TECHNICAL MEMORANDUM

TO: Chris Berry
City of Santa Cruz Water Department

FROM: Jeff Hagar
Hagar Environmental Science

DATE: June 8, 2024

PROJECT: City of Santa Cruz Habitat Conservation Plan, Lagoon Fish Population Sampling 2023

Steelhead (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*) population abundance and life-history characteristics were assessed in Laguna Creek Lagoon and the San Lorenzo River Lagoon during the summer of 2023 by the City of Santa Cruz Water Department and Hagar Environmental Science (HES). Mark-recapture abundance surveys were conducted in the early summer (June) and again in the late summer (September) using a large seine to capture fish (46 meter [150 foot] long by 2.4 meter [8 foot] deep), and PIT tag technology to identify recaptures. The net has a mesh size of 3/8 inch. The net was replaced in July 2021 due to damage. The replacement net of the same dimensions had a somewhat larger mesh (though still sold as 3/8-inch mesh) due to changes in net construction from the supplier. The new net may have a lower capture efficiency for very small young-of-year (YOY) steelhead (less than 80 mm). *O. mykiss* less than 80mm FL (YOY) may be under-reported in the catch rates after 2020 compared to before. This does not affect mark-recapture estimates since fish less than 80 mm are also too small to tag and this size class is excluded from population estimates. Catch per effort estimates may not be comparable if large numbers of YOY are involved (2017 and 2019 in the San Lorenzo River Lagoon and 2011, 2012, 2017 and 2020 in Laguna Creek Lagoon).

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 the subsequent two-day period. Additional catch per effort surveys were conducted in the San Lorenzo River Lagoon during July and August.

Laguna Creek

Summary

The wet winter of 2022-2023 resulted in spring high flows in Laguna Creek with mean daily flow exceeding 4 cfs through mid-June (Figure 1) (City of Santa Cruz stream monitoring data, Laguna Creek anadromous gage). The lagoon breached on November 8, 2022 and was open through May 18, 2023 except for the period from November 25 through December 1, 2022 (City of Santa Cruz lagoon depth record). Based on lagoon elevation records, there appeared to be two brief periods of closure of 3 to 4 days duration in May and June before the June survey. The lagoon had reopened about 4 days prior to the June survey. The lagoon was open at the time of sampling and had a long finger extending parallel to the beach to the northwest, eventually intersecting the ocean just below the access road. Lagoon levels were relatively high compared to previous years.

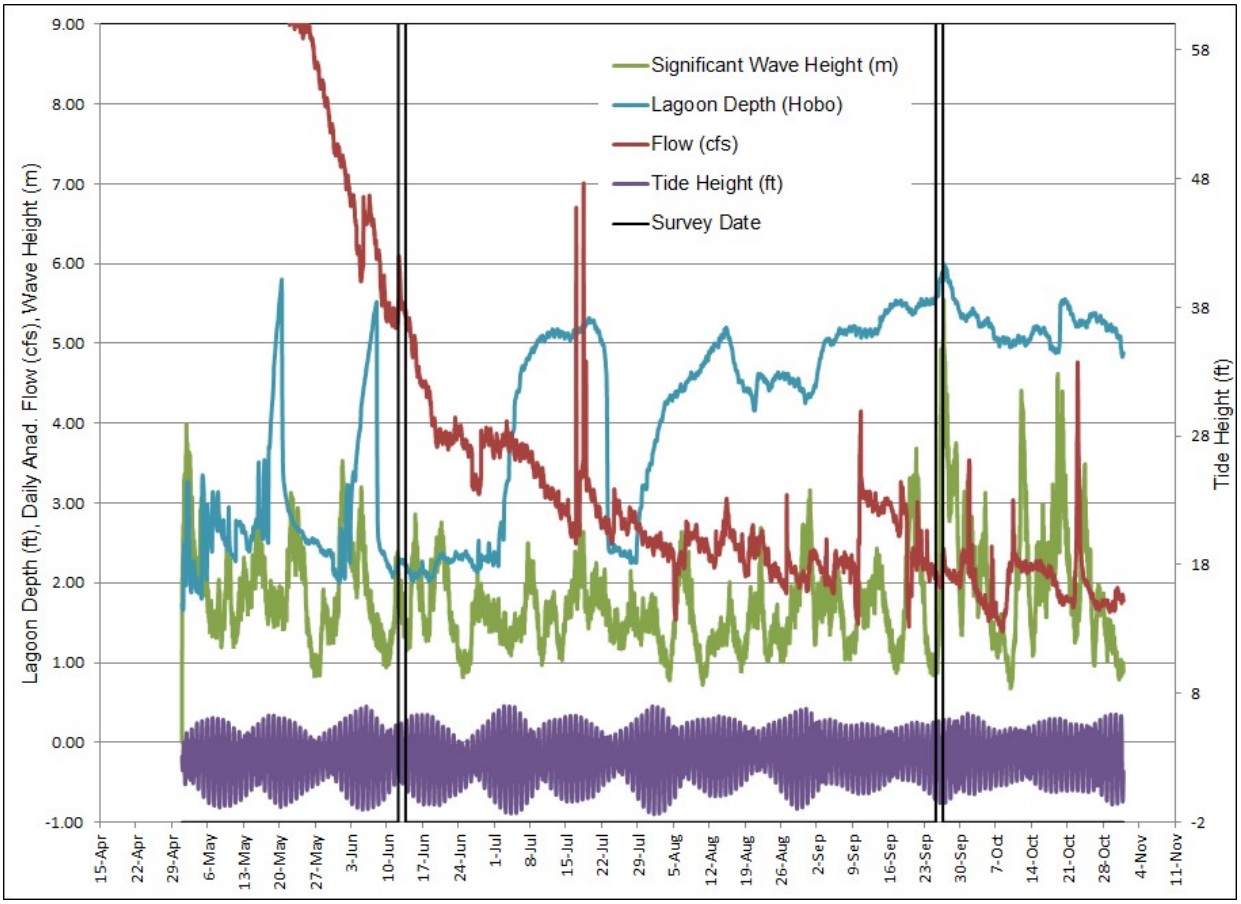

Figure 1. Laguna Creek Lagoon stage, streamflow, wave height, and tides 2023 (Source: lagoon depth from 2ND Nature and City of Santa Cruz, streamflow from City of Santa Cruz, wave and tide data from NOAA)

O. mykiss abundance (CPUE) was the third highest of all annual spring survey dates, after 2020 and 2017, and the second highest for fall surveys to date (Table 1). Population estimates were the second highest for spring surveys and highest to date for the fall survey (Table 2). The fall population estimate was over 70% larger than the spring estimate while the fall CPUE was only 52% of the spring CPUE. This is attributed to a higher capture probability in the spring compared to the fall. Although the sampling procedure was repeated similarly for both samples, fish were more confined in June and easier to capture due to a shallower, less extensive lagoon (lagoon stage 2.2-2.3 feet in June compared to 5.6-5.9 feet in September) and warm temperature and high salinity at depths below 1.0 meter. This would not affect the population estimates since they are independent of capture probability as long as the probability is the same for tagged and untagged individuals.

There was one *O. mykiss* captured that had been tagged in the lagoon in September of 2022. In spite of a large population of O. mykiss in the lagoon and the possibility for density dependent growth suppression, growth observed in 2023 was in the upper mid-range of the distribution of observations in previous years.

Two coho were captured in 2023, both in June. One was a YOY at about 40 mm length and one was 85 mm FL, likely a yearling.

Table 1. *O. mykiss* and coho salmon (*O. kisutch*) 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, HES 2016, HES 2017, HES 2018, HES 2019, HES 2020, HES 2021, HES 2022, and HES 2023).

	O. mykiss Catch per Haul				Coho (*O. kisutch*) 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*	
2017	*42.8*		*14.5*		*0*		*0*	
2018	*14.3*		*6.5*		*0*		*0*	
2019	*17.0*		*2.5*		*0*		*0*	
2020	*56.8*		*11.4*		*1.4*		*0*	
2021	*8.4*		*5.4*		*1.7*		*1.1*	
2022	*4.4*		*14.9*		*0*		*0*	
2023	*36.4*		*19.1*		*0.2*		*0*	

Table 2. *O. mykiss* mark-recapture population abundance estimates in Laguna Creek Lagoon for fish >80mm FL and <320mm FL (*Source: HES annual survey reports 2012-2023*)

	O. mykiss Population Estimate	
	Spring	Fall
2011	300	Early breach, insufficient catch
2012	Open lagoon, insufficient catch	370
2013	499	259
2014	256	828
2015	Recently closed, insufficient catch	267
2016	45	136
2017	641	548
2018	193	242
2019	Breaching lagoon, insufficient recaps	Open lagoon, insufficient catch
2020	Insufficient recaps, open population(?)	668
2021	Insufficient recaps, open population(?)	245
2022	168	373
2023	563	973

June Survey (June 12-13)

Early summer Site Conditions

- The mouth was open and the stage was low. In contrast to past years, the lagoon outlet was not directly next to the rock bluff but the outlet channel extended north along the beach before discharging into the ocean. (Figure 2, Figure 3). Stage ranged from 2.20 to 2.30 during the June survey (Figure 1).
- The water depth was shallow with greatest depths just over 3 feet along the rock bluff and the edge of the marsh upstream to the water quality recorder.
- Algal growth was moderate in the upstream sampling locations but did not hamper sampling effort significantly.
- Inflow from Laguna Creek ranged from 5.4 cfs to 6.1 cfs (Figure 1).
- The lagoon was fresh at the surface with a pronounced salinity layer beginning at a depth of 0.8 m. Peak salinity was 17-19 ppt at the bottom of the water column (Figure 4, center panel).
- Temperature was coolest at the surface (14°C to 17°C) and increased in the saline layer below 0.8 m. Temperature in the saline layer increased to lethal levels below 1 m depth (Figure 4, left panel).

- Dissolved oxygen was high throughout the water column, ranging from 9.8 mg/l to 11.3 mg/l at the surface to 15 mg/l to 21 mg/l in the saline layer at 0.8 m and deeper (Figure 4, right panel).
- The water column was clear with substrate visible at greatest depth surveyed (1.8 meters or 5.9 feet).

Figure 2. Laguna Creek Lagoon, June 12, 2023

Figure 3. Laguna Creek Lagoon mouth, June 13, 2023

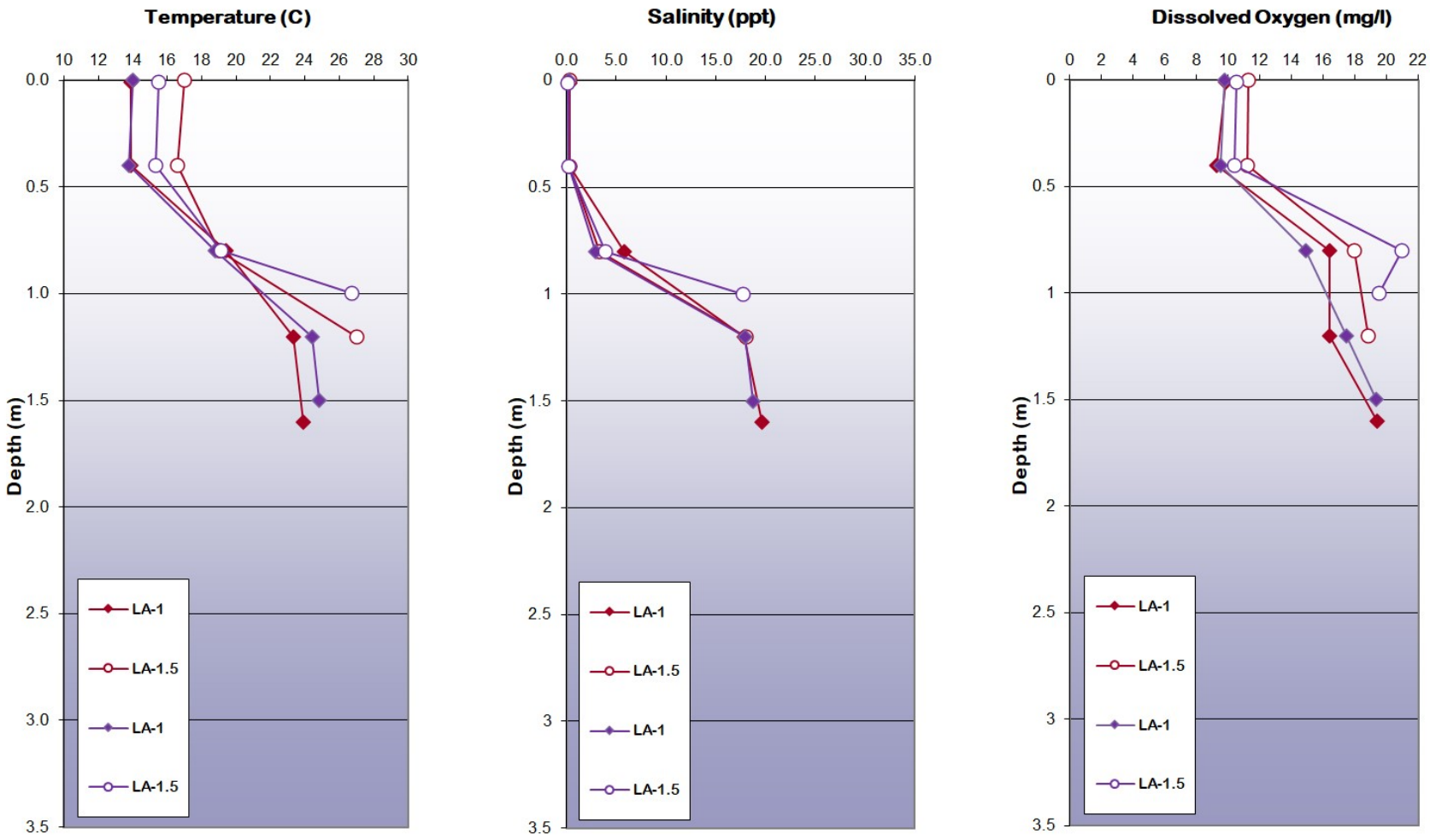

Figure 4. Depth profiles of water quality parameters in Laguna Creek Lagoon during June seining survey. Profiles plotted in red are June 12; profiles in blue are June 13

June Survey Results

- *O. mykiss* were captured and marked on June 12. On June 13 the lagoon was re-sampled and the proportion of re-captured fish was recorded. Six seine hauls were completed on each day from the beach (LA-1) upstream to the vicinity of the water quality buoy (LA-3).
- *O. mykiss* abundance (CPUE) was the third highest of all annual spring survey dates, after 2020 and 2017 (Table 1).
- Two coho were also captured; one was a YOY at about 40 mm length and one was a yearling at 85 mm FL.
- In addition to *O. mykiss*, the four other most commonly captured species in Laguna Creek Lagoon, threespine stickleback, staghorn sculpin, tidewater goby, and starry flounder were also captured (Table 3). Tidewater goby and stickleback are under-represented in the catch since the 3/8-inch mesh used for steelhead does not effectively retain these species, particularly the smaller individuals.

Table 3. Fish catch in Laguna Creek Lagoon, June 2023

	LA-1	LA-1.5	LA-2	LA-3	Grand Total
# Hauls	*6*	*4*	*2*	*0*	***12***
Species	***Number Caught***				
Coho	2				**2**
Steelhead	103	219	115		**437**
Threespine stickleback	16	57	21		**94**
Staghorn sculpin	2	2	1		**5**
Tidewater goby	4	19	8		**31**
Starry flounder	1	1	1		**3**
O. mykiss CPUE	***17.2***	***54.8***	***57.5***		***36.4***

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

- Ten percent of steelhead captured were characterized as YOY.
- Two percent of the steelhead were characterized as smolts, the rest were parr (77%) and silvery parr (11%).
- Three-hundred twenty-two *O. mykiss* were examined for external indications of disease and parasites. One of those examined was lightly infected with black-spot disease (BSD). No other external parasites, disease, or abnormalities were noted.
- All *O. mykiss* examined had an adipose fin present.
- One *O. mykiss* captured in June had been tagged in September 2022. The fish was marked on September 27, 2022 at a length of 225 mm FL, recaptured on September 28, 2022, and again on June 13 2023. It was measured at 296 mm FL. The average growth rate was 0.27

mm/day during the intervening period. The fish was in smolt condition when it was captured in June 2023.

- The length-frequency distribution for steelhead indicates a diverse range of sizes (age) of individuals using the lagoon (Figure 5). Fish 60-69 mm and less are likely YOY. YOY may be under-represented in the catch as the smaller individuals may be less likely to be retained by the mesh size in use. Fish in the 20 mm and 30 mm size classes must have emerged fairly recently, indicating possible late spawning (Figure 6). A possible mode focused on 70-110 mm FL would be consistent with age 1+ and the large group of fish in the 110-180 mm FL could be age 2+ fish that reared in the stream or, given high growth rates in the lagoon, these could also be age 1+ lagoon reared fish (Figure 5).

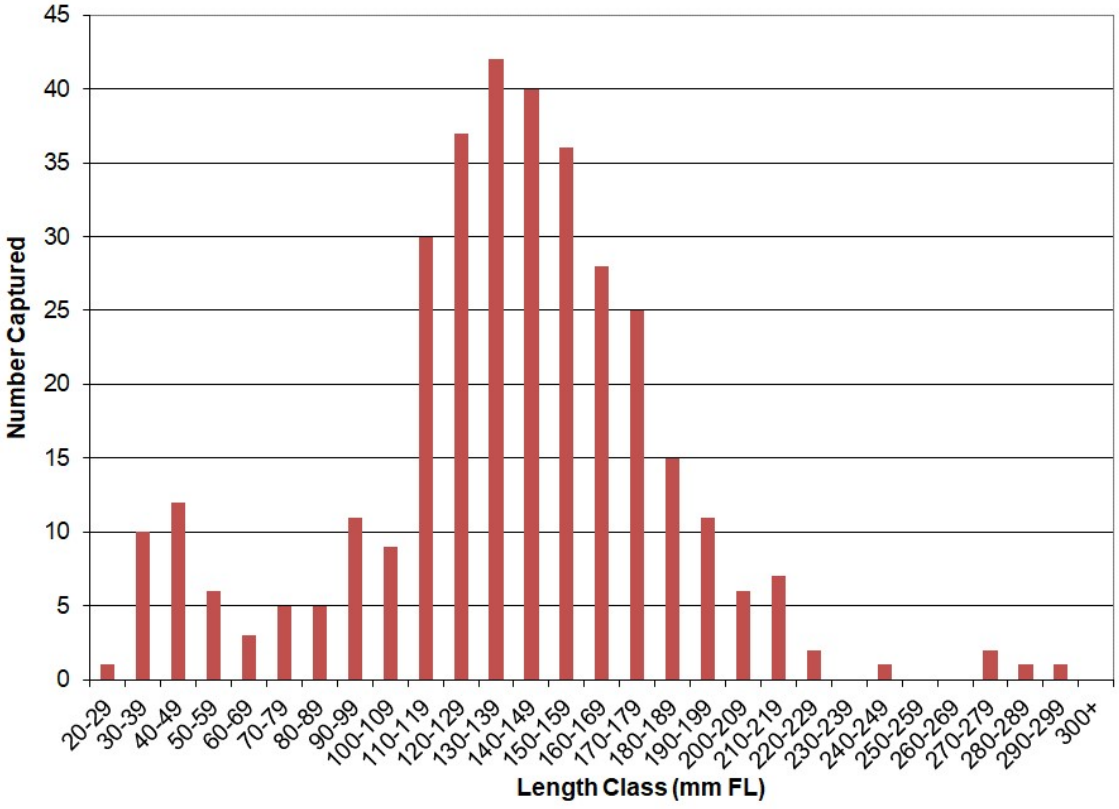

Figure 5. *O. mykiss* length classes in Laguna Creek Lagoon, June 2023

Figure 6. YOY *O. mykiss* from Laguna Creek Lagoon, June 2023

June *O. mykiss* Population Estimate

- Two-hundred and twelve *O. mykiss* were captured during the marking period on June 12. Twenty-five of these were too small to mark (less than 90mm) and 11 were recaptures from the marking period. Two fish died after being tagged on the second haul. One was 116 mm FL and one was 102 mm FL. As a result, the field crew decided to quit tagging fish smaller than 110 mm, resulting in 8 fish less than 110 mm not being tagged and 2 mortalities. Therefore, there were 166 individuals tagged and returned to the lagoon.
- Two-hundred and twenty-five *O. mykiss* were captured during the recapture period on June 13. Sixty-six of these had been tagged during the marking period and one had been tagged in the fall of 2022 and was not included in calculating the population estimate.
- Based on the Peterson method (Ricker 1975), the population estimate is 563 *O. mykiss* in the lagoon in mid-June. The 95% confidence limits for this estimate are 444 and 714. This estimate was the second highest abundance estimate for spring surveys in Laguna to date (Figure 7). Only the 2017 estimate was higher (641).
- CPUE was similar during the mark and recapture periods (35.3 vs. 37.5) and not statistically different, two sample t-test, equal variance, two-tail, p≈0.90).
- Untagged fish captured during the recapture period were tagged in order to collect over-summer information.

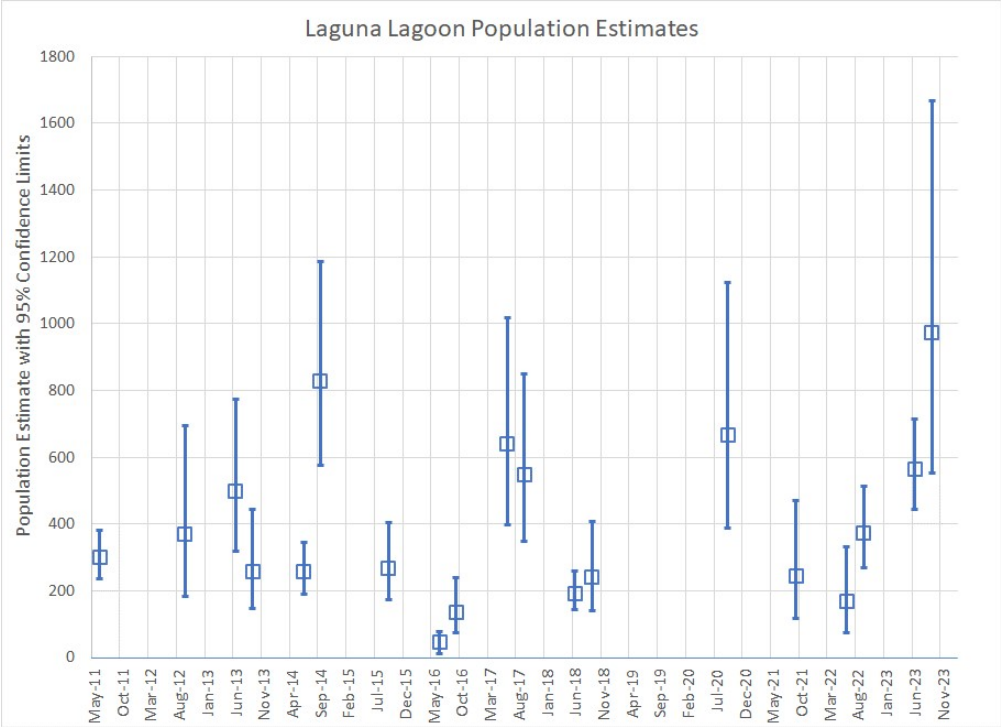

Figure 7. *O. mykiss* population estimates in Laguna Creek Lagoon over time[1]

September Survey (September 25-26)

Late summer Site Conditions

- The lagoon was closed at the time of the September survey and had been closed since July 30 (2nd Nature and City of Santa Cruz data) (Figure 1, Figure 8). The lagoon stage was at its highest level of the season, ranging from 5.6 feet to 5.9 feet. Much of the bordering beach/sandbar was flooded making for long, challenging hauls. There was a narrow finger of lagoon extending to the northwest just inside the surf zone (a long seine haul through this arm did not result in capture of any fish). The lagoon was significantly higher and more extensive than in June. Lagoon stage was higher on the 26th with frequent large waves overtopping the beach berm and increased salinity.
- Inflow from Laguna Creek during sampling ranged from 2.0 cfs to 2.4 cfs (Figure 1).
- Maximum depth measured was 2.5 meters (8.2 feet). The deepest water was available along the rock wall and along the interior marsh edge.

[1] Population estimates not available in Fall 2011, Spring 2012, Spring 2015, Spring and Fall 2019, Spring 2020, and Spring 2021 due to insufficient catch, low number of recaptures, and/or evidence of transient populations in the lagoon.

Figure 8. Laguna Creek Lagoon near mouth, September 25, 2023

- The lagoon temperature was good for rearing steelhead, ranging between 14°C and 18°C in most of the water column with some daily variation (Figure 9, left panel).
- The lagoon was fresh on the 25th with essentially zero salinity down to the bottom. On the 26th there were waves overtopping the beach berm at high tide and this resulted in an increase in salinity below 0.8 m with levels reaching 9 ppt to 10 ppt in the deepest water (Figure 9, center panel).
- Dissolved oxygen ranged between 6.8 mg/l and 11.5 mg/l in the upper 2 m of the water column with no significant stratification but some variation on the two sample dates (Figure 9, right panel).
- The water column was clear with secchi visibility to the bottom at depths up to 2.5 meters (8.2 feet). There was less visibility near the outlet on September 26, likely related to wave overwash of the sandbar.

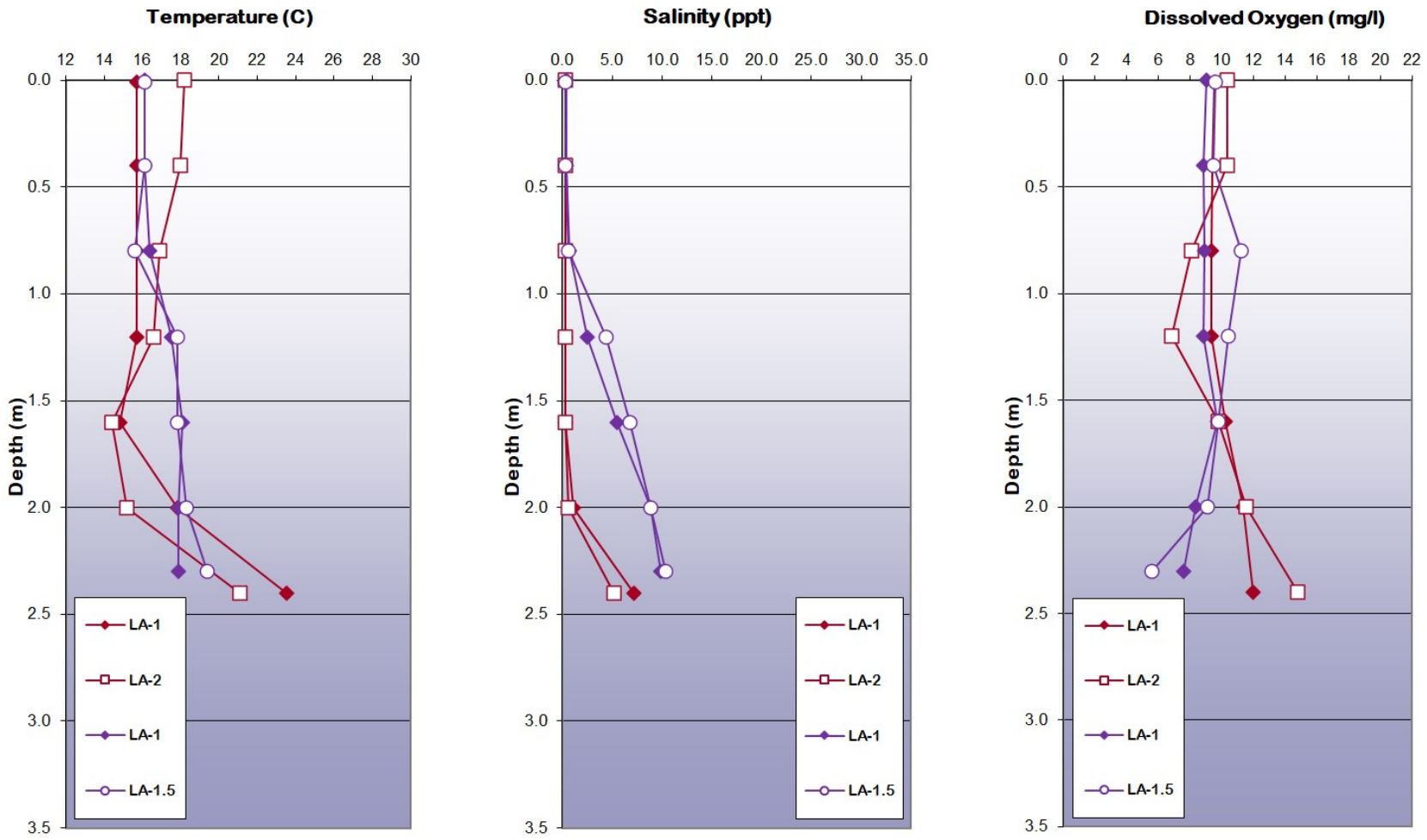

Figure 9. Depth profiles of water quality parameters in Laguna Creek Lagoon during September. Profiles plotted in red are September 25; profiles in blue are September 26

September Survey Results

- *O. mykiss* were captured and marked on September 25. On September 26 the lagoon was re-sampled and the proportion of re-captured fish was recorded.
- Eight seine hauls were completed on September 25 and 7 were completed on September 26. The lagoon was sampled from the beach (LA-1) upstream to near the water quality buoy (LA-3) (Table 4). Seining was difficult near mouth due to long channel that formed northward from the bluff and the high water levels due to the closed lagoon.
- Species representation was similar to June (Table 3, Table 4).

Table 4. Fish catch in Laguna Creek Lagoon, September 2023

	LA-1	LA-1.5	LA-2	LA-3	Grand Total
# Hauls	*9*	*2*	*2*	*2*	***15***
Species	***Number Caught***				
Steelhead	64	72	75	76	**287**
Threespine stickleback	93	4	18	7	**122**
Staghorn sculpin				2	**2**
Tidewater goby	2				**2**
Starry flounder				1	**1**
Unidentified fry	50				**50**
O. mykiss CPUE	*7.1*	*36.0*	*37.5*	*38.0*	***19.1***

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

- Overall abundance of *O. mykiss* based on catch per unit effort (CPUE) was the second highest for fall surveys to date (Table 1), but only about half the abundance in June (significant difference, two sample t-test, unequal variance, one-tail, p=0.04).
- There were no captures of *O. mykiss* tagged in previous years.
- Sixty-five *O. mykiss* tagged in June were recaptured in September. Growth rates ranged from 0.30 to 1.04 mm/day, averaging 0.58 mm/day. Growth observed in 2023 was in the upper mid-range of the distribution of observations in previous years (Table 5, Figure 10).
- There is some evidence for density dependent growth limitation in Laguna Lagoon. The years with highest growth rates have had the lowest fall CPUE and the years with lowest CPUE have had the highest growth rates (Figure 11). Three years had both low CPUE and low growth rates, indicating other factors besides density may limit growth rates (e.g. dry year conditions, high spring CPUE). There have been no years with both high CPUE and high growth rates (Figure 10). This relationship also holds if fall population estimate is used instead of CPUE.

Table 5. Laguna Creek Lagoon *O. mykiss* tagged in June and recaptured in September, annual averages

	Number Recaptured	Average Growth Rate (mm/day)	Range of Growth Rates (mm/day)	Fall CPUE	June CPUE
2012	1	0.86	NA	10.3	11.3
2013	10	0.48	0.22-0.78	8.6	28
2014	72	0.43	0.12-0.80	33	20
2015	1	0.99	NA	11.4	0.1
2016	0	NA	NA	5.2	1.1
2017	13	0.66	0.17-0.89	14.5	42.8
2018	23	0.99	0.87-1.34	6.5	14.3
2019	0	NA	NA	2.5	17.0
2020	4	0.46	0.27-0.62	11.4	56.8
2021	12	0.45	0.12-0.88	*5.4*	*8.4*
2022	6	0.69	0.57-0.88	*14.9*	*4.4*
2023	65	0.58	0.30-1.04	*19.1*	*36.4*

Figure 10. Laguna Creek Lagoon growth rates of *O. mykiss* tagged in June and recaptured in September

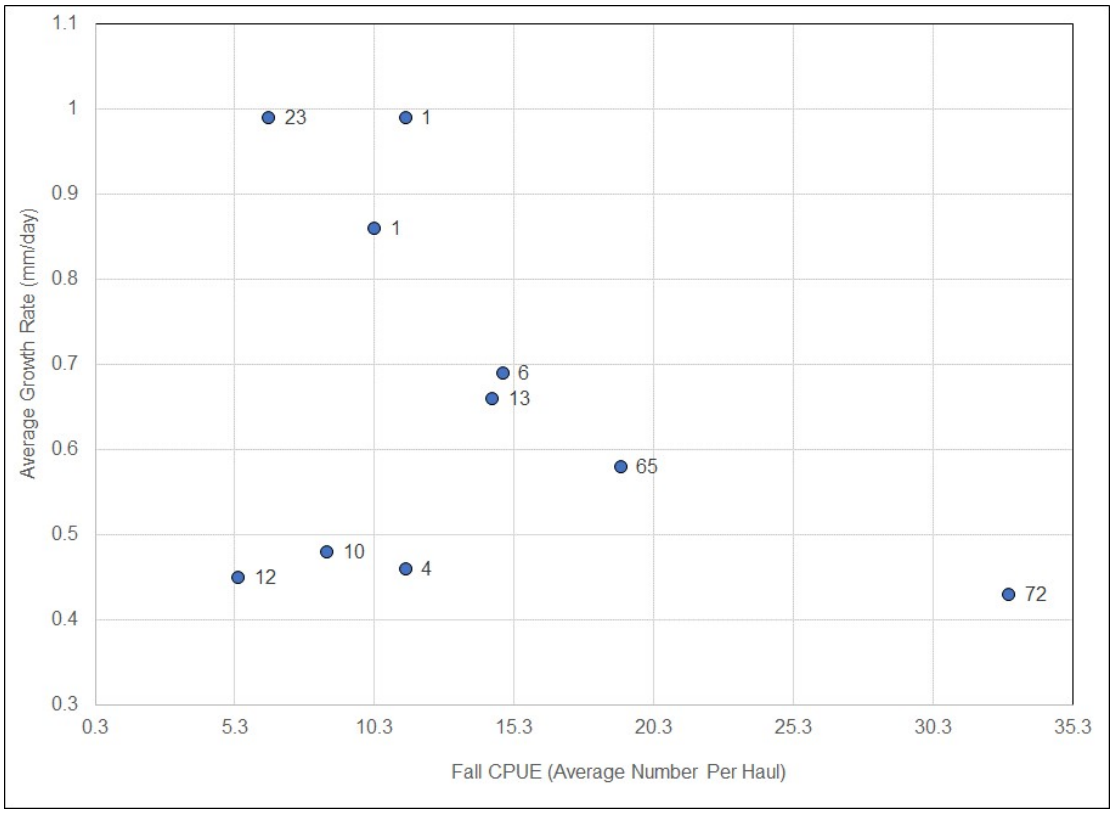

Figure 11. Possible density dependence of growth rates in Laguna Creek Lagoon (data in Table 5, sample size to right of data point).

- Captured *O. mykiss* in September ranged in length from 84 mm to 313 mm FL (Figure 12). The large mode of fish from 100 mm to 160 mm was likely composed of fish that had been in the YOY size class in June (20 mm to 70 mm). This would represent an average growth rate around 0.75 mm/day which is higher than the observed growth rates of older fish in the lagoon, as would be expected. This group was more abundant in September than in June which could have been due to lower capture efficiency of the small YOY in June with the equipment in use, migration of YOY into the lagoon after the June survey, or a combination of both.
- Based on growth rates from tag recovery data (Table 5), the numerous fish in the 110 mm to 170 mm mode in June would have grown to 170 mm to 230 mm by September. This can be seen as the second mode in the distribution in Figure 12. The lagoon was open for almost 3 weeks following the June survey, potentially allowing movement in or out between the ocean.

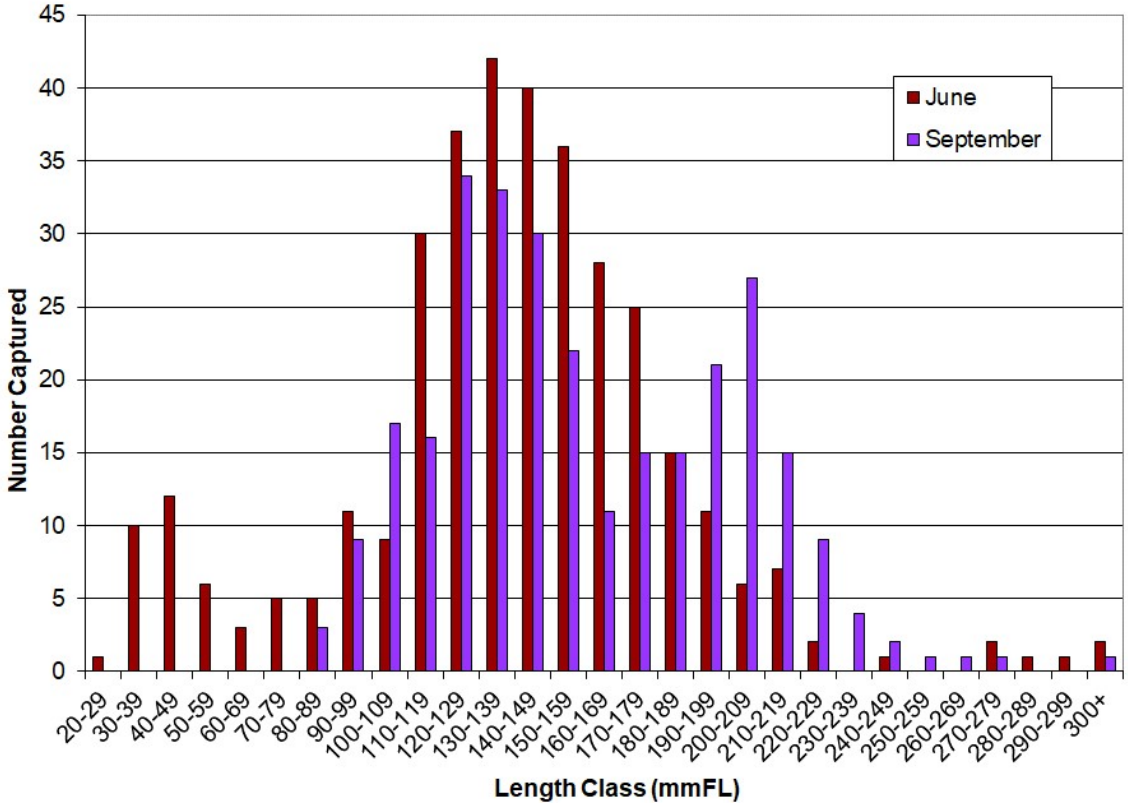

Figure 12. *O. mykiss* length classes in Laguna Creek Lagoon, late summer 2023 compared to spring 2023

- Seventy-two percent of the *O. mykiss* catch were characterized as parr or advanced parr and 28% were characterized as silvery parr or advanced silvery parr.
- No juvenile coho salmon were captured in September.
- Out of 287 *O. mykiss* examined (including recaptures) none had any external evidence of disease, parasites, or abnormalities.
- All *O. mykiss* had an adipose fin present.

September *O. mykiss* Population Estimate

- One hundred fifty-nine *O. mykiss* were captured during the marking period on September 25. Three fish were recaptures of fish already tagged during the marking period. Due to mortality of some larger individuals after tagging the minimum size for tagging was increased to 145 mm to avoid additional tagging mortality. Four *O. mykiss* died after tagging and 70 were below the 145 mm size limit and were not tagged. Therefore, there were 82 marked *O. mykiss* released in the lagoon on September 25 including 51 new tags and 31 tags from June.
- On September 28, 128 *O. mykiss* were captured, 10 of which were recaptures from the marking period.
- Based on the Peterson method (Ricker 1975), the population estimate is 973 *O. mykiss* in the lagoon in mid-September. The 95% confidence limits for this estimate are 551 and 1668. This estimate was the highest for all surveys in Laguna Creek, both spring and fall (Figure 7).
- It is surprising that the fall estimate of 973 is larger than the spring estimate of 563 even though CPUE in the spring was nearly twice the CPUE in fall (36.4 vs. 19.1)[2]. The recapture rate for tagged fish (number of tagged fish captured during recapture period divided by number of fish marked during mark period) was only 12.2% in the fall compared to 39.8% in June. This is likely explained by change in lagoon configuration between June and September. Although the sampling procedure was repeated similarly for both samples, fish were more confined in June due to a shallower, less extensive lagoon (about 1.5 meters maximum depth compared to 2.5 meters in September) and warm temperature and high salinity at depths below 1.0 meter in June.
- CPUE was similar during the mark and recovery periods (19.9 and 18.3, respectively; no significant difference, two sample t-test, equal variance, two-tail, p=0.88). This would indicate that the lagoon population was relatively stable between the mark and recovery periods (i.e. few individuals moving between the lagoon and upstream areas).
- The relationship between the population estimates and CPUE was updated with the spring and fall 2023 data points (Figure 13). Least squares regression r^2 is 0.46 and was statistically significant with p=0.001. Forcing the relationship through the origin improves the r^2 to 0.83. The relationship was slightly weaker with the addition of the 2023 data points as a result of differences in capture probability with low lagoon stage and volume in June and high stage and volume in September leading to increase in CPUE in June and decrease in September relative to population levels.

[2] The population estimates are not significantly different (they lie within each other's 95% confidence limits). The CPUE index for fall is significantly larger than the CPUE in spring at the 0.04 probability level (two sample t-test, unequal variance, one-tail).

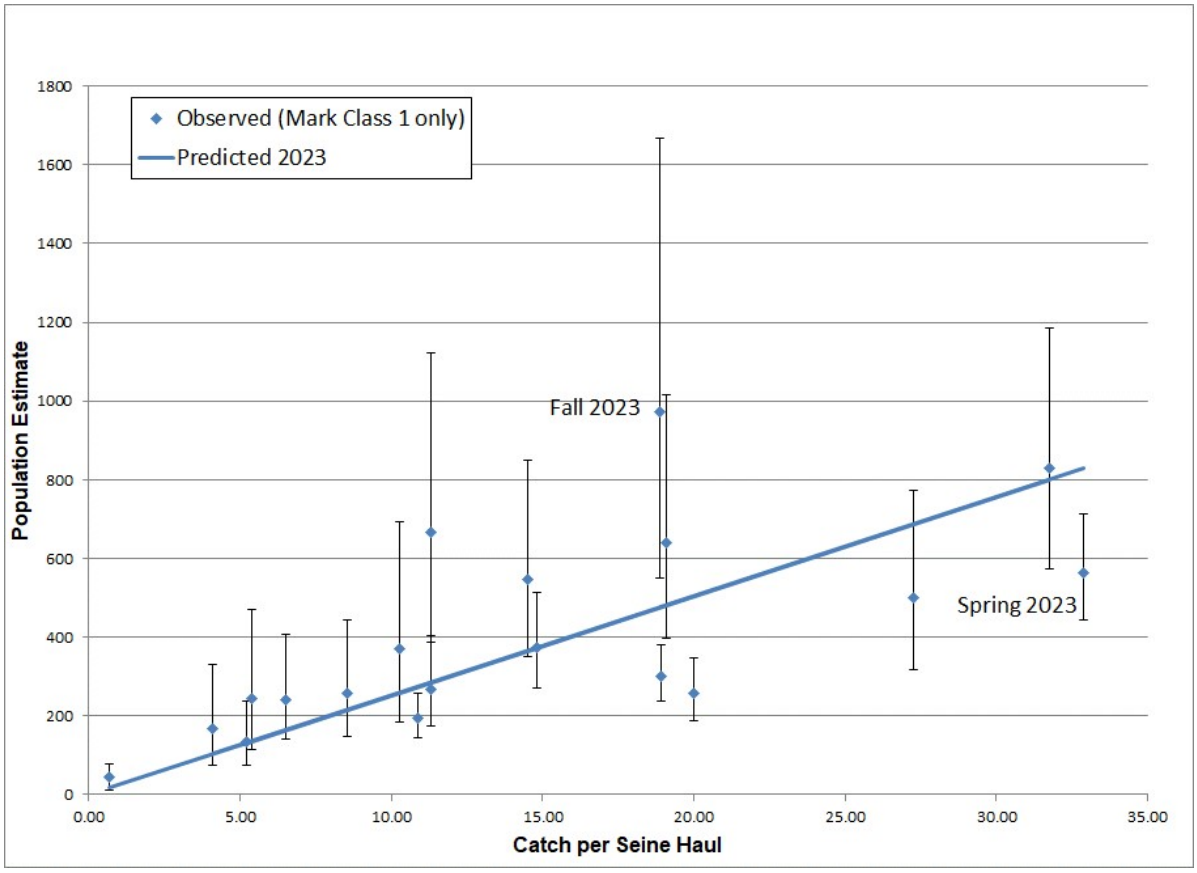

Figure 13. Relationship between *O. mykiss* population estimate and CPUE in Laguna Creek Lagoon[3]

[3] Population estimates not available in Fall 2011, Spring 2012, Spring 2015, Spring and Fall 2019, Spring 2020, and Spring 2021 due to insufficient catch, low number of recaptures, and/or evidence of transient populations in the lagoon.

San Lorenzo River

Summary

The winter of 2022-2023 was very wet with moderately high flows in the San Lorenzo River at Big Trees beginning in December and very high flows in January and March with both months having the second highest flow on record for that month (October 1936 to present) (USGS data for Station 11160500). Flows were high enough to be destructive to redds, based on evidence of substrate mobilization, and late spawning in April was possible with high but declining flows through the month. The lagoon remained open through late-August, after the third seining survey (Figure 14). Intermittent, short-duration closures occurred through at least the end of October.

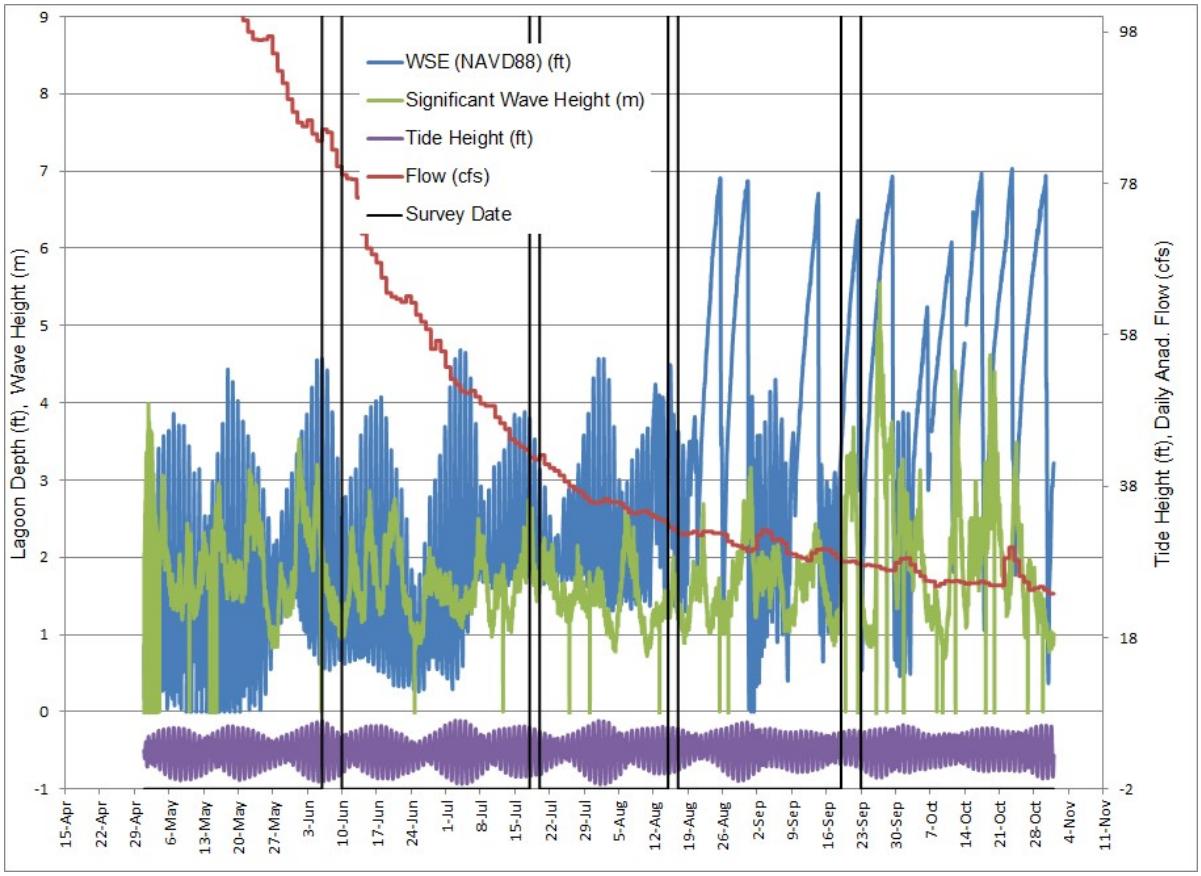

Figure 14. San Lorenzo River Lagoon stage, streamflow, wave height, and tides 2023 (Source: lagoon stage from City of Santa Cruz Public Works, streamflow from USGS, wave and tide data from NOAA)

The 2023 season continued the trend begun in the 2021 season of low abundance of *O. mykiss* in the lagoon in June compared to the 2016-2020 period of higher abundance (Table 6, Table 7), although catch rates rebounded in July and remained relatively high through the rest of the season. Growth rates were very good through August but diminished later in the summer. Seining was suspended due to low dissolved oxygen upstream of Riverside Bridge in July and tagging and measuring were suspended in August upstream of Riverside Bridge due to low dissolved oxygen and high temperature. Catch rates of *O. mykiss* peaked in August (Table 6) with fish concentrated around the Trestle bridge (Table 8).

Table 6. *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, HES 2016, HES 2017, HES 2018, HES 2019, HES 2020, HES 2021, HES 2022 and HES 2023)

	O. mykiss Catch per Haul				
Year	June	July	August	September	October
2008	2.6	NS	NS	NS	0.1
2009	0.3	NS	NS	1.0	0.5
2010	8.3	21.5	NS	NS	28.25
2011	13	NS	NS	NS	2.5
2012	1.7	NS	NS	14.4	NS
2013	2	8.4	NS	4.7	NS
2014	1.2	1.1	NS	0.0	NS
2015	2.6	0	0	NS	0
2016	39.7	1.0	2.0	7.8	NS
2017	134.4	452.0	272.0	328.5	NS
2018	23.3	2.5	6.4	6.3	NS
2019	92.2	53.4	277.7	228.2	NS
2020	146.1	120.6	NS	31.0	NS
2021	4.3	6.3	NS	NS	0.3
2022	2.4	20.5	2.3	8.8	NS
2023	5.8	30.8	46.0	24.1	NS
Average	30.0	59.8	86.6	59.5	5.3
Median	5.0	14.5	6.4	8.8	0.4

NS- Not Sampled

Table 7. *O. mykiss* mark-recapture population abundance estimates in San Lorenzo River Lagoon for fish >80mm FL and <320mm FL

	O. mykiss Population Estimate	
	Spring	Fall
2011	501	138
2012	60	714[1]
2013	207[2]	No estimate[3]
2014	No estimate[4]	None captured
2015	559[3]	None captured
2016	2,697	1,331
2017	3,636	>3,636[5]
2018	2,378	704
2019	7,637[6]	14,105
2020	26,815	18,720
2021	No estimate	No estimate
2022	53	721
2023	444	2046

Source: data from HES 2012, HES 2013, HES 2014a, HES 2015, and HES 2016

[1] May have been fish entering or leaving lagoon

[2] Low number of marks or recaptures, likely biased

[3] Evidence population not closed, violates assumption of the method

[4] No recaptures

[5] Estimate based on CPUE, mark-recapture estimate not possible, recapture period precluded due to incidental take limitations

[6] Based on proportion of fish in the catch greater and less than 80 mm FL there would have been an estimated 4,504 *O. mykiss* less than 80 mm FL for a total population of 12,141

Table 8. *O. mykiss* catch per haul for the San Lorenzo River Lagoon during 2023

		O. mykiss Catch per Haul				
Station	Location	Jun 6-9	Jul 18-19	Aug 15-16	Sep 19-22	Overall
SL-1	South of Trestle	0.2	24.3	1.3	1.8	**5.4**
SL-2	RR Trestle	7.4	44.7	146.0	46.4	**41.2**
SL-3	Near YSI Station	NS	NS	NS	NS	NS
SL-5	Riverside Drive	13.5	23.3	30.5	18.3	**18.9**
SL-6	U/S Bank Restoration	1.8		1.0	17.1	**7.8**
	Overall	**5.8**	**30.8**	**46.0**	**24.1**	**20.7**

NS- Not Sampled

June Survey (June 6-9)

June Site Conditions

- The lagoon was open and tidal through the June survey (Figure 15, Figure 16). Stage oscillated with the tides between 0.5 feet and 4.5 feet. The wide range of stage changes could have affected catch rates.
- Flow in the San Lorenzo River at Santa Cruz (USGS gage) ranged from 85 cfs on June 6 to 80 cfs at the end of the sampling period on June 9 (Figure 16). Mean flow for June during the period of record (1953-2022) is 34 cfs (historical discharge, USGS site 11161000 San Lorenzo River at Santa Cruz California).
- Due to the high lagoon level, the stretches of sand beach downstream of the trestle that are usually used for landing the hauls were submerged (Figure 15). The hauls were pulled through deep water and finished at the edge of the shelf at the canoe. Upstream of the trestle there was no sand beach with relatively deep (1 to 2 feet) water at the bank. Because of the dense filamentous algae, the hauls were pulled slowly and were heavy as they came in. The lagoon was open during the sampling upstream of Riverside Bridge and there were wide sand beaches extending from the bank. This required purse seine finishes at the canoe at the edge of the instream shelf. Some algal growth was present but was not a significant problem for sampling.
- The lagoon was strongly salinity stratified with a relatively fresh surface layer and a steep halocline beginning at 0.4 to 0.8 meters deep depending on location. Salinity ranged from 0.5 to 4.4 ppt in the surface layer and from 19 ppt to 28 ppt in the saline layer (Figure 17, center panel).

Figure 15. San Lorenzo River Lagoon mouth June 7, 2023

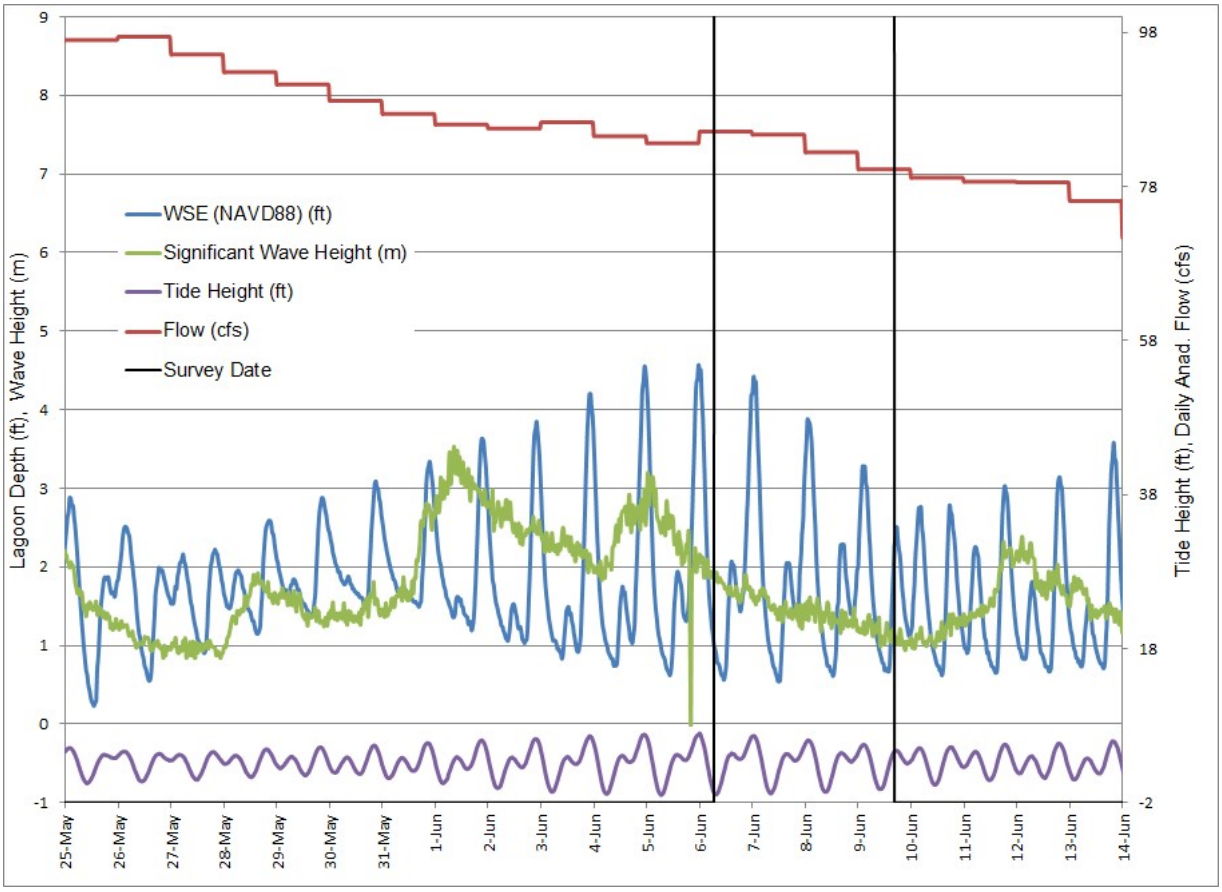

Figure 16. San Lorenzo River Lagoon stage, streamflow, wave height, and tides around June 2023 sample period (Source: lagoon stage from City of Santa Cruz Public Works, streamflow from USGS, wave and tide data from NOAA)

- Temperature was isothermal at 13.5°C to 16.5°C, ideal temperatures for rearing steelhead. These relatively cool temperatures persisted through the sample period (Figure 17, left panel). Temperature conditions were suitable for tagging through the mark and recovery periods.
- Dissolved oxygen was at relatively high levels in the surface layer (to 0.4 meters deep), ranging from 8.2 mg/l to 14 mg/l (Figure 17, right panel). DO levels in the lower water column remained above 7 mg/l at the Trestle and downstream but sagged to 6 mg/l at Stations 5 and 6.
- The water column was relatively clear with secchi disk visible at the substrate in up to 1.8 meters (5.9 feet) of depth.

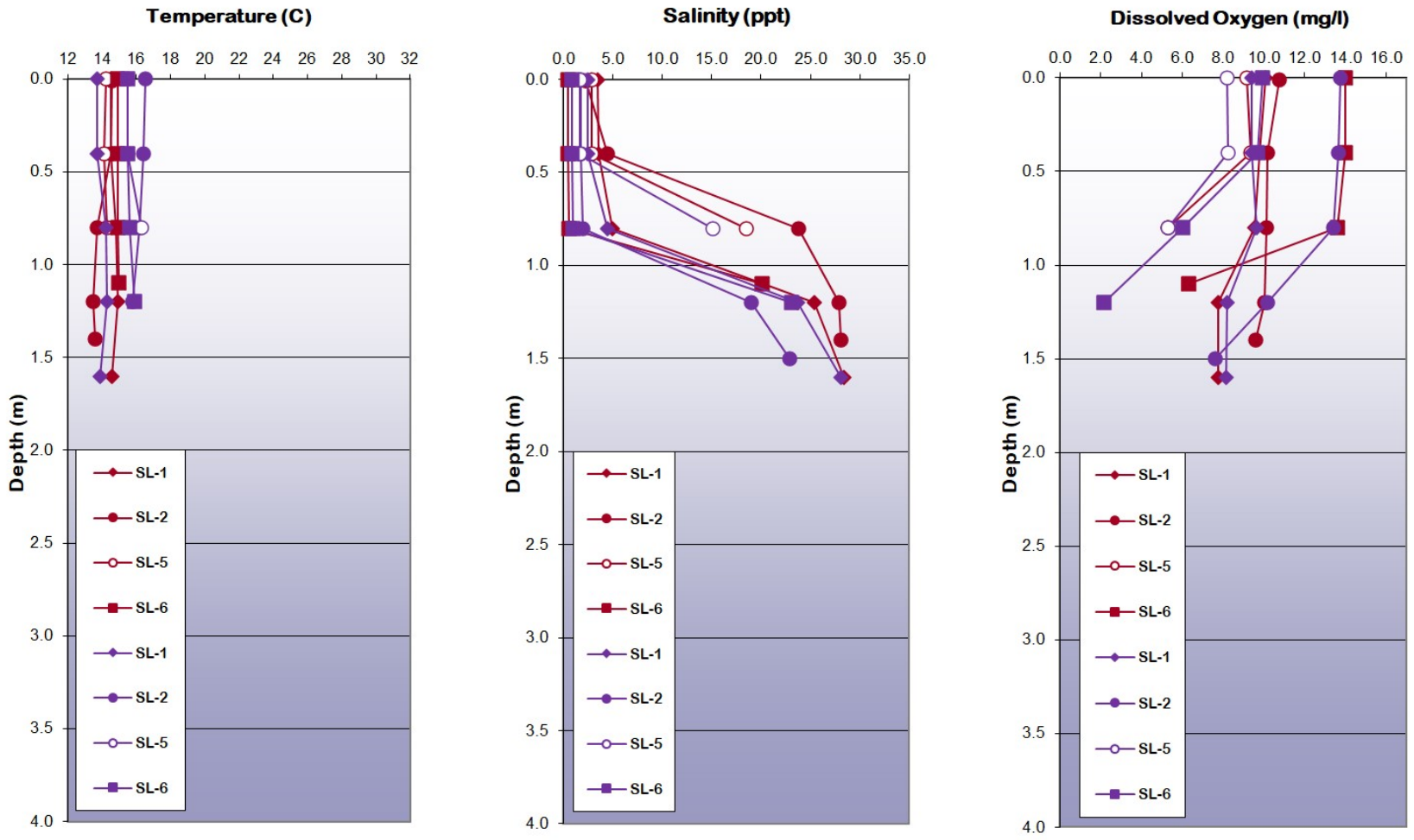

Figure 17. Depth profiles of water quality parameters in the San Lorenzo River Lagoon during June. Profiles plotted in red are June 7-8; profiles in blue are June 6-9

June Survey Results

- The lagoon was sampled between the beach and the bend upstream of Riverside Bridge on June 6 and 7 and again on June 8 and 9. All O. mykiss greater than 89 mm in length were tagged.
- Thirty-one seine hauls were completed at regularly sampled stations. One haul snagged badly and was not counted. The catch was dominated by topsmelt, followed by *O. mykiss* and Pacific herring (Table 9). A new species for this program, kelp greenling, was captured (Figure 18).
- *O. mykiss* abundance (CPUE), at 5.8 per haul, was near the median for all previous June surveys to date but well below average (Table 6). Even though the winter runoff was in the wet range, abundance was greatly reduced from the high levels observed in the 2016-2020 period. CPUE was highest near the trestle (SL-2) and immediately upstream of Riverside Bridge (SL-5) (Table 9).

Table 9. Fish catch in San Lorenzo River Lagoon, June 2023

	SL-1	SL-2	SL-5	SL-6	Grand Total
# Hauls	*5*	*11*	*6*	*9*	***31***
Species	***Number Caught***				
O. mykiss	1	81	81	16	**179**
Pacific herring		101			**101**
Topsmelt	564	1919	5549	1276	**9308**
Threespine stickleback		5	1	5	**11**
Prickly sculpin			1		**1**
Staghorn sculpin		32	7	1	**40**
Kelp greenling		1			**1**
Shiner surfperch	1	2			**3**
Tidewater goby		2	1	1	**4**
Starry flounder	11	16	16	8	**51**
Dungeness crab	8				**8**
O. mykiss CPUE	0.2	7.4	13.5	1.8	***5.8***

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

Figure 18. Kelp greenling juvenile, San Lorenzo River Lagoon mouth June 8, 2023. Note the cirri above the eyes and at the top of the head

- Most of the *O. mykiss* captured in June were in the 120 mm FL to 199 mm FL size classes (Figure 19). These fish were likely age 1+ and older, consistent with observations in previous years. A very small number of smaller fish in the 80 mm to 109 mm size range were likely larger YOY from early spawning. Migration events occurred in the San Lorenzo in November and December 2022 and high winter flows were continuous from January through April.
- Sixty-five percent of *O. mykiss* captured were classified as parr or advanced parr and 35% were classified as silvery parr.
- All *O. mykiss* captured had an adipose fin present, indicating they were not of hatchery origin.
- Thirty-two percent of *O. mykiss* examined had black-spot disease (BSD) lesions, most were lightly affected. Incidence of BSD has ranged between 11% and 68% in previous spring surveys since 2010.

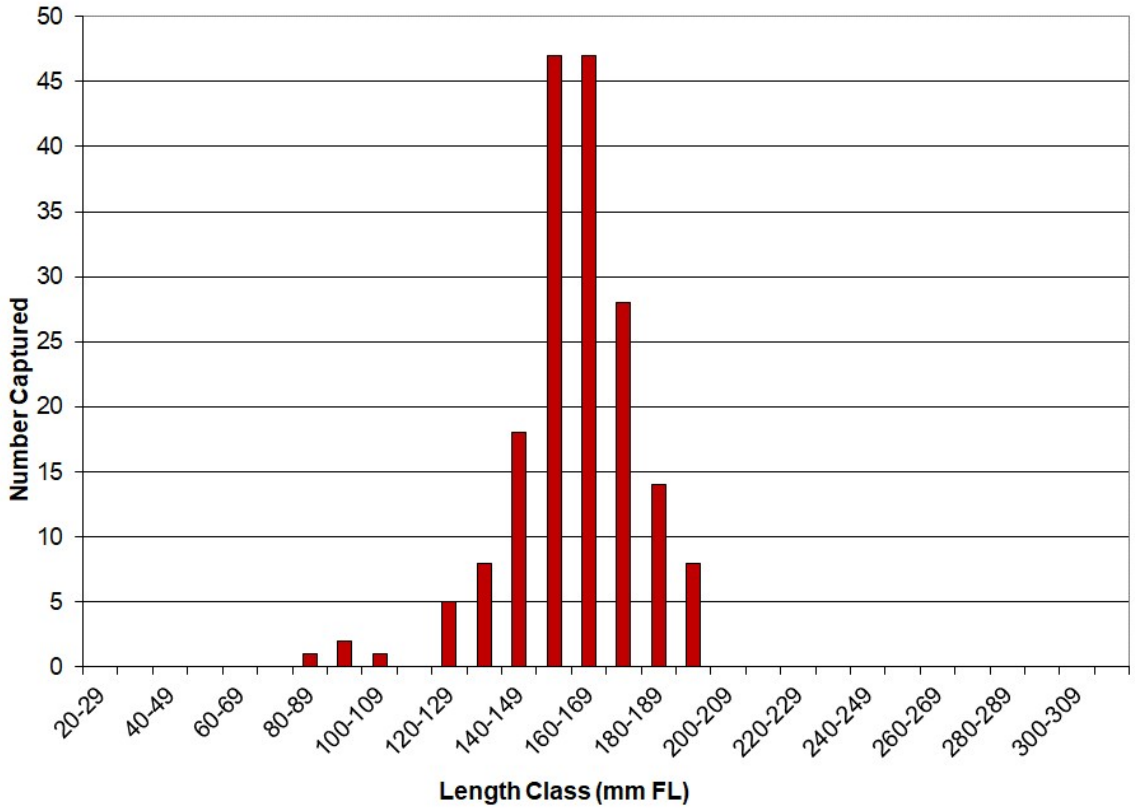

Figure 19. *O. mykiss* length classes in San Lorenzo River Lagoon, June 2023

June *O. mykiss* Population Estimate

- One-hundred and six *O. mykiss* were captured during the marking period (June 6-7). All captures were over the minimum limit for tagging (90 mm). Ten were recaptures of fish already tagged and one was not tagged. Ninety-five tagged *O. mykiss* had been released in the lagoon following the marking period.
- Seventy-three *O. mykiss* were captured during the recapture period. One fish was less than the 90 mm tagging limit. Fifteen of the captured fish had tags from the marking period.
- The Peterson population estimate (Ricker 1975) is 444 *O. mykiss* in the lagoon in June. The 95% confidence limits for this estimate are 276 and 705. Only three of the ten years when population estimates are available had lower estimates in June (Table 7). As with the CPUE, abundance was low for a wet year, though higher than the 2022 estimate.
- Changes in CPUE and size distribution between the mark period and recapture period can indicate movement of fish in and out of the lagoon and violation of the assumption of a closed population. Size distribution was comparable for the mark and recovery periods (Figure 20). CPUE was lower during the recovery period than during the marking period (7.1 vs. 4.3). The difference in CPUE between mark and recovery periods was not significantly different (two sample t-test, equal variance, two-tail, p=0.46).

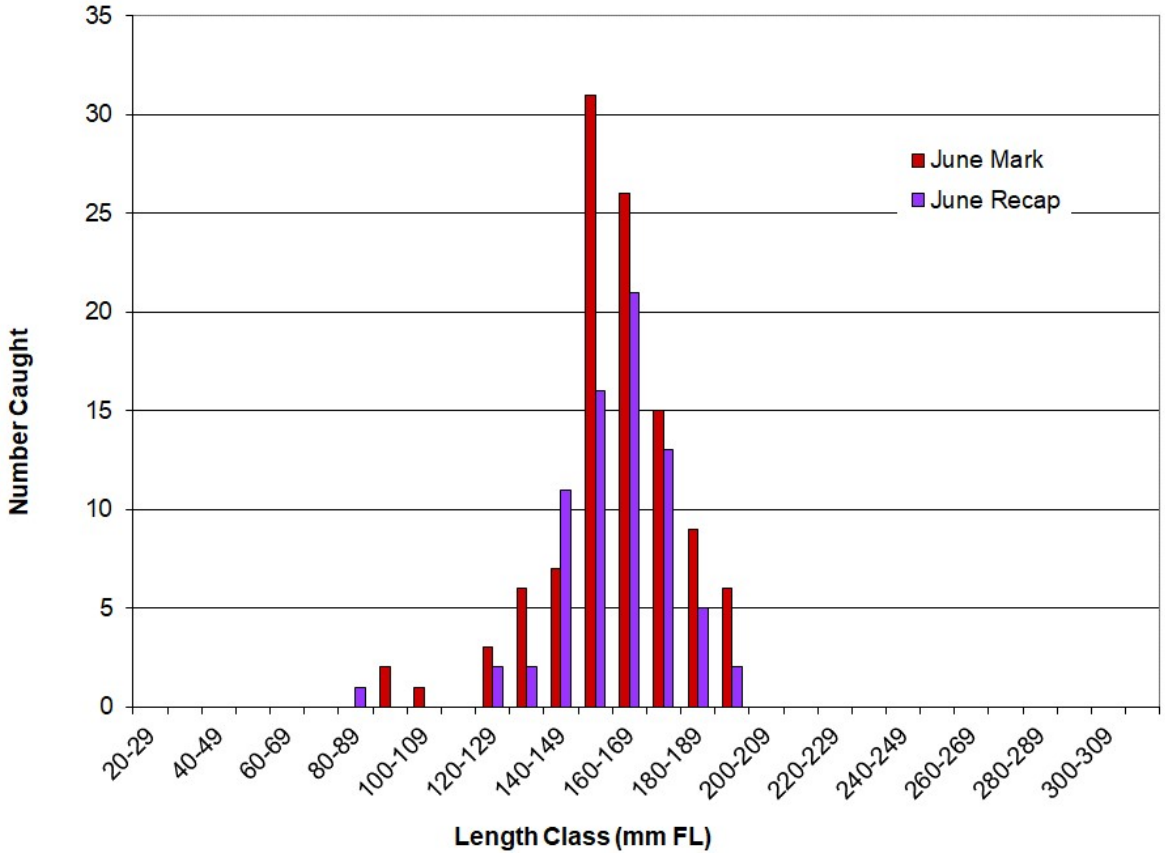

Figure 20. *O. mykiss* size distributions in San Lorenzo River Lagoon, June 2023 during mark and recapture periods

July Survey (July 18-19)

The July survey was a two-day relative abundance survey without mark-recapture population estimates. Sampling was conducted at standard sampling Stations SL-1 and SL-2, downstream and around the trestle; and Stations SL-5 upstream of Riverside Bridge. Station SL-6 was not sampled due to low dissolved oxygen (<5 mg/l in half the water column). Low levels of dissolved oxygen upstream of Riverside Bridge limited ability to survey in that area.

July Site Conditions

- The lagoon was open and tidal at the time of sampling and had been since the June survey and before (Figure 21). Lagoon stage ranged between 1.7 feet and 3.5 feet during the survey period (City of Santa Cruz data). The high tide was near midnight so maximum stage during the actual sampling ranged only between 1.9 and 2.1 feet.
- Inflow from the San Lorenzo River had declined from 80 cfs at the end of the June survey to 41 cfs during the July survey (Figure 14, Figure 21).

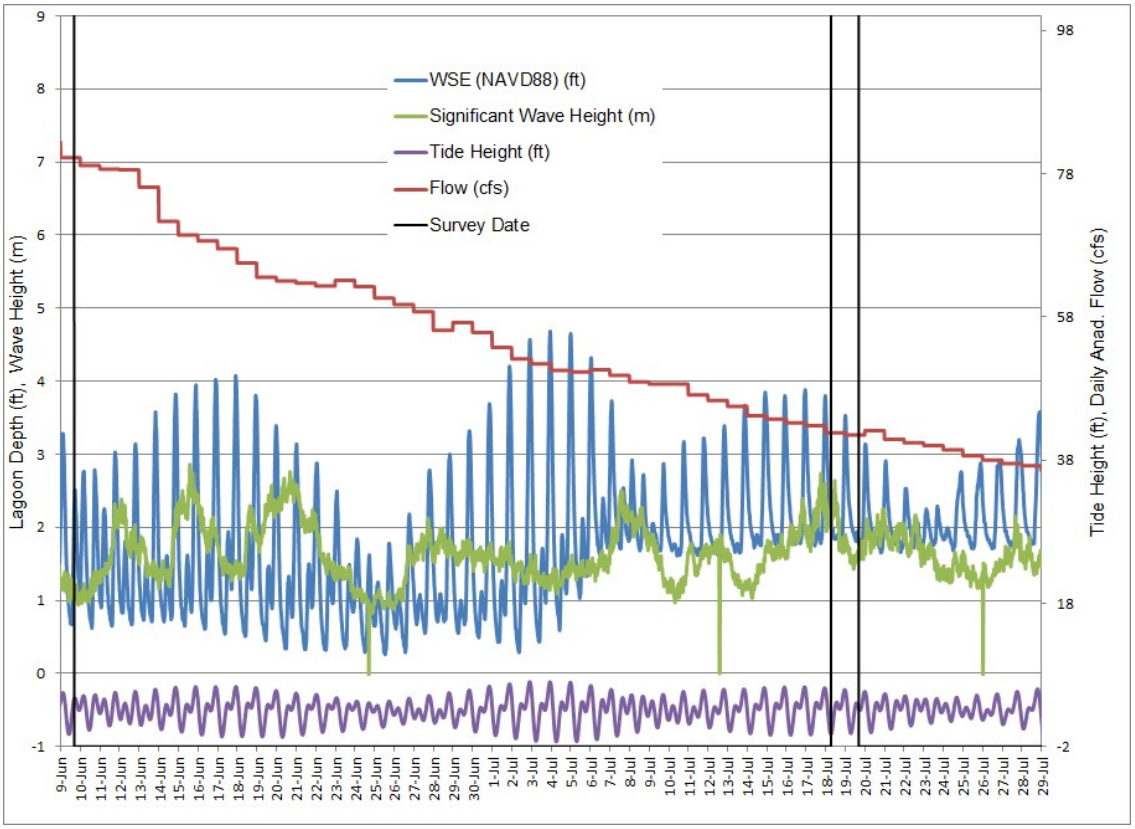

Figure 21. San Lorenzo River Lagoon stage, streamflow, wave height, and tides around July 2023 sample period (Source: lagoon stage from City of Santa Cruz Public Works, streamflow from USGS, wave and tide data from NOAA)

- There was fresh water at the surface and a strong salinity gradient between 0.4 meters (1.3 feet) and 0.8 meters depth (2.6 feet) (Figure 22, middle panel). Salinities ranged from 0.1 ppt to 0.8 ppt in the surface layer (to 0.4 meters deep) and increased to 28 ppt or more (approaching full seawater) at a depth of 0.8 m and below.
- Water temperature was relatively cool at the surface (for July in the San Lorenzo River lagoon) (18.5°C to 20.4°C) and in the deeper part of the water column (17.4°C to 20.1°C) due to the open lagoon condition. Temperatures were slightly warmer at the bottom of the halocline with a maximum measured temperature of 21.2°C at a depth of 0.8 meters (2.6 feet) (Figure 22, left panel).
- Dissolved oxygen was well-saturated at lower lagoon stations with at least 7 mg/l in the entire water column. Upstream stations (SL-5 and SL-6) had depressed oxygen levels with increasing depth and DO levels below 6 mg/l in depths greater than 0.4 meters (1.3 feet) (Figure 22, right panel).
- Water clarity was moderate with secchi disk visibility up to 1.8 meters in 2.2 meters of depth near the mouth, and visibility at the substrate (up to 1.4 meters) upstream of Riverside Bridge. Algae was not extensive and not an issue for sampling.

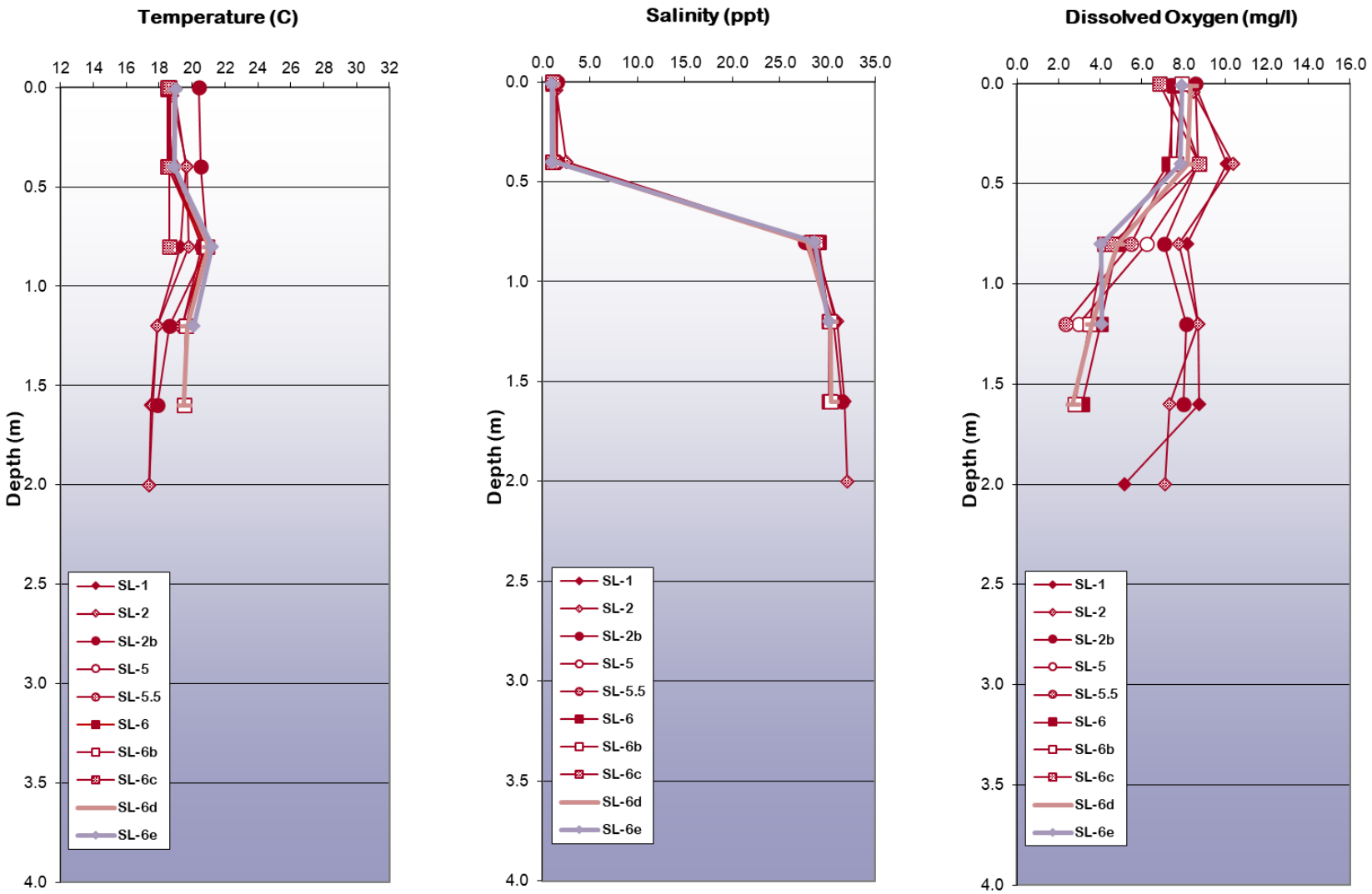

Figure 22. Depth profiles of water quality parameters in the San Lorenzo Lagoon during the July two day relative abundance survey. Profiles plotted in red are July 18 and 19; profiles plotted in salmon and lilac are additional sampling on July 19

July Survey Results

- Nine seine hauls were completed between the beach and upstream of the trestle (SL-2), and upstream of Riverside Bridge (Table 10).

Table 10. Fish catch in San Lorenzo River Lagoon, July 2023

	SL-1	SL-2	SL-5	SL-6	Grand Total
# Hauls	*3*	*3*	*3*		***9***
Species	***Number Caught***				
O. mykiss	73	134	70		**277**
Pacific herring	29	1			**30**
Chinook salmon	2				**2**
Topsmelt	1457	323	648		**2428**
Threespine stickleback			1		**1**
Staghorn sculpin		4	45		**49**
Shiner surfperch	12	8			**20**
Tidewater goby			4		**4**
Starry flounder	4	6	1		**11**
Crab		2			**2**
Shrimp	0	1			**1**
O. mykiss CPUE	*24.3*	*44.7*	*23.3*		***30.8***

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

- The *O. mykiss* captured on July 18th were noticeably sluggish and were not anesthetized for tagging. A large number of *O. mykiss* (119) captured in a single haul at the trestle were counted but released without measuring due to concerns with water quality and fish health.
- CPUE for *O. mykiss* was the fourth highest for July in the twelve years when surveys were conducted in July (Table 6). CPUE in July was over 5 times the CPUE in June (difference marginally significant: two sample t-test, unequal variance, one-tail, $p<0.05$).
- Pacific herring, topsmelt, and starry flounder CPUE were all down from June; staghorn sculpin CPUE was similar, and shiner surfperch CPUE was up (Table 9, Table 10).
- Two chinook salmon smolts were captured near the mouth. They were 129 mm (Figure 23) and 130 mm fork length.
- Six *O. mykiss* captured in July had been tagged in June (Table 11). The two fish with recorded lengths grew at an average rate of 1.18 mm/day. Although the sample size is small, growth rates of these individuals was among the highest observed in the San Lorenzo lagoon (Table 12).

Figure 23. Chinook salmon smolt, San Lorenzo River Lagoon mouth July 18, 2023

Table 11. *O. mykiss* tagged in June and recaptured in July 2023

Previous Capture Date	Recapture Date	Initial Capture Location	Recapture Location	Initial Length (mm)	Length at Recapture (mm)	Growth Rate (mm/day)
06/07/23	7/18/2023	SL-5	SL-2	138	NA	NA
06/08/23	7/19/2023	SL-2	SL-5	141	197	1.37
06/06/23	7/18/2023	SL-2	SL-2	155	NA	NA
06/06/23	7/18/2023	SL-2	SL-2	162	NA	NA
06/08/23	7/18/2023	SL-2	SL-1	167	207	1.00
06/09/23	7/18/2023	SL-5	SL-2	169	NA	NA

- The size distribution for O. mykiss is somewhat difficult to interpret since only a portion of the catch (55%) had length measured (Figure 24). If fish with measured lengths came from the same distribution as the catch as a whole, it appears that the distribution became wider and flatter in July with fish in the abundant 150 mm to 180 mm size class in June growing 30 mm to 40 mm by July; and a greater abundance of fish in the smaller size classes, likely as a result of migration into the sampling areas from further upstream.
- Forty-nine percent of the catch was evaluated for smolt stage. Seventy-one percent were characterized as parr or advanced parr and 39% were characterized as silvery parr.
- All *O. mykiss* examined (115) had an adipose fin, indicating they were not of hatchery origin.
- Eleven percent of the O. mykiss examined had black spot disease (BSD) lesions. Incidence of BSD in the San Lorenzo River Lagoon has ranged between 8% and 72% in annual surveys since 2009.

Table 12. *O. mykiss* Growth Rates for Years Available

Year	Period	N	Average Growth (mm/day)	Range (mm/day)	End of Period CPUE
2012	June-Sept	4	0.72	0.58-0.84	14.4
2013	June-Sept	2	0.34	0.27-0.41	4.7
2014		None captured			
2015		None captured			
2016	June-Sept	21	0.90	0.45-1.14	7.8
2017	June-July	35	0.78	0.42-1.16	452
	July-Aug	18	0.62	0.34-1.00	272
	Aug-Sept	15	0.40	0.05-0.73	328
	June-Sept	40	0.46	0.02-0.86	328
2018	June-July	2	0.98	0.88-1.08	2.5
	June-Aug	6	0.55	0.38-0.69	6.4
	June-Sept	10	0.39	0.26-0.49	6.3
2019	June-July	33	0.56	0.14-1.06	53
	July-Aug	57	0.45	0.04-0.89	278
	Aug-Sept	85	0.36	0.00-0.75	228
	June-Sept	88	0.38	0.03-0.85	228
2020	June-July	5	0.51	0.27-0.69	121
	July-Sept	3	0.45	0.25-0.58	31
	June-Sept	5	0.41	0.22-0.62	31
2021	June-July	1	0.26		6.3
2022	June-July	2	0.30	0.21-0.38	20
	July-Aug	1	0.20		2.3
	Jun-Aug	1	0.18		2.3
2023	Jun-Jul	2	1.18	1.00-1.37	
	Jun-Aug	4	0.88	0.69-1.04	
	Jun-Sept	6	0.68	0.46-0.85	
	Jul-Sept	7	0.24	0.06-0.48	
	Aug-Sept	7	0.21	0.03-0.43	

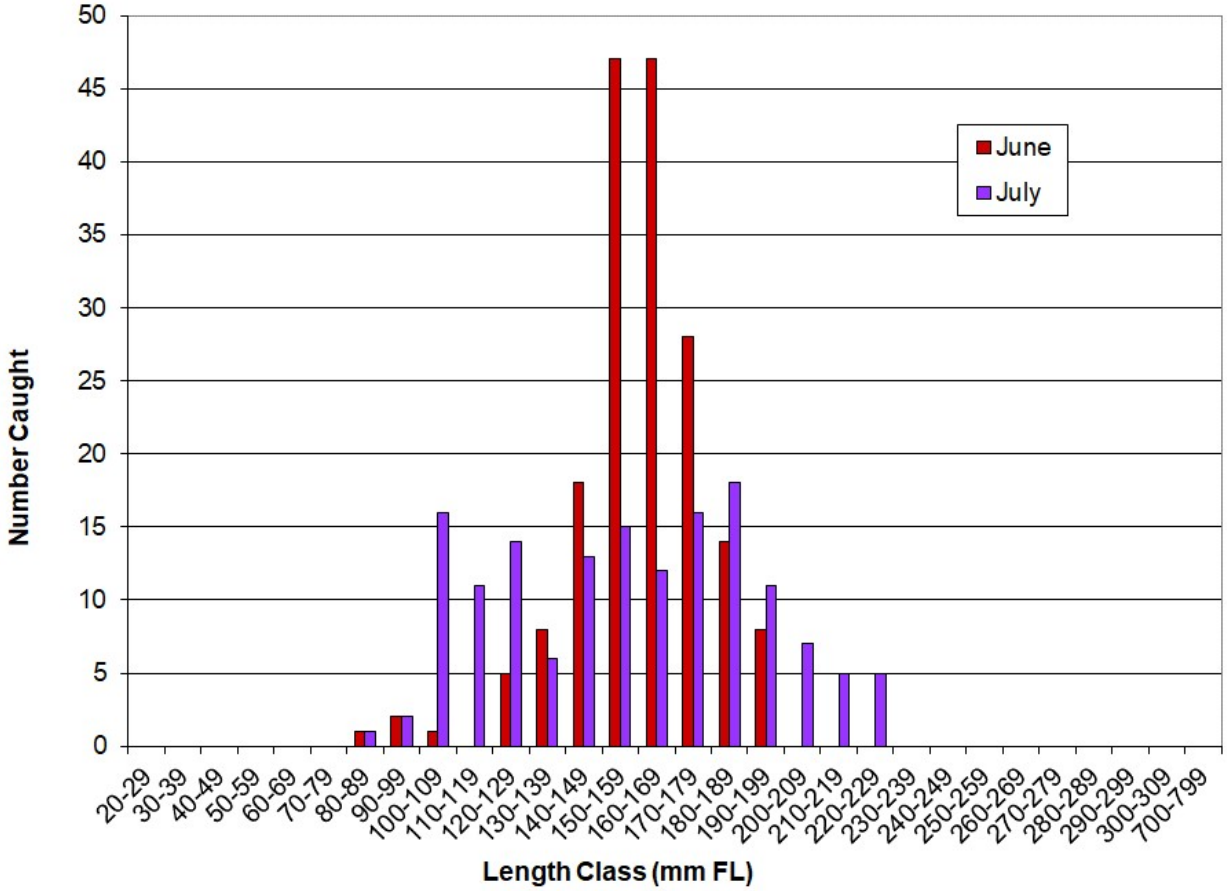

Figure 24. *O. mykiss* length classes in San Lorenzo River Lagoon during June and July 2023

August Survey (August 15-16)

The August survey was a two-day relative abundance survey without mark-recapture population estimates. Sampling was conducted at standard sampling Stations SL-1 and SL-2, downstream and around the trestle; and Stations SL-5 and SL-6 upstream of Riverside Bridge. In contrast to 2022, there were no construction or repair activities on the culvert project at the lagoon mouth.

August Site Conditions

- The lagoon had been mostly open since the July survey but closed for a tidal cycle or two about a week before the survey. The mouth was closed and full (4.4 feet NGVD) at the beginning of the survey. Stage declined to about 3 feet in the afternoon (Figure 25). During the August 15th sampling, the lagoon was closed but was breached sometime in the morning and then fully open that afternoon after sampling was completed (Figure 26, Figure 27). Stage declined to about 3 feet in the afternoon. Stage dropped further to 1.8 feet the morning of the 16th, and continued to drop through mid-morning before increasing again to about 2.2 feet in the middle of the afternoon, apparently tracking the tides again.

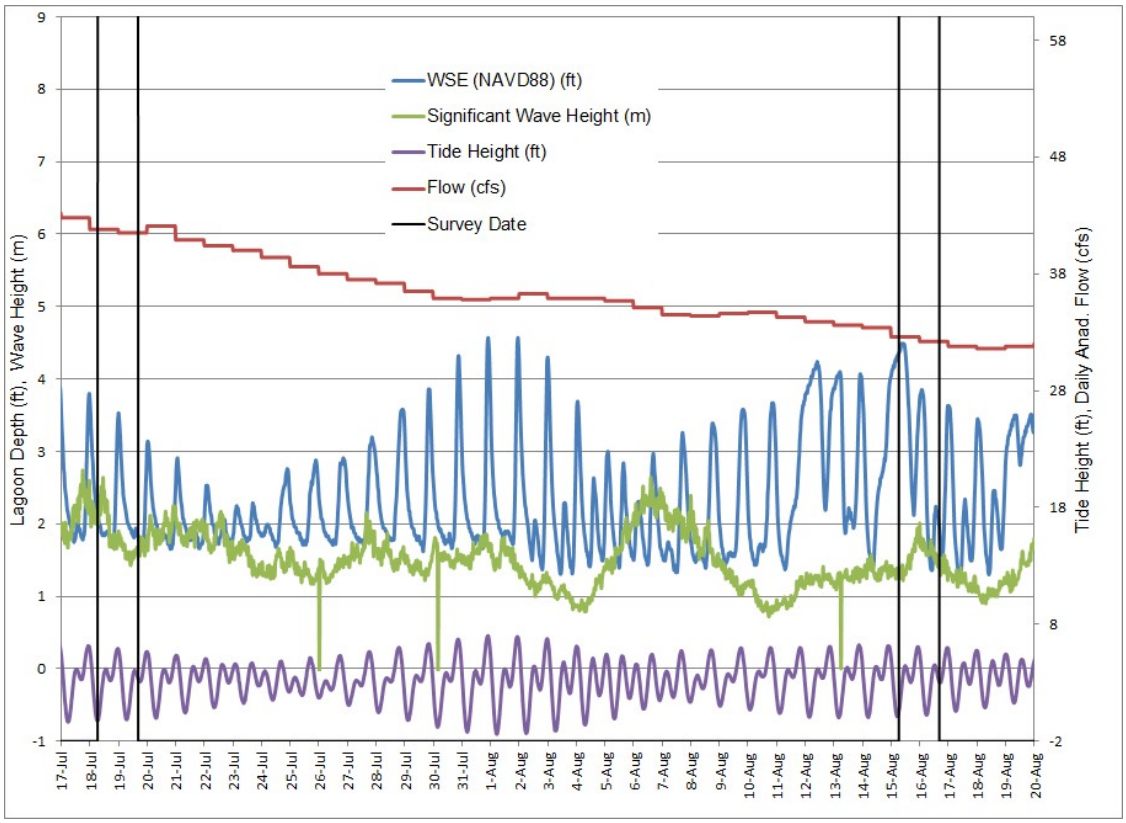

Figure 25. San Lorenzo River Lagoon stage, streamflow, wave height, and tides preceding August 2023 sample period (Source: lagoon stage from City of Santa Cruz Public Works, streamflow from USGS, wave and tide data from NOAA)

Figure 26. Lower San Lorenzo River Lagoon August 15, 2023

Figure 27. San Lorenzo River Lagoon mouth August 15, 2023. Photo taken soon after breaching and after sampling

- Inflow from the San Lorenzo River was at 33 cfs to 32 cfs during the sample period (Figure 25).
- The initial hauls on August 15th were brought into a sand "island" near the boardwalk wall since the higher water levels inundated the usual beach landing sites. As the lagoon levels dropped, the hauls were finished at the outer edge of the shallow bench and by the canoe. All hauls were deployed as a purse seine.

- Lagoon was strongly salinity stratified with a halocline between 0.4 meters (1.3 feet) and 0.8 meters (2.6 feet). The surface, relatively fresh layer, had salinity between 0.5 ppt and 7.6 ppt. At 0.8 meters salinity ranged from 20.3 ppt to 30.3 ppt with increases in deeper water to 30.8 ppt (Figure 28, center panel).
- Surface water temperature ranged from 19.0°C to 21.9°C with slight increases in some profiles around the halocline (Figure 28, left panel). Seining was cut short upstream of Riverside Bridge when surface temperature rose above 21°C. Water temperature approached the sampling limit at the lower stations and limited the number of fish that could be tagged and measured.
- Dissolved oxygen was mostly above 7 mg/l in the lower lagoon (SL-1 and SL-2) with levels around 9 mg/l above the halocline (Figure 28, right panel). Upstream of Riverside Bridge (SL-5 and SL-6) dissolved oxygen was between 7 mg/l and 8 mg/l above the halocline but decreased to less than 5 mg/l below the halocline. Tagging and measuring were suspended due to the low DO levels.
- Secchi disk visibility was 1.4 meters to 1.5 meters (4.6 feet to 4.9 feet) upstream of Riverside Drive. Little to no algae was encountered and did not compromise sampling.

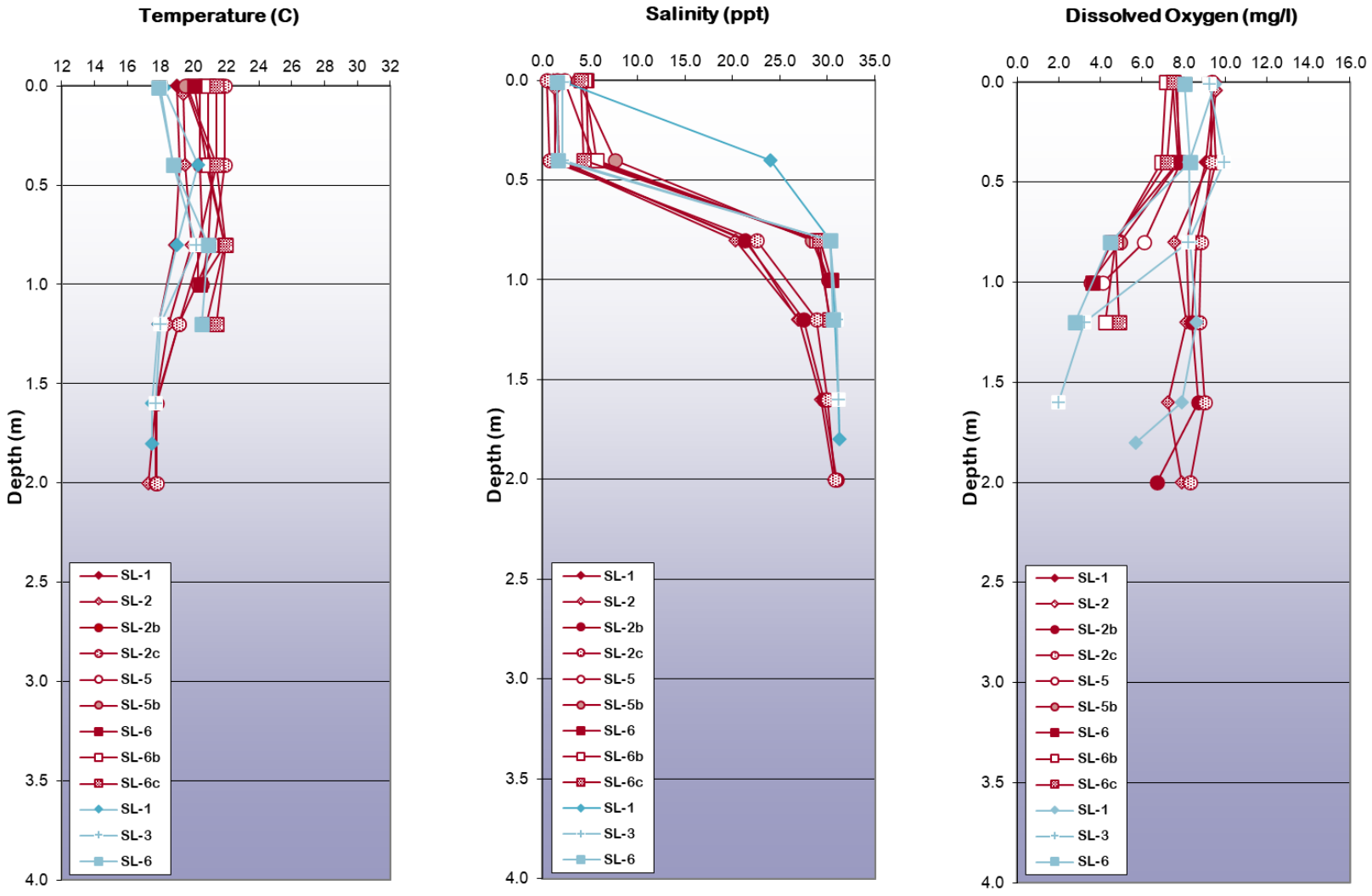

Figure 28. Depth profiles of water quality parameters in the San Lorenzo River Lagoon in August. Profiles plotted in red are August 15 and 16 during the two-day relative abundance survey; profiles plotted in pale blue are August 9 and measured by City staff

August Survey Results

- Eleven seine hauls were completed at standard sampling stations (Table 13). The majority of O. mykiss were captured in one haul just upstream of the trestle. Given high temperature and low DO, a limited number (~100) were kept for processing and the rest scanned for tags and released. Due to low DO in holding containers, many of these were also scanned for tags and released. Recaptures were measured before release.
- CPUE for *O. mykiss* was intermediate between high numbers observed in 2017 and 2019 (>200) and low numbers observed the other 4 years (6.4 or less) when surveys were conducted in August (Table 6). CPUE was up 50% from July and over 8 times the June level (46.0 in August compared to 5.6 in June and 30.8 in July). The difference was not statistically significant (ANOVA single factor, Tukey HSD, $p \approx 0.14$).
- Topsmelt numbers were still high but Pacific herring had largely disappeared. Shiner surfperch became very abundant in the August catch (Table 13).

Table 13. Fish catch in San Lorenzo River Lagoon, August 2023

	SL-1	SL-2	SL-5	SL-6	Grand Total
# Hauls	*3*	*3*	*2*	*3*	***11***
Species	***Number Caught***				
O. mykiss	4	438	61	3	**506**
Pacific herring		1			**1**
Topsmelt	188	454	583	378	**1603**
Threespine stickleback			1		**1**
Prickly sculpin			1		**1**
Staghorn sculpin			72	13	**85**
Barred surfperch	4				**4**
Shiner surfperch		1	1163		**1164**
Starry flounder	14	4	2	1	**21**
crab	2	2	6	2	**12**
shrimp	15	12			**27**
O. mykiss CPUE	*1.3*	*146.0*	*30.5*	*1.0*	***46.0***

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

- Sixteen *O. mykiss* captured in August had been tagged in June. Most were scanned and released without measuring due to large numbers captured and marginal water quality conditions. Four were measured and showed good growth rates averaging 0.88 mm/day and ranging from 0.69 mm/day to 1.04 mm/day (Table 14). Two O. mykiss were captured in

August that had also been captured in July. These fish were either not measured in July or not measured in August so growth rates could not be estimated.

- Length was measured for only 16% of the *O. mykiss* catch (Figure 29). If it is assumed that the length distribution of measured fish was representative of the entire catch, abundance of all size classes present in August would have been 6 times greater than indicated in Figure 29. The size of the smallest fish captured increased by about 30 mm between July and August, consistent with observed growth rates (Table 14, Figure 29).
- Water quality conditions precluded holding and close observation of fish and only 17% of the catch was evaluated for smolt stage. The majority of the catch were advanced parr (34%) and silvery parr (60%) with the remaining 6% classified as parr.
- All *O. mykiss* examined (81) had an adipose fin, indicating they were not of hatchery origin.
- Thirteen of 81 individuals (16%) examined had black spot disease (BSD) lesions of varying severity. Incidence of BSD in the San Lorenzo River Lagoon has ranged between 8% and 72% in annual surveys since 2009.

Table 14. *O. mykiss* tagged earlier in the season and recaptured in August 2023

Previous Capture Date	Recapture Date	Initial Capture Location	Recapture Location	Initial Length (mm)	Length at Recapture (mm)	Growth Rate (mm/day)
06/07/23	8/15/2023	SL-5	SL-2	138	198	0.87
06/09/23	8/15/2023	SL-5	SL-2	141	211	1.04
06/08/23	8/15/2023	SL-2	SL-2	149	210	0.90
06/08/23	8/15/2023	SL-2	SL-2	156	203	0.69

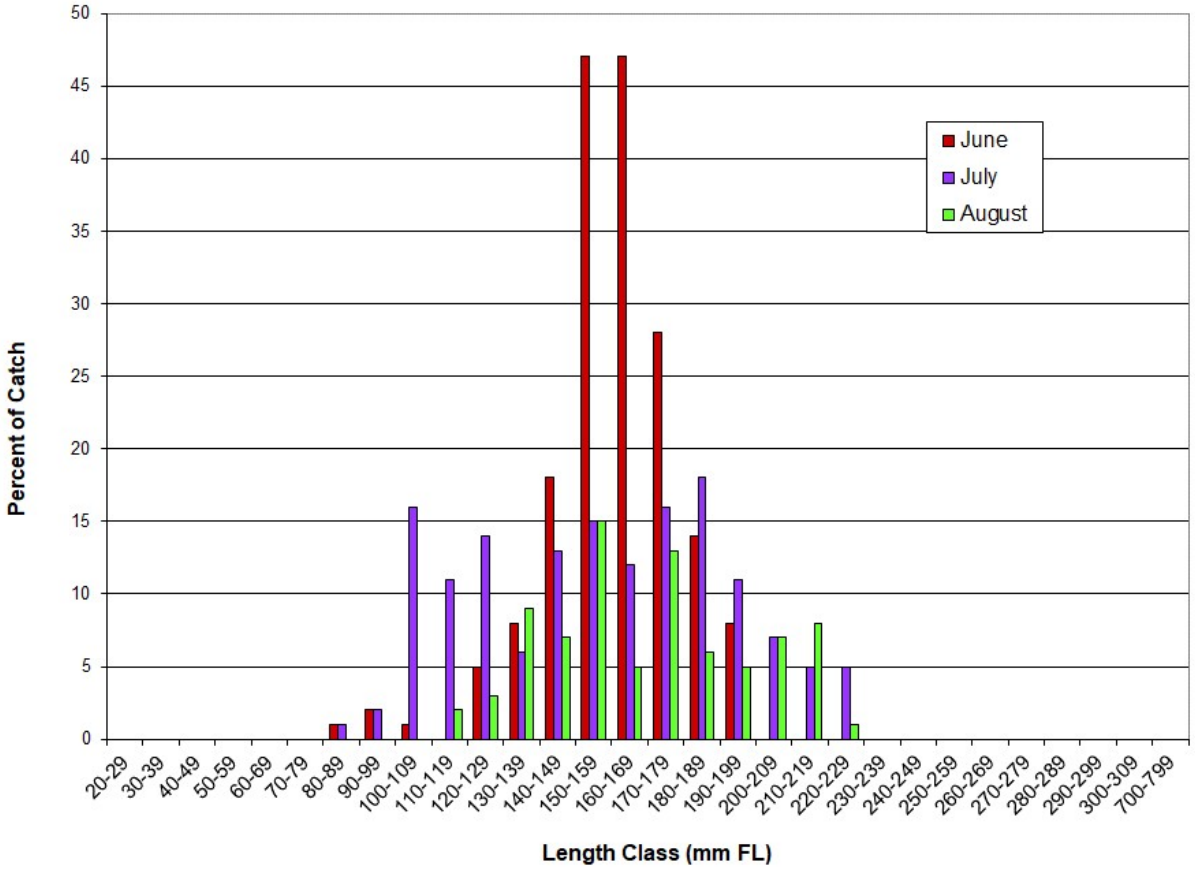

Figure 29. *O. mykiss* length classes in San Lorenzo River Lagoon during June, July, and August 2023

September Survey (September 19-22)

The September survey was a complete survey with mark-recapture population estimate. Sampling was conducted twice at standard sampling Stations SL-1 and SL-2, downstream and around the trestle; and Stations SL-5 and SL-6 upstream of Riverside Bridge. *O. mykiss* were captured and tagged on September 19 and 20 with the sites resampled on September 21 and 22 for recaptures.

There had been three lagoon closures since the August survey, each lasting four days, with open, tidal conditions between (Figure 30). Flow in the San Lorenzo River trended from about 32 cfs at the end of the August survey to 28 cfs at the beginning of the September survey. Sampling was initiated the morning of September 19. The lagoon had just closed and stage had risen to 3.7 feet. Stage continued to rise, reaching 6.36 feet at 10:00 am September 22, the final day of sampling. Minor stage decline occurred until about 11:30 am and then a loss of 3 feet in 1.5 hours. Water quality conditions were good and did not result in any limitations on seining or tagging and measuring. Tagging was limited due to a shortage of tags.

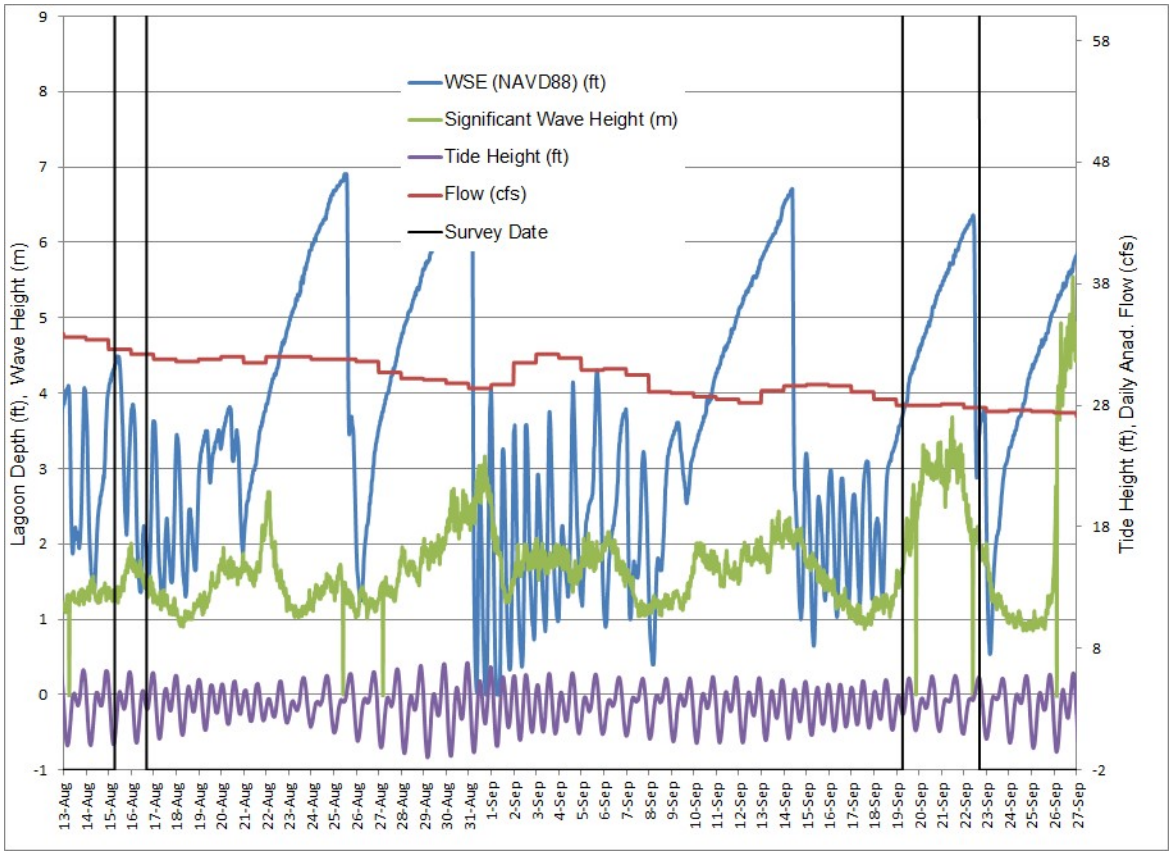

Figure 30. San Lorenzo River Lagoon stage, streamflow, wave height, and tides preceding September 2023 sample period (Source: lagoon stage from City of Santa Cruz Public Works, streamflow from USGS, wave and tide data from NOAA)

Fall Site Conditions

- The lagoon remained closed but with rising water levels throughout the survey period until just before the last seine haul on September 22. Stage during the marking period ranged from 3.73 initially to 5.14 on September 20. Stage during the recovery period ranged from 5.64 initially to 6.36 on September 22 just before breaching. The seine could not be deployed near the mouth due to the high stage condition. Daily average flow at Santa Cruz gage was 28 cfs through the survey period (historical discharge, USGS site 11161000 San Lorenzo River at Santa Cruz California).
- Salinity was stratified with fresh water (3 ppt or less) in the upper 0.4 m (1.3 ft) and increasing salinity in deeper water (Figure 31, center panel). Stratification was strongest, with higher salinity at depth, during the mark period (Sept 19-20) and closer to the mouth. The lagoon was freshening markedly during the recovery period (Sept 21-22).
- Water temperature was not strongly stratified but increased slightly with depth down to 1.2 m (3.9 ft). Surface temperature ranged from 15.4°C to 18.6°C and the maximum temperature recorded was 21.2°C. These are fairly moderate temperatures for the San Lorenzo lagoon during the summer rearing period.
- Dissolved oxygen was not strongly stratified but tended to decrease moderately with depth, particularly during the mark period (Figure 31, right panel). Surface DO ranged from 9.8 mg/l to 11.6 mg/l. DO was at least 7 mg/l throughout the water column except for the deepest water during the mark period. DO levels generally increased slightly during the recovery period.
- Turbidity by the lagoon mouth was measurable on September 19 with a Secchi depth of 1.5 to 2.1 meters (4.9 to 6.9 feet) in water depths of 2.6 to 2.9 meters (8.5 to 9.5 feet). It did not show improvement on September 21 with Secchi depths of 1.6 to 2.6 meters (5.2 to 8.5 feet) in water depths of 3.1 to 3.3 meters (10.2 to 10.8 feet). Water clarity was to the bottom at the sampling sites upstream of Riverside Bridge

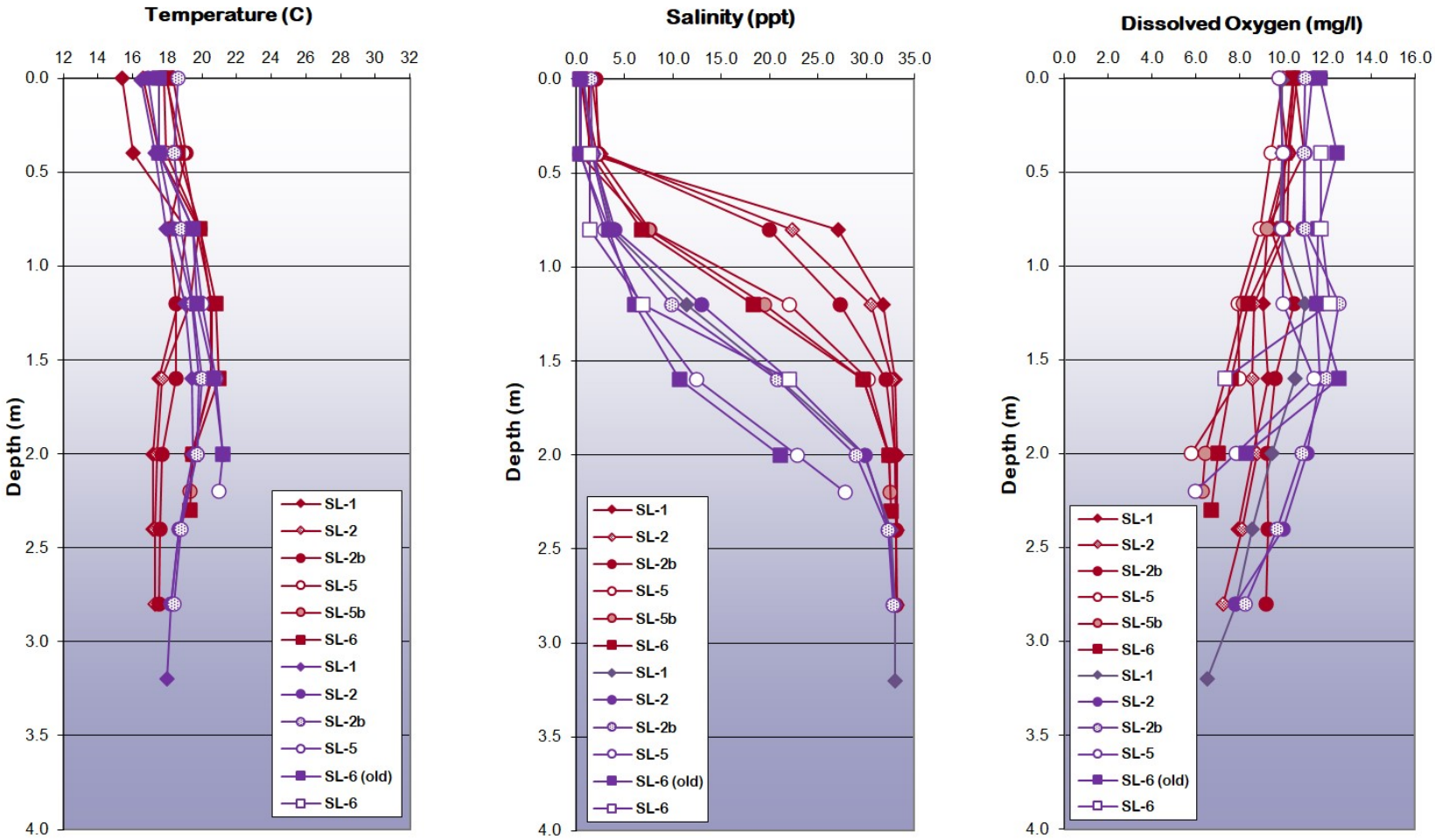

Figure 31. Depth profiles of water quality parameters in the San Lorenzo River Lagoon during September. Profiles plotted in red are September 19-20; profiles in blue are September 21-22. Note: the location of SL-6 (old) was the original site of SL-6 prior to the winter storms of 2021-2022

Fall Survey Results

- Twenty-eight seine hauls were completed at regularly sampled Stations (SL-1, SL-2, SL-5, and SL-6). The catch was dominated by topsmelt and *O. mykiss* (Table 15). CPUE for shiner surfperch, though still abundant, was down from August. An unusual species was one yellowfin goby (Figure 32) captured upstream of the trestle.

Table 15. Fish catch in San Lorenzo River Lagoon, September 2023

	SL-1	SL-2	SL-5	SL-6	Grand Total
# Hauls	*5*	*9*	*6*	*8*	***28***
Species	***Number Caught***				
O. mykiss	9	418	110	137	**674**
Sacramento sucker				1	**1**
Chinook salmon		1			**1**
Topsmelt	257	1075	423	920	**2675**
Threespine stickleback		1		4	**5**
Staghorn sculpin	3	1			**4**
Barred surfperch	6				**6**
Shiner surfperch		266	84		**350**
Yellowfin goby		1			**1**
Starry flounder	6	8	3	4	**21**
Crab	1	59		13	**73**
Shrimp	1				**1**
O. mykiss CPUE	*1.8*	*46.4*	*18.3*	*17.1*	***24.1***

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

- *O. mykiss* CPUE was moderate for September surveys with three years having higher CPUE and seven years having lower (Table 6). *O. mykiss* were concentrated near the trestle bridge (Table 15). CPUE was down from August and July but higher than June (Table 6). None of the differences in CPUE for the monthly surveys in 2023 was statistically significant (ANOVA single factor, Tukey HSD, $p \approx 0.18$).
- The size distribution in September was nearly uni-modal with a possible break around 170-179 mm (Figure 33). Smaller fish generally have faster growth rates than larger fish so this could have caused the young-of year fish to "bunch up" toward older fish in the length distribution. Based on observed growth rates, YOY could have grown as much as 70 mm between the June and September sampling dates (Figure 34).

Figure 32. **Yellowfin goby San Lorenzo River Lagoon mouth September 21, 2023**

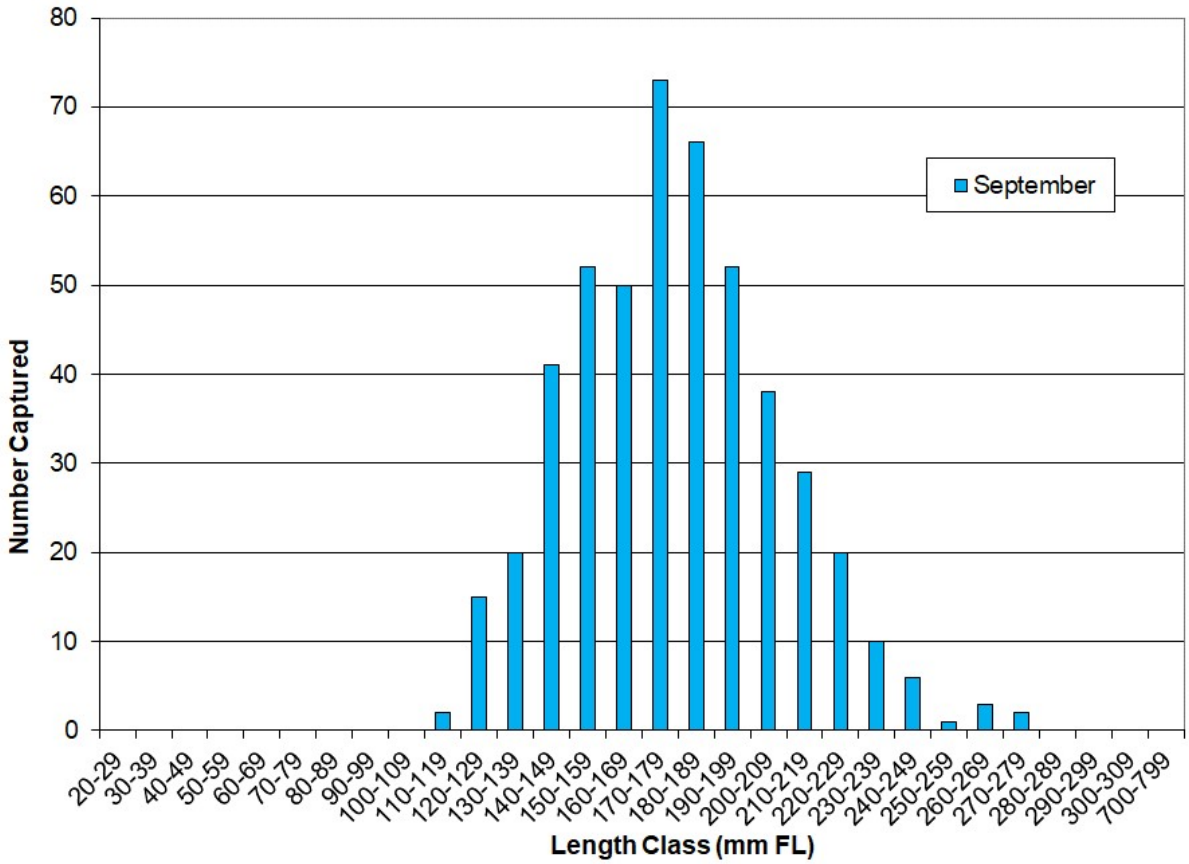

Figure 33. *O. mykiss* length classes in San Lorenzo River Lagoon during September 2023

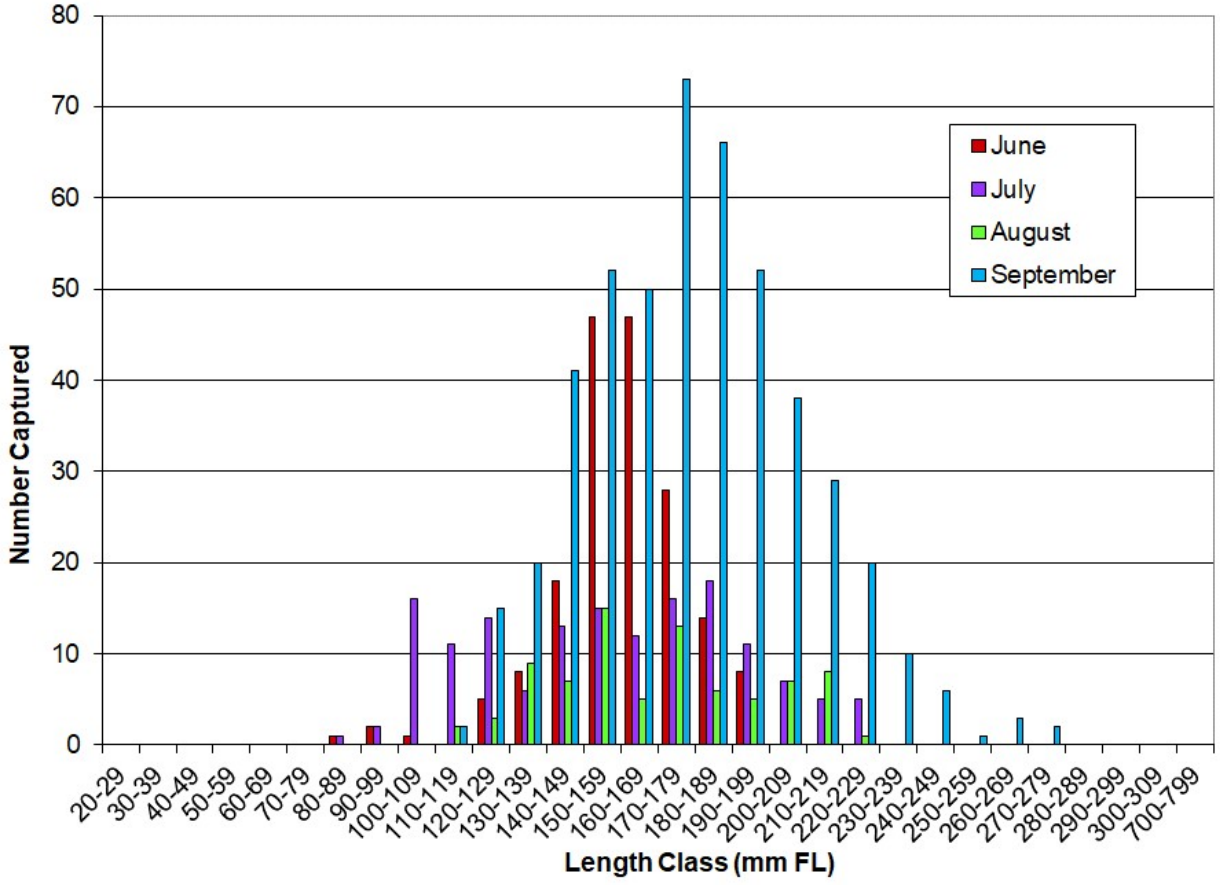

Figure 34. *O. mykiss* length classes in San Lorenzo River Lagoon during June, July, August, and September 2023

- Thirty-four *O. mykiss* captured in September had been tagged earlier in the summer. Twenty of these had length information that allowed growth calculations (Table 16). Growth rates earlier in the summer appeared to be highest with growth between August and September the lowest (Table 16). This observation is consistent with previous years (Table 12)

Table 16. *O. mykiss* tagged earlier in the season and recaptured in September 2023

Previous Capture Date	Recapture Date	Initial Capture Location	Recapture Location	Initial Length (mm)	Length at Recapture (mm)	Growth Rate (mm/day)
06/07/23	9/19/2023	SL-5	SL-2	140	213	0.70
06/07/23	9/19/2023	SL-5	SL-2	154	230	0.73
06/09/23	9/21/2023	SL-5	SL-2	155	243	0.85
06/08/23	9/21/2023	SL-2	SL-2	156	204	0.46
06/08/23	9/21/2023	SL-2	SL-2	168	240	0.69
06/06/23	9/21/2023	SL-2	SL-2	169	239	0.65
Average						***0.68***
07/18/23	9/22/2023	SL-1	SL-5	152	167	0.23
07/19/23	9/20/2023	SL-5	SL-5	155	185	0.48
07/18/23	9/22/2023	SL-1	SL-6	160	171	0.17
07/18/23	9/19/2023	SL-1	SL-2	170	179	0.14
07/18/23	9/19/2023	SL-1	SL-2	180	184	0.06
07/18/23	9/21/2023	SL-1	SL-2	185	193	0.12
07/18/23	9/19/2023	SL-1	SL-2	191	221	0.48
Average						***0.24***
08/16/23	9/22/2023	SL-5	SL-6	144	160	0.43
08/16/23	9/19/2023	SL-5	SL-1	165	179	0.41
08/15/23	9/19/2023	SL-2	SL-2	165	169	0.11
08/16/23	9/20/2023	SL-5	SL-5	194	199	0.14
08/16/23	9/22/2023	SL-5	SL-6	196	206	0.27
08/16/23	9/19/2023	SL-5	SL-2	203	206	0.09
08/15/23	9/21/2023	SL-2	SL-2	203	204	0.03
Average						***0.21***

- Fifty percent of *O. mykiss* examined were classified as parr or advanced parr and 50% were classified as silvery parr or advanced silvery parr. One adult was captured. It was estimated at 425 mm FL and did not have an adipose fin (Figure 35).
- Two hundred *O. mykiss* were examined for presence of an adipose fin; one did not have one present (the adult mentioned previously). Adipose fins are typically removed from hatchery produced steelhead.
- Twenty-eight percent of *O. mykiss* examined had black-spot disease (BSD) lesions, most were lightly affected. Incidence of BSD has ranged between 4% and 100% and averaged 36% in previous fall surveys since 2009.

Figure 35. **Adult *O. mykiss* without adipose fin, San Lorenzo Lagoon mouth September 19, 2023**

September *O. mykiss* Population Estimate

- A total of 412 *O. mykiss* were captured during the marking period (September 19 and 20). One-hundred seventy-nine were not tagged due to warm temperature conditions. Nine were smaller than the 130 mm tagging limit and one exceeded the upper tagging limit (320 mm FL). Twelve were recaptures of fish that were tagged previously in the marking period. A total of 189 *O. mykiss* were tagged. Two of the tagged fish died after tagging. In addition to the 187 surviving tagged fish, 22 fish tagged during June, July, and August were also captured during the marking period and these were added to make a total of 209 known unique tagged *O. mykiss* in the lagoon at the end of the marking period.
- A total of 262 *O. mykiss* were captured during the recapture period, 26 of which were tagged during the marking period.
- The Peterson population estimate (Ricker 1975) is 2046 *O. mykiss* in the lagoon in September. The 95% confidence limits for this estimate are 1412 and 2948. This is in the upper 40% for the eleven years for which an estimate was possible for fall surveys in the San Lorenzo Lagoon (Table 7).
- Changes in CPUE and size distribution between the mark period and recapture period can indicate movement of fish in and out of the lagoon and violation of the assumption of a closed population. CPUE during the recovery period was lower than during the marking period (20.2 vs 27.5), which would indicate fewer fish in the lagoon. Increasing lagoon stage between the mark and recovery periods could also have accounted for a decline in CPUE. In any case, the difference was not statistically significant (two sample t-test, unequal variance, two-tail, p=0.66). The size distribution appeared to be similar during the mark and recapture periods (Figure 36).
- The relationship between the population estimates and CPUE was updated with the spring and fall 2022 data points (Figure 37). Excluding the questionable 2020 data points (low recapture rates and questionable validity of the population estimates, see HES 2021), the least squares regression estimate for adjusted r^2 is 0.92 and was statistically significant with $p<0.01^{-12}$.

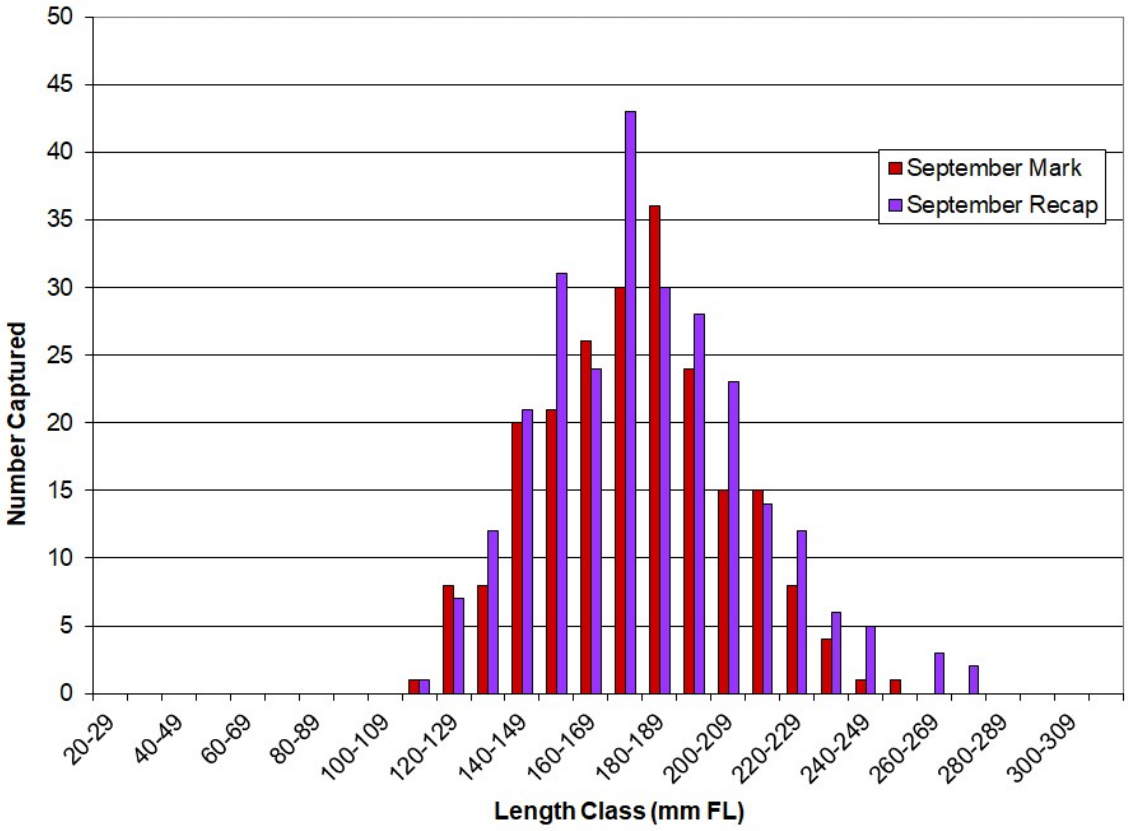

Figure 36. *O. mykiss* size distributions in San Lorenzo River Lagoon, September 2023 during mark and recapture periods

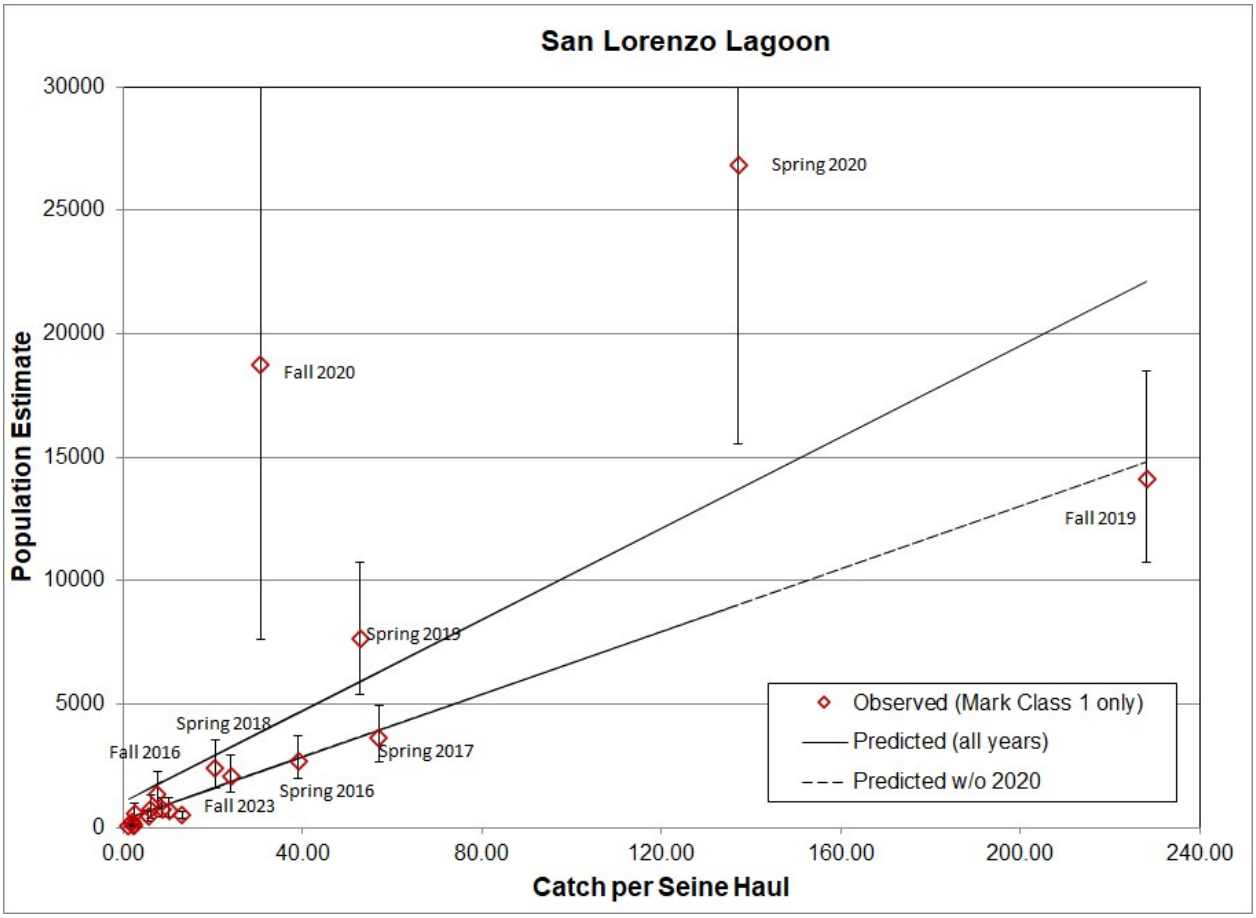

Figure 37. Relationship between *O. mykiss* population estimate and CPUE in the San Lorenzo River Lagoon[4]

[4] The Early Summer 2013 and Early Summer 2015 estimates are likely biased due to the small number of marked fish and small number of recaptures. Population estimates are not available for Late Summer 2013 and Early Summer 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 Late Summer 2014 and Late Summer 2015 so CPUE was zero and populations were also assumed to be near zero. CPUE values adjusted to reflect portion of population in tagging size range only.

Appendix A

Table A-1. *O. mykiss* catch per haul for the San Lorenzo River Lagoon during 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, HES 2016, HES 2017, HES 2018a, HES 2019, HES 2020, HES 2021, HES 2022, and HES 2023)

Station	Location	*O. mykiss* Catch per Haul					
2002						Oct 1	Nov 20
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			July 6		Sep 21	Sep 29	
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		Jun 14	Jul 14	Aug 16		Oct 5	
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		Jun 8, 19				Oct 7-8	
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		Jun 10-11			Sep 16	Oct 21	
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		Jun 22-23	Jul 17			Oct 6-7	
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	6.0				80.0	
	Overall	***7.7***	***21.5***			***28.25***	
2011		Jun 9-14				Oct 13-18	
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 A-1 (continued)

Station	Location	*O. mykiss* Catch per Haul					
2012		Jun 7-12			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		Jun 6-11	July 17		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		Jun 5-10	July 17		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[5]	***1.2***	***1.1***		***0.0***		
2015		Jun 4-9	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		Jun 9-14	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***		
2017		Jun 15-20	July 11	Aug 15	Sept 21		
SL-1	South of Trestle	5.5	466.0	265.0	643.0		
SL-2	RR Trestle	100.9	424.0	279.0			
SL-5	Riverside Drive	566.7			13.0		
SL-6	U/S Bank Restoration	76.6			15.0		
	Overall	***134.4***	***452.0***	***272.0***	***328.5***		

[5] Standard sites only (SL1-SL6) used in Overall calculation

Table A-1 (continued)

Station	Location	*O. mykiss* Catch per Haul					
2018		Jun 7-12	Jul 16-17	Aug 14-15	Sep 20-25		
SL-1	South of Trestle	12.8	5.3	8.5	8.8		
SL-2	RR Trestle	20.5	0.0	1.5	6.0		
SL-3	Near YSI Station	11.0	0.5	0.0	3.0		
SL-5	Riverside Drive	59.8	2.5	14.5	3.0		
SL-6	U/S Bank Restoration	14.8	2.8	5.3	7.3		
	Overall	***23.3***	***2.5***	***6.4***	***6.3***		
2019		Jun 13-18	Jul 16-17	Aug 13-14	Sep 19-24		
SL-1	South of Trestle	1.0	10.0	49.7	7.2		
SL-2	RR Trestle	55.8	95.7	440.0	509.0		
SL-3	Near YSI Station				35.0		
SL-5	Riverside Drive	274.4	59.0	457.5	462.3		
SL-6	U/S Bank Restoration	40.5	22.0		66.6		
	Overall	***92.2***	***53.4***	***277.7***	***228.2***		
2020		11-16 Jun	Jul 7-8	Aug 19-20*	Sep 17-22		
SL-1	South of Trestle	70.5	29.5	NS	0.1		
SL-2	RR Trestle	75.0	369.0	NS	30.1		
SL-3	Near YSI Station	155.0	NS	NS	NS		
SL-5	Riverside Drive	257.0	70.5	NS	19.0		
SL-6	U/S Bank Restoration	207.3	13.5	NS	83.8		
	Overall	***146.1***	***120.6***	NS	***30.7***		
2021		Jun 8-11	Jul 13-14	Aug*	Sep	Oct 12-13	
SL-1	South of Trestle	3.9	1.0	NS	NS	0.0	
SL-2	RR Trestle	4.2	9.7	NS	NS	0.2	
SL-3	Near YSI Station	0.0	NS	NS	NS	0.5	
SL-5	Riverside Drive	7.0	9.5	NS	NS	0.5	
SL-6	U/S Bank Restoration	4.0	6.0	NS	NS	0.3	
	Overall	***4.3***	***6.3***	***NS***	***NS***	***0.3***	
2022		Jun 7-10	Jul 13-14	Aug 16-17	Sep 20-23		
SL-1	South of Trestle	4.0	0.7	3.0	25.0		
SL-2	RR Trestle	2.7	73.0	1.6	8.7		
SL-3	Near YSI Station	NS	NS	NS	NS		
SL-5	Riverside Drive	0.5	10.0	4.0	13.8		
SL-6	U/S Bank Restoration	0.8	5.0	0.0	1.4		
	Overall	***2.4***	***20.5***	***2.3***	***8.8***		
2023		Jun 6-9	Jul 18-19	Aug 15-16	Sep 19-22		
SL-1	South of Trestle	0.2	24.3	1.3	1.8		
SL-2	RR Trestle	7.4	44.7	146.0	46.4		
SL-3	Near YSI Station	NS	NS	NS	NS		
SL-5	Riverside Drive	13.5	23.3	30.5	18.3		
SL-6	U/S Bank Restoration	1.8		1.0	17.1		
	Overall	***5.8***	***30.8***	***46.0***	***24.1***		

Figure A-1. Laguna Creek Lagoon sampling stations

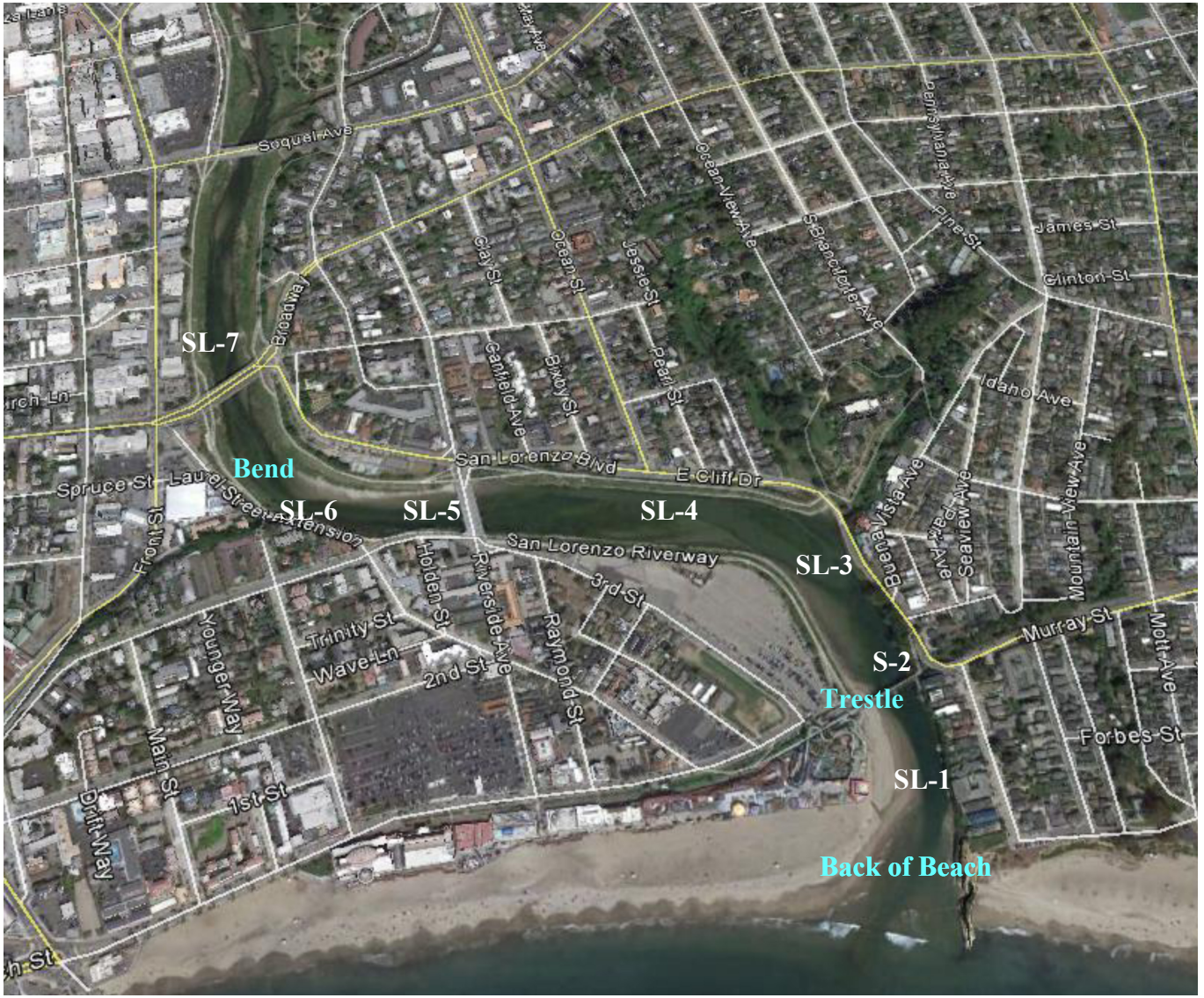

Figure A-2. San Lorenzo River Lagoon sampling stations

Acknowledgements

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