected.

Hook and Line Sampling

In summer of 2018, fish samples were collected in Almaden and Guadalupe Reservoirs using hook and line sampling from an aluminum Jon Boat, as reservoir elevations were too low to allow for launching of the electrofishing boat. Two methods of fishing were used at each reservoir to catch different species and different size classes, with a primary focus on collecting samples for the body burden analysis. The first method used was open water trolling along two to three offshore transects by two anglers. Each transect was trolled for 15 minutes. The other method used stationary angling along the shore margins at seven stations. The boat was anchored and two anglers fished from the boat using two different techniques to increase catch rates of target species for half-hour increments. Lures and hooks were scaled to catch fish of various sizes and each lure size and technique was used for an equal amount of time at each station. If a specific lure was working well to catch desired species for the body burden analysis, no changes were made and that lure was fished for the entire duration. Lures used in fish collection methods included .04 gram jig heads fitted with Berkley Gulp!® 25 mm minnows and 50 mm Gulp!® Earthworms, 3.5 gram Kastmasters®, and various Rapala® floating minnows. All fish collected using both methods were held in a livewell and fork length was taken for the first 25 individuals of each species measured at each station; additional fish beyond the first 25 individuals of each species were plus counted. All other fish were immediately released unharmed back to the reservoir from which they were collected. If non-target fish showed signs of stress induced from the capture method, they were held on board in an aerated livewell until they visibly recovered and were then released without measurement to reduce incidents of mortality.

Sampling Bias

Sampling bias is associated with all sampling methods, especially in an uncontrolled field environment. Boat electrofishing and hook and line survey both possess various biases associated with the limitations of the sampling equipment. Boat electrofishing only samples the water column between the surface and approximately 4.5 m deep, depending on the conductivity and settings. This limits the area that can be sampled, thus only targeting fish nearshore or within the top of the water column. Electrofishing also has bias in terms of specific species' catchability, fish size, and netting efficiency. Certain species (especially bottom-dwelling fish such as *Ictalurus*, *Cottus*, and *Catostomus* species) are not as easily captured due to morphological and physiological characteristics. Often larger fish are more readily collected with electrofishing since they are more susceptible to electric shock and they are highly visible when stunned (Mantyniemi et al. 2005; Marshal 2009). Netting efficiency also results in bias as human error is a variable that is difficult to control. Hook and line sampling is biased by location of sampling, limitations of the equipment, and ability of the sampler. The sample size of fish measured (25 individuals of each species at each station) is sized to reduce bias in length frequency, but no true randomization of which fish were measured occurred. Length frequency may not be a true representation of fish size within the station and size data could be skewed based on how fish were removed from the livewell.

Largemouth Bass Age Analysis

Scale analysis on largemouth bass was completed on samples collected from 2015-2017, to further understand age distribution and growth rates within Almaden, Guadalupe, Calero, and Stevens Creek Reservoirs. Samples for this analysis were collected in the months of March, April, August, and October, and were combined to determine a standard growth rate based on season. Fish collected outside of the months where this data was collected might not exhibit the same growth as predicted by this analysis. The age of a fish was determined by counting completed annuli, or growth rings, on the scale. Annuli are typically characterized by wide rings indicating fast summer growth, and consistent crowding of rings indicating slow winter growth. Each annulus represents one year (Schneider et al. 2000). However, due to the temperate Santa Clara County climate spacing of annuli is often less clearly defined, making results frequently inconclusive, or confidence is low.

The scale analysis provides age estimates, which when compared to the respective fish lengths collected during the sampling event can indicates the average size of fish in each age class. To estimate length-to-age relationships within the study areas, the results were combined and an overall largemouth bass age estimate was generated by looking at size distributions and assessing size range overlap.

Mean comparisons to investigate differences in length-age relationships were done using the Kruskal Wallis one-way analysis of variance. The results of the test are shown in Table 1. The age category 0+ is used to describe a fish in its first year of life. Age 1+ is a fish greater than one year of age, but less than two, and this pattern continues for all age categories.

Table 1: Summary statistics of the length-age relationship for largemouth bass in the Almaden, Guadalupe, Calero, and Stevens Creek Reservoirs.

Age Category	n	Mean (mm)	Min (mm)	Max (mm)	Standard Error (mm)
Age 0+	31	89.10	82.37	95.82	6.73
Age 1+	14	132.21	121.46	142.97	10.76
Age 2+	33	221.21	208.29	234.13	12.92
Age 3+	26	305.27	292.93	317.61	12.34
Age 4+	7	367.00	325.20	408.80	41.80
Age 5+	5	469.60	444.76	494.44	24.84

Results

Guadalupe Reservoir

Spring and Summer 2018

Sampling occurred on the Guadalupe Reservoir on April 3, 2018 and August 28, 2018. Reservoir water surface elevation at the time of spring sampling was 175.6 m (33.1% capacity) and summer sampling was 173.3 m (25.0% capacity). In the spring, a total of 1,333 linear meters of the reservoir margin was sampled via four sampling stations using boat electrofishing (Figure 2). Four species were collected: largemouth bass, bluegill, black crappie, and rainbow trout (*Oncorhynchus mykiss*). Common carp (*Cyprinus carpio*) were observed but not collected due to their large size, to avoid overcrowding the livewell.

In summer, 1,820 linear meters were trolled in a Jon boat over two transects. Additionally, seven stationary angling points were sampled via hook and line (Figure 2). Both sampling methods yielded fish. The primary focus of this sampling was to collect fish for the body burden analysis. Angling methods therefore were not designed to capture fish within all feeding guilds in the reservoir; rather, this sampling method targeted predatory fish. Three species were collected: largemouth bass, bluegill, and black crappie. Only two species (rainbow trout and common carp) that were observed during the electrofishing effort were not encountered during the hook and line survey. Aside from the native rainbow trout, the remaining four species encountered in Guadalupe Reservoir are non-native. Total capture data for each sampling station and standardized results (catch per minute (CPM), or fish captured per minute of sampling) are reported in Table 2.

Bluegill was the dominant species encountered during the spring electrofishing sampling. Largemouth bass was the dominant species collected during the summer hook and line sampling. The abundance of fish collected in spring and summer cannot be compared as the sampling methods are different and the hook and line sampling focused on obtaining samples for the body burden analysis over community assemblage. Because of this, summer size distribution is skewed towards fish that that were the target size for analysis. Also, the gape size of smaller fish limits detection by hook and line sampling, so size distribution in summer is slightly skewed towards larger fish. The size distribution of collected fish can be seen in Figure 3.

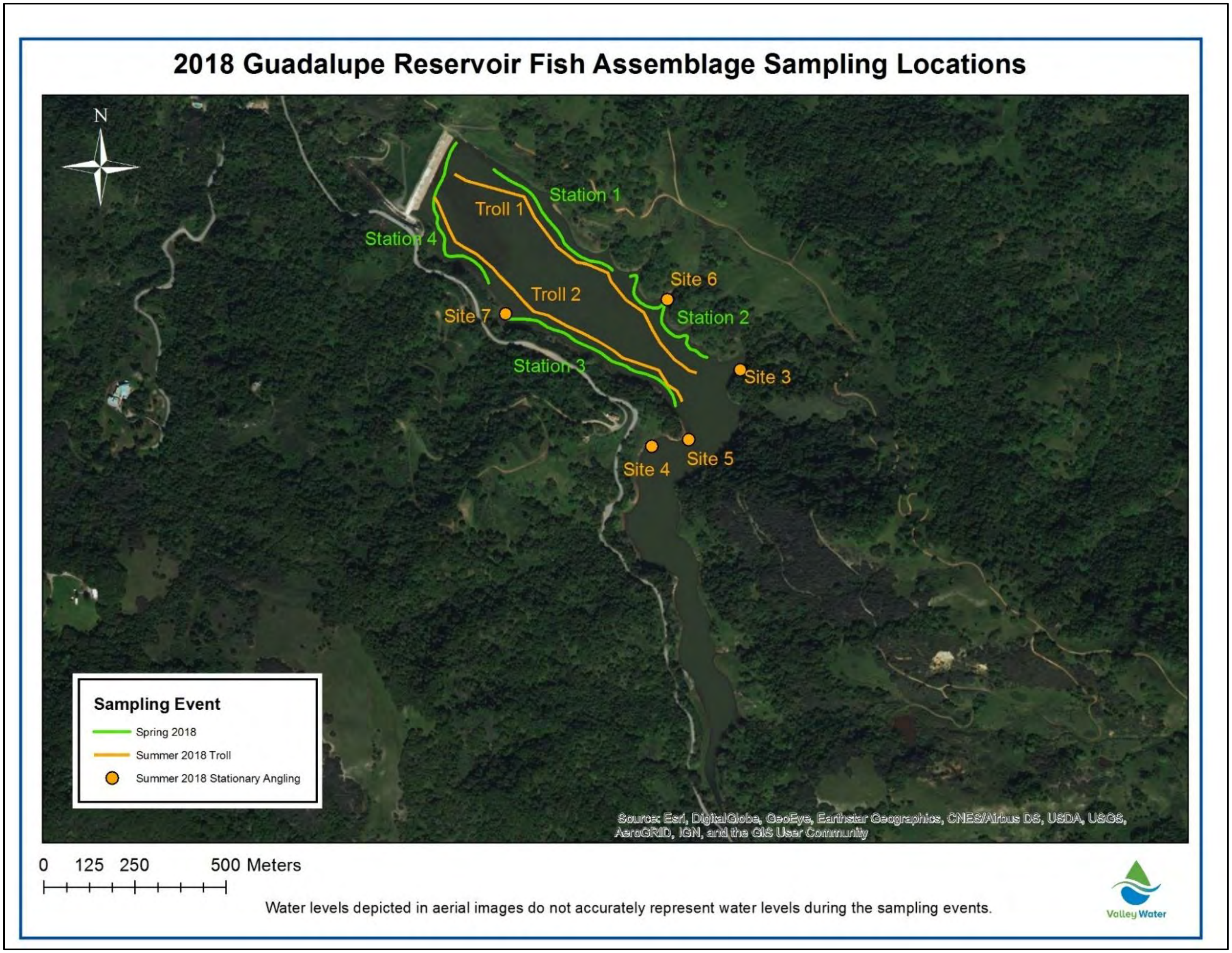

Figure 2: Guadalupe Reservoir sampling locations, spring and summer (2018).

Table 2: Electrofishing and hook and line captures in Guadalupe Reservoir spring and summer 2018.

Guadalupe Reservoir Spring Electrofishing Fish Captures (April 3, 2018)					
Station	**Duration (min)**	**Largemouth bass**	**Bluegill**	**Black crappie**	**Rainbow trout**
1	15	16	56	19	0
2	15	15	125	5	0
3	15	13	117	7	0
4	15	10	79	11	1
Total	60	54	377	42	1
CPM		0.900	6.283	0.700	0.017
Guadalupe Reservoir Summer Hook and Line Fish Captures (August 28, 2018)					
Station	**Duration (min)**	**Largemouth bass**	**Bluegill**	**Black crappie**	**Rainbow trout**
Troll 1	15	0	0	1	0
Troll 2	15	0	0	4	0
Site 3	30	2	15	0	0
Site 4	30	5	0	0	0
Site 5	30	2	0	0	0
Site 6	30	7	1	0	0
Site 7	30	4	1	0	0
Total	180	20	17	5	0
CPM		0.111	0.094	0.028	0.000

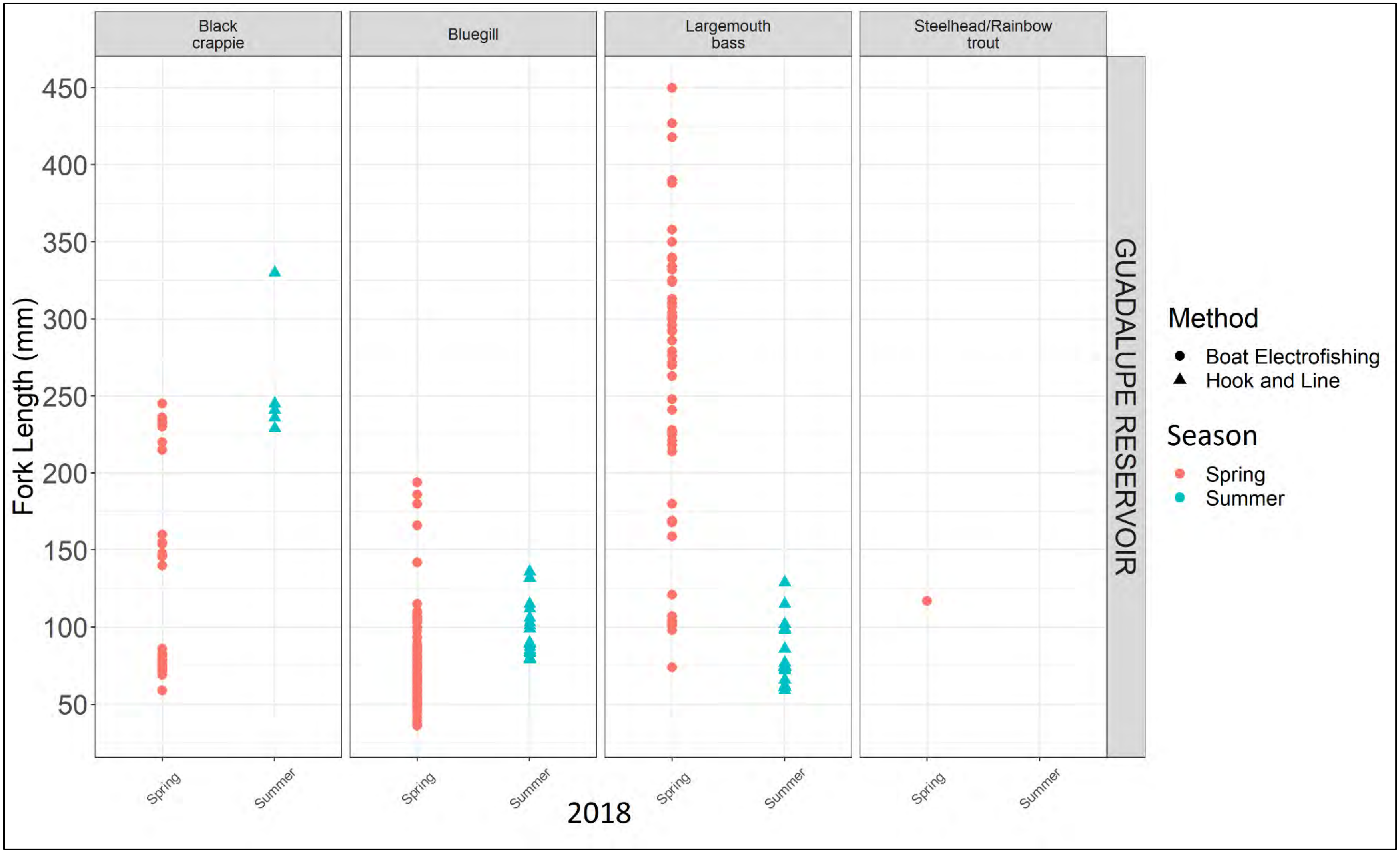

Figure 3: Guadalupe Reservoir fish size distribution in spring and summer 2018.

According to Moyle (2002), black crappie 40 mm to 80 mm are first year, 120 mm to 210 mm are second year, and fish 150 mm to 280 mm are at the end of their third year. Black crappie collected in spring spanned all three of these age classes. The summer hook and line sampling only encountered fish that would be considered in their third year. This is likely due to the alteration in method of capture from boat electrofishing to hook and line sampling, not a lack of reproduction in the system.

Spring bluegill size distribution was limited. Moyle (2002) indicates that bluegill at the end of their first year will be between 40 mm and 60 mm and tend to grow 20 mm to 50 mm each additional year. Moyle (2002) indicates that growth of small bluegill is primarily limited by intraspecific competition. This could be the case in Guadalupe Reservoir as bluegill were the most abundant fish observed. Bluegill under 40 mm were observed during the spring sampling event when these fish would be expected to be approaching one year of age. Due to the small size of first year bluegill it is possible that older bluegill may be smaller than what is typical. This observation was also made in the 2016-2017 Guadalupe Watershed Assemblage report (Valley Water 2018). Based on the literature, bluegill size distribution indicates the presence of fish that are over five to six years of age, but could potentially be older if stunting is occurring in the water body. The species has been observed at over eight years old, but very few live longer than six years (Moyle 2002). This could indicate why few fish are captured in the larger size ranges. The size data in summer is skewed towards larger fish as bluegill are gape-limited and hook and line sampling would not allow for smaller fish to be captured.

The size distribution between summer and spring in largemouth bass indicates successful spawning occurred (young of the year fish captured in summer), and the spring sampling event likely occurred before spawning or before juvenile fish were large enough to be detected by electrofishing. Largemouth bass growth rates are highly variable due to temperature, competition, genetic background, forage availability, and limnological conditions (Moyle 2002). As expected, the spring event had larger fish in the first size cohort than the summer event due to the seasonal timing. Spring sampling occurs at the start of the breeding season, so all fish in the reservoir are expected to be approaching one-year of age or older. The smallest fish collected during the summer event are expected to be true young of the year age class. Due to their large gape size, it is possible to capture smaller bass via hook and line sampling than some other centrarchid species observed in the reservoir. Based on Moyle's length-age relationships (2002), fish were observed that were young of the year ranging to likely in their fourth or fifth year. A more detailed analysis of largemouth bass ages within Guadalupe Reservoir based on local data is discussed later in this document.

A single rainbow trout was captured in spring and was 117 mm. Per Moyle (2002), rainbow trout growth rates are variable, but in reservoirs they are typically between 100 and 160 mm fork length in their first year. The one trout captured was likely at the end of its first year. This fish may have migrated into the reservoir from upstream tributaries (Guadalupe, Rincon, or Los Capitancillos Creeks) during high spring flows.

Spring and Summer 2019

Sampling occurred on Guadalupe Reservoir on April 17, 2019 and July 22, 2019. Reservoir water surface elevation at the time of the spring sampling was 182.1 m (62.3% capacity) and summer sampling was 179.3 m (48.4% capacity). The summer sampling occurred earlier in the summer than the previous three years of sampling with consistent seasonal sampling timing (2016-2018). A total of 1,842 linear meters and 2,084 linear meters of the reservoir margin was sampled in the spring and summer, respectively, through four sampling stations (Figure 4). Six species were encountered: largemouth bass, bluegill, black crappie, prickly sculpin (*Cotus asper*), Sacramento sucker (*Catostomus occidentalis*), and white crappie (*Pomoxis annularis*). Common carp were observed but not collected to avoid overcrowding the livewell.

Prickly sculpin and white crappie were not detected during any of the previous sampling events associated with this monitoring and the last record of Sacramento sucker was from 2013. White and black crappie have limited morphological distinctions. Slight differences associated with number of dorsal spines, markings, and body shape are present but can be difficult to detect in the low light conditions of nocturnal sampling. It is likely this species was present but misidentified as black crappie in previous sampling events, but it appears to be in low density. Presence of prickly sculpin could have been a result the wet winter of 2019 moving fish downstream. Total capture data for each sampling station and standardized results (CPM) are reported in Table 3.

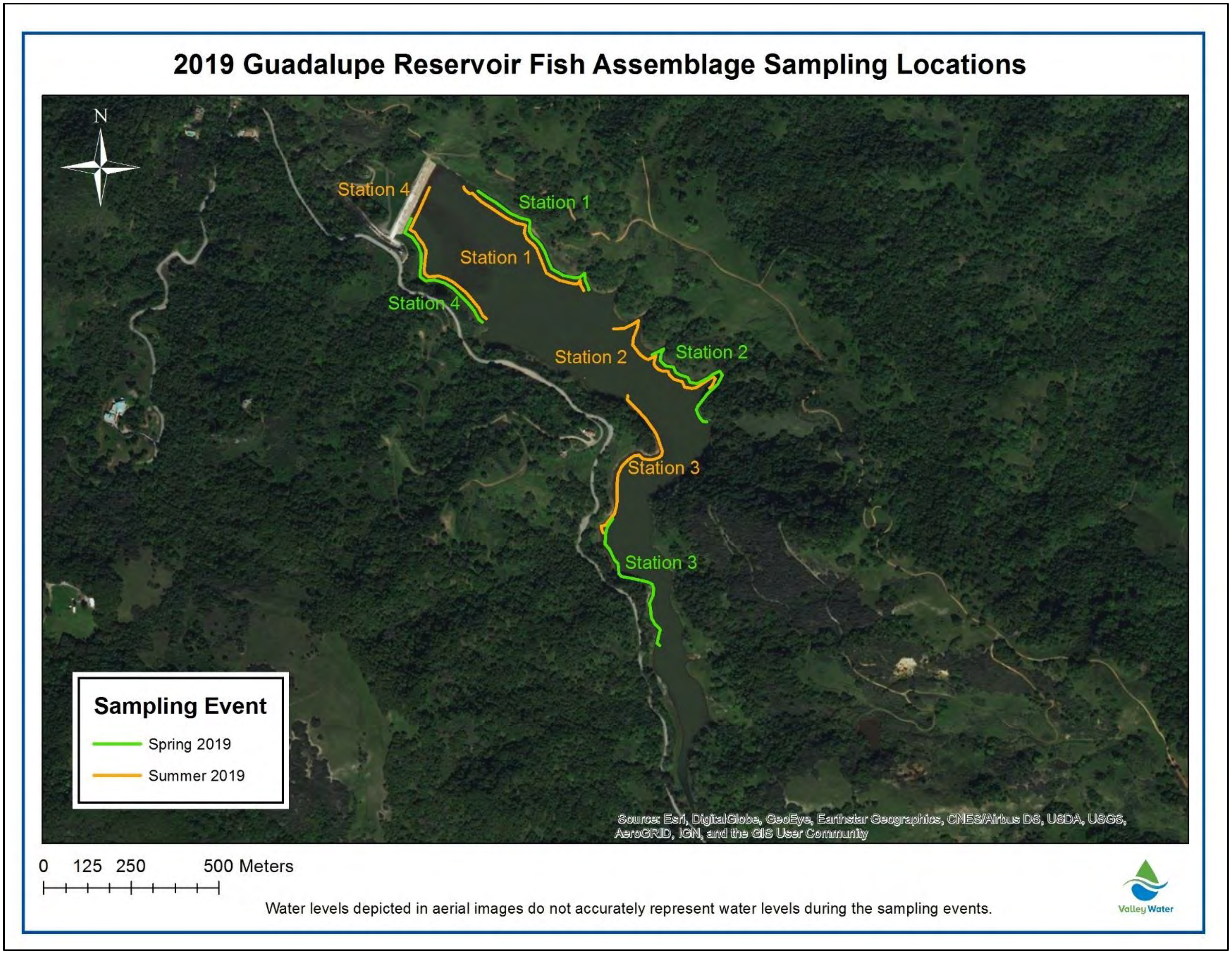

Figure 4: Guadalupe Reservoir sampling locations, spring and summer (2019).

Table 3: Electrofishing captures in Guadalupe Reservoir, spring and summer 2019.

Guadalupe Reservoir Spring Fish Captures (April 17, 2019)							
Station	**Duration (min)**	**Largemouth bass**	**Bluegill**	**Black crappie**	**Prickly sculpin**	**White crappie**	**Sacramento sucker**
1	15	7	103	7	1	0	0
2	15	17	77	10	0	2	1
3	15	7	92	3	0	1	0
4	15	5	25	0	0	0	0
Total	60	36	297	20	1	3	1
CPM		0.600	4.950	0.333	0.017	0.050	0.017
Guadalupe Reservoir Summer Fish Captures (July 22, 2019)							
Station	**Duration (min)**	**Largemouth bass**	**Bluegill**	**Black crappie**	**Prickly sculpin**	**White crappie**	**Sacramento sucker**
1	15	346	37	33	0	0	0
2	15	175	76	70	0	0	0
3	15	121	91	30	0	0	0
4	15	126	60	23	0	0	0
Total	60	768	264	156	0	0	0
CPM		12.800	4.400	2.600	0.000	0.000	0.000

Bluegill were by far the most frequently captured species during the spring sampling event, while largemouth bass were most frequent in the summer. Overall total fish capture was higher in summer, but only three species were observed. The higher number of fish captured in summer is expected, as the sampling occurs after spawning and a higher abundance of young of the year fish are present. The dramatic increase in number of largemouth bass and black crappie captured during summer sampling compared to previous years of summer sampling in Guadalupe Reservoir could be a result of the earlier sampling timing. A larger percentage of young of the year fish could be present and/or using the portions of the reservoir that are sampled via electrofishing at this time of year.

The size distribution of fish collected in 2019 (Figure 5) shows different age classes of largemouth bass, bluegill, and black crappie in both sampling events and indicates that successful reproduction occurred. Size data associated with prickly sculpin, Sacramento sucker, and white crappie does not provide much information in terms of population dynamics due to the small sample size and these species only being collected in one sampling event (the spring).

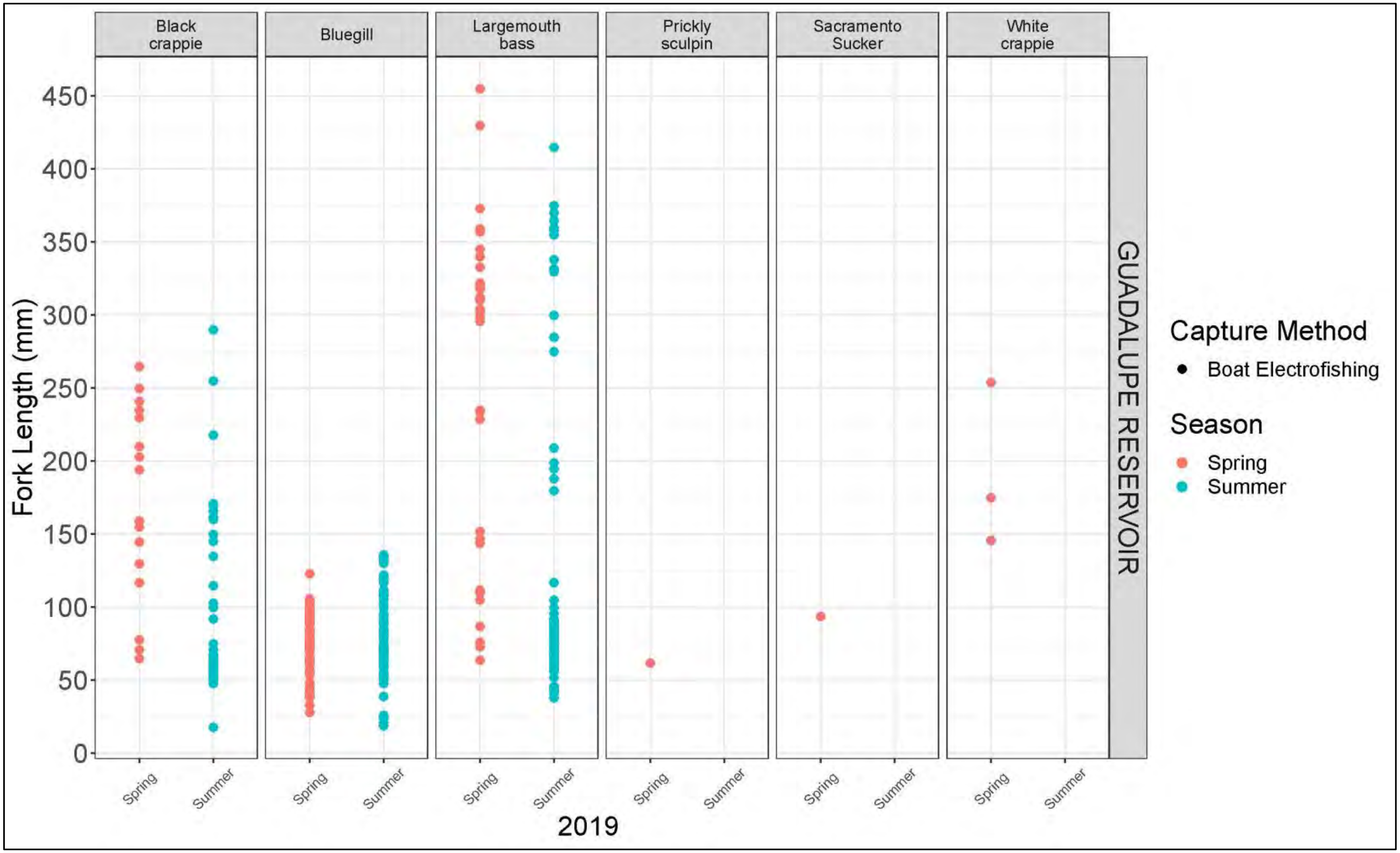

Figure 5: Guadalupe Reservoir fish size distribution in spring and summer 2019.

Based on the age-length relationship literature for black crappie (Moyle 2002), fish that were captured in the summer at Guadalupe Reservoir in 2019 ranged from young of the year to their fourth year.

As in 2018, the size distribution in bluegill does not show a clear size variation between age classes. There is a slight distinction between the smallest size class of bluegill between spring and summer. This size distribution again points to the intraspecific competition and possible stunting in the water body. The size distribution observed puts bluegill within young of the year size range and could extend into the fourth or fifth year.

The size distribution between summer and spring in largemouth bass indicates successful spawning occurred. Again, as expected, the spring event had larger largemouth bass in the first size cohort than the summer event due to the seasonal timing. A more detailed analysis of largemouth bass age within Guadalupe Reservoir will be discussed later in this document.

Growth rates in Sacramento suckers can be variable depending on water temperature of the region they are found in. The single Sacramento sucker observed during sampling was likely in its first year.

According to Moyle (2002), white crappie tend to grow more slowly in California reservoirs compared to their native region. They reach 50 to 100 mm in their first year, 110 to 180 mm in their second year, 170 to 210 mm in their third year, and 200 to 270 in their fourth year. The white crappie collected fall within a size range that put them in their second year with fish potentially extending into their fourth year, indicating the fish have been present for multiple years, unless they were recently introduced as adults (Moyle 2002).

Guadalupe Reservoir Summary

Standardization of sampling timing began in 2016, so a consistent dataset is beginning to build. During all sampling events in Guadalupe Reservoir, bluegill made up a large portion of the catch (Table 4). Summer of 2019 was the first year (except during hook and line surveys) that bluegill were not the most dominant species captured. When yearly average CPM of all species is compared (Figure 6), limited change in capture has been observed during the seven years of data collection, with the exception of an increase in largemouth bass and black crappie in summer 2019. This increase could have been a result of the seasonal timing of the sampling or above average reproduction. Common carp were observed during each sampling event, but not collected. In 2019, Sacramento sucker were captured for the first time since 2013. Another benthic species, prickly sculpin, was captured for the first time in spring 2019. Bias associated with the sampling method, overall low abundance, or spatial distribution of the sampling could contribute to the lack of detection in previous years. White crappie is another species that was first detected in spring 2019. As mentioned above, it is likely this species was present in previous sampling events but was misidentified as black crappie, but it is also possible that the species was recently illegally introduced into the system. No white crappie were observed in summer of 2019, and extra care was taken to look for identifying characteristics of all crappie encountered. This species is present in lower abundance than black crappie or using portions of the reservoir not sampled using electrofishing. The third new species identified in the 2018-2019 sampling period was rainbow trout, which was collected in spring 2018. The occurrence of rainbow trout, for the first time, provides potential insight into life history of the rainbow trout population above Guadalupe Reservoir. There is a potential of adfluvial life histories occurring within the system. In years of increased rainfall, the fish might be traveling downstream into the reservoir.

Table 4: Guadalupe Reservoir CPM 2012-2013, 2015-2019 (P - present but not quantified).

Sampling Date	Largemouth bass	Bluegill	Black crappie	Common carp	Sacramento sucker	Rainbow trout	Prickly sculpin	White crappie
7/12/2012	5.33	10.55	1.16	0.19	0.05	0.00	0.00	0.00
7/17/2013	0.69	9.19	0.91	0.11	0.00	0.00	0.00	0.00
10/6/2015	1.93	5.15	0.27	P	0.00	0.00	0.00	0.00
3/24/2016	0.57	4.05	0.67	P	0.00	0.00	0.00	0.00
8/30/2016	1.47	14.05	0.53	P	0.00	0.00	0.00	0.00
4/25/2017	0.70	9.72	0.17	P	0.00	0.00	0.00	0.00
8/28/2017	2.85	12.38	0.07	P	0.00	0.00	0.00	0.00
4/3/2018	0.90	6.28	0.70	P	0.00	0.02	0.00	0.00
8/28/2018*	0.11	0.09	0.03	P	0.00	0.00	0.00	0.00
4/17/2019	0.60	4.95	0.33	P	0.02	0.00	0.02	0.05
7/22/2019	12.80	4.40	2.60	P	0.00	0.00	0.00	0.00
*Hook and line sampling methods used.								

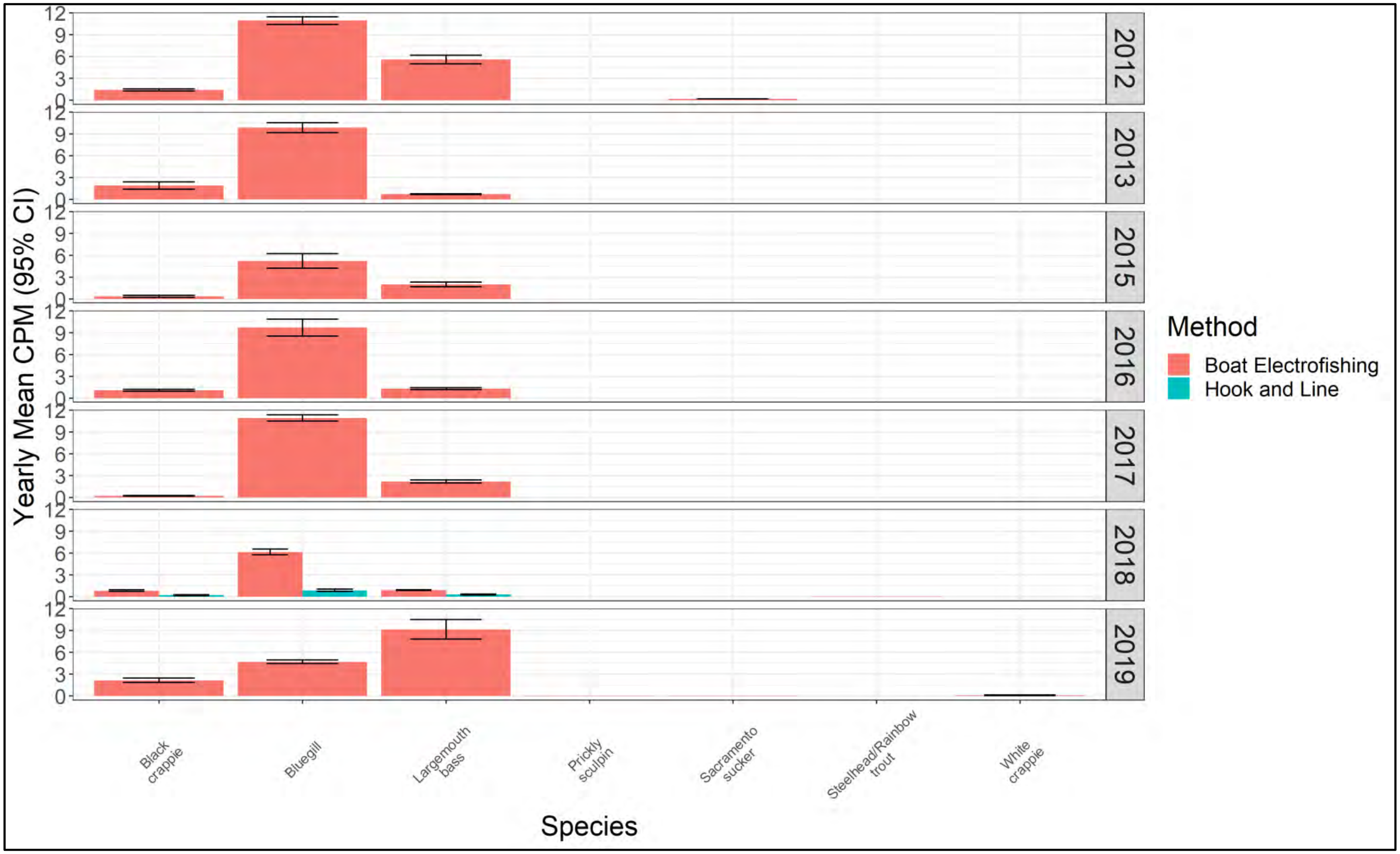

Figure 6: Yearly average CPM for Guadalupe Reservoir for 2012-2013, 2015-2019.

Based on the sampling results, the trophic distribution within Guadalupe Reservoir is limited. The three-additional species detected and the reoccurrence of Sacramento sucker does not appear to dramatically change the food web structure. No fish species were observed that effectively bridge the gap of phytoplankton and zooplankton to primary predators. No forage fish were present (inland silverside, threadfin shad, etc.). The only fish present that are assigned below trophic level three is Sacramento sucker (trophic level 2.8 ±.02), and this species does not make up a substantial portion of the population (Fishbase 2019). In this system, it is possible that cannibalism and predation between individuals of higher trophic level species is occurring. This lack of lower trophic level species as potential prey could shorten the pelagic food chain, which could influence mercury accumulation (Cabana et al., 1995).

Age analysis based on available literature indicates that Guadalupe Reservoir bluegill may have slower than average growth rates. The presence of bluegill under 40 mm in both sampling events indicates that stunting might be occurring, and fish may be older than lengths indicate. This could be influencing the results of the mercury body burden analysis for this species. Based on the 2019 sampling it appears that black crappie are following a normal growth pattern typical of black crappie in California.

Length data for largemouth bass in Guadalupe Reservoir were compared to the scale analysis information collected by Valley Water. Figure 7 shows the lengths of largemouth bass from 2018 and 2019 with the age estimates overlaid. The age estimates are based on the average length and standard error of largemouth bass of each age class in Santa Clara County as evaluated by the analysis (Table 1). The length distribution in summer of 2018 is limited due to the bias associated with hook and line sampling.

When the age 0+ category, or fish within their first year (smallest size cohort in the summer sampling event), is evaluated for 2018, it shows that most largemouth bass tend to fall below the predicted average size, while in spring 2018 largemouth bass lengths were closer to what would be expected for the 0+ age category; however, this is when the seasonal timing would put this cohort closer to age 1+ category.

In Guadalupe Reservoir, it appears that size overlaps occur between age classes, especially in 0+ and 1+, and often the size clusters (potential age cohorts) fall below the predicted size for the watershed. This could indicate potential stunting is occurring, but it is not as evident as observed with the bluegill. Based on the length-age analysis conducted within the County, Guadalupe Reservoir has largemouth bass that range from young of the year to fish that are potentially in their fifth year. Due to the evidence of potential stunting, these large fish could be older than anticipated. A predicted growth spurt is observed between the 1+ and 2+ age category, which could be a result of a diet change. This growth is observed in the scale analysis data as well, showing Guadalupe Reservoir largemouth bass growth is trending with what is observed elsewhere in Santa Clara County in terms of the age when growth spurts occur, but might be occurring at a slower rate.

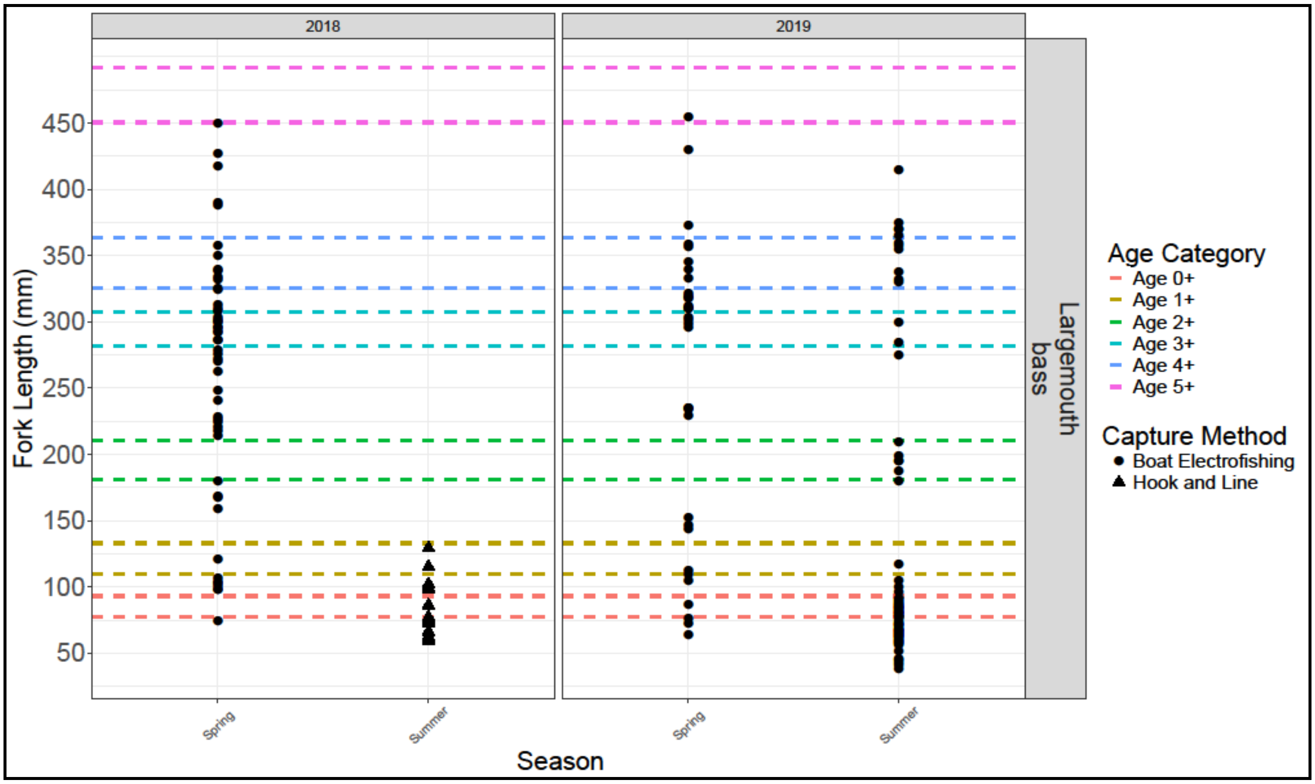

Figure 7: Largemouth bass lengths from Guadalupe Reservoir with age class estimates (2018 and 2019).

Calero Reservoir

Spring and Summer 2018

Spring sampling occurred at Calero Reservoir on April 19, 2018 and summer sampling on August 30, 2018. Reservoir water surface elevation was 140.6 m (40.8% capacity) at the time of the spring survey and 141.4 m (46.0% capacity) for the summer survey. Reservoir fluctuations occurred, with drawdowns in February. The reservoir was never reduced to below 35% and did not exceed 47% capacity. A total of 1,884 linear meters of reservoir margin was sampled at four survey stations in spring and 1,974 linear meters at four sampling stations in summer (Figure 8).

Twelve species were collected in 2018: largemouth bass, bluegill, black crappie, threadfin shad, inland silverside (*Menidia beryllina*), bigscale logperch (*Percina macrolepida*), golden shiner (*Notemigonus crysoleucas*), tule perch (*Hysterocarpus traskii*), and Sacramento sucker were collected during both sampling events, with brown bullhead (*Ameiurus nebulosus*), prickly sculpin, and redear sunfish (*Lepomis microlophus*) collected only in summer. Common carp were observed in both spring and summer, but were not collected to avoid overcrowding in the livewell. All carp observed were estimated at over 300 mm and potentially exceeded 600 mm. Tule perch, Sacramento sucker, and prickly sculpin were the only California native species collected; however, while tule perch are native to California (ex., the Coyote Watershed), they are not native to the Guadalupe Watershed. This was the first instance of redear sunfish being identified in Calero Reservoir. Previous sampling efforts identified pumpkinseed. Pumpkinseed and redear sunfish have similar morphological characteristics. No pumpkinseed were observed during the 2018 sampling effort. It is possible that in previous sampling efforts, redear sunfish were misidentified as pumpkinseed, and redear sunfish may not be a new arrival in the system. Total capture data is reported in Table 5, and to standardize the results, data were converted to CPM.

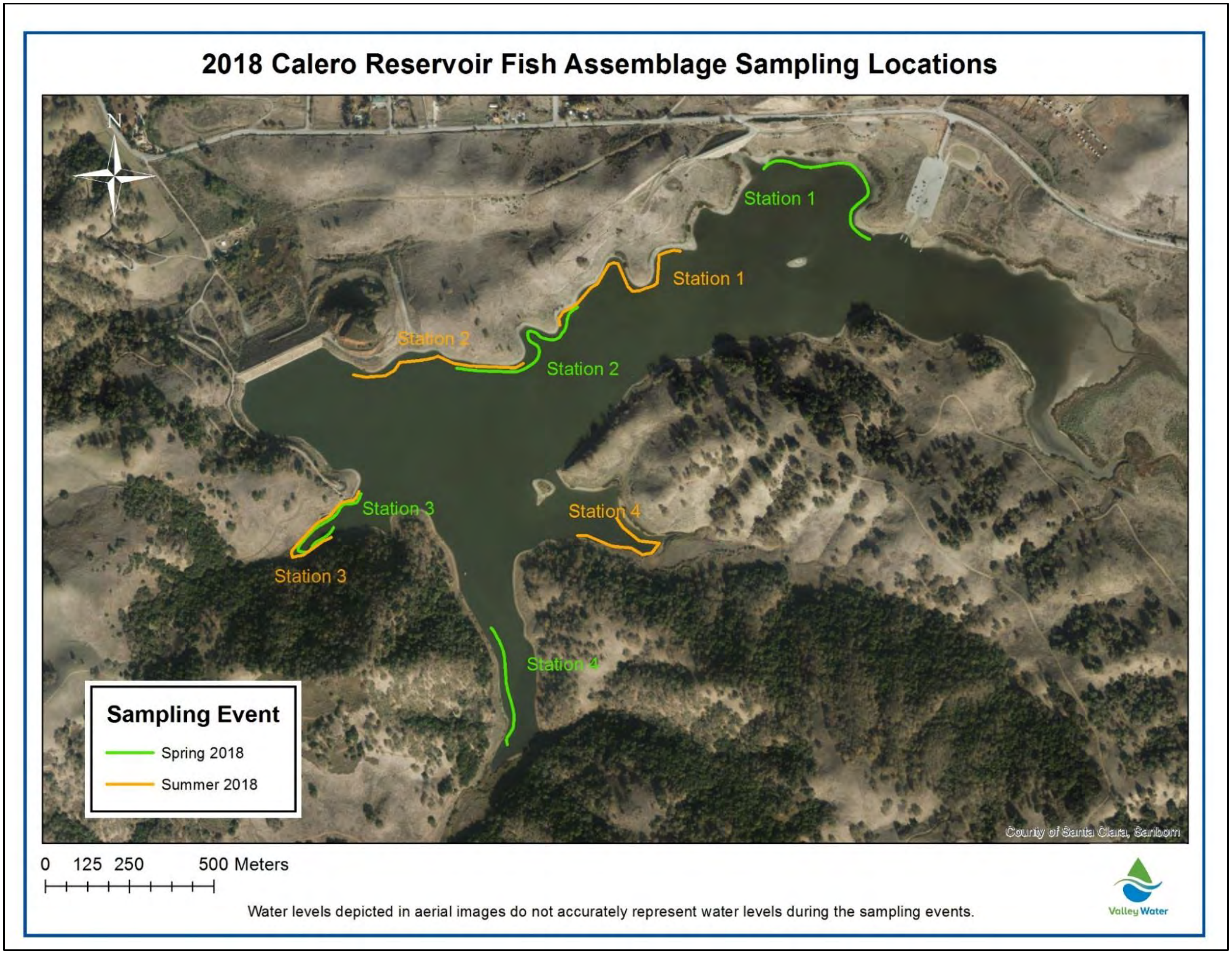

Figure 8: Calero Reservoir sampling locations, spring and summer (2018).

Table 5: Electrofishing captures in Calero Reservoir, spring and summer 2018.

Calero Reservoir Spring Fish Captures (April 19, 2018)													
Station	**Duration (min)**	**Largemouth bass**	**Bluegill**	**Black crappie**	**Threadfin shad**	**Inland silverside**	**Sacramento sucker**	**Tule perch**	**Golden shiner**	**Bigscale logperch**	**Brown bullhead**	**Prickly sculpin**	**Redear sunfish**
1	15	8	2	30	56	1	2	4	0	0	0	0	0
2	15	14	5	12	6	11	0	3	0	0	0	0	0
3	15	17	7	63	3	3	0	8	4	0	0	0	0
4	15	14	12	16	46	19	0	5	2	0	0	0	0
Total	60	53	26	121	111	34	2	20	6	0	0	0	0
CPM		0.88	0.43	2.02	1.85	0.57	0.03	0.33	0.10	0.00	0.00	0.00	0.00
Calero Reservoir Summer Fish Captures (August 30, 2018)													
Station	**Duration (min)**	**Largemouth bass**	**Bluegill**	**Black crappie**	**Threadfin shad**	**Inland silverside**	**Sacramento Sucker**	**Tule perch**	**Golden shiner**	**Bigscale logperch**	**Brown bullhead**	**Prickly sculpin**	**Redear sunfish**
1	15	63	4	3	6	117	1	109	10	6	0	0	0
2	15	58	3	4	16	84	0	110	17	19	1	2	0
3	15	47	10	1	173	17	0	23	10	1	0	0	1
4	15	29	1	1	139	2	0	0	11	0	1	1	2
Total	60	197	18	9	334	220	1	242	48	26	2	3	3
CPM		3.28	0.30	0.15	5.57	3.67	0.02	4.03	0.80	0.43	0.03	0.05	0.05

Total capture of fish in spring was low (n=373) in comparison to summer sampling (n=1,103). Slightly turbid conditions limited the sampling efficiency in spring. Black crappie were the dominant species encountered during the spring sampling event, followed by threadfin shad. The most abundant species captured in summer was threadfin shad, followed by tule perch. Variation in numbers captured between spring and summer occurred for most species. Low occurrence of Sacramento sucker, prickly sculpin, and brown bullhead can be attributed to sampling method bias (discussed previously) and is likely not an indicator of abundance.

The size distribution of collected fish (Figure 9) shows different size (and presumably age) classes of most fish species where multiple individuals were captured. As expected, larger fish were observed in most species (of those collected in both seasons) in the spring sampling event prior to spawning, except in black crappie, bluegill, and Sacramento sucker where smaller fish were not encountered in summer. The overall low detection of Sacramento sucker (n=3) does not provide enough data to draw any conclusions, but it is likely the smaller black crappie and bluegill are using portions of the reservoir that are not sampled using electrofishing or limited reproductive success occurred.

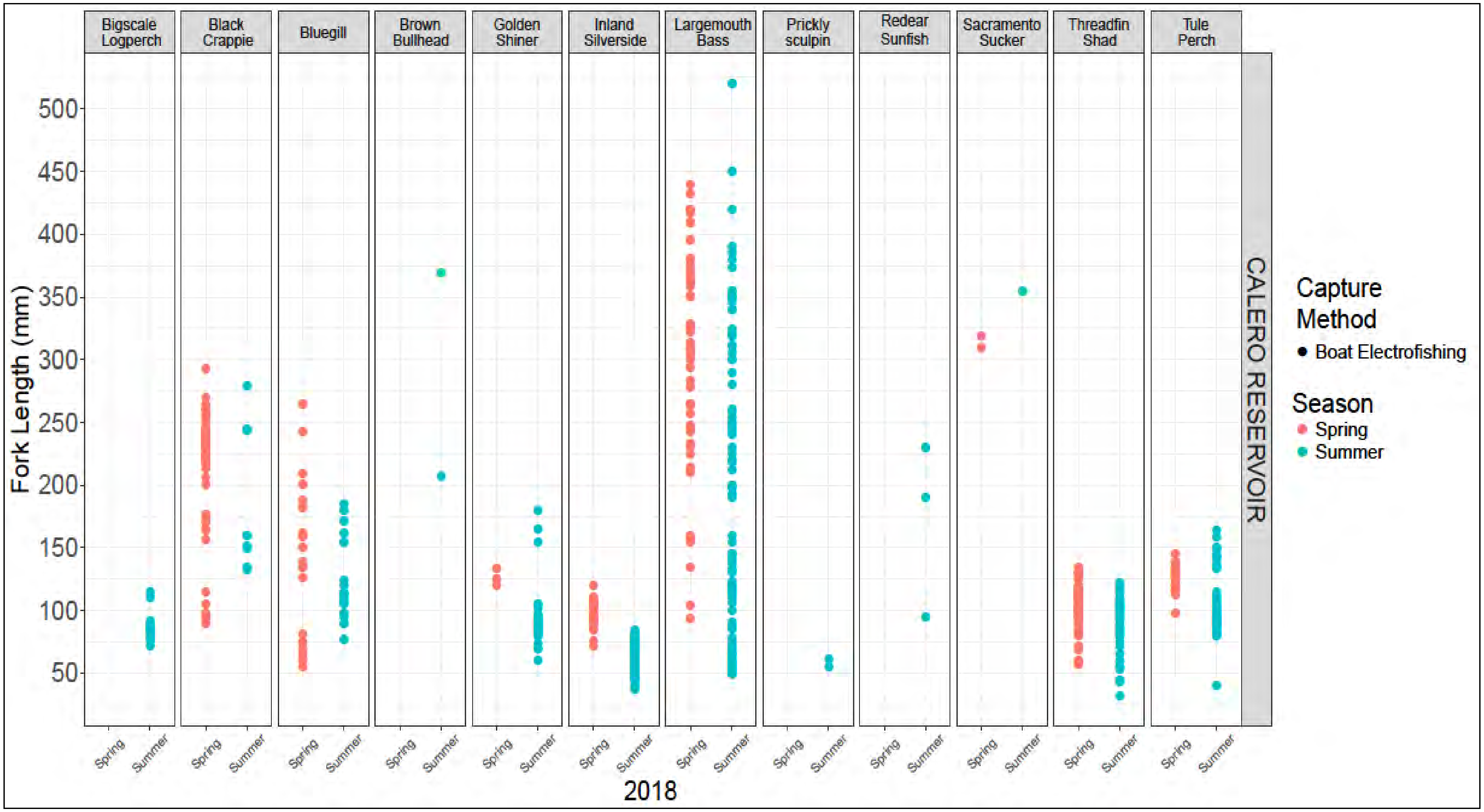

Figure 9: Calero Reservoir fish size distribution in spring and summer 2018.

The size data suggests that tule perch are successfully reproducing in the system. The growth rate of this species is variable by water body (Moyle 2002), but an estimate of reproductive success occurring for at least three years is plausible, as distinct size classes are present and the fluctuation of larger-sized fish in spring vs. summer (after reproduction) occurred. Few young of the year tule perch were observed in summer, potentially indicating that reproduction was limited or this age class is using a different portion of the reservoir not sampled by electrofishing.

The size distribution data for bluegill is as expected in spring, with fish in the size range of one-year old and extending to potentially over five years old (Moyle 2002). Few bluegill were captured in the young of the year size range in summer, and it also seems that between spring and summer sampling survival of one-year old fish may have been low. This potentially indicates that limited reproduction occurred, or young of the year bluegill and fish approaching their second year were using different portions of the reservoir than what was sampled. Similar trends are observed with black crappie. In spring, fish in the upper size range of one-year old fish were observed, while very few fish in the young of the year size range were captured in summer. It is possible that reproduction of bluegill and black crappie had limited success in 2018. The trends of increased collection in spring and limited age structure distribution observed in summer is a trend that was observed in 2016-2017 assemblage report (Valley Water 2018). It appears that the fish are using different portions of the reservoir than sampled by electrofishing during this time period as no clear declining trend in overall abundance of these species is occurring over time.

The size distribution of largemouth bass indicates that successful spawning has occurred over multiple years and the population is doing well. A more detailed analysis of largemouth bass age structure is included later in this document.

Spring and Summer 2019

Spring sampling occurred at Calero Reservoir on April 11, 2019 and summer sampling on August 6, 2019. The summer sampling event occurred approximately a month earlier than it had occurred in the previous three years. Reservoir water surface elevation at the time of the spring survey was 141.2 m (42.5% capacity) and 141.4 m (44.3% capacity) during the summer. Reservoir fluctuations occurred, with drawdowns in November, February, March, and May. The reservoir was never reduced to below 35% and did not exceed 45% capacity. A total of 1,821 linear meters of reservoir margin was sampled at four survey stations in spring, and 2,054 linear meters were sampled at four stations in summer (Figure 10). A small break in the linear transect in station 1 during summer is due to an area of shallow water.

Eleven species were collected in 2019: largemouth bass, bluegill, black crappie, threadfin shad, inland silverside, bigscale logperch, golden shiner, redear sunfish, tule perch, and brown bullhead were collected during both sampling events, with prickly sculpin only captured in spring. Common carp were observed in both surveys, but were not collected to avoid crowding in the livewell. All carp observed were estimated at over 300 mm and potentially exceeded 600 mm. Again, redear sunfish were captured, but pumpkinseed were not detected. Tule perch, Sacramento sucker, and prickly sculpin were the only California native species collected. Total capture data is reported in Table 6, and to standardize the results, data were converted to CPM.

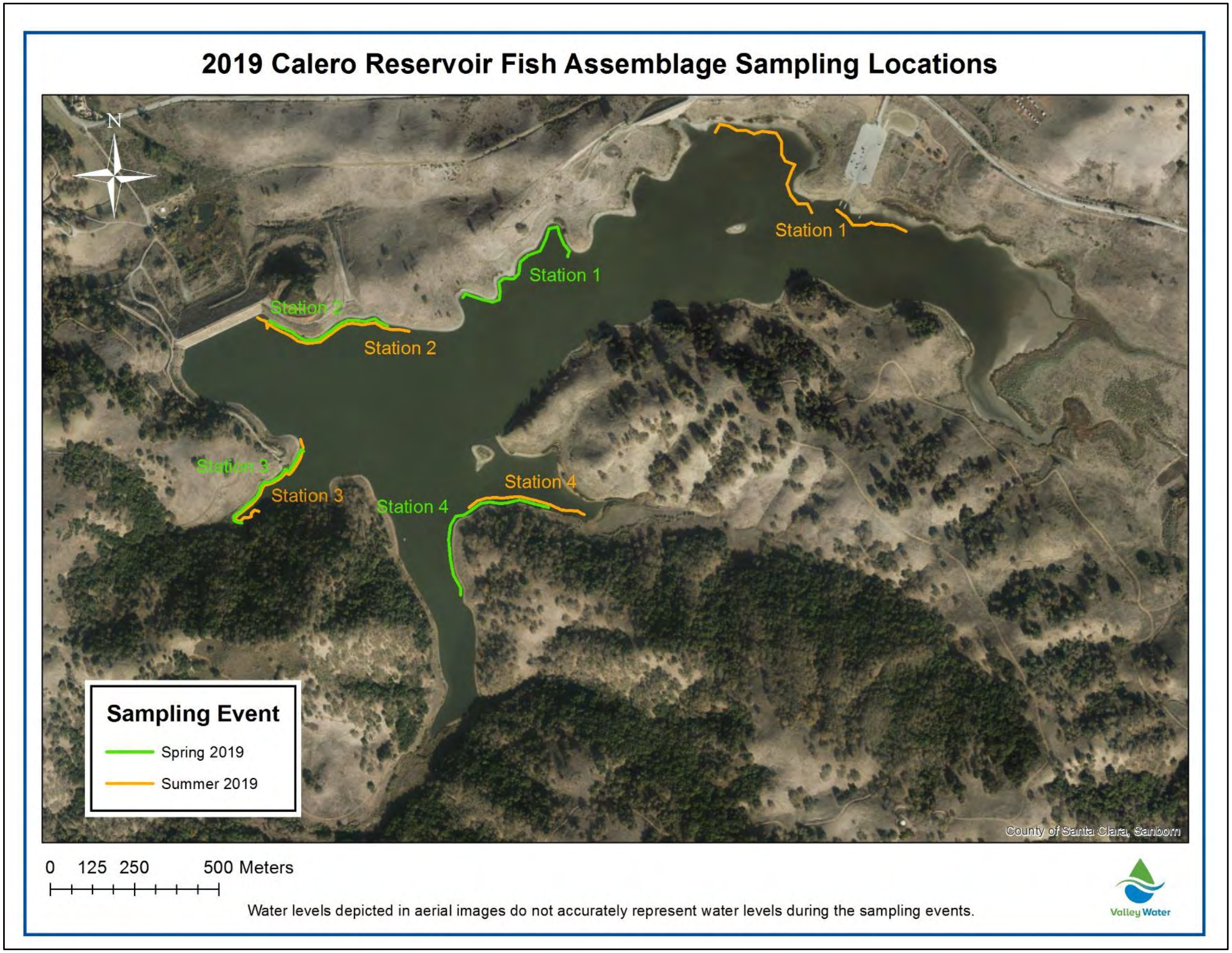

Figure 10: Calero sampling locations, spring and summer (2019).

Table 6: Electrofishing captures in Calero Reservoir, spring and summer 2019.

Calero Reservoir Spring Fish Captures (April 11, 2019)													
Station	**Duration (min)**	**Largemouth bass**	**Bluegill**	**Black crappie**	**Threadfin shad**	**Inland silverside**	**Sacramento sucker**	**Tule perch**	**Golden shiner**	**Bigscale logperch**	**Brown bullhead**	**Prickly sculpin**	**Red-eared sunfish**
1	15	14	32	9	4	11	0	47	0	0	0	0	1
2	15	15	16	6	2	11	0	35	6	1	1	0	8
3	15	16	19	13	22	56	0	59	2	0	0	1	2
4	15	14	15	22	0	2	17	67	1	1	0	0	0
Total		59	82	50	28	80	17	208	9	2	1	1	11
CPM		0.98	1.37	0.83	0.47	1.33	0.28	3.47	0.15	0.03	0.02	0.02	0.18
Calero Reservoir Summer Fish Captures (August 6, 2019)													
Station	**Duration (min)**	**Largemouth bass**	**Bluegill**	**Black crappie**	**Threadfin shad**	**Inland silverside**	**Sacramento sucker**	**Tule perch**	**Golden shiner**	**Bigscale logperch**	**Brown bullhead**	**Prickly sculpin**	**Redeared sunfish**
1	15	33	6	12	18	28	0	13	7	6	0	0	0
2	15	45	6	3	17	5	0	8	6	0	1	0	0
3	15	46	3	5	21	47	0	0	12	3	0	1	2
4	15	62	32	9	23	11	0	6	20	2	1	1	7
Total		186	47	29	79	91	0	27	45	11	2	2	9
CPM		3.10	0.78	0.48	1.32	1.52	0.00	0.45	0.75	0.18	0.03	0.03	0.15

Total capture of fish in spring (n=548) and summer (n=528) were relatively similar. Tule perch was the most frequently captured species during the spring sampling event, followed by bluegill. Largemouth bass were the most frequently captured in summer, followed by inland silverside. As discussed previously, low occurrence of prickly sculpin, brown bullhead, and Sacramento sucker, can likely be attributed to sampling method bias and is not necessarily an indicator of population level. Tule perch were captured at a higher rate than other species in a similar niche (bluegill and black crappie) in spring, but the number captured declined in summer and was similar to black crappie. Bluegill were captured in higher numbers than black crappie or tule perch in summer. Redear sunfish was the least frequently captured sunfish species in spring and summer.

The size distribution of collected fish can be seen in Figure 11. The size distribution shows different size classes for the majority of fish species collected. As expected, larger fish were observed in the spring event prior to spawning in most species, though this was not the case for redear sunfish and tule perch. No young of the year redear sunfish were observed in summer 2019. The size distribution of largemouth bass indicates that successful spawning has occurred over multiple years. A more detailed analysis of largemouth bass age will occur later in this document.

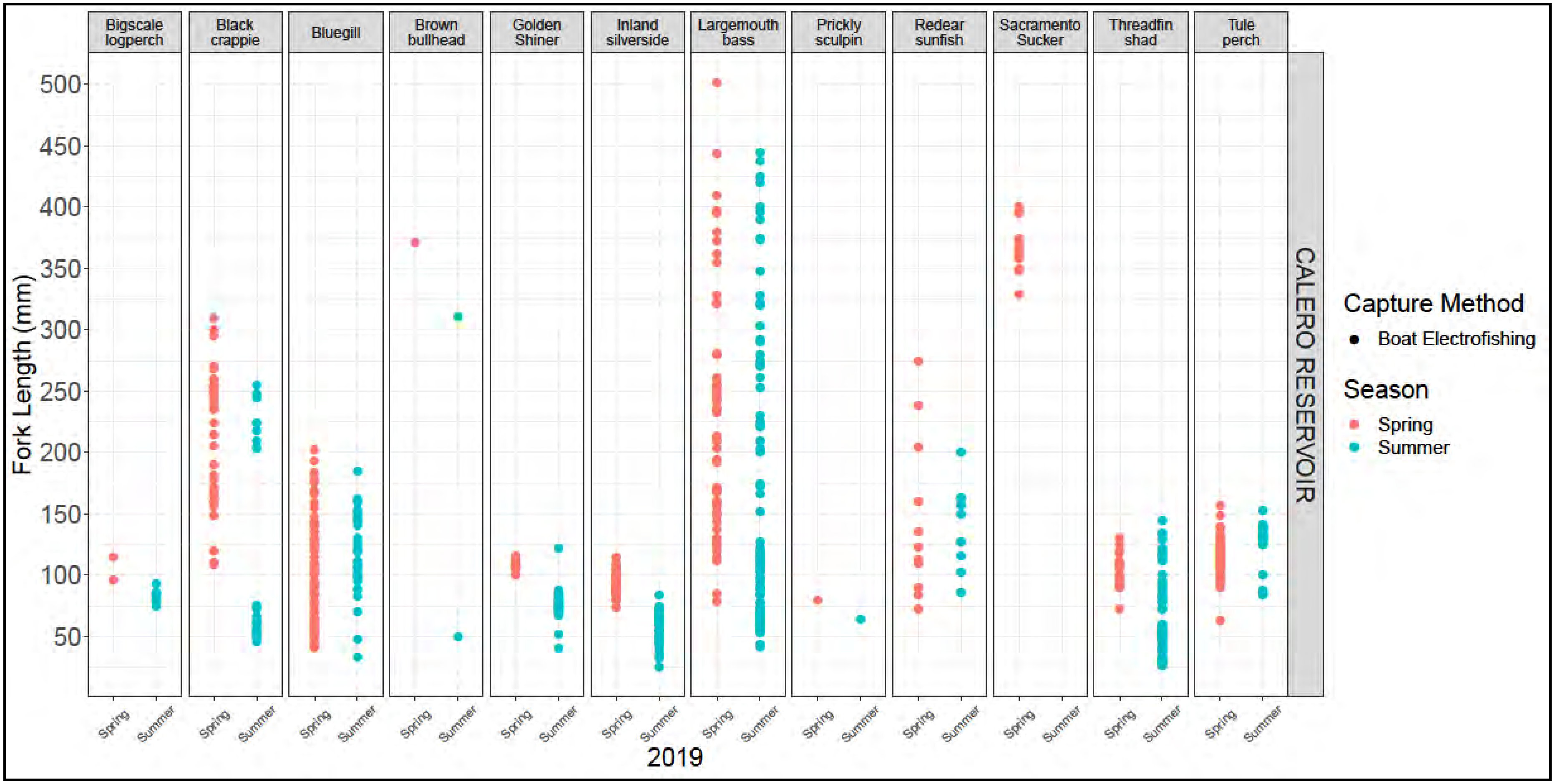

Figure 11: Calero Reservoir fish size distribution in spring and summer 2019.

The size distribution data for bluegill is as expected in spring, with fish in the size range of one-year old and extending into their fifth year (Moyle 2002). Size distribution of bluegill in summer potentially indicates that limited reproduction occurred, or smaller bluegill were using different portions of the reservoir than what was sampled. No bluegill were captured in the young of the year size range defined by Moyle (2002). Similar trends are observed with black crappie. In the summer event, there were few individuals within the young of the year size range as defined by Moyle (2002). This trend was also observed in the 2016 and 2017 monitoring (Valley Water 2018), as well as 2018. Because the spring events indicate multiple age classes, we know survival is occurring and can confidently say that the reduction in number and size classes in the summer sampling event is a result of these species using different portions of the reservoir not sampled via electrofishing. The data continues to suggest that conditions favor growth in predatory species (ex., adequate forage is available), as longevity within individuals is common.

Calero Reservoir Summary

In 2018, spring sampling events had a lower capture rate of fish compared to summer sampling. In 2019, the number of fish captured during each sampling event was relatively the same. The CPM of all sampling events can be seen in Table 7. Calero Reservoir had the most comprehensive and seasonally diverse data set of all reservoirs sampled during the eight-year monitoring period. The data presented in Table 7 is standardized in terms of effort, but does not represent the same season of sampling in every year, so direct comparisons or trends are difficult to determine.

An attempt to standardize the data collection timeframe began in 2016. The 2016 through 2019 results provide more consistent comparisons in terms of seasonal timing. Capture rates of individual species fluctuates with the seasons. It is difficult to determine if these fluctuations are a result of natural abundance cycles within the reservoir, fish habitat use at different times of the year, or physical conditions such as increased turbidity in the reservoir during spring sampling, which could impact netting efficiency or could change fish behavior.

Table 7: Calero Reservoir CPM 2012-2019 (P- present but not quantified).

Sampling Date	Largemouth bass	Bluegill	Black crappie	Pumpkinseed	Common carp	Tule perch	Inland silverside	Prickly sculpin	Bigscale logperch	Green Sunfish	Threadfin shad	Sacramento sucker	Golden shiner	Brown bullhead	Redear sunfish
6/28/2012	1.70	2.30	0.17	0.08	0.05	0.42	0.53	0.18	0.23	0.00	0.42	0.00	0.03	0.00	0.00
11/7/2012	5.37	0.25	0.67	0.05	0.03	0.07	5.35	0.05	0.22	0.00	0.73	0.05	0.17	0.02	0.00
7/31/2013	5.30	0.40	1.33	0.07	0.13	2.98	3.27	0.08	1.08	0.00	2.13	0.00	0.08	0.02	0.00
12/3/2013	6.67	1.85	3.60	0.02	0.10	0.10	11.45	0.07	0.35	0.00	0.45	0.05	0.22	0.02	0.00
4/21/2014	1.23	1.33	5.05	0.00	0.02	0.78	2.90	0.18	0.35	0.00	1.00	0.03	0.00	0.00	0.00
8/7/2014	4.32	1.15	0.78	0.12	0.00	0.85	1.32	0.02	1.00	0.00	0.55	0.02	0.00	0.00	0.00
11/4/2014	9.67	1.02	1.82	0.10	0.02	0.00	0.47	0.10	0.35	0.00	0.15	0.00	0.00	0.00	0.00
10/15/2015	4.62	0.56	0.31	0.27	P	1.38	2.62	0.00	0.20	0.00	3.98	0.02	0.27	0.00	0.00
4/7/2016	0.67	0.82	0.27	0.23	P	1.05	1.43	0.00	0.02	0.03	1.25	0.15	0.15	0.02	0.00
9/13/2016	2.08	0.40	0.22	0.07	P	2.02	0.90	0.02	0.22	0.00	9.80	0.02	0.93	0.00	0.00
4/3/2017	0.80	0.88	1.05	0.07	P	1.68	0.07	0.02	0.12	0.00	2.75	0.00	0.03	0.02	0.00
9/6/2017	2.30	0.48	0.33	0.02	P	0.78	1.63	0.00	0.10	0.00	5.07	0.00	0.97	0.03	0.00
4/19/2018	0.88	0.43	2.02	0.00	P	0.33	0.57	0.00	0.00	0.00	1.85	0.03	0.10	0.00	0.00
8/30/2018	3.28	0.30	0.15	0.00	P	4.03	3.67	0.05	0.43	0.00	5.57	0.02	0.80	0.03	0.05
4/11/2019	0.98	1.37	0.83	0.00	P	3.47	1.33	0.02	0.03	0.00	0.47	0.28	0.15	0.02	0.18
8/6/2019	3.10	0.78	0.48	0.00	P	0.45	1.52	0.03	0.18	0.00	1.32	0.00	0.75	0.03	0.15

The yearly average CPM also does not show any clear trends in terms of increases or declines in individual species occurrence, but does show lower abundance of threadfin shad in 2019 when compared to the 2016-2018 standardized dataset (Figure 12). If the lower number captured was representative of the system, and the results are not affected by sampling bias, the lower population of forage fish could influence mercury accumulation in fishes that eat threadfin shad, potentially shifting diet to more benthic sources that are known to host lesser bioaccumulation (Stewart et al., 2008)

In summer 2018, tule perch had its highest observed CPM, but a reduction was observed between spring and summer of 2019. The overall abundance of fish captured at Calero appears to be remaining stable over time. The addition of redear sunfish, and lack of capture of pumpkinseed, brings to question the potential of misidentification of the species in past years. Future sampling will indicate if both species are still present in the reservoir, but correction of the previous records will not be possible. Aside from the addition of redear sunfish, no major changes to assemblage or abundances were observed during the 2018 and 2019 sampling period.

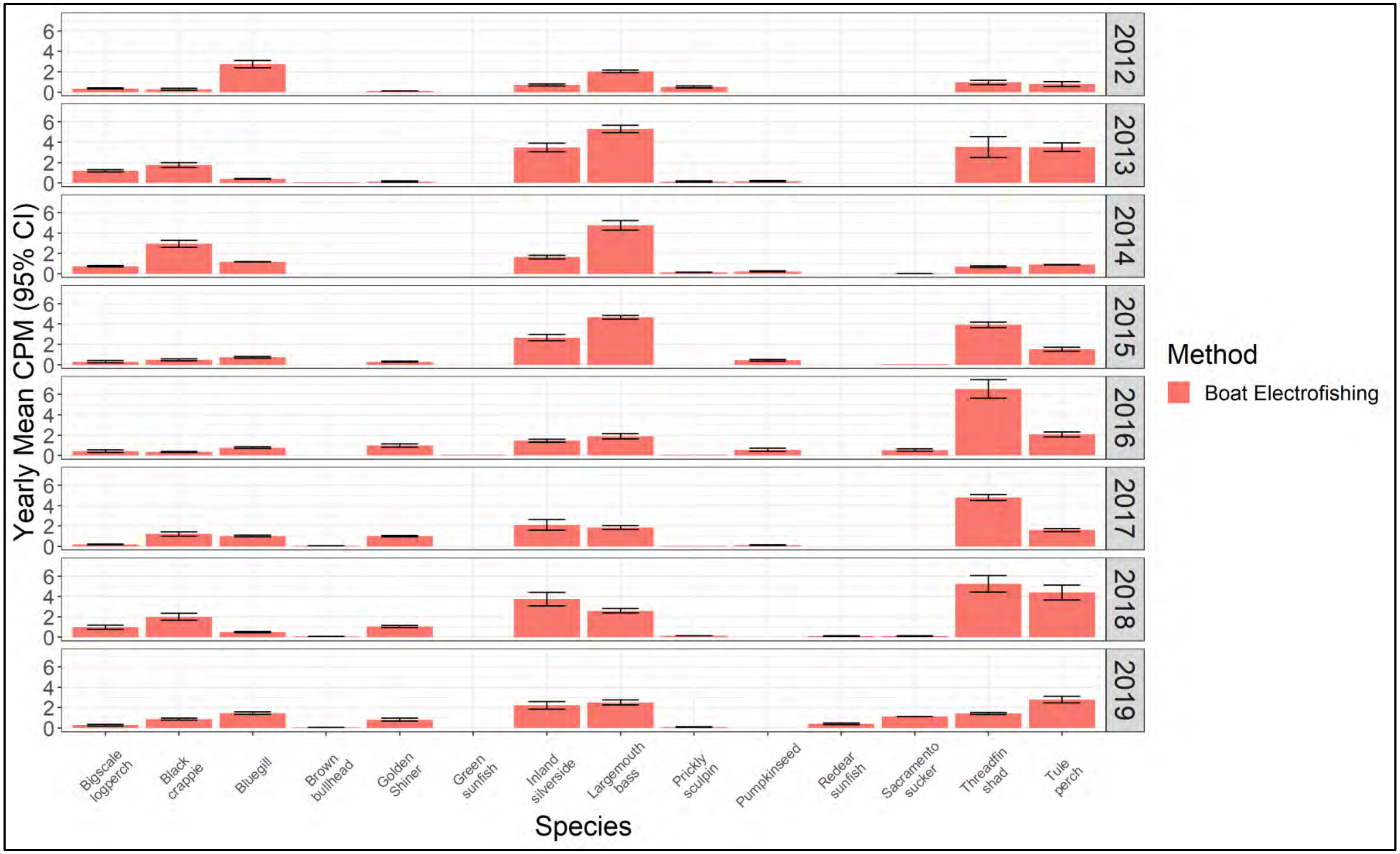

Figure 12: Yearly average CPM Calero Reservoir 2012-2019.

Largemouth Bass Scale Analysis

Size data for largemouth bass in Calero Reservoir in 2018 and 2019 were compared to the scale analysis information collected by Valley Water (Figure 13). The age estimates are based on the average length and standard error of largemouth bass of each age class throughout the Guadalupe Watershed and Stevens Creek Reservoir as evaluated by the analysis (see Table 1). When the age 0+ category (smallest size cohort in the summer sampling events of 2018 and 2019) is evaluated for Calero Reservoir, it shows that largemouth bass tend to fall within the predicted average size. For the spring events, the smallest cohort of largemouth bass is at the higher end of the 0+ size range or just above it, when the seasonal timing puts them closer to the 1+ size range. A predicted growth spurt is observed between the 1+ and 2+ age category, which could be the result of a diet change. This growth is observed in the scale analysis data as well, showing that Calero Reservoir largemouth bass growth is trending with what is observed at sample locations elsewhere in the county. The growth spurt seen between 1+ and 2+ aged fish appears to be greater than the county average. Fish also appear to fall between the 3+ and 4+ size range. These factors could indicate that largemouth bass in Calero Reservoir may have a faster growth rate than those in other reservoirs sampled in the county. This was also observed in 2016 and 2017 (Valley Water 2018). The slight downward shift in size ranges in 2019 could be a result of the earlier sampling timing. The data used for age analysis was collected later in summer, allowing time for more growth. Based on the age analysis conducted within the Guadalupe Watershed, Calero Reservoir largemouth bass range in age from young of the year to fish potentially in their sixth year.

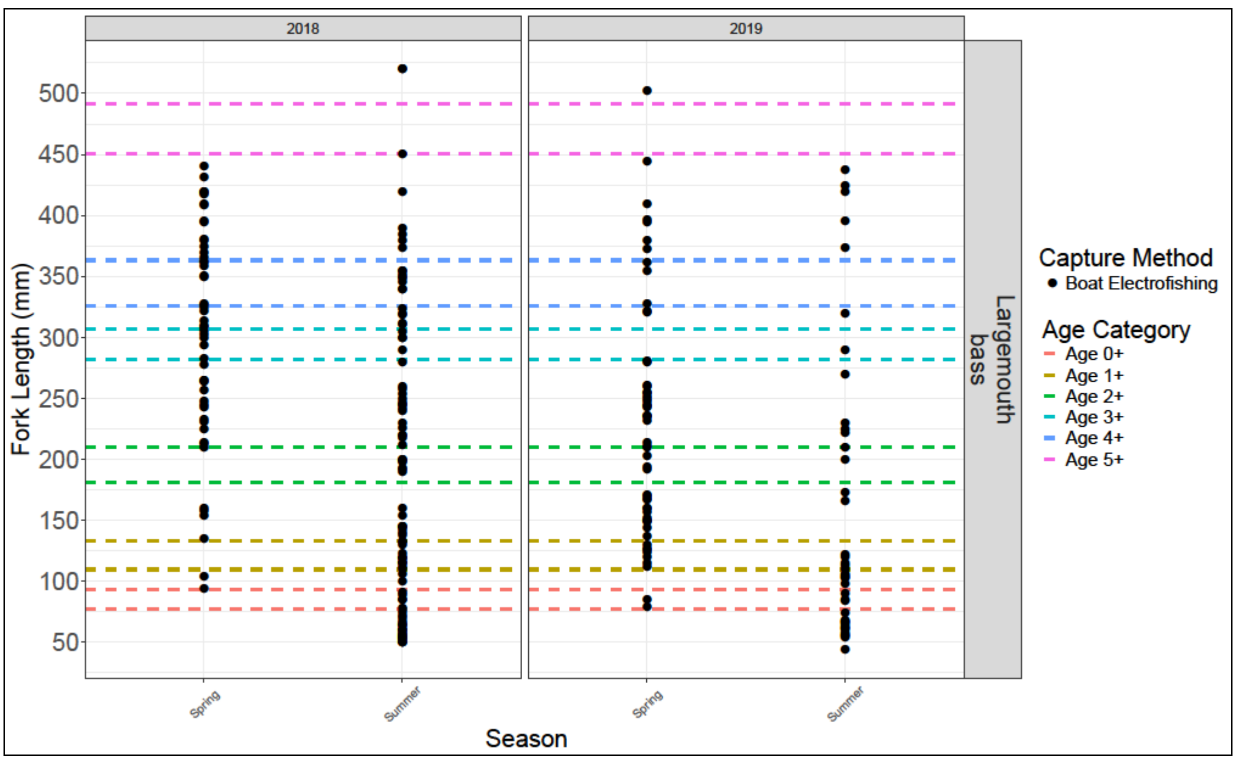

Figure 13: Largemouth bass lengths from Calero Reservoir with age class estimates (2018 and 2019).

Almaden Reservoir

Spring and Summer 2018

Spring sampling occurred on Almaden Reservoir on April 4, 2018 using boat-based electrofishing, and in summer on August 29, 2018 using hook and line sampling. During the spring sampling reservoir water surface elevation was 184.6 m, which is 89.0% capacity. The summer sampling had a water surface elevation of 181.6 m, which is approximately 59.3% capacity. The 2018 dataset has sampling that occurred at both high and low water conditions, but different sampling methods were used. Spring high water conditions allowed for launching of the electrofishing boat. Four sampling stations totaling 1,972 linear meters were sampled along the reservoir margin (Figure 14). The reservoir water surface elevation during the spring event created deeper water conditions along the margin of the reservoir. Depths greater than 3 m were observed within 0.6 m of the wetted edge. This deep water reduces the efficiency of boat-based electrofishing. Seven species were collected: largemouth bass, bluegill, black crappie, pumpkinseed, threadfin shad, rainbow trout, and Sacramento sucker. Rainbow trout and Sacramento sucker are the only native species detected and this was the first detection of these species in this reservoir.

During the summer of 2018, low water surface elevation made it impossible to launch the electrofishing boat. Sampling was conducted using hook and line sampling methods. A total of seven stationary angling stations and three trolling transects covering 2,542 linear meters were sampled. Both sampling methods yielded fish. The primary focus of this sampling was to collect fish for the body burden analysis. Angling methods were not designed to capture fish within all feeding guilds in the reservoir; this sampling method targeted predatory fish. Four species were collected: largemouth bass, bluegill, pumpkinseed, and rainbow trout. Threadfin shad and Sacramento sucker were not expected to be captured via hook and line due to bias associated with the sampling method, but black crappie were targeted and also not captured. Total capture and standardized data is reported in Table 8.

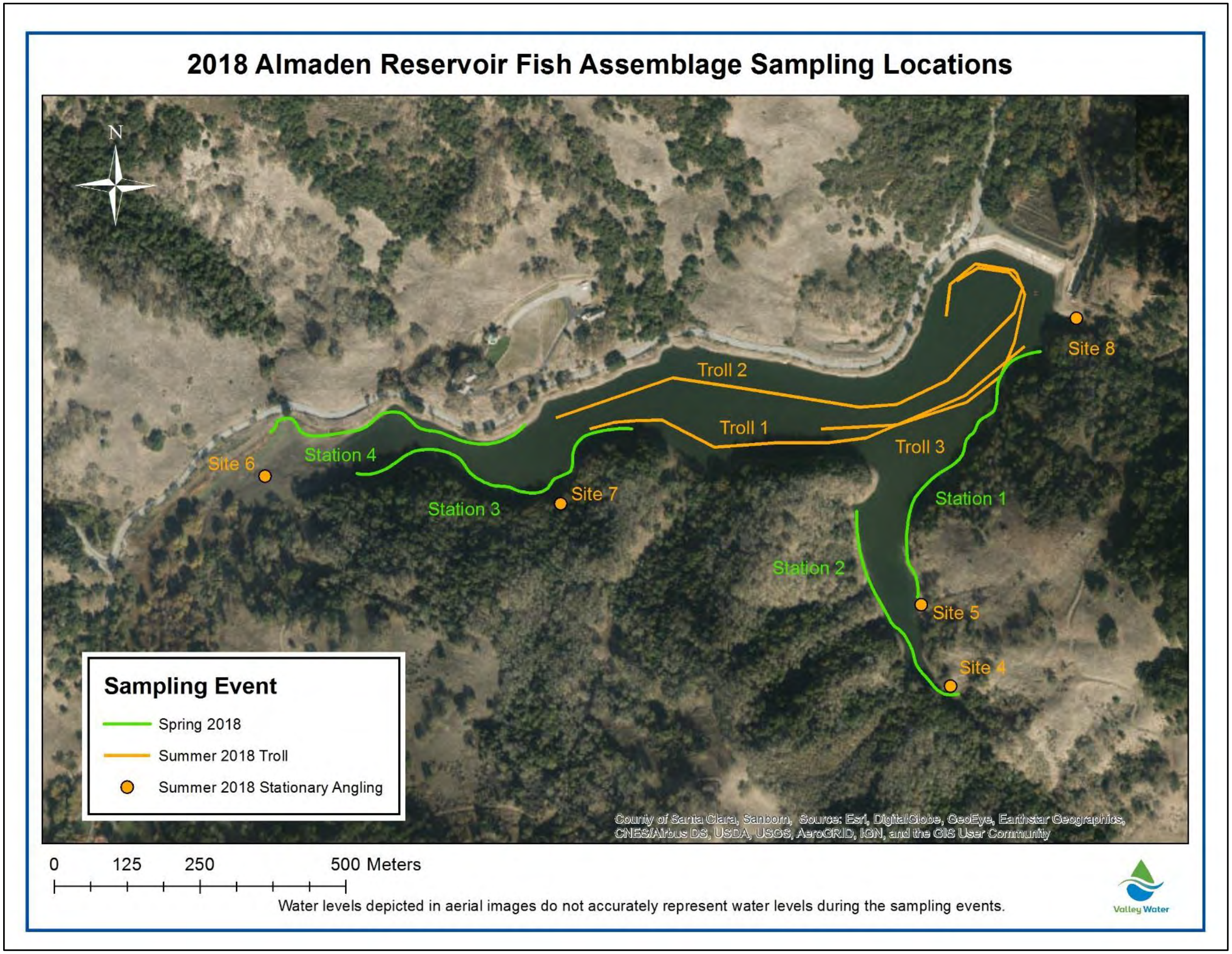

Figure 14: Almaden Reservoir sampling locations spring and summer (2018).

Table 8: Captures in Almaden Reservoir for spring and summer 2018.

Almaden Reservoir Spring Fish Captures (April 4, 2018)								
Station	**Duration (min)**	**Largemouth bass**	**Bluegill**	**Black crappie**	**Threadfin shad**	**Pumpkinseed**	**Sacramento sucker**	**Rainbow trout**
1	15	18	2	2	1	0	1	0
2	15	13	9	4	127	0	0	1
3	15	9	14	8	14	1	7	0
4	15	13	30	17	3	3	2	1
Total	60	53	55	31	145	4	10	2
CPM		0.88	0.92	0.52	2.42	0.07	0.17	0.03
Almaden Reservoir Summer Fish Captures (August 29, 2018)								
Station	**Duration (min)**	**Largemouth bass**	**Bluegill**	**Black crappie**	**Threadfin shad**	**Pumpkinseed**	**Sacramento sucker**	**Rainbow trout**
Troll 1	15	1	0	0	0	0	0	0
Troll 2	15	0	0	0	0	0	0	0
Troll 3	15	1	0	0	0	0	0	1
Site 4	30	24	2	0	0	0	0	0
Site 5	30	17	1	0	0	1	0	0
Site 6	30	7	0	0	0	0	0	0
Site 7	30	12	20	0	0	0	0	0
Site 8	30	12	3	0	0	0	0	0
Total	195	74	26	0	0	1	0	1
CPM		0.38	0.13	0.00	0.00	0.01	0.00	0.01

Capture rates during the spring electrofishing sampling event were low. The effectiveness of electrofishing was limited due to high reservoir surface elevation, which due to the steep reservoir margins cause areas of deep water near the reservoir margins. Poor water clarity associated with spring runoff also influenced capture efficiency due to not being able to see the fish. Because these conditions reduce effectiveness of electrofishing sampling, the low capture rates are not necessarily indicative of population levels. Threadfin shad were the most abundant species encountered in the spring, followed by largemouth bass and bluegill. The summer hook and line sampling event had a higher capture rate of largemouth bass than any other species. This is as expected, as this method has certain biases, and as mentioned previously, was specifically designed to capture fish for the body burden analysis. During both the summer and spring events, black crappie and pumpkinseed had the lowest capture rate of the non-native predatory fish. These fish may use different portions of the reservoir not sampled by electrofishing or angling, or potentially make up the smallest proportion of the community. Because electrofishing is conducted at night and angling was conducted during the day, some species may have been using different areas in the reservoir based on the time of day. Rainbow trout were captured in both spring and summer, which indicates the potential of an adfluvial population within the reservoir.

Figure 15 shows the size distribution of collected fish. Different age classes of largemouth bass and bluegill are apparent in both spring and summer, but due to bias associated with the hook and line sampling method in summer, size distribution is not accurately depicted. Even with the shift of sampling methods between spring and summer, the presence of young of the year largemouth bass in summer is apparent. This anticipated shift towards smaller fish in summer after spawning was not observed in bluegill or pumpkinseed and can likely be attributed to the switch to hook and line sampling. The gape size of bluegill in the young of the year size range, and potentially one-year old fish, limits detection by hook and line sampling. The low capture rates of black crappie and pumpkinseed make determining age distribution difficult. Based on size distributions in the literature (Moyle 2002), black crappie caught in spring were young of the year and third or fourth year fish, with no intermediate age classes detected. Based on the literature (Moyle 2002), it appears pumpkinseed from two years of age to fish extending past their fourth year were present. The presence of bluegill can influence the size and spatial distribution of pumpkinseed, as bluegill competition can influence feeding habits. Due to the high abundance of bluegill, small pumpkinseeds may be forced to use more open water habitats not sampled via electrofishing. The size distribution of bluegill in spring shows fish ranging in age from their first year to fish potentially in their fifth year. In summer, bluegill again were observed potentially into their fifth year, but as mentioned above, smaller fish were not encountered due to the method of capture. The size distribution of largemouth bass indicates that successful spawning occurred in the reservoir. A more detailed analysis of largemouth bass size will be discussed later in this document.

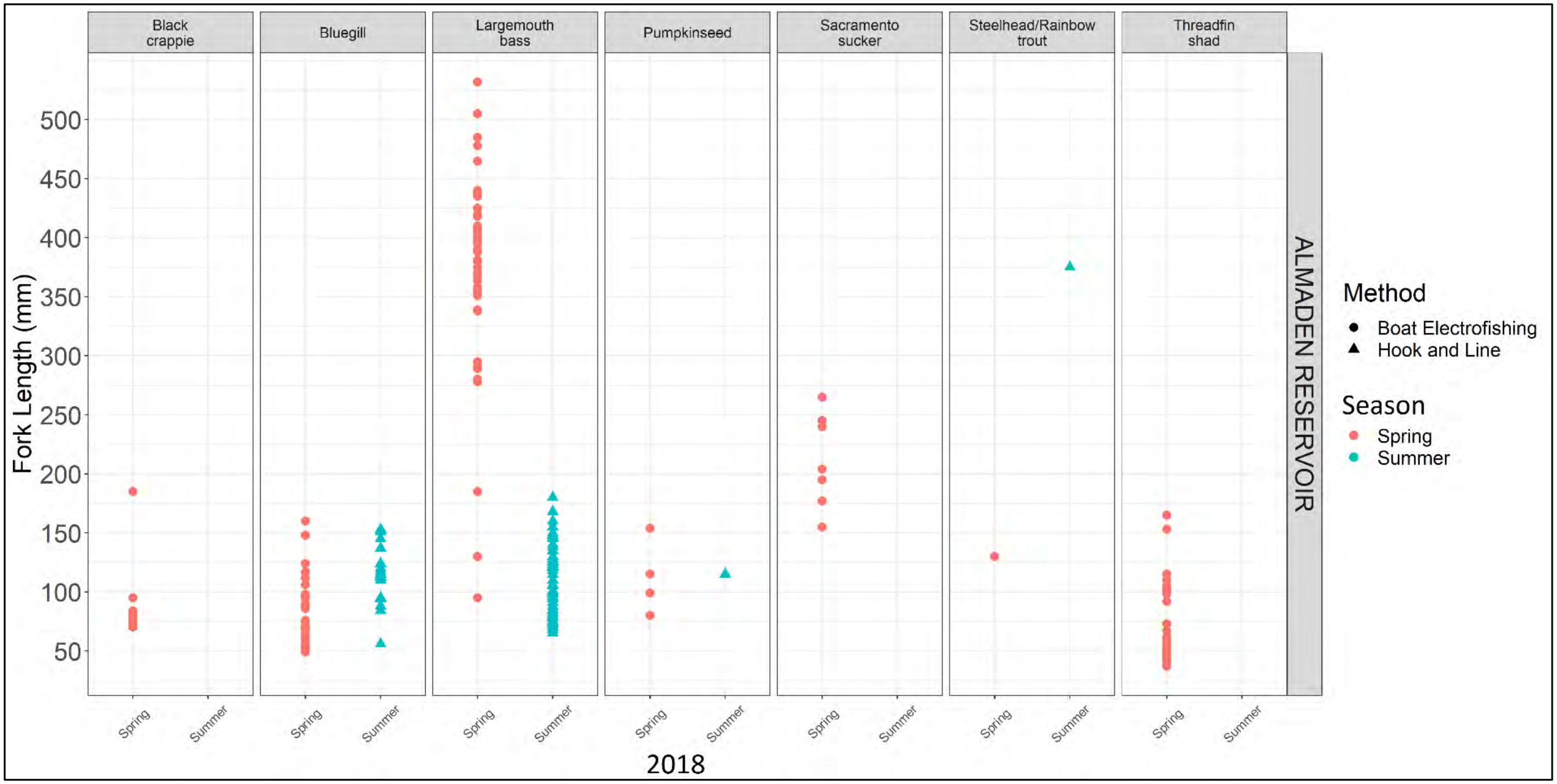

Figure 15: Almaden Reservoir fish size distribution in spring and summer 2018.

The rainbow trout collected in spring (130 mm FL), is expected to be in its first or second year. It is likely this fish migrated into the reservoir from upstream tributaries (Jacques Gulch and Herbert Creek) during the spring high flows. The rainbow trout collected during the hook and line sampling in summer was 375 mm FL, which according to Moyle (2002) would be over 3 years old. This fish would be considered adult size and was over-summering in the reservoir, further suggesting an adfluvial population.

Spring and Summer 2019

Sampling occurred on Almaden Reservoir in spring on April 2, 2019 and in summer on June 18, 2019 using boat-based electrofishing. The spring sampling event had a water surface elevation of 184.7 m, which is approximately 90.0% capacity. The summer sampling event had a water surface elevation of 183.9 m, which is approximately 81.0% capacity. The 2019 dataset had sampling that occurred at relatively high water conditions in both sampling periods. Sampling in summer occurred approximately a month earlier than the 2016-2018 timeframe, which allowed for boat electrofishing to be used in both spring and summer. Four sampling stations totaling 1,635.6 linear meters were sampled in spring and four stations totaling 1,469.4 linear meters were sampled in summer along the reservoir margin (Figure 16). Ten species were collected: largemouth bass, bluegill, black crappie, pumpkinseed, threadfin shad, brown bullhead, inland silverside, prickly sculpin, Sacramento sucker, and rainbow trout. Prickly sculpin, Sacramento sucker, and rainbow trout were the only native species encountered. 2019 was the first documented occurrence of both brown bullhead and inland silverside in Almaden Reservoir. CPM and total catch for both sampling events can be seen in Table 9.

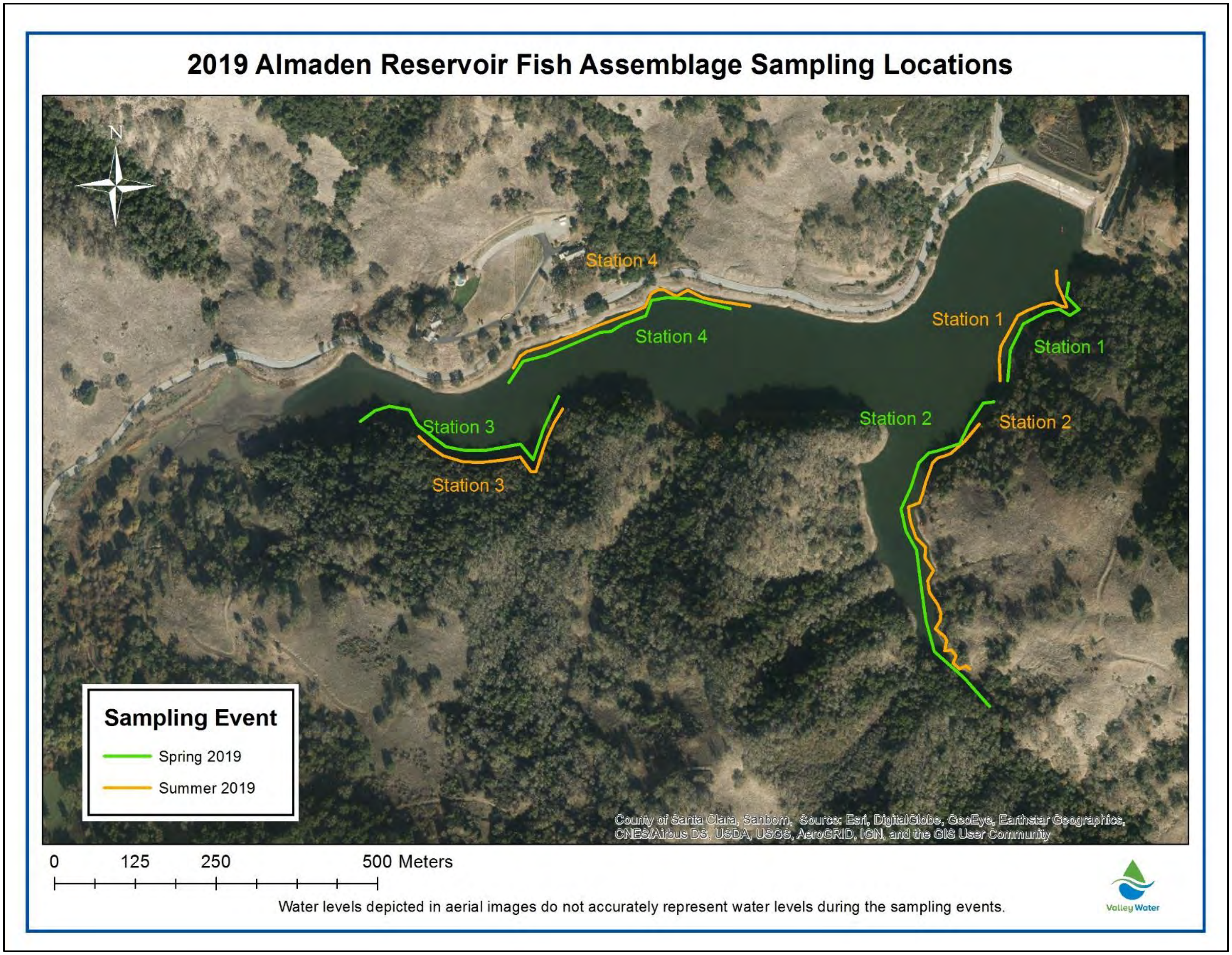

Figure 16: Almaden Reservoir sampling locations, spring and summer (2019).

Table 9: Captures in Almaden Reservoir for spring and summer 2019.

Almaden Reservoir Spring Fish Captures (April 2, 2019)											
Station	**Duration (min)**	**Largemouth bass**	**Bluegill**	**Black crappie**	**Threadfin shad**	**Prickly sculpin**	**Sacramento sucker**	**Pumpkinseed**	**Rainbow trout**	**Brown bullhead**	**Inland silverside**
1	15	14	45	6	1	2	0	0	0	0	0
2	15	13	19	1	0	0	0	0	1	0	0
3	15	8	20	5	1	0	0	1	0	0	0
4	15	13	23	8	28	0	2	0	0	0	0
Total	60	48	107	20	30	2	2	1	1	0	0
CPM		0.80	1.78	0.33	0.50	0.03	0.03	0.02	0.02	0.00	0.00
Almaden Reservoir Summer Fish Captures (June 18, 2019)											
Station	**Duration (min)**	**Largemouth bass**	**Bluegill**	**Black crappie**	**Threadfin shad**	**Prickly sculpin**	**Sacramento sucker**	**Pumpkinseed**	**Rainbow trout**	**Brown bullhead**	**Inland silverside**
1	15	29	37	1	0	1	0	4	0	1	1
2	15	19	46	0	0	1	0	1	0	0	0
3	15	32	56	3	1	1	0	3	0	0	1
4	15	32	64	1	2	0	0	5	0	2	0
Total	60	112	203	5	3	3	0	13	0	3	2
CPM		1.87	3.38	0.08	0.05	0.05	0.00	0.22	0.00	0.05	0.03

In spring, effectiveness of electrofishing was limited due to the high reservoir surface elevation which caused deep reservoir margins, and rainwater inflow resulted in poor water clarity. This resulted in lower capture rates compared to summer sampling. The summer reservoir elevations were also high, but shallower shoals and margins were present. During the spring event a total of 211 fish were captured, with bluegill being the most common, followed by largemouth bass. In summer, a total of 344 fish were captured and again, bluegill and largemouth bass were the most abundant. All other species made up a small percentage of the total capture.

The size distribution of captured fish shows different age classes of largemouth bass, bluegill, and black crappie in both sampling events and indicates that successful reproduction occurred (Figure 17). Size data associated with pumpkinseed, prickly sculpin, Sacramento sucker, brown bullhead, inland silverside, and rainbow trout does not provide useful information in terms of population dynamics due to low sample size as well as many of these species only being collected in one sampling event.

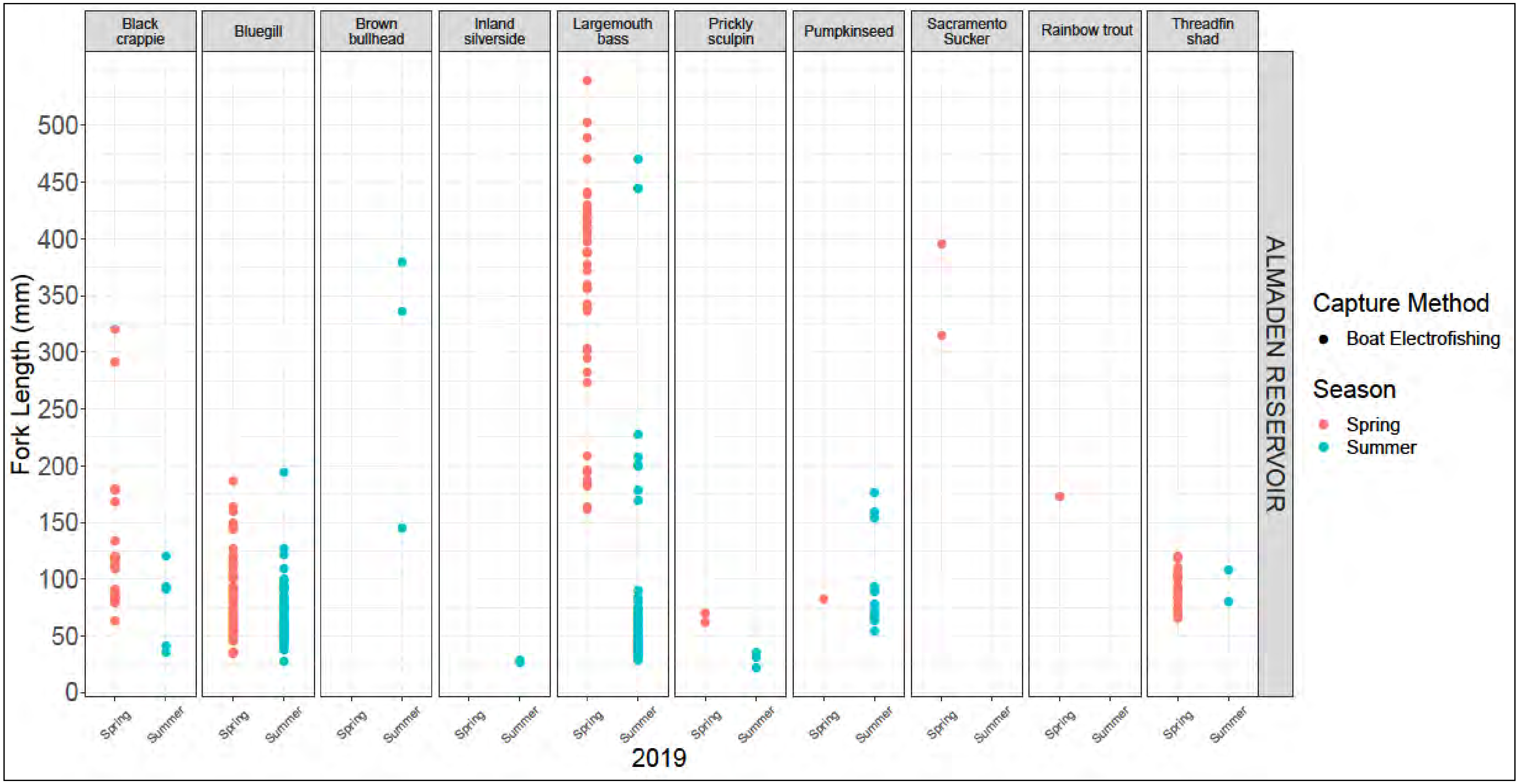

Figure 17: Almaden Reservoir fish size distribution in spring and summer 2019.

Based on the literature (Moyle 2002), young of the year-sized black crappie (40-80 mm) were present in summer. This shows that reproduction occurred in 2019. Multiple age classes of black crappie were present in spring, with fish potentially up to their fourth year.

As in 2018, no young of the year-sized pumpkinseeds were collected in spring, and the possibility that bluegill competition could potentially be influencing feeding habits and position in the reservoir is still plausible. Based on the literature, it appears the pumpkinseed collected in summer were likely in their second year and potentially over four years of age (Moyle 2002). The size distribution in bluegill does not show a clear size variation between age classes until fish exceed 100 mm. There is a slight distinction between the smallest size class of bluegill between spring and summer, potentially indicating successful reproduction and presence of young of the year fish. The size distribution of bluegill in spring shows fish in their first year, that extend potentially into their fifth year. In summer, bluegill size data shows similar results with fish in the young of the year size range extending potentially to the fifth year.

The size distribution of largemouth bass indicates that successful spawning occurred in the reservoir. A more detailed analysis of largemouth bass size will be discussed later in this document. The rainbow trout collected in spring (173 mm FL), is likely in its second year. As mentioned previously, it is possible this fish migrated into the reservoir from upstream tributaries during spring high flows and may have over-summered.

Almaden Reservoir Summary

The 2018 and 2019 fish assemblages were similar, but notably four species not observed during prior years were detected. The variation in methods among years makes year to year comparison difficult (Table 10). The spring 2018 sampling event had the first documented occurrence of Sacramento sucker and rainbow trout, and the 2019 summer sampling documented the first occurrence of brown bullhead and inland silverside. The wet winters of 2017-2019 may have caused downstream movement of the native species, resulting in their presence in the samples. The occurrence of brown bullhead does not necessarily indicate that this species was not previously present in the reservoir, as sampling method bias could have contributed to the lack of detection in prior years. The collection of inland silverside for the first time is an interesting development. It is likely that this is the first year of occurrence of this species as it is often readily collected via electrofishing due to its more pelagic nature. The low number of inland silverside collected also indicates that this may be the start of the species establishment in the system, or it might be a single year occurrence. This species could have been transferred by fisherman using inland silversides as bait, or via bird from Calero Reservoir. The addition of this species, if it becomes established, could influence the food web by adding an additional low trophic level forage fish, increasing trophic linkages and mercury bioaccumulation (Cabana et al., 1995).

When the CPM data from all sampling events is compared, no clear trends emerge (Figure 18). Capture rates of individual species fluctuate with the seasons, year to year, and by methods. The shift in methods make comparisons over time difficult. The yearly average CPM showed an increase in threadfin shad production in spring 2018, the highest capture rate of bluegill in summer 2019, and the second highest capture rate of largemouth bass in summer 2019. It appears the increase in largemouth bass might be attributed to the sampling timing, as the next highest year on record was also sampled in July.

Table 10: Almaden Reservoir CPM 2012, 2015-2019 (P - present but not quantified).

Sampling Date	Largemouth bass	Bluegill	Black crappie	Common carp	Threadfin shad	Pumpkinseed	Prickly sculpin	Sacramento sucker	Rainbow trout	Brown bullhead	Inland silverside
7/19/2012	1.95	0.20	1.17	P	0.02	0.00	0.00	0.00	0.00	0.00	0.00
10/15/2015*	0.63	0.02	0.00	P	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3/22/2016	0.60	1.48	0.08	P	0.98	0.10	0.00	0.00	0.00	0.00	0.00
9/2/2016 and 9/8/2016*	0.38	0.19	0.01	P	0.00	0.01	0.00	0.00	0.00	0.00	0.00
4/11/2017	0.60	1.92	0.03	P	0.08	0.05	0.02	0.00	0.00	0.00	0.00
9/1/2017*	0.27	0.08	0.004	P	0.00	0.12	0.00	0.00	0.00	0.00	0.00
4/4/2018	0.88	0.92	0.52	P	2.42	0.07	0.00	0.17	0.02	0.00	0.00
8/29/2018*	0.35	0.12	0.00	P	0.00	0.00	0.00	0.00	0.01	0.00	0.00
4/2/2019	0.80	1.78	0.33	P	0.50	0.02	0.03	0.03	0.02	0.00	0.00
7/18/2019	1.87	3.38	0.08	P	0.05	0.22	0.05	0.00	0.00	0.05	0.03

*Hook and line sampling methods used.

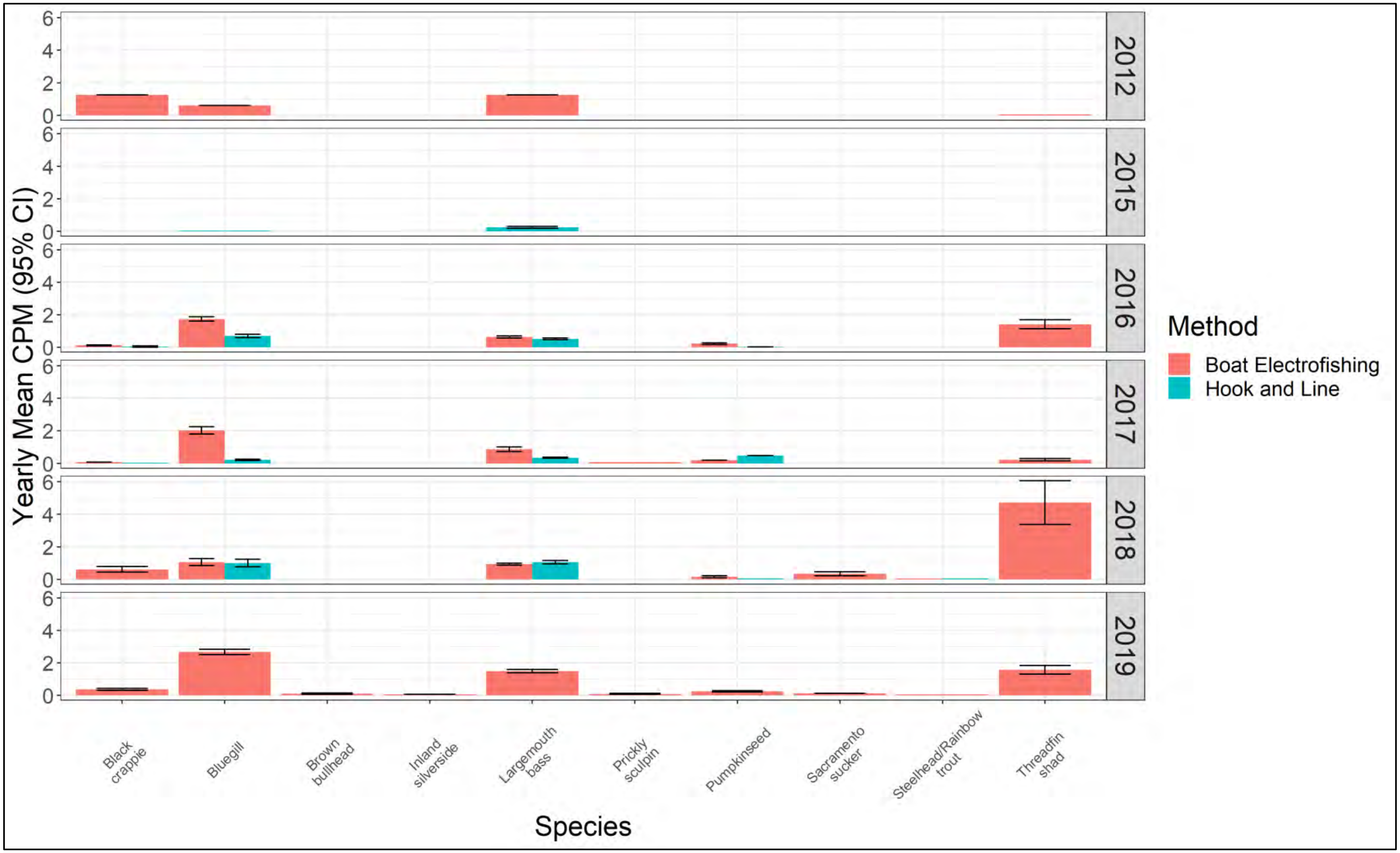

Figure 18: Yearly average CPM for Almaden Reservoir 2012-2019 (no sampling occurred 2013-2014).

Largemouth Bass Scale Analysis

Size data for largemouth bass in Almaden Reservoir in 2018 and 2019 were compared to the scale analysis information collected by Valley Water (Figure 19). The age estimates are based on the average and standard error of largemouth bass lengths in each age class throughout sampled reservoirs in the county (Table 1). This dataset is more difficult to interpret than those from reservoirs where boat electrofishing was the exclusive sampling method, due to sampling method bias. When the 2018 age 0+ category (smallest size cohort in the summer sampling event) is evaluated, it shows that largemouth bass tended to fall within the predicted average size, but there is limited size distribution between fish that would be considered young of the year (0+) and fish in their first year. This is not seen in summer 2019, as most largemouth bass fell below the young of the year predicted size range. This could be influenced by the earlier sampling period or growth rates may have been slower than in previous years. In spring 2019, no largemouth bass in the young of the year or 1+ size range were captured. This could influence the body burden analysis, as samples that were taken may be older than in previous years or at other reservoirs. There is also a large cluster of fish in spring of both years that fall between the 4+ and 5+ age range. It is difficult to determine if we are seeing slower growth of older fish or faster growth of younger fish. Based on the age analysis conducted within the Guadalupe Watershed, Almaden Reservoir has largemouth bass ranging in age from young of the year to fish potentially in their sixth year.

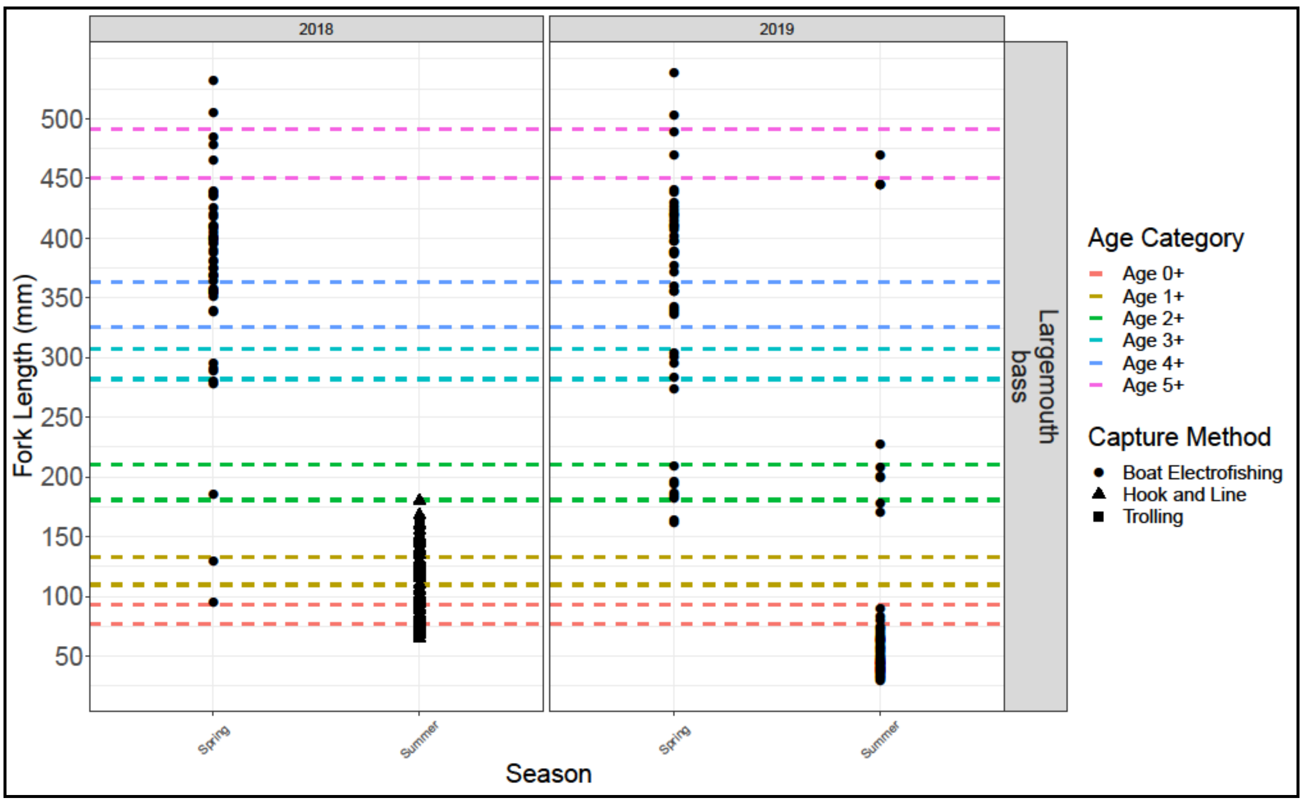

Figure 19: Largemouth bass lengths from Almaden Reservoir with age class estimates (2018 and 2019).

Stevens Creek Reservoir

Spring and Summer 2018

Stevens Creek Reservoir was sampled on April 17, 2018 and September 4, 2018. Reservoir water surface elevation at the time of the spring sampling was 157.5 m (55.7% capacity) and summer sampling was 153.7 m (32.0% capacity). A total of 1,646.8 linear meters in spring and 1,826.6 linear meters in summer of reservoir margin was sampled (Figure 20). Four species were collected in spring: largemouth bass, bluegill, black crappie, and rainbow trout. Common carp were observed but not collected to avoid overcrowding the livewell. Four species were also collected in summer: largemouth bass, bluegill, black crappie, and Sacramento sucker. Again, common carp were observed, but not collected. Sacramento sucker and rainbow trout were the only native species encountered during the sampling effort. No new species were encountered during this sampling period. Total capture data for each sampling station and CPM are reported in Table 11.

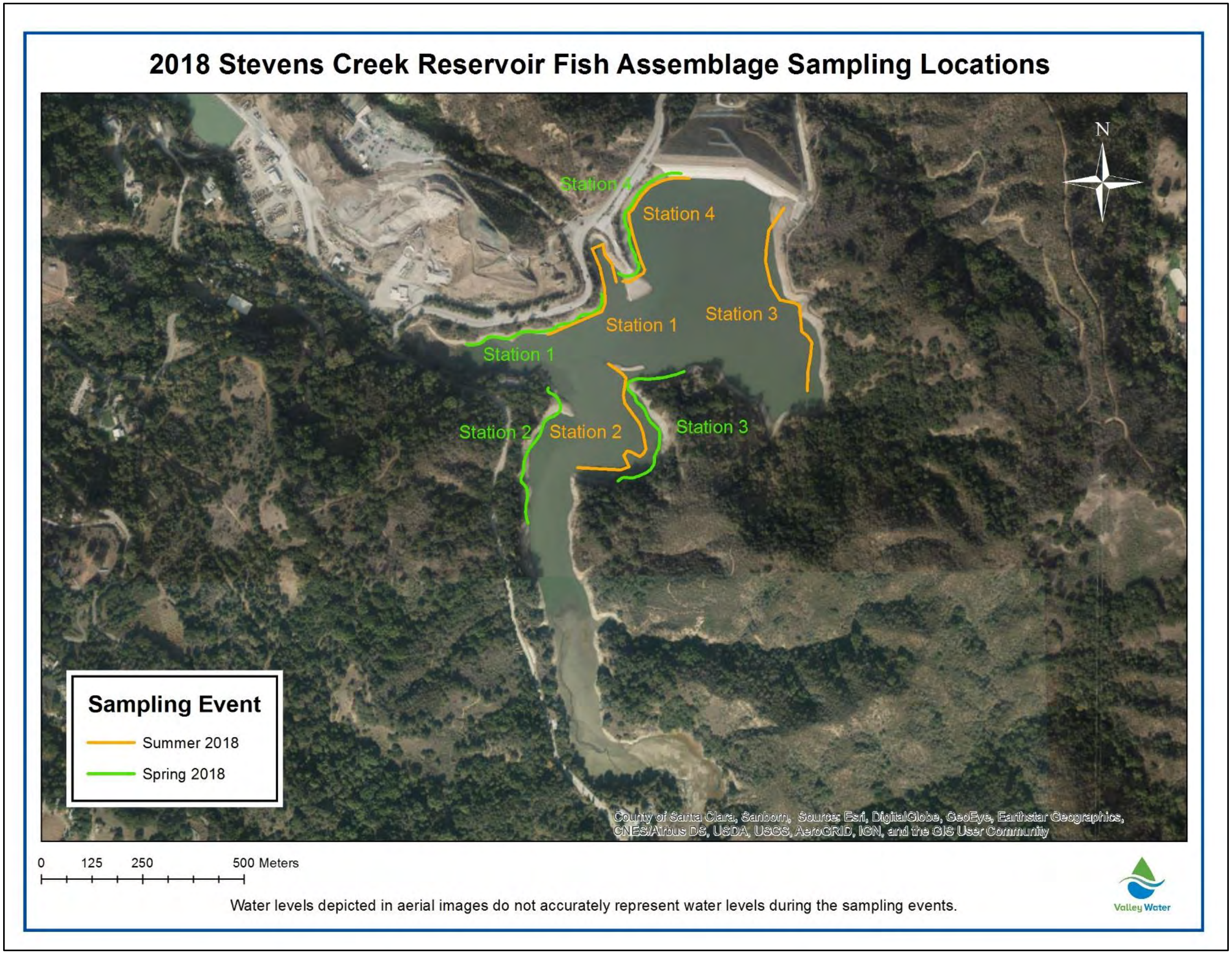

Figure 20: Stevens Creek Reservoir sampling locations spring and summer (2018).

Table 11: 2018 Stevens Creek Reservoir capture table for spring and summer sampling events.

Stevens Creek Reservoir Spring Fish Captures (April 17, 2018)						
Station	Duration (min)	Largemouth bass	Bluegill	Black crappie	Rainbow trout	Sacramento sucker
1	15	4	112	37	0	0
2	15	5	144	18	1	0
3	15	10	108	35	0	0
4	15	5	89	13	1	0
Total	60	24	453	103	2	0
CPM		0.40	7.55	1.72	0.03	0.00
Stevens Creek Reservoir Summer Fish Captures (September 4, 2018)						
Station	**Duration (min)**	**Largemouth bass**	**Bluegill**	**Black crappie**	**Rainbow trout**	**Sacramento sucker**
1	15	23	130	3	0	1
2	15	21	196	13	0	2
3	15	17	179	9	0	1
4	15	12	198	8	0	0
Total	60	73	703	33	0	4
CPM		1.22	11.72	0.55	0.00	0.07

Bluegill were the most frequently captured species by a large margin during both sampling events. Sacramento sucker and rainbow trout made up a small percentage of fish captured. The total number of fish captured in summer (n=813) was much higher than in spring (n=582). The higher total number in the summer is expected as the summer sampling occurs after spring spawning and more young of the year fish are present.

Figure 21 shows the size distribution of fish collected in 2018. Different age classes of largemouth bass and bluegill are evident in both sampling events, but black crappie size distribution was limited in spring. All but one black crappie were greater than 140 mm in spring. The smaller black crappie fell into a size category that indicates it was at the end of its first year. In summer, the size distribution shows multiple age classes were present, and either young of the year fish were not captured, or they tend to be on the larger side of what is stated in the literature.

The size distribution of bluegill and largemouth bass in summer indicates that successful spawning occurred in 2018. The size distribution data for bluegill indicates that fish range in size from young of the year to fish potentially in their fifth year (Moyle 2002). A more detailed analysis of largemouth bass age will occur later in this document.

Growth rates of Sacramento sucker are highly variable (Moyle 2002). There is a potential that Sacramento sucker over 350 mm are over seven years old. The two rainbow trout collected were likely in their second year. As in Guadalupe and Almaden Reservoirs, it is likely these fish migrated into the reservoir from upstream tributaries (Stevens Creek) during spring high flows. The occurrence of rainbow trout, now in multiple years, provides potential insight into life history of the landlocked rainbow trout population above Stevens Creek Reservoir. There is a potential of adfluvial life histories occurring within the system.

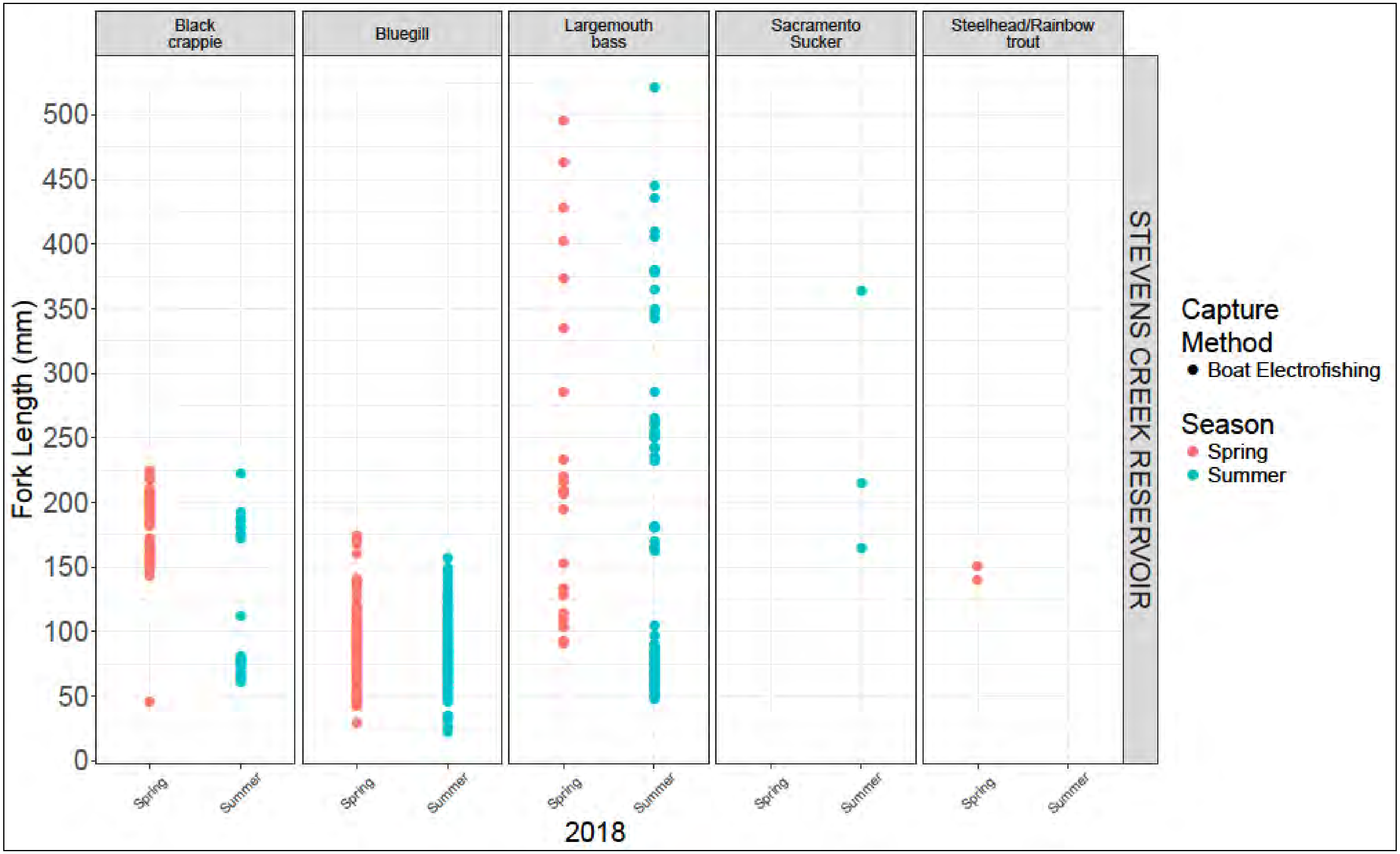

Figure 21: Stevens Creek Reservoir fish size distribution in spring and summer 2018.

Spring and Summer 2019

Stevens Creek Reservoir was sampled on April 3, 2019 and August 5, 2019. Reservoir water surface elevation at the time of the spring sampling event averaged 163.0 m (99.1% capacity) 161.3 m (83.9% capacity) in the summer sampling. A total of 1,825.8 linear meters in spring and 2,001.9 linear meters in summer of reservoir margin was sampled at four sampling stations (Figure 22). Five species were collected in spring: largemouth bass, bluegill, black crappie, Sacramento sucker, and rainbow trout. Four species were collected in summer: largemouth bass, bluegill, black crappie, and Sacramento sucker. Again, common carp were observed both years, but not collected. Sacramento sucker and rainbow trout were the only native species encountered during the sampling effort. This was the third consecutive year that rainbow trout were collected during the spring sampling event. Total capture data for each sampling station and CPM are reported in Table 12.

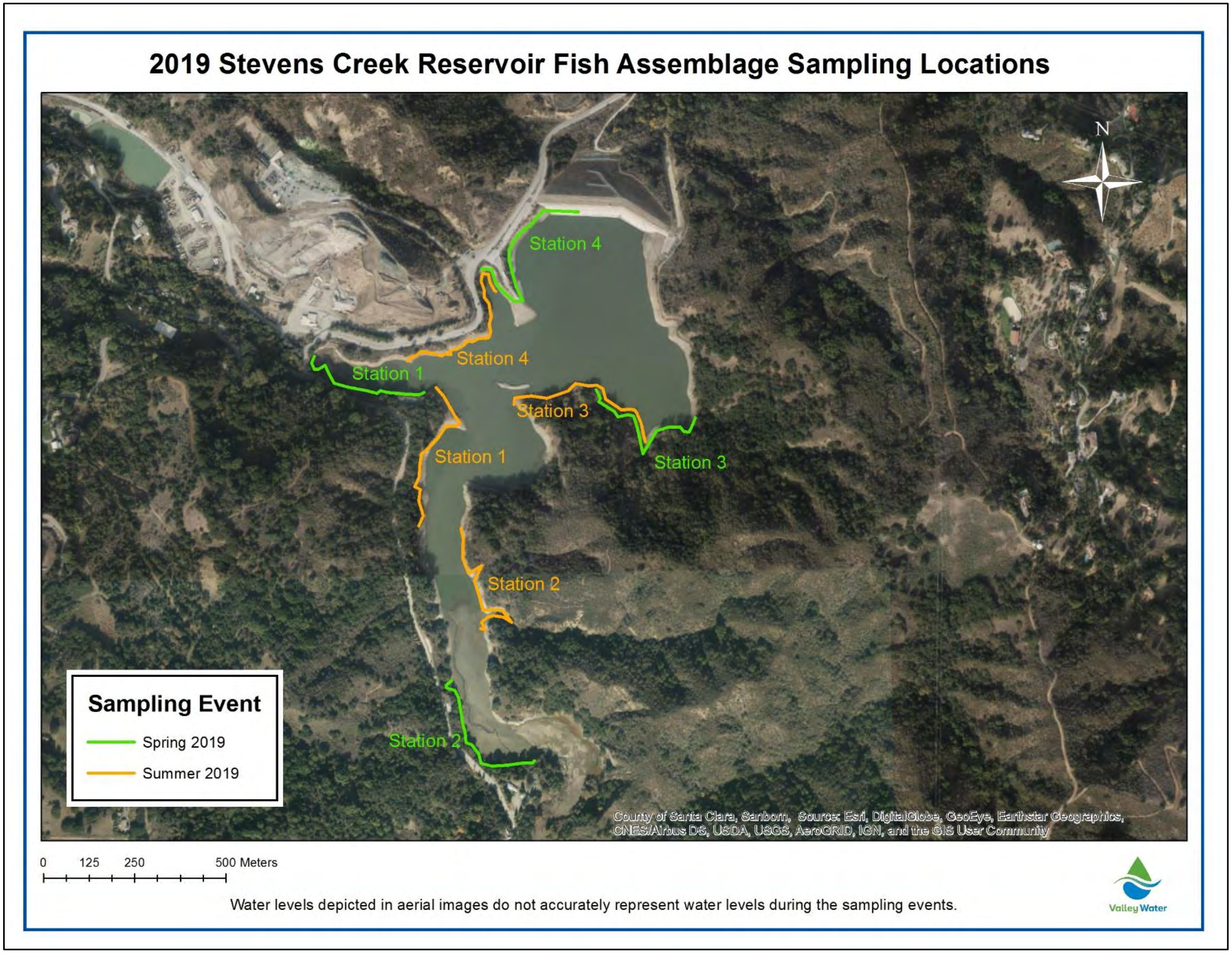

Figure 22: Stevens Creek Reservoir sampling locations, spring and summer (2019).

Table 12: 2019 Stevens Creek Reservoir capture table for spring and summer sampling events.

Stevens Creek Reservoir Spring Fish Captures (April 3, 2019)						
Station	**Duration (min)**	**Largemouth bass**	**Bluegill**	**Black crappie**	**Rainbow trout**	**Sacramento sucker**
1	15	4	33	3	3	0
2	15	6	64	22	4	0
3	15	4	29	25	0	4
4	15	5	5	17	0	0
Total	60	19	131	67	7	4
CPM		0.317	2.183	1.117	0.117	0.067
Stevens Creek Reservoir Summer Fish Captures (August 5, 2019)						
Station	**Duration (min)**	**Largemouth bass**	**Bluegill**	**Black crappie**	**Rainbow trout**	**Sacramento sucker**
1	15	31	61	16	0	0
2	15	52	128	19	0	2
3	15	30	86	46	0	2
4	15	32	35	21	0	3
Total	60	145	310	102	0	7
CPM		2.417	5.167	1.700	0.000	0.117

Bluegill were the most abundant species during both sampling events, followed by black crappie in the spring and largemouth bass in the summer. Sacramento sucker and rainbow trout made up a small percentage of fish captured. The total number of fish captured in summer (n=564) was more than double what was captured in spring (n=228). While higher numbers of fish are expected in the summer, the high water surface elevation of the reservoir in spring and the associated deep water around the margins was likely a contributing factor, limiting electrofishing efficiency. The seven rainbow trout collected in spring is the highest number of this species collected at any of the reservoirs sampled under this monitoring protocol.

The size distribution of collected fish (Figure 23) shows different age classes of largemouth bass and bluegill in both sampling events, but black crappie size distribution was limited in spring. The same trend of black crappie greater than 140 mm, seen in spring 2018, was again observed in spring 2019; this size range indicates fish that are potentially in their fourth year. In summer, the size distribution indicates black crappie ranging in age from young of the year to fish potentially in their fourth year. This indicates that smaller-sized black crappie are likely using areas of the reservoir not sampled during the spring events. The size distribution of bluegill and largemouth bass in summer indicates that successful spawning occurred in 2019. A more detailed analysis of largemouth bass age is provided later in this document.

The size distribution data for bluegill is as expected in spring, with fish in the one year size range to fish extending potentially into their sixth year. In summer, bluegill were collected ranging in age from young of the year to fish potentially in their fifth or sixth year (Moyle 2002). The rainbow trout captured were likely in their second year, and their presence further confirms the potential of an adfluvial population.

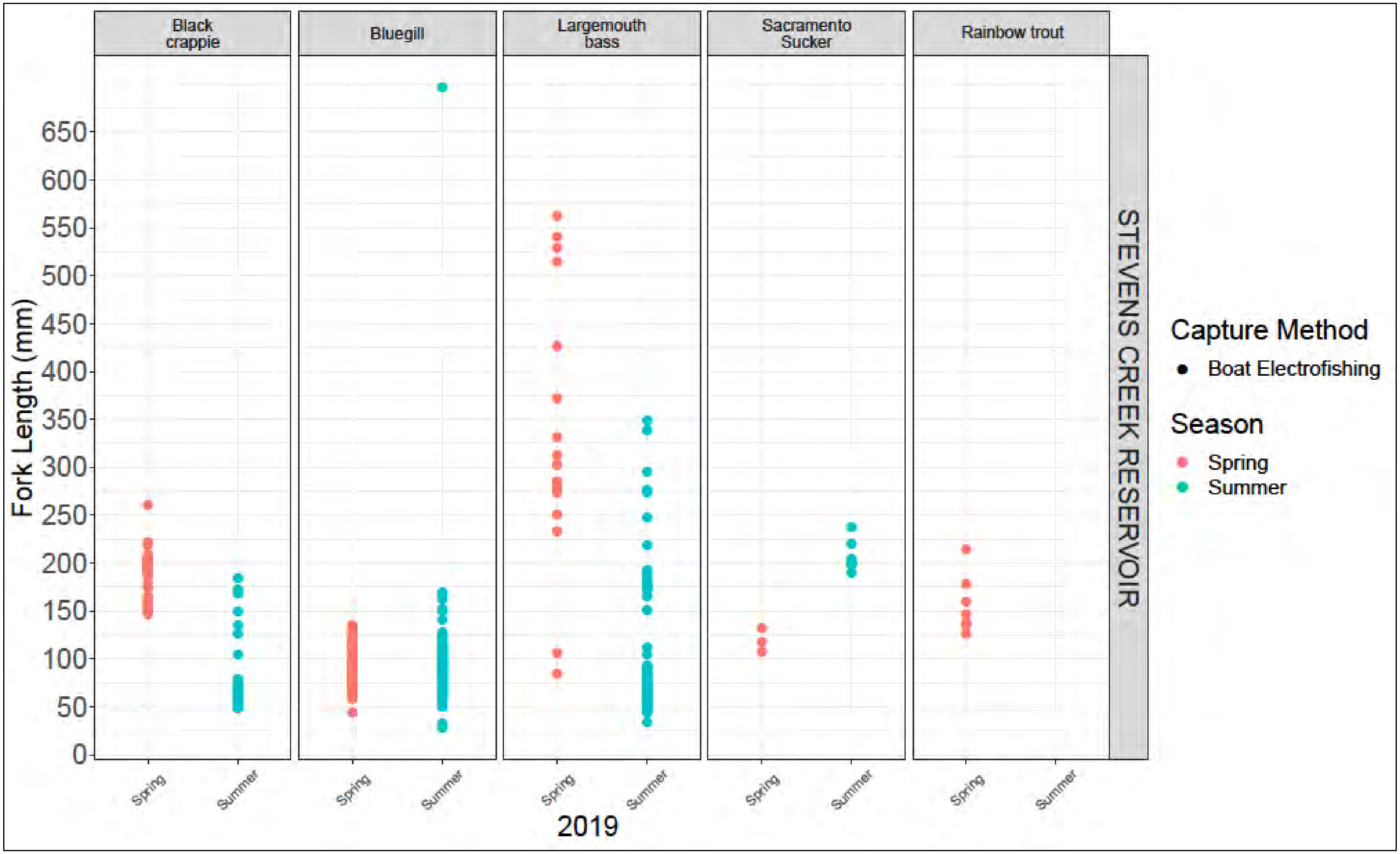

Figure 23: Stevens Creek Reservoir fish size distribution in spring and summer 2019.

Stevens Creek Reservoir Summary

In Stevens Creek Reservoir, bluegill made up the majority of the catch, followed by largemouth bass and black crappie (Table 13). In every sampling event, Sacramento sucker and white catfish were either a very small percentage of the species encountered or not present. This is expected due to electrofishing bias associated with those specific species. The reoccurrence of rainbow trout in 2018 and 2019 (in addition to 2017, when the species was first detected) provides potential insight into life history of an *O. mykiss* population above Stevens Creek Reservoir, indicating the potential of an adfluvial population.

The variation in seasonal timing of sampling events over the years makes a direct comparison of each sampling event difficult. When yearly average CPM over the entire sampling period of primary species encountered (largemouth bass, bluegill, and black crappie) is compared, limited change in capture rate has been observed (Figure 24). The higher capture of bluegill compared to other species in each sampling event could be a result of abundance, but is also a result of life history traits indicated earlier in this document.

Data suggest the trophic distribution within Stevens Creek Reservoir is limited. No prey fish species are observed that effectively bridge the gap between the phytoplankton and zooplankton and primary predators. No forage fish (inland silverside, threadfin shad, etc.) were present. Only trophic level three or higher fish (Fishbase 2019) were captured. In this system, it is predicted that cannibalism and predation between higher trophic level species (e.g., largemouth bass eating juvenile largemouth bass) is occurring. The juvenile predatory fish are likely the link between phytoplankton and zooplankton and adult predatory fish. This lack of lower trophic level species as potential prey could be causing a shortened food chain, which could influence mercury accumulation.

Table 13: Stevens Creek Reservoir CPM 2012-2013, 2015-2019 (P - present but not quantified). Sampling did not occur in 2014.

Sampling Dates	Largemouth bass	Bluegill	Black crappie	Common carp	Sacramento sucker	White catfish	Rainbow trout
5/24/2012	0.13	0.38	0.02	0.00	0.00	0.00	0.00
6/21/2012	5.20	9.62	0.53	0.20	0.10	0.00	0.00
8/9/2012	3.25	0.28	0.12	0.00	0.12	0.02	0.00
6/26/2013	1.30	7.53	0.45	0.20	0.03	0.02	0.00
10/7/2015	1.87	3.89	1.93	0.13	0.02	0.00	0.00
4/12/2016	0.43	3.03	0.25	P	0.00	0.00	0.00
9/6/2016	0.95	11.33	0.75	P	0.03	0.02	0.00
4/19/2017 and 4/24/2017	0.40	6.78	0.97	P	0.03	0.00	0.02
9/12/2017	1.12	14.33	0.15	P	0.03	0.02	0.00
4/17/2018	0.40	7.55	1.72	P	0.00	0.00	0.03
9/4/2018	1.22	11.70	0.55	P	0.07	0.00	0.00
4/3/2019	0.32	2.18	1.12	P	0.07	0.00	0.12
8/5/2019	2.42	5.20	1.70	P	0.12	0.00	0.00

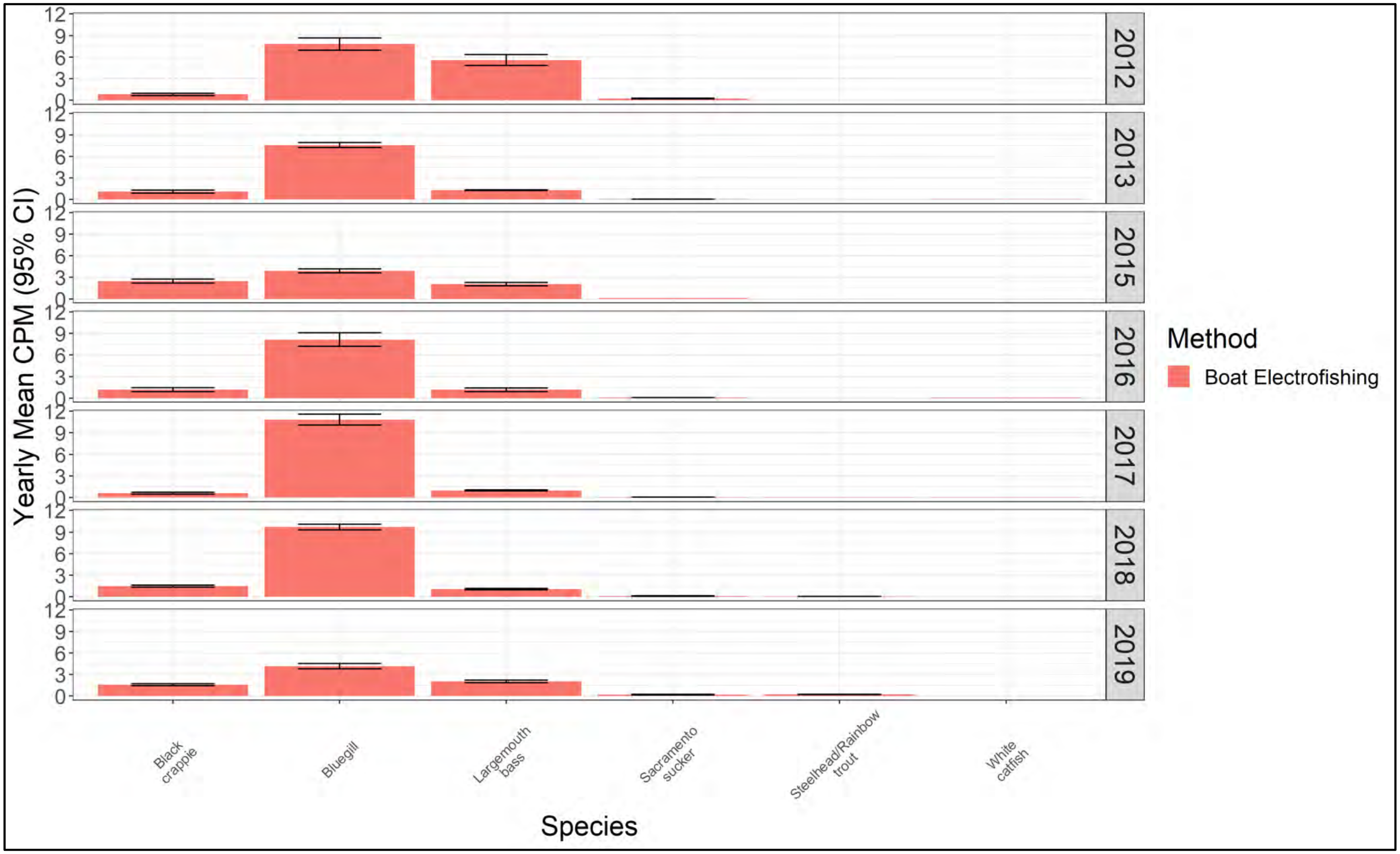

Figure 24: Yearly average CPM for Stevens Creek Reservoir, 2012-2019 (no sampling occurred 2014).

Largemouth Bass Scale Analysis

Figure 25 shows the lengths of largemouth bass from 2018 and 2019 with the age estimates from Valley Water scale analysis overlaid. The age estimates are based on the average length and standard error of largemouth bass of each age class throughout reservoirs sampled as part of the monitoring effort in Santa Clara County as evaluated by the analysis (see Table 1). When the age 0+ category (smallest size cohort in the summer sampling event) is evaluated, it shows that most largemouth bass tend to fall below the predicted average size. Fish in the size cohort that would be estimated at age 1+ due to seasonal timing (smallest fish in spring sampling event) tend to fall slightly below the predicted size range as well. In both years, a size cluster falls between the 2+ and 3+ and the 3+ and 4+ age category. This could indicate potential stunting. Based on the age analysis conducted within the Guadalupe Watershed and Stevens Creek Reservoir, Stevens Creek Reservoir has largemouth bass that range from young of the year to fish potentially past their fifth year. Due to the evidence of potential stunting, fish could be older than size would otherwise indicate.

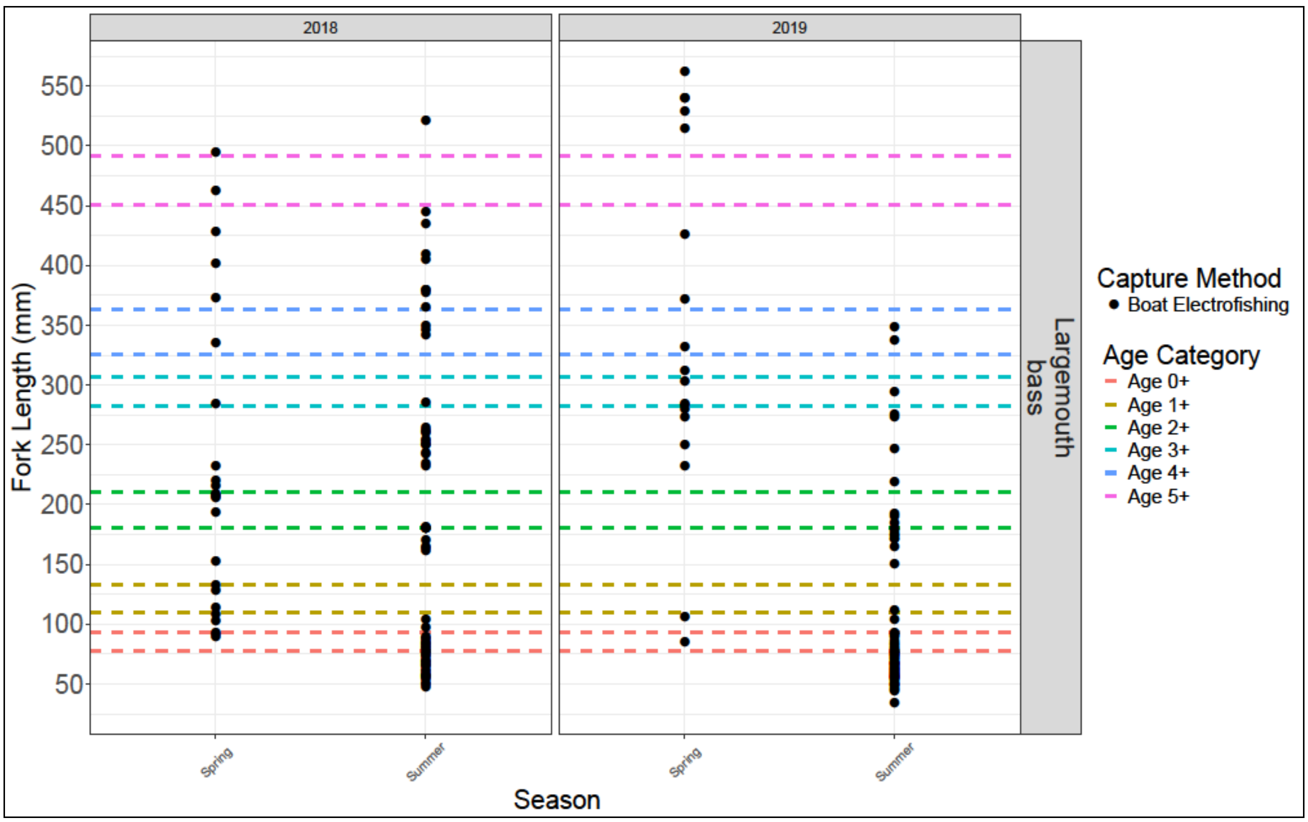

Figure 25: Largemouth bass lengths from Stevens Creek Reservoir with age class estimates overlaid (2018 and 2019).

2018 and 2019 Monitoring Year Discussion

As in previous years, it was not anticipated that the addition of oxygen to the reservoirs would significantly change the nearshore fish assemblages sampled by boat electrofishing. Changes to the species that occur in the deeper water levels may result from additional oxygenated habitat, but detecting that would require a change in the sample collection methodology. Oxygenation is more likely to change the amount of mercury and nutrients biologically available to the food web than to significantly alter the food web directly. Changes in fish tissue methylmercury over time are monitored and reported in a related effort.

Dams impact natural hydrology, fish movement, and connectivity of habitat. They can also alter trophic interactions. Native fish have evolved in fluvial systems and are not adapted to lentic habitats. This can result in an increase in non-native species, generalist species, and predatory species (higher trophic level) better suited to survival in the reservoirs. Water drawdowns can further benefit piscivores by concentrating prey fish. These factors could result in a reduction of prey species (lower trophic level, ex., benthivorous and planktivorous fish), which would create an overall increase in higher trophic level species in reservoirs. Largemouth bass in particular, a species present in all reservoirs sampled, are known to predate lower trophic level species. Changes in species assemblages could impact the structure and stability of reservoir food webs. Some research indicates that species' trophic positions can change in altered habitats (Turgeon et. al 2019).

Trends and comparisons between all sampling years have been difficult to discern as there have been gaps in the data when sampling events could not occur due to reservoir conditions (i.e., boat launch accessibility). Also, sampling did not occur at standardized time frames until 2016. Starting in 2016, a more standardized approach to the monitoring effort was taken and multiple methods were employed to ensure more consistent and continuous data collection. More consistent trends are starting to develop, but the reservoirs appear to be dynamic and fluctuations occur even with the sampling being more standardized. Some apparent trends in capture might lead to predictions of how fish are using different portions of the reservoir in the spring and summer months. Capture rates of largemouth bass are often higher in summer than spring, and a higher percentage of larger fish are captured in spring. The larger, more mature fish are likely using the shallow water habitats for spawning in the spring, pushing juveniles away from shore. The opposite trend appears to occur with black crappie, which typically had a higher abundance of fish caught in the spring sampling period than the summer sampling period. These trends could provide insight on seasonal fish location in the reservoir, and thus feeding behaviors which could contribute to fluctuations of mercury in fish tissue. As standardized sampling progresses, more trends should be discernable and a better understanding of habitat use may develop.

The 2018 and 2019 sampling results indicate changes in species assemblage within the reservoirs in the Guadalupe Watershed. In most cases the same species occur at each reservoir, but the abundance fluctuates. These fluctuations can be attributed to shifting population dynamics as well as sampling method bias. Guadalupe Reservoir and Almaden Reservoir each had three newly detected species. Guadalupe Reservoir added rainbow trout, prickly sculpin, and white crappie to its assemblage, and rainbow trout, brown bullhead, and inland silverside were detected in Almaden Reservoir. If inland silverside in Almaden Reservoir continue to occur and begin to flourish, it could lengthen the food chain and provide a more direct connection between phytoplankton and zooplankton to primary predators, influencing mercury transfer in the system. Calero Reservoir had the addition of redear sunfish, but this could be the result of misidentification of the species as pumpkinseed during previous years' sampling events. Continuing this sampling effort will help determine if both pumpkinseed and redear sunfish are present in the system. No new species have been identified in Stevens Creek Reservoir since rainbow trout were detected in 2017.

In Calero Reservoir, the high abundance and various size classes of tule perch indicate a potential stronghold of a California native fish species within a system normally dominated by non-native species. This species was not historically detected in the Guadalupe Watershed, but is native to Santa Clara

County (ex., Coyote Creek Watershed). Based on observations in 2018 and 2019, there is potential that this species is outcompeting non-native species in the same niche.

As seen in previous years, there is a potential that largemouth bass in Guadalupe and Stevens Creek Reservoirs are stunted or experiencing slower growth rates. This could be resulting from the lack of forage fish. Stunting or slower growth rates may also be occurring in Guadalupe Reservoir bluegill. This potential stunting could result in fish that are older than anticipated being analyzed for mercury concentrations. Currently, all bluegill analyzed for mercury concentration are greater than 50 mm. These fish could be older than estimated, resulting in a higher mercury concentration than expected based on perceived age. In 2019, the summer sampling event occurred earlier in the season than in previous years. This resulted in sizes of young of the year fish being smaller than what was seen in 2018. This was a result of seasonal timing and not a reduction of growth in the systems.

It is recommended that future sampling efforts continue to occur consistently each year within a standardized time frame to provide a comparable dataset over time. Also, the continual implementation of multiple fishing methods going forward will provide a means to sample in a variety of conditions and help to avoid data gaps. This will provide greater insight into fish assemblages in the reservoirs and help identify trends over time. The occurrence of new species not previously detected indicates we are still learning about fish assemblage in the system and continued monitoring is providing new and interesting results.

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