TECHNICAL MEMORANDUM

TO: Chris Berry
City of Santa Cruz Water Department

FROM: Jeff Hagar
Hagar Environmental Science

DATE: June 30, 2017

PROJECT: City of Santa Cruz Habitat Conservation Plan, Lagoon Fish Population Sampling 2016

Steelhead (*O. mykiss*) population abundance and life-history characteristics were assessed in Laguna Creek Lagoon and the San Lorenzo River Lagoon during the summer of 2016 by the City of Santa Cruz Water Department and Hagar Environmental Science (HES). Mark-recapture abundance surveys were conducted in the early summer and again in the fall using a large seine (150 ft long by 8 ft deep). Additional catch per effort surveys were conducted in the San Lorenzo Lagoon during July and August. Spring and fall mark-recapture abundance estimates for *O. mykiss* were completed using PIT tags. Fish were tagged one day and recaptured the next day in Laguna Creek. In the larger San Lorenzo River Lagoon, fish were captured and tagged on two consecutive days and recaptured during a subsequent two-day period (there were two days between the end of the mark period and the beginning of the recapture period). During July and August only catch per unit effort (CPUE) was assessed, no PIT tagging was implemented. A summary of the results of the surveys follows.

Both Laguna and San Lorenzo Lagoons were open intermittently through the summer of 2016. The *O. mykiss* population estimate in Laguna Lagoon was the lowest recorded in surveys since 2011 and though it increased by September it was still lower than any of the previous fall estimates and all of the spring estimates except 2016. In contrast, the June population estimate and CPUE of *O. mykiss* in the San Lorenzo River Lagoon were the highest of any survey completed to date. Numbers in the San Lorenzo Lagoon decreased in July and August but rebounded somewhat by September. The September population estimate in the San Lorenzo Lagoon was almost twice the previous highest fall abundance and higher than all previous spring estimates except 2016. Growth rates of recaptured fish were excellent.

In 2016 we obtained some data on movement of *O. mykiss*. NOAA Fisheries installed a PIT tag recorder at Felton in 2016 and fish that were tagged in the lagoon were recorded at Felton beginning June 29 and continuing at least through January 17, 2017 when the last downloaded data was available. A large number of *O. mykiss* tagged in the Lagoon in June were recorded

passing Felton later in the summer. Although movement of juvenile steelhead between the lagoon and upstream rearing areas during the summer has been documented in Scott Creek (Hayes et al. 2011, Kiernan et al. 2016), this was the first observation in the San Lorenzo River. Of the total 392 *O. mykiss* tagged in the lagoon in June, 94 were recorded at Felton as of January 17, 2017. *O. mykiss* tagged in the lagoon in September were also recorded at Felton. Of the 114 fish tagged in September, 34 have been recorded at Felton. In addition, an *O. mykiss* tagged in Laguna Creek lagoon on September 20 was recorded at Felton on November 8. This fish was 159mm FL at the time of tagging. It would have left Laguna lagoon after it opened October 15 and entered the San Lorenzo lagoon, also mostly open after October 14.

It appears that a large proportion of the O. mykiss population in the San Lorenzo Lagoon in June left sometime after the June survey. A large decline in CPUE in July together with the recovery of tags at Felton suggests many of these fish returned upstream. It is also possible that fish went back upstream but did not go as far as Felton. In addition, there are indications that some fish tagged in June went to the ocean. Numbers of large, very silver O. mykiss were captured in the lagoon in September. Many of these fish had been tagged in June but were not captured in the lagoon in July or August. Growth rates of some of these fish were higher than any that have previously been seen in the lagoons (0.8 mm to over 1.0 mm per day). The recovery of the Laguna tagged fish at Felton confirms that fish can enter the ocean from lagoon habitat and re-enter a lagoon in the same season.

Laguna Creek

Summary

The winter of 2015-2016 was dry through mid-December. Storms resulted in flow peaks in mid-December, early January, mid- to late January, early March, and mid-March. Flow gradually receded from around 10 cfs at the end of March to around 4 cfs at the end of May, just above the smolt migration threshold of 3.8 cfs. Summer flows at the anadromous gage gradually receded from around 3.5 cfs in late June to 1.3 cfs October 1 (Figure 1). Lagoon formation was highly unusual in 2016 with a fill and breach dynamic and intervening open tidal conditions through mid-August (Figure 1). This was an unusual condition in that closure in past surveys usually occurs by June and remains through the dry season. The lagoon opened on October 15 in association with increased wave height (Figure 1).

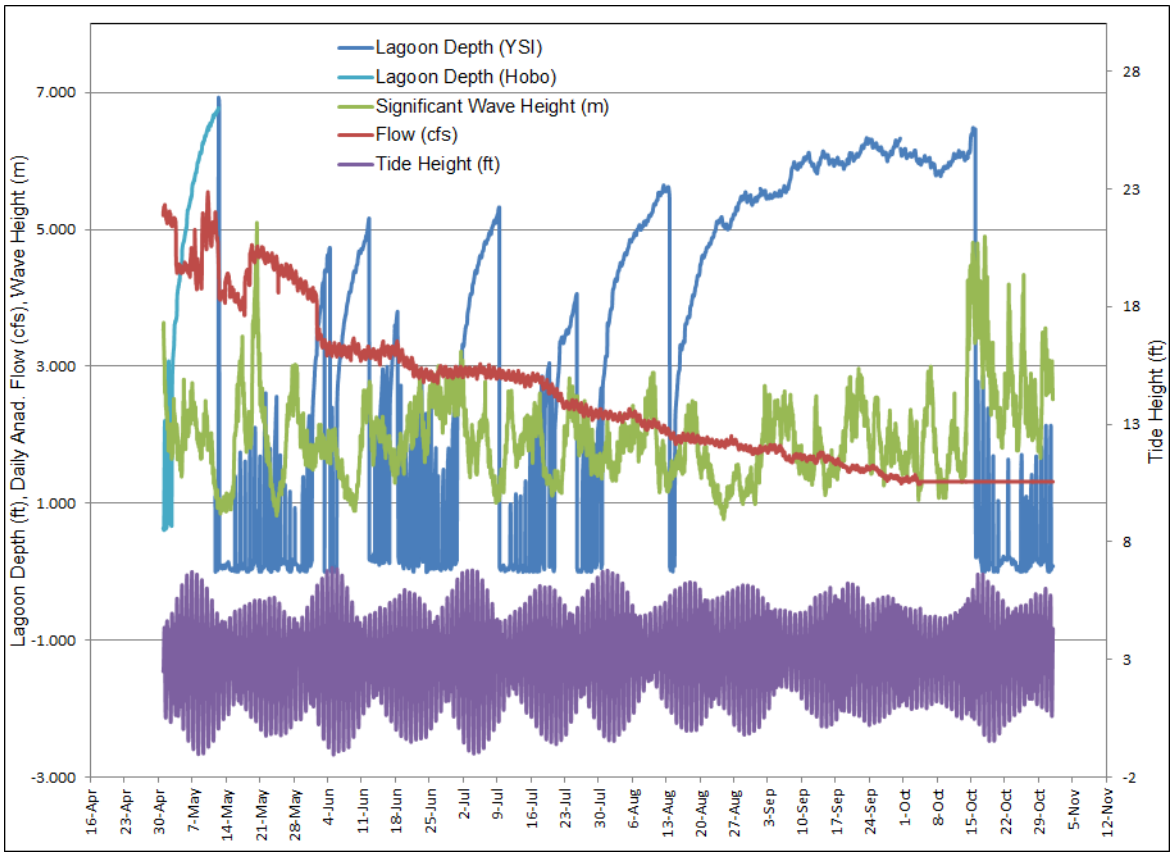

Figure 1. Laguna Creek Lagoon stage, streamflow, wave height, and tides 2016, preliminary data (Source: lagoon depth from 2ND Nature and City of Santa Cruz, streamflow from Balance Hydrologics, wave and tide data from NOAA)

On the June 7 initial sample date, the lagoon was closed but it had only been closed since June 5. The water column was stratified with a halocline and thermocline between 0.4 m and 1.2 m and high salinity and warm temperature (up to 22.4°C) at 1.2 m depth and below. Catch of *O. mykiss* was low, the second lowest since regular surveys began in 2004. Abundance of *O.*

mykiss increased by fall but was still relatively low compared to other years. None of the fish marked in June were recaptured in September. One of the *O. mykiss* tagged on September 20 was recorded by the NOAA monitoring antenna at Felton on November 8. In the intervening 49 days the fish would have exited Laguna Lagoon into the ocean, entered the mouth of the San Lorenzo River, and swum upstream past Felton. This behavior does not fit any of the life-history patterns commonly attributed to steelhead though it has recently been reported for both steelhead and coho salmon in nearby Scotts Creek (Kiernan, et al. 2017).

Spring (June 7-8)

Spring Site Conditions

- The mouth appeared to have closed recently. There was a lot of kelp in the lagoon near the mouth that was cleared before seining (Figure 2). Stage was 3.89 ft at the water quality buoy the afternoon of June 7 and increased to 4.24 ft. the afternoon of June 8. The usual pockets of deep water were present along the rock bluff, the sand beach at the back of the mouth, and along the edge of the marsh inland (Figure 2). Greatest depth was 1.9 to 2 meters.

Figure 2. Laguna Creek Lagoon, June 7, 2016

- Inflow from Laguna Creek ranged from 3.3 cfs on the morning of June 7 to 3.1 on the afternoon of June 8.

- The lagoon was salinity stratified with relatively fresh water at the surface (1.0 to 8.2 ppt), a halocline between 0.4 and 1.2 meters, and elevated salinity (26.1 ppt to 29.4 ppt) at 1.2 meters and below (Figure 3, center panel). The lagoon was freshening between the 7th and the 8th (Figure 3).
- Temperature was reverse stratified (cooler at the surface and increasing with depth) and temperature was increasing from June 7 to June 8 (Figure 3, left panel). The surface 0.4 meters was 16.9°C or less, with increases at depth to 22.4°C.
- The water column was well oxygenated with dissolved oxygen ranging from 7.9 mg/L to 13.5 mg/L (saturation 88% to 183%).
- The water column was clear with substrate visible at greatest depth surveyed (2 meters).

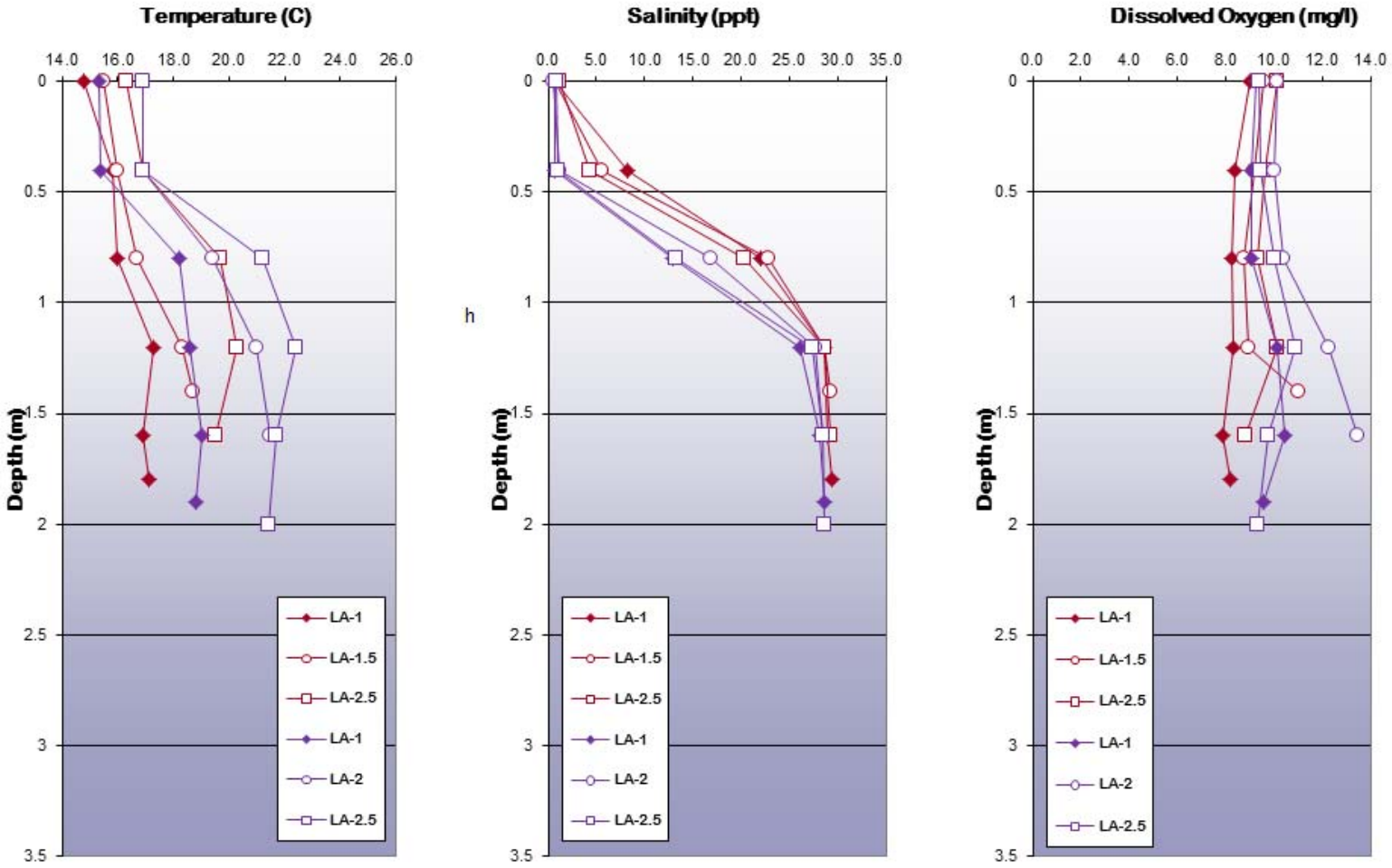

Figure 3. Depth profiles of water quality parameters in Laguna Creek Lagoon during June. Profiles plotted in red are June 7, profiles in blue are June 8.

Spring Survey Results

- Steelhead abundance was low during the June sample period. A total of 21 *O. mykiss* were captured in 20 hauls on June 7 and 8 between the beach and the water quality monitoring station (LA-3) (Table 1).

Table 1. Fish catch in Laguna Creek Lagoon, June 2016

Species	LA-1	LA-1.5	LA-2	LA-3	Grand Total
	June 7-8				
# Hauls	*7*	*6*	*5*	*2*	*20*
Steelhead	1	15	2	3	21
Threespine stickleback	1				1
Staghorn sculpin			1		1
O. mykiss CPUE	*0.1*	*2.5*	*0.4*	*1.5*	*1.1*

Note: See Figures at end of document for sample station locations.

- CPUE for *O. mykiss* was 1.1, the second lowest catch for June in all survey years (Table 2).

Table 2. *O. mykiss* and coho salmon catch per seine haul in Laguna Creek Lagoon at consistently sampled stations (data from HES 2005, HES 2009, HES 2010, HES 2011, HES 2012, HES 2013, HES 2014, HES 2015, and HES 2016)

	O. mykiss Catch per Haul				Coho Catch per Haul			
	Jun	Jul	Sep	Oct	Jun	Jul	Sep	Oct
2004		*2.4*	*0*			*0*	*0*	
2008	*11*		*6*		*0*		*0*	
2009	*7*		*19*		*0*		*0*	
2010	*13*			*1.7*	*0*			*0*
2011	*19.8*			*0.1*	*0*			*0*
2012	*11.3*		*10.3*		*0*		*0*	
2013	*28*		*8.6*		*0*		*0*	
2014	*20*		*33*		*0*			
2015	*0.1*			*11.4*	*0*			*0*
2016	*1.1*		*5.2*		*0*		*0*	

- *O. mykiss* included fish in a smaller size group of 35mm to 68mm FL, larger individuals from 115mm to 168mm FL, and one at 190mm FL (Figure 4).
- The smaller *O. mykiss* and many of the larger ones were parr stage. A few of the larger individuals were characterized as silvery parr.
- A few small *O. mykiss* were observed escaping through the net as it was landed.
- All *O. mykiss* had adipose fins present.
- Juvenile staghorn sculpin and threespine stickleback were captured in very low numbers.
- The over-wash pond was not sampled.

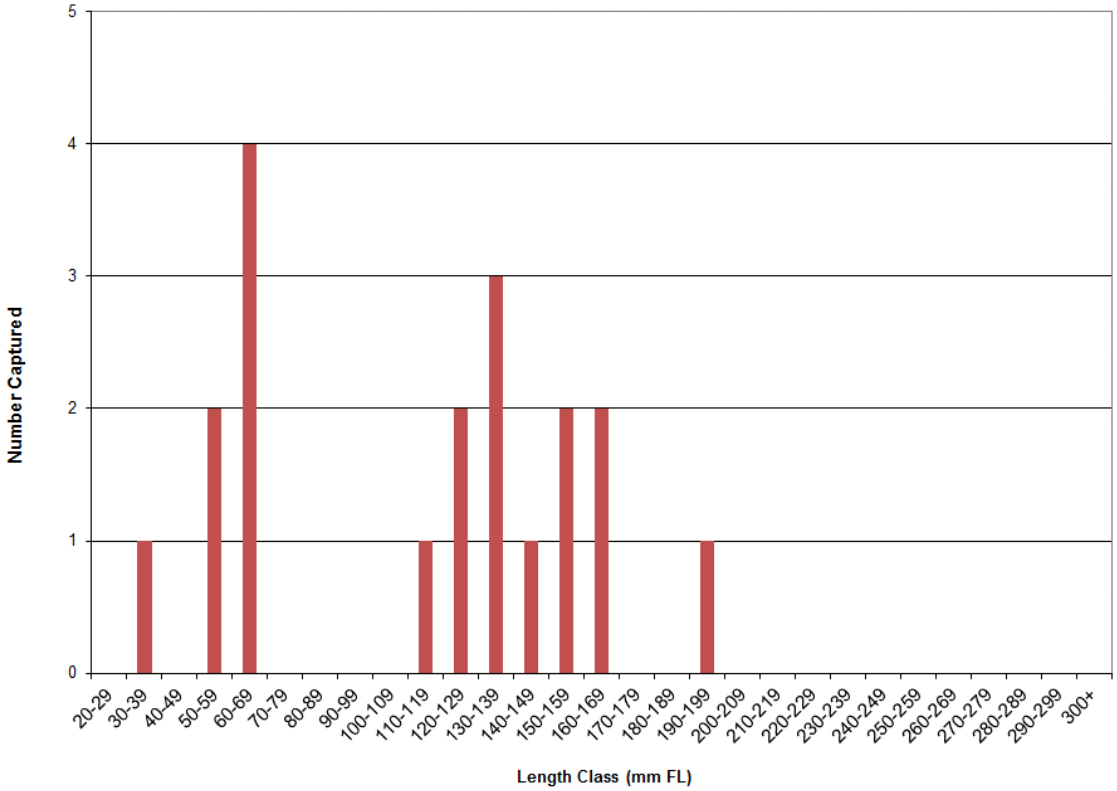

Figure 4. *O. mykiss* length classes in Laguna Creek Lagoon, June 2016

Spring *O. mykiss* Population Estimate

- Of the 12 *O. mykiss* captured during the marking period on June 7, one was a recapture and two were too small to mark (<60mm FL). Therefore, a total of 9 *O. mykiss* were marked and released.
- On June 8, a total of 9 *O. mykiss* were captured. One was below the minimum size range and was not included in the calculations. There was one recapture from the mark period out of the eight eligible fish.

- The population estimate using the Petersen method (Ricker 1975) is 45 *O. mykiss* in the lagoon in June. The 95% confidence limits for this estimate are 13 and 78. The estimate is likely biased due to the small number of marked fish and small number of recaptures.
- CPUE was similar during the mark and recapture periods (1.2 and 0.9 respectively). Size classes were somewhat different during the two periods but the catch was too low to draw firm conclusions about whether the population was closed.
- Untagged fish larger than 70mm captured during the recapture period were tagged in order to collect over-summer information.

Fall (September 20-21)

Fall Site Conditions

- The mouth was closed and had been closed since August 13. Stage was high at 6 to 6.1 feet (2nd Nature data) (Figure 1).
- The lagoon had breached four times since the June survey with periods of open, tidal conditions for up to 18 days. Surface water temperature varied between 12°C and 20°C over the summer with a peak at about 22°C (2nd Nature preliminary data).
- Inflow from Laguna Creek at the time of the survey was fluctuating around 1.5 cfs.
- Maximum depth to about 2.8 meters (9.2 feet). The deepest water was available in a narrow band along the rock wall and in the corner of the marsh and rock wall at LA-1, and along the marsh at LA 1.5 and LA-2 (Figure 5).

Figure 5. Laguna Creek Lagoon, September 20, 2016.

- The lagoon was fresh in the upper 1.6 meters with a lens of increasing salinity below to near 20 ppt in the deepest water (Figure 6, center panel).
- Temperature profiles were nearly isothermal between 17.4°C and 18.5°C in the upper 1.6 meters (Figure 6, left panel). Temperature increased in the halocline to a maximum of 23.3°C in the deepest water.
- Dissolved oxygen ranged from 6.1 mg/l to 8.2 mg/l in the upper 1.6 meters and declined in the halocline to near 0.0 mg/l in the deepest water (Figure 6, right panel).
- The upper part of the water column was relatively clear but lack of clarity in the halocline resulted in secchi depths between 2.3 meters (7.7 feet) near the mouth and 1.6 meters (5.1 feet) upstream (Station 1.5)

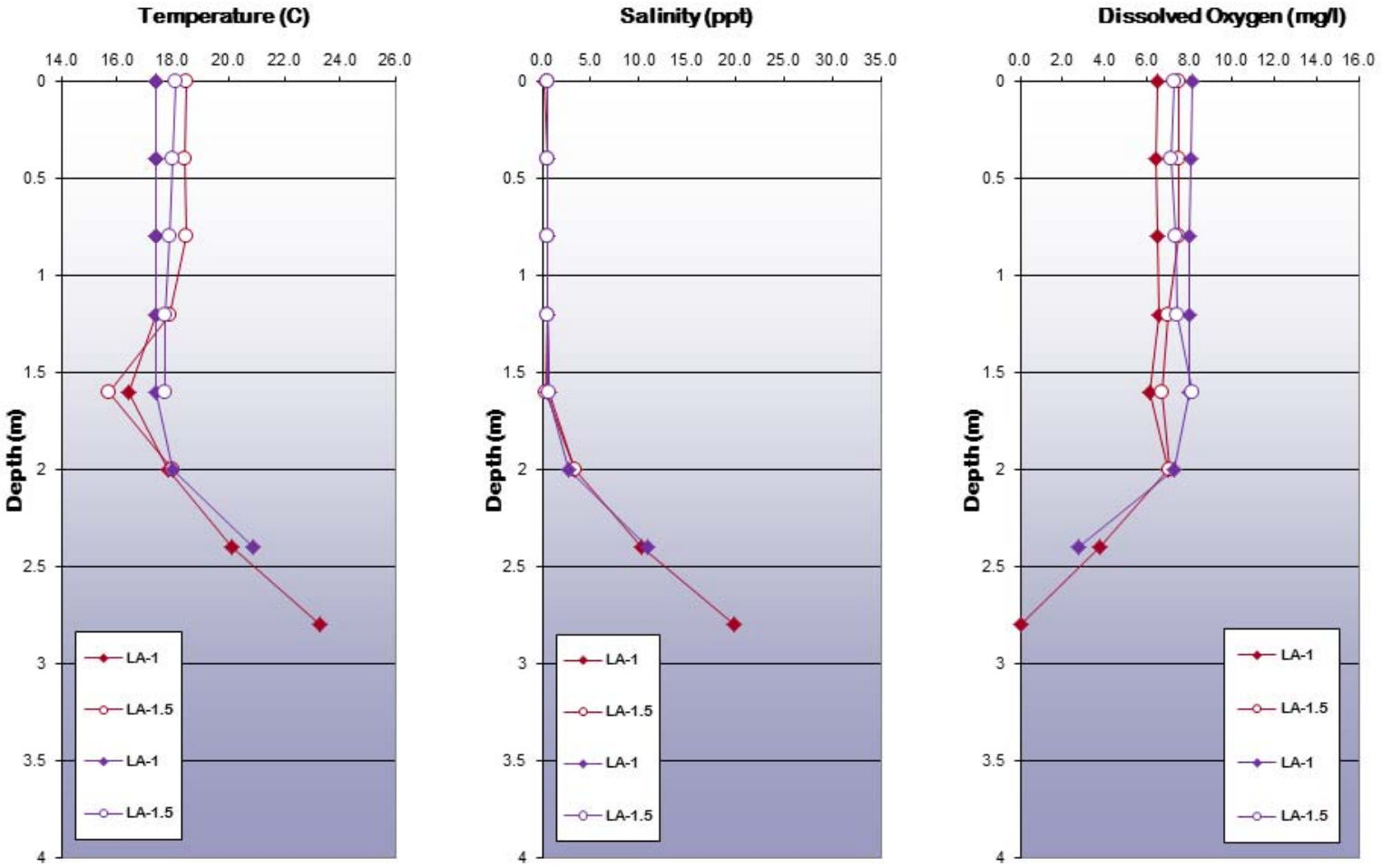

Figure 6. Depth profiles of water quality parameters in Laguna Creek Lagoon during September. Profiles plotted in red are September 20, profiles in blue are September 21.

Fall Survey Results

- *O. mykiss* were captured and marked on September 20. On September 21 the lagoon was re-sampled and the proportion of re-captured fish was recorded.
- Eight seine hauls were completed on September 20 and 10 hauls on September 21 between the beach (LA-1) and just downstream of the water quality monitoring station (Table 3).
- Overall abundance of *O. mykiss* based on number caught per seine haul (catch per unit effort or CPUE) at 5.2 per haul was at the low end for Laguna Creek in previous fall surveys with 6 years having higher CPUE and 3 having lower (Table 2). Abundance increased from 1.1 per haul in June to 5.2 per haul in September.
- *O. mykiss* were most abundant at Stations 1.5 and 1 (Table 3). Over half the total catch (48 out of 94) was taken in a single haul at Station 1.5 during the mark period. As a result, catch per unit effort decreased from 9.4 per haul on September 20 to 1.9 per haul on the 21st. These fish may have left the sampling area after the 20th or simply been together in a school that was not captured on the 21st. One of this group was recorded by the NOAA antenna at Felton on November 8, 2016. It was 159 mm FL at the time of tagging and was characterized as a silvery parr.
- The length distribution of *O. mykiss* had slightly greater representation in the 100 mm to 160mm size classes than the average size distribution from past years and slightly lower representation of fish over 200 mm (Figure 7).
- There were no *O. mykiss* captured in September that had been tagged in June or previous seasons. No growth estimates from recaptured fish was possible.
- Ninety-two percent of the catch were characterized as silvery parr and 8% were characterized as parr.
- One out of 76 *O. mykiss* examined had indication of black-spot disease.
- All *O. mykiss* examined had an adipose fin intact.
- In addition to *O. mykiss*, low numbers of topsmelt and staghorn sculpin, along with abundant hreespine stickleback were also in the lagoon.
- The over-wash pond was not sampled.

Table 3. Fish catch in Laguna Creek Lagoon, September 2016

Species	LA-1	LA-1.5	LA-2	LA-3	Grand Total
	September 20 and 21				
# Hauls	*10*	*5*	*2*	*1*	***18***
O. mykiss	38	52	4		**94**
Topsmelt	2				**2**
Threespine stickleback	125	1			**126**
Staghorn sculpin	2				**2**
O. mykiss CPUE	*3.8*	*10.4*	*2.0*	*0.0*	***5.2***

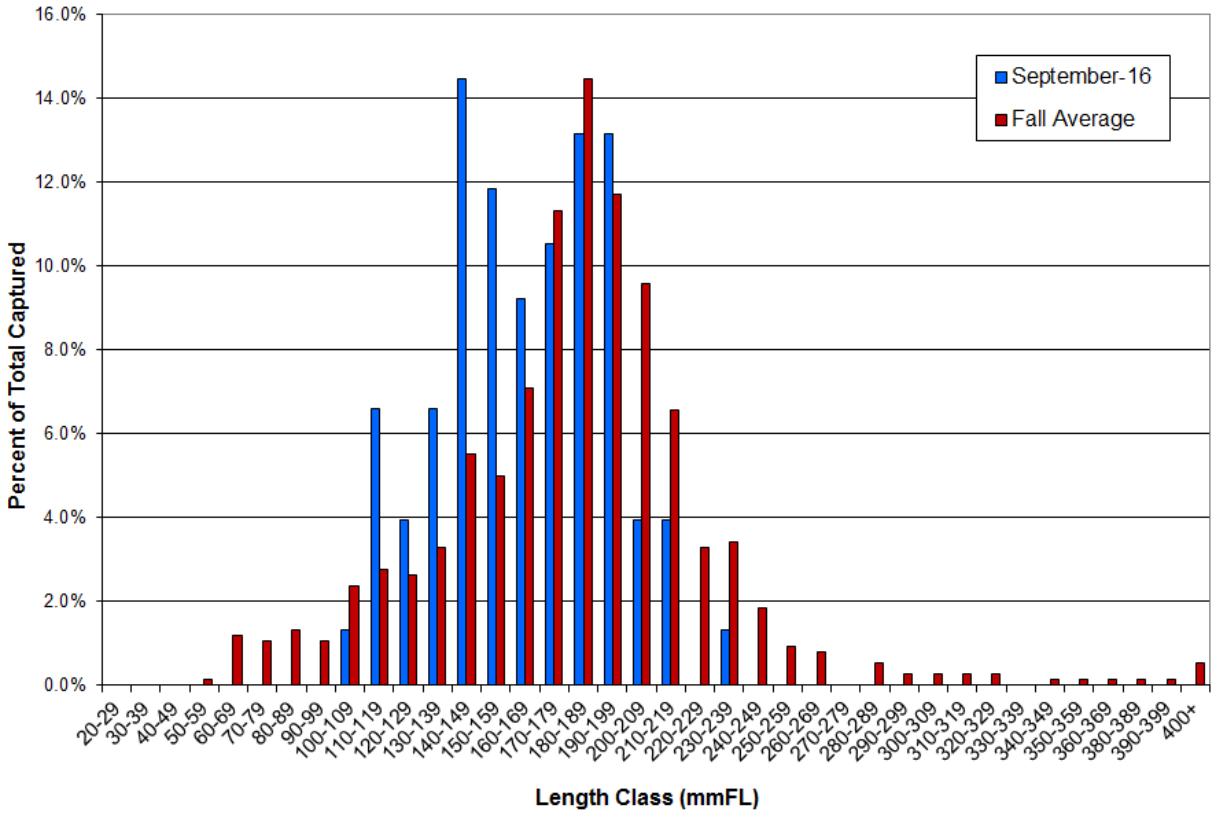

Figure 7. *O. mykiss* length classes in Laguna Creek Lagoon, fall 2016

Fall *O. mykiss* Population Estimate

- All *O. mykiss* captured on September 20 were larger than 50 mm FL and smaller than 320mm. A total of 67 *O. mykiss* were marked by insertion of a PIT tag in the abdominal cavity.
- On September 21, a total of 19 *O. mykiss* between 50 and 320 mm were captured. Of the 19 *O. mykiss* captured, 9 had been tagged on September 20.
- The population estimate using the Petersen method (Ricker 1975) is 136 *O. mykiss* larger than 50 mm and smaller than 320 mm in the lagoon on September 21. The 95% confidence limits for this estimate are 75 and 238. This estimate is about 3 times the abundance estimate in June.
- As previously noted, catch per unit effort decreased from 9.4 per haul on September 20 to 1.9 per haul on the 21st indicating that fish may have left the lagoon between the mark and recapture periods.
- The relationship between population estimate and CPUE was updated with the 2016 data (Figure 8). The least squares regression r^2 improved to 0.78 (from 0.65 previously), and was statistically significant with P=0.002. Prediction based on only the CPUE during the recapture period (which would be more accurate if the

population is changing) has an $r^2 = 0.97$ ($P<0.0001$). Both relationships are heavily influenced by the fall 2014 data point.

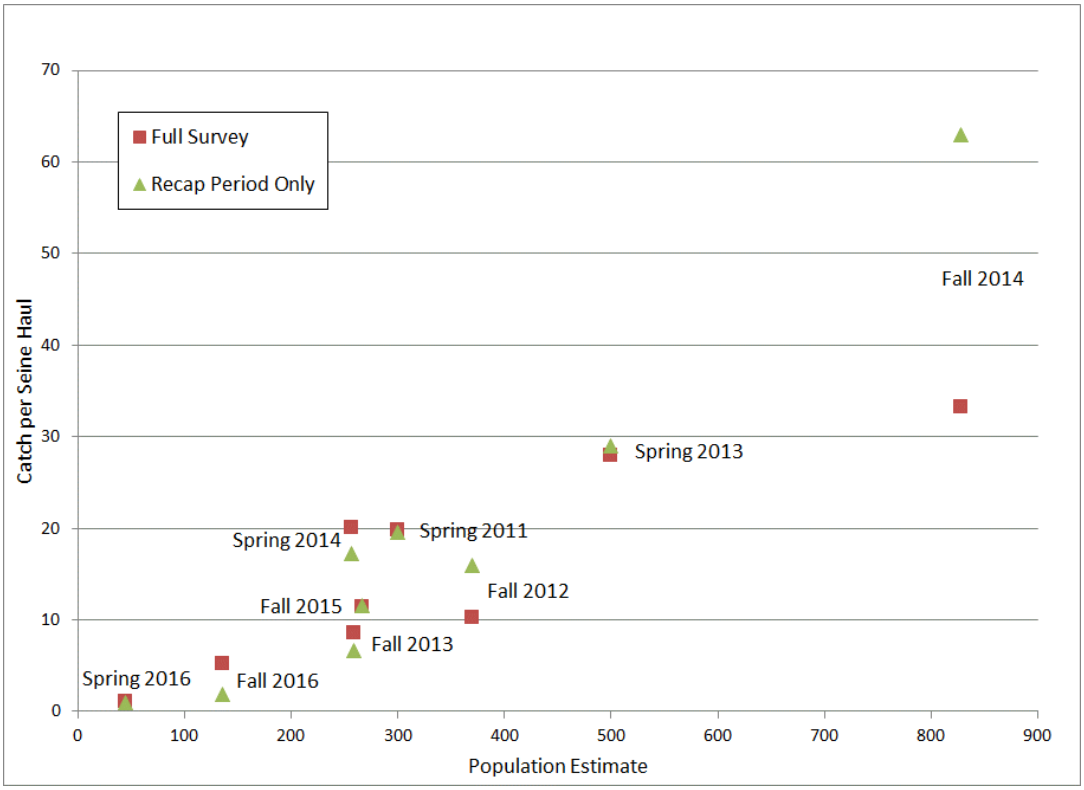

Figure 8. Relationship between *O.mykiss* population estimate and CPUE in Laguna Creek Lagoon[1].

[1] Population estimates not available in Fall 2011, Spring 2012, and Spring 2015 due to insufficient catch. In two cases (Fall 2011 and Spring 2012) the lagoon was open and in one case (2015) it had only recently closed.

San Lorenzo River

Summary

The lagoon first closed on June 13 and opened briefly again between June 18 and 22. Relatively high inflows from the San Lorenzo River resulted in a pattern of filling and breaching throughout the summer. The lagoon outlet formed a long channel to the west along the beach and breaches were relatively controlled with stage never dropping lower than 3 to 4 ft. NGVD29 (Figure 9). The City of Santa Cruz modified the lagoon outlet on August 29 and October 26. On August 29 two sand sills were constructed in the outlet channel to raise the elevation of the lagoon from 4 feet to 5 feet and a new outlet channel was excavated near San Lorenzo Point with an invert elevation slightly above the lagoon level. On October 26 the western outlet channel was closed and a new outlet near San Lorenzo Point was created with a low sill at the edge of the lagoon.

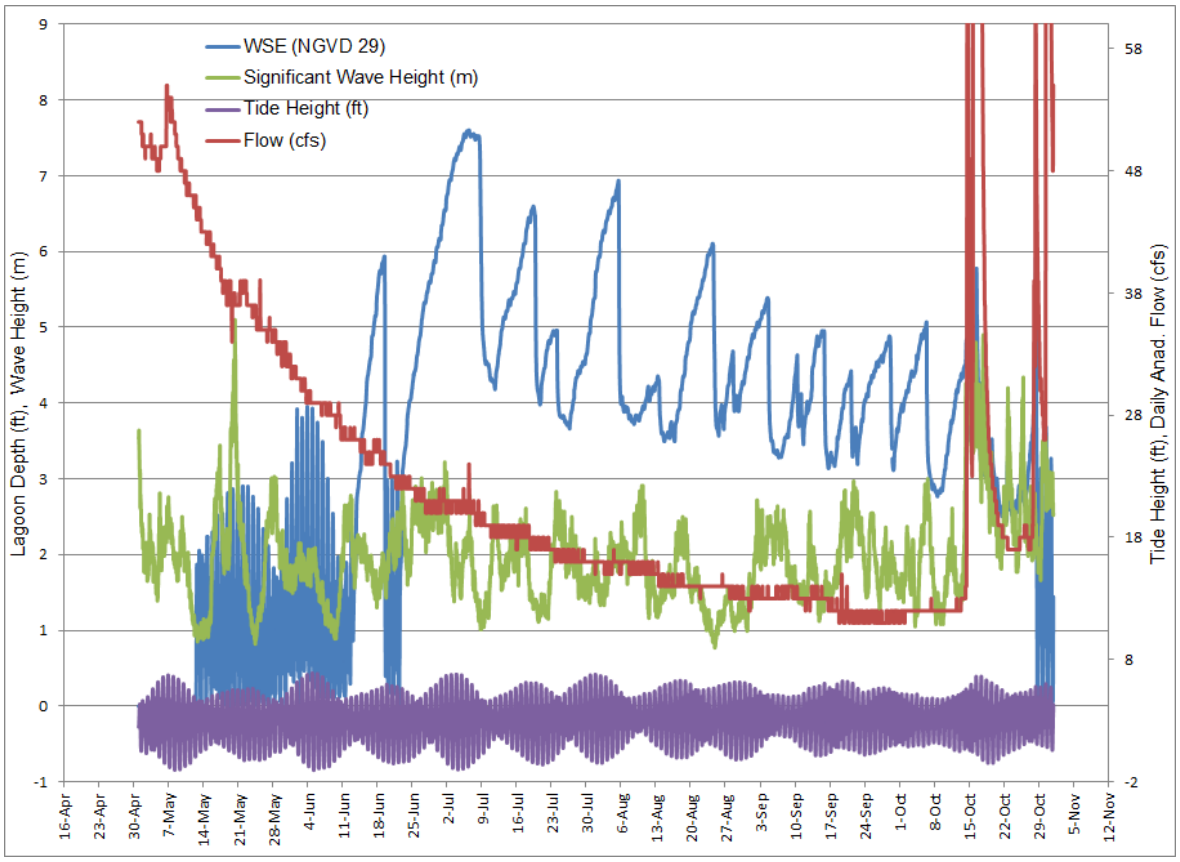

Figure 9. San Lorenzo Lagoon stage, streamflow, wave height, and tides 2016, preliminary data (Source: lagoon stage from 2ND Nature, streamflow from USGS, wave and tide data from NOAA)

The San Lorenzo lagoon was sampled four times during the summer of 2016 (Table 4). The initial seining survey began on June 9 with an open lagoon. *O. mykiss* were captured and marked on June 9-10 and sites were resampled for recaptures on June 13-14. Mid-season surveys were completed in July (13-14) and August (16-17), and a final survey was conducted on September 22-27 with marking on the first two days and recapture on the last two days. The two mid-season surveys measured CPUE only; no tagging was completed. The purpose was to get an estimate of steelhead abundance in the lagoon without subjecting fish to the stress of tagging during the period when conditions are likely to be most stressful.

Table 4. *O.mykiss* catch per haul for the San Lorenzo River Lagoon during 2016

Station	Location	*O. mykiss* Catch per Haul				
2016		9-14 Jun	July 13-14	Aug 16-17	Sept 22-27	
SL-1	South of Trestle	38.0	2.8	1.8	13.1	17.4
SL-2	RR Trestle	138.5	0.5	2.8	4.4	28.9
SL-3	Near YSI Station	2.0	1.0	0.3	17.0	3.5
SL-4	U/S YSI		0.0			0.0
SL-5	Riverside Drive	0.7	0.0	2.5	3.3	1.5
SL-6	U/S Bank Restoration	22.0	0.0	2.4	8.0	7.8
	Overall	***39.7***	***1.0***	***2.0***	***7.8***	***13.8***

The June CPUE, as well as the population estimate, was the highest observed in the San Lorenzo Lagoon in all surveys to date for the spring survey. The lagoon was open initially but closed on the 14th. Temperature was relatively cool for the lagoon (below 21.5°C), salinity was high except for the surface, and dissolved oxygen was variable but generally in excess of 6 mg/l.

In July the recently closed lagoon was much warmer than in June, with relatively high oxygen levels and low salinity through all but the deepest waters. Dissolved oxygen levels were higher than June and salinity was close to fresh down to a depth of 2 meters. Steelhead catch per effort was way down from June, at 1 fish per haul compared to 39 fish per haul in June. Since both dissolved oxygen levels and salinity had improved since June, higher temperatures appeared to be the factor driving steelhead from the lagoon.

At the time of the August survey the lagoon had just closed after opening on August 5 and being in a micro-tidal condition during the intervening period. The lagoon was also warm though slightly cooler than July. Dissolved oxygen levels were high and salinity was fresh in the upper 1.5 meters, comparable to July. Catch rates for steelhead increased from 1 per haul in July to 2 per haul in August, but still way down from the 39 per haul in June.

The lagoon experienced increased open periods after the August survey with six breach events

between the August and September surveys. Numbers of O. mykiss in the lagoon rebounded in September. The population estimate was 1331, the second highest abundance estimated since surveys began in 2011. A large proportion of O. mykiss tagged in June were estimated to be present in the lagoon in September (254/392 or 65%) based on PIT tag recoveries. Another 2% of June tagged fish were recorded at Felton before the September sample date. Others could have been in the river downstream of Felton.

Twenty-four percent of June tagged fish (94/392) and 30% (34/114) of September tagged fish were recorded at Felton as of January 25, 2017. The first June tagged fish was recorded at Felton on June 29, 16 days after being tagged and the first September tagged fish was recorded at Felton on November 1, 36 days after being tagged in the lagoon.

Spring (June 9-10, 13-14)

Spring Site Conditions

- The lagoon was open during the initial part of the sampling period but was closing by the 14th. It had been open since at least May 12 when the recorder was first installed for the season (Figure 9). Daily average flow at Santa Cruz gage ranged from 28 on the 9th to 25 cfs on the 14th (USGS provisional data).
- Lagoon stage was initially relatively low (0.2 ft. NGVD29) making for good seining conditions at most sites (Figure 10) but gradually increased during the sampling period. Stage was 1.5 to 1.8 ft. NGVD29 on the 13th and 3.0 to 3.1 ft. NGVD29 on the 14th (2NDNATURE preliminary data). As lagoon stage increased there were more areas with extensive shallow water at the end of the hauls (Figure 11).
- The lagoon was salinity stratified with salinity close to seawater at depths of 1.2 meters or more (Figure 12, center panel). Salinity decreased somewhat at the surface over the course of the survey, particularly upstream of Riverside (stations 5 and 6), as the mouth was closing.
- Temperature was minimally stratified depending on time of day and location (upstream vs. downstream). Maximum recorded temperature during the sampling period was 21.5°C (Figure 12, left panel).
- Dissolved oxygen levels were generally above 5.5 mg/L. Levels increased later in the survey period in the upper 1 to 1.5 meters of the water column (Figure 12, right panel).
- Water clarity was high with secchi disk visible at the substrate at all stations (up to 3.1 meters deep).

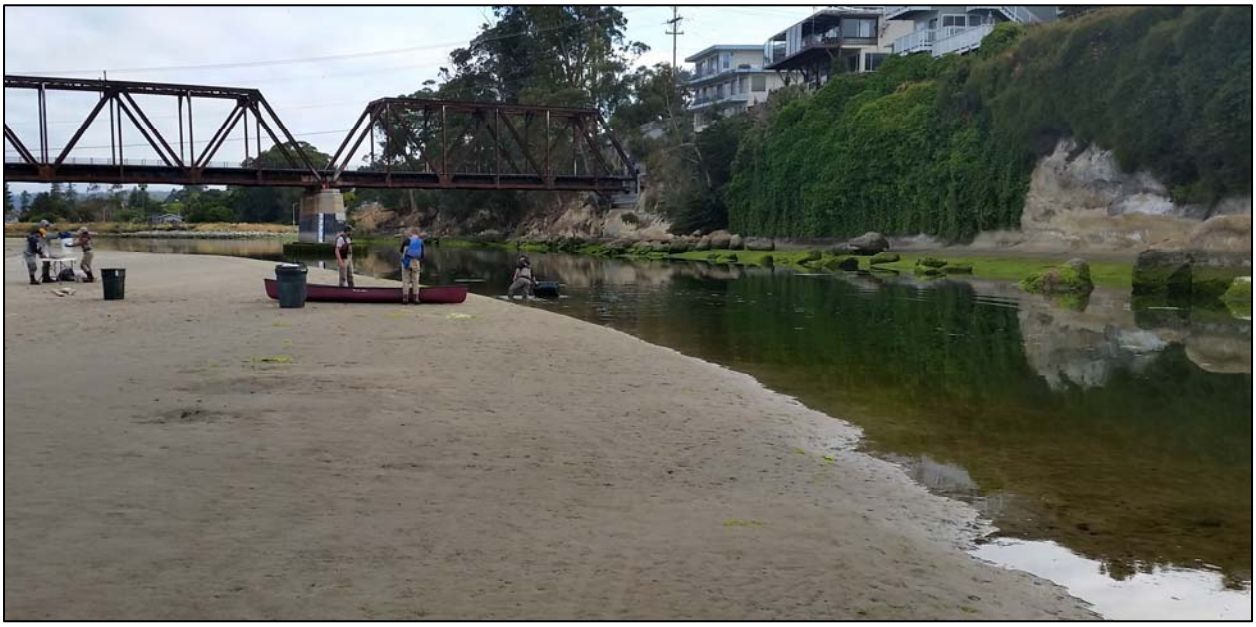

Figure 10. San Lorenzo Lagoon, June 9, 2016.

Figure 11. San Lorenzo Lagoon just upstream of Riverside Bridge, June 14, 2016.

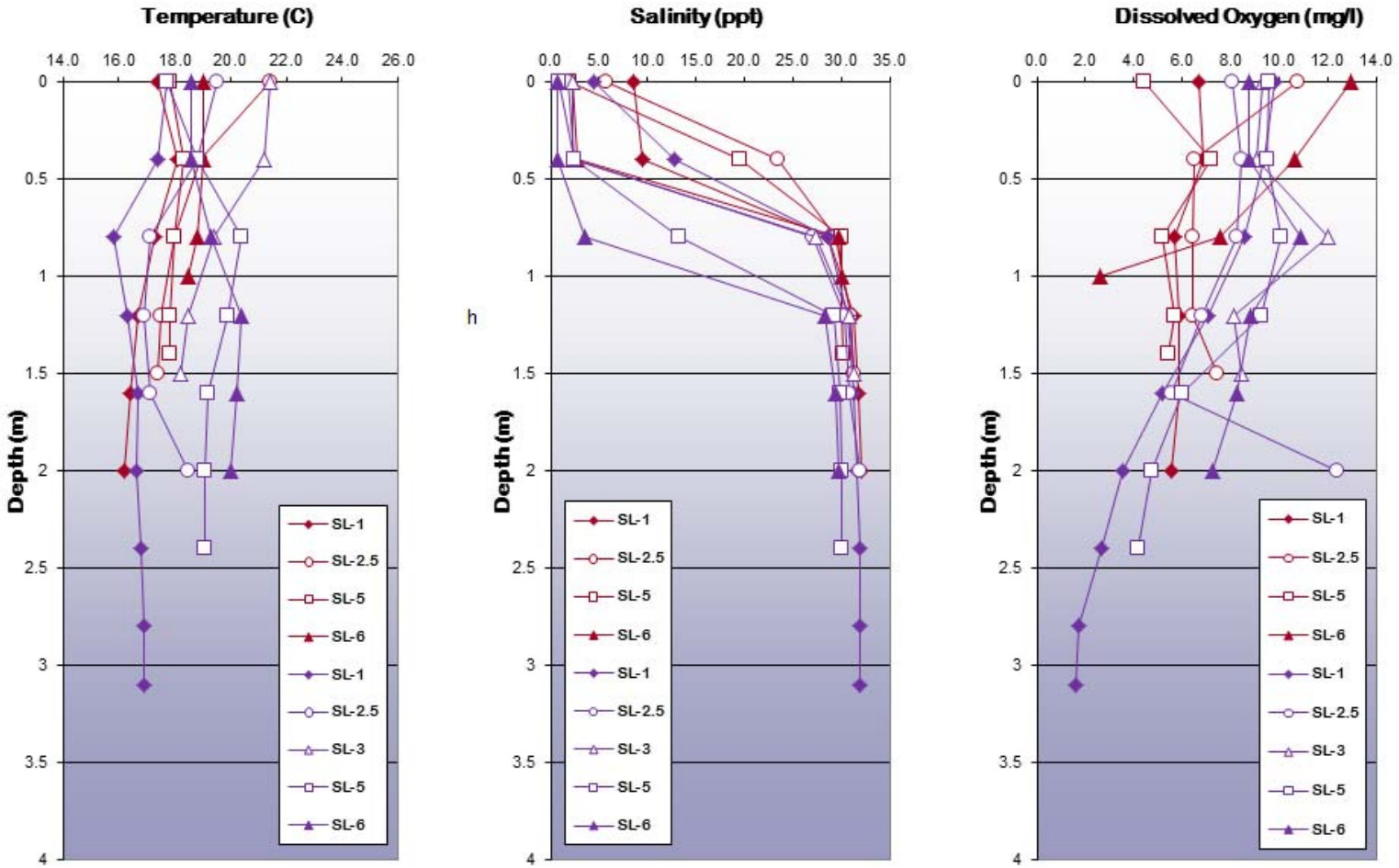

Figure 12. Depth profiles of water quality parameters in the San Lorenzo Lagoon during June. Profiles plotted in red are June 9-10, profiles in blue are June 13-14.

Spring Survey Results

- *O. mykiss* were captured and marked on June 9 and 10 and the lagoon was resampled on June 13 and 14. Untagged *O. mykiss* captured on June 13 and 14 were also tagged for over-summer information.
- 24 seine hauls were completed at regularly sampled stations between the beach and the bend upstream of Riverside Bridge.
- *O. mykiss* abundance was the highest observed in annual surveys to date (39.7 per haul) and were most abundant at the trestle and downstream to the outlet (Tables 5 and 6).
- Two size classes of *O. mykiss* were present: smaller fish from 60mm to 130mm FL and a group of larger fish from 130mm to 250mm FL (Figure 13).
- The smaller size group was characterized as parr and silvery parr. A small proportion (4%) of the 403 fish examined were characterized as smolts. A few of the larger fish were deep bodied and very silver with no sign of parr marks (Figure 14).
- All 401 *O. mykiss* examined had an adipose fin, indicating they were not of hatchery origin.
- 272 out of 403 (67%) *O. mykiss* examined had black-spot disease (BSD) lesions.
- The overall fish catch was dominated by very abundant topsmelt (Table 6). Ten other species were captured including a number of marine/estuary species such as Bay pipefish, staghorn sculpin, starry flounder, Dungeness crab, and several species of surfperch including rainbow surfperch which have not been captured in previous lagoon surveys (Figure 15).

Table 5. *O.mykiss* catch per haul for the San Lorenzo River Lagoon by month and year (data from HES 2009, HES 2010, HES 2011, HES 2012, HES 2013, HES 2014, HES 2015, and HES 2016).

	O. mykiss Catch per Haul				
Year	June	July	August	September	October
2008	2.6				0.1
2009	0.3			1.0	0.5
2010	8.3	21.5			28.25
2011	13				2.5
2012	1.7			14.4	
2013	2	8.4		4.7	
2014	1.2	1.1		0.0	
2015	2.6	0	0		0
2016	39.7	1.0	2.0	7.8	

Table 6. Fish catch in San Lorenzo River Lagoon, June 2016

Species	South of Trestle (1)	Around Trestle (2)	Between Trestle and WQ site (3)	Upstream of Riverside Bridge (5)	Bend downstream of Laurel Ave. (6)	Grand Total
# Hauls	*8*	*4*	*1*	*7*	*4*	***24***
O. mykiss	304	554	2	5	88	**953**
Pacific herring	9	1			1	**11**
Topsmelt	4320	413	78	64	771	**5646**
Threespine stickleback					4	**4**
Bay pipefish	7					**7**
Staghorn sculpin	2	7	16	1	1	**27**
Barred surfperch	1					**1**
Shiner surfperch	9	1			1	**11**
Walleye surfperch	4					**4**
Rainbow seaperch	1					**1**
Starry flounder		1	3	1		**5**
Dungeness crab	3					**3**
Crab		3				**3**
O. mykiss CPUE	*38.0*	*138.5*	*2.0*	*0.7*	*22.0*	***39.7***

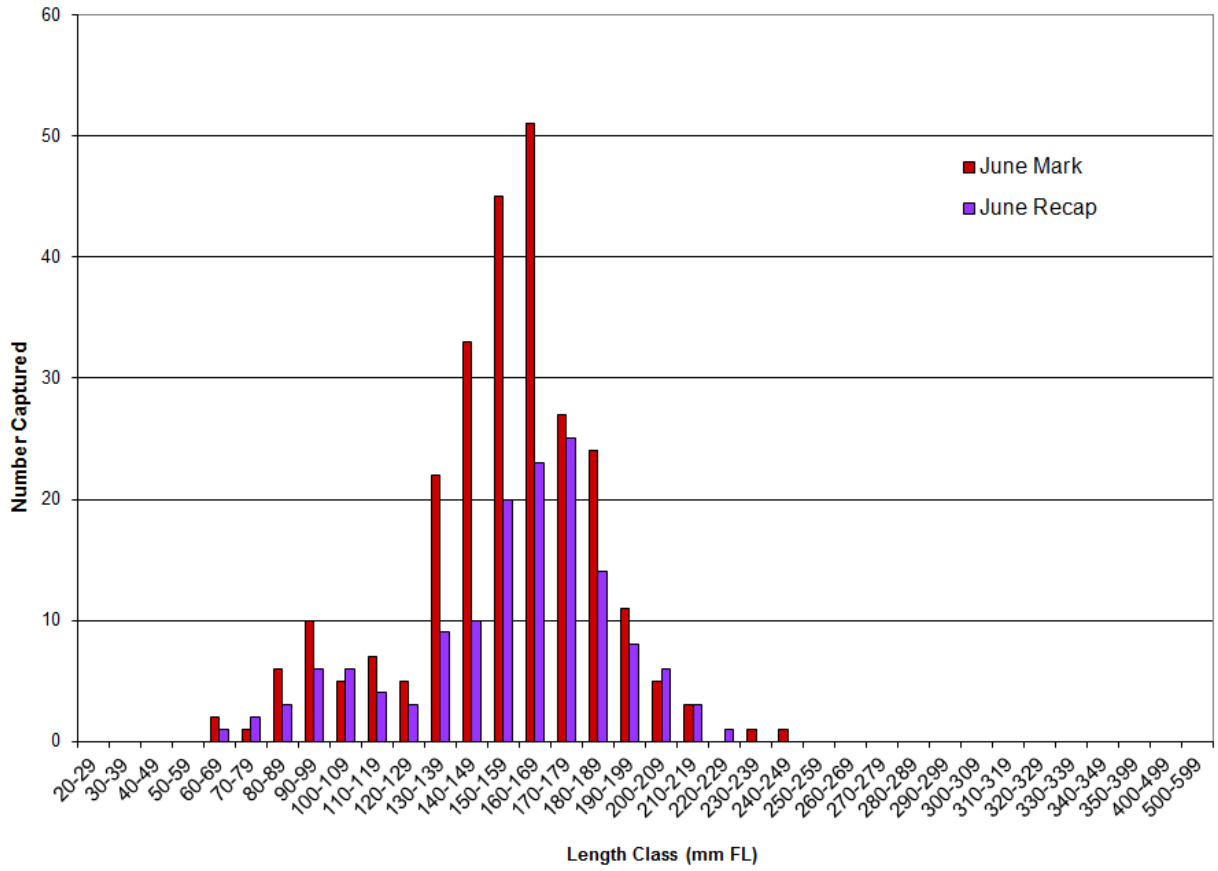

Figure 13. *O. mykiss* length classes in San Lorenzo Lagoon during mark and recapture periods, June 2016.

Figure 14. O. mykiss, 227 mm FL, captured in the San Lorenzo River lagoon June 13, 2016.

Figure 15. Rainbow surfperch captured in the San Lorenzo River lagoon June 09, 2016.

Spring *O. mykiss* Population Estimate

- Due to very large numbers of fish in some seine hauls, not all captured fish could be tagged. Of the 552 *O. mykiss* captured 267 were released without processing. An additional 26 were recaptures that had already been marked. Typically all fish 50 mm FL or larger are tagged but two fish in the 80-89 mm size class died after tagging so only fish 90 mm FL or larger were tagged. This eliminated an additional 8 fish (including the 2 mortalities), leaving a total of 251 tagged *O. mykiss* at the end of the mark period.
- A total of 401 *O. mykiss* were captured during the recapture period but only 395 were 90 mm FL or greater. Thirty-six of these had been tagged during the marking period.
- Population estimate using the Petersen method (Ricker 1975) is 2697 *O. mykiss* in the lagoon in June. The 95% confidence limits for this estimate are 1963 and 3696.
- CPUE was 46 per haul during the mark period and 33 per haul during the recapture period. This, and the fact that the lagoon was open initially, indicates the potential for an unstable population in the lagoon. The size distribution (Figure 13) indicates there may have been fewer O. mykiss in the 130mm to 170mm size classes during the recap period.

- All untagged fish captured during the recapture period were tagged in order to collect over-summer information. Several of these were recaptured during the recapture period.

Summer (July 13-14)

The July survey was a two-day relative abundance survey. In order to minimize potential harmful effects during potentially stressful mid-summer conditions, captured fish were not tagged and no population estimation was conducted. Sampling was conducted at standard sampling Stations 1, 2, and 3, around the trestle and up to the WQ Station and Stations 5 and 6 upstream of Riverside Bridge. One haul was also completed at Station 4.

Summer Site Conditions

- At the time of sampling the lagoon was refilling after having breached on July 8 (Figure 9). Inflow from the San Lorenzo River was still relatively high at 18 to 19 cfs (Figure 9).
- The lagoon stage was at about 5.25 feet on the trestle gage with no beach available for finishing seine hauls in many areas and expanses of very shallow water near shore downstream of the trestle.
- There was little to no salinity stratification during the July sample period (Figure 16, center panel) and salinity values were close to fresh throughout the upper 2 meters of the water column and at Stations 5 and 6.
- Water temperature was very warm, approaching incipient lethal levels, with surface temperature increasing from 21°C in the early morning to 24.2°C in the afternoon at Station SL-1 (Figure 16, left panel). Temperature was warmest below 1.6 meters depth, ranging from 22.1°C to 25.2°C.
- Dissolved oxygen was at supersaturated levels throughout much of the upper water column, ranging from 8.2 to 11.6 mg/L in the surface 1.6 meters (Figure 16, right panel). Below 1.6 meters depth the lowest dissolved oxygen measured was 3.6 mg/l at Station SL-6.
- The water column was less clear than in June with secchi depth averaging about 1.3 meters and ranging from 0.9 meters at SL-3 to 1.5 meters at SL-1.

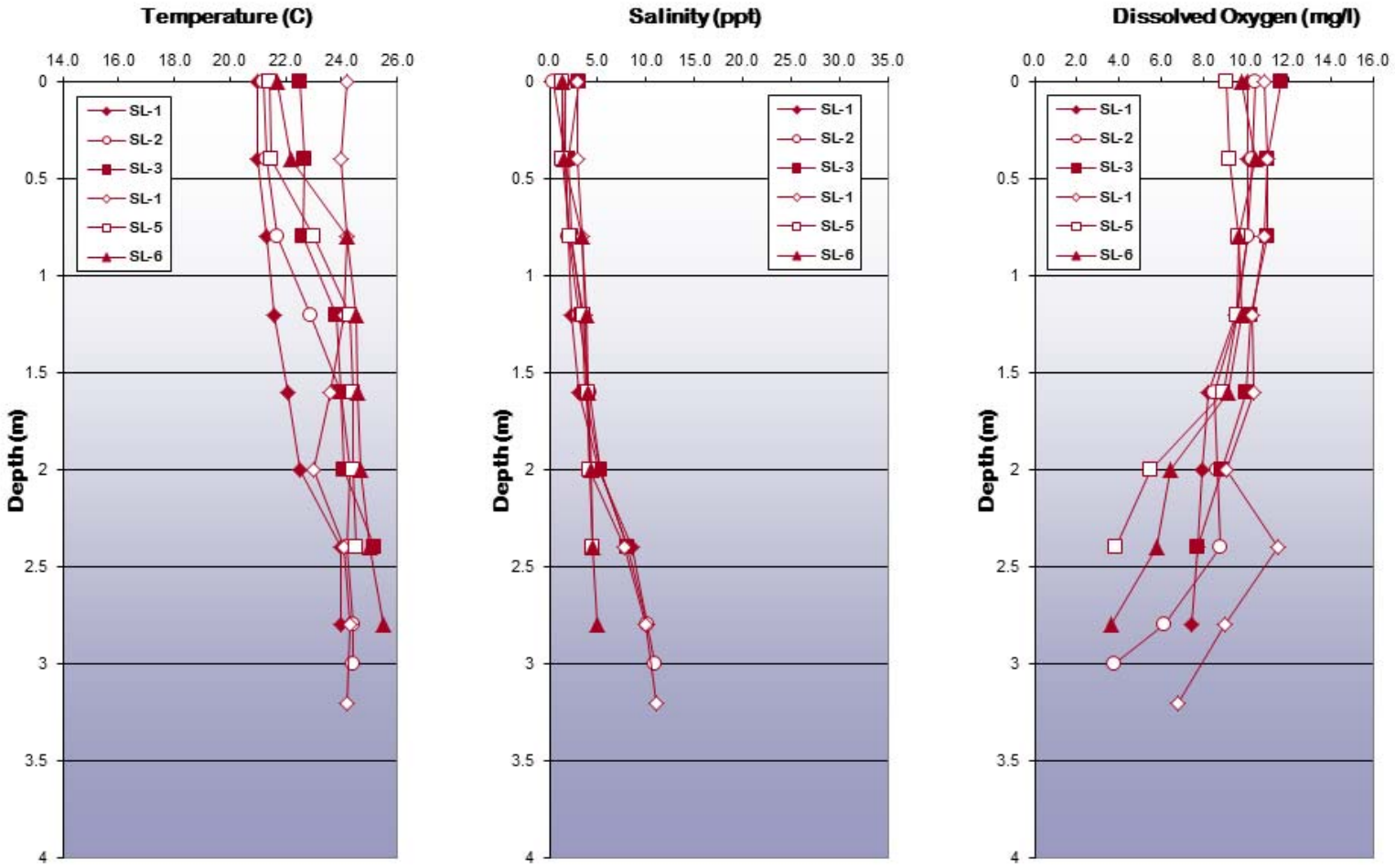

Figure 16. Depth profiles of water quality parameters in the San Lorenzo Lagoon during July Survey (July 13-14).

Summer Survey Results

- Seventeen seine hauls were completed between the beach and the water quality buoy and upstream of Riverside Bridge (Table 7).
- Abundance of *O. mykiss* was greatly reduced since June. A total of 17 steelhead were captured in the lagoon in July. CPUE was 1 per haul, compared to 39.7 per haul in June. O. mykiss were concentrated near the mouth (Table 7).
- O. mykiss remaining in the lagoon in July were at the larger end of the size range seen in June (Figure 17). Growth could have accounted for the differences in size distributions. Four O. mykiss captured in July had been tagged in June. These fish grew at an average rate of 0.88 mm/day (range 0.70 to 1.06 mm/day). They ranged in size from 139 mm to 166 mm in June and 163 mm to 192 mm in July.
- Catch consisted of abundant topsmelt and Pacific herring along with staghorn sculpin, Sacramento sucker and small numbers of typical estuarine species generally encountered here (Table 7). Catch rates for topsmelt were comparable to June (206 vs. 235 per haul) while catch of Pacific herring was much higher than June (33.5 per haul vs. 0.5 per haul). Most topsmelt were in the 100 mm to 180 mm size classes. Many of the herring were small enough to swim through the mesh of the net. A new species, bonefish (*Albula vulpes*) was captured for the first time (Figure 18).

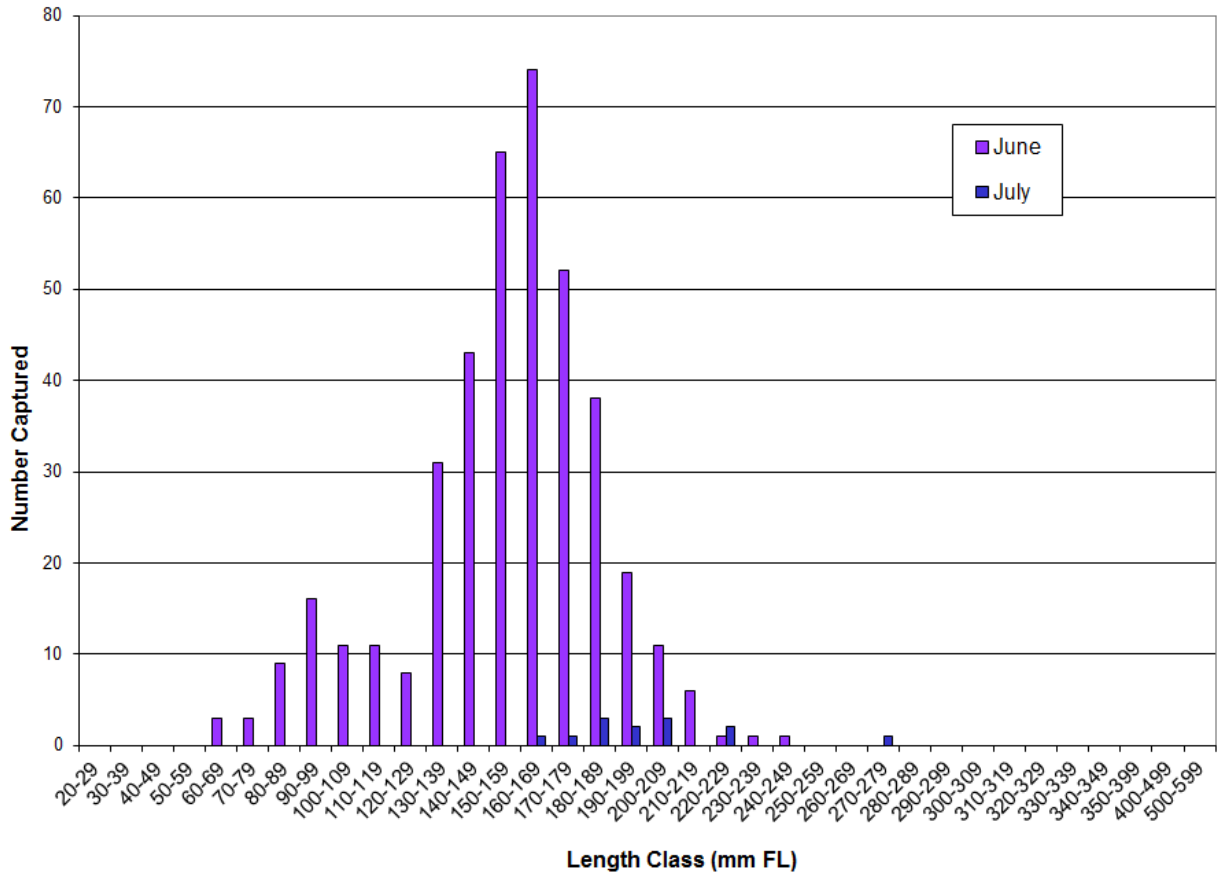

Figure 17. *O. mykiss* length classes in San Lorenzo Lagoon during June and July 2016.

Table 7. Fish catch in San Lorenzo River Lagoon, July 2016

Species	South of Trestle (1)	Around Trestle (2)	Between Trestle and WQ site (3)	Below Riverside (4)	Upstream of Riverside Bridge (5)	Bend near Laurel Ave. (6)	Grand Total
# Hauls	*5*	*4*	*1*	*1*	*2*	*4*	***17***
Steelhead	14	2	1				**17**
Bonefish					1		**1**
Pacific herring	448	74	1		1	45	**569**
Sacramento sucker		1	3	4	5		**13**
Topsmelt	496	604			6	2390	**3496**
Threespine stickleback		1			1		**2**
Staghorn sculpin	2	8	2	14	1	2	**29**
Striped bass					1	1	**2**
Shiner surfperch	1						**1**
Tidewater goby	1						**1**
Starry flounder		3					**3**
Crab	1	4	2	3	1		**11**
O. mykiss CPUE	*2.8*	*0.5*	*1.0*	*0.0*	*0.0*	*0.0*	***1.0***

Figure 18. Bonefish (*Albula vulpes*) captured in the San Lorenzo River lagoon July 14, 2016.

Late-Summer (August 16-17)

The August survey, as in July, was a two-day relative abundance survey. Sampling was conducted at standard sampling stations from downstream of the trestle and up to the WQ Station (Stations 1, 2, and 3) and Stations 5 and 6 upstream of Riverside Bridge.

Late-Summer Site Conditions

- The lagoon had just closed at the time of the survey. It had opened on August 5 and remained in a micro-tidal condition until about the 16th. It had filled and breached five times since the June survey. Lagoon stage was down at least a foot from July (stage of 3.7 feet NGVD29 on August 16, 3.9 feet NGVD29 on August 17) (2NDNATURE preliminary data).
- There was salinity stratification in the lagoon below about 1.5 meters depth in August with salinity increasing to 16 to 17 ppt at the greatest depths. Surface salinities ranged from 1.5 to 3 ppt. (Figure 19, center panel).
- Water temperature was warm but slightly cooler than July, with surface temperature increasing from near 22°C in the early morning to 23.0°C in the afternoon. Below the surface, water temperature ranged from 22.4°C to 24.1°C (Figure 19, left panel).
- As in July, dissolved oxygen was near or above saturated levels in the upper water column. DO was above 7 mg/l at depths down to 2.8 meters in the lower lagoon (Stations 1-3) but was that high down to only 1.2 to 1.6 meters depth above Riverside Bridge. The lowest level measured was 3.2 mg/L near the bottom at Station SL-6 (Figure 19, right panel).
- The water column was clear with secchi depth of 3.0 meters at SL-1 and visible to the bottom at all other stations (up to 2.4 meters).

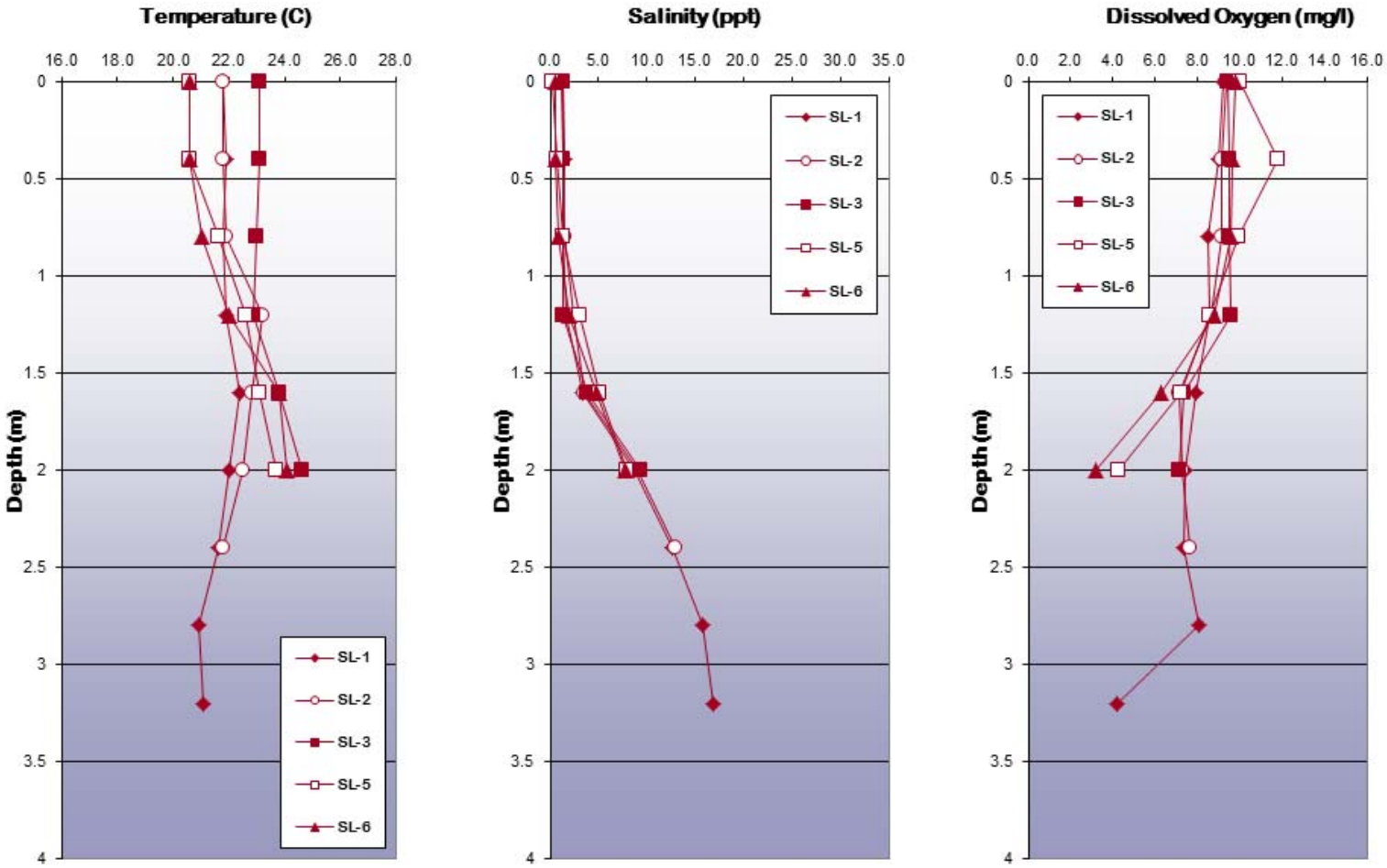

Figure 19. Depth profiles of water quality parameters in the San Lorenzo Lagoon during August Survey (August 16-17).

Late-Summer Survey Results

- Eighteen seine hauls were completed between the beach and the water quality buoy and upstream of Riverside Bridge (Table 8).
- Abundance of *O. mykiss* was up from July but still well below June levels. CPUE was 2 per haul, compared to 1 per haul in July and 39.7 per haul in June. *O. mykiss* were equally abundant near the mouth and upstream of Riverside (Table 8).
- There were larger and smaller *O. mykiss* present in the lagoon compared to July but the median length was very similar in both months (Figure 20). All of the *O. mykiss* smaller than 180 mm FL were captured at Station 6, while the majority of larger O. mykiss (larger than 260 mm FL) were captured at Stations 1 and 2.
- Four O. mykiss captured in August had been tagged in June. These fish grew at an average rate of 0.90 mm/day (range 0.66 to 1.09 mm/day). They ranged in size from 159 mm to 211 mm in June and 208 mm to 270 mm in August.
- Large numbers of small invertebrates (mostly gammarid amphipods) were present in the lagoon in August. These are ideal prey for O. mykiss. All O. mykiss captured were fat and healthy looking. Some of the O. mykiss looked as though they could have been in the ocean recently (Figure 21).
- No Pacific herring were captured in August after being very abundant in July. Topsmelt abundance was greatly reduced from 206 per haul in July to 9 per haul in August. A large school of striped bass (330 mm to 610 mm FL) was captured at Station 2 and may be related to the disappearance of herring and diminishment of topsmelt, which would be preferred prey. Most of the topsmelt we did capture were larger individuals that may have been less susceptible to predation. The bass could have entered the lagoon from Monterey Bay during one of the periods the lagoon was open.
- A school of bluegill (Lepomis macrochirus) was captured at Station 6. These warmwater sunfish were likely planted somewhere in the watershed and made their way to the lagoon. They have not been captured in previous surveys. They appeared to be spawning as many nests were visible in the area.

Table 8. Fish catch in San Lorenzo River Lagoon, August 2016

Species	South of Trestle (1)	Around Trestle (2)	Between Trestle and WQ site (3)	Upstream of Riverside Bridge (5)	Bend near Laurel Ave. (6)	Grand Total
# Hauls	*4*	*4*	*3*	*2*	*5*	***18***
Steelhead	7	11	1	5	12	**36**
Bonefish			1			**1**
Sacramento sucker	1		1	17	3	**22**
Topsmelt	115		47		2	**164**
Threespine stickleback	2	9	2	2	8	**23**
Bay pipefish	1					**1**
Staghorn sculpin	1	6	3		1	**11**
Striped bass		27	1			**28**
Bluegill			1		16	**17**
Tidewater goby					2	**2**
Starry flounder					1	**1**
Crab	25	1	4			**30**
O. mykiss CPUE	*1.8*	*2.8*	*0.3*	*2.5*	*2.4*	***2.0***

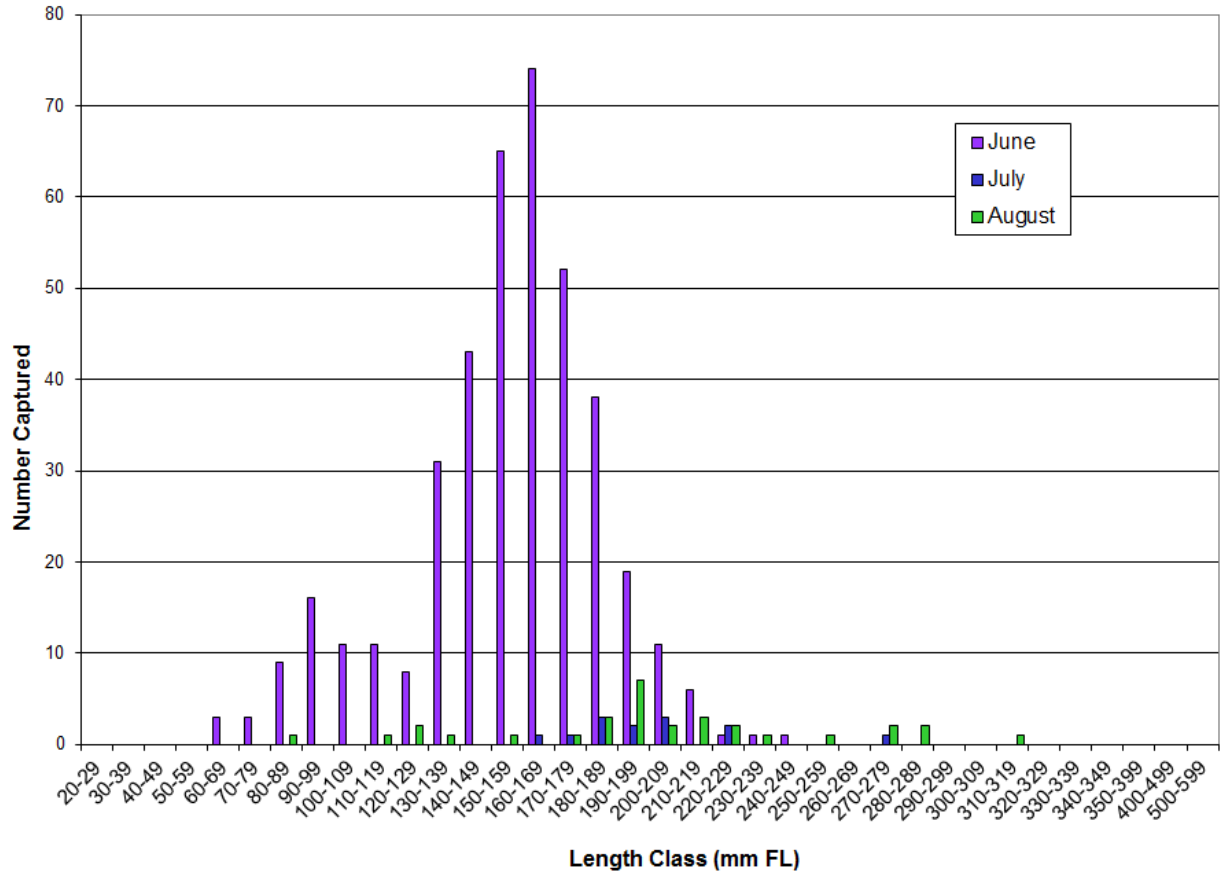

Figure 20. *O. mykiss* length classes in San Lorenzo Lagoon during June and July 2016.

Figure 21. O. mykiss, 275 mm FL, captured in the San Lorenzo River Lagoon 16 Aug 2016.

Fall (September 22-23, 26-27)

Fall Site Conditions

- Lagoon was open during the mark period (22nd and 23rd) but closed just before the recapture period (26th and 27th). The frequency of breaching and open lagoon conditions had increased since August with the lagoon opening six times since the August survey.
- The lagoon stage was relatively low at about 3.2 feet on September 22 and rose to about 4.5 on September 26 (2NDNATURE preliminary data). Even at these stages, there was no beach upstream of the Trestle or upstream of Riverside and a narrow beach with an expanse of very shallow water near shore downstream of the trestle.
- The lagoon was relatively fresh in the upper 1.2 meters with salinity increasing to a maximum of about 18.9 ppt in the deepest waters (Figure 22, center panel).
- Water temperature was cooler than August or July, ranging from 17.9°C to 22.3°C in the upper 1.2 meters of the water column (no temperature below 22°C was measured in August). Temperature increased to 20.8°C to 24.4°C at 1.6 meters and remained close to this range in the deepest waters (Figure 22, left panel). Temperature was warmest below 1.6 meters depth, ranging from 22.1°C to 25.2°C.
- Dissolved oxygen levels were generally above 8.7 mg/l in water up to 1.6 meters deep (Figure 22, right panel). There was a slight depression to 5.9 mg/l to 6.4 mg/l in midwater at depths of 1.2 to 1.6 meters at Station 1. DO levels dropped as low as 3 mg/l near the substrate at Station 6.
- The secchi disk was visible at the substrate in 2.8 meters at Station 1 and 2.0 meters at Station 6 during the mark period (September 22-23). Visibility was comparable during the recapture period (September 26-27).

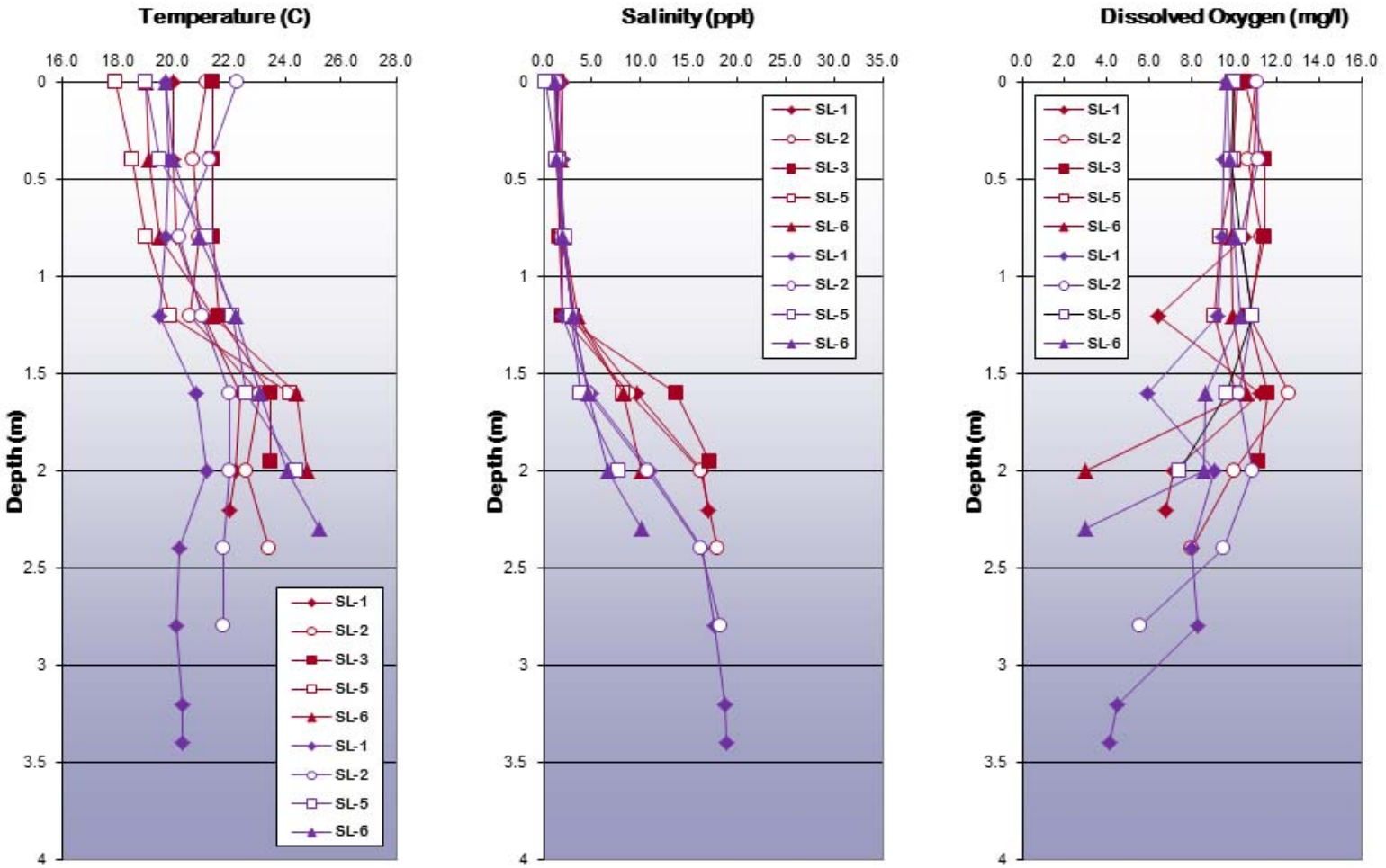

Figure 22. Depth profiles of water quality parameters in the San Lorenzo Lagoon during September. Profiles plotted in red are September 22-23, profiles in blue are September 26-27.

- *O. mykiss* were captured and marked on September 22 and 23 and the lagoon was resampled on September 26 and 27. Untagged *O. mykiss* captured during the recapture period were not tagged due to deteriorating water quality conditions, large size of fish, and large numbers in some hauls.
- Thirty-two seine hauls were completed at regularly sampled stations between the beach and the bend upstream of Riverside Bridge.
- *O. mykiss* CPUE was 7.8 per haul overall, substantially higher than July (1 per haul) or August (2 per haul) but not nearly matching the 39.7 per haul in June (Table 5). Abundance was in the mid-range compared to other fall surveys.
- In September there were two modes of the *O. mykiss* size distribution, one containing fish approximately 130 mm FL to 220 mm FL and the other with fish from 220 mm FL to 300 mm FL or larger (Figure 23). These could correspond the two modes seen in June with the shift to larger size in both modes consistent with observed growth rates. The smaller mode was similar in abundance to the analogous mode in June but the larger mode was much reduced in abundance. The larger fish were found primarily at Stations 1 and 2 and the smaller fish were primarily at Station 6. Seventy-nine percent of the *O. mykiss* near the mouth (Stations 1 and 2) were deep bodied and very silvery in coloration and were characterized as adult/oceanic in appearance. Only 31% of the *O. mykiss* upstream of Riverside were characterized that way.

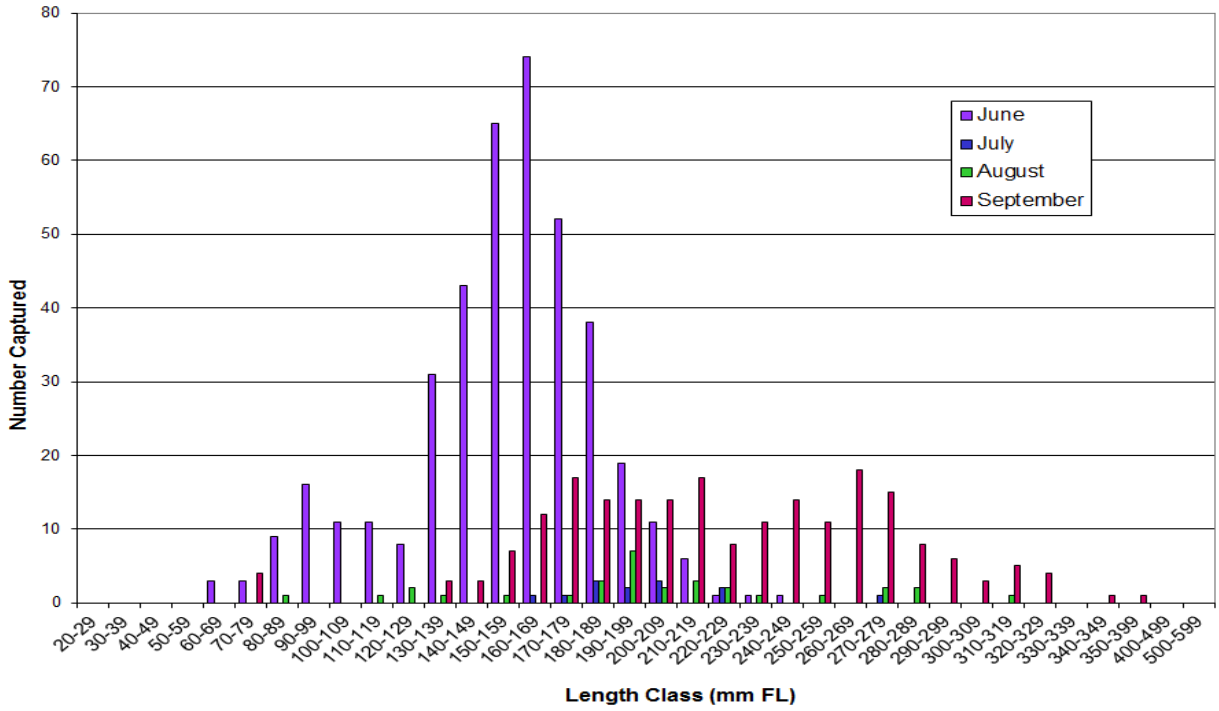

Figure 23. *O. mykiss* length classes in San Lorenzo Lagoon during different sample periods in 2016.

- The smaller size group (104 fish of 130-219 mm FL) were characterized as parr (5%), silvery parr and advanced silvery parr(70%), and adult/ocean (25%). The larger size group (105 fish of 220-359 mm FL) were characterized as advanced silvery parr (8%) and adult/ocean (92%) (Figure 24).
- Twenty-one *O. mykiss* captured in September had been tagged in June. These fish grew at an average rate of 0.90 mm/day (range 0.45 to 1.14 mm/day). They ranged in size from 121 mm to 213 mm in June and 219 mm to 318 mm in August.
- All 208 *O. mykiss* examined had an adipose fin, indicating they were not of hatchery origin.
- 168 out of 209 (80%) *O. mykiss* examined had black-spot disease (BSD) lesions.
- Topsmelt numbers were a bit higher than August (CPUE 19.9 vs 9.1 in August) (Tables 8 and 9). Pacific herring were still absent though they are typically found in June and July in the San Lorenzo lagoon when they are present. Striped bass were also not captured. A few striped mullet were found at Station 6, having previously been captured near there in August 2015. They were larger this year, averaging just over 300mm FL compared to less than 200 mm FL in 2015.

Table 9. Fish catch in San Lorenzo River Lagoon, September 2016

Species	South of Trestle (1)	Around Trestle (2)	Between Trestle and WQ site (3)	Upstream of Riverside Bridge (5)	Bend near Laurel Ave. (6)	Grand Total
# Hauls	*7*	*9*	*1*	*4*	*11*	***32***
Sacramento sucker				4	7	**11**
Steelhead	92	40	17	13	88	**250**
striped mullet					5	**5**
Topsmelt	8	268	10	45	306	**637**
threespine stickleback	53	248	2	3	113	**419**
Staghorn sculpin	1	8			1	**10**
tidewater goby		15				**15**
shiner surfperch		7				**7**
starry flounder	1	1				**2**
Crab		6				**6**
O. mykiss CPUE	*13.1*	*4.4*	*17.0*	*3.3*	*8.0*	***7.8***

Figure 24. O. mykiss, 353 mm FL, captured in the San Lorenzo River Lagoon 22 Sept. 2016.

Table 10. *O.mykiss* catch per haul for the San Lorenzo River Lagoon during recent sampling events (data from H.T. Harvey and Associates 2003, 2NDNATURE 2006, Ellen Freund (NOAA Fisheries), HES 2005, HES 2009, HES 2010, HES 2011, HES 2012, HES 2013, HES 2014, HES 2015, and HES 2016).

Station	Location	*O. mykiss* Catch per Haul					
2002						1 Oct	20 Nov
SL-2	RR Trestle						0.0
SL-3	Near YSI Station					5.5	
SL-4	Below Riverside						
SL-5	Riverside Drive						9.0
SL-7	Laurel St.						1.0
SL-8	Soquel Ave.					20.0	0.3
2004			6 July		21 Sep	29 Sep	
SL-1	Near Mouth				0.0	0.0	
SL-2	RR Trestle		24.5			0.5	
SL-3	Near YSI Station		20.0				
SL-4	Below Riverside		0.0				
SL-5	Riverside Drive		62.0		0.0	0.0	
SL-6	U/S Bank Restoration		3.0			0.0	
SL-7	Laurel St.		3.0				
SL-8	Soquel Ave.				0.0	0.0	
2005		14 Jun	14 Jul	16 Aug		5 Oct	
SL-1	Near Mouth	0.0	0.0	1.7		0.0	
SL-2	RR Trestle	28.0	5.3	179.5		0.0	
SL-5	Riverside Drive	0.0	12.3	10.7		62.7	
SL-8	Soquel Ave.	7.7	1.0	0.0		0.0	
2008		8, 19 Jun				7-8 Oct	
SL-1	Near Mouth	0				0	
SL-2	RR Trestle	9				0.25	
SL-3	Near YSI Station	0				0	
SL-5	Riverside Drive	0				0	
SL-6	U/S Bank Restoration	0				0	
SL-8	Soquel Ave.	0				0	
	Overall	***2.6***				***0.1***	
2009		10-11 Jun			16 Sep	21 Oct	
SL-2	RR Trestle	0.75			1.0	0.25	
SL-3	Near YSI Station	0.25					
SL-5	Riverside Drive	0				0	
SL-6	U/S Bank Restoration	0				1.5	
	Overall	***0.3***			***1.0***	***0.5***	
2010		22-23 Jun	17 Jul			Oct	
SL-1	Near Mouth	0.0				0	
SL-2	RR Trestle	11.7	0.5			31.3	
SL-3	Near YSI Station		42.5			0	
SL-5	Riverside Drive	0.0				9.0	
SL-6	U/S Bank Restoration	9.0				80.0	
	Overall	***8.3***	***21.5***			***28.25***	
2011		9-14 Jun				Oct	
SL-2	RR Trestle	11.7				1.7	
SL-3	Near YSI Station	7.8				5.7	
SL-4	Near Marsh Outlet	16.0				1.0	
SL-5	Riverside Drive	48.5				2.2	
SL-6	U/S Bank Restoration	0.5				0.3	
	Overall	***13***				***2.5***	

Table 10 (continued)

Station	Location	*O. mykiss* Catch per Haul					
2012		7-12 Jun			Sep 13-18		
SL-2	RR Trestle	5.2			21.3		
SL-3	Near YSI Station	0.8			17.5		
SL-4	Near Marsh Outlet	0					
SL-5	Riverside Drive	0			3.5		
SL-6	U/S Bank Restoration	0.1			5.0		
	Overall	***1.7***			***14.4***		
2013		6-11 Jun	17 July		Sep 12-17		
SL-1	South of Trestle	0.6			13		
SL-2	RR Trestle	0.8	2.2		1.6		
SL-3	Near YSI Station	6	24		1		
SL-4	Near Marsh Outlet	3			2		
SL-5	Riverside Drive	3			5.8		
SL-6	U/S Bank Restoration	0.3			6		
	Overall	***2***	***8.4***		***4.7***		
2014		5-10 Jun	17 July		Sep 11-15		
SL-1	South of Trestle	3.2	0		0		
SL-2	RR Trestle	0.9	3.5		0		
SL-3	Near YSI Station	1.0	0.5		0		
SL-5	Riverside Drive	0.5	0		0		
SL-6	U/S Bank Restoration	0.8	1		0		
SL-8	Water Street				1.1		
	Overall[2]	***1.2***	***1.1***		***0.0***		
2015		4-9 Jun	July 28-29	Aug 18-19		Oct 8-9	
SL-1	South of Trestle	0.8	0	0		0	
SL-2	RR Trestle	1.4	0	0		0	
SL-3	Near YSI Station	0.4	0	0		0	
SL-5	Riverside Drive	8.8	0	0		0	
SL-6	U/S Bank Restoration	2	0	0		0	
SL-10	Water Street	0					
	Overall[4]	***2.6***	***0***	***0***		***0***	
2016		9-14 Jun	July 13-14	Aug 16-17	Sept 22-27		
SL-1	South of Trestle	38.0	2.8	1.8	13.1		
SL-2	RR Trestle	138.5	0.5	2.8	4.4		
SL-3	Near YSI Station	2.0	1.0	0.3	17.0		
SL-4	Near Marsh Outlet		0.0				
SL-5	Riverside Drive	0.7	0.0	2.5	3.3		
SL-6	U/S Bank Restoration	22.0	0.0	2.4	8.0		
	Overall	***39.7***	***1.0***	***2.0***	***7.8***		

[2] Standard sites only (SL1-SL6)

Fall *O. mykiss* Population Estimate

- A total of 131 *O. mykiss* were captured during the mark period (September 22 and 23). Four of these were not marked because they were less than 80 mm FL and judged too small to mark based on the mortalities experienced in the June survey. Six additional *O. mykiss* were recaptures of fish tagged during the mark period. Therefore, there were a total of 121 marked *O. mykiss* at the end of the marking period. Nine fish were originally tagged in June and are included in the 121 total tagged fish.
- A total of 119 *O. mykiss* were captured during the recapture period, all were 90 mm FL or greater. Ten of these had been tagged during the marking period.
- Untagged fish captured during the recapture period were not tagged in order to minimize handling and minimize potential for handling losses.
- The population estimate using the Petersen method (Ricker 1975) is 1331 *O. mykiss* in the lagoon at the end of September. The 95% confidence limits for this estimate are 754 and 2281.
- Although CPUE was similar during the mark and recapture periods (8.7 vs 7.0 per haul respectively), the size distribution of captured O. mykiss was different between the two periods (Figure 25). The smaller size class decreased while the large size class increased.
- CPUE increased at the lower stations (Stations 1-3) from 6.1 per haul during the marking period to 11.1 per haul during the recapture period. The increase was primarily among the larger size class. CPUE at the upper stations (Stations 5 and 6) decreased from 11.7 per haul during the mark period to 2.4 per haul during the recapture period. Many of the smaller fish captured at Station 6 during the mark period were not seen in the upper or lower lagoon during the recapture period.
- Twenty-one *O. mykiss* captured in September were tagged in June. If recapture rates were the same for these fish as for the September marked fish (10/121 or 0.0826), there would have been 254 June tagged *O. mykiss* in the lagoon in September. There were 251 *O. mykiss* tagged during the mark period in the lagoon in June, and an additional 141 tagged during the recap period for a total of 392 tagged fish in June. In addition, 9 June tagged fish were recorded at Felton after June 29 and before the September survey (Table 11). An unknown number may have moved from the lagoon into the river downstream of Felton.
- As of January 25, 2017 a total of 34 *O. mykiss* tagged in the lagoon in September had been recorded at Felton. The first record was on November 1, 39 days after tagging was completed.
- The relationship between population estimate and CPUE was updated with the 2016 data (Figure 26). Least squares regression gives a significant relationship (P=0.002) with an r^2 value = 0.79. The spring 2015 data point is problematic and may be biased due to low number of recaptures. Without the 2015 data point, the relationship is also significant (P=0.004) with an r^2 value= 0.81.

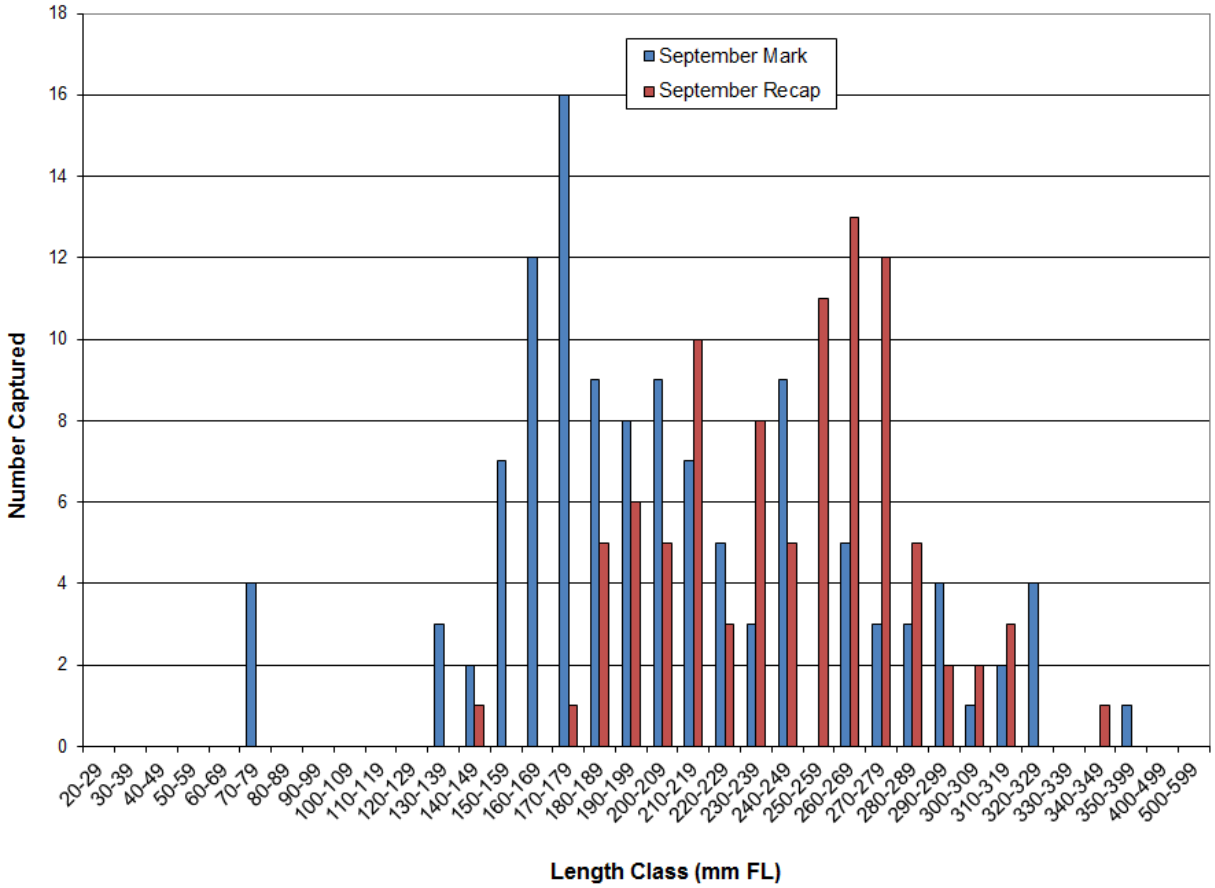

Figure 25. *O. mykiss* length classes in San Lorenzo Lagoon during the mark and recapture periods in 2016.

Table 11. Lagoon tagged *O.mykiss* recorded at Felton NOAA Fisheries PIT tag antenna.

First Record at Felton	Tagged in June	Tagged in September	Total
Jun	2		2
Jul	6		6
Aug	1		1
Sep			
Oct	11		11
Nov	59	29	88
Dec	15	5	20
Total as of Jan 25, 2017	94	34	128

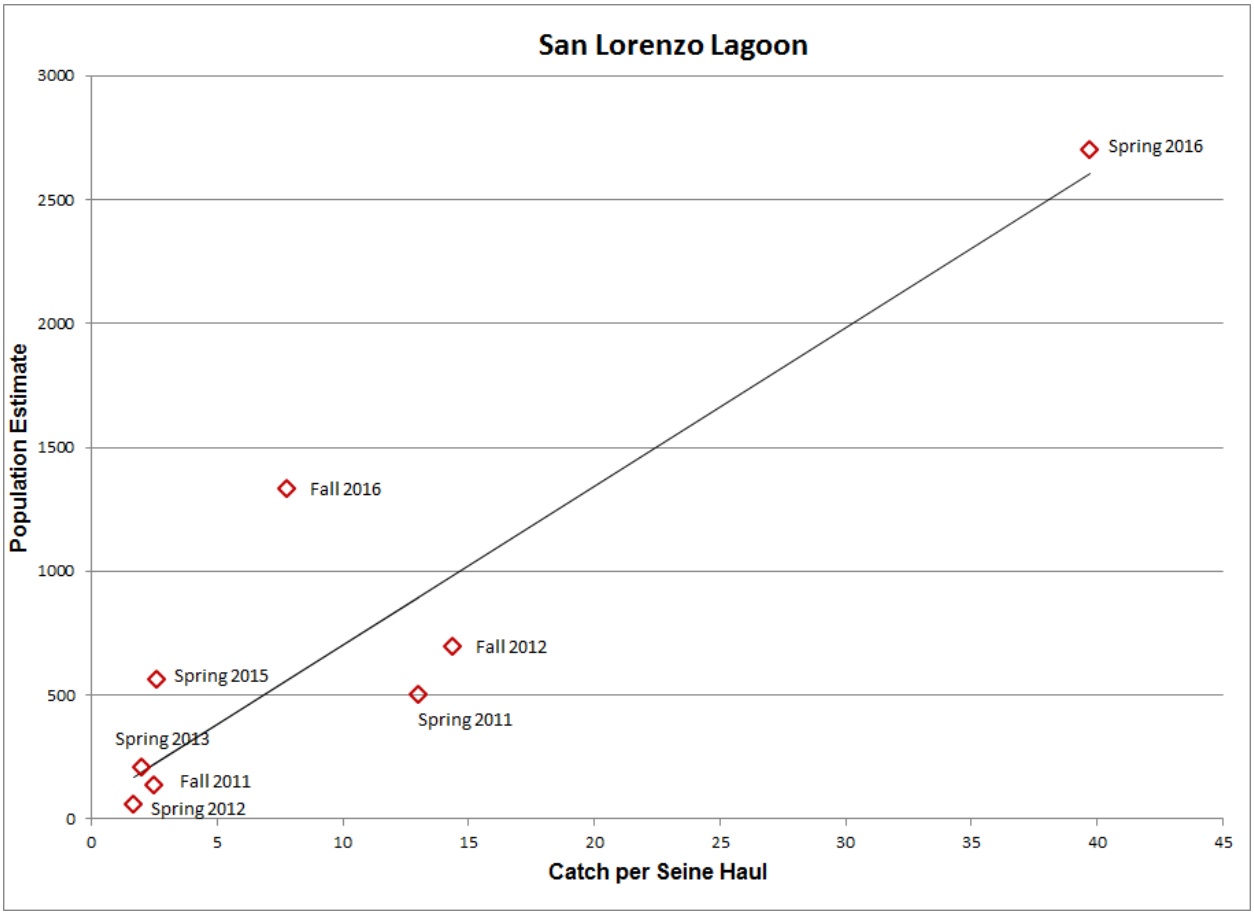

Figure 26. Relationship between *O.mykiss* population estimate and CPUE in the San Lorenzo River Lagoon[3]

[3] The spring 2013 and spring 2015 estimates are likely biased due to the small number of marked fish and small number of recaptures. Population estimates are not available for Fall 2013 and Spring 2014 due to low recapture rates and indications that the assumption of closed population was violated (2013) or lack of recaptures (2014). No *O. mykiss* were captured in Fall 2014 and Fall 2015 so CPUE was zero and populations were assumed to be near zero also.

Figure A-1. Laguna Creek Lagoon sampling stations

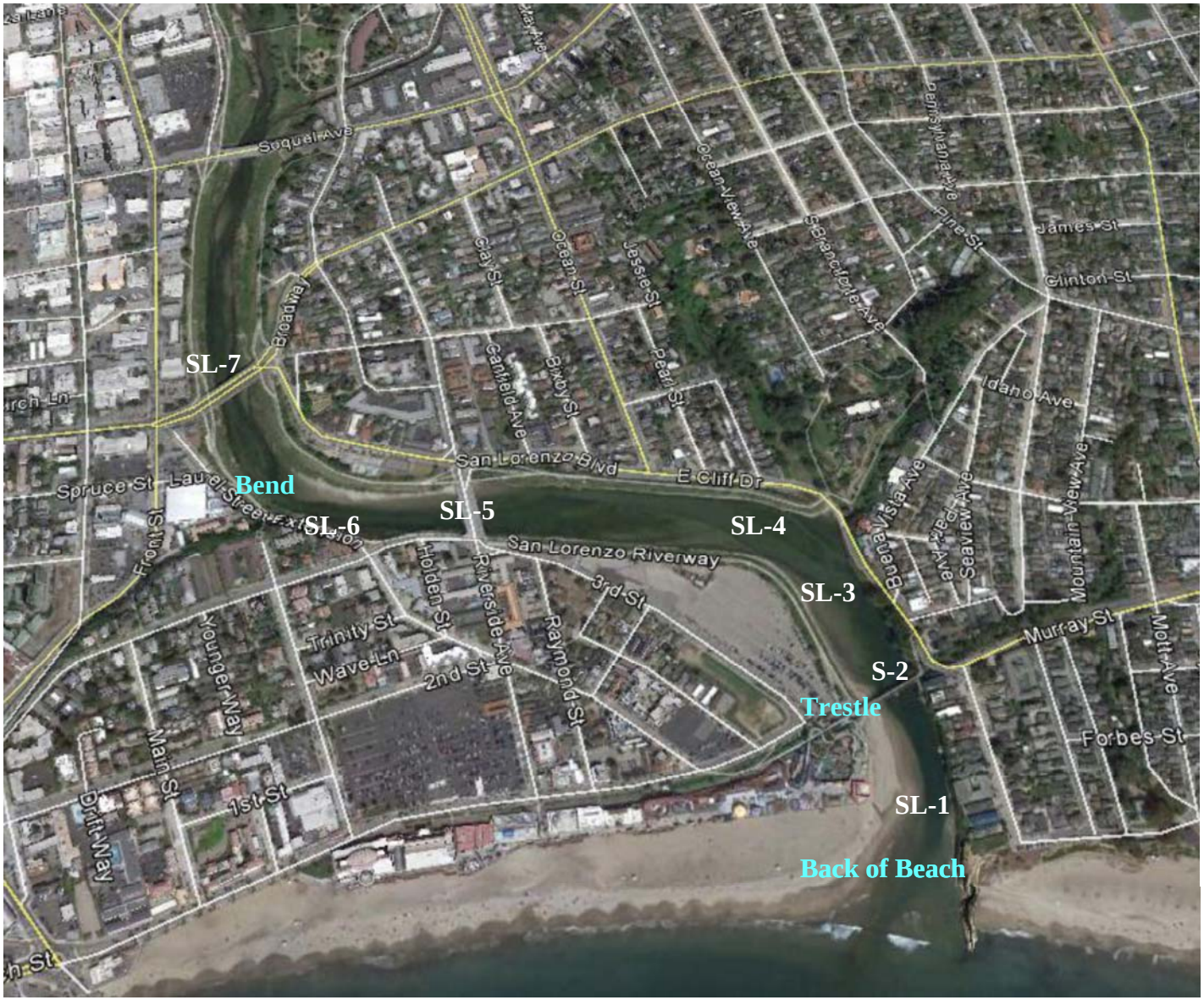

Figure A-2. San Lorenzo River Lagoon sampling stations

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